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June 8, 2021

VIA: ELECTRONIC FILING

Mr. Adam J. Teitzman
Commission Clerk
Florida Public Service Commission
2540 Shumard Oak Boulevard
Tallahassee, Florida 32399-0850

Re: Petition for approval of new environmental program for cost recovery through Environmental Cost Recovery Clause, by Tampa Electric Company
Dkt.: 20210087-EI

Dear Mr. Teitzman:

Attached for filing in the above docket is Tampa Electric Company's Response to Staff's First Data Request (Nos. 1-7), propounded on May 18, 2021.

Thank you for your assistance in connection with this matter.

Sincerely,

Malcolm N. Means

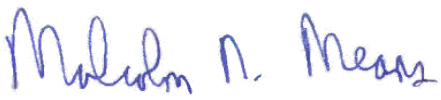
MNM/bmp
Attachment

cc: All Parties of Record (w/attachment)
Jeff Doehling (jdoehlin@psc.state.fl.us)

CERTIFICATE OF SERVICE

I HEREBY CERTIFY that a true and correct copy of the foregoing responses of Tampa Electric Company to Staff's 1st Data Request (Nos. 1-7), have been furnished by electronic mail on this 8th day of June 2021 to the following:

Ashley Weisenfeld
Attorney
Office of General Counsel
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ATTORNEY

TAMPA ELECTRIC COMPANY
DOCKET NO. 20210087-EI
STAFF'S FIRST DATA REQUEST
REQUEST NO. 1
BATES PAGE: 1
FILED: JUNE 8, 2021

1. Please explain why TECO is requesting to recover the costs of the project through the ECRC, instead of its rate proceeding, Docket No. 20210034-EI.

A. For projects eligible for Environmental Cost Recovery Clause ("ECRC") recovery, Tampa Electric's regular practice is to seek recovery of those projects through the ECRC. The compliance costs associated with Bayside 316(b) are eligible for ECRC recovery pursuant to Order No. PSC-94-0044-FOF-EI, wherein the Commission granted Gulf Power Company the ability to recover the costs associated with environmental compliance activity through an environmental cost recovery factor. The costs associated with Tampa Electric's request are related to a legally required environmental compliance project and as such, ECRC recovery is appropriate. Furthermore, at the time Tampa Electric was preparing its current rate case filing, the company did not have the specific information necessary to include it in its rate proceeding in Docket No. 20210034-EI.

2. Please refer to page 2, paragraph 3 of the petition, for the following questions.

a. Please identify the referenced EPA rule.

b. Please explain whether the rule will impact the cooling water intake structure ("CWIS") of TECO's other generating stations.

A. a. The rule referenced is the Clean Water Act ("CWA") Section 316(b) rule for existing facilities (Federal Register, Volume 79, No. 158, Pages 48300-48439), known as the final 316(b) rule, which was published August 15, 2014, by the U.S. Environmental Protection Agency ("EPA"). The rule established regulations related to the design and operation of intake structures to minimize adverse impacts on marine life.

b. In addition to Bayside Station, the final 316(b) rule applies to Big Bend Station.

3. Please refer to page 2, paragraph 4 of the petition, for the following questions.

a. Please provide the cumulative design intake flow of the existing CWIS.

b. Please provide the maximum intake flow of the existing CWIS.

A. a. The cumulative design intake flow for Units 1 and 2 of the existing Cooling Water Intake Structure ("CWIS") is 628 million gallons per day ("MGD").

b. The maximum permitted intake flow for the existing CWIS is 1,346 MGD.

4. Please refer to page 3, paragraph 6 of the petition, for the following questions.

a. Please identify the consulting firm hired to conduct the study.

b. Please explain how cost-effectiveness was determined. As part of your response, explain whether the cost-effectiveness of each alternative compliance method was determined.

c. Please explain if the study was reviewed or approved by the DEP.

d. Please provide a copy of the study.

A. a. The consulting firm that performed the study was Environmental Consulting and Technology, Inc. ("ECT").

b. The final 316(b) rule listed seven compliance methods to reduce impingement mortality. All options were considered. The ECT study (attached), Section 6.0, presents a review of the compliance approaches and discusses the cost effectiveness as well as other significant attributes of each alternative. The selected method was the least expensive option that achieves the objective of compliance with rule 316(b).

c. The study was submitted and reviewed by Florida Department of Environmental Protection ("FDEP") as a part of the National Pollutant Discharge Elimination System ("NPDES") permit renewal submitted in 2018. Tampa Electric met with FDEP in February 2021 to confirm that there were no issues with proceeding with installation of the impingement mortality reduction compliance method. FDEP agreed with Tampa Electric that the compliance method selected met the best technology available ("BTA") standard.

d. An electronic copy of the ECT study, titled "FL0000809 TEC Bayside R4 Application 316(b)", is attached.

ECT Environmental Consulting & Technology, Inc.
3701 Northwest 98th Street, Gainesville, Florida 32606-5004

Clean Water Act §316(b) Evaluation to Support 40 CFR 122.21(r)

H.L. Culbreth Bayside Power Station
Hillsborough County, Florida

TECO TAMPA ELECTRIC AN EMERA COMPANY
Tampa, Florida

Prepared with substantial assistance from:

HDR ALDEN VERITAS Economic Consulting

February 2018
ECT No. 170205-0100

Complex Challenges . . . PRACTICAL SOLUTIONS

Document Review

The dual signatory process is an integral part of Environmental Consulting & Technology, Inc.'s (ECT's) Document Review Policy No. 9.03. All ECT documents undergo technical/peer review prior to dispatching these documents to any outside entity.

This document has been authored and reviewed by the following employees:

Jennifer S. Mathia	Mark W. Gerath
Author	Peer Review
	
Signature	Signature
February 26, 2018	February 26, 2018
Date	Date

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List of Acronyms and Abbreviations

°C	degree Celsius
°F	degree Fahrenheit
ΔT	delta T
AAA	American Automobile Association
AACE	Association for the Advancement of Cost Engineering
AC	alternating current
ACC	air-cooled condenser
AFB	aquatic filter barrier
AIF	actual intake flow
Anclote	Anclote Power Plant
AOI	area of influence
AQF	aquatic filter barriers
ASMFC	Atlantic States Marine Fisheries Commission
Bayside	H.L. Culbreth Bayside Power Station
BPJ	best professional judgment
BTA	best technology available
Btu	British thermal units
C/R	commercial and recreational
CFR	Code of Federal Regulations
cfs	cubic feet per second
CO_2	carbon dioxide
COC	cycle of concentration
CPUE	catch per unit effort
CTI	Cooling Technology Institute
CWA	Clean Water Act
CWIS	cooling water intake structure
dB	Decibels
DBA	design-basis accident

List of Acronyms and Abbreviations (Continued, Page 2 of 5)

DC	direct current
DCS	distributed control system
DIF	design intake flow
DO	dissolved oxygen
DOE	U.S. Department of Energy
EA	equivalent adult
EAC	equivalent annual cost
ECT	Environmental Consulting & Technology, Inc.
El.	elevation
EPA	U.S. Environmental Protection Agency
EPC	Environmental Protection Commission
EPRI	Electric Power Research Institute
ESA	Environmental Species Act of 1973
F.A.C.	Florida Administrative Code
FAA	Federal Aviation Administration
FDEP	Florida Department of Environmental Protection
FIM	Fisheries Independent Monitoring
FMMC	Florida Municipal Power Pool
FMPP	Florida Municipal Power Pool
FMS	fine-mesh screens
FNAI	Florida Natural Areas Inventory
fps	foot per second
FR	Federal Register
ft	foot
ft^2	square foot
FWC	Florida Fish and Wildlife Conservation Commission
GAM	generalize additive model
Gannon	F.J. Gannon Station

List of Acronyms and Abbreviations (Continued, Page 3 of 5)

gpm	gallons per minute
GWhr	gigawatts per hour
hp	horsepower
HVAC	heating, ventilation, and air conditioning
Hz	hertz
ID	inside diameter
IM	impingement mortality
IPaC	Information Planning and Conservation
ITPOS	impingement technology performance optimization study
IUCN	International Union for Conservation of Nature
kg	kilogram
lb/hr	pounds per hour
lb/MMBTu	Pounds per million British thermal units
lb/yr	pound per year
lb_m	pound-mass
MDCT	mechanical draft cooling tower
MGD	million gallons per day
mm	millimeter
MMBtu/hr	million British thermal units per hour
mph	miles per hour
msl	mean sea level
MW	megawatt
MWh	megawatt-hour
MWIS	makeup water intake structure
NAAQS	National Ambient Air Quality Standards
NDCT	natural draft cooling tower
NEPA	National Environmental Policy Act
NFMS	National Marine Fisheries Service

List of Acronyms and Abbreviations (Continued, Page 4 of 5)

NOAA	National Oceanic and Atmospheric Administration
NOAA Fisheries	National Oceanic and Atmospheric Administration National Marine Fisheries Service
NO_x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
O&M	operation and maintenance
ONAC	Office of Noise Abatement and Control
PaR	Planning and Risk model
PM	particulate matter
ppm	part per million
PSC	Public Service Commission
psi	pound per square inch
QCT	cooling water circulation rate per unit
RAOI	radius of area of influence
RUM	random utility maximization
SO_2	sulfur dioxide
SWFWMD	Southwest Florida Water Management District
T&E	threatened and endangered
TDS	total dissolved solids
TECO	Tampa Electric Company
tpy	ton per year
TS	total solids
TSCT	total solids in circulating water
TSS	total suspended solids
TSV	through-screen/slot velocity
TWS	traveling water screen
USACE	U.S. Army Corps of Engineers

List of Acronyms and Abbreviations (Continued, Page 5 of 5)

USFWS	U.S. Fish & Wildlife Service
USGS	U.S. Geological Survey
VFD	variable-frequency drive
VSP	variable-speed pump
WBAN	Water Bureau Army Navy
WMO	World Meteorological Organization
WWTP	wastewater treatment plant

1.0 Introduction and Executive Summary

This report has been prepared to address the final Clean Water Act (CWA) Section 316(b) rule for existing facilities (Federal Register [FR], Volume 79, No. 158, Pages 48300-48439), known as the final 316(b) rule, which was published August 15, 2014, by the U.S. Environmental Protection Agency (EPA). Specifically, this report addresses the 316(b) rule's requirements for the permit application as described at Title 40, Parts 122.21(r)(2) through (13), of the Code of Federal Regulations (CFR).

Tampa Electric Company (TECO) owns and operates two natural gas-fired combined-cycle units at the H.L. Culbreath Bayside Power Station (Bayside), located at 3602 Port Sutton Road, Hillsborough County, Tampa, Florida (Figures 1-1 and 1-2). Unit 1 has three combustion turbines and one steam turbine (i.e., a three-on-one configuration generating 746 megawatts [MW] nominal). Unit 2 has a four-on-one configuration generating 1,090 MW nominal. Bayside has the potential to generate approximately 1,836 MW of electrical power using natural gas. Bayside is located on the site that was formally known as F.J. Gannon Station (Gannon), which was constructed between 1957 and 1967. Gannon had a total of six coal-fired units. Units 5 and 6 were repowered in 2003 and 2004 to natural gas to become Bayside Units 1 and 2. Gannon Units 1 through 4 were retired at that time. However, the cooling water intake bays remain, though they are inactive (Table 1-1). This document covers Bayside Units 1 and 2 only as existing units at an existing facility under the 316(b) rule (Figure 1-2).

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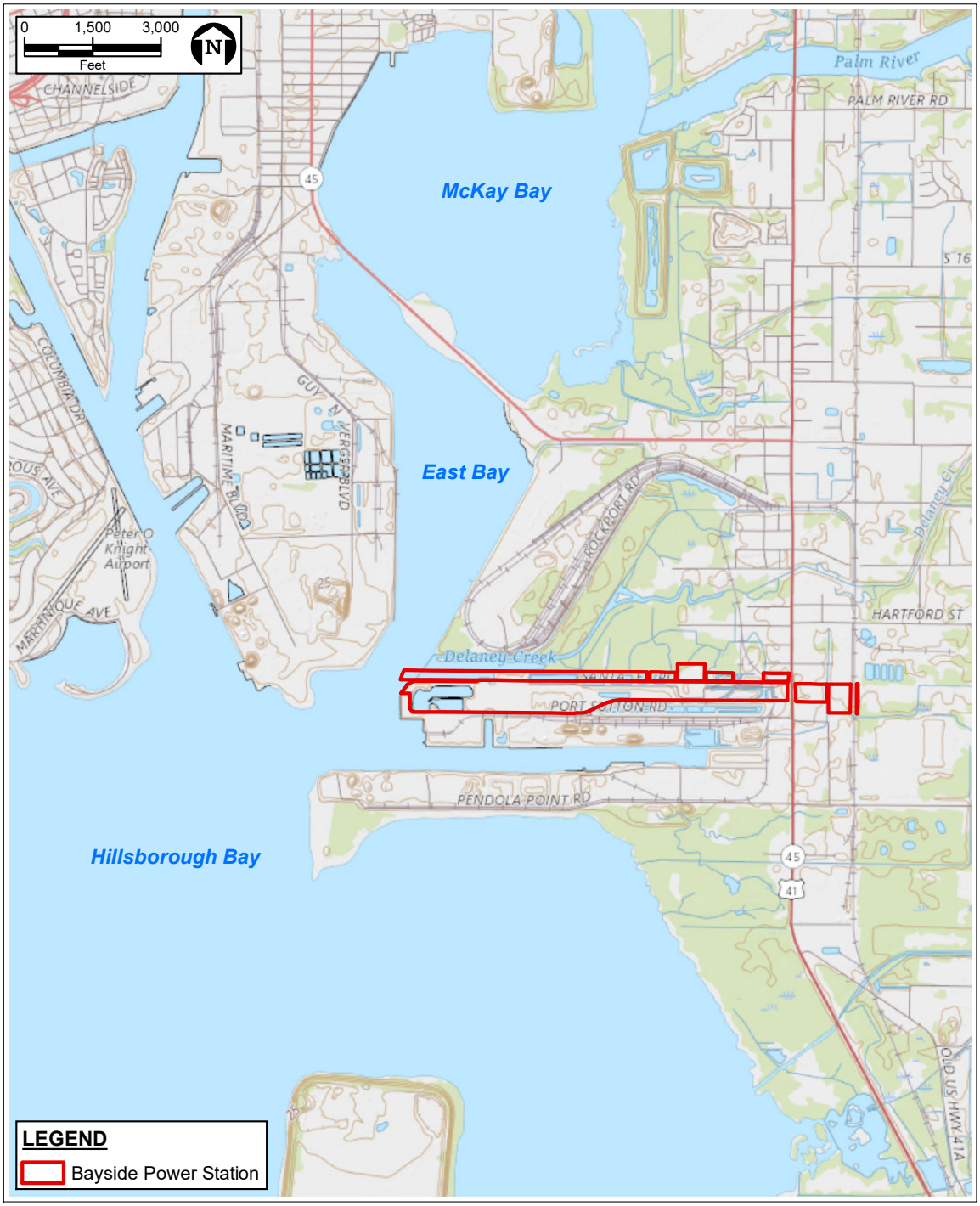


FIGURE 1-1.
SITE LOCATION MAP
BAYSIDE POWER STATION

Sources: USGS, 2017; ECT, 2018.

ECT Environmental Consulting & Technology, Inc.



FIGURE 1-2.
BAYSIDE POWER STATION SITE

Sources: FLDOT, 2014; TECO, 2016; ECT, 2016.

ECT Environmental Consulting & Technology, Inc.

TAMPA ELECTRIC COMPANY
DOCKET NO. 20210087-EI
STAFF'S FIRST DATA REQUEST
BATES PAGES: 4 - 968
FILED: JUNE 8, 2021

Table 1–1. Bayside Power Station Unit Status and Capacity

Gannon Units	Status	Power Generation Capacity (MW)	Intake Bay
1	Retired and dismantled		1
2			2
3			3
4			4
5	Bayside Unit 1	746	5
6	Bayside Unit 2	1,090	6

Source: TECO, 2018.

1.1 Regulatory Background

Bayside is subject to the final 316(b) rule for existing facilities, which regulates the location, design, construction, and operation of cooling water intake structures (CWISs) at existing facilities that hold a national pollutant discharge elimination system (NPDES) permit, have a design intake flow (DIF) greater than 2 million gallons per day (MGD) from Waters of the United States, and use at least 25 percent of that water exclusively for cooling purposes. The rule supersedes the Phase II rule, which was remanded in 2007, and the remanded existing facility portion of the previously promulgated Phase III rule. The final 316(b) rule for existing facilities became effective on October 14, 2014.

The 316(b) rule requires each affected facility develop and submit to the NPDES Director (i.e., Florida Department of Environmental Protection [FDEP]) specific submittals and supporting information to address compliance with the rule's performance standards. Submittal of 316(b) rule-related reports is generally coordinated with the facility's application to renew its NPDES permit. Bayside's NPDES permit (FL0000809) expires on August 27, 2018, and the 316(b)-related materials are due with the application to renew the NPDES permit, which is due 180 days before that date.

Existing facilities with a DIF greater than 2 MGD are required to submit a set of documents with their NPDES application for renewal to establish compliance with the rule, 40 CFR 122.21(r)(2) through (8):

- (2), Source Water Physical Data
- (3), Cooling Water Intake Structure Data
- (4), Baseline Biological Characterization
- (5), Cooling Water System Data
- (6), Chosen Method of Compliance with Impingement Mortality Standard
- (7), Entrainment Performance Studies
- (8), Operational Status

Facilities such as Bayside, with an actual intake flow (AIF) of greater than 125 MGD, are required to submit five additional documents to establish compliance with 40 CFR 122.21(r)(9) through (13):

- (9), Entrainment Characterization Study
- (10), Feasibility and Cost Study
- (11), Benefits Valuation Study
- (12), Environmental and Other Impacts
- (13), Peer Review of (r)(10), (r)(11), and (r)(12)

The sections of the document are numbered consistent with the relevant sections of 40 CFR 122.21(r), e.g., Section 2 addresses the rule's requirements as specified at 40 CFR 122.21(r)(2).

1.2 Executive Summary

This is the executive summary of the submittals prepared for Bayside under 40 CFR 122.21(r)(2) through (13) of the 316(b) existing facilities rule. These submittals constitute the balance of this document. Section 1.2.1 presents the provisional recommendations for impingement mortality (IM) best technology available (BTA) under the rule. Section 1.2.2 will summarize the information relevant to assessment of entrainment BTA on a best-professional-judgment (BPJ) basis, as required by 316(b) rule. Section 1.2.2.1 includes a brief summary of the analyses performed. The rule specifies site-specific factors available to the NPDES Director (i.e., FDEP)

in considering entrainment BTA on a BPJ basis. These factors include those FDEP "must"[1] consider per at 40 CFR 125.98(f)(2), as summarized in Section 1.2.2.2, and those FDEP "may" consider per 40 CFR 125.98(f)(3), as summarized in Section 1.2.2.3. Section 1.2.2.4 presents a summary of the entrainment BTA findings and recommendations.

1.2.1 Proposed IM BTA

Section 6.0 presents the information required under 40 CFR 122.21(r)(6) of the final rule. This section makes the recommendation for retrofit of the existing traveling water screens (TWSs) with modified TWSs and a fish return as defined at 40 CFR 125.92(s) and to achieve IM BTA consistent with 40 CFR 125.94(c)(5). Section 6.0 reviews the alternative impingement BTA approaches specified at 40 CFR 125.94(c) and selects modified TWSs as the most cost-effective and reliable approach for Bayside. Under the proposed approach, a fish return would be constructed that runs west approximately 2,200 feet (ft) to return impinged organisms to Hillsborough Bay beyond the area of influence (AOI) of the intake (see Figure 10-24).

Final selection of IM BTA will follow selection of entrainment BTA, and TECO's recommendation of IM BTA may change based on the nature of the entrainment BTA. This sequence is anticipated per the rule and is the subject of precedent.

The choice of IM BTA has the potential to affect the nature of the fine-mesh screen (FMS) that would be most effective at Bayside. Therefore, approaches to IM BTA were assessed in coordination with the potential to retrofit the intake with FMS for a potential approach to entrainment BTA, as described in Section 10.4. As explained in Section 1.2.3.4, TECO finds FMS has unfavorable net social benefits and does not recommend them as entrainment BTA. Despite this, in the event FMS are selected as entrainment BTA, TECO would propose to install a second set of TWSs equipped with FMS upstream of the existing coarse mesh screens. Such an intake configuration and its operation are consistent with successful operation of FMS at TECO's Big Bend Units 3 and 4. The low-pressure spray wash water and organisms returned from the FMS would be routed to the same fish return as the coarse mesh screens.

[1] FDEP may weigh the factors according to its discretion.

If modified TWSs and a fish return are selected as impingement BTA, the operation of the modified TWSs would be the subject of an optimization study to minimize post-IM as described at 40 CFR 122.21(r)(6)(i). This section of the rule suggests a study plan be submitted to FDEP as part of the 316(b) submittals. As discussed in Section 6.0, TECO proposes to develop such a study plan for FDEP's review after the approach to IM BTA is finalized and with the benefit of the more complete design of the modified TWSs to be installed. Such an approach to an optimization study plan has regulatory precedent and is consistent with the provisional nature of TECO's recommendation for IM BTA pending determination of entrainment BTA.

1.2.2 Information Relevant to Entrainment BTA

This section summarizes the analyses intended by the 316(b) rule to support FDEP in its assessment of entrainment BTA under a site-specific BPJ review. While information presented under 40 CFR 122.21(r)(2) through (8) often provides useful perspective on the entrainment BTA, this summary focuses on those reports prepared under 40 CFR 122.21(r)(9) through (13).

1.2.2.1 Summary of the Setting

Bayside consists of two combined-cycle generating units that withdraw up to 668.1 MGD from Hillsborough Bay for use as cooling water. The cooling water intake structure consists of two pumps and traveling water screens for each generating unit. Debris from the screens is washed off and disposed of offsite. The two combined-cycle units rely, in part, on multiple combustion turbines that do not require use of cooling water. Both units also employ a heat recovery steam generator and steam turbine for part of the unit's power output. In addition, Bayside has four combustion turbines that operate in simple-cycle mode with no association with steam turbines or cooling water demand.

Bayside withdraws cooling water from an intake canal that connects to Hillsborough Bay to the west. Hillsborough Bay is the northwestern arm of Tampa Bay, the largest open-water estuary in Florida, and constitutes approximately 10 percent of Tampa Bay's 400 square miles. The outlet to the Gulf of Mexico is located at the southwest corner of Tampa Bay. The watershed of Hillsborough Bay is highly developed and supports residences, commercial development, industry, agriculture, and a diverse and productive ecosystem.

The fish population within Hillsborough Bay has been classified as balanced and indigenous, consisting of a wide variety of forage and higher trophic level species, including both freshwater/brackish and marine species (Environmental Consulting & Technology, Inc. [ECT], 2013). Tampa Bay and Hillsborough Bay both support strong commercial and recreational fisheries as demonstrated by on-going monitoring by FWC.

1.2.2.2 Summary of Analyses

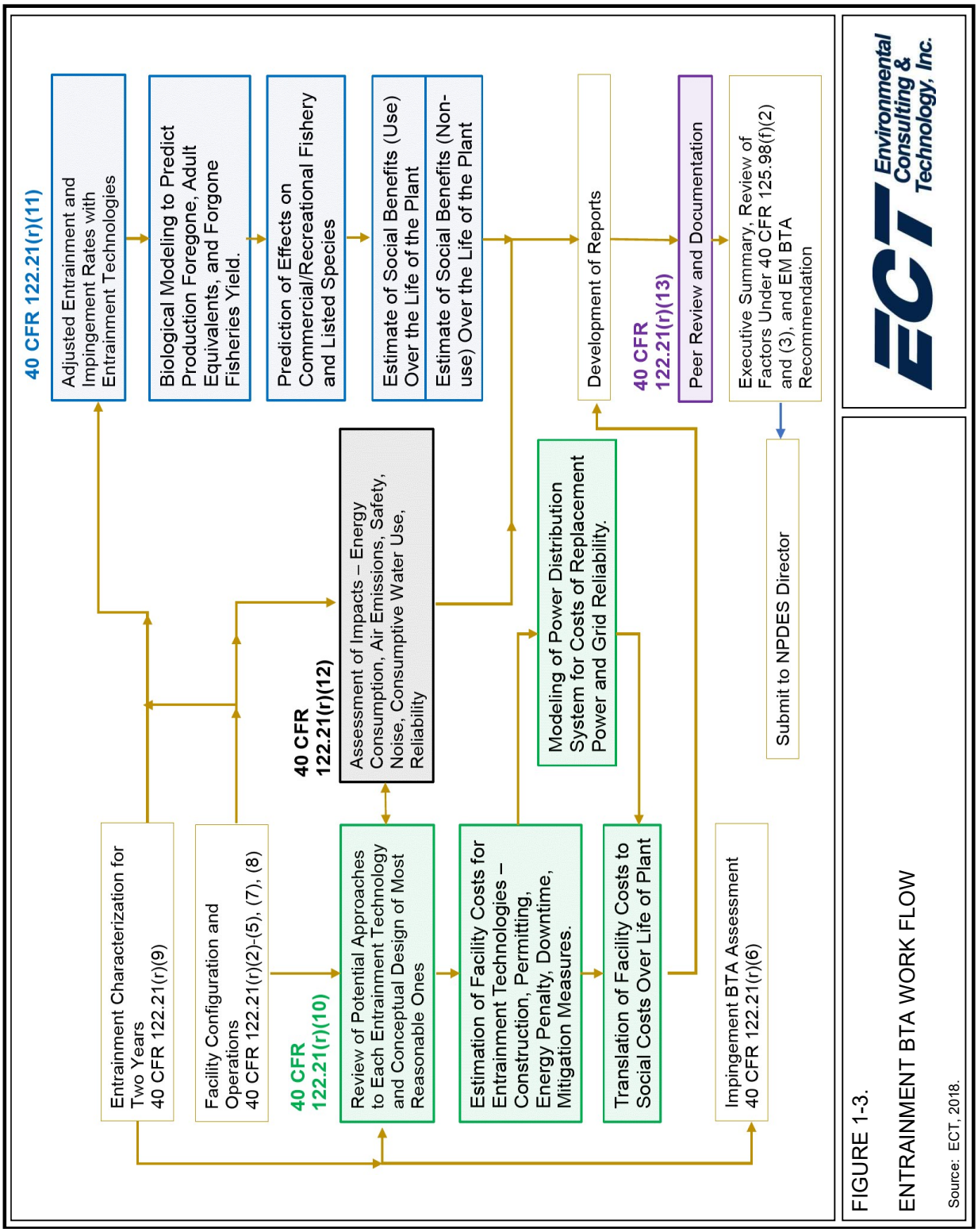
This section summarizes the approach used in each of the entrainment BTA-related reports. In the subsequent sections of the executive summary, the findings are summarized in the context of the entrainment BTA decision factors the rule provides to FDEP.

Figure 1-3 presents the sequence of analyses used in assessing entrainment BTA under the rule. The work flow includes integration of information on the configuration and operation of the facility, as well as measured rates of entrainment. The steps involved in assessing social costs, social benefits, and other environmental impacts are outlined along with the peer review process.

Entrainment Characterization Study—40 CFR 122.21(r)(9)

Following review by FDEP and staff at Florida Fish and Wildlife Conservation Commission (FWC), FDEP approved the use of entrainment data collected by TECO at Bayside under the 316(b) Phase II effort. TECO demonstrated the nature of the Phase II effort addressed the specific requirements of the entrainment characterization study, including level of taxonomic resolution, seasonal and diel patterns, etc. Section 9.0 summarizes the entrainment characterization.

For the purposes of estimating the benefits of potential entrainment reduction measures (Section 11.0), the Bayside-specific data were supplemented in two ways: (1) rates of entrainment of noncommercial, nonrecreational shellfish that might contribute to the forage base were estimated from the Phase II effort at a nearby facility located on Tampa Bay; and (2) rates of exclusion by FMS and rates of postexclusion survival were estimated for the relevant taxa based on performance studies performed at Big Bend Units 3 and 4.


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40 CFR 122.21(r)(11)
Adjusted Entrainment and Impingement Rates with Entrainment Technologies
Biological Modeling to Predict Production Foregone, Adult Equivalents, and Forgone Fisheries Yield.
Prediction of Effects on Commercial/Recreational Fishery and Listed Species
Estimate of Social Benefits (Use) Over the Life of the Plant
Estimate of Social Benefits (Non-use) Over the Life of the Plant
Development of Reports
40 CFR 122.21(r)(13)
Peer Review and Documentation
Executive Summary, Review of Factors Under 40 CFR 125.98(f)(2) and (3), and EM BTA Recommendation
Submit to NPDES Director
40 CFR 122.21(r)(12)
Assessment of Impacts – Energy Consumption, Air Emissions, Safety, Noise, Consumptive Water Use, Reliability
Modeling of Power Distribution System for Costs of Replacement Power and Grid Reliability.
Entrainment Characterization for Two Years 40 CFR 122.21(r)(9)
Facility Configuration and Operations 40 CFR 122.21(r)(2)-(5), (7), (8)
40 CFR 122.21(r)(10)
Review of Potential Approaches to Each Entrainment Technology and Conceptual Design of Most Reasonable Ones
Estimation of Facility Costs for Entrainment Technologies – Construction, Permitting, Energy Penalty, Downtime, Mitigation Measures.
Translation of Facility Costs to Social Costs Over Life of Plant
Impingement BTA Assessment 40 CFR 122.21(r)(6)
Environmental Consulting & Technology, Inc.
ECT
FIGURE 1-3.
ENTRAINMENT BTA WORK FLOW
Source: ECT, 2018.

Comprehensive Technical Feasibility and Cost Evaluation Study—40 CFR 122.21(r)(10)

The 316(b) rule requires the feasibility and costs of alternative entrainment measures be considered. This includes the potential quantification of the social costs of alternative entrainment control measures be estimated and compared to potential social benefits. This estimation proceeded in three steps:

- The set of potential entrainment mitigation measures was identified, and the most cost-effective[2] configuration of the measure was selected from the available options.
- Based on a conceptual design that considers site-specific constraints, the costs to the facility were estimated. These costs include those associated with construction, permitting, and increased operation and maintenance associated with the measure. Loss of generation output was also calculated based on, as appropriate for the technology, increased parasitic load, loss of generation efficiency, outage of the unit with construction, and potential for deratings.
- Social costs were estimated based on how increased facility costs are likely to be distributed to society over the life of the technology. Estimated social costs include those associated with increased price of power when lost generation must be replaced with a higher-priced source(s). Such social costs were estimated using TECO's existing power system model used to support system planning.

As required by the final 316(b) rule, TECO considered the feasibility and costs of three potential technologies that could reduce rates of entrainment: (a) retrofit to closed-cycle cooling, (b) use of FMS at the intake, and (c) use of alternative water supplies to replace some or all of the water used in the once-through cooling system. TECO also considered installation and use of variable-speed pumps (VSPs) to reduce the rate of water withdrawal and, therefore, entrainment. In discussions with TECO, FDEP did not identify other entrainment measures that should be considered at Bayside. Section 10.0 also provides a more general review of the available approaches to reduction of entrainment and, for each of the four technologies, summarizes available alternatives. Retrofit to closed-cycle cooling, FMS, and VSPs were all found to be

[2] In the context of the 316(b) rule and this document, most cost-effective means the lowest cost option technically feasible that yields a reliable and significant rate of entrainment reduction. The approach to this assessment (e.g., capturing relevant benefits while neglecting some costs) is discussed further in Section 10.0.

feasible at Bayside. No alternative water supply was found to provide a reasonable alternative to replace even a small fraction of Bayside's intake flow.

For the other three potential measures, a conceptual design, including location of the facility, facility costs, and schedule for design, permitting, and construction, was developed. The net present value (NPV) of the social costs of each technology was also developed based on the estimated start of the technologies' operation and retirement date for the facility.

Section 10.0 addresses each of the requirements of the rule at 40 CFR 122.21(r)(10).

For potential retrofit with closed-cycle cooling and VSPs, the rate of water use reduction was estimated as a means of estimating reductions in entrainment in Section 11.0. The conceptual design for all three measures was used to estimate any other environmental effects as described in Section 12.0.

Benefits Valuation Study—40 CFR 122.21(r)(11)

The goal of this section is the estimation of social benefits that would derive from additional controls on entrainment at Bayside. As with the estimation of social costs, this effort proceeds by way of a number of steps:

- The total rate of entrainment was estimated for the current cooling water system and its operation at Bayside. To illustrate the inter-annual variation in entrainment rates, the two years of Phase II entrainment data were considered separately. The rates were adjusted to reflect the recent 3-year AIF for the facility.
- Estimated decreases in the rates of entrainment for each technology were calculated. For potential retrofit with closed-cycle cooling or VSPs, reduction in entrainment was assumed to be equal to the reduction in cooling water flow. For FMS, the separate rates of organism exclusion and postexclusion survival were estimated based on empirical data available from historical studies at Big Bend Units 3 and 4. Separate empirical data were available for a variety of fish and shellfish taxa, as well as different life stages for the taxa. While the available data from Big Bend included mostly entrained organisms, in no case was any entrained organism excluded from the analysis. Instead, reasonable surrogates were selected from these and other biological parameters.

- Various rates of entrainment, including baseline and mitigated, were used to model the effects on commercial and recreational (C/R) harvest. This estimation was based on commonly applied population models to estimate the effects of direct reductions in entrainment and impingement of C/R species, as well as the effects of loss of forage associated with the entrainment of other finfish and shellfish. Changes in harvest were considered on a numerical and mass basis. Parameters used in population modeling were derived from the literature and also reflected the fishery of Tampa Bay and the nature of its C/R use. Uncertainty in selection of model parameters was considered and discussed.
- For each of the entrainment scenarios (baseline and potential reductions), change in social benefit associated with changes in C/R harvest were estimating using a random utility model calibrated to the use of the Tampa Bay fishery. This change is termed a "use" benefit and was calculated over the life the technology and beyond until any effects of the technology have dissipated. The total benefit over that period of time was expressed as an NPV.
- Nonuse benefits were also estimated based on EPA survey data on perception of the value of protected but unused fish and shellfish. Nonuse benefits were calculated for three separate regions: greater Tampa-St. Petersburg, the southeastern United States, and the United States as a whole. Nonuse benefits were also expressed as an NPV to facilitate combining with use benefits and comparing with social costs.

Non-water Quality Environmental and Other Impacts Study—40 CFR 122.21(r)(12)

The report under 40 CFR 122.21(r)(12) calls for assessment of other environmental impacts, including estimates of the level of impact. It also calls for discussion of reasonable efforts to mitigate the impacts. Section 12.0 describes the following changes associated with the potential entrainment mitigation measures in the order they are presented in the rule:

- Estimates of changes to energy consumption associated with parasitic load, loss of generation efficiency, and downtime associated with construction
- Estimates of increases in air emissions
- Estimates of changes in noise generation
- Discussion of potential impacts to safety
- Discussion of potential impacts to facility reliability

- Estimation of changes in water consumption
- Discussion of efforts to mitigate these adverse effects

While Section 12.0 addresses these issues for each of the candidate technologies, potential retrofit to VSPs and FMS are likely to exhibit relatively modest effects compared to closed-cycle cooling.

Sections 10.0 and 12.0 were developed with a high degree of coordination. Such coordination is necessary, because the conceptual approach to each technology is defined in Section 10.0, and that approach (e.g., nature of the cooling towers, their position, etc.) has an important effect on the level of impacts. As importantly, the quantitative engineering and costing analyses performed in Section 10.0 have been developed to provide estimates of the level of impacts as well as incorporate reasonable estimates for their mitigation. For example, changes in energy consumption and production were estimated in Section 10.0 as part of the conceptual design and were used to estimate both facility and social costs. Similarly, reasonable measures to ensure facility reliability with the potential installation of FMS (e.g., two sets of TWSs in series) and potential retrofit to closed-cycle cooling (e.g., selection of critical wet bulb temperature for cooling tower design) were incorporated into the costing exercise in Section 10.0.

Therefore, in many cases, Section 12.0 summarizes analyses performed in Section 10.0, while in other cases (e.g., changes in water consumption and noise), analyses independent of those in Section 10.0 are presented.

Peer Review—40 CFR 122.21(r)(13)

The reports prepared under 40 CFR 122.21(r)(10) through (12) were peer-reviewed by external experts as required by 40 CFR 122.21(r)(13). Three peer reviewers were employed consisting of qualified experts in power plant engineering, aquatic biology, and resource economics. The qualifications of the peer reviewers were submitted to FDEP for review and approval and were subsequently approved by FDEP. Consistent with the 316(b) rule's requirements, Section 13.0 provides the peer reviewers' qualifications.

Given Bayside is one of the first facilities developed by the ECT team to submit its 316(b) compliance package, peer review was sought at two different points in the project: (1) during the planning stage where peer review was obtained on the overall approach to the entrainment-related reports, including specifics on key technical issues; and (2) on the draft final documents as required by the final rule. Section 13.0 provides documentation of both phases.

The final rule requires TECO "provide an explanation for any significant reviewer comments not accepted." TECO addressed all comments by the reviewers with changes in the analyses and/or summary text. Section 13.0 provides the full set of peer reviewers' comments along with TECO's responses. The peer reviewers each concurred that TECO's responses addressed their comments.

1.2.2.3 Entrainment BTA Factors that *Must* Be Considered

In this section and the following one (Section 1.2.2.3), factors the rule defines as available, required and optional, to FDEP to assess entrainment BTA on a site-specific BPJ basis are considered. While each factor is considered separately for each of the three potential mitigation measures, in the interest of brevity, references to the relevant section(s) of the report are provided along with a summary of findings relative to that factor.

Based on the review of the findings presented in Sections 10.0 through 12.0, TECO believes the net social benefits (i.e., social benefits minus social costs) is the best and most complete factor for assessing potential retrofits to mitigate entrainment. This conclusion is based on a number of considerations:

- Some factors (e.g., thermal discharge effects, impacts on water consumption, and availability of alternative water supplies) are not significant at Bayside.
- Estimation of both social costs and social benefits integrate several other decision factors available to FDEP. For example, the social costs of potential retrofits directly incorporate:
  - Land availability.
  - Remaining useful plant life.
  - Mitigation of potential impacts to facility reliability.

- Similarly, social benefits directly incorporate:
  - Numbers and types of organisms entrained.
  - Remaining useful plant life.
  - Entrainment impacts on the water body.
- Monetizing social costs and social benefits facilitates their comparison on a common basis. Consistent with this policy objective, TECO has carefully estimated all social benefits (e.g., all entrained organisms are considered as affecting C/R fisheries either directly or indirectly; nonuse benefits are quantified) while omitting some social costs that are uncertain and/or difficult to estimate (e.g., monetization of the health effects of increased air emissions, noise, and potential safety effects). Therefore, estimates of net social benefits should be viewed as a likely overestimation.

Numbers and Types of Entrained Organisms

Sections 9.0 and 11.0 present the number and type of entrained organisms. In Table 9-4, annualized, flow-adjusted counts of entrained organisms are presented for two different years. This table is based on the observed rates of entrainment during the Phase II investigation and included enumeration of only entrained finfish and C/R shellfish. Section 11.0 developed estimates of the numbers of non-C/R shellfish entrained, and those are used to predict the effects of loss of forage on C/R species.

The rates of entrainment reflect the highly productive nature of Hillsborough Bay and are typical of rates observed at other estuarine plants in Florida as well as the density of entrainable organisms in those waters (see Section 9.2.1). In the first year of sampling, an estimated 4.83 × 109 organisms were entrained, and in the second year, 9.51 × 109 individuals were estimated to be entrained. Of these, 91.9 percent and 94.2 percent of organisms were eggs in Year 1 and Year 2, respectively. Members of the drum family (drums) and bay anchovy dominate the entrainment of finfish at 96.1 percent and 98.9 percent for Year 1 and Year 2, respectively. While C/R shellfish (i.e., shrimp, blue crab, and stone crab) represent a relatively small proportion of total entrainment, 3.4 percent and 3.7 percent of total entrainment in the 2 years, estimated rates of non-C/R shellfish are similar to those finfish (see Section 11.0). No federally or state-listed species was entrained in either of the two study years.

Rates of entrainment observed at Bayside reflect typical densities of ichthyoplankton and larval shellfish in the coastal waters of Florida. Proper perspective on the rates of entrainment require consideration of two important factors:

- The fishery of Hillsborough Bay has been stable and reflects a balanced indigenous population as demonstrated by review of long-term, quantitative surveys by FWC and endorsed by FDEP in its review of the Section 316(a) thermal demonstration for the Big Bend Power Station (see Section 4.2).
- The direct and indirect effects of the loss of these organisms is found, through modeling designed to overestimate effects, to result in a modest impact to the C/R fishery (see Section 11.0).

These two findings are related and result from the same factors: (1) there is a high rate of baseline mortality among the entrainable life stages of fish and shellfish, and (2) entrainment losses affect a modest portion of the resource in Hillsborough Bay. These factors have been integrated into the assessment of social benefits in Section 11.0.

The average annual entrainment losses of fish eggs are estimated at 6.69 billion eggs. To put this in perspective, an average-sized female black drum (*Pogonias cromis*, Family: Sciaenidae), an important part of the commercial and recreational fishery within Hillsborough County, has an annual egg production rate of 32 million (Atlantic States Marine Fisheries Commission [ASMFC], 2017)[3]. Thus, the average entrainment of eggs at Bayside represent the annual egg production of only 209 female black drum, a small fraction of the harvest and local population. Being that the population within Hillsborough Bay has been determined to be stable, the substantial fecundity of the species affected by entrainment losses at Bayside allows the populations to accommodate these losses.

The average total annual foregone fishery yield is estimated as 10,931 kilograms (kg). This number represents the annual total loss of biomass from the C/R finfish fisheries due to the entrainment losses, both direct and of forage, from the operation of Bayside. This estimate is designed to be an overestimate of these losses by employ of a number of modeling assumptions

[3] For black drum in the Atlantic states, recreational landings are roughly four times higher than commercial ones (ASMFC, 2017).

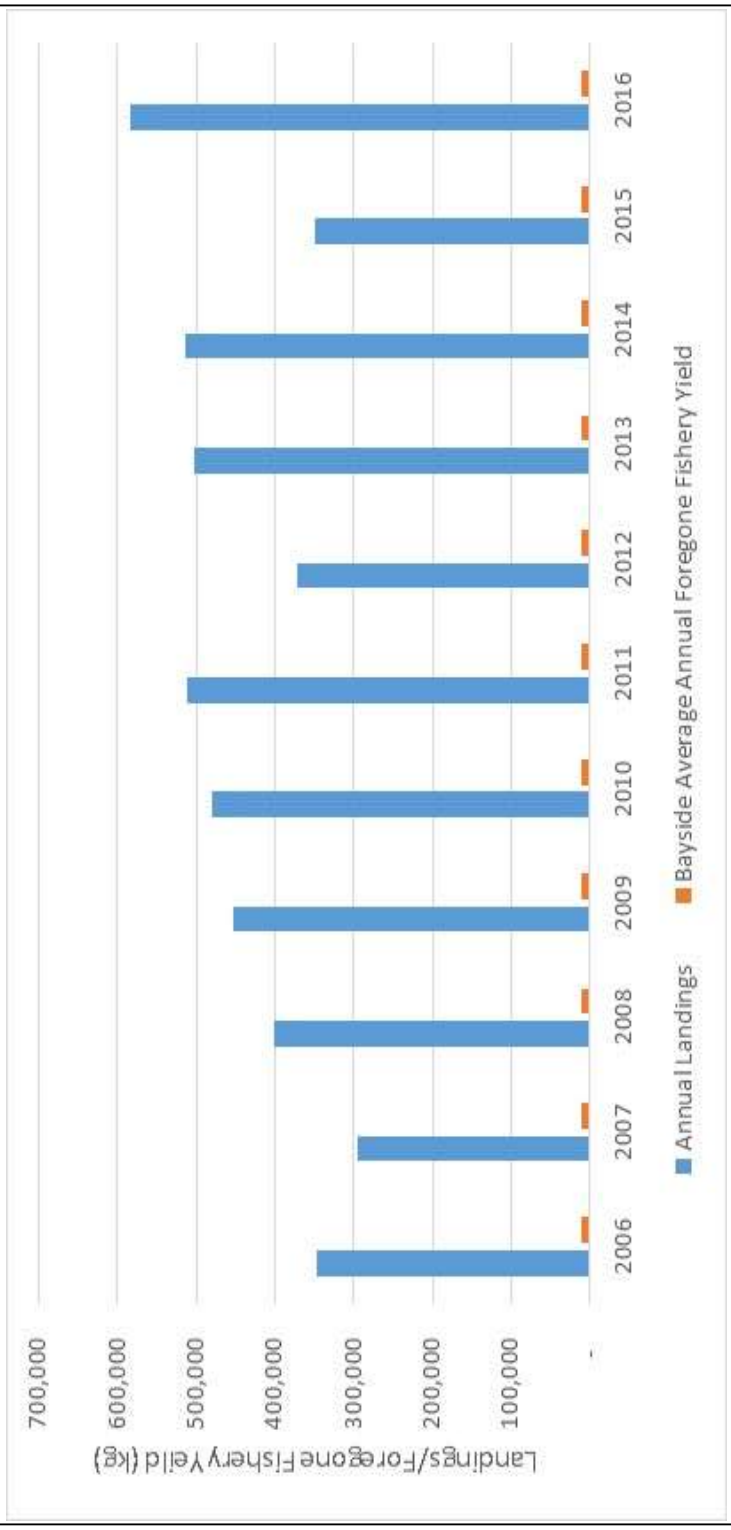
(i.e., entrainment results in 100-percent lethality, all entrainment losses affect C/R taxa and no others, and selection of various parameters to maximize the estimated effects on stocks). The annual commercial landings for Hillsborough County over the last 10 years range from 295,000 to 590,000 kg or an average of 443,000 kg. Thus, the foregone fishery yield due to the estimated entrainment rates at Bayside represents approximately 2.5 percent of the annual commercial yield of Hillsborough County (Figure 1-4).

The annual harvest estimate neglects recreational landings that are not available for the bay but, for many species including black drum,[3] are higher than the commercial landings. It also neglects commercial and recreational landings for Pinellas County, which includes the western half of Tampa Bay. Finally, the combined C/R landings represent a fraction of the total population in the bay consistent with the stable nature of the populations. Taken together, these factors indicate the effect of entrainment losses on the extant population is likely to be a small fraction of the 2.5 percent.

The potential for reduction in entrainment with the potential installation of entrainment mitigation measures has been quantified for the three feasible technologies. Potential retrofit to closed-cycle cooling was estimated to reduce entrainment by 85 percent, while application of VSPs was estimated to reduce entrainment by 4 percent and 27 percent, depending on the year considered.[4] Reduction of entrainment by FMS (i.e., the product of the rate of exclusion and postexclusion survival) was estimated based on empirical data available from Big Bend Units 3 and 4 and was estimated to be approximately 26 percent for finfish and 71 percent for shellfish. These rates will be used in the quantitative estimation of the social benefits of potential entrainment measures.

[4] The effectiveness of VSPs is uncertain and likely to vary substantially from year to year.

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FIGURE 1-4.

COMPARISON OF AVERAGE ANNUAL BAYSIDE TOTAL FOREGONE FISHERY YIELD AND ANNUAL TOTAL FINFISH COMMERCIAL LANDINGS OF HILLSBOROUGH COUNTY

Source: ECT, 2018.

In conclusion, TECO does not believe the number and type of organisms entrained provide a compelling basis under the final rule to evaluate additional entrainment measures. Importantly, no federally or state-listed species have been subject to entrainment. In addition, the rates of entrainment are not believed to affect the fishery of the bay. As noted previously, TECO believes quantification of the social benefits is the best means to evaluate the number and nature of entrained organisms in the context of the rule's goals.

Impacts of Changes in Emissions of Particulates and Other Pollutants

The entrainment BTA assessment considers changes in pollutant emissions to the atmosphere in Section 12.0. The increase in emissions is associated with two separate factors: (1) particulate emissions from the cooling tower associated with using salt water for make-up water, and (2) loss of generation capacity associated with parasitic loads and loss of efficiency and the resulting need to replace that power with other generator(s). As shown in Table 1-2, increased emissions are estimated to be far more substantial for potential retrofit to cooling towers than retrofit to either FMS or VSPs.

Table 1–2. Increased Air Emissions Associated with Potential Retrofits

Technology	Mechanical Draft Cooling Towers	0.5-mm Fine-mesh Ristroph TWSs	VSPs
Average increase in stack emissions (1,000 lb/yr):	Yes	Yes – minor	Yes
Carbon dioxide	88,205	675	9,797
Sulfur dioxide	0.6	*	0.1
Nitrogen oxides	17	*	1.1
Particulate matter	6	*	0.6
Emissions from the technology (tpy)			
Particulate matter	28.1 - 92.0	0	0
Particulate matter of 10 micrometers or less aerodynamic diameter	12.0 - 50.8		
Particulate matter less than 2.5 micrometers aerodynamic diameter	3.3 - 17.6		

Note: mm = millimeter.
lb/yr = pound per year.
tpy = ton per year.

*Too small to be quantified meaningfully.

Source: ECT, 2018.

Emissions of particulates, dominated by salts from sea water used as cooling tower make-up water, would result from the use of mechanical draft cooling towers (MDCTs) at Bayside. Particulate emissions are estimated to travel approximately 3,600 ft from the cooling towers and have the potential to result in damage to vegetation and infrastructure. Such effects would be somewhat mitigated by the industrial nature of the Bayside site and its environs.

Emissions associated with replacing lost generation would be dominated by carbon dioxide with far lower amounts of sulfur oxides, nitrogen oxides, and particulate matter. These increased emissions could occur on the site or at other fossil fuel-fired generators in the area. No attempt was made to monetize the social costs of these increased emissions.

Land Availability

The availability of space for infrastructure was considered in the assessment of entrainment BTA. While the Bayside site is constrained, space was identified for the placement of two sets of cooling towers, one for each unit, and the attending piping to transmit cooling water. While such a retrofit is believed to be feasible, the constrained site results in higher estimated installation costs, which affect the estimated social costs. The space constraints for FMS and VSPs were substantially less severe than for closed-cycle cooling but were also considered.

Remaining Useful Plant Life

TECO manages its generation fleet in an integrated fashion, including maintaining estimates of remaining facility life. For both units, the anticipated retirement date was assumed to be 2044,[5] the date used in TECO's system planning model. The potential social costs and social benefits were both modeled assuming the technology would be installed in a reasonable time frame and would remain in operation through that date of plant closure. Both social costs and social benefits were expressed as a NPV based on implementation, operation, and retirement time frames.

[5] Unit 1 is estimated to be retired in 2043. For simplicity, both units are assumed to be retired in 2044, which results in a slight overestimate of the potential benefits.

Social costs were estimated using TECO's power system model.[6] Not only does this model consider the facility's retirement date, it reflects the best available estimates of the relative dispatch priority of Bayside and the other generation assets based on their costs of generation, capacity, etc. Therefore, the social costs reflect the estimated rate of facility use in the future as well as the plant's lifetime.

Quantitative and Qualitative Social Benefits and Social Costs

TECO has developed rigorous estimates of both social costs and social benefits consistent with the final rule's requirements and subject to expert peer review. The estimation of social benefits included both use benefits (i.e., potential changes in C/R fishing stocks and their attending economic effects), as well as nonuse benefits.

TECO believes considering the net social benefits of a potential activity is a sound means of deciding whether the activity represents entrainment BTA on a BPJ basis. As noted in Section 1.2.2.5, the rule allows FDEP the discretion to "reject otherwise available entrainment controls if the costs of the controls are not justified by their associated benefits (taking into account monetized, quantified, and qualitative benefits), and the other factors discussed in the final rule." In the event the net social benefits of a proposed set of activities are negative (i.e., social costs outweigh social benefits), there is no reasonable justification for that activity to represent entrainment BTA. On the other hand, if the net social benefit is positive, the approach that provides for the greatest net social benefit or the greatest marginal net social benefit could be considered entrainment BTA.

The entrainment BTA assessment documented in Sections 9.0 through 13.0 has been summarized in Figure 1-5. In contrast to entrainment BTA, impingement BTA consists of a mandate to invest in one of a set of measures even if all of them have a negative net social benefit.

[6] The power system model is used to forecast future electricity demand, including seasonal variation, as well as match that demand to available sources of generation. As appropriate to the source of generation, the model integrates data on the efficiency, costs, fuel type, and rate of consumption and emissions. The model also incorporates constraints on transmission infrastructure that affect the priority of generation.

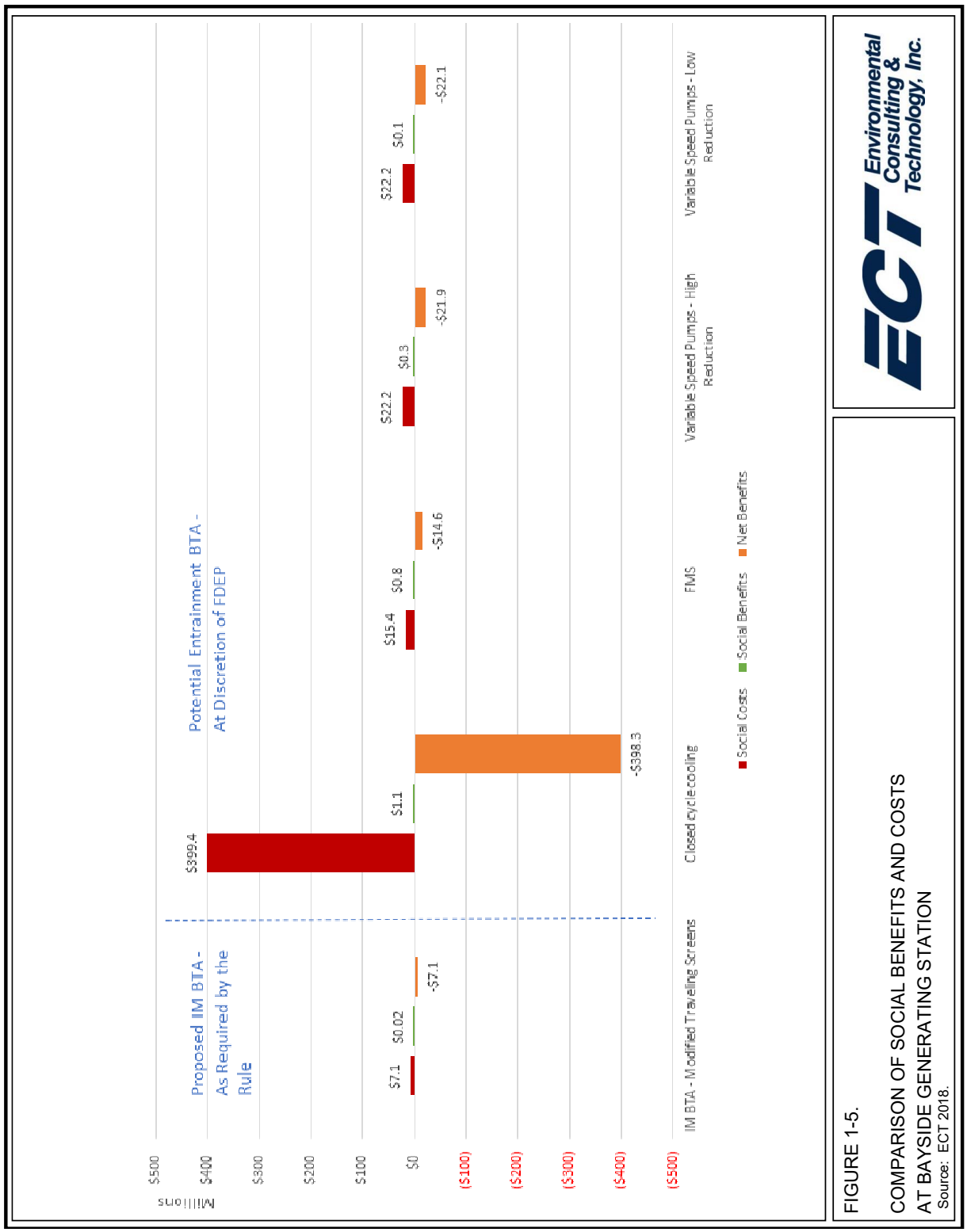


FIGURE 1-5.
COMPARISON OF SOCIAL BENEFITS AND COSTS AT BAYSIDE GENERATING STATION
Source: ECT 2018.

The proposed IM BTA measure, modified TWSs and a fish return, has been estimated to have a negative net social benefit. Despite this, TECO has concluded that modified TWSs and a fish return represent the least costly among the reliable and effective measures available.

Additional social costs spent on any of the three candidate entrainment measures would result in even more negative net social benefits. Retrofit to closed-cycle cooling has the most negative net social benefits, at ($398.3 million).[7] VSPs are considered an inferior alternative based on their social benefits being the lowest while having higher social costs than FMS. The FMS option has strong net negative benefits ($14.6 million) in the range of two times the negative net social benefit of meeting impingement BTA with modified TWS ($7.1 million).

Considering each of the three candidate entrainment measures results in more negative net social benefits, TECO concludes none of the three measures is justified as entrainment BTA on a BPJ basis, and the status quo at Bayside is BTA for entrainment (see Section 10.2.2.4).

1.2.2.4 Entrainment BTA Factors that *May* Be Considered

The following are the findings of the entrainment BTA assessment relative to the factors that FDEP may consider under 40 CFR 125.98(f)(3).

Entrainment Impacts on the Water Body

As discussed in Section 1.2.2.2, effects of entrainment on the fishery of Hillsborough and Tampa bays are believed to be modest based on the stability of the fishery and the presence of a balanced indigenous population. This was confirmed by quantitative modeling of the effects of entrainment, including direct losses of C/R species as well as losses of organisms that may serve as forage for C/R species.

Thermal Discharge Impacts

The thermal discharge from the Bayside facility has been reviewed and granted a variance under Section 316(a) of the CWA based on the finding it protects the balanced indigenous community in the receiving water. Based on this finding, TECO concludes reduction in the thermal loading

[7] For clarity, negative numbers are depicted in red font in parentheses, e.g., ($7 million).

associated with the potential retrofit to closed-cycle cooling would not have a meaningful beneficial effect to the nearby aquatic community.

TECO also notes Bayside is subject to an FDEP-approved manatee protection plan intended to ensure a reliable thermal refuge exists for manatees in the facility's thermal outfall. TECO notes that, given the state and federal protections on manatees, maintenance of the thermal refuge has high importance and high social benefits. If closed-cycle cooling was selected as entrainment BTA, the manatee protection plan would have to be amended to provide alternative means of maintaining the thermal refuge. While this would result in additional costs at the facility and social levels, the entrainment BTA assessment did not attempt to estimate those costs.

Flow Reduction with Earlier Unit Retirement

Bayside is the result of the repowering of two former coal-fired units in 2003 and 2004. As these units were repowered, four other units were retired. The effect was a reduction in DIF of 668 MGD or 50 percent of the existing facility's intake flow. Under 40 CFR 125.98(f)(3)(iii), reductions in flow associated with unit closure can only be credited if they occurred in the 10 years prior to the effective date of the rule. Therefore, TECO concludes the reduction in flow associated with unit closure is ambiguous with regard to credit toward entrainment mitigation.

On the other hand, the use of combined-cycle generation at the Bayside units greatly improves the efficiency of generation, particularly relative to cooling water use. The former Gannon units had a capacity of 1,272 MW with a DIF of 1,336 MGD, or 1.057 MGD per MW.[8] The repowered Bayside units have a capacity of 1,836 MW using a maximum of 668 MGD, or 0.36 MGD per MW, a decrease in cooling water flow of 69 percent on a MW basis.[9] In this case, the former Gannon units provide a benchmark of comparison for the new combined-cycle technology. A 65-percent reduction in intake flow translates to approximately the same level of decrease in entrainment and impingement.

[8] Analysis of the fisheries stock by FWC's Fisheries Independent Monitoring (FIM) program indicate populations of taxa most subject to entrainment were stable before the modernization and reduction in intake flow (see Section 11.0 for discussion of the trends in populations of the dominant entrained finfish).
[9] Bayside also employs four combustion turbines that are not associated with steam turbines. These generators do not use cooling water and, if considered in this calculation, would increase the flow reduction per MW relative to Gannon to 70 percent.

The preamble to the 316(b) rule calls for identification of combined-cycle cooling as an example of "existing impingement and entrainment technologies or operational measures." TECO believes it is appropriate to consider that combined-cycle technology greatly reduces the use of cooling water relative to other generation technologies when assessing whether entrainment BTA should involve substantial retrofit. In this context, the BPJ determination of entrainment BTA should consider the Bayside facility already reduces intake flow by 65 percent relative to facilities that rely solely on steam turbines.

Impacts on Reliability of Energy Delivery

Bayside represents a large and important asset in supplying electricity to TECO's customers. Maintenance of reliable energy delivery is an imperative of TECO and has been considered in the assessment of entrainment BTA approaches in three ways:

- During the conceptual design of potential measures, configurations were adjusted to improve generation reliability, including the assumption that two sets of TWSs would be necessary in series in the event FMS are pursued and the selection of a cooling tower critical wet bulb temperature that reduces the frequency of unit derating. Such design changes affect the capital and social costs estimated for the retrofit.
- The potential for VSPs to result in flow reduction and, therefore, entrainment reduction was discussed relative to the need to be able to dispatch the unit when required. VSPs represent a highly variable opportunity to reduce flow depending on environmental and market conditions. It was concluded that VSPs cannot result in a limitation on the facility's ability to run at full capacity.
- Power system modeling was performed to evaluate loss of generation capacity associated with retrofit in the context of the available electricity sources, both to ensure electricity was available and to estimate the social costs of securing it.

Potential retrofit of Bayside to include closed-cycle cooling would reduce the available electrical output, particularly during summertime periods, when electricity demand, and the price of electricity, is highest. Such reductions will have marginal effects on the reliability of energy delivery in TECO's service area.

Impacts on Water Consumption

Section 12.0 considers changes in water consumption for the three candidate technologies. Potential changes in water consumption with FMS and VSPs would be negligible. Water consumption in the form of increased evaporation with use of cooling towers was quantified and compared to the increased evaporation associated with discharge of heated effluent from the once-through cooling system. This analysis is dependent on ambient weather conditions and was performed monthly. Cooling towers were estimated to increase water loss by 25 to 64 percent, depending on the month. Such losses are unlikely to result in important ecological or water supply effects, given the source of cooling water is saline water from the bay.

Availability of Alternative Water Supplies

Based on a review of several potential sources of water in the area, no alternative source of cooling water was found to be feasible.[10] This assessment was based on the potential quantity of water available and the distance from the source to Bayside. Groundwater use in the greater Tampa area is severely limited and was found to be infeasible; the use of groundwater would exacerbate saltwater intrusion. Sources of gray water are generally a small fraction of Bayside's cooling water demand, have a strong potential to complicate discharge permitting, and would be costly to permit and construct the necessary conveyance systems.

1.2.2.5 Summary of Entrainment BTA and Recommendations

The 316(b) rule's summary of the requirements of the NPDES Director includes the following section under 40 CFR 125.98(f), Site-specific entrainment requirements:

> (4) If all technologies considered have social costs not justified by the social benefits, or have unacceptable adverse impacts that cannot be mitigated, the Director may determine that no additional control requirements are necessary beyond what the facility is already doing. The Director may reject an otherwise available technology as a BTA standard for entrainment if the social costs are not justified by the social benefits.

TECO has assessed the social costs and social benefits of potential retrofit to closed-cycle cooling, installation of FMS and an organism return system, and installation of VSPs. While all

[10] Bayside already uses treated contact stormwater and onsite sanitary wastewater as its source of service water.

three approaches are feasible, all three have negative net social benefits. The following are brief summaries of the three potential entrainment BTA measures.

Retrofit to Closed-cycle Cooling

The conceptual design of a closed-cycle cooling retrofit was performed for the steam-cycle portions of the two Bayside generating units. This design was used to estimate capital costs for the potential project as well as ongoing operation and maintenance costs. These costs were converted to social costs that would be borne by the rate payer. The anticipated reduction in cooling water flow was used to estimate changes in entrainment and impingement, which were converted to monetized social benefits.

Net social benefits over the anticipated lifetime of the plant and technology are estimated to be in excess of ($389 million) based on construction costs, increased price of power, as well as increased operation and maintenance costs. Due to loss of generation capacity associated with parasitic loads, decreased efficiency, weather-related de-rates, and construction downtime, air emissions from replacement power sources will increase. Use of saltwater cooling towers will also result in particulate emissions from the cooling tower. Use of cooling towers would also likely result in the need for amendment to the manatee protection plan at increased social cost, a factor that was not accounted for in this analysis.

Fresh water in sufficient quantity for evaporative cooling towers make-up water is not available at Bayside, making use of seawater necessary. Due to constraints in the Florida water quality standards, use of seawater will limit reduction in intake flow to a relatively low level: approximately 85 percent. This fact is reflected in the estimation of social benefits, and, while the social costs are far higher than FMS, the monetized social benefits are only approximately 10 percent higher than FMS. Therefore, retrofit to closed-cycle cooling should be rejected as entrainment BTA based on its highly negative net social benefits as well as its poor performance relative to other entrainment BTA approaches.

Potential retrofit to closed-cycle cooling is also associated with the highest level of unavoidable adverse effects, including increased noise, air emissions with attending effects, and loss of generation output with attending effects on system reliability. These effects, while real, have not

been monetized as a part of this effort. Therefore, the net social benefits are actually lower (i.e., more negative) than the figures provided previously.

Installation and Use of VSPs

Installation and operation of VSPs at Bayside would require replacement of the circulating water pumps, installation of variable-speed drives, and use of a climate-controlled facility for the drives. The capital and operation/maintenance costs of such an installation have been estimated. The potential to reduce intake flow was also examined based on 2 years of recent facility operation, as well as tentative operational rules based on the allowable change in temperature across the facility's condensers.

Estimation of the effectiveness of VSPs at reducing intake flow is both uncertain and variable from year to year. For the 2 modeled years, reduction in entrainment associated with flow reduction during the recruitment period was as low as 4 percent for one year and 27 percent for the other year. These potential reductions are subject to opportunities provided by electricity demand and water quality conditions in the context of the plant's thermal limitations. TECO cannot agree to a target flow reduction by VSPs, because the plant must be fully available to generate electricity as needed. On the other hand, while FMS and retrofit to closed-cycle cooling represent costly options, they would both allow the units to operate under a broad range of conditions.[11]

As shown in Figure 1-2, VSPs are estimated to result in a lower social benefit at a higher social cost than FMS. This estimated social benefit is highly uncertain and would likely be lower in some years. Therefore, VSPs were deemed unsuitable.

Installation and Operation of FMS

A FMS system has been operational at TECO's Big Bend Units 3 and 4 for many years.[12] The biological effectiveness of these screens has been well characterized, as have the costs of their

[11] Closed-cycle cooling would result in facility derating during hot and humid conditions based on the design parameters of the cooling towers.
[12] FMS were required at these two units as part of the site certification process associated with permitting and constructing Big Bend Unit 4. The decision to require FMS at the two units predates the current 316(b) rulemaking and did not rely on assessment of social costs and social benefits.

operation and maintenance. Importantly, the conceptual design of the FMS (i.e., seasonal deployment of screens upstream of the coarse mesh screens) was carefully considered and has been found to be important for reliable operation of the facility.[13] This information was used in the consideration of FMS at Bayside, including their conceptual design and estimation of social costs and social benefits.

The net social benefits for installation and operation of FMS is estimated to be approximately ($14 million) over the life of the technology. While this is the least adverse net social benefit of the three technologies, it is still a situation in which social costs outweigh social benefits by approximately 15 to 1. TECO believes this conforms to the rule's criteria of "social costs not justified by the social benefits."

1.3 Conclusion

TECO preliminarily selects modified traveling screens as the most cost-effective and reliable approach for IM BTA for Bayside. Under the proposed approach, a fish return would be constructed that runs west approximately 2,200 ft to return impinged organisms to Hillsborough Bay beyond the area of influence of the intake and the intake canal. The final selection of IM BTA will follow selection of entrainment BTA by FDEP, and TECO's selection of IM BTA may change based on the nature of the entrainment BTA. This sequence is anticipated by the rule and is the subject of precedent.

TECO believes none of the three entrainment mitigation technologies evaluated (closed-cycle cooling, VSPs, and FMS) are justified based on their relative social costs and social benefits. Alternative water supplies were found to be infeasible. While all three have some unavoidable adverse effects, potential retrofit to closed-cycle cooling would result in more adverse effects than the other two technologies. Not all of the social costs of these effects are monetized in this effort, but even the partial monetization of costs show they far outweigh the social benefits, and

[13] Consistent with the screens at Big Bend Units 3 and 4, the existing coarse-mesh screens at Bayside would be maintained to control debris during frequent servicing required by a FMS retrofit. To address impingement BTA, the coarse-mesh screens at Bayside are proposed for retrofit to modified TWS with a fish return consistent with 40 CFR 125.94(c)(5).

the net social benefits of the two remaining alternatives (i.e., VSPs and FMS) are substantially negative and, therefore, not justified.

Such a conclusion receives additional support by the fact that use of combined-cycle generation results in a reduction of intake flow by 65 percent on a MW-generation basis. Therefore, a facility with the same generation capacity that relied solely on steam turbine generation would use 65 percent more water and result in 65 percent higher rates of entrainment and impingement than Bayside. Consideration of this reduction is encouraged by the rule's preamble and supports the status quo at Bayside represents a reasonable entrainment BTA.

In conclusion, TECO believes none of the four entrainment mitigation technologies are justified based on their costs and benefits. Therefore, TECO respectfully requests FDEP reject the four potential technologies as entrainment BTA and conclude the existing design and operational measures, including use of combined-cycle technology, are entrainment BTA without additional measures.

1.4 References

Atlantic States Marine Fisheries Commission (ASMFC). 2017. Fisheries Management-Program overview. http://www.asmfc.org/fisheries-management/program-overview. Accessed December 20, 2017.

Environmental Consulting & Technology, Inc. (ECT). 2013. Biological Report in Support of 316(a) Thermal Variance Reissuance—Big Bend Power Station. Prepared for Tampa Electric Company, Tampa, Florida. October.

2.0 40 CFR 122.21(r)(2)—Source Water Physical Data

This section provides information on the physical characteristics of the source water body. The following is the text of 40 CFR 122.21(r)(2):

> Source water physical data. These include: (i) A narrative description and scaled drawings showing the physical configuration of all source water bodies used by your facility, including areal dimensions, depths, salinity and temperature regimes, and other documentation that supports your determination of the water body type where each cooling water intake structure is located; (ii) Identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods you used to conduct any physical studies to determine your intake's area of influence within the waterbody and the results of such studies; (iii) Locational maps; and, (iv) For new offshore oil and gas facilities that are not fixed facilities, a narrative description and/or locational maps providing information on predicted locations within the waterbody during the permit term in sufficient detail for the Director to determine the appropriateness of additional impingement requirements under §125.134(b)(4).

2.1 Description of Source Water Body—40 CFR 122.21(r)(2)(i)

Bayside withdraws cooling water from Tampa Bay, an estuary on the western coast of Florida. Bayside is located at 3602 Port Sutton Road, 3.5 miles south of Tampa, Florida, at the mouth of McKay Bay, in the upper portion of Tampa Bay/Hillsborough Bay, Hillsborough County. Tampa Bay is the largest open-water estuary in Florida, with 398 square miles of open water and 2,300 square miles of highly developed watershed that supports residences, commercial development, industry, agriculture, and a diverse and productive ecosystem. Average Tampa Bay basin precipitation levels are 44.77 inches per year. Hillsborough Bay is the permitted source water for Bayside and has a 1,281-square-mile watershed and 39.8 square miles of open water. The average water depth is 13 ft.

The area in the vicinity of Bayside is generally industrial and residential with some areas of undeveloped land. Tampa Bay and Hillsborough Bay receive runoff from McKay Bay, a shallow

urban estuary, which receives runoff from various tributaries and is located just north of the intake canal (Figure 1-1). McKay Bay receives a significant portion of runoff from Delaney Creek, a small tidal creek located north of the intake canal. The Delaney Creek watershed drains approximately 33.7 square miles from the eastern portion of urban and industrial Hillsborough County.

Hillsborough Bay and more than 100 tributaries enter Tampa Bay, including the Hillsborough, Alafia, Manatee, and Little Manatee rivers. In the undeveloped coastlines, shoreline vegetation consists largely of mangroves and marsh grasses, and bottom substrates are typically characterized as sand, mud, oyster beds, or a combination thereof. Large seagrass meadows also exist in numerous areas of the bay. Tampa Bay is connected to the Gulf of Mexico 20 miles southwest of Bayside.

Between 2001 and 2010, surface water temperatures at water monitoring stations within Tampa Bay ranged from 8.5 to 35.2 degrees Celsius (°C). The median temperature was 24.9°C (Environmental Protection Commission of Hillsborough County, 2014).

Median salinities within Tampa Bay between 2001 and 2010 at the surface, mid-depth, and bottom were 27.5, 27.7, and 28.0, respectively. The lowest salinity was observed in McKay Bay slightly north of Bayside's intake canal (Environmental Protection Commission of Hillsborough County, 2014).

Hillsborough Bay is designated as a Class III water body. This corresponds to uses such as recreation and propagation and maintenance of healthy and well-balanced fish and wildlife populations. The CWIS is located on part of East Bay by FDEP (water body identification No. 1584C). East Bay is considered impaired for dissolved oxygen (DO). Within Hillsborough Bay, DO was less than 4 milligrams per liter in more than 10 percent of the bay-wide samples from July to September (Tampa Bay Estuary Program, 2011). However, no total maximum daily load for East Bay nor any portion of Hillsborough Bay has been set (FDEP, 2017).

2.2 Characterization of Source Water Body—40 CFR 122.21(r)(2)(ii)

2.2.1 Hydrology

Tidal exchange is the principal mechanism for circulation of water within Tampa Bay. Currents are predominantly tidal within Tampa Bay with the exception of occasional wind-induced surface currents. The current velocity at the mouth of the bay can exceed 6 feet per second (fps) during maximum ebb tide.

Tidal currents within Hillsborough Bay are generally weak and variable, seldom exceeding 1 fps. Hillsborough Bay experiences a diurnal tide range of approximately 2.8 ft with average water levels of +1.4 ft at mean sea level (TECO, 1977). Table 2-1 summarizes the tidal datums at National Oceanic and Atmospheric Administration (NOAA) station 8726667, McKay Bay Entrance. McKay Bay experiences a mean tidal range of 1.82 ft and a great diurnal tide of 2.67 ft. Hillsborough Bay has the least tidal exchange of any portion of Tampa Bay because of its landward location and relatively closed nature (Tampa Bay Estuary Program, 2011).

Table 2–1. Datums of McKay Bay Entrance (NOAA Station 8726667)

Datums	McKay Bay (ft)
Mean higher-high water	2.94
Mean tide level	1.69
Mean sea level	1.71
Mean diurnal tide level	1.60
Mean lower-low water	0.27
North American Vertical Datum of 1988	1.93
Mean range of tide	1.82

Source: ECT, 2018.

The intake canal is partially fed by Delaney Creek, which experiences an average flow (period of record of 1984 to present) of 9.73 cubic feet per second (cfs) (U.S. Geological Survey [USGS],

2017)[14]. The maximum freshwater contribution to the intake canal by Delaney Creek is 588 cfs (September 1997) with a minimum of 0 cfs.

2.2.2 Geomorphology

The areas of the Tampa Bay basin considered in this report are Tampa Bay and the surrounding coastal regions to the north and east. Encompassing nearly 400 square miles, Tampa Bay is the largest open-water estuary in Florida. Because the bay averages approximately 12 ft in depth, man-made shipping channels have been dredged for safe passage of large ships. From the 1940s to the present, however, urbanization, dredge-and-fill, canal construction, airborne pollutants, and shoreline modification have threatened the bay's health. In addition, the over-pumping of groundwater and drought have resulted in saltwater intrusion and other aquifer impacts.

There are approximately 67 large lakes (more than 25 acres) and more than 200 small lakes in the basin. Many small lakes sampled are located in the lake-rich area just north of Tampa.

In recent years, groundwater over-pumping and drought have caused the shrinkage or disappearance of some area lakes, which are generally recharged by lateral groundwater seepage or by high groundwater levels.

Aquifers are permeable layers of sand, gravel, or rock that contain water. Unconfined aquifers are near the land surface and more easily affected by human activities. Confined aquifers lie below a layer of material, such as fine-grained clay, that generally limits the downward flow of water. Water in confined aquifers usually filters slowly through a layer of earth and is older and less affected by human activities.

The Bayside CWIS is connected to Hillsborough Bay (at the mouth of East Bay) by a canal on the north side of the power station. Hillsborough Bay is located below both the coastal lowlands of the Tampa area and the Hillsborough River Valley. The canal was originally dredged to a depth of approximately 45 ft and currently has a maximum depth of 25 to 30 ft. The canal

[14] The stream gauge is located approximately 3 miles inland from the bay; therefore, streamflow statistics are likely to under-represent the discharge to the bay.

transports cooling water for approximately 1,100 ft to the plant intake structure on the north side of Units 1 and 2. The average cross-sectional area of the canal is 2,407 square feet (ft^2).

Bayside's outfall discharges into a canal on the south side of the power station. The discharge canal is approximately 200 ft wide and 600 ft long and discharges into a dredged channel used for barge transportation (Figure 2-1). The channel is maintained at a depth of 34 ft at its center for a width of 200 ft (Figure 2-1). The dredged channel empties into Hillsborough Bay.

2.2.3 Determination of AOI

The AOI of a CWIS appears in three of the 40 CFR 122.21(r) sections of the Section 316(b) final rules for existing facilities:

- 40 CFR 122.21(r)(2), Source Water Physical Data, requires information on "the methods used to conduct any physical studies to determine the intake's area of influence in the waterbody and the results of such studies."
- 40 CFR 122.21(r)(4), Source Water Baseline Biological Characterization Data, states, "The study area should include, at a minimum, the area of influence of the cooling water intake structure."
- 40 CFR 122.21(r)(11), Benefits Valuation Study (in the final existing facilities rule), states, "The study would also include discussion of recent mitigation efforts already completed and how these have affected fish abundance and ecosystem viability in the intake structure's area of influence."

The Section 316(b) Phase I rule for new facilities states the AOI is "that portion of the source water body hydraulically affected by the cooling water intake structure withdrawal of water."

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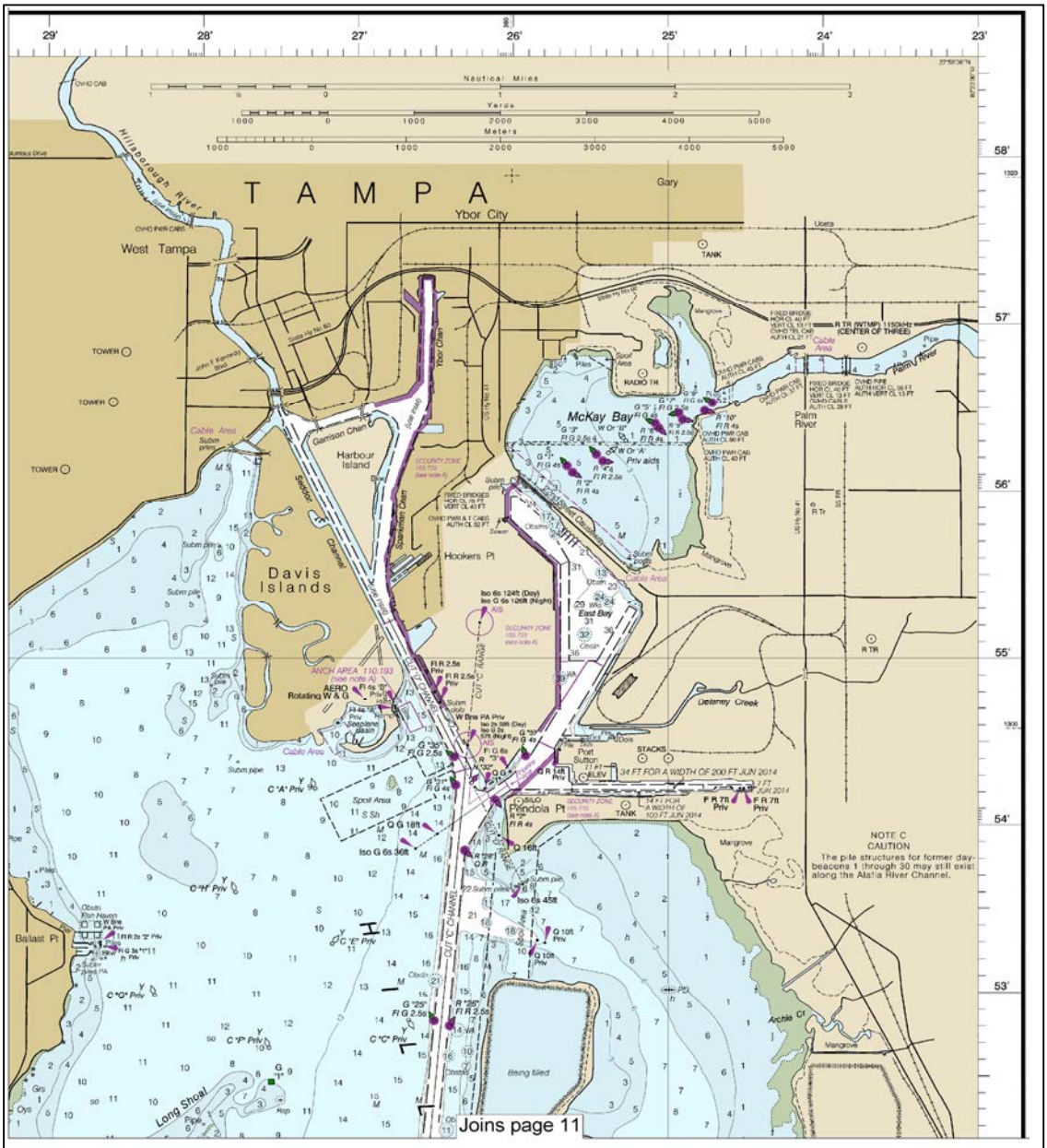


FIGURE 2-1.

NOAA CHART 11416

Source: NOAA, 2017.

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While this definition does not provide a clear means of estimating the AOI (e.g., the relevant threshold velocity), it is common understanding the AOI is that area of the source water body directly affected by the CWIS. Relative to impingeable organisms, generally juvenile and adult fish and shellfish, the concept is somewhat more concrete. It could be assumed it is the point at which the organism is no longer capable of overcoming the forces of water withdrawal and impinges upon an intake screen (Electric Power Research Institute [EPRI], 2007). This would be highly dependent on the swimming capabilities of the species and its life stage, size, and general health conditions, a point noted by EPRI in previous research on the relationship between intake approach velocity and the occurrence of impingement (EPRI, 2000).

EPA considers a 0.5-fps through-screen velocity to be a *de minimis* value for the probability of impingement, which means a fish can swim freely in a flow at this velocity and avoid impingement (in fact, the studies showed a 1.0-fps threshold was protective, but it was halved as a safety factor). As a compliance option for IM BTA in the 316(b) final rule for existing facilities, EPA indicates there is no need for any type of impingement protection, including IM studies, if the maximum design or actual maximum through-screen velocity of the CWIS is 0.5 fps or less, per 40 CFR 125.94(c)(2) and (3). Under these conditions, it is considered the facility has met the performance standards for IM. Therefore, the 0.5-fps contour for velocities induced by the CWIS delineates the CWIS's AOI for impingement.

Entrainable organisms have limited to no swimming capabilities and are passively transported by water currents by definition. The velocity threshold for the impingement AOI, 0.5 fps, is not necessarily relevant, since any free-floating particle may be drawn into the intake. In this case, the Phase I rule's criterion of "likely to be drawn" into the intake is applied by finding the boundary at which the intake-induced water velocity is estimated to be equal to ambient current speeds. In this case, two ambient current speeds are considered: 0.1 fps and 0.3 fps (Golder, 2009).

As previously stated, the impingement AOI is accepted to be the approximate area within the 0.5-fps, intake-induced velocity contour in the vicinity of the CWIS (Ohio Environmental Protection Agency, 2005). Similar calculations are performed for induced velocities of 0.1 and 0.3 fps to assess the potential AOI for entrainment.

The radius of AOI (RAOI) for a shoreline CWIS (180-degree arc angle at the mouth of the intake canal) is estimated as follows:

$$Q_i = \pi \times R_{AOI} \times d \times V$$

where: Q_i = intake flow (cfs).
R_{AOI} = radius of area of influence (ft).
d = water depth at R_{AOI} (ft).
V = threshold velocity (i.e., either 0.1, 0.3, or 0.5 fps).

Table 2-2 summarizes the results of determination of RAOI using three threshold velocities (0.1, 0.3, and 0.5 fps) using the maximum permitted intake volumes of 1,346.3 MGD (2,083.03 cfs). The assumed mean depth within the AOI is 25 ft in all scenarios (see Figure 2-1 and Table 2-1).

Table 2–2. Calculation of RAOI as Various Ambient Velocities

Parameter	Variable	Units	Scenarios		
			1	2	3
Design intake flow	Q_i	cfs	2,083	2,083	2,083
Mean depth at radius RHZI	dr	ft	25	25	25
Ambient mean velocity in Hillsborough Bay	Vam	fps	0.1	0.3	0.5
AOI radius from intake	RAOI	ft	265	88	53

Source: ECT, 2018.

The location of the AOI-line is an estimate. Varying withdrawal amounts, tidal stages, and changes in bottom elevations (associated with sediment deposition and dredging activities) will affect its calculated location (Figure 2-2). The maximum RAOI value associated with maximum day average design intake flow of 1,346.3 MGD is 265 ft from the end of the intake canal at a mean ambient velocity of 0.1 fps. The minimum RAOI value associated with maximum day average design intake flow is 53 ft at a mean ambient velocity of 0.5 fps. Consequently, at a given intake flow condition, inside the AOI-line defined by a mean ambient velocity of 0.5 fps, the probability of hydraulically influencing nonmotile organisms is high most of the time.

M:\acad\2016\160580\0100\Bayside_AoInfluence.mxd NAD 1983 StatePlane Florida West FIPS 0902 FeetTransverse Mercator unash 3/30/2017 9:46:44 AM



FIGURE 2-2.
AREA OF INFLUENCE AT VARIOUS TARGET AMBIENT VELOCITIES
BAYSIDE 316 (b) COMPLIANCE SUBMITTAL REQUIREMENTS

Sources: FLDOT, 2014; TECO, 2016; ECT, 2016.

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Furthermore, at a given intake flow condition, outside the AOI-line defined by a mean ambient velocity of 0.l fps, the probability of hydraulically influencing nonmotile organisms is low. Between these velocities, the probability of hydraulically influencing nonmotile organisms is moderate and variable.

For entrainment, since the canal is a dead-end inlet, all nonmotile organisms that enter the intake canal would likely be susceptible to entrainment at the CWIS. As such, the entire intake canal would be considered within the AOI for entrainment.

As previously described, the rule calls for the development of the AOI as a means of estimating the geographic area potentially affected by the intake and identifying the organisms within that geographic area affected by impingement and entrainment. When considering the organisms potentially affected by impingement and entrainment, we have included those that occur in the upper Hillsborough Bay, well beyond the estimated AOI.

2.3 References

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Florida Department of Environmental Protection (FDEP). 2017. Impaired Water, TMDLs, and Basin Management Action Plans Interactive Map. http://fdep.maps.arcgis.com/home/webmap/viewer.html?webmap=1b4f1bf4c9c3481fb2864a415fbeca77. Accessed March 1, 2017.

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Tampa Electric Company (TECO). 1977. Big Bend Station 316 Demonstration.

U.S. Geological Survey (USGS). 2017. Stream Flow Record for USGS Gauge No. 02301750, Delaney Creek Near Tampa, Florida.

3.0 40 CFR 122.21(r)(3)—CWIS Data

This section includes information on the CWIS that is used to determine potential for impingement and entrainment at the facility, including a description of the structures and their location in the water body, as well as daily and seasonal operations and intake flows. The text of 40 CFR 122.21(r)(3) is as follows:

> Cooling water intake structure data. These include: (i) A narrative description of the configuration of each of your cooling water intake structures and where it is located in the water body and in the water column; (ii) Latitude and longitude in degrees, minutes, and seconds for each of your cooling water intake structures; (iii) A narrative description of the operation of each of your cooling water intake structures, including design intake flows, daily hours of operation, number of days of the year in operation and seasonal changes, if applicable; (iv) A flow distribution and water balance diagram that includes all sources of water to the facility, recirculating flows, and discharges; and, (v) Engineering drawings of the cooling water intake structure.

3.1 Narrative Description of CWIS—40 CFR 122.21(r)(3)(i)

Bayside uses a once-through cooling system withdrawing water from Hillsborough Bay through an intake canal (Figure 1-2). The canal is 25 to 30 ft deep and actively maintained at those depths. The canal transports cooling water for approximately 1,100 ft to the CWIS on the north side of Units 1 and 2. The average cross-sectional area of the canal is 2,407 ft^2.

Bayside has one CWIS with six bays (one for each of the original steam turbines) located at 27° 54' 30.65" north, 82° 25' 22.03" west. The CWIS extends approximately 90 ft into the intake canal and is oriented perpendicular to the length of the canal. Historically, each bay had two circulating water pumps for a total of 12 pumps (Table 3-1). Currently, only Bays 5 and 6 remain and serve the steam turbines of Bayside Units 1 and 2 for once-through, noncontact cooling water (Table 3-1).

Table 3–1. Bayside Station Circulating Pump Capacities

Intake Number	Purpose	Capacity*	
		gpm	MGD
Gannon (inactive)			
Gannon 1 (inactive)	Once-through cooling	105,000	151.2
Gannon 2 (inactive)	Once-through cooling	105,000	151.2
Gannon 3 (inactive)	Once-through cooling	127,000	182.88
Gannon 4 (inactive)	Once-through cooling	127,000	182.88
	Subtotal inactive	**464,000**	**668.16**
Bayside (active)			
Unit 1	Once-through cooling	176,000	253.44
Unit 2	Once-through cooling	240,000	345.60
	Subtotal active	**416,000**	**599.04**
TOTAL		**880,000**	**1,267.20**

Note: gpm = gallon per minute.
MGD = million gallons per day.

*Reflects total rated capacity of two pumps per intake.

Source: TEC, 2018.

Units 1 and 2 each utilize two circulating water pumps with a capacity per pump of 126.72 MGD and 207.35 MGD, respectively, for a total of four circulating water pumps (Table 3-1). The intake structure that services Units 1 and 2 has four 7.5-ft-wide intake openings and contains a TWS in each opening. The TWSs are double-entry/single-exit, ⅜-inch mesh rotating TWSs (Figure 3-1). The description of the TWS provided is specifically for Unit 2; however, a similar configuration is present at Unit 1 with the only difference being a smaller circulating pump. The TWS has a basket frame measuring 7 ft wide by 18 inches high (Figure 3-1). The screen mesh dimensions for each basket are estimated to be 6 ft, 10 inches wide by 16 inches high (i.e., 9.1 ft^2). The percent open area for a screen with ⅜-inch square openings and No. 12 (0.104-inch diameter) mesh wire is 61.3 percent. The screens are suspended from a concrete platform at the surface and are thus not confined within a well (no-well design). The bottom of the screens is located at 21 ft, 5 inches below mean low water. The channel depth below the screen was excavated to 24.5 ft below mean low water (Section 5.0).

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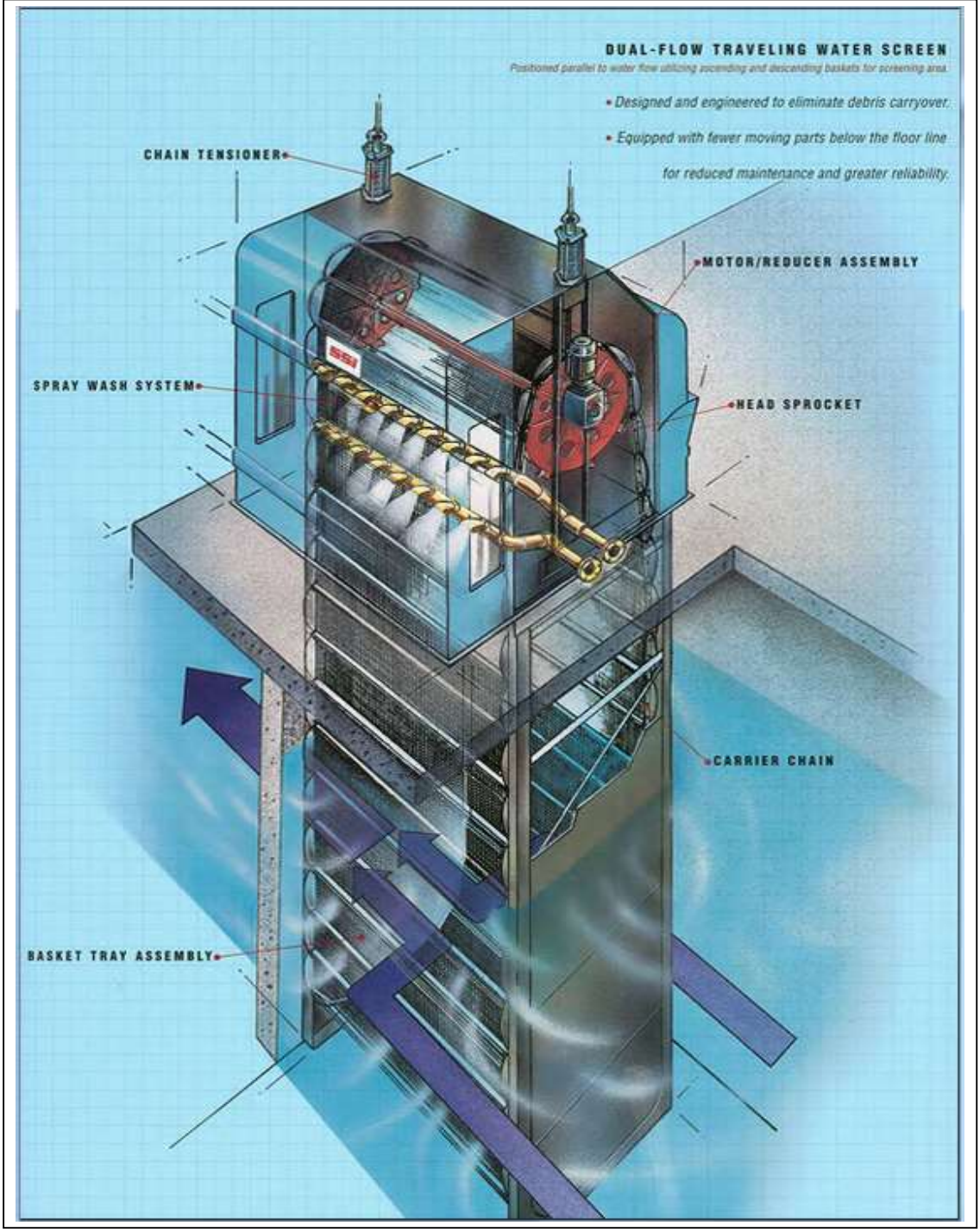


FIGURE 3-1.

TYPICAL TWS ASSEMBLY SHOWING
FLOW-THROUGH COARSE MESH SCREEN
Source: SSI, 2017.

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The screens are equipped with a spray wash system that washes debris and impinged organisms into a collection trough. Wash water for the TWSs is supplied by two screen wash pumps located in the intake house. Each pump is rated at 288 gallons per minute (gpm) at 100 pounds per square inch (psi). Debris and impinged organisms are taken offsite for disposal. The rotating screens are driven by a 1.5-horse power (hp), 1,800-revolutions-per-minute, 460-volt motor. Each screen is designed to start at 12 ft per minute at a head loss of 2.5 ft at maximum water level.

Bayside is permitting with a design intake capacity of 1,346 MGD. Based on operating data (circulating pump logs) for years 2014 through 2016, the maximum intake flow for Units 1 and 2 was 599.04 MGD (Figure 3-2).

Bayside's NPDES Permit No. FL0000809 authorizes operation of a once-through cooling water system that uses water from Hillsborough Bay. The cooling water is routed through plant condensers and then discharged back to Hillsborough Bay via a common discharge flume on the south side of the station (Figure 1-2).

3.2 CWIS Latitude and Longitude—40 CFR 122.21(r)(3)(ii)

The CWIS coordinates are latitude 27° 54' 30.65" north and longitude 82° 25' 22.03" west.

3.3 Description of CWIS Operation—40 CFR 122.21(r)(3)(iii)

Bayside and its cooling water system are designed for year-round, 24-hours-per-day operation, with the exception of down time due to maintenance outages. When the facility is producing electricity, the intake structure will generally be fully operational. The cooling water demand will change based on level of generation and weather conditions. Design intake capacity for Bayside is 1,267.2 MGD at full build-out. The gas-fueled, electric generating units have a combined nominal generating capacity of 1,836 MW (Unit 1 nominal 746 MW and Unit 2 nominal 1,090 MW). The facility is also equipped with natural gas-fired peaking units (Bayside Units 3 through 6), each with a nominal generating capacity of 62 MW (258 MW total). They consist of two simple-cycle combustion turbines coupled to one common generator per unit.

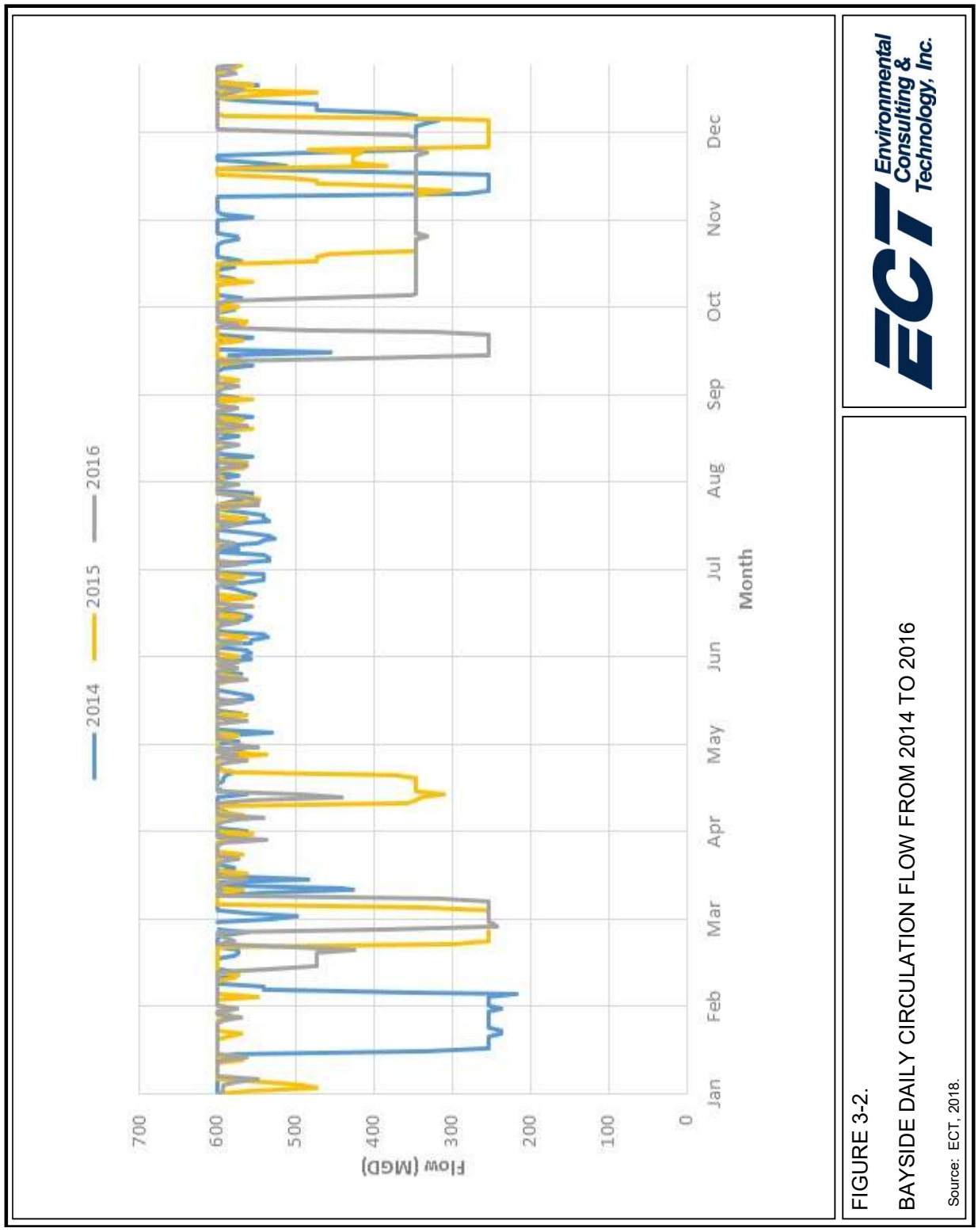


FIGURE 3-2.

BAYSIDE DAILY CIRCULATION FLOW FROM 2014 TO 2016

Source: ECT, 2018.

The combined total generation capacity is approximately 2,084 MW. However, cooling water from the bay, provided through the CWIS, is utilized for Units 1 and 2 only. Table 3-2 presents the net capacity factors and annual net generation for Units 1 and 2 only.

Table 3–2. Bayside Net Capacity Factors and Annual Net Generation

Year	Net Capacity Factor* (%)		Annual Net Generation† (MWh)	
	Unit 1	Unit 2	Unit 1	Unit 2
2012	49.30	47.06	3,157,085	3,990,147
2013	49.19	49.73	3,150,088	4,216,857
2014	42.17	49.20	2,700,690	4,172,225
2015	57.72	62.87	3,696,001	5,331,107
2016	51.88	54.17	3,321,868	4,593,164
5-Year average	**50.05**	**52.60**	**3,205,147**	**4,460,700**

Note: MWh = megawatt-hour.

*Calculated as annual net generation (MWh) for all unit components (combustion turbine and steam turbine) divided by nameplate capacity.
†Calculated as sum of MW by the hour for each year for all unit components (combustion turbine and steam turbine).

Source: TEC, 2018.

Based on operating data (circulating pump logs) for years 2014 through 2016, the maximum daily intake flow for Units 1 and 2 was 599.04 MGD (Figure 3-2). The average daily intake flow for the same time period is 538.5 MGD.

3.4 Intake Flow—40 CFR 122.21(r)(3)(iv)

Figure 3-3 presents a water balance diagram for the current operations.

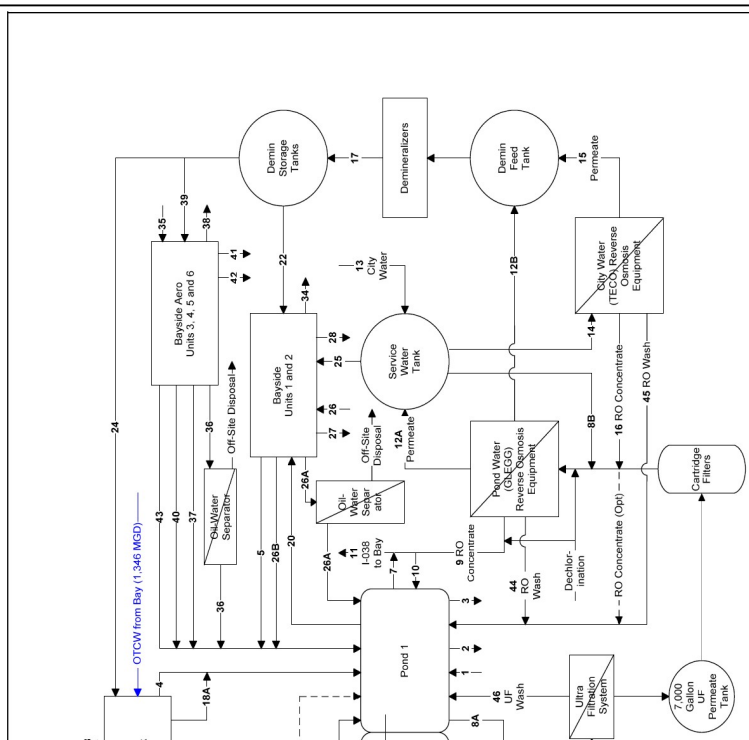
3.5 CWIS Engineering Drawings—40 CFR 122.21(r)(3)(v)

Figures 3-4 through 3-7 present the available engineering drawings of the CWIS.

3.6 References

Screening Systems International, Inc. 2017. Dual Flow Traveling Water Screens. http://www.screeningsystems.com/products/Dual-Flow. Accessed March 23, 2017.

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Reference Number	Stream Description	Average Conditions (gpd)	Wet Conditions (gpd)
1	Rainfall into Ponds	41,475	89,048
2	Evaporation from Ponds	26,861	16,874
3	Percolation from Ponds	20,015	20,015
4	Gannon Non-Contact Rainfall to Pond 1	137,779	411,731
5	Bayside to Pond 1	70,775	23,763
7	Pond to NPDES Outfall IO-38	132,250	200,000
8A	Feed to Pond Water RO 1st Pass from UF	1,500,000	1,875,000
8B	Service Water to Pond Water RO 2nd Pass	655,690	500,000
9	Pond Water RO Concentrate	1,477,600	1,659,750
10	Pond Water RO Concentrate to Ponds	1,416,000	1,509,750
11	Pond Water RO Concentrate to NPDES IO-38	61,600	150,000
12	Total Pond Water RO Permeate	731,138	850,000
12A	Pond Water RO Permeate 1st Pass	600,000	750,000
12B	Pond Water RO Permeate 2nd Pass	131,138	100,000
13	City Water Supply	470,000	300,000
14	City Water RO Feed	422,400	422,400
15	City Water RO Permeate	316,800	316,800
16	City Water RO Concentrate	115,200	115,200
17	Demineralizer to Demin Storage Tanks	476,738	532,000
18	Rainfall to Gannon	169,784	480,446
18A	Gannon Contact Rainfall to Pond 1	32,005	68,715
19	Gannon Cooling Tower Losses	120,000	100,000
20	Recycle Water to Bayside	50,000	25,000
21	Coal Field to Gannon	54,036	116,016
22	Demin Water to Bayside Power Block (Units 1 and 2)	300,000	175,000
23	Gannon Power Block Miscellaneous Losses	55,000	55,000
24	Demin Water to Gannon Power Block	176,738	357,000
25	Makeup Water to Bayside	68,710	118,000
26	Rainfall to Bayside	184,185	395,445
26A	Bayside Contact Rainfall to Pond 1	4,185	8,985
26B	Bayside Non-Contact Rainfall to Pond 1	180,000	386,460
27	Bayside Cooling Tower Evaporation	157,257	143,346
28	Bayside CT Evap Cooler Losses	10,000	0
29	Rainfall on Coal Field	62,827	134,890
30	Coal Field Percolation	628	1,349
31	Coal Field Evaporation	8,163	17,525
33	Pond 4 to RO (Rarely Used Option)	0	0
34	Bayside Power Block Miscellaneous Losses	134,863	134,876
35	Rainfall to Aero Units	73,750	158,341
36	Aero Contact Rainfall to Pond 1	3,750	8,051
37	Aero Non-Contact Rainfall to Pond 1	70,000	150,290
38	Aero NO_x Water Injection Losses	158,219	158,219
39	Demin Water to Aero Units	158,219	158,219
40	Aero CT Evaporative Cooling Return to Pond 1	5,434	5,434
41	Aero CT Evaporative Cooling Losses	21,415	21,415
42	Aero Units Miscellaneous Losses	10,000	10,000
43	Aero Compressor Washdowns	26	26
44	Pond Water RO Wash	86	86
45	City Water RO Wash	86	86
46	Ultrafiltration Wash	167	167

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Industrial Wastewater Permit FLA184713
Permit Renewal Application, January 2016

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FIGURE 3-3.

WATER BALANCE PROCESS FLOW DIAGRAM—AVERAGE AND WET CONDITIONS WATER USE

Source: TECO, 2016.

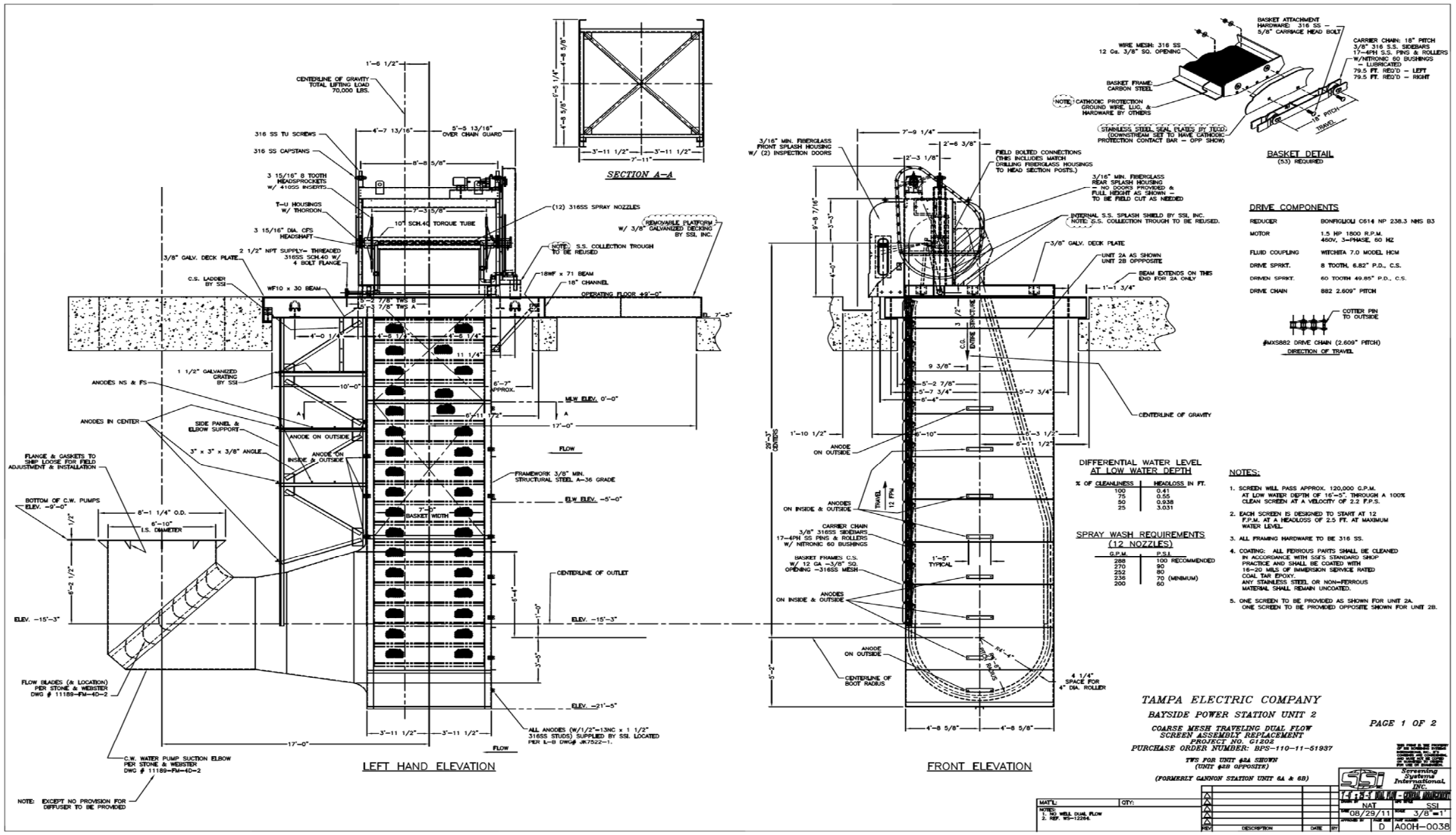


FIGURE 3-4.

BAYSIDE UNIT 2 COARSE-MESH DUAL-FLOW TWS ASSEMBLY

Source: TECO, 2011.

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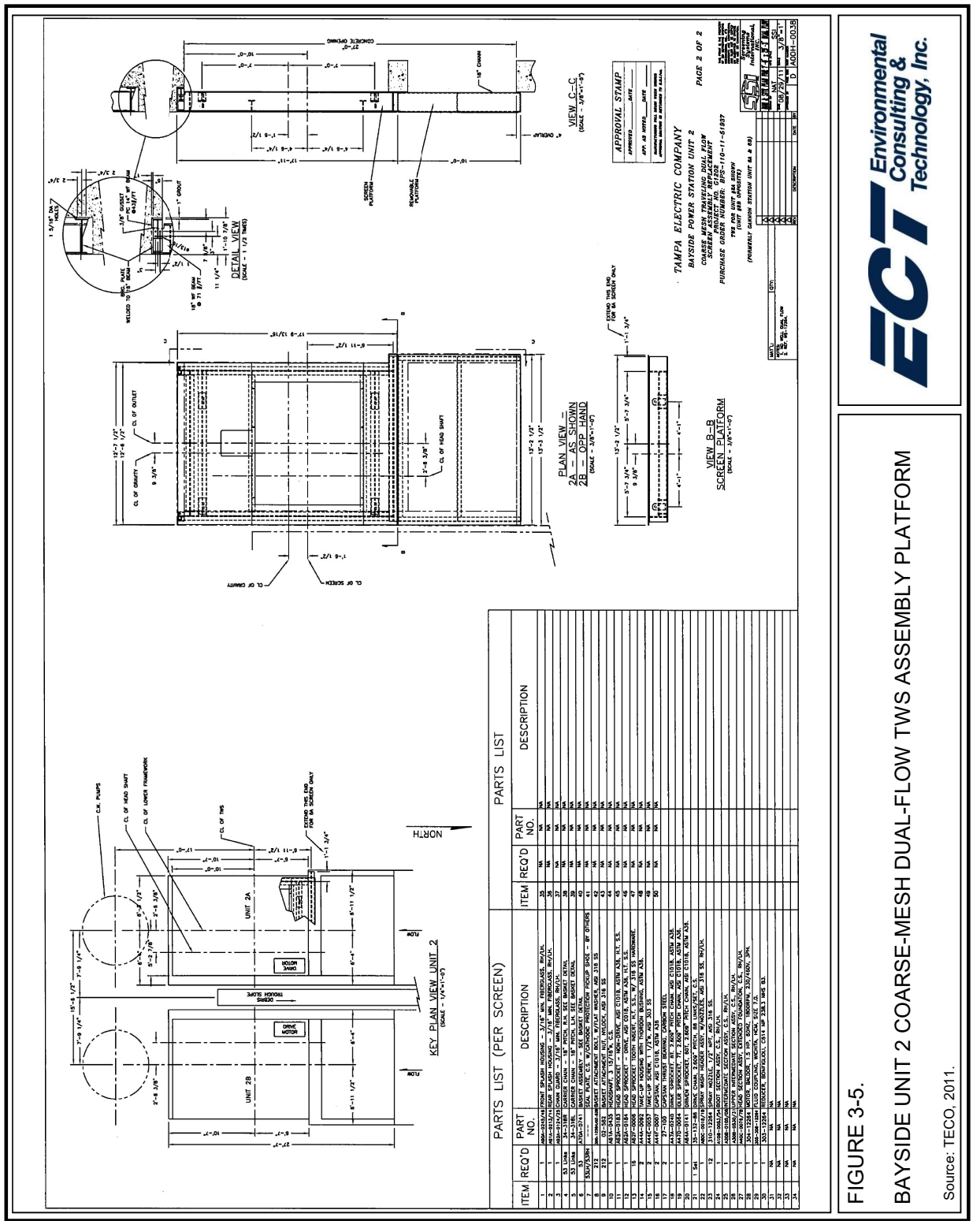


FIGURE 3-5.

BAYSIDE UNIT 2 COARSE-MESH DUAL-FLOW TWS ASSEMBLY PLATFORM

Source: TECO, 2011.

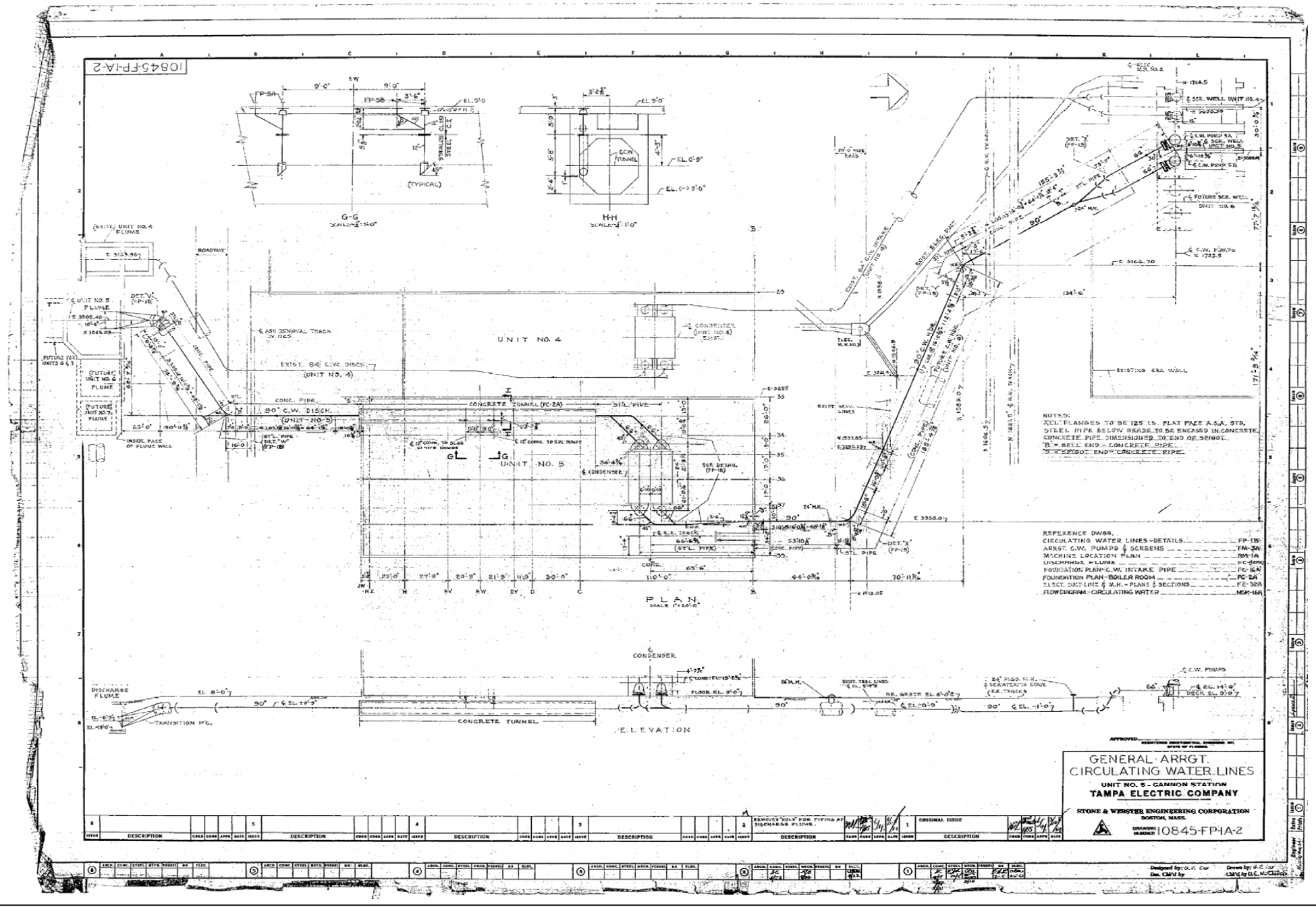


FIGURE 3-6.

UNIT 1 CIRCULATING WATER LINES

Source: TECO, 2011.

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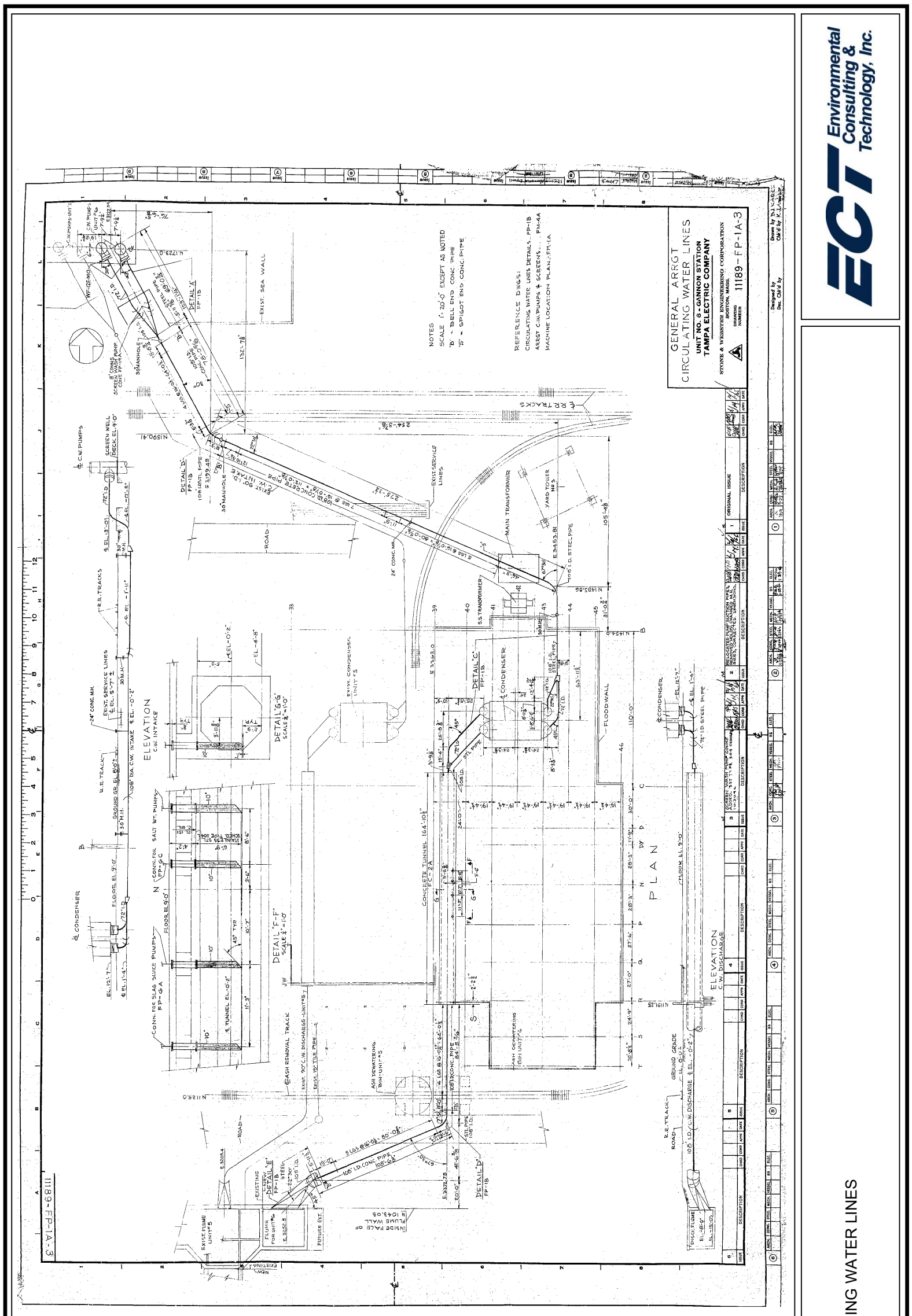


FIGURE 3-7.

UNIT 2 CIRCULATING WATER LINES

Source: TECO, 2011.

4.0 40 CFR 122.21(r)(4)—Baseline Biological Characterization Data

This section addresses each of the elements of 40 CFR 122.21(r)(4). The subsections are numbered and titled consistent with the sections of 40 CFR 122.21(r)(4). The following is the text of 40 CFR 122.21(r)(4):

> Source water baseline biological characterization data. This information is required to characterize the biological community in the vicinity of the cooling water intake structure and to characterize the operation of the cooling water intake structures. The Director may also use this information in subsequent permit renewal proceedings to determine if your Design and Construction Technology Plan as required in § 125.86(b)(4) or § 125.136(b)(3) of this chapter should be revised. This supporting information must include existing data (if they are available). However, you may supplement the data using newly conducted field studies if you choose to do so. The information you submit must include:
>
> (i) A list of the data in paragraphs (r)(4)(ii) through (vi) of this section that are not available and efforts made to identify sources of the data;
>
> (ii) A list of species (or relevant taxa) for all life stages and their relative abundance in the vicinity of the cooling water intake structure;
>
> (iii) Identification of the species and life stages that would be most susceptible to impingement and entrainment. Species evaluated should include the forage base as well as those most important in terms of significance to commercial and recreational fisheries;
>
> (iv) Identification and evaluation of the primary period of reproduction, larval recruitment, and period of peak abundance for relevant taxa;
>
> (v) Data representative of the seasonal and daily activities (e.g., feeding and water column migration) of biological organisms in the vicinity of the cooling water intake structure;
>
> (vi) Identification of all threatened, endangered, and other protected species that might be susceptible to impingement and entrainment at your cooling water intake structures;
>
> (vii) Documentation of any public participation or consultation with Federal or State agencies undertaken in development of the plan; and

(viii) If you supplement the information requested in paragraph (r)(4)(i) of this section with data collected using field studies, supporting documentation for the Source Water Baseline Biological Characterization must include a description of all methods and quality assurance procedures for sampling, and data analysis including a description of the study area; taxonomic identification of sampled and evaluated biological assemblages (including all life stages of fish and shellfish); and sampling and data analysis methods. The sampling and/or data analysis methods you use must be appropriate for a quantitative survey and based on consideration of methods used in other biological studies performed within the same source water body. The study area should include, at a minimum, the area of influence of the cooling water intake structure.

(ix) In the case of the owner or operator of an existing facility or new unit at an existing facility, the Source Water Baseline Biological Characterization Data is the information in paragraphs (r)(4)(i) through (xii) of this section.

(x) For the owner or operator of an existing facility, identification of protective measures and stabilization activities that have been implemented, and a description of how these measures and activities affected the baseline water condition in the vicinity of the intake.

(xi) For the owner or operator of an existing facility, a list of fragile species, as defined at 40 CFR 125.92(m), at the facility. The applicant need only identify those species not already identified as fragile at 40 CFR 125.92(m). New units at an existing facility are not required to resubmit this information if the cooling water withdrawals for the operation of the new unit are from an existing intake.

(xii) For the owner or operator of an existing facility that has obtained incidental take exemption or authorization for its cooling water intake structure(s) from the U.S. Fish and Wildlife Service or the National Marine Fisheries Service, any information submitted in order to obtain that exemption or authorization may be used to satisfy the permit application information requirement of paragraph 40 CFR 125.95(f) if included in the application.

The discussion of threatened and endangered (T&E) species as required by 40 CFR 122.21(r)(4)(vi) has been modified to also address the requirements to list federally listed species and designated critical habitat in the action area per 40 CFR 125.95(f).

4.1 List of Unavailable Biological Data—40 CFR 122.21(r)(4)(i)

The data needed to prepare the elements of the requirements of 40 CFR 122.21(r)(4) were available from previous sampling efforts conducted at Bayside as well as in the literature. No biological data were unavailable.

4.2 List of Species and Relative Abundance in the Vicinity of Bayside—40 CFR 122.21(r)(4)(ii)

Tampa Bay is an open water estuary on the west coast of Florida that is monitored by FWC through its Fisheries Independent Monitoring (FIM) Program. This program conducts intensive sampling of fish and selected invertebrates (initiated in 2015). Monthly stratified random sampling is completed in five geographically defined estuarine zones. Bayside is located within Zone C of Tampa Bay (Figure 4-1). Sampling within this zone is conducted using 21.3-meter seines (FIM Program Staff, 2016).

During the 2015 FIM Program sampling, 156 taxonomic groups of fishes and 10 taxa of invertebrates were collected from the 1,320 samples that took place in Tampa Bay (Table 4-1), with 66 species being observed within Zone C, the zone that contains the CWIS.

Relative abundance data were tabulated for the taxa observed within the zones of the FIM Program (Table 4-2). The numerically dominant taxon was anchovy (81.45 percent), followed by scaled sardine, mojarra, pinfish, and silverside, which together made up more than 85 percent of the total catch.

The fish and shellfish populations within Hillsborough Bay, in the vicinity of TECO's Big Bend Station, located approximately 7.5 miles south of Bayside, was determined to be stable following the 316(a) study as part of the thermal variance permit renewal application. It was determined, and verified by FDEP on July 10, 2014, that "a balanced and indigenous population exists in the [Hillsborough] bay."

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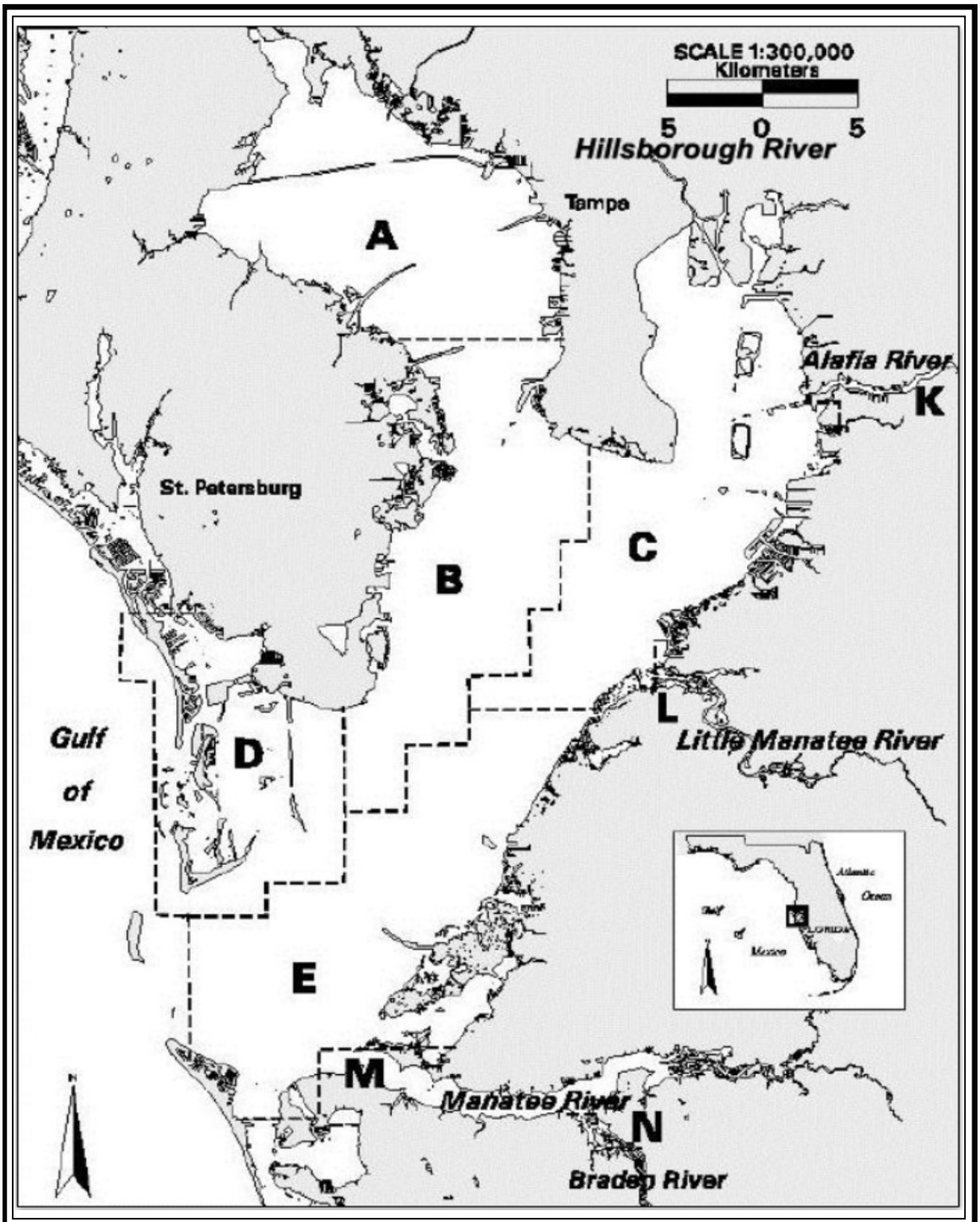


FIGURE 4-1.

MAP OF FIM PROGRAM TAMPA BAY SAMPLING AREA

Source: FIM Program Staff, 2016.

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Table 4–1. Summary by Gear and Zone of Species Collected during Tampa Bay's Stratified Random Sampling

Species	Zone									
	A	B	C	D	E	K	L	M	N	Totals
	E=168	E=156	E=204	E=120	E=180	E=120	E=180	E=108	E=84	E=1,320
Acanthostracion quadricornis	9	40	11	39	48					147
Achiridae sp.		1								1
Achirus lineatus	49	74	94	8	24	58	28	25	1	361
Adinia xenica		12								12
Aluterus schoepfii	2	3		1	2					8
Ameiurus catus							17			17
Anarchopterus criniger	2			2	1					5
Anchoa cubana		33	18	12	3					66
Anchoa hepsetus	10	3	54	51	22	2,735	12	13	5	2,905
Anchoa mitchilli	26,345	13,164	120,909	8,701	1,483	90,690	170,507	33,336	66,314	531,449
Anchoa spp.						21				21
Ancylopsetta quadrocellata		1		8	1					10
Archosargus probatocephalus	109	182	161	149	214	66	43	12	19	955
Argopecten spp.		3	1	18	2					24
Ariopsis felis	626	230	391	32	468	52	23	29	12	1,863
Astroscopus y-graecum		3		1						4
Bagre marinus	134	3	11		56	2	1			207
Bairdiella chrysoura	1,501	998	641	510	998	1,846	163	54	57	6,768
Bathygobius soporator	1			1		6	4	11	1	24
Bathygobius spp.							1		1	2
Belonesox belizanus						11	5			16
Brevoortia spp.	9	1	2	1,237	3	225	17		21	1,515
Calamus arctifrons			2		1					3
Calamus penna			2							2
Calamus spp.				1	1					2
Callinectes ornatus				1						1
Callinectes sapidus	89	331	309	128	83	81	139	80	78	1,318
Caranx crysos				6						6
Caranx hippos	15	18	6	9	18	1		1		68
Caranx latus					2	1				3
Centropomus undecimalis	289	448	295	163	639	53	110	18	68	2,083
Centropristis striata				10	16					26
Chaetodipterus faber	134	20	524	16	44	8	3			749
Chasmodes saburrae	77	17	46	15	25		6			186
Chilomycterus schoepfii	33	45	35	87	130		2	6		338
Chloroscombrus chrysurus	3	7	47	1	2	2		1	1	64
Citharichthys macrops		3		6	21					30
Ctenogobius boleosoma				1				2	2	5
Ctenogobius smaragdus					2		5			7
Cynoscion arenarius	161	10	254	21	71	267	84	58	24	950
Cynoscion nebulosus	280	143	182	35	144	110	19	28	11	952
Cyprinodon variegatus	430	165	66	1	1			2	25	690
Dasyatis americana		1		4	2				1	8
Dasyatis sabina	60	92	197	37	78	8	24	26	6	528
Dasyatis say	3	2	9	6	6					26
Decapterus punctatus					2					2
Diapterus auratus	17	2	1	5	14	3	7	4	7	60
Diplectrum formosum		2		3						5
Diplodus holbrookii		1		172	17					190
Dorosoma petenense			2			1				3

Table 4–1. Summary by Gear and Zone of Species Collected during Tampa Bay's Stratified Random Sampling (Continued, Page 2 of 4)

Species	Zone									
	A	B	C	D	E	K	L	M	N	Totals
	E=168	E=156	E=204	E=120	E=180	E=120	E=180	E=108	E=84	E=1,320
Echeneis neucratoides					1					1
Echeneis sp.		1								1
Elops saurus	107	286	88	138	180	76	3			878
Etropus crossotus		7	5	11	7					30
Eucinostomus argenteus			1							1
Eucinostomus gula	941	1,618	888	1,653	1,799	493	195	204	9	7,800
Eucinostomus harengulus	578	382	390	182	635	1,751	1,078	652	817	6,465
Eucinostomus spp.	1,679	2,618	3,854	2,713	5,178	4,479	5,440	3,130	2,326	31,417
Eugerres plumieri	102	802	163		59	489	795	19	343	2,772
Farfantepenaeus duorarum	286	450	1,049	451	1,563	118	209	291	132	4,549
Floridichthys carpio	1,866	320	454	385	95	177	2			3,299
Fundulus confluentus							3			3
Fundulus grandis	123	47	41	2	5	86	55		3	362
Fundulus seminolis						17	44			61
Fundulus similis	300	57	1,524	222	116	618		1		2,838
Fundulus spp.						3				3
Gambusia holbrooki			9				25		69	103
Gerreidae spp.							10			10
Gobiesox strumosus	2		1			2	5			10
Gobiosoma bosc			14			47	181	64	80	386
Gobiosoma longipala		1		3		1				5
Gobiosoma robustum	460	61	89	70	84	7	9			780
Gobiosoma spp.	292	32	75	20	47	66	229	117	92	970
Gymnura micrura	1	1		3	13					18
Haemulon plumierii				56	66					122
Harengula jaguana	3,458	754	4,191	1,083	1,098	309	1	969		11,863
Hippocampus erectus	4	7	5		2		1			19
Hippocampus zosterae	28	2	11	5	10					56
Hoplosternum littorale			1			1				2
Hyporhamphus meeki	28	4	8	5	5					50
Hyporhamphus spp.	7		3							10
Hypsoblennius hentz				3	2					5
Labidesthes sicculus							59			59
Lactophrys trigonus				1						1
Lagodon rhomboides	2,072	7,604	2,433	18,748	19,463	32	276	883	382	51,893
Leiostomus xanthurus	35	415	325	440	629	86	95	440	343	2,808
Lepisosteus osseus	1		2			2	6	2		13
Lepomis macrochirus						4				4
Lepomis microlophus							1			1
Lepomis spp.						7		2		9
Limulus polyphemus	2		9	3	26					40
Lophogobius cyprinoides						2		3		5
Lucania goodei							3			3
Lucania parva	6,000	3,138	1,452	1,641	519	29	239	4	104	13,126
Lutjanus griseus	6	21	30	188	109		27	12	4	397
Lutjanus synagris	3	6	3	62	25		1	1		101
Membras martinica	213	5	5			30	1	80	51	385
Menidia spp.	2,905	2,623	1,993	1,138	1,800	9,193	2,514	3,766	3,815	29,747
Menippe spp.	46	21	1	37	13					118
Menticirrhus americanus	48	23	225	4	61	415	14	18		808
Menticirrhus littoralis				1	7					8
Menticirrhus saxatilis		16	3		20			1		40

Table 4–1. Summary by Gear and Zone of Species Collected during Tampa Bay's Stratified Random Sampling (Continued, Page 3 of 4)

Species	Zone									
	A	B	C	D	E	K	L	M	N	Totals
	E=168	E=156	E=204	E=120	E=180	E=120	E=180	E=108	E=84	E=1,320
Microgobius gulosus	2,690	1,415	1,631	78	761	277	589	321	436	8,198
Microgobius thalassinus	2		8	2	16			46		74
Micropogonias undulatus	3			1			1	2		7
Micropterus salmoides							4			4
Monacanthus ciliatus				6	8					14
Mugil cephalus	71	95	86	67	255	2,242	58	20	40	2,934
Mugil curema	3	17	22	35	22	21	2	1		123
Mugil trichodon	436	119	195	107	105	8		6	2	978
Mycteroperca microlepis				1	3					4
Nicholsina usta				58	25					83
Notropis maculatus							1			1
Notropis petersoni							95			95
Ocyurus chrysurus				1						1
Ogcocephalus cubifrons	1	3	2	6	3					15
Oligoplites saurus	88	73	95	29	42	62	167	38	13	607
Ophidion holbrookii		1								1
Opisthonema oglinum	45	474	13	44	382	9		6		973
Opistognathus robinsi					1					1
Opsanus beta	35	14	5	33	47	4		5		143
Oreochromis/Sarotherodon spp.		18								18
Orthopristis chrysoptera	52	665	82	1,161	947			317	1	3,225
Paraclinus marmoratus					4					4
Paralichthys albigutta	51	101	20	59	71	5	12	33	2	354
Peprilus paru			4							4
Poecilia latipinna	7	1					11	5	17	41
Pogonias cromis	4	20	34	11	17		1		2	89
Pomatomus saltatrix			17							17
Portunus spp.		176	1,180	87	778					2,221
Prionotus scitulus	34	581	407	69	387	12	1	6		1,497
Prionotus tribulus	17	9	41	7	10	5	1	4	1	95
Pterygoplichthys spp.			1						1	2
Rhinobatos lentiginosus					1					1
Rhinoptera bonasus	1	10	8		11					30
Rimapenaeus constrictus		2								2
Sardinella aurita		181		1	291					473
Sarotherodon melanotheron	6	4				2				12
Sciaenops ocellatus	364	95	328	11	80	249	139	65	78	1,409
Scomberomorus maculatus	2	2	4	8	1					17
Scorpaena brasiliensis		1								1
Selene vomer		4	11	5	11					31
Serranus subligarius		1								1
Sicyonia laevigata				1						1
Sicyonia typica		2			2					4
Sphoeroides nephelus	141	92	43	28	78	2	2	3	1	390
Sphoeroides spengleri				2	1					3
Sphyraena barracuda		1	1	16	2			1		21
Sphyrna tiburo	2	7	5	5	9					28
Stephanolepis hispidus	3	6	1	26	39					75
Strongylura marina	8	4	1	2	2	13	3	1	1	35
Strongylura notata	147	158	136	229	316	46	16	39		1,087

Table 4–1. Summary by Gear and Zone of Species Collected during Tampa Bay's Stratified Random Sampling (Continued, Page 4 of 4)

Species	Zone									
	A	B	C	D	E	K	L	M	N	Totals
	E=168	E=156	E=204	E=120	E=180	E=120	E=180	E=108	E=84	E=1,320
Strongylura spp.	4			3		4	8	5		24
Strongylura timucu	1		1	2	1		4	26		35
Symphurus plagiusa	14	26	124	16	31	10	3	5		229
Syngnathus floridae	16	34	4	19	29	1				103
Syngnathus louisianae	50	34	28	10	11		4	5	1	143
Syngnathus scovelli	373	119	199	150	110	12	14	8	3	988
Synodontidae sp.					1					1
Synodus foetens	56	56	78	57	105	13	6	23	1	395
Tilapia mariae							1			1
Trachinotus carolinus		10			3					13
Trachinotus falcatus		41		14	17					72
Trinectes maculatus	56		10		8	852	1,335	76	332	2,669
Tylosurus crocodilus				1						1
Urophycis floridana	1	1	2	1	3					8
Totals	**56,765**	**42,053**	**148,442**	**43,235**	**43,328**	**118,636**	**185,219**	**45,432**	**76,156**	**759,266**

Source: FIM Program Staff, 2016.

Table 4–2. Relative Abundance by Zone of Species Collected during Tampa Bay Stratified-Random Sampling, 2015

Species	Common Name	Number of Organisms per 204 Hauls	Relative Abundance (percent of total)
Anchoa mitchilli	Bay anchovy	120,909	81.45
Harengula jaguana	Scaled sardine	4,191	2.82
Eucinostomus spp.	Mojarra	3,854	2.60
Lagodon rhomboides	Pinfish	2,433	1.64
Menidia spp.	Silverside	1,993	1.34
Microgobius gulosus	Clown goby	1,631	1.10
Fundulus similis	Longnose killifish	1,524	1.03
Lucania parva	Rainwater killifish	1,452	0.98
Portunus spp.	Swimming crab	1,180	0.79
Farfantepenaeus duorarum	Penaeid shrimp	1,049	0.71
Eucinostomus gula	Silver Jenny	888	0.61
Bairdiella chrysoura	Silver perch	641	0.43
Chaetodipterus faber	Atlantic spadefish	524	0.35
Floridichthys carpio	Goldspotted killifish	454	0.31
Prionotus scitulus	Leopard searobin	407	0.27
Ariopsis felis	Hardhead catfish	391	0.26
Sciaenops ocellatus	Red drum	328	0.22
Leiostomus xanthurus	Spot	325	0.22
Callinectes sapidus	Blue crab	309	0.21
Centropomus undecimalis	Common snook	295	0.20
Cynoscion arenarius	Sand seatrout	254	0.17
Menticirrhus americanus	Southern kingfish	225	0.15
Syngnathus scovelli	Gulf pipefish	199	0.13
Dasyatis sabina	Atlantic stingray	197	0.13
Mugil trichodon	Fantail mullet	195	0.13
Cynoscion nebulosus	Spotted seatrout	182	0.12
Eugerres plumieri	Striped mojarra	163	0.11
Archosargus probatocephalus	Sheepshead	161	0.11
Strongylura notata	Redfin needlefish	136	0.09
Symphurus plagiusa	Blackcheek tonguefish	124	0.08
Oligoplites saurus	Leatherjacket fish	95	0.06
Achirus lineatus	Lined sole	94	0.06
Gobiosoma robustum	Code boy	89	0.06
Elops saurus	Ladyfish	88	0.06
Mugil cephalus	Striped mullet	86	0.06
Orthopristis chrysoptera	Pigfish	82	0.06
Synodus foetens	Inshore lizardfish	78	0.05
Gobiosoma spp.	Goby	75	0.05
Cyprinodon variegatus	Sheepshead minnow	66	0.04
Anchoa hepsetus	Broad-striped anchovy	54	0.04
Chloroscombrus chrysurus	Atlantic bumper	47	0.03
Chasmodes saburrae	Florida blenny	46	0.03
Sphoeroides nephelus	Southern puffer	43	0.03
Fundulus grandis	Gulf killifish	41	0.03
Prionotus tribulus	Bighead searobin	41	0.03
Chilomycterus schoepfii	Striped burrfish	35	0.02
Pogonias cromis	Black drum	34	0.02
Lutjanus griseus	Grey snapper	30	0.02
Syngnathus louisianae	Chain pipefish	28	0.02
Mugil curema	White mullet	22	0.01
Paralichthys albigutta	Gulf flounder	20	0.01
Anchoa cubana	Cuban anchovy	18	0.01

Table 4–2. Relative Abundance by Zone of Species Collected during Tampa Bay Stratified-Random Sampling, 2015 (Page 2 of 2)

Species	Common Name	Number of Organisms per 204 Hauls	Relative Abundance (percent of total)
Pomatomus saltatrix	Bluefish	17	0.01
Gobiosoma bosc	Naked goby	14	0.01
Opisthonema oglinum	Atlantic thread herring	13	0.01
Acanthostracion quadricornis	Scrawled cowfish	11	0.01
Bagre marinus	Gafftopsail catfish	11	0.01
Hippocampus zosterae	Dwarf seahorse	11	0.01
Selene vomer	Atlantic lookdown	11	0.01
Trinectes maculatus	Hogchoker	10	0.01
Dasyatis say	Bluntnose stringray	9	0.01
Gambusia holbrooki	Eastern mosquitofish	9	0.01
Limulus polyphemus	Horseshoe carb	9	0.01
Hyporhamphus meeki	American halfbeak	8	0.01
Microgobius thalassinus	Green goby	8	0.01
Rhinoptera bonasus	Cownose ray	8	0.01
Totals		**148,442**	**100**

Source: FIM Program Staff, 2016.

4.3 Identification of Species and Life Stages Susceptible to Impingement and Entrainment—40 CFR 122.21(r)(4)(iii)

Table 4-3 outlines the potential for fish and shellfish to be present around the intake at Bayside, as well as the potential for impingement or entrainment for each species. The potential for impingement and entrainment was determined by the presence or absence of the species within the samples collected at the CWIS at Bayside as part of the 316(b) Phase II compliance efforts of 2005 through 2009 (Golder, 2009). However, since some shellfish species were not included when processing the entrainment samples (since the entrainment study was designed to target commercial and recreational species), the potential to occur near the intake and subsequent entrainment for species observed during the FIM stratified sampling of 2015 was determined by habitat preferences for the various species.

EPA, in its 316(b) rule-makings, assumed fish can detect and swim away from a through-screen velocity of 0.5 fps or lower as per 40 CFR 125.94(c)(2) and (3). The maximum average through-screen velocity at Bayside is 1.6 and 2.2 fps, while the approach velocity is 1.0 and 1.2 fps for Units 1 and 2, respectively. Though greater than 0.5 fps, the approach velocities are such that many larger species are able to swim away (Castro-Santos, 2005) and, thus, limit the degree of impingement.

Reproduction of most Tampa Bay species is dependent on several factors, such spawning habitat preference for small to medium streams versus offshore environments. The intake of Bayside is located off the connection between Hillsborough Bay with McKay Bay to the north. McKay Bay is fed by Palm River, while Hillsborough River is an arm of Tampa Bay. Some species, such as Florida gar and threadfin shad, use the bay, rivers, and tributaries for spawning grounds. Spawning often takes place around aquatic vegetation, sandy bottoms, rock formations, sunken stumps, and other benthic structures. Many of the species observed within the vicinity of the CWIS at Bayside are offshore spawners, requiring higher salinities over the those observed within Tampa Bay.

Table 4–3. Potential for Impingement and Entrainment of Fish Species Located in Zone C of Tampa Bay

Species Name	Common Name	Potential to Occur Near the Intake		Potential for Entrainment of Early Life Stages*	Potential for Impingement for Adults and Juveniles*
		Early Life Stages	Juveniles/Adults		
Acanthostracion quadricornis	Scrawled cowfish	Unlikely, spawn off Venezuela	Likely	Unlikely	Likely
Achirus lineatus	Lined sole	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Alpheus spp.	Pistol shrimp	Unlikely, parental care during early life stages	Yes	Unlikely	Yes
Anchoa cubana	Cuban anchovy	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Anchoa hepsetus	Broad-striped anchovy	Likely	Potential (*Anchoa* spp. found in impingement sample)	Likely	Potential (*Anchoa* spp. Found in impingement sample)
Anchoa spp.	Anchovy	Likely	Yes	Likely	Yes
Anchoa mitchilli	Bay anchovy	Likely	Yes	Yes	Yes
Archosargus probatocephalus	Sheepshead	Unlikely, spawn offshore	Likely	Unlikely	Likely
Argopecten spp.	Scallop	Slight potential, pelagic larvae	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Ariopsis felis	Hardhead catfish	Unlikely	Likely	Unlikely	Likely
Bagre marinus	Gafftopsail catfish	Unlikely	Likely	Unlikely	Likely
Bairdiella chrysoura	Silver perch	Likely	Yes	Yes	Yes
Bathygobius soporator	Frillfin goby	Likely	Unlikely	Likely	Unlikely, not found in any impingement sample
Blenniidae	Combtooth blenny	Likely	Likely	Yes	Likely
Brevoortia spp.	Menhaden	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Calamus arctifrons	Grass porgy	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Calamus penna	Sheepshead porgy	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Callinectes sapidus	Blue crab	Likely	Yes	Likely	Yes
Callinectes similis	Lesser blue crab	Likely	Likely	potential	Likely
Caranx hippos	Crevalle jack	Likely	Potential	Likely	Unlikely, not found in any impingement sample

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Table 4–3. Potential for Impingement and Entrainment of Fish Species Located in Zone C of Tampa Bay (Continued, Page 2 of 7)

Species Name	Common Name	Potential to Occur Near the Intake		Potential for Entrainment of Early Life Stages*	Potential for Impingement for Adults and Juveniles*
Centropomus undecimalis	Common snook	Unlikely	Unlikely	Unlikely	Unlikely
Chaetodipterus faber	Atlantic spadefishes	Likely	Yes	Likely	Yes
Chasmodes saburrae	Florida blenny	Likely	Potential	Likely	Potential
Chilomycterus schoepfii	Striped burrfish	Unlikely, thought to spawn offshore	Likely	Unlikely	Likely
Chloroscombrus chrysurus	Atlantic bumper	Likely	Yes	Likely	Yes
Cynoscion arenarius	Sand seatrout	Likely	Yes	Yes	Yes
Cynoscion nebulosus	Spotted seatrout	Likely	Likely	Yes	Likely
Cyprinodon variegatus	Sheepshead minnow	Unlikely, intake canal too deep and lacking vegetation	Unlikely, intake canal too deep and lacking vegetation	Unlikely	Unlikely
Cynoscion spp.	Seatrout	Likely	Likely	Likely	Potential
Dasyatis americana	Southern stingray	Unlikely	Likely	Unlikely	Likely
Dasyatis sabina	Atlantic stingray	Unlikely	Unlikely, not found in any impingement sample	Unlikely	Unlikely, not found in any impingement sample
Dasyatis say	Bluntnose stingray	Unlikely	Unlikely, not found in any impingement sample	Unlikely	Unlikely, not found in any impingement sample
Diapterus auratus	Irish mojarra	Slight potential, pelagic eggs	Likely	Unlikely	Likely
Dorosoma petenense	Threadfin shad	Unlikely	Likely	Unlikely	Likely
Elops saurus	Northern ladyfish	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Etropus crossotus	Fringed flounder	Slight potential	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Eucinostomus argenteus	Spotfin mojarra	Slight potential	Likely	Unlikely	Potential (*Eucinostomus* spp.)
Eucinostomus gula	Silver jenny	Slight potential	Likely	Unlikely	Likely
Eucinostomus harengulus	Tidewater mojarra	Slight potential	Likely (*Eucinostomus* spp)	Unlikely	Potential (*Eucinostomus* spp.)
Eucinostomus spp.	Mojarra	Slight potential	Yes	Unlikely	Yes

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Table 4–3. Potential for Impingement and Entrainment of Fish Species Located in Zone C of Tampa Bay (Continued, Page 3 of 7)

Species Name	Common Name	Potential to Occur Near the Intake		Potential for Entrainment of Early Life Stages*	Potential for Impingement for Adults and Juveniles*
Eugerres plumieri	Striped mojarra	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Farfantepenaeus duorarum	Penaeid shrimp	Likely	Yes	Potential, young enter estuaries on tide and migrate to low salinity waters	Yes
Floridichthys carpio	Goldspotted killifish	Slight potential	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Fundulus grandis	Gulf killifish	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Fundulus similis	Longnose killifish	Slight potential	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Gambusia holbrooki	Eastern mosquitofish	Unlikely	Potential	Unlikely	Slight potential (*Gambusia affinis* in impingement samples)
Gambusia affinis	Western mosquitofish	Slight potential	Likely	Unlikely	Likely
Gerreidae spp.	Mojarra	Slight potential	Likely	Unlikely	Likely
Gobiesox strumosus	Skilletfish	Likely	Slight potential	Yes	Unlikely, not found in any impingement sample
Gobiosoma bosc	Naked goby	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Gobiosoma robustum	Code goby	Likely	Slight potential	Yes	Unlikely, not found in any impingement sample
Gobiosoma spp.	Goby	Likely	Slight potential	Yes	Unlikely, not found in any impingement sample
Gymnura spp.	Butterfly rays	Unlikely	Likely	Unlikely	Likely
Haemulon plumierii	White grunt	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Harengula jaguana	Scaled sardine	Unlikely	Yes	Unlikely	Yes
Hemicaranx amblyrhynchus	Bluntnose jack	Slight potential	Yes	Unlikely	Yes
Hippocampus erectus	Lined seahorse	Likely	Likely	Likely	Likely
Hippocampus spp.	Seahorses	Likely	Yes	Potential	Yes

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Species Name	Common Name	Potential to Occur Near the Intake		Potential for Entrainment of Early Life Stages*	Potential for Impingement for Adults and Juveniles*
Hippocampus zosterae	Dwarf seahorse	Likely	Likely	Potential	Likely
Hoplosternum littorale	Brown hoplo	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Hyporhamphus meeki	American halfbeak	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Hyporhamphus spp.	Halfbeak			Unlikely	Unlikely, not found in any impingement sample
Lagodon rhomboides	Pinfish	Likely	Likely	Likely	Likely
Leiostomus xanthurus	Spot	Unlikely	Likely	Unlikely	Likely
Lepisosteus osseus	Longnose gar	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Lepomis spp.	Sunfish	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Limulus polyphemus	Horseshoe crab	Unlikely	Yes	Unlikely	Yes
Lolliguncula brevis	Atlantic brief squid	Likely	Yes	Yes	Yes
Lophogobius cyprinoides	Crested goby	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Lucania parva	Rainwater killifish	unlikely	Likely	Unlikely	Likely
Lutjanus griseus	Grey snapper	unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Lutjanus synagris	Lane snapper	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Membras martinica	Rough silverside	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Menidia spp.	Silversides	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Menippe mercenaria	Florida stone crab	Likely	Yes	Yes	Yes
Menippe spp.	Stone crab	Likely	Yes	Potential	Yes
Menticirrhus americanus	Southern kingfish	Likely	Likely	Yes	Likely
Menticirrhus littoralis	Gulf kingfish	Likely	Likely	Yes	Likely
Menticirrhus saxatilis	Northern kingcroaker	Likely	Likely	Yes	Potential (*Menticirrhus* spp. in impingement samples)

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Species Name	Common Name	Potential to Occur Near the Intake		Potential for Entrainment of Early Life Stages*	Potential for Impingement for Adults and Juveniles*
Microgobius gulosus	Clown goby	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Microgobius thalassinus	Green goby	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Mugil cephalus	Striped mullet	Unlikely	Likely	Unlikely	Likely
Mugil curema	White mullet	Unlikely	Likely	Unlikely	Potential (*Mugil* spp. in impingement samples)
Mugil trichodon	Fantail mullet	Slight potential	Likely	Unlikely	Potential (*Mugil* spp. in impingement samples)
Ogcocephalus cubifrons	Polka-dot batfish	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Oligoplites saurus	Leatherjacket fish	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Opisthonema oglinum	Atlantic thread herring	Unlikely	Yes	Unlikely	Yes
Opsanus beta	Gulf toadfish	Unlikely	Yes	Unlikely	Yes
Opsanus pardus	Leopard toadfish	Unlikely	Likely	Unlikely	Likely
Orthopristis chrysoptera	Pigfish	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Palaemonetes spp	Grass shrimp	Likely	Likely	Potential	Likely
Paralichthys albigutta	Gulf flounder	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Parapinnixa hendersoni	Pea crab	Likely	Likely	Potential	Likely
Penaeidae	Penaeid shrimp	Likely	Likely	Potential	Likely
Peprilus burti	Gulf butterfish	Unlikely	Unlikely	Likely	Unlikely
Peprilus paru	American harvestfish	Unlikely	Likely	Unlikely	Potential (*Peprilus* spp. found in impingement samples)
Petrolisthes spp.	Porcelain crabs	Likely	Yes	Potential	Yes
Pogonias cromis	Black drum	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Pomatomus saltatrix	Bluefish, shad	Slight potential	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Porcellana sayana	Spotted porcelain crab	Likely	Likely	Potential	Likely

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Species Name	Common Name	Potential to Occur Near the Intake		Potential for Entrainment of Early Life Stages*	Potential for Impingement for Adults and Juveniles*
Pogonias cromis	Black drum	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Porcellanidae	Porcelain crabs	Likely	Yes	Potential	Yes
Portunus spp.		Likely	Unlikely	Potential	Unlikely
Prionotus scitulus	Leopard searobin	Yes	Likely	Yes	Likely
Prionotus spp.	Searobins	Yes	Yes	Yes	Yes
Prionotus tribulus	Bighead searobin	Yes	Likely	Yes	Likely
Pterygoplichthys spp.	Sailfin catfish	Slight potential	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Rachycentron canadum	Cobia, ling, black king fish	Unlikely	Likely	Unlikely	Likely
Rhinoptera bonasus	Cownose ray	Unlikely	Likely	Unlikely	Likely
Rimapenaeus constrictus	Roughneck shrimp	Likely	Likely	Potential	Likely
Sardinella aurita	Round sardinella	Slight potential	Likely	Unlikely	Likely
Sciaenops ocellatus	Red drum	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Scomberomorus maculatus	Atlantic Spanish mackerel	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Selene vomer	Atlantic lookdown	Slight potential	Yes	Unlikely	Yes
Sesarma reticulatum	Purple marsh crab	Likely	Likely	Potential	Likely
Sphoeroides nephelus	Southern puffer	Slight potential; free swimming larvae	Yes	Unlikely	Yes
Sphyraena barracuda	Great barracuda	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Sphyrna tiburo	Bonnethead shark	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Squilla empusa	Sea scorpion	Slight potential	Likely	Unlikely	Likely
Stephanolepis hispidus	Planehead filefish	Potential	Likely	Slight potential	Likely
Strongylura marina	Atlantic needlefish	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Strongylura notata	Redfin needlefish	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample

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Table 4–3. Potential for Impingement and Entrainment of Fish Species Located in Zone C of Tampa Bay (Continued, Page 7 of 7)

Species Name	Common Name	Potential to Occur Near the Intake		Potential for Entrainment of Early Life Stages*	Potential for Impingement for Adults and Juveniles*
Strongylura timucu	Timucu	Unlikely	Unlikely	Unlikely	Unlikely, not found in any impingement sample
Symphurus plagiusa	Blackcheek tonguefish	yes	Likely	Yes	Likely
Syngnathus floridae	Dusky pipefish	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Syngnathus louisianae	Chain pipefish	Yes	Slight potential	Yes	Unlikely, not found in any impingement sample
Syngnathus scovelli	Gulf pipefish	Likely	Slight potential	Likely	Unlikely, not found in any impingement sample
Synodontidae spp.	Lizard fish	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Synodus foetens	Inshore lizardfish	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Trinectes maculatus	Hogchoker	Yes	Yes	Yes	Yes
Urophycis floridana	Southern hake	Unlikely	Slight potential	Unlikely	Unlikely, not found in any impingement sample
Xanthoidea	Mud crabs	Likely	Likely	Likely, includes *Menippe* spp., all found in entrainnent and impingement samples	Yes

*Likely; present within impingement or entrainment samples during biological characterization studies of 2005 through 2007 (Golder, 2009).
Unlikely; not present among impingement or entrainment samples in 2005 through 2007.
Yes; more than 200 individuals impinged in any given year (annualized) or had more than 1 million estimated to be entrained in any given year based on flow extrapolation.
Potential; characteristics that would support it being in the area or closely related species was observed but not observed in any impingement or entrainment samples (Golder, 2009).

Source: ECT, 2018.

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Of the 129 species observed within the vicinity of the CWIS (i.e., fish and shellfish taxa observed within Zone C, as well as within impingement and entrainment samples from 2005 through 2007), only 35 were identified as having been subject to entrainment during the Phase II characterization at Bayside (Table 4-3). This difference can be attributed to habitat preferences, spawning habits, and the behavior of early life stages. The majority of the 129 candidate species spawn in tributaries, areas with sufficient cover, shallow side waters, or several meters offshore. The intake is located within a man-made canal with little to no submerged aquatic vegetation. The lack of vegetation and depth is maintained by active dredging; therefore, the habitat near the intake consists of deeper waters with a bed characterized by fine-grained materials (sand and mud) associated with a depositional environment. In addition, many of the species spawn in nests, and one or both of the adults protect the eggs and may protect the young after hatching. However, as illustrated by the entrainment sampling that was conducted as part of the 316(b) Phase II effort, a number of species are entrained due to their pelagic habits, broadcast spawning behavior, and free-floating nature of their early life stages.

4.4 Identification and Evaluation of Primary Growth Period—40 CFR 122.21(r)(4)(iv)

The primary growth period for most species immediately follows their spawning and subsequent hatching. Shortly after hatching, larvae are at their greatest abundance and have rapid growth rates. The majority of the species found in Tampa Bay spawn in the spring and summer and, therefore, have their primary growth period in the summer and early fall when water is relatively warm, and food is abundant. Table 4-4 summarizes seasonal activities and spawning periods for the 15 most abundance species reported to occur within the impingement and entrainment samples at Bayside. These species constitute approximately 84 percent of the organisms collected by the FIM.

4.4.1 Period of Reproduction

The majority of species found in Tampa Bay near Bayside spawn in the spring and summer months, with a few species beginning spawning in late winter or spawning into the fall (e.g., blue crab, flounder, and mullet). Table 4-4 includes spawning habits for the 15 fish species identified to occur in Tampa Bay near Bayside.

Table 4–4. List of Seasonal Activities, Spawning Migration, Daily Activities, Migration, and Habitat for the 15 Most Abundant Species Observed in Impingement and Entrainment Samples at Bayside

Species Name	Common name	Seasonal Activities/Spawning Migration	Daily Activities/Migration/Habitat
ACHIRIDAE	Soles		
Achirus lineatus	Lined sole	Spawning has been reported to take place in the eastern Gulf of Mexico from April to November.	Sand-mud bottom substrata in estuaries and hypersaline lagoons. Tolerance to a wide range of salinities allows population of many habitats, including closed lagoons.
Trinectes maculatus		Spawns late spring and summer, migrates downstream to spawning areas in spring, upstream in fall. Spawns in various salinities and temperatures, mostly moderately saline.	Coastal waters (to approximately 75 meters), estuaries, and coastal rivers; may range hundreds of miles upstream
BLENNIIDAE	Blennies		
Blenniidae	Blenny	Spawn throughout the year, probably during the day. Some groups only spawn during warmer times of the year, and one species spawns every 3 to 4 days. Spawning usually occurs in the male's territory in a cave, crevice, or other shelter.	Shallow, inshore, often intertidal, waters. Generally benthic, occupying grass beds, tide pools, or areas near rocks.
CARANGIDAE	Jacks and pompanos		
Chloroscombrus chrysurus	Atlantic bumper	Spawns in Campeche Bay, Mexico, year-round, but mainly in the spring and summer in areas less than 40 meters deep.	Mostly in shallow water (both marine and estuarine waters) and mangrove-lined lagoons.
CLUPEIDAE	Shads, herrings, menhaden		
Opisthonema oglinum	Atlantic thread herring	Spawns offshore spring through summer.	Generally oceanic or coastal; fresh water in St. Johns River, Florida.
BATRACHOIDIDAE	Toadfishes		
Opsanus beta	Gulf toadfish	Off western Florida, adults spawn in February and March; female peak spawning occurs in March. Nests in a variety of cavities such as old conch shells, sponges, clam shells, and tin cans.	Shallow seagrass beds, oyster reefs, and rocky areas. Burrows or hides inside shells and crevices.
ENGRUALIDAE	Anchovies		
Anchoa mitchilli	Bay anchovy	Spawns in spring-summer over much of Atlantic coast, all year in southern Florida.	Lower freshwater and estuarine reaches of coastal rivers, bays, sounds, and high salinity nearshore marine waters; usually in shallow waters.

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Table 4–4. List of Seasonal Activities, Spawning Migration, Daily Activities, Migration, and Habitat for the 15 Most Abundant Species Observed in Impingement and Entrainment Samples at Bayside (Continued, Page 2 of 4)

Species Name	Common name	Seasonal Activities/Spawning Migration	Daily Activities/Migration/Habitat
EPHIPPIDAE	Spadefish, batfish, and scats		
Chaetodipterus faber	Atlantic spadefish	Spawning season runs from May through September on the inner shelf off the coast of the United States.	Along coasts over wrecks, reefs, and pilings and brackish lagoons, also around buoys and mangroves, under bridges, and in harbors; often circles divers. Juveniles abundant in estuaries often found in shallow water mimicking dead leaves or floating debris.
LIMULIDAE	Horseshoe crab		
Limulus polyphemus	Horseshoe crab	Timing of spawning varies with latitude. Spawn on sandy beach areas within bays and coves. Along the coast of the Florida Panhandle, breeding occurs from February through October with peaks in March and April. Spawning strongly associated with new and full moon high tides.	Habitat requirements change throughout life cycle, extending from intertidal beach fronts and tidal flats for eggs and larvae, to the edge of the continental shelf for adults.
LOLIGINIDAE	Pencil squid		
Loliguncula brevis	Atlantic brief squid	Small eggs are laid attached to the bottom in shallow waters.	Entirely coastal and generally limited to shallow water of less than 18 meters. Occurs in bays and estuaries; associated with low-salinity water.
PENAIDAE	Penaeus shrimp		
Farfantepenaeus duorarum	Pink shrimp	Spawning usually occurs in the ocean, ranging from near the beaches to several miles offshore, typically spawn in the spring and early summer. Exact timing of spawning period depends on water temperature.	Depths of 2 to 70 meters on compacted mud, silt, or sandy bottoms or among shells. Juveniles found in marine or estuarine waters; adults are marine.
SCIAENIDAE	Drums and croakers		
Bairdiella chrysoura	American silver perch	Spawns late spring or summer, beginning later and having shorter duration at higher latitudes. Spawning takes place in shallow, saline portions of bays and other inshore areas.	Common in estuaries and nearshore marine environments. Young mostly in estuaries, often in grass beds. Sometimes in fresh water. Pelagic eggs broadcast in coastal waters, particularly around inlets.

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Table 4–4. List of Seasonal Activities, Spawning Migration, Daily Activities, Migration, and Habitat for the 15 Most Abundant Species Observed in Impingement and Entrainment Samples at Bayside (Continued, Page 3 of 4)

Species Name	Common name	Seasonal Activities/Spawning Migration	Daily Activities/Migration/Habitat
Cynoscion arenarius	Sand seatrout	Migrates to offshore waters to spawn and escape harsh temperatures. In the Gulf of Mexico, spawning occurs in the inshore. Has a spring (March through May) peak and late summer peak. Use functioning offshore passes to facilitate egg and larval transport from spawning areas.	Inhabits inshore waters extensively but migrates to offshore waters.
Cynoscion nebulosus	Spotted seatrout	Spawns late spring through early fall. Peaks in June through August. Spawn at night in shallow bays and lagoons as well as deeper channels and depressions close to grass flats.	Euryhaline but prefers low to medium salinity of coastal waters and brackish estuaries. Young often in estuaries and grass beds.
Cynoscion spp.	Seatrout	See *C. nebulosus* or *C. arenarius*.	See *C. nebulosus* or *C. arenarius*.
GOBIIDAE	Gobies		
Gobiesox strumosus	Skilletfish	Eggs laid in empty oyster shells and tended by adults.	Associated with oyster reefs (takes shelter in empty shells) as well as grassy and rocky shallow areas, around pilings, or rocky tide pools.
Gobiosoma bosc	Naked goby	Spawning season in late April through October. Utilizes inside of oyster shells as spawning substrate (Crabtree and Middaugh, 1982); eggs laid and cemented at one end in empty, gaping oyster.	Widespread but seldom abundant in low to moderate salinity. Associated with patches of oysters or grass flats on sand and mud bottom estuaries. Sometimes enters fresh water.
Gobiosoma robustum	Code goby	Spawning occurs throughout the year in a population from a lagoon in Campeche, Mexico, with maximal spawning occurring in the cold, dry season when salinity levels become elevated.	Abundant in moderate to high salinity, especially on sandy bottoms with covering vegetation such as mangrove roots or grasses.
Gobiosoma spp.	Gobies	See *G. robustum* or *G. bosc*.	See *G. robustum* or *G. bosc*.
PORTUNIDAE	Swimming crab		
Callinectes sapidus	Blue crab	Spawning peaks closely associated with the region they inhabit with two spawning periods in Gulf of Mexico (February and March and August and September). Females mate only once. Eggs brooded for up to 17 days. Females migrate to mouths of estuaries to release larvae into high salinity waters (more than 20 parts per trillion).	Especially common in estuaries, this species ranges into fresh water, and may be found offshore. The blue crab's habitat ranges from the low tide line to waters 120 feet (36 meters) deep. Females remain in higher salinity portions of an estuary system, especially for egg laying.

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Table 4–4. List of Seasonal Activities, Spawning Migration, Daily Activities, Migration, and Habitat for the 15 Most Abundant Species Observed in Impingement and Entrainment Samples at Bayside (Continued, Page 4 of 4)

Species Name	Common name	Seasonal Activities/Spawning Migration	Daily Activities/Migration/Habitat
PORCELLANIDAE	Porcelain crabs		
Porcellana sayana	Spotted porcelain crab	Precopulatory courtship ritual is common; usually indirect sperm transfer.	Marine, common under rocks, and often found and observed on rocky beaches and shorelines. Commensally lives within shells of large hermit crabs.
Porcellanidae	Porcelain crabs	See *P. sayana*.	See *P. sayana*.
XANTHOIDEA	Mud crabs		
Menippe mercenaria	Florida stone crab	Peak mating season from August to September in southern Florida, breeds between spring and fall. Female broods eggs.	Sub-tidal regions; burrow under emergent hard substrate or in seagrass beds. Juvenile stone crabs found nearshore in marine waters on seagrass beds.

Source: ECT, 2018.

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4.4.2 Larval Recruitment and Period of Peak Abundance

The larval recruitment period follows spawning by a few days to a week or more depending on incubation times for each species and ambient water temperature. The period of peak abundance generally occurs around the time of hatching, as the new larval recruits greatly add to the abundance of each species. The spawning period for most species common in this area is in the spring and summer months leading to peak abundance in eggs around this time and larvae shortly thereafter. Peak abundance of juvenile fish will lag the spawn by a few months. Multiple-spawning fish show additional peaks through the summer and fall in relation to their multiple spawning times. These patterns were observed in the entrainment rate data collected at Bayside and TECO's Big Bend station during the Phase II effort. Figure 4-2 presents the entrainment rate data for the 2 years' effort at Bayside.

4.5 Data Representative of Seasonal and Daily Activities of Organisms in the Vicinity of SGS—40 CFR 122.21(r)(4)(v)

Table 4-4 summarizes the data representative of seasonal and daily activities for the dominant species observed in the Tampa Bay near Bayside. Seasonal activities consist of many species migrating upstream to tributaries in the spring and summer for spawning. Daily activities include movements for feeding and protection. Many species either move up and down in the water column or into deeper or shallower waters in response to either light or food availability.

Data on impingement and entrainment rates collected at Bayside under the 316(b) Phase II program help define seasonal and diel variations in impingement and entrainment (Golder, 2009).

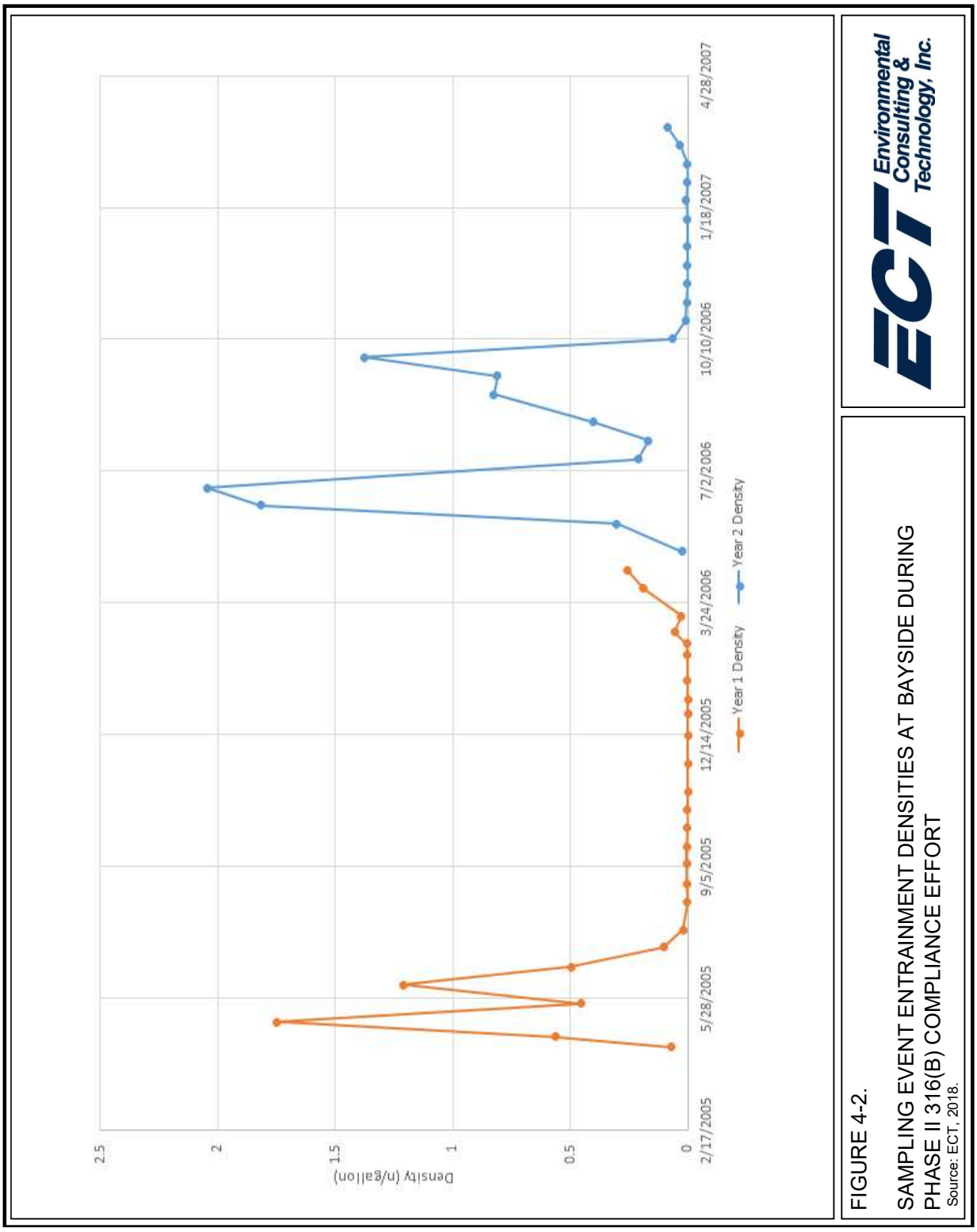


FIGURE 4-2.

SAMPLING EVENT ENTRAINMENT DENSITIES AT BAYSIDE DURING PHASE II 316(B) COMPLIANCE EFFORT

Source: ECT, 2018.

4.6 Identification of Threatened, Endangered, and Other Protected Species Susceptible to Impingement and Entrainment at CWIS—40 CFR 122.21(r)(4)(vi) and 125.95(f)

4.6.1 Threatened or Endangered Species Occurrence

The 316(b) rule modified the existing requirements of 40 CFR 122.21(r)(4)(vi) by replacing the former requirement to list state- and federally listed protected species with those listed by the federal government per 40 CFR 125.95(f). Given the likely interest in state-listed species, this section will address both state- and federally listed species.

4.6.1.1 Federally Listed Species

Federally listed T&E species and designated critical habitat are protected by the Endangered Species Act of 1973 (ESA) and subsequent amendments. The ESA is administered by two federal agencies: U.S. Fish & Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries). Generally, NOAA Fisheries oversees marine species, and USFWS has responsibility over freshwater fish and all other terrestrial and aquatic species. USFWS recommends use of its Information Planning and Conservation (IPaC) tool for determining which species may be affected by a project. This report relies on IPAC as well as Florida Natural Areas Inventory (FNAI) (2017).

Table 4-5 presents state- and federally listed species in the vicinity (1-mile radius) of Bayside (FNAI, 2017). Four federally listed terrestrial species (east indigo snake, Florida bonneted bat, piping plover, and wood stork) have been recorded to occur or likely occur within the vicinity of the Bayside intake (Table 4-5) (FNAI, 2017). None of these terrestrial species is subject to direct effects by the CWIS or the cooling water system. Given their habitat and forage preferences (Tables 4-5 and 4-6), secondary effects from the cooling water system (e.g., loss of forage base) are also unlikely.

Three federally listed aquatic species (Gulf sturgeon, hawksbill sea turtle, and Florida manatee [West Indian manatee subspecies]) have been recorded to occur or likely occur within the vicinity of Bayside (Tables 4-5 and 4-6) (FNAI, 2017). Each of these aquatic species is discussed further in the following paragraphs.

Table 4–5. List of State- and Federally Protected Species Whose Ranges Include the Vicinity of Bayside

Scientific name Common name	State Rank	Global Rank	State Status	Federal Status	Habitat Description
Amphibians					
Rana capito Gopher frog	S3	G3	SSC	N	Primarily native xeric upland habitats, particularly longleaf pine-turkey oak sandhill associations; also xeric to mesic longleaf pine flatwoods, sand pine scrub, xeric oak hammocks.
Beetles					
Bolbocerosoma hamatum Bicolored burrowing scarab beetle	S3	G3G4	N	N	Burrows and areas of light.
Phyllophaga elongate Elongate June beetle	S3	G3	N	N	Burrows and areas of light.
Selonodon mandibularis Large-jawed cebrionid beetle	S2S4	G2G4	N	N	Terrestrial beetle attracted to light. Females are flightless, so poor dispersal abilities. Habitat requirements are unknown but may be sandy uplands.
Birds					
Charadrius melodus Piping plover	S2	G3	FT	LT	Sandy beaches, sand flats, and mudflats along coastal areas.
Grus canadensis pratensis Florida wandhill crane	S2S3	G5T2 T3	ST	N	Freshwater marshes, prairies, and pastures.
Haliaeetus leucocephalus Bald eagle	S3	G5	N	N	Any forested area, riparian. Use standing snag/hollow trees. Breeding habitat most commonly includes areas close to (within 4 kilometers) coastal areas, bays, rivers, lakes, reservoirs, or other bodies of water.
Mycteria Americana Wood stork	S2	G4	FT	LT	Chiefly freshwater situations: marshes, swamps, lagoons, ponds, flooded fields; depressions in marshes are important during drought, also brackish wetlands. Nests mostly in upper parts of cypress trees, mangroves, or dead hardwoods over water or on islands along streams or adjacent to shallow lakes.
Rallus longirostris Florida clapper rail	S3?	G5T3?	N	N	Prefers a terrestrial habitat; found in herbaceous wetland, tidal flat/shore.
Fishes					
Acipenser oxyrhynchus desotoi Gulf sturgeon	S2	G2T2	FT	LT	Primarily marine/estuarine in winter; migrates to upper rivers in spring for spawning; returns to sea/estuary in fall; some may remain near spawning areas. First 2 years are spent in riverine habitats. Spawns in fresh water.

Table 4–5. List of State- and Federally Protected Species Whose Ranges Include the Vicinity of Bayside (Continued, Page 2 of 4)

Scientific name Common name	State Rank	Global Rank	State Status	Federal Status	Habitat Description
Mammals					
Eumops floridanus Florida bonneted bat	S1	G1	FE	LE	Florida bonneted bats occur in a wide range of habitats in urban, suburban, forested, and open areas, including areas with hardwoods or pines, mangroves, golf courses, and spaces over water bodies and wetlands
Mustela frenata peninsulae Florida long-tailed weasel	S3	G5T3	N	N	No clear habitat preference; observed in various habitats, including pine flatwoods, sandhills, hardwood forests, cypress swamps, tropical hammocks, and sand pine scrub habitats. Resting and birthing sites may include tree hollows and underground burrows.
Podomys floridanus Florida mouse	S3	G3	SSC	N	Restricted to fire-maintained, xeric, upland vegetation occurring on deep, well-drained sandy soils, including sand pine scrub, coastal scrub, scrubby flatwoods, longleaf pine-turkey oak, south Florida slash pine-turkey oak (southern ridge sandhill), upland hammock, live oak (xeric) hammock).
Trichechus manatus West Indian manatee	S2	G2	FE	LE	Shallow coastal waters, estuaries, bays, rivers, and lakes; throughout most of the range, appear to prefer rivers and estuaries over marine habitats. Not averse to traveling through dredged canals or using quiet marinas.
Reptiles					
Drymarchon couperi Eastern indigo snake	S3	G3	FT	LT	Sandhill regions dominated by mature longleaf pines, turkey oaks, and wiregrass; flatwoods; most types of hammocks; coastal scrub; dry glades; palmetto flats; prairie; brushy riparian and canal corridors; and wet fields.
Gopherus polyphemus Gopher tortoise	S3	G3	ST	C	Well-drained sandy substrate, ample herbaceous vegetation for food, and sunlit areas for nesting, including sandhill (pine-turkey oak), sand pine scrub, xeric hammock, pine flatwoods, dry prairie, coastal grasslands and dunes, and mixed hardwood-pine communities
Lampropeltis extenuate Short-tailed snake	S3	G3	ST	N	Dry sandy uplands, especially longleaf pine-turkey oak (sandhill) and sometimes adjacent xeric oak hammocks and rosemary-sand pine scrub; also found in sphagnum bog adjacent to typical habitat.

Table 4–5. List of State- and Federally Protected Species Whose Ranges Include the Vicinity of Bayside (Continued, Page 3 of 4)

Scientific name Common name	State Rank	Global Rank	State Status	Federal Status	Habitat Description
Turtles					
Dermochelys coriacea Leatherback sea turtle	G2	S2	FE	LE	Oceanic waters; nests on coastal sand beaches. Rarely seen in coastal waters except as hatchlings dispersing from nesting beaches and as adult females approaching the beach to nest.
Eretmochelys imbricate Hawksbill sea turtle	S1	G3	FE	LE	Uses a wide range of tropical and subtropical habitats, including shallow coastal waters with rocky bottoms, coral reefs, beds of sea grass or algae, mangrove-bordered bays and estuaries, and submerged mud flats.
Pseudemys concinna suwanniensis Suwannee cooter	S3	G5T3	SSC		Blackwater, alluvial (river with banks made of easily eroded soil), and spring-fed rivers; can also survive in some impoundments (e.g., Lake Talquin [Ochlockonee River] and Lake Rousseau [Withlacoochee River]). Key habitat features are moderate current, ample aquatic vegetation for feeding, and appropriate surfaces for basking (rocks, stumps, and logs). Found from the Tampa Bay region (Alafia River), northwest to the Ochlockonee River just west of Tallahassee.

Note:
C = candidate for listing at the federal level by USFWS.
FE = listed as endangered species at the federal level by the USFWS.
FT = listed as threatened species at the federal level by USFWS.
N = not currently listed, nor currently being considered for listing.
LT = listed as legally threatened by USFWS.
LE = listed as legally endangered by USFWS.
ST = state population listed as threatened by FWC. Defined as a species, subspecies, or isolated population acutely vulnerable to environmental alteration, declining in number at a rapid rate, or whose range or habitat is decreasing in area at a rapid rate and as a consequence is destined or likely to become an endangered species within the foreseeable future.
SSC = listed as species of special concern by FWC. Defined as a population that warrants special protection, recognition, or consideration because it has an inherent significant vulnerability to habitat modification, environmental alteration, human disturbance, or substantial human exploitation, which, in the foreseeable future, may result in its becoming a threatened species.

FNAI Global Element Rank
G1 = critically imperiled globally because of extreme rarity (5 or fewer occurrences or less than 1,000 individuals) or because of extreme vulnerability to extinction due to some natural or man-made factor.
G2 = imperiled globally because of rarity (6 to 20 occurrences or less than 3,000 individuals) or because of vulnerability to extinction due to some natural or man-made factor.
G3 = either very rare and local throughout its range (21 to 100 occurrences or less than 10,000 individuals) or found locally in a restricted range or vulnerable to extinction from other factors.

Table 4–5. List of State- and Federally Protected Species Whose Ranges Include the Vicinity of Bayside (Continued, Page 4 of 4)

G4 = apparently secure globally (may be rare in parts of range).
G5 = demonstrably secure globally.
G#? = tentative rank (e.g., G2?).
G#G# = range of rank; insufficient data to assign specific global rank (e.g., G2G3).
G#T# = rank of a taxonomic subgroup such as a subspecies or variety; the G portion of the rank refers to the entire species, and the T portion refers to the specific subgroup; numbers have same definition as above (e.g., G3T1).

FNAI State Element Rank

S1 = critically imperiled in Florida because of extreme rarity (5 or fewer occurrences or less than 1,000 individuals) or because of extreme vulnerability to extinction due to some natural or man-made factor.
S2 = imperiled in Florida because of rarity (6 to 20 occurrences or less than 3,000 individuals) or because of vulnerability to extinction due to some natural or man-made factor.
S3 = either very rare and local in Florida (21 to 100 occurrences or less than 10,000 individuals) or found locally in a restricted range or vulnerable to extinction from other factors.
S4 = apparently secure in Florida (may be rare in parts of range).

Sources: FWC, 2016.
FNAI, 2017.
USFWS, 2016.
NatureServe, 2016.

Table 4–6. Protected Aquatic Species Ranges and Reproductive Habits in Hillsborough County

Scientific Name Common Name	Range	Reproduction
Amphibians		
Rana capito Gopher frog	Coastal plain from the southern half of North Carolina (Beaufort County) to southern Florida (Collier County on the west coast, Broward County on the east coast), west to Alabama; isolated populations in central Alabama.	Breeding generally occurs in winter and early spring in most of the range. In southern Alabama and the panhandle of Florida, typically reproduces from January through April, although Bailey (1991) observed reproduction in southern Alabama in September and October following heavy rains associated with hurricanes
Fishes		
Acipenser oxyrhynchus desotoi Gulf sturgeon	Once widely distributed throughout the coastal rivers of the northeastern Gulf of Mexico, primarily from the Mississippi River east to Tampa Bay, including the states of Louisiana, Mississippi, Alabama, and Florida.	Takes at least 7 to 8 years to mature; females spawn at intervals of more than 1 year. Adults migrate between freshwater spawning areas and saltwater nonspawning areas. Moves into the Suwanne River February through May; may migrate as far as 140 miles upstream; subadults and adults return to the Gulf of Mexico in late fall
Mammals		.
Trichechus manatus West Indian manatee	In the United States, concentrated in Florida in the winter; in summer months, found as far west as Texas and as far north as Massachusetts. Migrates southward for winter; seasonal migrations of at least 530 miles to wintering areas have been documented along Atlantic Coast; home range varies widely throughout the year. In summer, males move over areas extending up to a couple hundred kilometers and tend to travel more widely than females.	Mating, calving, and care of young often occur in secluded canals, creeks, embayments, and lagoons.
Turtles		
Dermochelys coriacea Leatherback sea turtle	Circumglobal species, generally forages in temperate waters and nests in tropical and subtropical latitudes on beaches of the Atlantic, Indian, and Pacific oceans. In the Western Hemisphere, nesting also occurs in Florida (very rarely north to Georgia), along the shores of the Gulf of Mexico.	Nests at night, March through August in Western Hemisphere. Eggs hatch in 8 to 10 weeks. Nests on sloping sandy beaches backed up by vegetation, often near deep water and rough seas.
Eretmochelys imbricata Hawksbill sea turtle	Pantropical and warm-temperate regions, rarely venturing into higher latitudes; Atlantic, Pacific, and Indian oceans. Nests on beaches generally between 25 degrees latitude north and south, including tropical Gulf Coast of Mexico, West Indies, Bahamas, and the Americas.	Nesting occurs on undisturbed, deep-sand, insular or mainland beaches, from high energy ocean beaches to tiny pocket beaches several meters wide contained in crevices of cliff walls; typical site would be a low-energy sand beach with woody vegetation, such as sea grape or saltshrub, near the water line.

Table 4–6. Protected Aquatic Species Ranges and Reproductive Habits in Hillsborough County (Continued, Page 2 of 2)

Scientific Name Common Name	Range	Reproduction
Pseudemys concinna suwanniensis Swuannee cooter	Chiefly rivers in northern Florida that drain into the Gulf of Mexico. Populations inhabit multiple tributaries within the Suwannee River drainage, including the Withlacoochee and Alapaha rivers that extend into Georgia.	In northern Florida, nesting begins in late March or early April and extends into early August; individual lay as many as five clutches per season; most if not all females nest annually.

Sources: FNAI, 2017.
NatureServe, 2016.

TECO and ECT met with the 316(b) coordinator for NOAA Fisheries, Mr. Jason Rueter ([727] 824-5350) at the Big Bend Power Station on March 29, 2016, to tour the intakes and discuss the potential effects of the cooling systems of both Big Bend and Bayside on federally listed species. Mr. Rueter indicated neither Gulf sturgeon nor hawksbill sea turtle were likely to be found in the vicinities of the two plants due to their geographic range and habitat preferences. Neither species has ever been encountered in surveys of impingement or entrainment or in the FIM program. As noted in the following paragraphs, West Indian manatees are encountered at the plants, and both plants have in-place manatee protection plans developed under FWC and with review by NOAA Fisheries. Mr. Rueter indicated he did not have concerns about the interaction of the CWIS and the cooling system with aquatic federally listed species (NOAA, 2016).

Gulf Sturgeon

The historical range of the Gulf sturgeon included coastal river systems along the entirety of the Gulf of Mexico, from the Mississippi River east to Tampa Bay, Florida. Sporadic occurrences are known as far west as Texas (Rio Grande) and in marine waters in Florida south to Florida Bay. Gulf sturgeon numbers have declined due to overfishing in the 20th century. In 1950, the construction of dams and water control structures resulted in significant habitat loss for this species. They continue to decline at a rate of 10 to 30 percent per year (NOAA, 2016). Since adults migrate between freshwater spawning areas and saltwater nonspawning areas, water control structures have hindered breeding habits of the Gulf sturgeon. Continued implementation of United States laws, such as the Fish and Wildlife Coordination Act, should result in the improvement of sturgeon breeding and nursery habitats. All United States Gulf sturgeon fisheries have been closed since 1997. Approximately 2,780 kilometers of river have been designated as critical habitat for the Gulf sturgeon by USFWS (International Union for Conservation of Nature [IUCN] Red List, 2016). Impingement or entrainment of Gulf sturgeon is not expected at Bayside, since Gulf sturgeon are not known to be breeding within Tampa Bay or its tributaries, and juvenile and adult sturgeon have strong swimming abilities that would be able to overcome intake velocities experienced at Bayside. Furthermore, Bayside has no record of sturgeon entering the CWIS, and NOAA has determined no federally listed species are of concern due to the operation of the CWIS at Bayside (NOAA, 2016).

Hawksbill Sea Turtle

The hawksbill turtle frequents rocky areas, coral reefs, shallow coastal areas, lagoons, or oceanic island. It is seldom seen in water deeper than 65 ft. Hawksbills nest on almost any undisturbed deep-sand beach in the tropics. The hawksbill sea turtle maintains a warm-temperature range, primarily nesting on beaches in 25 degrees of latitude, north and south, including tropical Gulf Coast of Mexico, West Indies, Bahamas, and the Americas. It is rarely seen on the Atlantic Coast or north of the Florida Keys. The population is greatly reduced from historical levels; however, nesting populations in the Atlantic in general are doing better than their Indo-Pacific counterparts (USFWS, 2015). Harvesting for commercial purposes has contributed to population decline. There is also an increasing threat of beach development destroying the nesting habitats of the hawksbill sea turtle. Protection plans for this species include installing excluder devices from shrimp trawl nets and reducing the amount of lighting present at night on beaches (NatureServe, 2016). No nesting habitat is presenting near the CWIS. Thus, hawksbill sea turtles are not expected to be impinged or entrained at Bayside. Furthermore, Bayside has no record of any sea turtle entering the CWIS, and NOAA has determined no federally listed species are of concern due to the operation of the CWIS at Bayside (NOAA, 2016).

Leatherback Sea Turtle

Leatherback sea turtles are the largest, deepest diving, and most migratory sea turtles. They are globally distributed and migrate hundreds or thousands of kilometers between nesting beaches and distant marine waters. They are mainly pelagic, seldom approaching land except to nest. They concentrate in summer in waters between 20 and 40 meters deep near Cape Canaveral, Florida. Individual nesting females nest on multiple islands within a region. They nest on sloping sandy beaches backed by vegetation and often near deep water and rough seas. Though globally the population appears to be declining, Florida has seen an increase in nesting activity of 10 percent since 1979. The greatest threat to leatherbacks is habitat destruction/disturbance to their nesting sites (USFWS, 2013). There is currently critical habitat listed for leatherback; Bayside is not contained within any critical habitat (IPaC, 2016).

West Indian Manatee (Florida Manatee)

Hillsborough County is part of the USFWS West Indian manatee range. Their range is generally restricted to the southeastern United States with individuals occasionally ranging as far north as Massachusetts and as far west as Texas. Federal protection plans for manatees have been implemented on Tampa Bay (2003), limiting the construction of docks. Hillsborough County has set Manatee Protection Zones in 2005 (FWC, 2005).

The intake of Bayside is included in one of these zones designated by USFWS. Idle speed for boats must be maintained during manatee season, November 15 to March 31 (FWC, 2005). Manatees are not likely to spend much time near the intake due to the lack of forage habitat and ability to find warmer water elsewhere. In addition, it is unlikely a manatee will be negatively impacted by Bayside's intake due to their swimming abilities and large size. Furthermore, Bayside has no record of manatees entering the CWIS, and NOAA has determined no federally listed species are of concern due to the operation of the CWIS at Bayside (NOAA, 2016). Bayside has a manatee protection plan under the oversight of FWC, which includes required responses in the event that a manatee is found in the CWIS.

4.6.1.2 State-listed Species

In Florida, the state list of animals designated as federally designated endangered or threatened, state-designated threatened, or state-designated species of special concern is maintained by FWC in accordance with Sections 68A-27.003 and 68A-27.005, Florida Administrative Code (F.A.C.). Table 4-5 includes protected aquatic species listed for the area surrounding Bayside by the FNAI.

Table 4-6 has range and reproductive habits for protected aquatic species that may be located near the intake based on the potential presence within Hillsborough County.

4.6.2 Likelihood of Impingement or Entrainment

It is unlikely any T&E species that may occur in the vicinity of the intake would be impinged due to the use of an intake canal and lower intake velocities (less than 1.2 fps). No listed species were identified within Zone C as part of the FIM stratified random sampling program and are unlikely to be present within the area of the CWIS. No state-listed species was observed within

the impingement and entrainment samples collected at the CWIS as part of the 316(b) Phase II compliance efforts (Golder, 2009). The Florida manatee is unlikely to be impinged due its large size and the strong swimming ability of both the adults and juveniles. No spawning activity of Gulf sturgeon has been observed within the vicinity of the CWIS at Bayside.

4.7 Documentation of Consultation with Services—40 CFR 122.21(r)(4)(vii)

An informal consultation was held with NOAA concerning the possibility of the presence of three endangered species in waters near the intake: Gulf sturgeon, Hawksbill sea turtle, and West Indian manatee. This included a visit to Big Bend and a discussion of both Big Bend and Bayside. Confirmation was received that NOAA (2016) "did not have concerns regarding federally listed species under Section 316(b) and did not believe that seeking an incidental take authorization under the Endangered Species Act was appropriate."

4.8 Methods and Quality Assurance Procedures for Field Efforts—40 CFR 122.21(r)(4)(viii)

No new data were collected to support this biological baseline characterization. For methodology and quality assurance procedures associated with the data collection conducted in 2005 through 2007 as part of the 316(b) Phase II compliance effort, refer to the CWA Section 316(b) Biological Characterization Report for Bayside Power Station (Golder, 2009). Ambient data were collected by state and federal resource agencies that follow programmatic quality control procedures available through those agencies; therefore, there is no need to document methods or quality assurance procedures in this subsection.

4.9 Definition of Source Water Baseline Biological Characterization Data—40 CFR 122.21(r)(4)(ix)

This report acknowledges the final rule adds three additional subsections to the requirements of 40 CFR 122.21(r)(4). While this report has provided data to address 40 CFR 122.21(r)(4)(i) through (viii) and (x) through (xii), there is no required submittal under this subsection 40 CFR 122.21(r)(4)(ix).

4.10 Identification of Protective Measures and Stabilization Activities—40 CFR 122.21(r)(4)(x)

Bayside utilizes the following protective measures to limit the degree of impingement and entrainment at the facility:

- The CWIS of Bayside is located within an intake canal whose sole purpose is to convey water to the circulating system, thus limiting the effect of the intake velocities (threshold of 0.5 fps) to just beyond the mouth of the intake canal (Section 2.2.3).
- The intake employs coarse-mesh TWSs that reduce the degree of entrainment by limiting larger organisms from entering the circulating system.
- The CWIS is oriented perpendicular to the canal to allow fish room to avoid the CWIS.
- The approach velocity to the screen is 1.2 fps or less, allowing strong, mobile organisms to avoid the intakes.

4.11 List of Fragile Species—40 CFR 122.21(r)(4)(xi)

In the final 316(b) rule, EPA identified 14 species as fragile or having postimpingement survival rates of less than 30 percent:

- Alewife
- American shad
- Atlantic herring
- Bay anchovy
- Blueback herring
- Bluefish
- Butterfish[15]
- Gizzard shad
- Grey snapper
- Hickory shad
- Menhaden
- Rainbow smelt
- Round herring
- Silver anchovy

[15] The species of butterfish that was studied to determine "fragile species" as per the 2003 EPRI Report 1007821 Evaluating the Effects of Power Plant Operations on Aquatic Communities: Summary of Impingement Survival Studies, June 2003 is *Peprilus triacanthus*. This species was not observed in the impingement samples nor FIM data near Bayside. On the other hand, Gulf butterfish (*Peprilus burti*) was observed in the impingement samples of 2005 to 2006. Sensitivities of fish to handling is often similar in members of a genus but the fragility of Gulf butterfish is not known.

Of these species, bay anchovy, bluefish, grey snapper, and menhaden inhabit the waters within Zone C of the FIM stratified sampling (FIM, 2016). However, only bay anchovy were observed within impingement samples at Bayside (Golder, 2009).

4.12 Information Submitted to Obtain Incidental Take Exemption or Authorization from Services—40 CFR 122.21(r)(4)(xii)

Bayside has not sought or obtained an incidental take exemption or authorization for its CWIS from either USFWS or NOAA Fisheries. No take of federally listed species is known to have occurred at the CWIS. It is unlikely operation of the CWIS will result in an incidental take, and a NOAA staff member with 316(b) responsibility believes an incidental take permit is not necessary for the CWIS at Bayside (NOAA, 2016).

4.13 References

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5.0 40 CFR 122.21(r)(5)—Cooling Water System Data

This section provides information on the cooling water system, including a description of the system, analysis of water uses within the plant, impact of withdraw on source water body and description of impingement technology, and any reductions in impingement or entrainment.

The following is the text of 40 CFR 122.21(r)(5):

> Cooling Water System Data. The owner or operator of an existing facility must submit the following information for each cooling water intake structure used or intended to be used: (i) A narrative description of the operation of the cooling water system and its relationship to cooling water intake structures; the proportion of the design intake flow that is used in the system; the number of days of the year the cooling water system is in operation and seasonal changes in the operation of the system, if applicable; the proportion of design intake flow for contact cooling, non-contact cooling, and process uses; a distribution of water reuse to include cooling water reused as process water, process water reused for cooling, and the use of gray water for cooling; a description of reductions in total water withdrawals including cooling water intake flow reductions already achieved through minimized process water withdrawals; a description of any cooling water that is used in a manufacturing process either before or after it is used for cooling, including other recycled process water flows; the proportion of the source waterbody withdrawn (on a monthly basis); (ii) Design and engineering calculations prepared by a qualified professional and supporting data to support the description required by paragraph (r)(5)(i) of this section; and, (iii) Description of existing impingement and entrainment technologies or operational measures and a summary of their performance, including but not limited to reductions in impingement mortality and entrainment due to intake location and reductions in total water withdrawals and usage.

5.1 Cooling Water System Description—40 CFR 122.21(r)(5)(i)

Bayside's circulation water system is a once-through, open-cycle system: the cooling water enters the facility on one end, passes through the steam turbine condensers, and is returned back to the bay via the discharge canal. The plant currently has two generating units.

Between September 2012 and October 2016, plant intake of bay water has averaged 542 MGD. This noncontact cooling water comprises the only use of bay water (see Figure 3-3 for a water balance diagram). Recycled water and potable water purchased from Tampa is used for site service waters.

Bayside is permitted to withdraw 1,346 MGD from Hillsborough Bay to support plant operations. The cooling water system is in continuous operation except during periods of unit outage. Typically, a unit is scheduled for two outages per year. Bayside is operated as a baseload plant, and no regular seasonal variations exist in the water use data beyond the practice of performing outages during nonpeak months (winter).

Monthly water withdrawal from Hillsborough Bay expressed as a percent of the low flow and mean flow conditions relative to actual average monthly intake flow for a period from 2014 to 2016 and current design intake flow of 668.14 MGD for Units 1 and 2 only are shown in Table 5-1.

Table 5–1. Bayside Daily Withdrawal (Design and Actual) as Percent of Hillsborough Bay

Month	Historical AIF (MGD)	Percentage of Tidal Prism	Percentage of Source Water Body	
			Mean Volume	Mean Lowest Low Water Volume
January	532.63	3.53	0.49	0.55
February	526.93	3.49	0.49	0.54
March	525.89	3.48	0.49	0.54
April	558.74	3.70	0.52	0.58
May	591.34	3.91	0.55	0.61
June	587.87	3.89	0.54	0.61
July	583.25	3.86	0.54	0.60
August	592.47	3.92	0.55	0.61
September	555.41	3.68	0.51	0.57
October	511.44	3.39	0.47	0.53
November	411.47	2.72	0.38	0.42
December	492.00	3.26	0.46	0.51
DIF	668.14	4.42	0.62	0.69

Source: ECT, 2018.

Water from the intake canal is pumped via circulating pumps located at the intake platform (Figures 5-1 and 5-2). Each unit is serviced by two pumps (Pumps 1A and 1B, 2A and 2B). Water enters the screen bays from the north and travels through the no-well, coarse-mesh TWSs. The screen configuration is a suspended dual flow system with a double-entry-single-exit flow pattern. A screen wash is located outside each bay screen assembly that provides a high-pressure (100 psi) wash of debris from the TWSs into a collection trough (Figure 3-4) for offsite disposal. Water for the screen wash is provided through the CWIS.

5.1.1 Unit 1 (Former Gannon Unit 5)

The circulating water pumps for Unit 1 are Ingersoll-Rand 54 APMA vertical turbine pumps. They have a maximum flow capacity of 90,750 gpm via an 800-hp motor. Each pump discharges into a 66-inch inside diameter (ID) steel pipe (Figures 5-1 and 5-3). Water travels approximately 74 ft, where it converges with the flow from the unit's other circulating pump and enters a 90-inch ID concrete pipe. A combination of concrete and steel 90-inch ID pipes carry the water to the Unit 1 Alstom condenser within Building #5. Table 5-2 provides a summary of the condenser specifications for Units 1 and 2.

Table 5–2. Units 1 and 2 Condenser Specifications

	Unit 1	Unit 2
Steam load	1,660,000 lb/hr	2,160,000 lb/hr
Steam temperature	113°F	107°F
Duty	1,567 MMBtu/hr	2,130 MMBtu/hr
Effective tube length	36 ft	40 ft
Effective condenser surface	99,526 ft^2	183,655 ft^2
Circulating water quantity	184,800 gpm	252,000 gpm
Circulating water inlet temperature	78°F	78°F
Average circulating water velocity in tubes	7.76 fps	7.37 fps
Tube diameter	1-inch outside diameter	0.875-inch outside diameter

Note: °F = degree Fahrenheit.
fps = foot per second.
ft = foot.
ft^2 = square foot.
gpm = gallon per minute.
lb/hr = pound per hour.
MMBtu/hr = million British thermal units per hour.

Source: TECO, 2018.

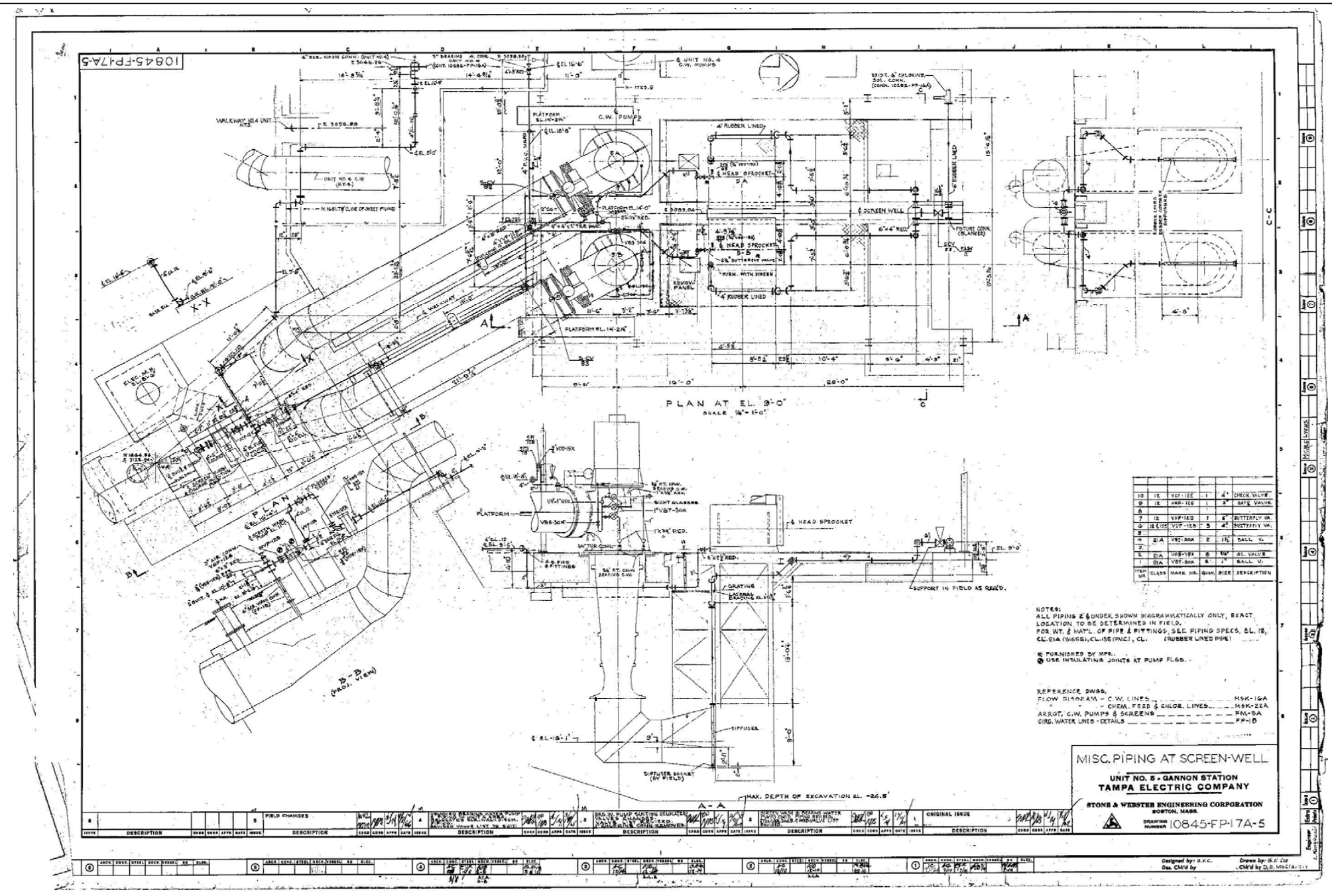


FIGURE 5-1.

BAYSIDE/GANNON UNIT 6 ENGINERING DRAWING

Source: TECO, 2011.

TAMPA ELECTRIC COMPANY
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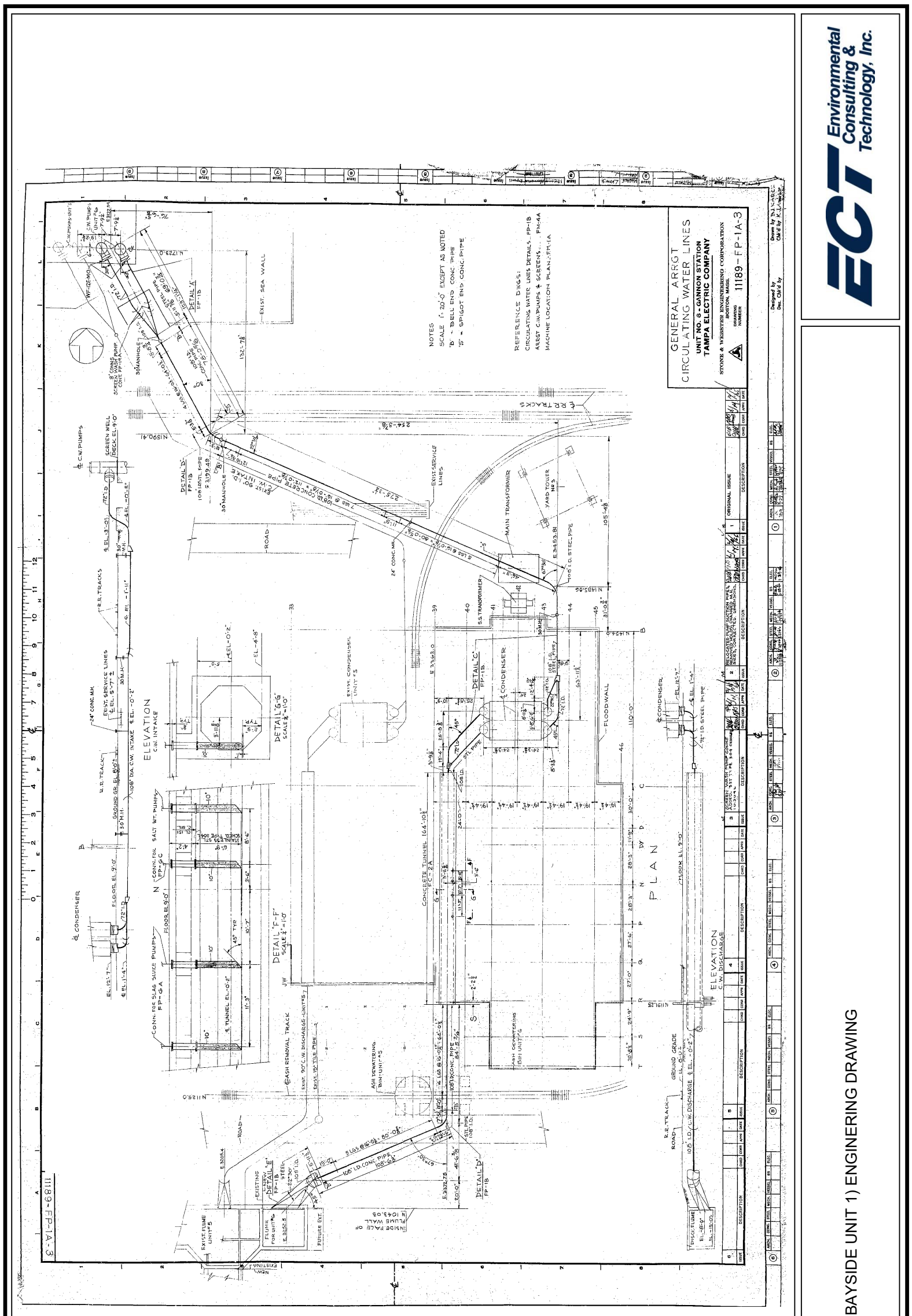
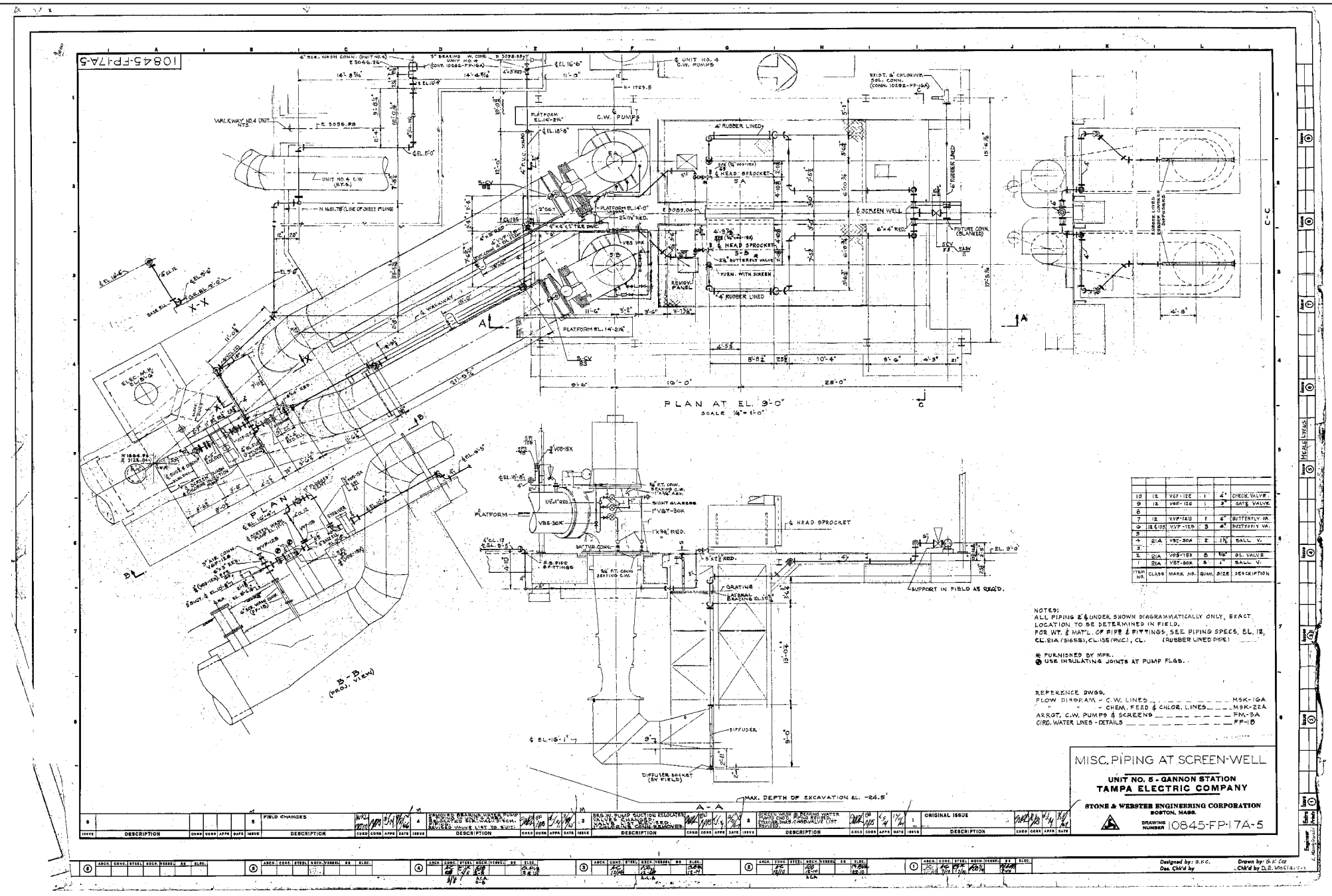


FIGURE 5-2.

GANNON UNIT 5 (BAYSIDE UNIT 1) ENGINERING DRAWING

Source: TECO, 2011.



ITEM NO.	CLASS	MARK NO.	QUAN.	SIZE	DESCRIPTION
10	12	VCF-TEE	1	4"	CHECK VALVE
9	12	VMF-TEE	1	3"	GATE VALVE
8					
7	12	VVF-FLG	1	4"	BUTTERFLY VA.
6	13S(R)	VVF-13S	3	4"	BUTTERFLY VA.
5					
4	21A	V85-30A	2	1½"	BALL V.
3					
2	21A	V05-10A	5	¾"	GL. VALVE
1	21A	V07-30A	5	1"	BALL V.

FIGURE 5-3.

BAYSIDE MISCELLANEOUS PIPING AT SCREENWALL

Source: TECO, 2011.

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The condenser tubes are oriented at right angles to the turbine generator shaft. The condenser is dual pressure, with inlet water entering the low-pressure side, and the water outlets on the high-pressure side. The circulating water enters the low-pressure side of the condenser and picks up heat from steam produced in the boiler condensing the steam to water. The heated water in the condenser exits the high-pressure side and enters the return main, where it is carried to the discharge flume through a 90-inch ID concrete pipe via an approximately 150-ft-long tunnel through Building #5.

5.1.2 Unit 2 (Former Gannon Unit 6)

The circulating water pumps for Unit 2 are Byron Jackson Co. Size 81 vertical turbine pumps, each with a maximum flow capacity of 199,250 gpm via a 1,000-hp motor. Each pump discharges into a 72-inch ID steel pipe (Figure 5-2). Water travels approximately 69 ft, where it converges with flow from the unit's other circulating pump and enters a 108-inch ID concrete pipe. A combination of concrete and steel 108-inch ID pipes carry the water to the Unit 2 Alstom condenser within Building #6. Table 5-2 provides a summary of the condenser specifications for Units 1 and 2.

5.1.3 Discharge Flumes

The discharge flumes consist of two large concrete basins that receive heated condenser water from each unit. The flumes act to dissipate the temperature and energy of the discharge water prior to entering the discharge canal and returning to Hillsborough Bay via Outfall D-001.

5.2 Calculations and Supporting Data—40 CFR 122.21(r)(5)(ii)

Table 5-3 provides the engineering calculations for the through-screen velocity.

Table 5–3. Bayside Units 1 and 2 Through-screen Velocity Determination

Parameter	Maximum Average 2014 to 2016		Maximum Design	
	Unit 1	Unit 2	Unit 1	Unit 2
Unit pump rate (MGD)	253.44	345.6	253.44	345.6
Total surface area of screens per unit (ft^2)	400.84	400.84	400.84	400.84
Total open area of intake per unit (ft^2)	245.71	245.71	245.71	245.71
Through-screen velocity (fps)	1.59	2.18	1.60	2.18

Source: ECT, 2018.

For the current design and configuration of the Bayside CWIS (see Section 3.0 for more details), assuming a low water level of 16.5 ft (eleven 18-inch screen panels submerged per side) and four pump capacity operation (maximum average for 2014 to 2016), through-screen velocity (v) was calculated as:

$$v = (maximum\ average\ unit\ pump\ rate\ MGD) \times (1{,}000{,}000) \times \left(\frac{1\ day}{24\ hours}\right) \times \left(\frac{1\ hour}{60\ min}\right) \times \left(\frac{1\ min}{60\ sec}\right) \times \left(\frac{0.1337\ ft^3}{gal}\right) \times \left(\frac{1}{open\ area\ of\ intake\ per\ Unit}\right)$$

where: $total\ open\ area\ of\ intake = 11\ screen\ panels\ submerged\ per\ side \times 2\ sides\ of\ each\ screen\ assembly \times 2\ screens\ per\ unit \times open\ area\ of\ individual\ screen$

$Surface\ area\ of\ individual\ screen\ panel = 9.11\ ft^2$

$POA = percent\ of\ open\ area\ of\ screen = 0.613$

5.3 Description of Existing Impingement and Entrainment Reduction Measures-40 CFR 122.21(r)(5)(iii)

Each unit at Bayside is equipped with coarse-mesh TWSs. However, the current configuration at Bayside does not provide a reduction in impingement due to lack of fish return system.

The CWIS at Bayside is located within an intake canal. The canal is off the channel leading from Hillsborough Bay to McKay Bay and, thus, out of the main flow of Tampa Bay's currents/tidal exchange. This limits the probability of fish entering the canal while migrating from higher to lower salinity waters. The differences in ambient densities and those observed at the intake is supported by the 316(b) Phase II studies that observed an impingement rate of 0.09 percent of the nearfield population (Golder, 2009). The CWIS is positioned mid-depth and perpendicular to the length of the canal. This orientation further limits the likelihood of fish approaching the screens if they enter the intake canal.

Bayside was repowered to a combined-cycle facility in 2003 and 2004. At the same time, four units were retired and dismantled, reducing the DIF for the facility from 1,336 to 668 MGD, a reduction of 50 percent. According to 40 CFR 125.98(f)(3)(iii), such a reduction in intake flow could be considered as credited to entrainment reduction if it occurred within 10 years prior to the effective date of the rule. TECO concludes credit of flow reduction associated with closure of the Gannon units is ambiguous under the rule.

TECO notes Bayside uses combined-cycle generation, which is considerably more efficient that a steam turbine alone and substantially reduces the demand for cooling water relative to MW generated. In fact, in the preamble to the rule that discusses the necessary contents of 40 CFR 122.21(r)(5),[16] EPA notes combined-cycle cooling should be considered an existing measure to reduce intake flow and, therefore, impingement and entrainment:[17]

> The applicant must also submit a description of existing impingement and entrainment technologies or operational measures and a summary of their performance, including for example reductions in entrainment due to intake location and **reductions in total water withdrawals and usage, and efficiencies in energy production for each producing unit that result in the use of less cooling water, including for example combined cycle** and cogeneration. (**emphasis** added)

As an illustration of the water use efficiency of the Bayside units, the following is a comparison of the water use performance of the Gannon units and the Bayside units. The former Gannon units had a capacity of 1,272 MW with a DIF of 1,336 MGD, or 1.05 MGD per MW. On the

[16] 79 FR 48364, August 15, 2014. 40 CFR 122.21(r)(5), Cooling Water System Data.
[17] TECO understands that, during development of the rule, EPA considered reducing the rule's requirements for facilities with low "heat rates" or generation efficiency such as combined-cycle plants.

other hand, the repowered Bayside units have a capacity of 1,836 MW using a maximum of 668 MGD, or 0.36 MGD per MW, a decrease of 65 percent on a MW basis.[18] TECO believes it is appropriate and consistent with the rule-making to consider this existing cooling water use reduction at Bayside when evaluating entrainment BTA on a site-specific BPJ basis. In summary, the existing Bayside facility already reduces entrainment by more than 50 percent by use of a combined-cycle generation.

Bayside only uses the bay water for cooling water. Other process water comes from recycled water onsite or is provided by the City of Tampa. Thus, withdrawals are limited to only cooling purposes, reducing the usage of bay water overall.

5.4 References

Golder Associates, Inc. 2009. Clean Water Act Section 316(b) Biological Characterization Report for Bayside Power Station. Prepared for Tampa Electric Company. September 22, 2009.

[18] Bayside also employs four combustion turbines not associated with steam turbines. These generators do not use cooling water and, if considered in this calculation, would increase the flow reduction per MW relative to Gannon to 70 percent.

6.0 40 CFR 122.21(r)(6)—Method of Compliance with IM BTA

This section addresses a portion of the rule's requirements under 40 CFR 122.21(r)(6), Chosen Method(s) of Compliance with Impingement Mortality Standard, for Bayside. As discussed further in this section, EPA's 2014 rule for existing facilities developed under the CWA Section 316(b) anticipates the selection of IM BTA by the NPDES Director should occur only after the entrainment BTA has been established at the site. Therefore, TECO's proposed approach to IM BTA should be considered contingent on FDEP's acceptance that retrofit to a closed-cycle recirculating cooling system is NOT an appropriate entrainment BTA approach at Bayside.

6.1 Introduction and Background

6.1.1 Rule Requirement

Bayside is regulated under Section 316(b) existing facilities rule. Under the rule, the station has to submit information required in 40 CFR 122.21(r)(6), Chosen Method(s) of Compliance with Impingement Mortality Standard. The method for IM BTA compliance must be chosen from the BTA standards for IM as defined in 40 CFR 125.94(c).[19]

The owner/operator of an existing facility must comply with one of the alternatives in paragraphs (c)(1) through (7):

(1) Closed-cycle recirculating system
(2) 0.5-fps through-screen design velocity
(3) 0.5-fps through-screen actual velocity
(4) Existing offshore velocity cap
(5) Modified TWSs

[19] 40 CFR 125.94(c)(11) and (12) provide two other approaches to IM BTA, neither of which applies to Bayside.

(6) System of technologies as the BTA for IM

(7) IM performance standard.

The text of 40 CFR 122.21(r)(6) is as follows:

The owner or operator of the facility must identify the chosen compliance method for the entire facility; alternately, the applicant must identify the chosen compliance method for each cooling water intake structure at its facility. The applicant must identify any intake structure for with a BTA determination for Impingement Morality under 40 CFR 125.94 (c)(11) or (12) is requested. In addition, the owner or operator that chooses to comply via 40 CFR 125.94 (c)(5) or (6) much also submit an impingement technology performance optimization study as described below:

(i) If the applicant chooses to comply with 40 CFR 125.94(c)(5), subject to the flexibility for timing provided in 40 CFR 125.95(a)(2), the impingement technology performance optimization study must include two years of biological data collection measuring the reduction in impingement mortality achieved by the modified traveling screes as defined at 40 CFR 125.92(s) and demonstrating that the operation has been optimized to minimize impingement mortality. A complete description of the modified traveling screens and associated equipment must be included, including, for example, type of mesh, mesh slot size, pressure sprays and fish return mechanisms. A description of any biological data collection and data collection approach used in measuring impingement morality must be included:

(A) Collecting data no less frequently than monthly. The Director may establish more frequent data collection:

(B) Biological data collection representative of the impingement and the impingement mortality at the intakes subject to this provision;

(C) A taxonomic identification to the lowest taxon possible of all organisms collected;

(D) The method in which naturally moribund organisms are identified and taken into account;

(E) The method in which mortality due to holding times is taken into account;

(F) If the facility entraps fish or shellfish, a count of entrapment, as defined at 40 CFR 125.92(j), as impingement mortality; and

(G) The percent impingement mortality reflecting optimized operation of the modified traveling screen and all supporting calculations.

(ii) If the application chooses to comply with 40 CFR 125.94(c)(6), the impingement technology performance optimization study must include biological data

> measuring the reduction in impingement mortality achieved by operation of the system of technologies, operational measures and best management practices, and demonstrating that operation of the system has been optimized to minimize impingement mortality. This system of technologies, operational measures and best management practices may include flow reductions, seasonal operation, unit closure, credit for intake location, and behavioral deterrent systems. The application must document how each system element contributes to the system's performance. The application must also include a description of any sampling or data collection approach used in measuring the rate of impingement mortality achieved by the system. The application must also include a description of any sampling or data collection approach used in measuring the rate of impingement, impingement mortality, or flow reductions.

The potential requirements of 40 CFR 122.21(r)(6) can be divided into three portions:

- Identification of the proposed method of compliance with IM BTA for each intake as described in the introduction to the section
- Description in Section (i) of the requirements of the impingement technology performance optimization study (ITPOS) for those facilities pursuing the IM BTA method that relies on modified TWSs and a fish return, per 40 CFR 125.94(c)(5).
- Definition in Section (ii) of the requirements of the ITPOS for those intakes proposed for IM BTA method based on the system of measure, per 40 CFR 125.94(c)(6)

The nature of this section of the rule requires the responses by the applicant be provisional based on the NPDES Director's pending decisions regarding what represents BTA for entrainment and IM. The implications of the pending entrainment and IM BTA decisions are discussed separately in the following subsections. TECO is aware of companies that have delayed submission, with NPDES Director approval, of any material under 40 CFR 122.21(r)(6) until the entrainment BTA decision has been made. Despite the potential that its proposal may change as the rule process moves forward, TECO believes it will be useful for FDEP to understand the proposed IM BTA approach when reviewing entrainment BTA materials. In addition, information presented in the entrainment BTA assessment, particularly in evaluating FMS, provides useful perspective on the proposed IM BTA approaches. Therefore, TECO is providing portions of requirements under 40 CFR 122.21(r)(6) while noting what will be submitted at a later date.

6.1.1.1 Entrainment BTA Decision May Affect Choice of IM BTA

The final decision for the method of compliance with the 40 CFR 125.94(c) BTA standards for IM will be made following the NPDES Director's decision on the 40 CFR 125.94(d) BTA standards for entrainment for existing facilities. This sequence is highlighted in the preamble to the rule[20] in which two examples are provided by which technologies installed to address IM BTA could be rendered superfluous by a subsequent decision on entrainment BTA. In both examples, the facility would incur costs needlessly for a technology that would be made irrelevant by the entrainment BTA. Consistent with this intention of the rule, TECO's proposal for IM BTA is provisional and subject to change based on FDEP's decision regarding entrainment BTA.

6.1.1.2 Nature of Impingement Technology Performance Optimization Study May Change with IM BTA Decision

The rule's requirement to develop an ITPOS is triggered if the facility installs modified TWSs and a fish return or by installation of a system of measures. For several reasons, TECO believes it is premature to finalize the ITPOS, including:

- As noted previously, the trigger for an ITPOS may be eliminated if the entrainment BTA decision changes the approach to IM BTA.
- Regardless of the entrainment BTA decision, FDEP and TECO have not reached a consensus on the IM BTA approach, suggesting the need for, and details of, the ITPOS may change in the future.
- If an ITPOS is necessary, the plan is likely to benefit from configuration and operation details of the IM BTA measure that will only be available after further design work.
- The plan for an ITPOS, should it be necessary, will likely benefit from experience gained by the industry in the coming years before the operational date of the IM BTA measure.

For these reasons, TECO has outlined an ITPOS that would be triggered by its provisionally proposed IM BTA measure but requests the ability to change the focus of the ITPOS as

[20] 79 FR 48327. EPA. 40 CFR 122 and 125. National Pollutant Discharge Elimination System – Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities; Final Rule. August 15, 2014.

necessary as well as provide additional details as the design is advanced. TECO acknowledges the plan for an ITPOS is subject to FDEP review and approval.

6.1.1.3 Section Organization

Section 6.2 of this document discusses the evaluation by TECO of the methods for compliance with the IM standard contained in 40 CFR 125.94(c). This includes assessment of each of the candidate approaches, including the integration of the assessment with entrainment BTA assessment performed under 40 CFR 122.21(r)(10).

Section 6.3 proposes the method for compliance with the IM BTA standard contained in 40 CFR 125.94(c) and how it would be applied at Bayside. In addition, a draft outline of an ITPOS plan in accordance with 40 CFR 122.21(r)(6) is also provided. Additional details of the ITPOS plan will be developed once the final entrainment BTA determination is made by the NPDES Director and as the modified intake structure is being designed and installed.

6.2 Evaluation of Options to Address the IM Standard of 40 CFR 125.94(c)

The rule allows for seven different approaches to IM BTA at affected facilities, each of which, if it meets the goals defined for the approach by the rule, would be considered fully compliant. Depending on site-specific considerations, the potential to retrofit to each of the seven IM BTA options is likely to vary substantially in terms of feasibility, cost,[21] and effectiveness. In addition, some alternatives have performance standards and/or conformational studies that should be considered.

This section considers information developed during the assessment of entrainment BTA in subsequent sections (Chapters 10.0 through 12.0). The information considered includes:

- The conceptual design and layout of potential retrofits to closed-cycle cooling, as well as various intake configurations.

[21] The rule indicates the NPDES Director may consider social costs and benefits in selection of entrainment BTA that may include the status quo at the facility. The rule is more prescriptive regarding IM BTA and requires one of the seven measures must be implemented regardless of the status quo condition. Despite this, TECO believes the relative costs of the measures are reasonable bases of comparison among the IM BTA allowed by the rule.

- The resulting facility costs (i.e., costs associated capital, operation and maintenance, and reduction in power output) associated with potential retrofit.
- The social costs and benefits due to entrainment reductions of these potential IM BTA measures.

Table 6-1 presents a summary of the seven IM BTA options and comments on their constraints at Bayside. Two of the alternatives, the one selected and next highest ranked, are discussed further in Section 6.3.

6.3 Comparison of the Two Favored Options for the IM Standard

Based on the information presented in Table 6-1, TECO has concluded two options would be favored as IM BTA measures at Bayside: expansion of the intakes to achieve intake velocities less than 0.5 fps and installation of modified TWSs and a fish return. The following comparison of the two potential technologies is supported by engineering analysis performed in Section 10.4: the assessment of FMS as measures to address entrainment BTA.

While TECO does not believe FMS represent entrainment BTA for Bayside based on the substantial disparity between social costs and benefits (see Section 11.0 and the Executive Summary), it recognizes the importance of considering them as an entrainment BTA alternative. With this in mind, TECO has coordinated its consideration of IM and entrainment BTAs to recognize the selected IM BTA should be able to accommodate FMS should that be selected as entrainment BTA. Therefore, TECO considered two alternatives that address IM BTA with the potential to include FMS:

- Alternative A—Expand the intake to achieve through-screen velocities of less than 0.5 fps with fine-mesh, modified TWSs, IM BTA under 40 CFR 125.94(c)(2) (see Section 10.4.1.2).
- Alternative B—Install fine-mesh, modified TWSs upstream of the existing coarse-mesh TWSs and retrofit the existing screens to modified TWSs, IM BTA under 40 CFR 125.94(c)(5) (see Section 10.4.1.3).

Table 6–1. Review of IM BTA Approaches for Bayside

40 CFR 125.94(c)	Title and Summary	Advantages	Disadvantages	Decision and Basis
(1)	Closed-Cycle Recirculating System Consistent with 40 CFR 125.92(c)	Monitoring restricted to intake and blowdown flows. Substantial reductions in entrainment (approximately 85 percent; see Sections 10.0 and 11.0).	Costs of construction as well as costs lost from generation due to parasitic load, loss of efficiency, and construction downtime are far higher than alternatives (see Chapter 10.0). Other environmental impacts result (see Chapter 12.0). Reductions in entrainment effects and social benefits not substantially greater than alternatives despite far higher costs (see Chapter 11.0 and Executive Summary).	Rejected. Costs prohibitive given fully compliant alternative for IM BTA. EPA did not intend the rule to force closed-cycle recirculating system retrofit to address IM BTA alone: "As stated in the June 11, 2012, NODA, EPA does not intend for facilities to install closed-cycle cooling solely for the purpose of meeting the IM requirements. In fact, EPA expects all facilities could comply with IM requirements without relying on retrofitting to closed-cycle cooling."[22]
(2)	0.5 fps Through-screen Design Velocity	Monitoring greatly reduced. Optimization studies and performance goals not necessary.	Intake structure must be greatly expanded to achieve lower intake velocity, resulting in greatly increased costs as well as permitting constraints relative to alternative (see Chapter 10.0).	Rejected. Capital and operation/ maintenance costs roughly twice as high as alternative. Permitting of construction associated with waterways impact would be extremely challenging. Simpler and less costly alternative for FMS is available should that be determined to be entrainment BTA (see additional discussion in the following and Section 6.3).
(3)	0.5 fps Through-screen Actual Velocity	See discussion of Alternative 2. Potential for smaller intake to achieve reduced velocity if AIF is applicable at all times.	To maintain its full generation capacity, Bayside must be able to pump cooling water at its DIF at times. Such operation would not meet 40 CFR 125.94(c)(3) requirements.	Rejected. Bayside must be able to pump its full DIF at times to generate its full power output. See previous for IM BTA Alternative 2.

[22] 79 FR 48239. EPA. 40 CFR 122 and 125. NPDES – Final Regulations to Establish Requirements for CWIS at Existing Facilities and Amend Requirements at Phase I Facilities; Final Rule. August 15, 2014.

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Table 6–1. Review of IM BTA Approaches for Bayside (Continued, Page 2 of 2)

40 CFR 125.94(c)	Title and Summary	Advantages	Disadvantages	Decision and Basis
(4)	Existing Offshore Velocity Cap per 40 CFR 195.92(v)	Potentially relatively simple technology requiring little monitoring and maintenance.	To avoid costly conformational studies, must have been installed prior to 2014. Suitable offshore location is not available and would involve costly piping and installation.	Rejected. Technology regulatory advantages not realized. Lack of suitable location to address rule requirements. Costs and potential impacts to navigation.
(5)	Modified Traveling Screens per 40 CFR 125.92(s)	No biological performance goal. Effective at higher intake velocities, allowing for lower construction and operation costs. Facilitates potential inclusion of FMS.	Relatively high maintenance costs. Costly requirement to perform 2 years of optimization studies per 40 CFR 122.21(r)(6)(i).	Selected. Relative capital and operation costs lower than IM BTA measure (2). Reduced complexity of compliance demonstration relative to IM BTA measure (6). Reduced regulatory risk relative to IM BTA measures (6) and (7) (see the following and Section 6.3).
(6)	System of Technologies as the BTA for IM	Allows for consideration of multiple factors in reductions to IM (e.g., flow reduction, intake position and configuration, etc.).	Potential for application of quantitative performance goal. Difficulty in quantifying some bases of IM reduction (e.g., effect of intake position). Costly requirement to perform 2 years of optimization studies per 40 CFR 122.21(r)(6)(i). Does not facilitate potential installation of FMS.	Rejected. Regulatory uncertainty increased and ability to demonstrate reductions reduced relative to IM BTA measures (2) and (5). Does not facilitate potential installation of FMS.
(7)	IM Performance Standard	None apparent relative to IM BTA measure (5).	Includes ongoing performance monitoring and quantitative performance standard. Costs not reduced relative to IM BTA measure (5).	Rejected. Unacceptable regulatory risk. Preamble to rule acknowledges few, if any, facilities likely to pursue this alternative due to risk and more favorable alternatives.

Source: ECT, 2018.

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Alternative A would require installation of eighteen 10-ft-wide TWSs as well as a sheet pile wall to provide for a common flow route to the circulating water pumps behind the screens (see Figure 10-17). For FMS to be effective, a fish return system would be required despite the designtarget through-screen velocity of less than 0.5 fps being fully compliant with IM BTA. Both Alternatives A and B would rely on a fish return that would be more than 2,000 ft in length.

Alternative B would be essentially the same as the FMS system in operation at Big Bend Units 3 and 4 (see Figure 10-19). This system uses the fine-mesh TWSs for the 7 months of the entrainment system and relies on the coarse-mesh TWSs during the other 5 months, as well as when some of the FMS are under maintenance. This system has been in operation for many years, and TECO well understands the necessary operation and maintenance requirements.

As discussed in Section 10.4, Alternative A was rejected as the potential entrainment BTA measure based on FMS for consideration of social costs and benefits, because Alternative B was estimated to be as effective at a cost less than half that of Alternative A. Alternative A was estimated to have total direct project costs of $51.9 million (see Table 10-18) while Alternative B was estimated to cost less than half of that ($22.5 million, see Table 10-19).[23] The operation and maintenance costs of Alternative A were also considerably higher than Alternative B.

If FMS are not adopted as entrainment BTA, achieving 0.5 fps using an expanded intake structure could be achieved at somewhat lower cost that Alternative A. This is because Alternative A assumes the TWSs will achieve less than 0.5 fps using FMS with an open area factor of 48 percent, while standard ⅜-inch coarse-mesh screens have an open area factor of 61 percent. Therefore, instead of the 18 screens anticipated in Alternative A, only 15 would be necessary (i.e., based on ratio of open area factors: 0.48 ÷ 0.61 × 18 screens = 15 screens after rounding up). If we assume the cost of Alternative A as shown in Table 10-18 are adjusted for 15 instead of 18 screens (by adjusting “Intake Structure” and “New Fine-mesh Screen” costs by 15/18) and omission of the costs for the fish return, the rough estimate of total direct project costs is $43.5 million.

[23] For purposes of estimating social costs, the facility costs that would be uniquely associated with the FMS ($15.5MM - see Table 10-21) were considered without the costs of retrofitting the coarse mesh screens and installing the fish return to address IM BTA ($5.3MM - see Table 10-20). Given that Alternative A was not carried forward, this distinction between costs for entrainment and IM BTA was not made in Section 10.4.

In contrast, a retrofit of the coarse-mesh TWSs as modified TWSs with a fish return to address IM BTA alone is estimated to have a total direct project cost of $7.13 million (see Table 10-20). The retrofit of the coarse-mesh screens alone is, therefore, 12 percent of the estimated costs of Alternative A modified to address IM BTA alone (as described previously). The discrepancies in operation and maintenance costs would also be substantial given the need to rotate and wash debris from 15 screens rather than the four existing coarse-mesh screens. Therefore, IM BTA Approach 5 would be far more cost effective than IM Approach 2.

In addition to the differences in cost, IM BTA Approach 5 has other advantages over IM Approach 2:

- Unlike IM BTA Approach 2, IM BTA Approach 5 has far less infrastructure construction in water and does not result in the hydraulic isolation of approximately 3 acres of Waters of the United States.
- Consistent with these differences in the effects to Waters of the United States, IM BTA Approach 2 is likely to be far simpler to permit allowing for lower permitting costs as well as an earlier "on-line" date.

6.3.1 IM Standard of 40 CFR 125.94 (c)(5) Modified TWSs

Based on the information developed previously, TECO proposes the existing TWSs will be retrofit to TWSs modified with fish protection features (also known as modified-Ristroph or Ristroph-type screens) and a fish return consistent with the definition of modified TWSs at 40 CFR 125.92(s). The screens would include fish lifting buckets, low-pressure spray washes, and continuous or near-continuous rotation. The mesh size will be maintained at ⅜-inch.[24]

Fish would be removed from the screens by low-pressure-spray washes that would flow into a fish trough separate from the debris trough. Auxiliary water would be added to the upstream end of the fish return trough to provide sufficient water to return the fish to Hillsborough Bay. The conceptual design of the fish return calls for an approximately 2,200-ft-long conduit with a discharge point to the bay as indicated in Figure 10-19. The fish return system will consist of a

[24] This is subject to change if FMS are found to be entrainment BTA.

gravity driven 3-ft diameter U-shaped trough. The trough would travel from the existing CWIS along the sheet pile wall that lines the southern side of the intake canal. The fish trough would follow the edge of the intake canal and discharge outside the intake canal into Hillsborough Bay. Grating will be placed over the trough to prevent predation. If chosen as the IM BTA compliance option, a more detailed analysis and design of the fish return system would be conducted.

High-pressure-spray washes would be applied to the screens following the low-pressure-spray wash to remove debris, which would be routed to offsite disposal in a dedicated trough.

TECO notes the specifics of this IM BTA approach are predicated on the finding that entrainment BTA is found to be the status quo at the plant (i.e., no additional changes are necessary to address entrainment BTA) and, potentially, if variable speed pumps are found to be entrainment BTA. If FMS are found to be entrainment BTA, a second set of screens would be constructed in front of the existing pair of TWSs. Section 10.4 describes the details of this configuration and motivation for it. In this case, both the new fine-mesh and existing coarse-mesh screens would be IM BTA-compliant under Approach 5. If closed-cycle cooling is found to be entrainment BTA, closed-cycle cooling, by itself, fully addresses IM BTA and no changes to the TWSs would be necessary. In any case, TECO plans to reevaluate its proposal for IM BTA after the NPDES Director's decision on entrainment BTA.

6.3.2 40 CFR 122.21(r)(6)(i) Impingement Technology Performance Optimization Study

As discussed previously, the requirement for an ITPOS, as well as the study's goals and procedures, will not be clear until decisions have been made regarding IM and entrainment BTA. For this reason, the following section will provide only an overview of the ITPOS plan that would be developed if IM BTA Approach 5 is pursued at Bayside.[25] The final ITPOS plan will be developed, as necessary, after selection of the IM BTA approach and as part of the design of the modified TWSs. The modified TWSs will be designed to facilitate sampling by having a

[25] The ITPOS requirement under 40 CFR 122.21(r)(6)(i) and (ii) apply only to optimization of the TWSs to reduce impingement mortality. If FMS are determined to be entrainmen BTA, the optimization studies would also focus on optimizing the screens in an attempt to reduce postimpingement mortality of fish and shellfish that would be impinged on coarse-mesh screens. TECO does not believe the rule requiremes screen optimization in an attempt to improve survival of otherwise entrainable organisms (i.e., those that would pass through an ⅜-inch mesh).

sampling port in the low-pressure wash trough, or fish return, close to the TWSs. TECO plans to sample fish as soon as practical after they are washed from TWSs. It is anticipated the fish-holding facility, including control tanks, water treatment, and any necessary climate control, will be installed on a temporary basis adjacent to the modified TWSs.

The ITPOS plan will address the requirements of 40 CFR 122.21(r)(6)(i) in the following ways:

- A complete description of the modified TWSs and attending equipment will be provided, including relevant drawings and key elements of the system that can be adjusted to optimize biological performance.
- A set of system elements that will be adjusted during optimization (for example, low-pressure wash header orientation, screen rotation) and the specific settings to be tested.
- The frequency of testing will be monthly for a 2-year period.
- Methods to ensure representative conditions and reasonable comparability (e.g., number of taxa to be tested, basis of comparing the candidate optimization states).
- The taxonomic resolution expected for collected organisms.
- Methods of identifying and considering "prior dead" and moribund fish.
- Procedures for measuring control mortality associated with holding fish alone.
- The holding time for the fish to measure latent mortality, likely 24 hours.
- One of the findings of the study will be the calculation of the percent IM of nonfragile species achieved after optimization.

While the rule requires the facility to consider entrapment as part of the optimization study, TECO does not believe entrapment is a meaningful phenomenon at Bayside because of the low velocities in the intake canal immediately adjacent to the TWSs.

Should FMS be selected as entrainment BTA, the FMS would be installed in series with the coarse-mesh screens and both would be IM BTA-compliant by virtue of modified TWSs and a (common) fish return. TECO anticipates the two sets of screens would be operated during different seasons, similar to those currently in use at Big Bend Units 3 and 4. Consequently,

testing of one setting of screens will be impossible while the other set is in operation.[26] Therefore, TECO anticipates the 2-year optimization study will vary its location to focus on the screens in operation during that month.

A draft plan that addresses 40 CFR 122.21(r)(6)(i) will be submitted to FDEP for review, comment, and approval.

TECO also notes it may be useful and cost-effective to coordinate optimization studies with other facilities, and it may explore that possibility with FDEP and other companies.

6.4 References

Federal Register (FR). 2014. EPA. 40 CFR 122 and 125. National Pollutant Discharge Elimination System – Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities; Final Rule. 79 FR 48327. August 15.

[26] When the FMS are in operation (at Big Bend Units 3 and 4 from March 15 to October 15), fish will be excluded from encountering the downstream coarse-mesh screens. Alternatively, when the coarse-mesh screens are in operation (from October 16 to March 14 at Big Bend Units 3 and 4), the fine-mesh panels will be removed from the upstream screens, eliminating any impingement.

7.0 40 CFR 122.21(r)(7)—Entrainment Performance Studies

This section provides information on the technologies currently employed at Bayside and those technologies being considered to provide compliance with the rule, particularly for entrainment BTA. The following is the text of 40 CFR 122.21(r)(7):

> The owner or operator of an existing facility must submit any previously conducted studies or studies obtained from other facilities addressing technology efficacy, through-facility entrainment survival, and other entrainment studies. Any such submittals must include a description of each study, together with underlying data, and a summary of any conclusions or results. Any studies conducted at other locations must include an explanation as to why the data from other locations are relevant and representative of conditions at your facility. In the case of studies more than 10 years old, the applicant must explain why the data are still relevant and representative of conditions at the facility and explain how the data should be interpreted using the definition of entrainment at 40 CFR 125.92(h).

While entrainment rates have been characterized (see Section 9.0), no entrainment performance studies such as through-plant survival have been conducted at Bayside. However, studies on the efficacy of FMS and postentrainment survival from FMS have been conducted at Big Bend Power Station (approximately 7.5 miles south on Hillsborough Bay). In addition, studies at Anclote Power Plant (Anclote) on the Gulf of Mexico have quantified the survival of entrained organisms through circulator pumps in 1995 and dilution pumps in 1995 and 2006. The studies at Anclote and Big Bend are relevant to Bayside as they utilize the same or similar source waters, and the CWIS structures are similar with the common use of dual-entry-single-exit, coarse-mesh TWSs and approach velocities. Though some of the studies were conducted more than 30 years ago, they are still relevant in that the technologies have not changed at the facilities in question, and the receiving water aquatic organism's populations have remained stable for Big Bend (ECT, 2013). Finally, the physical factors within the plant's affecting organism exclusion and survival have not changed since the studies were performed.

The data summarized in this section will be considered in assessing potential measures for entrainment BTA as described in Sections 10.0 through 12.0. Of particular importance is the data on FMS performance (i.e., exclusion and postexclusion survival of otherwise entrainable organisms) at Units 3 and 4 of Big Bend as described in Sections 7.1 to 7.3. These data will be used to estimate the potential effectiveness of FMS at Bayside (see Section 11.0).

Other entrainment performance data are related to through-plant survival of entrained organisms as measured at Anclote Station (see Section 7.4). Through-plant survival is substantial for many taxa, and these rates will be discussed in the context of survival following exclusion by FMS (see Section 11.0). However, for the purposes of biological modelling, through-plant survival was assumed to be zero.

Section 9.0 presents the rates of entrainment at Bayside as measured over 2 years.

7.1 Big Bend Full-scale Prototype System

In 1979, two separate studies were conducted to assess the impingement survival of organisms on FMS, with one looking at how impingement duration and velocity impact survival and the other at how representative species survive following impingement on a FMS installed on an existing screen design. These studies were conducted in 1980 on a full-scale, 0.6-meter-wide, dual-flow-type TWS prototype.

The results of these studies (Table 7-1) concluded FMS technology was a viable option for removing aquatic organisms from circulating cooling water, and a mesh size of 0.5 millimeters (mm) was effective at screening out representative species life stages (Brueggemeyer *et al.*, 1988).

Table 7–1. Initial Survival During Big Bend 1980 Prototype Survivability Study

Lifestage	Average Control Survival (%)		Average Organism Return Discharge Survival (%)	
	Initial	48 Hour	Initial	48 Hour
Fish				
Egg	95	95	76	
Hatched larvae				90
Larvae	34	0	12	42
Shellfish				
Zoea	88	56	97	91
Megalops	82	96	96	94

Source: Brueggemeyer *et al.*, 1988.

Following the study, the environmental agencies determined TECO could proceed with a full-scale installation of FMS at the new Unit 4 and existing Unit 3.

7.2 Big Bend 1980s FMS Studies

Big Bend's CWIS has standard coarse-mesh, dual-flow TWSs on all units that filter the water before it enters the circulating water pumps. The coarse-mesh screens act to protect the pumps and condenser from debris if the emergency slide gates open upon high differential pressure during FMS operation. In addition, as required by FDEP upon permitting, Big Bend Units 3 and 4 have, in addition to and separate from the coarse-mesh screens, a set of FMS TWSs with 0.5-millimeter (mm) mesh with an organism return on each circulating pump. These screens are operated seasonally to correspond with the highest periods of entrainment (spring and summer).

Following installation of the FMS system, TECO conducted two biological studies that looked at survivability of organisms, postexclusion, on the FMS and efficiency of the FMS at excluding organisms. These studies considered several common taxa as well as separate life stages (e.g., eggs, post-yolk sac larvae, etc.).

7.2.1 Survivability

During March through September 1985, the survivability of organism screened and washed into the screen return at Big Bend Unit 4 were studied. The results of the study concluded survival rates were consistent with the prototype study (Table7-2) (Brueggemeyer *et al.*, 1988).

Table 7–2. Initial Survival During Big Bend 1987 FMS Survivability Studies

Lifestage	Average Control Survival (%)		Average Organism Return Discharge Survival (%)	
	Initial	48 Hour	Initial	48 Hour
Fish				
Egg	74		41	
Hatched larvae		65		66
Larvae	28	63	27	68
Juvenile		0		0
Shellfish				
Zoea	78	81	84	74
Megalops	89	100	77	93

Source: Brueggemeyer *et al.*, 1988.

7.2.2 Efficiency

During March through September 1985, the efficiency of the FMS at excluding entrainment-sized organisms was conducted at two stations simultaneously at Big Bend. One sampling station was located within the intake canal, while the other was located in an access manhole behind the FMS. The results indicated organisms (especially larvae and eggs) were being entrained (i.e., sampled downstream of the screens) at considerable rates despite the installation of FMS (Table 7-3) (Brueggemeyer *et al.*, 1988).

Table 7–3. Entrainment Exclusion Efficiency During 1985 Big Bend FMS Efficiency Study

Life Stage	Average Density Intake	Average Density Manhole	Average Exclusion (%)
Fish eggs	12,184.90	9,545.25	21.66
Fish larvae	177.41	166.90	5.93
Invertebrates	203.31	29.15	85.66

Source: Brueggemeyer *et al.*, 1988.

Following this study, it was determined the FMS system's efficiency was impeded by biofouling, and additional studies were conducted in 1987 that improved the system operation as well as the sampling design at Big Bend Units 3 and 4. Results of this study indicate the screening efficiencies averaged values were in excess of the prototype study with eggs averaging 77 percent, larvae 86 percent, and invertebrates 98 percent (Table 7-4) (TECO, 1987).

Table 7–4. Entrainment Exclusion Efficiency During 1987 Big Bend FMS Optimization Study

Life Stage	Average Exclusion (%)
Fish	
Egg	89.76
Prolarvae	64.06
Postlarvae	86.59
Shellfish	
Invertebrates	98.06

Source: TECO, 1987

7.3 Big Bend 316(b) Phase II Compliance Entrainment Monitoring

Between 2006 and 2007, entrainment monitoring was conducted at Big Bend in response to the requirements of the Phase II 316(b) rule (TECO, 2010). The monitoring was conducted in a manner similar to the 1987 optimization study, with samples being collected both in front and behind the FMS following the same methodology and sampling frequency as was conducted at Bayside as part of the same 316(b) Phase II compliance monitoring (Section 9.0). Fish exclusion ranged from 52 percent to 76 percent depending on life stage (Table 7-5). Shellfish exclusion was between 50 and 59 percent.

Table 7–5. Entrainment Exclusion Efficiency During 2006-2007 Big Bend 316(b) Phase II Entrainment Monitoring

Life Stage	Average Exclusion (%)
Fish	
Egg	57
Larvae	76
Post-larvae	52
Juvenile	58
Adult	100
Unknown	39
Shellfish	
Larvae	59
Unknown	50

Source: TECO, 2010.

Section 11.0 evaluates the potential for exclusion and postexclusion survival of otherwise entrainable organisms. In considering both exclusion and postexclusion survival, performance of the taxa and life stage are considered when available. The two data sets on exclusion rates (Sections 7.2 and 7.3) were pooled prior to calculation of statistics by taxa and life stage.

7.4 Anclote Through-plant Entrainment Survival

Two studies have been conducted at Anclote, located in Tampa, Florida, that attempt to quantify the survival of entrained organisms through the circulating pumps and in one study, through the condensers as well. Anclote is located on the Gulf of Mexico, 40 miles north of the mouth of Tampa Bay, approximately 28 miles west of Bayside. It uses dual-flow TWS similar to Bayside and has a similar through-screen velocity (Melton and Serviss, 2000).

The first study, in 1995, evaluated the survival of organisms through the condenser pumps as well as the dilution pumps. The study used a control station located in the intake canal to the power station. Samples were collected via 1-meter diameter, 400-micron plankton nets connected to a bucket with 500-micron mesh side panels to allow for throughflow. Eight sampling events were conducted between September and November 1995. The study indicated

the mean overall rate of survival through the condensers was 68.2 percent for zooplankton tested and a mean overall survival of 78.3 percent through the dilution pumps (Table 7-6).

Table 7–6. Grand Average and Corrected Grand Average for Survival of Each Species Group at Control and Condenser Stations, Anclote Entrainment Study

Station	Species Group	Number*	Grand Average Survival†	Corrected Grand Average Survival‡	Mortality§
Intake canal (control)	*Acartia tonsa*	2,152	54.7		37.2
	Amphipoda	5,185	72.9		19.1
	Chaetognatha	1,549	44.0		42.7
	Crab larvae	3,007	71.7		20.5
	Caridean shrimp	2,728	72.4		21.0
	Isopoda	166	70.9		14.9
	Pisces juvenile	140	78.3		11.8
	Pisces larvae	109	64.1		19.0
	Penaeid shrimp	58	77.3		6.5
	Shrimp larvae	1,876	65.3		29.1
	Station Average		**67.2**		**22.2**
Condenser	*Acartia tonsa*	2,505	66.2	91.5	
	Amphipoda	2,632	29.4	48.5	
	Chaetognatha	495	28.3	67.1	
	Crab larvae	2,870	73.9	89.5	
	Caridean shrimp	1,026	45.1	63.8	
	Isopoda	485	69.7	79.4	
	Pisces juvenile	200	55.7	64.0	
	Pisces larvae	331	8.4	27.2	
	Penaeid shrimp	212	62.7	66.0	
	Shrimp larvae	975	60.5	84.6	
	Station Average		**50.0**	**68.2**	
Dilution Pumps	*Acartia tonsa*	3,393	63.0	89.3	
	Amphipoda	2,030	57.8	72.9	
	Chaetognatha	1,432	34.5	72.4	
	Crab larvae	3,275	79.9	91.8	
	Caridean shrimp	740	65.8	80.5	
	Isopoda	137	77.5	86.2	
	Pisces juvenile	144	63.0	69.6	
	Pisces larvae	143	47.2	62.2	
	Penaeid shrimp	202	71.1	75.1	
	Shrimp larvae	999	59.9	82.4	
	Station Average		**62.0**	**78.3**	

*Total number of individuals for all samples used to calculate grand average for that species group and station.
†Average survival of species group based on data for all samples in which it occurred.
‡Average survival of species groups at treatment stations after correcting for mortality at intake canal (control) station (mortality).
§Mortality to species group from natural causes and sampling-related stress. Calculated by using the control station grand average, adding the confidence interval, and subtracting the results from 100.

Source: Melton and Serviss, 2000.

Between 2006 and 2007, an additional entrainment survival study was conducted at Anclote to again determine the survival of organisms that pass through the dilution pumps. Eight monthly events were conducted during the peak recruitment period of August to October 2006 and March to July 2007. Survival was recorded after 24 hours holding time. Samples were collected in both the intake canal and dilution pump discharge canal. Samples were collected via a 1-meter diameter, 500-micron plankton net suspended with a 5-gallon capacity cod end from above and allowed to flow in the canal until an adequate plankton sample was collected. Average survival for all species sampled was 74 percent (Table 7-7). These results approximate the previous study results.

Table 7–7. 2006 to 2007 Entrainment Survival Results (Dilution Pumps), Anclote

Group	Life Stage (number)	Survival Estimate (%)
Fish	Juvenile (50)	70
	Larvae (27)	74
Shellfish	Juvenile (31)	44
	Larvae (28)	97
Other invertebrates	Juvenile (19)	76
	Larvae (1,068)	74
Total		**74**

Source: Larsen *et al.*, 2014

7.5 References

Brueggemeyer, V., D. Cowdrick, K. Durell, S. Mahadevan, and D. Bruzek. 1988. Full-scale operational demonstration of fine-mesh screens at power plant intakes. In: Proceedings: Fish Protection at Steam and Hydroelectric Power Plants. Palo Alto, Calif.: Electric Power Research Institute. EPRI CS/EA/AP-5663-SR.

Environmental Consulting & Technology, Inc. (ECT). 2013. Biological Report in Support of 316(a) Thermal Variance Reissuance—Big Bend Power Station. Prepared for Tampa Electric Company, Tampa, Florida. October.

Larsen, S., D. Bruzek, and B. Johnson. 2014. Impingement and Entrainment Survival Studies at Power Plants in Estuarine Systems of Florida. Presentation to 2014 AFS Annual Meeting, Questions City, Canada. August 18.

Melton, B.R., and G.M. Serviss. 2000. Florida Power Corporation-Anclote Power Plant Entrainment Survival of Zooplankton. Environmental Science and Policy 3: S233-S248.

Tampa Electric Company (TECO). 1987. Fine Mesh Screen (FMS) Optimization Study Final Report. Submitted by Mote Marine Laboratory. December 18.

———. 2010. Clean Water Act Section 316(b) Biological Characterization Report for Fish and Shellfish Impingement and Entrainment at the Tampa Electric Company Big Bend Power Station, Hillsborough County, Florida. Prepared by Golder Associates, Inc. March.

8.0 40 CFR 122.21(r)(8)—Operational Status

This section provides information on the operational status of Bayside Units 1 and 2. The following is the text of 40 CFR 122.21(r)(8):

> The owner or operator of an existing facility must submit a description of the operational status of each generating, production, or process unit that uses cooling water, including but not limited to: (i) For power production or steam generation, descriptions of individual unit operating status including age of each unit, capacity utilization rate (or equivalent) for the previous 5 years, including any extended or unusual outages that significantly affect current data for flow, impingement, entrainment, or other factors, including identification of any operating unit with a capacity utilization rate of less than 8 percent averaged over a 24-month block contiguous period, and any major upgrades completed within the last 15 years, including but not limited to boiler replacement, condenser replacement, turbine replacement, or changes to fuel type; (ii) Descriptions of completed, approved, or scheduled uprates and Nuclear Regulatory Commission relicensing status of each unit at nuclear facilities; (iii) For process units at your facility that use cooling water other than for power production or steam generation, if you intend to use reductions in flow or changes in operations to meet the requirements of 40 CFR 125.94(c), descriptions of individual production processes and product lines, operating status including age of each line, seasonal operation, including any extended or unusual outages that significantly affect current data for flow, impingement, entrainment, or other factors, any major upgrades completed within the last 15 years, and plans or schedules for decommissioning or replacement of process units or production processes and product lines; (iv) For all manufacturing facilities, descriptions of current and future production schedules; and (v) Descriptions of plans or schedules for any new units planned within the next 5 years.

Bayside currently consists of two units. Unit 1 came into service in May 2003 following the repowering of Gannon Unit 5 from coal-fired to natural-gas-fired, three-on-one configuration (746-MW nominal capacity). Unit 2 came into service in January 2004 following the repowering of Gannon Unit 5 from coal-fired to natural-gas-fired, four-on-one configuration (1,090-MW nominal capacity). During the 2003 and 2004 repowering, Gannon Units 1 through 4 were idled. Cooling water at Bayside is used only for power production. Table 3-2 in Section 3.3 provides utilization over the previous 5 years.

The major changes to the system in the last 15 years have been the repowering from coal to natural gas using combined-cycle technology as described previously and the idling of Gannon Units 1 through 4. Minor changes to Units 1 and 2 include routine refurbishment of the intake screens in 2009 without change to their technology. There are currently no plans for major expansions or modifications to Bayside Units 1 and 2 except for routine refurbishments of the intakes in the next several years. No new units are planned within the next 5 years.

9.0 40 CFR 122.21(r)(9)—Entrainment Characterization Study

This section provides information on the entrainment characterization study conducted by TECO at Bayside between 2005 and 2007 as part of the 316(b) Phase II rule. Use of this data for compliance with (r)(9) requirements was proposed to and approved by FDEP and FWC in a meeting on August 17, 2015 (TECO, 2015).

The following is the text of 40 CFR 122.21(r)(9):

> The owner or operator of an existing facility that withdraws greater than 125 mgd AIF, where the withdrawal of cooling water is measured at a location within the cooling water intake structure that the Director deems appropriate, must develop for submission to the Director an Entrainment Characterization Study that includes a minimum of two years of entrainment data collection. The Entrainment Characterization Study must include the following components: (i) Entrainment Data Collection Method; (ii) Biological Entrainment Characterization; and, (iii) Analysis and Supporting Documentation.

As part of the biological characterization study conducted at Bayside in 2005 through 2007 under the 316(b) Phase II rule compliance effort, an entrainment sampling program was used to identify and quantify the meroplanktonic organisms in the intake cooling water that pass through the screening systems and are entrained through the CWIS during plant operations (TECO, 2010). The scope of the study was described in a proposal for information collection, which was provided to FDEP for review and approval as required by the then-existing rule. The proposal for information collection was reviewed by FDEP, and comments were provided on June 1, 2005 (Golder, 2009). TECO (2010) provides more detail on the methods and results of the entrainment characterization, which is provided on a CD as Appendix 9.A to this document. Because of the availability of this document, this section serves as a summary of the larger report.

The data reporting in TECO (2010) includes a systematic error in the reporting convention associated with subsampling, such that annualized entrainment rates were over-stated by a factor

of approximately two-fold. That error has been addressed, and the following data and that in the accompanying data files are correct as stated.

The data described in this section will be used in the analysis of potential social benefits of potential entrainment mitigation measures as described in Section 11.0.

Entrainment sampling was collected behind the TWS (see Section 9.1). In addition, ichthyoplankton sampling was conducted in the nearfield environment (Figure 9-1) to estimate taxonomic composition and densities of organisms potentially vulnerable to entrainment at Bayside. Nearfield sampling was conducted once per month, concurrent with an entrainment sampling event.

9.1 Entrainment Data Collection Method—40 CFR 122.21(r)(9)(i)

9.1.1 Entrainment Sampling

Four entrainment samples (two day and two night samples) were collected during the 24-hour sampling event at approximate 6-hour intervals (Table 9-1) for the Phase II rule compliance effort (TECO, 2010).

Entrainment samples were collected behind Unit 1 only due to access restrictions at Unit 2. The configuration of the CWIS and circulation pump capacities were deemed similar enough that results of Unit 1 are representative of what would be expected at Unit 2. Intake cooling water was pumped from behind the screens at mid-depth (3 to 4 meters) using a polyvinyl chloride pipe connected to a 4-inch gasoline-powered dewatering pump with an in-line flow meter. The water was filtered through a 0.5-mm mesh plankton net suspended inside a supporting container (TECO, 2010).

Table 9–1. Sample Collection Dates and Numbers for Bayside Entrainment Characterization During Phase II Compliance Effort

Years	Sample Date	Entrainment Samples Collected	Nearfield Samples Collected
2005	04/19/05		12
	04/21/05	5	
	04/29/05	8	
	05/10/05	8	
	05/12/05		12
	05/24/05	8	
	06/07/05	8	
	06/08/05		12
	06/21/05	8	
	07/06/05	8	
	07/07/05		12
	07/19/05	8	
	08/09/05	8	
	08/10/05		21
	08/23/05	8	
	09/07/05	8	
	09/12/05		24
	09/20/05	8	
	10/04/05	8	
	10/06/05		24
	10/18/05	8	
	11/01/05	8	
	11/03/05		24
	11/22/05	8	
	12/13/05	8	
	12/15/05		24
	12/30/05	8	
2006	01/10/06	8	
	01/16/06		24
	01/24/06	8	
	02/09/06		24
	02/13/06	8	
	02/21/06	8	
	03/02/06	8	
	03/14/06	8	
	03/16/06		24
	04/04/06	8	
	04/06/06		24

Table 9–1. Sample Collection Dates and Numbers for Bayside Entrainment Characterization During Phase II Compliance Effort (Continued, Page 2 of 2)

Years	Sample Date	Entrainment Samples Collected	Nearfield Samples Collected
2006 (continued)	04/18/06	8	
	05/02/06	8	
	05/04/06		24
	05/23/06	8	
	06/06/06	8	
	06/08/06		24
	06/19/06	8	
	07/11/06	8	
	07/13/06		24
	07/25/06	8	
	08/08/06	8	
	08/10/06		24
	08/29/06	8	
	09/12/06	8	
	09/26/06	8	
	09/28/06		24
	10/10/06	8	
	10/24/06	8	
	10/26/06		24
	11/07/06	8	
	11/09/06		24
	11/21/06	8	
	12/05/06	8	
	12/07/06		24
	12/19/06	8	
2007	01/09/07	8	
	01/11/07		24
	01/23/07	8	
	02/06/07	8	
	02/08/07		24
	02/20/07	8	
	03/06/07	8	
	03/08/07		24
	03/20/07	8	

Source: TECO, 2010.

A volume of 50 cubic meters (13,210 gallons) of intake water was filtered for each entrainment sample as determined by the in-line flow meter. The resulting contents of the net were rinsed down with source water from the outside of the net into a 1-liter sample jar. The samples were preserved in a 10-percent buffered formalin solution, labeled, and transported to Mote Marine Laboratory for identification and enumeration. If more than one sample jar was required, the contents of the jars were composited at the laboratory for analysis (TECO, 2010).

These samples were analyzed in the laboratory. The meroplankton were separated from detritus, sorted, identified to the lowest practical taxon and life stage (e.g., egg, larvae, juvenile), and counted. When necessary, staining was used to distinguish species (TECO, 2010).

Length (standard length, notochord length, or total length as appropriate) was determined for up to 50 individuals of each fish species and life stage in each sample. In the event a sample contained a large number of organisms of various life stages (e.g., more than 500), sub-sampling was conducted, and the analyzed portion of the sample was extrapolated to the full sample volume. Sorting, identification, and enumeration of invertebrate plankton were limited to those taxa of commercial value in later life stages (i.e., stone crab, blue crab, etc.) (TECO, 2010).

For each sample collected, the following information was obtained and recorded:

- Volume of water filtered during sample collection
- Circulating water pumps in operation at the start and end of the sampling event
- Identification of the units in operation during the sampling event

Specimens were identified to the lowest practical taxonomic level (most often to species). Table 9-2 provides a list of identified taxa. Voucher specimens of all species were retained in a voucher collection. If taxonomic identification was not clear, a comparison to the laboratory taxonomic reference collection was made to assist with identification. Taxonomic identification was under Mote Marine Laboratory's quality assurance/quality control review. This review involved the reidentification of 5 percent of all samples selected at random for taxonomic quality control checks (TECO, 2010).

Table 9–2. Bayside Phase II Compliance Effort Entrainment Sampling Species List (41 Species)

Family	Species	Common Name
Fish		
Achiridae	*Trinectes maculatus*	Hogchoker
	Trinectes spp.	Flatfish
	Achiridae	American soles
	Achirus lineatus	Lined sole
Atherinopsidae	*Membras martinica*	Rough silverside
	Menidia spp.	Silverside
Blenniidae	Blenniidae	Blennies
	Chasmodes saburrae	Florida blenny
Carangidae	Carangidae	Jacks and pompanos
	Chloroscombrus chrysurus	Atlantic bumper
	Oligoplites saurus	Leatherjacket
Clupeidae	Clupeidae	Herrings, shads, sardines, menhadens
Engraulidae	*Anchoa hepsetus*	Striped anchovy
	Anchoa mitchilli	Bay anchovy
	Anchoa spp.	Anchovy
Ephippidae	*Chaetodipterus faber*	Atlantic spadefish
Gerreidae	*Eugerres plumieri*	Striped mojarra
Gobiesocidae	*Gobiesox strumosus*	Skilletfish
Gobiidae	*Bathygobius soporator*	Frillfin goby
	Gobiidae	Gobies
	Gobiosoma robustum	Code goby
	Gobiosoma spp.	Gobiosoma species unidentified
	Microgobius gulosus	Clown goby
	Microgobius spp.	Goby
Microdesmidae	*Microdesmus longipinnis*	Pink wormfish
Sciaenidae	*Bairdiella chrysoura*	Silver perch
	Cynoscion arenarius	Sand seatrout
	Cynoscion nebulosus	Spotted seatrout
	Menticirrhus spp.	Kingfish
	Sciaenidae	Drums and croakers
Scorpaenidae	Scorpaenidae	Scorpionfish
Sparidae	*Lagodon rhomboides*	Pinfish
Syngnathidae	*Hippocampus erectus*	Lined seahorse
	Symphurus plagiusa	Blackcheek tonguefish
	Syngnathus louisianae	Chain pipefish
Triglidae	*Prionotus scitulus*	Leopard searobin
	Prionotus spp.	Searobin
	Prionotus tribulus	Bighead searobin
Shellfish		
Portunidae	*Callinectes sapidus*	Blue crab
Xanthidae	*Menippe mercenaria*	Stone crab
Loliginidae	*Lolliguncula brevis*	Atlantic brief squid

Source: TECO, 2010.

9.1.2 Nearfield Plankton Sampling

Entrainable-sized organisms present within the nearfield of Bayside were sampled using plankton tows. Table 9-3 provides a comprehensive list of the collected taxa. These tows were conducted at approximately the same time as the entrainment samples. Samples were collected using a 0.5-meter diameter plankton net with a 500-micron mesh. The plankton net was towed obliquely through the water column starting just above the bottom of the water column to the surface for 5 minutes. A flow meter was mounted in the mouth of the plankton net to determine the volume of water being sampled (TECO, 2010).

Organisms collected in the plankton tows were treated in the same manner as the entrainment samples in all respects. For each collection, the following information was recorded:

- Beginning and end longitude and latitude of tow
- Soak time of tow
- Flow meter reading

Section 4.6 provides a description of federal or state listed species that have ranges that include the vicinity of the CWIS. No species observed within the entrainment samples or nearfield plankton tows are listed under any federal, state, or tribal law (FWC, 2017).

9.2 Biological Entrainment Characterization—40 CFR 122.21(r)(9)(ii)

The 2006 to 2007 Phase II compliance effort collected information on the yearly densities, seasonal, diel, and taxonomic variation of planktonic organisms within the vicinity of the intake canal, as well as those actually entrained into the Bayside plant.

Though the densities used in this calculation are from 2005 and 2006, due to the lack of modifications to operations, facility, stability of the organism's population etc., the data and associated results are still relevant today (see Section 4.0 for discussion of population stability within Hillsborough Bay). In addition, the use of this data was discussed with and assumed approved by FDEP and FWC on August 17, 2015, for use in the current 316(b) compliance reports for the TECO facilities. The following subsections summarize the results of this study.

Table 9–3. Bayside Phase II Compliance Effort Plankton Tow Sampling Species List (46 Species)

Family	Species	Common Name
Fish		
Achiridae	Achiridae	American soles
	Achirus lineatus	Lined sole
	Trinectes maculatus	Hogchoker
Atherinopsidae	*Membras martinica*	Rough silverside
	Menidia beryllina	Inland silverside
	Menidia spp.	Silverside
Blenniidae	Blenniidae	Blennies
Carangidae	Carangidae	Jacks and pompanos
	Chilomycterus schoepfii	Striped burrfish
	Chloroscombrus chrysurus	Atlantic bumper
	Oligoplites saurus	Leatherjacket
Clupeidae	*Brevoortia* spp.	Menhaden
	Clupeidae	Herrings, shads, sardines, menhadens
	Opisthonema oglinum	Atlantic thread herring
Cynoglossidae	*Cynoglossidae*	Tonguefish
	Symphurus plagiusa	Blackcheek tonguefish
Dactyloscopidae	*Dactyloscopidae*	Sand stargazers
Engraulidae	*Anchoa hepsetus*	Striped anchovy
	Anchoa mitchilli	Bay anchovy
	Anchoa spp.	Anchovy
Ephippidae	*Chaetodipterus faber*	Atlantic spadefish
Gerreidae	*Eucinostomus* spp.	Jenny mojarras
	Gerreidae	Mojarras
Gobiesocidae	*Gobiesox strumosus*	Skilletfish
Gobiidae	*Bathygobius soporator*	Frillfin goby
	Gobiidae	Gobies
	Gobiosoma robustum	Code goby
	Gobiosoma spp.	Gobiosoma species unidentified
	Microgobius spp.	Goby
Microdesmidae	*Microdesmus longipinnis*	Pink wormfish
Mugilidae	*Mugil cephalus*	Striped mullet
Sciaenidae	*Bairdiella chrysoura*	Silver perch
	Cynoscion arenarius	Sand seatrout
	Cynoscion nebulosus	Spotted seatrout
	Menticirrhus americanus	Southern kingfish
	Menticirrhus spp.	Kingfish
	Sciaenidae	Drums and croakers
Soleidae	Soleidae	True soles
Sparidae	*Lagodon rhomboides*	Pinfish
Syngnathidae	*Hippocampus erectus*	Lined seahorse
	Syngnathidae	Pipefishes and seahorses
	Syngnathus floridae	Dusky pipefish
	Syngnathus louisianae	Chain pipefish
Triglidae	*Prionotus* spp.	Searobin
Shellfish		
Xanthidae	*Menippe mercenaria*	Stone crab
Loliginidae	*Lolliguncula brevis*	Atlantic brief squid

Source: TECO, 2010.

9.2.1 Nearfield Plankton Sampling

Figure 9-1 depicts the tow sampling station locations. Figure 9-2 illustrates the relative abundance of planktonic taxa collected within the nearfield at those sampling stations. As shown, drum (Sciaenidae) was the most abundant taxon, representing 52.9 percent of all species collected. Anchovies (*Anchoa* spp.) were the second most abundant taxon, comprising 41.6 percent of the total. Stone crab (*Menippe mercenaria*) was the most abundant shellfish species at 2.0 percent of the total collected organisms.

Most ichthyoplankton collected within the nearfield plankton samples were found in the egg stage, representing 94.2 percent of the total ichthyoplankton collected (Figure 9-3). The second most abundant life stage was postlarvae at 4.8 percent. Almost all shellfish collected within the nearfield plankton samples were found in the prolarvae stage, representing 96.9 percent of the total shellfish collected (Figure 9-3).

Densities of entrainable-sized organisms collected from the nearfield were highest during the late spring and summer months and lowest in fall and winter (Figure 9-4). A peak density of 43,173 organisms per million gallons was observed in May 2006. The lowest mean daily density was 49 observed in December 2005. The average density of fish was higher than the average density of shellfish by approximately an order of magnitude (Figure 9-4). Densities were generally higher at night that during the day (Figure 9-5).

The rate of entrainment is determined by the rate of intake flow and the density of organisms present in the water (i.e., number/volume). The absolute rate of entrainment (number/year) at Bayside is approximately the same as those of other coastal plants in Florida as implied by the similar rates of water withdrawal and the similar densities of organisms (see Table 9-4). The densities of entrainable-sized organisms collected from the nearfield of Bayside are also approximately the same as those collected near other power generation facilities within Florida estuaries (Table 9-4). Therefore, the relatively high rates of entrainment observed at Bayside are a reflection of the productivity of the source waters. As noted in Section 11.4, review of population trends in Tampa Bay indicates the fishery has been stable for the last several years, suggesting entrainment losses do not adversely affect the bay's productivity.

M:\acad\2016\160580\0100\Bayside_PlanktonTow.mxd NAD 1983 StatePlane Florida West FIPS 0902 FeetTransverse Mercator unash 4/6/2017 12:57:44 PM



FIGURE 9-1.
PLANKTON TOW SAMPLING LOCATIONS
BAYSIDE POWER STATION

Sources: Mote, 2007; FDOT, 2014; ECT, 2017.

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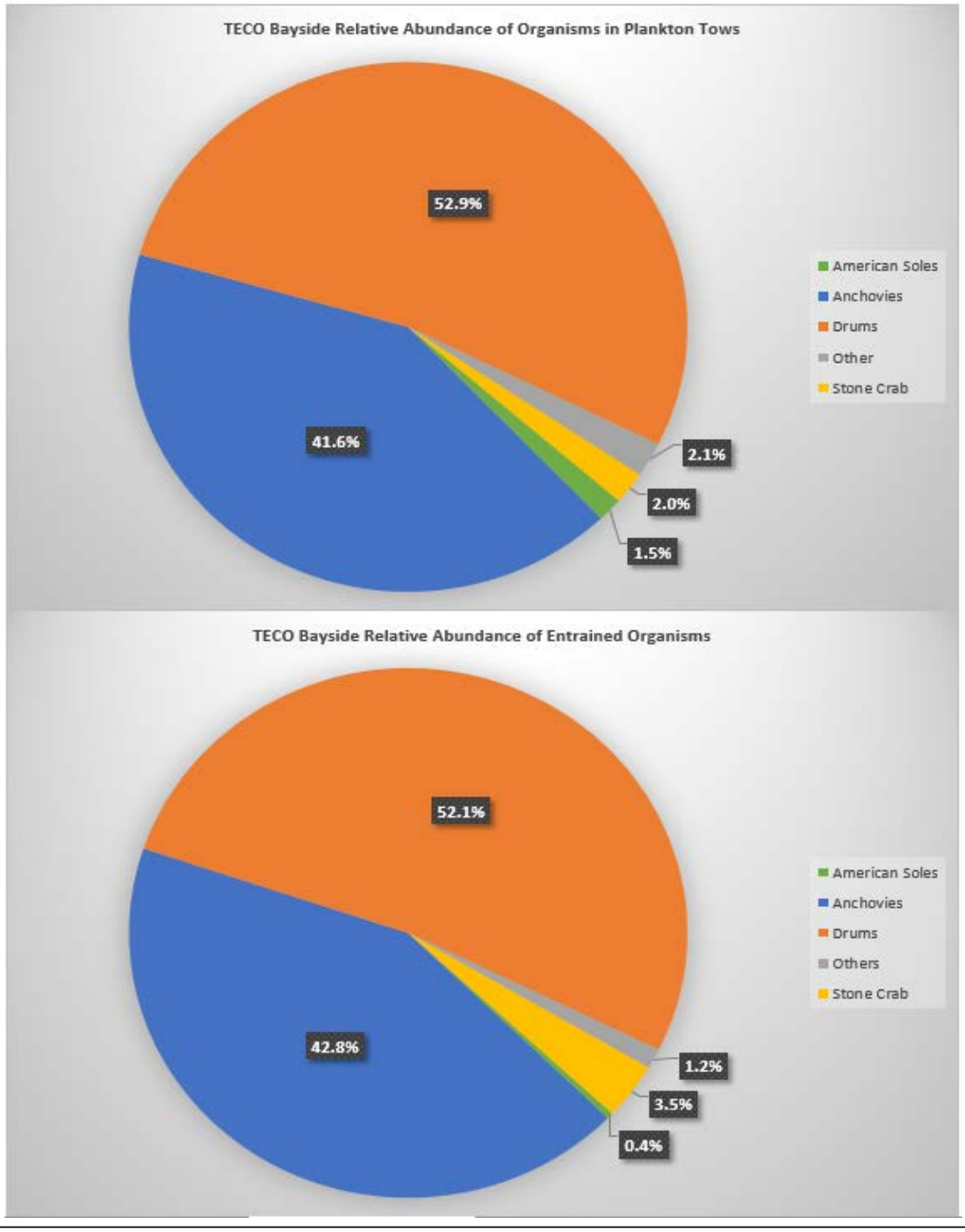


FIGURE 9-2.

TECO BAYSIDE RELATIVE ABUNDANCE OF ORGANISMS IN NEARFIELD PLANKTON TOWS AND ENTRAINMENT SAMPLES

Source: TECO, 2010.

ECT Environmental Consulting & Technology, Inc.

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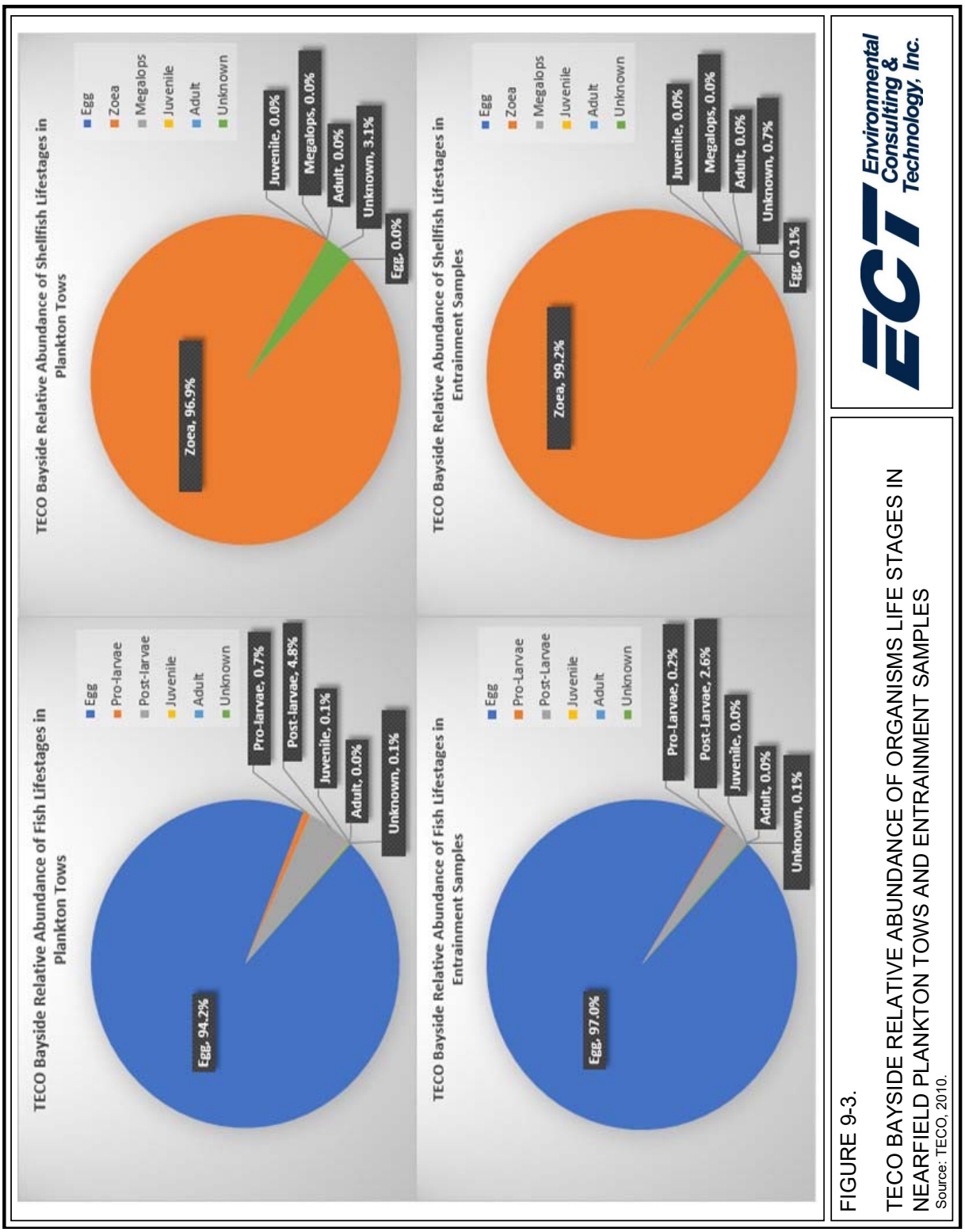


FIGURE 9-3.

TECO BAYSIDE RELATIVE ABUNDANCE OF ORGANISMS LIFE STAGES IN NEARFIELD PLANKTON TOWS AND ENTRAINMENT SAMPLES

Source: TECO, 2010.

ECT Environmental Consulting & Technology, Inc.

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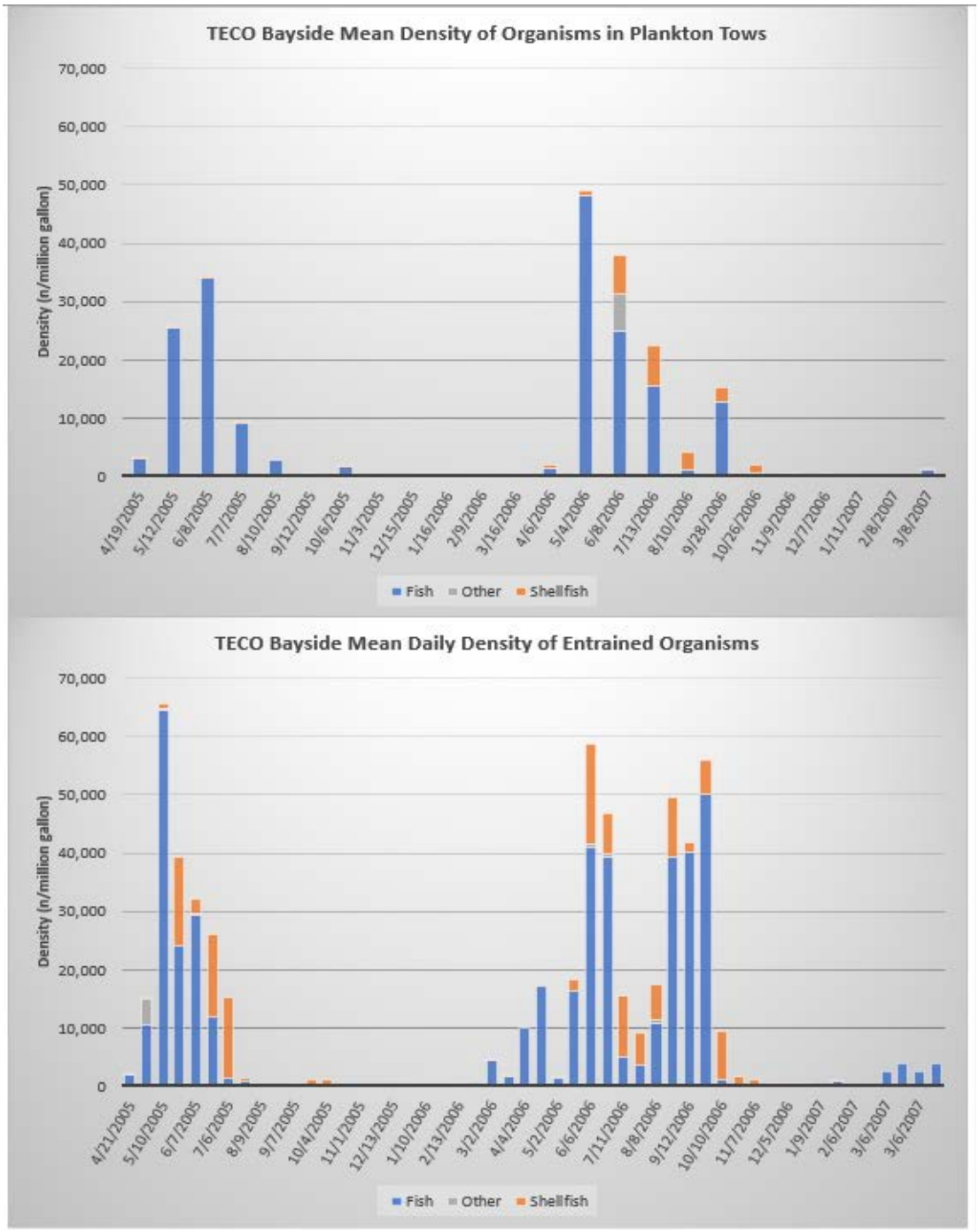


FIGURE 9-4.

TECO BAYSIDE MEAN DAILY DENSITY OF ORGANISMS IN NEARFIELD PLANKTON TOWS AND ENTRAINMENT SAMPLES

Source: ECT, 2010.

ECT Environmental Consulting & Technology, Inc.

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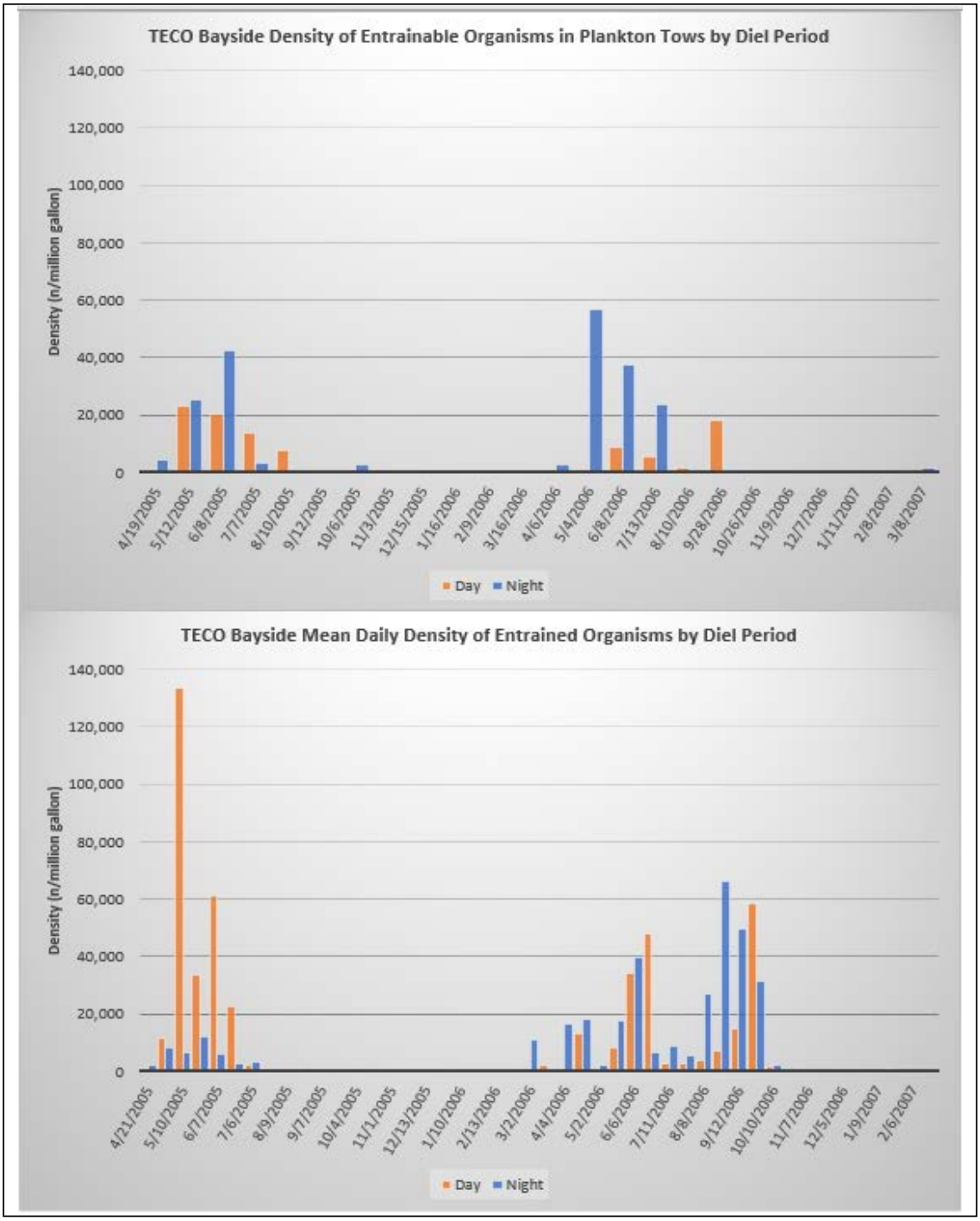


FIGURE 9-5.
TECO BAYSIDE MEAN DAILY DENSITY OF ORGANISMS BY DIEL PERIOD IN NEARFIELD PLANKTON TOWS AND ENTRAINMENT SAMPLES
Source: ECT, 2010.

ECT Environmental Consulting & Technology, Inc.

Table 9–4. Comparison of Nearfield Entrainable-sized Organisms within Florida Estuaries

	FPL Cutler	TECO Big Bend	TECO Bayside
Water body	Biscayne Bay	Hillsborough Bay	Hillsborough Bay
Entrainment density (n/MG)	12,354	31,021	68,711
Nearfield density (n/MG)	72,007	90,873	85,237
Entrainment % of nearfield	55.4%	34.1%	80.6%

Sources: Golder, 2009.
TECO, 2010.
AECOM, 2010

9.2.2 Entrainment Sampling

Figure 9-2 illustrates the relative abundance of taxon entrained through Bayside during the Phase II compliance effort. As shown, drum (Sciaenidae) was the most abundant taxon entrained, representing 52.1 percent of all species entrained. Anchovies (*Anchoa* spp.) represent the second most abundant taxon entrained, at 42.8 percent. Stone crab (*Menippe mercenaria*) were the most abundant shellfish entrained and third-most taxon at 3.5 percent. This is similar to the distribution of what was observed in the nearfield densities.

Bayside is entraining a similar distribution of taxon supporting the conclusion that the nearfield sampling is representative of the entrainment experienced at Bayside. As in the nearfield sampling, most ichthyoplankton entrained were in the egg stage, representing 97 percent of the total ichthyoplankton entrained (Figure 9-3). As in the nearfield, almost all shellfish entrained were found in the prolarvae stage, representing 99.2 percent of the total shellfish entrained (Figure 9-3).

Similar to the nearfield densities, densities of entrained organisms were highest during the late spring and summer months; during the second year of sampling, another peak was observed in early fall (Figure 9-4). A peak density of 51,423 organisms per million gallons of water was observed in May 2005. The lowest observed density was in December 2005. Unlike the nearfield, densities of entrained organisms were highest during the daytime samples. Day and night entrainment followed a similar pattern (Figure 9-5).

The nearfield densities observed at Bayside are similar to the nearfield ichthyoplankton (Figure 9-4). Entrainment densities observed at Bayside during the Phase II compliance effort are approximately 80 percent of the nearfield densities. This suggests perhaps the existence of the intake canal does not contribute to reduction in densities of early life stage organisms; however, the density of impingeable-sized organisms see a drastic reduction where the density of impingeable-sized organisms at the screens was less than 1 percent of the nearfield density (Golder 2009).

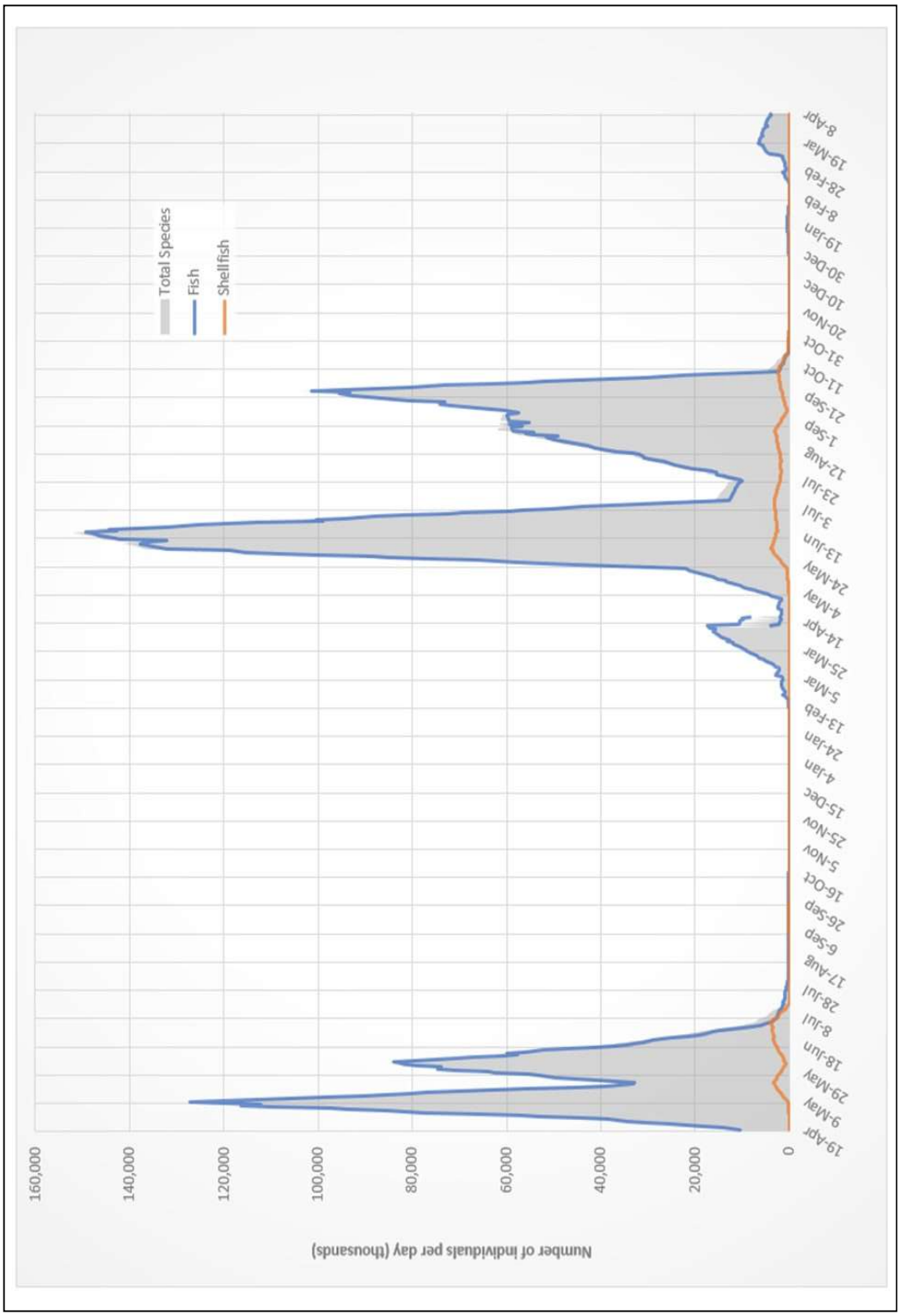
9.3 Analysis and Supporting Documentation—40 CFR 122.21(r)(9)(iii)

To determine the number of organisms currently (2014 to 2016) that can be expected to have been entrained through Bayside (flow adjusted entrainment), the densities presented previously were annualized using the actual average daily flows through Bayside for 2014 to 2016 (sample Year 1: 2014 through 2015 flow with 2005 through 2006 densities; sample Year 2: 2015 through 2016 flow with 2006 through 2007 densities) (Figure 3-2). Calculations were also made that used the DIF. Daily densities were linearly interpolated between sampling events then multiplied by the daily flow (MGD) for each corresponding day following the methodology used during the Phase II compliance effort.

The flow-adjusted entrainment numbers do not consider organism survival through the plant; for the purposes of this assessment in general, survival through the plant is assumed to be zero.

The interpolated densities of entrained organisms peaked in late spring/early summer of 2005 and summer/early fall of 2006 (Figure 9-6). Interpolating the numbers to an annual count using the average daily flows observed between 2014 and 2016 on the corresponding sampling dates, daily plant entrainment totals ranged between 0.01 and 152 million organisms per day. Interpolated entrainment counts for fish were an order of magnitude greater than for shellfish. Fish peaked at 149 million per day and shellfish at 4 million per day, both during the summer, however in different years (Figure 9-6). Fish and shellfish demonstrated similar seasonal patterns with higher entrainment rates observed from late spring to early fall.

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FIGURE 9-6.

TECO BAYSIDE DAILY ENTRAINMENT RATES (INTERPOLATED AND FLOW ADJUSTED)

Source: ECT, 2018.

Table 9-5 summarizes the estimated annualized interpolated number of organisms expected to have been entrained at Bayside based on the two years of entrainment densities combined with the average intake daily flows for April 2014 and April 2016. These two years of entrainment estimates are considered the baseline rate of entrainment that will be considered in the assessment of social benefits in Section 11.0. The total estimated number of fish entrained was 4,643,600,000 in sample year 1 (April 2014 to April 2015) and 9,153,300,000 in sample year 2 (April 2015 to April 2016). The total estimated number of shellfish entrained was 344,710,000 in sample year 1 and 349,470,000 in sample year 2.

Under DIF conditions, the total estimated number of fish entrained was 5,389,600,000 in sample year 1 and 10,364,000,000 in sample year 2. The total estimated number of shellfish entrained was 190,870,000 in sample year 1 and 396,650,000 in sample year 2.

9.4 References

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Table 9–5. Annualized Flow-adjusted Counts of Organisms Expected to Have Been Entrained at Bayside Between 2014 and 2016

Species	Sample Year 1						Sample Year 2					
	Eggs	Larvae/ Zoea	Postlarvae/ Megalops	Juvenile	Unknown	Species Total	Eggs	Larvae/ Zoea	Postlarvae/ Megalops	Juvenile	Unknown	Species Total
Fish												
Achiridae	1,854,800					1,854,800	52,973,000	71,299				53,044,000
Achirus lineatus			463,450			463,450		92,100	5,322,800			5,414,900
Anchoa hepsetus	262,450					262,450	1,814,000					1,814,000
Anchoa mitchilli	735,250,000	2,916,600	31,736,000	65,613		769,970,000	5,252,100,000	20,948,000	45,738,000		16,487,000	5,335,300,000
Anchoa spp.									142,540			142,540
Bairdiella chrysoura		73,460	60,904,000			60,977,000			9,814,900			9,814,900
Bathygobius soporator		73,749	8,595,100	85,721	73,460	8,828,000			4,477,800		147,280	4,625,000
Blenniidae		73,460	27,014,000			27,088,000			23,275,000		372,880	23,648,000
Carangidae									92,566			92,566
Chaetodipterus faber			71,985			71,985			354,220			354,220
Chasmodes saburrae			366,610			366,610						
Chloroscombrus chrysurus			146,100			146,100			377,250	665,550		1,042,800
Clupeidae			146,100			368,620	163,960	92,061	73,733			329,760
Cynoscion arenarius			16,204,000			16,204,000			2,465,600			2,465,600
Cynoscion nebulosus			1,654,700			1,654,700			2,754,500			2,754,500
Eugerres plumieri			228,270			228,270						
Gobiesox strumosus			5,208,400	74,022		5,282,500			1,707,700			1,707,700
Gobiidae		146,920	4,914,100			5,061,000			1,160,800			1,160,800
Gobiosoma robustum			16,548,000			16,548,000			9,563,400		361,880	9,925,300
Gobiosoma spp.			2,153,300			2,153,300						
Hippocampus erectus				34,247		34,247						
Lagodon rhomboides				74,054		74,054						
Membras martinica			146,480			146,480						
Menidia spp.	163,650					163,650						
Menticirrhus spp.			28,144,000			28,144,000			6,303,100	92,566		6,395,700
Microdesmus longipinnis			4,005,300			4,005,300			166,680			166,680
Microgobius gulosus			182,200			182,200						
Microgobius spp.			142,380			142,380						
Oligoplites saurus								71,284	502,880			574,170
Prionotus scitulus			143,970			143,970						
Prionotus spp.			143,750			143,750			715,870			715,870
Prionotus tribulus			171,720			171,720						
Sciaenidae	3,684,800,000	99,235	4,673,900			3,689,600,000	3,678,400,000		4,991,000		2,414,300	3,685,900,000
Scorpaenidae									92,566			92,566

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Table 9–5. Annualized Flow-adjusted Counts of Organisms Expected to Have Been Entrained at Bayside Between 2014 and 2016
(Continued, Page 2 of 2)

Species	Sample Year 1						Sample Year 2					
	Eggs	Larvae/ Zoea	Postlarvae/ Megalops	Juvenile	Unknown	Species Total	Eggs	Larvae/ Zoea	Postlarvae/ Megalops	Juvenile	Unknown	Species Total
Symphurus plagiusa			514,350			514,350			2,450,400			2,450,400
Syngnathus louisianae			360,630	257,350		617,970			2,031,600	402,970		2,434,600
Trinectes maculatus		73,460	1,732,200			1,805,700			952,520			952,520
Trinectes spp.	183,650					183,640						
Subtotal	**4,422,500,000**	**3,456,900**	**216,940,000**	**591,000**	**73,460**	**4,643,600,000**	**8,985,500,000**	**21,275,000**	**125,530,000**	**1,161,100**	**19,784,000**	**9,153,300,000**
Unidentified Species												
Unidentified species	13,792,000	591,370	1,647,000		81,657	16,112,000	1,358,900	826,780	3,326,800		1,522,500	7,035,000
Subtotal	**13,792,000**	**591,370**	**1,647,000**		**81,657**	**16,112,000**	**1,358,900**	**826,780**	**3,326,800**		**1,522,500**	**7,035,000**
Shellfish												
Callinectes sapidus			72,612			72,612						
Lolliguncula brevis		81,605				81,605		337,430				337,430
Menippe mercenaria		165,290,000				165,290,000	555,980	344,380,000			4,177,600	349,110,000
Subtotal		**165,370,000**	**72,612**			**165,440,000**	**555,980**	**344,710,000**			**4,177,600**	**349,450,000**
Total Species	**4,436,300,000**	**169,410,000**	**218,660,000**	**591,010**	**155,120**	**4,825,100,000**	**8,987,500,000**	**366,810,000**	**128,850,000**	**1,161,100**	**25,484,000**	**9,509,800,000**

Source: ECT, 2018.

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Appendix 9-A

Clean Water Act Section 316(b) Biological Characterization Report for Bayside Power Station

(Provided on CD)

10.0 40 CFR 122.21(r)(10)—Feasibility and Cost Study

10.1 Introduction and Background

10.1.1 Rule Requirement

Bayside consists of two gas-fired, combined-cycle generation units (1 and 2) and four natural gas-fired, simple-cycle peaking units (3 through 6). The gross summer generation capacity of Unit 1 is 710 MW, with 236 MW coming from the steam turbine and 474 MW from the three combustion turbines. The gross summer generating capacity of Unit 2 is 940 MW with 308 MW from the steam turbine and 632 MW from the four combustion turbines. Units 3 through 6 are 57 MW each. The total gross summer generation capacity of Bayside is therefore 1,878 MW (TECO, 2017). Cooling water is used only for the steam turbines or cycles; therefore, the remainder of this evaluation focuses on the electricity generation and water use associated with the steam cycle. Bayside is situated in Hillsborough County, Florida. The general layout of Bayside is shown on Figure 10-1.

Bayside is regulated under the EPA's 2014 rule for existing facilities developed under the 316(b) rule because it has a DIF of greater than 2 MGD, uses more than 25 percent of the total water withdrawn exclusively for cooling, and its discharge is regulated under the authorization of a NPDES permit. Bayside's AIF from the Hillsborough Bay is greater than 125 MGD; therefore, the station must submit information required in 40 CFR 122.21(r)(9) through (13), in addition to information required in 40 CFR 122.21(r)(2) through (8), which apply to all eule-regulated facilities. In 40 CFR 122.21(r)(10), Comprehensive Technical Feasibility and Cost Evaluation Study, the regulations state:

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FIGURE 10-1.

BAYSIDE POWER STATION LOCATION MAP

Source: HDR, 2018.

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The owner or operator of an existing facility that withdraws greater than 125 MGD AIF must develop for submission to the Director an engineering study of the technical feasibility and incremental costs of candidate entrainment control technologies. In addition, the study must include the following:

(i) Technical feasibility. An evaluation of the technical feasibility of closed-cycle recirculating systems as defined at 40 CFR 125.92(c), fine-mesh screens with a mesh size of 2 millimeters or smaller, and water reuse or alternate sources of cooling water. In addition, this study must include:

(A) A description of all technologies and operational measures considered (including alternative designs of closed-cycle recirculating systems such as natural draft cooling towers, mechanical draft cooling towers, hybrid designs, and compact or multi-cell arrangements);

(B) A discussion of land availability, including an evaluation of adjacent land and acres potentially available due to generating unit retirements, production unit retirements, other buildings and equipment retirements, and potential for repurposing of areas devoted to ponds, coal piles, rail yards, transmission yards, and parking lots;

(C) A discussion of available sources of process water, grey water, waste water, reclaimed water, or other waters of appropriate quantity and quality for use as some or all of the cooling water needs of the facility; and

(D) Documentation of factors other than cost that may make a candidate technology impractical or infeasible for further evaluation.

(ii) (ii) Other entrainment control technologies. An evaluation of additional technologies for reducing entrainment may be required by the Director.

(iii) (iii) Cost evaluations. The study must include engineering cost estimates of all technologies considered in paragraphs (r)(10)(i) and (ii) of this section. Facility costs must also be adjusted to estimate social costs. All costs must be presented as the net present value (NPV) and the corresponding annual value. Costs must be clearly labeled as compliance costs or social costs. The applicant must separately discuss facility level compliance costs and social costs, and provide documentation as follows:

(A) Compliance costs are calculated as after-tax, while social costs are calculated as pre-tax. Compliance costs include the facility's administrative costs, including costs of permit application, while the social cost adjustment includes the Director's administrative costs. Any outages, downtime, or other impacts to facility net revenue, are included in compliance costs, while only that portion of lost net revenue that does not accrue to other producers can be included in social costs. Social costs must also be discounted using social discount

rates of 3 percent and 7 percent. Assumptions regarding depreciation schedules, tax rates, interest rates, discount rates and related assumptions must be identified;

(B) Costs and explanation of any additional facility modifications necessary to support construction and operation of technologies considered in paragraphs (r)(10)(i) and (ii) of this section, including but not limited to relocation of existing buildings or equipment, reinforcement or upgrading of existing equipment, and additional construction and operating permits. Assumptions regarding depreciation schedules, interest rates, discount rates, useful life of the technology considered, and any related assumptions must be identified; and

(C) Costs and explanation for addressing any non-water quality environmental and other impacts identified in paragraph (r)(12) of this section. The cost evaluation must include a discussion of all reasonable attempts to mitigate each of these impacts.

This document evaluates the technical feasibility and associated costs of a closed-cycle recirculating system, FMS, alternate cooling water sources for Bayside, and VSP. Technical feasibility and facility cost evaluation for FMS has been developed by Alden while the assessment of other technologies was provided by HDR. Facility costs have been translated to social costs by Veritas Economic Consulting.

An important element of this document is the refinement of a variety of potential approaches to each technology (e.g., cooling tower type) to focus on the specific application that will be considered in the development of costs, social benefits, and other environmental impacts. Similarly, a wide range of potential technologies will be considered in a screening mode with the four described above carried forward for additional analysis in this document. Specific technology configurations that are potentially feasible will be considered further relative to their social benefits and other environmental impacts in subsequent reports.

This section, along with related sections 40 CFR 122.21(r)(9) and (11 through 13), are required of facilities with AIF greater than 125 MGD. Collectively, these five sections of the rule support assessment of potential measures to reduce entrainment and will be referred to collectively as the as the entrainment BTA evaluation. The entrainment BTA evaluation is provided to FDEP to

support its assessment of alternative technologies under a BPJ standard. This subsection provides background on the feasibility and cost estimation processes.

10.1.2 Technologies and Measures to Be Assessed

The focus of this section as well as the balance of the entrainment BTA evaluation section is to examine various measures that may reduce entrainment rates. The rule requires that three technologies be considered at the relevant facilities: retrofit to closed-cycle cooling, installation of FMS in the form of TWS or fixed wedgewire screens, and water reuse and/or securing of alternative water supplies. In addition to these three technologies, the rule at 40 CFR 122.21(r)(10)(ii) indicates that the FDEP Director may require consideration of additional technologies to reduce entrainment. While the Director has not required consideration of other technologies during coordination on Rule implementation at Bayside, it is prudent to review alternative technologies in the event that one or more represents a more feasible and cost-effective measure than the three approaches required to be considered under the Rule.

While the focus of the entrainment BTA assessment is a reduction in entrainment, it is very useful to consider how each candidate technology or measure may address IM BTA. While IM BTA is the subject of the 40 CFR 122.21(r)(6) Report, as required by 40 CFR 122.21(r)(6), the candidate approaches in this section will be considered in the context of IM BTA as well as entrainment BTA. Measures and technologies that are focused more exclusively on IM BTA rather than entrainment BTA (e.g., acoustic deterrents) are not considered here but were in the 40 CFR 122.21(r)(6) Report.

Finally, it should be noted that the range of measures that can be reasonably expected to reduce entrainment are relatively limited. Given the assumed planktonic (or non-motile) nature of the majority of entrained organisms, behavioral deterrents will not be effective. On the other hand, entrained organisms are generally small (e.g., on the order of a single millimeter) so that coarse-mesh screening devices are ineffective. Therefore, a relatively limited set of technologies and measures are available and will be considered here. In the following discussion, the measures are grouped by their essential mode of action (e.g., exclusion, intake flow reduction):

10.1.2.1 Overall Approach—Reduced Intake Flow

Specific Technology: Retrofit to Closed-cycle Cooling

Under this scenario, the existing once-through cooling system would be retrofitted to allow for a closed-cycle recirculating cooling system. A variety of closed-cycle configurations are available and will be considered below (see Section 10.3). A hallmark of all of the systems is that intake flow is reduced substantially, potentially by more than 90 percent, relative to once-through cooling systems. The State of Florida requires that the chloride concentration in the discharge not exceed 110 percent of the receiving water body chloride concentration; therefore, cooling towers need to be operated at lower cycles of concentration or the discharge needs to be diluted to meet NPDES requirements. Either way, the net effect is that flow reduction is approximately 85 percent compared to once-through cooling systems. On the other hand, retrofit to closed-cycle systems must account for the existing infrastructure and its constraints. Therefore, consideration of this scenario involves evaluation of several factors related to the existing facility and the potential closed-cycle retrofit.

Specific Technology: Water Reuse and/or Alternative Water Supplies

This measure relies on the potential for one or more alternative water sources to replace part or all of the cooling water withdrawn from Waters of the United States. Water reuse within the facility is also to be considered. This measure will consider alternative sources of water to supply the existing once-through system rather than a hypothetical closed-cycle cooling system, as described above.

Specific Technology: VSPs

This technology is based on the concept that the existing facility, with constant speed pumps, has opportunities to reduce its intake flow under some conditions (e.g., less than full power output and cooling demand; other conditions where operational and permitting constraints allow reduced flow). VSPs require the installation of variable-frequency drives (VFDs) and may require replacement of the circulating water pumps to those that can pump at variable speeds. While VSPs may use less power when operating at reduced intake flow, VSDs require climate control, which involves a new power demand.

10.1.2.2 Overall Approach—Fixed Screening Devices

Specific Technology: Wedgewire Screens

This technology relies on the exclusion of the organisms from the intake flow by a fixed screen. It is common for these systems to have low through-slot velocities (TSV) to reduce entrainment as well as address IM BTA. Such systems can be quite large at higher DIF plants and their biological effectiveness is greatly facilitated by water moving across and past the screen at velocities that are similar to or higher than the TSV. Such water movement is referred to as a sweeping flow.

Specific Technology: Aquatic Filter Barrier

Aquatic filter barriers (AFBs) consist of fabric barriers that are suspended from the water surface and secured to the bottom such that all cooling water should pass through the fabric. The pore size in the fabric is fine enough that entrainable fish and shellfish are excluded. Design guidelines for AFBs include target through-fabric velocities to prevent organism impingement as well as operational issues. AFBs include cleaning systems generally based on release of compressed air from within the AFB to directly remove debris and biofouling as well as shaking these materials from the AFB face.

Specific Technology: Porous Dikes

In theory, porous dikes behave in a fashion that is similar to AFBs but the system is based on a dike that emerges from the water surface. The dike is porous enough to allow water passage while excluding organisms. Porous dikes are not common because they require several acres and can pose significant operational challenges depending on the operating environment. Porous dikes constructed of a fine-grained material have been considered as a means of excluding entrainable organisms.

10.1.2.3 Overall Approach—Modification of TWS

Specific Technology: Installation of FMS on TWS with an Organism Return System

This system is based on the exclusion of the otherwise entrainable organisms from the intake water, washing them from the FMS, and returning them to the source water body. This represents one of the two forms of FMS, the other one being wedgewire screens with a slot size of 2 mm (see Section 10.4).

10.1.2.4 Overall Approach—Relocated Intake

Specific Technology: Relocation of the Intake to Locations with Lower Population Densities

Gradients in the densities of entrainable organisms have been demonstrated in freshwater, estuarine, and marine systems. These gradients have been exploited to reduce entrainment and impingement by placing the intake structure at locations exhibiting lower population densities. Such an approach was part of the basis for the Calculation Baseline defined in the 316(b) Phase II rule and it is discussed as a potential measure to reduce entrainment in the 2014 rule.

Each of these measures is reviewed briefly in Table 10-1. This review includes an assessment of each technology's ability to address IM and entrainment BTAs and whether the approach will be retained for further assessment in the balance of this section. The basis of the decision to retain or discard a measure is also explained in the table.

Based on the assessment provided in Table 10-1, the following approaches will be retained for further assessment: both forms of FMS (i.e., fixed wedgewire screens, fine mesh TWS), VSPs, alternative water supplies, and closed-cycle cooling.

10.1.3 Distinction Between Facility-level and Social Costs

EPA's interpretation and expectations of facility-level compliance costs and social costs are discussed in 79 FR 48367.

Social costs need to represent the burden on society and the economy; "it is the sum of all opportunity costs incurred", whereas facility-level costs need to represent only the costs that would be incurred by the facility. Per EPA (2014), social costs may be higher or lower than facility-level costs. Key differences between facility-level costs and social costs include:

- Facility-level costs include taxes, whereas social costs do not as "taxes are viewed as a transfer and not a real resource cost".
- When estimating net present value (NPV), facility-level costs use the market cost of capital in the interest rate, whereas the Rule requires that social costs use both 3 percent and 7 percent discount rates.

Table 10–1. Entrainment Reduction Technologies to be Assessed

Alternative	Approach to IM BTA	Effectiveness at Reducing E	Retained for More Detailed Assessment?	Basis of Decision
Traveling Screen Modifications				
Modified traveling screens, consistent with 40 CFR 125.92(s), with FMS and an organism return	Modified Traveling Screens per 40 CFR 125.94(c)(5)	Based on rates of exclusion and post-exclusion survival as affected by mesh size	Yes, see Section 10.4	Potential approach to FMS, assessment of which is required by 40 CFR 122.21(r)(10). Demonstrated technology at Big Bend Units 3 and 4 including availability of data on costs and biological performance. Modified traveling screens (with or without FMS) is a potential technology for achieving IM BTA.
Fixed Screening Devices				
Wedgewire screens with slot size ≤ 2 mm and through-slot velocity less than 0.5 fps	TSV less than 0.5 fps at DIF consistent with 40 CFR 125.94(c)(2)	Potential reductions but effectiveness is difficult to estimate, and reliability is uncertain.	Yes, see Section 10.4	Potential approach to FMS, assessment of which is required by 40 CFR 122.21(r)(10). Understanding costs, reliability, and effectiveness viewed as important perspective, particularly relative to modified traveling screens.
Aquatic filter barrier	Potentially reduced TSV, 40 CFR 125.94(c)(2), or contribution to system of measures, 40 CFR 125.94(c)(6). Significant reduction in IM possible if system is properly installed and reliable.	Low to high depending upon installation and reliability.	No	Aquatic filter barriers have very limited application, particularly in marine waters. Pilot projects in temperate marine waters demonstrated rapid, catastrophic failures. Target hydraulic loading parameters (3 to 4 gpm per ft^2 of fabric) would require a barrier of 83,200 to 138,700 ft^2. At a water depth of approximately 15 ft, such a barrier would be 1.05 to 1.75 miles in length. Such a system would represent an unacceptable impediment to navigation even if it were believed to be effective.
Porous dike	Potential contribution to system of measures, 40 CFR 125.94(c)(6). Substantial reduction in IM in freshwater systems.	Likely low due to imperfect exclusion and creation of artificial habitat.	No	Porous dikes have not been applied in marine waters and would require extensive filling of the waterway as well as isolation of portions of the intake canal. Effectiveness at reducing entrainment is poorly demonstrated.

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Table 10–1. Entrainment Reduction Technologies to be Assessed (Continued, Page 2 of 2)

Alternative	Approach to IM BTA	Effectiveness at Reducing E	Retained for More Detailed Assessment?	Basis of Decision
New Intake Location				
Relocated intake structure to access lower population densities.	Likely poor given nature of habitat and fisheries populations in Hillsborough Bay	Likely poor given nature of habitat and fisheries populations in Hillsborough Bay	No	Estimating potential benefit is subject to uncertainty. Site-specific data suggest that candidate locations in Hillsborough Bay are likely to have higher densities of impingeable organisms than the current location making relocation counterproductive (densities of meroplankton are similar between the nearfield and entrained) (Golder, 2009). Capital costs would be substantial particularly for a highly uncertain benefit. Environmental permitting is likely to be challenging and there is a potential for impacts to navigation.
Flow Reduction				
Closed-cycle cooling	IM BTA under 40 CFR 125.94(c)(1).	High. Approximately 85 percent reduction in E possible.	Yes, see Section 10.3.5	Assessment is required by 40 CFR 122.21(r)(10).
Alternative water supply	Potentially contributes to IM BTA under 40 CFR 125.94(c)(6)	Reductions in entrainment generally estimated as proportional to flow.	Yes, see Section 10.5	Assessment is required by 40 CFR 122.21(r)(10).
Variable speed pumps	Uncertain and variable. Very unlikely to address fully IM BTA under 40 CFR 125.94(c)(6).	Uncertain and variable.	Yes, see Section 10.6	Potential for reduction in IM and E. Difficult to assess potential opportunities and relative costs and benefits without more detailed analysis as provided below.

Note: A variety of other measures have applied at other facilities in an attempt to reduce rates of impingement including louvers, angled screens, and behavioral deterrents. These technologies were shown to have no meaningful effect on entrainment and, therefore, are not considered here. These technologies are considered in assessing BTA options for IM as required by 40 CFR 122.21(r)(6).

Source: ECT, 2018.

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- Social costs include the Director's administrative costs.
- Facility downtime associated with tie-ins results in lost revenue to the facility; however, if another facility were to dispatch to make up for lost generation, then the social cost would need to include only the increase in marginal cost of production at the other facility.

10.1.4 Overview of Facility Cost Development

This subsection will provide context for the nature of the facility cost estimation process.

10.1.4.1 Approach to Cost Estimation and Relationship to Design Process

The goal of this report is to understand the feasibility and approximate costs of a set of measures that may be appropriate to reduce entrainment at Bayside and in no case, is a detailed design developed for these measures (see Section 10.1.4.2). Instead, an estimate of the technology configuration at the site is used to develop approximate facility costs as well as identify constraints on installation and operation that would affect costs, feasibility, and effectiveness. While this is appropriate for this report, there is a possibility that some significant constraint (e.g., subsurface obstacles to construction; hydraulic issues associated with VSPs) has not been identified by this process and that a more complete design process would result in higher facility costs and/or lower feasibility. This evaluation attempts to develop a one to 15 percent design to enable an Association for the Advancement of Cost Engineering (AACE) Class 4 estimate to facilitate a BTA determination (see Section 10.1.4.2).

Similarly, the development of these estimates has required decisions to be made regarding the specific technology configurations to be used (e.g., the nature and target velocity of the FMS; the nature and location of potential cooling towers; the operating rules of VSPs). These decisions will be discussed in the relevant sections below but the fact remains that a more complete design process may reach different conclusions about the best configurations and operational strategies.

With this in mind, a system is specified for each technology that overcomes clear operational problems (e.g., does not result in unacceptable intake velocities; does not exceed the pressure specification of the condensers; accounts for obvious constraints on discharge of cooling tower blowdown) while minimizing the facility level costs to the extent practicable. A good example of

this tradeoff is the selection of evaporative cooling towers over air-cooled condensers. The selection of air-cooled condensers is believed to be construed to "stack the deck" by increasing facility costs (both capital and power costs) while reducing the intake flow only marginally relative to evaporative cooling.

Tie-ins to the existing station or other modifications to the existing cooling system invariably increase downtime and associated costs. Therefore, this evaluation considers scenarios where much of the hypothetical construction work would be carried out without disrupting the station's operations to the extent practicable and only perform the tie-ins and invasive construction steps, after the majority of the new construction is complete. This tradeoff is considered in several places in the following subsections.

While a detailed design process would be required before the installation of any one of these potential technologies or measures, two are associated with even higher uncertainty:

- The facility costs associated with any potential requirement to retrofit to closed-cycle cooling to address E BTA would be so large that they might cause TECO to consider modifications to the power plant to improve efficiencies.
- Successful installation of VSPs requires careful assessment of the existing condensers and water conveyance systems as well as the facility's thermodynamics. This will likely include specialized modeling of the condenser performance as well as the hydraulics of the intakes and the downstream cooling system. Similarly, the two years of plant performance data used to evaluate VSP opportunities are the product of electricity demand during those two years. TECO must maintain its ability to respond to the electricity demands of each year, therefore, any sort of limitation on operation or pumping rate associated with VSPs could impact electricity generation reliability towards the customer base as well as TECO's contractual obligations to provide power. In summary, the analyses of VSPs presented below should be considered a preliminary assessment of the opportunity for flow reductions as well as their potential costs. Prior to TECO's agreement to install VSPs, if selected as the appropriate measure, a more thorough, and much more costly analysis of their feasibility would be necessary.

10.1.4.2 Level of Facility Cost Estimation

The engineering evaluation presented herein aims to develop a Class 4 cost estimate as defined by AACE. A Class 4 costs estimate was conducted for all technologies except were indicated otherwise. As shown in Table 10-2, a Class 4 estimate suggests between one and 15 percent design of the system and is meant to assess the feasibility of a project (which is also the goal of the 40 CFR 122.21(r)(10) engineering evaluation). A Class 4 estimate does not need to assess all costs in detail; parametric estimates that apply to the system are acceptable. Such an estimate is expected to be accurate to -15 and -30 percent on the lower end to 20 and 50 percent on the upper end. Additional information about cost estimating accuracy may be found at AACE (2016).

Table 10–2. AACE Costing Categories

Estimate Class	Characteristics				
	Primary	Secondary			
	Level of Project Definition (% of Complete Definition)	End Usage (Typical Purpose of Estimate)	Methodology (Typical Estimating Method)	Expected Accuracy Range (Typical Variation in Low and High Ranges)	Preparation Effort (Typical Degree of Effort Relative to Least Cost Index of 1)
5	0 to 2	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%	1
4	1 to 15	Study of feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +5-%	2 to 4
3	10 to 40	Budget, authorization, or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%	3 to 10
2	30 to 70	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%	4 to 20
1	50 to 100	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%	5 to 100

Source: AACE, 2016.

10.1.4.3 Engineering Cost Methodology

The overall engineering cost estimate for each feasible/practical entrainment reduction technology will include the following cost elements:

- Capital and operation and maintenance (O&M) Costs
- Owner's taxes on capital and O&M costs
- Facility's administrative costs

- Facility downtime costs
- Mitigation costs associated with non-water quality impacts, discussed in the 40 CFR 122.21(r)(12) Report

Capital costs would include (as appropriate):

- Key components based on site-specific conditions such as:
  - Equipment
  - Installation
  - Foundation costs, including of piles depending on subsurface conditions
  - Key electrical equipment
  - Earth moving (assuming nonhazardous)
- Parametric estimates for:
  - Pumps
  - Pipelines
  - Conduits and pipes
- Lump sum placeholders for:
  - Permits
  - Valves
  - Signage
- Cost for modifying, restoring, or relocating infrastructure impacted by the installation of the entrainment reduction technology: these items will be identified and associated costs developed to the extent practicable for the purposes of this evaluation. These costs will be biased low to present a conservative cost to the permit writer and for the cost-benefit analysis.

O&M Costs will include (as applicable):

- Labor to maintain the new system
- Electricity needed to power new facility systems
- Chemicals associated with increased water treatment
- Maintenance and repair costs
- Solids/sludge removal from cooling tower basin

Facility's administrative costs: For simplicity, this evaluation assumed that the station's administrative costs would be approximately 10 percent of the total project costs, and spending in each year would be proportional to project spending.

Facility downtime costs: The engineering evaluation estimated the potential downtime associated with each technology implementation. Associated costs were provided by TECO.

Mitigation costs associated with non-water quality impacts, discussed in the 40 CFR 122.21(r)(12) Report: When mitigation measures were proposed in the 40 CFR 122.21(r)(12) Report, associated costs were included here.

The costs were estimated using material quantities and labor estimates developed from the conceptual designs. Most of the costing information is based on published materials and labor costs (RS Means, 2015). The costs from RS Means have been adjusted to reflect costs for Tampa Bay, Florida. Technology-specific costs are based on manufacturer quotes from several similar facilities that were adjusted for identifiable differences in project sizes and operations. The combined costs allow a valid comparison of the cost difference between alternatives and their associated benefits.

The estimated costs are based on the following:

- Direct costs for materials and labor required for construction of all major project features. Labor was assumed to account for 30 percent of the costs with the remaining 70 percent for materials. The direct costs also include the overhead and profit charged by the installing contractors which were 10 percent of the materials, labor and labor burden, and equipment costs.
- Distributable costs for the construction contractor including; non-manual supervision, temporary facilities, equipment rental, and support services incurred during construction. These costs have been taken as 15 percent of the direct costs for each alternative.
- Overhead and profit costs for the general contractor in charge of the project have been taken as 10 percent of the direct costs for each alternative

- Allowance for indeterminates to cover uncertainties in design and construction at this stage of study. An allowance for indeterminates is a judgment factor that is added to estimated figures to complete the final cost estimate, while still allowing for other uncertainties in the data used in developing these estimates. The allowance for indeterminates has been taken as 10 percent of the direct, distributable, overhead and profit cost of each alternative.
- A contingency factor is considered to account for possible additional costs that might develop but cannot be predetermined (e.g., labor difficulties, delivery delays, weather). The contingency factor has been taken as 20 percent of the of the direct, distributable, overhead and profit costs of each alternative.
- TECO costs for administration of project contracts and for engineering and construction management have been taken as 10 percent of the direct costs for each alternative.
- Permitting costs were taken as 2 percent of the direct costs for each alternative.
- Indirect costs are costs for labor and related expenses for preconstruction engineering services such as bathymetric, topographic, geotechnical and seismic soil sampling; wetlands delineation and mitigation; and detailed drawings, specifications, and design documents. The indirect costs have been taken as 15 percent of the direct costs for each alternative and are referred to as preconstruction engineering studies.

Construction-related shutdowns could have a significant impact on the feasibility and costs of the selected intake technologies. For this analysis construction techniques and sequencing were selected to minimize construction-related shutdowns and their impacts. The impact of construction related shutdowns identified in this study were included in the facility cost estimates, however uncertainty in the length and timing of any construction related shutdowns could result in higher construction costs.

Costs for additional laboratory or field studies that may be required, such as hydraulic model studies and biological or engineering evaluations of prototype fish protection systems, are also included when necessary. These study costs were estimated using historical study cost estimates developed by Alden for other projects.

Annual O&M costs were determined for each of the selected technologies. These costs are based on the power, labor, and minor component replacement costs needed to operate and maintain each technology. They are based on the same assumptions used in calculating the capital costs. The power cost to operate each technology was assumed to be $37/MWh. This value represents the average cost to operate and maintain an investor owned fossil-fueled plant in 2015 (U.S. Energy Information Administration, 2016).[1] This cost does not include the loss of revenue associated with the power not being available for sale.

Periodic component replacement costs assume that each of the intake technologies would require major overhauls periodically. In the technical development document for the final 316(b) existing facilities rule (EPA, 2014), EPA estimated the service life of the technologies selected for Bayside range from 20 to 30 years. The service life of any intake technology is very site-specific based on operating and water body conditions. Tampa Bay is a warm estuarine environment which is generally considered a highly corrosive environment. The manufacturer of the fine-mesh fish-friendly screens installed at Big Bend recommends a major screen overhaul every six years. This same schedule was assumed for any new screens at Bayside. The major screen overhaul costs were included as part of the annual O&M costs.

Engineering costs will be presented as NPV and equivalent annual costs (EAC). NPV is provided to convert all the present and future costs to a base year, assumed to be 2017. This was done to estimate the present cost of each alternative over its lifespan. EAC is the annual costs of owning, operating and maintaining each option over the life of the technology. The costs used for the NPV and EAC analysis are based on the incremental changes that TECO will incur if it must reduce both impingement mortality and entrainment compared to changes to reduce only impingement mortality. As discussed below, any costs associated with operation according to the status quo or dedicated to addressing impingement mortality BTA alone are not considered in the cost estimation for the entrainment BTA measure. A period of 28 years (2017 to 2044) was used for the cost analysis based on an expected retirement date of 2044 for Unit 2. Permitting and preconstruction study costs are assumed to start September 1, 2018. Capital costs are assumed to occur after completion of the design and permitting with and annual and periodic costs occur

[1] For determination of social costs, the energy cost used over the life of the facility is determined through the power system modelling as described in Section 10.1.5 and changes from year to year in response to market conditions etc.

thereafter. Constant dollars, as recommended by EPA for developing cost estimates during feasibility studies (EPA, 2000), were used in this present value analysis. Constant dollars assume the cost of goods and services remain the same over time and are not affected by inflation or deflation. These constant dollars were then adjusted with discount rates of both 3 percent and 7 percent to account for the time value of the money. The use of these discount rates is required by EPA under the 316(b) Rule. Taxes and depreciation were assumed to be 6.5 percent (Hillsborough county sales tax).[2]

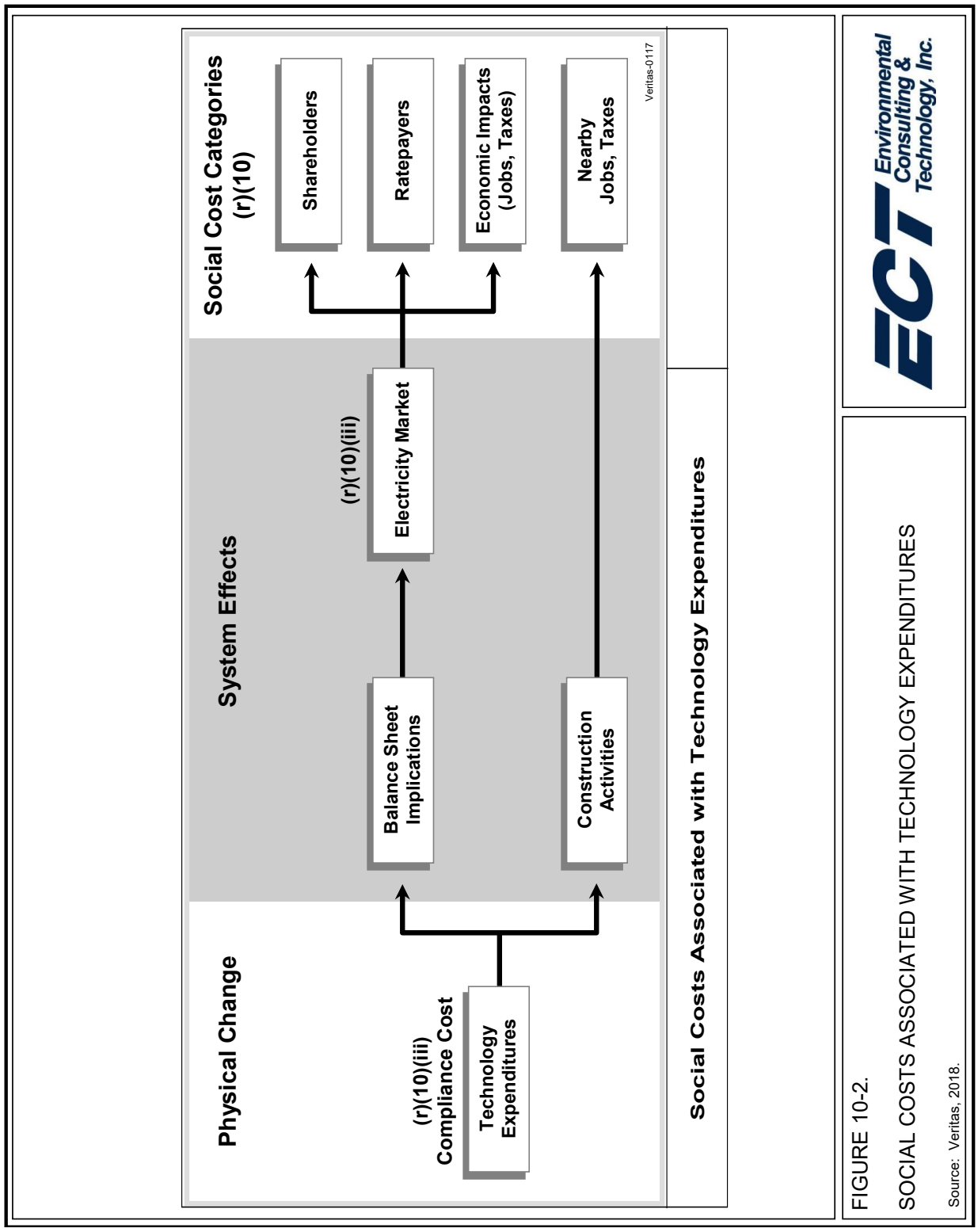
10.1.5 Overview of Social Cost Development

Reducing entrainment can generally be accomplished by altering operations; closing the facility; or by purchasing, installing, and operating entrainment reduction technologies. These activities lead to a number of physical changes and financial effects relating to social costs. EPA defines social costs as the "opportunity cost to society of employing scarce resources to prevent the environmental damage otherwise occurring except for the design and operation of compliance technology" (79 FR 158, 48387).

Figure 10-2 depicts how expenditures on entrainment reduction technologies would have implications for TECO's balance sheet and construction activities. As the figure depicts, construction generates nearby economic activity, which can lead to good social outcomes such as more jobs. These economic impacts can be studied via economic input-output analysis techniques. As related local outcomes are typically considered good, they are not measured under social costs and not considered further here.

Balance sheet implications are transmitted through financial, electricity, and regulatory markets to register as social costs to shareholders, ratepayers, and the general population. How these are realized as social costs depends upon the regulatory and market environments.

[2] FMS evaluation did not include 6.5-percent sales tax at this point; numbers are to be updated prior to submission.


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Physical Change
(r)(10)(iii) Compliance Cost
Technology Expenditures
System Effects
(r)(10)(iii)
Balance Sheet Implications
Electricity Market
Construction Activities
Social Cost Categories (r)(10)
Shareholders
Ratepayers
Economic Impacts (Jobs, Taxes)
Nearby Jobs, Taxes
Veritas-0117
Social Costs Associated with Technology Expenditures
Environmental Consulting & Technology, Inc.
FIGURE 10-2.
SOCIAL COSTS ASSOCIATED WITH TECHNOLOGY EXPENDITURES
Source: Veritas, 2018.

10.1.6 Remaining Life of the Station

The remaining life of each generating unit and technology impacts O&M costs, social costs, potential future technology repair costs (if the life of the unit is longer than the anticipated life of the technology) and the benefits. This evaluation assumes that each unit will operate through 2044. If the original entrainment reduction technology is in good operating order at that time, it is assumed that the technology would be retired at that time. Any potential salvage value is assumed to be minor and is not evaluated here. If the anticipated life of the technology is anticipated to be shorter than the anticipated life of the units, then this evaluation assumes that the technology would be repaired or rebuilt and somehow made available to service the generating unit through 2044.

10.1.7 Report Organization

The remainder of this document is organized as follows:

- Section 10.2 discusses the process for evaluating Social Costs
- Section 10.3 evaluates the feasibility and cost of closed-cycle cooling
- Section 10.4 evaluates feasibility and costs of FMS
- Section 10.5 evaluates the feasibility of using alternate water sources or reusing service water at Bayside
- Section 10.6 discussed VSPs
- Section 10.7 summarizes findings regarding the technical feasibility and cost evaluations

10.2 Process of Estimating Social Costs

10.2.1 Categories of Social Costs

Social costs can be delineated as each of the following:

- Real-resource compliance costs—direct purchase installation and operation
- Government regulatory costs—monitoring, administration, enforcement
- Environmental externalities—increased fuel cost impacts from energy penalty and proposed outages.

This report covers each of these social cost categories. Real-resource compliance costs result from purchasing and installing technologies at the Bayside. Government regulatory costs are

developed from EPA's estimates in the national rule (79 FR 158, 48300–48439). The social costs of environmental externalities are developed from the power system capacity loss and offsite emissions study, recreation study, and property value study conducted at Bayside (Veritas, 2017). The methods and results of those studies are presented in Appendix 10-A of this report.

10.2.2 Financial and Regulatory Environment

Bayside is owned by TECO, a subsidiary of the Emera Company in Halifax, Nova Scotia, Canada. TECO consists of two regulated natural gas utilities along with a regulated electric utility. TECO's electric assets include approximately 4,700 MW of natural gas, coal, and solar generation assets serving over 750,000 customers in west-central Florida. Figure 10-3 presents TECO's electric service territory and location of generating assets, and Figure 10-4 depicts TECO's generation portfolio by fuel type.

TECO is potentially eligible to recover all or part of the costs of installing entrainment reduction technologies. Electric utilities operating in Florida can file a rate request to the Florida Public Service Commission (PSC) for recovery of costs. The Florida PSC holds hearings and, based on the facts, can approve a settlement agreement authorizing cost recovery (PSC, 2017a). Procedures involved in rate request hearings include allowing intervener comments and TECO rebuttals. This process, along with the permitting itself, results in costs to the government, which are government regulatory costs.

Since installing entrainment-reducing technologies is a regulatory environmental compliance requirement (as opposed to typical operations and maintenance), these costs would be passed on to customers in the form of higher rates. These costs would need to be included in a future rate case filing.

TECO's recent rate case history is instructive with respect to the implications of additional rate increase filings. In 2013, the Florida PSC issued a settlement agreement order which allowed for a rate increase phased in over three years (PSC, 2017b). On November 1, 2013, rates were increased $57.5 million which resulted in a 5.5 percent increase in residential customer bills.

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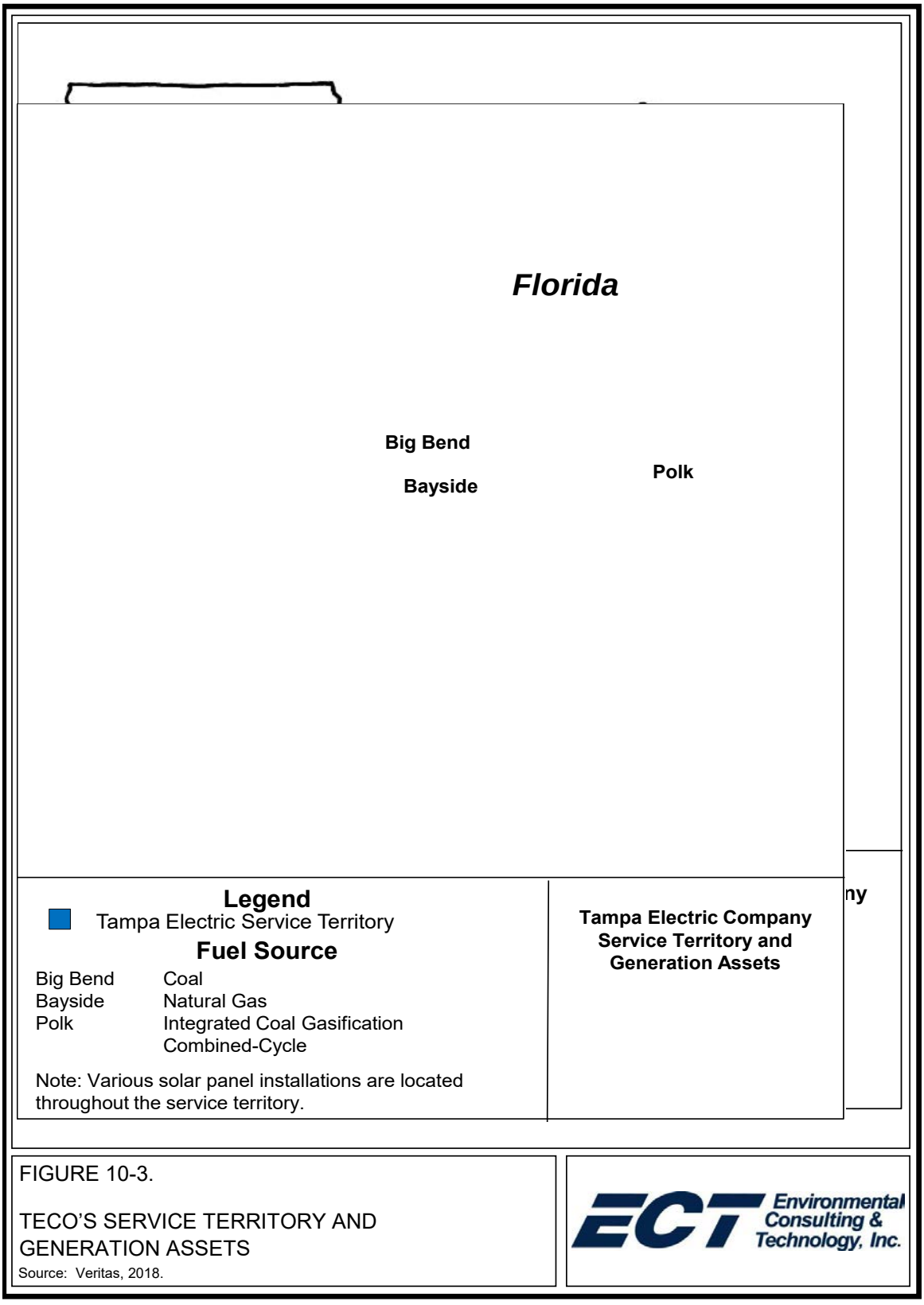


FIGURE 10-3.

TECO'S SERVICE TERRITORY AND GENERATION ASSETS

Source: Veritas, 2018.

ECT Environmental Consulting & Technology, Inc.

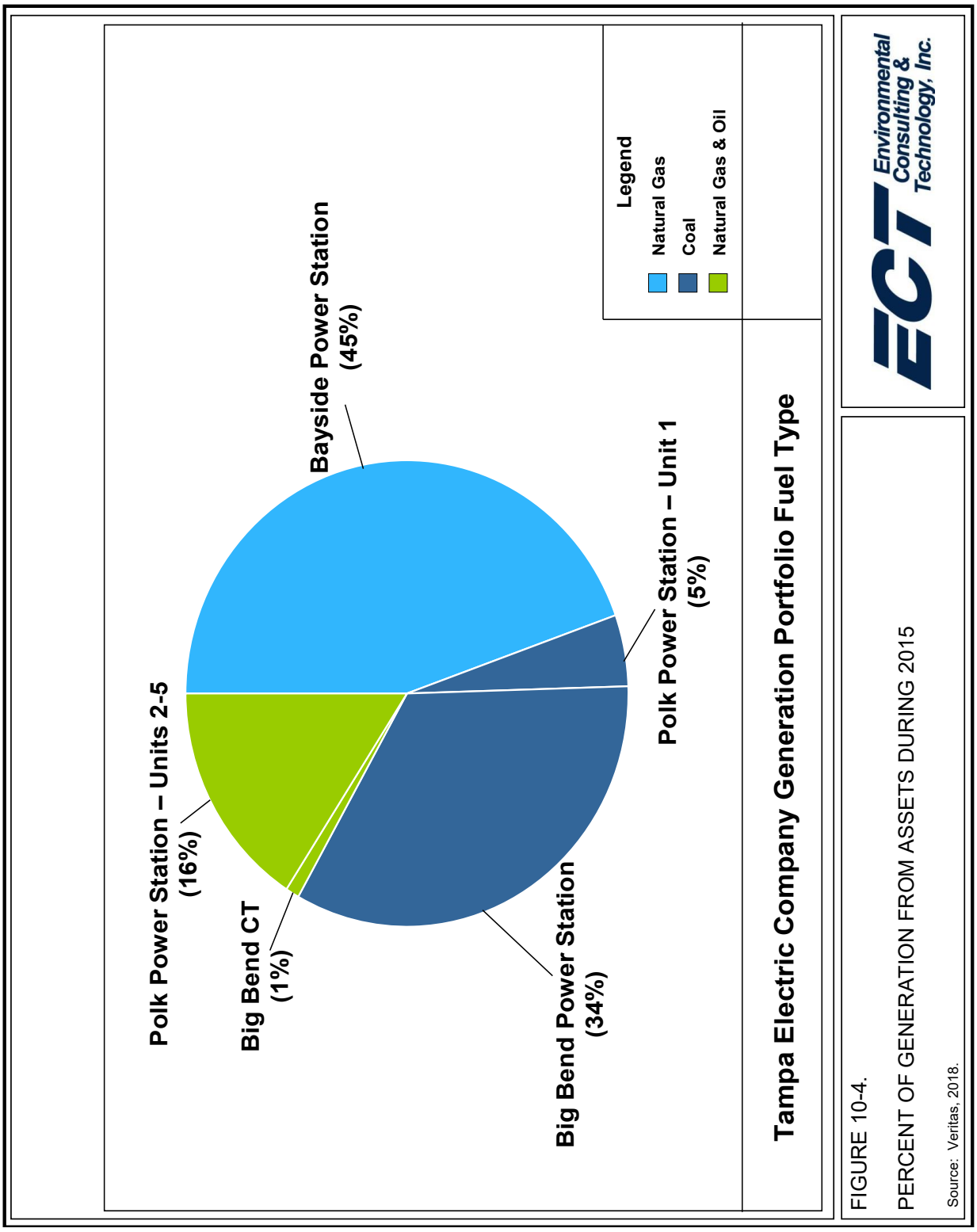


FIGURE 10-4.

PERCENT OF GENERATION FROM ASSETS DURING 2015

Source: Veritas, 2018.

An additional $7.5 million rate increase was implemented on November 1, 2014 with a final increase on November 1, 2015 for $5 million. The agreement included a provision to allow for the recovery of $110 million in January 2017 for the expansion of the Polk Power Station. The project involved converting turbines to combined-cycle units which has added approximately 460 MW of generating capacity and increased plant efficiency by 37 percent. Low natural gas prices and increased efficiencies have more than offset this cost increase, resulting in a 1.45-percent reduction in residential customer bills. With this reduction, TECO residential customer's bills are 19 percent below the national average.

The costs associated with new entrainment reduction technologies would be additional costs that could potentially lead to another rate increase filing which would result in higher prices for residential, commercial, and industrial customers. The magnitude of these additional increases could also lead to economic impacts that can accompany electricity price increases (Deschenes, 2010). Changes in electricity prices can lead to economy-wide employment impacts through their effect on residential and business electricity consumers. For business electricity impacts, the commercial and industrial sectors are all major users of electricity as an input to production. Electricity price increases would raise the costs of providing final goods and services in these sectors. The analysis does not quantify this effect on other sectors of the economy.

10.2.3 Market Environment

Retail electric markets in the state of Florida are currently not deregulated, they are served by a monopoly system of regulated utilities. The state has four investor-owned regulated utilities that collectively serve approximately 75 percent of the customers in Florida. The remainder is served by regulated municipalities and electric cooperatives. The regulated utilities generate power and transmit, distribute, and sell electricity to local customers that live in their defined geographic service territory. The Florida PSC regulates the utilities through a rate-making process that ensures electricity is produced and delivered at the lowest possible cost while allowing the utility to recover costs along with a fair rate of return. In addition to being subject to rate case discovery and hearings to prove that costs are just and reasonable, electric utilities are required to submit annual forecasted earnings surveillance reports to the Florida PSC to ensure that the utilities' rate of return is within an approved range.

The state of Florida does not currently participate in any of the multi-state regional transmission organizations. Rates are set for each regulated utility to cover the costs to produce and deliver reliable power to customers. To ensure reliability, rates include reserve capacity that is available as needed for peak periods. Electric utilities are required to maintain adequate reserve margins which would enable them to meet high demand during peak times and extreme weather events. Adequate reserve margins also enable the utility to meet demand during planned plant outages for maintenance, inspections, and refueling and for any unplanned outage that may occur. Customers pay for the year-round availability of reserve margin in the rates that they pay whether they use this electricity or not. TECO is considering joining the Florida Municipal Power Pool (FMPP), a group of three Florida municipal electric utilities that combine their generating plants as if they were one utility. The FMPP operates like an intra-state transmission organization in that it dispatches power from 51 power generators with the least cost units being dispatched first. The FMPP has a generating capacity of 4,700 MW and produced a savings of $45 million for customers in 2016. If TECO joins, the size of the power pool would effectively double which would produce additional savings for customers.

Bayside is one of three fossil plants that produce electricity for TECO's customers. Bayside is critical, providing 45 percent of TECO's total generation. Temporary outages to install entrainment reducing technologies would have a significant impact on TECO's operations. Construction would need to be scheduled during off-peak months and during a time when the other two generating plants are not undergoing routine scheduled maintenance. In addition, higher cost combustion turbines would need to be dispatched to help make up Bayside's lost power.

10.2.4 Methods for Social Cost Estimation

The first step in estimating the social costs of compliance is to determine whether the entrainment reducing technology costs result in the plant becoming uneconomic to operate. A pre-mature shutdown of the plant would have social costs related to loss of jobs, loss of income and expenditures, loss of tax base, increased electricity costs due to generation being dispatched at a higher price from less efficient plants, and increased infrastructure costs to maintain grid reliability. Installing entrainment reducing technologies at Bayside to comply with EPA's 316(b) rule represents an additional operation cost that would most likely be passed on to TECO's

customers in the form of higher rates. The plant's significance in TECO's generating portfolio suggests that only an extraordinarily expensive conversion requirement would lead to pre-mature closure. Therefore, this analysis specifies that TECO will incur the entrainment reducing compliance costs, continue to operate Bayside, and pass on the compliance costs to TECO's customers.

The social costs of installing entrainment reduction technologies are estimated by first determining the design, construction, and installation costs of the evaluated technologies along with the O&M, permitting, and fuel costs. Based on TECO's market conditions and ability to submit environmental compliance costs for rate recovery, this analysis specifies that all of Bayside's compliance costs would be passed on to TECO's customers.

Following the requirements of the rule, social costs are evaluated under two discount rates: 3 and 7 percent (79 FR 158, p. 48428).

For the determination of social costs, Bayside Unit 2 is estimated to retire in 2044, consistent with the capital costs. Therefore, engineering costs are specified as occurring over the remaining lifetime of the plant to develop the social cost estimates. Fuel costs are specified to occur during the time of both construction and operation. Regulatory documents will be submitted in 2018 and the timing for activities related to installation are dependent on the technology being installed.

The social costs of each technology include the expected electricity price increases associated with each technology, the additional, system-level fuel costs that would be incurred with each technology, the externality costs of each technology, and the permitting costs. As previously noted, the analysis specifies that all the engineering costs are passed on to TECO's rate payers resulting in increased electricity prices. To develop the price increases, the design, construction, and installation costs are allocated over the specified construction and installation time period.

O&M costs are then added for each year the technology is operational, and the future stream of those costs are discounted by 3 and 7 percent to develop the present value estimate for each discount rate.

Fuel costs represent the additional power needed to operate the new technologies and the additional fuel needed from running less efficient units during installation construction outages. The fuel costs are developed from evaluating backpressure and auxiliary load effects, capacity losses from each of the technologies with estimated outage times, and electricity consumption associated with each technology. Details of the fuel cost estimates are presented in Appendix 10-A.

The externality costs estimated for Bayside are specified to result from property value and recreational impacts associated with the plume from the cooling towers. Supplemental reports within Appendix 10-A presents the analysis and results of the recreational impacts and the property value impacts.

Permitting costs include the total costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These vary with the type of technology, as certain technologies require substantially more permitting. Those with more significant environmental effects would have higher permitting costs. These costs are initially borne by the government, but ultimately paid by taxpayers. Permitting costs are developed from EPA's estimates in the national rule (79 FR 158, 48300-48439) and are specified to be 2 percent of direct capital costs.

10.3 Closed-cycle Recirculating Systems

The 316(b) rule requires that this evaluation consider the retrofit of the existing plant cooling water system potentially including different cooling tower types. The suitability of a specific cooling tower type depends on the station's condenser design, local atmospheric conditions, site topography, site layout, the station's operating constraints, and a host of other site-specific criteria. The different cooling towers have different operating criteria. The evaluation therefore needs to match the operating criteria and constraints of the cooling tower types with conditions at the site, where possible.[3] Section 10.3.1 describes cooling tower principles, constraints associated with various cooling tower types, compares the suitability of each cooling tower type

[3] Counter-flow-type towers are more efficient than cross-flow-type towers.

to site conditions, and selects the cooling tower type that may be suitable (or least unsuitable) to be used for the remainder of the evaluation. Section 10.3.3 reviews cooling tower types. The cost evaluation in this report and the impacts evaluation in the 40 CFR 122.21(r)(12) report are based on that selection. Section 10.3.4 describes site conditions and constraints, and the existing cooling water system and how it may or may not be retrofitted. Section 10.3.5 describes the hypothetical system. Section 10.3.6 discusses alternate cooling tower locations. Subsequent sections discuss costs and schedule.

10.3.1 Cooling Tower Principles

The primary method used to dissipate waste heat rejected from a closed-cycle cooling water system is through a cooling tower. Once-through cooling systems can potentially be retrofitted with a variety of cooling tower designs. The designs can be grouped based on factors influencing the type of design, including:

- Method of heat transfer: wet, dry, or combination wet and dry heat transfer.
- Method of air flow: natural draft, mechanical forced draft, mechanical induced draft.
- Direction of air flow: counter-flow or cross-flow.
- Shape and Arrangement: rectilinear (i.e., in-line or back-to-back) or round.

These factors have the greatest impact on the cooling tower size and operation, which subsequently influence environmental and social impacts. The method of heat transfer is perhaps the most important factor in determining the type of cooling tower. The different types of cooling towers are described in Section 10.3.3.

10.3.1.1 Method of Heat Transfer

The cooling tower acts as a mechanism to transfer the waste heat[4] to the atmosphere. Heat transfer to the atmosphere can be carried out through one of three methods:

- Latent heat transfer, which is associated with the phase changes of water, such as evaporation.

[4] Heat energy is utilized in the generation of electricity; heat energy that is not converted to electricity is removed to cooling water within the condensers.

- Sensible heat transfer, which is associated with the incremental change in temperature of a medium, such as air in the atmosphere, or
- A combination of both latent heat transfer and sensible heat transfer.

Cooling towers that employ a combination of both sensible and latent heat transfers are evaporative-type towers and are typically referred to as wet cooling towers. Cooling towers that employ only sensible heat transfer utilize a dry-surface, finned-tube heat exchanger that transfers heat to the atmosphere; these towers are typically referred to as dry towers.

Similar to wet cooling towers, once-through cooling systems typically employ a combination of both heat transfer methods; heated water from the once-through system is discharged to a receiving water body, which is heated through sensible heat transfer. Latent heat transfer then drives evaporation of a small portion of the water body to the atmosphere for further cooling. Sensible heat transfer also occurs from the water body to the air but the cooling provided by sensible heat transfer is smaller than the cooling provided by latent heat transfer.

10.3.1.2 Method of Air Flow

Air flow through the cooling tower is critical to facilitate both latent and sensible heat transfer. In the absence of air exchange, moisture and heat would accumulate within the tower and retard heat transfer from the cooling tower.

The method of air flow can be either natural draft, mechanical forced draft, or mechanical induced draft. With respect to natural draft, the hyperboloid shape has been shown to improve air transfer efficiency. The density differential between the heated, less dense air inside the cooling tower and the cooler, denser air outside the cooling tower produces air flow upward through the tower (SPX, 2009).

Mechanical, forced draft cooling towers have a fan located on the ambient air intake and blow air through the tower. Forced draft towers typically have high entrance velocities and low exhaust velocities; therefore, they are susceptible to recirculation (SPX, 2009). Recirculation occurs when the exhaust is drawn back into the intake, increasing the ambient air wet-bulb temperature and decreasing the performance of the cooling tower (SPX, 2009).

Mechanical, induced draft cooling towers have a fan located on the exhaust side and draw air in through the tower. Induced draft towers can have an exhaust velocity of three to four times the entrance velocity, meaning there is little tendency for self-initiating recirculation (SPX, 2009).

10.3.1.3 Direction of Air Flow

Air flow through the towers can be either counter-flow or cross-flow. In counter-flow towers, air moves vertically through the tower fill,[5] counter to the downward cascade of water (SPX, 2009). In a cross-flow tower, the fill's configuration is such that the air flows horizontally across the downward cascading water (SPX, 2009).

In all types of cooling towers, the ambient air enters from the side and is exhausted through the top of the tower; the portion of water that evaporates into the air stream cools the remainder of the water and the heat dissipation surface of the cooling tower (EPRI, 2011).

When comparing counter-flow and cross-flow MDCTs, cross-flow offers several limitations. A cross-flow MDCT may have higher pumping head requirements. Cross-flow MCDT with splash-type media may not be able to provide comparable cooling water temperatures to the counter-flow MCDT with film-type fill media, when using the same thermal design requirements.

10.3.1.4 Shape and Arrangement

Cooling towers can also be characterized by their shape and arrangement. While natural draft cooling towers (NDCT) are round, an MDCT is usually comprised of multiple rectangular cells; however, the cells can be arranged in a rectilinear or round fashion. In a rectilinear arrangement, the cells can be aligned in a single row (i.e., in-line) or in a double row (i.e., back-to-back) (EPRI, 2011). In a rectilinear arrangement, evaporative cooling towers should be arranged parallel to prevailing wind patterns (SPX, 2009). The cells can also be arranged in a round configuration, where they are clustered as closely as possible to the center point of the tower. There is an alternate version of round towers where the cells are arranged in an octagonal

[5] Fill is an important component of cooling towers, because it determines the efficiency of the tower through maximizing contact surface and contact time between air and water while providing the least amount of restriction of air flow (SPX, 2009).

arrangement, allowing for larger heat loads that impact less area, compared to rectilinear towers (SPX, 2009).

10.3.2 Cooling Tower Terminology

Cooling towers are chosen based on factors that affect their performance. The atmosphere has various psychrometric properties,[6] and cooling towers react thermally or physically to each property (SPX, 2009). Similarly, properties of the power plant and cooling towers also affect cooling tower performance and sizing. Some properties, such as heat load, are more significant than others. The following is a discussion of some key terms with an emphasis on those relevant to evaporative MDCT.

10.3.2.1 Heat Load

Heat load is the total amount of heat removed from the circulating water by the cooling tower and is a function of the mass flow rate of water entering the cooling tower and the cooling tower range (EPRI, 2011; SPX, 2009). The heat load is designed to dissipate heat from condensation of steam generated in the steam cycle. The heat load can be related to the approach and range; this relationship is shown on Figure 10-5.

10.3.2.2 Range

The range is the difference between the hot water temperature entering the cooling tower and the cold water temperature exiting the cooling tower. The cooling tower range is equivalent to the temperature rise across the station's condensers, commonly referred to as the delta T (ΔT). The size and subsequent cost of a cooling tower is proportional to the heat load and the cooling tower range (SPX, 2009). The range is shown graphically on Figure 10-6.

10.3.2.3 Approach

Another factor that is part of the basis for thermal design and performance of a wet cooling tower is the approach. The approach is difference between the cold water temperature exiting the cooling tower and the ambient air wet-bulb temperature[7] entering the tower (Figure 10-6).

[6] Psychrometrics is the field of study relating to physical and thermodynamic properties of gas-vapor mixtures. Typical psychrometric parameters include dry-bulb, wet-bulb, and dew point temperatures.
[7] Wet-bulb temperature is the temperature of air if it were cooled to 100% relative humidity (i.e., saturation) by evaporation of water into it through latent heat transfer.

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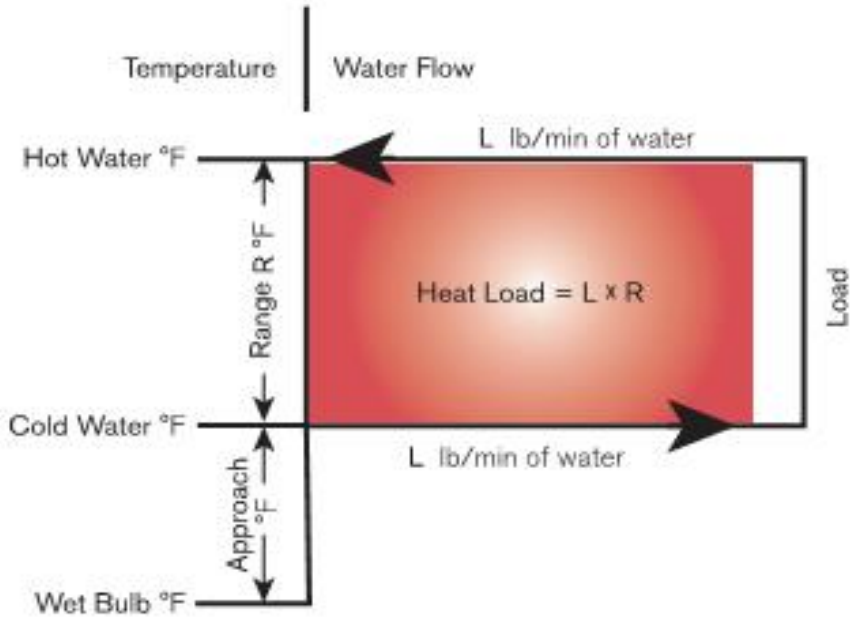


FIGURE 10-5.

RELATIONSHIP BETWEEN HEAT LOAD AND RANGE

Source: SPX, 2016.

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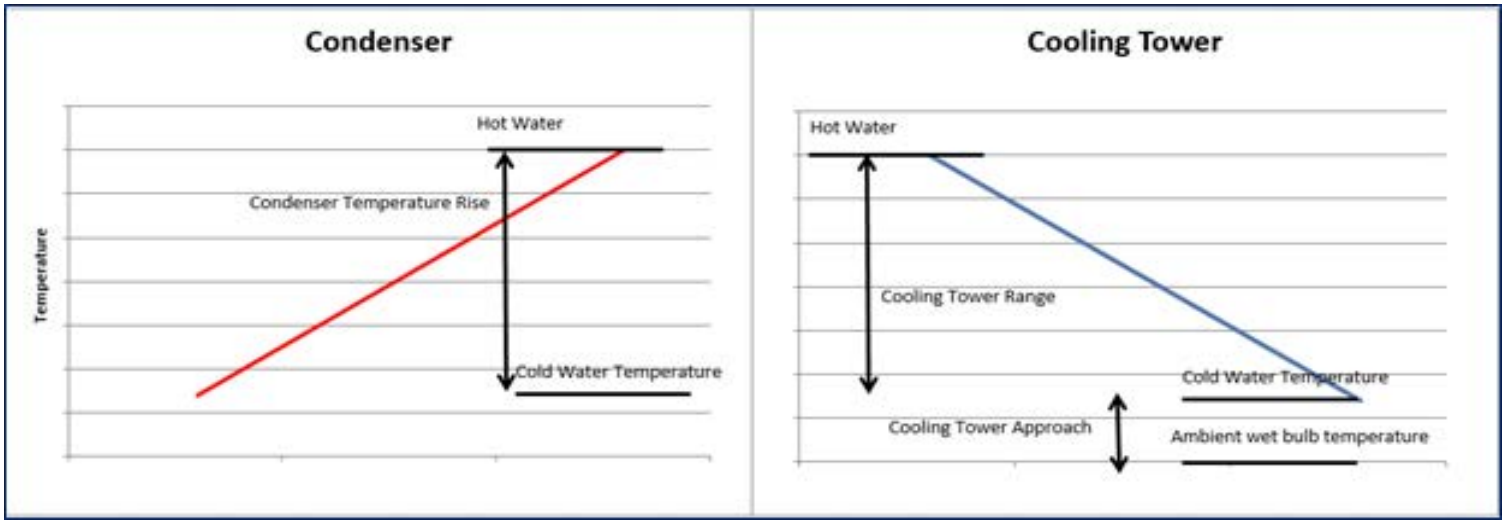


FIGURE 10-6.

CONDENSER AND COOLING TOWER WATER TEMPERATURE RELATIONSHIPS

Source: SPX, 2016.

ECT Environmental Consulting & Technology, Inc.

Cooling tower performance and size are inversely proportional to the approach. When varying cooling tower size, the approach starts to become asymptotic near 5 degrees Fahrenheit (°F). Approach temperatures less than 5°F are typically not guaranteed, because errors in measurement of performance are considered to be very significant (SPX, 2009); in addition, approach temperatures less than 10°F are not considered practical.

10.3.2.4 Drift

A portion of the circulating water in the cooling tower is lost[8] due to drift, evaporation, and blowdown. Drift occurs when circulating water is lost from the tower as liquid droplets entrained in the exhaust air stream (EPRI, 2011). To reduce the amount of water lost, drift eliminators can control the loss of water to as low as 0.0005 percent of the circulating water flow rate and can be installed in wet cooling towers (EPRI, 2011).

10.3.2.5 Evaporation

Water is also lost due to evaporation, which is the main method of removing the waste heat from the circulating water in wet cooling towers. Cooling towers operate on the principle of transferring heat from a large quantity of water to a small quantity of water. The portion of water absorbing heat evaporates; the remaining water cools down due to loss of energy.

10.3.2.6 Blowdown

A portion of the water that circulates between condensers and cooling towers is removed from the system to prevent the build-up of solids and minerals to concentrations high enough to cause corrosion and scaling of various cooling system components. The removal of a portion of the water is called blowdown. The higher the cycles of concentration, the lower the blowdown rate – see the following discussion of cycles of concentration. Bayside's NPDES permit would require a major modification to accommodate the discharge of the cooling tower blowdown. Operating at high levels of total dissolved solids (TDS) with the continued evaporation of water can cause the impurities to reach saturation levels which may produce scale and precipitate, lead to corrosion problems, and can increase operation and maintenance costs (U.S. Department of Energy [DOE], 2016; EPA, 2014).

[8] Basin leaks and overflows can also cause water to be lost from the system when the towers are not properly operated.

10.3.2.7 Cycles of Concentration

As water is evaporated from the tower, TDS remain in the recirculating water, and the concentration of TDS continues to increase as the process continues (DOE, 2016). Cooling towers are designed to operate within a particular cycle of concentration (COC), which is defined by the EPA as "the ratio of dissolved solids in the recirculated water versus that in the makeup water" (EPA, 2014). The COC is controlled through the intentional discharge of water from the system, referred to as blowdown.

Typically, in marine environments cooling towers are operated at around two COC. Operating the hypothetical cooling towers at Bayside at two COC would result in the blowdown concentration having discharge parameter concentrations that are 200 percent higher compared to Hillsborough Bay parameter concentration. The State of Florida (2015) requires that the discharge concentration of chlorides not exceed the receiving water body concentration by more than 10 percent. Operating the hypothetical cooling towers at 1.1 COC would result in high chemical use and other operating challenges. This evaluation therefore assumes that the cooling towers would be operated at 1.3 COC, and additional dilution water would be used to reduce the chloride concentration in the blowdown to 110 percent of background. Such an approach has recent precedent in Florida.

10.3.2.8 Makeup Water

Circulating water that is lost from the system due to evaporative, drift, and blowdown is replaced with makeup water. Makeup water is typically withdrawn from the source water body through the CWIS.

10.3.3 Review of Candidate Approaches

Based on an initial evaluation of MDCT, NDCT, dry towers and plume-abated cooling towers, described below, standard MDCT were selected for more detailed evaluations in subsequent sections. NDCT and air-cooled towers were found to be incompatible with the existing station. These cooling towers would also result in higher facility costs that would very likely result in higher social costs compared to MDCTs.

The following sections provide greater detail on the various cooling tower types, including the applicability of each at Bayside.

10.3.3.1 Mechanical Draft Cooling Towers

Description

MDCTs are comprised of multiple rectangular cells, arranged in a rectilinear or round fashion. MDCTs either induce or force air through the tower and can be susceptible to recirculation and interference from other towers (SPX, 2009). MDCTs are more fully discussed in Section 10.3.5.

Feasibility

The feasibility of MDCTs depends on design and siting, environmental, and overall station impacts. The footprint of MDCTs can be larger or smaller than other towers, but in most cases, the footprint will require a relatively flat, rectangular area. Both MDCTs and natural draft NDCTs have similar efficiencies. MDCTs use fans to move air through the towers, so they do not rely on a density differential that NDCTs rely on for cooling. However, MDCTs can be significantly shorter (up to 10 times), and because their air flow is mechanically forced they can be designed with a lower cooling tower range and approach temperature than NDCTs.

General environmental impacts include particulate matter (PM) emissions, increased water consumption, and increased residual waste generation. MDCTs produce noise from the use of fans and related appurtenances in addition to the noise from cascading water. Because of the lower height of the towers, there is a higher potential for fogging due to the plume where conditions allow.

MDCTs tend to have the lowest capital costs of all cooling tower types, but the operating costs can be greater than other tower types. The small capital and large operating costs of MDCTs may make them more expensive over the life of the station compared to NDCTs, when NDCTs are feasible.

10.3.3.2 Natural Draft Cooling Towers

Description

A NDCT is a wet cooling tower and typically has a hyperboloid shape, which has been found to improve performance efficiency (EPRI, 2011). Similar to MDCTs, water flows downward through fill material contacting air in either a counter-flow or cross-flow pattern.

NDCTs are more often used at nuclear plants and large coal-fired power plants, because they are more suited to large cooling water quantities. The advantage of a natural draft unit is that the power required for fans is eliminated.[9] Because these are very tall structures (up to 600 ft in height) ice and fogging impacts (if any) are not generally experienced within the immediate surroundings; however, these impacts are dependent upon the meteorological conditions of the site (Cooling Technology Institute [CTI], 2003).

Feasibility

The feasibility of NDCTs depends on design and siting, environmental, and overall station impacts. With respect to design and siting, compared to MDCTs, the footprint area of NDCTs can be larger or smaller, but in all cases, the footprint will require a relatively flat and extensive land area. The hyperboloid towers are the highest of all tower types and can be greater than ten times the height of MDCTs; therefore, they could pose potential adverse aesthetic impacts on the viewscape. Environmental impacts are generally similar between MDCTs and NDCTs for PM emissions, water consumption, and residual waste. While there is no fan noise related to NDCTs, the water noise due to cascading water can be significant. Due to the height of the tower, there is a higher visible plume; however, the fogging and icing issues are reduced compared to MDCTs.

While operating costs for NDCTs will be lower than MDCTs, capital costs for NDCTs can be significantly greater, with approximate costs ranging from one-and-a-half to two times the cost of MDCTs.

NDCTs are similar to MDCTs regarding efficiency; however, NDCTs are only suitable when a high cooling tower range and approach temperature are consistent with existing infrastructure.

[9] Per SPX (2016b), the wet deck (or top of fill) of a NDCT is at approximately the same height as for MDCTs; therefore, the energy requirements with respect to pumps is assumed to be similar.

NDCTs do not have fans to force/move air through them, instead the density differential induced by the temperature differential causes air to move upward. When the cooling tower range is large, the density differential is easily induced. When the cooling tower range is smaller, a taller cooling tower is needed to help induce an adequate density differential to cause air to move up through the tower. Additionally, the performance of the cooling tower is dependent on the ambient wet bulb temperature. As discussed on Section 10.3.2.3, the approach is the difference between cold water temperature and the ambient wet bulb temperature. The cooling tower performance improves when the tower is designed with a large approach (i.e., warmer cold water temperature). As the cold water temperature comes closer to wet bulb temperature the tower efficiency decreases, then a larger tower is needed to compensate for the lost efficiency. As such, the tower size increases rapidly when the approach and/or the range is smaller than approximately 20°F, and NDCT are infeasible when either approach or range is smaller than 15°F (SPX, 2009). The design is more practical when the approach temperature is larger than 20°F and the range is larger than 25°F (SPX, 2009). The approach and range required for the Bayside cooling system are smaller than what a NDCT can operate at, therefore NDCTs are eliminated from further consideration.

10.3.3.3 Plume-abated Towers

Description

Plume-abated cooling towers can be grouped into two major groups: those that add heat to the plume above the wet deck of the cooling tower, and those that do not add heat.

Plume-abated cooling towers that add heat above the wet section of the cooling tower are called hybrid towers. The wet portion of a hybrid tower can be similar to a MDCT or NDCT (assuming the system meets the necessary criteria for that type of tower) (SPX, 2009). A set of coils or finned-tubes are located above the wet portion to add heat/warmth to the near-saturated air leaving the tower to eliminate the visible plume. Addition of heat does not remove the water content, but only moves the air parcel away from the saturation curve as shown in Figure 10-7.

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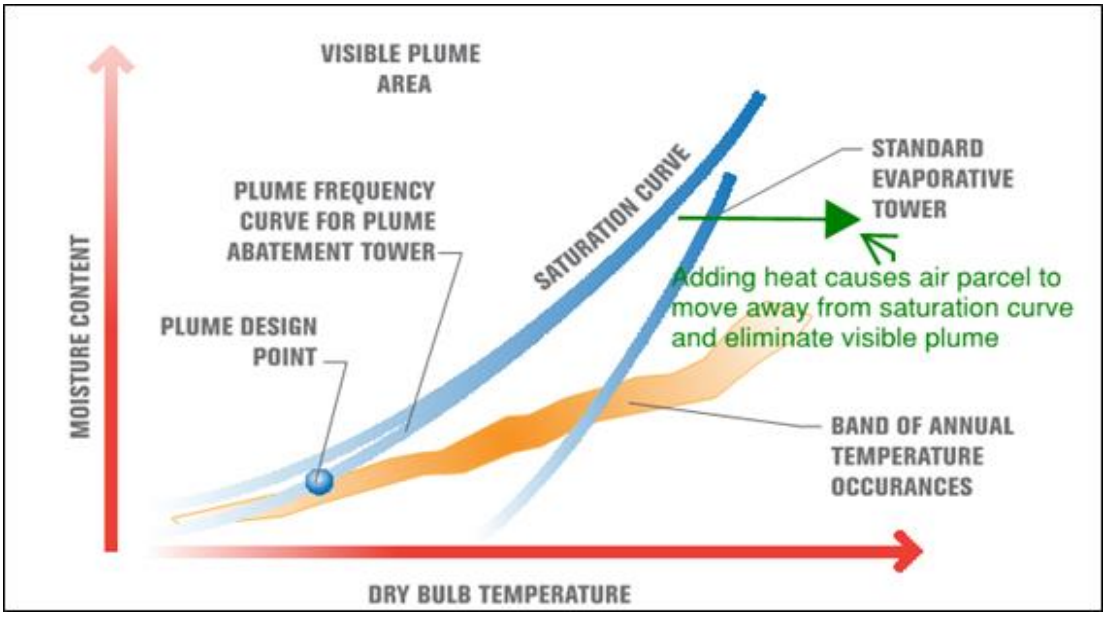


FIGURE 10-7.

ELIMINATING VISIBLE PLUME FROM HYBRID TOWER (CTI 2010)

Source: CTI, 2010.

ECT Environmental Consulting & Technology, Inc.

Plume-abated towers do not need to be operated in plume-abated mode at all times. They may be operated in plume-abated mode when needed (typically during cooler months when the visible plume is more likely) and operated in only-wet mode during other times of the year to save energy.

For hybrid towers, the hot water from the condenser may be used as the heat source. When operated in the hybrid mode with hot water from condensers as the heat source for the dry portion, water enters the tower at the top of the dry portion where sensible heat transfer lowers the temperature of the circulating water while raising the temperature of the air leaving the tower (thereby eliminating the visible plume); the slightly cooled circulating water then cascades down to the evaporative portion of the cooling tower where water is further cooled through latent heat transfer (EPRI, 2011). No contact is made between the air and water in the dry portion of the tower; however, there is contact between air and water in the lower, wet portion of the tower (EPRI, 2011).

Saturated air leaving the top of cooling towers is what causes the plume. The “dry section installed in the upper part of the cooling tower reduces the visible plume by heating wet air coming from the [lower] rain zone” (SPX, 2016b). Warm air has greater moisture assimilative capacity. Warming the air exiting the wet portion causes the air to be unsaturated, thereby reducing the visible plume. In the mechanical hybrid tower, the dry portion may be installed above or below the fan. When installed below the fan (like the configuration shown in Figure 10-8) the tower is called a parallel path wet/dry cooling tower. When the dry portion is installed above the fan, it is called Series Path Wet/Dry Cooling Tower. Parallel Path Wet/Dry Cooling Towers are presently more prevalent than Series Path Wet/Dry Cooling Towers (CTI, 2010).

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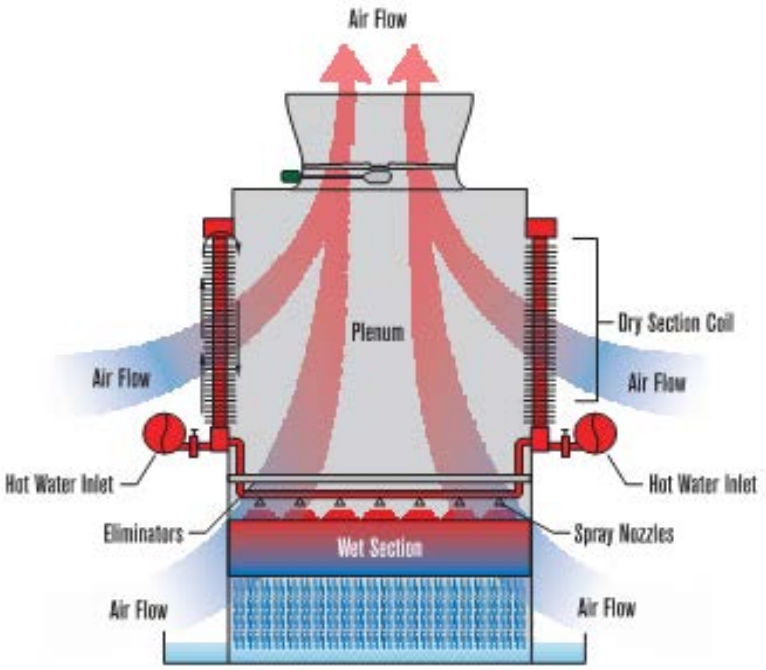


FIGURE 10-8.

CROSS-SECTION SCHEMATIC OF A PARALLEL PATH WET/DRY COOLING TOWER

Source: CTI, 2010.

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The second type of plume-abated tower developed by SPX is called ClearSky™ that blows additional cooler ambient air into the chamber above the wet portion to condense the moisture (Figure 10-9). The condensate may be collected for use in various facility equipment that requires high quality water. If the condensate is not collected, it would cascade down to the basin to be recirculated. This technology eliminates the visible plume by removing moisture from air leaving the tower. Operation of additional fans during cooler months poses a higher energy penalty than a standard MDCT.

Feasibility

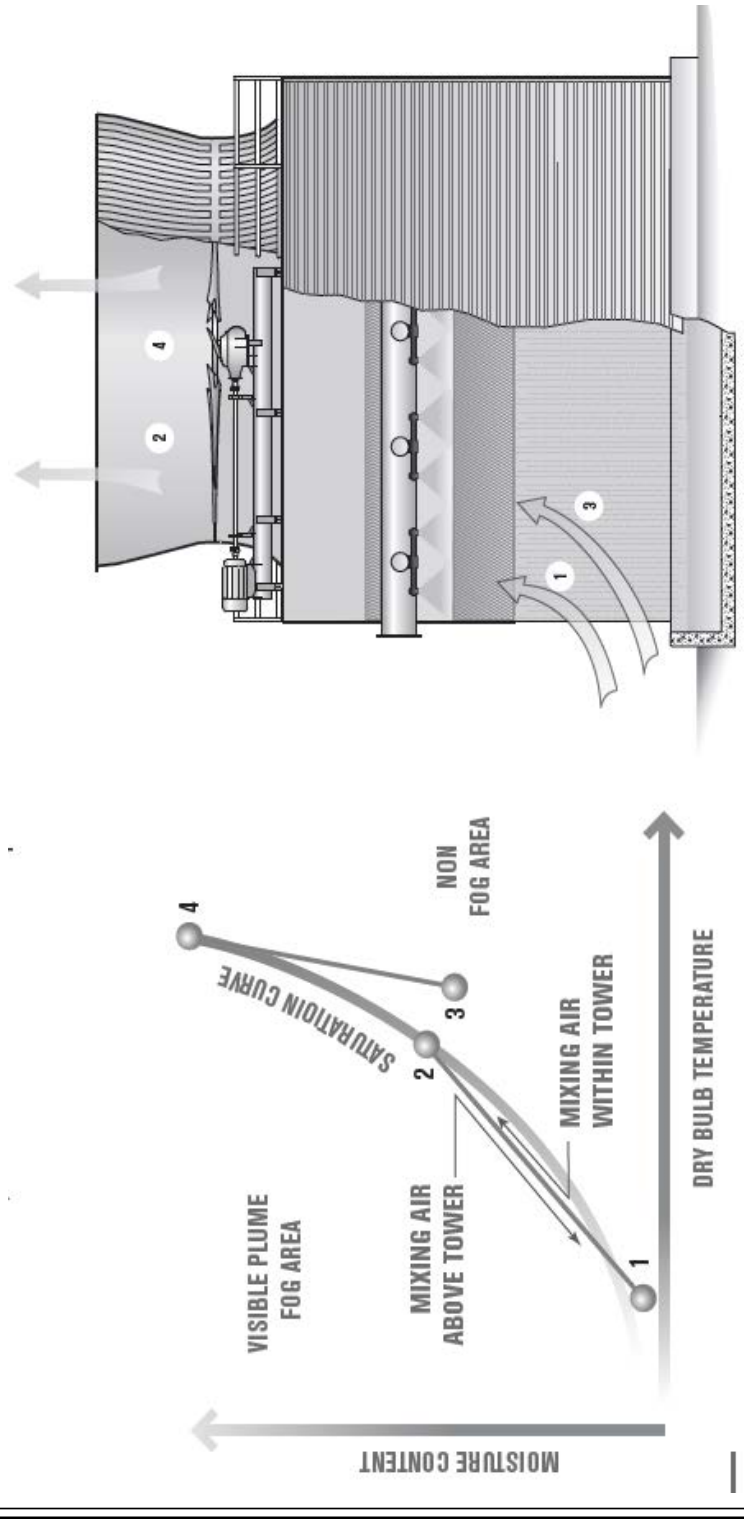
Plume-abated towers are available, and typically used in areas where the plume can have an adverse impact on the area. The adverse impact can be due to safety-concerns owing to fogging or icing or for areas where long-range visibility is needed, such as near airports.

Due to the design of hybrid towers, they have a larger base by approximately one to three times and a height of approximately one-and-a-half times that of standard MDCTs. In addition, these towers are restricted to in-line arrangement (i.e., cooling tower arrays must be a single cell wide). Hybrid towers have lower efficiency, a lower summer output, and a higher energy penalty compared to MDCTs.

Per SPX (2017a), ClearSky™ has lower efficiency in the summer and a high energy penalty in the winter compared to standard MDCTs.

With the exception of fan noise and loss of efficiency, most environmental impacts are less than or similar to MDCTs. Plume-abated towers can be operated in plume-abated mode by actuating the air-cooled portion of the tower (in hybrid towers) or the additional fans (in ClearSky™), and when operated as such there is usually a minimal or no visible plume. PM emissions are dependent upon the use of the plume-abatement portion of the tower but are generally lower than MDCTs. There is greater fan noise with the use of plume-abated towers.

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FIGURE 10-9.

CROSS-SECTION SCHEMATIC OF A CLEARSKY™ PLUME-ABATED COOLING TOWER BY MARLEY

Source: SPX, 2012.

Both capital and operating costs are greater compared to MDCTs (EPRI, 2011). Plume-abated towers would have similar challenges to MDCTs, such as limited suitable space and prohibitive site topography, potential major reconstruction of existing equipment and facilities, and space constraints associated with the property. Plume-abated towers will have a larger power loss due to a lower efficiency and greater energy penalty compared to MDCTs.

Overall, plume-abated MDCTs are technically feasible but costlier than standard MDCTs. Tampa climate reduces the potential for plume and fog, therefore this option is not pursued due to its higher cost and high energy penalty. Such a conclusion is consistent with our approach stated in Section 10.1.4.1 where capital and operating costs should only be inflated in the presence of clear site-related need.

10.3.3.4 Dry Cooling

Description

There are two key dry cooling methods: direct dry cooling (air-cooled condensers [ACCs]) and indirect dry cooling.

Dry cooling uses only sensible heat transfer and can use ambient air as the heat transfer medium either directly or indirectly. Through the use of direct dry cooling systems, a dry-surface, finned-tube heat exchanger provides for the non-evaporative transfer of heat to the atmosphere (SPX, 2009). Steam from the turbine is sent directly to the ACC where the steam is condensed inside air-cooled finned tubes; there is no steam surface condenser and there is no contact between the ambient air and the steam and condensate. An ACC can be up to two to three-times the height of MDCTs. Figure 10-10 shows a photograph of an ACC.

Indirect dry cooling systems use a combination of a dry cooling tower (natural or mechanical draft) with a steam surface condenser. In these cooling towers, the heated water is pumped to heat exchangers arranged vertically around what looks like a standard wet cooling tower. But as shown in Figure 10-11, no water cascades down through the tower; instead, water flows through the bundles of tubes placed around the tower. Air flow through the tower cools the water within the bundles of tubes (SPX, 2017b). There is no contact between air and the circulating water (EPRI, 2011).

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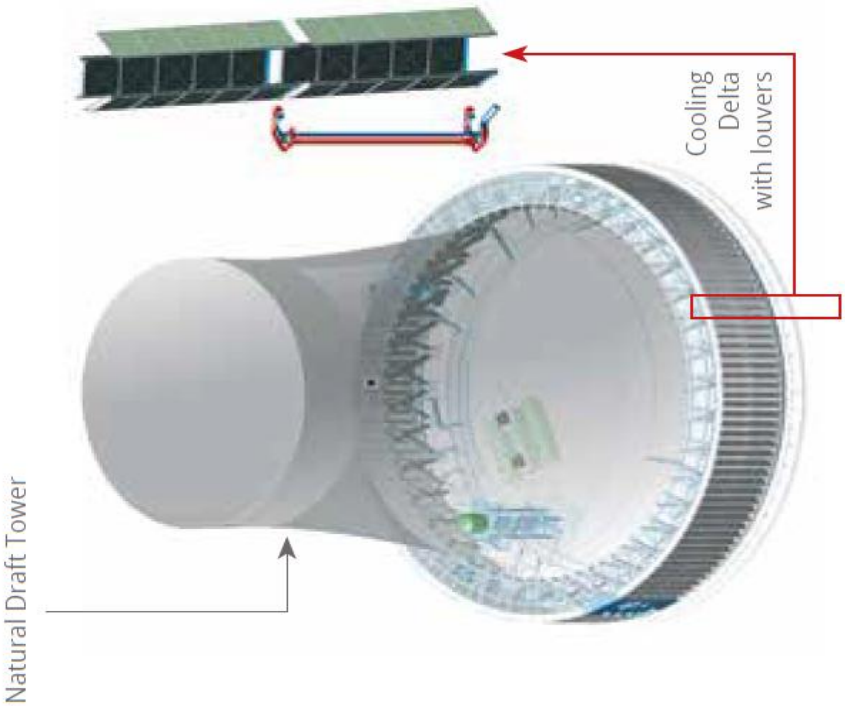
FIGURE 10-10.

AERIAL PHOTOGRAPH OF AN AIR-COOLED CONDENSER (DIRECT DRY COOLING)

Source: Enexio, 2016.

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FIGURE 10-11.

SCHEMATIC OF AN INDIRECT DRY COOLING TOWER

Sources: SPX, 2016c. Enexio, 2016.

Feasibility

When designing and siting ACCs, a considerable area of land is required. ACCs require the largest area of land of all towers because they only utilize sensible heat transfer requiring both larger heat exchange surfaces and higher capacity fans to move the required amount of air.[10]

ACCs have the lowest cooling efficiency and lowest summer output of all towers, which results in the greatest energy penalty (EPRI, 2011). ACCs have a considerable energy requirement to operate the fans. Cooling of ACCs is limited by the dry-bulb temperature, rather than the wet-bulb temperature and because the dry-bulb temperature is always higher than the wet-bulb temperature, the resulting cold water temperature is higher compared to wet cooling tower water temperatures. Therefore, the energy penalty with dry cooling is significantly higher than with wet cooling towers.

Because dry cooling towers use sensible heat transfer, there is no visible plume or related PM emissions, cascading water noise, water consumption, scale, sediment, or sludge accumulation. Dry cooling systems result in the greatest reduction in water use of all cooling towers. However, they result in the highest fan noise and in the largest land footprint, including potential land use impacts.

Capital and operating costs for dry cooling systems, especially ACCs, are the highest of all cooling towers. Capital costs can be up to four to six times that of MDCTs. ACCs are generally not compatible with existing condensers due to unacceptable turbine back pressure and hydraulic pressure on the condensers (EPRI, 2007). For this reason, installation of ACCs typically requires significant redesign and reconstruction of existing condensers, facility buildings, equipment, and piping. Due to the large energy penalty, ACCs may have impacts on the reliability of the facility and electric transmission distribution system.

[10] Wet cooling towers utilize both sensible and latent heat to transfer heat from water to air. The latent heat of vaporization for water is 970.3 British thermal units (Btu) per Pound mass (lbm) (Lindeburg, 2003). The specific heat of water is 1 Btu/lbm-°F. That is, it takes 970.3 Btu to evaporate a pound of water, and it takes only 1 Btu to raise the temperature of water by 1°F. Wet cooling towers operate by evaporating a small quantify of water and cooling the remaining large quantity of water. The portion that evaporates absorbs energy from the remaining hot water, which then cools. Cooling through evaporation of water using latent heat transfer is more effective than using sensible heat transfer.

It is likely that the existing condensers would not tolerate the necessary increases in back pressure (see Section 10.3.5.3) making ACC infeasible without condenser replacement. As importantly, the hypothetical use of ACC at Bayside would greatly increase the capital costs, operation and maintenance costs, and the loss of power generation capacity. Consistent with the assessment approach outlined in Section 10.1.4.1, the less costly MDCT is also the least impractical closed-cycle cooling system for Bayside. For these reasons, ACCs are not considered for the Bayside facility.

10.3.3.5 Condenser Replacement

The above discussion of cooling tower types (NDCT, MDCT, plume-abated towers and dry cooling) was based on reusing the existing condenser. Such a hypothetical closed-cycle cooling tower retrofit would have to accommodate the existing condenser characteristics such as its pressure rating, backpressure impacts, water flow rate, and temperature rise. A power plant's condensers and cooling towers need to complement each other; that is, all heat added at the condenser needs to be removed by the cooling tower.

When designing a new power plant, the cooling tower and condenser would be evaluated in tandem to achieve optimal performance of both based on site conditions. However, when retrofitting an existing power plant with cooling towers, the existing condensers are used as-is to the extent practicable (EPRI, 2007). While certain reinforcements to the condenser tubes or waterboxes can facilitate continued use of the existing condensers, the design, construction, and age of the existing condensers may not always allow for conversion of an existing once-through system to closed-cycle. Replacing the existing condensers with new condensers would eliminate those constraints, because the new condenser would be selected to meet the new hypothetical cooling tower performance criteria. However, a condenser replacement would result in significant reconstruction at the station as the condensers are located adjacent to and under the power plant. Such an extensive construction effort would idle the plant for several months or more. Therefore, the increased construction effort will result in increased outages (resulting in lower grid reliability), far higher cost, and greater disturbance to site and surroundings resulting in greater adverse impacts.

Owing to the longer construction outage and greater adverse impacts that would result from condenser replacement to accommodate different types of cooling towers, this option is considered inferior to the MDCT option discussed above and will not be evaluated further. Instead, this evaluation assumes that the existing condenser would remain in place and that the cooling tower retrofit would conform to the constraints of the existing condenser. This assumption has two important implications: (1) the steam turbine will experience back-pressure effects, reducing the electrical output; and (2) to adhere to the pressure ratings of the condenser, wet wells and booster pumps will be necessary to raise the circulating water into the cooling tower. Table 10-3 provides a summary comparison of the various cooling tower types.

Based on the assessment presented in Section 4.5 and summarized in Table 4-2, MDCT were selected for estimation of facility costs to address the Rule's requirements.

10.3.4 Existing Cooling System

Steam electric power generation facilities use steam turbines and condensers to generate electricity.[11] Turbines typically consist of a rotor assembly, which is a shaft or drum with blades attached; steam is generated and moves through the turbine turning the blades and shaft. The rotational energy from the rotor assembly is converted into usable energy to produce electricity.[12] The exhaust steam from the turbine is then condensed to liquid water for recirculation through the system by use of a condenser, which is a type of heat exchanger.

Both condensers for Unit 1 and Unit 2 consist of thousands of tubes as detailed in Table 10-4 each of which are encased in a shell, commonly referred to as "shell and tube" (Alstrom Power, Undated; Alstrom Power, 2001). Steam flows through the shell[13] and is condensed when passed across tubes, which circulate cold water. The condensate is then collected where it is reheated to steam and recirculated through the system.

[11] Bayside also uses combustion turbines and produces steam using the waste heat from the turbines. This technology is referred to as combined-cycle and is more efficient than steam turbines alone both in terms of fuel consumption and in terms of cooling water use.
[12] The rotor assembly operates in conjunction with an electrical generator.
[13] Depending on the specific design of the condenser, the steam may be instead routed through the tubes and the cold water through the shell.

Table 10–3. Matrix of Relative Impacts and Attributes of Cooling Tower Types

Attribute	Cooling Tower Types			
	MDCT (Base Case)	NDCT (Compare to MDCT)	Dry ACC (Compare to MDCT)	Plume-abated Cooling Towers (Compare to MDCT)
Design and Siting Impacts				
Footprint area	• MDCT would have the smallest footprint. Additionally, unlike a NDCT whose sizing requirements are inflexible, MDCT cells can be arranged in a modular fashion to meet onsite space constraints (with limitations).	• Larger footprint than base case • Large, circular areas required	• Largest area required, approximately 2 to 4 times the area required for the base case	• Larger footprint than base case • Rectilinear tracts of flat land required, ideally oriented with prevailing winds
Height	• Base case	• Highest of all towers • Approximately 500 ft-tall towers may be needed to induce the necessary draft	• Taller than base case	• Taller than base case
Efficiency	• Base case	• Similar to base case	• Lowest cooling system efficiency • Lowest summer output	• Less efficient than base case
Energy penalty	• Base case	• Lower than base case with respect to fan requirements	• Highest energy consumption; large energy requirement for fans • Cooling is limited by dry-bulb temperature rather than wet-bulb temperature; dry-bulb temperature always higher than wet-bulb temperature. Therefore, these systems have highest (warmest) resulting cold water temperature, and greatest backpressure energy penalty.	• Higher than base case

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Table 10–3. Matrix of Relative Impacts and Attributes of Cooling Tower Types (Continued, Page 2 of 3)

Attribute	Cooling Tower Types			
	MDCT (Base Case)	NDCT (Compare to MDCT)	Dry ACC (Compare to MDCT)	Plume-abated Cooling Towers (Compare to MDCT)
Environmental Impacts				
Visible plume*	• Potential for plume (lower likelihood for fogging or icing due to warm Tampa climate)	• Visible plume at higher elevation • Reduced likelihood for ground level fogging or icing, regardless of climate, due to height of plume emission	• No visible plume • No fogging or icing	• Minimal to no visible plume • Minimal fogging or icing
PM emissions	• Dependent upon source water total dissolved solids, cycles of concentration, and drift eliminator efficiency; anticipated to be moderate to high due to use of seawater from Hillsborough Bay	• Dependent upon source water total dissolved solids, cycles of concentration, and drift eliminator efficiency • Similar to MDCT	• No PM emissions	• Potentially reduced PM emissions • Dependent upon rate of use of dry portion of tower
Noise emissions	• Fan noise • Cascading water	• No fan noise • Greater water noise	• Greatest fan noise • No water noise	• Significant fan noise • Cascading water
Water consumption	• Significantly reduced water withdrawal rate, but larger evaporation rate, compared to once-through cooling. Water use reduction lessen due to need for dilution water	• Similar to base case	• No water consumption • Greatest reduction in water use of alternatives	• Similar to base case
Residual waste	• Dependent upon water and air quality, basin sizing, and use of chemical additives	• Similar to base case	• No scale, sediment, sludge accumulation	• Similar to base case

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Table 10–3. Matrix of Relative Impacts and Attributes of Cooling Tower Types (Continued, Page 3 of 3)

Attribute	Cooling Tower Types			
	MDCT (Base Case)	NDCT (Compare to MDCT)	Dry ACC (Compare to MDCT)	Plume-abated Cooling Towers (Compare to MDCT)
Overall Station Impacts				
Capital costs	• Base case	• Somewhat higher than base case	• Highest capital costs	• Higher than base case
Operating costs	• Base case	• Lower than base case	• Highest operating costs	• Higher than base case
Site-specific applicability	• Challenging due to existing buried infrastructure and difficulties with routing hot and cold water pipes	• Infeasible due to condenser temperature rise and approach temperatures. • NDCT require large flow rates, which can be achieved only if both units a single NDCTs.	• Infeasible • Incompatible with existing heat exchangers • Insufficient suitable space	• Similar to base case, except costlier
Overall feasibility	• Impractical from a construction and operational perspectives • Least expensive cooling alternative	• Infeasible due to condenser incompatibility. Range and approach temperatures at Bayside are smaller than required to facilitate the natural draft in a NDCT.	• Infeasible due to large real estate requirements and incompatibility with existing condensers	• May be feasible from an engineering perspective – needs further evaluation • Large cost and power consumption

Note: MDCT = mechanical draft cooling tower.
NDCT = natural draft cooling tower.
ACC = air-cooled condenser.

*Plume abatement technologies available for MDCTs. Hybrid cooling towers are typically always plume-abated.

Sources: EPRI, 2011.
CTI, 2003.
Maulbetsch and Stallings, 2012.
EPRI, 2002.

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Table 10–4. Pertinent Design Parameters from the Existing Condenser Specifications

Parameter	Unit 1	Unit 2	Units
Condenser			
Condenser duty	1,567,000,000	2,130,000,000	Btu/hr
Effective tube length	36	40.04	feet
Circulating water design flow	184,800	252,000	gpm
Circulating water design inlet temperature	78	78	°F
Circulating water temperature range	17	17	°F
Guaranteed backpressure	2.84	2.38	Inches mercury at absolute pressure
Tubes			
Number of tubes	10,560	20,020	-
Effective surface area	99,526	183,655	square feet
Cleanliness factor	85	85	%
Number of passes	1	1	—
Circulating water velocity through tubes	7.76	7.37	fps
Outer diameter of tubes	1	7/8	inch
Tube material	B338Gr2 Titanium	B338Gr2Titanium	—
Waterboxes			
Number per condenser	2	2	—
Design pressure	25	Unavailable	psig
Inlet and outlet IDs	66	Unavailable	inches

Source: Alstrom Power, Undated and 2001.

Bayside has split condensers with two waterboxes, one on the upstream end and one on the downstream end. On the inlet side, the cold water enters and is directed with uniform distribution towards the tube sheet, which is a metal sheet with perforations that allow for entry of water into the condenser tubes. On the discharge side, the warmed water is collected in the outlet waterbox and removed from the condenser. Figure 10-12 shows a photograph of the Bayside Unit 1 inlet waterboxes. In once-through cooling, the warmed water is discharged to the Hillsborough Bay via the discharge canal. If this system were operated as closed-cycle cooling, the warmed water would be directed to the cooling towers to be cooled and reused. This evaluation assumes that the hot water pipes would be intercepted prior to their discharge into the flume and rerouted to the hypothetical cooling towers. The existing waterboxes, condensers, entire length of cold water pipes and significant sections of the hot water pipes would be reused. Reusing existing components helps reduce retrofit costs, but the design and operation must accommodate the constraints imposed by the existing system.

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FIGURE 10-12.

BAYSIDE UNIT 1 CONDENSER INLET WATERBOX

Source: TECO, 2017.

Table 10-5 lists the calculated DIF and associated pumps.

Table 10–5. Bayside Pumping Capacity from Hillsborough Bay

Pump Description	Number of Pumps	Pump Rating	Flow per Unit
Circulating water pumps – Unit 1	2	92,400 gpm	184,800 gpm
Circulating water pumps – Unit 2	2	126,000 gpm	252,000 gpm
DIF for station			436,000 gpm 628 MGD

Source: TECO, 2018.

As discussed further in Section 10.5.1, Bayside does not withdraw service water from the Hillsborough Bay. Instead, Bayside collects and treats stormwater runoff for use in various processes. If during low rainfall periods the station does not have sufficient water in its ponds, then Bayside purchases fresh water from a water supplier.

10.3.5 Description of the Hypothetical Closed-cycle Cooling Tower—40 CFR 122.21(r)(10)(i)(A)

10.3.5.1 MDCT Design Assumptions

Several design conditions have been assumed with the selection of MDCTs. These assumptions are described in the following sections.

Flow

The existing once-through cooling water flow rate used in the condensers is approximately 184,800 gpm for Unit 1, and 252,000 gpm for Unit 2 (Table 10-5). This flow is assumed to be equivalent to the recirculating flow required for the cooling towers of each unit because the same amount of water would be required for the condensers in both once-through and closed-cycle cooling systems. This evaluation assumes that service water will remain in its current configuration, using treated contact stormwater runoff for much of the service water needs, and supplemented with purchased potable water.

Water evaporation rate in the cooling towers necessary to dissipate the required heat has been estimated and is listed in Table 10-6. The evaporation rate is estimated at approximately

5,906 gpm for the station using a cooling tower range of 17°F and cooling tower flow rates equal to the current condenser flow rates of 184,800 gpm and 252,000 gpm for Units 1 and 2. The blowdown rate is a function of source water quality and NPDES permit discharge quality requirements. The State of Florida requires that NPDES discharges not exceed 110 percent of source water chloride concentration. Meeting this requirement would necessitate the cooling tower to operate at an effective 1.1 COC without harnessing greater benefits of flow reductions that are typically possible with the use of cooling towers. Additionally, operating the cooling towers at very low cycles would necessitate the use of greater quantities of various chemicals.[14] This evaluation therefore assumes that the cooling tower would be operated at 1.3 COC, and the discharge would be diluted with additional dilution water pumped from the Hillsborough Bay to meet the 110 percent chloride rule. Such an approach has been used in Florida in the development of combined-cycle facility using MDCT made up by seawater. Per 40 CFR 125.92(e), dilution water would be regulated under the Rule.

Table 10–6. Estimated Water Use in Cooling Towers

Water Use	Unit 1	Unit 2	Station Total
Circulating water flow rate (gpm)	184,800	252,000	436,800
Evaporation rate (gpm)	2,498	3,407	5,906
Drift flow rate (gpm)	0.9	1.3	2.2
Blowdown rate (gpm)	8,327	11,356	19,683
Makeup rate (gpm)*	10,827	14,764	25,591
Dilution water flow rate (gpm)	16,655	22,711	39,366
Reduction in total water withdrawal rate (gpm)	157,318	214,525	371,843
Reduction in total water withdrawal rate (%)	85.1	85.1	85.1

*Assumes no other leaks in the system. Equals the sum of evaporation, drift, and blowdown.

Source: HDR, 2017.

This evaluation also assumes that the hypothetical cooling towers would employ the most efficient drift eliminators presently on the market with a 0.0005 percent efficiency. These values are discussed in more detail in the 40 CFR 122.21(r)(12) report.

[14] This evaluation assumes the closed-cycle system would use a dispersant, scale/corrosion inhibitor and sodium hypochlorite.

Engineering estimates of evaporation, drift, blowdown and makeup are provided in Appendix 10-C.

Temperatures

Because MDCTs are wet cooling towers, the ambient wet-bulb temperature that is exceeded during one percent of the record at Tampa, FL, 80°F, has been used for the basis of the design (World Meteorological Organization [WMO], 2017). We note that the selection of the design ambient wet-bulb temperature involves certain trade-offs. When the MDCT's design wet-bulb temperature is exceeded, the cooling tower will not be able to dissipate the full waste heat load of the steam turbine and the station would need to reduce output or "de-rate" the steam turbine. On the other hand, a cooling tower that is designed for a higher wet-bulb temperature must be larger and costlier. Therefore, selection of a higher wet-bulb temperature that is exceeded less often would reduce the frequency and magnitude of de-rating but only at an increase in cost. While different companies may reach different resolutions to this trade-off, TECO has indicated that the one percent wet-bulb temperature design criteria is consistent with its historical practice.

The cooling tower approach temperature is assumed to be 10°F,[15] meaning that during the warmest and most humid periods, the cold recirculating water temperature leaving the cooling towers would be approximately 90°F. The cooling tower range, which is equivalent to the ΔT across the condensers, is approximately 17°F. The ΔT was calculated using the condenser design parameters in Table 10-4. With a cooling tower range of 17°F, the hot water temperature entering the cooling tower is assumed to be equal to approximately 107°F (i.e., the addition of cold water temperature and ΔT).

10.3.5.2 Cooling Tower Sizing

Based on the design inputs described in Section 10.3.3, hypothetical MDCTs have been sized by SPX Cooling Technologies, Inc. (Overland Park, Kansas) for the cooling water system at Bayside. Summaries of vendor sizing information are provided in Table 10-7 and Table 10-8 (SPX, 2017c).

[15] This is the practical minimum approach temperature for MDCT; the required approach for NDCTs is larger.

Table 10–7. Cooling Tower Sizing Information for Unit 1

Description	Value	Units
Tower type	MDCT	
Number of cells	10	cells
Number of towers	1	towers
Cells per tower	10	cells per tower
Cell size (length × width × height)	48 × 55 × 45	ft
CT type/arrangement	Back-to-back	
CT basin size (length × width × depth)	248 × 104	ft
Motor output power for each fan	250	bhp
Total fan motor output power	2,500	hp
Total lift pump static head	31	ft
Condenser water flow rate	184,800	gpm
Condenser temperature differential	17	°F
Design wet bulb temperature	80	°F
Wet bulb temperature exceedance percentile	1	%
Prevailing wind direction	West	

Source: HDR, 2017.

Table 10–8. Cooling Tower Sizing Information for Unit 2

Description	Value	Units
Tower type	MDCT	
Number of cells	14	cells
Number of towers	1	towers
Cells per tower	14	cells/tower
Cell size (length × width × height)	56 × 55 × 47	ft
CT type/arrangement	Back-to-Back	
CT basin size (length × width × depth)	393 × 124	ft
Motor output power for fans	250	bhp
Total fan motor output power	3,500	hp
Total lift pump static head	29	ft
Condenser water flow rate	252,000	gpm
Condenser temperature differential	17	°F
Design wet bulb temperature	80	°F
Wet bulb temperature exceedance percentile	1	%
Prevailing wind direction	West	

Source: HDR, 2017.

10.3.5.3 Existing Conditions

A geotechnical engineering study performed for a design-build project at Bayside in 2009 (Nodarse & Associates, Inc., 2009) encountered load-bearing strata deeper than 28 ft in some sections of the site and deeper than 50 ft in other sections. This evaluation therefore assumes that pilings would be driven to 50 ft.

10.3.5.4 Potential Locations for MDCT—40 CFR 122.21(r)(10)(i)(B)

The following aspects were considered when identifying potential locations for cooling tower placement; two potential locations were then selected for use in the remainder of the feasibility and cost evaluation:

- The locations must have existing space available for construction—The footprint of the cooling tower basins, booster pumphouse, wet well, construction access, excavation space, and space to setup equipment were considered under this category. Topography of the site (Figure 10-13) was found to be amenable to construction, and not requiring extensive regrading.
- The locations must have existing space available for cooling tower operation—Good air circulation is needed for the cooling towers to operate efficiently.
- The locations must help minimize retrofit-related plant downtime to the extent practicable—Plant downtime is costly and affects the reliability of the electric grid.
- The locations must facilitate minimal construction-related disturbance to the extent practicable—Restoring a construction site is costly. This evaluation attempts to locate and sequence work to minimize disturbed areas.
- The potential cooling towers need to be located away from the switchyard and substations to avoid electrical arching—a problem that would be exacerbated by use of seawater as cooling tower makeup.
- The location must have sufficient power to energize new equipment such as pumps and fans, or a new power source would need to be brought to the potential cooling tower locations at significant cost.

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- The location must be in close proximity to existing condensers—Long distances between condensers and cooling towers increase the cost of construction and increase head loss through the system that would need to be compensated with larger pumps. Therefore, the distances between condensers and cooling towers were minimized to the extent practicable during the assessment.
- The locations must be in close proximity to the existing cooling water intake structure and discharge flume—Much of the existing cooling water pipe network is buried under the plant and intertwined with other utilities. This evaluation attempted to minimize disturbance to the plant by using existing pipes.
- The locations must have pipe or channel routes available between the condensers and cooling towers, and between cooling towers and condensers—Power plants have a myriad of above-ground and underground infrastructure. Pipe routes that avoid crossing transmission corridors and other densely utilized areas of the site are preferable. Cooling tower locations that allow for practical hot and cold water channel routes are also preferred. The evaluation also attempted to avoid cooling water pipe crossings.
- The location must have existing space available for equipment laydown—It is convenient and cost-effective for contractors to have laydown space readily available near construction activities. When there is not sufficient space, equipment needs to be hauled to the construction site as-needed.

10.3.5.5 Orientation of the Cooling Towers

Wind speed and direction significantly influence cooling tower performance as well as the potential effects of facility emissions. While moderate wind speeds are critical for transporting the saturated plume away from the tower and increasing cooling tower performance, excessive wind speeds can diminish cooling tower performance by restricting the plume from rising up and out of the tower. A cooling tower array performs best when its primary (long) axis is oriented in the predominant wind direction, because this orientation minimizes the potential for saturated air recirculation. When space and other physical conditions allow, MDCTs are oriented with the dominant wind direction that coincides with design wet bulb temperature. Meteorological data from the World Meteorological Organization (WMO Station No. 722110) for Tampa, FL was

used for this evaluation. Wind roses,[16] which depict prevailing wind direction and percent frequency of observed wind speeds, for Tampa, Florida, for the different months of the year are shown on Figure 10-14.

Recirculation occurs when the saturated air leaving the cooling tower is introduced back into the tower's air inlets (SPX, 2009). Interference is similar to recirculation, with the exception that the saturated air leaving the cooling tower is introduced into a nearby cooling tower's air inlet (SPX, 2009). When multiple cooling towers are utilized in a side-by-side fashion, a minimum distance[17] between the towers must be maintained to minimize interference.[18]

The winter (December, January, and February) wind rose shows that the majority of prevailing winds are from the east, northeast and north. Wind from the east and northeast occurs around 27 percent of the time and from the north and northeast direction occurs around 26 percent of the time (Figure 10-14). Wind speeds are commonly between 6 and 14 knots[19] (approximately 7 and 16 miles per hour [mph]).

The spring (March, April, and May) wind rose shows that the majority of prevailing winds is from the east, southeast and west. Wind speeds are commonly between 6 and 14 knots (approximately 7 and 16 mph).

[16] A wind rose is a graphical representation of how prevailing wind direction and percent frequency of wind speed are distributed at a specific location for a given period of record of data. The wind rose is plotted in a circular format. Straight lines directing towards the center represent the prevailing wind direction; the concentric circles (or dashes on the straight lines) represent the percent frequencies of wind speed, which increase in percent frequency from the center of the wind rose (NRCS 2016). The percent of time the wind speed is observed as calm is typically provided as a note to the wind rose. Wind speeds may be provided in units of either miles per hour (MPH) or in knots.
[17] The minimum distance is typically a function of the length of the cooling tower and the amount of offset between the side-by-side towers. When the site does not allow for this minimum separation between towers or does not allow for the appropriate orientation of towers, the inefficiencies may be overcome by using more powerful fans or adding a few extra cooling tower cells.
[18] Recirculation is minimized by limiting the size of any tower. For example, if a plant needs 48 cooling tower cells, the design can minimize recirculating by utilizing four 12-cell towers instead of a single 48-cell tower.
[19] A knot is a velocity measured in nautical miles per hour, where one nautical mile is equivalent to 1,852 meters, or approximately 6,076 ft. To convert from knots to MPH, the value in knots should be multiplied by 6,076 ft per hour per knot and then divided by 5,280 ft per mile.

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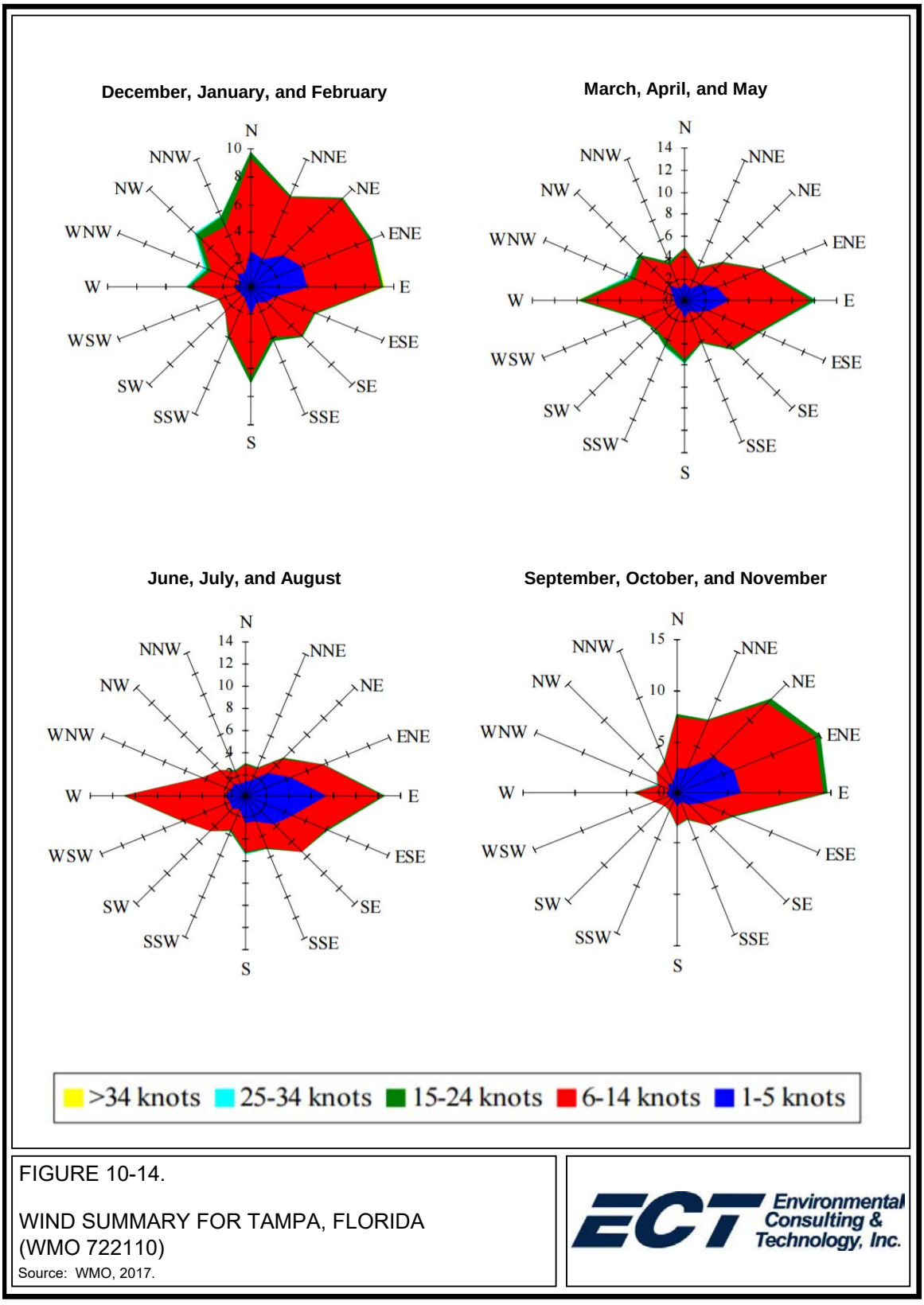


FIGURE 10-14.

WIND SUMMARY FOR TAMPA, FLORIDA
(WMO 722110)
Source: WMO, 2017.

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The summer (June, July, and August) wind rose shows that the majority of prevailing winds are from the east and southeast and occurs approximately 27 percent of the time; and also from the west. Wind speeds are commonly between 6 and 14 knots (approximately 7 and 16 mph).

The autumn (September, October, and November) wind rose shows that the majority of the prevailing winds are from the east and northeast directions, occurring approximately 42 percent of the time between 6 and 14 knots (approximately 7 and 16 mph).

The predominant wind during the highest wet bulb temperature conditions (i.e., the summer months) is from the east; therefore, the main axis of the cooling towers would be oriented in the east to west direction.

10.3.5.6 Conceptual Approach to Potential Closed-Cycle Cooling

Two MDCTs are assumed for the Bayside retrofit. The hypothetical back-to-back tower for Unit 1 is assumed to be located immediately northwest of the Unit 1 turbine building, and the Unit 2 back-to-back tower is assumed to be located immediately to the east of the CWIS.

This concept assumes that hot water pipes from each unit would be intercepted between the turbine building and discharge flume. The Unit 1 hot water channel would traverse west then north (via gravity) to the Unit 1 cooling tower wet well (see the red line in Figure 10-15). Booster pumps would pump water from the wet well to the tower. Cold water from tower basin would flow north then east (via gravity) to a newly-constructed forebay in front of the existing CWIS, where the existing circulating water pumps would route the water to the Unit 1 condenser to re-start the loop. The forebay would isolate the existing cooling water intake structure from the Waters of the United States making the structure serve as the reservoir (or wet well) to the circulators that feed the closed-cycle system. Given that water will be lost from the circulating flow due to evaporation, etc., the forebay would have to be equipped with makeup pumps to provide replacement (Appendix 10-B).

The Unit 2 hot water channel would traverse east then north to the Unit 2 cooling tower wet well (see the red line in Figure 10-15). Booster pumps would pump hot water from the wet well to the tower. Cold water from tower basin would flow west (via gravity) to the newly-constructed

forebay in front of the existing CWIS, where the existing circulating water pumps would route the water to the Unit 2 condenser to re-start the loop. Units 1 and 2 cold water can co-mingle in the forebay.

Units 1 and 2 blowdown would be routed to the existing discharge flume. It is likely that the blowdown lines would be installed in the same trench as their respective hot water channel.

A new makeup water intake structure (MWIS)[20] is assumed to be constructed to the west of the existing CWIS (Figure 10-15). Makeup water for both units would be routed to the forebay. The dilution water needed to comply with the State of Florida chloride rule would also be withdrawn by the MWIS. A pipe from MWIS would route dilution water south, east and south again to the discharge flume. Some sections of the dilution pipe may be installed in the same trench as the Unit 1 hot water. The MWIS has been preliminarily sized to be 75 ft long and 75 ft wide and would have a bar rack and two TWS with ⅜-inch mesh.

The Unit 1 MDCT would consist of 10 cells and the Unit 2 of 14 cells. Each of the wet wells has been sized to provide 5 minutes of residence time to the full flow associated with each unit.

Pipe, channel and wet well dimensions are summarized in Table 10-9. All pipes and channels, except the pipes that would be used to pump water from the wet well to the cooling towers, would be buried. The wet wells would also be installed below grade. Hot and cold water channels, wet well and the MWIS would be pile-supported.

[20] Such a structure would be regulated under Section 316(b) but, because it makes up a closed-cycle cooling system, would be compliant with IM BTA under 40 CFR 125.94(c)(1).

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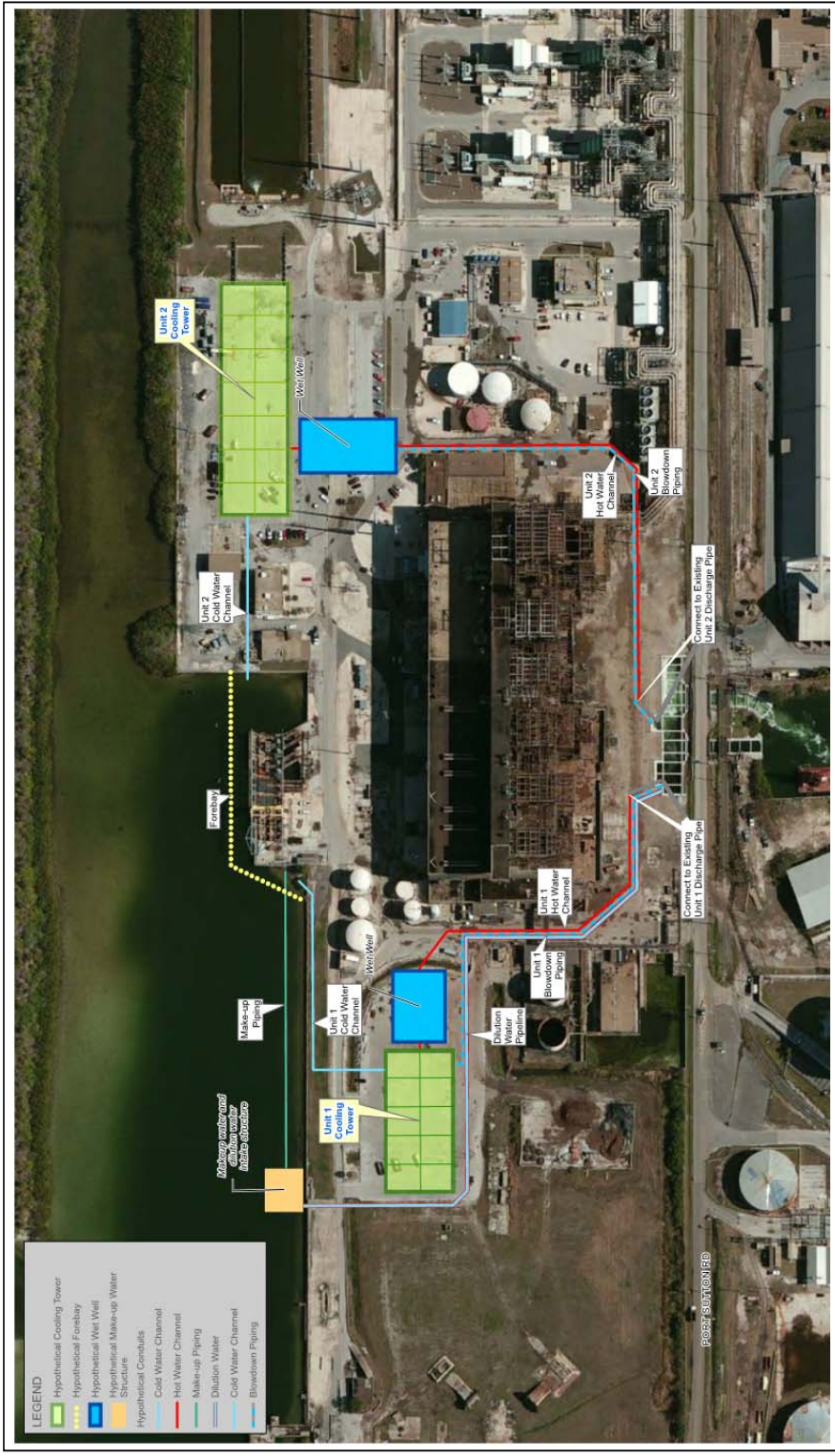


Table 10–9. Component Sizes of Cooling Tower Ancillary Equipment

	Measurement Units	Unit 1	Unit 2
Wet well (length × width × height)	ft	147 × 99 × 22	206 × 96 × 22
Wet well operating depth	ft	10	10
Hot water channel from intercept point to wet well (length × width × height)	ft	800 × 28 × 15	1,100 × 32 × 15
Hot water pipes from wet well to cooling tower, diameter and length	ft	4 pipes, one per booster pump, each 4 ft in diameter and 100 ft long	4 pipes, one per booster pump, each 5 ft in diameter and 100 ft long
Cold water channel (length × width × height)	ft	600 × 28 × 15	400 × 32 × 15
Blowdown pipe diameter and length	ft	2.5 diameter; 900 length	3 diameter; 1,200 length
Makeup water pipe diameter and length*	ft	3.5 diameter; 800 length	
Dilution water pipe diameter and length	ft	4 diameter; 1,700 length	

*Makeup water is necessary for the cooling towers and to replace losses of water recirculated through the condensers.

Source: HDR, 2017.

Figure 10-15 shows the layout of the hypothetical cooling towers and associated piping.

10.3.6 Alternate Locations

Figure 10-16 shows several alternate cooling tower locations considered. Each location is discussed below.

- Location A—Former coal stockpile. This location is suitable for use, but locations chosen are closer to the condensers and CWIS.
- Location B—Currently used as contractor parking and staging. The hypothetical Unit 2 tower has been located here.
- Location C—Contact stormwater ponds. These are critical components of the Bayside wastewater treatment system, which feeds the service water system at the station. The study assumed that these ponds would not be relocated.
- Location D—Located west of the substation and is relatively open and suitable for construction. But the operation of cooling towers at this location could cause potential arching at the substation. This location is significantly farther from the existing cooling water system than the spaces selected for the study. This space can house only one of the two cooling towers.

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FIGURE 10-16.

ALTERNATE COOLING TOWER LOCATIONS

Source: HDR, 2017.

- Location E—Located east of the substation and is relatively open and suitable for construction. But the operation of cooling towers at this location could also cause potential arcing at the substation. This location is significantly farther from the existing infrastructure than the spaces selected for the study. This space can house only one of the two cooling towers.
- Location F—Currently houses the sand filter for non-contact stormwater, which is an integral part of the onsite water reuse effort. This location is insufficient for either cooling tower.
- Location G—Administrative parking lot. There is not enough space at this location.
- Location H—Parking lot on the northeast corner of the former coal pile. This location was selected for the Unit 1 cooling tower.

All locations considered are within the Bayside property. The Hillsborough Bay is on the north and west of the site. An active Kinder Morgan facility is located to the south of Bayside and there is no space available there that may be utilized by Bayside.

10.3.7 Construction Sequence and Outage

10.3.7.1 Construction Sequence

This type of project may be sequenced and implemented in many different ways. The following construction sequence was assumed for this evaluation. Several of these tasks would overlap and be implemented using several crews. The strategy of the hypothetical construction sequencing was to minimize the downtime of each unit associated with final tie-in of the closed-cycle cooling system. Similarly, the schedule is a reasonably aggressive one intended to maximize the period in which the retrofitted cooling system would be effective before facility closure:

- Pilings for cooling tower basins and wet well foundations
- Pilings for cold water pipelines
- Pilings for hot water pipelines
- Pilings for forebay and makeup water intake structure
- Makeup water and dilution water intake structure
- Wet wells (to supply booster pumps)
- Construct hot water pipelines/channels and blowdown pipelines

- Install dilution water pipeline and makeup water pipeline
- Construct cold water channels
- Erect cooling towers, install booster pumps, dilution water pumps, and makeup water pumps
- Install screens for makeup water pumps
- Tie-in the new Unit 1 hot water pipe/channel to the existing Unit 1 hot water channel [requires Unit 1 to be offline]
- Tie-in the new Unit 2 hot water pipe/channel to the existing Unit 2 hot water channel [requires Unit 2 to be offline]
- Install sheet pile wall to enclose the forebay [requires both units to be offline for a portion of this time]
- Connect the blowdown pipelines and dilution water pipeline to the existing discharge flume [both units may need to be offline for a short period of time]

10.3.7.2 Construction-related Outage

Based on the above preliminary construction sequence, this evaluation estimated that an approximately 4-week outage would be needed to tie-in closed-cycle systems associated with both units.

10.3.8 Feasibility Discussion

This section discusses key construction components and feasibility of implementing closed-cycle cooling towers from a construction, operational and facility standpoint.

10.3.8.1 Retrofit Feasibility

Bayside Units 1 and 2 were originally built in 1950s and 1960s and converted from coal to gas-fired combined-cycle in 2003 and 2004, respectively. The remaining life of the units is likely shorter than the remaining life of cooling towers. While the actual remaining life is not known with certainty, this evaluation assumes that the two units would be shut down in 2044. It is impractical to implement a retrofit that would cost more than the remaining value of the units, where the remaining life of the units is shorter than the remaining life of the add-on technology, and when the technology (cooling towers) would not help to extend the life of the units.

10.3.8.2 Construction Feasibility

This evaluation assumes that the existing hot water pipes would be intercepted prior to their discharge into the flume. Figure 10-17 shows the elevation view of the cooling system from the condensers to the discharge flume. The hot water tie-in location would be outside the building to minimize impact on operations. Figure 10-18 has traced over a few hot and cold water pipe segments. The cold water pipe would not be retrofitted. No modifications are planned for within the condenser/turbine building.

Bayside is an old site with several buried infrastructure components. Running large hot water channels from near the discharge flume to the new wet wells would likely be one of the biggest challenges of the retrofit. Existing drawings show that there are several buried pipes within this site. This evaluation did not perform a utility and buried infrastructure survey. A survey would be needed to assess if the proposed channel routes are feasible. Rerouting and realigning may be infeasible.

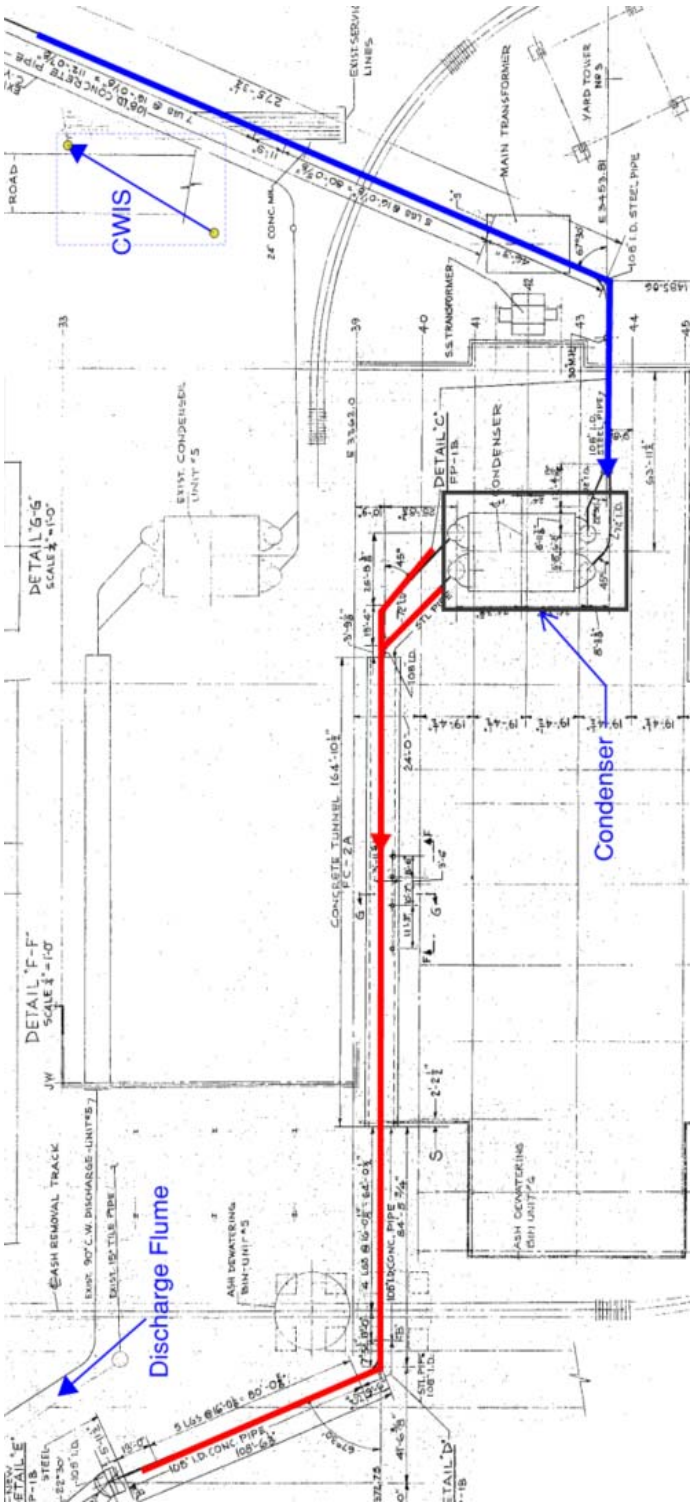
10.3.8.3 Operational Feasibility Due to Energy Requirements

Operation of MDCTs involves the addition of pumps, fans, and related equipment, which consume energy. These parasitic losses would reduce the station's electricity supply to the grid. The biggest parasitic draw and losses of efficiency would occur in hot weather when Bayside is most needed to feed the grid. Therefore, a cooling tower retrofit is likely to be operationally impractical.

10.3.8.4 Facility Operational Feasibility Due to Technology Retrofit

Bayside operations would be constrained when the cooling tower operations are constrained. In addition to the parasitic load, cooling tower performance would be compromised for approximately 88 hours on average, during the warmest and most humid periods of the year when ambient wet bulb temperature exceeds the design wet bulb temperature. Subsequently, the unit performance may be compromised due to the higher cooling water temperature and higher condenser backpressure. Summer is also when the station needs to generate at full capacity to meet grid requirements. Bayside's operational reliability is compromised with a cooling tower retrofit.

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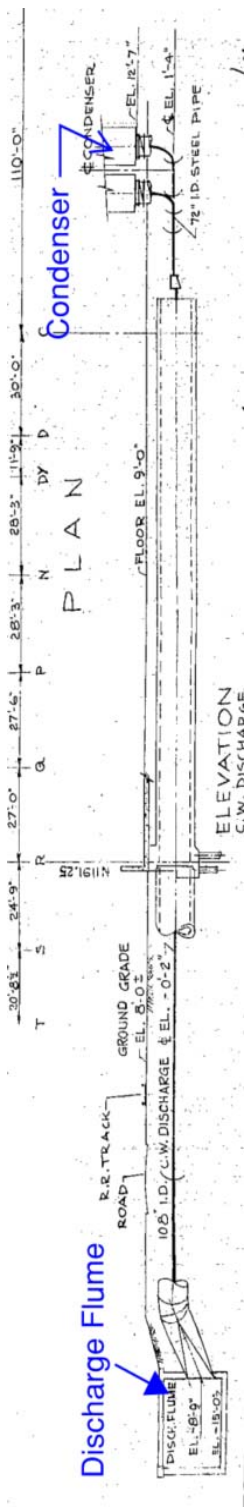
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FIGURE 10-17.

PLAN VIEW OF EXISTING COLD AND HOT WATER PIPES INTO AND OUT OF THE CONDENSERS

Sources: TECO, 1966a. HDR, 2017.

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FIGURE 10-18.

ELEVATION VIEW OF EXISTING COLD AND HOT WATER PIPES INTO AND OUT OF THE CONDENSERS

Sources: TECO, 1966a. HDR, 2017.

10.3.8.5 Overall Feasibility of Cooling Towers—40 CFR 122.21(r)(10)(i)(D)

Retrofitting Bayside from once-through to closed-cycle may be technically feasible, but it is very challenging (due to existing infrastructure) and impractical due to the old age of equipment that need to be retrofitted. The cooling tower retrofit could also render Bayside and the grid less reliable during the warmest days.

10.3.9 Permitting Requirements

Construction and operation of cooling towers at Bayside would trigger several additional federal, state, and local permitting efforts. These triggers and approvals include:

- Title V permit modification
- USACE Section 404/10 permit (includes coordination with National Marine Fisheries Service [NMFS], EPA, and the USFWS, which trigger an environmental impact statement under the National Environmental Policy Act [NEPA])
- FDEP Florida Coastal Management Program approval
- FDEP Environmental Resource Permitting and Submerged Lands approvals (potential)
- NPDES permit modification
- Federal Aviation Administration (FAA) Notice of Construction or Alteration (potential)
- Revisions to Spill Prevention Containment and Countermeasure Plans
- Revisions to Erosion and Sedimentation Control Plan
- FDEP NPDES General Stormwater Permit for Construction
- NPDES Construction Dewatering Discharge to Surface Waters Permit
- Township Preliminary/Final Site Plan approval
- Township construction permits

10.3.10 Anticipated Schedule

The schedule assumed for implementing the MDCT and for estimating the net present value of this technology is presented in Table 10-10.

Table 10–10. MDCT Implementation Schedule

Calendar Year	Year	MDCT
February 2018	0	Submit NPDES renewal application and 316(b) information
August 2018	0.5	Permit expiration
February 2019	1	Final BTA determination
August 2019	1.5	Engineering contract
February 2020	2	30 percent design
August 2020	2.5	Site investigations: geotech borings, soil and topographic surveys; permit applications
February 2021	3	Permitting; 60-percent design; procurement contracts
August 2021	3.5	
February 2022	4	95-percent design
August 2022	4.5	Bid construction. Select contractor. General conditions, prep and local permits.
February 2023	5	Construction
August 2023	5.5	
February 2024	6	Commissioning

Note: This schedule assumes the renewed permit would be delayed by 6 months, and the existing permit administratively continued as FDEP assesses the 316(b) compliance reports.

Source: HDR, 2017.

10.3.11 Costs—40 CFR 122.21(r)(10)(iii)

The costs associated with a MDCT retrofit are discussed below.

10.3.11.1 Capital

Based on the existing conditions and assumptions stated herein, as well as a conceptual-level design, the AACE Class 4[21] estimates were developed for the hypothetical MDCT retrofit at Bayside. The construction cost estimates utilize union wage rates specific to Tampa, FL area, budgetary equipment pricing obtained from major equipment suppliers, and construction standard pricing (using RSMeans's data). The cooling towers are rated for 150 miles per hour wind, and costs reflect that rating. Capital costs are presented in 2017 U.S. dollars. The owner's costs are included as 10 percent of total construction costs and design engineering costs. Contingency was also included at 20 percent of the major costs.

[21] A Class 4 estimate is typically used for study and feasibility purposes only, with a project percent completion between 1 and 15 percent; the accuracy may be between -30 and +50 percent of the estimated cost (AACE, 2016).

The Class 4 estimate for the capital costs for outside labor and materials for the implementation of two MDCT at Bayside would be approximately $234 million, if all work were implemented in 2017, and includes the following components and also listed in Table 10-11:

- Existing infrastructure demolition costs.
- Equipment costs, including cooling tower structural components and fill, booster pumps, dilution pump, and makeup water pump.
- Cooling tower basin construction.
- Earth moving and civil work.
- Piping and electrical work.
- Engineering and design of retrofit with existing station and condensers.
- Permitting.
- Non-water quality environmental and other impacts mitigation.

Table 10–11. Cooling Tower Capital Costs if Implemented in 2017 (2017 $ Millions)

Cost Components	Costs (2017 $ million)
Cooling towers	$37.66
Booster pumps and sumps	$35.60
Hot and cold water pipelines	$37.50
Makeup, dilution and blowdown system	$13.93
Forebay	$3.08
Contractor site supervision	$0.70
General conditions	$18.94
General admin and profit	$22.11
Total construction cost	**$169.53**
Design engineering	$8.94
Project management (engineering)	$1.20
Owners costs (10 percent)	$17.85
Contingency	$39.50
Total capital cost	**$237.02**

Source: HDR, 2017.

10.3.11.2 O&M

O&M cost for the hypothetical MDCT is estimated at approximately $3.75 million per year (if incurred in 2017), and includes labor, chemicals,[22] solids removal, parts replacement for pumps, fans, cooling tower, etc. and electricity as listed in Table 10-12. It is assumed that electricity consumption would be considered a net reduction in the station's power production. It is also assumed that makeup water would not need to be treated prior to use. Besides dechlorination, blowdown would not need to be treated. Circulating water is assumed to be treated to reduce biofouling, corrosion and scaling within the system.

Table 10–12. Cooling Tower Annual O&M Costs (2017 $)

O&M Cost Components	MDCT (2017 $ million)
Labor	$1.75
Chemicals for cooling water	$0.85
Solids removal*	$0.11
Parts replacement and maintenance	$1.04
Subtotal	$3.75
Electricity for pumps and fans†	$3.80‡

*Primarily cooling tower solids removal. This could be conducted every few years, but costs are presented as annual.
†Cost of electricity is included in the NPV estimate but is broken out separately in O&M.
‡The energy required to operate fans and pumps is 11.4 MW or approximately 100 GWhr. The impact of derate or backpressure energy penalty is not included here.

Source: HDR, 2017.

TECO's costs associated with derating and increased turbine back-pressure are estimated below in the discussion of power system modeling.

10.3.11.3 Environmental Mitigation Costs from 40 CFR 122.21(r)(12)

The design already incorporates potentially feasible impact mitigation measures listed below. No additional environmental mitigation efforts or costs are anticipated because additional measures

[22] Assumes chlorine would be added as 12-percent sodium hypochlorite (NaOCl) 1 to 3 days per week for biofouling control. During chlorination, the blowdown would be dechlorinated. A dispersant and a corrosion/scale inhibitor would be added continuously to cooling tower makeup at a low dose.

are not expected to be technically feasible. The following environmental mitigation measures have already been incorporated into the base design described above:

- Reduce additional energy consumption by assuming the implementation of the most energy efficient equipment.
- Installation of drift-eliminators.
- Provision of blow-down dilution water to facilitate cooling tower operation while meeting the relevant water quality standard for chloride.
- Safety features by way of allowing separation distance between the station and the tower, and switchyards/substations and the towers would reduce salt deposition and electrical arching.

10.3.11.4 Facility-level Compliance Cost (Annual and NPV)

The evaluation assumes that the hypothetical cooling towers would operate continuously using water of acceptable quality for the cooling tower fill, and therefore the fill would not need to be replaced for the remaining life of the station.

Per the schedule presented in Section 10.3.10, the hypothetical cooling towers are estimated to be operational in 2023. O&M costs are presented in two tables: Table 10-13 provides O&M costs excluding electricity costs; Table 10-14 provides electricity costs only assuming $50/MWhr. Table 10-15 overlays capital costs on the anticipated implementation schedule. The costs of lost generation capacity associated with increased turbine back-pressure and periodic de-rating are estimated below. The NPV of installing and operating cooling towers on a continuous basis is estimated at $281 million, and at $240 million if Bayside continues to operate at the historical capacity utilization rate.

Table 10–13. O&M Costs (Excluding Electricity Costs) for MDCT Implementation

Year	O&M Costs if Incurred in 2017 ($ million)	Costs in a Given Year ($ million)	Present Value ($ million)
2024	$1.87	$2.31	$1.45
2025	$3.75	$4.75	$2.80
2026	$3.75	$4.89	$2.70
2027	$3.75	$5.04	$2.61
2028	$3.75	$5.19	$2.51
2029	$3.75	$5.35	$2.42
2030	$3.75	$5.51	$2.34
2031	$3.75	$5.67	$2.25
2032	$3.75	$5.84	$2.17
2033	$3.75	$6.02	$2.10
2034	$3.75	$6.20	$2.02
2035	$3.75	$6.38	$1.95
2036	$3.75	$6.57	$1.88
2037	$3.75	$6.77	$1.81
2038	$3.75	$6.97	$1.75
2039	$3.75	$7.18	$1.69
2040	$3.75	$7.40	$1.63
2041	$3.75	$7.62	$1.57
2042	$3.75	$7.85	$1.51
2043	$3.75	$8.09	$1.46
2044	$3.75	$8.33	$1.41

Note: Costs if incurred in 2017, escalated costs in a given years, and present value of costs.

Source: HDR, 2017.

Table 10–14. Electricity Costs for Operating MDCT

Year	O&M Costs if Incurred in 2017 ($ million)	Costs in a Given Year ($ million)	Present Value ($ million)
2024	$2.57	$3.16	$1.99
2025	$5.13	$6.50	$3.84
2026	$5.13	$6.69	$3.70
2027	$5.13	$6.90	$3.57
2028	$5.13	$7.10	$3.44
2029	$5.13	$7.32	$3.32
2030	$5.13	$7.53	$3.20
2031	$5.13	$7.76	$3.09
2032	$5.13	$7.99	$2.98
2033	$5.13	$8.23	$2.87
2034	$5.13	$8.48	$2.77
2035	$5.13	$8.74	$2.67
2036	$5.13	$9.00	$2.57
2037	$5.13	$9.27	$2.48
2038	$5.13	$9.54	$2.39
2039	$5.13	$9.83	$2.31
2040	$5.13	$10.13	$2.23
2041	$5.13	$10.43	$2.15
2042	$5.13	$10.74	$2.07
2043	$5.13	$11.07	$2.00
2044	$5.13	$11.40	$1.92

Note: Costs if incurred in 2017, escalated costs in a given year, and present value of costs.

Source: HDR, 2017.

Table 10–15. Capital Cost Outlay for MDCT Implementation

Timeframe	Calendar Year	Year	Plume-abated MDCT Implementation	Cost if Implemented in 2017 ($ million)	Costs in a Given Year ($ million)	Present Value ($ million)
February 2018	2018	0	Submit NPDES renewal application and 316(b) information			
August 2018	2018	0.5	Permit expiration			
February 2019	2019	1	Final BTA determination			
August 2019	2019	1.5	Engineering Contract	$2.93	$3.11	$2.72
February 2020	2020	2	30 percent design	$6.51	$7.11	$5.83
August 2020	2020	2.5	Site investigations: geotech borings, soil and topographic surveys; permit applications	$5.28	$5.77	$4.73
February 2021	2021	3	Permitting; 60-percent design; procurement contracts	$10.51	$11.83	$9.09
August 2021	2021	3.5		$2.93	$3.30	$2.53
February 2022	2022	4	95-percent design	$4.72	$5.47	$3.93
August 2022	2022	4.5	Bid construction; select contractor; general conditions, prep, and local permits	$18.75	$21.74	$15.64
February 2023	2023	5	Construction	$117.54	$140.35	$94.52
August 2023	2023	5.5		$64.94	$77.54	$52.22
February 2024	2024	6	Commissioning	$2.93	$3.60	$2.27
	2034	16	Replace fill	$5.16	$8.53	$2.78

Source: HDR, 2017.

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FILED: JUNE 8, 2021

10.3.11.5 Social Cost (Annual and NPV)

The estimated social costs for a closed-cycle cooling retrofit range from $242.5M (7 percent discount rate) to $399.4M (3 percent discount rate) (Table 10-16).

Table 10–16. Total Social Costs of Retrofit to MDCT

Discount Rate (%)	Electricity Price Increase (million)	Fuel Costs* (million)	Externality Costs (million)	Permitting Costs* (million)	Total Social Costs (million)	Annual Social Costs (million)
3	$190.3	$160.7	$110.7	$2.5	$399.4	$20.0
7	$107.5	$160.7	$81.6	$2.5	$242.5	$12.1

*Permitting and fuel costs presented are undiscounted and in 2017 dollars.

Source: HDR, 2017.

10.3.12 Uncertainty

Key uncertainties associated with the MDCT evaluation include:

- Underestimating potential interference with existing buried infrastructure along hot and cold water channels.
- Costs of hot and cold water channels is based on the necessary length of pipe, and site-specific geotechnical evaluation or pipeline alignment has not be performed for this project.
- Permitting timelines associated with the NPDES renewal and permitting of new infrastructure can shift the overall construction schedule, which would have cost implications.
- This evaluation assumed that no hazardous materials would be encountered.
- Except for dechlorination (whenever the circulating flow is chlorinated for biofouling), the blowdown would not need to be treated prior to discharge.
- The concept designs for MDCTs have been based on specifications for the original condensers and pumps. Whether pumps and condensers still operate per the original specifications is unknown.
- There is an airport, an industrial complex and access road near Bayside. This evaluation assumed that the plume from the hypothetical standard MDCT would not have an impact on these spaces. Use of plume-abated MDCT would increase project cost and schedule.

10.4 FMS

10.4.1 Narrow–slot Cylindrical Wedgewire Screens

Narrow-slot wedgewire screens represent a potential approach to entrainment BTA under the rule. This technology has a typical design intake velocity of 0.5 fps or less, when used at power-plant intakes. With a velocity of 0.5 fps or less these screens would achieve impingement mortality BTA, under IM Compliance Approach 2.

Cylindrical wedgewire screens, including narrow-slot screens have been successfully used at a relatively limited number of marine/estuarine facilities, particularly at the scale of Bayside. Environmental conditions at marine and estuarine facilities present a myriad of issues that need to be addressed in order for a successful wedgewire screen installation and operation.

10.4.1.1 Description of Hypothetical Wedgewire Arrangement

A conceptual wedgewire arrangement was developed for screens with 2.0 mm slot openings, the largest opening classified by EPA as fine-mesh. Finer slot sizes are available but space requirement, biofouling and debris loading concerns are more severe with the smaller slots. Therefore, 2.0-mm slot openings are considered as a means of evaluating the overall feasibility of wedgewire screens as well as comparing them to fine-mesh traveling screens as described above. The 2-mm slot screens will however, exclude a lower proportion of organisms than either wedgewire or on a TWS, equipped with 0.5-mm mesh openings.

Fifteen 7-ft diameter wedgewire tee-screens with 2.0-mm slot widths would be necessary to screen the flow for Bayside Units 1 and 2 and achieve intake velocities of less than 0.5 fps. An extra screen was included in the design to balance the flow between the header pipes. The sixteen screens would be divided between four manifolds. The manifolds would be grouped in pairs and connect to a 12-ft diameter header pipes that would direct flow to a sheet pile plenum constructed in front of the existing CWIS. A plan of the wedgewire layout is provided on Figure 10-19. This wedgewire layout is intended for illustrative purposes only because wedgewire screens are not expected to be feasible at Bayside.

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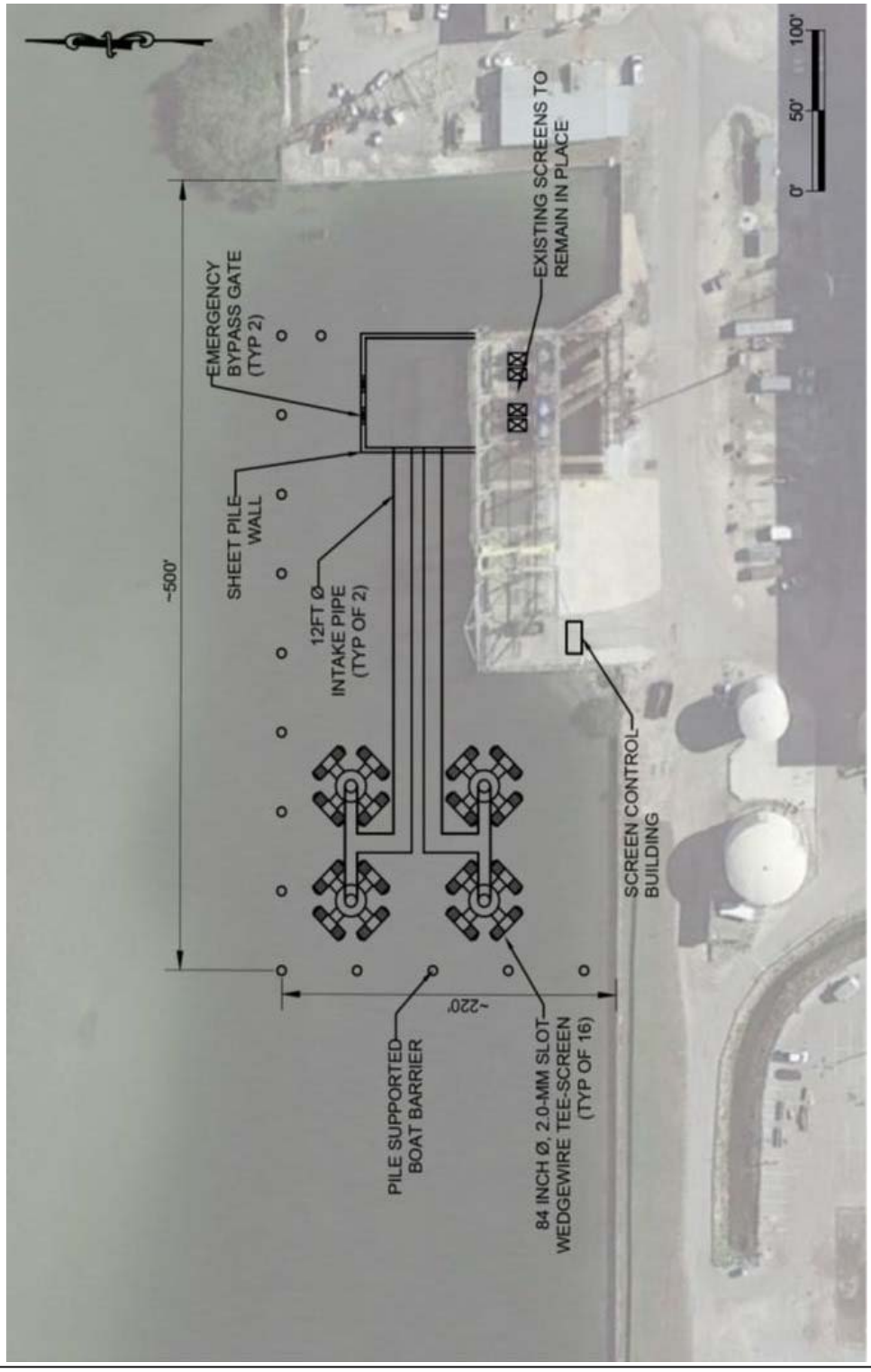


FIGURE 10-19.

2.0-mm WEDGEWIRE SCREEN ARRAY FOR BAYSIDE

Source: Alden, 2017.

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10.4.1.2 Feasibility Discussion

The major concerns that need to be considered when determining the feasibility of a wedgewire screen installation at Bayside include; lack of a sweeping current, potential for debris accumulation, clogging and screen maintenance, anticipated sedimentation, biofouling, organism attraction, corrosion, and navigational hazards. These issues are discussed in the sections below.

Sweeping Currents and Debris

A sweeping current is recommended with wedgewire screens to effectively transport organisms and debris past the screens. The debris load at Bayside mainly consists of floating garbage and typically includes oyster and mussel shells, leaves, twigs, sticks, horseshoe crabs, grass and algae. Based on laboratory evaluations, velocities as low as 0.25 fps are capable of carrying debris removed from the screens a sufficient distance to avoid re-impingement following cleaning. At estuarine facilities such as Bayside, tidal currents are typically the driving force behind sweeping flows. The location and arrangement of the Bayside CWIS are expected to result in sweeping velocities well below 0.25 fps.

Any wedgewire screen installation at Bayside would be located within the intake canal as placement in deeper water to the west would present an unacceptable impediment to navigation. This canal is fairly small, extending approximately 1,500 ft past the potential wedgewire deployment area, with a surface area of approximately 9.4 acres. The downstream portion of the intake canal and area used for estimating the surface area are shown in Figure 10-20. The invert at the canal near any potential wedgewire screens was assumed to be maintained at El. -24.5 ft, for approximately half the canal width. The other half of the canal was assumed to slope from El. -24.5 ft to El. 0.0 ft.



FIGURE 10-20.

AREA OF THE INTAKE CANAL USED FOR ESTIMATING TIDAL FLOW AND VELOCITY AT THE WEDGEWIRE SCREENS

Source: Alden, 2017.

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TAMPA ELECTRIC COMPANY
DOCKET NO. 20210087-EI
STAFF'S FIRST DATA REQUEST
BATES PAGES: 4 - 968
FILED: JUNE 8, 2021

A rough estimate of the average tidal velocity within the canal was developed to determine the ability of the currents to transport debris past a wedgewire screen deployment. The tidal velocity was estimated using the geometry of the canal, the great diurnal range of 2.67 ft for tides measured at the McKay Bay entrance (NOAA Station ID: 8726667), and an ideal semi-diurnal tide (two high waters and two low waters in 24 hours). NOAA Station 8726667 was selected because the station is located less than a half mile from the entrance to the intake canal. Using this information, the average tidal velocity was estimated to be 0.01 fps within the intake canal near the CWIS. This velocity is an order of magnitude less than the minimum velocity demonstrated to be capable of carrying debris removed from the screens past the screens and is not expected to be sufficient to transport debris past a wedgewire screen array installed within the intake canal.

The estimated tidal velocity is also an order of magnitude less than the estimated canal velocity resulting from the intake withdrawal (0.11 fps), therefore any debris that enters the canal is expected to become entrapped within the intake canal. The entrapment of debris within the intake canal is currently mitigated by the use of TWS that collect and remove the debris, so it can be properly landfilled. Wedgewire screens do not include any means to collect and remove the debris. Overtime this will lead to an accumulation of debris around the screens. As the debris loading in the canal increases the ability of a screen to maintain the through-screen velocity (TSV) required for compliance will be reduced.

Without the presence of sufficient sweeping currents to move debris past the screens, or the ability of the tidal currents to flush debris from the intake canal, the ability to maintain a wedgewire array at Bayside is highly suspect. Debris loading on the screens will lead to increased head losses, eventually resulting in damage to the circulating water pumps and screens, reducing overall station reliability.

Similarly, any non-motile organisms, including eggs and larvae, that encounter the screens will have little water velocity to move them off of and away from the screen. While not essential to entrainment and impingement performance of wedgewire screens, a sweeping velocity is very likely to improve that performance.

Clogging and Screen Maintenance

The wedgewire screen system design is based on a through screen velocity of 0.5 fps at design flow rates. Additional factors related to screen capacity for clogging and screen maintenance would need to be considered if this technology were required to be installed at Bayside. Screen clogging/fouling and maintenance would decrease the available area for through-screen flow. The margin for blockage factor (20 to 30 percent±) and screen maintenance (approximately 10 to 20 percent±) would result in the inclusion of additional screens and associated air purge systems.

Dredging and Sediment

The Bayside intake canal is 25 to 30 ft deep near the entrance to the CWIS with an invert at El. -24.5 ft at the existing CWIS. Sedimentation within the canal is a concern requiring TECO to actively maintain those depths. Sediment buildup in and around the screens, is a common concern at wedgewire screen installations. Unchecked, sediment deposition can lead to screens becoming buried. In riverine locations, where there is a constant sweeping flow, sediment sluicing systems have been successfully used to reduce siltation around the screens. As discussed earlier, currents in the intake canal are dominated by the station withdrawal, with only a minimal sweeping current present. Without a dominant sweeping current, a sediment sluicing system is not expected to be an effective means of reducing silt buildup around the wedgewire screens. Regular dredging around the screens would therefore be necessary to prevent sedimentation of the screens. Removing sediment around the screens would require diver operated suction dredging to avoid damaging the screens or intake pipes. This type of dredging is very labor-intensive and may require Bayside to be shutdown to prevent large amounts of sediment from entering the circulating water system.

Biofouling

Asian green mussels (*Perna viridis*) are prevalent in Tampa Bay. This invasive species tends to grow on hard surfaces and their colonization has led to operational impacts at a power plant and desalinization facility in Tampa Bay. Biofouling of both the wedgewire screens and intake piping by Asian green mussels and other organisms is a concern at Bayside. The most common method of controlling biofouling of circulating water systems is through the use of chemical biocides. Bayside currently regularly uses biocide (Spectrus®) in the cooling water system under very specific fee conditions to control mussels as approved in the current NPDES permit. Wedgewire

screens will likely require a substantial increase in the use of biocide to control biofouling at the screens that may be prohibitive.

Recent developments in wedgewire screen cleaning systems, such as brush-cleaned screens that physically brush along the internal and external components of the screen surface, have shown potential for preventing bio-growth on the surface of wedgewire screens in freshwater environments with high biofouling potential. Unfortunately, there is limited publicly available data on the ability to reduce biofouling issues in marine and estuarine environments. The physical brushing of the screen surface is expected to result in a similar reduction in bio-growth of the screen surface.

A brush cleaning system would not prevent bio-growth on internal screen components and distribution piping. Materials such as copper alloys are commonly used for to reduce biofouling in marine environments. Copper alloys prevent bio-fouling by forming a thin film of copper-oxides, a biocide, at the water metal interface. Once developed this film reduces the rate of copper reduction of the screens and therefore the amount of copper present in the discharge. However, cleaning of the screen would remove a portion of this film releasing copper oxides from the screens increasing the amount of copper in the discharge water. The amount of copper released by these screens has not been estimated but is not in line with efforts to reduce copper concentrations within Tampa Bay, therefore the use of copper alloys is not considered feasible at Bayside.

New super slick coatings have been used to reduce the attachment strength of biofouling agents on boat hulls and show potential for use as a coating for internal screen components and pipes. There are very limited data on their use for this application and additional testing would be required to determine their effectiveness on the bio-fouling community at Bayside. Thus, this is not considered a proven technology for this purpose.

Biofouling of wedgewire screens and associated piping are a major concern with any potential wedgewire deployment at Bayside. Recent advances in screen cleaning technology and antifouling coating have the potential to limit the impact of biofouling, but they are untested in the estuarine environments similar to those at Bayside. A site-specific pilot study would be

needed prior to determining if biofouling of cylindrical wedgewire screens and associated piping can be practicably managed and controlled. Without a site-specific study, the feasibility of controlling biofouling on a wedgewire screen deployment at Bayside cannot be determined.

Organism Attraction

The wedgewire screen array and intake tunnels will result in an artificial structure along the bottom the intake canal. This structure would act like an artificial reef, providing habitat that attracts a variety of species. The higher abundance of organisms within close proximity of the screens may result in more organisms being susceptible to entrainment.

Corrosion

Metals are prone to corrosion when exposed to saltwater. The rate of corrosion varies depending on the metal, with stainless steel being less prone to corrosion when compared to other metals such as copper and copper alloys. Over time this corrosion can lead to premature screen failure or replacement. Cathodic protection from sacrificial anodes, attached to the screen and other submerged equipment, will be needed to reduce corrosion on a wedgewire screen array at Bayside. These anodes would be inspected regularly and replaced as necessary. While corrosion can be an issue, neither potential corrosion, nor the effort require to inspect and replace the sacrificial anodes will preclude the use of wedgewire screens at Bayside.

Navigation

The wedgewire installation presented in Figure 10-19 is located near the terminus of the intake canal. At this location, the wedgewire screens are not expected to interfere with use of the docks located at the mouth of the canal. A boat exclusion zone around the screens would limit boat access to the end of the canal.

10.4.1.3 Uncertainty

There are many uncertainties and barriers that make the use of wedgewire screens infeasible at Bayside as described above such that wedgewire screens are not considered further in the assessment of technologies. While there are some uncertainties as to how wedgewire screens would behave, their performance, maintenance and costs relative to FMS is clear. This includes

the long-term successful application of such a system at Big Bend Unit 3 and 4. Therefore, wedgewire screens were eliminated from consideration.

10.4.2 Fine-mesh Modified TWS and a Fish Return System

10.4.2.1 Feasibility Discussion

Fine-mesh modified TWS with fish protection features could be installed at Bayside to reduce entrainment. TWS modified with fish protection features (also known as modified-Ristroph or Ristroph-type screens) are one of the most commonly used technologies for reducing adverse environmental impacts at CWISs. The new screens would include the BTA features identified in 40 CFR 125.92(s), including fish lifting buckets, low-pressure spray washes, and capacity for continuous or near-continuous rotation. These screens can be equipped with fine-mesh when entrainment reductions are sought. A section showing some of the fish protection features of a typical Ristroph-type screen is shown on Figure 10-21. These same fish-friendly features area available on dual-flow screens similar to what is currently installed at Bayside.

Fine-mesh material would be needed with the fish-friendly screens to reduce entrainment. Fine-mesh typically refers to screen meshes with 2.0 mm or smaller openings. The exact mesh size (e.g., 0.5 to 2.0 mm) is dependent on the species and life stages to be protected. For Bayside only 0.5-mm mesh screens were evaluated because this mesh size is considered BTA for Big Bend's Units 3 and 4. The Big Bend FMS system has been in operation under conditions similar to those at Bayside since the early 1980s so its feasibility and reliability as well as the costs of maintenance are well understood. The Big Bend FMS system at Units 3 and 4 also provides a robust, water body-specific data set on the effectiveness (both exclusion rate and survival) of such a system. Finally, a finer mesh size will likely result in exclusion of a wider suite of organisms at a relatively modest increase in costs.

At Bayside, three potential fine-mesh traveling water screen option were evaluated to determine their feasibility.

- Retrofit the existing intake with fish-friendly TWS with fine-mesh overlays and a fish return.

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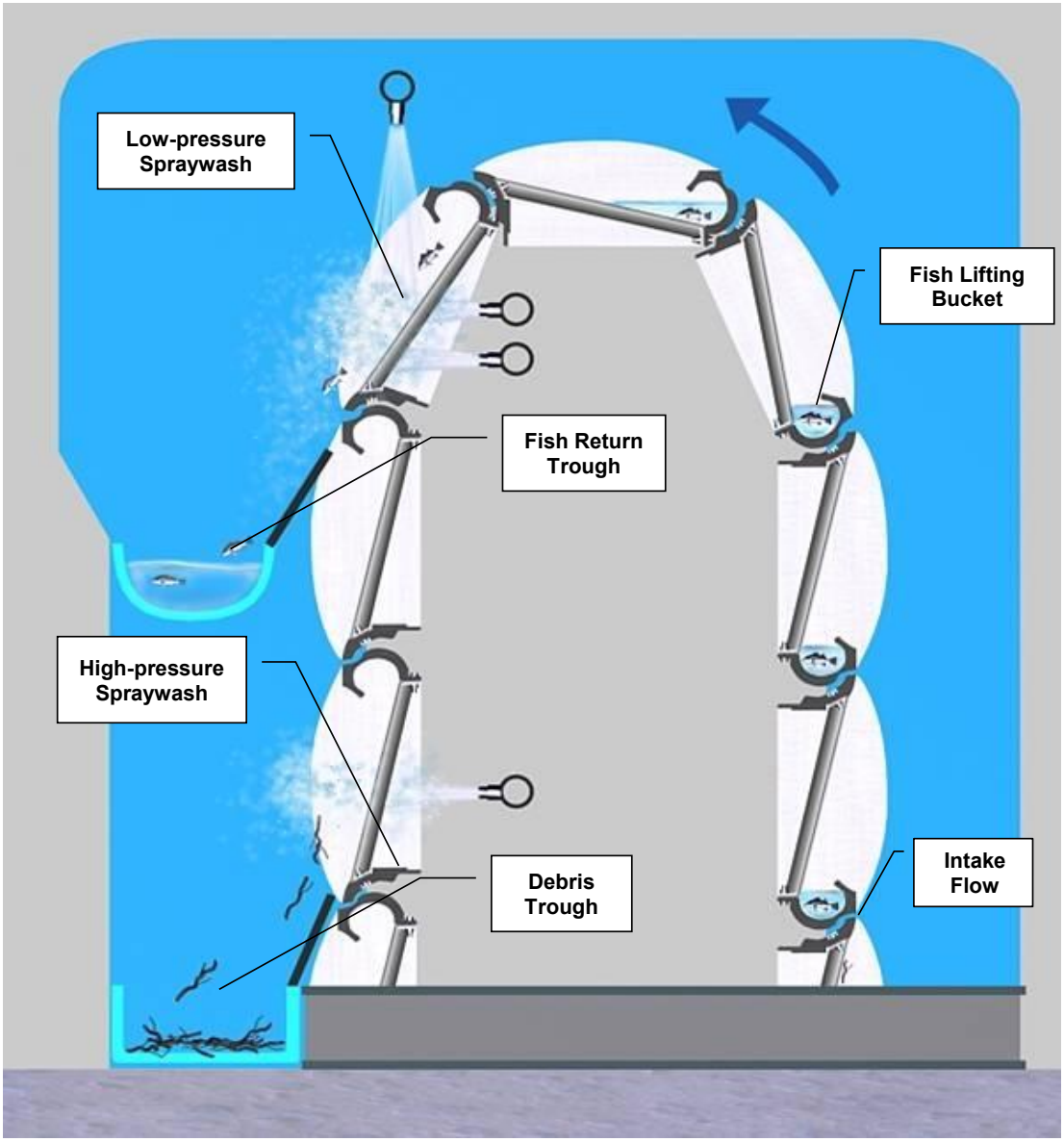


FIGURE 10-21.

TYPICAL FISH-FRIENDLY FEATURES OR A MODIFIED TWS

Source: CTI, 2010.

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- Expand or replace the existing intake with a new intake designed for full-time or seasonal fine-mesh use and an approximately 0.7-fps screen approach velocity (similar to the velocity at Big Bend Units 3 and 4).
- Expand or replace the existing intake with a new intake designed for full-time fine-mesh and a 0.5-fps TSV to meet IM BTA Approach 2.

Fine-mesh TWS typically result in an increase in clean screen head loss compared to coarse-mesh screens. The finer mesh would collect more debris than a coarse-mesh screen, further increasing the potential head loss across the screen. However, this increase in head loss would be partially mitigated by the improved cleaning efficiency associated with smoother mesh and continuous or near-continuous screen rotation. The estimated TSV during extreme low water levels through the existing screens and the potential 0.5 mm mesh fish-friendly screens mesh retrofit options are provided in Table 10-17. TSV were estimated for the screens under clean conditions, with 25 percent debris blockage and 50 percent debris blockage. The head loss for each of the potential retrofit alternatives at the three debris loadings is provided in Table 10-18.

Table 10–17. Estimated TSV for New Fish-friendly Screens with Fine Mesh during Extreme Low-water Level (Elevation -5.0 ft) at Bayside

Option	Mesh Size	Mesh Open Area	Approach Velocity (fps)	TSV (fps)		
				Clean Screens	25% Blocked Screens	50% Blocked Screens
Unit 1 existing*	⅜-inch square	61%	1.0	1.6	2.1	3.2
Unit 2 existing†	⅜-inch square	61%	1.6	2.6	3.5	5.2
0.5 mm in Unit 1 existing (full time fine-mesh)*	0.5 mm	48%	1.0	2.0	2.7	4.1
0.5 mm in Unit 2 existing (full time fine-mesh)†	0.5 mm	48%	1.6	3.3	4.4	6.7
0.5 mm in Unit 1 existing (overlay mesh)*	0.5 mm	29%	1.0	3.3	4.4	6.7
0.5 mm in Unit 2 existing (overlay mesh)†	0.5 mm	29%	1.6	5.5	7.3	10.9
0.5 mm with 6 screens‡	0.5 mm	48%	0.6	1.2	1.7	2.5
0.5 mm with 0.5-fps TSV‡	0.5 mm	48%	0.2	0.5	0.6	0.8

*Based on Unit 1 design flow of 176,000 gpm.
†Based on Unit 2 design flow of 287,986 gpm.
‡Based on a combined design flow of 463,986 gpm.

Source: ECT, 2018.

Table 10–18. Estimated Pressure Loss for New Fish-friendly Screens with Fine Mesh during Extreme Low-water Level (Elevation -5.0 ft) at Bayside

Option	Mesh Size	Mesh Open Area	Approach Velocity (fps)	Pressure Loss (ft)§		
				Clean Screens	25% Blocked Screens	50% Blocked Screens
Unit 1 existing*	⅜-inch square	61%	1.0	0.2	0.3	0.5
Unit 2 existing†	⅜-inch square	61%	1.6	0.6	0.8	1.3
0.5 mm in Unit 1 existing (full time fine-mesh)*	0.5 mm	48%	1.0	0.4	0.5	0.9
0.5 mm in Unit 2 existing (full time fine-mesh)†	0.5 mm	48%	1.6	1.0	1.3	2.3
0.5 mm in Unit 1 existing (overlay mesh)*	0.5 mm	29%	1.0	1.0	1.3	2.3
0.5 mm in Unit 2 existing (overlay mesh)†	0.5 mm	29%	1.6	2.6	3.5	6.2
0.5 mm with 6 screens‡	0.5 mm	48%	0.6	0.1	0.2	0.3
0.5 mm with 0.5-fps TSV‡	0.5 mm	48%	0.2	0.01	0.02	0.04

*Based on Unit 1 design flow of 176,000 gpm.
†Based on Unit 2 design flow of 287,986 gpm.
‡Based on a combined design flow of 463,986 gpm.
§4. Discharge Coefficients vary and are based on the design of the current Bayside and Big Bend fish-friendly screens.

Source: ECT, 2018.

Larval and early juvenile fish exclusion and survival on fine-mesh (≤2.0 mm) TWS as well as transport through fish return systems have been evaluated in several EPRI studies (EPRI, 2009a, 2009b, 2010, 2012). Among the species tested, fish that were 12 mm or greater in total length consistently showed high post-collection survival regardless of species, screen type, or approach velocity. The increased survival of fish 12 mm and greater appears to be correlated to scale development and general increase in body musculature. Post-collection survival of smaller (less than 12 mm) larval fish was generally poor (approximately 30 percent). This is largely because the larval fish are extremely fragile immediately following hatching in addition to the fact that normal survival for these early life stages is very low.

Screen approach velocity up to 1.5 fps had no or only minor effect on post-collection survival of the larger (≥ 12 mm) larvae tested during an EPRI sponsored fine-mesh fish-friendly screen laboratory study (EPRI, 2010). This is consistent with the findings of EPRI sponsored coarse-

mesh, fish-friendly screen laboratory studies (EPRI, 2006; Black, 2007) that reported approach velocities did not appear to affect post-impingement survival of juvenile and adult fish, ≥50 mm, over a range of 1 to 3 fps tested. During low water levels (Elevation [El.] -5 ft), the velocities approaching the existing TWS range from 1.0 fps for Unit 1 to 1.6 fps for Unit 2. The survival of smaller larvae (less than 12 mm) is expected to be low for both intakes. The higher velocity approaching the Unit 2 screens may also reduce the biological efficacy of larger larvae (≥12 mm). While these data are presented here in order to provide perspective on the selection of the FMS configuration, more specific data on organism exclusion and post-exclusion survival is presented in the section prepared under 40 CFR 122.21(r)(11).

The estimated TSV and head loss across the screen will be used to evaluate the various fine-mesh traveling screen options and select the ones that are most feasible and likely to have acceptable biological performance. As general guidelines, head loss across the screen should be minimized to the maximum extent possible and TSV should be maintained at less than 3 fps.

Fine-mesh Fish-Friendly TWS in the Existing Screen Bays

Four new fine-mesh, fish-friendly TWS could be installed in the existing screen bays, replacing the existing TWS. An organism return system would be installed along with the new screens to safely return fish back to the source water body. The fish-friendly features of these screens along with the organism return would meet the IM BTA requirements of IM BTA Approach 5. The fine-mesh used for these screens could be installed on either a full-time basis or seasonally using fine-mesh overlay panels. Full-time fine-mesh would increase the clean TSV to 2.0 fps for Unit 1 and 3.3 fps for Unit 2. Adding overlay panels to a coarse-mesh, fish-friendly screen would increase the TSV to 3.3 fps for Unit 1 and 5.4 fps for Unit 2. The FMS at Big Bend Units 3 and 4 have a TSV of 1.5 fps. The TSV at Big Bend is less than any of the FMS in the existing intake bay options at Bayside by a range of 0.5 fps to 3.9 fps. Increasing the TSV and, therefore, head loss across the screens, would increase the stress on the screens, motors and mesh. Additionally, FMS in the existing intake are not likely to have the same biological effectiveness as screens designed for lower velocities.

Operation and maintenance concerns limit the feasibility of full-time FMS at Bayside. If the FMS foul or are damaged with this option, there would be no redundant screening in place. This

can lead to both fish and debris interacting with the circulating water pumps and condenser cooling system leading to operational and performance issues. For full-time FMS to be considered feasible for application at Bayside, a redundant screening system would be necessary to ensure station reliability. This requirement has been demonstrated at Big Bend Units 3 and 4 where, with agreement of FDEP, a FMS may be removed from service for repair. This is possible at Big Bend because a set of coarse-mesh screens, located downstream of the FMS, can remove debris from the intake stream allowing continued unit operation.

Use of seasonal fine-mesh panels overlaying a coarse-mesh reduces the need for redundant screens because the coarse-mesh backing would provide screening if the fine-mesh is damaged. Replacing damaged fine-mesh panels and seasonal installation and removal of the fine-mesh can be completed without impacting unit operations, by manually rotating the screens so that the fine-mesh panel to be replaced is accessible. The use of a coarse-mesh backing would reduce the overall open area of the screens, exacerbating operating issues resulting from increased head loss as the FMS material begins to foul. Under clean conditions the head loss through the Unit 1 screens would be approximately one foot, which is 0.8 ft higher than current conditions. For Unit 2 the head loss through clean screens would be approximately 2.6 ft, 2 ft higher the existing conditions. The increase in head loss under clean conditions reduces the level of debris loading that the screens can effectively handle before screen failure and/or insufficient pump submergence occurs. Both of these scenarios would result in station reliability issues.

Based on the potential for both reduced biological performance and station reliability issues, adding FMS to the existing screen bays is not considered feasible at Bayside.

For FMS to be considered feasible for application at Bayside, additional screens would be necessary to reduce the TSV and therefore head losses across the screens. There is insufficient space for additional screens without expanding the intake outward, similar to the redundant screening system Big Bend Units 3 and 4. The use of FMS alone is considered less reliable than expanding the intake to lower the screen approach velocity, while providing redundant screens, because it would not allow damaged screens to be removed from service without impacting station reliability and generation. The option of expanding the intake with FMS while

maintaining redundant coarse-mesh screens is carried forward to address both biological performance and station reliability issues.

Fine-mesh Fish-friendly TWS Designed for a 0.5-fps or Less TSV

This option has the potential to address entrainment by excluding and returning aquatic organisms using 0.5 mm FMS. The excluded organisms would be returned to the source water by an organism return system. Expanding the Bayside CWIS to achieve a 0.5 fps or less TSV with fish-friendly TWS would allow TECO to meet the velocity requirements of IM BTA Approach 2. From an IM-compliance standpoint this alternative is advantageous compared to installing screens with a higher TSV since TECO would not be required to conduct any long-term impingement or velocity monitoring to demonstrate compliance. The lower velocity will also reduce the stresses on both the screens and the mesh, reducing potential operational issues. As noted below, this configuration is likely to be subject to substantial regulatory constraints in the form of Section 404/10 permitting by the FDEP and US Army Corps of Engineers (USACE). USACE approval will be challenging for this option because of the potential magnitude of loss of waterways anticipated by this design. While the design may be infeasible from a regulatory point of view, it is provided here to illustrate what would be necessary to achieve a design intake velocity of less than 0.5 fps while using FMS.

The Bayside intake canal is approximately 400 ft wide near the existing CWIS, limiting the space available for a new intake structures. The new screens would be spaced every 20 ft on-center, 10 ft less than the spacing of the Big Bend screens, to accommodate the number of screens necessary to achieve a 0.5 fps TSV within the confines of the intake canal. The hydraulic conditions approaching the screens would need to be investigated to determine if the spacing is sufficient to provide fairly uniform flow (i.e., velocity) through the screens. Poor screen hydraulics can lead to localized velocities that exceed 0.5 fps, uneven loads on the screens and motors, and reduced screen service life. Costs for a computational model study of this alternative are included in the overall cost estimate. If the results of this model study indicate unsatisfactory hydraulics conditions for this option, reducing the TSV to 0.5 fps or less using an expanded intake structure would no longer be considered a feasible option.

Design—Eighteen, 10 ft wide fish-friendly dual-flow screens with 0.5-mm mesh would be required to meet the 0.5-fps velocity criterion during extreme low water levels (El. -5.0 ft). This design assumes 15 percent screen blockage, providing a factor of safety to reduce the potential for exceeding a 0.5-fps TSV under normal operating conditions. This extra capacity also allows one to three of the screens to be removed for maintenance without exceeding the velocity criterion. In addition to the 18 in-service screens, three additional screens are included in the overall costs estimate. These screens would be stored on the intake deck and used as replacement screens when in-service screens are removed for major overhauls or other repairs.

No-well screens, similar to the existing Bayside screens and the fish-friendly screens installed at Big Bend, were assumed for this alternative to reduce the costs for the screen support structure. In addition to fine-mesh these screens would include all the fish-protection features identified in the previous section. The new screens would have heavy-duty mechanical components to allow for continuous or near continuous operation and include a new control system. Based on the screen manufacturers' recommendations and TECO's operating experience at Big Bend, each screen would be scheduled to be removed every six years for a major overhaul. Additionally, approximately 25 percent of the fine-mesh material is expected to need replacement every year, similar to operations at Big Bend.

The new intake structure would be 365 ft long with an invert at El. -24.5 ft. This intake structure would be oriented north-south to reduce the amount of dredging needed to obtain a sufficient screen depth. The new intake would include a work deck designed for light vehicle access. A crane would span the entire length of the structure to install and remove the screen, spray wash pumps and other large ancillary equipment. A sheet pile wall would extend from the northern corner of the new intake structure to the existing sheet pile wall, to the east, to isolate the flow through the screens from the source water body. The new intake structure and large plenum created behind the screens would eliminate approximately 3.2 acres of bottom habitat within the intake canal. Loss of bottom habitat at this scale is likely to introduce a challenging permitting obstacle that may make this option essentially infeasible. The new CWIS is shown on Figure 10-22.

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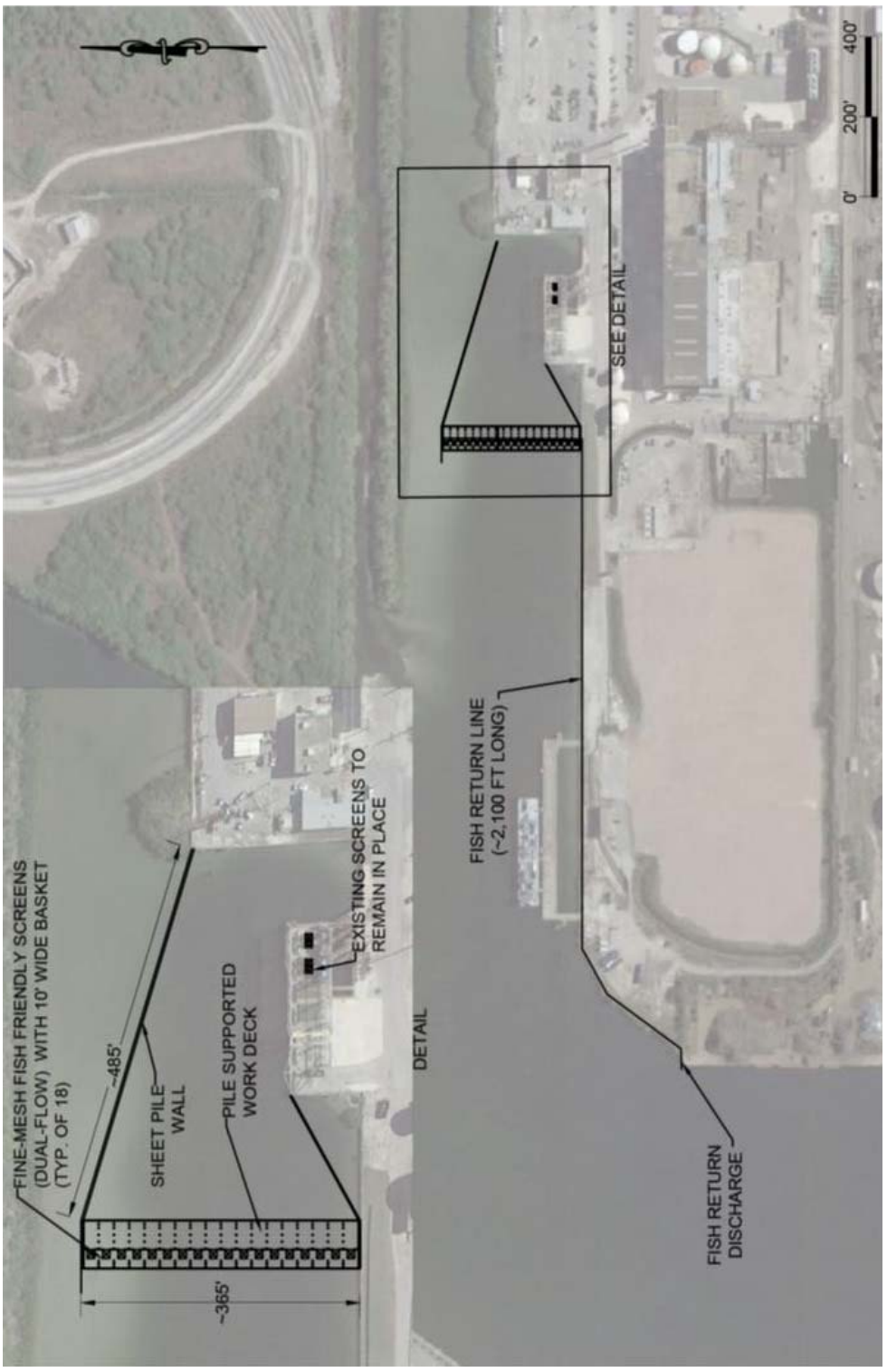


FIGURE 10-22.

CONCEPTUAL DESIGN FOR NEW INTAKE DESIGNED FOR FMS WITH A 0.5-FPS TSV AND NEW FISH RETURN – PLAN

Source: Alden, 2017.

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Fish and debris removed by the low-pressure spray washes would flow into a fish trough located above the debris trough. Auxiliary water would be added to the upstream end of the fish return trough to provide a water cushion for fish removed from the screens. Debris removed by the high-pressure debris wash would flow into a separate debris trough. The flow in the debris trough would be screened downstream of the last screen and the filtered flow combined with the flow in the fish trough. A 3-ft diameter U-shaped trough was assumed for this option based on a flow of 17.4 cfs (7,830 gpm) the combined low- and high-pressure spray wash volumes including an additional 180 gpm of auxiliary water. The combined fish and debris trough would be gravity driven, dropping approximately 7 ft from El. 10 ft to El. 3 ft over a 2,100 ft length. Water in the trough would have a flow depth of approximately 16 inches and a velocity of 5.6 fps. The new trough would be mounted to the sheet pile wall that forms the southern edge of the intake canal. After leaving the new CWIS the fish and debris trough would turn west then south following the edge of the intake canal, discharging outside of the intake canal. Grating placed over this section of the fish return would prevent avian and mammalian predation within the trough. A more detailed fish-return evaluation would be necessary to refine the fish and debris return layout and verify that ambient currents at the discharge location are sufficient to prevent re-impingement.

Construction—Prior to installation of the new intake structure the intake canal should be dredged down to a depth of El. -24.5 ft. Once the area is dredged the sheet pile wall and support piles would be installed. The sheet piling wall would be constructed out of two rows of sheet piling filled with reinforced tremi concrete. Round driven piles would be used to support the work deck and crane supports, while H-piles would support the screen wells. H-piles were selected for the screen wells to allow specially designed bulkhead fittings designed to line up with the center opening of the new no-wells screens to be installed. Once the new access deck and crane are in place the bulkhead fittings, spraywash pumps and screens would be installed. The fish return trough would be constructed at the same time as the screen bays so that it is operational as screens are being installed.

Active construction of this option is expected to take 16 months. The overall schedule for this option including detailed design and engineering, permitting and construction is provided on

Figure 10-23. For this evaluation, Bayside is expected to continue operation throughout the entire construction period. If construction cannot be sequenced to eliminate any shutdowns, TECO would incur a substantial cost associated with not meeting its generation requirements.

O&M—O&M procedures for the new screens would be similar to those required for the existing TWS. The screens would be rotated and cleaned continuously during the main recruitment season,[23] March 15 through October 15 (as required at Big Bend Units 3 and 4), to reduce the impingement duration of entrainable-sized organisms. With a TSV of less than 0.5 fps impingement of healthy juveniles and adults should not occur, potentially allowing TECO to reduce the screen rotation schedule when entrainable organisms are not present. Plugging of the fine-mesh material would still be an issue, therefore a 50-percent duty cycle was assumed from September 16 through March 14. Power requirements to clean and operate the screens year-round would be approximately 4,681 MWh per year.

FMS use small diameter wires that are more prone to damage from debris and fouled spray wash nozzles and require additional effort to inspect and maintain. Based on historic operations at Big Bend, approximately 25 percent of the fine-mesh material would be replaced annually, and three screens would be removed each year for a major overhaul. Each major overhaul is estimated to cost $560,000. The screens removed as part of the major overhaul would be replaced with the spare screens. Once the repaired screens are returned they would act as the spare screens for the following year's replacement. Bio-growth on the installed screens would be controlled in-place using divers to hydro burst the screen frames. High pressure water would be used to remove bio-growth from the inside of the spray wash piping. The spray wash system to each screen would be shut down during the cleaning. The fish return line would be inspected and cleaned daily to prevent any debris plugging and to remove bio-growth. Regular inspection and maintenance of the new screens and fish return, including replacing 25 percent of the fine-mesh material annually is expected to cost approximately $350,000 per year. Sediment buildup is expected both in front of the screens and within the large plenum behind the screens. Annual dredging of these areas is expected to cost $220,000. This cost is based on the level of effort necessary to maintain the Big Bend intake.

[23] The Rule indicates nearly continuous rotation is acceptable apparently to allow for short-term maintenance activities.

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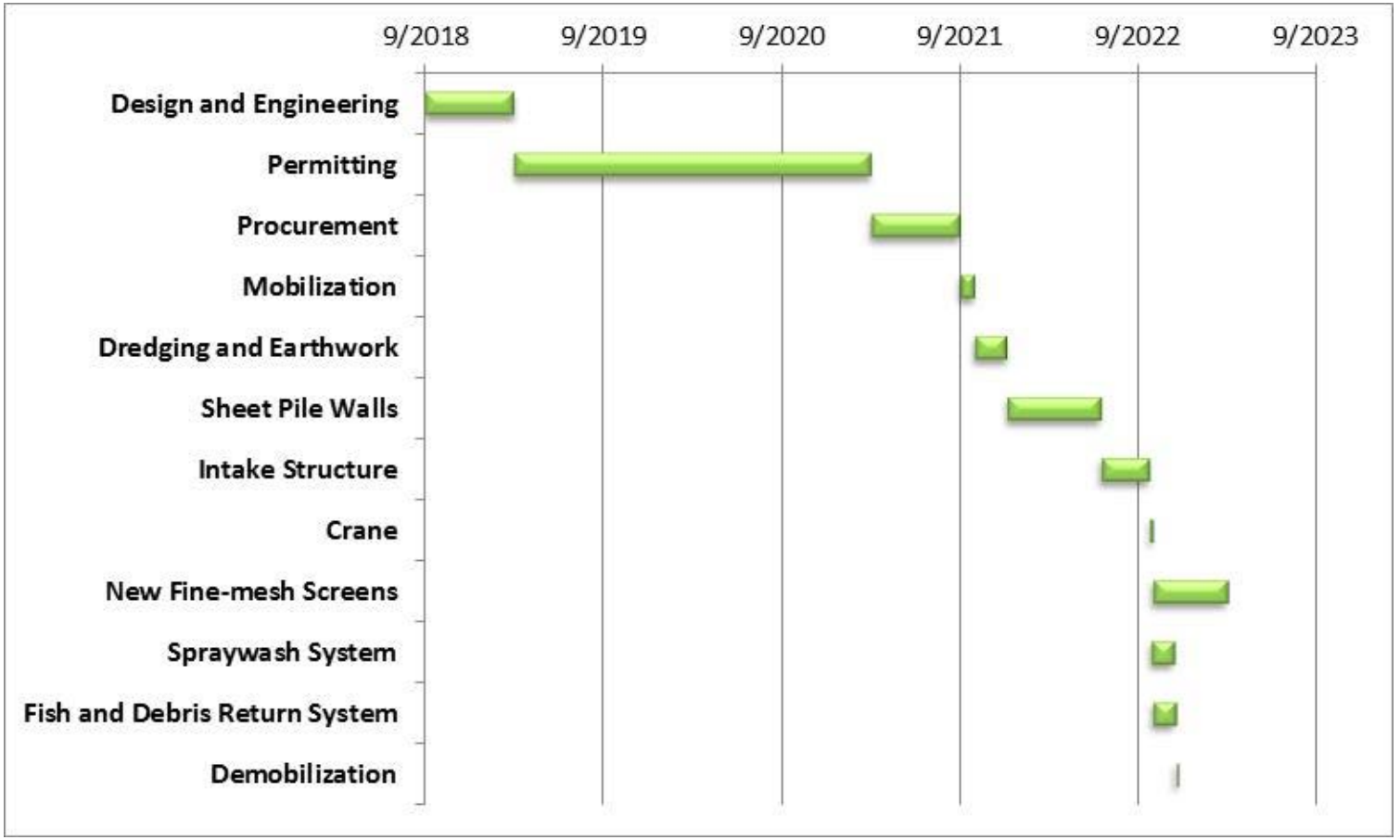


FIGURE 10-23.

CONSTRUCTION SEQUENCE NEW INTAKE DESIGNED FOR FMS WITH A 0.5-FPS TSV AND NEW FISH RETURN

Source: Alden, 2017.

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The existing TWS would remain in place to provide a redundant screening system if the FMS are damaged or need to be removed for maintenance. The existing screens were assumed to rotate for one hour per day to prevent fouling and ensure their operability. Maintenance requirements for the existing circulating water pumps with the fine-mesh TWS in place would not change from the existing requirements.

With both the fine-mesh and existing coarse-mesh screens installed, the clean screen head loss would increase less than one inch at the circulating water pumps. This change in head loss is not expected to impact the operation of the circulating pumps. However, hydraulic modeling of the intake with the new screens should be initiated to ensure balanced flow through the screens.

Fine-mesh Fish-friendly TWS Upstream of Coarse-mesh, Fish-friendly TWS

This option would rely on exclusion and return of entrainable sized organisms by FMS and an organism return system. IM BTA would be addressed under IM BTA Approach 5, fish-friendly screens and a fish return. This approach would rely on the screening strategy used at Big Bend Units 3 and 4 with the seasonal deployment of FMS at a new set of screens located upstream of the existing TWS. In order to fully address IM BTA Approach 5, the existing screens would be replaced with coarse-mesh, fish-friendly TWS and a return system to offer impingement protection when the FMS are not deployed.

This option incorporates two sets of fish-friendly TWS with six FMS located upstream of four new fish-friendly coarse-mesh screens, similar to the arrangement at Big Bend Units 3 and 4. This option would allow the FMS to be used from March 15 through October 15 when entrainment is a concern[24] and the coarse-mesh screens the remainder of the year. This option also provides TECO redundancy in their screening systems in the event that the FMS plug or are damaged. The TSV for both the fine- and coarse-mesh screens would be greater than 0.5 fps, therefore this option would not meet IM BTA Approach 2. Both the fine-mesh and coarse-mesh

[24] At both Bayside and Big Bend, the great majority of annual entrainment occurs from March 15 to October 15; see the reports prepared under 40 CFR 122.21(r)(9) and (11). In recognition of this, Big Bend Units 3 and 4 deploy their FMS system for these months alone.

screens would incorporate all the fish-friendly features, including a fish return, necessary to meet the BTA requirements of IM BTA Approach 5.

Design—The expanded intake structure would be designed for six, 10 ft wide fish-friendly no-well dual-flow screens with 0.5-mm mesh. The velocity approaching these screens would be approximately 0.6 fps during extreme low water levels (El. -5.0 ft), similar to the screen approach velocity at Big Bend Units 3 and 4. The screens would be spaced approximately 22 ft on-center, which is twice the screen basket width and is expected to result in fairly uniform flow approaching the screens. This spacing is 8 ft less than the screens at Big Bend, because the bypass gates would be located on the sides of the expanded intake, not between the screens as was done at Big Bend. As with the other expanded intake option, a hydraulic model study would be needed to verify suitable screen hydraulics. A 133-ft long intake structure with an invert at El. -24.5 ft would be needed to accommodate these screens and the screen lifting crane needed to install and remove the FMS. The expanded intake structure would extend the footprint of the existing intake by approximately 20 ft to both the north and east as shown in Figure 10-24.

The FMS would be mounted to custom bulkhead openings built into the sheet pile wall used to create a plenum between the fine- and coarse-mesh screens. This is similar to the system used for the expanded screens at Big Bend Units 3 and 4. This plenum would be 26 ft by 130 ft. Four emergency bypass gates build into the side wall of the plenum will allow the FMS to be bypassed if they cannot be maintained in a clean condition. These bypass gates could also be opened when the FMS are installed and removed to reduce the TSV and forces on the screens. As part of this option, the existing coarse-mesh TWS would be replaced with coarse-mesh, fish-friendly screens. The new coarse-mesh screens would be similar to the existing screens except they would include all the fish protection features identified in the previous section and required by the relevant parts of the 316(b) rule.

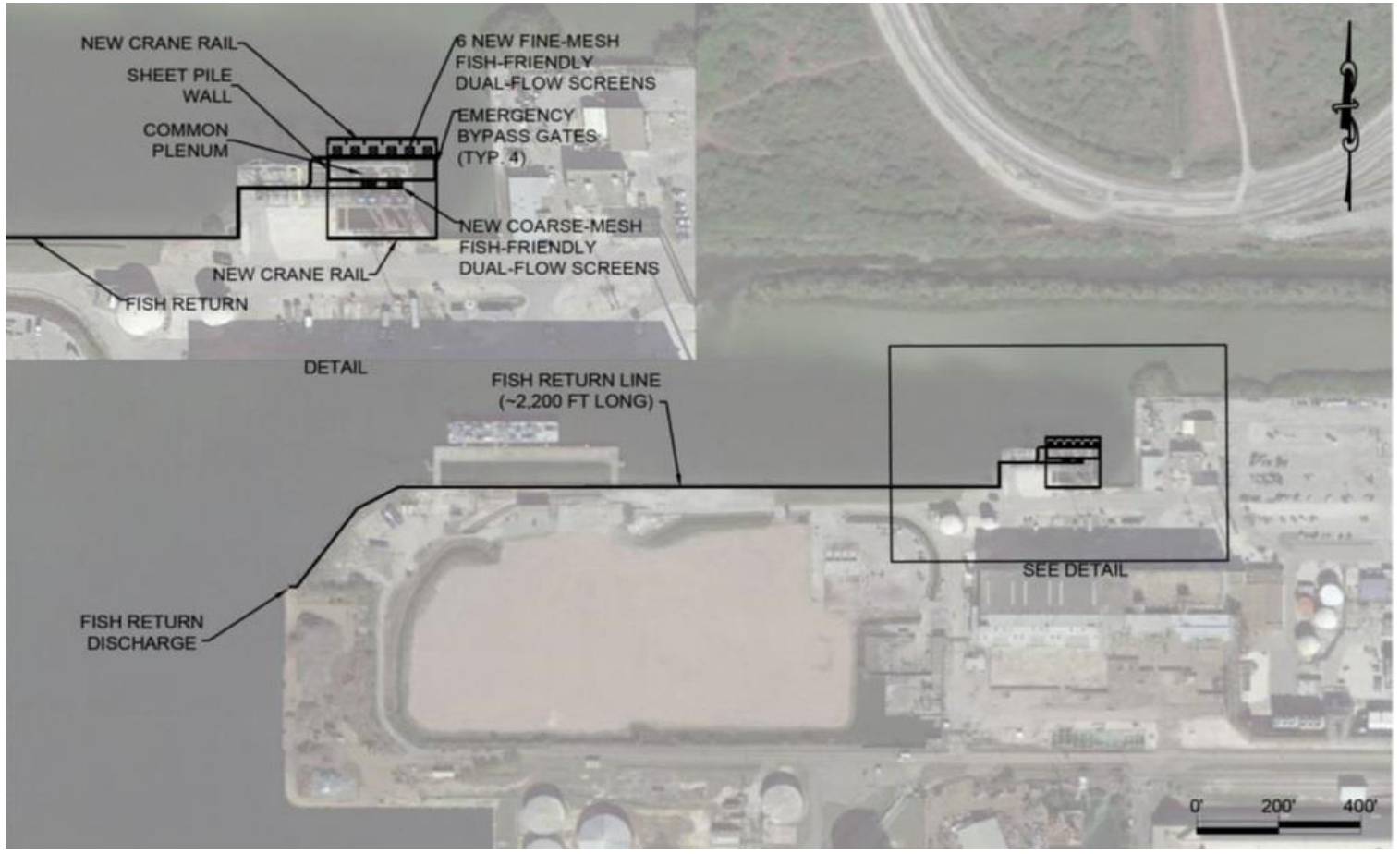


FIGURE 10-24.

CONCEPTUAL DESIGN FOR AN EXPANDED INTAKE DESIGNED FOR FMS WITH A 0.6-FPS SCREEN APPROACH VELOCITY AND A NEW FISH RETURN – PLAN

Source: TECO, 2018.

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Fish and debris removed by the low-pressure spray washes from both the fine- and coarse-mesh screens would flow into a fish trough located above the debris trough. Auxiliary water would be added to the upstream end of the fish return trough to provide a water cushion for fish removed from the screens. Debris removed by the high-pressure wash would be removed prior to the fish and debris troughs combining. The combined fish and debris trough would be mounted to the sheet pile wall that forms the southern edge of the intake canal and discharge outside the mouth of the intake canal. Grating placed over this section of the fish return would prevent avian and mammalian predation within the trough.

A flow of 4.9 cfs (2,210 gpm), which is the combined low- and high-pressure spray wash volumes from the FMS (including an additional 60 gpm of auxiliary water) was used to size the fish return trough. Assuming a drop of 7 ft over a total trough length of 2,200 ft a 2-ft diameter U-shaped trough would result in a 4.0 fps trough velocity at a depth of approximately 11 inches. This same trough would be used for the coarse-mesh screens when the FMS are removed. The combined spray wash flow for the coarse-mesh screens would be approximately 3.8 cfs (1,700 gpm). To attain a trough velocity of 4.0 fps or greater, approximately 1.1 cfs (510 gpm) of auxiliary flow would be needed. The spray wash pumps for the FMS would be used to provide this auxiliary flow.

The fish and debris trough would travel west then south following the edge of the intake canal, discharging outside of the intake canal. A more detailed fish-return evaluation would be necessary to refine the fish and debris return layout and verify that ambient currents at the discharge location are sufficient to prevent re-impingement.

Construction—Construction efforts would be sequenced to reduce effects on station operations. During the first stage of construction, the sheet pile wall, work deck and crane support system would be installed. Construction of the sheet pile wall would be in two parts allowing cooling water to flow around the active construction area. The emergency bypass gates and screen opening would be installed as part of the construction of the sheet pile wall. Both the emergency bypass gates and screen openings would remain open during construction allowing Bayside to operate throughout the construction period. Dredging of the screen deployment area, if needed to

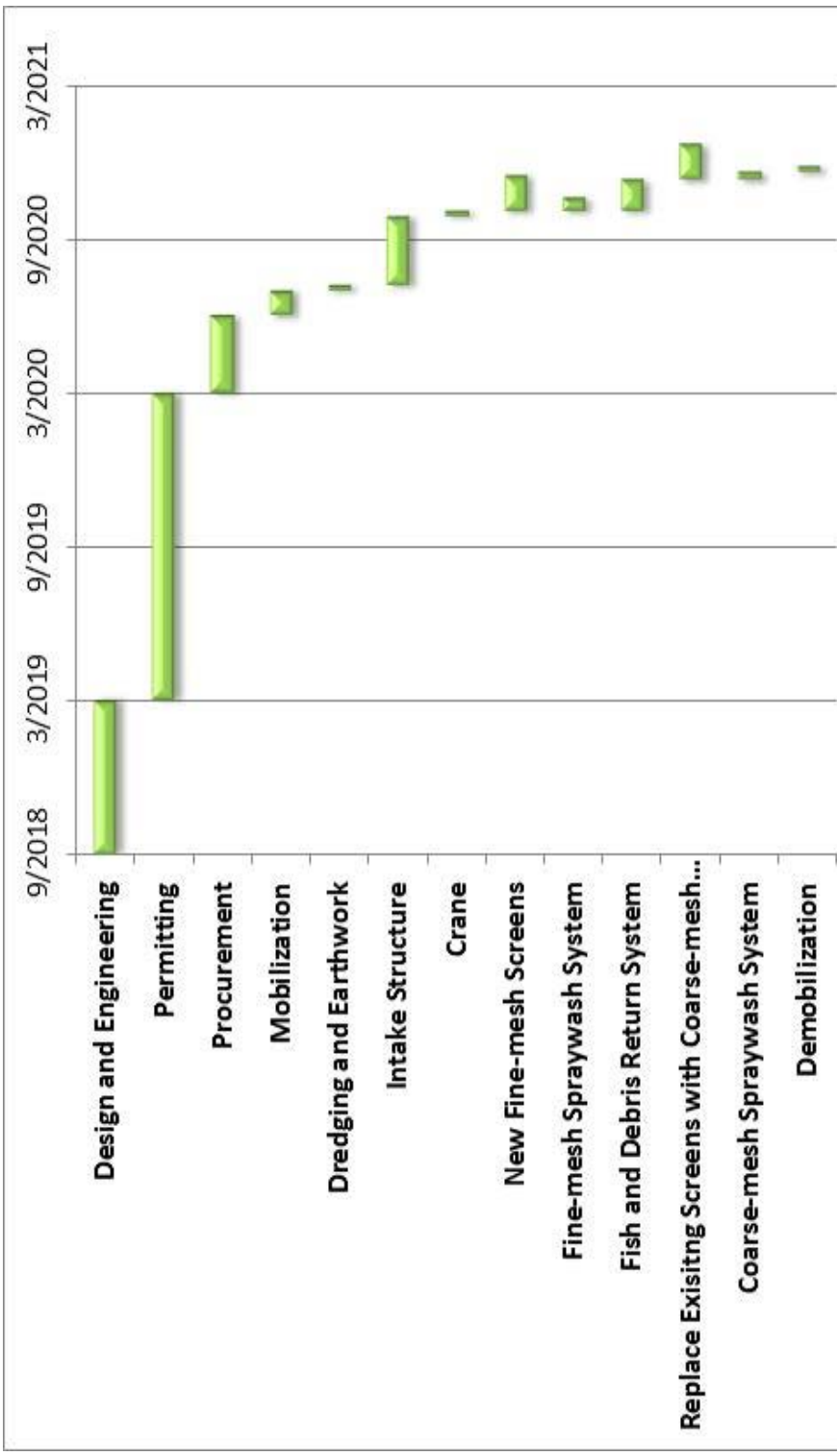
maintain an invert of El. -24.5 ft, would occur at the same time as the installation of the sheet pile wall and supports.

Once the new work deck and crane are in place the spray wash pumps and screens would be installed. The fish return trough would be constructed at the same time as the work deck so that it is operational once the screens are in place. The FMS would be installed next, after which the emergency bypass gates would be closed and the existing screens removed and replaced with new screens.

Active construction is expected to take approximately 7 months. Sequencing construction to allow the intake flow to bypass the active construction areas would allow Bayside to operate throughout the construction period. The overall schedule for this option including detailed design and engineering, permitting, and construction is provided on Figure 10-25.

O&M—O&M procedures for the new screens would be similar to those required for the existing TWS. In particular, Alden was provided current information on the maintenance strategies and cost for the FMS installed at Big Bend Station's Units 3 and 4 which are operated in the same fashion as anticipated by this potential option at Bayside. It should be noted that the maintenance strategy has recently been re-evaluated in an effort to increase reliability and reduce costs. Operations managers believe that the current system achieves both of those goals and that annual costs of maintenance have been reduced by approximately $150,000. The elements of the current maintenance program are defined in Appendix 10-D. The FMS would be rotated and cleaned continuously during the main recruitment season March 15 through October 15 to reduce the impingement duration of entrainable sized organisms. Outside of these dates the FMS baskets would be removed leaving only the coarse-mesh, fish-friendly screens in place. One screen per year would also be removed and sent back to the screen manufacture for a major overhaul. This major overhaul is expected to cost $187,000 per year. Seasonal installation and removal of the FMS baskets is expected to take 1 week, per change. FMS use small diameter wires that are more prone to damage from debris and fouled spray wash nozzles than coarse-mesh, as a result approximately 25 percent of the fine-mesh material would be replaced annually. Divers, using high pressure water inspect and clean the screen components that remain in place after the fine-

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FIGURE 10-25.

CONSTRUCTION SEQUENCE FOR AN EXPANDED INTAKE DESIGNED FOR FMS WITH A 0.6-FPS SCREEN APPROACH VELOCITY AND A NEW FISH RETURN

Source: Alden, 2017.

mesh has been removed. Power requirements to clean and operate the FMS and spray wash pumps during the 7-month operating window would be approximately 1,150 MWh per year.

When the FMS are in place, the coarse-mesh screens would be rotated once per day to maintain them in operational condition. After the FMS are removed, the coarse-mesh screens would rotate continuously or near-continuously to reduce impingement duration and achieve compliance with relevant portions of the rule. Power requirements to clean and operate the coarse-mesh screens and spray wash pumps would be approximately 579 MWh per year.

The fish return line would be inspected and cleaned daily to prevent any debris plugging and to remove bio growth. Regular inspection and maintenance of the fish return, fine-mesh and coarse-mesh screens is expected to cost $171,000 per year, not including major screen overhauls.

Dredging of the area in front of the FMS and in the plenum between the fine-mesh and coarse-mesh screens would be conducted annually to remove any sediment buildup. This dredging is expected to cost $100,000 per year.

With both the fine-mesh and existing coarse-mesh screens installed the clean screen head loss would increase less than 2 inches at the circulating water pumps. This change in head loss is not expected to impact the operation of the circulating pumps. However, hydraulic modeling of the intake with the new screens should be initiated to ensure balanced flow through the screens.

Permitting

Installation of either of the feasible fine-mesh TWS options would require construction and dredging activities within the intake canal. Federal, state, and local permits are expected to be required prior to construction for either option. TECO should consult with the Tampa Port Authority, FDEP, USACE, and the Southwest Florida Water Management District (SWFWMD).

The cost for these permits was taken as 2 percent of the direct capital costs estimated for this project. Sixteen to 24 months were anticipated for the application process, assuming all applications are submitted and reviewed concurrently.

10.4.2.2 Uncertainty and Additional Studies

TECO has many years of experience operating the FMS at Big Bend, reducing the uncertainty associated with operating and maintaining 0.5-mm FMS at Bayside. Site-specific studies would still be needed to refine the arrangement of the two options to identify any potential operational impacts to the circulating water system.

- Study to Evaluate Screen Impact on Cooling Water Pump Performance—Head loss across the screens will impact the water level at the circulating water pumps. The increase in head loss varies based on the installation type as shown in Table 10-17. In addition to the head loss through the FMS, coarse-mesh screens would be used to provide secondary screening for both expanded intake options, further reducing the water level at the pumps. Prior to moving forward with either option a pump intake model is necessary to investigate potential adverse impacts to the pump performance. This study is expected to cost approximately $50,000 for a computational model and is included in the overall cost estimate for this option.
- Study to Evaluate the Screen Hydraulics—A uniform screen approach velocity is necessary to ensure balanced flow through the new screens. Unbalanced flow can lead to areas of high TSV and debris loading. This would increase the torque on the screens, accelerate wear, and may lead to premature failure of the screens. The computational pump intake model used to investigate any impacts to the pump performance would be expanded and paired with a physical model study to optimize the flow distribution through the screens. Modifying the pump model and completing a physical model study is expected to cost approximately $100,000 for either of the expanded intake options.
- Fish Return Discharge Study—The fish return discharge location was selected to reduce the potential for re-impingement of organisms removed from the TWS. This discharge location is at the water's surface, outside of the intake canal but within the general vicinity of the mouth of the intake canal. At this location, non-volitional re-impingement of motile organisms is not expected because there is no velocity or other barriers preventing fish from remaining in the receiving water. Smaller organisms with limited motility could still become re-entrained in the intake flow and eventually recycled back to the intake screens under certain flood tide conditions. A numerical hydraulic model study of the intake canal and surrounding bay should be conducted to estimate the potential for re-impingement of non-motile life stages. This model could also be used to

select alternative fish return discharge locations. This study is expected to cost $50,000 and is included in the overall cost estimate.

- Pre-construction Studies—Additional studies including topographic, wetland delineation, geotechnical, and seismic investigations would be needed to determine the final layout and design of the fish return system. Cost for individual studies were not estimated as part of the preliminary designs but were accounted for as part of the indirect costs.

10.4.2.3 Compliance Costs

Feasibility level costs consistent with AACE Class 4 cost estimates were developed for both fine-mesh fish-friendly screen options. These estimates are composed of order-of-magnitude costs for direct, indirect, annual and periodic O&M, energy penalty, and compliance study costs. These costs are intended to be used to facilitate a BTA determination.

The expanded intake designed for FMS with a 0.6 fps velocity includes the retrofit of the existing TWS to fish-friendly screens with a fish return consistent the IM BTA Approach 5. The coarse-mesh screens are required with the option because the FMS would only be installed for the 7-month entrainment period. The costs for the coarse-mesh screens are considered as part of the overall facility cost for this option because they are necessary for this option to function effectively. However, the costs for the coarse-mesh screens are not considered as part of the overall entrainment compliance costs because their use is consistent with the proposed approach to IM BTA as described in the report under 40 CFR 122.21(r)(6) that would be selected in lieu of having to reduce entrainment.

The direct, indirect, annual and periodic O&M, and compliance study costs to expand the intake and add new FMS designed for a 0.5-fps TSV and a fish return are presented in Table 10-19. The costs for FMS designed for a 0.6 fps approach velocity with coarse-mesh, fish-friendly screens in the existing intake and a fish return are presented in Table 10-20. Costs to install coarse-mesh screens in the existing intake as a standalone option to meet IM BTA requirements are provided in Table 10-21. These measures would also be necessary for the option defined in Table 10-4 to achieve IM BTA when the FMS are not in place. The costs for the standalone coarse-mesh option were subtracted from the costs for the FMS designed for a 0.6 fps TSV in Table 10-22, to estimate just the portion of the costs resulting from the addition of entrainment reducing controls

Table 10–19. New FMS with 0.5-fps TSV and New Fish Return

Capital Costs	Estimated Cost
Indirect design and permitting costs	
Preconstruction engineering studies (indirect costs)	$4,639,000
Permitting	619,000
Hydraulic and fish return studies	200,000
Total indirect project costs (2017$)	**$5,458,000**
Direct construction costs	
Mobilization and demobilization	$2,812,000
Dredging and earthwork	3,407,000
Sheet pile walls	4,912,000
Intake structure	2,989,000
Screen lifting hoist	220,000
New FMS	15,300,000
Spray wash system	409,000
Fish and debris return system	879,000
Direct costs (2017$)	30,928,000
Taxes and depreciation (6.5% of materials)	1,279,000
Distributable costs (15%)	4,639,000
Overhead and profit (10%)	3,093,000
Subtotal	$39,939,000
Allowance for indeterminates/contingencies (20%)	$7,988,000
Tampa Electric administrative (10%)	3,994,000
Total direct project costs (2017$)	**$51,921,000**
Construction activities and impacts	
Permitting (months)	16 to 24
Construction duration (months)	16
Outage (months per unit)	0
Annual and periodic costs	
Annual labor and equipment*	$350,000
Major screen overhaul†	$560,000
Intake dredging‡	$220,000
Annual energy§ (MWh)	4,681
Annual energy§	$173,000

*Inspect and maintain 18 FMS, the fish return and replace 25 percent of the mesh material annually.
†Each fish-friendly TWS is replaced every 6 years (average of three screens per year).
‡$10,000 per screen for both the fine-mesh and coarse-mesh screens.
§Continuous rotation of the new screens for 7 months and 50 percent utilization for 5 months.

Source: Alden, 2017.

Table 10–20. New FMS Designed for 0.6-fps Approach Velocity with Coarse-mesh, Fish-friendly Screens in the Existing Intake and a New Fish Return

Capital Costs	Estimated Cost
Indirect design and permitting costs	
Preconstruction engineering studies (indirect costs)	$2,015,000
Permitting	269,000
Hydraulic and fish return studies	200,000
Total indirect project costs (2017$)	**$2,484,000**
Direct construction costs	
Mobilization and demobilization	$1,121,000
Dredging and earthwork	212,000
Intake structure	3,288,000
Screen lifting hoist	273,000
New FMS	4,395,000
Fine-mesh spray wash system	169,000
Fish and debris return system	614,000
Replace existing screens with coarse-mesh screens	2,165,000
Coarse-mesh spray wash system	89,000
Repairs to the existing intake structure	1,005,000
Direct costs (2017$)	13,431,000
Taxes and depreciation (6.5% of materials)	556,000
Distributable costs (15%)	2,015,000
Overhead and profit (10%)	1,343,000
Subtotal	17,345,000
Allowance for indeterminates/contingencies (20%)	3,469,000
Tampa Electric administrative (10%)	1,735,000
Total direct project costs (2017$)	**$22,549,000**
Construction activities and impacts	
Permitting (months)	6 to 9
Construction duration (months)	7
Outage (months per unit)	0
Annual and periodic costs	
Annual labor and equipment*	$210,000
Major screen overhaul†	$311,000
Intake dredging‡	$100,000
Annual energy§ (MWh)	1,720
Annual energy§	$64,000

*Inspect and maintain six FMS and four coarse-mesh screens, and the fish return and replace 25 percent of the fine-mesh material annually.
†Each fish-friendly TWS is replaced every 6 years (average of 1.67 screens per year).
‡$10,000 per screen for both the fine-mesh and coarse-mesh screens.
§Continuous rotation of the FMS for 7 months and continuous rotation of the coarse-mesh screens for 5 months.

Source: Alden, 2017.

Table 10–21. Coarse-mesh, Fish-friendly Screens in the Existing Intake

Capital Costs	Estimated Cost
Indirect design and permitting costs	
Preconstruction engineering studies (indirect costs)	$637,000
Permitting	85,000
Hydraulic and fish return studies	50,000
Total indirect project costs (2017$)	**$772,000**
Direct construction costs	
Mobilization and demobilization	$386,000
Replace existing screens with coarse-mesh screens	2,165,000
Coarse-mesh spray wash system	89,000
Fish and debris return system	601,000
Repairs to the existing intake structure	1,005,000
Direct costs (2017$)	4,246,000
Taxes and depreciation (6.5% of materials)	175,630
Distributable costs (15%)	637,000
Overhead and profit (10%)	425,000
Subtotal	$39,939,000
Allowance for indeterminates/contingencies (20%)	$1,097,000
Tampa Electric administrative (10%)	548,000
Total direct project costs (2017$)	**$7,129,000**
Construction activities and impacts	
Permitting (months)	3 to 6
Construction duration (months)	4
Outage (months per unit)	0
Annual and periodic costs	
Annual labor and equipment*	$108,000
Major screen overhaul†	$124,000
Intake dredging‡	$40,000
Annual energy§ (MWh)	1,314
Annual energy§	$49,000

*Inspect and maintain four coarse-mesh screens.
†Each screen is replaced every 6 years (average of 0.67 screens per year).
‡$10,000 per screen bay.
§Continuous rotation of the coarse-mesh screens throughout the year.

Source: Alden, 2017.

Table 10–22. New FMS Designed for 0.6-fps Approach Velocity

Capital Costs	Estimated Cost
Indirect design and permitting costs	
Preconstruction engineering studies (indirect costs)	$1,378,000
Permitting	184,000
Hydraulic and fish return studies	150,000
Total indirect project costs (2017$)	**$1,712,000**
Direct construction costs	
Mobilization and demobilization	$835,000
Dredging and earthwork	212,000
Intake structure	3,288,000
Screen lifting hoist	273,000
New FMS	4,395,000
Fine-mesh spray wash system	169,000
Fish and debris return system	13,000
Replace existing screens with coarse-mesh screens	0
Coarse-mesh spray wash system	0
Repairs to the existing intake structure	0
Direct costs (2017$)	9,185,000
Distributable costs (15%)	379,925
Taxes and depreciation (6.5% of materials)	1,378,000
Overhead and profit (10%)	919,000
Subtotal	$11,862,000
Allowance for indeterminates/contingencies (20%)	$2,372,000
Tampa Electric administrative (10%)	1,186,000
Total direct project costs (2017$)	**$15,420,000**
Construction activities and impacts	
Permitting (months)	6 to 9
Construction duration (months)	7
Outage (months per unit)	0
Annual and periodic costs	
Annual labor and equipment*	$102,000
Major screen overhaul†	$187,000
Intake dredging‡	$60,000
Annual energy§ (MWh)	415
Annual energy§	$15,000

*Inspect and maintain six FMS and replace 25 percent of the fine-mesh material annually.
†Each fine-mesh fish-friendly TWS is replaced every 6 years (average of 1.0 screens per year).
‡$10,000 per screen for the fine-mesh.
§Continuous rotation of the FMS for 7 months.

Source: Alden, 2017.

as distinct from the rule-required IM BTA. The cost components that are used to estimate the total facility cost for each option are defined in Section 10.1.4.3.

The facility costs for each option were then used to estimate the net present value and annualized compliance costs for each option at two discount rates, 3 percent and 7 percent, with an estimated plant life of 28 years (2044). The use of these discount rates is consistent with the social discount rates required as part of the social cost analysis required by EPA under the 316(b) rule. The compliance costs for both fine-mesh entrainment reducing options are presented in Table 10-23. Compliance costs represent the incremental change in capital and operating costs associated with reducing both IM and entrainment compared to the cost for only reducing impingement using the preferred BTA technology (coarse-mesh, fish-friendly screens in the existing intake).

Table 10–23. Incremental NPV and Equivalent Annual Compliance Cost Estimate to Retrofit Existing CWIS with Fine-mesh Modified TWS with New Fish Return System

Discount Rate	Fine-mesh Modified TWS with New Fish Return (2017 $)	
	Designed for 0.5-fps TSV	Designed for 0.6-fps Approach Velocity
Net present value		
7% discount rate	$42,636,000	$16,773,000
3% discount rate	$55,660,000	$21,007,000
Equivalent annual cost		
7% discount rate	$3,513,000	$1,382,000
3% discount rate	$2,966,000	$1,120,000

Note: Incremental costs are the difference in costs associated with additional fish protection measures to reduce both impingement mortality and entrainment compared to the cost of meeting only the impingement mortality BTA requirements.

Source: Alden, 2017.

Social Costs (Annual and NPV)

The estimated social costs for installing FMS upstream of the existing intake system along with a new fish return range from $9.2M (7-percent discount rate) to $15.4M (3-percent discount rate) (Table 10-24). These are the incremental social costs for the FMS installation and operation and do not include the coarse-mesh modified traveling screens with a fish return.

Table 10–24. Total Social Costs of Retrofit to FMS

Discount Rate (%)	Electricity Price Increase (million $)	Costs (million $)				
		Fuel*	Externality	Permitting*	Total Social (NPV)	Annual Social
3	$14.6	$1.1	$0	$0.2	$15.4	$0.7
7	$8.8	$1.1	$0	$0.2	$9.2	$0.4

*Permitting and fuel costs presented are undiscounted and in 2017 dollars.

Source: Veritas, 2018.

10.5 Alternate Cooling Water Sources

Alternate water sources, such as groundwater and grey water sources, have been evaluated for potential use at Bayside to supplement the current water withdrawal. Consistent with the 316(b) rule's requirements, this evaluation is focused on supplying water to supplement the existing once-through cooling system. The evaluation has been performed in two steps. The first step is to compare the distance and potential flow rate of the alternate water source to the location of the station. The second step involves a further evaluation of any alternate water sources identified as reasonable candidates.

In the first step, the daily flow rate of any alternate water source within a specific mile radius is compared to Bayside's DIF (Table 10-25). Due to permitting challenges such as stream and wetlands crossings, numerous rights-of-way required over private properties,[25] and prohibitive construction costs, alternate water sources greater than a radial distance of 5 miles from the station are not considered to be practicable. If the flow rate from the water source as a percent of the station's DIF is considered to be practicable, the water source moves to the second step. However, if the flow rate of the water source is considered to be impracticable, that water source is eliminated from further evaluation.

[25] While eminent domain may provide an alternate mechanism for acquiring rights-of-way over private properties, the lengthy legal proceedings would not allow availability of alternate water sources from long distances in a timely manner.

Table 10–25. Radial Distance from Bayside for Alternate Water Sources to be Considered Practicable

Radius from Station (miles)	Percent of Station's DIF*	Approximate Minimum Target Flow Rate for Further Evaluation (MGD)
0 to 1	5%	31.5
1 to 2	10%	62.9
2 to 3	15%	94.4
3 to 4	20%	125.8
4 to 5	25%	157.3

*629 MGD for combined Units 1 and 2.

Source: HDR, 2017.

In the second step, the potential alternate water source would undergo further evaluation to understand the practicability of utilizing the water source. The evaluation would include an approximate pipeline alignment from the alternate source to the station. Additional aspects of the water source that will be evaluated would be dependent on the type of water source.

Reclaimed sources with sufficient capacity will be further evaluated for the following: reliability of supply, water quality compatibility, additional necessary treatment, cost of conveying from the source, the relative effort to negotiate rights-of-way, and the impact of discharge, including permitting issues.

Groundwater sources with sufficient well yields to serve as a viable source will be further evaluated for the following:

- Water quality compatibility with equipment.
- Groundwater and surface water compatibility.
- Groundwater discharge options and the potential impacts of comingling ground and surface waters.

- Potential need for additional chemical use.
- Cursory evaluation of the impact of groundwater on the biota in the receiving water body.
- The impact of groundwater extraction on the aquifer, other wells, and other groundwater uses.

It should be noted that the Tampa Bay area and indeed much of Florida regulates water use very strictly. For example, new uses of groundwater are highly restricted being reserved for the highest quality uses. In fact, a substantial increase in groundwater use for industrial purposes is very unlikely to be approved. Similarly, discharge and reuse of reclaimed water is subject to regulatory review. Finally, use of alternative water supplies has a potential to complicate the NPDES permit to discharge cooling water, particularly if reclaimed water is used. For all of these reasons, the simple presence of an alternative water source does not suggest that it is a feasible supply.

10.5.1 Description of Water Uses within the Facility, Quantities, and Quality Required for Those Uses

Bayside uses water from the Hillsborough Bay for once-through cooling of Units 1 and 2 steam condensers, and a combination of the City of Tampa's municipal water and stormwater collected in onsite ponds and treated wastewater for service water uses. Stormwater and treated wastewater are the primary service water sources; City of Tampa water is used as a supplementary source.

Per TECO (2016a) as shown in Figure 10-26, the inflow to Units 1 and 2 (disregarding uses at Bayside simple-cycle units) from the onsite treatment systems is 0.6 MGD (419 gpm) under average conditions and 0.7 MGD (495 gpm) during wet weather conditions. This does not include purchases from the City of Tampa. The flow rates corresponding to the inflow reference numbers shown on Figure 10-26 are provided in Table 10-26.

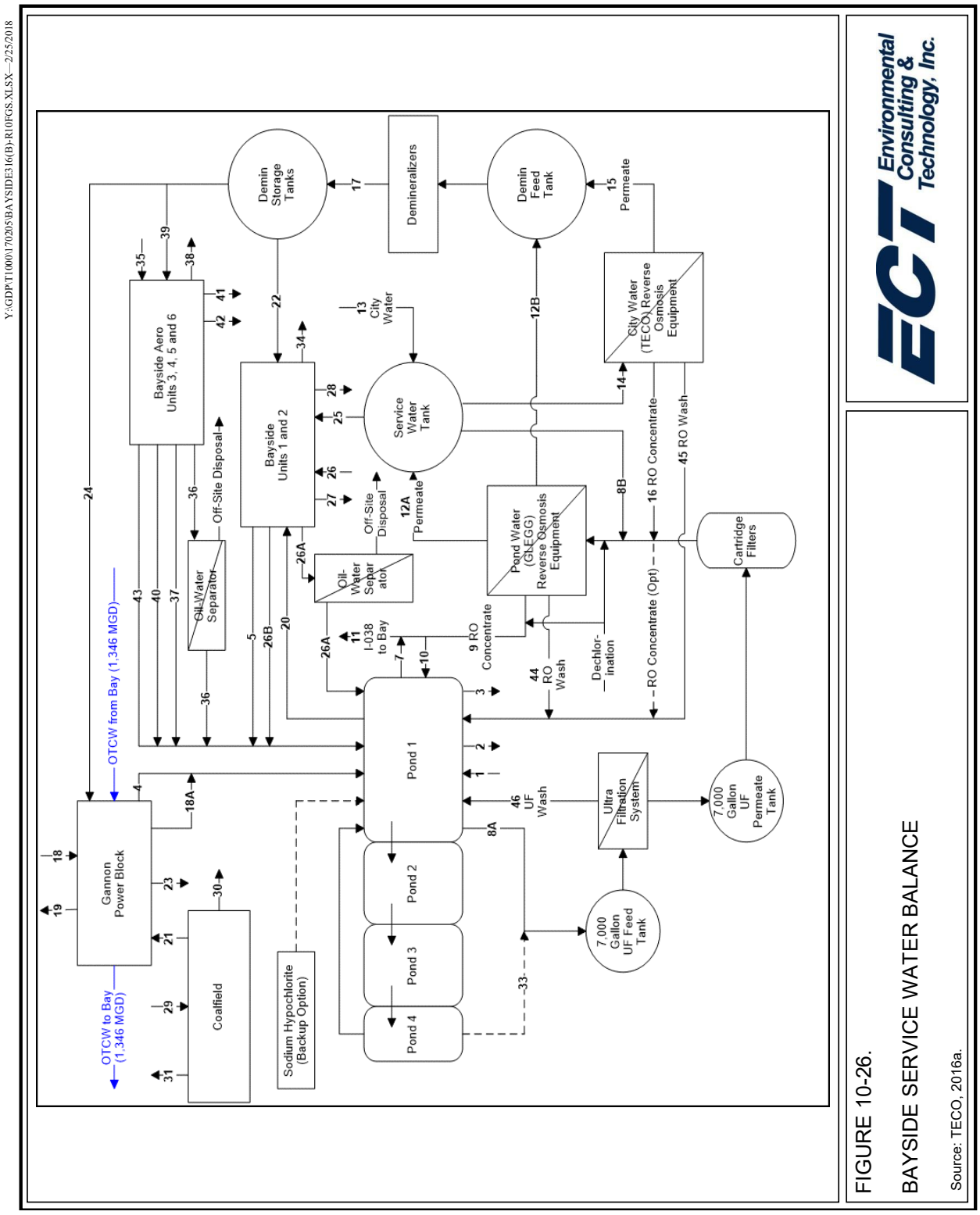

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Demin Storage Tanks
Demineralizers
Demin Feed Tank
15 Permeate
City Water (TECO) Reverse Osmosis Equipment
Bayside Aero Units 3, 4, 5 and 6
Bayside Units 1 and 2
13 City Water
Service Water Tank
12B
14
8B
16 RO Concentrate
45 RO Wash
Off-Site Disposal
Off-Site Disposal
12A Permeate
Pond Water (GLEGG) Reverse Osmosis Equipment
Cartridge Filters
Oil-Water Separator
Oil-Water Separator
I-038 to Bay
9 RO Concentrate
44 RO Wash
Dechlor-ination
RO Concentrate (Opt)
OTCW from Bay (1,346 MGD)
Pond 1
Pond 2
Pond 3
Pond 4
Gannon Power Block
OTCW to Bay (1,346 MGD)
Coalfield
Sodium Hypochlorite (Backup Option)
46 UF Wash
Ultra Filtration System
7,000 Gallon UF Permeate Tank
7,000 Gallon UF Feed Tank
Environmental Consulting & Technology, Inc.
FIGURE 10-26.
BAYSIDE SERVICE WATER BALANCE
Source: TECO, 2016a.

Table 10–26. Onsite Treated Water Inflow Rates to Units 1 and 2

Reference Number	Stream Description	Average Conditions (gpd)	Wet Conditions (gpd)
20	Recycle water to Bayside	50,000	25,000
22	Demin water to Bayside power block (Units 1 and 2)	300,000	175,000
25	Makeup water to Bayside	68,710	118,000
26	Rainfall to Bayside	184,185	395,445

Source: TECO, 2016a.

Different quality water is required for various purposes. The boiler requires the highest quality water (which requires demineralized water), whereas some of the other service water users may utilize lesser quality water (which has been treated via the onsite ultrafiltration system).

The potential to reuse service water as cooling water will be considered below.

10.5.2 Description of Alternate Water Sources

Onsite water use primarily consists of circulating water, service water, and screen backwash water. Water reuse on site would include reusing water from existing station uses in support of the condenser cooling water. Intake screen backwash water is not suitable for reuse, as it is intended to remove debris from the screens and convey that debris back to Hillsborough Bay.

Service water is the only potential source of water reuse on the site. In addition to the approximately 0.6 MGD of treated water from onsite ponds, (TECO 2016a), Bayside uses 0.47 MGD (326.4 gpm) of municipal water from the City of Tampa for service uses. When the design service water is compared to the design circulating water flow, service water is approximately 0.2 percent of the design circulating water flow (Table 10-27). In addition, some of the service water is lost to processes such as evaporation prior to discharge. Because of this, reusing service water on site is not considered practical and, therefore, not evaluated further.

Table 10–27. Onsite Water Reuse Evaluation

Unit	Design Circulating Water Flow (gpm)	Design Service Water Flow (gpm)	Service Water Flow as Percent of Circulating Water Flow	Candidate for Further Evaluation
1	184,800	745	0.2%	No
2	252,000			
Total	**436,800**			

Source: ECT, 2018.

10.5.2.1 Grey Water Sources

Seven wastewater dischargers, including several municipal wastewater treatment plants (WWTPs) have been identified within the 5-mile radius of the station; these WWTPs are plotted on Figure 10-27. These wastewater dischargers represent a potential supply of reclaimed water that could be used to reduce the amount of water that Bayside withdraws from Hillsborough Bay, thereby also reducing potential entrainment. The average discharge rate is compared to the station's DIF in Table 10-28.

Table 10–28. Grey Water Alternate Water Source Evaluation

Water Source	Straight Line Distance from Station	Average Flow	Percent of Station DIF	Candidate for Further Evaluation
Farmland Hydro, LP, WWTP	Less than 1 mile	Small local system		No
Tampa Port Services, LLC, WWTP	Less than 1 mile	Small local system		No
City of Tampa Howard F. Current AWTP	1.5 miles across the bay	55 MGD*	8.7	No
Tampa MS4	3.2 miles	Stormwater outfall, not regular/reliable flow		
Mosaic Fertilizer LLC, Riverview	3.2 miles along bay	Small local system		No
Hillsborough County	3.5 miles across the bay and congested residential properties	Unavailable		No
Falkenberg AWTP	5 miles through congested residential properties	12 MGD	1.9	No

*55 MGD would not be available, since there is an existing reclaimed water system in South Tampa that utilizes some of this flow.

Sources: HDR, 2017.
City of Tampa, 2017

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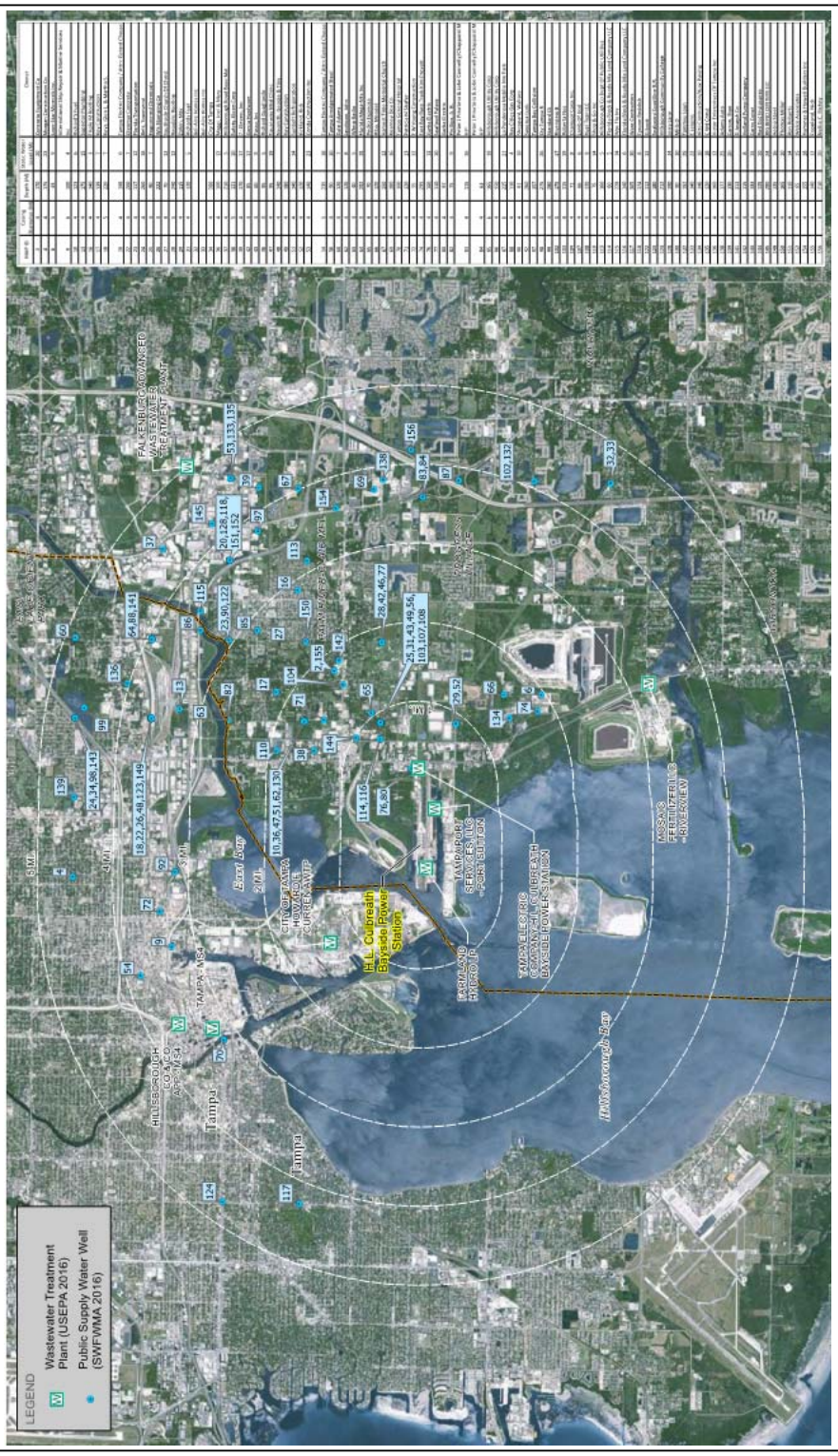


FIGURE 10-27.

GROUNDWATER WELLS AND POTENTIAL GREY WATER SOURCES WITHIN A 5-MILE RADIUS OF BAYSIDE

Source: HDR, 2017.

ECT Environmental Consulting & Technology, Inc.

Of the seven discharges, one is a stormwater outfall which would not provide a reliable source of water to Bayside. Four of the dischargers are local small systems whose specific discharge rates are unknown but are expected to be on the order of Bayside's service water treatment system. Two discharges are larger. The City of Tampa Howard F. Curren Advanced Wastewater Treatment Plant has a design discharge rate of 55 MGD; this plant is located across the Bay from Bayside approximately 1.5 miles away when measured on a straight line. The other potential reclaimed water source is smaller and at a greater distance. Routing a pipeline through the Bay, industrial complexes and residential properties would be very challenging given the number of water, sewer, fiber optic, telephone, and gas lines alone that would need to be crossed. Given the highly built-up area, there are no potential alignments to route water around those properties. Additionally, the flow rates provided are the design capacities of the treatment systems and do not reflect what may be available for use reliably. Given the relatively small quantities that may or may not be available, and the long distances that the water needs to be conveyed, the use of reclaimed water is deemed infeasible and impractical.

10.5.2.2 Groundwater Sources

Groundwater is the principal source of water for domestic, agricultural, and industrial use in Hillsborough County.

Groundwater in Hillsborough County is divided into three distinct aquifer systems: the surficial, intermediate, and Floridan (Hillsborough County, 2008). The surficial aquifer system supplies the least quantity of water in the county. Small volumes of water are used for domestic use, lawn irrigation, or stock watering. Most wells that tap the surficial aquifer have small diameters and yield less than 25 gpm (Hillsborough County, 2008). Due to low yield in the surficial aquifer system, groundwater from this aquifer does not appear to be a feasible alternate water supply source at Bayside.

The quality of water in the intermediate aquifer system in Hillsborough County is generally good except near the coast, where saltwater or residual seawater has not been completely flushed. Water from the intermediate aquifer system is primarily used for domestic supply in extreme southern Hillsborough County. Small diameter wells (2 inches) may produce up to 30 gpm.

Large diameter wells (6 inches or larger) that fully penetrate the aquifer can yield more than 200 gpm in southern areas. The intermediate aquifer system is most productive in the eastern and southern parts of the county (Hillsborough County, 2008). Due to low groundwater yield in the intermediate aquifer system, it does not appear to be a feasible alternate water supply source at Bayside, primarily because Bayside cooling would compete with potable needs and because of low yield.

The upper Floridan aquifer system is the principal source of groundwater in Hillsborough County. The upper Floridan aquifer well yields vary from less than 500 gpm for 6-inch or smaller diameter wells partially penetrating the aquifer system to greater than 5,000 gpm for 12-inch or greater diameter wells which fully penetrate the aquifer system. The wells range in depth from about 100 to 1,500 ft, depending on the quality and quantity of water needed. Well depths are generally less than 700 ft, primarily because of poor water quality at depth greater than 700 ft. Based on existing data, areas most suitable for groundwater development from the upper Floridan aquifer appear to be in the extreme northeastern and southeastern areas of the county. Salt intrusion along the coast, and heavy use in central, northwestern, and southwestern areas, make these areas least suitable for potable water resource development (Hillsborough County, 2008). Also, SWFWMD has documented saltwater intrusion occurring along coastal portions of the county in the vicinity of Bayside. Hillsborough County has been identified as an area experiencing some aquifer contamination. Recent studies conducted by SWFWMD have detected pollutants seeping into the Floridan aquifer and returning through springs (Hillsborough County, 2008). While saline water is usable at Bayside, withdrawal of large quantities of water would exacerbate saltwater intrusion and would be unallowable. As such, using groundwater from the upper Florida aquifer system as an alternate water supply source at Bayside does not appear to be feasible.

Groundwater wells within the 5-mile radius have been identified and plotted on Figure 10-27. There are 100 groundwater public supply wells within 5 miles of Bayside; due to the number of wells located, these have been grouped with the largest yield well compared to Bayside's DIF (see Table 10-29). Original well yield logs, when available, provided their yields, but in recent years, owing to saltwater intrusion, these wells are now restricted to withdraw at a lower capacity.

Table 10–29. Groundwater Alternate Water Source Evaluation

Radial Distance from Station (miles)	Number of Wells within Radius	Potential Quantity of Well Water Available (gpm)	Percent of Station DIF*	Candidate for Further Evaluation
0 to 1	15	2,625	1%	No
1 to 2	22	3,850	1%	No
2 to 3	7	1,225	< 1%	No
3 to 4	33	5,775	1%	No
4 to 5	23	4,025	1%	No

*629 MGD.

Source: SWFWMD, 2017.

Each of the wells listed in Figure 10-27, have casing sizes between 4 and 6 inches, and the well depths are between 40 and 313 ft. Based on these well characteristics, and yields known for the various aquifers, each well may be expected to produce between 30 gpm and 500 gpm. Table 10-29 estimates the potential quantity of well water that might be available if all the groundwater wells were available to Bayside. Column 4 estimate the total groundwater as a percent of the station DIF. In all cases, no more than 1 percent of Bayside's cooling water needs is available from the group of wells.

In addition to the low water yield of any single groundwater supply well compared to the DIF at Bayside, the following difficulties are also relevant to the evaluation of local groundwater wells as an alternate water source at Bayside:

- Water management officials prioritize groundwater for potable use and are generally working to reduce use to minimize salt water intrusion and other adverse impacts. Obtaining permits to withdraw groundwater for cooling water use is not expected to be feasible.
- Well capacity/yield is not guaranteed over time and thus cannot be relied on as a continuous source of cooling water.
- Much of the cooling water is brackish. Comingling brackish water with fresh groundwater would render the freshwater source unusable for other more valuable needs.

- Overhead (electric) and underground (gas, water, sewer, telephone, fiber optic) obstructions would affect the construction of the pipeline between the selected groundwater supply well(s) and the Bayside cooling system.
- Permitting requirements for water transmission may be extensive due to the potential length and size of pipeline(s) needed to connect the selected groundwater source(s) to the Bayside cooling system and the various types of lands needed to cross.

Given the scarcity of the resource, the potential to exacerbate saltwater intrusion which would challenge the permitting effort, impracticality of all these groundwater wells being allocated to Bayside, and the impracticality of routing multiple pipelines to Bayside, the use of groundwater is deemed infeasible.

10.5.3 Uncertainty

Key uncertainties associated with the alternate water use evaluation include:

- Incomplete water source information available. The state database provided locations of existing wastewater treatment plants; their design capacities were obtained from various sources. In some cases, the design capacities were not available.
- The actual water quantity that might be available for reuse was unavailable. This value would be smaller than the design capacity, which would make each resource even less practical/feasible.
- The distance between Bayside and potential alternate source was measured in a straight line, but potential pipeline alignment would need to weave through properties via existing rights-of-way. Such a route would make the distance longer, and the resource even less practical/feasible.
- Groundwater well yields and well locations were available from the state database, but due to groundwater restrictions, wells are not allowed to be pumped at their full yield. Therefore, actual flow rate would be lower than assumed for this evaluation, making each well even less practical/feasible.
- The quality of reclaimed water or groundwater was not evaluated to assess compatibility with plant equipment, and compliance with the Bayside NPDES permit.

10.6 VSPs

Bayside has two constant speed water intake pumps per generating units. Typically, all four pumps withdraw water at their design capacity regardless of the station's generation rate. This is done in order to avoid short-term cycling of the pumps on and off, which has adverse effects on the pumps, as well as to avoid biofouling and sedimentation within the condenser tubes. VSPs (or the existing pumps retrofitted with VFD) would allow the station to modulate cooling water pump flow rates to match electricity generation load thereby withdrawing only the quantity of water needed to support generation (with some other limitations discussed below). The reduction in flow is expected to reduce entrainment proportionately and to help reduce impingement mortality as well. At Bayside, entrainment rates are seasonal with the majority of entrainment occurring between March 15 and October 15.[26] The potential for flow reduction associated with VSPs will also be assessed during this portion of the year.

This section first describes the technology. Section 10.6.2 examines cooling water flow rates, intake water temperatures, generating rates and condenser backpressure on an hourly basis to assess the potential reductions in flow that may be achievable at Bayside. Section 10.6.3 sizes VSPs and power draw of the system. Section 10.6.4 assesses feasibility of implementing VSPs at Bayside. Section 10.6.5 discusses the anticipated schedule, Section 10.6.6 provides costs, and Section 10.6.7 discusses uncertainties associated with the evaluation.

It is important to note that TECO is under contractual obligations to ensure that Bayside is available to generate should electricity supply and demand determine it is needed. Therefore, any reductions in intake flow driven by reductions in capacity are opportunistic and TECO is not in a position to commit to any fixed reductions in generation or intake flow.

10.6.1 Description of the Technology

Pump speed refers to the rotational speed of the pump shaft, which is connected to the impeller, which in turn causes water to move. Slowing the rotational speed of the impeller reduces the

[26] The seasonality of entrainment is similar at the Big Bend power plant where FMS are installed on Units 3 and 4 only during these months.

water flow rate. Pump performance parameters are related to pump speed through Affinity Laws as shown below (Hydraulic Institute, 2004):

$$\frac{Q_1}{Q_2} = \frac{\omega_1}{\omega_2}$$
$$\frac{H_1}{H_2} = \frac{\omega_1^2}{\omega_2^2}$$
$$\frac{BHP_1}{BHP_2} = \frac{\omega_1^3}{\omega_2^3}$$

where: Q = flow rate
H = head or pressure
BHP = brake horsepower (bhp)
ω = rotational speed (rpm).

Changing the pump's rotational speed directly impacts the water flow rate and significantly impacts the energy consumption rate (i.e., brake horsepower changes with cube of rotational speed).

The total energy requirement of the cooling water system consists of the static head, friction head and velocity head. "System" refers to Bayside-specific topography, water flow rate, pipe diameter which impacts the water flow velocity, friction in the condensers and the lengths of pipe. The pump motor needs to meet the energy requirements of the system under the range of design conditions.

The effective capacity of the pump is determined by the intersection point of the pump curve and the system curve as shown in Figure 10-28. When the pumping head requirement of the system is driven by friction losses, reducing the speed may allow the pump to continue to operate efficiently; but still within a certain flow range. Beyond that range, the pump could become inefficient (NRCS, 2010). The system curve shown in dark blue in Figure 10-28 corresponds to a system where the pumping head is primarily for overcoming friction (and does not need to lift the water). Pump efficiency curves are shown in light blue. Within a narrow flow range, the pump can remain at its optimal efficiency even as the pump discharge rate changes (Hydraulic Institute, 2004).

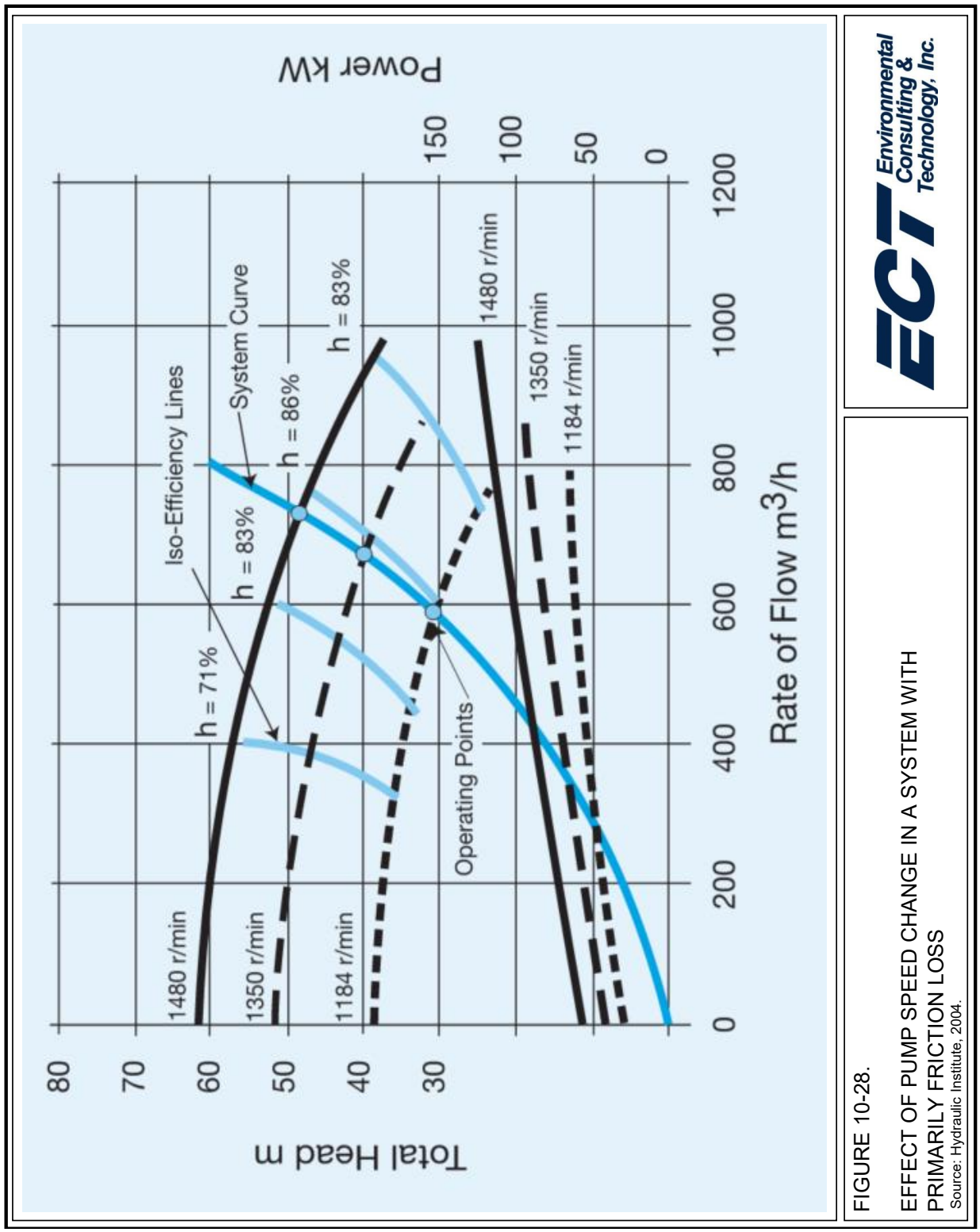


FIGURE 10-28.

EFFECT OF PUMP SPEED CHANGE IN A SYSTEM WITH PRIMARILY FRICTION LOSS

Source: Hydraulic Institute, 2004.

When the pumping head is driven by static head requirements, changing the speed of the pump could cause the system curve to deviate from efficient operating points (NRCS, 2010). The system curve shown in dark blue in Figure 10-29 corresponds to a system where pumping head is primarily supplied to add static head (and where flow velocities would be so low that friction losses are negligible). Here, too, pump efficiency curves are shown in light blue. As the pump discharge rate changes, the system curve cuts through many efficiency curves and soon becomes inefficient (Hydraulic Institute, 2004).

The Bayside system curve is a combination of the two extremes situations shown in Figure 10-28 and Figure 10-29. The site has little topographical variation, however, the pumps lift water from sea-level which fluctuates with the tide to 13 ft above msl (Figure 10-30), for a total of approximately 15 ft of head (HDR, 2017). While the Bayside system curve is unavailable, based on other parameters known, it is anticipated that about 60 to 70 percent of the pump head is utilized to develop static head, and the remainder to overcome friction. What this means is that the pump would move out of its high-efficiency band quite quickly. Therefore, understanding the required optimal pumping range is important and must be done on a site-specific basis, as discussed in Section 10.6.2.2.

The speed of a motor is calculated as: synchronous speed = $\frac{120 \times frequency}{Number\ of\ poles}$ (NRCS, 2010).

When converting an existing motor to variable speed, the only parameter that can be changed in the synchronous speed equation is the frequency of the power supply, hence the use of a VFD.[27] The frequency of alternating current (AC) in the United States is 60 hertz (Hz). VFDs convert AC to direct current (DC) and the simulate AC with the desired frequency, thereby changing the motor speed. The motor speed is directly proportional to the current frequency as set by the VFD. These conversions result in a loss in pump efficiency.[28]

[27] When a new pump is manufactured as a variable speed pump, it can be built to vary flow and have greater flexibility.
[28] Because energy conversions result in efficiency losses.

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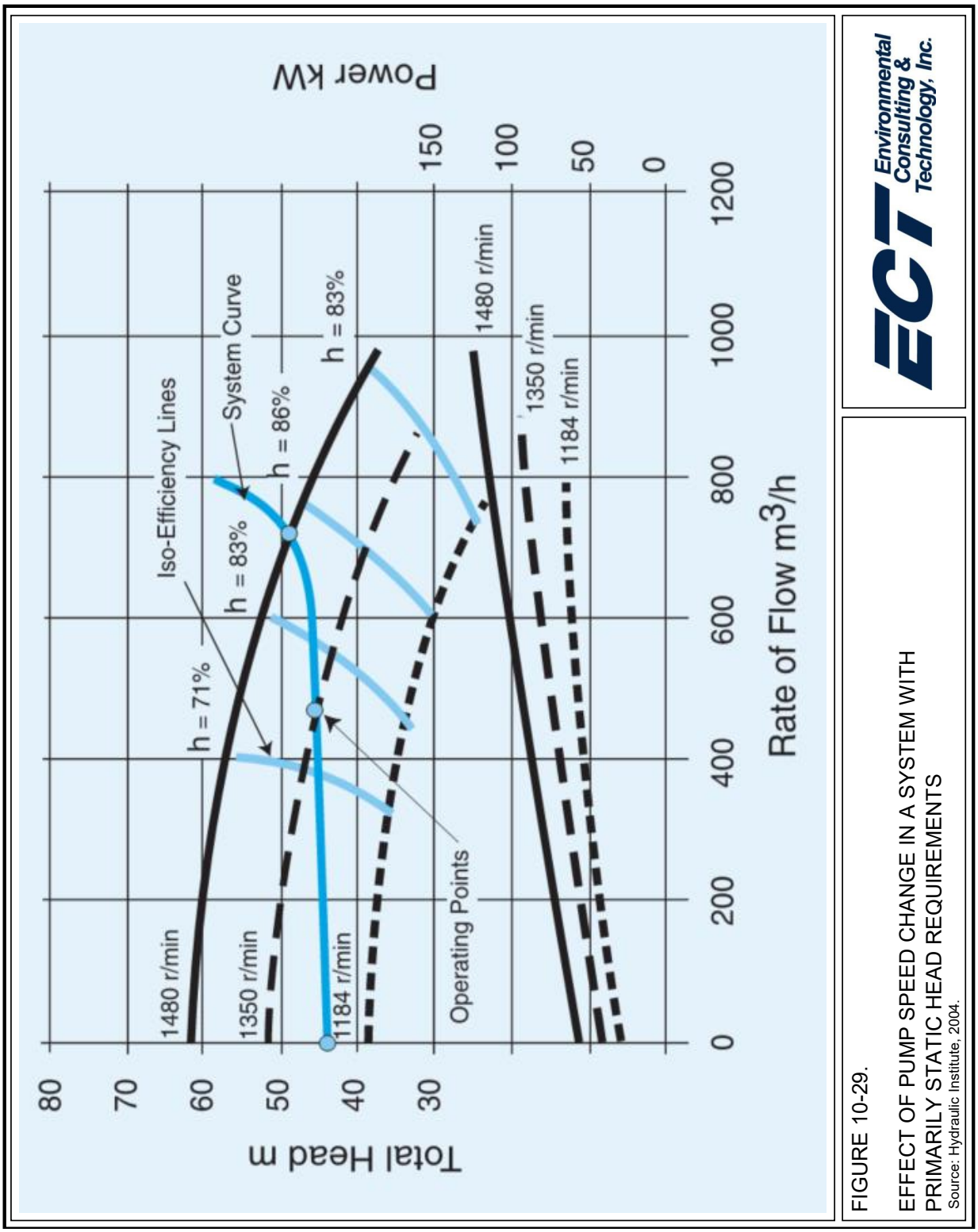


FIGURE 10-29.

EFFECT OF PUMP SPEED CHANGE IN A SYSTEM WITH PRIMARILY STATIC HEAD REQUIREMENTS

Source: Hydraulic Institute, 2004.

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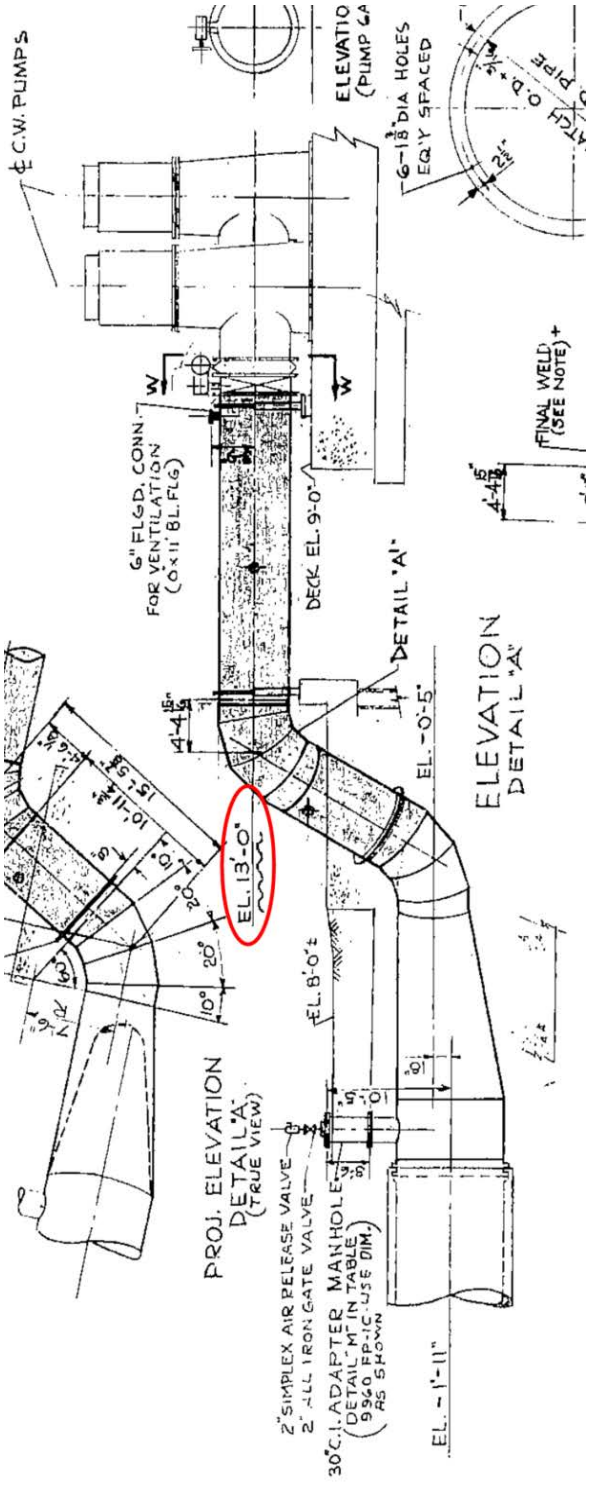


FIGURE 10-30.

STATIC HEAD DEVELOPED BY EXISTING CIRCULATING WATER PUMPS

Source: TECO, 1966b.

ECT Environmental Consulting & Technology, Inc.

Use of VFDs have advantages and disadvantages (Hydraulics Institute, 2004). The key advantage is that VFDs and VSPs help save energy (because the pump discharges at a lower rate when less water is needed, granted that the pump may be less efficient at certain operating points), and at power plants VFDs and VSPs can help reduce impingement and entrainment as well (which is the focus of this evaluation). However, the following potential disadvantages are of concern:

- VFDs can generate high frequency current pulses through motor bearings thereby damaging motor bearings.
- Most variable frequency controllers inject harmonic currents, due to high switching frequency of the VFDs, into the power supply side and all circuits connected to that supply. Harmonics present themselves as hums, flickering lights, overheating of wires, circuit trips, etc. Installation of a buffer transformer helps isolate supply line disturbances. Additionally, filters can help protect individual electrical equipment.[29]
- Overheating and voltage spikes can cause motor insulation damage.
- Excessive vibration may be introduced.
- VFDs are more sensitive to temperature and humidity fluctuations (and high elevations although not relevant at Bayside). VFDs cannot tolerate dust or dampness, therefore, they need to be installed in National Electrical Manufacturers Association 4-rated enclosures.[30] As a result, the proposed system would be climate controlled, increasing the cost of installation and operation.

10.6.2 Flow Reduction Calculation Methodology

VFDs or VSPs are meaningful only if the operation of Bayside provides opportunities for flow reductions. For example, a system that operates at 100 percent capacity for only 9 months per year without operating in the other three months is unlikely to produce opportunities for flow reduction. On the other hand, a system that operates at 75 percent capacity all 12 months of the year is more likely to be able to reduce flow with VSPs. This section evaluates Bayside data from 2015 and 2016 on electricity generation, intake water temperature, permits limits, and water flow rates to assess if the system provides an opportunity for flow reduction using VSPs.

[29] These protective and precautionary measures add to the cost of VFD, VSP installations.
[30] Dustproof and watertight.

Hourly intake flow, cold water temperature (prior to condenser heat exchange), and hot water temperature (after condenser heat exchange) data for the cooling systems for Unit 1 and Unit 2 at Bayside was analyzed for 2015 and 2016. This analysis was restricted to the entrainment period (March 15 to October 15) as flow reductions in the other months are very unlikely to reduce entrainment. Using the record for the two years, a set of hypothetical rules were established to determine if the rate of cooling water flow could be reduced and by how much. It is important to note that these rules are an illustration of potential rules and that any adopted operations logic must be the result of a more rigorous design process considering the condenser thermodynamics, the logistics of intake operation, and the potential demand for power including TECO's contractual obligations.

When the measured temperature rise across the condensers (ΔT) was less than the NPDES permit limit of 17°F, the intake flow values were initially adjusted to achieve a "target" ΔT of 17°F. These hypothetical reduced intake flow values were further adjusted to account for maintaining an appropriate water velocity through the condensers to avoid sedimentation and biofouling, then averaged across four-hour increments. Reduced intake flow values were then adjusted to maintain the desired ΔT on a monthly average basis,[31] and the percent of flow reduction was calculated for the full calendar year as well as the "recruitment period". Percent of flow reduction was iterated for a ΔT of 17°F, 16°F, and 15°F for both Unit 1 and Unit 2 in 2015 and 2016 to get a sense of the potential for intake flow reduction at Bayside.

Annual average flow reduction that would have been available during the recruitment period in 2015 and 2016 were estimated to assess the potential reduction in entrainment that would have been possible in the past. This information was also used to evaluate the potential optimal operating range for pumps, and the variability in flow reductions that may be available in the future. Each of these factors affect the design of the VSP/VSD system which, in turn, affects the opportunity for flow reduction.

[31] The NPDES ΔT of 17°F is a monthly-averaged limit and does not apply on an instantaneous basis.

10.6.2.1 VSP/VFD Operating Rules based on Historical Data

The hourly record of station operating parameters described above was used as the basis of a spreadsheet model of the potential to reduce intake flow. Two years of data were used: 2015 when the facility had a relatively high capacity factor and 2016 when the facility was dispatched less frequently. In general, changes in capacity utilization for the two units are determined by changes in electricity demand and price competitiveness of the units relative to other sources of electricity. Therefore, in particularly hot summers or when other generating sources are unavailable, demand on Bayside will be higher.

This evaluation followed the steps below to assess potential flow reductions at Bayside:

1. Obviously erroneous or missing data from the 2015 and 2016 intake flow and temperature data sets were deleted. This included ΔT values of less than 1.0°F, condenser vacuum pressure values of greater than 8.0 in mercury (absolute), and all missing data points. The potential that some erroneous data were retained was viewed as acceptable in order to maintain a large dataset as well as the difficulty associated with their identification.
2. Hourly data was grouped by cold water temperature as a means to organize the potential flow reduction output values. Cold water/condenser inlet temperature directly affects condenser performance. The groups correspond to temperature ranges presented in Bayside's condenser specification. These cold water temperature ranges include 0°F to 60°F; 61°F to 65°F; 66°F to 70°F; 71°F to 78°F; 79°F to 85°F; 86°F to 90°F; and 91°F and above.
3. It is assumed that both pumps for each unit would be variable speed. This is necessary as the two pumps feed a common pipe and condenser. If one pump was constant speed and the other variable, hydraulic issues in the conveyance system and condenser could occur.
4. The actual total pump rate for each unit at Bayside (Unit 1 = 184,800 gpm; Unit 2 = 252,000 gpm) was added to the dataset if the pump status was active. For data points where the ΔT exceeded 17°F, no flow reduction was evaluated. For data points where the ΔT was less than 17°F, the flow rate for each unit was hypothetically reduced until the monthly average of ΔT was equal to the target of 17°F. The allowable percent of flow reduction was fixed for each unit to achieve the target ΔT. There were hourly instances

when the ΔT was larger than 17°F; ΔT greater than 32°F were deleted as likely unrealistic, others were retained.

5. The percent of flow reduction was further adjusted to account for a minimum water velocity through each condenser of 3 ft per second to avoid sedimentation within the condenser tubes.
6. The hourly percent of flow reduction was averaged across four-hour time steps, meaning that the VFDs/VSPs would not be adjusted more often than once every four hours. The time step is meant to account for time required to activate or deactivate the hypothetical VFDs or VSPs on an operations level and approximate realistic operational conditions at the station.
7. Bayside presently operates circulating water pumps continuously to limit biological growth within pipes. Biological growth is discernible/considerable when the station is required to shutdown circulating pumps for more than 8 hours or more. Operations personnel have found that operating the pumps at full flow for approximately 8 to 10 hours inhibits and/or removes biological growth. This evaluation therefore assumes that on days when there is no generation, the pumps would be operated at full flow for 8 hours.
8. These flow reduction calculations were performed to maintain a monthly average ΔT of 16°F and 15°F for both generating units at Bayside in 2015 and 2016. When flow reductions were viable, monthly allowable reductions were distributed proportionately to water use rate in any four-hour step. This was to mimic the fact that the station would operate all month if it were asked to dispatch and all flow reductions would not be concentrated to a few days of the month. At no point is the hourly flow rate allowed to exceed pump ratings.
9. Bayside needs to meet a ΔT limit of 17°F downstream of the confluence of the hot water discharges from Units 1 and 2. Because of the operating complexity that flow reduction would pose, this evaluation assumed that the target ΔT would be 15°F or 16°F (instead of 17°F), to provide operator margin and avoid potential thermal violations.
10. Potential flow reduction was estimated for both the full calendar year and the recruitment period.

10.6.2.2 Hypothetical Flow Reductions During the Recruitment Period

This subsection summarizes data from 2015 and 2016, with a focus on the recruitment period, to assess potential flow reduction opportunities at Bayside, specifically, how much flow reduction may be available and when such reductions would be available.

1. Flow, generation, and ambient water temperature characteristics are different for 2015 and 2016. On average, the above operating rules indicate that there would have been no potential flow reductions during the recruitment period in 2015 if the target ΔT were 15°F, and only up to 4 percent if the ΔT were 16°F.
2. In 2016, the potential flow reductions during the recruitment period may have been up to 23 percent if the target ΔT were 15°F, and up to 27 percent if the ΔT were 16°F. Table 10-30 shows potential flow reductions that may have been possible in 2015 while meeting a ΔT of 15°F. Table 10-31 shows similar information for 2016. The 'Average Annual Flow Reduction for Recruitment Period Only' considers values for the recruitment period only. Table 10-32 and Table 10-33 show potential flow reductions in 2015 and 2016 if the target ΔT were 16°F.
3. Units 1 and 2 flow reduction potential looks nearly-identical because Bayside presently monitors discharge temperature at a location downstream of where the two discharges mix. The two discharges would need to be monitored upstream of the mixing basin to obtain a better idea of the differences between the two units. Such monitoring is also likely to advisable in a further evaluation of VSP/VSD that would be necessary before committing to its installation.
4. Table 10-30 shows that 2015 would not have allowed a target ΔT of 15°F in June, July or August. Table 10-32 shows that a target ΔT of 16°F would not have been possible in July or August of 2015. These data also indicate that the operating rule needs to be adaptable to the target ΔT temperature depending on generation intensity; that when demand for electricity is high, flow reductions may not be possible and the lower target ΔTs also may not be possible.

Table 10–30. 2015 Average Monthly Intake Flow Reductions that May Have Been Possible at Bayside, While Meeting a Monthly ΔT of 15°F

Month	Average Flow Reduction (%)		
	Unit 1	Unit 2	Plant Total
January	No data	No data	No data
February	No data	No data	No data
March	No data	No data	No data
April	No data	No data	No data
May	1	1	1
June*	0	0	0
July*	0	0	0
August*	0	0	0
September	1	1	0
October	0	0	1
November	35	34	34
December	14	14	15
Average annual flow reduction for recruitment period only	0*	0	0

Note: Shading represents recruitment period for which average annual flow reduction percent is calculated.

*Cannot reach the 15°F ΔT limit.

Source: HDR, 2017.

Table 10–31. 2015 Average Monthly Intake Flow Reductions that May Have Been Possible at Bayside, While Meeting a Monthly ΔT of 16°F

Month	Average Flow Reduction (%)		
	Unit 1	Unit 2	Plant Total
January	No data	No data	No data
February	No data	No data	No data
March	No data	No data	No data
April	No data	No data	No data
May	8	8	8
June	7	7	7
July*	0	0	0
August*	0	0	0
September	8	8	8
October	8	8	8
November	39	38	38
December	19	19	19
Average annual flow reduction for recruitment period only	4	4	4

Note: Shading represents recruitment period for which average annual flow reduction percent is calculated.

*Cannot reach the 16°F ΔT limit.

Source: HDR, 2017.

Table 10–32. 2015 Average Monthly Intake Flow Reductions that May Have Been Possible at Bayside, While Meeting a Monthly ΔT of 16°F

Month	Average Flow Reduction (%)		
	Unit 1	Unit 2	Plant Total
January	0	0	0
February	8	10	9
March	17	25	21
April	12	12	12
May	26	26	26
June*	21	21	21
July*	19	19	19
August*	21	21	21
September	30	34	32
October	27	36	32
November	No data	26	15
December	60	57	58
Average annual flow reduction for recruitment period only	23*	23	23

Note: Shading represents recruitment period for which average annual flow reduction percent is calculated.

*Cannot reach the 15°F ΔT limit.

Source: HDR, 2017.

Table 10–33. 2016 Average Monthly Intake Flow Reductions that may have been Possible at Bayside, While Meeting a Monthly ΔT of 16°F

Month	Average Flow Reduction (%)		
	Unit 1	Unit 2	Plant Total
January	0	0	0
February	14	16	15
March	21	29	26
April	17	17	17
May	30	30	30
June*	25	25	25
July*	23	23	23
August*	26	26	26
September	34	37	36
October	31	39	35
November	No data	30	17
December	62	59	60
Average annual flow reduction for recruitment period only	27	27	27

Note: Shading represents recruitment period for which average annual flow reduction percent is calculated.

*Cannot reach the 16°F ΔT limit.

Source: HDR, 2017.

5. Where reductions on the order of 20 percent appear to have been available each month (Table 10-31) during the recruitment period in 2016, minimal flow reduction opportunities were available in 2015 because of high rate of facility dispatch. These two years of data indicate variability in generation. Units 1 and 2 information is similar, therefore only Unit 2 is shown in Figure 10-31. Also, the information pattern is similar for a target ΔT of 15°F and 16°F. Therefore, information for a target ΔT of 15°F is shown.

Table 10-32 shows potential flow reductions that may have been possible in 2015 while meeting a ΔT of 16°F. Table 10-33 shows similar information for 2016. As would be expected, flow reduction opportunities are greater for both years when the target temperature is higher (16°F).

While outside the recruitment period, Table 10-31 and Table 10-33 show that a target ΔT of 15°F and 16°F, respectively, would not have been possible in January.[32] These data indicate that flow reduction opportunities may be lower during 'winter' months.

Based on the above observations, 16°F was selected as the target ΔT. This temperature target would balance potential flow reductions while giving the operator margin to control the system.

10.6.2.3 Hypothetical Primary Operating Range of Pumps

Section 10.6.2.2 assessed potential flow reductions that may be available at Bayside during the recruitment period. Potential flow reductions are not uniform across all months. This subsection assesses the variability in reductions in different months to evaluate the primary pump operating range to achieve maximum overall reductions.

[32] January data are unavailable for 2015, but January is outside the recruitment periods, so perhaps flow reductions need not be sought in January.

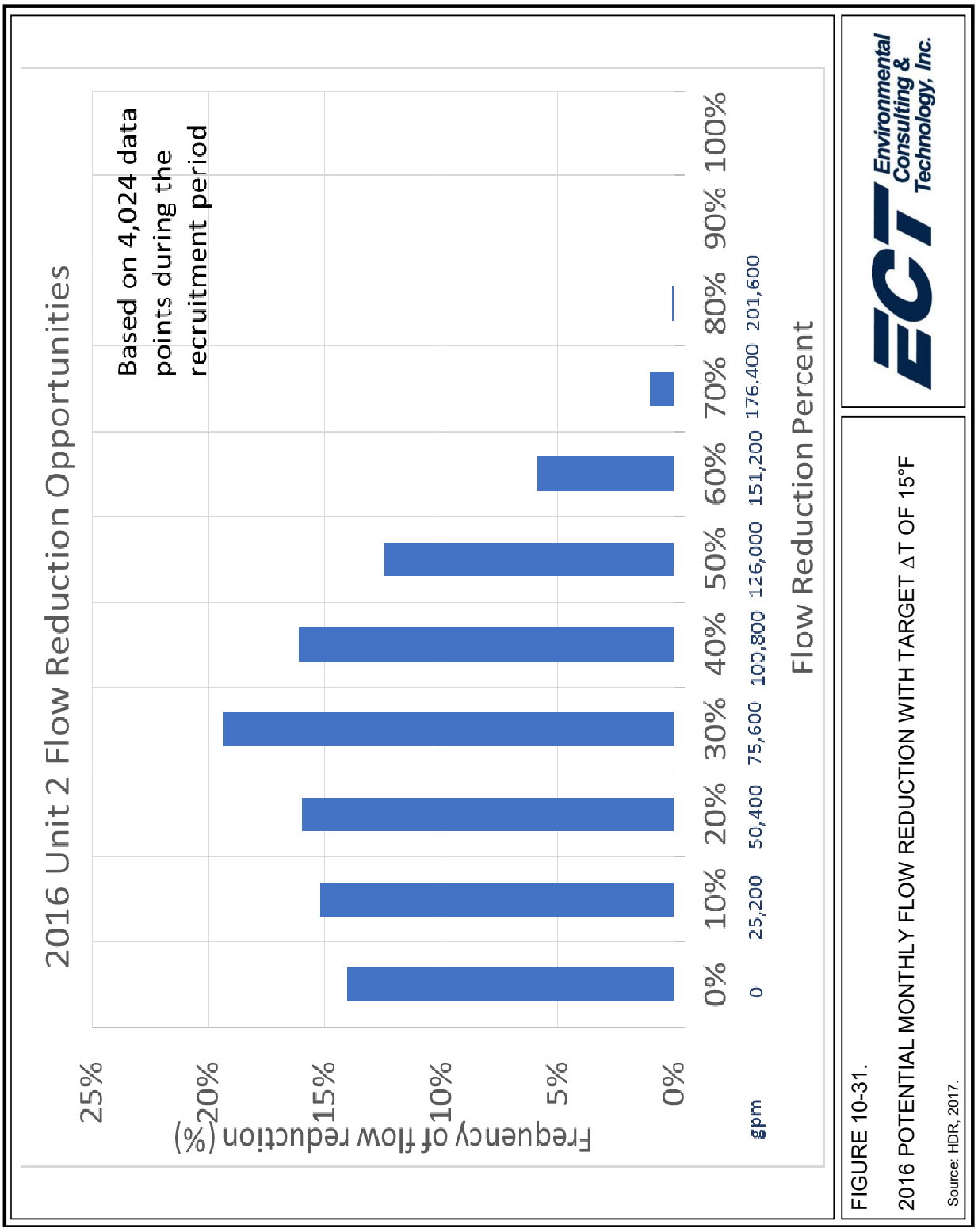


FIGURE 10-31.

2016 POTENTIAL MONTHLY FLOW REDUCTION WITH TARGET ΔT OF 15°F

Source: HDR, 2017.

Understanding how the 0, 4, 23, or 27 percent reductions would be achieved under various scenarios is important. Figure 10-32 shows how the 27 percent annual flow reduction during the recruitment period occurs. Flow reductions between 0 and 10 percent contribute less to the overall reductions (even though their occurrence frequency is high – see Figure 10-31). As shown in Figure 10-32, flow reductions between 20 and 30, 30 and 40, and 40 and 50 percent contribute to the largest overall reductions. Approximately 18 percent of the 27 percent annual reductions (i.e., 18/27 percent) are due to 30-, 40-, and 50-percent reductions. Approximately 22 percent are due to between 30- and 60-percent reductions.

To take advantage of pump efficiency, the pump needs to be optimized for a certain range. Based on the trends illustrated in Figure 10-32, the optimal flow reduction range observed in historical data is between 20 and 60 percent or between 30 and 50 percent (using 2016 data).

Assuming a potential 40 percent operating band for a pump (shown by the brackets in Figures 10-33 and 10-34), flow reductions between 20 and 60 percent allow the greatest overall reductions in 2016 -see Figure 10-33. However, Figure 10-34 shows that during high dispatch years, a lower band (0 to 40) may afford greater pump fine-tuning opportunities. Given the two years of data, a pump operating band of 50 to 90 percent is selected. Such a system would allow reasonable fine-tuning in both years but may not capture the optimal reductions in any year.[33]

Advance (12 to 24 hours) knowledge of dispatch requirements would help execute this operating rule.

10.6.3 Sizing

Even though the pumps would be adjusted only once per 4 hours, generation, ambient water temperature, discharge temperature, etc. would need to be monitored more regularly (likely hourly) to allow sufficient time for planning and pump adjustments. A robust automated monitoring and distributed control system (DCS) would be needed for this system as operator implementation would be too burdensome.

[33] This does not mean the VSP would be unavailable outside this range, but that its operations would not be optimal.

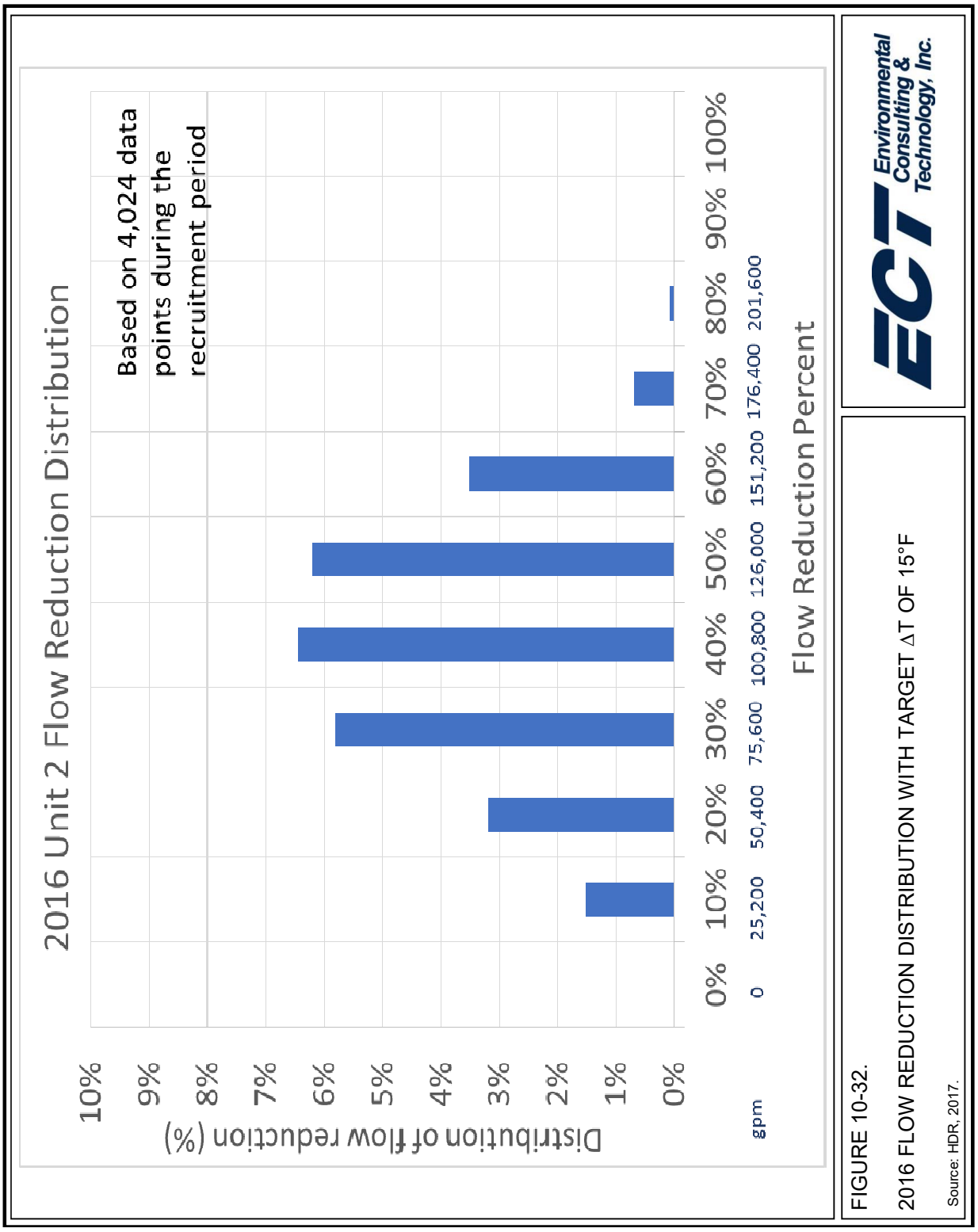
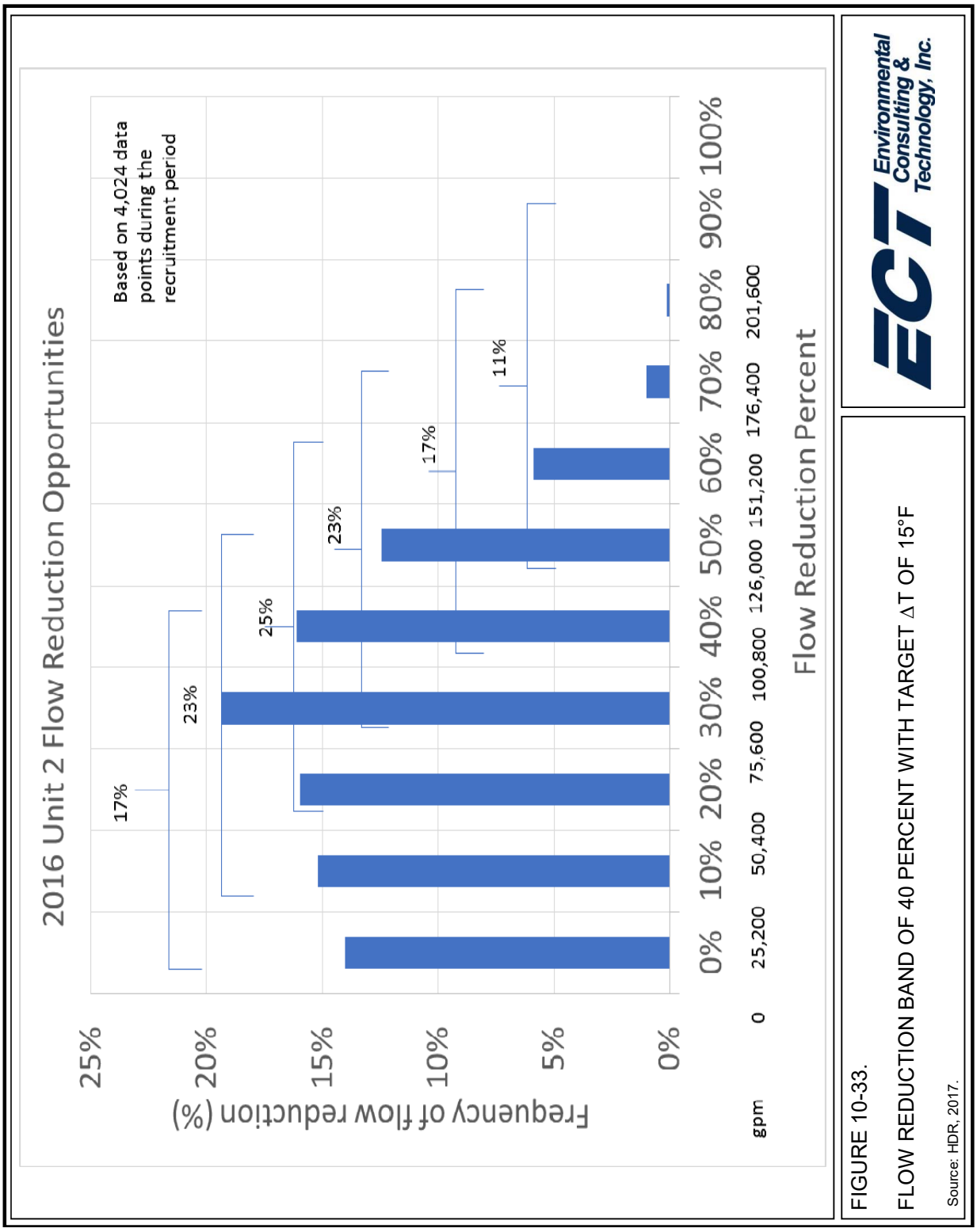


FIGURE 10-32.

2016 FLOW REDUCTION DISTRIBUTION WITH TARGET ΔT OF 15°F

Source: HDR, 2017.


Y:\GDP\T1000\170205\Bayside316(b)-R10Figs.xlsx—02/26/18
2016 Unit 2 Flow Reduction Opportunities
Based on 4,024 data points during the recruitment period
Frequency of flow reduction (%)
25%
20%
15%
10%
5%
0%
17%
23%
25%
23%
17%
11%
gpm
0
25,200
50,400
75,600
100,800
126,000
151,200
176,400
201,600
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Flow Reduction Percent
Environmental Consulting & Technology, Inc.
FIGURE 10-33.
FLOW REDUCTION BAND OF 40 PERCENT WITH TARGET ΔT OF 15°F
Source: HDR, 2017.

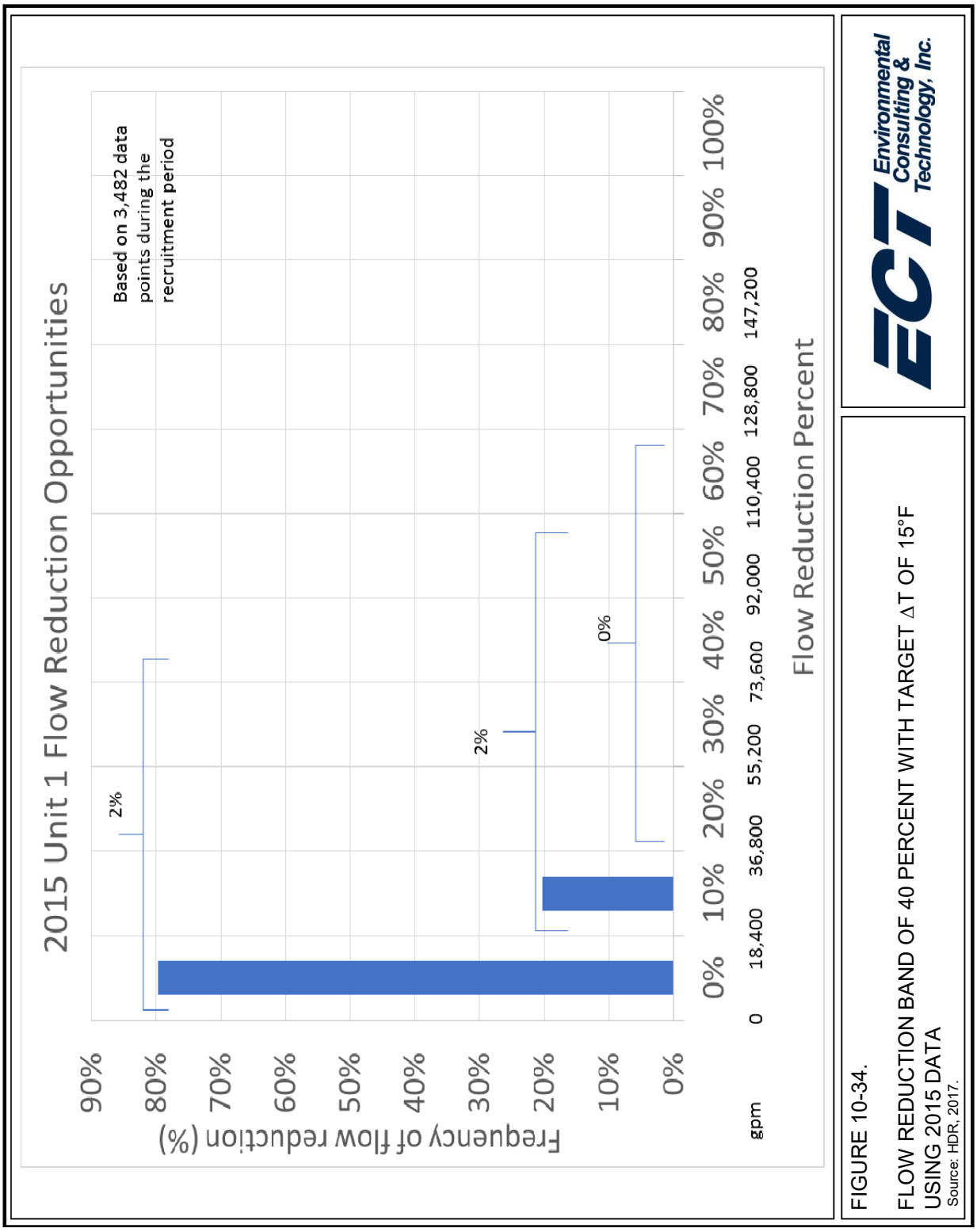


FIGURE 10-34.

FLOW REDUCTION BAND OF 40 PERCENT WITH TARGET ΔT OF 15°F USING 2015 DATA

Source: HDR, 2017.

Assuming that 40-percent range of flow reduction may be available as a control window on the VSP, controlling flow between 50 percent and 90 percent of the pump capacity may provide the largest overall flow reduction.

This evaluation looks at an entire month at time when assessing potential flow reductions. If this option were implemented, the Operator or system logic would be able to evaluate the station's temperature compliance information in the preceding days in that month, but not the future. The Operator (or the system logic) may choose to exceed the target temperature during the early days of the month if the demand for electricity is high, while reducing flow to the level required, but as the month progresses, the Operator (or system logic) would need to be more cautious in the allowable flow reductions in order to meet the monthly-averaged 17°F ΔT limit. This evaluation was performed using Microsoft Excel™, which is not conducive this the type of programming needed for the forward-looking assessment. This limitation on the current assessment is an example of why a more in-depth feasibility and design study would be necessary prior to committing to VSP/VSD.

10.6.4 Feasibility Discussion

10.6.4.1 Feasibility of Retrofitting Existing Pumps with VFDs

The system curve for Bayside is unavailable; as discussed in Section 10.6.1, more of the pump head requirements are expected to develop static head and the remainder to overcome friction losses. As such, the pumps' operating efficiencies are expected to erode as the operating point deviates from the previously optimized range. The pumps are old but have been refurbished and are in good condition; however, plant operators believe that the pumps would have to be replaced prior to VFD retrofit. While small reductions in water flow would not significantly impede condenser performance and or hydraulic stability, large (greater than approximately 30 percent) flow reductions could. The larger reductions in flow are what contributes to meaningful reductions in entrainment. Given the pump characteristics and the operating range needed for meaningful flow reductions at Bayside, retrofitting the existing constant speed pumps with VFDs is deemed infeasible, and therefore not discussed further.

10.6.4.2 Feasibility of Replacing Existing Pumps with VSPs

Replacing the existing pumps with VSPs is technically feasible, but impractical. Replacing the pumps would require that a building to house the new drivers be constructed near the CWIS. This new building would need climate control and dust control, as discussed in Section 10.6.1. The CWIS decking and pump supports may require some modifications depending on the size of the VSP base as compared to the size of the existing pump base (this would be in addition to any other repairs needed at the CWIS). One pump at a time would be isolated at the butterfly valve (shown with a red rectangle in Figure 10-35), the old pump removed, and a new pump installed.

If the existing pumps were replaced with VSPs, this evaluation assumes that an automated logic control or DCS would incorporate the various operating rules, dispatch requirements, permit limitations and compliance record for the preceding days of the month, pipe biofouling potential, minimum flow velocity required within condenser tubes, etc. and modulate the speed of the pump within an allowable band. Doing so manually would be impractical and infeasible.

Even with a DCS, modulating pump flows and allowing for ΔT greater than 17°F when power requirements are particularly high, and then making up on compliance later in the month when the demand is lower would be challenging.

This option is viable only if the station is allowed to reduce flow to the extent practicable when the demand for electricity allows. Bayside is an important asset in the Tampa area, and needs to be able to generate when it is required. If the NPDES permit allows for flexibility in impingement mortality and entrainment reduction, then this technology may be potentially feasible (after extensive additional design evaluations). However, if the NPDES permit impose specific flow reductions via VSPs during certain weeks of the year or hours in the day, then this option would be infeasible and impractical.

Cooling water flow rate and heat load can impact the performance efficiency of the condensers. This evaluation assumed that the maximum heat load of the condenser would not be exceeded at any time. Additionally, the cooling water flow rate would be reduced only to the extent that the ΔT does not exceed the permit limit of 17°F on a monthly-averaged basis; and that the instantaneous ΔT would be allowed to increase up to 32°F (consistent with current practices).

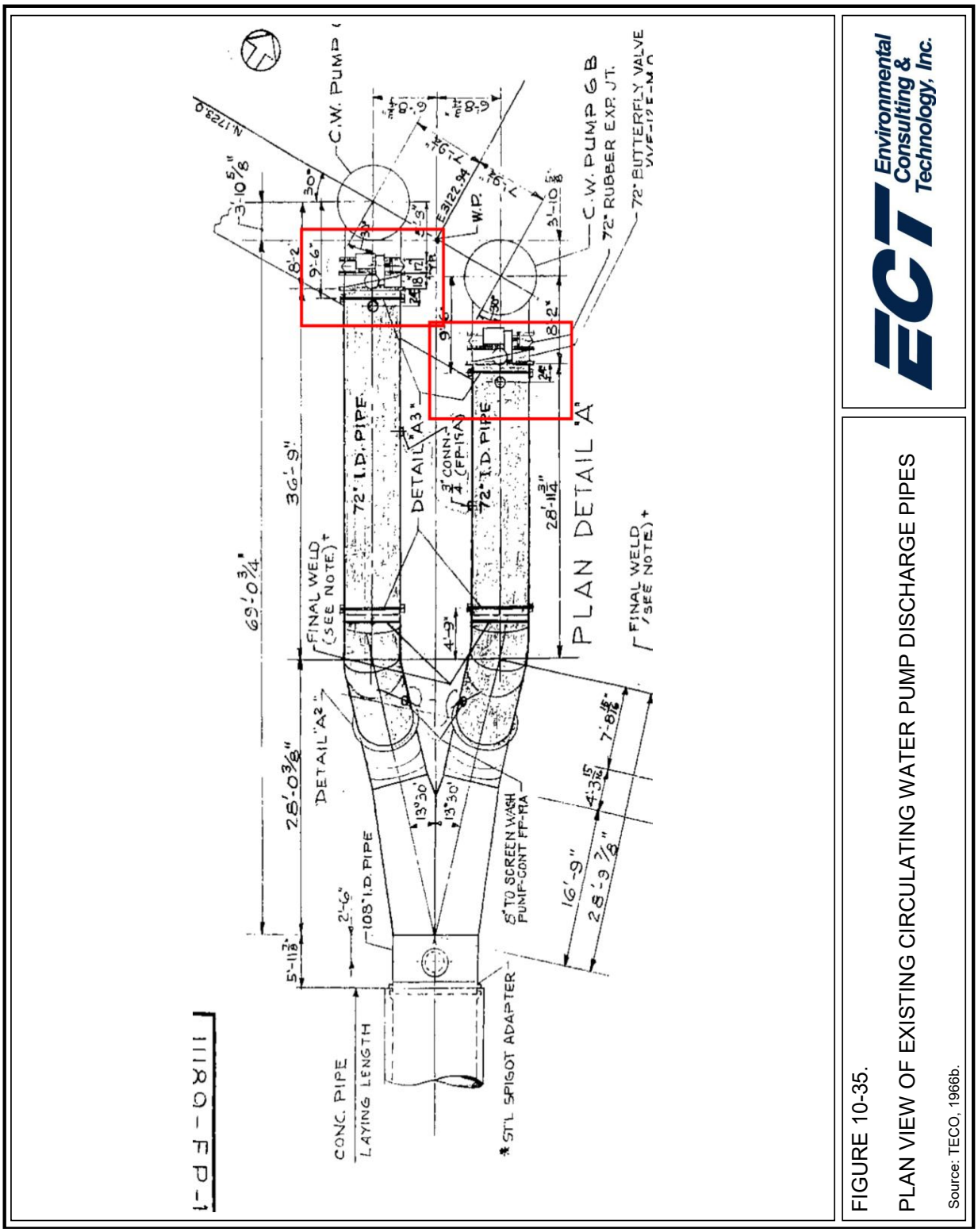


FIGURE 10-35.

PLAN VIEW OF EXISTING CIRCULATING WATER PUMP DISCHARGE PIPES

Source: TECO, 1966b.

Allowing the ΔT to increase could result in a marginal reduction in condenser performance, however, because flow reductions occur: (1) only within the historically observed range, and (2) under reduced heat load conditions, condenser performance would not decrease compared to current performance levels.

10.6.5 Anticipated Schedule

The schedule assumed for implementing VSPs and for estimating the net present value of this technology is presented in Table 10-34.

Table 10–34. VSP Implementation Schedule

Calendar Year	Year	VSPs
February 2018	0	Submit NPDES renewal application and 316(b) information
August 2018	0.5	Permit expiration
February 2019	1	Final BTA determination
August 2019	1.5	Pump evaluation; Engineering Contract
February 2020	2	30 percent design; permit applications
August 2020	2.5	Permitting; 60 percent design
February 2021	3	95 percent design; procure pumps, permits, bid construction work, select contractor
August 2021	3.5	Install pumps. Construct building to house VSDs.
February 2022	4	Testing and commissioning

Source: HDR, 2017.

10.6.6 Costs

The costs associated with VSPs are discussed below. This option assumes that the existing pumps would be replaced with VSPs.

10.6.6.1 Capital

Based on the existing conditions and assumptions stated herein, the AACE Class 4 estimate was developed to replace the existing constant speed pumps with VSPs. Capital costs are presented in 2017 U.S. dollars. The owner's costs are included as 10 percent of total construction costs and design engineering costs. Contingency was also included at 20 percent of the major costs.

The Class 4 estimate for the capital costs for outside labor and materials for four VSPs, their drives, inverters, a building to house the drives, and pipe and electrical reconnections at Bayside would be approximately $11 million, if all work were implemented in 2017 (Table 10-35).

Table 10–35. VSP Capital Costs if Implemented in 2017 (2017 $ Millions)

Capital Costs	Estimated Cost
Construction Direct Costs	
Variable Speed Vertical Turbine Pumps - 127 MGD	$1.67
Variable Speed Vertical Turbine Pumps - 208 MGD	2.28
Removal of Existing Pumps	0.06
Seating and Tie-in of New Pumps	0.06
Cleaning and Restorations	0.00
Pipe Connects	0.08
Electrical	0.22
Prefabricated Housing for Drivers	1.07
Subtotal Direct Construction Costs	$5.43
Construction Indirect Costs	
Contractor Site Supervision	$0.24
General Conditions	0.64
General Admin & Profit	1.26
Subtotal Indirect Construction Costs	$2.14
Total Construction Cost	**$7.57**
Other Capital Costs	
Design Engineering	$0.35
Permitting	0.13
Owners Costs	0.80
Contingency	2.21
Total Capital Cost	**$11.07**

Source: HDR, 2017.

10.6.6.2 O&M

O&M cost for the hypothetical VPSs is estimated at approximately $0.3 million per year (if incurred in 2017), and parts repair and replacement for pumps, drives, and heating, ventilation, and air conditioning (HVAC) as listed in Table 10-36.

Table 10–36. VSP Annual O&M Costs

O&M Cost Components	MDCT (2017 $M)
Labor	$0.08
Parts replacement and maintenance	$0.26
Total	**$0.34**

Source: HDR, 2017.

10.6.6.3 Environmental Mitigation Costs From 40 CFR 122.21(r)(12)

This evaluation assumes that energy efficient pumps would be used and they would be operated as efficiently as practicable given operating limits. No additional impact mitigation measures have been contemplated.

10.6.6.4 Facility-Level Compliance Cost (Annual and NPV)

The evaluation assumes that the hypothetical VSPs would follow the generation load to the extent practicable, and the HVAC system would be active continuously and would operate based on a thermostat.

Per the schedule presented in Section 10.6.5, the VSPs would be operational in 2022.
Table 10-37 overlays capital costs on the anticipated implementation schedule. O&M costs are presented in two tables: Table 10-38 provides O&M costs associated with labor and parts repair and replacement, Table 10-39 provides additional electricity costs for pumps and associated equipment assuming $5,037/MWhr. Note that potential flow reductions at Bayside are small and VSPs would have their own inefficiencies. Energy requirements for the HVAC system in Tampa far outweighs energy savings from turning down circulating pumps.

Table 10–37. Capital Cost Outlay for VSP Implementation

Timeframe	Calendar Year	Year	VSP Implementation	Costs (million $)		Present Value (million $)
				If Implemented in 2017	In a Given Year	
February 2018	2018	0	Submit NPDES renewal application and 316(b) information	$0	$0	$0
August 2018	2018	0.5	Permit expiration	$0	$0	$0
February 2019	2019	1	Final BTA determination	$0	$0	$0
August 2019	2019	1.5	Pump evaluation; engineering contract	$0.20	$0.21	$0.19
February 2020	2020	2	30-percent design; permit applications	$0.57	$0.63	$0.52
August 2020	2020	2.5	Permitting; 60-percent design	$0.37	$0.41	$0.33
February 2021	2021	3	95-percent design; procure pumps, permits, bid construction work, select contractor	$6.50	$7.32	$5.62
August 2021	2021	3.5	Install pumps; construct building to house drivers	$3.32	$3.74	$2.87
February 2022	2022	4	Testing and commissioning	$0.16	$0.19	$0.14

Source: HDR, 2017.

Table 10–38. O&M Costs (Excluding Electricity Costs) for VSP Implementation

Year	Costs (million $)		Present Value (million $)
	O&M If Incurred in 2017	In a Given Year	
2022	$0.17	$0.20	$0.14
2023	$0.34	$0.40	$0.27
2024	$0.34	$0.42	$0.26
2025	$0.34	$0.43	$0.25
2026	$0.34	$0.44	$0.24
2027	$0.34	$0.45	$0.24
2028	$0.34	$0.47	$0.23
2029	$0.34	$0.48	$0.22
2030	$0.34	$0.50	$0.21
2031	$0.34	$0.51	$0.20
2032	$0.34	$0.53	$0.20
2033	$0.34	$0.54	$0.19
2034	$0.34	$0.56	$0.18
2035	$0.34	$0.58	$0.18
2036	$0.34	$0.59	$0.17
2037	$0.34	$0.61	$0.16
2038	$0.34	$0.63	$0.16
2039	$0.34	$0.65	$0.15
2040	$0.34	$0.67	$0.15
2041	$0.34	$0.69	$0.14
2042	$0.34	$0.71	$0.14
2043	$0.34	$0.73	$0.13
2044	$0.34	$0.75	$0.13

Source: HDR, 2017.

Table 10–39. Electricity Costs for Operating VSPs

Year	Costs (million $)		Present Value (million $)
	O&M If Incurred in 2017	In a Given Year	
2022	$0.44	$0.51	$0.37
2023	$0.88	$1.05	$0.71
2024	$0.88	$1.08	$0.68
2025	$0.88	$1.11	$0.66
2026	$0.88	$1.15	$0.63
2027	$0.88	$1.18	$0.61
2028	$0.88	$1.22	$0.59
2029	$0.88	$1.25	$0.57
2030	$0.88	$1.29	$0.55
2031	$0.88	$1.33	$0.53
2032	$0.88	$1.37	$0.51
2033	$0.88	$1.41	$0.49
2034	$0.88	$1.45	$0.47
2035	$0.88	$1.49	$0.46
2036	$0.88	$1.54	$0.44
2037	$0.88	$1.59	$0.42
2038	$0.88	$1.63	$0.41
2039	$0.88	$1.68	$0.39
2040	$0.88	$1.73	$0.38
2041	$0.88	$1.78	$0.37
2042	$0.88	$1.84	$0.35
2043	$0.88	$1.89	$0.34
2044	$0.88	$1.95	$0.33

Source: HDR, 2017.

10.6.6.5 Social Cost (Annual and NPV)

The estimated social costs for replacing the existing constant speed pumps with variable speeds pumps range from $12.9M (7-percent discount rate) to $22.2M (3-percent discount rate) (Table 10-40).

Table 10–40. Total Social Costs of Retrofit to MDCT

Discount Rate (%)	Electricity Price Increase (million $)	Costs (million $)				
		Fuel*	Externality	Permitting*	Total Social (NPV)	Annual Social
3	$11.9	$16.7	$0	$0.1	$22.2	$1.0
7	$7.1	$16.7	$0	$0.1	$12.9	$0.6

*Permitting and fuel costs presented are undiscounted and in 2017 dollars.

Source: Veritas, 2018.

10.6.7 Uncertainty

The following uncertainties are associated with this preliminary evaluation of the feasibility of VSPs or VFDs at Bayside:

1. Data points that included abnormal values for ΔT or condenser pressure were excluded from the analysis. The exclusion was based on BPJ instead of actual operating conditions at Bayside. Some erroneous data may have been retained.
2. Condenser performance evaluation assumes that the original condenser performance curves still represent Units 1 and 2 operations, which they probably do not. When generation or water temperature corresponded to a value between two condenser performance curves, for simplicity, the performance value from the nearest curve was used. This introduces an error each time.
3. The two units appear to behave similarly. But this may be due to the discharge temperature monitoring location instead of actual operating conditions. Current data do not allow independent evaluation of the two units.
4. Maximum ΔT in the record is 32.1 °F (in 2016), therefore occasionally the ΔT was allowed to rise to 32 °F as long as the monthly ΔT met the target temperature criterion. Because this is outside of the recruitment period, the operating rule was not corrected. Maximum ΔT in 2015 was 29.9 °F.

5. This evaluation assessed the increase in backpressure when the flow rate is reduced and the ΔT across the condenser is allowed to increase. Prior to estimating the increase in back pressure, this study first tried to mimic condenser performance and backpressure using unit load and cooling water temperature and found that condenser performance deviates from the original condenser performance curve. The change in flow rate appears to have a backpressure effect. But because the newly estimated ΔT are well-within historical ΔT values, the ensuing backpressure effects are not considered unacceptable and any decline in generation efficiency was neglected. Neglecting any such reductions in output reduces the estimated facility and social costs and is, therefore, conservative relative to the goals of the Rule.
6. The four-hour pump adjustment interval was based on best professional judgment and would need to be determined with additional input from operations personnel and pump vendor.
7. The logic used to control the VSP/VSD and the resulting opportunity to reduce flow must be refined during a more detailed feasibility and design study that includes input from pumping and condenser specialists as well as facility engineering and operations staff.
8. The variation in estimated flow reduction opportunity between 2015 and 2016 illustrates that any opportunity is likely to vary dramatically based on changes in electricity supply and demand. Regardless of the estimates of flow reduction provided here, TECO must be able to run Bayside at up to full capacity throughout the year. TECO is not in a position to accept limitations in generation capacity or intake flow less than the DIF.

As noted in the introduction to this section, this assessment of VSP/VSD has been prepared in support of the 316(b) regulatory exercise. This includes assessment of the potential configuration, feasibility, costs and benefits through an illustration of potential opportunities. Should this screening assessment suggest that VSP/VSDs represent the most promising measure, including favorable comparison to existing design and operational measures, additional feasibility and design studies would be necessary to confirm the practicality of the installation of VSPs.

10.7 Summary of the Engineering Feasibility and Cost Findings

This report evaluated the following technologies as potential entrainment reduction measures at Bayside to comply with the CWA 316(b) Existing Facilities Rule:

- Closed-cycle recirculating cooling – natural draft cooling towers, plume-abated mechanical draft cooling towers, and dry cooling, as well as a more in-depth evaluation of the preferred cooling tower technology, which is standard mechanical draft cooling towers.
- FMS – 0.5 mm modified Ristroph TWS (as a permanent screen replacement, mesh basket overlays, and intake expansion), and 0.5 mm wedgewire screens.
- Alternate water sources and water reuse options.
- VSPs and VFDs.

10.7.1 Summary of Evaluation Findings and Reasoning

Evaluation findings are summarized in Table 10-41. The summary includes whether the technology was found to be feasible and practical including factors that determine that status. A subset of technologies, as noted in the table, will be evaluated further in the submittals under 40 CFR 122.21(r)(11) and (12) for their potential social benefits and their other environmental impacts, respectively.

10.7.2 Technologies Retained for Biological Efficacy and Impacts Evaluations

Based on the summary in Table 10-41, technologies retained for biological and costing evaluations are listed in Table 10-42.

10.8 Summary of Social Costs for Candidate Technologies

Table 10-43 provides a summary comparison of the social costs for each candidate technology at both annual and net present value and a 3 and 7 percent discount rate.

Table 10–41. Summary of Evaluation Findings

Technology	Feasibility/Practicality Finding	Key Reasoning for Finding
Natural draft cooling towers	Infeasible	Approach and range of cooling tower needed for Bayside are too small for this type of tower.
Mechanical draft cooling towers	Impractical	Technology appears to be technically feasible where this evaluation assumes that existing infrastructure is in good condition. A detailed condition assessment of existing infrastructure is needed prior to implementing this option. The remaining life of the condenser and other key components is shorter than the life of the proposed components. Under such conditions, retrofitting this system is impractical.
Plume-abated mechanical draft cooling towers	Impractical and unnecessary	Technology technically feasible. But similar to the standard MDCT, such a retrofit would be impractical due to the age of existing infrastructure. Given the site and its environs, plume abatement is not necessary or beneficial.
Air-cooled condensers	Infeasible	Technology's design characteristics incompatible with Bayside's existing condenser. Costs far higher than alternative technology of MDCT.
Reuse existing water sources	Infeasible	Only reusable water source is service water, which is already used for certain cooling needs. Insufficient quantity.
Replace existing surface water source, at least in part, with alternate reclaimed water or groundwater sources	Infeasible	Insufficient quantities. Evaluated WWTP and groundwater sources within 5 miles of the station. Even if those sources were available, and transfers were allowable, the quantities available are insufficient to supplement a portion of the station's usage rate meaningfully. Fresh groundwater is scarce and highly regulated. Using fresh groundwater would not be allowable. Using saline groundwater would be acceptable to the station because it already uses water from the Hillsborough Bay, however, aquifers that have sufficient yield could exacerbate saltwater intrusion if groundwater is pumped in large quantities. Shallow unconfined aquifers do not have sufficient yield.
FMS, wedgewire	Infeasible relative to alternative FMS technology	The use of wedgewire screens, even with relatively coarse slots, would be very costly relative to the traveling screen option. It would also have significant issues reliability as well as likely poor biological effectiveness.
FMS on TWS	Potentially feasible and demonstrated at big bend station units 3 and 4; hydraulic investigation likely necessary before determined to be feasible	A system like that at Big Bend Units 3 and 4 (installation of new TWS in series with the existing coarse-mesh) is considered to be the most practical of the FMS options in terms of maximizing organism survival after exclusion and of protecting the condensers from debris by maintaining coarse-mesh screens in the intake at all times. The alternative approach of reducing TSV to less than 0.5 fps with FMS is a far costlier option and introduces permitting challenges.

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Table 10–41. Summary of Evaluation Findings (Continued, Page 2 of 2)

Technology	Feasibility/Practicality Finding	Key Reasoning for Finding
Install VFDs on existing pumps	Infeasible	Given the pump design, age and operating characteristics, installing VFDs on existing pumps in infeasible.
VSPs	Feasible but practicality and effectiveness uncertain	The conceptual approaches to estimating both opportunity for flow reduction and facility costs are relatively uncertain and would require refinement prior to commitment to the technology. Inter-annual variation in opportunity is expected to be substantial and Tampa Electric cannot accept limits on potential capacity utilization to meet a specified rate of flow reduction.

Source: ECT, 2018.

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Table 10–42. Technologies Retained for Further Evaluation

Technology	Retained for Further Evaluation of Social Costs, Social Benefits, and Other Environmental Impacts
Natural draft cooling towers	No
Mechanical draft cooling towers	Yes
Plume-abated mechanical draft cooling towers	No
Dry cooling	No
Fine mesh Ristroph traveling screens in series with existing coarse-mesh screens	Yes
Fine mesh Ristroph traveling screens with through screen velocity of less than 0.5 ft/s	No
Fine slot (2 mm) wedgewire screens	No
Reuse existing service water sources	No
Replace existing surface water source, at least in part, with alternate reclaimed water or groundwater sources	No
Install variable frequency drives on existing constant speed pumps	No
Replace existing constant speed pumps with variable speed pumps	Yes

Source: ECT, 2018.

Table 10–43. Total Engineering and Social Costs of Feasible Technology Options at Bayside

Discount Rate	Technology Type	Engineering* (million $)		Social Costs (million $)					
		Total Design, Construction, and Installation Costs	Annual O&M Costs	Electricity Price Increase	Fuel Costs*	Externality Costs	Permitting Costs*	Total Social Costs (NPV)	Annual Social Costs
3%	Closed-cycle cooling retrofit	$234.0	$3.7	$190.3	$160.7	$110.7	$2.5	$399.4	$20.0
	0.5mm fine-mesh modified traveling screens	$15.4	$0.4	$14.6	$1.1	$0	$0.2	$15.4	$0.7
	VSPs	$11.1	$0.3	$11.9	$16.7	$0	$0.1	$22.2	$1.0
7%	Closed-cycle cooling retrofit	$234.0	$3.7	$107.5	$160.7	$81.6	$2.5	$242.5	$12.1
	0.5mm fine-mesh modified traveling screens	$15.4	$0.4	$8.8	$1.1	$0	$0.2	$9.2	$0.4
	VSPs	$11.1	$0.3	$7.1	$16.7	$0	$0.1	$12.9	$0.6

*Engineering, permitting, and fuel costs presented are undiscounted and in 2017 dollars. The social costs associated with each technology are discounted at 3 and 7 percent.

Source: HDR, 2017.
Veritas, 2018.

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Appendix 10-A

Social Costs of Purchasing and Installing Entrainment Reduction Technologies: Bayside Power Station

Social Costs of Purchasing and Installing Entrainment Reduction Technologies:

Bayside Power Station

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1. The Social Costs of Purchasing and Installing Technologies

Reducing entrainment can generally be accomplished by altering operations; closing the facility; or by purchasing, installing, and operating entrainment reduction technologies. These activities lead to a number of physical changes and financial effects relating to social costs. EPA defines social costs as the "opportunity cost to society of employing scarce resources to prevent the environmental damage otherwise occurring except for the design and operation of compliance technology" (79 *Fed. Reg.* 158, 48387). These are further delineated as each of the following:

- Real-Resource Compliance Costs—direct purchase installation and operation
- Government Regulatory Costs—monitoring, administration, enforcement
- Environmental Externalities—increased fuel cost impacts from energy penalty and proposed outages.

This report covers each of these social cost categories. Real-Resource Compliance Costs result from purchasing and installing technologies at the Bayside Power Station (Bayside). Government Regulatory Costs are developed from EPA's estimates in the national rule (79 *Fed. Reg.* 158, 48300–48439). The social costs of environmental externalities are developed from the Power System Capacity Loss and Offsite Emissions Study, Recreation Study, and Property Value Study conducted at Bayside. The methods and results of those studies are presented in Appendix A, B, and C of this report.

Figure 1 depicts how expenditures on entrainment reduction technologies would have implications for TECO's balance sheet and construction activities. As the figure depicts, construction generates nearby economic activity, which can lead to good social outcomes such as more jobs. These economic impacts can be studied via economic input-output analysis techniques. As related local outcomes are typically considered good, they are not measured under social costs and not considered further here.

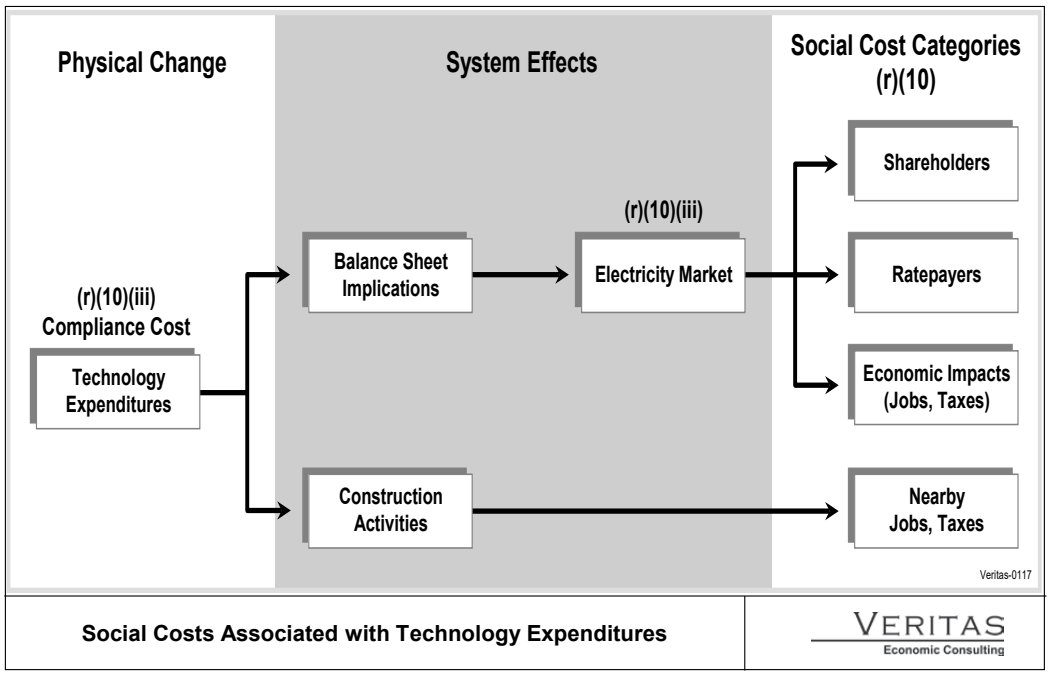


Figure 1: Social Costs Associated with Technology Expenditures

Balance sheet implications are transmitted through financial, electricity, and regulatory markets to register as social costs to shareholders, ratepayers, and the general population. How these are realized as social costs depends upon the regulatory and market environments.

1.1 Entrainment Reduction Technology Options

Bayside is a natural gas plant located on Hillsborough Bay approximately 4 miles southeast of the city of Tampa, Florida. Units 1 and 2 are combined cycle gas turbine generating units with a combined gross summer capacity of 1,650 MW. The units replaced the coal fired Gannon Power Station and have been operational since 2003 and 2004, respectively. Units 3-6 are natural gas fired peaking units that supply peak demand power when needed and have a combined capacity of 228 MW. HDR (HDR 2017) and ALDEN Research Laboratory (ALDEN 2017) have considered several alternative screen, water reuse, and closed-cycle cooling technologies and have evaluated the following four options:

- Closed-cycle recirculating cooling – natural draft cooling towers, plume-abated mechanical draft cooling towers, and dry cooling, as well as a more in-depth evaluation of the preferred cooling tower technology: mechanical draft cooling towers.

- Fine mesh screens (FMS) – 0.5 mm modified Ristroph traveling water screens (as a permanent screen replacement, mesh basket overlays, and intake expansion), and 0.5 mm wedgewire screens.
- Alternate water sources and water reuse options.
- Variable speed pumps and variable frequency drives.

Table 1 summarizes the results of whether the technology was found to be feasible and practical. As the table shows, the technologies retained for biological and costing evaluations include mechanical draft cooling towers, retrofitting the existing traveling water screens to coarse mesh and installing FMS upstream of the existing intake, and replacing the existing constant speed pumps with variable speed pumps.

Table 1
Technologies Evaluated at Bayside

Technology	Feasible and Considered for Social Cost Evaluation
Natural Draft Cooling Towers	
Mechanical Draft Cooling Towers	•
Plume-abated Mechanical Draft Cooling Towers	
Dry cooling	
Fine mesh Ristroph traveling screens in series with existing coarse mesh screens	•
Fine mesh Ristroph traveling screens with through screen velocity of less than 0.5 ft/s	
Fine slot (2 mm) wedgewire screens	
Reuse Existing Service Water Sources	
Replace Existing Surface Water Source, at least in part, with Alternate Reclaimed Water or Groundwater Sources	
Install variable frequency drives on existing constant speed pumps	
Replace existing constant speed pumps with variable speed pumps	•

1.2 Financial and Regulatory Environment

Bayside is owned by the Tampa Electric Company (TECO), a subsidiary of the Emera Company in Halifax, Nova Scotia, Canada. TECO consists of 2 regulated natural gas utilities along with Tampa Electric, a regulated electric utility. TECO's electric assets include approximately 4,700 MW of natural gas, coal, and solar generation assets serving over 750,000 customers in West Central Florida. Figure 2 presents TECO's electric service territory and location of generating assets, and Figure 3 depicts TECO's generation portfolio by fuel type.

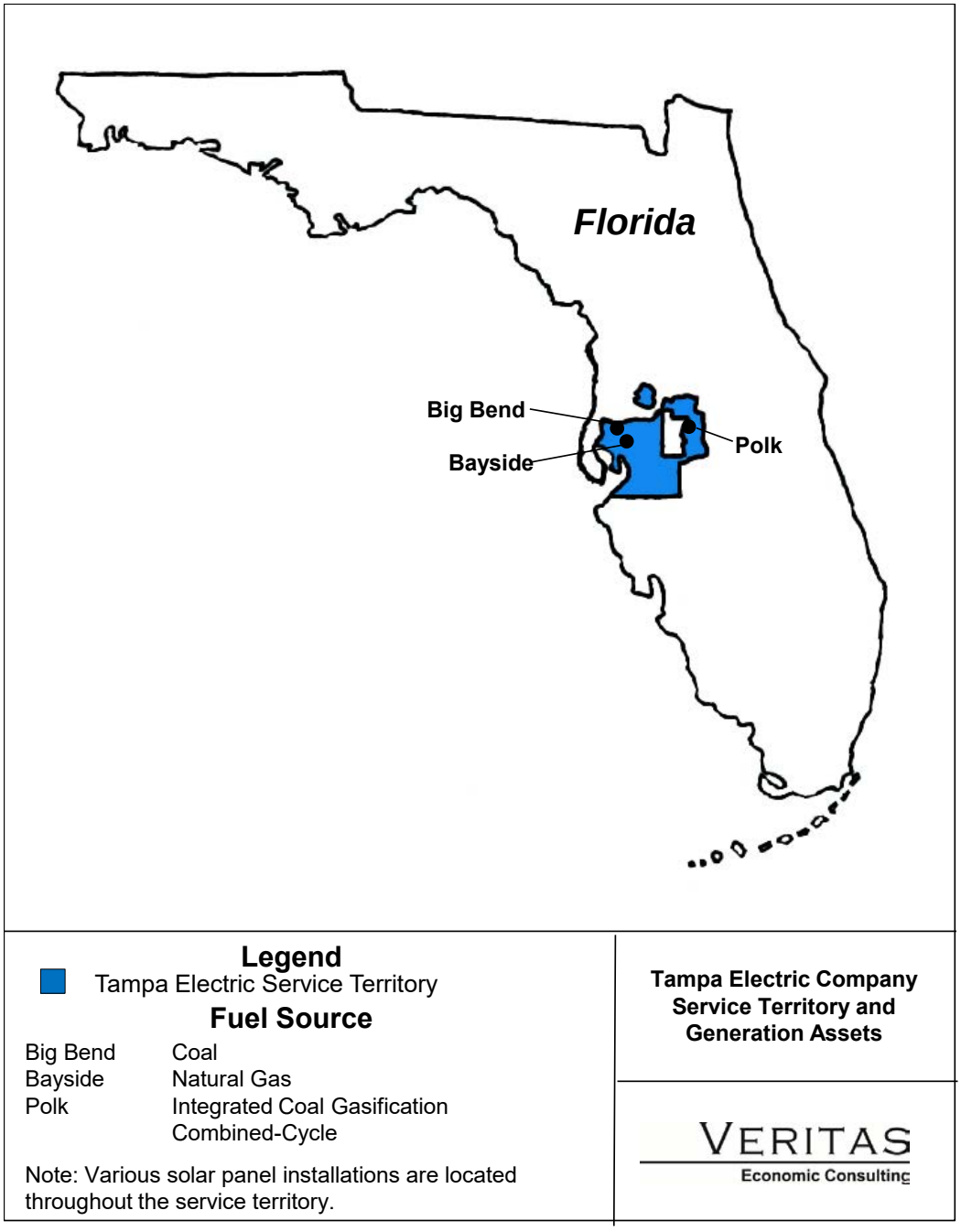


Figure 2: TECO's Service Territory and Generation Assets

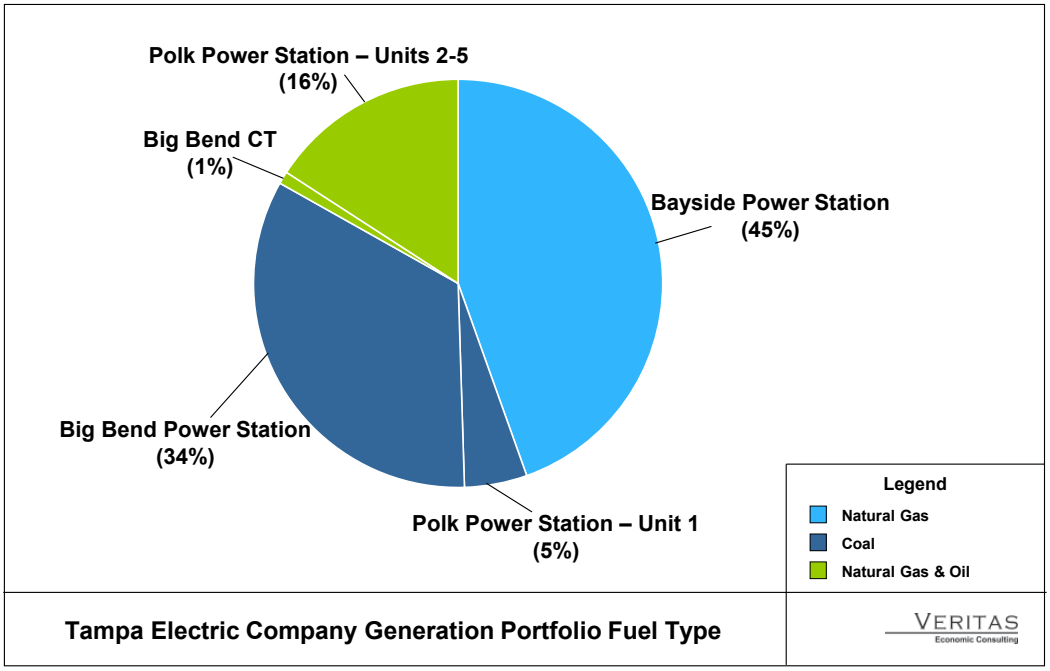


Figure 3: Percent of Generation from Assets during 2015

TECO is potentially eligible to recover all or part of the costs of installing entrainment reduction technologies. Electric utilities operating in Florida can file a rate request to the Florida Public Service Commission (PSC) for recovery of costs. The Florida PSC holds hearings and based on the facts can approve a settlement agreement authorizing cost recovery (FPSC 2017a). Procedures involved in rate request hearings include allowing intervener comments and TECO rebuttals. This process, along with the permitting itself, results in costs to the government, which are Government Regulatory Costs.

Since installing entrainment-reducing technologies is a regulatory environmental compliance requirement (as opposed to typical operations and maintenance), we expect that these costs would be passed on to customers in the form of higher rates. These costs would need to be included in a future rate case filing.

TECO's recent rate case history is instructive with respect to the implications of additional rate increase filings. In 2013, the Florida PSC issued a settlement agreement order which allowed for a rate increase phased in over three years (FPSC 2017b). On November 1, 2013, rates were increased $57.5 million which resulted in a 5.5% increase in residential customer bills. An additional $7.5 million rate increase was implemented on November 1, 2014 with a final increase

on November 1, 2015 for $5 million. The agreement included a provision to allow for the recovery of $110 million in January 2017 for the expansion of the Polk Power Station. The project involved converting turbines to combined cycle units which has added approximately 460 MW of generating capacity and increased plant efficiency by 37%. Low natural gas prices and increased efficiencies have more than offset this cost increase, resulting in a 1.45% reduction in residential customer bills. With this reduction, Tampa Electric residential customer's bills are 19% below the national average.

The costs associated with new entrainment reduction technologies would be additional costs that could potentially lead to another rate increase filing which would result in higher prices for residential, commercial, and industrial customers. The magnitude of these additional increases could also lead to economic impacts that can accompany electricity price increases (Deschenes 2010). Changes in electricity prices can lead to economy-wide employment impacts through their effect on residential and business electricity consumers. For business electricity impacts, the commercial and industrial sectors are all major users of electricity as an input to production. Electricity price increases would raise the costs of providing final goods and services in these sectors. The analysis does not quantify this effect on other sectors of the economy.

1.3 Market Environment

Retail electric markets in the state of Florida are currently not deregulated, they are served by a monopoly system of regulated utilities. The state has four investor-owned regulated utilities that collectively serve approximately 75% of the customers in Florida. The remainder is served by regulated municipalities and electric cooperatives. The regulated utilities generate power and transmit, distribute, and sell electricity to local customers that live in their defined geographic service territory. The Florida PSC regulates the utilities through a rate-making process that ensures electricity is produced and delivered at the lowest possible cost while allowing the utility to recover costs along with a fair rate of return. In addition to being subject to rate case discovery and hearings to prove that costs are just and reasonable, electric utilities are required to submit annual forecasted earnings surveillance reports to the Florida PSC to ensure that the utilities' rate of return is within an approved range.

The state of Florida does not currently participate in any of the multi-state Regional Transmission Organizations. Rates are set for each regulated utility to cover the costs to produce and deliver reliable power to customers. To ensure reliability, rates include reserve capacity that is available as needed for peak periods. Electric utilities are required to maintain adequate reserve margins which would enable them to meet high demand during peak times and extreme weather events. Adequate reserve margins also enable the utility to meet demand during planned

plant outages for maintenance, inspections, and refueling and for any unplanned outage that may occur. Customers pay for the year-round availability of reserve margin in the rates that they pay whether they use this electricity or not. TECO is considering joining the Florida Municipal Power Pool (FMPP), a group of 3 Florida municipal electric utilities that combine their generating plants as if they were one utility. The FMPP operates like an intra-state transmission organization in that it dispatches power from 51 power generators with the least cost units being dispatched first. The FMPP has a generating capacity of 4,700 MW and produced a savings of $45 million for customers in 2016. If TECO joins, the size of the power pool would effectively double which would produce additional savings for customers.

The Bayside Power Station is one of three fossil plants that produce electricity for Tampa Electric's customers. Bayside is critical, providing 45% of TECO's total generation. Temporary outages to install entrainment reducing technologies would have a significant impact on TECO's operations. Construction would need to be scheduled during off-peak months and during a time when the other two generating plants are not undergoing routine scheduled maintenance. In addition, higher cost combustion turbines would need to be dispatched to help make up Bayside's lost power.

1.4 Social Costs of Compliance

The first step in estimating the social costs of compliance is to determine whether the entrainment reducing technology costs result in the plant becoming uneconomic to operate. A pre-mature shutdown of the plant would have social costs related to loss of jobs, loss of income and expenditures, loss of tax base, increased electricity costs due to generation being dispatched at a higher price from less efficient plants, and increased infrastructure costs to maintain grid reliability. Installing entrainment reducing technologies at Bayside to comply with EPA's 316(b) Rule represents an additional operation cost that would most likely be passed on to TECO's customers in the form of higher rates. The plant's significance in TECO's generating portfolio suggests that only an extraordinarily expensive conversion requirement would lead to pre-mature closure. Therefore, this analysis specifies that TECO will incur the entrainment reducing compliance costs, continue to operate Bayside, and pass on the compliance costs to TECO's customers.

The social costs of installing entrainment reduction technologies are estimated by first determining the design, construction, and installation costs of the evaluated technologies along with the O&M, permitting, and fuel costs. Based on TECO's market conditions and ability to submit environmental compliance costs for rate recovery, this analysis specifies that all of

Bayside's compliance costs would be passed on to TECO's customers. Table 2 summarizes the results of this evaluation and its implication for social costs.

Following the requirements of the rule, Table 2 evaluates social costs under two discount rates: 3 and 7 percent (79 Fed. Reg. 158, p. 48428). As the first column of Table 2 shows, the top half of the table presents the present value of social costs discounted at 3 percent, and the bottom half presents the social costs discounted at 7 percent. The next column of the table presents each of the feasible technologies evaluated at Bayside. The third and fourth columns present the engineering costs estimated for each feasible technology. The third column presents the estimated design, construction, and installation costs, and the fourth column presents the annual operation and maintenance (O&M) costs for each feasible technology.

The remaining columns in the table present the individual categories of social costs developed for this analysis: electricity price increases, fuel costs, externality costs, and permitting costs. The analysis discounts the future stream of each of these social costs at the relevant discount rate and sums them over the years they are specified to occur to develop the Total Social Cost estimate presented in the penultimate column. The table concludes by presenting the Annual Social Cost estimate for each technology. The annual estimate divides the Total Social Cost by the number of years the analysis is conducted over.

Bayside Unit 2 is scheduled for retirement in 2044, and, therefore, engineering costs are specified as occurring over the remaining lifetime of the plant to develop the social cost estimates. Fuel costs are specified to occur during the time of both construction and operation. Regulatory documents will be submitted in 2018 and the timing for activities related to installation are dependent on the technology being installed. Table 3 reflects the timing specifications for each of the three feasible alternatives.

Table 2
Total Engineering & Social Costs of Feasible Technology Options at Bayside

Discount Rate	Technology Type	Engineering[a]		Social Costs					
		Total Design, Construction, & Installation Costs	Annual O&M Costs	Electricity Price Increase	Fuel Costs[a]	Externality Costs	Permitting Costs[a]	Total Social Costs	Annual Social Costs
3%	Closed-Cycle Retrofit	$234.0M	$3.7M	$190.3M	$160.7M	$110.7M	$2.5M	$399.4M	$20.0M
	0.5mm Fine-mesh Ristroph Traveling Screens in Series with Existing Coarse Mesh Screens	$15.4M	$0.4M	$14.6M	$1.1M	$0	$0.2M	$15.4M	$0.7M
	Variable Frequency Pumps	$11.1M	$0.3M	$11.9M	$16.7M	$0	$0.1M	$22.2M	$1.0M
7%	Closed-Cycle Retrofit	$234.0M	$3.7M	$107.5M	$160.7M	$81.6M	$2.5M	$242.5M	$12.1M
	0.5mm Fine-mesh Ristroph Traveling Screens in Series with Existing Coarse Mesh Screens	$15.5M	$0.3M	$8.8M	$1.1M	$0	$0.2M	$9.2M	$0.4M
	Variable Speed Pumps	$11.1M	$0.3M	$7.1M	$16.7M	$0	$0.1M	$12.9M	$0.6M

[a] The engineering, permitting, and fuel costs presented in Table 2 are undiscounted and in 2017 dollars. The social costs associated with each technology are discounted at 3 and 7 percent using the specifications outlined in Table 3.

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Table 3
Timing Specified for Feasible Technologies at Bayside

Entrainment Reducing Technology	Regulatory Documents Submitted	Permitting, Design, Construction & Installation	O&M Costs Begin	Years of Operation
Closed-Cycle Retrofit	2018	2018-2024	2024	20
0.5mm Fine-mesh Ristroph Traveling Screens in Series with Existing Coarse Mesh Screens	2018	2018-2021	2021	23
Variable Speed Pumps	2018	2018-2022	2022	22

As Table 2 shows, the social costs of each technology include the expected electricity price increases associated with each technology, the additional, system-level fuel costs that would be incurred with each technology, the externality costs of each technology, and the permitting costs. As previously noted, the analysis specifies that all of the engineering costs are passed on to TECO's rate payers resulting increased electricity prices. To develop the price increases, the design, construction, and installation costs are allocated over the specified construction and installation time period presented in Table 3. Operation and maintenance costs are then added for each year the technology is operational, and the future stream of those costs are discounted by 3 and 7 percent to develop the present value estimate for each discount rate.

Fuel costs represent the additional power needed to operate the new technologies and the additional fuel needed from running less efficient units during installation construction outages. The fuel costs are developed from evaluating backpressure and auxiliary load effects, capacity losses from each of the technologies with estimated outage times, and electricity consumption associated with each technology. Details of the fuel cost estimates are presented in Appendix A.

The externality costs estimated for Bayside are specified to result from property value and recreational impacts associated with the plume from the cooling towers. Appendix B presents the analysis and results of the recreational impacts, and Appendix C presents the analysis and results of the property value impacts.

Permitting costs include the total costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These vary with the type of technology, as certain technologies require substantially more permitting. Those with more significant environmental effects would have higher permitting costs. These costs are initially borne by the government, but ultimately paid by taxpayers. Permitting costs are developed from

EPA's estimates in the national rule (79 Fed. Reg. 158, 48300-48439) and are specified to be 2% of direct capital costs.

As Table 2 shows, the estimated social costs for a closed-cycle cooling retrofit range from $242.5M (7% discount rate) to $399.4M (3% discount rate). The estimated social costs for retrofitting with coarse mesh screens and installing FMS upstream of the existing intake system along with a new fish return range from $9.2M (7%) to $15.4M (3%). These are the incremental social costs for the FMS installation and operation and do not include the coarse mesh ristroph screens with a fish return because those costs will be incurred under the rule's requirement to meet the impingement reduction standard. The estimated social costs for replacing the existing constant speed pumps with variable speed pumps range from $12.9M (7%) to $22.2M (3%).

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Appendix A
Power System and Off-Site Emissions Study for Bayside Power Station

Power System and Off-Site Emissions Study for Bayside Power Station

Prepared for:

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Power System Overview

Many important physical and economic effects of reducing entrainment are transmitted through the power system. These arise from outages for technology installation, electricity consumption, and cooling water temperature related unit-efficiency changes. This report studies these effects to develop information for (r)(10), (r)(12), and Must & May factors.

Outages

Extended outage times during technology installation are effectively temporary capacity reductions. As depicted in Figure 1, these construction outages lead to system level efficiency and capacity changes. Significant capacity reductions can affect system reliability which can have social costs. Reliability effects are to be evaluated under (r)(12) (12)(v)—Facility Reliability and are a factor that Directors may consider under § 125.98(f)(3)(iv) (May Factor 4—Reliability Impacts). These are unlikely with planned outages but offset costs may be identified if extended outages for multiple units were anticipated. These are not evaluated in this study.

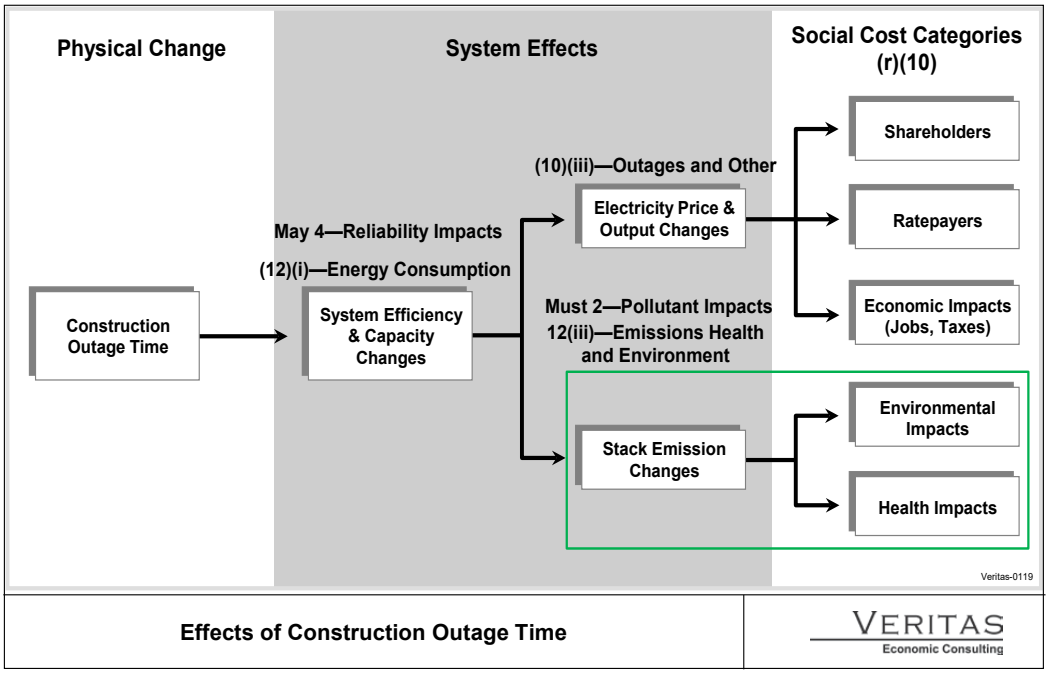


Figure 1: Effects of Construction Outage Time

Outages always lead to a less-efficient dispatch. These lead to changes in energy consumption that are to be assessed under (r)(12) (12)(i)—Energy Consumption. These will

impact electricity costs and outputs leading to social costs that must be quantified in (r)(10)(iii)—Outages Other. Also, the re-dispatch associated with the system-level efficiency changes lead to stack emission changes which are to be studied under (r)(12) (12)(ii)—Emissions Health and Environment. Moreover, these are a factor that Directors are required to consider § 125.98(f)(2)(ii) (Must 2—Pollutant Impacts), and they can have important social costs.

Outages for equipment installation occur as facilities must not be drawing water for certain operations such as connecting cooling towers. When these occur during a time period that is not already scheduled as an outage, opportunity costs result. Outages could potentially be required for any technology but are most significant with cooling towers. The effects depicted in Figure 1 would accompany this outage. These result in system level social costs both in the costs of meeting load and through off-site emissions.

The effect of an outage for equipment installation is evaluated by modeling the outage within the context of the relevant power and economic systems. This is accomplished by developing a counterfactual "With-Construction-Outage" specification in which the capacity at Tampa Electric Company's (TECO) Bayside Power Station is reduced to zero because the facility is required to have an outage to retrofit with an entrainment reduction technology.

Backpressure and Equipment Load

Certain other effects become important once entrainment reduction is underway. These can occur with most approaches but are typically more pronounced with cooling towers. As depicted in the figure below, when operated, cooling towers require electricity to operate. This leads to net electrical generation efficiency/capacity effects and increases in decibel levels (primarily from operating fans). These effects result in energy consumption that must be identified under (r)(12) (12)(i)—Energy Consumption. As with outages, these energy consumption changes have social costs and lead to stack emission changes. The Rule requires a "detailed" and peer-reviewable assessment of related effects under (r)(12) (12)(i)—Energy Consumption, (12)(ii)—Emissions Health and Environment—and these are a factor Directors must consider (Must 2—

Pollutant Impacts). Moreover, there is significant discussion in the preamble indicating the importance of related effects.[1,2,3,4]

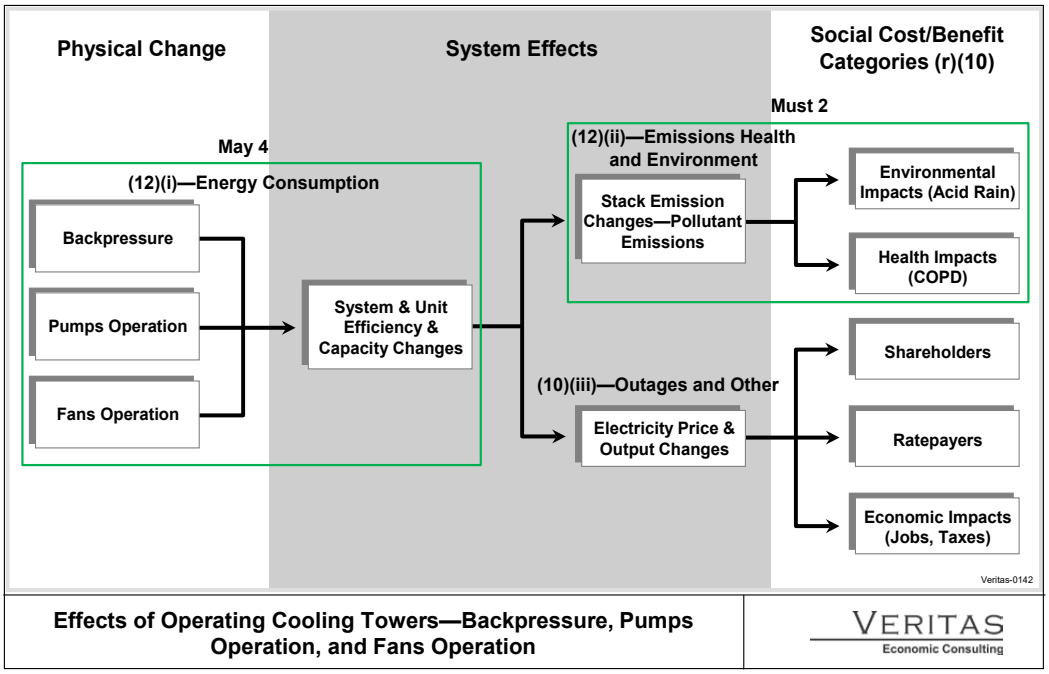


Figure 2: Effects of Operating Cooling Towers—Backpressure, Pumps Operation, and Fans Operation

Power System

The outage and operational implications described previously are initial physical effects. These costs would be reflected in the power system as social costs. Understanding how these physical effects would ultimately be reflected as social costs requires considering the relevant power system vis a vis unit owners and customers and the operation of TECO's generating stations.

[1] "… the social cost of the energy penalty is the cost of generating the electricity that would otherwise be available for consumption except for the energy penalty. Again, an assessment of these costs would be determined under the §122.21(r)(10) demonstration" (79 *Fed. Reg.* 158, p. 48370).
[2] "EPA's review of emissions data … suggests that impacts from these pollutant discharges could be significant. These include the human health and welfare and global climate change effects—all associated with a variety of pollutants that are emitted from fossil fuel combustion" (79 *Fed. Reg.* 158, p. 48341).
[3] "While both of these factors contribute to increased air emissions, the larger contributor to projected increased air emissions is by far the energy penalty" (79 *Fed. Reg.* 158, p. 48341).
[4] "EPA is not able to quantify the frequency with which facilities could experience these local impacts, and therefore has concluded that the proper forum to address such local impacts fully is in a site-specific setting" (79 *Fed. Reg.* 158, p. 48342).

Bayside is owned by TECO, a subsidiary of the Emera Company in Halifax, Nova Scotia, Canada. TECO consists of two regulated natural gas utilities along with Tampa Electric, a regulated electric utility. TECO's electric assets include approximately 4,700 MW of natural gas, coal, and solar generation assets serving over 750,000 customers in West Central Florida. Figure 3 presents TECO's electric service territory and location of generating assets. Figure 4 depicts TECO's generation portfolio by fuel type.

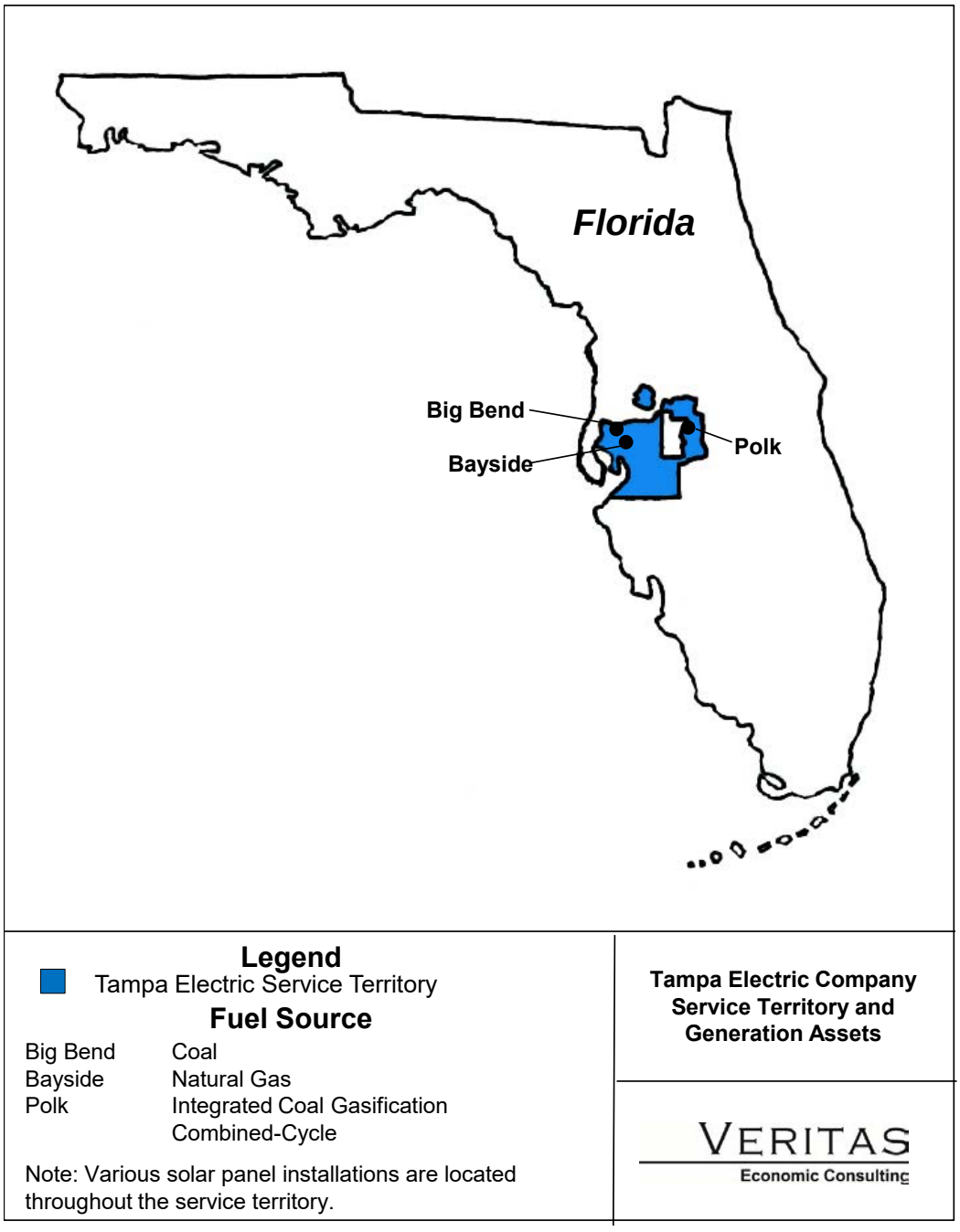


Figure 3: TECO Electric Service Territory and Generation Assets

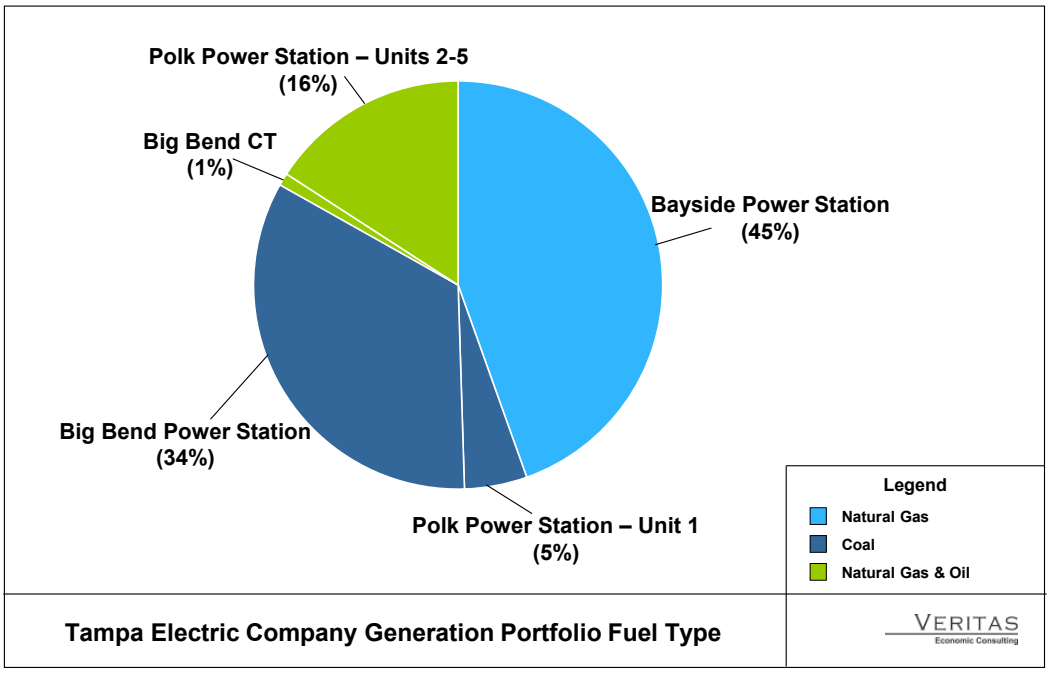


Figure 4: TECO Generation Portfolio Fuel Type

TECO is potentially eligible to recover all or part of the costs of installing entrainment reduction technologies. Electric utilities operating in Florida can file a rate request to the Florida Public Service Commission (PSC) for recovery of costs. The Florida PSC holds hearings and based on the facts can approve a settlement agreement authorizing cost recovery (FPSC 2017a). Procedures involved in rate request hearings include allowing intervener comments and TECO rebuttals. This process, along with the permitting itself, results in costs to the government, which are Government Regulatory Costs.

Since installing entrainment-reducing technologies is a regulatory environmental compliance requirement (as opposed to typical operations and maintenance), we expect that these costs would be passed on to customers in the form of higher rates. These costs would need to be included in a future rate case filing.

TECO's recent rate case history is instructive with respect to the implications of additional rate increase filings. In 2013, the Florida PSC issued a settlement agreement order which allowed for a rate increase phased in over three years (FPSC 2017b). On November 1, 2013, rates were increased $57.5 million which resulted in a 5.5% increase in residential customer bills. An additional $7.5 million rate increase was implemented on November 1, 2014 with a final increase

on November 1, 2015 for $5 million. The increase would cover investments to modernize electric plants and generate cleaner energy.

The costs associated with new entrainment reduction technologies would be additional costs that could potentially lead to another rate increase filing which would result in higher prices for residential, commercial and industrial customers. The magnitude of these additional increases could also lead to economic impacts that can accompany electricity price increases (Deschenes 2010). Changes in electricity prices can lead to economy-wide employment impacts through their effect on residential and business electricity consumers. For business electricity impacts, the commercial and industrial sectors are all major users of electricity as an input to production. Electricity price increases would raise the costs of providing final goods and services in these sectors.

Market Environment

Retail electric markets in Florida are served by a monopoly system of regulated, investor-owned utilities, municipally-owned utilities, and electric membership cooperatives. The regulated utilities generate power and transmit, distribute, and sell electricity to local customers that live in their defined geographic service territory. The Florida PSC regulates the utilities through a rate-making process that ensures electricity is produced and delivered at the lowest possible cost while allowing the utility to recover costs along with a fair rate of return. In addition to being subject to rate case discovery and hearings to prove that costs are just and reasonable, electric utilities are required to submit annual forecasted earnings surveillance reports to the Florida PSC to ensure that the utilities' rate of return are within an approved range.

The state of Florida (and therefore TECO) does not currently participate in any of the multi-state Regional Transmission Organizations. Rates are set for each regulated utility to cover the costs to produce and deliver reliable power to customers. To ensure reliability, rates include reserve capacity that is available as needed for peak periods. Electric utilities are required to maintain adequate reserve margins which would enable them to meet high demand during peak times and extreme weather events. Adequate reserve margins also enable the utility to meet demand during planned plant outages for maintenance, inspections and refueling and for any unplanned outage that may occur. Customers pay for the year-round availability of reserve margin in the rates that they pay whether they use this electricity or not. TECO is considering joining the Florida Municipal Power Pool (FMPP), a group of 3 Florida municipal electric utilities that combine their generating plants as if they were one utility. The FMPP operates like an intra-state transmission organization in that it dispatches power from 51 power generators with the least cost units being dispatched first.

The Bayside Power Station is one of three fossil plants that produce electricity for TECO's customers. Bayside is critical, providing 45 percent of TECO's total generation (see Figure 4). Temporary outages to install entrainment reducing technologies would have a significant impact on TECO's operations. Construction would be scheduled during off-peak months and during a time when the other two generating plants are not undergoing routine scheduled maintenance to enable TECO to continue to meet reserve margin requirements.

Identification of Effects

Effects are identified by specifying relevant Baseline and Counterfactual conditions and then simulating outcomes using TECO's Planning & Risk (PaR) production cost model. PaR is an hourly chronological production cost simulation model. Given inputs of electric demand, fuel price, generating unit characteristics, and transmission constraints, the model simulates the operation of TECO's electric power system. For this evaluation, PaR is used to determine the annual system production cost difference and emission differences between various alternatives throughout the planning horizon. The least cost dispatch calculation may be affected by several characteristics of the electric system, such as transmission constraints, must run units for voltage control and ancillary requirements, as well as other factors. In addition, over the planning horizon plant retirements, unit efficiencies, and replacement generation alter the dispatch order. TECO's PaR model accounts for these characteristics in the electric system and known changes to future generation. Initially, annual system production costs are determined based on existing operations (i.e., Baseline conditions). Counterfactual annual system production costs are determined based on the alternatives evaluated for this study which include closed-cycle cooling and screen technologies.

Specific steps in the power system modeling process include each of the following:

1. Determine regional total hourly load based on a 25-year retail and wholesale hourly load forecast.
2. Conduct PaR model to meet load under Baseline conditions.
3. Create Counterfactual conditions that characterize conversion downtime and ongoing operations.
4. Conduct PaR model simulations to identify changes under Counterfactual conditions.
5. Calculate differences in annual costs.

These steps are implemented as follows.

Specify Regional Total Hourly Load

Since electricity production costs vary hourly and important cooling tower effects are hourly, it is useful to model power system effects at the hourly level. To do this, TECO's future retail and wholesale hourly load forecasts based on internal projections are specified as Baseline load conditions. Projected hourly load for TECO in 2016 (a typical operating year) is an input to the modeling process and is depicted below (Figure 5).

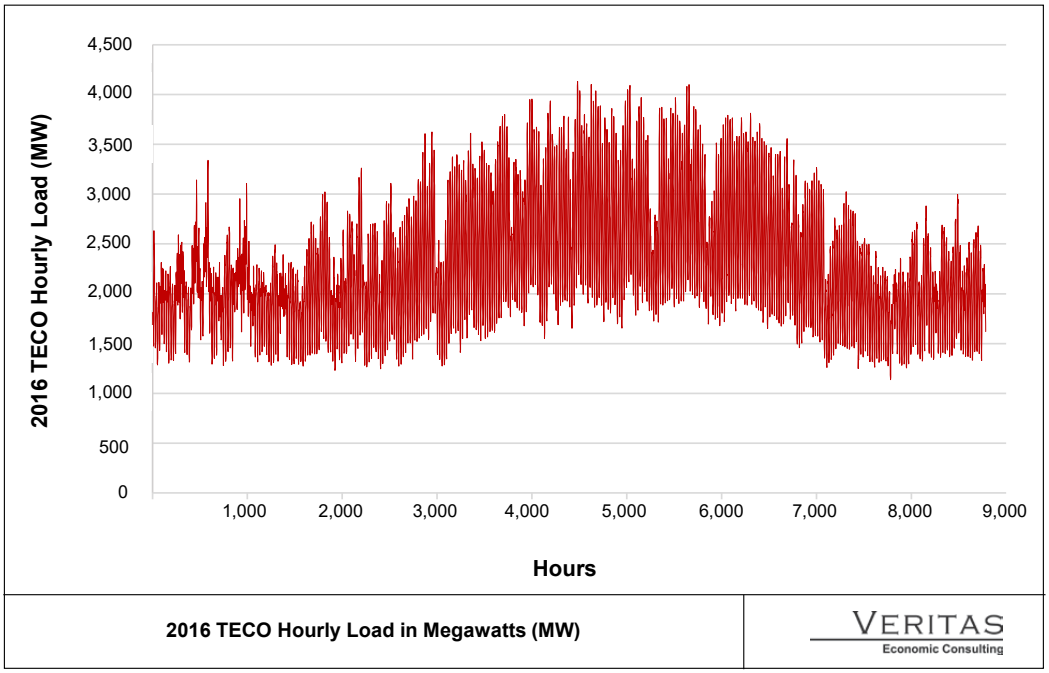


Figure 5: TECO Hourly Load

Develop Baseline Model

To create baseline outputs, the PaR least cost dispatch model is operated to meet the load of Figure 5 (and further years) with appropriate sensitivity to factors relevant for 316(b) determinations. This includes sensitivity of unit efficiency to inlet water temperatures at an hourly level. Predicted historical hourly generation is used to specify baseline conditions. Figures 6 and 7 depict a Baseline year in which both of Bayside's units are operating for the entire year. Both of Bayside's Units 1 and 2 are combined cycle units, meaning they have both combustion turbines and steam turbines. For simplicity of the presentation, Figures 6 and 7 only present the output from the Unit's 1 and 2 steam turbines.

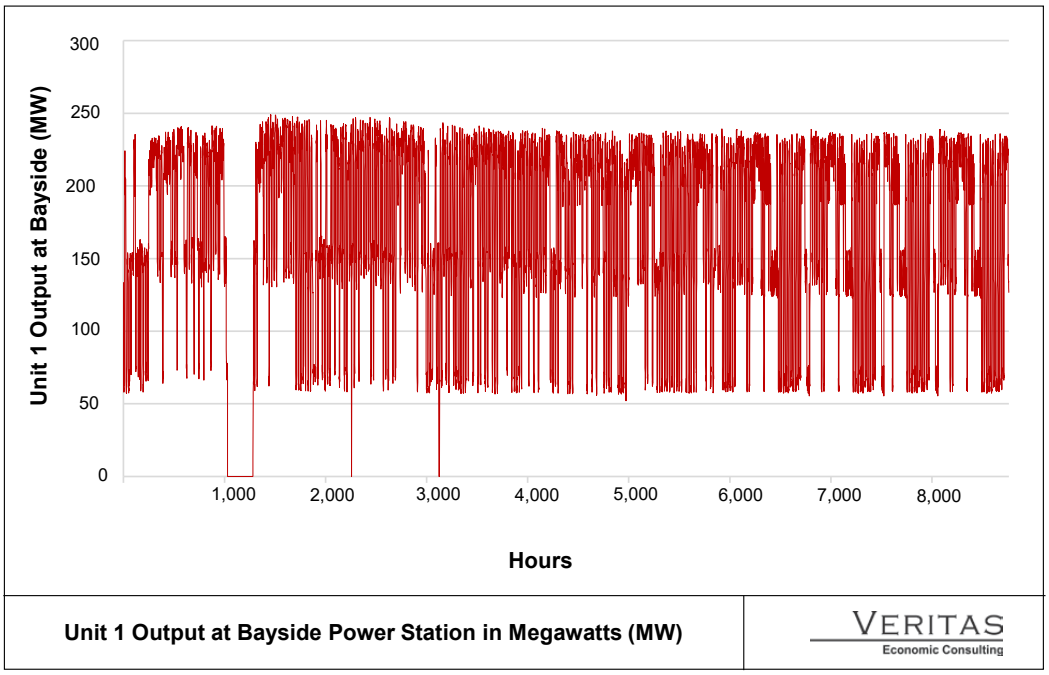


Figure 6: Unit 1 Baseline Output

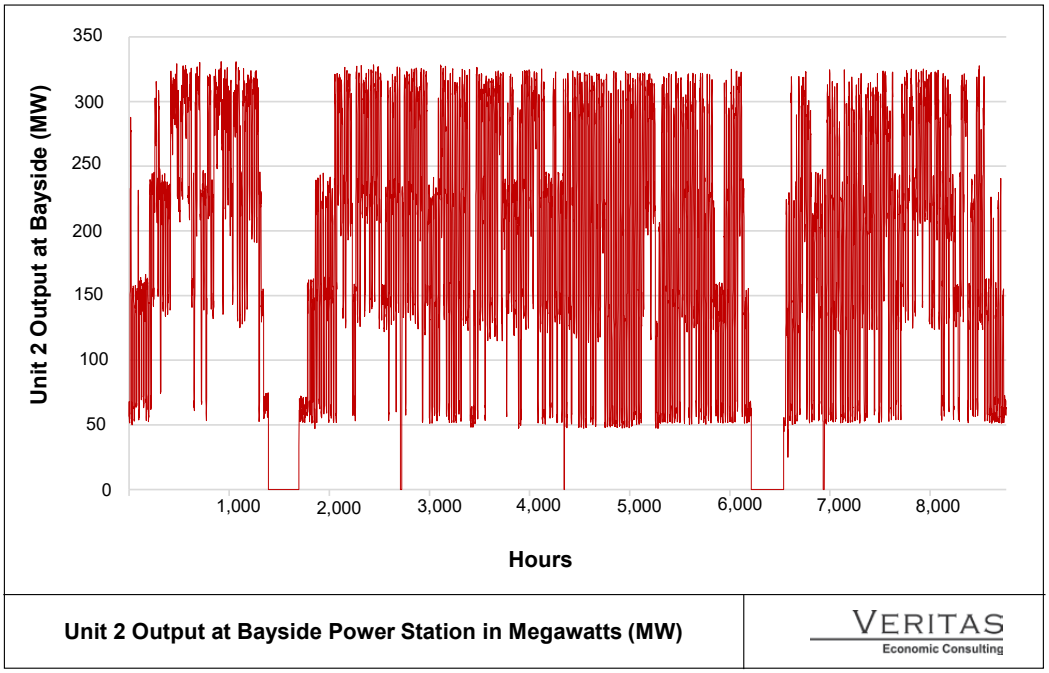


Figure 7: Unit 2 Baseline Output

To create the baseline model, the output specified for Bayside Units 1 and 2 and PaR is calibrated to be consistent with the 2016 average hourly prices depicted in Figure 8.



Figure 8: 2016 Hourly Prices for TECO's Service Territory

Create Counterfactual Output Schedules

Counterfactual output schedules are used to identify the difference between output under Baseline conditions and with technology options. Counterfactual output schedules are created by specifying output from the plant being evaluated and then operating PaR.

Counterfactual output schedules are identified for an appropriate number of years to include outage years and ongoing operations. The figures below depict the results of the model for Bayside's two units in two modeled years. In the first year, identified as Year 1, the plant operates without cooling towers for the majority of the year, both units close for a four-week winter conversion, and then resume operation with auxiliary load and backpressure effects. For the second year, auxiliary load and backpressure effects occur over the entire year. Figures 9 and 10 illustrate this modeled effect for Unit 1 and Figures 11 and 12 illustrate it for Unit 2. As with the baseline model output figures presented above, Figures 9 through 12 illustrate the modeled output for the each unit's steam turbines only for simplicity of presentation and to better illustrate the modeled effects.

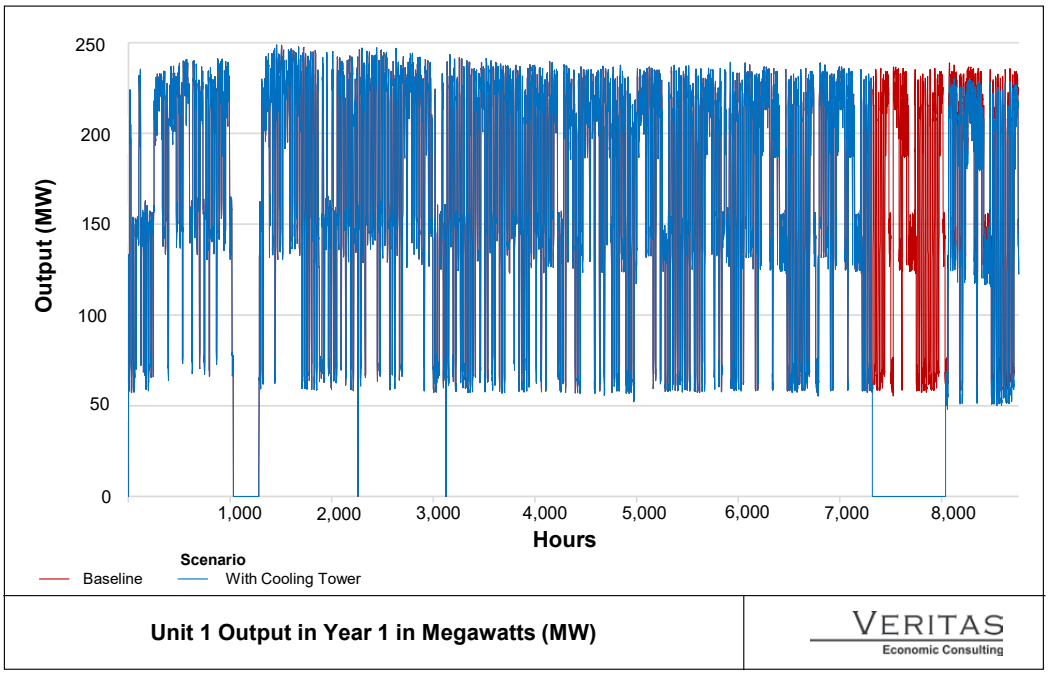


Figure 9: Bayside Unit 1 Output in Year 1

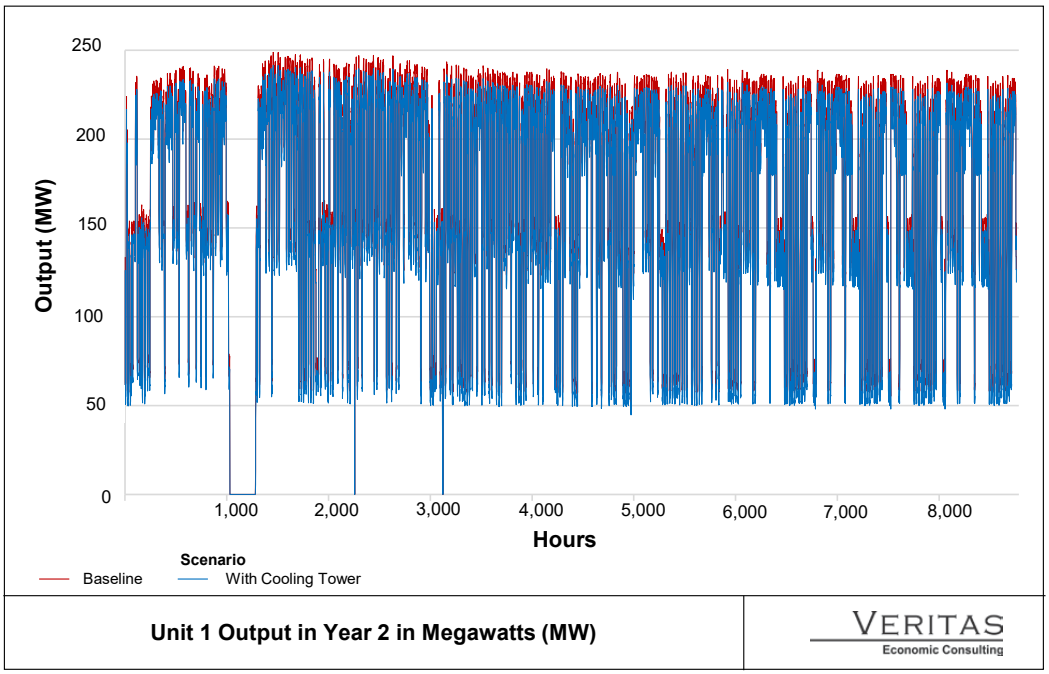


Figure 10: Bayside Unit 1 Output in Year 2

As Figure 9 shows, the modeled Baseline output (illustrated by the red line in Figure 9) and the modeled With-Cooling-Tower output (illustrated by the blue line in Figure 9) are exactly the same for the first 7,000 hours of Year 1. Then at hour 7,324, the hour that corresponds with November 1st, the With-Cooling-Tower output goes to 0, illustrated by the blue line at 0, while the baseline output remains at its non-zero modeled output. The With-Cooling-Tower output stays at 0 for 720 hours to illustrate the effect of the four week outage to connect the cooling towers and then Unit 1 comes back on line at hour 8,044. However, as Figure 9 shows, when Unit 1 comes back on line with the cooling towers, it has a lower level of output in every hour because of the auxiliary load and backpressure effects from the cooling towers. This is illustrated by the fact that the blue, With-Cooling-Tower output line is shorter than the red, Baseline output line for every hour after 8,044.

Figure 10 illustrates this same effect for Year 2, the first full modeled year once the cooling tower has been installed on Unit 1. The figure does not include the same outage effect as Figure 9, because the outage is complete in Year 1, but it does show the auxiliary load and backpressure effects. These two effects are illustrated by the fact that the blue, With-Cooling-Tower output line is shorter than the red, Baseline output line for every hour of the year in Year 2. Figures 9 and 10 illustrate this effect for the year that the cooling towers are installed and the unit becomes operational with cooling towers (Year 1) and the first full year that the unit runs with the cooling towers installed (Year 2). The model continues this Baseline and With-Cooling-Tower comparison for the entire time period that the cooling towers are modeled to be in place and operational at the units. Those additional years are not presented for simplicity. Figures 11 and 12 illustrate the same Baseline and With-Cooling-Tower evaluation for Unit 2.

Once unit dispatch has been modeled under Baseline and With-Cooling-Tower conditions, the model can then identify changes in costs required to make up Unit 1 and 2's lost generation. With output from Bayside Units 1 and 2 specified as illustrated in Figures 9 through 12, PaR is simulated to identify the counterfactual outcomes in which additional units are dispatched to make up for the lost capacity at Bayside 1 and 2.

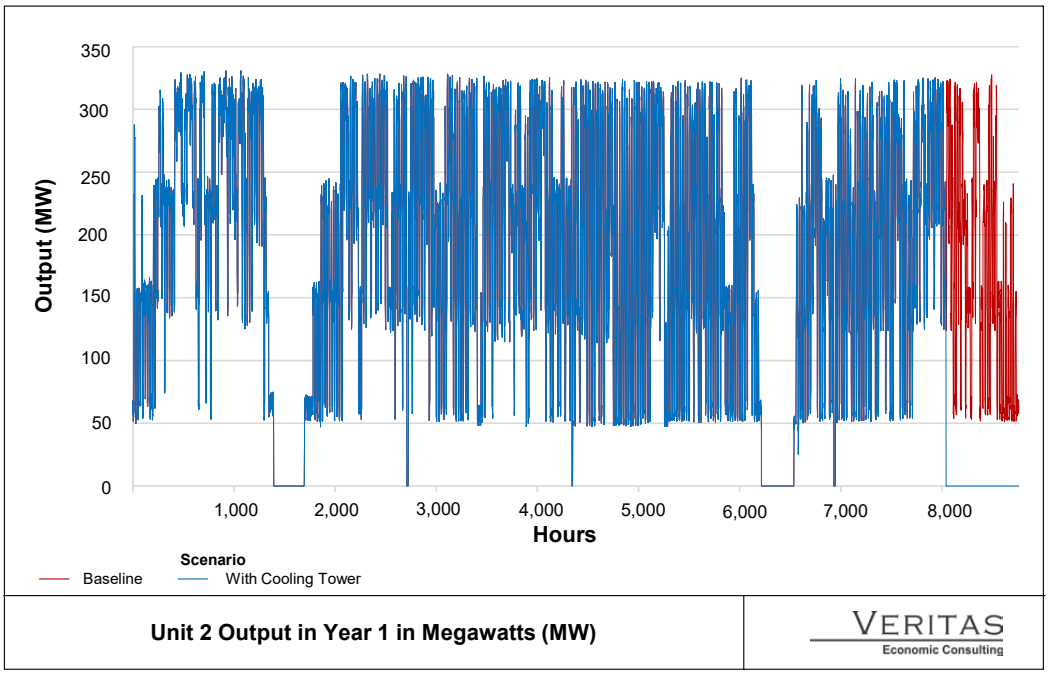


Figure 11: Bayside Unit 2 Output in Year 1

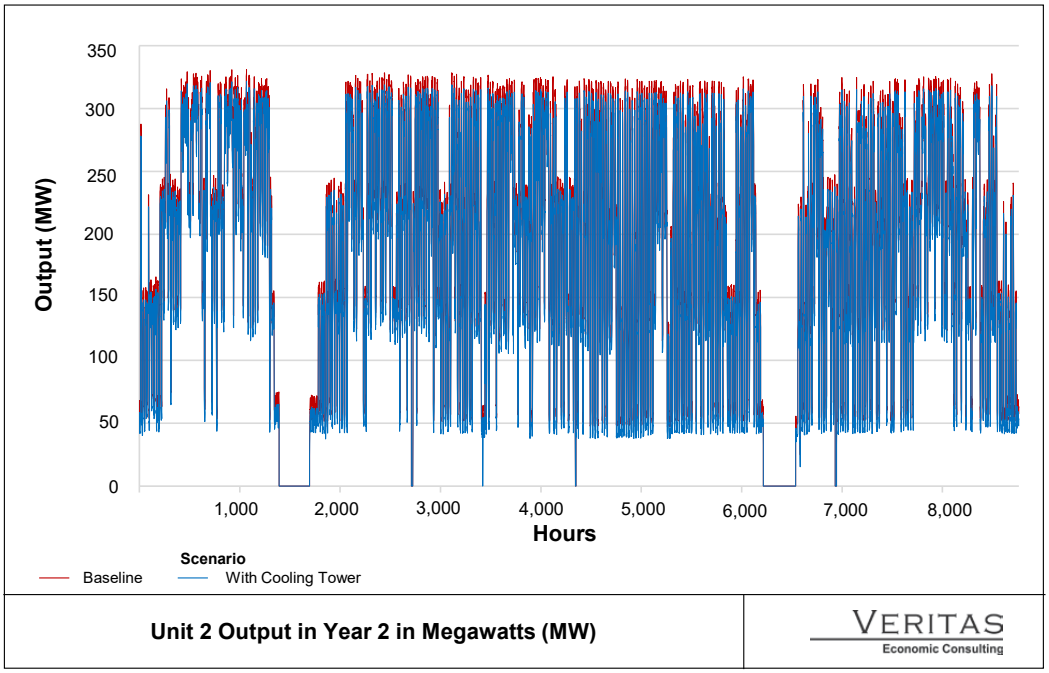


Figure 12: Bayside Unit 2 Output in Year 2

Calculate Net Differences in Fuel Consumption, Cost, and Emissions

With changes in fuel consumption identified, it is possible to identify net differences in fuel consumption and costs. Table 1 summarizes the estimated increase in fuel consumption and costs resulting from a closed-cycle cooling retrofit at Bayside. The table also includes fuel consumption and cost increases for the other technologies evaluated at Bayside: fine-mesh traveling screens and variable speed pumps. The fuel and fuel costs presents in Table 1 are fuel consumption and costs elsewhere in TECO's service territory that are required to offset change in output from the entrainment reduction technology. Variable O&M (VOM) costs are the costs associated with the auxiliary energy penalty (the additional energy needed to operate the technology). Capacity costs include the costs associated with the construction outage and the backpressure.

As Table 1 summarizes, the total cost of a closed-cycle retrofit is $160M. Fuel and VOM costs are lowest in 2023, when the cooling towers are being constructed. Capacity cost is highest in 2023 because capacity costs include costs associated with the construction outage. When the cooling towers come online in February 2024, fuel and VOM costs increase, while capacity costs decrease. Fine-mesh traveling screens are specified to begin operation in 2021. Costs remain fairly constant from 2021 through 2043, with a total cost of almost $1.1M. Variable speed pumps are specified to be installed in 2021, with commissioning in early 2022. Like with the closed-cycle retrofit, fuel and VOM costs are lowest in the installation year (2021) and rise when the technology begins operation (2022). Capacity costs are highest in the installation year (2021) and decrease when the technology begins operation. Total fuel costs for TECO's service territory from the installation and construction of variable speed pumps is approximately $16.7M.

Table 2 presents the resulting emissions associated with the increased fuel consumption presented in Table 1. The increased emissions in Table 2 are calculated based on changes in unit operations and unit emission factors.

Table 1
Increased Fuel Consumption and Costs for TECO's Service Territory with Entrainment Reduction Technologies at Bayside

Technology	Metric	2021	2022	2023	2024	2025	…	2043	Total
Closed-Cycle Retrofit	Fuel (mmBTU)	—	—	31,935	737,216	819,508		524,005	17,339,435
	Fuel Cost ($000)	—	—	$126	$3,218	$3,767		$5,383	$128,874
	VOM Cost ($000)	—	—	$9	$232	$264		$265	$6,986
	Capacity Cost ($000)	—	—	$2,454	$847	$911		$919	$24,843
	Total Cost ($000)	—	—	$2,590	$4,297	$4,943		$6,567	$160,702
0.5mm Fine-mesh Ristroph Traveling Screens in Series with Existing Coarse Mesh Screens	Fuel (mmBTU)	6,612	6,285	6,087	5,163	5,412		2,943	132,767
	Fuel Cost ($000)	$24	$24	$25	$23	$25		$30	$917
	VOM Cost ($000)	$2	$2	$2	$2	$2		$1	$50
	Capacity Cost ($000)	$4	$4	$4	$4	$4		$3	$103
	Total Cost ($000)	$30	$30	$31	$28	$30		$35	$1,070
Variable Speed Pumps	Fuel (mmBTU)	11,817	56,768	86,903	76,359	80,769		61,514	1,925,839
	Fuel Cost ($000)	$43	$221	$357	$331	$371		$632	$13,842
	VOM Cost ($000)	$3	$17	$25	$23	$25		$30	$735
	Capacity Cost ($000)	$308	$34	$65	$69	$68		$84	$2,143
	Total Cost ($000)	$355	$272	$447	$423	$464		$746	$16,720

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Table 2
Increased Emissions (1000s Pounds)

Technology	Emissions	2021	2022	2023	2024	2025	…	2043	Total
Closed-Cycle Retrofit	CO_2 Output	—	—	3,736	86,254	95,882		61,309	2,028,714
	SO_2 Output	—	—	0	1	1		0	13
	NOx Output	—	—	0	18	19		12	396
	PM Output	—	—	0	5	6		4	129
0.5mm Fine-mesh Ristroph Traveling Screens in Series with Existing Coarse Mesh Screens	CO_2 Output	774	735	712	604	633		344	15,534
	SO_2 Output	0.0	0.0	0.0	0.0	0.0		0.0	0.1
	NOx Output	0.1	0.1	0.1	0.1	0.1		0.0	1.7
	PM Output	0.0	0.0	0.0	0.0	0.0		0.0	1.0
Variable Speed Pumps	CO_2 Output	1,383	6,642	10,168	8,934	9,450		7,197	225,323
	SO_2 Output	0.0	0.0	0.1	0.0	0.0		0.0	1.2
	NOx Output	0.2	0.7	1.1	1.0	1.0		0.8	25.0
	PM Output	0.1	0.4	0.6	0.6	0.6		0.5	14.3

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Appendix B
Study of Recreation Effects for Bayside Power Station

Bayside Power Station: Study of Recreation Effects from a Closed Cycle Cooling Conversion

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Recreation Effects

The Bayside Power Station (Bayside), located on the shore of Hillsborough Bay in the City of Tampa, Hillsborough County, Florida, consists of two generating units (Units 1 and 2) with a combined gross summer capacity of 1,650 MW and four natural gas fired simple cycle peaking units (Units 3-6). This report assesses changes in recreation values attributable to a closed-cycle cooling conversion at Bayside. The focus of this analysis is cooling tower effects from noise, tower profile, and cooling tower plumes. Figure 1 below depicts the location of Bayside Power Station as well as a satellite image of the plant and surrounding recreation areas.

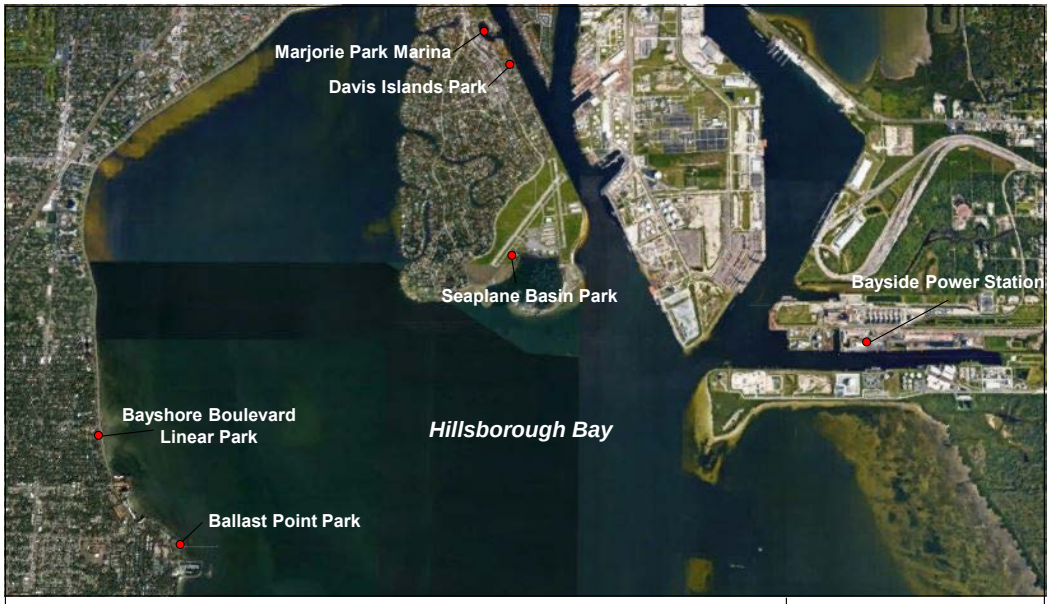


Figure 1: Aerial View of Bayside Power Station and Nearby Recreation Areas

Bayside is located on the right side of the embedded satellite image. Recreation areas located 3 to 3½ miles in straight-line directions from Bayside include Marjorie Park (consisting of Marjorie Park Marina and other sites), Roy Jenkins Pool, Davis Islands Park, and Seaplane Basin Park. Popular parks located within 5 miles in straight-line directions from Bayside include Ballast Point Park, Bayshore Boulevard Linear Park, and DeSoto Park.

Nature of the Issue and Identifying Possible Effects

Evaluated entrainment reduction technologies include variable speed pumps, fine-mesh traveling screens, and mechanical draft cooling towers. Of these, mechanical draft cooling towers are expected to have the most recreational value impacts. Physical effects from the other two evaluated technologies are limited and not expected to impact recreation values. Recreational value effects are expected to be most pronounced when physical effects from cooling towers impact the quality of visits to recreational sites. The primary pathways for this include change in viewshed and noise levels. These linkages and related studies required for 316(b) permitting are depicted in Figure 2 below.

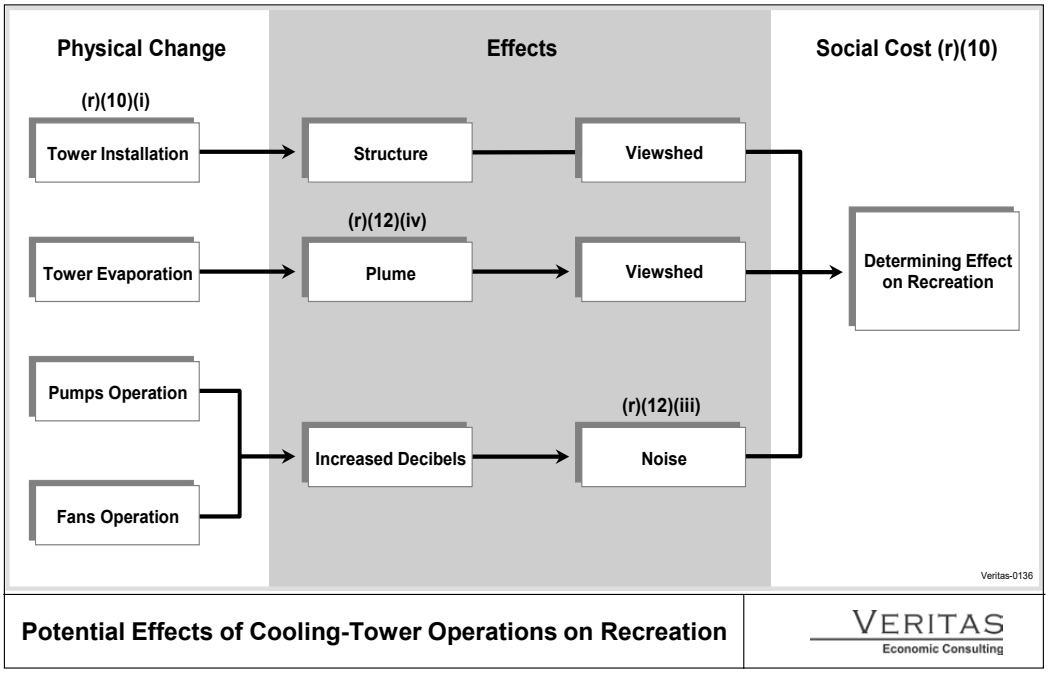


Figure 2: Potential Effects of Cooling-Tower Operations on Recreation

The view from a recreational site could be impacted by the profile of a cooling tower and by the presence of a visible plume. Noise levels at a recreational site could be impacted by the operation of cooling tower pumps and fans. As depicted in Figure 2, cooling tower noise and plume are studied under §122.21(r)(12) (iii) and (iv) and the dimensions of cooling towers will be determined from the cost and feasibility studies that are conducted under §122.21(r)(10)(i).

Approach and Available Information

The effects of cooling tower plumes and noise on recreational trips have not been the subject of primary studies. The most comprehensive work in this area was conducted by the Electric Power Research Institute (EPRI) (2011) which studied viewshed deterioration and noise as quality-of-life issues associated with cooling towers. EPRI (2011) estimated willingness to pay (WTP) to avoid possible impacts to non-local users of recreational areas based on "incremental changes to consumer surplus associated with varying site attributes." Proceeding similarly, this study evaluates recreational trip value losses using the following five steps:

1. Identify relevant cooling tower options
2. Identify differences in noise between Baseline and With-Cooling-Tower conditions
3. Identify differences in viewshed between Baseline and With-Cooling-Tower conditions.
4. Identify the number and value of recreational trips that could have noise or viewshed effects.
5. Where meaningful changes in noise or viewshed are expected to occur to recreational sites, characterize them and identify changes in value.

Relevant Cooling Tower Options

Closed-cycle cooling tower options for Bayside were evaluated by HDR (2017). The feasible cooling tower option being considered for Bayside is mechanical draft. Figure 3 depicts the placement of the mechanical draft towers that HDR developed for Bayside.



Figure 3: Placement of Mechanical Draft Towers

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Noise Effects

Changes in noise can be quantified as changes in decibels (dB). The dB scale uses the hearing threshold (20 micropascals) as a point of reference, defined as 0 dB. Other sound pressures are compared to 0 dB, and a logarithm is used for keeping the numbers in a practical range. On the dB scale, a million-fold increase in sound pressure is expressed as 120 dB. Changes in dB levels correspond closely to human perception of relative loudness. People may react subjectively to different types of sounds and changes in A-weighted decibel (dBA) level. J.C. Brennan and Associates, Inc. (2010) noted that:

- Except in carefully controlled laboratory experiments, people cannot perceive a change of 1 dBA.
- Outside of a laboratory, people barely perceive a 3 dBA change.
- A change of at least 5 dBA must occur before any noticeable change in human response would be expected.
- People subjectively perceive a 10 dBA change as approximately a doubling in loudness. Such a change could cause an adverse response (J.C. Brennan and Associates, Inc. 2010).

An additional consideration is the level of permissible noise. If towers without noise abatement exceed allowable noise levels, abatement would be required. The City of Tampa's Code of Ordinances Section 27-282.7 defines performance standards for noise emitted by industrial, manufacturing, and processing operations (Municipal Code Corporation, 2017). These standards differ based on the receiving location and time of day, with lower allowable noise levels during nighttime hours. In the City of Tampa, permissible sound levels "shall not exceed the following standards":

Table 1
City of Tampa: Permissible Sound Levels

Receiving Area	Time	Sound Limit dBA
Residential	7:00 a.m. to 10:00 p.m.	60 dBA
	10:00 p.m. to 7:00 a.m.	55 dBA
Commercial	7:00 a.m. to 10:00 p.m.	65 dBA
	10:00 p.m. to 7:00 a.m.	60 dBA
Industrial	All hours	75 dBA

Source: City of Tampa Code of Ordinances, Section 27-282.7 (Municipal Code Corporation, 2017)

The noise evaluation analysis conducted for Bayside for the 40 CFR §122.21(r)(12) report (ECT 2017) indicates the possibility of a 70 dB noise level within 50 feet of the cooling tower.

Since this 50 foot buffer around the tower is contained within the site, the City of Tampa's noise ordinances will not be violated by operating a cooling tower. In addition, the distance between the location of the cooling towers are more than 50 feet away from potentially affected recreation areas so that natural sound attenuation will be sufficient to keep recreators at those sites from experiencing a noticeable noise increase. Therefore, the analysis does not estimate any recreation losses from noise increases.

Viewshed Effects

Various factors can alter a viewshed, including topography, distance to objects, haze, humidity, background landscape, atmospheric conditions, and weather (Development Partners Funding I, LLC 2013). The tower options under consideration could impact the viewshed through presence of a plume.

The profile of a tower is simply the physical space the equipment occupies in a viewshed. Mechanical draft towers are relatively low profile. Bayside with the height of the towers proposed to be 42.6 feet and 36.6 feet, respectively (HDR 2017). The mechanical draft towers would generate a visible plume.

A visible plume from a cooling tower is composed of water vapor and a small amount of water droplets. Viewshed effects of a visible plume would apply over a much larger distance than would noise effects and tower height and plume height are important factors in determining this distance. Several studies have modeled viewshed effects using these factors:

- Saratoga Associates (2009) used a 10-mile distance for modeling viewshed effects of plumes rising 1,200 feet above a cooling tower.
- Niagara Mohawk Power Corporation et al. (1984) considered a 10-mile viewshed to be appropriate for estimating visibility of plumes rising from a 536-foot natural draft cooling tower.
- Development Partners Funding I, LLC (2013) estimated that plumes from a proposed facility with mechanical draft cooling towers would potentially be visible in a community 7.2 miles from the site.
- Tronaas (2002) estimated that a residential population had a moderate view of 470-foot-high plumes from mechanical draft cooling towers 4 miles away.
- EPRI (2011) cited a 6-mile distance for viewshed effects.

The Electric Power Research Institute (EPRI 2011) used the Seasonal Annual Cooling Tower Impact (SACTI) model to estimate the potential for fogging, icing, and shadowing impacts from cooling towers. EPRI (2011) included illustrations and summaries of plume fogging impacts for several representative facilities. Summaries for some facilities focused on a 1.2-mile distance

used in calculating viewshed effects from cooling towers, and others cited a 6-mile distance for those effects.

Recreational Value at Risk

The plumes generated by the cooling towers being considered for Bayside would have a significant impact to the viewshed. The distance from which plumes can be seen depends upon topography and visibility. Application of the Pythagorean Theorem indicates that at sea level an object 500 feet tall could be seen up to 27.4 miles away.[5] As described previously, cooling tower plume viewshed effects have been studied at distances ranging from 4 to 10 miles. This analysis uses the 6-mile distance from EPRI (2011) as this falls within the range of estimated distances. Table 1 characterizes activities and economic values for nearby recreational areas that could experience degraded viewsheds with a closed cycle conversion at Bayside. The table includes the number of trips taken to each site per year and the value of each trip. All of these recreation sites are within 6 miles of Bayside and produce approximately $85,996,221 million in recreational value under Baseline conditions.

[5] Based on earth radius of 20.9 million feet: $((20.9M+500)^2-(20.9M)^2)^{1/2}$ = 144,568 ft = 27.4 miles

Table 1
Recreation Sites within 6 Miles of Bayside with Potential Viewshed Degradation

Site Name	Activities Available at Site	Recreational Value per Visit ($ 2016)	Estimated Annual Attendance	Annual Value at Risk
Alfred "Al" Barnes Park	1 ballfield, 2 tennis courts, 2 basketball courts, 3 racquetball courts, picnicking	$48.65 other recreation	29,000	$1,410,850
Sandra W Freedman Tennis Complex	8 tennis courts	$48.65 other recreation	33,280	$1,619,072
Marjorie Park Marina	32 monthly and 19 transient slips	$44.36 motorized boating	35,369	$1,568,947
Roy Jenkins Pool	Family swimming pool, children's pool	$28.74 swimming	184,875	$5,313,308
Davis Islands Park	4 ballfields, basketball court, picnicking	$48.65 other recreation	102,353	$4,979,471
Davis Island Dog Beach	Facilities for dogs	$6.48 dog walking	20,445	$132,484
Davis Islands Rat King Beach	Beach only	$68.79 beach activity	7,560	$520,052
Hixon Waterfront Park	Trails, splash pad, monthly concerts	$48.65 other recreation	68,235	$3,319,647
Joseph Frye Park	Shady place to eat lunch	$31.98 picnicking	6,000	$191,880
Cotanchobee Fort Brooke Park	Waterfront, fishing pier, jogging, canoe launch, playground, Tampa Riverwalk	$48.65 other recreation	42,647	$2,074,779
Cuscaden Park	Ballfield, basketball court, soccer field, gym, playground, picnicking, pool	$48.65 other recreation	51,176	$2,489,735
Water Works Park	Riverfront, green space, playground, picnicking, splash pad, movies	$48.65 other recreation	42,647	$2,074,779
Ballast Point Park	Boat ramp, 600-foot fishing pier, splash pad, picnicking	$124.44 saltwater fishing $48.65 other recreation	68,710 76,290	$12,261,781
Julian B. Lane Riverfront Park (under renovation)	Will reopen Fall 2017; 6 tennis courts, 2 pickleball courts, multi-purpose field, 2 event lawns, other	$48.65 other recreation	196,176	$9,543,985
MacDill Park	Riverwalk and monuments tracing MacDill Air Force Base's history from World War II	$48.65 other recreation	29,000	1,410,850

Table 1, continued

Site Name	Activities Available at Site	Recreational Value per Visit	Estimated Annual Attendance	Annual Value at Risk
Cyrus Greene Park	2 basketball courts, 4 ballfields, picnicking, swimming pool	$48.65 other recreation	42,647	$2,074,779
Centennial Park	Festivals and events, picnicking, art studio	$48.65 other recreation	45,313	$2,204,453
McKay Bay Nature Park	Nature trail, avian sanctuary, biking, picnicking; location along Great Florida Birding Trail	$59.33 wildlife viewing	22,353	$1,326,200
Jose Marti Park	Historic site	$48.65 other recreation	4,060	$197,519
Lykes Gaslight Park	Hosts Pops in the Park concerts, Latin Fest, other events	$48.65 other recreation	2,755	$134,031
Bayshore Boulevard Linear Park	4.5 miles passing homes on National Historic Register; 3-mile bike lane	$48.65 other recreation	129,050	$6,278,283
DeSoto Park	Skate park, basketball courts, playground, ball field, bike trail, jogging path, fishing pier, Spicola Family Pool	$48.65 other recreation ($ 2016)	140,479	$6,834,323
Herman Massey Park	Dog walking	$6.48 dog walking ($ 2016)	14,500	$93,960
Perry Harvey Sr. Park	3 basketball courts, skate park, historical, artwork	$48.65 other recreation ($ 2016)	78,471	$3,817,594
Larry Sanders Sports Complex	4 ballfields, football field, sports leagues	$48.65 other recreation ($ 2016)	99,728	$4,851,767
Palm River Park	Community center, 2 basketball courts, 3 ballfields, picnics, playground	$48.65 other recreation ($ 2016)	42,647	$2,074,779
Progress Village Park	3 ballfields, 2 tennis courts, 2 basketball courts, football field, picnics, playground	$48.65 other recreation ($ 2016)	65,484	$3,185,797
Rubin Padgett Sports Complex	3 ballfields, picnicking	$48.65 other recreation ($ 2016)	49,860	$2,425,689
Estimated Recreation Value at Risk			**1,670,929**	**$85,996,221**

Sources: City of Lakeland (2014); Hillsborough County Board of County Commissioners (2013); Hillsborough County Parks and Recreation (2017); Industrial Economics, Incorporated (2016); National Recreation and Park Association (2016); Rosenberger (2016); EPRI (2011); State of Florida Division of Recreation and Parks (2013); Google Earth

Changes in Value at Recreation Sites

As Table 1 shows, there are approximately $86 million of consumer surplus at risk. However, a plume will not be present every day. Therefore, the analysis has to consider the percentage of days the plume will most likely be in place, how many trips would be affected, how much loss in consumer surplus would occur. Based the results from EPRI (2011), the analysis specifies that a plume would be present approximately 1.1 percent of the time. This is based on using the analysis EPRI (2011) conducted using a representative facility in the Southeast that is most comparable to Bayside. Assuming recreation visits occur proportionally throughout the year, 1.1 percent of the annual recreation trips at these parks could be potentially impacted due to the presence of a plume.

There is a lack of primary studies monetizing cooling tower plume impacts to recreational trip values. EPRI (2011) used a 1.8 percent reduction in the value of each recreational visit attributable to the introduction of a plume based on a hedonic study of industrial plume and odor impacts on housing values presented in Anstine (2003). Anstine (2003) studied the impacts of a plume and odor from two manufacturing facilities in Tennessee and found that these two disamenities caused a maximum reduction in home values of 7.32 percent. EPRI (2011) calculated the midpoint of Anstine's (2003) range to be 3.6 percent then divided it in half to estimate the decreased home value from one disamenity, or 1.8 precent. While Anstine (2003) does not specifically evaluate recreational impacts from a plume, EPRI (2011) applied the 1.8 percent property value decrease to losses in consumer surplus from the effect of a plume on recreational trips.

Table 2 provides estimates of losses in consumer surplus from plume visibility using EPRI's (2011) 1.8 percent estimate. The present value of recreational losses range from just over $0.1M (7% discount rate) to approximately $0.2M (3% discount rate). [6]

[6] Recreation trips that occur when there is no visible plume will not be negatively impacted. The number of hours each day that a plume is visible will vary due to changes in weather conditions and plant operating schedules. For this reason, this estimate can be assumed to be the maximum potential impact.

Table 2
Recreational Sites with Potential Viewshed Degradation from a Cooling Tower at Bayside Power Station

Total Annual Trips to Parks within 6 Miles of Bayside	Percent of Year Plume is Visible	Number of Trips Affected	Decrease in Trip Value with Plume	Total Annual Loss in Consumer Surplus	Present Value of Recreational Losses	
					3% Discount Rate	7% Discount Rate
1,670,929	1.1	18,380	1.8%	$15,102	$194,971	$109,043

Sources: City of Lakeland (2014); Hillsborough County Board of County Commissioners (2013); Hillsborough County Parks and Recreation (2017); Industrial Economics, Incorporated (2016); National Recreation and Park Association (2016); Rosenberger (2016); EPRI (2011); State of Florida Division of Recreation and Parks (2013); Google Earth

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Appendix C
Study of Property Value Impacts for Bayside Power Station

Bayside Power Station: Study of Property Value Impacts from a Closed Cycle Cooling Conversion

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Property Value Effects

The Bayside Power Station (Bayside) is located on the shores of Hillsborough Bay in the City of Tampa, Hillsborough County, Florida. The plant consists of two generating units (Units 1 and 2) with a combined gross summer capacity of 1,650 MW and four natural gas fired simple cycle peaking units (Units 3-6). Figure 1 depicts the generating station and immediate surroundings. This report assesses changes in property values attributable to a closed cycle cooling conversion at Bayside focusing on effects from tower profile, cooling tower plumes, and noise.

The generating plant is located in a dense, urban geographic area less than 5 miles southeast of downtown Tampa. The Tampa-St. Petersburg-Clearwater Metropolitan Statistical Area (MSA) ranks 18th largest in the Unites States with a population of approximately 3 million people (U.S. Department of Commerce, Bureau of Economic Analysis 2016). The plant site is in a heavily industrialized area with commercial and industrial businesses. Over half a million people live in the immediate area and several parks and marinas are within 5 miles of the plant.

Significant changes to the site could potentially impact the quality of life on nearby properties and thereby impact the value of those properties. Residential properties are expected to be most impacted (EPRI 2011). Population centers that are close to Bayside include the City of Tampa (population about 356,000), Brandon (population about 108,000), Gibsonton (population about 18,000), Palm River – Clair Mel (population about 23,000), Progress Village (population about 7,000), and Riverview (population about 80,000) (U.S. Census Bureau 2017).



Figure 1: Location of Bayside Power Station and Surrounding Communities

Nature of the Issue and Identifying Possible Effects

Evaluated entrainment reduction technologies include variable speed pumps, fine-mesh traveling screens, and mechanical draft cooling towers. Of these, mechanical draft cooling towers are expected to have the most property value impacts. Property value effects are expected to be most pronounced when physical effects from cooling towers impact the quality of life of residential property owners. The primary pathways considered include change in viewshed and noise levels. These linkages and related studies required for 316(b) permitting are depicted in Figure 2 below.

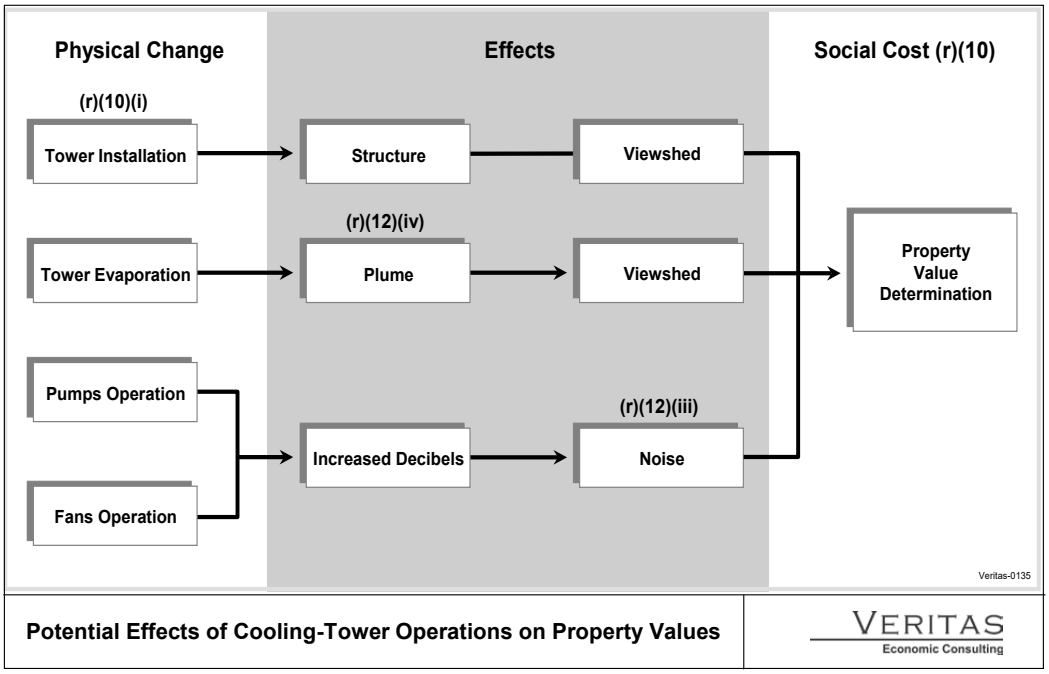


Figure 2: Potential Effects of Cooling-Tower Operations on Property Values

The view from a property could be impacted by the profile of a cooling tower structure and by the presence of a visible plume. Noise levels on a property could be impacted by the operation of cooling tower pumps and fans. As depicted in Figure 2, cooling tower noise and plume are studied under §122.21(r)(12) (iii) and (iv) and the dimensions and design of cooling towers will result from the cost and feasibility studies that are conducted under §122.21(r)(10)(i).

Approach and Available Information

Scientific studies to understand the determinants of property values typically apply the hedonic modeling approach (Freeman, Herriges, and King 2014). In such studies, statistical

modeling is used to relate the price of a property to its characteristics (such as size, features, and condition) and characteristics of the surrounding neighborhood (such as accessibility to schools and shopping, value of other homes). These studies have also been used to identify the impact that environmental dis-amenities such as industrial sites and noise (i.e., from roadways and airports) have on property values.

The hedonic concept that a property's value arises from its individual components has intuitive appeal. The approach also has strong economic foundations and support in numerous applications (Freeman, Herriges, and King 2003). The results are derived from market exchanges and hedonic studies are consistently able to rigorously and statistically separate effects. However, hedonic studies can be data and resource intensive. Moreover, independent of effort requirements, it is not technically feasible to develop an original hedonic study for the 316(b)-permitting context. The primary reason for this is that hedonic property value studies are by nature empirical whereas the 316(b)-permitting process is forward looking; because the towers have not been installed, site-specific empirical studies are not possible.

Given this situation, some sort of transfer approach is required. That is, results from one or more other studies of *realized* effects must be applied to evaluate *likely* effects. Under the study transfer paradigm, high-quality transfer studies are important, as is coherence between the nature of effects from the transfer site and the study site. Here additional challenges arise. Closed-cycle-cooling conversions are a very particular type of incremental change to an existing industrial site. Although hedonic studies of nearby property values that include transactions before and after a conversion can estimate the incremental effect of installing and operating cooling towers, no such studies have been conducted. As a result, the best feasible methods currently available for studying cooling tower impacts to property value must rely on inferring a reduction in property value rather than empirically identifying one.

Viewshed Effects

Various factors can alter a viewshed, including topography, distance to objects, haze, humidity, background landscape, atmospheric conditions, and weather (Development Partners Funding I, LLC 2013). Residential properties located nearest to Bayside are most likely to receive negative property value effects from viewshed impacts. A study of the influence of viewsheds on residential home sales found that residential property owners value larger total views and larger continuous view segments (Hindsley, Hamilton, and Morgan 2013). The proximity of residential properties to the visible plume is an important aspect in determining negative impacts.

A visible plume from a cooling tower is composed of water vapor and a small amount of water droplets. Viewshed effects of a visible plume would apply over a much larger distance than would noise effects and tower height and plume height are important factors in determining this distance. Several studies have modeled viewshed effects using these factors:

- Saratoga Associates (2009) used a 10-mile distance for modeling viewshed effects of plumes rising 1,200 feet above a cooling tower.
- Niagara Mohawk Power Corporation et al. (1984) considered a 10-mile viewshed to be appropriate for estimating visibility of plumes rising from a 536-foot natural draft cooling tower.
- Development Partners Funding I, LLC (2013) estimated that plumes from a proposed facility with mechanical draft cooling towers would potentially be visible in a community 7.2 miles from the site.
- Tronaas (2002) estimated that a residential population had a moderate view of 470-foot-high plumes from mechanical draft cooling towers 4 miles away.

The Electric Power Research Institute (EPRI 2011) used the Seasonal Annual Cooling Tower Impact (SACTI) model to estimate the potential for fogging, icing, and shadowing impacts from cooling towers. EPRI (2011) included illustrations and summaries of plume fogging impacts for several representative facilities. Summaries for some facilities focused on a 1.2-mile distance used in calculating viewshed effects from cooling towers, and others cited a 6-mile distance for those effects.

Viewshed Effect Quantification

The viewshed near Bayside would be affected by both a visible tower and plume. Engineering studies have evaluated the installation of two mechanical draft cooling towers at Bayside with the height of the towers proposed to be 42.6 feet and 36.6 feet, respectively (HDR 2017). Residential properties located nearest to the plant are the most likely to receive negative effects from cooling towers. The quantification of property value losses from cooling tower related viewshed effects is accomplished by conducting three steps:

1. Identify changes in viewshed under Baseline and With-Cooling-Towers conditions by characterizing changes at Bayside, including cooling tower profile and plume.
2. Identify the value of property that could have viewshed effects.
3. Where meaningful changes in viewshed are expected to occur to residential properties, characterize them and assign related changes in value.

This analysis considers effects of cooling tower plumes within a six-mile radius of the site. Under certain conditions, fogging could extend six miles in any direction from Bayside. Industrial and other commercial businesses are located within the most immediate area of the plant. Other

properties located within six miles of Bayside are residential housing, several parks and marinas, the Peter O. Knight airport, and numerous roadways and bridges.

Figure 3 depicts cities and census tracts located within six miles of the Bayside plant that potentially could be affected by a visible plume from cooling towers at the site. In this figure, the total residential property value for each Census tract/city near the power plant is depicted, as are the nearby cities.

Residential properties located within six miles of Bayside are collectively valued at approximately $7.8 billion. The value of these properties could potentially be negatively impacted by changes in viewshed from a visible plume. There is a lack of primary studies monetizing cooling tower plume impacts on property values. EPRI (2011) developed an estimate of plume impacts on property values using results from a hedonic analysis conducted by Anstine (2003). Anstine (2003) studied the property value impacts from a plume and odor at two manufacturing facilities in Tennessee. Anstine (2003) estimated that property values decreased by a maximum of 7.32 percent from the two disamenities. EPRI (2011) calculated the midpoint of Anstine's (2003) estimated range to be 3.6 percent then divided it in half to estimate the decreased value from one disamenity, or 1.8 precent. Applying EPRI's (2011) 1.8-percent propery value reduction to the residential properties within 6 miles of Bayside results in an estimated property value decrease of $140 million.

Noise Effects

Detailed results presented in the (r)(10) and (r)(12) studies for Bayside state the areas which may be impacted by the noise generated by the cooling towers are within the Bayside facility boundaries or over Hillsborough Bay. Therefore, the noise impact is assumed to have no measurable effect on property values.

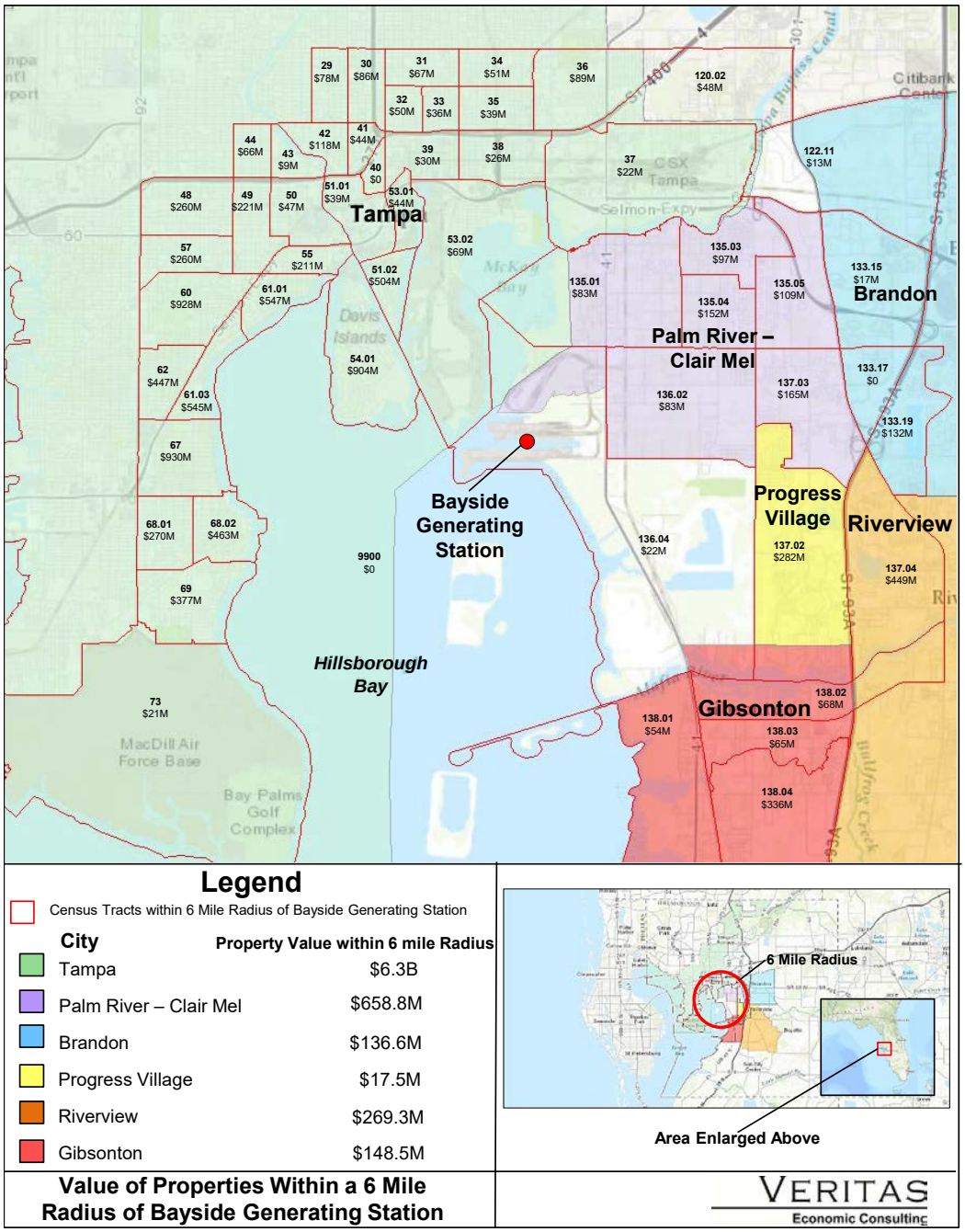


Figure 3: Value of Properties within 6 miles of Bayside Power Station

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Appendix 10-B

Pump and Pipe Selection Calculations for the Cooling Tower Retrofit

TECO | H.L. Culbreath Bayside Power Station

Revision: 1
Issue Date: 9/8/2017

Additional Pipe Network Head Required for Cooling System Modification

Originator:	**Nicholas Thomas, PhD**	4/3/2017
Reviewer:	**Radhika de Silva, PhD, PE**	6/9/2017
Approver:	**Radhika de Silva, PhD, PE**	6/9/2017

Revision No.	Revised by:	Approved by:	Description
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Calculation Summary:

Pump Requirements	**Unit 1**	**Unit 2**
Number of cooling tower booster pumps:	4	4
Cooling tower booster pump flow rate (gpm):	46,200	63,000
Cooling tower booster pump total dynamic head (ft):	63.1	60.0

Number of makeup water pumps:	1	1
Makeup water pump flow rate (gpm):	10,827	14,764
Makeup water pump total dynamic head (ft):	16.0	14.8

Number of dilution water pumps:	1	1
Dilution water pump flow rate (gpm):	16,655	22,711
Dilution water pump total dynamic head (ft):	21.2	21.0

System Description:

Bayside Power Station is fossil fuel driven power generation plant consisting of two combined cycle gas turbine generation units (1 & 2) and four natural gas fired peaking units (3 - 6). The gross summer generation capacity of Unit 1 is 710 MW (with 236 MW from the steam turbine and 474 MW from the three combustion turbines). The gross summer generating capacity of Unit 2 is 940 MW (with 308 MW from the steam turbine and 632 MW from the four combustion turbines). Units 3 - 6 are 57 MW each. The total gross summer generation capacity of Bayside is therefore 1,878 MW. Once through cooling water is withdrawn from Hillsborough Bay for cooling the steam turbines associated with Unit 1 and Unit 2.

This evaluation assumes that the cooling water system associated with the steam cycle for Units 1 and 2 would be converted from once-through to closed-cycle. The State of Florida has a 110 percent chloride discharge limit (compared to the receiving waterbody). The evaluation therefore assumes that the cooling towers would be operated at 1.3 cycles of concentration and that the blowdown would be diluted using additional Bay water to achieve the 110 percent discharge limitation.

Calculation Purpose:

Estimate the additional head loss through the cooling water pipe associated with the hypothetical cooling tower retrofit, and size new booster pumps and makeup pumps for the new system.

Calculation Objectives:

1. List the calculation methodology and data required for the calculations.
2. Identify the inputs required for the calculations.
3. Estimate the dynamic head required for the booster pump system.
4. Estimate the dynamic head required for the make-up water system.
5. Estimate the dynamic head required for the dilution water system.
6. Estimate the additional head required for the closed-cycle cooling system.

Calculation Methodology:

Reference:

Formula 1

$$H_{Lf} = [\ 10.44 * L * Q^{1.85}\ ] / [\ C^{1.85} * (\ C1 * d\ )^{4.87}\ ]$$

Units: ft

where:

H_{Lf} = Head loss due to pipe wall friction for each new pump/pipe system (ft)

L = Total pipe length per pump (ft)

Q = Flow rate through pipe per pump (gallon per minute (gpm))

C = Hazen-Williams roughness coefficient

d = Pipe diameter (in)

C1 = Conversion factor from feet to inches (in/ft)

Formula 2

$$H_{Lm} = \Sigma k * V^2 / (\ 2 * g\ )$$

Units: ft

where:

H_{Lm} = Minor head loss due to irregularities in each pipe/pump system (ft)

Σk = Sum of minor head loss coefficients which are specified for each head loss feature

V = Flow velocity [$V = Q / (\ \pi * d^2 / 4\ )$] (ft/s)

g = Gravitational acceleration (ft/s^2)

Formula 3

$$H_T = H_{LF} + H_{Lm} + H_S$$

Units: ft

where:

H_T = Total dynamic head required (ft)

H_S = Static head (ft)

Calculation Inputs:

Parameters and Variables		Measurement Units	Unit 1	Unit 2	Reference/Note
Circulating water flow rate	Q	GPM	184,800	252,000	Note 6
Number of cooling tower booster pumps	N_{Bpump}	-	4	4	Note 3
Make-up pump discharge capacity	Q_M	GPM	10,827	14,764	Note 5
Number of additional make up pumps	N_{Mpump}	-	1	1	As. 2 Note 3
Dilution pump discharge capacity	Q_D	GPM	16,655	22,711	Note 7
Number of dilution pumps	N_{Dpump}	-	1	1	As. 2 Note 3
Pipe length for each booster pump	LB	ft	900	1,200	Note 2
Pipe length for each make-up pump	L_M	ft	100	100	Note 2
Pipe length for each dilution pump	L_D	ft	1500	1500	Note 2
Pipe diameter for each booster pump	d_B	ft	4.0	5.0	Note 1
Pipe diameter for each make-up pump	d_M	ft	2.0	2.5	Note 1
Pipe diameter for each dilution pump	d_D	ft	3.5	4.0	Note 1
Pipe roughness	C	-	100	100	[1]
Gravitational acceleration	g	ft/s^2	32.2	32.2	
Static head for each booster pump	H_{SB}	ft	41.0	41.0	As. 1
Static head for each make-up pump	H_{SM}	ft	10.0	10.0	As. 1
Static head for each dilution pump	H_{SD}	ft	15.0	15.0	As. 1

Intermediate Calculations:

Booster pump discharge capacity	Q_B	GPM	46,200	63,000	As. 2 Note 3
Velocity in each booster pipe	V_B	ft/s	8.2	7.1	Note 1
Velocity in each make-up pipe	V_M	ft/s	7.7	6.7	Note 1
Velocity in each dilution pipe	V_M	ft/s	3.9	4.0	Note 1
Sum of minor head loss coefficients	Σk_B	ft	6.1	6.1	Note 4
Sum of minor head loss coefficients	Σk_M	ft	2.4	2.4	Note 4
Sum of minor head loss coefficients	Σk_D	ft	0.7	0.8	Note 4

Fittings along the cooling water pipeline:

Minor Head Losses		Unit 1		Unit 2	
Description	k	Number	Head loss (ft)	Number	Head loss (ft)
90 Elbow	0.3	10	3.13	10	3.13
Wye	0.2	8	1.67	8	1.67
Entrance loss	0.5	1	0.52	1	0.52
Exit loss	1.0	1	1.04	1	1.04
Total			6.36		6.36

Fittings along the makeup water pipeline:

Minor Head Losses		Unit 1		Unit 2	
Description	k	Number	Head loss (ft)	Number	Head loss (ft)
90 Elbow	0.3	3	0.82	3	0.63
Wye	0.2	0	0.00	0	0.00
Entrance loss	0.5	1	0.46	1	0.35
Exit loss	1.0	1	0.92	1	0.70
Total			2.20		1.67

Fittings along the dilution water pipeline:

Minor Head Losses		Unit 1		Unit 2	
Description	k	Number	Head loss (ft)	Number	Head loss (ft)
90 Elbow	0.3	5	0.35	5	0.38
Wye	0.2	0	0.00	0	0.00
Entrance loss	0.5	1	0.12	1	0.13
Exit loss	1.0	1	0.23	1	0.25
Total			0.69		0.76

Conversion Factors:

1	foot		=	12 inches
C1 =		12.0	in per ft	

Assumptions:

1. Booster pump static head is based on cooling tower height, and wet well depth.
2. Two booster pumps for each of the two existing once-through cooling pumps.
3. Assume one make-up pump and one dilution water pump per unit, with same efficiency as booster pumps.

Notes:

1. Pipe diameters were selected to maintain a relatively consistent flow velocity within the pipe network.
2. Pipe lengths were estimated based on approximate cooling tower booster pumps, dilution pump and make-up pump locations.
3. Existing cooling system requires two pumps with a per pump capacity of 92,400 gpm, and 126,000 gpm for Unit 1 and Unit 2, respectively.
4. Description of specific minor losses are found in appended tab including elbows, entrance, exit, and wye loses
5. Required make-up discharge based on evaporation calculations
6. Circulating water flow rate is divided between each of the cooling tower booster pumps to exchange hot and cold water.
7. Required dilution discharge rate based on flow required to dilute the 130 percent blowdown to 110 percent required by the State of Florida.

References:

[1] Lindeburg, Michael, R., 2003. Environmental Engineering Reference Manual for PE Exam, Second Edition. Professional Publications, Inc.

Calculations:

1. Estimate the Additional Dynamic Head Required for the Booster Pumps

Formulas Used: 1, 2, 3

Parameters and Variables		Units	Unit 1	Unit 2
Booster Pump Friction Head Loss	H_{Lf}	ft	5.2	4.1
Booster Pump Minor Head Loss	H_{Lm}	ft	6.36	4.84
Booster Pump Total Head Required (with 20 % contingency)	H_T	ft	63.1	60.0

2. Estimate the Additional Head Required for the Make-up Pump System

Formulas Used: 1, 2, 3

Parameters and Variables		Units	Unit 1	Unit 2
Make-up Pump Friction Head Loss	H_{Lf}	ft	1.15	0.69
Make-up Pump Minor Head Loss	H_{Lm}	ft	2.20	1.67
Make-up Pump Total Head Required (with 20% contingency)	H_T	ft	16.0	14.8

3. Estimate the Additional Head Required for the Dilution Pump System

Formulas Used: 1, 2, 3

Parameters and Variables		Units	Unit 1	Unit 2
Dilution Pump Friction Head Loss	H_{Lf}	ft	2.51	2.32
Dilution Pump Minor Head Loss	H_{Lm}	ft	0.16	0.19
Dilution Pump Total Head Required (with 20% contingency)	H_T	ft	21.2	21.0

Appendix 10-C

Estimated Evaporation due to a Hypothetical Cooling Tower

TECO | H.L. Culbreath Bayside Power Station

Cooling Tower Evaporation and Percent Reduction in Water Use

Revision: 1
Issue Date: 9/8/2017

Originator:	**Nicholas Thomas, PhD**	Date:	4/3/2017
Reviewer:	**Samantha Schneider, EIT**	Date:	5/18/2017
Approver:	**Radhika de Silva, PhD, PE**	Date:	6/9/2017

Revision No.	Revised by:	Approved by:	Description
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Calculation Summary:

	Unit 1	Unit 2	Total
Cooling Tower Evaporation Rate (GPM):	2,498	3,407	5,906
Drift Flow Rate (GPM):	0.9	1.3	2.2
Blowdown Flow Rate (GPM):	8,327	11,356	19,683
Make-up Flow Rate (GPM):	10,827	14,764	25,591
Dilution Water Flow Rate (GPM):	16,655	22,711	39,366
Reduction in Water Withdrawal (GPM:	157,318	214,525	371,843
Percent Reduction in Water Use (%):	85.1%	85.1%	85.1%

System Description:

Bayside Power Station is fossil fuel driven power generation plant consisting of two combined cycle gas turbine generation units (1 & 2) and four natural gas fired peaking units (3 - 6). The gross summer generation capacity of Unit 1 is 710 MW (with 236 MW from the steam turbine and 474 MW from the three combustion turbines). The gross summer generating capacity of Unit 2 is 940 MW (with 308 MW from the steam turbine and 632 MW from the four combustion turbines). Units 3 - 6 are 57 MW each. The total gross summer generation capacity of Bayside is therefore 1,878 MW. Once through cooling water is withdrawn from Hillsborough Bay for cooling the steam turbines associated with Unit 1 and Unit 2. [5].

Calculation Purpose:

Estimate the cooling tower evaporation from the hypothetical cooling tower installation. In addition, estimate the percent change in cooling water withdrawal rate and evaporative loss rate if the station were converted from once-through cooling to closed-cycle cooling.

Calculation Objectives:

1. List the calculation methodology and data required for the calculations
2. Identify the inputs required for the calculations
3. Estimate the cooling tower evaporative water loss
4. Estimate the percent reduction in water withdrawal rate if the station were retrofitted from once-through cooling to closed-cycle cooling

Calculation Methodology:

Reference/Note:

Formula 1 $E = 0.0008 * R * Q_{CT}$ [1], Assumption 4

Units: GPM

where:

E = Rate of Cooling Tower Evaporation (GPM)
R = Cooling Tower Range (°F), assumed to be the same as the rise in temperature across the condenser, ΔT
Q_{CT} = Cooling Tower Water Flowrate (GPM)

Formula 2 $D = DE * Q_{CT}$ [1], Assumption 4

Units: GPM

where:

D = Drift Flow Rate (GPM)
DE = Drift Eliminator Efficiency (%)
Q_{CT} = Cooling Tower Water Flowrate (GPM)

Formula 3 $B = (E - [(C - 1) * D]) / (C - 1)$ [1]

Units: GPM

where:

B = Blowdown Flow Rate (GPM)
E = Rate of Cooling Tower Evaporation (GPM)
C = Cooling Tower Cycles of Concentration

Formula 4 $M = E + B + D$

Units: GPM

where:

M = Make-up Flow Rate (GPM)

Formula 5 $Q_R = Q_O - M$

Units: GPM

where:

Q_R = Water Withdrawal Reduction (GPM)
Q_O = Once-Through Flow Rate (GPM)

Formula 6 $PR = Q_R / Q_O$

Units: %

where:

PR = Percent Reduction in Water Withdrawal Rate (%)

Formula 7 $B * C + Q_D * 1 = (B + Q_D) * 110\%$

$Q_D = (C - 110\%) / (110\% - 1) * B$ *Rearranged*

where:

Q_D = Additional dilution water withdrawn to dilute cooling tower blowdown to meet the Florida 110 percent chloride limit

Calculation Inputs:

Parameters and Variables		Units	Unit 1	Unit 2	Reference/Note
Condenser cooling water flow rate	Q_C	GPM	184,800	252,000	[2], [3]
Condenser temperature rise	ΔT	°F	16.9	16.9	Note 1
Cooling tower range	R	°F	16.9	16.9	Assumption 1
Cooling tower water flow rate	Q_{CT}	GPM	184,800	252,000	Assumption 2
Cycles of concentration	C	-	1.3	1.3	Assumption 3
Florida chloride discharge limit		%	110%	110%	[6]
Drift eliminator efficiency	DE	%	0.0005%	0.0005%	[4]
Once-Through Flow Rate	Q_O	GPM	184,800	252,000	Assumption 4

Assumptions:

1. Cooling tower range is equivalent to the condenser temperature rise.
2. Cooling tower water flow rate is the same as the condenser water flow rate.
3. The evaluation assumes 1.3 cycles of concentration due to brackish water source and Florida chloride discharge limit of 110 percent of receiving water. The evaluation assumes that the discharge would be diluted with additional source water so the blowdown would meet the 110 percent requirement.
4. Once-through flowrate is assumed to be equal to the condenser cooling water flow rate.

Notes:

1. Condenser temperature rise calculated using the unit condenser duty of 1,567,000,000 BTU/hr [2] for Unit 1 and nit condenser duty of 2,130,000,000 BTU/hr [3] for Unit 2.
2. Minor losses of water due to potential leaks, windage, and forced evaporation in the receiving waterbody are not included in these calculations.
3. Per TECO (2016), Bayside Steam Turbine 1 gross Summer Capacity is 236 MW and gross Winter Capacity is 246 MW. Bayside Steam Turbine 2 gross Summer Capacity is 308 MW and gross Winter capacity is 318 MW. Because cooling tower operations are more constrained during the summer than winter, summer capacities are used in the evaluation. Also based on that same Memo, internal plant load throughout the year is approximately 3 MW.

References:

[1] SPX Cooling Technologies, INC. 2009. Cooling Tower Fundamentals.
[2] Tampa Electric Company. [Undated]. Bayside Unit #1 Specification 01-5988 Alstom condenser data sheet
[3] Tampa Electric Company. [Undated]. Bayside Unit #2 Alstom condenser data sheet
[4] EvapTech. 2017. Cooling Tower Quote TECO Bayside dated January 23, 2017.
[5] Tampa Electric Company (2016). Generating Unit Capability Update Memo from Tom Hernandez (dated July 1, 2016).
[6] Florida Administrative Code (FAC). 2015. Chapter 62-302: Surface Water Quality Standards, Part 62-302.530Table: Surface Water Quality Criteria, Effective May 19, 2015. At https://www.epa.gov/sites/production/files/2014-12/documents/fl_section62-302.pdf.

Calculations:

1. Estimate Cooling Tower Evaporation

Formulas Used: 1, 2, 3, 4

Parameters and Variables		Units	Unit 1	Unit 2	Total
Evaporation rate	E	GPM	2,498	3,407	5,906
Drift flow rate	D	GPM	0.9	1.3	2.2
Blowdown rate	B	GPM	8,327	11,356	19,683
Makeup rate	M	GPM	10,827	14,764	25,591

2. Dilution Water Needed to Meet Florida 110% Chloride Requirement

Formulas Used: 7

Parameters and Variables		Units	Unit 1	Unit 2	Total
Dilution water needed	Q_D	GPM	16,655	22,711	39,366

3. Estimate Percent Reduction in Water Use

Formulas Used: 5, 6

Parameters and Variables		Units	Unit 1	Unit 2	Total
Once-through rate	Q_O	GPM	184,800	252,000	436,800
Makeup rate	M	GPM	10,827	14,764	25,591
Makeup and dilution rate	$M+Q_D$	GPM	27,482	37,475	64,957
Reduction in water withdrawal	Q_R	GPM	157,318	214,525	371,843
Percent reduction in water withdrawal rat	PR	%	85.1%	85.1%	85.1%

Appendix 10-D

Maintenance Costs for FMS Systems at Big Bend Station Units 3 and 4 Presented as an Estimate of FMS Retrofit at Bayside

Notes:
Four traveling screens with FMS are supposed to be operational from March 15 to October 15 each year.
Six FMS traveling screens are in place. All six are typically operated
Coarse mesh screens are located downstream of the FMS and are operated in the same fashion with and without the FMS.
The effort and costs described below are based on recently changed strategy and reflect a substantial reduction in costs from previous efforts (i.e., ~$150,000/year).
Effort and costs are not included for emergency repair associated with ripped screens, which are common but irregular. Labor for that effort is made up by available maintenance staff.
Labor costs are marked up by 50.9% - 29% for benefits, 8% for payroll taxes, and 13.9% for administrative and general
costs.
All costs are in $2017.

System	Maintenance Item	Cost	Number of Screens Affected	Frequency of Effort	Annual Cost	Notes
Traveling Water Screens	Cleaning, coating, and repairing of trays, chains, tracks, etc.	$350,000	2	Every other year ensuring that every screen is serviced at a 6-year interval	$175,000	Done by manufacturer (SSI) at considerable annual cost savings
	Routine on-site maintenance - greasing, lubing, check nozzles, etc. (FMS)	$64,434	6	During FMS season - March 15 to October 15	$64,434	Difference in staffing levels during FMS (2 FTE) vs. Coarse Mesh (0.5 FTE). Assumes 5 days/week and March 15 to October 15. $36/hour mechanic; $17/hour Special Utility Worker.
	Dredging of FMS intakes	$60,000	6	Annual	$60,000	By contracted dive team for 2 to 3 weeks
	Annual repair to poly screen	$72,000	6	Annual	$18,000	The cost for all six screens was $72,000. The plant intends to service 1.5 screens/year in the future.
	Hydrolase in-service screens	$1,500	1	Annual	$7,500	Anticipate servicing five screens/year
	Pull Screens and frames	$11,517	1	Annual	$11,517	I was not sure if the $175,000 included the cost to pull the screen. Do we have costs to reinstall?
	Install panels in March	$5,070	6	Annual	$5,070	Two staff for 3/4 shift/screen
	Remove panels in October	$3,839	6	Annual	$3,839	Two staff for shift/screen
Spray Wash System	Hydrolase spray wash feed pipes	$10,000	6	Annual	$10,000	12-inch pipe will be closed to 2- to 4-inch opening by biofouling due to barnacles.
Organism Return	Fish pump maintenance	Minor - <2 hour/week	6			Major rebuild will take two staff 2 weeks
	Organism return pipes	Minor	6			Two pipes are used alternatively and cleaned approximately one per week
Total Annual Cost of Maintenance					**$355,360**	

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11.0 40 CFR 122.21(r)(11)—Benefits Valuation Study

11.1 Introduction and Background

This section provides information on the incremental benefits of the candidate entrainment reduction technologies and operational measures evaluated in Section 10.0 using the entrainment characterization results presented in Section 9.0. The following is the text of 40 CFR 122.21(r)(11):

> The benefits valuation study must include, but is not limited to, the following elements:
>
> (i) Incremental changes in the numbers of individual fish and shellfish lost due to impingement and entrainments as defined in 40 CFR 125.92, for all life stages of each exposed species;
> (ii) Description of basis for any estimates of changes in the stock sizes or harvest levels of commercial and recreational fish or shellfish species or forage fish species;
> (iii) Description of basis for any monetized values assigned to changes in the stock size or harvest levels of commercial and recreational fish or shellfish species, forage fish and to any other ecosystem or non-use benefits;
> (iv) A discussion of mitigation efforts completed prior to October 14, 2014, including how long they have been in effect and how effective they have been;
> (v) Discussion, with quantification and monetization, where possible, of any other benefits expected to accrue to the environmental and local communities, including but not limited to improvements for mammals, birds, and other organisms and aquatic habitats;
> (vi) Discussion, with quantification and monetization, where possible, of any benefits expected to result from any reductions in thermal discharges from entrainment technologies.

The methodology described in the following subsections is similar to that of EPA as presented in the Case Study Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule Part D: Tampa Bay Watershed Case Study document (EPA, 2002). The steps pursued during the analysis are described in Section 11.2.

11.2 Review of Methods

The estimation of benefits was a multistep process:

1 Calculate incremental changes in entrained and impinged organisms annually.
2 Convert, using commonly applied and accepted models, incremental changes into equivalent adults (EAs) and foregone production.
3 Transfer the foregone production of forage taxa to a commercially important finfish (drums/croakers) using a trophic transfer model.
4 Calculate equivalent yield of C/R taxa by combining the foregone production of each C/R taxa with the trophic transferred foregone production of forage taxa.
5 Monetize the changes in yield (recreational, commercial, and nonuse values).

This process was followed to calculate the baseline losses as well as reductions in entrainment and relevant changes in impingement for the three potential technologies described in Section 10.0:

- Retrofitting to closed-cycle cooling in the form of MDCTs
- Installation of fish-friendly FMS in front of existing coarse-mesh screens and operation on a seasonal basis
- Replacement of existing circulating pumps with VSPs and drives

As noted in Section 10.0, alternative water supplies were determined to be infeasible and were not carried forward to the estimation of benefits.

11.2.1 Incremental Changes in Fish and Shellfish

11.2.1.1 Definition of Baseline Losses

To quantify the loss of fish and shellfish due to the operation of Bayside, a determination of the annual losses of fish and shellfish was calculated from the sample event densities and cooling water intake flow as detailed in Section 9.0.

For this assessment and subsequent discussions, shellfish are defined to include crustaceans and mollusks, regardless of their C/R status. That is to say, shellfish with no C/R value but that may serve as forage have been considered in addition to direct losses of C/R species. Because of the

potentially large proportion of forage shellfish that may be entrained at Bayside and their potential contribution to the food web of commercially and recreationally important species, TECO believed it prudent to account for their losses and subsequent benefits with the application of each technology. The following paragraphs describe the manner in which this was conducted.

Entrainment

During the Phase II entrainment sampling at Bayside, only C/R shellfish were identified and enumerated. The enumeration of only commercially and recreationally important shellfish was consistent with the Phase II rule. In addition, the exclusion of forage shellfish from the entrainment collection was approved by FDEP following the submission of Baysides' Plan for Information Collection (Golder, 2002). As stated previously, TECO believes shellfish, both C/R and those that potentially contribute to the C/R forage base, should be included in the assessment of potential benefits of each technology considered. To account for the non-C/R shellfish taxa that might contribute to the forage base, the densities of all shellfish (Table 11-1) observed during Phase II sampling at the Duke Energy Bartow Plant (Bartow), Pinellas County, located approximately 12 miles west of Bayside on the west side of the opening to Old Tampa Bay, were applied based on scaling of the relative numbers of common taxa observed at the two plants. The Bartow data was collected under the Phase II rule and included the enumeration of both forage and C/R shellfish species as described in the Impingement Mortality and Entrainment Characterization Report (Golder, 2008). The non-C/R shellfish taxa includes mud crabs (Xanthoidea), pea crabs (Pinnnotheroidea), and porcelain crabs (Porcellanidae). These groups comprised of 98 percent of other shellfish group at Bartow and were concluded to reasonable represent forage for C/R species. These two factors support their importance to the characterization of the entrainment effects at Bayside.

Table 11–1. Relative Abundance of Shellfish Taxa at Bartow Plant during Phase II 316(b) Compliance Sampling (2005-2006)

Scientific Name	Common Name	Shellfish Taxa Relative Abundance (%)	Relative Abundance of Life Stages (%)					
			Eggs	Pro-yolk - sac Larvae	Post-yolk-sac Larvae	Juvenile	Adult	Life Stage Unknown
Callinectes sapidus	Blue crab	0.41	0	0	0	8	0	92
Callinectes spp.	Swimming crabs	0.16	0	100	0	0	0	0
Farfantepenaeus duorarum	Pink shrimp	0.31	0	0	0	0	0	100
Menippe sp.	Stone crabs	3.5	0	29	0	0	0	71
Penaeidae	Penaeid shrimp	0.02	0	0	0	0	0	100
Sepioteuthis sepioidea	Caribbean reef squid	0.02	0	0	0	0	0	100
Other shellfish*		95	<1	52	<1	5	<1	41

Note: Shading indicates taxa observed in Bayside entrainment samples

*Assumed to be forage taxa.

Source: Golder, 2008

The identified entrained C/R species (*Callinectes* spp. and stone crab) observed at Bayside make up 4.03 percent of the taxa observed at Bartow. To calculate the total shellfish (forage and C/R) estimated to be entrained at Bayside, the count of C/R (165,357,701 sample Year 1, 349,108,664 sample Year 2) was set to 4.03 percent. This total count was then spread across the shellfish taxa using the cumulative proportion of C/R taxa observed at Bartow. Life stages were classified based on the Bartow entrainment results proportions. No adjustment was made to the observed C/R shellfish numbers at Bayside. The effect of this process is to greatly increase the estimated number of entrained organisms at Bayside to include numerous small shellfish that may contribute to the forage base.

Impingement Under BTA Scenario

The rate of impingement of fish and shellfish (commercial, recreational, and forage) that occur at Bayside under the BTA scenario of modified travelling screens was calculated in the same manner as entrainment: sample event densities (number per gallon) from each sample year (2006 and 2007) were independently interpolated between sample events and multiplied by actual daily flow (as MGD) for 2015 and 2016, respectively.

Shellfish observed within the impingement samples were identified and enumerated; therefore, no accounting for unenumerated forage shellfish, as was done with the entrainment samples, was

needed. Horseshoe crabs, which were impinged but not entrained at Bayside, are not included in the following analysis because of their lack of C/R importance in Tampa Bay. Having said this, impingement of horseshoe crabs is expected to be reduced proportionally to flow reduction, and impingement mortality is expected to be substantially reduced by the chosen IM BTA compliance method (Section 6.0).

Of the three entrainment BTA technologies considered, only retrofit to closed-cycle cooling would directly address the rule's requirements for IM BTA, albeit at extremely high cost relative to the alternatives. Therefore, impingement reduction benefit from the installation of an entrainment BTA technology was only assumed to occur with the potential installation of closed-cycle cooling in proportion to the reduction in intake flow. On the other hand, as considered in Section 10.0, FMS must include fish-friendly screens and a fish return, itself a fully compliant IM BTA measure. For this reason, the FMS themselves are estimated to have no separate IM reduction benefit. Similarly, VSPs would require the installation of a fish return to address IM BTA; thus, any reduction in intake flow will not result in a proportional impingement reduction benefit, because the modified TWS and fish return would provide 100-percent impingement reduction benefit. Consistent with these assumptions, the costs of retrofit for modified traveling screens and a fish return were not included in the cost estimation of the FMS and VSP options.

11.2.1.2 Retrofit to Closed-cycle Cooling

Retrofitting Bayside with closed-cycle cooling is estimated to result in an 85.1-percent reduction in cooling water withdrawal. Since the reduction in flow will qualify as IM BTA, this option details the benefit of reduced entrainment and impingement by applying an 85.1-percent reduction in the baseline annualized entrainment and impingement numbers.

11.2.1.3 FMS

Entrainment Reduction

To determine the benefits of the addition of FMS, exclusion efficiencies and survival off the screens as observed at Big Bend (see Section 7.0) were applied to the annual entrainment numbers calculated for Bayside (Figure 11-1).

FIGURE 11-1.

CALCULATION METHODOLOGY OF FMS BENEFITS SUMMARY

Source: ECT, 2018.

For determining the exclusion efficiency of FMS, the average exclusion rate ($\bar{E}$) observed at Big Bend for the pooled data from the 1987 studies (Section 7.2.2) and the Phase II 316(b) compliance monitoring in 2005 (Section 7.3) were calculated (Table 11-3). Average survival rates (or live return frequency) off the screens was calculated from the 1986 studies at Big Bend (Section 7.2.1) using the initial survival at the organisms' return discharge station values (Table 11-2). Rates of exclusion and survival were calculated by taxa (i) and life stage (j), when possible. The combined taxa and life stage is referred to a Class (k).

Table 11–2. Average Family Survivability of Organisms Excluded on FMS at Big Bend (1986)

Family	Egg (%)	Prolarvae/Zoea (%)	Postlarvae/Megalops (%)	Family Average (%)
Fish				
Blennidae		100		100
Clupeidae	49	0		25
Engraulidae	30	12		21
Gobbidae		0		0
Sciaenidae	40	29		33
Soleidae	62	0		31
Fish average	**45**	**24**		**32**
Shellfish				
Caridea		69		69
Grapsidae		95	76	86
Paguridae		78		78
Penaeidae		50		50
Pinnotheridae		83		83
Portunidae		100		100
Xanthidae		88	80	84
Shellfish average		**81**	**78**	**80**

Source: TECO, 1986.

Because of inconsistencies between the taxa observed during the studies as well as the lack of empirical data on exclusion and survival for some taxa and life stages, weighted averages were calculated based on family as well as genus, when possible. If the average species value was based on less than five individuals, the family values were used. If no family values were available, the average fish and shellfish survivability and/or exclusion efficiency was applied.

Table 11–3. Exclusion Efficiency of FMS at Big Bend (1987 and 2005 Studies)

Scientific Name	Family	Egg (%)			Prolarvae/Zoea (%)			Postlarvae/Megalopae (%)			Juvenile (%)			Adult (%)			Unknown (%)		
		1987	2005	Avg	1987	2005	Avg	1987	2005	Avg	1987	2005	Avg	1987	2005	Avg	1987	2005	Avg
Fish																			
Achiridae	Achiridae		77	77					33	33									
Achirus lineatus	Achiridae							91	48	70		55	55						
Anchoa hepsetus	Engraulidae		43	43															
Anchoa mitchilli	Engraulidae	87	47	67	66	73	70	93	38	65		0	0					0	0
Anchoa sp.	Engraulidae	75		75	50		50	93		93									
Archosargus probatocephalus	Sparidae							100		100									
Atherinidae	Atherinidae								100	100									
Bairdiella chrysoura	Sciaenidae							98	32	65		0	0					100	100
Bathygobius soporator	Gobiidae							51	46	49								0	0
Belonidae	Belonidae								100	100									
Blenniidae	Blenniidae							73	44	58		100	100						
Brevoortia sp.	Clupeidae							83		83									
Carangidae spp.	Carangidae				100		100		0	0									
Chaetodipterus faber	Ephippidae								62	62		0	0						
Chloroscombrus chrysurus	Carangidae							100	66	83		100	100					100	100
Clupeidae	Clupeidae	0	33	17	100		100	100	0	50									
Cynoglossidae	Cynoglossidae								0	0									
Cynoscion arenarius	Sciaenidae							100	62	81		0	0					0	0
Cynoscion nebulosus	Sciaenidae							100	78	89									
Diodontidae	Diodontidae								100	100									
Elops saurus	Elopidae							100		100									
Engraulidae	Engraulidae	99		99				50		50									
Ephippidae spp.	Ephippidae							100		100									
Gerridae spp.	Gerridae							100		100									
Gobiesox strumosus	Gobiesocidae							74	50	62									
Gobiidae	Gobiidae							77	63	70		100	100					50	50
Gobiosoma robustum	Gobiidae								24	24		0	0					0	0
Gobiosoma sp.	Gobiidae							65	0	32									
Harengula jaguana	Clupeidae							49		49									
Hippocampus erectus	Syngnathidae							100	100	100		100	100						
Hippocampus zosterae	Syngnathidae											0	0						
Lagodon rhomboides	Sparidae							100		100									
Membras martinica	Atherinopsidae							100	50	75									
Menidia beryllina	Atherinopsidae							84	100	92								100	100
Menitcirrhus americanus	Sciaenidae							100		100									

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Table 11–3. Exclusion Efficiency of FMS at Big Bend (1987 and 2005 Studies) (Continued, Page 2 of 2)

Scientific Name	Family	Egg (%)			Prolarvae/Zoea (%)			Postlarvae/Megalopae (%)			Juvenile (%)			Adult (%)			Unknown (%)		
		1987	2005	Avg	1987	2005	Avg	1987	2005	Avg	1987	2005	Avg	1987	2005	Avg	1987	2005	Avg
Menitcirrhus saxatilis	Sciaenidae							92		92									
Menticirrhus spp.	Sciaenidae							87	58	73		100	100					0	0
Microdesmus longipinnis	Microdesmidae							66	0	33									
Microgobius gulosus	Gobiidae							96	0	48									
Monacanthidae	Monacanthidae											100	100						
Oligoplites saurus	Carangidae							94	90	92									
Orthopristis chrysoptera	Hameulidae							100		100									
Pogonias cromis	Sciaenidae							100		100									
Polydactylus sp.	Polynemidae								0	0									
Polynemidae	Polynemidae								100	100									
Prionotus sp.	Triglidae								10	10		33	33						
Sciaenidae	Sciaenidae	97	58	77	40	83	62	83	82	83									
Sciaenops ocellatus	Sciaenidae							100		100									
Soleidae	Soleidae				64		64												
Soleidae/Triglidae	Soleidae/Triglidae	100		100															
Stromatidae spp.	Stromatidae							100		100									
Symphurus plagiusa	Cynoglossidae							88	82	85									
Syngnathidae	Syngnathidae								100	100									
Syngnathus floridae	Syngnathidae								100	100		100	100						
Syngnathus louisianae	Syngnathidae								43	43		80	80		100	100			
Syngnathus scovelli	Syngnathidae								75	75		100	100						
Syngnathus spp.	Syngnathidae							98	100	99									
Tetradontidae spp.	Tetradontidae							100	50	75									
Triglidae spp.	Triglidae		77	77				70		70									
Trinectes maculatus	Achiridae							100	83	92		100	100						
Unidentified species	Unidentified Fish	79	75	77	67	67	67	88	20	54								50	50
	Fish average		71			73			73			59			100			40	
Shellfish																			
Callinectes sp.	Portunidae				100		100												
Lolliguncula brevis	Loliginidae				94	40	67											100	100
Menippe mercenaria	Xanthoidea				99	64	81											0	0
Penaeus sp.	Penaeidae				100		100												
	Shellfish average					87												50	

Note: Blank cells indicate no observation of that taxa/life stage.

Source: TECO, 1987 and 2005.

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The rate of survival (Survival) of otherwise entrainable organisms is the product of their rate of exclusion for the class and the live return frequency by class:

$$Survival_k = \bar{E}_k \times LRF_k$$

The reduction in EM (annual estimated life return number per year) with the application of the FMS[1] was calculated by the product of the rate of Survival for the class and the sum of the product of the density of individuals in the class (Density) during the sampling period (l) and the AIF for the period:

$$Annual\ estimated\ life\ return_k = Survival_k \times \sum Density_{kl} \times AIF_l$$

The exclusion rate and average survival rates for the taxa/life stage pairs, and, when necessary, their surrogates, are illustrated in Table 11-4. Values have been coded by color to quickly illustrate the use of surrogates for each value.

When considering the exclusion efficiency and survival of the forage shellfish, the exclusion efficiency and survival of *Callinectes* spp. and stone crab was first applied to the observed entrainment numbers at Bayside. This reduced number was then set to 4.03 percent of shellfish taxa, and the balance (96 percent) was carried through as non-C/R shellfish as described in Section 11.2.1.1.

Impingement Reduction

No additional change in impingement is assumed with the potential addition of FMS; thus, no incremental benefits associated with impingement reductions were estimated.

11.2.1.4 VSPs

The option to replace the existing circulating pumps with VSPs was modelled to result in two scenarios: (1) a reduction of flow estimated for operations in 2015 of 4 percent, and (2) a reduction of flow estimated for operations in 2016 of 27 percent. Both flow reduction percentages were calculated for the recruitment period (i.e., March 15 through October 15). Because recruitment outside this period of the year is negligible, flow reduction achieved by

[1] Referred to in Figure 11-1 as the annual estimated life return.

Table 11–4. Summary of Exclusion Rates and Survival Rates Used in the Assessment of Benefits of FMS at Bayside

Species	Family	Efficiency					Survival					
		Egg	Pro-larvae	Post-larvae	Juvenile	Unknown	Eggs	Pro-larvae	Post-larvae	Juvenile	Adult	Unknown
Fish												
Achiridae	Achiridae	77	73	73	70	40	62	24	24	24	24	24
Achirus lineatus	Achiridae	77	73	70	55	40	62	24	24	24	24	24
Anchoa hepsetus	Engraulidae	43	60	79	0	0	30	12	12	12	12	12
Anchoa mitchilli	Engraulidae	67	70	65	0	0	30	12	12	12	12	12
Anchoa spp.	Engraulidae	62	60	79	0	0	30	12	12	12	12	12
Bairdiella chrysoura	Sciaenidae	77	62	65	0	33	40	29	29	29	29	29
Bathygobius soporator	Gobiidae	71	73	49	25	20	45	0	0	0	0	0
Blenniidae	Blenniidae	71	73	58	100	40	45	24	24	24	24	24
Carangidae	Carangidae	71	100	86	100	100	45	24	24	24	24	24
Chaetodipterus faber	Ephippidae	71	73	62	0	40	45	24	24	24	24	24
Chasmodes saburrae	Blenniidae	71	73	58	100	40	45	24	24	24	24	24
Chloroscombrus chrysurus	Carangidae	71	100	83	100	100	45	24	24	24	24	24
Clupeidae	Clupeidae	17	100	41	59	40	49	24	24	24	24	24
Cynoscion arenarius	Sciaenidae	77	62	81	0	0	40	29	29	29	29	29
Cynoscion nebulosus	Sciaenidae	77	64	89	33	33	40	29	29	29	29	29
Eugerres plumieri	Gerridae	71	73	100	59	40	45	24	24	24	24	24
Gobiesox strumosus	Gobiesocidae	71	73	62	59	40	45	24	24	24	24	24
Gobiidae	Gobiidae	71	73	59	25	20	45	0	0	0	0	0
Gobiosoma robustum	Gobiidae	71	73	24	0	0	45	0	0	0	0	0
Gobiosoma spp.	Gobiidae	71	73	32	0	0	45	0	0	0	0	0
Hippocampus erectus	Syngnathidae	71	73	100	100	40	45	24	24	24	24	24
Lagodon rhomboides	Sparidae	71	73	100	59	40	45	24	24	24	24	24
Membras martinica	Atherinopsidae	71	73	75	59	40	45	24	24	24	24	24
Menidia spp.	Atherinopsidae	71	73	92	59	40	45	24	24	24	24	24
Menticirrhus spp.	Sciaenidae	77	62	88	100	40	40	29	29	29	29	29
Microdesmus longipinnis	Microdesmidae	71	73	33	59	40	45	24	24	24	24	24
Microgobius gulosus	Gobiidae	71	73	48	25	20	45	24	24	24	24	24
Microgobius spp.	Gobiidae	71	73	48	25	20	45	24	24	24	24	24
Oligoplites saurus	Carangidae	71	100	92	59	100	45	24	24	24	24	24
Prionotus scitulus	Triglidae	77	73	10	33	40	45	24	24	24	24	24
Prionotus spp.	Triglidae	77	73	10	33	40	45	24	24	24	24	24

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Table 11–4. Summary of Exclusion Rates and Survival Rates Used in the Assessment of Benefits of FMS at Bayside
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Species	Family	Efficiency					Survival					
		Egg	Pro-larvae	Post-larvae	Juvenile	Unknown	Eggs	Pro-larvae	Post-larvae	Juvenile	Adult	Unknown
Prionotus tribulus	Triglidae	77	73	10	33	40	45	24	24	24	24	24
Sciaenidae	Sciaenidae	77	62	77	33	33	40	29	29	29	29	29
Scorpaenidae	Scorpaenidae	71	73	73	59	40	45	24	24	24	24	24
Symphurus plagiusa	Cynoglossidae	71	73	85	59	40	45	24	24	24	24	24
Syngnathus louisianae	Syngnathidae	71	73	43	80	40	45	24	24	24	24	24
Trinectes maculatus	Achiridae	77	73	92	100	40	62	24	24	24	24	24
Trinectes spp.	Achiridae	77	73	92	100	40	62	24	24	24	24	24
Unidentified Fish		77	67	54	59	50	45	24	24	24	24	24
Shellfish												
Callinectes sp.	Portunidae	71	100	100		50	45	100	78			
Lolliguncula brevis	Loliginidae	71	67	67		100	45	81	78			
Menippe mercenaria	Xanthoidea	71	81	81		0	45	88	80			

Average fish value
Average family value
Genus value
Species value

Source: ECT, 2018.

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VSPs in the other months would be of minor biological effect. Both scenarios were applied to calculate the incremental changes in entrainment because of the reduction in flow associated with VSPs. The reduction in flow (4 percent or 27 percent) because of VSPs applied to the entrainment numbers is applied to the full entrainment rate for the recruitment period. No attempt was made to match measured entrainment rates for shorter periods (e.g., days or weeks) with the rate of reduced intake flow.

Since the retrofit to VSPs would not provide enough flow reduction to quality as IM BTA, the addition of fish-friendly travelling screens with a fish return will be needed. Thus, with the retrofit to VSPs, no incremental benefits to impingement will result.

To calculate the incremental benefits to entrainment, the baseline annualized entrainment numbers were reduced by 4 percent and 27 percent, independently.

11.2.2 Basis for Estimates of Changes in Stock Size or Harvest Levels

To quantify the benefits of a technology for comparison between technologies, the annual entrainment losses of C/R taxa were converted to EAs using the forward projection approach (EPRI, 2012). The forward protection approach uses the life history parameters of the taxa (i.e., growth rate and rate of survival) to estimate the number of individuals of the taxa to survive to a specific age as well as their mass at that age. For C/R taxa, the age of equivalence is defined for each surrogate taxa as described in Table 11-5. Table 11-5 summarizes the life history parameters used in the models.

Prior to calculating the EAs and production foregone, surrogates were assigned to individual taxa if and when life-history parameters were not available for that taxa. Table 11-6 summarizes the application of surrogates. Where unknown taxa were observed, their annualized counts were applied to the identified surrogates based on the proportion of the surrogates to the total annualized count. Unknown life stage numbers were distributed in the same manner across the life stages of the candidate surrogates. Unknown adult shellfish were assigned to the brachyuran crab surrogate, because no adult blue crab, stone crab, or shrimp would be identified as "unknown"in an entrainment sample due to adult size. The "fish" and "shellfish" surrogates were distributed across the other surrogates based on the proportion of those other surrogates.

Table 11–5. Biological Model Surrogate Taxa Life History Parameters

Taxa	Common Name	Status	Trophic Level	Life Stage	Total Stage Mortality (per stage)	Fishing Mortality (per stage)	Stage Duration (d)	% Mature	% Female	Fecundity (n per year)	Start Weight (g)	Source	Rationale for Choice of Age of Equivalence
Anchoa mitchilli	Bay anchovy	Forage	3.46	Egg	1.2	0	1	0	50	—	7.83E-07	EPRI, 2012	
				Prolarvae	1.8	0	2	0	50	—	8.42E-06		
				Postlarvae 1	2.42	0	11	0	50	—	4.21E-05		
				Postlarvae 2	4.62	0	21	0	50	—	2.09E-03		
				Juvenile 1	0.095	0	21	0	50	—	0.023		
				Juvenile 2	0.099	0	22	0	50	—	0.090		
				Juvenile 3	0.149	0	33	0	50	—	0.24		
				Juvenile 4	1.143	0	254	0	50	—	0.52		
				Age 1	1.62	0	365	100	50	38,206	0.91		
				Age 2	1.62	0	365	100	50	38,206	1.63		
				Age 3	1.62	0	365	100	50	38,206	1.85		
Bairdiella chrysoura	Silver perch	Forage	3.2	Egg	4.21	0	1.2	0	50	—	4.70E-05	EPRI, 2012	Unidentified entrained Sciaenidae were treated as C/R, even though a large proportion of the identified Sciaenids were silver perch. This errs on the conservative side.
				Prolarvae	1.12	0	3.4	0	50	—	4.70E-05		
				Postlarvae	4.26	0	20	0	50	—	4.70E-05		
				Juvenile	3.92	0	343.4	0	50	—	5.30E-02		
				Age 1	2.01	0	365	100	50	1,079,186	29		
				Age 2	2.01	0	365	100	50	2,294,933	62		
				Age 3	2.01	0	365	100	50	3,568,181	96		
				Age 4	2.01	0	365	100	50	4,880,269	132		
Gerriedae	Mojarra	Forage	3.03	Egg	1.47	0	1.1	0	50	—	4.70E-05	EPRI, 2012	
				Prolarvae	0.87	0	3.4	0	50	—	4.70E-05		
				Postlarvae	2.97	0	20	0	50	—	4.70E-05		
				Juvenile	5.76	0	340.5	0	50	—	5.30E-02		
				Age 1	1.5	0	365	100	50	100,000	30.90		
				Age 2	1.5	0	365	100	50	100,000	48.60		
				Age 3	1.5	0	365	100	50	100,000	67.70		
				Age 4	1.5	0	365	100	50	100,000	87.00		
				Age 5	1.5	0	365	100	50	100,000	105.60		
Sciaenidae	Drums and croakers	Commercial/ Recreational	4.21	Egg	2.625	0	1.6	0	50	—	3.60E-05	EPRI, 2012	The Bayside C/R Sciaenidae in the entrainment data is dominated by *Cynoscion arenaris* and nebulosus species. These are the same genus as weakfish; thus, the fishing mortality and EA age chosen for weakfish was applied to Sciaenidae. The maximum age was set to 5 years to better represent the age limit of *Cynoscion* spp. within Florida waters (http://myfwc.com/media/204265/weakfish01_3539.pdf; http://myfwc.com/media/1355905/Spotted_seatrout.pdf; http://goms.disl.org/assets/goms_disl/uploads/toc/1991_2010/Vol24P45-60.pdf).
				Prolarvae	1.23	0	3.2	0	50	—	3.60E-05		
				Postlarvae	5.31	0	18.5	0	50	—	1.70E-04		
				Juvenile	2.51	0	237.2	0	50	—	29.55		
				Age 1	1.142	0.028	288.5	90	50	541,880	74.50		
				Age 2	1.1615	0.1355	365	100	50	1,156,310	161		
				Age 3	1.21	0.268	365	100	50	1,809,316	263		
				Age 4	1.285	0.218	365	100	50	2,499,391	381		
				Age 5 (A_max)	0.56	0.177	365	100	50	243,829	1050		
Cynoscion regalis	Weakfish	Commercial/ Recreational	3.77	Egg	1.04	0	2	0	50	—	3.60E-05	EPRI, 2012; FWC, 2011	Fishing mortality from FWC 2009 stock assessment report on weakfish (FWC, 2011). Other parameters from EPRI, 2012.
				Early larvae	1.34	0	3	0	50	—	3.60E-05		
				Late larvae	6.36	0	17	0	50	—	1.70E-04		
				Early juvenile	2.43	0	131	0	50	—	0.01		
				Late juvenile	1.18	0	212	0	50	—	59.10		
				Age 1	0.274	0.028	365	90	50	4,574	120		
				Age 2	0.313	0.1355	365	100	50	17,686	260		
				Age 3	0.41	0.268	365	100	50	50,451	430		
				Age 4	0.56	0.218	365	100	50	118,512	630		
				Age 5	0.56	0.177	365	100	50	243,829	1050		
				Age 6	0.56	0.1265	365	100	50	455,727	1610		
				Age 7	0.56	0.123	365	100	50	790,330	2980		
				Age 8	0.56	0.123	365	100	50	1,293,948	4920		
				Age 9	0.56	0.123	365	100	50	2,015,934	5000		
				Age 10	0.56	0.123	365	100	50	3,031,887	5680		
				Age 11	0.56	0.123	365	100	50	4,407,990	5800		
				Age 12 (A_max)	0.56	0.123	365	100	50	6,229,687	6000		

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Table 11–5. Biological Model Surrogate Taxa Life History Parameters (Continued, Page 2 of 3)

Taxa	Common Name	Status	Trophic Level	Life Stage	Total Stage Mortality (per stage)	Fishing Mortality (per stage)	Stage Duration (d)	% Mature	% Female	Fecundity (n per year)	Start Weight (g)	Source	Rationale for Choice of Age of Equivalence
Trinectes maculatus	Hogchoker	Forage	3.4	Egg	2.712	0	1.2	0	50	—	5.0E-5	EPRI, 2012	
				Larvae	2.822	0	34	0	50	—	5.00E-05		
				Juvenile	2.37312	0	329.6	0	50	—	5.0E-3		
				Age 1	0.87965	0	365	0	50	—	4		
				Age 2	0.87965	0	365	100	50	7,579	18		
				Age 3	0.87965	0	365	100	50	11,822	27		
				Age 4	0.87965	0	365	100	50	20,146	47		
				Age 5	0.87965	0	365	100	50	29,205	68		
				Age 6 (_ max)	0.87965	0	365	100	50	37,295	86		
Gobiosoma spp.	Naked goby	Forage	3.2	Egg	0.08	0	5	0	50	—	1.00E-04	EPRI, 2012	
				Larvae	0.52	0	31	0	50	—	1.00E-04		
				Juvenile	5.48	0	329	0	50	—	0.009		
				Age 1	1.93	0	365	100	50	904	0.050		
				Age 2	1.93	0	365	100	50	1,419	0.14		
				Age 3	1.93	0	365	100	50	2,207	0.37		
				Age 4 (A_max)	1.93	0	365	100	50	3,157	0.77		
Brevoortia patronus	Gulf menhaden	C/R	2.19	Egg	0.74	0	1.2	0	50	—		EPRI, 2012; SEDAR, 2012.	Age of equivalence chosen as earliest age of maximum fishing mortality.
				Early larval	1.45	0	34	0	50	—	1.44E-05		
				Late larval	2.16	0	329.6	0	50	—	2.43E-04		
				Juvenile	3.54	0	365	0	50	—	0.23		
				Age 1	1.73	0.1	365	0	50	—	44		
				Age 2	1.73	0.26	365	100	50	1,962	96.00		
				Age 3	1.73	0.26	365	100	50	588	148.00		
				Age 4	1.73	0.26	365	100	50	142	191.00		
				Age 5 (A max)	1.73	0.26	365	100	50	31	225.00		
Leiostomux xanthurus	Spot	C/R	3.23	Egg/larval	7.68	0	20	0	50	—	5.90E-05	EPRI, 2012	Age of equivalence chosen as earliest age of maximum fishing mortality.
				Early juvenile	2.3	0	120	0	50	—	0.10		
				Late juvenile	1.066	0.026	225	0	50	—	8		
				Age 1	2.1	1.2	365	100	50	100,000	120		
				Age 2	2.1	1.2	365	100	50	180,009	181		
				Age 3	2.1	1.2	365	100	50	187,361	189		
				Age 4	2.1	1.2	365	100	50	187,916	189		
				Age 5 (A_max)	2.1	1.2	365	100	50	187,957	189		
Brachyuran	Brahyuran crabs	Forage	2.6	Eggs/zoea	1.84	0	11.5	0	50	—	7.60E-05	EPRI, 2012; Dame and Vernberg, 1982; Welch and Epifanio, 1995; McDonald, 1982; Epifanio *et al.*, 1994; Murphy *et al.*, 2007; Sastry, 1970; Lin, 1990; Epifanio, 1971; Epifanio *et al.*, 1991; Birkely and Gulliksen, 2003; McKinney *et al.*, 2004; Peterson and Wroblewski, 1984	
				Megalopae	2.88	0	17.8	0	50	—	2.10E-04		
				Juvenile	3.21	0	336	0	50	—	0.35		
				Age 1	0.51	0	365	100	50	11,700	2.50		
				Age 2	0.51	0	365	100	50	11,700	4.60		
				Age 3	0.51	0	365	100	50	11,700	13.90		
				Age 4	0.51	0	365	100	50	11,700	25		
				Age 5	0.51	0	365	100	50	11,700	40		
				Age 6 (_max)	0.51	0	365	100	50	11,700	60		
Anomuran	Anomuran crabs	Forage	2.6	Egg/zoea	3.58	0	28	0	50	—	5.70E-05	Birkley and Gulliksen, 2003; Ricciardi and Bourget, 1998; Diaz, 1980; Edritanti *et al.*, 2016; Rees, 1959; Petracco *et al.*, 2003.	
				Megalopa	2.17	0	17	0	50	—	0.013		
				Juvenile	2.92	0	255	0	50	—	0.10		
				Adult (max)	3	0	300	100	50	1,491	0.50		
Callinectes sapidus	Blue carb	C/R	4	Eggs	0.02	0	12	0	50	—	2.05E-05	NOAA, 1984; Kannupandi *et al.*, 1999; PSEG, 1999; EPRI, 2012.	Age of equivalence chosen as earliest age of maximum fishing mortality.
				Zoeae/megalopae	9.56	0	40	0	50	—	7.60E-05		
				Juvenile	4.74	0	313	0	50	—	0.010		
				Adult (max)	1.125	0.45	330	100	50	5,500,000	177.50		

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Table 11–5. Biological Model Surrogate Taxa Life History Parameters (Continued, Page 3 of 3)

Taxa	Common Name	Status	Trophic Level	Life Stage	Total Stage Mortality (per stage)	Fishing Mortality (per stage)	Stage Duration (d)	% Mature	% Female	Fecundity (n per year)	Start Weight (g)	Source	Rationale for Choice of Age of Equivalence
Menippe mercenaria	Stone crab	C/R	2.6	Egg/zoea 1	1.930	0	4	0	50	—	4.58E-05	EPA, 2002; Croker, 1962; Starck, 1971; Claro-Madruga and Bustamete Pola, 1977; Porter, 1960; Binford, 1913; Noe, 1967; ADW, 2017; McKinney *et al.*, 2004; Gerhart and Bert, 2008.	Recruitment to the Florida fishery occurs at age 3 for males and age 4 for females (based on CW and associated claw size). Age of equivalence of age 3 was chosen, because this is the age 50 percent are vulnerable to the fishery and all have reached maturity.
				Zoea 2	1.930	0	4	0	50	—	1.89E-04		
				Zoea 3	1.930	0	4	0	50	—	4.94E-04		
				Zoea 4	1.930	0	4	0	50	—	1.03E-03		
				Zoea 5	1.930	0	4	0	50	—	1.84E-03		
				Megalopae	1.930	0	5	0	50	—	3.00E-03		
				Juvenile	1.930	0	297	0	50	—	8.26E-03		
				Age 1	0.939	0	365	0	50	—	16.50		
				Age 2	0.939	0	365	100	50	2,512,500	86.31		
				Age 3	1.315	0.376	365	100	50	2,512,500	184.89		
				Age 4+ (A_max)	1.690	0.751	365	100	50	2,512,500	330.32		
Penaeid shrimp	Commercial shrimp	C/R	3	Eggs	3.57	0	1.5	0	50	—	7.60E-06	EPRI, 2012; Birkely and Gulliksen, 2003; Franco *et al.*, 2006; Kasper, 2017; Ramirez-Rodriquez and Arreguin-Sanchez, 2003; SAFMC, 1998.	Pink shrimp are harvested as adults outside the estuaries, and the adult stage is therefore set as the age of equivalence, because this is when they contribute to the fishery. The fishing pressure appears to be greatest as pre-adults, because the fishing mortality value is a consequence of assigning the same daily fishing mortality as daily natural mortality (EPRI, 2012) and balancing. Since subadult experience the greatest natural mortality, under the stated assumptions for modelling purposes, they also experience the greatest fishing mortality.
				Prolarvae	1.89	0	9.5	0	50	—	5.70E-05		
				Postlarvae	1.89	0	15	0	50	—	8.00E-04		
				Juveniles	1.74	0	56	0	50	—	0.0053		
				Subadults	7.38	3.50	125	0	50	—	2.50		
				Adult (max)	0.30	0.14	323	100	50	500,000	6.60		
Caridea	Grass shrimp	Forage	2.6	Eggs/larvae	1.34	0	16	0	50	—	5.86E-06	Peterson and Wroblewski, 1984; Bauer and Abdalla, 2000; Schultze and Anger 1997; Gottstein Matacec *et al.*, 2006; Provenzano *et al.*, 1978; Birkley and Gulliksen, 2003; Haefner, 1973; Anderson, 1985; Welsh, 1975; SCDNR, 2017	
				Postlarvae/juvenile	0.23	0	30	0	50	—	0.006		
				Adult	4.64	0	330	0	66	31	0.13		

Shading indicates EA age used in the models.

Sources: EPRI, 2012.
EPA, 2002.
Sea Around Us, 2017.
ECT, 2018.

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Unknown invertebrates were distributed across the brachyuran crabs, anomuran crabs, and "shellfish" surrogates based on the proportion observed in the Bartow Phase II data, published literature, and BPJ (Weiss and Phillips, undated; Schomer and Johnson 1990; Barns and Culter, 1998). Thus, all organisms entrained and impinged have been accounted for in the benefits analysis. No group or individual was excluded for any reason.

Foregone production of biomass for each sample year for each surrogate taxa was also calculated using Rago's (1984) model as described by EPRI (2012). The biomass of unknown taxa was accounted for through the dispersion of their counts across the other surrogate taxa as described previously.

The life history parameters used in the EA model and production foregone models were largely based on parameters presented in EPRI (2012). However, because of errors observed for some models, rebalancing2 of the parameters was needed in some cases. In addition, some species were not covered adequately by EPRI (2012) (i.e., stone crab, blue crab, caridean shrimp, brachyuran crabs, and anomuran crabs), so life history parameters were provided by other sources and, when necessary, balanced appropriately. Life history parameters do not assume any density dependence. Thus, as the population increases, it is able to do so unhindered by the number of individuals in the population. Similarly, if the populations' sizes are below the system's capacity, the rate of survival and recruitment does not exhibit "compensation" to exploit that capacity. This is clearly not how ecosystems function; however, it provides a method of accounting for changes in populations that is useful for this type of assessment and supported by EPA (2002).

To analyze the benefit of each proposed technology carried forward from (Section 10.0), the total benefit that would be observed if there were no impingement or entrainment at Bayside was calculated (without-entrainment). In this case, benefit is defined as the addition of C/R taxa that would occur because of the complete survival of the entrained and impinged fish and shellfish at Bayside.

[2] Life history parameters are called balanced when the modeled population replaces itself from generation to generation. Checking for balance and providing adjustments in the parameters to achieve balance is performed using solvers in Excel™.

Table 11–6. Modeling Surrogate Taxa

Surrogate	Scientific Name
Anchoa mitchilli	*Anchoa hepsetus*
	Anchoa mitchilli
	Anchoa spp.
Anomura crabs	Proportion of unknown invertebrates
Bairdiella chrysoura	*Bairdiella chrysoura*
Blue crab	Portunidae
Brachyura crabs	Proportion of unknown invertebrates
Callinectes sapidus	*Callinectes sapidus*
Caridean shrimp	Caridea
	Eualus gaimardii
	Hippolytidae
	Palaemonidae
	Tozeuma sp.
Cynoscion regalis	*Cynoscion arenarius*
	Cynoscion nebulosus
Fish	Blenniidae
	Chaetodipterus faber
	Chasmodes saburrae
	Clupeidae
	Hippocampus erectus
	Lagodon rhomboides
	Membras martinica
	Menidia spp.
	Microdesmus longipinnis
	Prionotus scitulus
	Prionotus spp.
	Prionotus tribulus
	Scorpaenidae
	Syngnathus louisianae
Gerreidae	*Eugerres plumieri*
Gobiosoma bosc	*Bathygobius soporator*
	Gobiesox strumosus
	Gobiidae
	Gobiosoma robustum
	Gobiosoma spp.
	Microgobius gulosus
	Microgobius spp.
Menippe mercenaria	*Menippe mercenaria*
Penaeidae	Penaeidae

To analyze the benefit of each proposed technology carried forward from (Section 10.0), the total benefit that would be observed if there were no impingement or entrainment at Bayside was calculated (without-entrainment). In this case, benefit is defined as the addition of C/R taxa that would occur because of the complete survival of the entrained and impinged fish and shellfish at Bayside.

Table 11–6. Modeling Surrogate Taxa (Continued, Page 2 of 2)

Surrogate	Scientific Name
Sciaenidae	Carangidae
	Chloroscombrus chrysurus
	Menticirrhus spp.
	Oligoplites saurus
	Sciaenidae
Shellfish	Proportion of unknown invertebrates
	Sepioteuthis sepioidea
Trinectes maculatus	Achiridae
	Achirus lineatus
	Symphurus plagiusa
	Trinectes maculatus
	Trinectes spp.

Source: ECT, 2018.

The first step was to transfer the kilograms of production foregone of forage fish and shellfish surrogate taxa to the C/R taxa that occur within Hillsborough Bay and have recorded landings in Hillsborough County, the county where Bayside resides. For both entrainment and impingement, Sciaenidae (drums/croakers) was chosen as the taxa of finfish to model as benefiting from the increased forage based on the occurrence observed within the entrainment and impingement sampling and the presence of a C/R fishery within Hillsborough County. Sciaenidae dominated both the entrainment and impingement densities observed at Bayside during the Phase II sampling (approximately 62 percent of entrainment [Appendix 11-A] and 52 percent of entrainment [Section 9.2.2, Appendix 11-A]). In addition, Sciaenidae are an important component of the recreational fishery within Hillsborough Bay (FWC, 2017, Section 11.3.1). While applying the foregone biomass to one taxa is not realistic, as there are many consumers within Hillsborough Bay (i.e., tarpon, snook, sharks, Spanish mackerel, etc. [Tampa Bay Estuary Program, 2017]), it provides a simple method of accounting that allows for comparisons between technologies and provides a method of incorporating the forage base into the C/R harvest analysis.

The conversion of forage biomass as production foregone to Sciaenidae was conducted using a trophic transfer model. Table 11-5 provides the trophic level of each surrogate taxa modelled. For a transfer between trophic levels differing by less than or equal to one full trophic level, a 10-percent transfer efficiency was used (EPA 2002; May, 1976; Pauly and Christensen, 1995). For a transfer between trophic levels greater than one, trophic transfer coefficient (TT) was calculated as follows (Lindeman, 1942):

$$TT_{i,j} = 10^{TL_j - TL_i}$$

where: $TT_{i,j}$ = aggregate trophic transfer coefficient from forage taxa j, to Sciaenidae.
TL_j = trophic level of the forage taxa j.
TL_i = trophic level of Sciaenidae.

The trophic transfer model is one widely used to model the transfer of energy within food webs due to its simplicity and applicability to many systems (Pauly and Christensen, 1995). Trophic levels for different taxa were obtained from the Sea Around Us (2017).

The biomass that was transferred to Sciaenidae via the trophic transfer described previously was converted into EAs by dividing the biomass by the average weight of an age 3 (age fully exploited in fishery) Sciaenid (Table 11-5).

The total number of EAs (from production foregone of forage taxa plus direct entrainment/impingement) were then used to calculate the loss of biomass to the fishery of all C/R taxa considered (Sciaenidae, weakfish, spot, Gulf menhaden, blue crab, stone crab, Penaeid shrimp) because of entrainment and impingement using the Equivalent Yield model (EPRI, 2012) to provide the benefit to the fishery as kilograms of C/R catch. Since Sciaenidae is both commercially (approximately 3 percent of commercial finfish harvest between 2007 and 2016 within Hillsborough County) and recreationally important, the calculated yield was split based on the 2015 reported landing within Hillsborough County (approximately 89-percent recreational yield, approximately 11-percent commercial yield). Biomass is representative of the whole fish or shellfish with the exception of stone crab, which are reported in the landings as claw weight. To convert the whole organism weight to claw weight, the following steps were taken:

1. Total biomass was multiplied by 25.5 percent to represent the proportion of a single claw weight to total weight (Duermit *et al.*, 2015).
2. Resulting biomass was multiplied by 1.2 to represent the average number of claws per stone crab that are harvested over their lifetime (FWC, 2006).
3. Result was divided by 2 to account for the number of years an individual stays in the fishery (FWC, 2006).

To determine how the changes in annual impingement and entrainment as a result of the proposed technology would affect the C/R fisheries of Hillsborough Bay, the annual benefits were projected over the life of the potential technology at the facility. Each technology will have a different startup date when the benefits are first realized (Table 11-7). Regardless of technology, the life of the plant is assumed as 40 years postcommission (2044 inclusive).

Table 11–7. Years of Projection for Each Technology Considered

Technology	Without Entrainment	Closed-cycle Cooling	FMS	VSP
Start year	2021	2024	2021	2022
End year	2044	2044	2044	2044

Source: TECO, 2018.

To simulate how the benefits would change over the life of the plant, dynamic Leslie matrix (Leslie, 1945) models are populated with survival rates and weights at age from Table 11-6 and simulated forward until they reach the estimates of EAs:

1. For entrained taxa, in the year the technology comes online, there is no benefit observed, because no age class has yet hit the age of equivalence.
2. The following year, each life stage is "grown" up (using the survival parameters from Table 11-6). Only those life stages that have reached the age of equivalence are counted.
3. For subsequent years, as each life stage "grows" up to the age of equivalence, their numbers are added to the benefits.
4. Once each age has hit their maximum age, they begin to die-off and thus hit a steady state of EAs, in which the rate of organisms attaining EA and those subject to mortality are equal. This steady state is the calculated total yearly EA from the models.
5. When Bayside is assumed to be decommissioned (2044), the maximum age EA counts decay via the survival parameter for the EA of that taxa.

The same was also done for projecting the change in forage biomass as production foregone except instead of EA (counts), the production foregone (kg) was used which also includes the biomass of organisms entrained.

These projected annual EAs and production foregone underwent the same procedure as described previously to convert counts of individual organisms to biomass of C/R taxa considered.

11.2.3 Basis for Monetized Values Assigned to Changes in Stock Size or Harvest Levels

Estimating the benefits of entrainment reductions requires assessing the relationship between entrainment, its corresponding changes to the relevant fishery, and the social impact of any fishery changes. For example, properly assessing recreational values requires understanding how entrainment at Bayside affects recreational fishing catch rates and how those changed catch rates affect the well-being of anglers located in the plant's relevant vicinity. Properly assessing commercial values requires understanding of how entrainment affects commercial catch rates, the profitability of commercial harvesters, and the prices consumers pay for commercially harvested fish.

The methodology uses a resource-economic simulation to evaluate the effects entrainment has on C/R fisheries. To evaluate the effect of entrainment, the analysis modifies site catch estimates to generate C/R catch that could occur without the plant's entrainment. The methodology determines the economic value of the estimated catch changes by linking them to a model of recreational angling demand (Bingham *et al.*, 2011) and evaluations of the relevant commercial fishing markets.

The methodology extends the most relevant fishery and resource-economic studies published in the peer-reviewed literature. Important modeling features include linking yield equivalence, expected catch, and choice-based behavioral fishing models. These integrated partial equilibrium models are used to simulate conditions under with-entrainment (utilizing conditions observed in sample Year 1 and sample Year 2) and without-entrainment conditions, and the differences between these two conditions determine the benefits of entrainment reductions. As described in EPA's Guidelines for Preparing Economic Analysis, equilibrium modeling using the with- and without-impact approach is central to all sound benefit estimation processes and regulatory impact analysis (EPA, 2010).

Figure 11-2 provides an overview of the methodology for evaluating the economic benefits of reducing entrainment at Bayside. Appendix 11-A provides a more detailed description of the methodology employed. The shading in the bottom portion of the figure denotes the evaluation is separated into two parts: with-entrainment (top white portion) and without-entrainment (bottom

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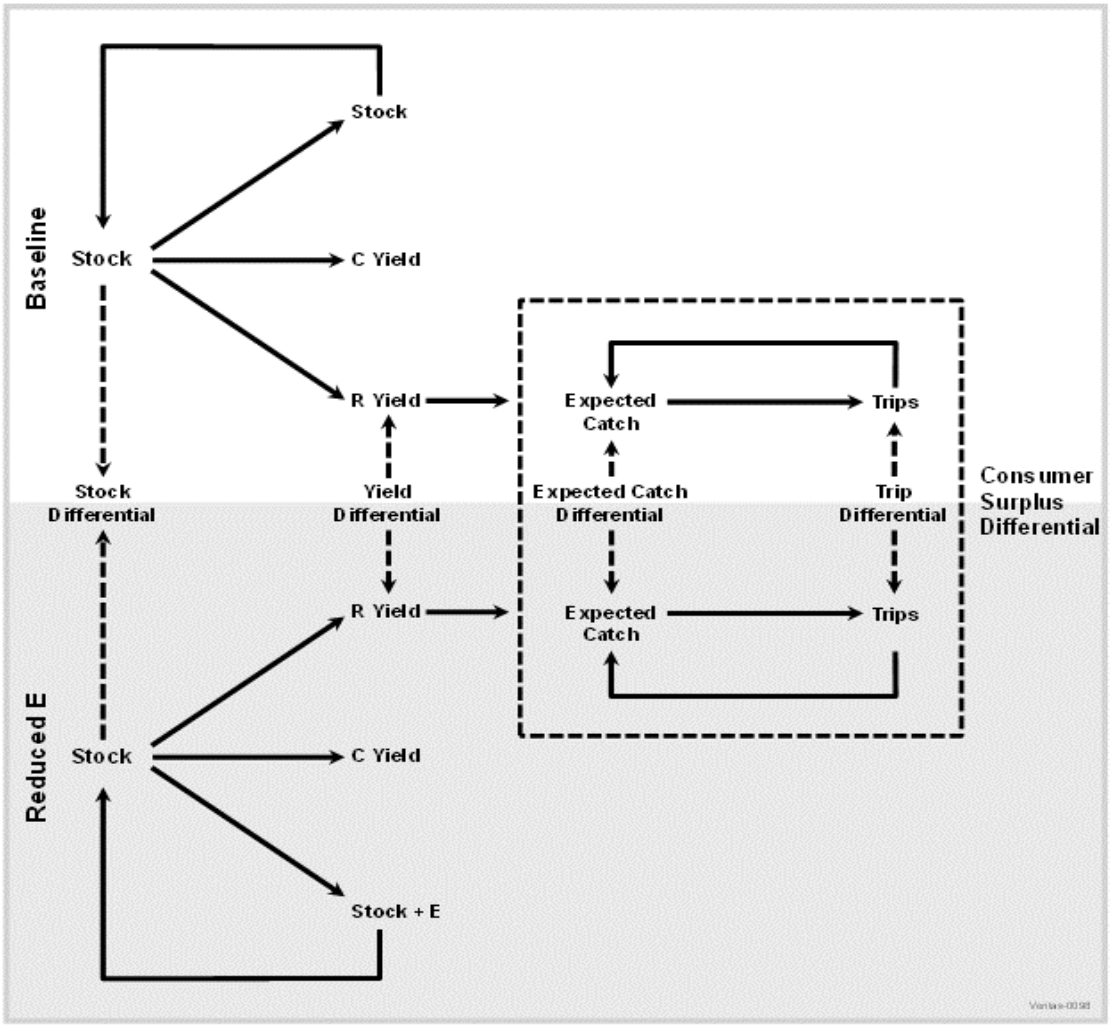


FIGURE 11-2.

OVERVIEW OF METHODOLOGY FOR ESTIMATING THE BENEFITS OF ENTRAINMENT REDUCTIONS

Source: Veritas, 2018.

ECT Environmental Consulting & Technology, Inc.

shaded portion). The calculated difference in recreational and commercial yield, catch rates, trips, angler welfare, and commercial profits represent the benefits of entrainment reductions. As the top portion of the figure shows, the approach begins by specifying the with-entrainment yield for each evaluated species and dividing that into recreational (R) and commercial yield (C). The model then relates that yield to expected catch rates for the affected water body under with-entrainment conditions (for brevity, the figure illustrates this process for estimating recreational fishing benefits). Those catch rates are apportioned over the estimated number of trips occurring at affected sites.

Under without-entrainment conditions, reduction in entrainment and the change in C/R yield that would accompany the entrainment reduction are identified. The new recreational yield is incorporated into changes in expected catch rates, and the corresponding changes in trips that would accompany increase catch rates are estimated. To calculate recreational fishing benefits, the model evaluates the differences between the two states of the world, including yield, expected catch, and trips. The box around the expected catch and trip differentials identifies these result in the recreational fishing benefits measured as the consumer surplus differential. Consumer surplus is the difference between what an angler has to pay for a fishing trip and what the angler would be willing to pay.

Simulating the linked models produces equilibrium-based changes in stock, yield, trips, and expected catch under without-entrainment conditions. Equations from welfare and market-based economics are used to identify changes in consumer and producer surplus, which are then discounted to calculate present values. The following subsections provide additional detail on the recreational, commercial, and nonuse value components of the model.

11.2.3.1 Recreational Benefits

Hillsborough Bay provides a recreational fishery for residents and visitors. Anglers catch seatrout, sheepshead, snapper, mullet, snook, tarpon, and other sportfish in Hillsborough Bay. Hillsborough County enables access for anglers at 33 boat ramps, 8 fishing piers, 15 marinas, and many shore access points on Hillsborough Bay (FDEP, 2010).

Stock-level effects could be experienced as changes in catch rates by people hoping to catch the affected species in Hillsborough Bay. Recreational anglers modeled as potentially being affected include those fishing Hillsborough Bay from Hillsborough County and neighboring counties.

Correctly calculating recreational benefits requires a significant amount of information and calculations. As the 2014 316(b) rule describes:

> …assessing recreational use benefits involves estimating the improvements in recreational fishing opportunities resulting from reduced impingement mortality and entrainment, and assigning a value to these improvements. The value assignment is based on the estimated population profile—in particular, number and proximity to affected water resources—of recreational users, the availability of alternative competing water resources for recreational usage [alternative substitute sites], and the resulting estimated change in demand for use and value of the affected water resources based on reduced impingement mortality and entrainment and increased recreational fishing performance (EPA, 2014 p. 48,371).

To account for this information, the methodology for estimating recreational angler benefits is based on simulating angler behavior and estimate changes in social welfare resulting from reductions in entrainment and the associated increases in expected catch. To do this, a mathematical representation of angler demand (recreational angling demand model) for the population expected to be affected by reductions in entrainment at Bayside was developed. The recreational angling demand model identifies angler behavior across site characteristics that occur in both the with- and without-entrainment conditions. Important modeling features include fusing an existing, behavioral (choice-based) preference function to spatially represented population data. This fusing process produces integrated partial equilibrium models used to simulate conditions under with- and without-entrainment conditions. The differences between these two conditions determine the social welfare changes associated with the entrainment reductions resulting from an individual entrainment control technology.

Important factors accounted for in the recreation angling demand model include angler preferences; attributes associated with the choice of fishing sites; the number, quality, and availability of substitute fishing sites; the geographic range of impacted species; the number of

trips with improved catch rates;[3] and the number of anglers associated with those trips (estimated population profile of recreational users).

Preference functions are used to identify how anglers trade off the characteristics of alternative fishing sites when they choose how and where to participate in recreational fishing. When anglers take a trip, they have a choice of which site to visit. The sites from which they can choose have numerous characteristics such as the distance from their home, catch rates, facility amenities (e.g., presence of a boat launch), and water body characteristics and surroundings (e.g., fresh versus saltwater, level of crowding, and remoteness of the surroundings).

Preference functions include the (nonmarket) price of fishing as the costs anglers incur in traveling from their homes to recreation sites. These "prices" vary according to angler locations. When existing fishing sites have their features changed, such as a change in catch rates that could occur with entrainment reductions at a power plant, the preference function allows interpreting the value of the quality change in terms of travel costs. Anglers respond to catch rate changes by reallocating their trips to maximize the value of their fishing experience. For example, if entrainment rates are reduced and catch rates increase, an angler who typically visits a site farther away with a higher catch rate under with-entrainment conditions would not have to travel as far to achieve a similar fishing experience under without-entrainment conditions. This angler would incur lower travel and time costs and experience welfare improvement, because the same fishing experience costs the angler less in avoided travel and time costs.

Random Utility Analysis

Random utility analysis is the best method for evaluating angler preferences across these different site attributes and valuing entrainment reductions on recreational fishing (EPA, 2010). Random utility maximization (RUM) models are recognized in the U.S. Department of the Interior regulations (43 CFR 11.83) as an appropriate method for quantifying recreation service losses in natural resource damage claims.[4] EPA endorsed the use of RUMs for 316(b)

[3] Resulting estimated change in demand for use and value of the affected water resource based on reduced entrainment and increased recreational fishing performance.
[4] Currently, the RUM is the most widely used model for quantifying and valuing natural resource services. RUMs are also widely accepted in other areas of the economics profession. RUMs have been used in transportation (Beggs, Cardell, and Hausman, 1981; Hensher, 1991), housing (McFadden, 1997), and electricity demand estimation (Cameron 1985), as well as more recently in environmental and resource economics.

applications in the now remanded rule (69 [131] FR 41658, July 9, 2004).[4] However, conducting an original RUM study can require extensive primary data collection. Developing a recreation demand model using a site-calibrated transfer of a preference function from an existing RUM study can capture important behavioral responses (i.e., changes in trip-taking behavior because of changes to a fishery) without requiring survey-data collection. The accuracy of this methodology is limited only by the analyst's ability to calibrate an already estimated preference function to a different population using appropriate economic methodologies (Smith, van Houtven, and Pattanayak, 2002).

Economists have long used the preference functions from RUMs to estimate demand curves (Bingham *et al.*, 2011; Kinnell *et al.*, 2006; Bockstael *et al.*, 1991; Morey *et al.*, 1991; Bockstael *et al.*, 1987; Bockstael *et al.*, 1986; Caulkins *et al.*, 1986; Feenberg and Mills 1980). The RUM is based on welfare theory and posits that individuals make choices that maximize their utility, subject to constraints.

The analysis uses four main steps to develop the recreational angling demand model and estimate the benefits associated with reductions in entrainment at Bayside:

1. Select the angling preference function from the best available RUM study.
2. Identify the appropriate geographic scope for substitute sites and select a representative sample of substitute sites.
3. Fuse the preference function to the affected population and calibrating the model's prediction of the population's trips.
4. Simulate changes in trip patterns that anglers make in response to changes in catch rates.

Step 1: Select the Angling Preference Function from the Best Available RUM Study—The RUM is based on choice theory and posits that individuals make choices that maximize their utility, subject to constraints. In this framework, anglers choose which sites to visit, based on costs and fishing opportunities at the sites. Because anglers trade off factors, such as the cost of getting to the site against the quality of the fishing opportunity, this approach can evaluate the relative influence of these variables as revealed by anglers' decisions.

Bingham *et al.* (2011) covers fishing sites across New Jersey and explicitly consider various fishing experiences, including ocean, estuarine, and freshwater sites (e.g., inland lakes, rivers, and stream). The survey process was consistent with accepted survey protocols. The study's response rate is consistent with survey research standards, and its models are rigorous, perform well, and reveal results that are consistent with expectations (Bingham *et al.* 2011).

The statistical model estimated in Bingham *et al.* (2011) is a nested logit. To delineate potential differences in angler preferences with respect to fishery type, Bingham *et al.* (2011) uses a three-level fishing structure. On the first level, anglers choose if they will fish. On the second level, anglers choose which water body type to fish from (freshwater, saltwater, or tidal sites). Lastly, after selecting a water body type, anglers decide which site to choose.

The model output is a coefficient for each site characteristic. Each coefficient reflects the importance of that site characteristic to angler welfare. These coefficients play a key role in the approach used in this assessment. Table 11-8 contains the relevant coefficients and t-statistics from the Bingham *et al.* (2011) model.

Table 11–8. Coefficients from the Bingham *et al.* (2011) Model

Characteristic	Coefficient	t-Statistic
Travel cost	-0.024	-9.93
Advisory	-0.42	-2.30
Boat ramp	1.49	19.69
Trout and shad	0.31	7.42
Panfish	0.16	4.72
Freshwater game	0.16	8.67
Other freshwater	0.08	2.71
Other saltwater	0.36	8.86
Saltwater small game	0.16	3.01
Flatfish	0.95	10.70

Source: Veritas, 2018.

When considering yield changes, value at the species level is a critical component of overall value. The Bingham *et al.* model includes coefficients for catch rates for both freshwater and saltwater species. Saltwater small game species include bluefish, sea bass, weakfish, and sea

trout. The other saltwater species group includes species such as drums, croakers, jacks, kingfish, and leatherjacket. Relative species values can be evaluated by comparing these coefficients. Other saltwater species are valued higher than saltwater small game.

Values at the species level are typically identified by coefficients from RUMs. However, species-level values are notoriously difficult to estimate. For example, although anglers have different preferences, most models are based on an "average" angler. In addition, anglers often misidentify catch (Page *et al.*, 2012) and many "species" coefficients are based on species groupings (Lupi *et al.*, 1998).

Step 2: Identify the Appropriate Geographic Scope for Substitute Sites and Select a Representative Sample of Substitute Sites—Available information on recreation in the area and typical travel distances are used to develop an appropriate area of alternative, substitute sites to include in the model (generally within 100 to 200 miles of the affected site). Several substitute sites are used that are representative and reasonable and provide a similar fishing experience for anglers who potentially fish near Bayside. By capturing substitution among sites, the simulation adds a critical level of realism relative to approaches that ignore substitution possibilities.

Step 3: Fuse the Preference Function to the Affected Population and Calibrating the Model's Prediction of the Population's Trips—For this analysis, the affected anglers can include any angler located in the counties adjacent to Hillsborough County. Because distance-based travel cost is an important variable in the recreational angling demand model, anglers closer to the site have a higher predicted likelihood of visiting the site than those farther away, but the model does not make any specification of which anglers are included in the model or not. For the sites affected by entrainment at Bayside, we fix the number of trips to correspond to the best available information on current visitation. Within these constraints, the remaining trips are distributed among the substitute sites in an appropriate manner, also based on available visitation information.

The distance traveled to a site are calculated using the most recent version of a popular transportation routing software called PC*Miler (ALK Technologies, 2010). Travel costs reflect both direct costs and travel time costs. Direct costs are calculated by multiplying the round-

trip miles by $0.1864 per mile, which is the American Automobile Association's (AAA's) 2015 per-mile cost of operating a motor vehicle (AAA, 2015). The cost per mile includes gas, maintenance, and tires and is averaged across five types of vehicles: small, medium, and large sedans; SUVs; and minivans. Direct costs are calculated by multiplying the round-trip miles by the standard per-mile reimbursement. The average hourly wage of each ZIP Code within the 50-mile radius is calculated by dividing household income from the U.S. Census by 2,000 work hours per year (U.S. Census Bureau, 2017). Travel time in minutes is also calculated by PC*Miler. The round-trip time estimate is multiplied by one-third of the average hourly wage rate to reflect the opportunity cost of time based on the original research of Cesario (1976) and the more recent evaluation by Phaneuf and Smith (2004). The travel cost included in the model is the sum of the direct travel cost and the opportunity cost of time.

The analysis apportions the estimated yield changes over the affected sites according to angling pressure. This approach results in similar changes in per-trip expected catch across sites.

USFWS conducts the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation every 5 years. Among other information, the survey collects data on anglers and the types of fish they catch. This assessment uses data from the 2011 survey for Florida, because those are the most recent, complete data on angling activity. According to the national survey, 12 percent of Florida residents 16 years of age and older fished during 2011 (USFWS, 2013 and 2014).

Step 4: Simulate Changes in Trip Patterns that Anglers Make in Response to Changes in Catch Rates—After estimating the changes in catch resulting from the reduced entrainment, the analysis simulates the changes in trip patterns that anglers make in response to changes in catch rates in Hillsborough Bay. The economic assessment proceeds by developing the estimated changes in social welfare, in dollars, associated with the changes in trips that result from the changes in catch and trips. The analysis estimates the monetized benefits by calculating the difference in angler welfare with and without the increased catch rates and trips associated with reduced entrainment at Bayside.

For the purposes of this assessment, only the catch rates in Hillsborough Bay are simulated to increase in response to the changes in entrainment.

These annual changes are then projected forward through the life of the facility. The future baseline of fishing participation, trips to sites, and expected catch was specified consistent with the pre-2012 calibrated baseline estimates described in Section 11.3.

11.2.3.2 Commercial Benefits

Commercial benefits from entrainment reductions accrue to commercial anglers as increased profit attributable to the higher catch per unit effort (CPUE). The CPUE is associated with increases in fish populations and/or to fish consumers in the form of lower prices. The ability of commercial anglers to realize sustained increased profits depends on the responsiveness of market prices to higher CPUE. Market extremes determine the upper and lower bounds on commercial benefits. In competitive markets, prices adjust instantly, and benefits accrue to consumers. In restricted markets, prices do not change, and commercial benefits are maximized in the form of producer surplus at price times quantity (P × Q). As the rule describes, estimating the commercial benefits of entrainment reductions involves consideration of the fishery's relevant market conditions. Specifically, the 2014 Rule notes:

> …assessing the productivity and value of commercial fisheries involves estimating the expected increases in commercial yield of economically valued species over time as a result of reduced impingement mortality and entrainment, and valuing these at market prices minus any incremental production costs associated with the incremental catch (EPA, 2014 p. 48,371).

To assess the commercial fishing benefits, the methodology first characterizes the current market conditions that exist in the relevant vicinity of Bayside. The methodology characterizes the operation of that commercial fishery under the with-entrainment conditions and evaluates the commercial fishing market conditions. It then uses the information from changes in commercial yield to determine the effect on CPUE, market prices, producer surplus, and consumer surplus under without-entrainment conditions. Finally, the methodology estimates the difference in producer surplus and consumer surplus under the with- and without-entrainment conditions to determine the commercial fishing benefits.

Commercial fishers that were modeled as potentially being affected include those fishing Hillsborough Bay from Hillsborough County and neighboring counties. To assess the

commercial fishing benefits, the analysis applies the price per pound from the National Marine Fisheries Service's 2016 data of annual Hillsborough County landings (FWC, 2017d; NOAA Office of Science and Technology, 2017b) to the changes in commercial yield estimated to result from a complete elimination of entrainment at Bayside. The analysis specifies the additional harvest will be sold at the 2016 prices.

11.2.3.3 Nonuse Benefits

The final category of benefits that could be monetized is nonuse benefits. Since the development of the 2004 version of the 316(b) rule, EPA has used a number of different methods to measure the potential nonuse values associated with reductions in impingement and entrainment. These include techniques such as habitat replacement cost, societal revealed preference, and the Fisher-Raucher approximation. Most recently, as part of supporting the development of the 2014 version of the 316(b) rule, EPA administered a stated preference survey to develop the total values (use and nonuse) associated with the rule. While EPA developed econometric models of the survey data and estimated respondents' willingness to pay for alternative impingement and entrainment reductions, they did not incorporate the results of the survey into the estimate of the rule's benefits. Regardless, states have issued suggestions for how the stated preference survey results can be used to inform site-specific benefit estimates (e.g., Wisconsin 2016), regulators have made suggestions in public meetings that benefit valuation studies should, in the least, identify the implications that the stated preference study results have for an individual site's nonuse benefit estimates, and peer reviewers have asked whether the results of the stated preference survey have been considered as part of the 316(b) benefits valuation study.

Given the survey's existence and these suggestions and questions from regulators and peer reviewers, a simulation model has been developed that uses the best available information from EPA's stated preference survey and the literature to identify the implications of what the survey results imply for the potential nonuse benefits of 100-percent reduction in impingement and entrainment at Bayside.

To develop site-specific, nonuse benefit estimates, a simulation model was developed that incorporates the best of the available information relevant for developing site-specific, nonuse

benefits estimates of entrainment reductions (Veritas, 2017). The following steps to construct and develop the inputs for the simulation model were taken:

1. Collect and compile the data from EPA's stated preference survey.
2. Replicate the econometric models and willingness-to-pay estimates EPA developed and presented in its 2012 notice of data availability (EPA, 2012).
3. Decompose the willingness-to-pay estimates into individual value categories, and identify which categories are recoverable using the parameters estimated from EPA's stated preference survey.
4. Place the plant's entrainment impacts in EPA's study context. The simulation model places Bayside's maximum annual EA estimates of approximately 155,000 EAs in the context of the 400 million annual EA estimate that EPA presents for all of the plants included in the southeast region version of its stated preference survey.
5. Estimate differences in willingness to pay by demographics, collect and compile ZIP-Code level demographic data for the region(s) specified to contain the population having nonuse values for reductions in entrainment at Bayside (U.S. Census Bureau, 2018) and simulate household willingness to pay by demographics for each region. The regions evaluated include Hillsborough County, Florida (514,487 households), states included in the southeast region of EPA's stated preference survey (34,340,769 households), and all households in the United States (118,860,065 households).
6. Adjust the estimates to account for the survey-induced bias present in the willingness-to-pay estimates and the awareness bias present in the extrapolation. Because Bayside is in Hillsborough County, the simulation model specifies that all Hillsborough County residents will be aware of entrainment reductions at Bayside and applies the willingness-to-pay estimates to all households in the county. For the households in the southeast region and the entire United States, the simulation model applies the results from the 2012 Environmental Impacts Awareness Survey (Kinnell *et al*., 2012), specifying that 12 percent of households in each area are aware of impingement and entrainment and can therefore hold nonuse values).
7. Sum the adjusted estimates across all the individuals of each demographic profile in each ZIP Code included in the affected population.

Appendix 11-G provides a more detailed description of the steps taken to quantify nonuse benefits and the results of that quantification.

11.2.4 Discussion of Mitigation Efforts Made Prior to the Rule

The rule requires a discussion of mitigation efforts completed prior to October 14, 2014, be discussed. Completed in 2004, the facility, now known as H.L. Culbreath Bayside, went from a coal-fired boiler facility (Gannon Units 1 through 6) to a natural gas-fired, combined-cycle facility (Bayside Units 1 and 2; combined-cycle gas turbine system; Bayside Units 3 through 6 as natural gas-fired peaking units with two simple-cycle combustion turbines per unit).

Typical coal-fired generating stations use between 20,000 and 50,000 gallons of once-through cooling water per MWh. Natural gas combined-cycle facilities use on average 7,500 to 20,000 gallons per MWhr (Macknick *et al.*, 2012). Gannon Units 1 through 6 have a DIF of 1,336 MGD once-through cooling water combined. Bayside Units 1 and 2 use a maximum of 668 MGD once-through-cooling water (Section 3.0). Thus, the repowering of Bayside resulted in a large increase in efficiency because of the drastic reduction (more than 50-percent reduction) in water use and in turn an assumed more than 50-percent reduction in entrainment (Table 11-9).

Table 11–9. Changes in MGD per MW Following Repowering of Bayside

	MW	MGD	MGD per MW
Gannon	1,272	1,267	1.05
Bayside	1,836	668	0.36
Flow reduction (MGD) per MW			0.65

Source: ECT, 2018.

However, as stated by the rule in 40 CFR 125.98(f)(3)(iii), any such reductions in flow can only be considered as credit in entrainment and impingement reductions if such modifications were completed within 10 years of the final rule (2014). However, as stated in the preamble of the rule, water use efficiencies in energy production are to be described. Bayside experienced an increase in water use efficiency from 1.05 to 0.36 MGD per MW when it converted to combined-cycle, which is a 65-percent reduction in water use on a MW basis (Table 11-9). Thus, this measure should be considered toward the facility's efforts to reduce entrainment.

11.2.5 Discussion, with Quantification and Monetization where Possible, of Other Benefits

Other benefits that may result from a reduction in entrainment and impingement include an indirect effect on birds and terrestrial species that might use Hillsborough Bay for habitat or food supply.

Four orders of colonial waterbird species dominate Tampa Bay (Hodgson and Paul, 2010):

- Pelecaniformes (pelicans, cormorants, anhingas)
- Ciconiiformes (herons, ibis, spoonbills, storks)
- Anseriformes (waterfowl)
- Charadriformes (shorebirds, gulls, and terns)

A wide variety of marsh, mangrove, and coastal uplands species occur along Hillsborough Bay, with distribution heavily dependent on the availability and quality of suitable habitat.

These terrestrial and avian species would benefit from an increase in their food base if their populations were food limited. However, current conditions do not indicate a food-limited community, and thus an increase in forage base due to decreased impingement and entrainment is not expected to result in any change to terrestrial or avian species populations (Hodgson and Paul, 2010).

As discussed in Section 6.0, horseshoe crabs, neither fish nor shellfish, may experience a benefit due to the reduction in their impingement associated with technologies that reduce flow. This benefit would be equivalent to the reduction in flow. No monetization is provided due to the lack of a C/R fishery for horseshoe crab within Hillsborough Bay.

11.2.6 Discussion, with Quantification and Monetization where Possible, from Reductions in Thermal Discharges

The cooling water discharge from Bayside is subject to numeric temperature limitations in Florida water quality standards (Section 62-302.520, F.A.C.). However, in the individual

wastewater facility Permit No. FL0000809 includes alternative thermal limitations for the discharge authorized under Section 316(a) of the CWA and approved by EPA.

Section 316(a) allows for a variance from numeric limitations on the thermal component of a discharge if the permittee is able to demonstrate the limitations for thermal components are more stringent than necessary to assure the protection and propagation of a balanced and indigenous population of shellfish, fish, and wildlife in and on the receiving body of water. The variance is granted for the 5-year permit periods, and reissuance must be requested by the permittee as part of the application of permit renewal. Bayside's variance, under 316(a), is defined as a 17°F monthly average temperature difference between the intake and discharge.

Bayside, as a closed-cycle cooled facility, would continue to be consistent with the 316(a) thermal variance granted under the current NPDES permit. Subsequent discussions with regard to thermal discharge fall under the current thermal variance condition.

In the following sections, the effects of changes in thermal discharge are discussed specific to each technology considered.

As part of Bayside's FL0000809 NDPES permit issued January 26, 2001, TECO is held to Special Condition No. 20, which requires the development of a plan and procedures addressing potential manatee impacts. On February 18, 2002, following the review of FWC and USFWS, the Manatee Protection Plan for TECO's Gannon Station dated December 3, 2001, was approved.

The component of Special Condition No. 20 that requires TECO to minimize disruption to warm-water outflows during the winter is relevant to this analysis, because it works to limit the degree of changes to the thermal discharge of the facility in an effort to protect its function as a thermal refuge for the federal- and state-protected manatee (see Section 4.0). The condition defines the period between November 15 and March 31 as the time of year where the temperature in the discharge is not to be impacted to the point it would cause harm to manatees that overwinter there.

Manatees, especially juveniles, are vulnerable to death from cold stress when temperatures fall below 18 to 20°C (64 to 68°F) for long periods of time or to temperatures of 10 to 12°C (50 to 54°F) or less for short periods of time (a few days or less) (Laist *et al.*, 2013). In light of this, TECO attempts to maintain their discharge canal temperature at 68°F. During the winter, as power demand drops, maintaining the temperature within the discharge at 68°F can be challenging under existing conditions. Modification to the status quo will affect how the discharge temperatures are managed in light of Special Condition No. 20. Under each technology of the following discussions, potential impacts to manatees as it relates to the thermal discharge changes will be discussed.

11.3 Baseline Fishing Conditions

Existing fishing conditions are defined as the current conditions at Bayside, which include entrainment. The characterization of baseline fishing conditions considers recreational and commercial fishing, both current and into the future. To characterize existing fishing conditions, an assessment of current C/R yield with entrainment at Bayside, the number of C/R anglers potentially affected by the impact of entrainment at Bayside on C/R yield, the number of fishing trips the anglers take, the sites those anglers visit, and catch rates was completed.

11.3.1 Baseline Recreational Fishing Conditions

11.3.1.1 Angler Preferences

When anglers take a fishing trip, they have many sites to choose from with varying attributes. These attributes include how far the site is from the angler's house, the type and number of fish the angler can expect to catch at each site, and the level of development at each site. Angler preferences across varying site attributes are characterized using recreational angling demand models as described previously with regard to the Bingham *et al.* (2011) model.

11.3.1.2 Angler Participation: Population Size and Annual Fishing Trips

USFWS conducts the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation every 5 years. Among other information, the survey collects data on anglers and the types of fish they catch. This assessment uses data from the 2011 survey for Florida, because those are the most recent, complete data on angling activity. According to the national survey, 10.09 percent

of Florida residents 16 years of age and older fished during 2011 (USFWS 2013, U.S. Census Bureau, 2017). To develop the estimate of total angling days, the analysis applies the average number of days Florida anglers spend fishing from the 2011 USFWS survey (23 days) to the number of anglers residing in the affected ZIP Codes.

11.3.1.3 Angling Sites

In addition to using information on angler preferences and participation, the recreational angling demand model should contain information on the sites an angler can potentially visit. This information is collected from publicly available sources on the most popular inland river and lake sites. Fishing sites include shore and boat fishing.

Figure 11-3 illustrates the recreational fishing sites and the angling population used in the model. The red circles represent the aggregated fishing sites specified to be most likely affected by changes in Bayside's entrainment. The angling population specified as being most likely affected by changes in Bayside's impingement and entrainment is illustrated by the shaded polygon. The shading illustrates the number of anglers residing in each ZIP Code contained in the counties adjacent to Hillsborough County. Figure 11-3 also illustrates the location of alternative, substitute sites (yellow triangles) included in the model. These are sites where anglers can fish that are not affected by Bayside's entrainment. Model sites include fishing sites on Hillsborough Bay, Tampa Bay, the Gulf of Mexico, and Florida's inland lakes and rivers. Fishing sites include shore and boat fishing. Appendix 11-G presents the characteristics of the sites included in the model. Table 11-10 summarizes the data on anglers, trips, and sites illustrated in Figure 11-3 and used to develop the site-choice simulation of recreational angling demand.

The shading represents the number of anglers residing in each Florida ZIP Code contained in the model. The number of anglers is derived from using the 2010 U.S. Census population by ZIP Code and the percent of anglers from the 2011 Florida USFWS Survey of Fishing, Hunting, and Wildlife-Watching (U.S. Census Bureau, 2017; USFWS, 2013).

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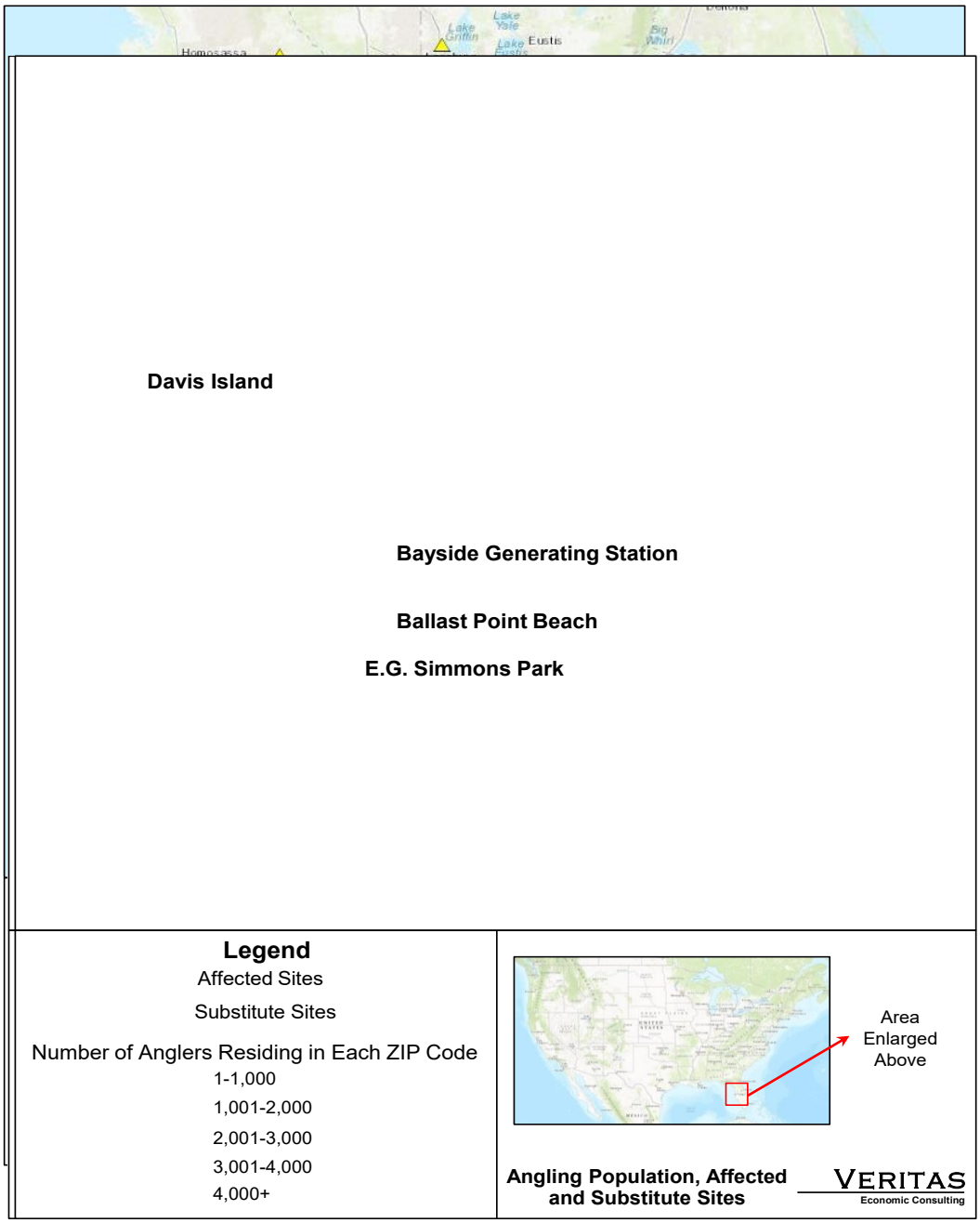


FIGURE 11-3.
LOCATION OF SITES WITH AFFECTED CATCH RATES, LOCATION OF SUBSTITUTE SITES, AND CONCENTRATION OF ANGLERS
Source: Veritas, 2018.

ECT Environmental Consulting & Technology, Inc.

Table 11–10. Affected Population, Trips, and Sites Included in the Recreation Angling Demand Model

Data Components	Estimate
Total number of ZIP Codes in affected population*	203
Total population residing in affected ZIP Codes†	3,949,080
Total anglers residing in affected ZIP Codes‡	398,415
Total annual fishing days by anglers in affected ZIP Codes‡	9,163,536
Number of modeled fishing sites	207
Total annual fishing days by affected population to modeled sites§	2,792,706
Number of affected sites	3
Total annual fishing days to affected sites¥	104,458

Sources and Notes:

*The analysis specifies the affected population as those anglers residing in Hillsborough County and adjacent counties.
†2010 Census, U.S. Census Bureau, 2017.
‡Developed from information from USFWS's 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation for Florida and the 2010 U.S. Census (USFWS, 2013; U.S. Census Bureau, 2017). The analysis uses the 2010 Census population for Florida and the 2011 estimate of the total number of resident anglers from the 2011 USFWS to estimate the percentage of the population that are anglers (10.09 percent). The analysis applies this percentage to the population in the affected ZIP Codes. To develop the estimate of total angling days, the analysis applies the average number of days Florida anglers spend fishing from the 2011 USFWS survey (23 days) to the number of anglers residing in the affected ZIP Codes.
§While the model accounts for all of the anglers in the affected population, it does not account for all of the sites where they can take their fishing trips. Therefore, not all of their trips are included in the model. The analysis uses annual trip information that is available for each site in the model to determine the total number of modeled trips (30.5 percent of affected population's total trips).
¥Developed from the Florida Coastal Management Program (2011), FWC (2013), and State of Florida Division of Recreation and Parks (2013).

Anglers can choose among many quality fishing sites within 100 miles of Bayside. Sargeant (1992) notes that Tampa Bay to Cedar Kay are among "hundreds of outstanding fishing areas along Florida's west coast." FWC (2017a) identifies the top spots for freshwater fishing for popular species such as black bass (*Micropterus* spp.). Many substitute fishing sites feature attractive amenities, such as parks and marinas.

Table 11-11 lists conditions at affected sites in Hillsborough Bay. Catch rates are specified to be the catch per hour and are listed for six categories. Saltwater small game species include bluefish (*Pomatomus saltatrix*), sea bass (*Centropristis striata*), weakfish, and seatrout. The other saltwater species group includes species such as drums, croakers, jacks, kingfish, and leatherjacket. Flatfish includes flounder (*Paralichthys albigutta*).

Table 11–11. Conditions of Affected Sites: Catch Rates

Category	Ballast Point Beach	Davis Island	E.G. Simmons Park
Angler trips:	**68,710**	**17,780**	**17,878**
Trout or shad	0.0000	0.0000	0.0000
Panfish	0.0000	0.0000	0.0000
Freshwater game	0.0000	0.0000	0.0000
Other freshwater fish	0.0000	0.0000	0.0000
Saltwater small game	0.0537	0.0537	0.0537
Other saltwater fish	2.6790	2.6348	2.6790
Flatfish	0.0106	0.0106	0.0106

Sources: DeLorme, 2006.
Florida Coastal Management Program, 2011.
FWC, 2013.
NOAA Office of Science and Technology, 2017a.
Saltchef.com, 2016a–2016o.
State of Florida Division of Recreation and Parks, 2013.
USFWS, 2013.

11.3.1.4 Calibrates With-Entrainment Trips and Expected Catch

Travel costs and the other site characteristics are combined with coefficients from the Bingham *et al.* (2011) model to allocate the estimated annual trips by the affected angling population to the affected and substitute sites. Total trips to the affected portion of Hillsborough Bay are calibrated to correspond to the best available visitation information for the affected sites. This process results in the distribution of trips to the affected sites. The remaining trips are distributed among the substitute sites using the best available visitation information.

In the calibrated baseline dynamic recreational fishing model, baseline trips (as described previously) and yield (as described in Section 3.1) were combined by dividing recreational catch

by trips to identify a calibrated baseline expected catch for each affected species. To simplify the modeling, identical expected catches were specified for each site.[5]

11.3.2 Commercial Fishery

Florida Statute 68B and its individual chapters govern commercial fishing in Florida's marine waters (Florida Department of State, 2017). Hillsborough Bay can support commercial fishing and aquaculture. Table 11-12 lists the top species landed commercially in Hillsborough County, Florida.

Table 11–12. Species Landed Commercially in Hillsborough County from 2007–2016

Species	Dollars ($)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Pink shrimp	1.98 M	2.48 M	2.21 M	3.25 M	2.53 M	2.77 M	2.74 M	5.97 M	3.56 M	3.09 M
Mullet	268 K	303 K	358 K	381 K	671 K	310 K	830 K	629 K	538 K	721 K
Grouper	312 K	568 K	581 K	352 K	506 K	551 K	380 K	332 K	—	63.4 K
Blue crab	256 K	166 K	197 K	328 K	280 K	270 K	265 K	403 K	287 K	383 K
Brown shrimp	218 K	—	169 K	18.4 K	—	130 K	146 K	182 K	141 K	5.5 K
Other shrimp	45.5 K	38.4 K	80.8 K	160 K	469 K	71.5 K	350 K	180 K	149 K	104 K
Ladyfish	35.2 K	62.2 K	1.2 K	57.7 K	13.8 K	16.7 K	23.9 K	53.5 K	16.7 K	212 K
Tilapia	41.4 K	16.6 K	30.0 K	54.6 K	19.8 K	52.6 K	48.2 K	55.2 K	22.9 K	20.7 K
Mojarra	30.6 K	30.8 K	21.7 K	18.5 K	6.2 K	10.6 K	10.9 K	17.9 K	10.1 K	32.8 K
Jacks, pompano	17.2 K	15.8 K	14.0 K	13.9 K	9.7 K	9.5 K	22.8 K	15.5 K	21.2 K	47.3 K
Pinfish	51.6 K	40.5 K	24.4 K	13.0 K	8.4 K	9.0 K	9.4 K	21.4 K	17.2 K	10.9 K
Stone crab	4.8 K	7.3 K	2.9 K	2.8 K	1.0 K	5.2 K	0.7 K	—	8.5 K	17.7 K

Source: Veritas, 2017.

Commercial fishery landings in Hillsborough County totaled approximately $4.81 million during 2015, the latest year with complete data. Pink shrimp comprise 74 percent of the landings; much of the pink shrimp is caught in the Gulf of Mexico. The shrimp fleet (as many as 50 boats) operates out of the Port of Tampa. Besides pink shrimp, the top ten species landed in Hillsborough County are mullet, brown and other shrimp, grouper, blue crab, ladyfish, tilapia, mojarra, jacks and pompano, and pinfish. Also, a modest volume of stone crabs is landed commercially in Hillsborough County (Table 11-12). The Tampa Bay metropolitan area has dozens of large- and small-scale seafood processors (FWC, 2017a; Huang, 2003).

[5] Inducing realistic-looking, catch-rate variation across sites would require identifying three (one for each site) exploitation rates for each species.

The stone crab fishery is unique in that the crabs are caught in crab pots, one or both of each crab's claws are removed if legal sized, and the crabs are returned to the water alive to regenerate claws. Although stone crabs occur in the U.S. Atlantic Ocean and Gulf of Mexico from North Carolina to Texas, more than 98 percent of stone crabs are landed in Florida. The stone crab fishery in the southeastern United States, including Florida, is October 15 through May 15 (7 months). During 2015, the most recent year with complete data, nearly 2.76 million pounds of stone crab claws were landed commercially in Florida (Miller, 2013; NOAA Office of Science and Technology, 2017b; FWC, 2012).[6]

11.4 Technology-specific Findings

11.4.1 Without-entrainment Condition

11.4.1.1 Changes in Fish and Shellfish

Table 11-13 summarizes the numbers of fish and shellfish that would no longer be entrained or impinged if Bayside were to shut down the cooling water intake completely (Table 11-13, Appendix 11-A). The baseline impingement results also represent the benefits that would be observed under the IM BTA option of fish-friendly travelling screens with a fish return.

Table 11–13. Annual Benefit as Reduction in Impingement and Entrainment Resulting If Bayside Were to Shut Down the Cooling Water Intake

Animal	Entrainment Sample Year		Impingement Sample Year	
	1	2	1	2
Fish	4,644 M	9,160 M	13,800	8,560
Shellfish	4,107 M	8,671 M	14,100	17,800
Total	8,767 M	17,831 M	27,900	26,300

Source: ECT, 2018.

The average annual entrainment losses of fish eggs are estimated at seven billion eggs. To put this in perspective, an average sized female black drum (*Pogonias cromis*, Family Sciaenidae), an important part of the C/R fishery within Hillsborough County, has an annual egg production rate of 32 million (ASMFC, 2017). Thus, the average entrainment of eggs at Bayside represents

[6] Stone crabs are harvested recreationally in Florida, also, but the number of participants and magnitude of their harvests are unknown (FWC, 2012).

the annual egg production of only 209 female black drum, a small fraction of the harvest and the local population. The fish population within Hillsborough Bay has been determined to be stable; therefore, the substantial fecundity of the species affected by entrainment losses at Bayside allows the stable populations to accommodate these losses.[7]

11.4.1.2 Changes in Stocks and Harvest

Table 11-14 provides the results of the estimation of benefits (as kilograms of C/R harvest returned to the fishery) if Bayside were to shut down in 2021 (Appendix 11-A). As is observed in the results, the transferred forage biomass (indirect yield) contributes more to the C/R harvest benefit of Sciaenidae than the direct fishery yield.

Recreational harvest account for 89 percent of total harvest of Sciaenidae in Hillsborough Bay (Section 11.3). Thus, 89 percent of the total (direct and indirect) C/R yield is treated as recreational yield with the remainder being applied as commercial yield.

Figure 11-4 illustrates the estimated total (direct and indirect) recreational yield changes for recreational taxa (Sciaenidae and weakfish) entrained at Bayside following complete elimination of entrainment at Bayside. The shape of the curves is a result of the methodology described in Section 11.2.2, which has the population "growing up" from their respective life stages to the annual EAs and then decaying after decommission of the facility (2044) via the survival parameters presented in Table 11-5.

Figure 11-5 illustrates the estimated changes in kilograms of commercially harvest taxa in response to the elimination of entrainment at Bayside.

[7] The report discusses data from other facilities in the area that document losses associated with entrainment are far less than 100 percent. This analysis is predicted on the assumption that all entrained organisms are subject to lethality, an assumption that likely overestimates the level of impact.

Table 11–14. Modelled Annual Benefits of Baseline Condition

Scientific Name	Common Name	Entrainment								Impingement							
		Entrained Equivalent Adults (number)		Production Foregone (kg)		Direct Foregone Fishery Yield (kg)		Total Foregone Fishery Yield (kg)		Entrained Equivalent Adults (number)		Production Foregone (kg)		Direct Foregone Fishery Yield (kg)		Total Foregone Fishery Yield (kg)	
		Sample Years															
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Fish																	
Anchoa mitchilli	Bay anchovy			588	1,668							1	1				
Bairdiella chrysoura	Silver perch			2,100	362							8	7				
Cynoscion regalis	Weakfish	1,027	444			505	219	505	219	321	120			158	59	158	59
Gobiosoma bosc	Naked goby			184	85							4	12	9	45	9	45
Gerreidae	Mojarra			10	0							1	0				
Sciaenidae	Drums/croakers	15,067	25,101			1,446	2,409	7,030	14,109	0	0			0	0	1	1
Leiostomus xanthurus	Spot											2	0	105	0	105	0
Trinectes maculatus	Hogchoker			511	2,164							4	2				
Fish Total		**16,094**	**25,545**	**3,393**	**4,279**	**1,951**	**2,627**	**7,535**	**14,327**	**312**	**120**	**20**	**22**	**272**	**104**	**273**	**104**
Percent reduction by technology		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Shellfish																	
Anomura	Anomuran crab			4,071	8,594												
Callinectes sapidus	Blue crab	0	0			0	0	0	0	359	160			11	5	11	5
Brachyura	Brachyuran crab			693,660	1,464,500							66	22				
Caridea	Grass shrimp			343	724							0	0				
Menippe mercenaria	Stone crab	3,327	7,021			25	52	25	52	670	886			5	7	5	7
Penaeidae	Commercial shrimp	89	188			0	0	0	0	131	1,659			0	1	0	1
Shellfish Total		**35,604**	**7,210**	**698,080**	**1,473,800**	**25**	**52**	**25**	**52**	**1,161**	**2,706**	**67**	**23**	**16**	**13**	**16**	**13**
Percent reduction by technology		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Annual Total		**51,698**	**32,755**	**701,470**	**1,478,100**	**1,976**	**2,679**	**7,559**	**14,379**	**1,482**	**2,826**	**87**	**45**	**289**	**117**	**290**	**117**
Percent reduction by technology		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Shading indicates C/R taxa.

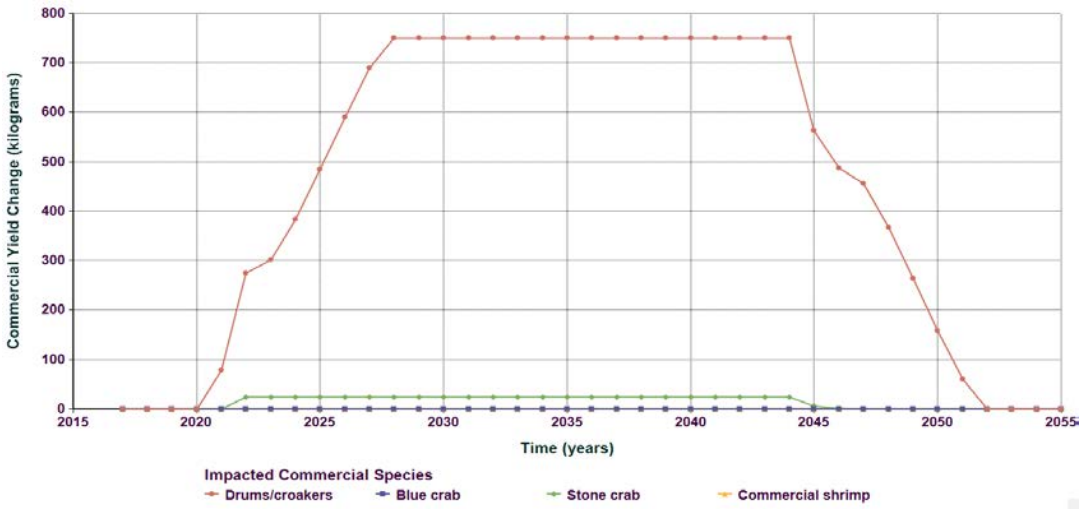
Source: ECT, 2018.

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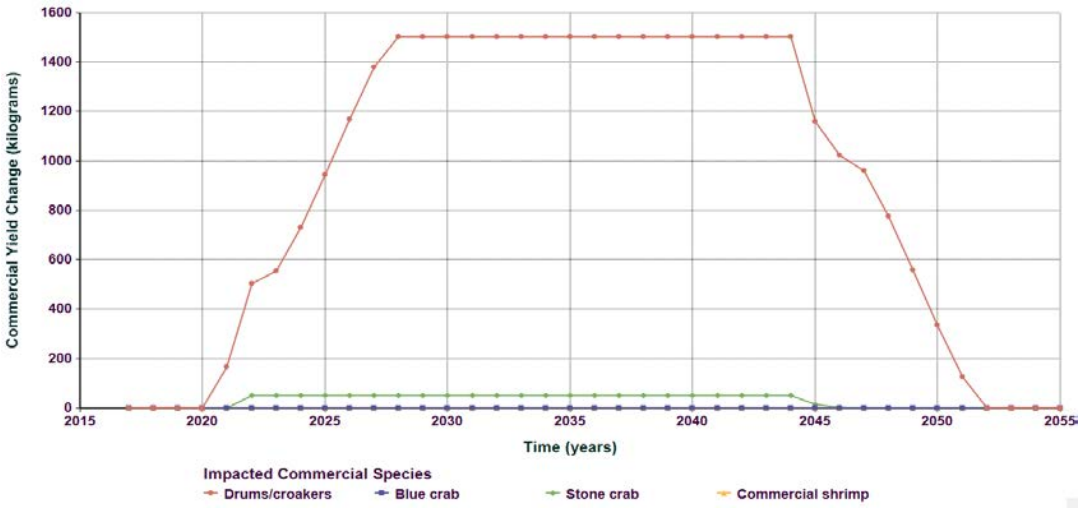
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STAFF'S FIRST DATA REQUEST
BATES PAGES: 4 - 968
FILED: JUNE 8, 2021

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Panel A: Sample Year 1



Panel B: Sample Year 2



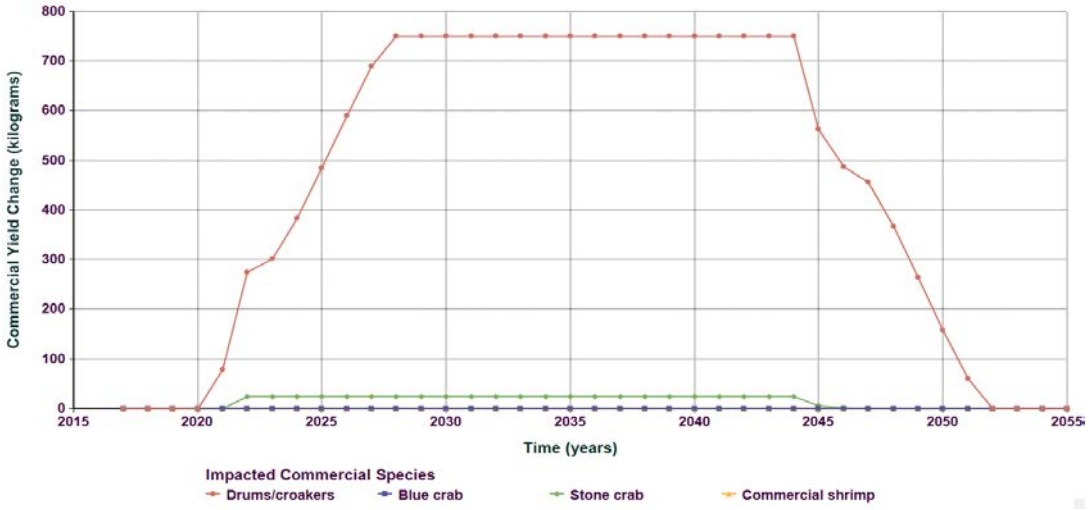
Commercial Yield

FIGURE 11-4.
TOTAL (DIRECT AND INDIRECT) CHANGES IN RECREATIONAL YIELD OF DRUMS/CROAKERS AND WEAKFISH
Source: Veritas, 2018.

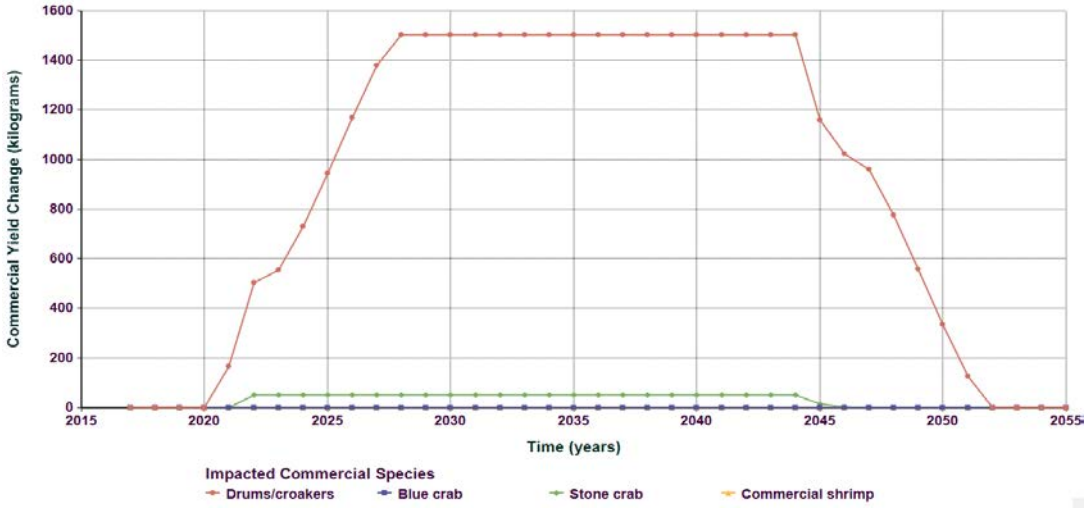
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Panel A: Sample Year 1



Panel B: Sample Year 2



Commercial Yield

FIGURE 11-5.

TOTAL (DIRECT AND INDIRECT) CHANGES IN COMMERCIAL YIELD

Source: Veritas, 2018.

ECT Environmental Consulting & Technology, Inc.

The average total annual foregone fishery yield is estimated as 10,931 kg (Table 11-14). This number represents the annual total loss of biomass from the C/R fisheries due to entrainment losses, both direct and of forage, from the operation of Bayside. This estimate is designed to be an overestimation of these losses by employ of a number of modeling assumptions (i.e., entrainment results in 100-percent lethality, all entrainment losses affect C/R taxa and no others, and selection of various parameters to maximize the estimated effects on stocks). For perspective, the annual commercial finfish landings for Hillsborough County over the last 10 years range from 295,000 to 590,000 kg, or an average of 443,000 kg. Thus, the foregone fishery yield because of the estimated entrainment rates at Bayside represents approximately 2.5 percent of the annual commercial yield of Hillsborough County (Figure 11-6).

The annual harvest estimate neglects recreational landings that are not available for the bay but, for many species including black drum,[8] are higher than the commercial landings. It also neglects C/R landings for Pinellas County, which include the western half of Tampa Bay. Finally, the combined C/R landings represent a fraction of the total population in the bay consistent with the stable nature of the populations. Taken together, these factors indicate the effect of entrainment losses on the extant population is likely to be a small fraction of the 2.5 percent.

It is important to put the estimated changes in fishery stock into perspective on the ecosystem level to better understand how these changes may affect populations within Hillsborough Bay. The finfish population within Hillsborough Bay has been shown to be stable in data available from 1996 as collected by the FIM run by FWC (ECT, 2013). FIM data updated for the last few years continues to support this conclusion. Figures 11-7 to 11-10 show the results of a trend analysis using generalize additive models (GAMs) (Wood, 2006) for the dominant taxa found to be entrained at Bayside: bay anchovy (42.8 percent of entrainment) and black drum (representing Sciaenidae, which was used as a surrogate for C/R taxa and represented 52.1 percent of entrained organisms).

[8] For black drum in the Atlantic states, recreational landings are roughly four times higher than commercial ones (ASMFC, 2017).

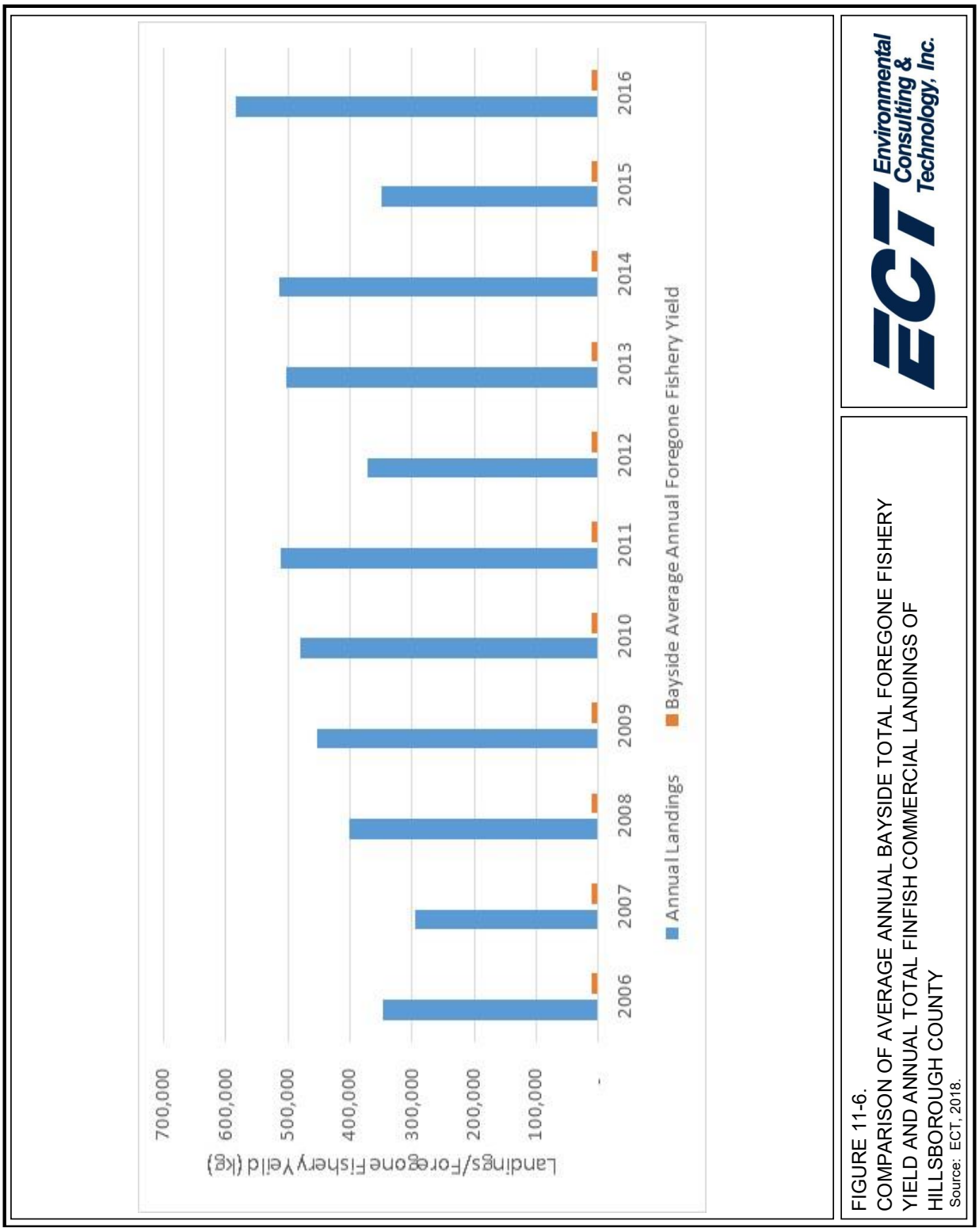


FIGURE 11-6.
COMPARISON OF AVERAGE ANNUAL BAYSIDE TOTAL FOREGONE FISHERY YIELD AND ANNUAL TOTAL FINFISH COMMERCIAL LANDINGS OF HILLSBOROUGH COUNTY
Source: ECT, 2018.

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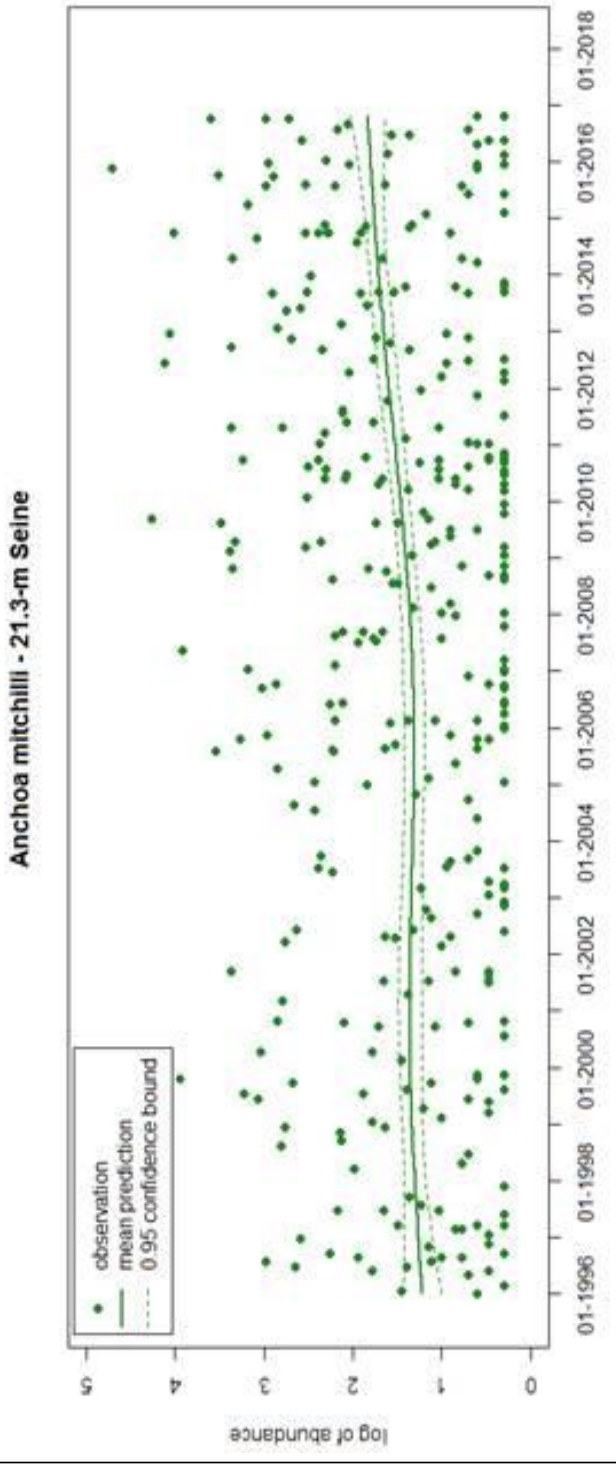


FIGURE 11-7.

BAY ANCHOVY ABUNDANCE TREND WITHIN THE 21.3-METER SEINE SAMPLES OF FWC FIM PROGRAM

Source: ECT, 2018.

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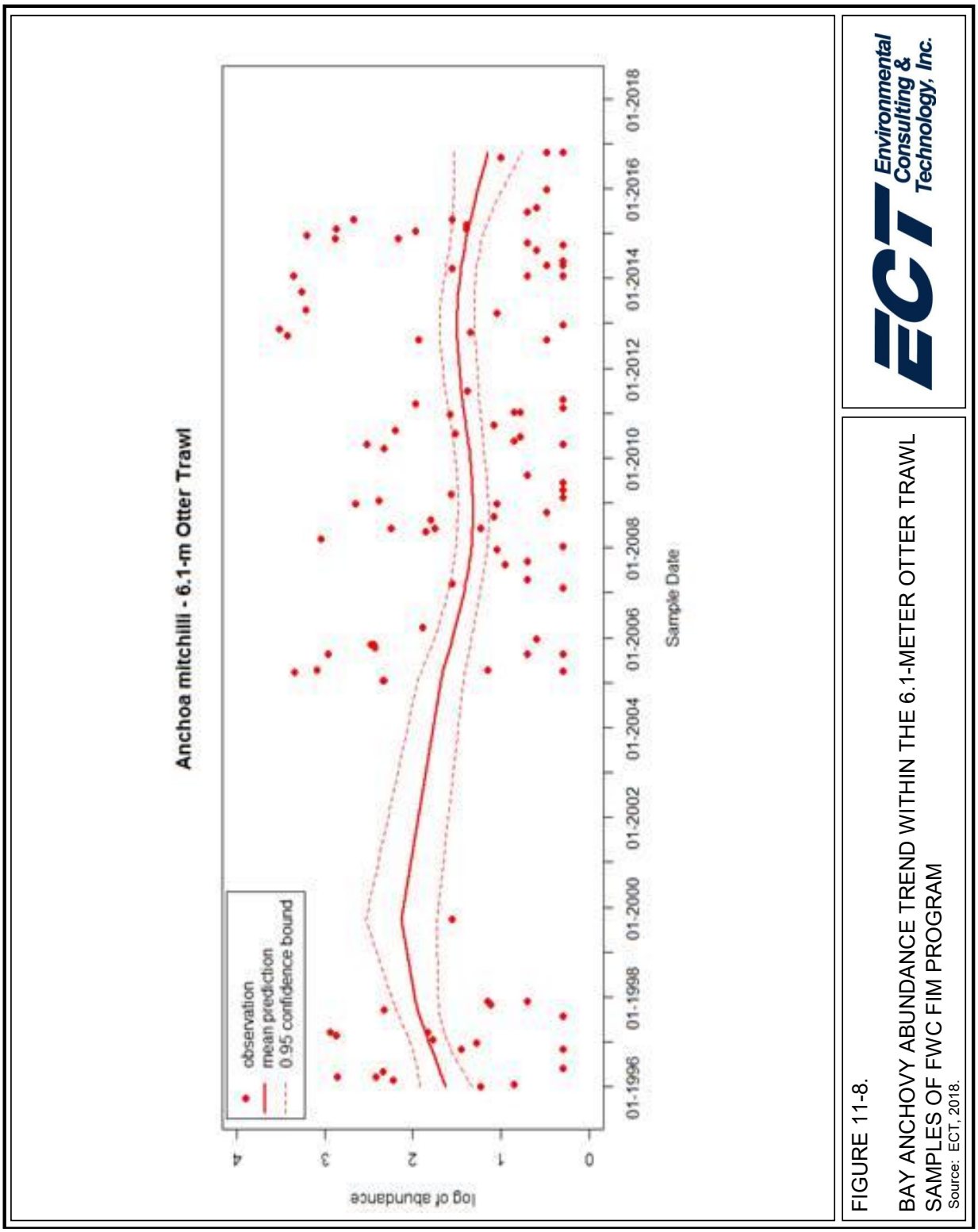


FIGURE 11-8.

BAY ANCHOVY ABUNDANCE TREND WITHIN THE 6.1-METER OTTER TRAWL SAMPLES OF FWC FIM PROGRAM

Source: ECT, 2018.

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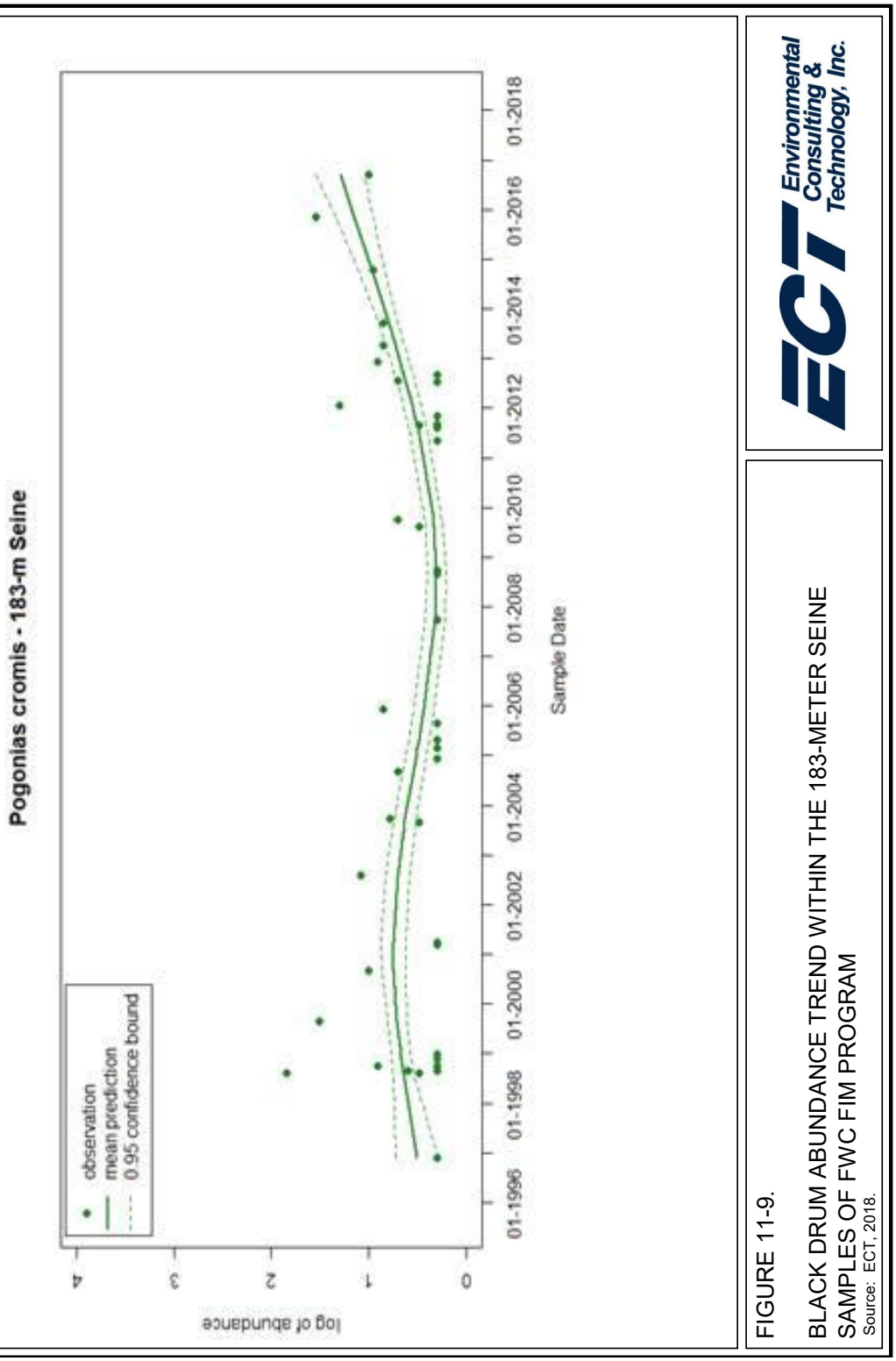


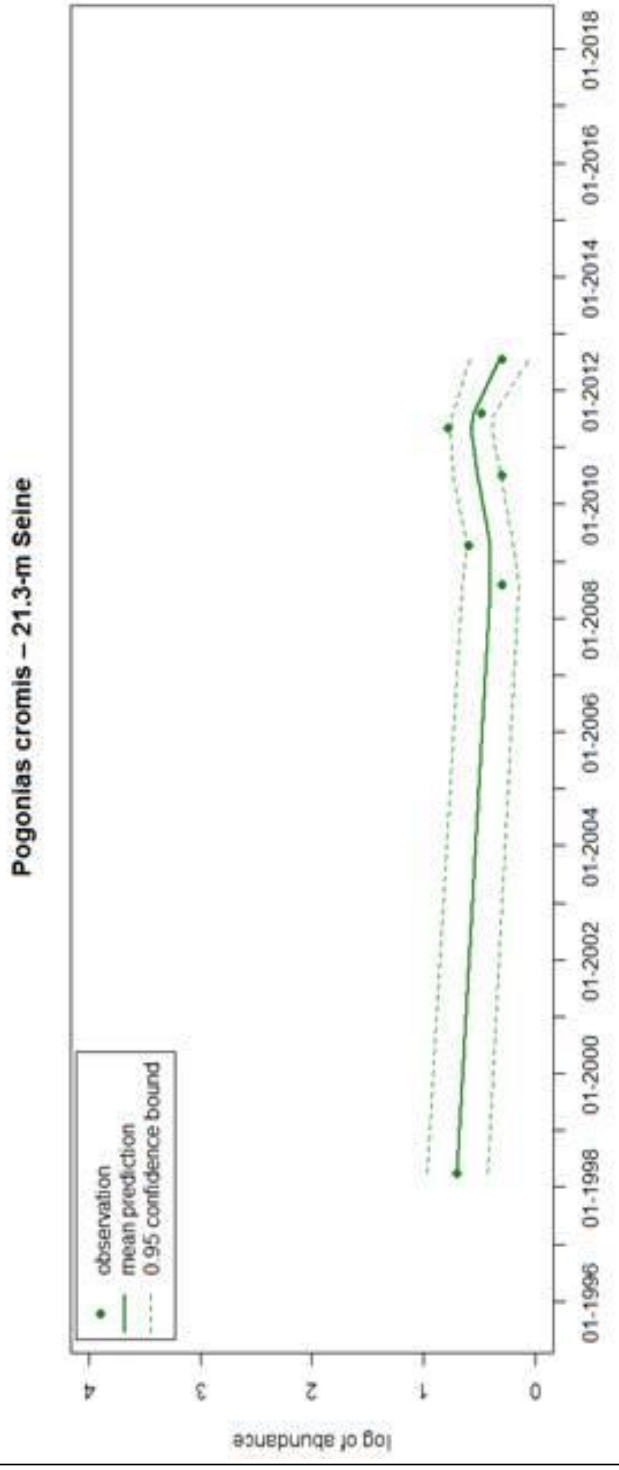
FIGURE 11-9.

BLACK DRUM ABUNDANCE TREND WITHIN THE 183-METER SEINE SAMPLES OF FWC FIM PROGRAM

Source: ECT, 2018.

ECT Environmental Consulting & Technology, Inc.

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Environmental Consulting & Technology, Inc.

FIGURE 11-10.

BLACK DRUM ABUNDANCE TREND WITHIN THE 21.3-METER SEINE SAMPLES OF FWC FIM PROGRAM

Source: ECT, 2018.

GAM uses a cubic spline smoothing function to track trends in a time series of data without assuming specific mathematical trend line (such as linear trend or quadratic trend). Figures 11-7 and 11-8 present the GAMs for total abundance results for the FIM seine collections for Hillsborough Bay for bay anchovy for the 21.3-seaine and 6.1-meter otter trawl, respectively. Abundances were log-transformed.

The anchovy population within Hillsborough bay appears to be increasing in the 21.3-meter seine samples from 2008 to present with a stable population post 2005 in the otter trawl samples.[9] Bay anchovy have not undergone a stock assessment. However, the International Union for Conservation of Nature (IUCN) Red List indicates bay anchovy as stable because of the large populations, large range extent, apparently stable trend, and lack of major threats (NatureServe, 2013).

Figures 11-9 and 11-10 show the GAM trend analysis results for black drum for the 183- and 21.3-meter seine, respectively. Black drum appears to be increasing the 183-meter seine post-2010 and relatively stable in the 21.3-meter seine over the sampling period. Catch rates in the 21.3-meter seine were often low, and the 183-meter seine data should be given priority for black drum. ASMFC has assessed black drum as not being overfished and not experiencing overfishing. The median biomass is estimated to be declining slowly, though it is still estimated to be well above that necessary to produce maximum sustainable yield (ASMFC, 2017).

From the observed species trends, it would appear the substantial fecundity of the species affected by entrainment losses at Bayside allows the populations to accommodate the ongoing losses.

11.4.1.3 Monetized Value of Changes in Stocks and Harvest

The benefits from a shutdown of the cooling water intake at Bayside would be experienced over the otherwise expected remaining life of the plant from the day it shut down. For modelling purposes, the year of shut down is defined as 2021 with the planned life of Bayside ending in 2044.

[9] The gap in anchovy data for otter trawl is due to the lack of sampling of that gear type from 2000 to 2005.

Benefits are assumed to commence on January 1 and end on December 31 for each year. No changes in density are expected to occur from one year to the next for each scenario (i.e., the organism densities are assumed to be fixed according to the year that the entrainment characterization was performed).

Figure 11-11 illustrates how those benefits (as kilograms of C/R taxa) would be realized over the projected life of Bayside to define the baseline condition in which all other technologies will be compared.

Valuing Changes in Recreational Yield

After apportioning the estimated yield changes over the affected sites identified in Figure 11-3, the per-trip expected catch changes can be calculated. Figure 11-12 presents the per-trip change in the expected catch of each recreationally harvested taxa at each of the affected sites.

Figure 11-13 depicts the annual change in dollar-valued welfare associated with the estimated trip changes from a complete elimination in entrainment at Bayside.

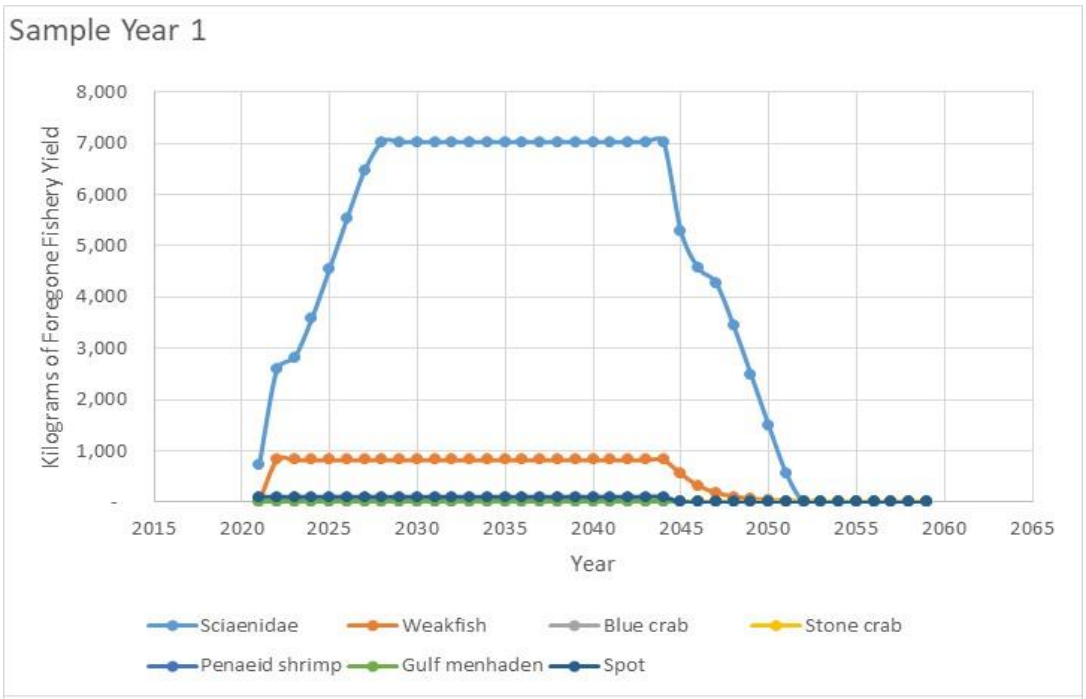
Table 11-15 summaries the total social benefits as a result of changes in the recreational stock in response to the complete elimination of entrainment at Bayside (Appendix 11-A). Values are presented in both present value (over the life of the facility) and annual value.

Table 11–15. Summary of Recreational Social Benefits as a Result of Complete Elimination of Entrainment at Bayside.

Discount Rate	Technology	Entrainment Reduction	Present Value ($)		Annual Value ($)	
			Sample Years			
			1	2	1	2
3%	Baseline	100%	0.58 M	1.11 M	17.03 k	32.74 k
7%	Baseline	100%	0.30 M	0.58 M	8.87 k	16.93 k

Source: Veritas, 2018.

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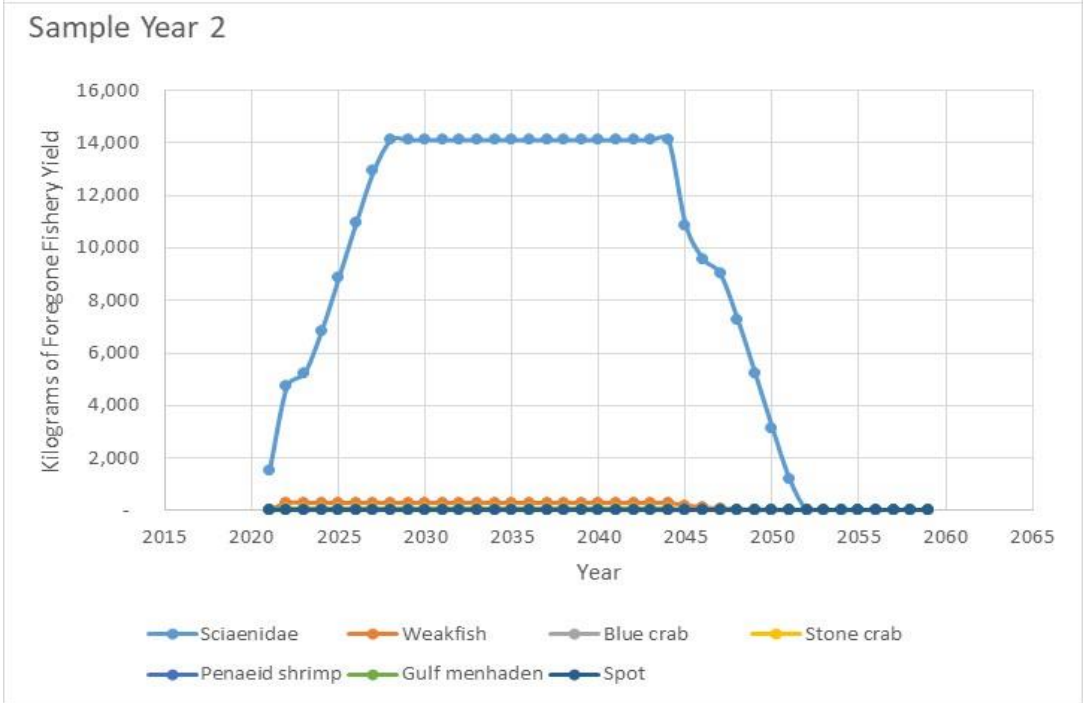


FIGURE 11-11.

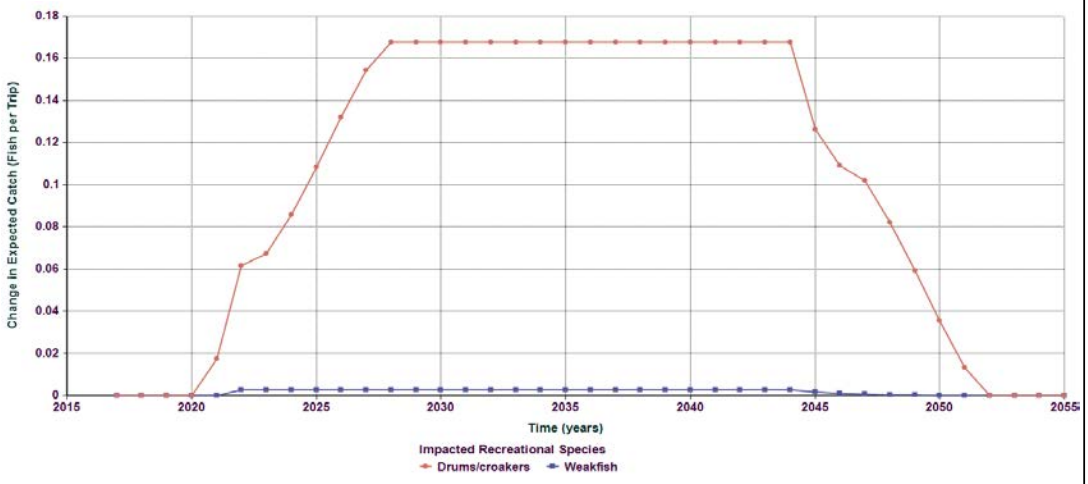
BAYSIDE PLANT LIFE FISHERY YIELD BENEFIT UNDER BASELINE CONDITIONS

Source: ECT, 2018.

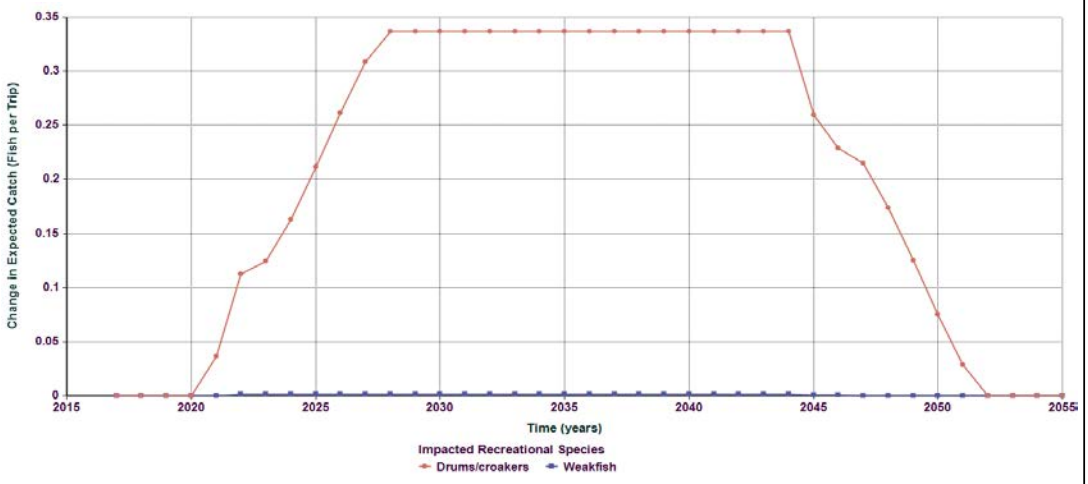
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Panel A: Sample Year 1



Panel B: Sample Year 2



Expected Catch

FIGURE 11-12.

CHANGE IN EXPECTED RECREATIONAL CATCH PER TRIP BY TAXA

Source: Veritas, 2018.

ECT Environmental Consulting & Technology, Inc.

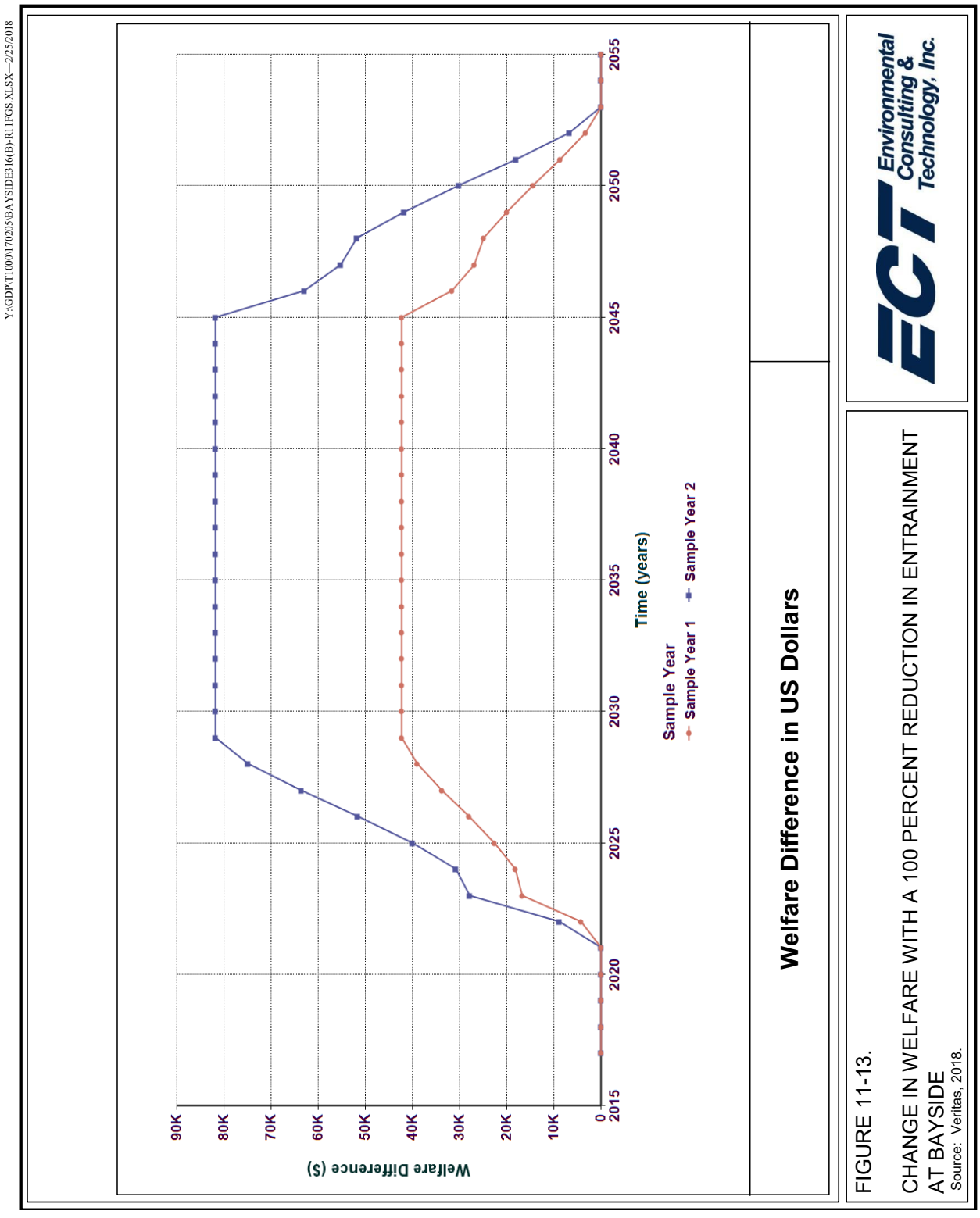


FIGURE 11-13.

CHANGE IN WELFARE WITH A 100 PERCENT REDUCTION IN ENTRAINMENT AT BAYSIDE

Source: Veritas, 2018.

Valuing Changes in Commercial Yield

Figure 11-14 illustrates the changes in commercial value in response to the complete elimination of entrainment at Bayside.

Table 11-16 summaries the total social benefits as a result of changes in the commercial stock in response to the complete elimination of entrainment at Bayside (Appendix 11-A). Values are presented in both present value (over the life of the facility) and annual value.

Table 11–16. Summary of Commercial Social Benefits as a Result of Complete Elimination of Entrainment at Bayside

Discount Rate	Technology	Entrainment Reduction	Present Value ($)		Annual Value ($)	
			Sample Years			
			1	2	1	2
3%	Baseline	100%	0.07 M	0.15 M	2.11 k	4.39 k
7%	Baseline	100%	0.04 M	0.09 M	1.21 k	2.52 k

Source: Veritas, 2018.

Nonuse Value

Table 11-17 summarizes the nonuse benefits estimates and presents three different regions used to evaluate the nonuse benefits of reductions in entrainment at Bayside:

- All the households in Hillsborough County, Florida, the county where Bayside is located
- All the households in the states included in the southeast region of EPA's stated preference survey
- All the households in the United States.

Table 11–17. Summary of Nonuse Benefits for 100-Percent Entrainment Reduction at Bayside

Specified Population of Households	3% Discount Rate				7% Discount Rate			
	Present Value ($)		Annual Value ($)		Present Value ($)		Annual Value ($)	
	Sample Years							
	1	2	1	2	1	2	1	2
Hillsborough County	782	1,552	23	46	440	869	13	26
EPA's Southeast Region*	6,947	13,783	204	405	3,912	7,721	115	227
United States	22,966	45,560	675	1,340	12,930	25,522	380	751

*Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas, and Virginia.

Source: Veritas, 2018.



FIGURE 11-14.

CHANGE IN COMMERCIAL VALUE WITH A 100 PERCENT REDUCTION IN ENTRAINMENT AT BAYSIDE

Source: Veritas, 2018.

The nonuse benefits are estimated over the same time period as the C/R benefits: from 2021 to 2044. Table 11-17 presents the nonuse benefit of 100-percent reduction in Bayside's entrainment across the two different entrainment sample years using two different discount rates: 3 and 7 percent. As the results show, the estimated nonuse benefits range from $440 to $45,560.

11.4.2 Closed-cycle Cooling

11.4.2.1 Changes in Fish and Shellfish

Table 11-18 summarizes annual entrainment and impingement numbers of fish and shellfish that would no longer be entrained or impinged if Bayside were to retrofit with closed-cycle cooling (Appendix 11-B), representing an 85.1-percent decrease in entrainment and impingement.

Table 11–18. Annual Benefit (as Reduction in Impingement and Entrainment) that Would Result if Bayside Were to Retrofit with Closed-cycle Cooling

Animal	Entrainment		Impingement	
	Sample Years			
	1	2	1	2
Fish	3,965,000	7,795,000	11,800	7,290
Shellfish	3,495,000	7,379,000	12,000	15,100
Total	7,460,000	15,174,000	23,700	22,400

Note: Difference may exist in totals due to rounding.

Source: ECT, 2018.

11.4.2.2 Changes in Stocks and Harvest

Table 11-19 provides the results of the estimation of benefits (as kilograms of commercial harvest returned to the fishery) if Bayside were to be retrofit with closed-cycle cooling (Appendix 11-B). The benefits would be first observed in 2024. As with the baseline condition, the transferred forage biomass (indirect yield) contributes more to the C/R harvest benefit of Sciaenidae than the direct fishery yield.

11.4.2.3 Monetized Value of Changes in Stocks and Harvest

The benefits of retrofitting to closed-cycle cooling at Bayside would be experienced over the expected reaming life of the plant from the day the cooling towers came online. For modeling purposes, the year of retrofit is defined as 2024 with the expected life of Bayside ending in 2044.

Table 11–19. Modelled Annual Benefits of Retrofit to Closed-cycle Cooling

Scientific Name	Common Name	Entrainment								Impingement							
		Entrained Equivalent Adults (number)		Production Foregone (kg)		Direct Foregone Fishery Yield (kg)		Total Foregone Fishery Yield (kg)		Entrained Equivalent Adults (number)		Production Foregone (kg)		Direct Foregone Fishery Yield (kg)		Total Foregone Fishery Yield (kg)	
		Sample Years															
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Fish																	
Anchoa mitchilli	Bay anchovy			500	1,419							1	1				
Bairdiella chrysoura	Silver perch			1,787	308							7	6				
Cynoscion regalis	Weakfish	874	378			430	186	430	186	274	102			135	50	135	50
Gobiosoma bosc	Naked goby			157	73							3	11	7	38	7	38
Gerreidae	Mojarra			9	0							1	0				
Sciaenidae	Drums/croakers	12,822	21,361			1,230	2,050	5,982	12,006	0	0			0	0	1	0
Leiostomus xanthurus	Spot	0	0							993	0			90	0	90	0
Trinectes maculatus	Hogchoker			435	1,841							3	2				
Fish Total		**16,094**	**13,696**	**21,739**	**2,887**	**3,641**	**1,951**	**2,627**	**7,535**	**14,327**	**274**	**102**	**17**	**20**	**232**	**88**	**232**
Percent reduction by technology		100%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
Shellfish																	
Anomura	Anomuran crab			3,464	7,314							0	0				
Callinectes sapidus	Blue crab	0	0			0	0	0	0	306	136			10	4	10	4
Brachyura	Brachyuran crab			590,310	1,246,300							56	19				
Caridea	Grass shrimp			292	616							0	0				
Menippe mercenaria	Stone crab	2,831	5,975			21	44	21	44	570	754			4	6	4	6
Penaeidae	Commercial shrimp	76	160			0	0	0	0	111	1,412			0	1	0	1
Shellfish Total		**35,604**	**2,970**	**6,135**	**594,070**	**1,254,200**	**21**	**44**	**21**	**44**	**987**	**2,302**	**56**	**19**	**14**	**11**	**14**
Percent reduction by technology		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Annual Total		**51,698**	**16,603**	**27,874**	**569,950**	**1,257,900**	**1,681**	**2,280**	**6,433**	**12,237**	**1,261**	**2,404**	**73**	**33**	**246**	**99**	**246**
Percent reduction by technology		100%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%

Shading indicates C/R taxa.

Source: ECT, 2018.

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Figure 11-15 illustrates how those benefits (as kilograms of commercial taxa) would be realized over the projected life of Bayside. This represents a total benefit of 79 percent of the baseline conditions (21 percent less than complete Bayside closure).

Valuing Changes in Recreational Yield

Table 11-20 summaries the total social benefits as a result of changes in the recreational stock in response to the reduction in entrainment resulting from the retrofit to closed-cycle cooling (Appendix 11-B). Values are presented in both present value (over the life of the facility) and annual value.

Table 11–20. Summary of Recreational Social Benefits as a Result of the Reduction in Entrainment from Closed-cycle Cooling

Discount Rate	Technology	Entrainment Reduction	Present Value ($)		Annual Value ($)	
			Sample Years			
			1	2	1	2
3%	Closed-cycle cooling	85.1%	0.46 M	0.88 M	14.72 k	28.45 k
7%	Closed-cycle cooling	85.1%	0.23 M	0.44 M	7.38 k	14.18 k

Source: Veritas, 2018.

Valuing Changes in Commercial Yield

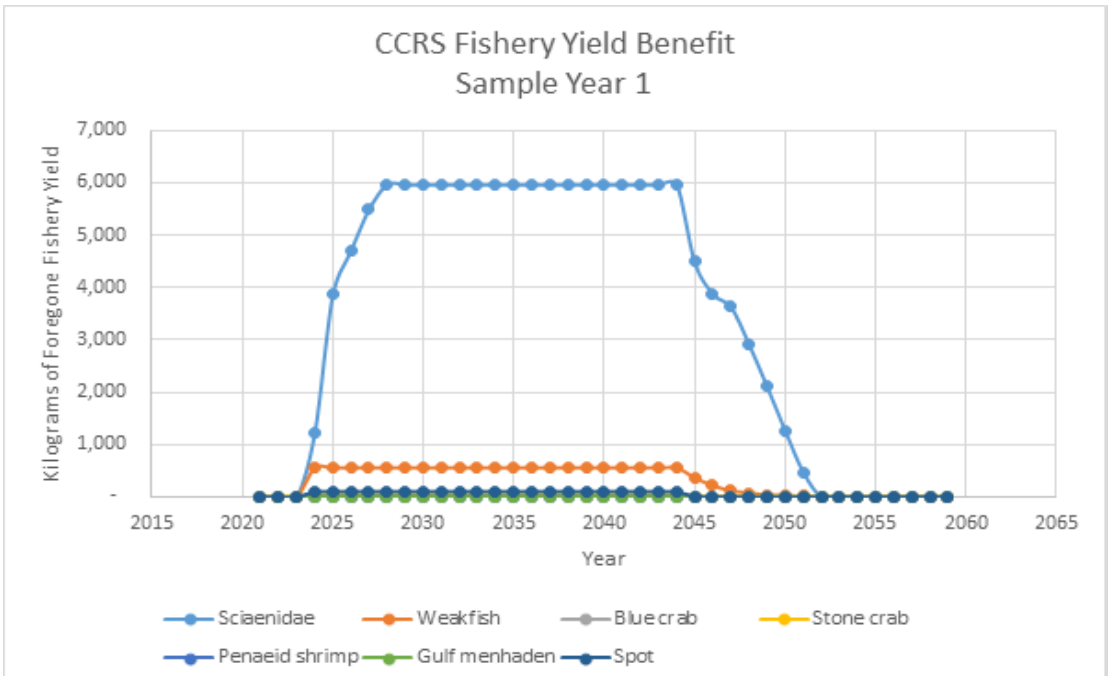
Table 11-21 summaries the total social benefits as a result of changes in the commercial stock in response to the reduction in entrainment resulting from the retrofit to closed-cycle cooling (Appendix 11-B). Values are presented in both present value (over the life of the facility) and annual value.

Table 11–21. Summary of Commercial Social Benefits as a Result of the Reduction in Entrainment from Closed-cycle Cooling

Discount Rate	Technology	Entrainment Reduction	Present Value ($)		Annual Value ($)	
			Sample Years			
			1	2	1	2
3%	Closed-cycle cooling	85.1%	0.05 M	0.11 M	1.76 k	3.66 k
7%	Closed-cycle cooling	85.1%	0.03 M	0.06 M	962	2.01 k

Source: Veritas, 2018.

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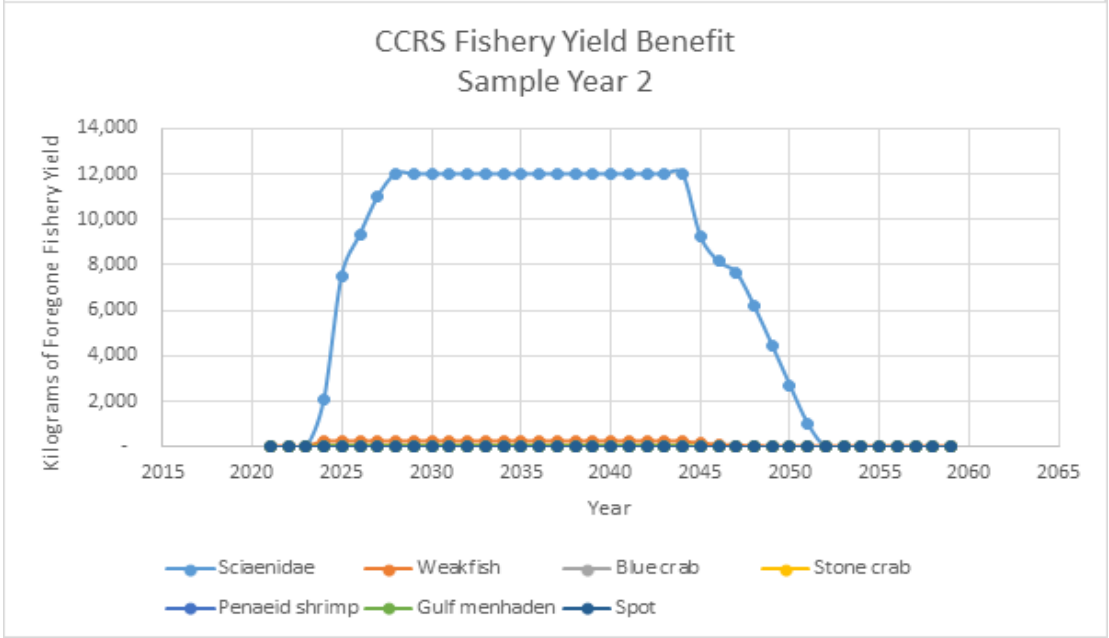


FIGURE 11-15.

BAYSIDE PLANT LIFE FISHERY YIELD BENEFITS AFTER RETROFIT TO CLOSED-CYCLE COOLING

Source: ECT, 2018.

ECT Environmental Consulting & Technology, Inc.

Nonuse Value

Table 11-22 summarizes the nonuse benefits of reductions in entrainment at Bayside due to closed-cycle cooling for all households in the United States.

Table 11–22. Summary of Nonuse Benefits as a Result of the Reduction in Entrainment from Closed-cycle Cooling

Specified Population of Households	3% Discount Rate				7% Discount Rate			
	Present Value ($)		Annual Value ($)		Present Value ($)		Annual Value ($)	
	Sample Years				Sample Years			
	1	2	1	2	1	2	1	2
United States	18.09 k	36.01 k	0.58 k	0.16 k	9.79 k	5.88 k	0.32 k	0.63 k

Source: Veritas, 2018.

The nonuse benefits are estimated over the same time period as the C/R benefits for closed-cycle cooling reductions: from 2024 to 2044.

11.4.2.4 Mitigation Effort Made Prior to Rule

Refer to Section 11.2.4.

11.4.2.5 Other Benefits

Refer to Section 11.2.5.

11.4.2.6 Reduction in Thermal Discharge

The rule requires the benefits expected to result from any reduction in thermal discharges from each technology be discussed. Since there will be a reduction in flow because of closed-cycle cooling of 85.1 percent, the amount of heated water entering the Bay will also be decreased. In addition, the water discharged from the closed-cycle cooling system in the form of blow down will not generally be heated relative to ambient to the extent the discharged currently is. This will result in a substantial reduction of the warm water addition to discharge canal.

Elimination of the warm water may allow some early life stages of fish and shellfish, who would otherwise not enter the channel because of the warm water, to use it. Stages that are less sensitive to the warm water (e.g., adults) currently use the canal. It is critical to note that 316(a) variance in effect at Bayside is predicated on the finding that the balanced, indigenous population is

protected in the vicinity of the facility. Given this is the case, little or no real benefit would be expected to accrue to the biological community near the outfall.

As discussed in Section 11.2.6.1, manatee currently use the discharge channel as a thermal refuge during winter months, and elimination of the warm water discharge would remove the discharge channel as suitable habitat. Maintenance of this thermal refuge under key winter time conditions is a requirement of Bayside's Manatee Protection Plan developed with input from FDEP and FWC. The thermal refuge is dependent upon a rate of thermal discharge from Bayside that would not be supported by a closed-cycle recirculating system.

11.4.3 FMS

11.4.3.1 Changes in Fish and Shellfish

Table 11-23 summarizes the annual entrainment and impingement number of fish and shellfish that would no longer be entrained or impinged if Bayside were to be retrofit with FMS (Appendix 11-C). This represents a 71- and 68-percent decrease in entrainment (as numbers of organisms) in sample years 1 and 2, respectively.

Table 11–23. Annual Benefit (as Reduction in Entrainment) that Would Result if Bayside Were to Retrofit with FMS

Animal	Sample Year 1	Sample Year 2
Fish	1,327 M	2,237 M
Shellfish	2,933 M	6,113 M
Total	4,260 M	8,350 M

Note: Difference may exist in totals due to rounding for reporting purposes.

Source: Veritas, 2018.

11.4.3.2 Changes in Stocks and Harvest

Table 11-24 provides the results of the estimate of benefits (as kilograms of commercial harvest returned to the fishery) if Bayside were to be retrofit with FMS. The benefits would be first observed in 2021. As with the baseline condition, the transferred forage biomass (indirect yield) contributes more to the C/R harvest benefit of Sciaenidae than the direct fishery yield.

Table 11–24. Modelled Annual Benefits of Retrofit to FMS

Scientific Name	Common Name	Entrainment							
		Entrained Equivalent Adults (number)		Production Foregone (kg)		Direct Foregone Fishery Yield (kg)		Total Foregone Fishery Yield (kg)	
		Sample Years							
		1	2	1	2	1	2	1	2
Fish									
Anchoa mitchilli	Bay anchovy			125	491				
Bairdiella chrysoura	Silver perch			395	67				
Cynoscion regalis	Weakfish	236	85			116	42	116	42
Gobiosoma bosc	Naked goby			4	4				
Gerreidae	Mojarra			2	0				
Sciaenidae	Drums/croakers	3,670	6,353			352	610	4285	8,801
Leiostomus xanthurus	Spot								
Trinectes maculatus	Hogchoker			112	574				
	Fish Total	**3,906**	**6,438**	**638**	**1,136**	**468**	**651**	**4,401**	**8,843**
	Percent reduction by technology	16%	25%	25%	25%	24%	25%	58%	62%
Shellfish									
Anomura	Anomuran crab			2,921	6,089				
Callinectes sapidus	Blue crab	0	0			0	0	0	0
Brachyura	Brachyuran crab			495,580	1,032,800				
Caridea	Grass shrimp			248	517				
Menippe mercenaria	Stone crab	2,799	5,872			21	44	21	44
Penaeidae	Commercial shrimp	64	133			0	0	0	0
	Shellfish Total	**2,863**	**6,005**	**498,750**	**1,039,400**	**21**	**44**	**21**	**44**
	Percent reduction by technology	71%	68%	71%	71%	84%	84%	84%	84%
	Annual Total	**6,769**	**12,443**	**499,390**	**1,010,500**	**489**	**695**	**4,422**	**8,887**
	Percent reduction by technology	71%	68%	67%	67%	25%	26%	58%	62%

Shading indicates C/R taxa.

Source: ECT, 2018.

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11.4.3.3 Monetized Value of Changes in Stocks and Harvest

Figure 11-16 illustrates how the benefits of retrofitting Bayside with FMS would be experienced over the projected life of Bayside. This represents a total benefit (as C/R biomass) of 58 percent from baseline conditions (42 percent less than complete Bayside closure).

Valuing Changes in Recreational Yield

Table 11-25 summaries the total social benefits as a result of changes in the recreational stock in response to the reduction in entrainment resulting from the use of FMS (Appendix 11-C). Values are presented in both present value (over the life of the facility) and annual value.

Table 11–25. Summary of Recreational Social Benefits as a Result of the Reduction in Entrainment from FMS

Discount Rate	Technology	Entrainment Reduction	Present Value ($)		Annual Value ($)	
			Sample Years			
			1	2	1	2
3%	FMS	68 to 71%	0.34 M	0.68 M	9.96 k	20.20 k
7%	FMS	68 to 71%	0.17 M	0.35 M	5.10 k	10.26 k

Source: Veritas, 2018.

Valuing Changes in Commercial Yield

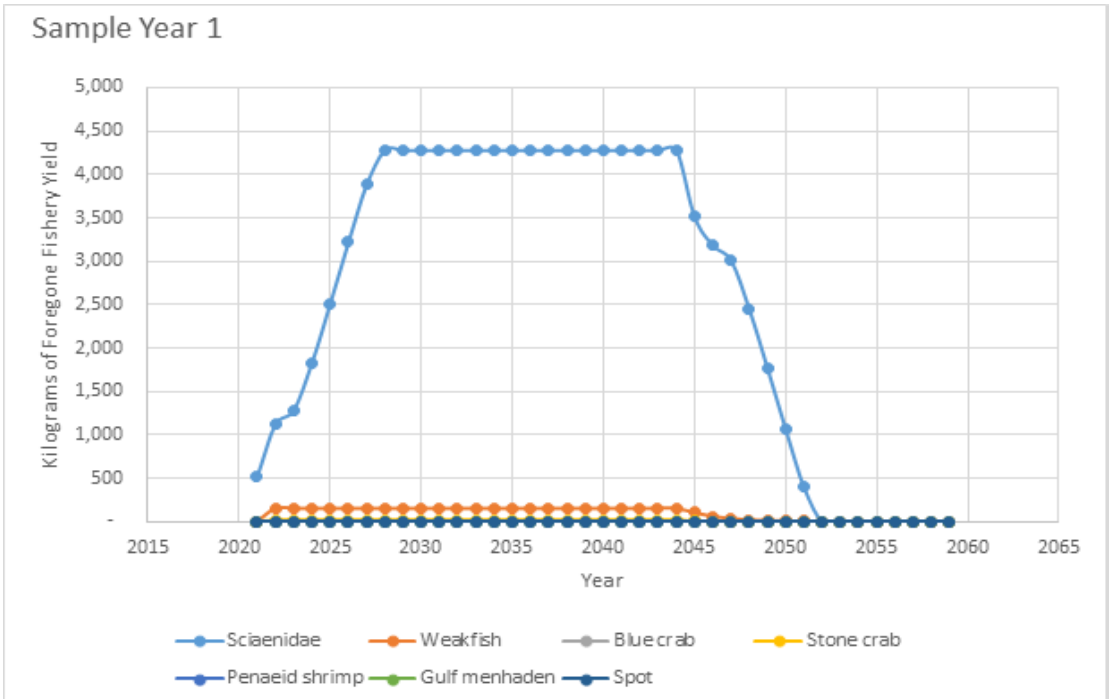
Table 11-26 summaries the total social benefits as a result of changes in the commercial stock in response to the reduction in entrainment resulting from the use of FMS (Appendix 11-C). Values are presented in both present value (over the life of the facility) and annual value.

Table 11–26. Summary of Commercial Social Benefits as a Result of the Reduction in Entrainment from FMS

Discount Rate	Technology	Entrainment Reduction	Present Value ($)		Annual Value ($)	
			Sample Years			
			1	2	1	2
3%	FMS	68 to 71%	0.06 M	0.12 M	1.65 k	3.45 k
7%	FMS	68 to 71%	0.03 M	0.06 M	952	1.99 k

Source: Veritas, 2018.

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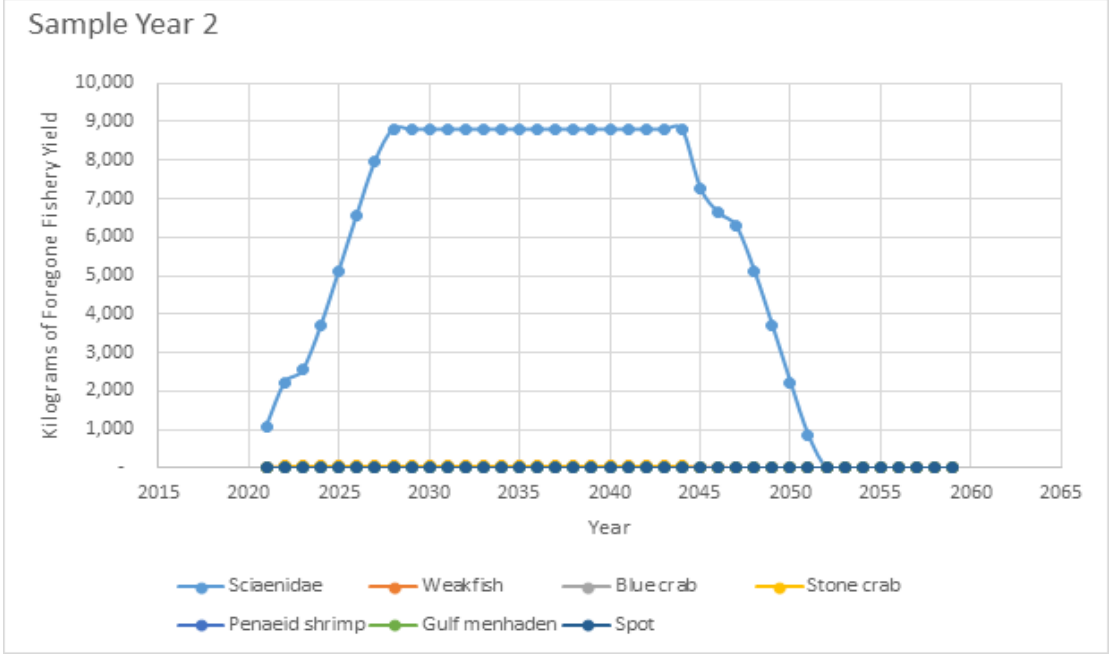


FIGURE 11-16.

BAYSIDE PLANT LIFE FISHERY YIELD BENEFITS AFTER RETROFIT TO FMS

Source: ECT, 2018.

ECT Environmental Consulting & Technology, Inc.

Nonuse Value

Table 11-27 summarizes the evaluate the nonuse benefits of reductions in entrainment at Bayside due to FMS for all households in the United States

Table 11–27. Summary of Nonuse Benefits as a Result of the Reduction in Entrainment from FMS

Specified Population of Households	3% Discount Rate				7% Discount Rate			
	Present Value ($)		Annual Value ($)		Present Value ($)		Annual Value ($)	
	Sample Years				Sample Years			
	1	2	1	2	1	2	1	2
United States	14.00 k	28.63 k	0.41 k	0.84 k	7.78 k	4.80 k	0.23 k	0.47 k

Source: Veritas, 2018.

The nonuse benefits are estimated over the same time period as the C/R benefits for FMS reductions: from 2021 to 2044.

11.4.3.4 Mitigation Effort Made Prior to Rule

Refer to Section 11.2.4.

11.4.3.5 Other Benefits

Refer to Section 11.2.5.

11.4.3.6 Reduction in Thermal Discharge

Addition of FMS would not affect the thermal loading; therefore, there would be no change in the thermal discharge.

11.4.4 VSPs

11.4.4.1 Changes in Fish and Shellfish

Table 11-28 summarizes the annual entrainment and impingement numbers of fish and shellfish that would no longer be entrained or impinged if Bayside were to be retrofit with VSPs for both a 4-percent reduction and a 27-percent reduction in total annual flow (Appendix 11-D and Appendix 11-E).

Table 11–28. Annual Benefit (as Reduction in Impingement and Entrainment) that would Result if Bayside Were to Retrofit with VSPs

Animal	Entrainment			
	Sample Year 1		Sample Year 2	
	VSP (%)			
	4	27	4	27
Fish	186 M	1,258 M	366 M	2,473 M
Shellfish	164 M	1,109 M	347 M	2,341 M
Total	351 M	2,367 M	713 M	4,814 M

Note: Difference may exist in totals due to rounding for reporting purposes.

Source: ECT, 2018.

11.4.4.2 Changes in Stocks and Harvest

Tables 11-29 and 11-30 provide the results of the estimation of benefits (as kilograms of commercial harvest returned to the fishery) if Bayside were to be retrofit with VSPs with a 4- and 27-percent reduction in flow, respectively (Appendices 11-D and 11-E). The benefits of VSPs would first be observed in 2022. As with the baseline condition, the transferred forage biomass (indirect yield) contributes more to the C/R harvest benefit of Sciaenidae than the direct fishery yield.

11.4.4.3 Monetized Value of Changes in Stocks and Harvest

Figures 11-17 and 11-18 illustrate how the benefits of VSP would be realized over the projected life of Bayside. A 4-percent reduction in flow due to VSP would represent a total benefit of 4 percent from baseline conditions. Similarly, a 27-percent reduction in flow due to VSP would represent a 27-percent benefit from baseline conditions.

Valuing Changes in Recreational Yield

Table 11-31 summarizes the total social benefits as a result of changes in the recreational stock in response to the reduction in entrainment resulting from the use of VSP (Appendices 11-D and 11-E). Values are presented in both present value (over the life of the facility) and annual value.

Table 11–29. Modelled Annual Benefits of Retrofit to VSP with 4-Percent Flow Reduction

Scientific Name	Common Name	Entrainment							
		Entrained Equivalent Adults (numbers)		Production Foregone (kg)		Direct Foregone Fishery Yield (kg)		Total Foregone Fishery Yield (kg)	
		Sample Years							
		1	2	1	2	1	2	1	2
Fish									
Anchoa mitchilli	Bay anchovy			24	67				
Bairdiella chrysoura	Silver perch			84	14				
Cynoscion regalis	Weakfish	41	18			20	9	20	9
Gobiosoma bosc	Naked goby			7	3				
Gerreidae	Mojarra			0	0				
Sciaenidae	Drums/croakers	603	1,004			58	96	281	564
Leiostomus xanthurus	Spot								
Trinectes maculatus	Hogchoker			20	87				
Fish Total		**644**	**1,022**	**135**	**171**	**78**	**105**	**301**	**573**
Percent reduction by technology		4%	4%	4%	4%	4%	4%	4%	4%
Shellfish									
Anomura	Anomuran crab			163	344				
Callinectes sapidus	Blue crab	0	0			0	0	0	0
Brachyura	Brachyuran crab			27,747	58,580				
Caridea	Grass shrimp			14	29				
Menippe mercenaria	Stone crab	133	281			1	2	1	2
Penaeidae	Commercial shrimp	4	8			0	0	0	0
Shellfish Total		**137**	**289**	**27,924**	**58,953**	**1**	**2**	**1**	**2**
Percent reduction by technology		4%	4%	4%	4%	4%	4%	4%	4%
Annual Total		**781**	**1,311**	**28,059**	**59,124**	**79**	**107**	**302**	**575**
Percent reduction by technology		4%	4%	4%	4%	4%	4%	4%	4%

Shading indicates C/R taxa.

Source: ECT, 2018.

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Table 11–30. Modelled Annual Benefits of Retrofit to VSP with 27-Percent Flow Reduction

Scientific Name	Common Name	Entrainment							
		Entrained Equivalent Adults (numbers)		Production Foregone (kg)		Direct Foregone Fishery Yield (kg)		Total Foregone Fishery Yield (kg)	
		Sample Years							
		1	2	1	2	1	2	1	2
Fish									
Anchoa mitchilli	Bay anchovy			159	450				
Bairdiella chrysoura	Silver perch			567	98				
Cynoscion regalis	Weakfish	277	120			136	59	136	59
Gobiosoma bosc	Naked goby			50	23				
Gerreidae	Mojarra			3	0				
Sciaenidae	Drums/croakers	4,058	6,777			390	650	1,898	3,809
Leiostomus xanthurus	Spot								
Trinectes maculatus	Hogchoker			20	87				
Fish Total		**4,345**	**6,897**	**917**	**1,155**	**527**	**709**	**2,034**	**3,868**
Percent reduction by technology		27%	27%	27%	27%	27%	27%	27%	27%
Shellfish									
Anomura	Anomuran crab			1,099	2,320				
Callinectes sapidus	Blue crab	0	0			0	0	0	0
Brachyura	Brachyuran crab			187,290	395,420				
Caridea	Grass shrimp			93	195				
Menippe mercenaria	Stone crab	898	1,896			7	14	7	14
Penaeidae	Commercial shrimp	24	51			0	0	0	0
Shellfish Total		**922**	**1,947**	**188,480**	**397,930**	**7**	**14**	**7**	**14**
Percent reduction by technology		27%	27%	27%	27%	27%	27%	27%	27%
Annual Total		**5,267**	**8,844**	**189,400**	**399,090**	**533**	**723**	**2,041**	**3,882**
Percent reduction by technology		27%	27%	27%	27%	27%	27%	27%	27%

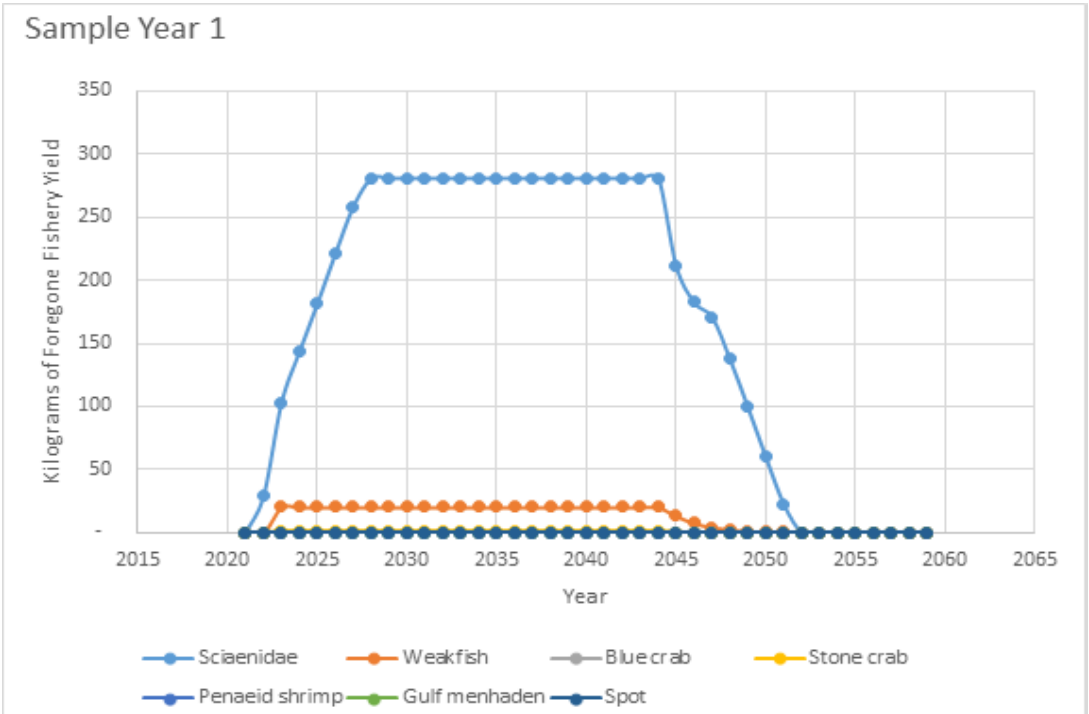
Shading indicates C/R taxa.

Source: ECT, 2018.

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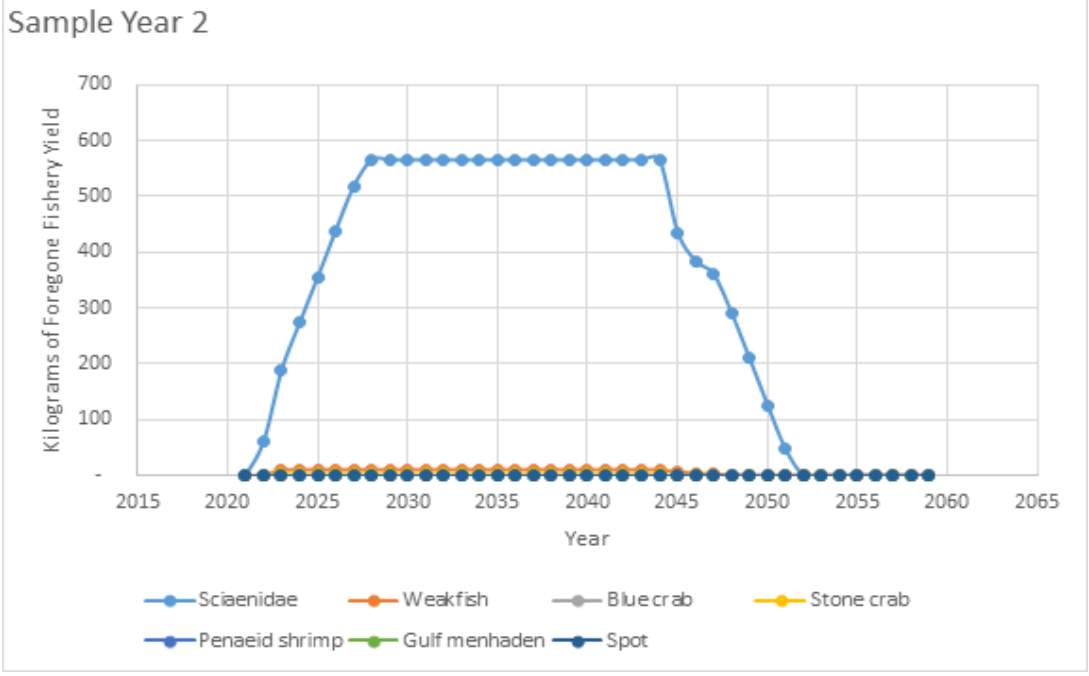


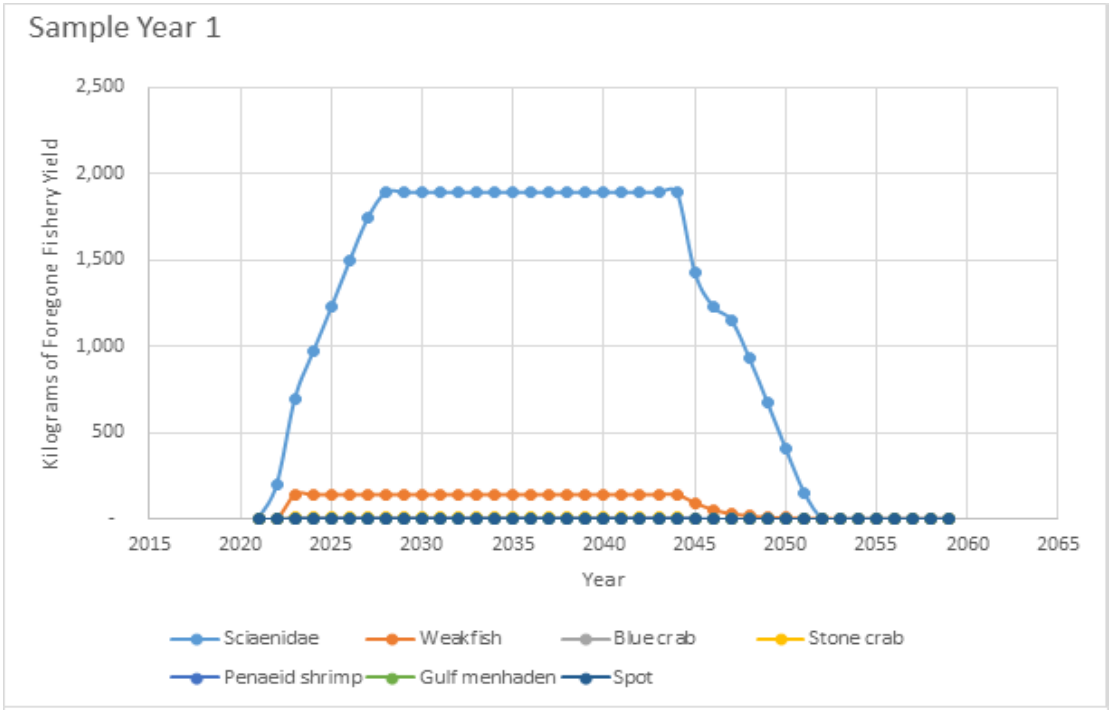
FIGURE 11-17.

BAYSIDE PLANT LIFE FISHERY YIELD BENEFITS AFTER RETROFIT TO VSP WITH 4-PERCENT FLOW REDUCTION

Source: ECT, 2018.

ECT Environmental Consulting & Technology, Inc.

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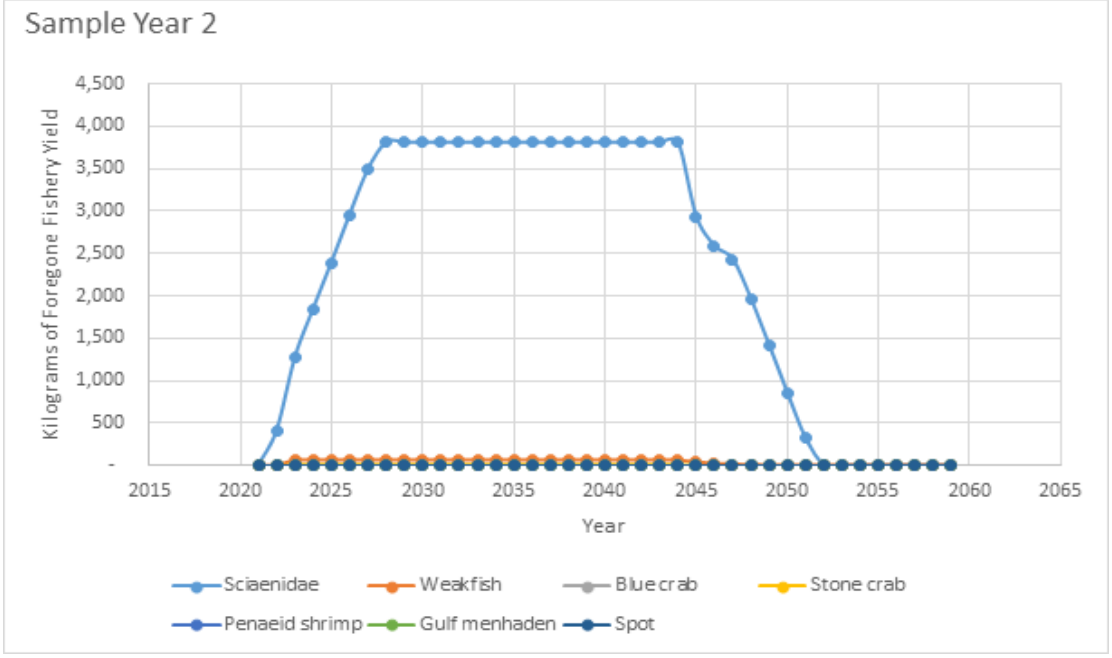


FIGURE 11-18.

BAYSIDE PLANT LIFE FISHERY YIELD BENEFITS AFTER RETROFIT TO VSP WITH 27-PERCENT FLOW REDUCTION

Source: ECT, 2018.

ECT Environmental Consulting & Technology, Inc.

Table 11–31. Summary of Recreational Social Benefits as a Result of the Reduction in Entrainment from VSP

Discount Rate	Technology	Entrainment Reduction	Present Value ($)		Annual Value ($)	
			Sample Years			
			1	2	1	2
3%	VSP	4%	$0.02 M	$0.04 M	$683	$1.32 k
		27%	$0.15 M	$0.29 M	$4.61 k	$8.89 k
7%	VSP	4%	$0.01 M	$0.02 M	$351	$672
		27%	$0.08 M	$0.15 M	$2.37 k	$4.54 k

Source: Veritas, 2018.

Valuing Changes in Commercial Yield

Table 11-32 summaries the total social benefits as a result of changes in the commercial stock in response to the reduction in entrainment resulting from the use of VSP (Appendices 11-D and 11-E). Values are presented in both present value (over the life of the facility) and annual value.

Table 11–32. Summary of Commercial Social Benefits as a Result of the Reduction in Entrainment from VSP

Discount Rate	Technology	Entrainment Reduction	Present Value ($)		Annual Value ($)	
			Sample Years			
			1	2	1	2
3%	VSP	4%	$2.72 k	$0.01 M	$82	$172
		27%	$0.02 M	$0.04 M	$556	$1.16 k
7%	VSP	4%	$1.53 k	$3.18 k	$46	$96
		27%	$0.01 M	$0.02 M	$312	$651

Source: Veritas, 2018.

Nonuse Value

Table 11-33 summarizes the nonuse benefits of reductions in entrainment at Bayside due of VSP for all households within the United States.

Table 11–33. Summary of Nonuse Benefits as a Result of the Reduction in Entrainment from VSP

Specified Population of Households United States	3% Discount Rate				7% Discount Rate			
	Present Value ($)		Annual Value ($)		Present Value ($)		Annual Value ($)	
	Sample Years				Sample Years			
	1	2	1	2	1	2	1	2
4% entrainment reduction	$0.89k	$1.78k	$0.03k	$0.05k	$0.05k	$0.3k	$0.02k	$0.03k
27% entrainment reduction	$6.03k	$12.00k	$0.18k	$0.36k	$3.35k	$2.00k	$0.10k	$0.20k

Source: Veritas, 2018.

The nonuse benefits are estimated over the same time period as the recreational and commercial benefits for VSP reductions: from 2022 to 2044.

11.4.4.4 Mitigation Effort Made Prior to Rule

Refer to Section 11.2.4.

11.4.4.5 Other Benefits

Refer to Section 11.2.5.

11.4.4.6 Reduction in Thermal Discharge

The retrofit of VSP may only result in a maximum of 27-percent reduction of flow annually. This will result in a 27-percent reduction in entrainment; however, the thermal impacts may, in reality, increase, because the water used to cool will actually be hotter, on average, than what would otherwise occur. This is because the reduction of flow through the use of VSPs is accomplished by using the minimum amount of water (with a margin of error incorporated) possible while not exceeding the ΔT limits (17°C) of the discharge permit (Section 10.0). Thus, less water is used to cool the same power generation, making the change in temperature greater than if the full pump capacity was being used. While the temperature increases, the volumetric flow rate decreases, suggesting the extent of the thermal plume in the discharge canal is likely to be little affected.

As noted under the discussion of potential thermal benefits of hypothesized retrofit to closed-cycle cooling, the current situation (i.e., use of open-cycle cooling) has been found to be protective of the local biological community under a Section 316(a) variance. The marginal change in the rate of thermal discharge estimated for VSP will, therefore, not likely result in any

benefit to the local fishery, and, similarly, no impact to the function of the discharge canal as a thermal refuge for manatee is expected.

11.4.5 Summary of Monetized Benefits for Candidate Measures

Table 11-34 and Figure 11-19 summarize the monetized recreational, commercial, and nonuse benefits of the candidate measures as detailed previously. Following the complete elimination of entrainment at Bayside, closed-cycle cooling provides the greatest social benefit as is expected, because it provides the greatest reduction in entrainment.

Table 11–34. Summary of Recreational and Commercial Social Benefits of Entrainment Reduction Alternatives at Bayside

Discount Rate	Technology	Entrainment Reduction	Present Value ($)				Annual Value ($)			
			Rec	Com	Nonuse	Total	Rec	Com	Nonuse	Total
Sample Year 1										
3%	Without entrainment	100%	0.58 M	0.07 M	22.97 k	0.67 M	17.03 k	2.11 k	0.68 k	19.81 k
	Closed-cycle	85%	0.46 M	0.05 M	18.09 k	0.53 M	14.72 k	1.76 k	0.58 k	17.06 k
	FMS	68 to 71%	0.34 M	0.06 M	14.00 k	0.41 M	9.96 k	1.65 k	0.41 k	12.02 k
	VSP	4%	0.02 M	2.72 k	0.89 k	0.03 M	683	82	0.03 k	0.79 k
		27%	0.15 M	0.02 M	6.03 k	0.18 M	4.61 k	556	0.18 k	5.35 k
7%	Without entrainment	100%	0.30 M	0.04 M	12.93 k	0.36 M	8.87 k	1.21 k	0.38 k	10.46 k
	Closed-cycle	85%	0.23 M	0.03 M	9.79 k	0.27 M	7.38 k	962	0.32 k	8.65 k
	FMS	68 to 71%	0.17 M	0.03 M	7.78 k	0.21 M	5.10 k	952	0.23 k	6.28 k
	VSP	4%	0.01 M	1.53 k	0.50 k	0.01 M	351	46	0.02 k	0.41 k
		27%	0.08 M	0.01 M	3.35 k	0.09 M	2.37 k	312	0.10 k	2.78 k
Sample Year 2										
3%	Without entrainment	100%	1.11 M	0.15 M	45.56 k	1.31 M	32.74 k	4.39 k	1.34 k	38.46 k
	Closed-cycle	85%	0.88 M	0.11 M	36.01 k	1.03 M	28.45 k	3.66 k	1.16 k	33.28 k
	FMS	68 to 71%	0.68 M	0.12 M	28.63 k	0.83 M	20.10 k	3.45 k	0.84 k	24.40 k
	VSP	4%	0.04 M	0.01 M	1.78 k	0.05 M	1.32 k	172	0.05 k	1.54 k
		27%	0.29 M	0.04 M	12.00 k	0.34 M	8.89 k	1.16 k	0.36 k	10.41 k
7%	Without entrainment	100%	0.58 M	0.09 M	7.72 k	0.67 M	16.93 k	2.52 k	0.75 k	20.20 k
	Closed-cycle	85%	0.44 M	0.06 M	5.88 k	0.51 M	14.18 k	2.01 k	0.63 k	16.82 k
	FMS	68 to 71%	0.35 M	0.06 M	4.80 k	0.42 M	10.26 k	1.99 k	0.47 k	12.72 k
	VSP	4%	0.02 M	3.18 k	0.30 k	0.03 M	672	96	0.03 k	0.80 k
		27%	0.15 M	0.02 M	2.00 k	0.17 M	4.54 k	651	0.20 k	5.39 k

Source: Veritas, 2018.

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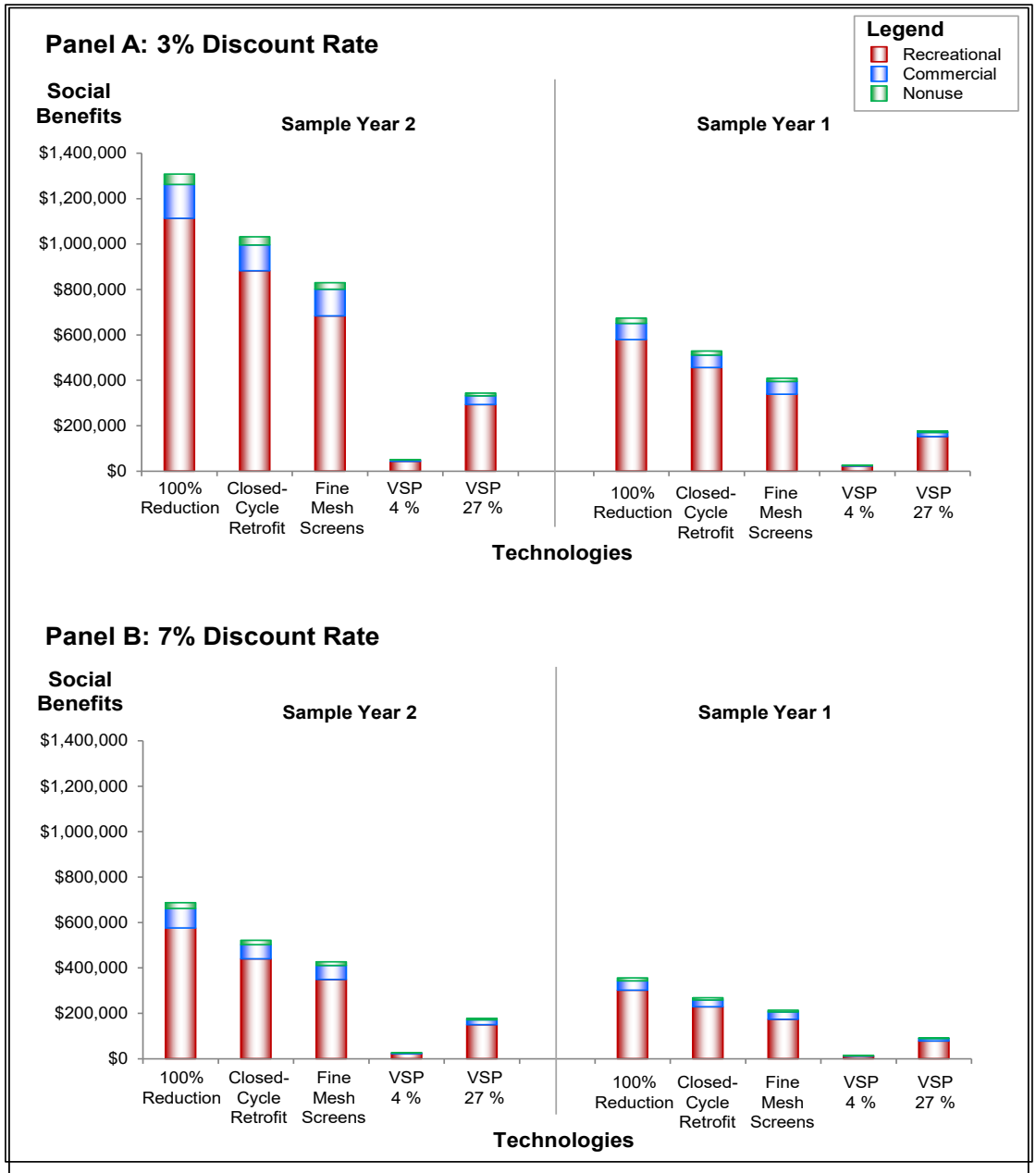


FIGURE 11-19.

SUMMARY OF TOTAL SOCIAL BENEFITS OF ENTRAINMENT REDUCTION ALTERNATIVES AT BAYSIDE

Source: Veritas 2018.

ECT Environmental Consulting & Technology, Inc.

11.5 Discussion of Uncertainty

Due to the complex interactions of environmental systems, there is, understandably, a level of uncertainty that comes along with biological models. It is important to understand these uncertainties and how each parameter can affect the end results. Though there are statistical methods that attempt to quantify the degree of uncertainty, it was believed, for this application, such statistical methods were not necessary or useful, and a qualitative approach was taken. Table 11-35 summarizes the parameters used in the biological modelling described previously and includes a discussion, and quantification where appropriate, of how changes to the parameters affect the end results used to formulate the decision on entrainment BTA.

Finally, when completing the social costs, it is recognized that, since the modeling goes out decades into the future, differences from the current state of fishing could impact results. This means anticipated changes in site quality and availability or changes in economic conditions and fishing preferences should be expressed in the with-entrainment case going forward.

Although participation in recreational fishing declined nationally years ago, fishing license sales have rebounded in recent years—dramatically in some states. According to the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, the number of anglers rose 11 percent from 2006 to 2011. Based on fishing license sales from 2006 to 2011, fishing participation increased nearly 4.8 percent among Florida anglers. However, between 2004 and 2015, Florida's fishing license sales increased 25.9 percent (USFWS, 2017). Thus, it is reasonable to state that the current C/R fishing status is appropriate to apply to future conditions.

11.5.1 Cumulative Effects of Uncertainty

Several areas of uncertainty have been described in Table 11-35. Independently, these uncertainties may not have a large impact on the final social benefits and/or they deliberately overestimate likely benefits. However, when combined, they have the potential to become additive and possibly (though unlikely in most circumstances) change the results of the assessment, including the relative ranking of potential entrainment measures.

Table 11–35. Uncertainties of Benefits Valuation Study

Category of Input	Range of Variation or Options	Rationale for Value Chosen	Sensitivity of Alternative Choice
Rates of entrainment	Two years of entrainment data are available at Bayside. The total rate of entrainment in the two years differ by approximately a factor of two. There are also differences in the rates of the various taxa. Interannual variation of this magnitude is not unusual, particularly for individual taxa. This is illustrated in a recent assessment of FWC's FIM data collected over several years (ECT, 2013). This analysis also indicated there is no significant temporal trend in the dominant species during the sampling period.	Given the variation seen in the two years of data appears to be typical, the decision was made to consider quantitatively both sets of data. Therefore, both sets will be used to estimate reductions in entrainment and attending social benefits. The alternative approaches of selecting one year over another or averaging the two years would fail to illustrate the variation in social benefits.	The alternative options would fail to illustrate the variation in entrainment and attending benefits. Depending upon approach selected (maximum, average, or minimum), the range of benefits would be incompletely characterized.
Consideration of forage shellfish	Under the FDEP-approved sampling and enumeration methods used in the Phase II effort, only C/R shellfish were enumerated in the entrainment samples. In retrospect, TECO believes non-C/R shellfish lost to entrainment may have an effect on the forage base. Reductions in entrainment of these "forage" shellfish may therefore result in a social benefit.	While TECO had approval from FDEP and FWC to use the Phase II entrainment data, it has elected to estimate the number of entrained forage shellfish based on data collected at another facility located on Tampa Bay. Forage shellfish represented a substantial majority of the entrained shellfish and considering their effect on the forage base and potential production foregone makes the assessment of benefits more complete.	The alternative options would be to exclude these species (which, as already stated, is not appropriate at this facility) or use a different data set. The alternative dataset could be from a different facility or based on additional entrainment sampling at Bayside, which would not have been possible under the rule's schedule. The facility chosen to provide the supplemental data, Duke Energy's Bartow station was selected due to the proximity of the facility and the similar CWIS design. Though Florida does have other, similarly designed CWISs at different facilities, Bartow is the only other facility that shares the source water body with Bayside that has a full entrainment dataset for the same sample period.
Consideration of FMS exclusion and post-exclusion survival	The approach to estimating the efficacy of FMS relied on empirical data collected at TECO's Big Bend station in three separate studies. Two studies evaluated the rates of exclusion of different taxa and life stages. The other study considers the postexclusion survival rates, also by taxa and life stage. When multiple values are available, there is variation in both of these parameters for a given taxa/life stage pair. There is also literature on rates of exclusion and/or survival at other facilities and laboratory settings. Estimates of rates of exclusion have also been made based on head capsule dimensions. When we consider the addition of the forage shellfish to the entrainment set, we could: (1) do it prior to exclusion and calculate the amount of C/R shellfish Callinectes spp. and stone crab present in the Bartow data and then apply the exclusion efficiencies and survival parameters, or (2) do it after we have applied those parameters to the observed C/R shellfish at Bayside (as was done).	Variation in the rates of exclusion and postexclusion survival are expected and, in response, the mean value was used to estimate the population's behavior. Data from the two studies on rates of exclusion were combined prior to calculating the mean value. Both rates of exclusion and postexclusion survival appear to be approximately normally distributed, making the arithmetic mean a reasonable estimate of the population's central tendency. The data analysis approach recognizes live return to the water body is dependent on three conditions: (1) exclusion by the screen; (2) survival of the exclusion or impingement process; and (3) survival of the return process. Reliance on site-specific empirical data is justified based on the relevance of the species, similar hydrologic setting, and conformance of the intake system contemplated (i.e., essentially the same as the one studied at Big Bend). The methodology employed uses the exclusion and survival values of taxa that were observed and puts as much reliance on the observed entrainment counts as possible.	The approach employed uses the most relevant data and analyzes them in a way that is unbiased. While there are likely errors in the estimates of the rates of exclusion and postexclusion survival, such errors are likely to be random in nature, and there is no known bias in the approach that would over- or underestimate live return. Uncertainty in the estimates are considerably higher for those taxa and life stages that were not characterized directly in the Big Bend investigations. The decision to apply surrogates to those organisms is more accurate than omitting them from the analysis. The chosen point for the addition of forage shellfish (before or after FMS effects) could have the potential to change the benefits of the FMS application if the efficiencies, and survival parameters differ greatly between the species observed at Bayside and those that comprise the forage shellfish at Bartow. However, because the exclusion efficiencies and survival of the forage shellfish taxa (anomuran crabs, brachyuran crabs, etc) are similar to the values for C/R taxa observed at Bayside, there would be little difference in the final estimates of forage shellfish entrainment and postexclusion survival.
Use of initial versus latent postexclusion survival	For many studies, there is the option to choose initial survival or latent (e.g., 96-hour) survival. In our experience, latent survival is approximately 50 percent of the initial survival.	The data set from the Big Bend study contained latent survival. However, there were few species included in the study, and it was not conducted in unison with the initial survival study, thus creating a disconnect between the data sets. Because of the need to maximize the data available, the initial survival was utilized.	Using the initial survival overestimates the benefit of FMS, it is recognized that the survival, and thus, benefit, of FMS would be lower than what is reported here. The degree to which is it overreported is not apparent, though a reasonable estimate is that latent survival is approximately 50 percent of initial survival. Reliance on latent survival would eliminate much of the relevant site-specific data.
Survival rate in the fish return	Following exclusion by and wash-off from the screens, the organisms would be returned to Hillsborough Bay via a flume approximately 2200 feet in length. The rate of survival in the flume is unknown, and survival in such circumstances has not been well characterized. It is reasonable to assume that survival would not be 100 percent, given the stresses associated with potential changes in temperature and turbulence in flume.	The rate of survival in the return system was assumed to 100 percent, given the lack of more specific data. This value was selected to maximize the estimated social benefit in the absence of more definitive information.	The rate of survival in the return system is almost certainly less than 100 percent, making the estimated rates of life return, and social benefits, an overestimate of actual rates.

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Table 11–35. Uncertainties of Benefits Valuation Study (Continued, Page 2 of 3)

Category of Input	Range of Variation or Options	Rationale for Value Chosen	Sensitivity of Alternative Choice
Through plant survival	In this assessment, through plant survival (postentrainment) is assumed to be zero. There have been some studies (see Section 9.0) that have looked at the survival of organisms through circulating water pumps/condensers and dilution pumps at power plants (Melton and Serviss, 2000; Larsen et al, 2014). The study reports a mean survival rate of 68.2 percent through the condensers (Melton and Serviss, 2000).	TECO does not have site-specific through plant survival data for Bayside, thus the data from Anclote is the best available surrogate. A more thorough understanding of the cooling water system at Anclote would be required to analyze the application of this data more closely. A 0-percent through-plant survival was assumed to maintain a higher level of conservatism. This is also a commonly used assumption in the 316(b) process and has been encouraged by the rule itself in the absence of site-specific information.	If some survival was assumed through the condensers, this would reduce the benefits of each potential technology in direct proportion to the percent survival assumed.
Trophic levels	The trophic level of a taxa may vary based on changes in feeding habits through its life cycle, variation in feeding opportunities in space and time, and inclusion of multiple species based on the inability to perform definitive identifications. It is common practice in modeling of food chain dynamics to assign an average trophic level to a species based its range of feeding habits. Trophic levels are typically expressed to the tenths place (e.g., 3.2). It is also common practice to assign trophic levels based on best professional judgment when the data are missing or when individual species may be considered under a single higher-level category (e.g., family rather than species).	The trophic levels used to model the food chain transfers were taken from the SeaAroundUs.org database. These values reflect the range of dietary habits of the species based on their position in the ecosystem. The values correspond well with the trophic levels of other sources (e.g., fishbase.org). These parameters represent a consensus approach from a creditable source. When necessary, alternative sources for trophic levels were obtained from the literature or developed based on best professional judgment. Such an alternative is more appropriate than omitting the organism from the modeling.	No systematic bias is associated with the use of consensus trophic levels. Any divergence in the actual trophic levels are likely to be distributed about the consensus value, suggesting that some parameters may be high and some low. Failure to model the taxa in the absence of a literature trophic level would underestimate potential benefits.
Trophic transfer efficiency	The trophic transfer approach interprets observed average biomasses at different trophic levels. Typically, a 10-to-1 forage to predator ratio is applied. Additional options include a blended transfer efficiency of 2.5 percent as was presented by EPA (2002).	A trophic transfer efficiency of 10 percent was chosen due to the wide use of the value and support for application in food web modelling (Pauly, and Christensen, 1995). To account for variations in the trophic levels, a modified transfer efficiency was applied as detailed in Section 11.2.2. When converting the entrained forage biomass to C/R biomass using the methodology described in Section 11.2.2, C/R biomass equals 2.49 percent of the forage biomass, supporting the methodology as it is consistent with 2.5-percent average rate applied by EPA (2002).	There are recognized inconsistencies of the 10-percent trophic transfer efficiency with the estimates developed for recreational and commercial species. In particular, it is specified that higher trophic level species are under fishing pressure from above (humans), rendering them unlikely to be constrained by forage availability. Use of the 10-percent trophic transfer is likely to provide an overestimate of increased C/R stocks. No alternative approach is viewed as more realistic.
Life history parameters	The literature often states the need to exercise caution when choosing and assigning life history parameters when doing EA and production foregone modelling as small changes in these parameters can have a large impact on the final EA numbers or production foregone biomass (EPRI, 2012). Also, the number of life stages chosen can also greatly affect these end results. Having mortalities associated with each individual life stage, especially when the mortality differs between life stages, is felt to be the best way to model the population. This methodology also allows one to apply the proper weights and growth rates of each life stage to more closely model how growth progresses. Also, ensuring the parameters are balanced (i.e., the modeled population is stable) is important and was a crucial part of determining the appropriate life history parameter values.	The values chosen for each species modelled was based on a thorough literature search of accredited sources as well as a consideration of the biology of each species. Each suite of life history parameters was tested for balance and adjusted if necessary. Fishing mortality rates were modified to fit the conditions near Bayside if site specific data were available. Model application made no attempt to consider "compensation," the phenomena of reproductive success and recruitment increasing at lower population densities and decreasing at higher densities.	To the extent possible, reliance was placed on accepted sources of life cycle parameters (e.g., EPRI, 2012; prior analysis by EPA). These parameters include the number of life stages as well as the life stage-specific survival rates and sizes. Each set of parameters was checked for balance. Given the nature of the biological modeling, errors in parameterization may result in substantial changes in the model estimates. While this potential is acknowledged, this assessment attempted to minimize errors by relying on parameters developed by recognized authorities.
Age of equivalence	Age of equivalence is the ultimate age of the organism considered in the modeling. Given that mortality prior to the age of equivalence acts to limit the number of organisms at that age, the assumed age of equivalence has an important effect on the resulting population and social benefits. On the other hand, as organisms age, their mass generally increases potentially mitigating mortality when considering biomass. A number of candidate age of equivalence could be considered (e.g., age at maturity, a fixed age [e.g., Age-1], onset of C/R harvest, etc.).	C/R taxa age of equivalence was assumed to be the age at which the given taxa experience the maximum C/R harvest. For C/R species, it is reasonable to define the age of equivalence at the point at which the organism is subject to maximum harvest. Such an approach accounts for harvest patterns as well as fishing regulations.	Choosing a different age for the EA target could have an important effect on the final numbers and biomass of EAs. If the age is set too low, the numbers would be overestimated, and if set too high, the numbers would be underestimated. As noted previously, errors in biomass under these circumstances are likely to be muted given the growth of organisms as they age. It is difficult to quantify the potential errors associated with these factors. It is likely the selected age of equivalence results in overestimates for some taxa and underestimates for others.

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Table 11–35. Uncertainties of Benefits Valuation Study (Continued, Page 3 of 3)

Category of Input	Range of Variation or Options	Rationale for Value Chosen	Sensitivity of Alternative Choice
Application of surrogates	Through the benefits valuation process, surrogates were used in two places: application of FMS exclusion efficiency and modelling of EA and production foregone. The choice of surrogate for modeling purposes made every effort to maintain the taxa within the same Family if data at the species level were not available. However, many taxa observed at Bayside did not have Family surrogates, and they were subsequently placed into the 'fish' or 'shellfish' grouping, as appropriate. These groupings accounted for less than 5 percent of the total entrainment. These groupings were then distributed into the surrogates that did have life history parameters for modelling. The error associated with this approach is not well understood.	In general, the 'fish' and 'shellfish' groupings were distributed into the surrogates based on the proportion of the surrogate taxa to the whole sample. This was done to provide a meaningful range to the potential parameters. For some taxa that were entrained as adults, the fish/shellfish grouping category was only divided into the surrogate taxa that would be realistically entrained as adults. Thus, penaeid shrimp, stone crab, and blue crab did not get any proportion of the shellfish group as they are too large to pass the existing screens and hypothetical FMS. The choice to exclude taxa as surrogates was based on knowledge of the species' life histories and observations of the type and size of organisms actually being entrained at Bayside.	While use of modeling parameters derived from surrogate species results in potential error, the alternative of excluding those organisms from the assessment was viewed as unacceptable, as it would result in an underestimate of social benefits. If the decision to exclude adult shellfish group numbers from penaeid, stone crab, and blue crab surrogates was not made, adults would have been modelled as entrained. Modelling stone crabs, blue crabs, and penaeid shrimp adults as entrained would unrealistically increase the number of EAs and amplify the production foregone inappropriately.
Applying forage biomass to C/R taxa	When modeling the potential impacts of the loss of forage biomass, it is possible to consider the contribution of biomass as production foregone of a variety of C/R taxa. Approaches considered included: (1) distribution of production foregone among C/R taxa that were subject to impingement and entrainment in proportion to their rate of C/R landings; and (2) application of production foregone to a single C/R taxon understood to have C/R relevance and is biologically appropriate (i.e., it is known to prey on the forage shellfish).	In the modeling of production foregone for C/R species, the assumption was made that a single taxon, Sciaenidae, would benefit from the reduction in the losses of forage shellfish. This was done largely on biological grounds based on: (1) the knowledge that the Sciaenidae use Hillsborough Bay and Tampa Bay as feeding grounds; and (2) based on their trophic position, they are likely to feed on forage shellfish. In addition, the Sciaenidae are a dominant component of the nearfield fish community (Golder, 2009) and they have a strong presence within the C/R landings of Hillsborough county and the balance of Tampa Bay as well (FWC, 2017). It should be noted that the increase in Sciaenidae biomass predicted represents a substantial portion of the C/R landings for Hillsborough County. On the other hand, the increase in Sciaenidae biomass represents a small fraction of the total C/R landings of finfish for the county. This finding is consistent with the decision to focus on the Sciaenidae as a surrogate for other C/R taxa. The alternative approach of distributing forage shellfish among a set of C/R species was rejected because of the tenuous biological connections implied. For example, some C/R species are known to feed and be subject to harvest in offshore waters (e.g., penaeid shrimp) and/or unlikely to prey in a substantial way on forage shellfish due to their similar trophic levels (e.g., Gulf Menhaden, stone crabs, penaeid shrimp).	The alternative approach of applying increased biomass of forage shellfish to a spectrum of C/R species is likely to overestimate their increase in harvest due to inappropriate assumptions regarding their residence in the area and/or their predator-prey relationship with the forage shellfish. The approach selected is believed to be more realistic. Selection of a predator taxa that is relatively high in the food chain (i.e., Sciaenidae) does result in loss of biomass associated with greater change in trophic levels and the attending reduction in trophic transfer. This is believed to be realistic and acceptable based on the attributes of the taxa. It is important to highlight that this approach assumes all foregone production of forage shellfish is consumed by C/R species. This is certainly not the case and, therefore, results in an overestimate of potential benefits.

Source: ECT, 2018.

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Furthermore, the cumulative effects for one technology (FMS) may be greater than others, because that technology has more assumptions associated with it (exclusion and survival parameters) or the assumptions (addition of forage shellfish, which have a larger exclusions efficiency and postexclusion survival than finfish) affect that technology more than others.

The largest perceived impact to uncertainty is associated with the consideration of forage shellfish as an indirect effect to C/R species. It is possible that if this step was not taken, the social benefit of FMS may be much lower, because the exclusion efficiency and survival of forage shellfish drives the FMS performance. However, FMS performance would not be lower than VSPs, because the average exclusion efficiency and survival of finfish is still above a 27-percent reduction in entrainment (the maximum performance potentially of VSPs). Thus, while the decision to incorporate forage shellfish enhances the net social benefits of FMS, failure to do so would not result in the net social benefits of VSP eclipsing those of FMS. Most importantly, inclusion of forage shell fish does not impact the recommendations presented regarding entrainment BTA, which are based on the fact that the net social benefits of all alternatives are strongly negative. In fact, without consideration of forage shellfish, the net social benefits of FMS would be substantially more negative.

Every effort was made to recognize, process, and choose the appropriate value for the assessment using BPJ. The decisions made for this assessment were carefully considered and vetted by the team and others and represent the BPJ at the time of writing this report.

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Appendix 11-A

Baseline Condition, Modeling Results Expressed as Benefits of Technology

11-A

Annualized entrainment counts

Scientific Name	Common Name	Sample Year 1							Sample Year 2						
		Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total	Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total
FISH															
Achiridae	American soles	1,854,800	-	-	-	-	-	1,854,800	52,973,000	71,299	-	-	-	-	53,044,000
Achirus lineatus	Lined sole	-	-	463,450	-	-	-	463,450	-	92,100	5,322,800	-	-	-	5,414,900
Anchoa hepsetus	Broad-striped anchovy	262,450	-	-	-	-	-	262,450	1,814,000	-	-	-	-	-	1,814,000
Anchoa mitchilli	Bay anchovy	735,250,000	2,916,600	31,736,000	65,613	-	-	769,970,000	5,252,100,000	20,948,000	45,738,000	-	-	16,487,000	5,335,300,000
Anchoa spp.	Common anchovy	-	-	-	-	-	-	-	-	-	142,540	-	-	-	142,540
Bairdiella chrysoura	Silver perch	-	73,460	60,904,000	-	-	-	60,977,000	-	-	9,814,900	-	-	-	9,814,900
Bathygobius soporator	Frillfin goby	-	73,749	8,595,100	85,721	-	73,460	8,828,000	-	-	4,477,800	-	-	147,280	4,625,000
Blenniidae	Blennies	-	73,460	27,014,000	-	-	-	27,088,000	-	-	23,275,000	-	-	372,880	23,648,000
Carangidae	Jacks and Pompanos	-	-	-	-	-	-	-	-	-	92,566	-	-	-	92,566
Chaetodipterus faber	Atlantic spadefish	-	-	71,985	-	-	-	71,985	-	-	354,220	-	-	-	354,220
Chasmodes saburrae	Florida blenny	-	-	366,610	-	-	-	366,610	-	-	-	-	-	-	-
Chloroscombrus chrysurus	Atlantic bumper	-	-	146,100	-	-	-	146,100	-	-	377,250	665,550	-	-	1,042,800
Clupeidae	Herrings	-	-	368,620	-	-	-	368,620	163,960	92,061	73,733	-	-	-	329,760
Cynoscion arenarius	Sand seatrout	-	-	16,204,000	-	-	-	16,204,000	-	-	2,465,600	-	-	-	2,465,600
Cynoscion nebulosus	spotted seatrout	-	-	1,654,700	-	-	-	1,654,700	-	-	2,754,500	-	-	-	2,754,500
Eugerres plumieri	Striped mojarra	-	-	228,270	-	-	-	228,270	-	-	-	-	-	-	-
Gobiesox strumosus	Skilletfish	-	-	5,208,400	74,022	-	-	5,282,500	-	-	1,707,700	-	-	-	1,707,700
Gobiidae	Gobies	-	146,920	4,914,100	-	-	-	5,061,000	-	-	1,160,800	-	-	-	1,160,800
Gobiosoma robustum	Naked goby	-	-	16,548,000	-	-	-	16,548,000	-	-	9,563,400	-	-	361,880	9,925,300
Gobiosoma spp.	Naked gobies	-	-	2,153,300	-	-	-	2,153,300	-	-	-	-	-	-	-
Hippocampus erectus	Lined seahorse	-	-	-	34,247	-	-	34,247	-	-	-	-	-	-	-
Lagodon rhomboides	Pinfish	-	-	-	74,054	-	-	74,054	-	-	-	-	-	-	-
Membras martinica	Rough silverside	-	-	146,480	-	-	-	146,480	-	-	-	-	-	-	-
Menidia spp.	Atlantic silverside	163,650	-	-	-	-	-	163,650	-	-	-	-	-	-	-
Menticirrhus spp.	kingfish	-	-	28,144,000	-	-	-	28,144,000	-	-	6,303,100	92,566	-	-	6,395,700
Microdesmus longipinnis	Pink wormfish	-	-	4,005,300	-	-	-	4,005,300	-	-	166,680	-	-	-	166,680
Microgobius gulosus	Clown goby	-	-	182,200	-	-	-	182,200	-	-	-	-	-	-	-
Microgobius spp.	Gobies	-	-	142,380	-	-	-	142,380	-	-	-	-	-	-	-
Oligoplites saurus	Leatherjacket	-	-	-	-	-	-	-	-	71,284	502,880	-	-	-	574,170
Prionotus scitulus	Leopard searobin	-	-	143,970	-	-	-	143,970	-	-	-	-	-	-	-
Prionotus spp.	Searobins	-	-	143,750	-	-	-	143,750	-	-	715,870	-	-	-	715,870

ECT

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Scientific Name	Common Name	Sample Year 1							Sample Year 2						
		Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total	Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total
Prionotus tribulus	Bighead searobin	-	-	171,720	-	-	-	171,720	-	-	-	-	-	-	-
Sciaenidae	Drums and croakers	3,684,800,000	99,235	4,673,900	-	-	-	3,689,600,000	3,678,400,000	-	4,991,000	-	-	2,414,300	3,685,900,000
Scorpaenidae	Scorpionfish	-	-	-	-	-	-	-	-	-	92,566	-	-	-	92,566
Symphurus plagiusa	Blackcheek tonguefish	-	-	514,350	-	-	-	514,350	-	-	2,450,400	-	-	-	2,450,400
Syngnathus louisianae	Chain pipefish	-	-	360,630	257,350	-	-	617,970	-	-	2,031,600	402,970	-	-	2,434,600
Trinectes maculatus	Hogchoker	-	73,460	1,732,200	-	-	-	1,805,700	-	-	952,520	-	-	-	952,520
Trinectes spp.	Soles	183,650	-	-	-	-	-	183,650	-	-	-	-	-	-	-
Unidentified species		13,792,000	591,370	1,647,000	-	-	81,657	16,112,000	1,358,900	826,780	3,326,800	-	-	1,522,500	7,035,000
	Fish Total	***4,436,300,000***	***4,048,300***	***218,580,000***	***591,010***	***-***	***155,120***	***4,659,700,000***	***8,986,900,000***	***22,102,000***	***128,850,000***	***1,161,100***	***-***	***21,306,000***	***9,160,300,000***
SHELLFISH															
Callinectes sapidus	Blue crab	-	-	72,612	-	-	-	72,612	-	-	-	-	-	-	-
Menippe sp.	Stone crab	-	165,290,000	-	-	-	-	165,290,000	555,980	344,380,000	-	-	-	4,177,600	349,110,000
Penaeidae	Penaeid shrimp	-	-	-	-	-	13,451,000	13,451,000	-	-	-	-	-	35,915,000	50,470,000
Sepioteuthis sepioidea	Caribbean reef squid	-	-	-	-	-	796,620	796,620	-	-	-	-	-	1,681,900	1,681,900
Other shellfish*		1,762,700	2,176,300,000	219,960,000	1,666,800	32,883,000	1,495,000,000	3,927,300,000	3,721,500	4,594,900,000	463,820,000	3,519,100	69,424,000,	3,156,300,000	8,291,700,000
	Shellfish Total	***1,762,700***	***2,341,600,000***	***219,770,000***	***1,666,800***	***32,883,000***	***1,509,200,000***	***4,106,900,000***	***4,277,500***	***4,939,300,000***	***463,820,000***	***3,519,100***	***69,424,000***	***3,190,500,000***	***8,670,800,000***
	GRAND TOTAL	**4,438,100,000**	**2,345,700,000**	**438,350,000**	**2,257,800**	**32,883,000**	**1,509,400,000**	**8,766,600,000**	**8,991,200,000**	**4,961,400,000**	**592,680,000**	**4,680,100**	**69,424,000**	**3,211,800,000**	**17,831,000,000**

Annualized entrainment counts of surrogates

Scientific Names	Proportion of Surrogates	Sample Year 1						Sample Year 2					
		Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH													
Anchoa mitchilli	16.72%	737,830,000	3,430,000	37,500,000	126,730	-	778,890,000	5,254,800,000	21,778,000	69,502,000	67,359	-	5,346,100,000
Bairdiella chrysoura	1.33%	2,181	87,169	61,805,000	4,857	-	61,899,000	2,178	1,271	10,445,000	5,353	-	10,453,000
Cynoscion regalis	0.39%	639	335	18,123,000	1,422	-	18,125,000	638	372	5,466,700	1,568	-	5,469,200
Gobiosoma bosc	0.83%	1,370	259,140	38,461,000	162,790	-	38,884,000	1368	798	18,138,000	3,363	-	18,144,000
Gerreidae	0.00%	8	4	231,640	18	-	231,670	8	5	1,383	20	-	1,416
Sciaenidae	80.62%	3,696,400,000	185,570	59,854,000	294,800	-	3,756,800,000	3,679,100,000	151,160	37,621,000	1,083,000	-	3,718,000,000
Trinectes maculatus	0.11%	2,045,000	86,117	2,765,300	384	-	4,896,800	52,981,000	169,850	8,986,200	423	-	62,138,000
	Fish total	***4,436,300,000***	***4,048,300***	***218,740,000***	***591,010***	***-***	***4,659,700,000***	***8,986,900,000***	***22,102,000***	***150,160,000***	***1,161,100***	***-***	***9,160,300,000***
SHELLFISH													
Anomura crabs	12.65%	222,700	504,540,000	9,943,300	865,040	4,100,500	519,670,000	470,170	1,065,200,000	20,992,000	1,826,300	8,657,100	1,097,200,000
Callinectes sapidus	0.00%	32	1,507	72,829	2	-	74,370	2	3,067	347	4	-	3,420
Brachyuran crabs	79.31%	1,395,900	2,923,200,000	305,780,000	1,087,000	27,340,000	3,258,800,000	2,947,100	6,171,700,000	645,570,000	2,295,000	57,722,000	6,880,200,000
Caridean shrimp	3.50%	61,579	140,290,000	1,634,500	3,656	1,704,800	143,700,000	130,010	296,190,000	3,450,600	7,719	3,599,300	303,380,000
Menippe mercenaria	4.15%	73,123	168,720,000	494,460	4,341	-	169,290,000	710,420	355,800,000	1,043,700	9,166	-	357,570,000
Penaeid shrimp	0.34%	5,951	12,583,000	1,187,600	353	-	13,776,000	12,563	26,573,000	2,499,600	746	-	29,086,000
	Shellfish total	***1,759,300***	***3,749,300,000***	***319,110,000***	***1,960,400***	***33,146,000***	***4,105,300,000***	***4,270,300***	***7,915,500,000***	***673,550,000***	***4,139,000***	***69,979,000***	***8,667,400,000***

Entrainment equivalent adults of surrogate groupings

Scientific Names	Sample Year 1						Sample Year 2					
	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH												
Cynoscion regalis	<1	<1	941	86	-	1,027	<1	<1	284	160	-	444
Sciaenidae	5,857	3	4,780	4,427	-	15,067	5,829	3	3,004	16,265	-	25,101
Fish total	***5,857***	***3***	***5,721***	***4,513***	***-***	***16,094***	***5,829***	***3***	***3,288***	***16,425***	***-***	***25,545***
SHELLFISH												
Callinectes sapidus	-	<1	<1	<1	-	<1	-	<1	<1	<1	-	<1
Menippe mercenaria	47	330	2,782	168	-	3,327	100	695	5,872	355	-	7,021
Penaeidae	<1	55	34	<1	-	89	<1	116	72	<1	-	188
Shellfish total	***47***	***385***	***2,816***	***168***	***-***	***3,416***	***100***	***811***	***5,944***	***355***	***95,754,000***	***7,209***

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Entrainment foregone production (kg) of surrogate groupings

Scientific Names	Sample Year 1						Sample Year 2					
	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH												
Anchoa mitchilli	182	3	290	113	-	588	1,296	17	294	60	-	1,668
Bairdiella chrysoura	<1	1	2,091	8	-	2,100	<1	<1	353	9	-	362
Gobiosoma bosc	<1	182	-	2	-	184	<1	85	-	<1	-	85
Gerreidae	<1	<1	10	<1	-	10	<1	<1	<1	<1	-	<1
Trinectes maculatus	23	487	-	1	-	511	600	1,563	-	1	-	2,164
Fish total	***205***	***672***	***2,391***	***125***	***-***	***3,393***	***1,896***	***1,665***	***647***	***70***	***-***	***4,279***
SHELLFISH												
Anomura crabs	-	1,213	610	198	2,050	4,071	-	2,560	1,287	418	4,329	8,594
Brachyuran crabs	-	54,791	36,390	2,291	600,190	693,660	-	115,680	76,827	4,838	1,267,200	1,464,500
Caridean shrimp	-	45	76	-	222	343	-	95	161	-	468	724
Shellfish total	***-***	***56,049***	***37,076***	***2,489***	***602,460***	***698,070***	***-***	***118,330***	***78,275***	***5,256***	***1,272,000***	***1,473,800***

Annualized impingement counts

Scientific Name	Common Name	Sample Year 1								Sample Year 2							
		Juvenile	Late juveniles	Age 1	Age 2	Age 3	Age 4	Age 5	Taxa Total	Juvenile	Late juveniles	Age 1	Age 2	Age 3	Age 4	Age 5	Taxa Total
FISH																	
Anchoa mitchilli	Bay anchovy	435	-	54	-	-	-	-	490	802	-	100	-	-	-	-	902
Anchoa spp.	Anchovy	52	-	6	-	-	-	-	58	-	-	-	-	-	-	-	-
Archosargus probatocephalus	Sheepshead	-	-	-	-	-	-	-	-	29	2	1	-	-	-	<1	33
Ariopsis felis	Hardhead catfish	22	2	1	-	-	-	<1	25	15	1	1	-	-	-	<1	17
Bagre marinus	Gafftopsail catfish	-	-	-	-	-	-	-	-	14	1	1	-	-	-	<1	16
Bairdiella chrysoura	Silver perch	2,757	-	-	-	-	-	-	2,757	1,500	-	-	-	-	-	-	1,500
Blenniidae	Blenny	30	2	1	-	-	-	<1	35	-	-	-	-	-	-	-	-
Chaetodipterus faber	Atlantic spadefish	303	25	14	-	-	-	3	344	252	20	11	-	-	-	3	286
Chilomycterus schoepfii	Striped burrfish	49	4	2	-	-	-	<1	55	-	-	-	-	-	-	-	-
Chloroscombrus chrysurus	Atlantic bumper	73	6	3	-	-	-	1	83	973	79	44	-	-	-	10	1,106
Cynoscion arenarius	Sand seatrout	5,794	-	-	-	-	-	-	5,794	1,189	-	-	-	-	-	-	1,189
Cynoscion nebulosus	Spotted seatrout	58	-	-	-	-	-	-	58	-	-	-	-	-	-	-	-
Cynoscion spp.	Seatrout	-	-	-	-	-	-	-	-	93	-	-	-	-	-	-	93
Dasyatis americana	Southern stingray	-	-	-	-	-	-	-	-	89	7	4	-	-	-	1	101
Diapterus auratus	Irish pompano	50	4	2	-	-	-	1	57	-	-	-	-	-	-	-	-
Dorosoma petenense	Threadfin shad	30	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-
Eucinostomus gula	Silver jenny	53	-	-	-	-	-	4	56	23	-	-	-	-	-	2	25
Eucinostomus spp.	Mojarra	287	-	-	-	-	-	19	306	-	-	-	-	-	-	-	-
Gambusia affinis	Eastern mosquito fish	33	3	2	-	-	-	<1	38	-	-	-	-	-	-	-	-
Gymnura spp.	Butterfly ray	-	-	-	-	-	-	-	-	27	2	1	-	-	-	<1	31
Harengula jaguana	Scaled sardine	27	-	-	-	-	-	-	27	173	-	-	-	-	-	-	173
Hemicaranx amblyrhynchus	Bluntnose jack	-	-	-	-	-	-	-	-	162	13	7	-	-	-	2	184
Hippocampus erectus	Lined seahorse	6	1	<1	-	-	-	<1	7	83	7	4	-	-	-	1	94
Hippocampus spp.	Seahorse	140	11	6	-	-	-	1	159	-	-	-	-	-	-	-	-
Hippocampus zosterae	Dwarf seahorse	-	-	-	-	-	-	-	-	40	3	2	-	-	-	0	45
Lactophrys quadricornis	Scrawled cowfish	24	2	1	-	-	-	<1	27	-	-	-	-	-	-	-	-
Lagodon rhomboides	Pinfish	77	6	3	-	-	-	1	88	-	-	-	-	-	-	-	-
Leiostomus xanthurus	Spot	29	29	-	-	-	-	-	58	-	-	-	-	-	-	-	-
Lucania parva	Rainwater killifish	113	9	5	-	-	-	1	129	50	4	2	-	-	-	1	57
Menticirrhus americanus	Southern kingfish	47	4	2	-	-	-	<1	54	-	-	-	-	-	-	-	-
Menticirrhus littoralis	Gulf kingfish	95	8	4	-	-	-	1	108	-	-	-	-	-	-	-	-
Mugil cephalus	Striped mullet	-	-	-	-	-	-	-	-	96	8	4	-	-	-	1	109
Opisthonema oglinum	Atlantic thread herring	474	-	-	-	-	-	-	474	896	-	-	-	-	-	-	896
Opsanus beta	Gulf toadfish	472	38	21	-	-	-	5	536	444	36	20	-	-	-	5	504
Opsanus pardus	Leopard toadfish	42	3	2	-	-	-	<1	47	-	-	-	-	-	-	-	-
Peprilus burti	Gulf butterfish	100	8	5	-	-	-	1	114	-	-	-	-	-	-	-	-

Scientific Name	Common Name	Sample Year 1								Sample Year 2							
		Juvenile	Late juveniles	Age 1	Age 2	Age 3	Age 4	Age 5	Taxa Total	Juvenile	Late juveniles	Age 1	Age 2	Age 3	Age 4	Age 5	Taxa Total
Prionotus scitulus	Leopard searobin	89	7	4	-	-	-	1	101	156	13	7	-	-	-	2	177
Prionotus spp.	Searobin	509	41	23	-	-	-	5	578	24	2	1	-	-	-	<1	27
Prionotus tribulus	Bighead searobin	34	3	2	-	-	-	<1	39	50	4	2	-	-	-	1	57
Rachycentron canadum	Cobia	26	2	1	-	-	-	<1	29	-	-	-	-	-	-	-	-
Rhinoptera bonasus	Cownose ray	-	-	-	-	-	-	-	-	47	4	2	-	-	-	<1	53
Sardinella aurita	Spanish sardine	-	-	-	-	-	-	-	-	80	-	-	-	-	-	-	80
Selene vomer	Lookdown	24	2	1	-	-	-	<1	27	291	24	13	-	-	-	3	330
Sphoeroides nephelus	Southern puffer	268	22	12	-	-	-	3	304	164	13	7	-	-	-	2	186
Stephanolepis hispida	Planehead filefish	-	-	-	-	-	-	-	-	22	2	1	-	-	-	<1	25
Symphurus plagiusa	Blackcheek tonguefish	24	2	1	-	-	-	<1	27	-	-	-	-	-	-	-	-
Trinectes maculatus	Hogchoker	628	51	28	-	-	-	6	713	232	19	10	-	-	-	2	264
	Fish Total	***13,272***	***295***	***209***	***-***	***-***	***-***	***56***	***13,832***	***8,016***	***265***	***247***	***-***	***-***	***35***		***8,563***
OTHER																	
Limulus polyphemus	Horseshoe crab	-	-	22,185	-	-	-	-	22,185	-	-	55,081	-	-	-	-	55,081
	Other Total	***-***		***22,185***	***-***	***-***	***-***	***-***	***22,185***		***-***	***-***	***-***	***-***	***-***	***-***	***55,081***
SHELLFISH																	
Alpheus spp.	Snapping shrimp	42	3	26	1	<1	-	-	73	285	23	178	7	2	-	-	494
Callinectes sapidus	Blue crab	455	-	114	-	-	-	-	569	220	-	55	-	-	-	-	275
Callinectes similis	Lesser blue crab	21	-	5	-	-	-	-	27	-	-	-	-	-	-	-	-
Farfantepenaeus duorarum	Pink shrimp	242	139	49	-	-	-	-	430	3,574	2,063	726	-	-	-	-	6,364
Lolliguncula brevis	Brief squid	1,306	-	1,314	-	-	-	-	2,620	1,388	-	1,397	-	-	-	-	2,785
Menippe mercenaria	Stone crab	2,172	-	964	316	29	-	-	3,480	3,087	-	1,370	450	41	-	-	4,948
Menippe spp.	Stone crab	129	-	57	19	2	-	-	207	-	-	-	-	-	-	-	-
Palaemonetes spp.	Grass shrimp	-	-	-	-	-	-	-	0	-	-	26	-	-	-	-	26
Parapinnixa hendersoni	Pea crabs	29	-	8	1	1	-	-	38	-	-	-	-	-	-	-	-
Penaeidae	Commercial shrimp	8	5	2	-	-	-	-	15	-	-	-	-	-	-	-	-
Petrolisthes spp.	Porcelain crab unidentified	-	-	-	-	-	-	-	0	339	-	87	7	7	-	-	439
Porcellana sayana	Spotted porcelain crab	46	-	12	1	1	-	-	60	-	-	-	-	-	-	-	-
Porcellanidae	Porcelain crab	125	-	32	2	2	-	-	162	641	-	165	13	13	-	-	831
Rimapenaeus constrictus	Roughneck shrimp	18	11	4	-	-	-	-	33	-	-	-	-	-	-	-	-
Sesarma reticulatum	Heavy marsh crab	42	-	11	1	1	-	-	54	41	-	10	1	1	-	-	53
Squilla empusa	Mantis shrimp	84	7	53	2	<1	-	-	146	58	5	36	2	<1	-	-	101
Xanthoidea	Mud crabs	4,753	-	1,219	94	94	-	-	6,160	1,116	-	286	22	22	-	-	1,446
	Shellfish Total	***9,473***	***165***	***3,869***	***437***	***130***	***-***	***-***	***14,074***	***10,748***	***2,091***	***4,337***	***501***	***85***	***-***	***-***	***17,762***
	GRAND TOTAL	***22,745***	***460***	***26,263***	***437***	***130***	***-***	***56***	***50,091***	***18,765***	***2,355***	***59,665***	***501***	***85***	***-***	***35***	***81,405***

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Annualized counts of surrogates from impingement

Scientific Names	Sample Year 1									Sample Year 2								
	Species proportion of type (fish or shellfish)	juveniles	late juvenile	age 1	age 2	age 3	age 4	age 5	Species Total	Species proportion of type (fish or shellfish)	juveniles	late juveniles	age 1	age 2	age 3	age 4	age 5	Species Total
FISH																		
Anchoa mitchilli	5%	622	11	67	-	-	-	1	701	18%	1,336	43	124	-	-	-	5	1,509
Bairdiella chrysoura	25%	3,432	55	30	-	-	-	7	3,524	29%	2,387	72	40	-	-	-	9	2,508
Cynoscion regalis	54%	7,285	116	65	-	-	-	15	7,480	25%	2,040	62	34	-	-	-	8	2,143
Brevoortia patronus	5%	660	11	6	-	-	-	1	678	22%	1,828	55	31	-	-	-	7	1,921
Gerreidae	3%	428	7	4	-	-	-	24	463	0%	38	1	1	-	-	-	2	42
Leiostomus xanthurus	1%	43	30	1	-	-	-	<1	74	0%	-	-	-	-	-	-	-	-
Trinectes maculatus	7%	802	65	36	-	-	-	8	912	5%	388	31	17	-	-	-	4	441
	Fish total	***13,272***	***295***	***209***	***-***	***-***	***-***	***56***	***13,832***		***8,016***	***265***	***247***	***-***	***-***	***-***	***35***	***8,563***
SHELLFISH																		
Callinectes sapidus	5%	553	1	193	<1	<1	-	-	746	2%	253	1	86	<1	<1	-	-	340
Menippe mercenaria	33%	2,770	3	1,478	336	31	-	-	4,619	34%	3,683	9	1,924	453	42	-	-	6,110
Penaeidae	4%	329	155	114	<1	<1	-	-	598	44%	4,340	2,075	1,439	4	1	-	-	7,860
Caridea	0%	-	-	-	-	-	-	-	0	0%	3	<1	29	<1	<1	-	-	33
Brachyura	58%	5,821	6	2,084	101	99	-	-	8,110	19%	2,469	5	858	44	43	-	-	3,419
	Shellfish total	***9,473***	***165***	***3,869***	***437***	***130***	***-***	***-***	***14,074***		***10,748***	***2,091***	***4,337***	***501***	***85***	***-***	***-***	***17,762***

Equivalent adults of surrogate groupings from impingement

Scientific Names	Sample Year 1								Sample Year 2							
	Juveniles	Late juvenile	Age 1	Age 2	Age 3	Age 4	Age 5	Taxa Total	Juveniles	Late juvenile	Age 1	Age 2	Age 3	Age 4	Age 5	Taxa Total
FISH																
Cynoscion regalis	201	30	41	-	-	-	49	321	56	16	22	-	-	-	26	120
Brevoortia patronus	7	-	2	-	-	-	402	410	19	-	9	-	-	-	2,101	2,129
Leiostomus xanthurus	3	16	1	-	-	-	1,147	1,167	-	-	-	-	-	-	-	-
Fish total	***211***	***46***	***44***	***-***	***-***	***-***	***1,598***	***1,898***	***75***	***16***	***31***	***-***	***-***	***-***	***2,127***	***2,249***
SHELLFISH																
Callinectes sapidus	10	-	350	-	-	-	-	359	4	156	-	-	-	-	-	160
Menippe mercenaria	108	-	325	189	48	-	-	670	143	-	423	255	66	-	-	886
Penaeidae	-	<1	131	-	-	-	-	131	-	1	1,658	-	-	-	-	1,659
Shellfish total	***118***	***<1***	***806***	***189***	***48***	***-***	***-***	***1,160***	***147***	***157***	***2,081***	***255***	***66***	-	-	***2,705***

Foregone production (kg) of surrogate groupings from impingement

Scientific Names	Sample Year 1								Sample Year 2							
	Juveniles	Late juvenile	Age 1	Age 2	Age 3	Age 4	Age 5	Taxa Total	Juveniles	Late juvenile	Age 1	Age 2	Age 3	Age 4	Age 5	Taxa Total
FISH																
Anchoa mitchilli	<1	<1	<1	-	<1	-	-	1	1	<1	<1	-	<1	-	-	1
Bairdiella chrysoura	6	-	2	-	-	1	-	8	4	-	2	-	-	1	-	7
Gerreidae	<1	-	<1	-	-	-	1	1	<1	-	<1	-	-	-	<1	<1
Trinectes maculatus	2	-	1	-	-	-	1	4	1	-	<1	-	-	-	<1	2
Fish total	***8***	***<1***	***3***	***-***	***<1***	***1***	***2***	***14***	***6***	***<1***	***2***	***-***	***<1***	***1***	***1***	***10***
SHELLFISH																
Caridea	-	-	-	-	-	-	-	-	-	-	<1	-	-	-	-	<1
Brachyura	12	-	46	3	5	-	-	66	4	-	16	1	1	-	-	22
Shellfish total	***12***	***-***	***46***	***3***	***5***	***-***	***-***	***66***	***4***	***-***	***16***	***1***	***1***	***-***	***-***	***22***

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Appendix 11-B

Closed-cycle Cooling, Modeling Results Expressed as Benefits of Technology

11-B

Annualized entrainment counts

Scientific Name	Common Name	Sample Year 1							Sample Year 2						
		Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total	Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total
FISH															
Achiridae	American soles	1,578,435	-	-	-	-	-	1,578,435	45,080,023	60,675	-	-	-	-	45,140,444
Achirus lineatus	Lined sole	-	-	394,396	-	-	-	394,396	-	78,377	4,529,703	-	-	-	4,608,080
Anchoa hepsetus	Broad-striped anchovy	223,345	-	-	-	-	-	223,345	1,543,714	-	-	-	-	-	1,543,714
Anchoa mitchilli	Bay anchovy	625,697,750	2,482,027	27,007,336	55,837	-	-	655,244,470	4,469,537,100	17,826,748	38,923,038	-	-	14,030,437	4,540,340,300
Anchoa spp.	Common anchovy	-	-	-	-	-	-	-	-	-	121,302	-	-	-	121,302
Bairdiella chrysoura	Silver perch	-	62,514	51,829,304	-	-	-	51,891,427	-	-	8,352,480	-	-	-	8,352,480
Bathygobius soporator	Frillfin goby	-	62,760	7,314,430	72,949	-	62,514	7,512,628	-	-	3,810,608	-	-	125,335	3,935,875
Blenniidae	Blennies	-	62,514	22,988,914	-	-	-	23,051,888	-	-	19,807,025	-	-	317,321	20,124,448
Carangidae	Jacks and Pompanos	-	-	-	-	-	-	-	-	-	78,774	-	-	-	78,774
Chaetodipterus faber	Atlantic spadefish	-	-	61,259	-	-	-	61,259	-	-	301,441	-	-	-	301,441
Chasmodes saburrae	Florida blenny	-	-	311,985	-	-	-	311,985	-	-	-	-	-	-	-
Chloroscombrus chrysurus	Atlantic bumper	-	-	124,331	-	-	-	124,331	-	-	321,040	566,383	-	-	887,423
Clupeidae	Herrings	-	-	313,696	-	-	-	313,696	139,530	78,344	62,747	-	-	-	280,626
Cynoscion arenarius	Sand seatrout	-	-	13,789,604	-	-	-	13,789,604	-	-	2,098,226	-	-	-	2,098,226
Cynoscion nebulosus	spotted seatrout	-	-	1,408,150	-	-	-	1,408,150	-	-	2,344,080	-	-	-	2,344,080
Eugerres plumieri	Striped mojarra	-	-	194,258	-	-	-	194,258	-	-	-	-	-	-	-
Gobiesox strumosus	Skilletfish	-	-	4,432,348	62,993	-	-	4,495,408	-	-	1,453,253	-	-	-	1,453,253
Gobiidae	Gobies	-	125,029	4,181,899	-	-	-	4,306,911	-	-	987,841	-	-	-	987,841
Gobiosoma robustum	Naked goby	-	-	14,082,348	-	-	-	14,082,348	-	-	8,138,453	-	-	307,960	8,446,430
Gobiosoma spp.	Naked gobies	-	-	1,832,458	-	-	-	1,832,458	-	-	-	-	-	-	-
Hippocampus erectus	Lined seahorse	-	-	-	29,144	-	-	29,144	-	-	-	-	-	-	-
Lagodon rhomboides	Pinfish	-	-	-	63,020	-	-	63,020	-	-	-	-	-	-	-
Membras martinica	Rough silverside	-	-	124,654	-	-	-	124,654	-	-	-	-	-	-	-
Menidia spp.	Atlantic silverside	139,266	-	-	-	-	-	139,266	-	-	-	-	-	-	-
Menticirrhus spp.	kingfish	-	-	23,950,544	-	-	-	23,950,544	-	-	5,363,938	78,774	-	-	5,442,741
Microdesmus longipinnis	Pink wormfish	-	-	3,408,510	-	-	-	3,408,510	-	-	141,845	-	-	-	141,845
Microgobius gulosus	Clown goby	-	-	155,052	-	-	-	155,052	-	-	-	-	-	-	-
Microgobius spp.	Gobies	-	-	121,165	-	-	-	121,165	-	-	-	-	-	-	-
Oligoplites saurus	Leatherjacket	-	-	-	-	-	-	-	-	60,663	427,951	-	-	-	488,619
Prionotus scitulus	Leopard searobin	-	-	122,518	-	-	-	122,518	-	-	-	-	-	-	-
Prionotus spp.	Searobins	-	-	122,331	-	-	-	122,331	-	-	609,205	-	-	-	609,205
Prionotus tribulus	Bighead searobin	-	-	146,134	-	-	-	146,134	-	-	-	-	-	-	-

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Scientific Name	Common Name	Sample Year 1							Sample Year 2						
		Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total	Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total
Sciaenidae	Drums and croakers	3,135,764,800	84,449	3,977,489	-	-	-	3,139,849,600	3,130,318,400	-	4,247,341	-	-	2,054,569	3,136,700,900
Scorpaenidae	Scorpionfish	-	-	-	-	-	-	-	-	-	78,774	-	-	-	78,774
Symphurus plagiusa	Blackcheek tonguefish	-	-	437,712	-	-	-	437,712	-	-	2,085,290	-	-	-	2,085,290
Syngnathus louisianae	Chain pipefish	-	-	306,896	219,005	-	-	525,892	-	-	1,728,892	342,927	-	-	2,071,845
Trinectes maculatus	Hogchoker	-	62,514	1,474,102	-	-	-	1,536,651	-	-	810,595	-	-	-	810,595
Trinectes spp.	Soles	156,286	-	-	-	-	-	156,286	-	-	-	-	-	-	-
Unidentified species		11,736,992	503,256	1,401,597	-	-	69,490	13,711,312	1,156,424	703,590	2,831,107	-	-	1,295,648	5,986,785
Fish Total		***3,775,291,300***	***3,445,103***	***186,011,580***	***502,950***	***-***	***132,007***	***3,965,404,700***	***7,647,851,900***	***18,808,802***	***109,651,350***	***988,096***	***-***	***18,131,406***	***7,795,415,300***
SHELLFISH															
Callinectes sapidus	Blue crab	-	-	61,793	-	-	-	61,793	-	-	-	-	-	-	-
Menippe sp.	Stone crab	-	140,661,790	-	-	-	-	140,661,790	473,139	293,067,380	-	-	-	3,555,138	297,092,610
Penaeidae	Penaeid shrimp	-	-	-	-	-	11,446,801	11,446,801	-	-	-	-	-	30,563,665	42,949,970
Sepioteuthis sepioidea	Caribbean reef squid	-	-	-	-	-	677,924	677,924	-	-	-	-	-	1,431,297	1,431,297
Other shellfish*		1,500,058	1,852,031,300	187,185,960	1,418,447	27,983,433	1,272,245,000	3,342,132,300	3,166,997	3,910,259,900	394,710,820	2,994,754	69,424,000,	2,686,011,300	7,056,236,700
Shellfish Total		***1,500,058***	***1,992,701,600***	***187,024,270***	***1,418,447***	***27,983,433***	***1,284,329,200***	***3,494,971,900***	***3,640,153***	***4,203,344,300***	***394,710,820***	***2,994,754***	***59,079,824***	***2,715,115,500***	***7,378,850,800***
GRAND TOTAL		***3,776,823,100***	***1,996,190,700***	***373,035,850***	***1,921,388***	***27,983,433***	***1,284,499,400***	***7,460,376,600***	***7,651,511,200***	***4,222,151,400***	***504,370,680***	***3,982,765***	***59,079,824***	***2,733,241,800***	***15,174,181,000***

Annualized counts of surrogates

Scientific Names	Proportion of Surrogates	Sample Year 1						Sample Year 2					
		Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH													
Anchoa mitchilli	4.51%	627,893,330	2,918,930	31,912,500	107,847	-	662,835,390	4,471,834,800	18,533,078	59,146,202	57,323	-	4,549,531,100
Bairdiella chrysoura	0.36%	1,856	74,181	52,596,055	4,133	-	52,676,049	1,853	1,082	8,888,695	4,555	-	8,895,503
Cynoscion regalis	0.11%	543.789	285.085	15,422,673	1,210	-	15,424,375	542.938	316.572	4,652,162	1,334	-	4,654,289
Gobiosoma bosc	0.22%	1,166	220,528	32,730,311	138,534	-	33,090,284	1,164	679.098	15,435,438	2,862	-	15,440,544
Gerreidae	0.00%	6.808	3.404	197,126	15.318	-	197,151	6.808	4.255	1,177	17.02	-	1,205
Sciaenidae	21.77%	3,145,636,400	157,920	50,935,754	250,875	-	3,197,036,800	3,130,914,100	128,637	32,015,471	921,633	-	3,164,018,000
Trinectes maculatus	0.03%	1,740,295	73,286	2,353,270	326.784	-	4,167,177	45,086,831	144,542	7,647,256	359.973	-	52,879,438
	Fish total	***3,775,291,300***	***3,445,103***	***186,147,740***	***502,950***	***-***	***3,965,404,700***	***7,647,851,900***	***18,808,802***	***127,786,160***	***988,096***	***-***	***7,795,415,300***
SHELLFISH													
Anomura crabs	12.65%	189,518	429,363,540	8,461,748	736,149	3,489,526	442,239,170	400,115	906,485,200	17,864,192	1,554,181	7,367,192	933,717,200
Callinectes sapidus	0.002%	27.232	1,282	61,977	1.702	-	63,289	1.702	2,610	295.297	3.404	-	2,910
Brachyuran crabs	79.31%	1,187,911	2,487,643,200	260,218,780	925,037	23,266,340	2,773,238,800	2,507,982	5,252,116,700	549,380,070	1,953,045	49,121,422	5,855,050,200
Caridean shrimp	3.50%	52,404	119,386,790	1,390,960	3,111	1,450,785	122,288,700	110,639	252,057,690	2,936,461	6,569	3,063,004	258,176,380
Menippe mercenaria	4.15%	62,228	143,580,720	420,785	3,694	-	144,065,790	604,567	302,785,800	888,189	7,800	-	304,292,070
Penaeid shrimp	0.34%	5,064	10,708,133	1,010,648	300.403	-	11,723,376	10,691	22,613,623	2,127,160	634.846	-	24,752,186
	Shellfish total	***1,497,164***	***3,190,654,300***	***271,562,610***	***1,668,300***	***28,207,246***	***3,493,610,300***	***3,634,025***	***6,736,090,500***	***573,191,050***	***3,522,289***	***59,552,129***	***7,375,957,400***

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Equivalent adults of surrogate groupings

Scientific Names	Sample Year 1						Sample Year 2					
	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH												
Cynoscion regalis	<1	<1	801	73	-	874	<1	<1	242	136	-	378
Sciaenidae	4,984	3	4,068	3,767	-	12,822	4,961	3	2,556	13,842	-	21,361
Fish total	***4,984***	***3***	***4,869***	***3,841***	***-***	***13,696***	***4,961***	***3***	***2,798***	***13,978***	***-***	***21,739***
SHELLFISH												
Callinectes sapidus	-	<1	<1	<1	-	<1	-	<1	<1	<1	-	<1
Menippe mercenaria	40	281	2,367	143	-	2,831	85	591.445	4,997	302	-	5,975
Penaeidae	<1	47	28.934	<1	-	75.739	<1	98.716	61.272	<1	-	159.988
Shellfish total	***40***	***328***	***2,396***	***143***	***-***	***2,907***	***85***	***690***	***5,058***	***302***	***-***	***6,135***

Foregone production (kg) of surrogate groupings

Scientific Names	Sample Year 1						Sample Year 2					
	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH												
Anchoa mitchilli	155	3	247	96	-	500	1,103	14	250	51	-	1,420
Bairdiella chrysoura	<1	1	1,779	7	-	1,787	<1	<1	300	8	-	308
Gobiosoma bosc	<1	155	-	2	-	157	<1	72	-	<1	-	72
Gerreidae	<1	<1	9	<1	-	9	<1	<1	<1	<1	-	<1
Trinectes maculatus	20	414	-	1	-	435	511	1,330	-	1	-	1,842
Fish total	***174***	***573***	***2,035***	***106***	***-***	***2,887***	***1,614***	***1,417***	***551***	***60***	***-***	***3,641***
SHELLFISH												
Anomura crabs	-	1,032	519	169	1,745	3,464	-	2,179	1,095	356	3,684	7,314
Brachyuran crabs	-	46,627	30,968	1,950	510,760	590,300	-	98,444	65,380	4,117	1,078,390	1,246,300
Caridean shrimp	-	38	65	-	189	292	-	81	137	-	398	616
Shellfish total	***-***	***47,698***	***31,552***	***2,118***	***512,690***	***594,060***	***-***	***100,700***	***66,610***	***4,473***	***1,082,500***	***1,254,200***

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TAMPA ELECTRIC COMPANY
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Appendix 11-C

Fine-mesh Screens, Modeling Results Expressed as Benefits of Technology

11-C

Annualized entrainment counts

Scientific Name	Common Name	Sample Year 1							Sample Year 2						
		Eggs	Larvae/	Post larvae	Juvenile	Adult	Unknown	Taxa Total	Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total
FISH															
Achiridae	American soles	887,300	-	-	-	-	-	887,300	25,341,000	12,522	-	-	-	-	25,353,000
Achirus lineatus	Lined sole	-	-	77,494	-	-	-	77,494	-	16,176	890,020	-	-	-	906,200
Anchoa hepsetus	Broad-striped anchovy	34,137	-	-	-	-	-	34,137	235,950	-	-	-	-	-	235,950
Anchoa mitchilli	Bay anchovy	147,610,000	244,110	2,482,400	-	-	-	150,340,000	1,054,400,000	1,753,300	3,577,700	-	-	-	1,059,800,000
Anchoa spp.	Common anchovy	-	-	-	-	-	-	-	-	-	13,554	-	-	-	13,554
Bairdiella chrysoura	Silver perch	-	13,137	11,520,000	-	-	-	11,533,000	-	-	1,856,400	-	-	-	1,856,400
Bathygobius soporator	Frillfin goby	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Blenniidae	Blennies	-	12,902	3,789,300	-	-	-	3,802,200	-	-	3,264,900	-	-	35,796	3,300,700
Carangidae	Jacks and Pompanos	-	-	-	-	-	-	-	-	-	19,043	-	-	-	19,043
Chaetodipterus faber	Atlantic spadefish	-	-	10,734	-	-	-	10,734	-	-	52,819	-	-	-	52,819
Chasmodes saburrae	Florida blenny	-	-	51,425	-	-	-	51,425	-	-	-	-	-	-	-
Chloroscombrus chrysurus	Atlantic bumper	-	-	28,989	-	-	-	28,989	-	-	74,853	159,730	-	-	234,590
Clupeidae	Herrings	-	-	14,218	-	-	-	14,218	13,390	22,095	7,176	-	-	-	42,660
Cynoscion arenarius	Sand seatrout	-	-	3,811,300	-	-	-	3,811,300	-	-	579,920	-	-	-	579,920
Cynoscion nebulosus	spotted seatrout	-	-	426,550	-	-	-	426,550	-	-	710,060	-	-	-	710,060
Eugerres plumieri	Striped mojarra	-	-	54,784	-	-	-	54,784	-	-	-	-	-	-	-
Gobiesox strumosus	Skilletfish	-	-	777,230	10,544	-	-	787,770	-	-	254,830	-	-	-	254,830
Gobiidae	Gobies	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiosoma robustum	Naked goby	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiosoma spp.	Naked gobies	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippocampus erectus	Lined seahorse	-	-	-	8,219	-	-	8,219	-	-	-	-	-	-	-
Lagodon rhomboides	Pinfish	-	-	-	10,549	-	-	10,549	-	-	-	-	-	-	-
Membras martinica	Rough silverside	-	-	26,367	-	-	-	26,367	-	-	-	-	-	-	-
Menidia spp.	Atlantic silverside	52,162	-	-	-	-	-	52,162	-	-	-	-	-	-	-
Menticirrhus spp.	kingfish	-	-	7,191,200	-	-	-	7,191,200	-	-	1,610,500	26,844	-	-	1,637,400
Microdesmus longipinnis	Pink wormfish	-	-	315,320	-	-	-	315,320	-	-	13,122	-	-	-	13,122
Microgobius gulosus	Clown goby	-	-	21,073	-	-	-	21,073	-	-	-	-	-	-	-
Microgobius spp.	Gobies	-	-	16,467	-	-	-	16,467	-	-	-	-	-	-	-
Oligoplites saurus	Leatherjacket	-	-	-	-	-	-	-	-	17,108	111,020	-	-	-	128,130
Prionotus scitulus	Leopard searobin	-	-	3,593	-	-	-	3,593	-	-	-	-	-	-	-
Prionotus spp.	Searobins	-	-	3,588	-	-	-	3,588	-	-	17,866	-	-	-	17,866
Prionotus tribulus	Bighead searobin	-	-	4,286	-	-	-	4,286	-	-	-	-	-	-	-
Sciaenidae	Drums and croakers	1,140,300,000	17,747	1,050,400	-	-	-	1,141,400,000	1,138,300,000	-	1,121,700	-	-	233,380	1,139,700,000
Scorpaenidae	Scorpionfish	-	-	-	-	-	-	-	-	-	16,107	-	-	-	16,107
Symphurus plagiusa	Blackcheek tonguefish	-	-	104,530	-	-	-	104,530	-	-	498,010	-	-	-	498,010
Syngnathus louisianae	Chain pipefish	-	-	37,013	49,411	-	-	86,424	-	-	208,510	77,371	-	-	285,880
Trinectes maculatus	Hogchoker	-	12,902	381,110	-	-	-	394,020	-	-	209,570	-	-	-	209,570
Trinectes spp.	Soles	87,850	-	-	-	-	-	87,850	-	-	-	-	-	-	-

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Scientific Name	Common Name	Sample Year 1							Sample Year 2						
		Eggs	Larvae/	Post larvae	Juvenile	Adult	Unknown	Taxa Total	Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total
Unidentified species		4,766,600	94,624	214,820	-	-	9,799	5,085,800	469,660	132,290	433,920	-	-	182,700	1,218,600
	Fish Total	***1,293,700,000***	***395,420***	***32,414,000***	***78,723***	***-***	***9,799***	***1,326,600,000***	***2,218,800,000***	***1,953,500***	***15,542,000***	***263,950***	***-***	***451,880***	***2,237,000,000***
SHELLFISH															
Callinectes sapidus	Blue crab	-	-	56,637	-	-	-	56,637	-	-	-	-	-	-	-
Menippe sp.	Stone crab	-	118,040,000	-	-	-	-	118,040,000	177,210	245,940,000	-	-	-	-	246,120,000
Penaeidae	Penaeid shrimp	-	-	-	-	-	9,606,500	9,606,500	-	-	-	-	-	20,020,000	20,020,000
Sepioteuthis sepioidea	Caribbean reef squid	-	-	-	-	-	568,950	568,950	-	-	-	-	-	1,185,700	1,185,700
Other shellfish*		1,258,900	1,554,300,000	156,900,000	1,190,400	23,485,000	1,067,700,000	2,804,900,000	2,623,600	3,239,300,000	326,990,000	2,480,900	48,943,000	2,225,200,000	5,845,500,000
	Shellfish Total	***1,258,900***	***1,672,400,000***	***156,960,000***	***1,190,400***	***23,485,000***	***1,077,900,000***	***2,933,100,000***	***2,800,800***	***3,485,300,000***	***326,990,000***	***2,480,900***	***48,943,000***	***2,246,400,000***	***6,112,800,000***
	GRAND TOTAL	***1,295,000,000***	***1,672,700,000***	***189,370,000***	***1,269,200***	***23,485,000***	***1,077,900,000***	***4,259,800,000***	***2,221,600,000***	***3,487,200,000***	***342,530,000***	***2,744,900***	***48,943,000***	***2,246,800,000***	***8,349,800,000***

Annualized counts of surrogates

Scientific Names	Proportion of Surrogates	Sample Year 1						Sample Year 2					
		Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH													
Anchoa mitchilli	11.43%	148,195,632	322,841	2,988,482	73,403	-	151,580,359	1,054,886,915	1,883,349	21,917,181	8,840	-	1,078,696,285
Bairdiella chrysoura	0.88%	460	17,419	1,634,021	599	-	11,652,498	118	208	1,945,618	680	-	1,946,623
Cynoscion regalis	0.32%	169	55	4,279,898	220	-	4,280,342	43	76	1,340,210	250	-	1,340,579
Gobiosoma bosc	0.06%	33	11	822,897	10,587	-	33,527	8	15	813,064	49	-	813,136
Gerreidae	0.00%	2	1	55,328	3	-	55,334	1	1	170	3	-	175
Sciaenidae	87.19%	1,144,544,878	38,117	12,061,109	59,444	-	1,156,703,548	1,138,565,193	39,014	9,183,109	254,036	-	1,148,041,351
Trinectes maculatus	0.12%	978,816	16,981	571,961	81	-	1,567,838	25,345,989	30,811	1,648,312	91	-	27,025,203
	Fish total	***1,293,719,991***	***395,423***	***32,413,696***	***144,336***	***-***	***1,326,673,447***	***2,218,798,267***	***1,953,474***	***36,847,663***	***263,948***	***-***	***2,257,863,352***
SHELLFISH													
Anomura crabs	12.65%	159,052	360,339,137	7,330,426	617,810	2,928,534	371,374,959	331,468	750,967,367	15,297,766	1,287,534	6,103,195	773,987,330
Callinectes sapidus	0.00%	25	1,175	56,843	1	0	58,044	1	2,360	346	3	0	2,710
Brachyuran crabs	79.31%	996,953	2,087,735,161	219,822,996	776,365	19,526,400	2,328,857,876	2,077,674	4,350,965,249	458,247,799	1,617,983	40,693,877	4,853,602,581
Caridean shrimp	3.50%	43,980	100,194,921	1,230,683	2,611	1,217,593	102,689,787	91,655	208,811,927	2,570,575	5,442	2,537,509	214,017,107
Menippe mercenaria	4.15%	52,222	120,490,459	428,292	3,100	0	120,974,074	286,096	251,049,845	899,548	6,462	0	252,241,950
Penaeid shrimp	0.34%	4,250	8,986,373	854,292	252	0	9,845,168	8,857	18,733,549	1,775,514	526	0	20,518,446
	Shellfish total	***1,256,482***	***2,677,747,226***	***229,723,533***	***1,400,140***	***23,672,528***	***2,933,799,908***	***2,795,750***	***5,580,530,296***	***478,791,548***	***2,917,949***	***49,334,581***	***6,114,370,124***

Equivalent adults of surrogate groupings

Scientific Names	Sample Year 1						Sample Year 2					
	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH												
Cynoscion regalis	0	0	222	13	-	236	0	0	70	15	-	85
Sciaenidae	1,813	1	963	893	-	3,670	1,804	1	733	3,815	-	6,353
Fish total	***1,813***	***1***	***1,185***	***906***	***-***	***3,906***	***1,804***	***1***	***803***	***3,830***	***-***	***6,438***
SHELLFISH												
Callinectes sapidus	-	0	0	0	0	0	-	0	0	0	0	0
Menippe mercenaria	34	235	2,410	120	0	2,799	70	490	5,061	250	0	5,872
Penaeidae	0	39	-	25	0	64	0	82	-	51	0	133
Shellfish total	***34***	***274***	***2,410***	***145***	***0***	***2,863***	***70***	***572***	***5,061***	***301***	***0***	***6,005***

Foregone production (kg) of surrogate groupings

Scientific Names	Sample Year 1						Sample Year 2					
	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH												
Anchoa mitchilli	37	0	23	66	-	125	260	1	169	60	-	491
Bairdiella chrysoura	0	0	394	1	-	395	0	0	66	1	-	67
Gobiosoma bosc	0	0	1	2	-	3	0	0	0	3	-	3
Gerreidae	0	4	-	0	-	4	0	4	-	0	-	4
Trinectes maculatus	11	100	-	<1	-	112	287	287	-	<1	-	574
Fish total	***48***	***104***	***418***	***69***	***-***	***639***	***547***	***292***	***235***	***64***	***-***	***1,139***
SHELLFISH												
Anomura crabs	-	866	450	141	1,464	2,921		1,805	938	295	3,052	6,089
Brachyuran crabs	-	39,131	26,160	1,637	428,656	495,583		81,551	54,534	3,411	893,337	1,032,833
Caridean shrimp	-	32	57		158	248		67	120		330	517
Shellfish total	***-***	***40,029***	***26,667***	***1,778***	***430,280***	***498,750***	***-***	***83,423***	***55,592***	***3,705***	***896,720***	***1,039,400***

Appendix 11-D

Variable-speed Pumps 4-Percent, Modeling Results Expressed as Benefit of Technology

11-D

Annualized entrainment counts

Scientific Name	Common Name	Sample Year 1							Sample Year 2						
		Eggs	Larvae/	Post larvae	Juvenile	Adult	Unknown	Taxa Total	Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total
FISH															
Achiridae	American soles	74,194	-	-	-	-	-	74,194	2,118,900	2,852	-	-	-	-	2,121,800
Achirus lineatus	Lined sole	-	-	18,538	-	-	-	18,538	-	3,684	212,910	-	-	-	216,590
Anchoa hepsetus	Broad-striped anchovy	10,498	-	-	-	-	-	10,498	72,561	-	-	-	-	-	72,561
Anchoa mitchilli	Bay anchovy	29,410,000	116,660	1,269,400	2,625	-	-	30,799,000	210,090,000	837,920	1,829,500	-	-	659,490	213,410,000
Anchoa spp.	Common anchovy	-	-	-	-	-	-	-	-	-	5,702	-	-	-	5,702
Bairdiella chrysoura	Silver perch	-	2,938	2,436,200	-	-	-	2,439,100	-	-	392,600	-	-	-	392,600
Bathygobius soporator	Frillfin goby	-	2,950	343,800	3,429	-	2,938	353,120	-	-	179,110	-	-	5,891	185,000
Blenniidae	Blennies	-	2,938	1,080,600	-	-	-	1,083,500	-	-	931,020	-	-	14,915	945,930
Carangidae	Jacks and Pompanos	-	-	-	-	-	-	-	-	-	3,703	-	-	-	3,703
Chaetodipterus faber	Atlantic spadefish	-	-	2,879	-	-	-	2,879	-	-	14,169	-	-	-	14,169
Chasmodes saburrae	Florida blenny	-	-	14,664	-	-	-	14,664	-	-	-	-	-	-	-
Chloroscombrus chrysurus	Atlantic bumper	-	-	5,844	-	-	-	5,844	-	-	15,090	26,622	-	-	41,712
Clupeidae	Herrings	-	-	14,745	-	-	-	14,745	6,559	3,682	2,949	-	-	-	13,190
Cynoscion arenarius	Sand seatrout	-	-	648,150	-	-	-	648,150	-	-	98,623	-	-	-	98,623
Cynoscion nebulosus	spotted seatrout	-	-	66,188	-	-	-	66,188	-	-	110,180	-	-	-	110,180
Eugerres plumieri	Striped mojarra	-	-	9,131	-	-	-	9,131	-	-	-	-	-	-	-
Gobiesox strumosus	Skilletfish	-	-	208,340	2,961	-	-	211,300	-	-	68,309	-	-	-	68,309
Gobiidae	Gobies	-	5,877	196,560	-	-	-	202,440	-	-	46,433	-	-	-	46,433
Gobiosoma robustum	Naked goby	-	-	661,920	-	-	-	661,920	-	-	382,540	-	-	14,475	397,010
Gobiosoma spp.	Naked gobies	-	-	86,131	-	-	-	86,131	-	-	-	-	-	-	-
Hippocampus erectus	Lined seahorse	-	-	-	1,370	-	-	1,370	-	-	-	-	-	-	-
Lagodon rhomboides	Pinfish	-	-	-	2,962	-	-	2,962	-	-	-	-	-	-	-
Membras martinica	Rough silverside	-	-	5,859	-	-	-	5,859	-	-	-	-	-	-	-
Menidia spp.	Atlantic silverside	6,546	-	-	-	-	-	6,546	-	-	-	-	-	-	-
Menticirrhus spp.	kingfish	-	-	1,125,800	-	-	-	1,125,800	-	-	252,120	3,703	-	-	255,830
Microdesmus longipinnis	Pink wormfish	-	-	160,210	-	-	-	160,210	-	-	6,667	-	-	-	6,667
Microgobius gulosus	Clown goby	-	-	7,288	-	-	-	7,288	-	-	-	-	-	-	-
Microgobius spp.	Gobies	-	-	5,695	-	-	-	5,695	-	-	-	-	-	-	-
Oligoplites saurus	Leatherjacket	-	-	-	-	-	-	-	-	2,851	20,115	-	-	-	22,967
Prionotus scitulus	Leopard searobin	-	-	5,759	-	-	-	5,759	-	-	-	-	-	-	-
Prionotus spp.	Searobins	-	-	5,750	-	-	-	5,750	-	-	28,635	-	-	-	28,635
Prionotus tribulus	Bighead searobin	-	-	6,869	-	-	-	6,869	-	-	-	-	-	-	-
Sciaenidae	Drums and croakers	147,390,000	3,969	186,960	-	-	-	147,580,000	147,140,000	-	199,640	-	-	96,571	147,430,000
Scorpaenidae	Scorpionfish	-	-	-	-	-	-	-	-	-	3,703	-	-	-	3,703
Symphurus plagiusa	Blackcheek tonguefish	-	-	20,574	-	-	-	20,574	-	-	98,016	-	-	-	98,016
Syngnathus louisianae	Chain pipefish	-	-	14,425	10,294	-	-	24,719	-	-	81,264	16,119	-	-	97,383
Trinectes maculatus	Hogchoker	-	2,938	69,289	-	-	-	72,227	-	-	38,101	-	-	-	38,101
Trinectes spp.	Soles	7,346	-	-	-	-	-	7,346	-	-	-	-	-	-	-

Scientific Name	Common Name	Sample Year 1							Sample Year 2						
		Eggs	Larvae/	Post larvae	Juvenile	Adult	Unknown	Taxa Total	Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total
Unidentified species		551,670	23,655	65,879	-	-	3,266	644,470	54,357	33,071	133,070	-	-	60,902	281,400
	Fish Total	***177,450,000***	***161,930***	***8,743,400***	***23,640***	***-***	***6,205***	***186,390,000***	***359,480,000***	***884,060***	***5,154,200***	***46,444***	***-***	***852,240***	***366,410,000***
SHELLFISH															
Callinectes sapidus	Blue crab	-	-	2,905	-	-	-	2,905	-	-	-	-	-	-	-
Menippe sp.	Stone crab	-	6,611,400	-	-	-	-	6,611,400	22,239	13,775,000	-	-	-	167,100	13,964,000
Penaeidae	Penaeid shrimp	-	-	-	-	-	538,030	538,030	-	-	-	-	-	1,135,900	1,135,900
Sepioteuthis sepioidea	Caribbean reef squid	-	-	-	-	-	31,865	31,865	-	-	-	-	-	67,274	67,274
Other shellfish*		70,508	87,053,000	8,787,700	66,673	1,315,300	59,800,000	157,090,000	148,860	183,800,000	18,553,000	140,760	2,777,000	126,250,000	331,670,000
	Shellfish Total	***70,508***	***93,664,000***	***8,790,600***	***66,673***	***1,315,300***	***60,370,000***	***164,280,000***	***171,100***	***197,570,000***	***18,553,000***	***140,760***	***2,777,000***	***127,620,000***	***346,830,000***
	GRAND TOTAL	***177,520,000***	***93,826,000***	***17,534,000***	***90,313***	***1,315,300***	***60,376,000***	***350,670,000***	***359,650,000***	***198,450,000***	***23,707,000***	***187,210***	***2,777,000***	***128,470,000***	***713,250,000***

Annualized counts of surrogates

Scientific Names	Proportion of Surrogates	Sample Year 1						Sample Year 2					
		Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH													
Anchoa mitchilli	16.72%	29,513,200	137,200	1,500,000	5,069	-	31,155,600	210,192,000	871,120	2,780,080	2,694	-	213,844,000
Bairdiella chrysoura	1.33%	87	3,487	2,472,200	194	-	2,475,960	87	51	417,800	214	-	418,120
Cynoscion regalis	0.39%	25.56	13.4	724,920	57	-	725,000	25.52	14.88	218,668	63	-	218,768
Gobiosoma bosc	0.83%	55	10,366	1,538,440	6,512	-	1,555,360	55	31.92	725,520	135	-	725,760
Gerreidae	0.00%	0.32	0.16	9,266	0.72	-	9,267	0.32	0.2	55	0.8	-	57
Sciaenidae	80.62%	147,856,000	7,423	2,394,160	11,792	-	150,272,000	147,164,000	6,046	1,504,840	43,320	-	148,720,000
Trinectes maculatus	0.11%	81,800	3,445	110,612	15.36	-	195,872	2,119,240	6,794	359,448	16.92	-	2,485,520
	Fish total	***177,452,000***	***161,932***	***8,749,600***	***23,640***	***-***	***186,388,000***	***359,476,000***	***884,080***	***6,006,400***	***46,444***	***-***	***366,412,000***
SHELLFISH													
Anomura crabs	12.65%	8,908	20,181,600	397,732	34,602	164,020	20,786,800	18,807	42,608,000	839,680	73,052	346,284	43,888,000
Callinectes sapidus	0.002%	1.28	60	2,913	0.08	-	2,975	0.08	123	13.88	0.16	-	137
Brachyuran crabs	79.31%	55,836	116,928,000	12,231,200	43,480	1,093,600	130,352,000	117,884	246,868,000	25,822,800	91,800	2,308,880	275,208,000
Caridean shrimp	3.50%	2,463	5,611,600	65,380	146	68,192	5,748,000	5,200	11,847,600	138,024	309	143,972	12,135,200
Menippe mercenaria	4.15%	2,925	6,748,800	19,778	174	-	6,771,600	28,417	14,232,000	41,748	367	-	14,302,800
Penaeid shrimp	0.34%	238	503,320	47,504	14.12	-	551,040	503	1,062,920	99,984	29.84	-	1,163,440
	Shellfish total	***70,372***	***149,972,000***	***12,764,400***	***78,416***	***1,325,840***	***164,212,000***	***170,812***	***316,620,000***	***26,942,000***	***165,560***	***2,799,160***	***346,696,000***

Equivalent adults of surrogate groupings

Scientific Names	Sample Year 1						Sample Year 2					
	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH												
Cynoscion regalis	<1	<1	38	3	-	41	<1	<1	11	6	-	18
Sciaenidae	234	<1	191	177	-	603	233	<1	120	651	-	1,004
Fish total	***34***	***<1***	***229***	***181***	***-***	***644***	***233***	***<1***	***132***	***657***	***-***	***1,022***
SHELLFISH												
Callinectes sapidus	-	<1	<1	<1	-	<1	-	<1	<1	<1	-	<1
Menippe mercenaria	2	13	111	7	-	133	4	28	235	14	-	281
Penaeidae	<1	2	1	<1	-	4	<1	5	3	<1	-	8
Shellfish total	***2***	***15***	***113***	***7***	***-***	***137***	***4***	***32***	***238***	***14***	***-***	***288***

Foregone production (kg) of surrogate groupings

Scientific Names	Sample Year 1						Sample Year 2					
	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH												
Anchoa mitchilli	7	<1	12	4	-	23	52	1	12	2	-	67
Bairdiella chrysoura	<1	<1	84	<1	-	84	<1	<1	14	<1	-	14
Gobiosoma bosc	<1	7	-	<1	-	7	<1	3	-	<1	-	3
Gerreidae	<1	<1	<1	<1	-	<1	<1	<1	<1	<1	-	<1
Trinectes maculatus	1	19	-	<1	-	20	24	63	-	<1	-	87
Fish total	***8***	***27***	***96***	***5***	***-***	***136***	***76***	***67***	***26***	***3***	***-***	***171***
SHELLFISH												
Anomura crabs	-	49	24	8	82	163	-	102	51	17	173	344
Brachyuran crabs	-	2,192	1,456	92	24,008	27,746	-	4,627	3,073	194	50,688	58,580
Caridean shrimp	-	2	3	-	9	14	-	4	6	-	19	29
Shellfish total	**-**	**2,242**	**1,483**	**100**	**24,099**	**27,923**	**-**	**4,733**	**3,131**	**210**	**50,880**	**59,953**

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Appendix 11-E

Variable-speed Pumps 27-Percent, Modeling Results Expressed as Benefit of Technology

11-E

Annualized entrainment counts

Scientific Name	Common Name	Sample Year 1							Sample Year 2						
		Eggs	Larvae/	Post larvae	Juvenile	Adult	Unknown	Taxa Total	Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total
FISH															
Achiridae	American soles	500,810	-	-	-	-	-	500,810	14,303,000	19,251	-	-	-	-	14,322,000
Achirus lineatus	Lined sole	-	-	125,130	-	-	-	125,130	-	24,867	1,437,100	-	-	-	1,462,000
Anchoa hepsetus	Broad-striped anchovy	70,862	-	-	-	-	-	70,862	489,790	-	-	-	-	-	489,790
Anchoa mitchilli	Bay anchovy	198,520,000	787,490	8,568,600	17,716	-	-	207,890,000	1,418,100,000	5,656,000	12,349,000	-	-	4,451,500	1,440,500,000
Anchoa spp.	Common anchovy	-	-	-	-	-	-	-	-	-	38,485	-	-	-	38,485
Bairdiella chrysoura	Silver perch	-	19,834	16,444,000	-	-	-	16,464,000	-	-	2,650,000	-	-	-	2,650,000
Bathygobius soporator	Frillfin goby	-	19,912	2,320,700	23,145	-	19,834	2,383,600	-	-	1,209,000	-	-	39,765	1,248,800
Blenniidae	Blennies	-	19,834	7,293,800	-	-	-	7,313,700	-	-	6,284,400	-	-	100,680	6,385,100
Carangidae	Jacks and Pompanos	-	-	-	-	-	-	-	-	-	24,993	-	-	-	24,993
Chaetodipterus faber	Atlantic spadefish	-	-	19,436	-	-	-	19,436	-	-	95,640	-	-	-	95,640
Chasmodes saburrae	Florida blenny	-	-	98,984	-	-	-	98,984	-	-	-	-	-	-	-
Chloroscombrus chrysurus	Atlantic bumper	-	-	39,448	-	-	-	39,448	-	-	101,860	179,700	-	-	281,560
Clupeidae	Herrings	-	-	99,526	-	-	-	99,526	44,270	24,856	19,908	-	-	-	89,034
Cynoscion arenarius	Sand seatrout	-	-	4,375,000	-	-	-	4,375,000	-	-	665,700	-	-	-	665,700
Cynoscion nebulosus	spotted seatrout	-	-	446,770	-	-	-	446,770	-	-	743,720	-	-	-	743,720
Eugerres plumieri	Striped mojarra	-	-	61,632	-	-	-	61,632	-	-	-	-	-	-	-
Gobiesox strumosus	Skilletfish	-	-	1,406,300	19,986	-	-	1,426,300	-	-	461,080	-	-	-	461,080
Gobiidae	Gobies	-	39,668	1,326,800	-	-	-	1,366,500	-	-	313,420	-	-	-	313,420
Gobiosoma robustum	Naked goby	-	-	4,468,000	-	-	-	4,468,000	-	-	2,582,100	-	-	97,708	2,679,800
Gobiosoma spp.	Naked gobies	-	-	581,390	-	-	-	581,390	-	-	-	-	-	-	-
Hippocampus erectus	Lined seahorse	-	-	-	9,247	-	-	9,247	-	-	-	-	-	-	-
Lagodon rhomboides	Pinfish	-	-	-	19,995	-	-	19,995	-	-	-	-	-	-	-
Membras martinica	Rough silverside	-	-	39,550	-	-	-	39,550	-	-	-	-	-	-	-
Menidia spp.	Atlantic silverside	44,186	-	-	-	-	-	44,186	-	-	-	-	-	-	-
Menticirrhus spp.	kingfish	-	-	7,598,900	-	-	-	7,598,900	-	-	1,701,800	24,993	-	-	1,726,800
Microdesmus longipinnis	Pink wormfish	-	-	1,081,400	-	-	-	1,081,400	-	-	45,004	-	-	-	45,004
Microgobius gulosus	Clown goby	-	-	49,194	-	-	-	49,194	-	-	-	-	-	-	-
Microgobius spp.	Gobies	-	-	38,442	-	-	-	38,442	-	-	-	-	-	-	-
Oligoplites saurus	Leatherjacket	-	-	-	-	-	-	-	-	19,247	135,780	-	-	-	155,020
Prionotus scitulus	Leopard searobin	-	-	38,872	-	-	-	38,872	-	-	-	-	-	-	-
Prionotus spp.	Searobins	-	-	38,811	-	-	-	38,811	-	-	193,280	-	-	-	193,280
Prionotus tribulus	Bighead searobin	-	-	46,364	-	-	-	46,364	-	-	-	-	-	-	-
Sciaenidae	Drums and croakers	994,900,000	26,793	1,262,000	-	-	-	996,190,000	993,180,000	-	1,347,600	-	-	651,860	995,180,000
Scorpaenidae	Scorpionfish	-	-	-	-	-	-	-	-	-	24,993	-	-	-	24,993
Symphurus plagiusa	Blackcheek tonguefish	-	-	138,870	-	-	-	138,870	-	-	661,610	-	-	-	661,610
Syngnathus louisianae	Chain pipefish	-	-	97,369	69,484	-	-	166,850	-	-	548,530	108,800	-	-	657,330
Trinectes maculatus	Hogchoker	-	19,834	467,700	-	-	-	487,540	-	-	257,180	-	-	-	257,180
Trinectes spp.	Soles	49,584	-	-	-	-	-	49,584	-	-	-	-	-	-	-

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Scientific Name	Common Name	Sample Year 1							Sample Year 2						
		Eggs	Larvae/	Post larvae	Juvenile	Adult	Unknown	Taxa Total	Eggs	Larvae	Post larvae	Juvenile	Adult	Unknown	Taxa Total
Unidentified species		3,723,800	159,670	444,680	-	-	22,047	4,350,200	366,910	223,230	898,230	-	-	411,090	1,899,500
	Fish Total	***1,197,800,000***	***1,093,000***	***59,018,000***	***159,570***	***-***	***41,882***	***1,258,100,000***	***2,426,500,000***	***5,967,400***	***34,791,000***	***313,500***	***-***	***5,752,600***	***2,473,300,000***
SHELLFISH															
Callinectes sapidus	Blue crab	-	-	19,605	-	-	-	19,605	-	-	-	-	-	-	-
Menippe sp.	Stone crab	-	44,627,000	-	-	-	-	44,627,000	150,110	92,981,000	-	-	-	1,127,900	94,259,000
Penaeidae	Penaeid shrimp	-	-	-	-	-	3,631,700	3,631,700	-	-	-	-	-	7,667,400	7,667,400
Sepioteuthis sepioidea	Caribbean reef squid	-	-	-	-	-	215,090	215,090	-	-	-	-	-	454,100	454,100
Other shellfish*		475,930	587,610,000	59,317,000	450,040	8,878,400	403,650,000	1,060,400,000	1,004,800	1,240,600,000	125,230,000	950,140	18,744,000	852,200,000	2,238,700,000
	Shellfish Total	***475,930***	***632,230,000***	***59,337,000***	***450,040***	***8,878,400***	***407,500,000***	***1,108,900,000***	***1,154,900***	***1,333,600,000***	***125,230,000***	***950,140***	***18,744,000***	***861,450,000***	***2,341,100,000***
	GRAND TOTAL	***1,198,300,000***	***633,330,000***	***118,350,000***	***609,610***	***8,878,400***	***407,540,000***	***2,367,000,000***	***2,427,600,000***	***1,339,600,000***	***160,020,000***	***1,263,600***	***18,744,000***	***867,200,000***	***4,814,400,000***

Annualized counts of surrogates

Scientific Names	Proportion of Surrogates	Sample Year 1						Sample Year 2					
		Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH													
Anchoa mitchilli	16.72%	199,214,100	926,100	10,125,000	34,217	-	210,300,300	1,418,796,000	5,880,060	18,765,540	18,187	-	1,443,447,000
Bairdiella chrysoura	1.33%	589	23,536	16,687,350	1,311	-	16,712,730	588	343	2,820,150	1,445	-	2,822,310
Cynoscion regalis	0.39%	172.53	90.45	4,893,210	384	-	4,893,750	172.26	100.44	1,476,009	423	-	1,476,684
Gobiosoma bosc	0.83%	370	69,968	10,384,470	43,953	-	10,498,680	369	215.46	4,897,260	908	-	4,898,880
Gerreidae	0.00%	2.16	1.08	62,543	4.86	-	62,551	2.16	1.35	373	5.4	-	382
Sciaenidae	80.62%	998,028,000	50,104	16,160,580	79,596	-	1,014,336,000	993,357,000	40,813	10,157,670	292,410	-	1,003,860,000
Trinectes maculatus	0.11%	552,150	23,252	746,631	103.68	-	1,322,136	14,304,870	45,860	2,426,274	114.21	-	16,777,260
Fish total		***1,197,801,000***	***1,093,041***	***59,059,800***	***159,573***	***-***	***1,258,119,000***	***2,426,463,000***	***5,967,540***	***40,543,200***	***313,497***	***-***	***2,473,281,000***
SHELLFISH													
Anomura crabs	12.65%	60,129	136,225,800	2,684,691	233,561	1,107,135	140,310,900	126,946	287,604,000	5,667,840	493,101	2,337,417	296,244,000
Callinectes sapidus	0.002%	8.64	407	19,664	0.54	-	20,080	0.54	828	93.69	1.08	-	923
Brachyuran crabs	79.31%	376,893	789,264,000	82,560,600	293,490	7,381,800	879,876,000	795,717	1,666,359,000	174,303,900	619,650	15,584,940	1,857,654,000
Caridean shrimp	3.50%	16,626	37,878,300	441,315	987	460,296	38,799,000	35,103	79,971,300	931,662	2,084	971,811	81,912,600
Menippe mercenaria	4.15%	19,743	45,554,400	133,504	1,172	-	45,708,300	191,813	96,066,000	281,799	2,475	-	96,543,900
Penaeid shrimp	0.34%	1,607	3,397,410	320,652	95.31	-	3,719,520	3,392	7,174,710	674,892	201.42	-	7,853,220
Shellfish total		***475,011***	***1,012,311,000***	***86,159,700***	***529,308***	***8,949,420***	***1,108,431,000***	***1,152,981***	***2,137,185,000***	***181,858,500***	***1,117,530***	***18,894,330***	***2,340,198,000***

Equivalent adults of surrogate groupings

Scientific Names	Sample Year 1						Sample Year 2					
	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH												
Cynoscion regalis	<1	<1	254	23	-	277	<1	<1	77	43	-	120
Sciaenidae	1,581	1	1,291	1,195	-	4,068	1,574	1	811	4,392	-	6,777
Fish total	***1,581***	***1***	***1,545***	***1,219***	***-***	***4,345***	***1,574***	***1***	***888***	***4,435***	***-***	***6,897***
SHELLFISH												
Callinectes sapidus	-	<1	<1	<1	-	<1	-	<1	<1	<1	-	<1
Menippe mercenaria	13	89	751	45	-	898	27	188	1,585	96	-	1,896
Penaeidae	<1	15	9	<1	-	24	<1	31	19	<1	-	51
Shellfish total	***13***	***104***	***760***	***45***	***-***	***922***	***27***	***219***	***1,605***	***96***	***-***	***1,946***

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Foregone production (kg) of surrogate groupings

Scientific Names	Sample Year 1						Sample Year 2					
	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total	Eggs	Larvae	Post larvae/ megalopae	Juvenile	Adult	Taxa Total
FISH												
Anchoa mitchilli	49	1	78	30	-	159	350	5	79	16	-	450
Bairdiella chrysoura	<1	<1	565	2	-	567	<1	<1	95	2	-	98
Gobiosoma bosc	<1	49	-	1	-	50	<1	23	-	<1	-	23
Gerreidae	<1	<1	3	<1	-	3	<1	<1	<1	<1	-	<1
Trinectes maculatus	6	131	-	<1	-	138	162	422	-	<1	-	584
Fish total	***55***	***182***	***646***	***33***	***-***	***916***	***512***	***450***	***175***	***19***	***-***	***1,155***
SHELLFISH												
Anomura crabs	-	328	165	53	554	1,099	-	691	347	113	1,169	2,320
Brachyuran crabs	-	14,794	9,825	619	162,050	187,290	-	31,234	20,743	1,306	342,144	395,420
Caridean shrimp	-	12	21	-	60	93	-	26	43	-	126	195
Shellfish total	***-***	***15,134***	***10,011***	***672***	***162,660***	***188,480***	***-***	***31,951***	***21,134***	***1,419***	***343,430***	***397,940***

Appendix 11-F

Surrogate Taxa Life History Summary

This appendix provides life history information for taxa chosen as surrogates for the benefits valuation study.

1. Bay anchovy (*Anchoa mitchilli*)

Common Names: Common anchovy, Mitchill's anchovy, whitebait, little anchovy.

Similar Species: Atlantic silverside.

Appearance: The bay anchovy has a slender, silvery-green, translucent body. A silver stripe runs along its sides. The bay anchovy has a large mouth, a single dorsal fin on its back, and a forked tail fin.

Length: Adult length is about 2.95 inches. Can grow to 4 inches.

Geographic Range: One of the most common species in the Tampa Bay estuary, as well as one of the most abundant species in estuaries along the mid-Atlantic Ocean region and throughout the Gulf of Mexico. Bay anchovy range from Maine to the coastal Gulf of Mexico to Yucatan, Mexico.

Habitat: Bay anchovies tolerate a wide range of temperatures and salinities. They are found along both the Atlantic and Gulf coasts of Florida. Adult anchovies inhabit shallow to moderately deep offshore water, nearshore waters off sand beaches, open bays, and muddy coves. Often appears in higher densities in vegetated areas such as eelgrass beds.

Lifespan: Up to 2 years.

Fecundity: The anchovy spawning period is long and typically occurs in water less than 20 meters deep. Anchovies generally spawn in the evening between 6 p.m. and 9 p.m. Females can produce 44 to 3,963 eggs. Anchovy eggs are pelagic and found throughout the water column, but they tend to concentrate near the surface.

Food Source: Bay anchovies feed mostly on mysis and copepods, also small fishes, gastropods, and isopods.

Taxonomy:
Kingdom—Animalia
Phylum—Chordata
Subphylum—Vertebrata
Class—Osteichthyes
Order—Clupeiformes
Family—Engraulidae
Genus—*Anchoa*
Species—*Mitchilli*

Sources of Information:
Chesapeake Bay Program (2012)
Fishbase (2017a)
Morton (1989)

2. Anomura crabs (Pea crabs, Representative: *Pinnotheres pisum*)

Common Names: Pea Crab, Oyster Crab

Similar Species: *Pinnotheres ostreum, Austinotheres angelicus*

Appearance: The body of the female is pinkish white and up to 2 cm (about 0.75 inch) across. An irregular stripe runs from front to back across the carapace, or back. Males, seldom seen, are smaller, dark brown,

Length:. For *P. Pisum*, Females grow up to a maximum of 13 millimeters in length and the males only 6 millimeters. For *P.maculatus*, 2cm.

Geographic Range: Found in oysters of the Atlantic coastal waters of North America and are especially abundant in oysters of Chesapeake Bay. *P. pisum*, found in European coastal waters

Habitat:. Found in the shells of scallops, clams, and mussels. Living in the mantle cavity of certain bivalve mollusks, echinoderms, and polychaetes as a commensal

Fecundity: Mean fecundity was 2677 in Stage I and 4890 embryos in females with brood masses in Stage III *(Reproductive traits of the symbiotic pea crab Austinotheres angelicus (Crustacea, Pinnotheridae) living in Saccostrea palmula (Bivalvia, Ostreidae), Pacific coast of Costa Rica)*

Food Source:. Pea Crabs steal food from their host (oysters, mussels, etc.) in order to survive. Feed on plankton brought in by host.

Taxonomy:

Kingdom—Animalia
Phylum— Arthropoda
Subphylum— Crustacea
Class— Malacostraca
Order— Decapoda
Family— Pinnotheridae
Genus— *Pinnotheres*
Species—*pisum*

Sources of Information:

Encyclopedia Britannica (2008)
Encyclopedia of Life (2017).
Pangea Shellfish & Seafood Company, Inc. (2016)
Salas-Moya *et al. (*2014)

3. Silver perch (*Bairdiella chrysoura)*

Common Names: Silver perch, silver croaker.

Similar Species: Closely related to other drums such as red drum, black drum, spotted seatrout, weakfish, spot, and Atlantic croaker.

Appearance: Silvery, greenish, or bluish above, bright silvery to yellowish on belly. Lower fins mostly yellowish to dusky. Mouth terminal, moderately large and oblique. Chin without barbel.

Length: Adult length can be up to 11.8 inches.

Geographic Range: Found along the U.S. Atlantic coast, through the Gulf of Mexico, and into northern Mexico. Silver perch are one of the top five most abundant species of sciaenids in estuaries along the Gulf of Mexico and the Atlantic coast of the U.S.

Habitat: Silver perch favor estuarine and coastal waters with sandy or muddy substrates and use estuaries as nurseries and feeding areas during the warmer months. Juveniles settle in shallow seagrass beds. Silver perch may retreat to deeper bay waters in the colder months and often will migrate to warmer waters during especially cold winters.

Lifespan: Up to 5 years.

Fecundity: Silver perch spawn from March to May in nearshore environments. Females produce 151 to 1,387 eggs. The eggs of the silver perch are buoyant and the larvae are pelagic.

Food Source: Silver perch feed mainly on crustaceans, worms, and occasionally fishes.

Taxonomy:

Kingdom—Animalia
Phylum—Chordata
Subphylum—Vertebrata
Class—Actinopterygii (ray-finned and spiny rayed fishes)
Order—Perciformes
Family—Sciaenidae
Genus—*Bairdiella*
Species—*chrysoura*

Sources of Information:

Fishbase (2017b)
Neely, J.A. (2015)
Waggy *et al.* (2006)

4. Blue crab (*Callinectes sapidus)*

Common Names: Blue Crab**,** Atlantic blue crab, Chesapeake blue crab.

Similar Species: *Callinectes similis, Callinectes ornatus*

Appearance: Body color is bright blue along the frontal area, especially along the chelipeds. Remainder of body is an olive brown color. Fifth leg is adapted to a paddle-shape. Females have broad triangular or rounded aprons and red fingers on the chelae.

Length: 120 to 170mm.

Geographic Range: Western Atlantic Ocean from Nova Scotia to Argentina. Mostly found in Cape Cod to Uruguay. Has been introduced to Hawaii and Japan.

Habitat: Ranges from salt water of gulf to the freshwater of back bays. Favors estuaries. Can be found at low tide line to 120ft deep.

Lifespan: 1 – 2 years.

Fecundity: Females mate only once in their lifetime, producing 2-8 million eggs per spawn. Incubation time is 14-17 days.

Food Source: Clams, oysters, and mussels. Also any vegetation or animal matter. Sometimes eat young crabs.

Taxonomy:

Kingdom—Animalia
Phylum— Arthropoda
Subphylum— Crustacea
Class— Malacostraca
Order— Decapoda
Family— Portunidae
Genus— *Callinectes*
Species— sapidus

Sources of Information:
Bluecrab.info (2010)
Bodden (2017)

5. Brachyuran crab (Representative: *Panopeus herbstii*)

Common Names: Mud Crab, Atlantic Mud Crab.

Similar Species: Florida stone crab, *Menippe mercenaria*. The strongtooth mud crab, *Panopeus bermudensis*; Say mud crab, *Dyspanopeus sayi*; Florida grassflat crab, *Neopanope packardii*; and the flatback mud crab, *Eurypanopeus depressus*.

Appearance: The fingers, or top and bottom portions of the closable claw, are usually black to brown in most species; whereas, the interior portion at the base of the claw, called the palm, is usually pale. The claws are distinctly unequal in size, and the body is brownish. The carapace of P. herbstii is brownish green and slightly granular in texture**.** Their shells vary in color from dark blue-green to mottled brown. They have five teeth lining the outside of the carapace on each side, the first two mostly fused

Length: Widths of 3-4 cm

Geographic Range: The range of *P. herbstii* extends from Massachusetts to Brazil

Habitat: Most populations inhabit muddy bottoms, mainly in mangrove swamps and oyster beds. However, both adults and juveniles can also be found on jetty rocks, shell or cobble bottoms, and marsh edges. In oyster beds and under rocks, individuals may excavate shallow burrows to a depth of 4-10 cm

Lifespan: Unknown.

Fecundity:. Fecundity ranged between 32,105 and 165,826 eggs per female with a mean (±SE) of 97,736 ± 6,850 eggs/female.

Food Source: The diet of the Atlantic mud crab is primarily carnivorous. Individuals prey on a variety of organisms, including: oysters and clams; crustaceans; annelid worms; fishes; and the marsh periwinkle

Taxonomy:
Kingdom—Animalia
Phylum— Arthropoda
Subphylum— Crustacea
Class— Malacostraca
Order— Decapoda
Family— Panopeidae
Genus— *Panopeus*
Species— *herbstii*

Sources of Information:
Marine Education Society of Australasia (2014)
SMS (2009)

6. Caridean shrimp (Caridea) *Palaemonetes pugio*

Common Names: common grass shrimp, grass shrimp, daggerblade grass shrimp,

Similar Species: *Pandalus kessleri*, *Palaemon* spp., *Macrobrachium* spp., marsh grass shrimp (*Palaemonetes vulgaris*), brackish grass shrimp (*Palaemonetes intermedius*)

Appearance: The common grass shrimp has a segmented, nearly transparent body that is compressed on either side. It has a pointed, serrated “horn” that extends over its eyes. Its first two pairs of walking legs have claws. It has well-developed eyes with globular pigmented corneas and some slight yellow pigmentation in the eyestalks.

Length: The shrimp grows to 1.5 inches in length.

Geographic Range: Found throughout most of the Chesapeake Bay and its tidal rivers.

Habitat: Shallow waters, often among bay grass beds. May move to warmer, deeper waters in winter.

Lifespan: Grass shrimp live approximately one year.

Fecundity: Fecundity in *P. pugio* is reportedly variable depending on geographic location. Females collected from Rhode Island in June averaged 486 eggs per female, while in Texas the average was only 372 eggs/female and only up to 247 in South Carolina. Usually spawns in summer, when water temperatures warm. Females must molt before mating.

Food Source: Grass shrimp forage for worms, algae and tiny crustaceans.

Taxonomy:

Kingdom—Animalia
Phylum— Arthropoda
Class— Malacostraca
Order— Decapoda
Family— Palaemonidae
Genus— *Palaemonetes*
Species—*pugio*

Sources of Information:

Chesapeake Bay Program (2017a)
SMS (2008)

7. Sand seatrout (*Cynoscion arenarius*)

Common Names: Sand seatrout, white trout.

Similar Species: Weakfish.

Appearance: Pale yellowish color above, silvery below, without well-defined spots. The center of the scales above the gill opening sometimes forms faint, oblique rows of cloudy areas. The back of a young sand seatrout is cloudy, with the cloudy areas tending to form indefinite crossbands. Sand seatrout have a large mouth, oblique, with lower jaw slightly projecting. The inside of the mouth is yellow.

Length: Adult length is 12 to 15 inches.

Geographic Range: West coast of Florida, Gulf of Mexico to Texas and as far south as the Gulf of Campeche, Mexico.

Habitat: Sand seatrout are one of the most abundant fishes in the estuarine and nearshore waters of the Gulf of Mexico. Young sand seatrout are found in shallow bays of the Gulf Coast, especially in reduced salinity.

Lifespan: Up to 3 years.

Fecundity: In a prolonged period of spawning during spring and late summer, sand seatrout spawn in the lower estuarine environments or inshore waters of the Gulf of Mexico. Sand seatrout have a mean fecundity of 100,990 eggs. Post-spawn adults and post-larvae move into estuarine environments, often riding incoming tides. The inshore movement of young sand seatrout coincides with rising sea levels in the Gulf caused by surface currents and prevailing inshore winds. This movement facilitates the transport of eggs and larvae from inshore spawning areas to estuarine and gulf nurseries.

Food Source: Sand seatrout feed mainly on small fish and mysid shrimp.

Taxonomy:
Kingdom—Animalia
Phylum—Chordata
Subphylum—Vertebrata
Class—Actinopterygii (ray-finned and spiny rayed fishes)
Order—Perciformes
Family—Sciaenidae
Genus—*Cynoscion*
Species—*Arenarius*

Sources of Information:
Arenarius Technical Task Force (2011)
McClane (1998)
Sutter and McIlwain (1987)

8. Spotted seatrout (*Cynoscion nebulosus)*

Common Names: Speckled seatrout, spotted weakfish, seatrout, spotted seatrout, spotted squeteague, spotted trout

Similar Species: *Otolithus nebulosus*

Appearance: Body color is silvery, with the dorsal surface a darker gray tinged with blue. Many small black spots are scattered over the dorsal surface of the body above the lateral line and extend onto the dorsal and caudal fins. The spinous dorsal fin is dusky in color, while all other fins are pale to yellowish in color. The dorsal fin has 12 spines and 25-28 soft rays, with the spinous portion of the fin separated from the soft dorsal fin by a deep notch. The anal fin has 2 spines and 10-11 rays.

Length: Maximum length of 100 cm

Geographic Range: This species is distributed in the western Atlantic from Long Island, New York south along the U.S. coast and throughout the Gulf of Mexico except for Cuba

Habitat: Occurs in shallow coastal and estuarine areas.

Lifespan: The lifespan is approximately 18 years

Fecundity: Fecundity increases with size in *Cynoscion nebulosus*. In Florida, Moody (1957) reported a 39.7 cm (15.6 inches) female collected at Cedar Key contained 464,000 eggs. Tabb (1961) reported 15,000 - 1.1 million eggs per female from a collection of females,

Food Source: Consume fish and shrimp

Taxonomy:

Kingdom—Animalia
Phylum—Chordata
Subphylum—Vertebrata
Class— Actinopterygii
Order— Perciformes
Family— Sciaenidae
Genus— *Cynoscion*
Species— *nebulosus*

Sources of Information:
SMS (2005)
Chao *et al. (*2015)

9. Weakfish (*Cynoscion regalis*)

Common Names:.Weakfish

Similar Species: *Macrodon ancylodon*

Appearance: Body greenish grey above and silvery below, back with small spots forming undulating dotted lines. Pelvic fins and anal fin yellowish other fins pale, sometimes with a yellowish tinge. Inside of opercle dark, visible externally. Mouth large, oblique, lower jaw projecting. Upper jaw with a pair of large canine-like teeth at tip

Length: Maximum 70cm

Geographic Range: Weakfish are an Atlantic coast fish, possibly found in the extreme southeastern Gulf.

Habitat: Occurs usually in shallow coastal waters over sand and sandy mud bottoms.

Lifespan:. Lifespan is 18 years

Fecundity:. he number of eggs of 199 females varied from 59,850 for 33.4 cm TL fish to over 358,450 for 37.2 cm TL; the mean fecundity verified was 165,273 eggs per female.

Food Source: Weakfish feed on a wide variety of animals, including crabs, amphipods, mysid and decapod shrimps, squid, shelled mollusks, and annelid worms, but chiefly on smaller fish, such as menhaden, butterfish, herring, scup, anchovies, silversides, and mummichogs

Taxonomy:

Kingdom—Animalia
Phylum—Chordata
Subphylum—Vertebrata
Class— Actinopterygii
Order— Perciformes
Family— Sciaenidae
Genus— *Cynoscion*
Species—*regalis*

Sources of Information:
Fishbase (2017c)
Bigelow and Schroeder (2002)
Juras and Yamaguti (1989)

10. Striped mojarras (*Eugerres plumieri*)

Common Names:. Striped mojarra, mojarra

Similar Species: ***Diapterus plumieri***.

Appearance: rather deep-bodied fish, dark olive above and tan to silvery on the sides, often with a metallic sheen. Bold black stripes run along the scale rows (excluding the belly). All fins except for the pectoral fins are dusky in large adults; the pelvic and anal fins are sometimes dark orange. The pectoral fin is transparent.

Length: common length: 30.0 cm TL male/unsexed

Geographic Range: This species is distributed in the western Atlantic from Emerald Isle, North Carolina south along the U.S. coast, in the Gulf of Mexico from the Florida Keys to Crystal River, Florida and from Matagorda Bay, Texas along the northern Yucatan to northwestern Cuba, in the Caribbean from Cuba to Puerto Rico (except the Cayman Islands), and along the Central and South American coast from Quintana Roo, Mexico to Colombia.

Habitat: inhabits shallow coastal waters in mangrove-lined creeks and lagoons (Randall and Vergara 1978). It prefers fine, sandy substrates and lower salinity (Rueda 2001). It is common in brackish waters and often enters a considerable distance into freshwater.

Lifespan: Up to 2 years.

Fecundity: This species has high fecundity, producing 85,345 to 953,870 eggs.

Food Source: It feeds on aquatic insects, crustaceans, micro-bivalves and detritus.

Taxonomy:
Kingdom—Animalia
Phylum—Chordata
Subphylum—Vertebrata
Class— Actinopterygii
Order—Perciformes
Family— Gerreidae
Genus— *Eugerres*
Species— *plumieri*

Sources of Information:
Fishbase (2017d)
Fraser and Gilmore (2015)
Sobczak (2017)

11. Naked goby (*Gobiosoma bosc)*

Common Names: Naked Goby.

Similar Species: code goby (*G. robustum*).

Appearance: Ground color light tan to nearly black, usually brown; body with 9-10 vertical bars separated by narrow lighter interspaces, bars faint or indistinct in specimens with light or dark ground color; fins dusky. Body shape is short and stout; body depth contained fewer than seven times in standard length.

Length: common length: 4.1 cm TL male/unsexed.

Geographic Range: Western Atlantic: Massachusetts to Florida, (not Florida Keys), Everglade City, Florida along Gulf of Mexico coast to Veracruz, Mexico.

Habitat: Inhabit estuaries and weedy, protected coastal waters and rivers, with salinity ranging from 0.0 to 33.0 ppt. Marine; brackish; demersal. Tropical; 11°C - 33°C.

Lifespan: 4 years.

Fecundity: Ovaries of females (27-35 mm SL) collected in Georgia contained from 701-1,382 eggs; egg diameters ranged from 0.112-0.720 mm; most nests contained 332-2,000 eggs, but three others had 3.933, 8,000, and over 9,000 eggs (Dahlberg and Conyers 1973). Egg with a bundle of adhesive eggs attached to the egg membrane serving to attach the egg to submerged objects.

Food Source: Adults feed mainly on annelids and small crustaceans; also attracted to injured or dead oysters.

Taxonomy:

Kingdom—Animalia
Phylum—Chordata
Subphylum—Vertebrata
Class— Actinopterygii
Order—Perciformes
Family— Gobiidae
Genus— *Gobiosoma*
Species—*bosc*

Sources of Information:

Fishbase (2017e)
van Tassell (2015)

12. Southern kingfish (*Menticirrhus americanus*)

Common Names: Southern kingfish, whiting, southern kingcroaker.

Similar Species: Gulf kingfish and northern kingfish.

Appearance: Southern kingfish have an inferior mouth with a single barbel on the chin. Southern kingfish are grayish brown or copper colored above with silvery sides. The southern kingfish has dark mottling or 7–8 diagonal dusky bars or blotches on each side, and the scales on its chest are the same size as those on its sides.

Length: Up to 15 inches.

Geographic Range: New York to Argentina to the northern Gulf of Mexico.

Habitat: Southern kingfish live near shore, generally in the surf, but also in shallow coastal waters with a muddy-sand bottom. They also inhabit high salinity bays and estuaries along the coast.

Lifespan: 4 to 6 years.

Fecundity: Southern kingfish spawn from February or March to November in Florida. Batch fecundity ranges from 17,338 to 80,495 eggs with a mean of 35,571 eggs per female.

Food Source: Mostly bivalve siphons and cumaceans, followed by mysids, polychaetes, brachyurans, and gammarid amphipods.

Taxonomy:

Kingdom—Animalia
Phylum—Chordata
Subphylum—Vertebrata
Class—Actinopterygii (ray-finned and spiny rayed fishes)
Order—Perciformes
Family—Sciaenidae
Genus—*Menticirrhus*
Species—americanus

Sources of Information:

Clardy et al. (2014)
Florida Fish and Wildlife Conservation Commission (2017)
McClane (1998)
Willis et al. (2015)

12. Stone crab (*Menippe mercenaria*)

Common Names: Florida stone crab.

Similar Species: Mud crabs.

Appearance: Stone crabs have exoskeletons and have a brown and black speckled carapace that is oval, smooth, and convex. Adult females and are smaller than adult males. The Florida stone crab has a large crusher claw with an enlarged basal tooth. The smaller pincer claw has many small teeth that can be used for cutting. Adult Florida stone crabs have a trunk composed of 14 segments and 5 pairs of stout walking legs that have reddish and yellow bands and distal hairs. Juveniles appear dark purplish-blue and have a white spot on the carpus when they are very young.

Length: Adults can reach 5½ to 6 inches carapace width (the widest part of the body).

Geographic Range: Stone crabs range from Cape Lookout in North Carolina southward and throughout the Gulf of Mexico to the Yucatan Peninsula.

Habitat: Stone crab larvae are planktonic and are found in nearshore coastal waters and within estuaries. Larvae are sensitive to lower salinities. Juveniles live beneath shell fragments in deeper water. As they mature, they move into the shallower waters and live in the crevices of rocks, jetties, pilings, and oyster shell rubble. Adult Florida stone crabs live in seagrass beds or rocky substrate in higher salinity waters.

Lifespan: Up to 6 to 7 years.

Fecundity: Spawning is believed to occur from November to March in Florida and is believed to be regulated by photoperiod and temperature. Single females can produce up to six egg masses or sponges during a single season. Each egg sponge may contain 160,000 to 1,000,000 eggs. Oyster reefs and seagrass beds may be important habitat for spawning.

Food Source: The larvae and pre-juvenile stone crabs feed on smaller zooplankton. Juvenile and adult stone crabs feed on animals that are larger than the zooplankton. Adult stone crabs feed on acorn barnacles, hard shelled clams, scallops, and conch.

Taxonomy:
Kingdom—Animalia
Phylum—Arthropoda
Class—Malacostraca
Order—Decapoda
Family— Xanthidae
Genus—*Menippe*
Species—*mercenaria*

Sources of Information:
Brinkman (2002)
Key Largo Fisheries (2010)
LGL Ecological Research Associates, Inc. and Science Applications International Corporation (1998)
McClane (1998)

13. Pink shrimp (*Farfantepenaeus duorarum*)

Common Names: Pink shrimp, spotted shrimp, northern pink shrimp.

Similar Species: Brown shrimp, white shrimp.

Appearance: Pink shrimp can be distinguished from other families of shrimp by their antennae, which are longer than their body lengths, and by their first three pairs of walking legs. Overall body color varies, but generally it is gray, bluish, or red-brown. The sides of pink shrimp are somewhat flattened. The carapace has a medial carina that extends nearly to its posterior end and is bordered by a broad, rounded groove on either side. The rostrum bears 6–7 sharp teeth on the dorsal surface. Ventrally, the rostrum may have 1–3 teeth. The abdomen has 4–6 carinate segments, with the carina of the sixth segment ending in a spine. A dark, distinct spot between the 3rd and 4th abdominal segments distinguishes pink shrimp. Its tail is edged with blue.

Length: Females grow to 11 inches long, and males grow to 10.6 inches long.

Geographic Range: Pink shrimp range from the lower Chesapeake Bay, Maryland to the tip of the Yucatan Peninsula, Mexico, and have major centers of abundance along the west coast of Florida and in the Bay of Campeche.

Habitat: Pink shrimp are most abundant in waters of 36–121 feet, although in some areas they may be abundant as deep as 213 feet. Pink shrimp are common in the estuaries and shallow marine waters of southern Florida and into deep water (approximately 100 meters) southeast of the Florida Keys. Pink shrimp are the dominant species within the Dry Tortugas shrimping grounds and Florida Bay. They prefer sand, sand-shell, or coral-mud bottoms. Growth of pink shrimp is optimal at 30-percent salinity.

Lifespan: Pink shrimp live an average of 16 months.

Fecundity: Pink shrimp begin reproducing at age 6–8 months. They migrate offshore to spawn in the spring and continue spawning migration throughout the summer. A female can release 215,000 to 1 million eggs every 3 days.

Food Source: Juvenile pink shrimp eat bivalves, calcareous algae, plant detritus, copepods, and seagrass fragments. Adults eat copepods, small mollusks, benthic diatoms, algae, detritus, bacterial films, slime molds, and yeast.

Taxonomy:

Kingdom—Animalia
Phylum—Anthropoda
Class—Malacostraca
Order—Decapoda
Family—Penaeidae
Genus—*Penaeus*
Species—*Duorarum*

Sources of Information:

Encyclopedia of Life (2012)
Laramore *et al.* (2016)
McClane (1998)
McMillen-Jackson and Bert (2004)
NOAA Sustainable Fisheries Partnership (2013)
Turrell Associates (undated)

14. Hogchoker (*Trinectes maculatus)*

Common Names: Freshwater Flounder, Freshwater Sole, Hogchoker

Similar Species: *Pleuronectes maculatus, Achirus fasciatus*

Appearance: The hogchoker has a flat, rounded body that grows to about 6 inches in length. It is a dark brownish-gray on top and pale on the bottom, with narrow, black vertical lines or spots on the top side of its body. It has a rounded head with a small mouth. Both its small eyes are located on the top side of its body. Its dorsal and anal fins stretch around its body from its head to its rounded tail fin.

Length: 6 inches

Geographic Range: Atlantic coast from Massachusetts to Yucatan, Mexico

Habitat: Coastal waters (to about 75 m), estuaries, and coastal rivers; may range hundreds of miles upstream. Found in both shallow and deep waters. Bottom-dwellers that prefer sandy, silty or muddy bottoms.

Lifespan: Estimated anywhere from 6-12 years along Atlantic Coast, usually 7 years

Fecundity: Has been estimated at 10,000 to 34,000 eggs

Food Source: Hogchokers eat worms and crustaceans.

Taxonomy:
Kingdom—Animalia
Phylum— Chordata
Class— Actinopterygii
Order— Pleuronectiformes
Family— Achiridae
Genus— *Trinectes*
Species—*malculatus*

Sources of Information:
Chesapeake Bay Program (2017b)
Nature Serve (2013)
Hassan-Williams *et al*. (2007)

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Appendix 11-G

Entrainment Reduction Benefits Study: Bayside Power Station

Entrainment Reduction Benefits Study: Bayside Power Station

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1. Overview and Results

The U.S. Environmental Protection Agency's (USEPA's) 2014 316(b) Rule (79 *Fed. Reg.* 158, 48300–48439) (2014 Rule) requires that applicants submit studies of technologies or operational measures that can reduce entrainment. The studies must discuss cost, feasibility, impact, and social cost/benefit of technologies including cooling towers, 2 mm or smaller screens, and water reuse or alternative water sources (§ 122.21(r)(10)(i–iii) and § 122.21(r)(11)(i-vi)). The Benefits Valuation Study presents the benefits of each technology and must include the following elements as defined in 79 *Fed. Reg.* 158, 48428 (r)(11):

(i) Incremental changes in the numbers of individual fish and shellfish lost due to impingement mortality and entrainment as defined in 40 *CFR* 125.92, for all life stages of each exposed species

(ii) Description of basis for any estimates of changes in the stock sizes or harvest levels of commercial and recreational fish or shellfish species or forage fish species

(iii) Description of basis for any monetized values assigned to changes in the stock size or harvest levels of commercial and recreational fish or shellfish species, forage fish, and to any other ecosystem or nonuse benefits

(iv) A discussion of mitigation efforts completed prior to October 14, 2014 including how long they have been in effect and how effective they have been

(v) Discussion, with quantification and monetization, where possible, of any other benefits expected to accrue to the environment and local communities, including but not limited to improvements for mammals, birds, and other organisms and aquatic habitats

(vi) Discussion, with quantification and monetization, where possible, of any benefits expected to result from any reductions in thermal discharges from entrainment technologies.

This report contains the results, data, and methods for estimating the fishing benefits associated with entrainment reductions at Bayside Power Station (Bayside). The remainder of this section summarizes the data, methods, and results for the §122.21(r)(11)(i)-(iii) requirements listed above.

1.1 § 122.21(r)(11)(i): Incremental Changes in Fish and Shellfish

Table 1.1 provides the reduction in impingement mortality of all species and life stages of fish and shellfish that will occur with a complete impingement mortality reduction at Bayside. The data presented in Table 1.1 are impinged equivalent adults estimated using the impingement data that Golder collected at Bayside from April 21, 2005 to March 20, 2007 (Golder 2009) and actual intake flows (AIF) at Bayside for 2015 and 2016. The Bayside impingement densities are applied to the AIF as follows: 2005 densities with 2015 AIF (Sample

Year 1) and 2006 densities with 2016 AIF (Sample Year 2). No threatened or endangered species were collected during impingement sampling.

Table 1.1
Bayside Power Station: Total Impingement Equivalent Adults

Species	Impingement Year		Species Classification			
	Sample Year 1	Sample Year 2	Forage	Commercial	Recreational	Threatened or Endangered
Fish:						
Bay anchovy	361	858	•			
Silver perch	5,211	6,765	•			
Weakfish	321	120			•	
Naked goby	410	2,129	•			
Mojarra	5,378	1,128	•			
Drums/croakers	0	0		•	•	
Spot	1,167	0			•	
Hogchoker	244	118	•			
Fish Totals	13,092	11,119				
Shellfish:						
Anomuran crab	0	0	•			
Blue crab	359	160		•		
Brachyuran crab	3,609	1,503	•			
Grass shrimp	0	65	•			
Stone crab	670	886		•		
Commercial shrimp	131	1,659		•		
Shellfish Totals	4,769	4,273				

Sources: Environmental Consulting & Technology, Inc. (2017); Florida Fish and Wildlife Conservation Commission (2017a); U.S. Fish and Wildlife Service (2017a)

Table 1.2 presents the estimated entrainment of all species and shellfish that will occur with a complete entrainment reduction at Bayside. The data are entrained equivalent adults estimated from the entrainment data Golder collected at Bayside from April 21, 2005 to March 20, 2007. Entrainment data is provided for two years: 2005 and 2006. No threatened or endangered species were collected during entrainment sampling (Golder 2009).

Table 1.2
Bayside Power Station: Total Entrained Equivalent Adults

Species	Entrainment Year		Species Classification			
	Sample Year 1	Sample Year 2	Forage	Commercial	Recreational	Threatened or Endangered
Fish:						
Bay anchovy	193,170	469,090	•			
Silver perch	34,355	5,980	•			
Weakfish	1,027	444			•	
Naked goby	121,740	56,428	•			
Mojarra	71	1	•			
Drums/croakers	15,067	25,101		•	•	
Spot	0	0			•	
Hogchoker	12,994	54,963	•			
Fish Totals	378,430	612,000				
Shellfish:						
Anomuran crab	8,179,000	17,268,000	•			
Blue crab	1	1		•		
Brachyuran crab	37,377,000	78,912,000	•			
Grass shrimp	51,109,000	107,900,000	•			
Stone crab	3,327	7,021		•		
Commercial shrimp	89	188		•		
Shellfish Totals	96,668,000	204,090,000				

Sources: Environmental Consulting & Technology, Inc. (2017); Florida Fish and Wildlife Conservation Commission (2017a); U.S. Fish and Wildlife Service (2017a)

1.2 § 122.21(r)(11)(ii): Description of Changes in Stock or Harvest Levels

Differences between With-Entrainment (baseline) and Without-Entrainment conditions are used to quantify the benefits of entrainment reductions. Simulation models of fish species were developed to represent the changes to stocks affected by entrainment reduction technologies. This is accomplished by creating age-structured transition (i.e., Leslie) matrices (Leslie 1945, 1948; Caswell 2001) that characterize the modeled stocks. The Leslie matrix model is frequently used in fisheries management and has long been an important component of professional judgment (PJ) 316(b) assessments under 1977 draft guidance (Akçakaya, Burgman, and Ginzburg 2002; Public Service Electric and Gas Company [PSEG] 1999; USEPA 2002). These dynamic matrix models are populated with survival rates and weights at age ((r)(11) report Table 11-6) and simulated forward to identify changes in fish stocks that are associated with each evaluated technology.

Table 1.2 indicates whether each entrained organism is a forage species or a recreationally and/or commercially harvested species. As Table 1.2 shows, the entrained species that have commercial or recreational value include drums/croakers (Sciaenidae), weakfish (*Cynoscion regalis)*, blue crab (*Callinectes sapidus)*, stone crab (*Menippe* spp.), and commercial shrimp (Penaeid shrimp). Figure 1.1 depicts the estimated changes in fish stocks for each species with the complete elimination of Bayside's entrainment. Weakfish includes sand (*Cynoscion arenarius)* and spotted seatrout (*Cynoscion nebulosus)*. The drums/croakers group includes Atlantic bumpers (*Chlorscombrus chrysurus))*, jacks (Carangidae), kingfish (*Menticirrhus* spp.), and leatherjacket (*Oligoplites saurus*). The unidentified species presented in Table 1.2 are apportioned across the commercial, recreational, and forage species based on the percentage that each commercial, recreational, and forage species comprises of the total entrainment.

In addition to the direct estimates of increased commercial and recreational fish stocks, the analysis also accounts for the recreational and commercial impacts associated with the entrainment of forage species. In assessments of entrainment impacts, it is conventional to monetize impacts to forage species by converting them to recreational and commercial species via the "trophic transfer" method. As typically applied, this approach multiplies adult equivalent forage biomass by some factor to identify changes in higher trophic level species that are recreationally and commercially valuable. Adult equivalent forage biomass is identified using methods described in ECT's Benefits Valuation Study (see Section 11.2.2 of the main body of the report) for the higher trophic level species to identify numbers and then multiplying by weight at age to calculate biomass. Figure 1.2 depicts the adult equivalent forage biomass for the entrained forage species.

The approach of directly converting this biomass into commercial/recreational biomass has had some important advantages in the historical 316(b) regulatory context. These include that it allows "accounting for" all entrained species and that it is straightforward to implement in that it requires no conceiving of the complex and changeable predator-prey relationships of actual food webs.

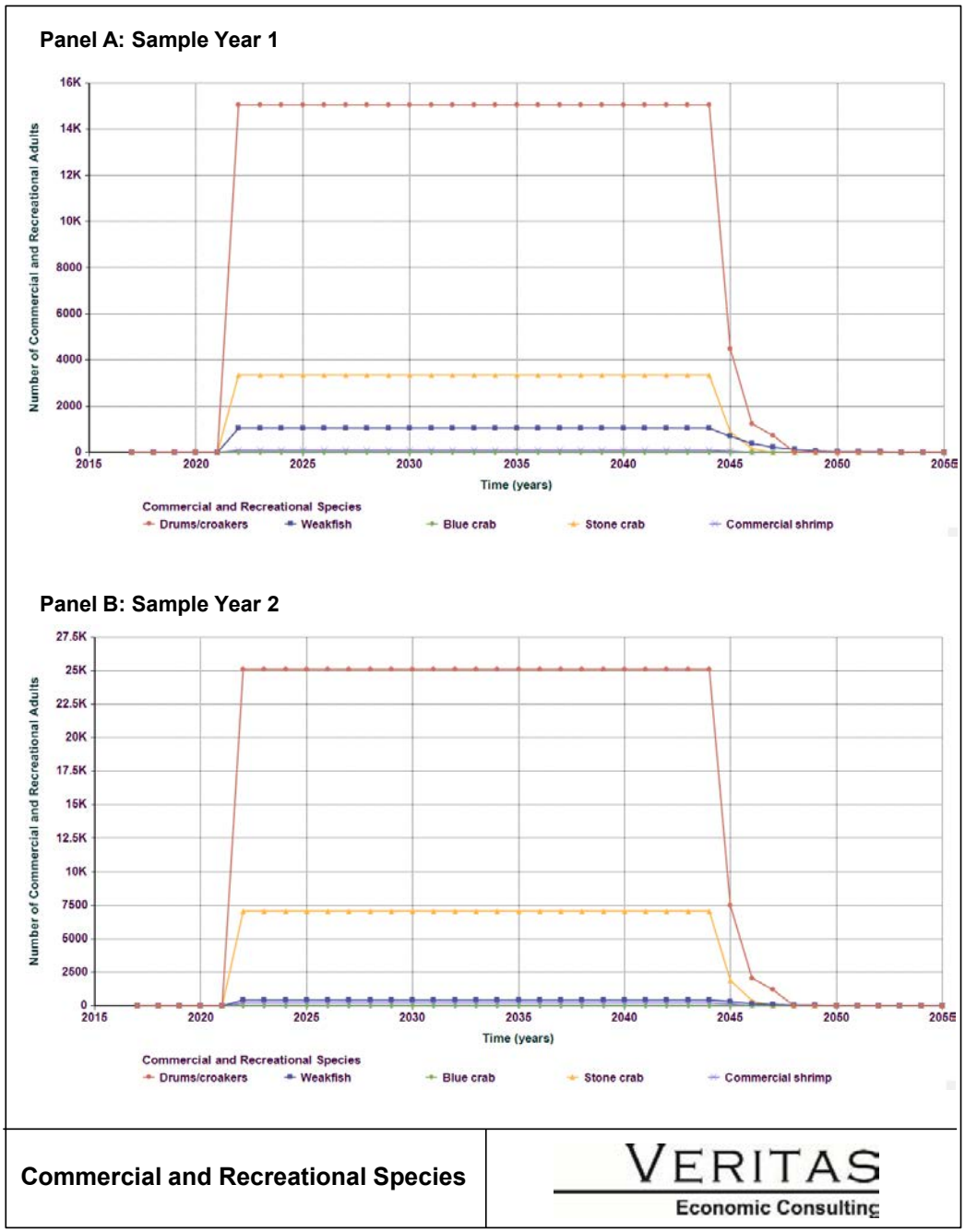


Figure 1.1: Direct Changes in Hillsborough Bay's Commercial and Recreational Fish Stocks as Equivalent Adults with Elimination of Bayside's Entrainment

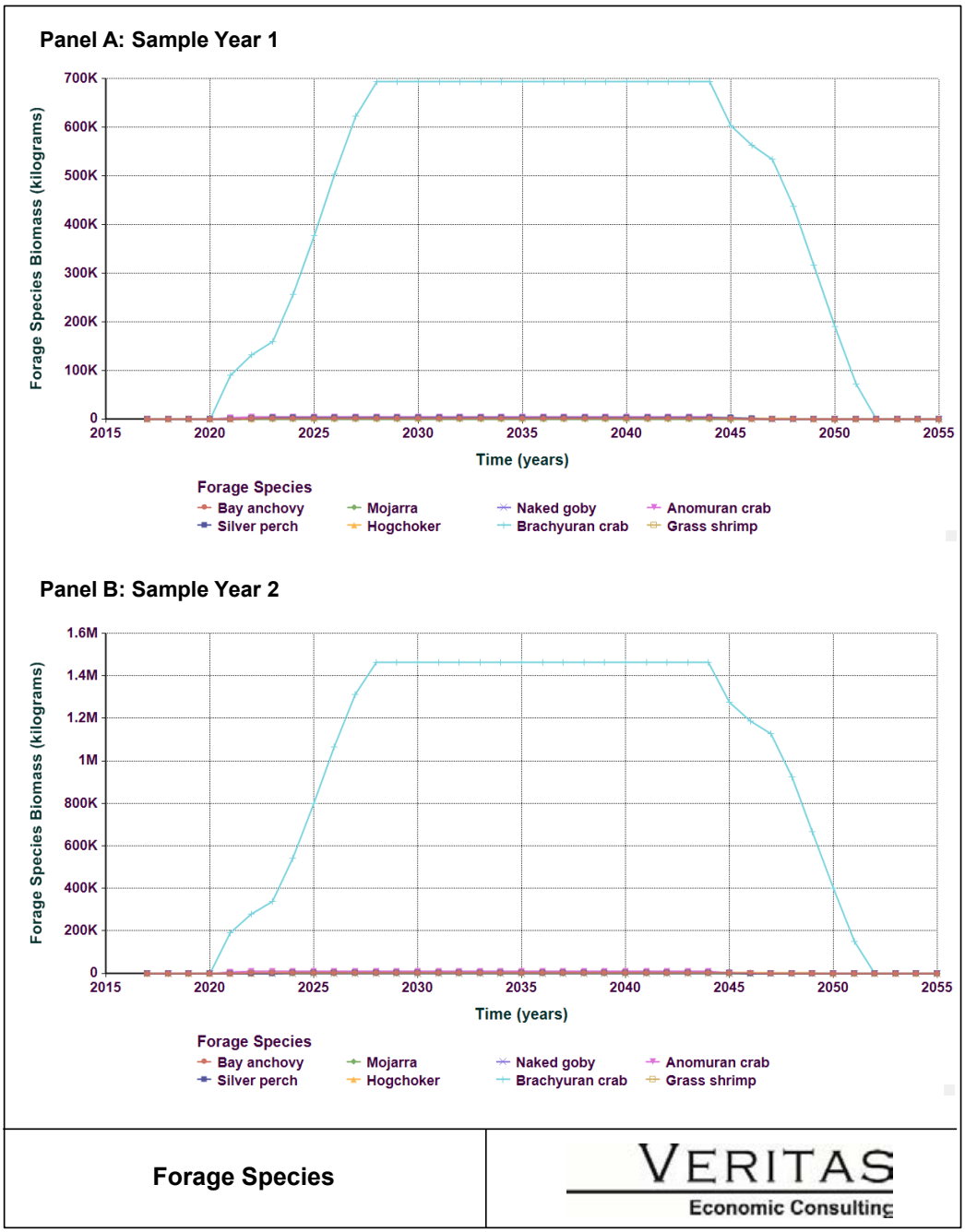


Figure 1.2: Direct Changes in Forage Stocks as Biomass (kilograms) with Elimination of Bayside's Entrainment

Under the 2014 Rule's peer-review requirement, it is important that the deficiencies of this approach not be ignored. Primarily, the trophic transfer approach interprets observed average biomasses at different trophic levels (i.e., 10-to-1 forage to predator) as causal without meaningful foundations for doing so and in the face of extensive information that indicates otherwise (Pauly and Christensen, 1995; Zhao, Kocovsky; Madenjian, 2013; Madenjian *et al.* 1996). Perhaps the most glaring problem with this approach is its inconsistency with the estimates developed for recreational and commercial species. In particular, it is specified that higher trophic level species are under fishing pressure from above (humans), rendering them unlikely to be constrained by forage availability. Moreover, if forage constraints *do* limit populations of higher trophic levels, consistency would require considering that some or all of the increased stocks implied by the reduced entrainment such as those depicted in Figure 1.1 would consume the increase in forage biomass. Unlike complex, food-web based considerations this concern about the trophic transfer approach is a simple one of consistency and the avoidance of double counting within a benefits analysis. With these deficiencies recognized, the trophic transfer approach is applied. The selected predator is drums/croaker. Figure 1.3 depicts trophic transfer-based changes to the drum/croaker stock as a result of the changes in forage biomass (in kilograms).

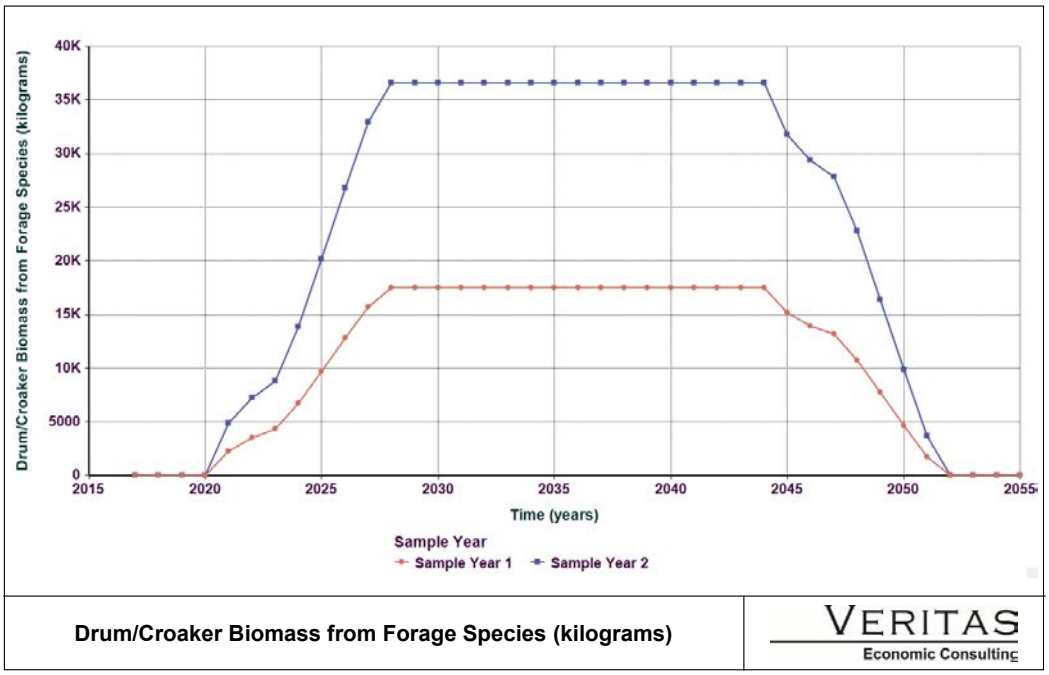


Figure 1.3: Trophic Transfer Based Changes in Kilograms of Drum/Croaker Biomass with Elimination of Bayside's Entrainment

To identify the yield changes associated with changes in stocks, fishing mortality rates from Table 11-5 in the main body of the report are applied to stock changes. Drum/croaker is harvested recreationally and commercially (see Table 1.2) so the direct and indirect annual increase in drums/croakers is distributed. The distribution of recreational to commercial is based on 2014 recreational catch and commercial landings (National Oceanic and Atmospheric Administration [NOAA] Office of Science and Technology 2017b; Florida Fish and Wildlife Conservation Commission 2017b).[1] The species included in the calculation are croaker, black drum, and red drum. Using this process, about 89% of drum/croakers pounds caught are caught recreationally. This percentage is applied to the annual increase to distribute the increase across commercial and recreational. All other recreational and commercial species are either recreational or commercial, not both. Figure 1.4 depicts the estimated recreational yield changes for the drum/croaker and weakfish entrained at Bayside inclusive of the stock changes as a result of forage biomass. Panel A presents the Sample Year 1 data, and Panel B presents the Sample Year 2 data.

[1] The 2014 data is most recent year with complete data for recreational catch and commercial landings. Therefore, this data is used to calculate the recreational and commercial distribution of drum/croaker.

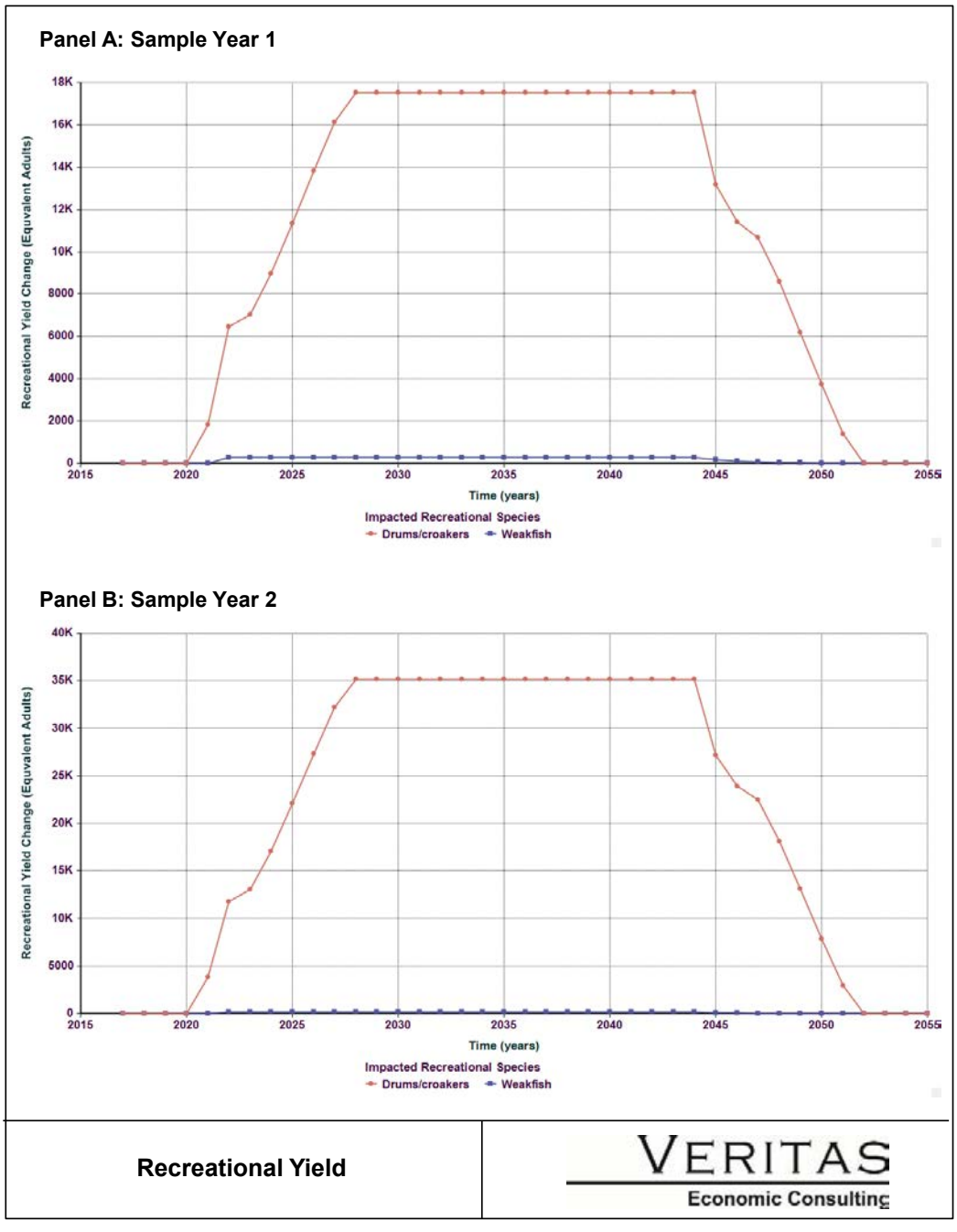


Figure 1.4: Total (Direct and Indirect) Changes in Recreational Yield of Drums/Croakers and Weakfish

In addition to recreational yield changes, the analysis also considers commercial yield changes. As Table 1.1 and 1.2 illustrate, Bayside's entrained species of drums/croakers, blue crabs, stone crabs, and commercial shrimp are identified as potentially having commercial value. This identification is based on the evaluation of the 2015 commercial harvest data from landings in Hillsborough County (National Oceanic and Atmospheric Administration [NOAA] Office of Science and Technology 2017b; Florida Fish and Wildlife Conservation Commission 2017b).

Based on the entrainment rates of these species and commercial fishing conditions, the analysis evaluates changes in commercial yield for the species entrained at Bayside that are commercially harvested in Hillsborough Bay and expected to have a change in commercial yield with a reduction of Bayside's entrainment. Figure 1.5 depicts the estimated changes (both direct and indirect) in kilograms of these commercially harvested taxa if there were to be a complete reduction of Bayside's entrainment.

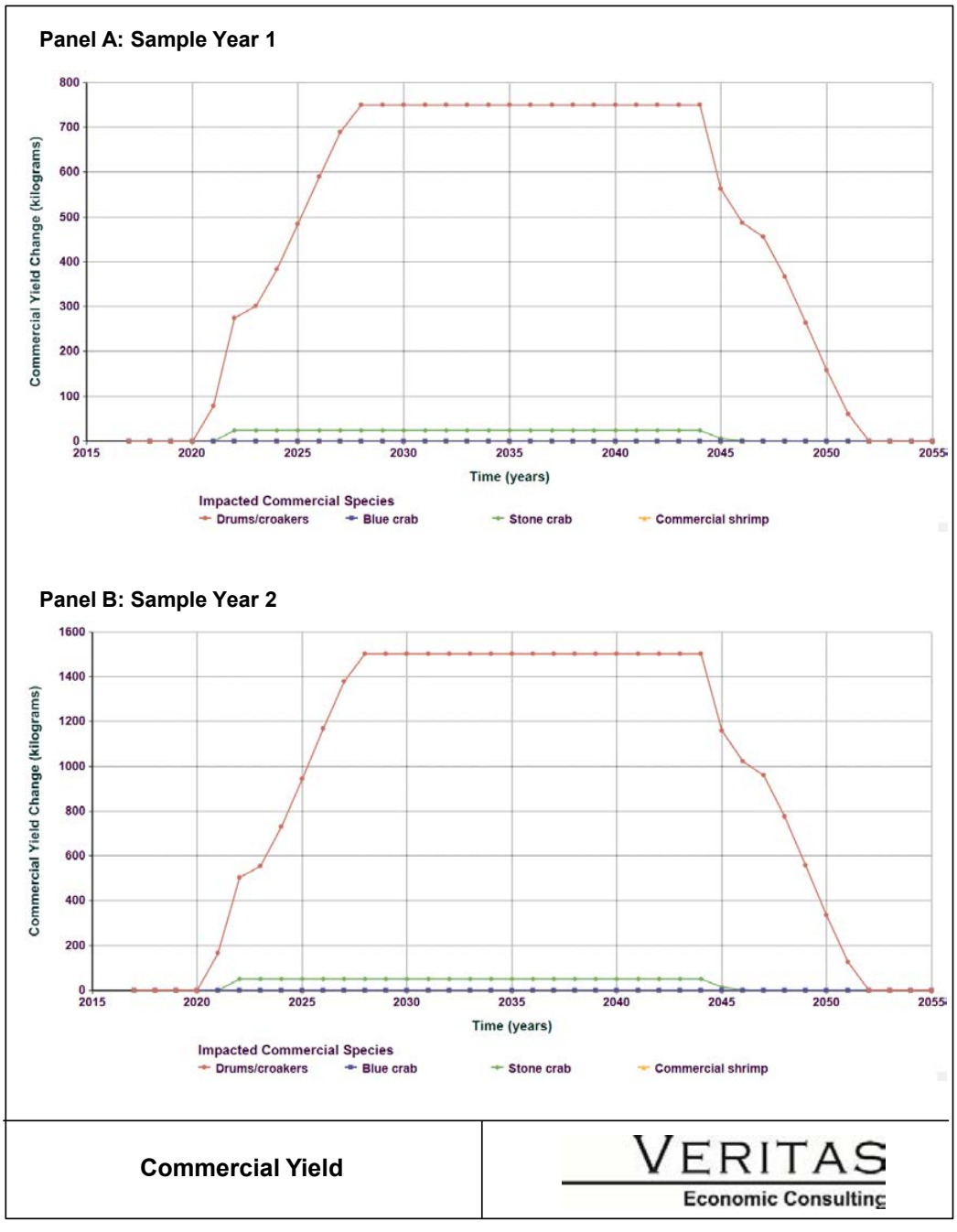


Figure 1.5: Total (Direct and Indirect) Changes in Commercial Yield

1.3 § 122.21(r)(11)(iii): Description of Monetized Values of Commercial, Recreational, and Forage Species

Estimating the benefits of entrainment reductions requires assessing the relationship between entrainment, fishery changes, and the impact that fishery changes have on people. For recreational values this includes understanding how Bayside's entrainment affects recreational fishing catch rates and how those changed catch rates affect angler well-being.

The methodology uses a site-choice simulation to evaluate the effects that entrainment have on recreational fisheries. To evaluate the effect of entrainment, the analysis modifies site catch estimates to generate recreational catch that could occur with entrainment reductions. The methodology determines the economic value of the estimated catch changes by linking them to models of recreational angling demand presented in Bingham et al. (2011).

The models used to generate age-structured changes in stock use survival parameters are from Table 11-6 of the main body of the report. These are linked to the site-choice simulation model through fishery-specific catch and effort rates. This forms a bio-economic equilibrium (i.e., yield, trips, and expected catch are integrated) for the With-Entrainment representation of the Hillsborough Bay fishery expected to be affected by Bayside's entrainment. These integrated partial equilibrium models are used to simulate conditions under With-Entrainment (baseline) and Without-Entrainment conditions, and the monetized welfare differences between these two conditions determine the benefits of entrainment reductions. As described in USEPA's *Guidelines for Preparing Economic Analysis*, equilibrium modeling using the With- and Without-Impact approach is central to all sound benefit estimation processes and regulatory impact analysis (USEPA 2010).

1.3.1 Recreational Benefits

Changes in yield could occur at recreational sites throughout Hillsborough Bay and are specified to occur at the set of aggregated sites illustrated by the red circles in Figure 1.6. In addition to the affected sites, Figure 1.6 also shows the angling population that is specified to be most likely affected by changes in Bayside's entrainment. These are the anglers located in the counties that are adjacent to Hillsborough County. The shading illustrates the number of anglers residing in each ZIP Code contained in the counties. Figure 1.6 also illustrates the location of alternative, substitute sites (yellow triangles) included in the model. These are sites where anglers can fish that are not affected by Bayside's entrainment. Table 1.3 summarizes the data on anglers, trips, and sites illustrated in Figure 1.6 and used to develop the site-choice simulation of recreational angling demand.

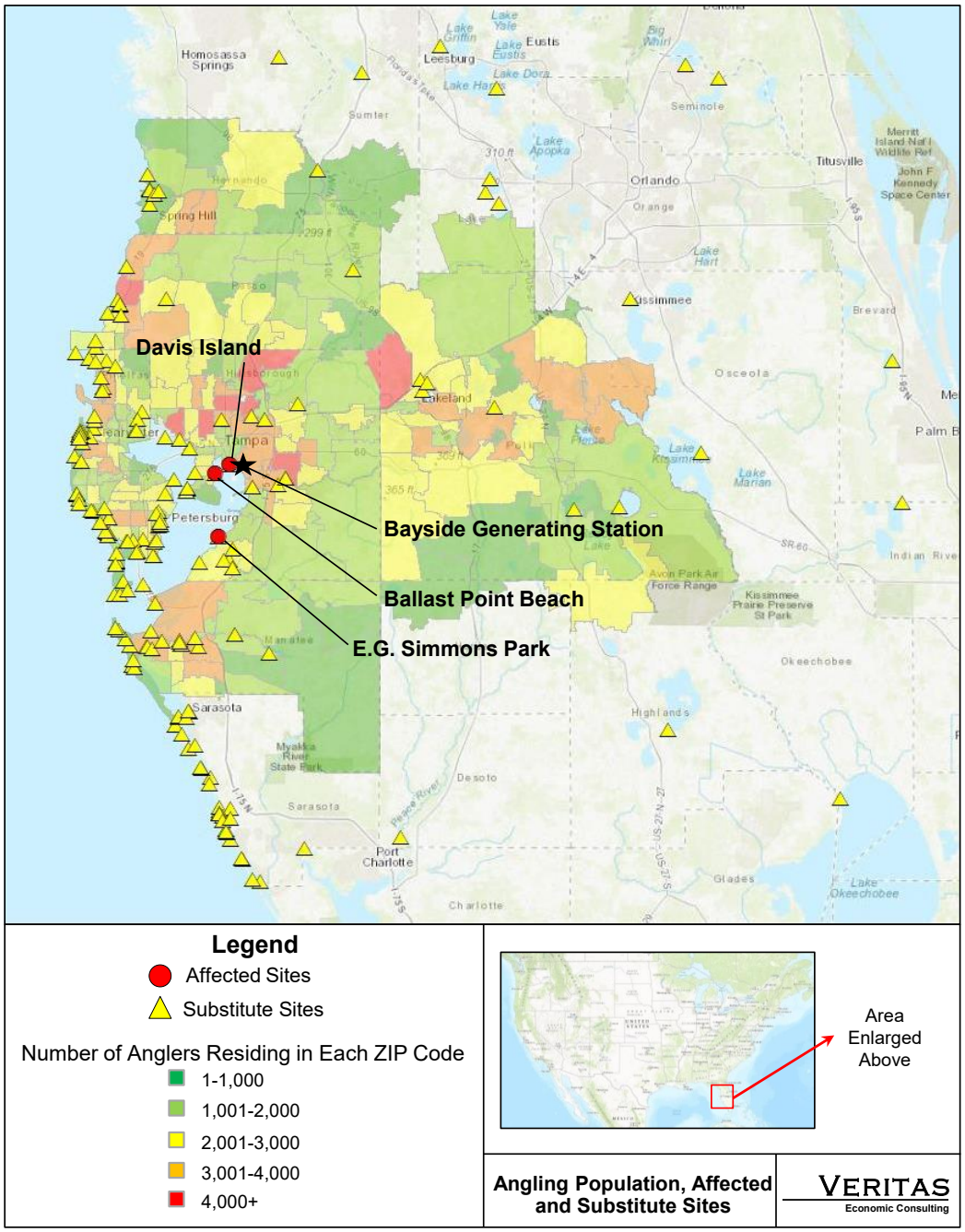


Figure 1.6: Location of Sites with Affected Catch Rates, Location of Substitute Sites, and the Concentration of Anglers

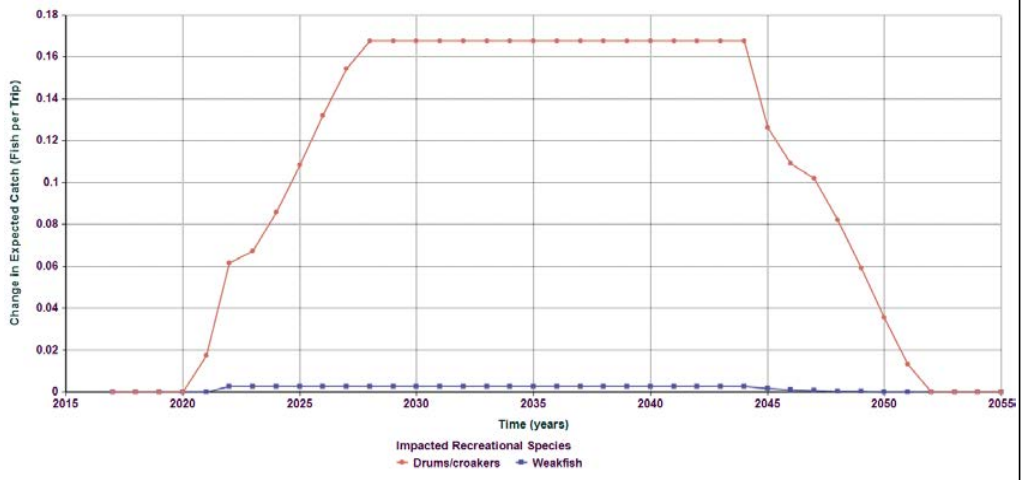
Table 1.3
Affected Population, Trips, and Sites included in the Recreation Angling Demand Model

Data Components	Estimate
Total Number of ZIP Codes in Affected Population [a]	203
Total Population Residing in Affected ZIP Codes [b]	3,949,080
Total Anglers Residing in Affected ZIP Codes [c]	398,415
Total Annual Fishing Days by Anglers in Affected ZIP Codes [c]	9,163,536
Number of Modeled Fishing Sites	207
Total Annual Fishing Days by Affected Population to Modeled Sites [d]	2,792,706
Number of Affected Sites	3
Total Annual Fishing Days to Affected Sites [e]	104,458

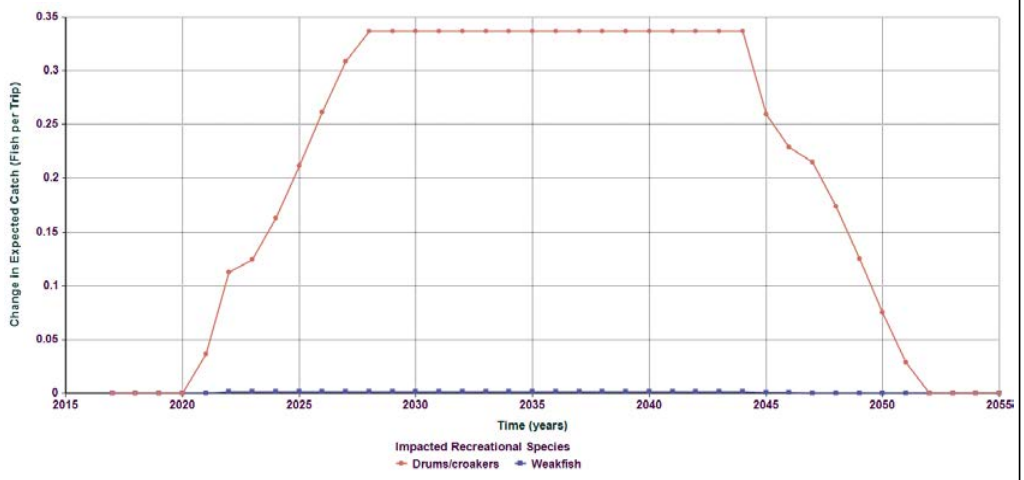
Sources and Notes:
[a] The analysis specifies the affected population as those anglers residing in Hillsborough County and adjacent counties.
[b] ZIP Code population is from the 2010 Census (U.S. Census Bureau 2017).
[c] The estimate of the total anglers in the affected population is developed from information from the U.S. Fish and Wildlife Survey's 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation for Florida and the 2010 U.S. Census (USFWS 2013, U.S. Census Bureau 2017). The analysis uses the 2010 Census population for Florida and the 2011 estimate of the total number of resident anglers from the 2011 USFWS to estimate the percentage of the population that are anglers (10.09%). The analysis applies this percentage to the population in the affected ZIP Codes. To develop the estimate of total angling days, the analysis applies the average number of days that Florida anglers spend fishing from the 2011 USFWS (23 days) to the number of anglers residing in the affected ZIP Codes.
[d] While the model accounts for all of the anglers in the affected population, it does not account for all of the sites where they can take their fishing trips. Therefore, not all of their trips are included in the model. The analysis uses annual trip information that is available for each site in the model to determine the total number of modeled trips (30.5 percent of affected population's total trips).
[e] The estimated number of total angling days to the affected sites is developed from the following publicly-available sources: Florida Coastal Management Program (2011), Florida Fish and Wildlife Conservation Commission (2013), and State of Florida Division of Recreation and Parks (2013).

The analysis apportions the estimated yield changes over the affected sites according to angling pressure. This approach results in similar changes in per-trip expected catch across sites. Figure 1.7 presents the per-trip change in the expected catch of each recreationally harvested species at the affected sites. The model specifies the three affected sites to have the same change in expected catch per trip.

Panel A: Sample Year 1



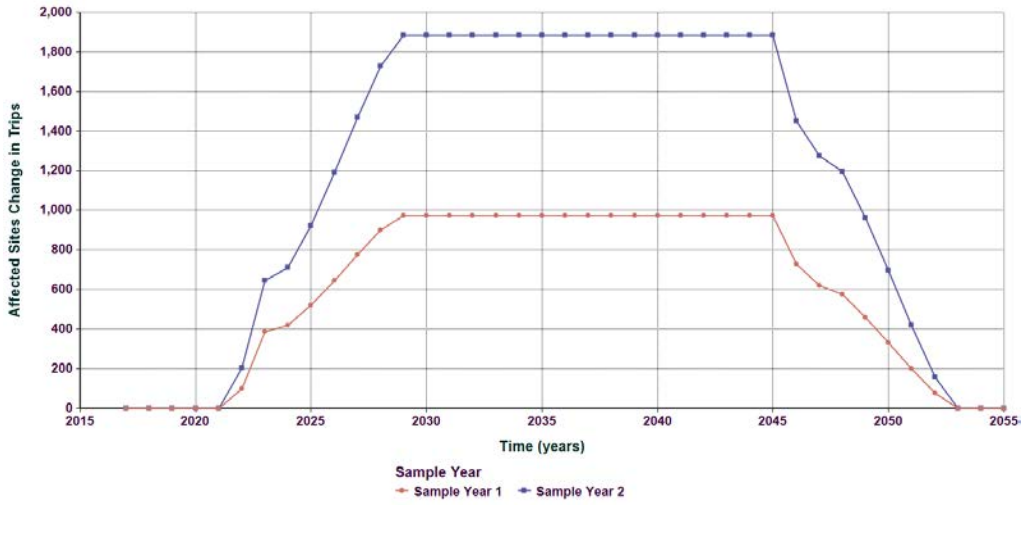
Panel B: Sample Year 2



Expected Catch	VERITAS Economic Consulting

Figure 1.7: Change in Expected Catch per Trip by Species at Affected Sites

Based on these expected catch changes, equations from welfare economics are used to identify annual changes in trips and economic benefits (based on changes in expected catch for all affected species). As detailed in Section 4, changes in consumer surplus that arise from changes in site demand is the metric for economic benefits. This methodology is consistent with economic theory and adheres to rule discussion with respect to considering the "the availability of alternative competing water resources for recreational usage [alternative substitute sites], and the resulting estimated change in demand for use and value of the affected water resources" (USEPA, 2014, p. 48,371). Figure 1.8 depicts the total change in trips at the three sites where catch changes are specified to occur based on the complete elimination of Bayside's entrainment.



Affected Sites Change in Trips | VERITAS Economic Consulting

Figure 1.8: Estimated Trip Change with a 100-Percent Reduction in Bayside's Entrainment

Figure 1.9 depicts the annual change in dollar-valued welfare associated with the estimated trip changes from a complete reduction in Bayside's entrainment.

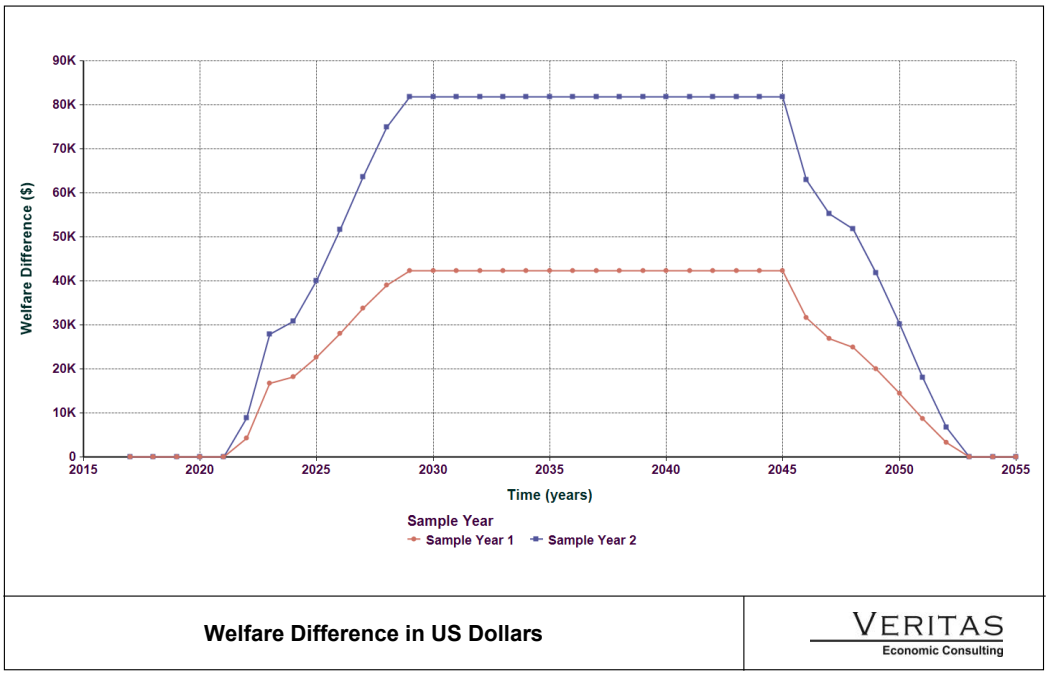


Figure 1.9: Change in Welfare with a 100-Percent Reduction in Bayside's Entrainment

1.3.2 Commercial Benefits

To assess the commercial fishing benefits, the analysis applies the price per pound from the National Marine Fisheries Service's 2016 data of annual Hillsborough County landings (Florida Fish and Wildlife Conservation Commission 2017d; NOAA Office of Science and Technology 2017b) to the changes in commercial yield estimated to result from a complete elimination of Bayside's entrainment. The analysis specifies that all of the additional harvest will be sold at the 2016 prices. Figure 1.10 presents the results of the evaluation for a complete elimination of Bayside's entrainment.

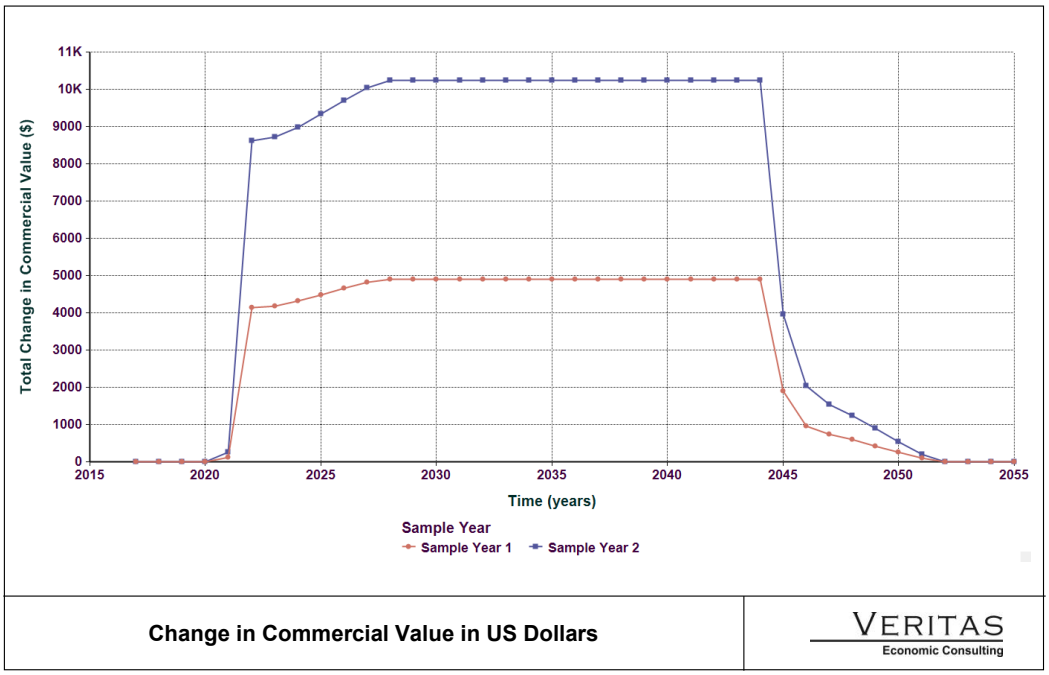


Figure 1.10: Change in Commercial Value with a 100-Percent Reduction in Bayside's Entrainment

1.3.3 Nonuse Benefits

The final category of benefits that could be monetized is nonuse benefits. Krutilla (1967) presented the original philosophical underpinning for nonuse values, arguing that individuals do not have to be active consumers of unique, irreplaceable resources in order to derive value from the continuing existence of such resources. He wrote:

> "when the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability are a significant part of the real income of many individuals" (Krutilla 1967 p. 779).

Important components of Krutilla's original concept are that nonuse values are related to the continuing existence of unique resources. Under this framework, common resources suffering from limited injury do not generate significant nonuse values. The economic literature emphasizes the relationship between nonuse values and both the uniqueness of the resource in question and the irreversibility of the loss or injury (Freeman, Herriges, and Kling 2014; Freeman 2003). Freeman (2003) summarizes this relationship as follows:

> "…economists have suggested that there are important nonuse values in …preventing the global or local extinction of species and the destruction of unique ecological communities. In contrast, resources such as ordinary streams and lakes or a subpopulation of a widely dispersed wildlife species are not likely to generate significant nonuse values because of the availability of close substitutes (Freeman 2003 p. 156)."

As Freeman's text indicates, common resources (i.e., resources that are not unique) that do not experience irreversible losses are not likely to generate significant nonuse value.

While experts tend to concur on the existence of nonuse values, they are inherently difficult to observe. As a result, they are looked upon quite differently from use values such as the recreational and commercial benefits of entrainment reductions. By comparison with use values, there is less agreement among experts about how nonuse values should be measured and the reliability of the techniques to measure them (Barnthouse, Bingham, and Kinnell 2016).

Since the development of the 2004 version of the 316(b) rule, USEPA has used a number of different methods to measure the potential nonuse values associated with reductions in impingement and entrainment. These include techniques such as Habitat Replacement Cost, Societal Revealed Preference, and the Fisher-Raucher Approximation. Most recently, as part of supporting the development of the 2014 version of the 316(b) Rule, USEPA administered a Stated Preference Survey to develop the total values (use and nonuse) associated with the Rule. While USEPA developed econometric models of the survey data and estimated respondents' willingness to pay for alternative impingement and entrainment reductions, they did not incorporate the results of the survey into the estimate of the Rule's benefits. Regardless, states have issued suggestions for how stated preference survey results can be used to inform site-specific benefit estimates (Wisconsin 2016), regulators have made suggestions in public meetings that Benefit Valuation Studies should, in the least, identify the implications that the stated preference study results have for an individual site's nonuse benefit estimates, and peer reviewers have asked whether the results of the stated preference survey have been considered as part of the 316(b) Benefits Valuation Study.

Given the survey's existence and these suggestions and questions from regulators and peer reviewers, we have developed a simulation model that uses the best available information from USEPA's Stated Preference Survey and the literature to identify the implications of what the survey results imply for the potential nonuse benefits of entrainment reductions at Bayside. Table 1.6 summarizes the benefit estimates and presents three different regions used to evaluate the nonuse benefits of Bayside's entrainment reductions:

1. All the households in Hillsborough County, Florida—the county where Bayside is located
2. All the households in the states included in the Southeast Region of USEPA's Stated Preference Survey
3. All the households in the United States.

The nonuse benefits are estimated over the same time period as the recreational and commercial benefits for 100-percent entrainment reductions: from 2021 to 2054. The table also includes nonuse benefit estimates across two different entrainment sample years and two different discount rates. As the results in Table 1.4 show, the estimated present value of nonuse benefits range from $440 to $45,560.

Table 1.4
Summary of Nonuse Benefits for 100 Percent Entrainment Reduction at Bayside

		Sample Year 1		Sample Year 2	
Discount Rate	Specified Population of Households	Present Value	Annual Value	Present Value	Annual Value
3%	Hillsborough County	$782	$23	$1,552	$46
	USEPA's Southeast Region[a]	$6,947	$204	$13,783	$405
	United States	$22,966	$675	$45,560	$1,340
7%	Hillsborough County	$440	$13	$869	$26
	USEPA's Southeast Region[a]	$3,912	$115	$7,721	$227
	United States	$12,930	$380	$25,522	$751

Notes: [a] The states in USEPA's Southeast Region include Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas, and Virginia.

1.4 Summary of Benefits

The results presented throughout this section have shown the effects of each step to develop the benefits of a complete reduction in Bayside's entrainment. In addition to a 100-percent reduction, the analysis also considers the benefits that would result from the entrainment reduction alternatives that have been evaluated at Bayside. Table 1.5 presents the timing specifications for each of the feasible technologies.

Table 1.5
Timing Specified for Feasible Technologies at Bayside

Entrainment Reducing Technology	Regulatory Documents Submitted	Permitting, Design, Construction & Installation	O&M Costs Begin	Years of Operation
Closed-Cycle Retrofit	2018	2018-2024	2024	20
0.5mm Fine-mesh Ristroph Traveling Screens	2018	2018-2021	2021	23
Variable Speed Pumps	2018	2018-2022	2022	22

Table 1.6 presents the recreational, commercial, and nonuse benefits for each evaluated technology. The table presents both the present and annual value of benefits using both sample years of Bayside's entrainment data and separates the benefits into recreational, commercial, and nonuse. To develop the present value estimates, the benefits estimated for each feasible alternative are discounted at 3 and 7 percent annually and summed over the specified time period used in the analysis.

For the closed-cycle retrofit, this produces a present value estimate ranging from almost $0.3M to over $1.0M. Annualizing these results over the specified 31-year time period results in annual benefits ranging from over $8,500 to a little over $33,000. Table 1.6 also presents the benefits of the 0.5mm fine mesh wedgewire screens and two variable speed pumps that vary by flow reduction: 4% flow reduction and 27% flow reduction. Figure 1.11 summarizes the present value benefit estimates of each technology using both a 3 percent and 7 percent discount rate.

Table 1.6
Summary of Total Social Benefits of Entrainment Reduction Alternatives at Bayside

Discount Rates	Sample Year	Technology	Entrainment Reduction	Present Value				Annual Value			
				Rec	Com	Nonuse[a]	Total	Rec	Com	Nonuse[a]	Total
3%	Sample Year 1	100% Reduction	100%	$0.58M	$0.07M	$22.97k	$0.67M	$17.03k	$2.11k	$0.68k	$19.81k
		Closed-Cycle Retrofit	85%	$0.46M	$0.05M	$18.09k	$0.53M	$14.72k	$1.76k	$0.58k	$17.06k
		0.5mm Fine Mesh Screens	68-71%	$0.34M	$0.06M	$14.00k	$0.41M	$9.96k	$1.65k	$0.41k	$12.02k
		Variable Speed Pumps	4%	$0.02M	$0.003M	$0.89k	$0.03M	$0.68k	$0.08k	$0.03k	$0.79k
			27%	$0.15M	$0.02M	$6.03k	$0.18M	$4.61k	$0.56k	$0.18k	$5.35k
	Sample Year 2	100% Reduction	100%	$1.11M	$0.15M	$45.56k	$1.31M	$32.74k	$4.39k	$1.34k	$38.46k
		Closed-Cycle Retrofit	85%	$0.88M	$0.11M	$36.01k	$1.03M	$28.45k	$3.66k	$1.16k	$33.28k
		0.5mm Fine Mesh Screens	68-71%	$0.68M	$0.12M	$28.63k	$0.83M	$20.10k	$3.45k	$0.84k	$24.40k
		Variable Speed Pumps	4%	$0.04M	$0.01M	$1.78k	$0.05M	$1.32k	$0.17k	$0.05k	$1.54k
			27%	$0.29M	$0.04M	$12.00k	$0.34M	$8.89k	$1.16k	$0.36k	$10.41k
7%	Sample Year 1	100% Reduction	100%	$0.30M	$0.04M	$12.93k	$0.36M	$8.87k	$1.21k	$0.38k	$10.46k
		Closed-Cycle Retrofit	85%	$0.23M	$0.03M	$9.79k	$0.27M	$7.38k	$0.96k	$0.32k	$8.65k
		0.5mm Fine Mesh Screens	68-71%	$0.17M	$0.03M	$7.78k	$0.21M	$5.10k	$0.95k	$0.23k	$6.28k
		Variable Speed Pumps	4%	$0.01M	$0.002M	$0.50k	$0.01M	$0.35k	$0.05k	$0.02k	$0.41k
			27%	$0.08M	$0.01M	$3.35k	$0.09M	$2.37k	$0.31k	$0.10k	$2.78k
	Sample Year 2	100% Reduction	100%	$0.58M	$0.09M	$7.72k	$0.67M	$16.93k	$2.52k	$0.75k	$20.20k
		Closed-Cycle Retrofit	85%	$0.44M	$0.06M	$5.88k	$0.51M	$14.18k	$2.01k	$0.63k	$16.82k
		0.5mm Fine Mesh Screens	68-71%	$0.35M	$0.06M	$4.80k	$0.42M	$10.26k	$1.99k	$0.47k	$12.72k
		Variable Speed Pumps	4%	$0.02M	$0.003M	$0.30k	$0.03M	$0.67k	$0.10k	$0.03k	$0.80k
			27%	$0.15M	$0.02M	$2.00k	$0.17M	$4.54k	$0.65k	$0.20k	$5.39k

Notes: [a] The nonuse benefits presented above are the benefits associated with the United States from Table 1.4.

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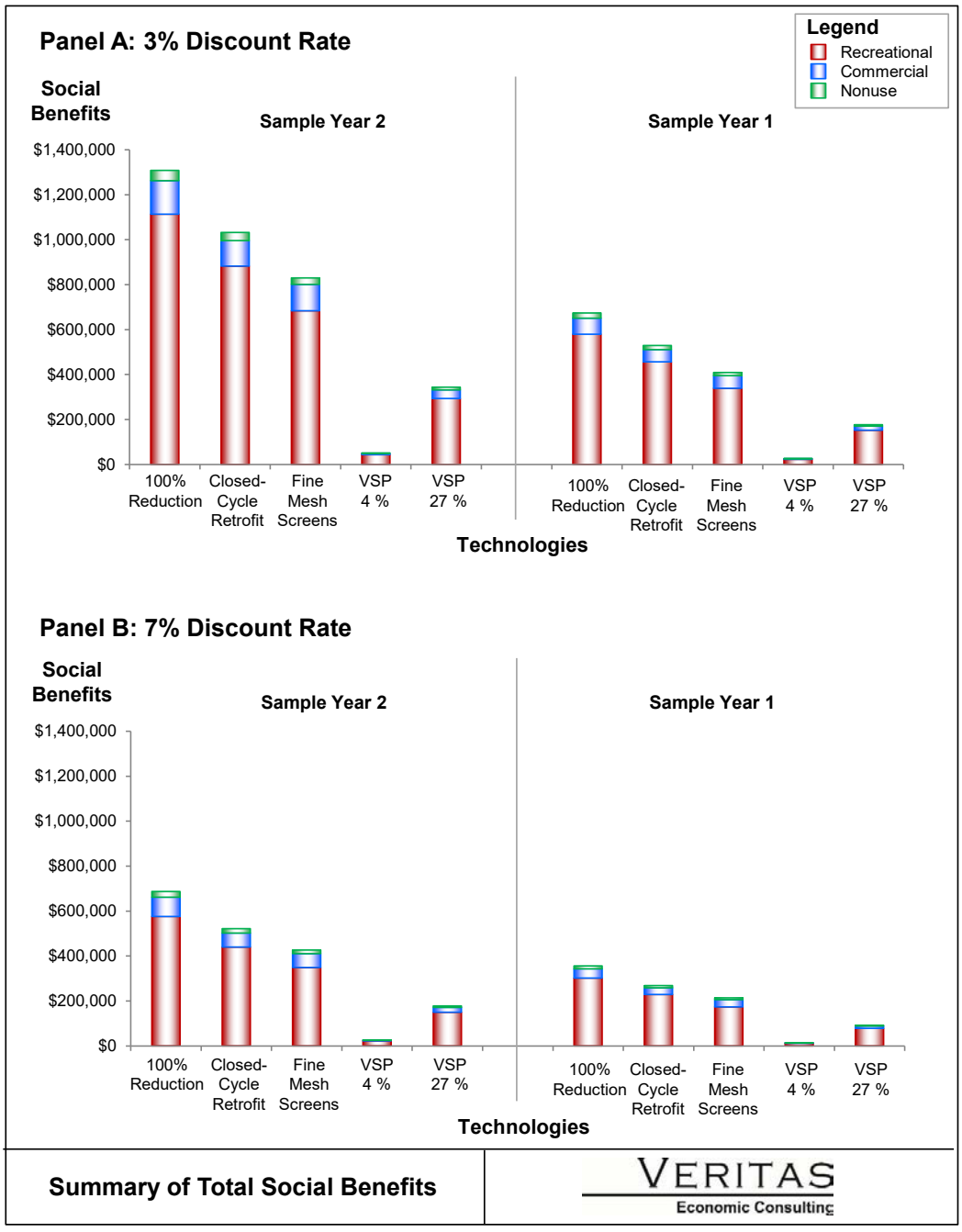


Figure 1.11: Summary of Total Social Benefits of Entrainment Reduction Alternatives at Bayside

1.5 Report Organization

The following sections present more detailed discussions of the data, and methods. Section 2 presents a detailed discussion on the methods used to assess the commercial, recreational, and nonuse values associated with entrainment reduction alternatives. Section 3 then provides a characterization of the baseline fishery (i.e., the state of the fishery with Bayside's current entrainment). Section 4 concludes by presenting the methods for evaluating the recreational and commercial benefits resulting from the changes in yield.

2. Methodological Overview

The U.S. Environmental Protection Agency's (USEPA's) 2014 316(b) Rule (79 *Fed. Reg.* 158, 48300–48439) requires that applicants submit studies of technologies or operational measures that can reduce entrainment. This section presents an overview of the methods for estimating the fishing benefits associated with entrainment reductions at Bayside Power Station (Bayside) as required by § 122.21(r)(11)(i-iii)).

Bayside is located at 3602 Port Sutton Road, Tampa, Hillsborough County, Florida. In the course of its normal operation, Bayside withdraws water from Hillsborough Bay through a cooling water intake structure (CWIS). As this water is withdrawn, entrainment occurs. Because aquatic systems are interrelated, Bayside's operations could potentially affect any of the species found in Hillsborough Bay (see Section 4, Table 4-1 of the main body of the report). Figure 2.1 shows an aerial view of Bayside on the shore of Hillsborough Bay.

2.1 Effects Studied

Although any of the species residing in Hillsborough Bay could potentially be affected by Bayside's entrainment, for practical reasons it is useful to limit the evaluation to effects most likely to have meaningful magnitudes. Accordingly, this assessment was limited to species that are most affected by Bayside's entrainment, as indicated by 2005–2007 entrainment estimates (Golder 2009), and the effects on important commercial and recreational fisheries in Hillsborough Bay.

Hillsborough Bay provides a recreational fishery for residents and visitors. Anglers catch seatrout, sheepshead, snapper, mullet, snook, tarpon, and other sportfish in Hillsborough Bay. Hillsborough County enables access for anglers at 33 boat ramps, 8 fishing piers, 15 marinas, and many shore access points on Hillsborough Bay (Florida Department of Environmental Protection 2010).

Stock-level effects could be experienced as changes in catch rates by people hoping to catch the affected species in Hillsborough Bay. Commercial and recreational anglers that were modeled as potentially being affected include those fishing Hillsborough Bay from Hillsborough County and neighboring counties.



Source of aerial photo: Google Earth

Figure 2.1: Aerial View of Bayside

2.2 Methods

Cooling water intake structures are regulated under Section 316(b) of the Clean Water Act (CWA). Under the proposed rule (76 *Fed. Reg*. 76, April 20, 2011), social benefits and social costs of entrainment control remedies as identified in peer-reviewed studies will play a role in establishing case-by-case Best Technology Available (BTA) entrainment mortality reduction standards (§ 125.98(e), p. 22,288). Social benefits must be assessed by the facility owner and included in the plant's permit application submissions. An important part of this evaluation is the identification of fishery impacts from entrainment. These impacts are uncertain and could result in no effect.[2]

Estimating the benefits of entrainment reductions requires assessing the relationship between entrainment, its corresponding changes to the relevant fishery, and the impact that fishery changes have on people. For example, properly assessing recreational values requires understanding how Bayside's entrainment affects recreational fishing catch rates and how those changed catch rates affect the well-being of anglers located in the plant's relevant vicinity. Properly assessing commercial values requires understanding how entrainment affects commercial catch rates, the profitability of commercial harvesters, and the prices consumers pay for commercially harvested fish.

The methodology uses a resource-economic simulation to evaluate the effects that entrainment has on recreational and commercial fisheries. To evaluate the effect of entrainment, we modify site catch estimates to generate recreational and commercial catch that could occur without the plant's entrainment. The methodology determines the economic value of the estimated catch changes by linking them to a model of recreational angling demand and evaluations of the relevant commercial fishing markets.

The methodology extends the most relevant fishery and resource-economic studies published in the peer reviewed literature. Important modeling features include linking yield equivalence, expected catch, and choice-based behavioral fishing models. These integrated partial equilibrium models are used to simulate conditions under With-Entrainment (baseline) and Without-Entrainment conditions, and the differences between these two conditions determine the benefits of entrainment reductions. As described in USEPA's *Guidelines for Preparing Economic Analysis*, equilibrium modeling using the With- and Without-Impact approach is central to all sound benefit estimation processes and regulatory impact analysis (USEPA 2010).

[2] Barnthouse (2013) notes that the available peer-reviewed literature does not support a conclusion that entrainment reductions will produce measurable improvements in recreational or commercial fish populations.

Figure 2.2 provides an overview of the methodology for evaluating the economic benefits of reducing entrainment at Bayside. The shading in the bottom portion of the figure denotes that the evaluation is separated into two parts: a Baseline (With-Entrainment) evaluation (top white portion) and a Without-Entrainment evaluation (bottom shaded portion). The calculated difference in recreational and commercial yield, catch rates, trips, angler welfare, and commercial profits represent the benefits of entrainment reductions. As the top portion of the figure shows, the approach begins by specifying the baseline yield for each evaluated species and dividing that into recreational (R) and commercial yield (C). The model then relates that yield to expected catch rates for the affected waterbody under the baseline, With-Entrainment, conditions (for brevity, the figure illustrates this process for estimating recreational fishing benefits). Those catch rates are apportioned over the estimated number of trips that are occurring at affected sites.

Under the Without-Entrainment conditions, the reduction in entrainment and the change in recreational and commercial yield that would accompany the entrainment reduction are identified. The new recreational yield is incorporated into changes in expected catch rates and the corresponding changes in trips that would accompany increase catch rates are estimated. To calculate recreational fishing benefits the model evaluates the differences between the two states of the world, including yield, expected catch, and trips. The box around the expected catch and trip differentials identifies that these result in the recreational fishing benefits measured as the consumer surplus differential. Consumer surplus is the difference between what an angler has to pay for a fishing trip and what the angler would be willing to pay.

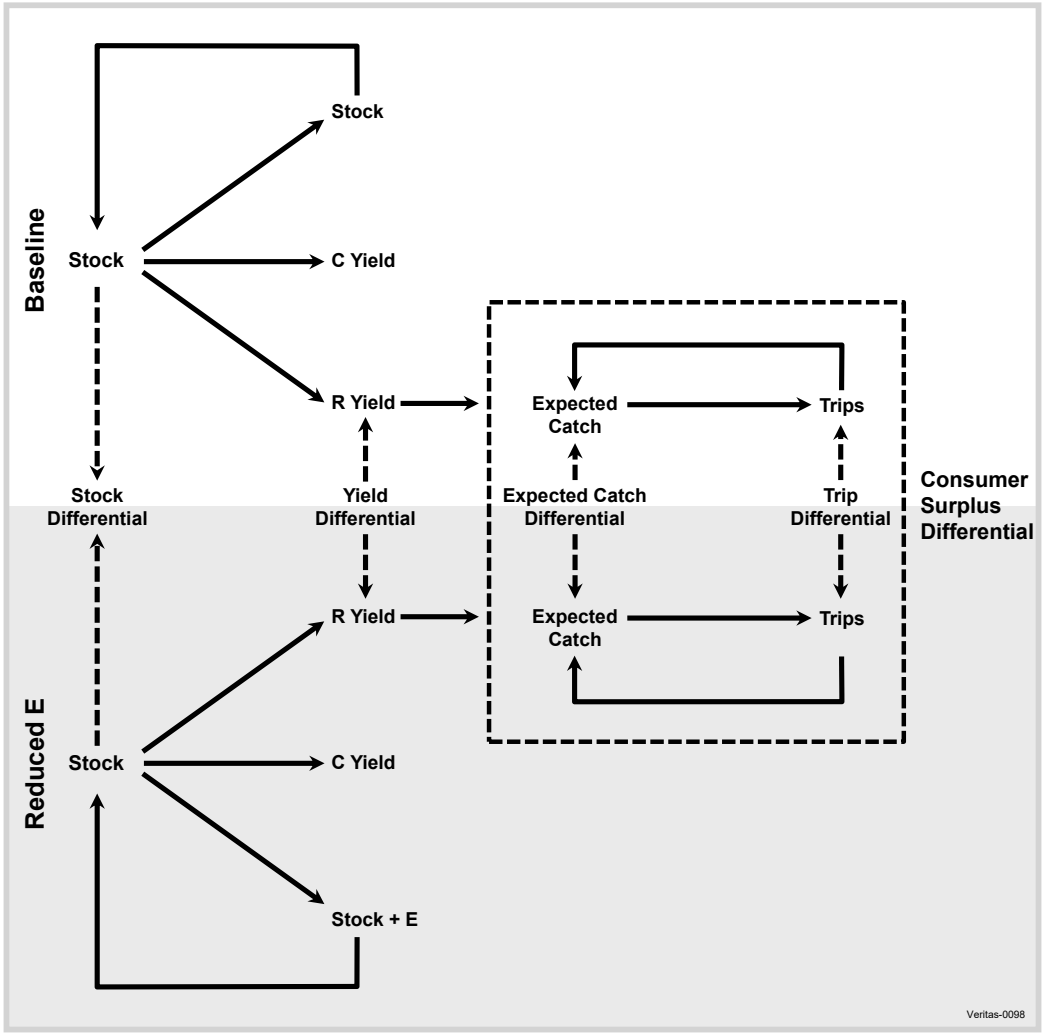


Figure 2.2: Overview of Methodology for Estimating the Benefits of Entrainment Reductions

Simulating the linked models produces equilibrium-based changes in stock, yield, trips and expected catch under Without-Entrainment conditions. Equations from welfare and market-based economics are used to identify changes in consumer and producer surplus which are then discounted to calculate present values. The following subsections provide additional detail on the recreational, commercial, and nonuse value components of the model.

2.3 Recreational Benefits

Correctly calculating recreational benefits requires a significant amount of information and calculations. As the 2014 Rule describes,

> "…assessing recreational use benefits involves estimating the improvements in recreational fishing opportunities resulting from reduced impingement mortality and entrainment, and assigning a value to these improvements. The value assignment is based on the estimated population profile—in particular, number and proximity to affected water resources—of recreational users, the availability of alternative competing water resources for recreational usage [alternative substitute sites], and the resulting estimated change in demand for use and value of the affected water resources based on reduced impingement mortality and entrainment and increased recreational fishing performance (USEPA, 2014, p. 48,371)."

To account for all this information, the methodology for estimating recreational angler benefits is based on simulating angler behavior and changes in social welfare resulting from reductions in entrainment and the associated increases in expected catch. To do this, a mathematical representation of angler demand (recreational angling demand model) for the population expected to be affected by reductions in Bayside's entrainment was developed. The recreational angling demand model identifies angler behavior across site characteristics that occur in both the Baseline and With-Out Entrainment conditions. Important modeling features include fusing an existing, behavioral (choice-based) preference function to spatially represented population data. This fusing process produces integrated partial equilibrium models that are used to simulate conditions under Baseline and Without-Entrainment conditions. The differences between these two conditions determine the social welfare changes associated with the entrainment reductions resulting from an individual entrainment control technology.

Important factors accounted for in the recreation angling demand model include angler preferences; attributes associated with the fishing sites they have to choose from; the number, quality, and availability of substitute fishing sites; the geographic range of impacted species; the number of trips with improved catch rates; and the number of anglers associated with those trips.

Preference functions are used to identify how anglers tradeoff the characteristics of alternative fishing sites when they choose how and where to participate in recreational fishing. When anglers take a trip, they have a choice of which site to visit. The sites from which they can choose have numerous characteristics such as the distance from their home, catch rates, facility amenities (e.g., presence of a boat launch), and water-body characteristics and

surroundings (e.g., fresh versus saltwater, level of crowding, and remoteness of the surroundings).

Preference functions include the (nonmarket) price of fishing as the costs anglers incur in traveling from their homes to recreation sites. These "prices" vary according to angler locations. When existing fishing sites have their features changed, such as a change in catch rates that could occur with entrainment reductions at a power plant, the preference function allows interpreting the value of the quality change in terms of travel costs. Anglers respond to catch rate changes by reallocating their trips so as to maximize the value of their fishing experience. For example, if entrainment rates are reduced and catch rates increase, an angler who typically visits a site farther away with a higher catch rate under Baseline conditions, would not have to travel as far to achieve a similar fishing experience under Without-Entrainment conditions. This angler would incur lower travel and time costs and experience welfare improvement because the same fishing experience costs the angler less in avoided travel and time costs.

Random utility analysis is the best method for evaluating angler preferences and valuing entrainment reductions on recreational fishing.[3] However, conducting an original random utility maximization (RUM) study can require extensive primary data collection. Developing a recreation demand model using a site-calibrated transfer of a preference function from an existing RUM study can capture important behavioral responses (i.e., changes in trip-taking behavior as a result of changes to a fishery) without requiring survey-data collection. The accuracy of this methodology is limited only by the analyst's ability to calibrate an already estimated preference function to a different population using appropriate economic methodologies (Smith, van Houtven, and Pattanayak 2002).

Economists have long used the preference functions from random utility models (RUMs) to estimate demand curves (Bingham et. al 2011; Kinnell et al. 2006; Bockstael, McConnell, and Strand 1991; Morey, Shaw, and Rowe 1991; Bockstael, Hanemann, and Kling 1987; Bockstael, Hanemann, and Strand 1986; Caulkins, Bishop, and Bouwes 1986; Feenberg and Mills 1980). The USEPA endorsed the use of RUMs for 316(b) applications in the now remanded rule (USEPA, 2004, p. 41,658). The RUM is based on welfare theory and posits that individuals make choices that maximize their utility, subject to constraints.

[3] Random Utility Maximization (RUM) models are recognized in the Department of the Interior (DOI) regulations (43 *CFR* §11.83) as an appropriate method for quantifying recreation service losses in natural resource damage claims. Currently, the RUM is the most widely used model for quantifying and valuing natural resource services. RUMs are also widely accepted in other areas of the economics profession. RUMs have been used in transportation (Beggs, Cardell, and Hausman 1981; Hensher 1991), housing (McFadden 1997), and electricity demand estimation (Cameron 1985), as well as more recently in environmental and resource economics.

RUMs divide fishing areas into discrete sites, each site being a plausible destination for fishing. In this framework, anglers choose which sites to visit, based on costs and fishing opportunities at the sites. Because anglers trade off factors, such as the cost of getting to the site against the quality of the fishing opportunity, this approach can evaluate the relative influence of these variables as revealed by anglers' decisions. Incorporating the relevant alternative, substitute sites allows evaluating the importance of site characteristics at each of these sites to identify the site-demand curves. These form the foundation for appropriately estimated economic benefits of changes in site attributes such as catch rate improvements.

The focus on site characteristics, such as catch rates, allows for the isolation of benefits to recreational fishing due to entrainment reductions. All other site characteristics are held constant. The better the characteristics of a site are, the higher the probability that an angler will choose that site, which is reflected in a higher value for the site. RUMs can be used to estimate both the distribution of trips among various sites and the total satisfaction received from a given set of fishing opportunities.

The analysis uses four main steps to develop the recreational angling demand model and estimate the benefits associated with reductions in Bayside's entrainment.

1. The first step involves selecting the angling preference function from the best available RUM study.
2. The next step identifies the appropriate geographic scope for substitute sites and selects a representative sample of substitute sites. Available information on recreation in the area and typical travel distances are used to develop an appropriate area of alternative, substitute sites to include in the model (generally within 100–200 miles of the affected site). Most RUMs based on original data use studies providing high-quality data. Several substitute sites are used that are representative and reasonable and provide a similar fishing experience for anglers who potentially fish near Bayside. By capturing substitution among sites, the simulation adds a critical level of realism relative to approaches that ignore substitution possibilities.
3. The third step in the analysis entails fusing the preference function to the affected population and calibrating the model's prediction of the population's trips. For this analysis, we allow the affected anglers to include any angler located in the counties that are adjacent to Hillsborough County. Because distance-based travel cost is an important variable in the recreational angling demand model, anglers closer to the site have a higher predicted likelihood of visiting the site than those farther away, but the model does not make any specification of which anglers are included in the model or not. For the sites affected by Bayside's entrainment, we fix the number of trips to correspond to the best available information on current visitation. Within these constraints, the remaining trips are distributed among the substitute sites in an appropriate manner, also based on available visitation information.

The distance traveled to a site is one of the most important site characteristics in a RUM. It directly influences the travel cost to each site for each angler. A critical factor for the site-calibrated benefits transfer is distance from each angler's residence (ZIP code) to each site included in the recreational angling demand model. These distances are calculated using the most recent version of a popular transportation routing software called PC*Miler (ALK Technologies 2010). Travel costs reflect both direct costs and travel time costs. Direct costs are calculated by multiplying the round-trip miles by $0.1864 per mile, which is the American Automobile Association's (AAA) 2015 per-mile cost of operating a motor vehicle (AAA 2015). The cost per mile includes gas, maintenance, and tires and is averaged across 5 types of vehicles: small, medium, and large sedans; SUVs; and minivans. The average hourly wage of each ZIP code within the model is calculated by dividing household income from the U.S. Census by 2,000 work hours per year (U.S. Census Bureau, 2017).[4] Travel time in minutes is also calculated by PC*Miler. The round-trip time estimate is multiplied by one-third of the average hourly wage rate to reflect the opportunity cost of time based on the original research of Cesario (1976) and the more recent evaluation by Phaneuf and Smith (2004).

4. In the fourth step, changes in trip patterns that anglers make in response to changes in catch rates are simulated. For purposes of this assessment, we increase catch only for sites in Hillsborough Bay. The increased catch rate is incorporated into the calibrated RUM while all other site characteristics for the relevant sites are held constant.

2.4 Commercial Benefits

Commercial benefits from entrainment reductions accrue to commercial anglers as increased profit attributable to the higher catch per unit effort (CPUE). The CPUE is associated with increases in fish populations and/or to fish consumers in the form of lower prices. The ability of commercial anglers to realize *sustained* increased profits depends on the responsiveness of market prices to higher CPUE. Market extremes determine the upper and lower bounds on commercial benefits. In competitive markets, prices adjust instantly and benefits accrue to consumers. In restricted markets, prices do not change and commercial benefits are maximized in the form of producer surplus at price times quantity (P * Q). As the rule describes, estimating the commercial benefits of entrainment reductions involves consideration of the fishery's relevant market conditions. Specifically, the 2014 Rule notes that

> "…assessing the productivity and value of commercial fisheries involves estimating the expected increases in commercial yield of economically valued species over time as a result of reduced impingement mortality and entrainment, and valuing these at market prices minus any incremental production costs associated with the incremental catch (USEPA, 2014, p. 48,371)."

[4] While the U.S. Census' household income data can include income from more categories than just the amount of earnings for a household's hourly wages times the number of hours worked in a year, the US Census' household income by ZIP Code is the best data source available to estimate the modeled population's opportunity cost of time. The potential effect on benefit estimates from using the U.S. Census income data would be to have an upward bias on benefit estimates.

To assess the commercial fishing benefits, the methodology first characterizes the current market conditions that exist in the relevant vicinity of Bayside. The methodology characterizes the operation of that commercial fishery under the With-Entrainment conditions and evaluates the commercial fishing market conditions. It then uses the information from changes in commercial yield to determine the effect on commercial catch per unit effort, market prices, producer surplus, and consumer surplus under Without-Entrainment conditions. Finally, the methodology estimates the difference in producer surplus and consumer surplus under the With and With-Out entrainment conditions to determine the commercial fishing benefits.

2.5 Nonuse Benefits

Recreational and commercial benefits from entrainment reductions arise from changes in catch rates and therefore accrue to people who use the affected resource. Another benefit category, nonuse benefits, results from changes in values that people may hold for a resource, independent of their use of the resource. These can arise for a number of reasons: they may be happy that other people can use the resource, they may want it to be available for people to use in the future, or they may believe the resource has some inherent right to exist.

While experts tend to concur on the existence of nonuse values, they are inherently difficult to observe. As a result, these values are looked upon quite differently from recreational and commercial values. By comparison with use values, there is less agreement among experts about how nonuse values should be measured, and the reliability of measurement techniques (Barnthouse, Bingham, and Kinnell 2016).

There are a handful of approaches that have been applied to quantify nonuse values both in the context of entrainment reductions and more generally. These include the non-economic methods of Habitat Replacement Cost (HRC) and Societal Revealed Preference (SRP), a "rule-of-thumb" approach called the Fisher-Raucher approximation, and two approaches that require administering surveys that pose hypothetical questions called Contingent Valuation (CV) and Discrete Choice Experiments (DCE).[5] Appendix C summarizes these methods as they've been applied for estimating the benefits of entrainment reductions.

Given the background on nonuse values presented in Appendix C, of all the methods that USEPA has used to develop estimates of nonuse benefits from entrainment reductions, its stated preference survey provides the best available approach. To develop site-specific,

[5] Both CV and DCE can also appropriately be called "Stated Preference" (SP) techniques as they both rely on stated rather than revealed (i.e., by taking fishing trips) preferences. Although DCE is often called SP, here we use the more precise term. Also, DCE is often referred to as "conjoint analysis" which is a related, but not identical technique.

nonuse benefit estimates, a simulation model was developed that incorporates the best of all the available information that is relevant for developing site-specific, nonuse benefits estimates of entrainment reductions. Appendix C presents a detailed description of the model and its results. The following steps were taken to construct and develop the inputs for the simulation model:

1. Collect and compile the data from USEPA's Stated Preference Survey;
2. Replicate the econometric models and willingness-to-pay estimates USEPA developed and presented in its 2012 Notice of Data Availability (USEPA, 2012);
3. Decompose the willingness-to-pay estimates into individual value categories and identify which categories are recoverable using the parameters estimated from USEPA's stated preference survey;
4. Place the plant's entrainment impacts in USEPA's study context;
5. Estimate differences in willingness to pay by demographics, collect and compile ZIP-Code level demographic data for the region(s) specified to contain the population having nonuse values for Bayside's entrainment reductions, and simulate willingness to pay by demographics for each Region;
6. Adjust the estimates to account for the Survey-Induced Bias present in the willingness-to-pay estimates and the Awareness Bias present in the extrapolation; and
7. Sum the adjusted estimates across all the individuals of each demographic profile in each ZIP Code included in the affected population.

Appendix C provides a more detailed description of the steps taken to quantify nonuse benefits and the results of that quantification.

3. Baseline Fishing Conditions

Baseline fishing conditions are defined as the current conditions at Bayside which include entrainment. The characterization of baseline fishing conditions considers recreational and commercial fishing, both current and into the future. To characterize baseline fishing conditions, we assess current recreational and commercial yield with Bayside's entrainment, the number of recreational and commercial anglers potentially affected by the impact of Bayside's entrainment on recreational and commercial yield, the number of fishing trips the anglers take, the sites that those anglers visit, and catch rates.

3.1 Baseline Recreational Fishing Conditions

When anglers take a fishing trip, they have many sites to choose from with varying attributes. These attributes include how far the site is from the angler's house, the type and number of fish the angler can expect to catch at each site, and the level of development at each site. Angler preferences across varying site attributes are characterized using recreational angling demand models.

3.1.1 Angler Preferences

The most sophisticated angling demand models are econometrically estimated using RUMs. RUMs are the best method for evaluating angler preferences across these different site attributes (USEPA 2010). The USEPA endorsed the use of RUMs for 316(b) applications in the now remanded rule (USEPA, 2004, p. 41658).[6] The RUM is based on choice theory and posits that individuals make choices that maximize their utility, subject to constraints. In this framework, anglers choose which sites to visit, based on costs and fishing opportunities at the sites. Because anglers trade off factors, such as the cost of getting to the site against the quality of the fishing opportunity, this approach can evaluate the relative influence of these variables as revealed by anglers' decisions.

To evaluate the factors influencing anglers' decisions, the analysis uses the angler preference function presented in Bingham *et al.* (2011). Bingham *et al.* (2011) covers fishing sites across New Jersey and explicitly consider various fishing experiences, including ocean, estuarine, and freshwater sites (e.g., inland lakes, rivers, and stream). The survey process was consistent with accepted survey protocols. The study's response rate is consistent with survey research standards, and its models are rigorous, perform well, and reveal results that are consistent with expectations (Bingham *et al.* 2011).

[6] RUMs are also widely accepted in other areas of the economics profession. RUMs have been used in transportation (Beggs, Cardell, and Hausman 1981; Hensher 1991), housing (McFadden 1997), and electricity demand estimation (Cameron 1985).

The statistical model estimated in Bingham *et al.* (2011) is a nested logit. To delineate potential differences in angler preferences with respect to fishery type, Bingham *et al.* (2011) uses a three-level fishing structure. On the first level, anglers choose whether or not they will fish. On the second level, anglers choose which waterbody type to fish from (freshwater, saltwater, or tidal sites). Lastly, after selecting a water body type, anglers decide which site to choose.

The model output is a coefficient for each site characteristic. Each coefficient reflects the importance of that site characteristic to angler welfare. These coefficients play a key role in the approach used in this assessment. Table 3.1 contains the relevant coefficients and t-statistics from the Bingham *et al*. (2011) model.[7]

Table 3.1
Coefficients from the Bingham *et al.* (2011) Model

Characteristic	Coefficient	t-Statistic
Travel cost	-0.024	-9.93
Advisory	-0.42	-2.30
Boat ramp	1.49	19.69
Trout and shad	0.31	7.42
Panfish	0.16	4.72
Freshwater game	0.16	8.67
Other freshwater	0.08	2.71
Other saltwater	0.36	8.86
Saltwater small game	0.16	3.01
Flatfish	0.95	10.70

When considering yield changes, value at the species level is a critical component of overall value. The Bingham et al. model includes coefficients for catch rates for both freshwater and saltwater species. Saltwater small game species include bluefish, sea bass, weakfish, and sea trout. The other saltwater species group includes species such as drums, croakers, jacks, kingfish, and leatherjacket. Relative species values can be evaluated by comparing these coefficients. Other saltwater species are valued higher than saltwater small game.

[7] While Bingham et al., (2011) is the most recently published applicable study for this site-calibrated benefits transfer, Greene, Moss, and Spreen (1997) present the results of a random utility maximization based model of angler preferences in Tampa Bay. The analysis uses Bingham et al. (2011) because its modeled catch rates are species-group specific, it accounts for the impact of urban characteristics, and is estimated using a repeated nested logit specification that evaluates ocean, estuarine, and freshwater trips. Comparing the two studies, the results from Bingham et al. (2011) estimate a per trip value of approximately $42 (2011$ - 1/0.024) per trip and Greene, Moss, and Spreen (1997) estimates a per trip value of approximately $2.48 (1997$ - 1/.404).

Values at the species level are typically identified by coefficients from RUMs. However, species-level values are notoriously difficult to estimate. For example, although anglers have different preferences, most models are based on an "average" angler. In addition, anglers often misidentify catch (Page *et al.* 2012) and many "species" coefficients are actually based on species groupings (Lupi *et al.* 1998).

3.1.2 Angler Participation: Population Size and Annual Fishing Trips

The U.S. Fish and Wildlife Service (USFWS) conducts the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation every five years. Among other information, the survey collects data on anglers and the types of fish that they catch. This assessment uses data from the 2011 survey for Florida because those are the most recent, complete data on angling activity. According to the national survey, 10.09 percent of Florida residents 16 years of age and older fished during 2011 (USFWS 2013, U.S. Census Bureau 2017). . To develop the estimate of total angling days, the analysis applies the average number of days that Florida anglers spend fishing from the 2011 USFWS (23 days) to the number of anglers residing in the affected ZIP Codes.

3.1.3 Angling Sites

In addition to using information on angler preferences and participation, the recreational angling demand model has to contain information on the sites an angler can potentially visit. We collect information from publicly available sources on the most popular inland river and lake sites. Model sites include fishing sites on Hillsborough Bay, Tampa Bay, the Gulf of Mexico, and Florida's inland lakes and rivers. Fishing sites include shore and boat fishing. Appendix B presents the characteristics of the sites included in the model.

Anglers can choose among many quality fishing sites within 100 miles of Bayside. Sargeant (1992) notes that Tampa Bay to Cedar Kay are among "hundreds of outstanding fishing areas along Florida's west coast." Florida Fish and Wildlife Conservation Commission (FWC) (2017c) identifies the top spots for freshwater fishing for popular species such as black bass (*Micropterus* spp.). Many substitute fishing sites feature attractive amenities, such as parks and marinas.

Table 3.2 lists conditions at affected sites in Hillsborough Bay. Catch rates are specified to be the catch per hour and are listed for six categories. Saltwater small game species include bluefish (*Pomatomus saltatrix)*, sea bass (*Centropristis striata)*, weakfish, and seatrout. The other saltwater species group includes species such as drums, croakers, jacks, kingfish, and leatherjacket. Flatfish includes flounder (*Paralichthys albigutta)*.

Table 3.2
Conditions of Affected Sites

Category	Ballast Point Beach	Davis Island	E.G. Simmons Park
Angler trips	68,710	17,780	17,878
Catch rate:			
Trout or shad	0.0000	0.0000	0.0000
Panfish	0.0000	0.0000	0.0000
Freshwater game	0.0000	0.0000	0.0000
Other freshwater fish	0.0000	0.0000	0.0000
Saltwater small game	0.0537	0.0537	0.0537
Other saltwater fish	2.6790	2.6348	2.6790
Flatfish	0.0106	0.0106	0.0106

Sources: DeLorme (2006); Florida Coastal Management Program (2011), Florida Fish and Wildlife Conservation Commission (2013); NOAA Office of Science and Technology (2017); Saltchef.com (2016a–2016o), State of Florida Division of Recreation and Parks (2013); U.S. Fish and Wildlife Service (2013)

The distance traveled to a site is one of the most important site characteristics in a recreational angling demand model. It directly influences the travel cost to each site for each angler. Thus, a critical factor in the simulation model is distance from each angler's residence (ZIP Code) to each site. These distances are calculated using the most recent version of a popular transportation routing software called PC*Miler (ALK Technologies 2010). Travel costs reflect both direct costs and travel time costs. Direct costs are calculated by multiplying the round-trip miles by the standard per mile reimbursement. The average hourly wage of each ZIP Code within the 50-mile radius is calculated by dividing household income from the U.S. Census by 2,000 work hours per year (U.S. Census Bureau, 2017). Travel time in minutes is also calculated by PC*Miler. The round-trip time estimate is multiplied by one-third of the average hourly wage rate to reflect the opportunity cost of time. The travel cost included in the model is the sum of the direct travel cost and the opportunity cost of time.

3.1.4 Calibrated Baseline Trips and Expected Catch

Travel costs and the other site characteristics are combined with the coefficients from the Bingham *et al.* (2011) model to allocate the estimated annual trips by the affected angling population to the affected and substitute sites. Total trips to the affected portion of Hillsborough Bay are calibrated to correspond to the best available visitation information for the affected sites. This process results in the distribution of trips to the affected sites listed in Table 3.2. The remaining trips are distributed among the substitute sites using the best available visitation information.

In the calibrated baseline dynamic recreational fishing model, baseline trips (from above) and yield (as described in Section 3.1) were combined by dividing recreational catch by trips, to identify a calibrated baseline expected catch for each affected species. To simplify the modeling identical expected catches were specified for each site.[8]

3.2 Commercial Fishery

Florida Statute 68B and its individual chapters govern commercial fishing in Florida's marine waters (Florida Department of State 2017). Hillsborough Bay can support commercial fishing and aquaculture. Table 3.3 lists the top species landed commercially in Hillsborough County, Florida.

Table 3.3
Species Landed Commercially in Hillsborough County from 2007–2016

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Pink shrimp	$1.98M	$2.48M	$2.21M	$3.25M	$2.53M	$2.77M	$2.74M	$5.97M	$3.56M	$3.09M
Mullet	$268K	$303K	$358K	$381K	$671K	$310K	$830K	$629K	$538K	$721K
Grouper	$312K	$568K	$581K	$352K	$506K	$551K	$380K	$332K	—	$63.4K
Blue crab	$256K	$166K	$197K	$328K	$280K	$270K	$265K	$403K	$287K	$383K
Brown shrimp	$218K	—	$169K	$18.4K	—	$130K	$146K	$182K	$141K	$5.5K
Other shrimp	$45.5K	$38.4K	$80.8K	$160K	$469K	$71.5K	$350K	$180K	$149K	$104K
Ladyfish	$35.2K	$62.2K	$1.2K	$57.7K	$13.8K	$16.7K	$23.9K	$53.5K	$16.7K	$212K
Tilapia	$41.4K	$16.6K	$30.0K	$54.6K	$19.8K	$52.6K	$48.2K	$55.2K	$22.9K	$20.7K
Mojarra	$30.6K	$30.8K	$21.7K	$18.5K	$6.2K	$10.6K	$10.9K	$17.9K	$10.1K	$32.8K
Jacks, pompano	$17.2K	$15.8K	$14.0K	$13.9K	$9.7K	$9.5K	$22.8K	$15.5K	$21.2K	$47.3K
Pinfish	$51.6K	$40.5K	$24.4K	$13.0K	$8.4K	$9.0K	$9.4K	$21.4K	$17.2K	$10.9K
Stone crab	$4.8K	$7.3K	$2.9K	$2.8K	$1.0K	$5.2K	$0.7K	—	$8.5K	$17.7K

Sources: Florida Fish and Wildlife Conservation (2017b)

The stone crab fishery is unique in that the crabs are caught in crab pots, one or both of each crab's claws are removed if legal sized, and the crabs are returned to the water alive to regenerate claws. Although stone crabs occur in the U.S. Atlantic Ocean and Gulf of Mexico from North Carolina to Texas, more than 98 percent of stone crabs are landed in Florida. The stone crab fishery in the southeastern U.S., including Florida, is October 15 through May 15 (seven months). During 2015, the most recent year with complete data, nearly 2.76 million

[8] Inducing realistic-looking catch-rate variation across sites would require identifying three (one for each site) exploitation rates for each species.

pounds of stone crab claws were landed commercially in Florida (Miller 2013; NOAA Office of Science and Technology 2017b; Florida Fish and Wildlife Conservation Commission 2012).[9]

3.3 Future Baseline Fishing Participation, Trips, and Site Quality

Because the modeling goes out decades into the future, differences from the current state of fishing could impact results. This means anticipated changes in site quality and availability or changes in economic conditions and fishing preferences should be expressed in the baseline case going forward.

Although participation in recreational fishing declined nationally years ago, fishing license sales have rebounded in recent years—dramatically in some states. According to the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, the number of anglers rose 11 percent from 2006 to 2011. Based on fishing license sales from 2006 to 2011, fishing participation increased nearly 4.8 percent among Florida anglers. However, between 2004 and 2015, Florida's fishing license sales increased 25.9 percent (U.S. Fish and Wildlife Service 2017b).

Based on this information, the future baseline of fishing participation, trips to sites, and expected catch was specified consistent with the pre-2012 calibrated baseline estimates described in Section 3.2.4.

[9] Stone crabs are harvested recreationally in Florida, also, but the number of participants and the magnitude of their harvests are unknown (Florida Fish and Wildlife Conservation Commission 2012).

4. Modeling and Valuing Changes in Recreational and Commercial Yield

Once the baseline stock and fishing conditions have been established, the next step in the analysis was to model the recreational and commercial yield impacts associated with Bayside's entrainment. The model uses two types of yield changes associated with simulating a reduction in Bayside's entrainment: direct and indirect yield changes. The direct yield changes are the increases in recreational and commercial species that would occur as a result of removing entrainment. The indirect yield changes are the increases in recreational and commercial yields that would occur as a result of removing Bayside's entrainment of forage species. ECT undertook the evaluation of direct yield changes to commercial and recreational, and forage yield impacts (see Section 11.2.2 of the main body of the report).

After modeling the yield impacts associated with Bayside's entrainment, changes in recreational and commercial yield was valued. Developing these values requires assessing the relationship between the recreational and commercial yield changes and the impact that these yield changes have on people. For example, properly assessing recreational values requires understanding how Bayside's entrainment affects recreational fishing catch rates and how those changed catch rates affect the well-being of anglers located in the plant's relevant vicinity. Properly assessing commercial values requires understanding how Bayside's entrainment affects fishery yields and how those changes in fishery yields affect commercial catch rates, the profitability of commercial harvesters, and the prices consumers pay for commercially harvested fish.

4.1 Valuing Changes in Recreational Yield

For a recreational fishery, the appropriate measure for valuing changes in recreational yield is the increase in consumer surplus resulting from changes in catch rates attributable to entrainment reductions. Consumer surplus is measured using demand functions. Demand functions describe the maximum number of trips a person would be willing to take at each price over a given time period. For a nonmarket service like recreational fishing, "price" is the cost of taking a trip to that site. This cost may include transportation costs, the opportunity cost of time, entrance fees, and other trip-related costs. Differences across demand functions under Baseline and Without-entrainment catch rates are used to identify economic benefits.

Figure 4.1 depicts an econometrically estimated demand curve from Bingham *et al.* (2011) for exposition purposes. Here, the example angler's round-trip travel cost is $25.[10]

[10] Travel cost consists of direct expenditures and the value of time going to and from the site.

Consistent with the concept of diminishing marginal utility, each additional trip is valued somewhat less than the previous trip. The fifth (and higher) trip is valued at less than travel cost. Therefore, the angler maximizes his utility by taking four trips. In the figure, the gray area above the per-trip cost and below the demand curve is the difference between what an angler pays for fishing trips to a site and the value that the angler has for those trips. This area is called consumer surplus, and it is the dollar measure of the satisfaction received from trips to the site. It is the difference between what the angler actually has to pay to visit a site and how much she would be willing to pay to visit the site.

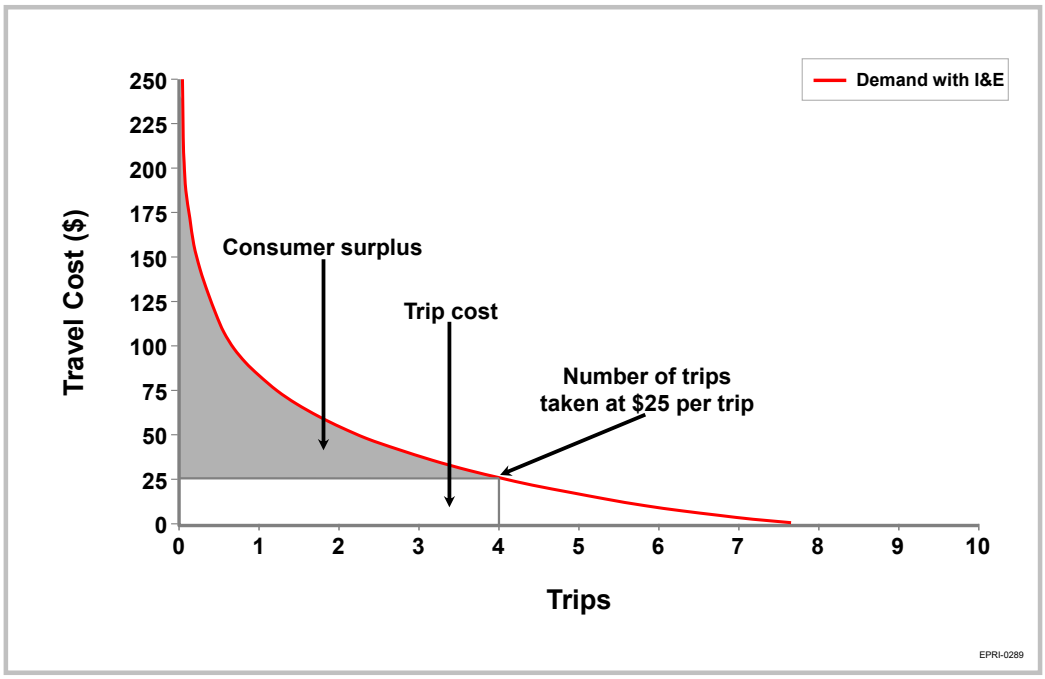


Figure 4.1: Example Site Demand Curve and Consumer Surplus

Consumer surplus changes when a site's catch rates change. Figure 4.2 depicts the process. In the figure, the red demand curve reflects catch rates with entrainment. The blue curve depicts demand curve when the site has higher, without-Entrainment catch rates. This new demand curve is to the right of the with-Entrainment curve. For each level of visitation, the trip is more valuable because of the higher catch rates. Consequently, the angler takes more trips to the site (five trips rather than four) and these trips have a higher value.

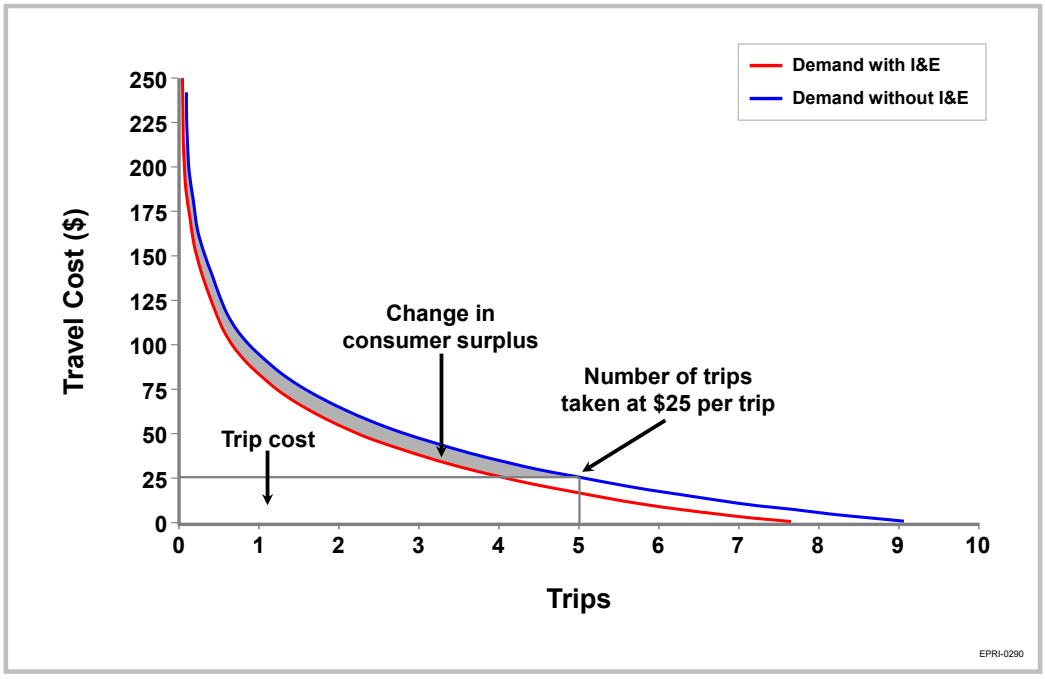


Figure 4.2: Increase in Consumer Surplus from Increase in Catch Rates

Developing these estimates of demand and changes in consumer surplus requires estimating changes in angler utility associated with changes in catch rates resulting from entrainment reductions. In mathematical terms, an individual angler's utility, U_{ipwj} (the well-being they receive from a fishing trip), is treated as a random variable composed of a deterministic component and a random component. The utility associated with a recreational fishing trip to site j of waterbody type w after making participation decision p by angler i can be expressed as:

$$U_{ipwj} = V_{ipwj} + \varepsilon_{ipwj} \quad (1)$$

where V_{ipwj} is the deterministic part of the utility function and ε_{ipwj} represents the random terms, which are assumed to be jointly distributed according to the generalized extreme value (GEV) distribution. V is a function of site characteristics, such as how far the site is from the angler's house, what type of fish he can catch there, how many fish he might expect to catch there, and how developed the site is.

For this assessment, the analysis uses the structure from Bingham *et al.* (2011) to estimate changes in angler utility resulting from reductions in Bayside's entrainment. An important aspect of the angling demand model is that it can be used to estimate changes in consumer surplus attributable to site quality changes, such as improved catch rates resulting from reduced entrainment, as well as the addition or elimination of a site. For this analysis, to estimate the changes in demand that would occur if Bayside's entrainment was not occurring, the analysis uses the results from Bingham *et al.* (2011) to determine how changes in catch would change anglers' trip-taking behavior and utility. The coefficients on expected catch in Bingham *et al.* (2011) are used to link the recreational yield changes to the preferences of affected anglers presented earlier.

After estimating the changes in catch resulting from the reduced entrainment, the analysis simulates the changes in trip patterns that anglers make in response to changes in catch rates in Hillsborough Bay. The economic assessment proceeds by developing the estimated changes in social welfare, in dollars, associated with the changes in trips that result from the changes in catch and trips. The analysis estimates the monetized benefits by calculating the difference in angler welfare without and with the increased catch rates and trips associated with reduced entrainment at Bayside.

4.2 Valuing Changes in Commercial Yield

Valuing changes in commercial yield entails evaluating the effect of changes in commercial harvest rates on the economic welfare of both commercial anglers and consumers of commercially harvested fish. This involves understanding how changes in catch rates affect the profitability of commercial harvesters and the prices faced by fish consumers. Doing so requires adding the supply curve to the concepts of demand curves and consumer surplus presented in Section 5.1 and evaluating supply implications under the current conditions versus the conditions that would result with reductions in Bayside's entrainment. Economic benefits from entrainment reductions could accrue to commercial anglers as increased profit attributable to higher catch per unit effort (CPUE), as surplus to consumers arising from lower fish prices, or some mixture of these. The ability of commercial anglers to realize sustained increased profits depends on the responsiveness of market prices to higher CPUE.

Generally speaking, the nature of commercial fishing benefits resulting from yield increases or improvements in CPUE depend on the type of fishery as summarized below:

- Case 1: Commercial anglers experience increases in catch rates, but fish prices do not change.

- Case 2: Commercial anglers experience increases in catch rates, and fish prices do change.
- Case 3: Commercial anglers experience increases in catch rates, the commercial fishing market is in short-run equilibrium, and there are no explicit regulatory quotas.

Appendix A provides a detailed discussion of these three cases for commercial fisheries. As Appendix A describes, commercial harvesters consider many factors when making business decisions about fishing including the fact that catch rates are seasonal and stochastic, fish and fuel prices vary, vessels often target a variety of species and can switch gear if needed, boats can sail from and offload at various ports, the number of crewmembers can vary, the weather has implications for catch and safety, and so on. This complicated supply picture interacts with consumer demand that is impacted by a number of factors, including quality of catch (i.e., freshness), cost of substitutes (other fish and foods), and eating trends. Regulatory actions, such as quota-setting, impact both harvest costs and market prices.

Commercial fishery landings in Hillsborough County totaled about $4.81 million during 2015, the latest year with complete data. Pink shrimp comprise 74 percent of the landings; much of the pink shrimp is caught in the Gulf of Mexico. The shrimp fleet (as many as 50 boats) operates out of the Port of Tampa. Besides pink shrimp, the top ten species landed in Hillsborough County are mullet, brown and other shrimp, grouper, blue crab, ladyfish, tilapia, mojarra, jacks and pompano, and pinfish. A modest volume of stone crabs are landed commercially in Hillsborough County (Table 3.8). The Tampa Bay metropolitan area has dozens of large-scale and small-scale seafood processors (FWC 2017b; Huang 2003).

Economic benefits from entrainment reductions could accrue to commercial anglers as increased profit attributable to higher CPUE, as surplus to consumers arising from lower fish prices, or some mixture of these. The ability of commercial anglers to realize sustained increased profits depends on the responsiveness of market prices to higher CPUE. This is particularly important for quantitative results for Hillsborough Bay.

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Appendix A
Commercial Fishery Benefits Theoretical Overview

Both the supply and demand components of commercial fishing markets are quite complex and empirical applications that link commercial catch rates to economic benefits are limited. These limitations vis-a-vis the economic valuation of entrainment reductions were thoroughly considered by authors of this study and Ted McConnell (resource economist, University of Maryland) as part of the EPRI Closed-Cycle Cooling Program (EPRI 2011). As described in the body of this report, the limited change in commercial yield that is projected from entrainment reductions at Bayside is monetized by specifying that no price changes occur as a result of reductions in Bayside's entrainment and that commercial anglers are able to sell all of their additional catch at these unchanged prices. This approach does not rely on the preferred partial equilibrium structure and as such produces only economic values with no characterization of behaviors. This is a result of the lack of study information for performing functional benefits transfer.

This appendix is intended for reviewers with interest in the rationale for not applying partial equilibrium modeling and provides a conceptual characterization of commercial fishing economics. Consistent with relevancy for entrainment reductions the focus is on the supply side. To provide a behavioral foundation for the concept of the supply curve, this exposition uses results from a simulation model of vessel behavior. This model simulates optimizing behavior under various complex changes. It was constructed to understand behaviors in the important and contentious New England groundfish fleet (Bingham et al. 2010).

To provide a behavioral foundation for the concept of the supply curve, this exposition uses a model of vessel behavior that is based on the New England groundfish fleet.[11] A typical vessel in this fleet might be a trawler that is 55 to 65 feet in length. Fixed annual costs for owning such a vessel include dock fees, insurance, and loan repayment.[12] For owning the boat to be profitable, the fixed costs of ownership must be covered by revenues net of operating costs. Revenues are the dockside value of catch (i.e., pounds landed times price per pound). Boat owners seek to increase revenues by traveling to fishing grounds with high catch rates. Operating (or variable) costs include costs for fuel, ice, and the crew. Owners consider these costs when deciding where to fish.

An optimization model was developed to simulate the behavior of owners of groundfish trawlers less than 65 feet operating out of New Bedford. The model simulates behavior of a

[11] Ultimately analysts are interested in knowing impacts to *all* commercial fishing. This example considers a single vessel out of approximately 1,000 similar vessels participating in the New England groundfishery.

[12] Typical terms for purchase of a fishing boat might be 25 percent down with a payout over 7–12 years. There might be a fixed interest rate for the first five years at about 2.5 percent to 2.75 percent over the cost of funds, which is the federal home loan bank rate (Tim Kelleher, TD Bankworth).

profit-maximizing vessel owner who chooses where and when to fish based on costs and catch rates. The model is calibrated to produce trip-taking behavior that is like the "average" or "typical" behavior. Under these conditions, the minimum cost of catching any given quantity of groundfish is determined, and from that cost one can derive the marginal cost curve depicted in Figure A.1 below.[13] This With-Entrainment minimum cost curve is generated by successively simulating the behavior of a typical groundfishing vessel, where dockside price is fixed and the quantity of catch is constrained at various (increasing) levels.

The profit-maximizing vessel owner chooses the most profitable opportunities first. As the artificially imposed catch constraint is loosened, less productive (or equivalently more costly) alternatives are chosen.

The successive loosening of the total catch constraint produces the rising marginal cost curve shown below. By implication, the average cost of harvest also increases. Including the market price for groundfish allows assessing the variable economics of the boat. In the figure, a market price of $1 per pound is specified.[14] With market price at $1 per pound, the owner chooses to take all trips that are expected to result in an average per-trip harvest cost of less than $1 per pound. This leads to an annual groundfish harvest of 80,000 pounds for this vessel.[15] This is consistent with a typical vessel in the New England groundfishery from 2003 to 2008. Total variable costs observed visually as the area under the marginal cost (supply) curve, equals approximately $40,000 in fuel and ice costs. The remaining $40,000 (the area above the supply curve and below price) is revenue less non-labor variable costs. Skipper and crew shares generally are about 50 percent of net returns. This would total about $20,000, leaving $20,000 to pay for dock fees, insurance, boat loan payments, and maintenance.

[13] Optimization is conducted in Analytica 4.2 using mixed integer formulation and Frontline optimizer.
[14] This is consistent with average historical dockside price for groundfish in New England.
[15] This curve is also known as the boat's *supply* curve because it represents the quantity of fish that the boat would supply at each market price.

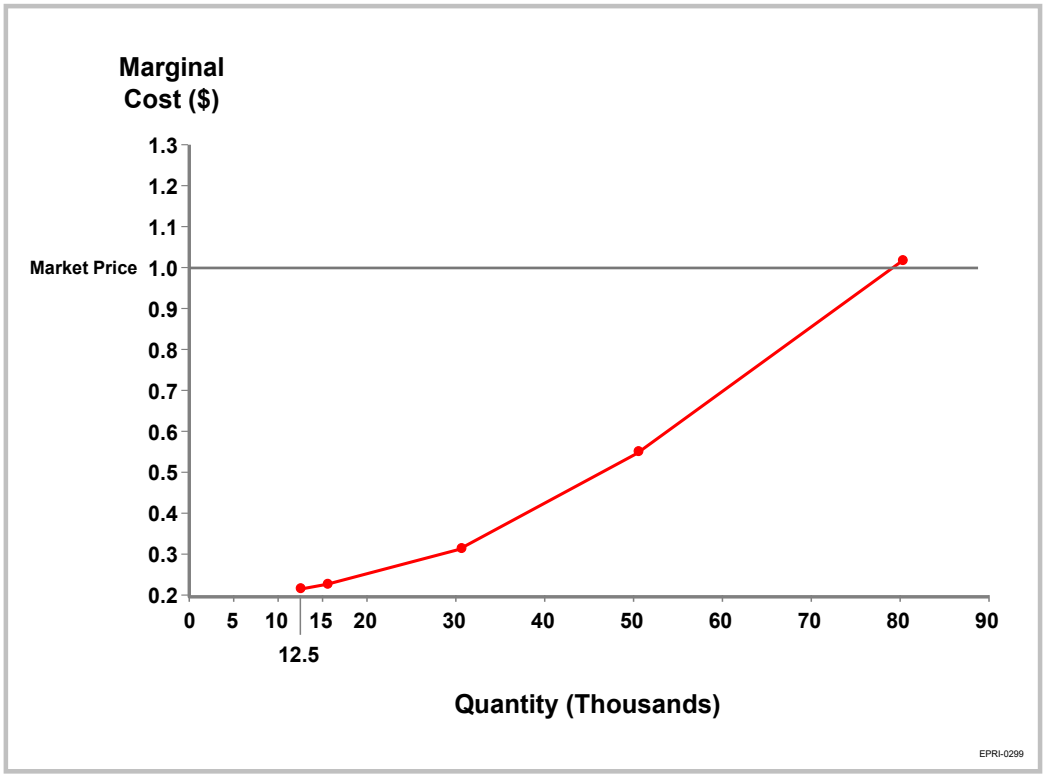


Figure A.1: With-Entrainment Variable Costs

Commercial Fishing Without-Entrainment

The difficulty of identifying economic benefits under Without-Entrainment conditions depends upon a number of factors that are considered in the cases described below.

Case 1: Harvesters experience an increase in catch rates, but fish prices do not change.

In this simple case, higher catch rates lead to harvest increases and/or cost decreases. Depending on the form (i.e., magnitude and location) of catch-rate improvements, the vessel can either fish as it did under With-Entrainment conditions; adjust its effort in a number of ways, including changing gear, fishing longer, choosing different locations; or make many other marginal adjustments short of investment or exit/entry. To simulate this effect in the model of commercial fishing behavior, catch rates are increased within the optimization model at certain locations and times. This effect can be seen graphically in the new cost curve depicted below.

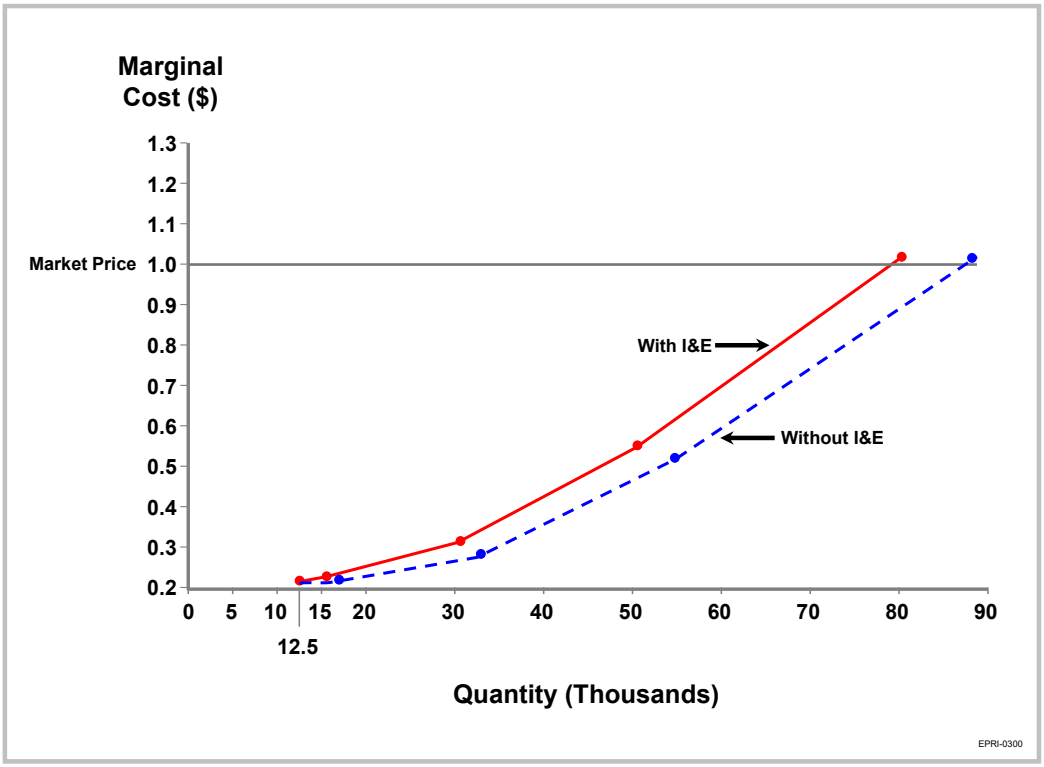


Figure A.2: Vessel Supply Curve with Improved Catch Rates and Constant Prices

With this new cost curve, the financial picture of the boat is improved. If that market price stays at $1 per pound, the boat increases its harvest to 90,000 pounds and total revenue increases to $90,000. Now total variable costs are $45,000. Of the $45,000 remaining ($90,000–$45,000) half goes to the captain and crew. Their economic status is somewhat improved; they now divide $22,500 compared to the previous $20,000. Furthermore, under these Without-Entrainment catch rates, there is a return to ownership of the vessel of $2,500 per year.

Ultimately analysts are interested in understanding how economic welfare might change across *all* commercial fishing. The fishery regulatory structure most likely to have constant prices is a fishery regime that restricts harvest. In such markets there is a strict quota on the quantity of commercial stock sold, which determines the equilibrium price. As shown in Figure A.3, improved catch rates reduce costs; however, the quantity supplied remains at the quota level and the corresponding equilibrium price remains at the original (With-Entrainment) price.

In this situation, there would be an increase in producer surplus because costs are lower, but revenues remain the same.

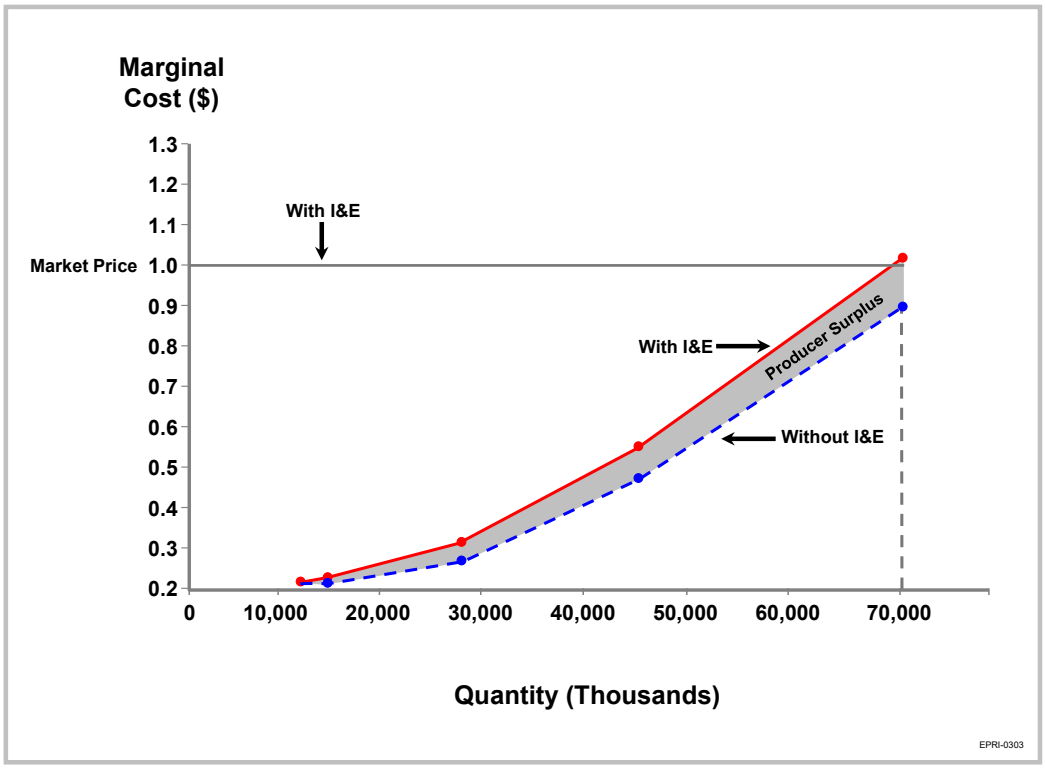


Figure A.3: Commercial Fish Market (with a Quota)

In the very simplest of cases, there is no change in fishing behavior, and the change in producer surplus is equal to the change in catch multiplied by dockside value. In the more general case when fishing behavior changes, identifying producer surplus changes requires estimating the area between the two supply curves. Doing so requires a times series of data on the market of the species as well as sufficient data to estimate the impact of biomass changes. This would include harvest, effort, price of output, input prices, biomass, and information on the regulatory structure.

Under these conditions, econometric modeling of the response of commercial harvesters to changes in biomass falls roughly into one of these categories:

1. Estimating a random utility model of harvester choice among locations, using the idea that improved biomass at some of the locations could then be valued using the same

ideas as recreational anglers (for example, Haynie and Layton 2004). This requires trip-level data on expenditures by vessel and expected returns or catch rates by location.

2. Using trip or seasonal-level data by vessel to estimate cost or production function that can be converted to supply functions. These models are estimated at the individual level and typically not aggregated. (See Squires and Kirkley 1991 for an example.)
3. Estimating models of bioeconomic equilibrium. This approach typically begins by modeling effort, including the biological growth function and then whatever market structure is appropriate. This approach implicitly creates a cost function but it entails an equilibrium bioeconomic model of the species. These models are more appropriate for the long run when both vessels and biomass adjust. See, for example, Homans and Wilen (1997).
4. Estimating each of these models is feasible but far exceeds the time and expense warranted for assessment of the benefits for the typical species affected by entrainment.

Case 2: Harvesters experience an increase in catch rates and fish prices do change.

In the previous example, the wholesale price of ground fish has been specified as remaining constant. This example was motivated at the market level by introducing a quota based management system. For open-access fisheries, the degree to which prices of commercial fish are "sticky" (i.e., not responsive to changes in quantity) would depend on a number of factors. For example, small percentage yield changes would be less likely to lead to price changes. Species that are marketed from different areas would tend to keep those differences damped by absorbing supply increases across a broader area. The more general case in which prices respond to yield changes is depicted at the vessel level in Figure A.4.

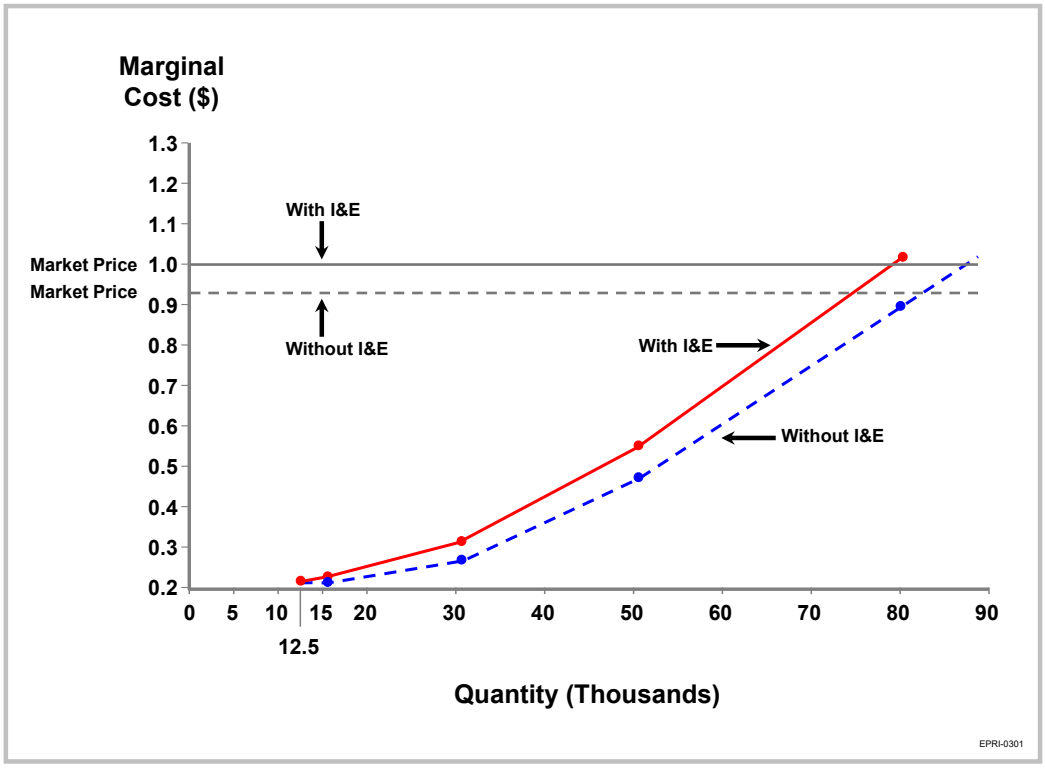


Figure A.4: Commercial Fish Market with Open Access

In this figure, with higher catch rates, the vessel maximizes profit by increasing harvest. When all harvesters face lower harvest costs, they may compete to sell additional fish by lowering prices. If the market for fish is small relative to the increased harvest, these individual efforts can result in lower market prices. This is a natural consequence of a large number of owners independently maximizing profit. The introduction of the market demand curve in Figure A.5 represents this condition, Case 3.

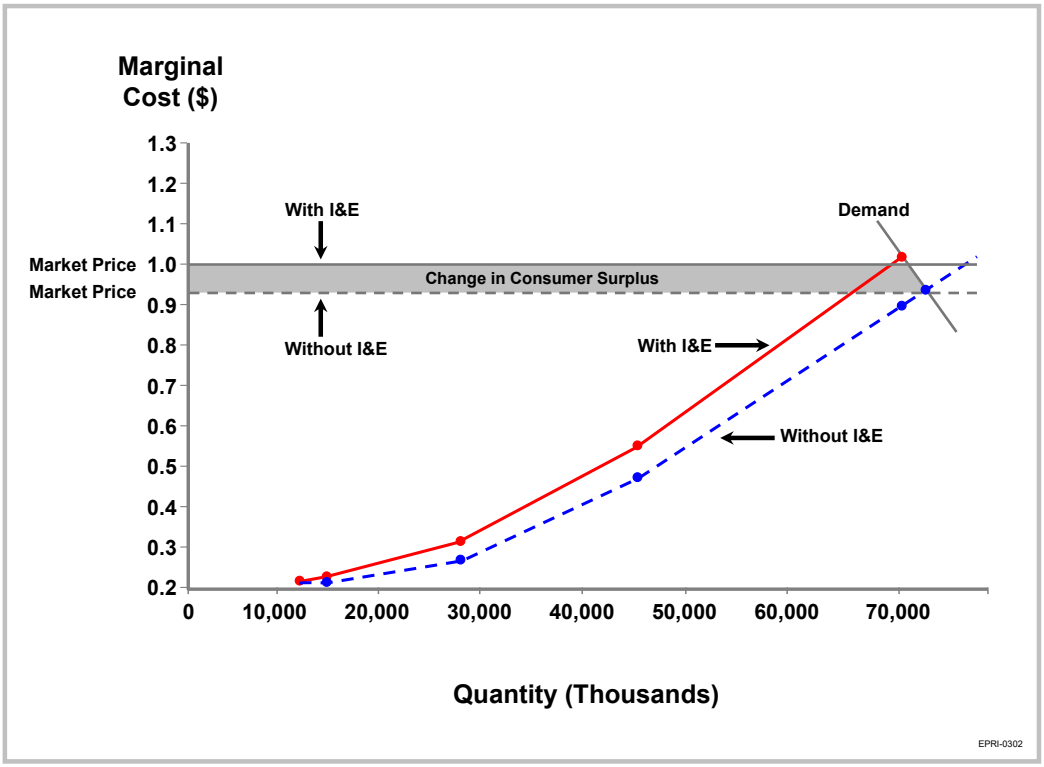


Figure A.5: Case 3: Most Complicated Case—Effort and Price Changes

This figure shows a new supply curve generated from the model with more identical vessels and more output per vessel. Two points on the market demand curve arise from the price and quantity observed in With-Entrainment, and the price observed in Without-Entrainment conditions. Solving for profit-maximizing output for each boat at this new market price and summing returns the total quantity supplied.[16] Consumer surplus is the difference between what consumers are willing to pay (as represented by the demand curve) and market price.

This case has the same intense need for data and modeling as in Case 1. In addition, it is now necessary to have the correct instruments for identifying both supply and demand curves because structural econometric modeling of these benefits takes the supply and how it shifts with increases in biomass, as well as the dockside demand curve. This means the demand function must be estimated and the market model and data must allow the identification of supply and demand curves. This would require the estimation of a system such as Hermann

[16] Here this is greatly simplified by assuming 1,000 identical boats.

and Criddle (2006) or a bioeconomic model such as Homans and Wilen (1997) with endogenous demand.

Summary and Implications for Methods

Figure A.6 provides a summary of the most complicated case. This figure features a fishery in short-run equilibrium without explicit regulatory quotas.

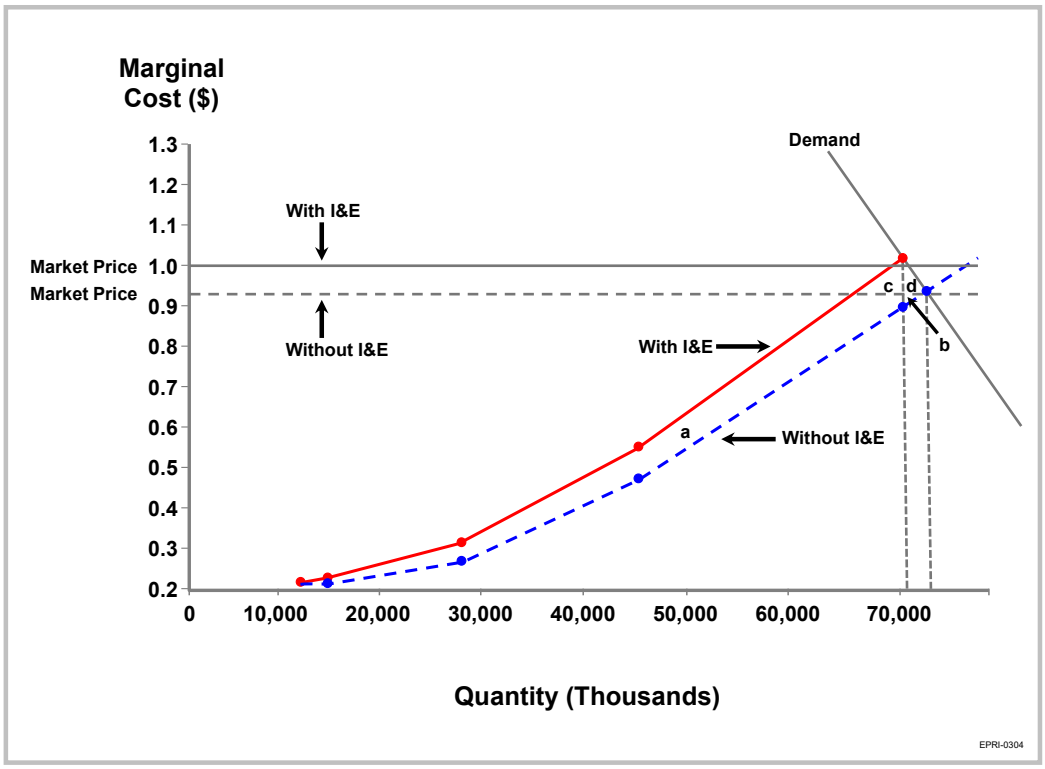


Figure A.6: Summary of the Benefits of Reduced Entrainment

As depicted in the figure, catch-rate improvements reduce the cost of harvesting. This leads to the supply curve shift across With-Entrainment and Without-Entrainment. The dockside demand is given by the Demand curve. In the figure, landings increase and the price falls. The change in producer surplus equals the area a+b+c. The change in consumer surplus is d. The net change in social surplus is the sum: a+b+c+d.

Important to the analysis of benefits to commercial fisheries is that even this admittedly complicated example is a great simplification of commercial fishing behavior and markets. Commercial harvesters consider many factors when making business decisions about fishing.

Among these considerations, catch rates are seasonal and stochastic; fish and fuel prices vary; vessels often target a variety of species and can switch gear if needed; boats can sail from and offload at various ports; the number of crewmembers can vary; the weather has implications for catch and safety, and so on. This complicated supply picture interacts with consumer demand that is impacted by a number of factors, including quality of catch (i.e., freshness), cost of substitutes (other fish and foods), and eating trends. Regulatory actions impact both harvest costs and market prices. Given these complexities, it is useful to assess what approaches are available and to consider their implications with respect to errors in the estimation of benefits.

In many cases familiarity with the fishery, including processing and downstream marketing, can help determine whether price changes could be expected for given changes in landings. Such judgments would help rule out price changes in some cases, but would not provide empirical support when price would be expected to change. Using data sets such as those employed by Kirkley (2006) and Bishop and Holt (2002), it would be feasible to estimate aggregate inverse demand functions.

The flexibility of price with respect to landings separates Case 1 from Case 2. To sort out the cases, it would be necessary to have estimates of the price flexibility or to estimate the relationship. Estimating the flexibility of price with respect to landings involves a model with price as a function of landings and other exogenous variables. This model stems from the notion that landings are exogenous with respect to contemporaneous price and the fact that the commodity is perishable, so that supply cannot be provided from storage. Each assumption is true at some time scale, but the scale differs across species. Increasingly fish are flash frozen as they are harvested, making supply more endogenous.

There are two basic approaches to estimating this model. One is to assume that the correct model represents the valuation placed on harvest by consumers and to adopt a flexible functional form of consumers' preferences. This is the approach taken by Bishop and Holt (2002) and others. The other approach is to estimate a model with less structure—basically an aggregate inverse demand function.

The Holt-Bishop paper provides flexibilities that could be used with entrainment cases on the Great Lakes. Kirkley (2006) provides estimates for a number of saltwater species. There are reasons to be concerned with these estimates. First, the preference functions are based on household's valuation of exogenous changes in fish. The structure of dockside demand reflects in part the structure of household demand buyers for households paying posted prices. Fish are not exogenous to them. Further, there are other outlets for landings so the supply going to

households will be endogenous. For example, landings of species that are traded internationally will be divided between domestic consumption and export.

The more low-tech but intuitive approach of Graddy (2006) is perhaps more appropriate for modeling dockside demand. This model explains the price as a function of landings. This is an aggregate dockside price model that captures the various influences on price. Structurally it is an inverse demand function, and so represents the responses of buyers. It provides estimates of price flexibility that would be ideal for using in entrainment assessments. It recognizes that price responds to landings, but does not give more structure to the model than that.

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Appendix B
Substitute Fishing Sites and Characteristics of Sites

Table B.1 lists recreational saltwater fishing sites in Florida that are within 100 miles of Bayside, and Table B.2 lists recreational freshwater fishing sites in Florida that are within 100 miles of Bayside.

Table B.1
Recreational Saltwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Site Name	Affected Site	Latitude	Longitude	Boat Launch	Advisory	Trout, Shad	Panfish	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Other Information	Estimated Annual Trips[a]
Ballast Point Beach, 5300 Interbay Boulevard, Tampa, FL (Hillsborough County)	Hillsborough Bay, Tampa Bay	1	27.889553	-82.480869	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	68,710
Davis Island Boat Ramp, 825 South Severn Avenue, Tampa, FL (Hillsborough County)	Hillsborough Bay	1	27.910822	-82.445878	1	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Catch rate: MRIP	17,870
E.G. Simmons Park, 2401 19th Avenue Northwest, Ruskin, FL (Hillsborough County)	Pelican Cove, leads to Tampa Bay	1	27.746152	-82.473349	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,878
Bayport Park Boat Ramp, 4140 Cortez Boulevard, Spring Hill, FL (Hernando County)	Weeki Wachee River, leads to Gulf of Mexico	1	28.536134	-82.649813	1	1	0.0000	0.0000	0.0007	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	14,528
Bayport Park, 4140 Cortez Boulevard, Spring Hill, FL (Hernando County)	Weeki Wachee River	1	28.533681	-82.650233	0	1	0.0000	0.0000	0.0007	0.0000	0.0000	0.0537	0.0106	Fishing pier Catch rate: MRIP	31,574
Hernando Beach Public Boat Ramp, 4477 Calienta Drive, Hernando Beach, FL (Hernando County)	Little Pine Island Bay, Gulf of Mexico	1	28.499696	-82.650090	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	14,528
Jenkins Creek Park Ramp, 6401 Shoal Line Boulevard, Spring Hill, FL (Hernando County)	Rice Creek Bay, Centipede Bay, Rock Island Bay, Chassahowitzka River	1	28.522992	-82.637760	1	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0000	Catch rate: MRIP	14,528
Jenkins Creek Fishing Pier, 6401 Shoal Line Boulevard, Spring Hill, FL (Hernando County)	Jenkins Creek	0	28.522303	-82.637461	0	0	0.0000	0.0000	0.0007	0.0000	0.0000	0.0537	0.0000	Fishing pier Catch rate: MRIP	31,574
Rogers Park Boat Ramp, 7244 Shoal Line Boulevard, Spring Hill, FL (Hernando County)	Leads to Gulf of Mexico	1	28.531477	-82.626861	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Watch for manatees Catch rate: MRIP	14,528
Alfred McKethan Pine Island Beach, 10840 Pine Island Drive, Spring Hill, FL (Hernando County)	Rock Island Bay	1	28.568005	-82.656469	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0000	On the beach Catch rate: MRIP	5
Alafia River Boat Ramp, 4020 Alafia Boulevard, Brandon, FL (Hillsborough County)	Alafia River, leads to Hillsborough Bay	1	27.880550	-82.299803	1	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0106	Catch rate: MRIP	17,870
Cockroach Bay Boat Ramp, western Cockroach Bay Road, Ruskin, FL (Hillsborough County)	Tampa Bay, Old Tampa Bay, Hillsborough Bay	1	27.686956	-82.520475	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,870
Courtney Campbell Causeway Boat Ramp, Westbound SR 60 on Old Tampa Bay, Town 'N' Country, FL (Hillsborough County)	Old Tampa Bay	1	27.972283	-82.611205	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,870

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

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Location	Site Name	Affected Site	Latitude	Longitude	Boat Launch	Advisory	Trout, Shad	Panfish	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Other Information	Estimated Annual Trips[a]
Domino Park Boat Ramp, 22nd Avenue and 8th Street Southwest, Ruskin, FL (Hillsborough County)	Mill Bayou, leads to Tampa Bay	0	27.693896	-82.445269	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,870
Lowry Park Boat Ramp, 1204 West Flora Street, Tampa, FL (Hillsborough County)	Hillsborough River, leads to Hillsborough Bay	0	28.012561	-82.465153	1	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0106	Catch rate: MRIP	17,870
Picnic Island Park Boat Ramp, 7404 Picnic Island Boulevard, Tampa, FL (Hillsborough County)	Old Tampa Bay, Tampa Bay	0	27.857826	-82.551735	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,870
Picnic Island beach, off Picnic Island Boulevard, Tampa, FL (Hillsborough County)	Old Tampa Bay	0	27.853630	-82.553108	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	8
Picnic Island beach, off Picnic Island Boulevard, Tampa, FL (Hillsborough County)	Old Tampa Bay	0	27.850799	-82.554803	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	8
Picnic Island Park Fishing Pier, 7404 Picnic Island Boulevard, Tampa, FL (Hillsborough County)	Old Tampa Bay	0	27.857765	-82.552738	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	50,840
Riverview Park Boat Ramp, 11020 Park Drive, Riverview, FL (Hillsborough County)	Alafia River, leads to Hillsborough Bay	0	27.865759	-82.319244	1	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0106	Catch rate: MRIP	17,870
Ruskin Commongood Park Boat Ramp, 1st Avenue and 2nd Street Northwest, Ruskin, FL (Hillsborough County)	Ruskin Inlet, leads to Tampa Bay	0	27.719532	-82.435833	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,870
Salty Sol Fleishman Boat Ramp, 5120 Gandy Boulevard, Tampa, FL (Hillsborough County)	Old Tampa Bay, Tampa Bay	0	27.892381	-82.532951	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,870
Sun City Heritage Park, 3030 South Highway 41, Ruskin, FL (Hillsborough County)	Hayes Bayou, leads to Tampa Bay	0	27.693181	-82.457867	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Hand launch Catch rate: MRIP	17,870
Wildcat Creek Boat Ramp, 110 Stephens Road, Ruskin, FL (Hillsborough County)	Bolster Bayou, leads to Tampa Bay	0	27.676000	-82.436090	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,870
Williams Park Boat Ramp, 8749 US-41, Riverview, FL (Hillsborough County)	Alafia River, leads to Hillsborough Bay, Tampa Bay	0	27.860084	-82.384657	1	1	0.0000	0.0000	0.0007	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,870

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

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Williams Park Fishing Pier, 8749 US-41, Riverview, FL (Hillsborough County)	Alafia River	0	27.859747	-82.384140	0	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	50,840
Cypress Point Park, 5620 West Cypress Street, Tampa, FL (Hillsborough County)	Old Tampa Bay	0	27.947462	-82.546211	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	8
Ben T. Davis Beach, 7650 West Courtney Campbell Causeway, Tampa, FL (Hillsborough County)	Old Tampa Bay	0	27.967174	-82.573403	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	8
Braden River SR64 Boat Ramp, 3020 Manatee Avenue East, Bradenton, FL (Manatee County)	Braden River, Manatee River, Tampa Bay, Gulf of Mexico	0	27.496109	-82.525579	1	1	0.0000	0.0000	0.0007	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
Coquina Bayside North Boat Ramp, Gulf Drive South, Bradenton Beach, FL (Manatee County)	Gulf of Mexico	0	27.455589	-82.693290	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
Off Gulf Drive South, Bradenton Beach, FL (Manatee County)	Gulf of Mexico	0	27.452167	-82.694331	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	2
Coquina Bayside South Boat Ramp, Gulf Drive South, Bradenton Beach, FL (Manatee County)	Gulf of Mexico	0	27.447874	-82.688789	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
Bradenton Beach City Pier, 200 Bridge Street, Bradenton Beach, FL (Manatee County)	Sarasota Bay	0	27.466680	-82.693788	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	9,256
Emerson Point Boat Ramp, 5801 17th Street SW, Palmetto, FL (Manatee County)	Tampa Bay	0	27.532399	-82.646548	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
Fort Hamer Boat Ramp, End of Fort Hamer Road, Parrish, FL (Manatee County)	Manatee River, leads to Tampa Bay	0	27.524625	-82.430025	1	1	0.0000	0.0000	0.0007	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
Highland Shores Boat Ramp, 351 Shore Drive, Ellenton, FL (Manatee County)	Manatee River, leads to Tampa Bay	0	27.515055	-82.533504	1	1	0.0000	0.0000	0.0007	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
Kingfish Boat Ramp, 752 Manatee Avenue, Holmes Beach, FL (Manatee County)	Gulf of Mexico, Sarasota Bay, Palma Sola Bay, Tampa Bay	0	27.497482	-82.702366	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
Palma Sola Boat Ramp, Manatee Avenue/Route 64, Bradenton, FL (Manatee County)	Palma Sola Bay, Anna Maria Sound, Tampa Bay, Gulf of Mexico	0	27.495809	-82.659851	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
Palma Sola Fishing Pier, 9450 Manatee Avenue West, Bradenton, FL (Manatee County)	Palma Sola Bay	0	27.496710	-82.656430	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	9,256
Rose Park Fishing Pier, 1002 Palma Sola Boulevard, Bradenton, FL (Manatee County)	Palma Sola Bay	0	27.492034	-82.644317	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	9,256
Riverwalk Park, Bradenton, FL (Manatee County)	Manatee River	0	27.500085	-82.570262	0	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	9,256

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

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Rossi Park Fishing Pier, near 1st Avenue West and 10th Street West, Bradenton, FL (Manatee County)	Manatee River	0	27.500597	-82.567251	0	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	9,256
Riverside Park Palmetto Boat Ramp, 801 Riverside Drive, Palmetto, FL (Manatee County)	Manatee River, leads to Tampa Bay	0	27.511850	-82.573935	1	1	0.0000	0.0000	0.0007	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
Riverside Park Palmetto Boat Ramp, 801 Riverside Drive, Palmetto, FL (Manatee County)	Manatee River	0	27.506641	-82.572620	0	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	9,256
Warners Bayou Boat Ramp, 5800 Riverview Boulevard, Bradenton, FL (Manatee County)	Manatee River, leads to Tampa Bay	0	27.509654	-82.618328	1	1	0.0000	0.0000	0.0007	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
63rd Street Boat Ramp, East 63rd Street and Marina Drive, Holmes Beach, FL (Manatee County)	Bimini Bay, Anna Maria Sound, Tampa Bay, Gulf of Mexico	0	27.513506	-82.714079	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,125
Anna Maria Historic City Pier, 340 South Bay Boulevard, Anna Maria, FL (Manatee County)	Anna Maria Sound	0	27.534586	-82.730603	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	9,256
Rod & Reel Pier, 875 North Shore Drive, Anna Maria, FL (Manatee County)	Passage Key Inlet	0	27.538392	-82.739352	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	9,256
Skyway Fishing Pier South, near Terra Ceia, FL (Manatee County)	Tampa Bay	0	27.594906	-82.634645	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	9,256
Anclote River Park Boat Ramp, 1119 Baillies Bluff Road, Holiday, FL (Pasco County)	Anclote River, leads to Sting Ray Cove, Anclote Anchorage, Gulf of Mexico	0	28.176245	-82.788757	1	1	0.0000	0.0000	0.0007	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,061
Anclote Gulf Park Fishing Pier, 2305 Bailey's Bluff Rd., Holiday, FL (Pasco County)	Anclote River	0	28.193078	-82.788862	0	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	22,752
Brasher Park, 4951 Koons Road, Port Richey, FL (Pasco County)	Boggy Bay, leads to Gulf of Mexico	0	28.285216	-82.732037	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Hand launch Catch rate: MRIP	17,061
Nicks Park Boat Ramp, 7929 Bayview Street, Port Richey, FL (Pasco County)	Pithlachascotee River, leads to Gulf of Mexico	0	28.272352	-82.726131	1	1	0.0000	0.0000	0.0007	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,061
Port Richey Waterfront Park Fishing Pier, 8119 Old Post Road, Port Richey, FL (Pasco County)	Millers Bayou	0	28.274850	-82.726631	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	22,752
R.J. Strickland Boat Ramp (Hudson Beach Park), 6345 Clark Street, Hudson, FL (Pasco County)	Gulf of Mexico	0	28.361393	-82.708480	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,061
Robert Rees Memorial Park, 4835 Green Key Road, New Port Richey, FL (Pasco County)	Gulf of Mexico	0	28.253857	-82.759032	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	9
Sims Park/City Boat Ramp, 5443 Main Street, New Port Richey, FL (Pasco County)	Pithlachascotee River, leads to Gulf of Mexico	0	28.250562	-82.723223	1	1	0.0000	0.0000	0.0007	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	17,061

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

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Table B.1, Recreational Saltwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Site Name	Affected Site	Latitude	Longitude	Boat Launch	Advisory	Trout, Shad	Panfish	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Other Information	Estimated Annual Trips[a]
Morgan Park, 2650 Gulf Boulevard, Belleair Beach, FL (Pinellas County)	Gulf of Mexico	0	27.929625	-82.843194	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	4
Belleaire Causeway Boat Ramp, 3900 West Bay Drive, Belleair Bluffs, FL (Pinellas County)	Clearwater Pass, leads to Gulf of Mexico	0	27.917535	-82.826590	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Belleaire Causeway fishing pier, 3900 West Bay Drive, Belleair Bluffs, FL (Pinellas County)	Clearwater Pass	0	27.917576	-82.828079	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Edgewater Drive Park, 1920 Edgewater Drive, Clearwater, FL (Pinellas County)	Charlotte Harbor	0	27.992127	-82.795714	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Shoreline Catch rate: MRIP	4
Seminole Street Boat Ramp, 201 Seminole Street, Clearwater, FL (Pinellas County)	Intracoastal Waterway, leads to Gulf of Mexico	0	27.974276	-82.802562	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Sand Key Park Fishing Piers, 1060 Gulf Boulevard, Clearwater, FL (Pinellas County)	Clearwater Pass	0	27.960431	-82.824228	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier, two other piers at park also Catch rate: MRIP	11,308
Clearwater Beach Recreation Center Boat Ramp, 69 Bay Esplanada, Clearwater Beach, FL (Pinellas County)	Gulf of Mexico	0	27.984840	-82.823788	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Beach off Idlewild Street, Clearwater Beach, FL (Pinellas County)	Gulf of Mexico	0	27.988176	-82.828927	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	4
Beach near Esplanade Street, Clearwater Beach, FL (Pinellas County)	Gulf of Mexico	0	27.983908	-82.829359	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	4
Clearwater Beach Fishing Pier 60, 25 Causeway Boulevard, Clearwater Beach, FL (Pinellas County)	Gulf of Mexico	0	27.977726	-82.832231	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Beach off Baymont Street, Clearwater Beach, FL (Pinellas County)	Gulf of Mexico	0	27.982194	-82.829422	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	4
Beach off Coronado Drive, Clearwater Beach, FL (Pinellas County)	Gulf of Mexico	0	27.975710	-82.830185	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	4
Beach near city parking lot, off South Gulfview Boulevard, Clearwater Beach, FL (Pinellas County)	Gulf of Mexico	0	27.970786	-82.831363	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	4
Fishing jetty, off South Gulfview Boulevard, Clearwater Beach, FL (Pinellas County)	Gulf of Mexico	0	27.970992	-82.831840	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing jetty Catch rate: MRIP	4
Dunedin Marina Boat Ramp Edgewater Park, 51 Main Street, Dunedin, FL (Pinellas County)	Gulf of Mexico	0	28.010975	-82.792703	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Josiah Cephas Weaver Park Fishing Pier, 1249 Bayshore Boulevard, Dunedin, FL (Pinellas County)	St. Joseph Sound	0	28.020391	-82.792422	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

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Table B.1, Recreational Saltwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Site Name	Affected Site	Latitude	Longitude	Boat Launch	Advisory	Trout, Shad	Panfish	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Other Information	Estimated Annual Trips[a]
Gandy Wayside Park Boat Ramp, western end Gandy Bridge (Route 92), outside Gandy, FL (Pinellas County)	Old Tampa Bay, Tampa Bay, Gulf of Mexico	0	27.877086	-82.588283	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Skyway Fishing Pier North, south of Gulfport, FL (Pinellas County)	Tampa Bay	0	27.636462	-82.668199	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Gulfport City Marina Boat Ramp, 4630 29th Avenue South, Gulfport, FL (Pinellas County)	Tampa Bay, leads to Gulf of Mexico	0	27.740679	-82.668199	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Gulfport Beach Park, 5730 Shore Boulevard, Gulfport, FL (Pinellas County)	Boca Ciega Bay	0	27.735909	-82.711058	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Shoreline Catch rate: MRIP	4
Clam Bayou Nature Park Fishing Docks, 29th Ave South & Miriam Street South, Gulfport, FL (Pinellas County)	Clam Bayou	0	27.737471	-82.693761	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Williams Fishing Pier, 5400 Shore Boulevard South, Gulfport, FL (Pinellas County)	Boca Ciega Bay	0	27.736208	-82.706619	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Park Boulevard Boat Ramp, 186th Avenue and Gulf Boulevard, Indian Shores, FL (Pinellas County)	Intracoastal Waterway, leads to Gulf of Mexico	0	27.842416	-82.839100	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Park Boulevard Fishing Pier, 186th Avenue and Gulf Boulevard, Indian Shores, FL (Pinellas County)	Intracoastal Waterway	0	27.843495	-82.838569	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Town Square Nature Park, 191st Ave and Gulf Boulevard, Indian Shores, FL (Pinellas County)	Intracoastal Waterway	0	27.845296	-82.839339	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Madeira Beach Municipal Marina, 503 150th Avenue, Madeira Beach, FL (Pinellas County)	Boca Ciega Bay, leads to Gulf of Mexico	0	27.804338	-82.795553	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Madeira Beach pier, 424 150th Avenue, Madeira Beach, FL (Pinellas County)	Boca Ciega Bay	0	27.806642	-82.800280	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Sutherland Bayou Boat Ramp, 2119 US Alt. 19, North Palm Harbor, FL (Pinellas County)	Sutherland Bayou, Intracoastal Waterway, Gulf of Mexico	0	28.086361	-82.770882	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
R.E. Olds Park Fishing Pier, 107 Shore Drive West, Oldsmar, FL (Pinellas County)	Tampa Bay	0	28.029946	-82.670106	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Stansell Memorial Park, 8th Street and Florida Avenue, Palm Harbor, FL (Pinellas County)	Sutherland Bayou	0	28.079005	-82.771971	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Wall Springs, 3725 De Soto Boulevard, Palm Harbor, FL (Pinellas County)	Boggy Bayou	0	28.108708	-82.776156	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier; site has three other piers Catch rate: MRIP	11,308

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

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Table B.1, Recreational Saltwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Site Name	Affected Site	Latitude	Longitude	Boat Launch	Advisory	Trout, Shad	Panfish	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Other Information	Estimated Annual Trips[a]
Del Bello Park Fishing Pier, 17957 Gulf Boulevard, Redington Shores, FL (Pinellas County)	Intracoastal Waterway	0	27.831008	-82.831116	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Redington Long Pier, 17490 Gulf Boulevard, Redington Shores, FL (Pinellas County)	Gulf of Mexico	0	27.821771	-82.831514	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Philippe Park Boat Ramp, 2525 Philippe Park, Safety Harbor, FL (Pinellas County)	Tampa Bay, leads to Gulf of Mexico	0	28.013947	-82.682516	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Safety Harbor Marina Park Boat Ramp, 131 South Bayshore Boulevard, Safety Harbor, FL (Pinellas County)	Old Tampa Bay, Tampa Bay, Gulf of Mexico	0	27.989248	-82.686877	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Safety Harbor Marina Park fishing pier, 131 South Bayshore Boulevard, Safety Harbor, FL (Pinellas County)	Old Tampa Bay	0	27.988366	-82.685008	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Crisp Park Boat Ramp, 3500 Poplar Street NE, St. Petersburg, FL (Pinellas County)	Several bayous, leads to Tampa Bay	0	27.803866	-82.626930	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Coffee Pot Park Boat Ramp, 1st Street and 31st Avenue NE, St. Petersburg, FL (Pinellas County)	Coffeepot Bayou, leads to Tampa Bay	0	27.800238	-82.633449	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Demens Landing Boat Ramp, Bayshore Drive and 1st Avenue Southeast, St. Petersburg, FL (Pinellas County)	Tampa Bay	0	27.771363	-82.628016	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Grandview Park Boat Ramp (Coquina Key), 3800 6th Street South, St. Petersburg, FL (Pinellas County)	Bog Bayou, leads to Tampa Bay	0	27.734310	-82.639914	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Jungle Prada Park Boat Ramp, Park Street & Elbow Lane North, St. Petersburg, FL (Pinellas County)	Boca Ciega Bay, leads to Gulf of Mexico	0	27.788262	-82.754287	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Jungle Prada Park fishing pier, Park Street & Elbow Lane North, St. Petersburg, FL (Pinellas County)	Boca Ciega Bay	0	27.788571	-82.755063	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Maximo Park Boat Ramp 1, 66th Avenue South and 31st Street South, St. Petersburg, FL (Pinellas County)	Tampa Bay, leads to Gulf of Mexico	0	27.712250	-82.682746	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Maximo Park Boat Ramp 2, 66th Avenue South and 31st Street South, St. Petersburg, FL (Pinellas County)	Tampa Bay, leads to Gulf of Mexico	0	27.711645	-82.683453	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Bay Vista Park Boat Ramp, 7000 4th Street South, St. Petersburg, FL (Pinellas County)	Tampa Bay	0	27.703788	-82.639945	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Bay Vista Park fishing pier, 7000 4th Street South, St. Petersburg, FL (Pinellas County)	Tampa Bay	0	27.703363	-82.640971	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

VERITAS. Economic Consulting

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Table B.1, Recreational Saltwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Site Name	Affected Site	Latitude	Longitude	Boat Launch	Advisory	Trout, Shad	Panfish	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Other Information	Estimated Annual Trips[a]
Coquina Key Park, 3595 Locust Street Southeast, St. Petersburg, FL (Pinellas County)	Big Bayou	0	27.739261	-82.631607	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Shoreline Catch rate: MRIP	4
Flora Wylie Park, North Shore Drive NE and 15th Ave NE, St. Petersburg, FL (Pinellas County)	Tampa Bay	0	27.785254	-82.622443	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Shoreline Catch rate: MRIP	4
War Veterans Memorial Park Boat Ramp, 9600 Bay Pines Boulevard, St. Petersburg, FL (Pinellas County)	Long Bayou, Boca Ciega Bay, Gulf of Mexico	0	27.812096	-82.768053	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Spa Beach Pier, 2nd Avenue Northeast, St. Petersburg, FL (Pinellas County)	Tampa Bay	0	27.773229	-82.621605	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Weedon Island Fishing Pier, 1800 Weedon Drive NE, St. Petersburg, FL (Pinellas County)	Riviera Bay	0	27.843543	-82.611270	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Vinoy Park, Bay Shore Drive NE and 7th Ave NE, St. Petersburg, FL (Pinellas County)	Tampa Bay	0	27.779001	-82.624776	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Shoreline Catch rate: MRIP	4
7th Avenue Fishing Pier, 7th Avenue and Pass A Grille Way, St. Petersburg Beach, FL (Pinellas County)	Boca Ciega Bay	0	27.687319	-82.736088	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
11th Avenue Fishing Pier, 11th Avenue and Pass A Grille Way, St. Petersburg Beach, FL (Pinellas County)	Boca Ciega Bay	0	27.689660	-82.735547	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Don CeSar Boat Ramp, West Maritana Drive and Casablanca Avenue, St. Petersburg Beach, FL (Pinellas County)	Several bayous, leads to Gulf of Mexico	0	27.708537	-82.735866	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Egan Park Boat Ramp, 9101 Blind Pass Road, St. Petersburg Beach, FL (Pinellas County)	Tampa Bay, leads to Gulf of Mexico	0	27.754949	-82.756299	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Egan Park fishing pier, 9101 Blind Pass Road, St. Petersburg Beach, FL (Pinellas County)	Tampa Bay	0	27.754543	-82.755725	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
McKenney Park Fishing Pier, 9300 Blind Pass Road, St. Petersburg Beach, FL (Pinellas County)	Intracoastal Waterway	0	27.755351	-82.759907	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Pass A Grille Fishing Jetty, Gulf Way and 1st Avenue, St. Petersburg Beach, FL (Pinellas County)	Gulf of Mexico	0	27.683140	-82.739142	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing jetty Catch rate: MRIP	4

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

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Location	Site Name	Affected Site	Latitude	Longitude	Boat Launch	Advisory	Trout, Shad	Panfish	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Other Information	Estimated Annual Trips[a]
Anclote Key Preserve State Park fishing pier, Tarpon Springs, FL (Pinellas County)	Gulf of Mexico	0	28.165502	-82.840349	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Access to preserve by boat or ferry only Catch rate: MRIP	11,308
Coburn Park, South Spring Boulevard and Beekman Lane, Tarpon Springs, FL (Pinellas County)	Spring Branch, Whitcomb Bayou	0	28.145956	-82.762025	1	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0106	Catch rate: MRIP	6,201
Fred Howard Park, 1700 Sunset Drive, Tarpon Springs, FL (Pinellas County)	Anclote Anchorage	0	28.152844	-82.806569	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Shoreline Catch rate: MRIP	4
Sunset Beach, 1800 Gulf Road, Tarpon Springs, FL (Pinellas County)	Gulf of Mexico	0	28.143552	-82.791054	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	4
Fort De Soto Park Boat Ramp, 3100 Pinellas Bayway South, Tierra Verde, FL (Pinellas County)	Bunces Pass, leads to Gulf of Mexico	0	27.646043	-82.717302	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Multiple lanes (20) Catch rate: MRIP	62,010
Fort De Soto Park gulf side fishing pier, 3100 Pinellas Bayway South, Tierra Verde, FL (Pinellas County)	Gulf of Mexico	0	27.613843	-82.739899	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Fort De Soto Park bay side fishing pier, 3100 Pinellas Bayway South, Tierra Verde, FL (Pinellas County)	Tampa Bay	0	27.615332	-82.725637	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	11,308
Fort De Soto Park east side beach, 3100 Pinellas Bayway South, Tierra Verde, FL (Pinellas County)	Tampa Bay	0	27.624276	-82.707476	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	4
84th Avenue Boat Ramp, 84th Avenue and Bayshore Drive, Treasure Island, FL (Pinellas County)	Intracoastal Waterway, leads to Gulf of Mexico	0	27.747421	-82.759519	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
100th Avenue Boat Ramp, 100th Avenue and Gulf Boulevard, Treasure Island, FL (Pinellas County)	Intracoastal Waterway, leads to Gulf of Mexico	0	27.759228	-82.765200	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
123rd Avenue Boat Ramp, 123rd Avenue and Lagoon Lane, Treasure Island, FL (Pinellas County)	Boca Ciega Bay, leads to Gulf of Mexico	0	27.778785	-82.778555	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	6,201
Indian Mound Park Boat Ramp, 210 Winson Avenue, Englewood, FL (Sarasota County)	Lemon Bay	0	26.957458	-82.363371	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,131
Manasota Beach Boat Ramp, 8570 Manasota Key Road, Englewood, FL (Sarasota County)	Lemon Bay	0	27.010258	-82.410414	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,131
Manasota Beach, 8570 Manasota Key Road, Englewood, FL (Sarasota County)	Gulf of Mexico	0	27.011576	-82.413912	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	3
Lido Beach Park, 400 Ben Franklin Drive, Lido Key, FL (Sarasota County)	Gulf of Mexico	0	27.315321	-82.583195	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	3
Ken Thompson Park Boat Ramp, 1700 Ken Thompson Parkway, Lido Key, FL (Sarasota County)	Sarasota Bay	0	27.333677	-82.574883	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,131

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

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Table B.1, Recreational Saltwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Site Name	Affected Site	Latitude	Longitude	Boat Launch	Advisory	Trout, Shad	Panfish	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Other Information	Estimated Annual Trips[a]
Ken Thompson Park fishing dock, 1700 Ken Thompson Parkway, Lido Key, FL (Sarasota County)	Sarasota Bay	0	27.336731	-82.575695	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing dock (second dock nearby) Catch rate: MRIP	6,919
Ted Sterling South Lido Beach Park, 2201 Ben Franklin Drive, Lido Key, FL (Sarasota County)	Gulf of Mexico	0	27.296053	-82.566877	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	3
Blind Pass Park, 6725 Manasota Key Road, Manasota Key, FL (Sarasota County)	Gulf of Mexico	0	26.962634	-82.385167	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	3
Nokomis Beach, Albee Road West and South Casey Key Road, Venice, FL (Sarasota County)	Gulf of Mexico	0	27.121410	-82.470981	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	3
Nokomis Boat Ramp, 100 Casey Key Road, Casey Key, Nokomis, FL (Sarasota County)	Lyons Bay	0	27.128361	-82.470443	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,131
Loreto Boat Ramp, 800 Loreto Court, Nokomis, FL (Sarasota County)	Dona Bay	0	27.126427	-82.441525	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,131
Osprey Fishing Pier, Main Street & Pine Avenue, Osprey, FL (Sarasota County)	Little Sarasota Bay	0	27.197622	-82.494173	0	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Fishing pier Catch rate: MRIP	6,919
Blackburn Point Park, 800 Blackburn Point Road, Sarasota, FL (Sarasota County)	Little Sarasota Bay	0	27.180850	-82.495525	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Hand launch Catch rate: MRIP	4,131
Centennial Park Boat Ramp, 1059 North Tamiami Trail, Sarasota, FL (Sarasota County)	Sarasota Bay	0	27.346031	-82.548461	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,131
Siesta Beach, 948 Beach Road, Siesta Key, FL (Sarasota County)	Gulf of Mexico	0	27.262979	-82.550489	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	3
Turtle Beach Boat Ramp, Turtle Beach Road and Midnight Pass Road, Siesta Key, FL (Sarasota County)	Blind Pass, Little Sarasota Bay	0	27.218538	-82.516189	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,131
Turtle Beach Park, 8918 Midnight Pass Road, Siesta Key, FL (Sarasota County)	Gulf of Mexico	0	27.219790	-82.518061	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	3
Causeway Park Fishing Pier (Saprito Pier), 420 John Ringling Boulevard, Sarasota, FL (Sarasota County)	Sarasota Bay	0	27.333840	-82.555818	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	6,919
Phillippi Estate Fishing Piers, 5500 South Tamiami Trail, Sarasota, FL (Sarasota County)	Phillippi River	0	27.271139	-82.534343	0	1	0.0000	0.0000	0.0007	0.0000	2.6348	0.0537	0.0106	Fishing pier, two others at site Catch rate: MRIP	6,919
Whitaker Gateway Park Fishing Pier, 1455 North Tamiami Trail, Sarasota, FL (Sarasota County)	Sarasota Bay	0	27.350045	-82.550899	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier Catch rate: MRIP	6,919
Caspersen Beach, 4100 Harbor Drive, Venice, FL (Sarasota County)	Gulf of Mexico	0	27.055576	-82.442587	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	3

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

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Table B.1, Recreational Saltwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Site Name	Affected Site	Latitude	Longitude	Boat Launch	Advisory	Trout, Shad	Panfish	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Other Information	Estimated Annual Trips[a]
Higel Marine Park Boat Ramp, 1330 Tarpon Center Drive, Venice, FL (Sarasota County)	Roberts Bay	0	27.108265	-82.461899	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,131
Humphris Park Jetty Fishing, Tarpon Center Drive & Inlet Circle, Venice, FL (Sarasota County)	Gulf of Mexico	0	27.112124	-82.469536	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Jetty Catch rate: MRIP	3
Maxine Barritt Beach Park, 1800 S. Harbor Drive, Venice, FL (Sarasota County)	Gulf of Mexico	0	27.070869	-82.450320	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	3
North Jetty Park beach, Albee Road West and South Casey Key Road, Venice, FL (Sarasota County)	Gulf of Mexico	0	27.115558	-82.469214	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach Catch rate: MRIP	3
North Jetty Park fishing jetty, Albee Road West and South Casey Key Road, Venice, FL (Sarasota County)	Gulf of Mexico	0	27.112935	-82.469710	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Jetty Catch rate: MRIP	3
Service Club Park, 1190 S. Harbor Drive, Venice, FL (Sarasota County)	Gulf of Mexico	0	27.078753	-82.453138	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach	3
Venice Beach, 101 The Esplanade, Venice, FL (Sarasota County)	Gulf of Mexico	0	27.098117	-82.460284	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	On the beach	3
Venice Fishing Pier, 1600 Harbor Drive South, Venice, FL (Sarasota County)	Gulf of Mexico	0	27.072535	-82.452794	0	1	0.0000	0.0000	0.0000	0.0000	2.6348	0.0537	0.0106	Fishing pier	6,919
Venice Marina Boat Ramp Park, 301 East Venice Avenue, Venice, FL (Sarasota County)	Intracoastal Waterway, Roberts Bay	0	27.102076	-82.441332	1	1	0.0000	0.0000	0.0000	0.0000	2.6790	0.0537	0.0106	Catch rate: MRIP	4,131

[a]Multiply number of anglers at shoreline locations times 528 for anglers per mile.

Sources: DeLorme (2006); Florida Coastal Management Program (2011), Florida Fish and Wildlife Conservation Commission (2013); NOAA Office of Science and Technology (2017); Saltchef.com (2016a–2016o), State of Florida Division of Recreation and Parks (2013); U.S. Fish and Wildlife Service (2013)

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Table B.2
Recreational Freshwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Acreage or River Segment	Site Name	Affected Site	Latitude	Longitude	Boat Launch	No. Boat Ramps	Trout, Shad	Panfish[a]	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Trips	Fishing Pressure	Angler Hrs/Acre[b]	Hours per Trip	Advisory	Sportfish Caught from Waterbody
Aerojet (C-111) Canal, Miami-Dade County, FL	6.4 miles	Off South Dixie Highway, near Everglades National Park	0	25.288057	-80.442291	1	1	0.0000	0.0000	0.5300	4.1700	0.0000	0.0000	0.0000	562	2,247	351.07	4.00	Mercury	Butterfly peacock bass, largemouth bass, sunfish
Alafia River, Brandon (Hillsborough County), FL	25 miles	Alafia River Public Boat Ramp, Brandon, FL	0	27.880656	-82.299691	1	1	0.0000	0.0000	0.0000	1.6200	0.0000	0.0000	0.0000	2,194	8,777	351.07	4.00	Mercury	Bluegill, catfish, largemouth bass, spotted sunfish
Caloosahatchee River (freshwater), Alva (Lee County), FL	38 miles	Alva boat ramp, 21580 Pearl Street, Alva, FL	0	26.713944	-81.605998	1	1	0.0000	0.7600	0.4700	3.0600	0.0000	0.0000	0.0000	3,335	13,341	351.07	4.00	Mercury	Crappie, largemouth bass, sunfish
Crescent Lake (Putnam and Flagler Counties), FL	15,960 acres	Margary Neal Nelson Sunrise Park and Boat Ramp, 107 Cypress Street, Crescent City, FL	0	29.428286	-81.506705	1	2	0.0000	1.5900	0.5200	2.7300	0.0000	0.0000	0.0000	45,440	181,760	11.39	4.00	Mercury	Crappie, largemouth bass, sunfish
Crooked Lake, Babson Park (Polk County), FL	4,274 acres	Bob's Landing Mobile Home Park and Boat Ramp, Babson Park, FL	0	27.808458	-81.555607	1	1	0.0000	1.1600	0.5900	3.2000	0.0000	0.0000	0.0000	13,239	52,955	12.39	4.00	Mercury	Bluegill, crappie, catfish, largemouth bass, redear sunfish
Dead Lakes (Gulf and Calhoun Counties), FL	6,700 acres	Dead Lakes County Park, Gary Rowell Road, Wewahitchka, FL	0	30.136392	-85.199424	1	2	0.0000	1.5700	0.4600	1.2600	0.0000	0.0000	0.0000	51,858	207,433	30.96	4.00	Mercury	Crappie, largemouth bass, sunfish
Deer Point Lake, Southport (Bay County), FL	5,000 acres	High Point Landing, High Point, FL	0	30.293638	-85.583092	1	2	0.0000	1.1700	0.4200	0.9100	0.0000	0.0000	0.0000	21,307	85,229	17.05	4.00	Mercury	Crappie, largemouth bass, sunfish
Hillsborough River, City of Temple Terrace (Hillsborough County), FL	54 miles	Riverhills Park Boat Ramp, City of Temple Terrace, FL	0	28.021213	-82.387773	1	6	0.0000	1.1600	0.5300	1.6200	0.0000	0.0000	0.0000	4,739	18,958	351.07	4.00	Mercury	Bluegill, catfish, largemouth bass, redbreast and redear sunfish, spotted sunfish, warmouth
Inverness Pool (Big Henderson Lake, Little Henderson Lake, Lake Tsala Apopka), Inverness (Citrus County), FL	22,000 acres	Lake Henderson Public Boat Ramp, 1025 Hwy 44 E, Inverness, FL	0	28.833634	-82.317388	1	2	0.0000	0.7800	0.8400	1.2800	0.0000	0.0000	0.0000	159,356	637,422	28.97	4.00	Mercury	Crappie, largemouth bass, sunfish
L-67A Canal (Broward County), FL	26 miles	Everglades Holiday Park, 21940 Griffin Rd, Fort Lauderdale, FL	0	26.060147	-80.446358	1	2	0.0000	0.0000	4.4200	4.1700	0.0000	0.0000	0.0000	6,001	24,005	923.27	4.00	Mercury	Largemouth bass, sunfish
Lake George, Putnam County, FL	46,000 acres	Boat ramp off Highway 309 north of Georgetown, FL	0	29.422837	-81.647203	1	2	0.0000	1.5900	0.5200	2.7300	0.0000	0.0000	0.0000	39,749	158,996	3.46	4.00	Mercury	Crappie, largemouth bass, sunfish
Lake Gibson, Lakeland (Polk County), FL	483 acres	Lake Gibson Park & Public Boat Ramp, Lakeland, FL	0	28.104506	-81.950659	1	1	0.0000	1.1600	0.5900	3.2000	0.0000	0.0000	0.0000	1,496	5,984	12.39	4.00	None	Catfish, crappie, largemouth bass
Lake Griffin, Harris Chain of Lakes (Lake and Orange Counties), FL	9,327 acres	Lake Griffin State Park boat ramp, Fruitland Park, FL	0	28.857409	-81.899965	1	6	0.0000	1.1100	0.3000	0.7700	0.0000	0.0000	0.0000	15,086	60,343	6.47	4.00	Mercury	Bluegill, catfish, crappie, largemouth bass, redear sunfish (shellcracker)
Lake Harris, Harris Chain of Lakes (Lake and Orange Counties), FL	13,788 acres	Lake Harris Resort, 29115 Eichelberger Rd, Tavares, FL	0	28.764841	-81.754756	1	6	0.0000	1.1100	0.3000	0.7700	0.0000	0.0000	0.0000	22,301	89,204	6.47	4.00	Mercury	Crappie, largemouth bass, sunfish

[a]Note that panfish are crappie and yellow perch in this study.

[b]If river, angler hours per mile.

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Table B.2, Recreational Freshwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Acreage or River Segment	Site Name	Affected Site	Latitude	Longitude	Boat Launch	No. Boat Ramps	Trout, Shad	Panfish[a]	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Trips	Fishing Pressure	Angler Hrs/Acre[b]	Hours per Trip	Advisory	Sportfish Caught from Waterbody
Lake Istokpoga (Highlands County), FL	26,763 acres	Lake Istokpoga West Windy Point Park, 65 Windy Point Rd, Lake Placid, FL	0	27.306783	-81.313055	1	10	0.0000	1.3400	0.6100	3.1400	0.0000	0.0000	0.0000	59,891	239,562	8.95	4.00	Mercury	Crappie, largemouth bass, sunfish
Lake Kissimmee (Osceola County), FL	34,948 acres	Joe Overstreet Landing, Kenansville, FL	0	27.937255	-81.225958	1	2	0.0000	1.6100	0.5300	3.0200	0.0000	0.0000	0.0000	128,280	513,121	14.68	4.00	Mercury	Crappie, largemouth bass, sunfish
Lake Manatee, Bradenton (Manatee County), FL	2,400 acres	Lake Manatee State Park, Bradenton, FL	0	27.481601	-82.340861	1	2	0.0000	1.1600	0.5900	3.2000	0.0000	0.0000	0.0000	7,436	29,743	12.39	4.00	Mercury	Bluegill, catfish, largemouth and sunshine bass, redear sunfish, speckled perch
Lake Minnehaha, Clermont (Lake County), FL (Palatlakaha River watershed)	2,298 acres	Jones Cypress Cove Marina, Clermont, FL	0	28.529487	-81.782798	1	1	0.0000	1.1100	0.3000	0.7700	0.0000	0.0000	0.0000	3,717	14,867	6.47	4.00	Mercury	Black crappie, bluegill, channel catfish, largemouth bass, redbreast and redear sunfish, warmouth, yellow bullhead
Lake Minneola, Clermont (Lake County), FL (Palatlakaha River watershed)	1,888 acres	Clermont Lake Minneola Public Boat Ramp, Clermont, FL	0	28.558562	-81.772443	1	1	0.0000	1.1100	0.3000	0.7700	0.0000	0.0000	0.0000	3,054	12,215	6.47	4.00	Mercury	Bluegill, channel catfish, largemouth bass, redear sunfish
Lake Monroe, City of Lake Monroe (Seminole and Volusia Counties), FL	9,258 acres	Monroe Harbour Marina, 531 North Palmetto Avenue, Sanford, FL	0	28.815510	-81.265312	1	5	0.0000	1.8900	0.2800	3.5600	0.0000	0.0000	0.0000	12,339	57,992	6.26	4.70	Mercury	Black crappie, catfish, largemouth bass, sunfish
Lake Okeechobee, Okeechobee (Glades, Hendry, Martin, Okeechobee, and Palm Beach Counties), FL	467,028 acres	Boat Ramp-Kissimmi, 10209-10223 FL-78, Okeechobee, FL	0	27.148295	-80.868316	1	3	0.0000	0.7600	0.4700	3.0600	0.0000	0.0000	0.0000	403,562	1,614,247	3.46	4.00	Mercury	Crappie, largemouth bass, sunfish
Lake Osborne, Lake Worth (Palm Beach County), FL	275 acres	John Prince Park public boat ramp, 2520 Lake Worth Road, Lake Worth, FL	0	26.614973	-80.078101	1	2	0.0000	0.7600	1.0000	3.0600	0.0000	0.0000	0.0000	238	951	3.46	4.00	Mercury	Crappie, largemouth and sunshine bass, sunfish
Lake Panasoffkee, City of Lake Panasoffkee (Sumter County), FL	4,460 acres	Coleman Landing Public Boat Ramp, City of Lake Panasoffkee, FL	0	28.799103	-82.103484	1	1	0.0000	0.8500	0.8300	1.4700	0.0000	0.0000	0.0000	18,940	75,761	16.99	4.00	Mercury	Black crappie, bluegill, brown bullhead, catfish, largemouth bass, redear sunfish
Lake Parker, Lakeland (Polk County), FL	2,272 acres	Lake Parker Park Public Boat Ramp, Lakeland, FL	0	28.077967	-81.945669	1	3	0.0000	1.1600	0.5900	3.2000	0.0000	0.0000	0.0000	7,038	28,150	12.39	4.00	Mercury	Black crappie, bluegill, brown bullhead, catfish, largemouth bass, redear sunfish
Lake Seminole, Jackson County, FL	37,500 acres (mostly in Georgia)	From Chattachoochee River, south of Highway 2, Jackson County, FL	0	30.973769	-85.005944	1	2	0.0000	1.1100	0.2800	4.0700	0.0000	0.0000	0.0000	31,725	126,900	3.38	4.00	Mercury	Catfish, crappie, largemouth bass, sunfish
Lake Talquin, Leon and Gadsden Counties, FL	8,804 acres	Lake Talquin State Park, Jack Vause Landing Rd, Tallahassee, FL	0	30.439385	-84.529211	1	14	0.0000	2.3200	0.3700	10.3000	0.0000	0.0000	0.0000	27,955	111,819	12.70	4.00	Mercury	Black crappie, catfish, largemouth and striped bass, sunfish

[a]Note that panfish are crappie and yellow perch in this study.

[b]If river, angler hours per mile.

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Table B.2, Recreational Freshwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Acreage or River Segment	Site Name	Affected Site	Latitude	Longitude	Boat Launch	No. Boat Ramps	Trout, Shad	Panfish[a]	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Trips	Fishing Pressure	Angler Hrs/Acre[b]	Hours per Trip	Advisory	Sportfish Caught from Waterbody
Lake Tarpon, Tarpon Springs (Pinellas County), FL	2,534 acres	A.L. Anderson Park, Tarpon Springs, FL	0	28.133297	-82.738320	1	3	0.0000	1.1600	0.5900	3.2000	0.0000	0.0000	0.0000	7,849	31,396	12.39	4.00	Mercury	Black crappie, bluegill, catfish, largemouth bass, redear sunfish
Lake Thonotosassa, Thonotosassa (Hillsborough County), FL	839 acres	Baker Creek Public Boat Ramp, Thonotosassa, FL	0	28.048607	-82.268480	1	1	0.0000	1.1600	0.5900	3.2000	0.0000	0.0000	0.0000	2,599	10,395	12.39	4.00	Mercury	Black crappie, bluegill, brown bullhead, catfish, largemouth bass, redear sunfish
Lake Tohopekaliga, Kissimmee (Osceola County), FL	11,968 acres	Kissimmee Lakefront Park, 250 Lakeshore Blvd, Kissimmee, FL	0	28.287008	-81.408463	1	6	0.0000	1.8400	0.6400	2.0300	0.0000	0.0000	0.0000	20,506	82,026	6.85	4.00	Mercury	Crappie, largemouth bass, sunfish
Lake Trafford, Immokalee (Collier County), FL	1,500 acres	Ann Olesky Park, Immokalee, FL	0	26.432901	-81.485774	1	2	0.0000	1.1200	0.0000	3.9800	0.0000	0.0000	0.0000	13,133	52,533	35.02	4.00	Mercury	Crappie, sunfish
Lake Washington, Melbourne (Brevard County), FL	4,362 acres	Lake Washington Park, 6000 Lake Washington Road, Melbourne, FL	0	28.147505	-80.734129	1	1	0.0000	0.4900	0.1700	1.4000	0.0000	0.0000	0.0000	8,441	33,762	7.74	4.00	Mercury	Crappie, largemouth bass, sunfish
Lake Weohyakapka, Lakeshore (Polk County), FL	7,528 acres	Lake Walk-In-Water boat ramp, Boat Landing Rd, Frostproof, FL	0	27.813647	-81.438467	1	2	0.0000	1.1600	0.5900	3.2000	0.0000	0.0000	0.0000	23,323	93,294	12.39	4.00	Mercury	Crappie, largemouth bass, sunfish
Little Manatee River, Ruskin (Hillsborough County), FL	40 miles	Wildcat Creek Park Public Boat Ramp, Ruskin, FL	0	27.675998	-82.436094	1	2	0.0000	1.1600	0.5300	1.6200	0.0000	0.0000	0.0000	3,511	14,043	351.07	4.00	Mercury	Black crappie, bluegill, bream, catfish, largemouth bass, redear sunfish, spotted sunfish
Lochloosa Lake (Alachua County), FL	5,700 acres	Lochloosa Park, 16204 SE 207th Lane, Hawthorne, FL	0	29.505319	-82.101860	1	3	0.0000	0.8100	0.7800	1.7700	0.0000	0.0000	0.0000	18,902	75,607	13.26	4.00	Mercury	Crappie, largemouth bass, sunfish
Manatee River, Bradenton (Manatee County), FL	36 miles	Fort Hamer Public Boat Ramp, Bradenton, FL	0	27.524636	-82.430026	1	1	0.0000	1.1600	0.5300	1.6200	0.0000	0.0000	0.0000	3,160	12,639	351.07	4.00	None	Black crappie, bluegill, catfish, largemouth bass
Moon Lake, New Port Richey (Pasco County), FL	127 acres	Moon Lake Park, New Port Richey, FL	0	28.286298	-82.607246	1	1	0.0000	0.0000	0.8400	1.2800	0.0000	0.0000	0.0000	574	2,296	18.08	4.00	None	Catfish, largemouth bass
Myakka River, North Port (Sarasota County), FL	67.7 miles	Northport Marina Park, North Port, FL	0	27.033648	-82.249783	1	2	0.0000	1.1600	0.5300	1.6200	0.0000	0.0000	0.0000	5,942	23,767	351.07	4.00	Mercury	Bluegill, blue tilapia, crappie, gar, largemouth bass, redear sunfish, spotted sunfish (stumpknocker), warmouth, white catfish
Newnan Lake, Gainesville (Alachua County), FL	7,520 acres	Newnan Lake boat ramp, 5910 SE Hawthorne Rd, Gainesville, FL	0	29.617870	-82.253546	1	1	0.0000	0.5300	0.0400	1.2500	0.0000	0.0000	0.0000	18,967	75,866	10.09	4.00	Mercury	Crappie, largemouth bass, sunfish
Orange Lake, Cross Creek and Orange Lake (Alachua County), FL	12,550 acres	Heagy Burry Park, 5005 Lake Ave, Citra, FL	0	29.427065	-82.207467	1	2	0.0000	0.8000	1.2200	3.0600	0.0000	0.0000	0.0000	26,880	107,518	8.57	4.00	Mercury	Crappie, largemouth bass, sunfish
Palatlakaha River, Clermont (Lake County), FL	44 miles	Palatlakaha River Park, Clermont, FL	0	28.504211	-81.749318	1	2	0.0000	0.7800	0.8400	1.2800	0.0000	0.0000	0.0000	3,862	15,447	351.07	4.00	None	Catfish, largemouth bass, panfish

[a]Note that panfish are crappie and yellow perch in this study.

[b]If river, angler hours per mile.

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Table B.2, Recreational Freshwater Fishing Sites within 100 miles of the Bayside Power Station

Location	Acreage or River Segment	Site Name	Affected Site	Latitude	Longitude	Boat Launch	No. Boat Ramps	Trout, Shad	Panfish[a]	Freshwater Game	Other Freshwater	Other Saltwater	Saltwater Small Game	Flatfish	Trips	Fishing Pressure	Angler Hrs/Acre[b]	Hours per Trip	Advisory	Sportfish Caught from Waterbody
Peace River, North of Lake Suzy (DeSoto County), FL	80 miles (freshwater)	Deep Creek Park Public Boat Ramp, Lake Suzy, FL	0	27.060687	-82.002940	1	2	0.0000	0.0000	0.5500	2.2500	0.0000	0.0000	0.0000	7,021	28,086	351.07	4.00	Mercury	Bluegill, brown and yellow bullhead, channel and white catfish, redear sunfish, spotted sunfish, warmouth
Rodman Reservoir (Lake Ocklawaha), Marion and Putnam Counties, FL	9,500 acres	Off Kenwood Boat Ramp Rd, Interlachen, FL	0	29.518383	-81.867368	1	6	0.0000	0.0000	0.6900	3.0500	0.0000	0.0000	0.0000	19,540	78,161	8.23	4.00	Mercury	Largemouth bass, sunfish
Santa Fe Lake, Melrose (Alachua County), FL	5,850 acres	Melrose Boat Ramp, 6116 Trout St, Melrose, FL	0	29.712972	-82.052761	1	2	0.0000	0.6300	0.4500	1.0600	0.0000	0.0000	0.0000	18,449	73,795	12.61	4.00	Mercury	Crappie, largemouth bass, sunfish
Silver Lake, Brooksville (Hernando County), FL	640 acres approx.	Withlacoochee State Forest, Silver Lake Campground	0	28.578831	-82.217196	1	2	0.0000	0.7800	0.8400	1.2800	0.0000	0.0000	0.0000	1,982	7,930	12.39	4.00	None	Largemouth bass, redbreast sunfish, white catfish
Stick Marsh/Farm 13, near Fellsmere (Indian River County), FL	6,500 acres	Fellsmere Grade Road, Fellsmere, FL	0	27.823181	-80.709005	1	1	0.0000	0.7300	0.8500	1.1800	0.0000	0.0000	0.0000	34,996	139,985	21.54	4.00	Mercury	Crappie, largemouth bass, sunfish
St. Johns River between Lake Jessup and Lake Harney (Seminole and Volusia Counties), FL	7.4 miles	Cameron Wight Park boat ramp, 5502 Old Geneva Rd, Sanford, FL	0	28.786190	-81.180644	1	1	0.6300	0.0000	0.5300	0.0000	0.0000	0.0000	0.0000	465	1,860	251.35	4.00	Mercury	American and hickory shad
Tampa Bypass Canal, Tampa (Hillsborough County), FL	14 miles	Harney Park, Tampa, FL	0	28.013095	-82.353048	1	1	0.0000	1.1600	0.5300	1.6200	0.0000	0.0000	0.0000	1,229	4,915	351.07	4.00	Mercury	Bluegill, largemouth bass, redbreast and redear sunfish, spotted sunfish
Tenoroc Fish Management Area, (Polk County), FL; besides boat ramps, has 6 hand launch sites	8,300 acres (23 lakes from 7 to 227 acres)	Fish Hook Lake, 3829 Tenoroc Mine Road, Lakeland, FL	0	28.096951	-81.933176	1	16	0.0000	1.1600	0.5900	3.2000	0.0000	0.0000	0.0000	25,715	102,861	12.39	4.00	Mercury	Crappie, largemouth bass, sunfish
Winter Haven South Chain of Lakes (14 lakes), Polk County, FL	4,361 acres	Lake Cannon Park public boat ramp, West Lake Cannon Drive, Winter Haven, FL	0	28.040446	-81.759473	1	9	0.0000	0.0000	0.5500	2.2500	0.0000	0.0000	0.0000	8,185	32,741	7.51	4.00	Mercury	Bream, largemouth bass
Withlacoochee River, Dade City (Pasco County), FL	157 miles	Green Swamp Wilderness Preserve West Tract Small Boat Launch, Dade City, FL	0	28.353896	-82.125430	1	6	0.0000	0.7800	0.8400	1.2800	0.0000	0.0000	0.0000	13,779	55,118	351.07	4.00	Mercury	Catfish, largemouth bass, panfish

[a]Note that panfish are crappie and yellow perch in this study.

[b]If river, angler hours per mile.

Sources: Atlantic States Marine Fisheries Commission (2007); Citrus/Hernando Waterways Restoration Council (2011); DeLorme (2006); Doroshoff (2004); Florida Fish and Wildlife Conservation Commission (2013, 2017a–2017e); Florida Fish and Wildlife Conservation Commission Exotic Fisheries Office (2015); Hyle 2012; Mesing (2003); Slipke, Maceina, and Grizzle (1998); Southwest Florida Water Management District (1998); Southwest Florida Water Management District (2011); State of Florida (2017); State of Florida Game and Fresh Water Fish Commission (2000); *The City Fisher* (2010)

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Appendix C
Development of Nonuse Benefit Estimates

Development of Nonuse Benefit Estimates for Tampa Electric Company's Bayside Power Station

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Introduction

This report presents the results of Veritas Economic Consulting's (Veritas') efforts to develop estimates of the nonuse values associated with entrainment reductions at Tampa Electric Company's Bayside Power Station (Bayside). Tampa Electric Company is in the process of developing Bayside's regulatory submittals for compliance with the United States Environmental Protection Agency's (USEPA) 2014 §316(b) Rule (79 *Fed. Reg.* 158, 48300–48439) (Rule). One of the Rule's regulatory submission requirements is the Benefits Valuation Study (§122.21(r)(11)), which requires that the facility estimate the benefits of entrainment reductions that are expected to occur from alternative entrainment reduction technologies evaluated at the facility.

One component of the benefits are the nonuse values associated with entrainment reductions (122.21(r)(11)(iii)). Nonuse benefits result from the values that people may hold for a resource, independent of their use of the resource. While experts tend to concur on the existence of nonuse values, they are inherently difficult to observe. As a result, they are looked upon quite differently from use values such as the recreational and commercial benefits of entrainment reductions. By comparison with use values, there is less agreement among experts about how nonuse values should be measured and the reliability of the techniques to measure them (Barnthouse, Bingham, and Kinnell 2016).

Since the development of the 2004 version of the 316(b) rule, USEPA has used a number of different methods to measure the potential nonuse benefits associated with reductions in impingement and entrainment. These include techniques such as Habitat Replacement Cost, Societal Reveled Preference, and the Fisher-Raucher Approximation. Most recently, as part of supporting the development of the 2014 version of the 316(b) Rule, USEPA administered a Stated Preference Survey to develop the total values (use and nonuse) associated with the Rule. Appendix A presents examples of the questionnaires used in the survey. While USEPA developed econometric models of the survey data and estimated respondents' willingness to pay for alternative impingement and entrainment reductions, they did not incorporate the results of the survey into the estimate of the Rule's benefits. Regardless, states have issued suggestions for how the results from the stated preference survey can be used to inform site-specific benefit estimates (Wisconsin 2016), regulators have made suggestions in public meetings that Benefit Valuation Studies should, in the least, identify the implications that the stated preference study results have for an individual site's nonuse benefit estimates, and peer reviewers have asked whether the results of the stated preference survey have been considered as part of the Benefits Valuation Study.

Given the survey's existence and these suggestions and questions from regulators and peer reviewers, we have developed a simulation model that uses the best available information from USEPA's Stated Preference Survey and the literature to identify the implications of what the survey results imply for the potential nonuse benefits of impingement and entrainment reductions at Bayside.

Methodology Overview

To develop the nonuse benefits of entrainment reductions, Veritas developed a Nonuse Benefits Simulation Model. The methodology that supported the model's development included each of the following steps:

1. Collecting and compiling the data from USEPA's Stated Preference Survey;
2. Replicating the econometric models and willingness-to-pay estimates USEPA developed and presented in its 2012 Notice of Data Availability (USEPA 2012);
3. Decompose the willingness-to-pay estimates into individual value categories and identify which categories are recoverable using the parameters estimated from USEPA's stated preference survey;
4. Place the plant's entrainment impacts in USEPA's study context;
5. Estimate differences in willingness to pay by demographics, collect and compile ZIP-Code level demographic data for the region(s) specified to contain the population having nonuse values for Bayside's entrainment reductions, and simulate willingness to pay by demographics for each Region;
6. Adjust the estimates to account for the Survey-Induced Bias present in the willingness-to-pay estimates and the Awareness Bias present in the extrapolation; and
7. Sum the adjusted estimates across all the individuals of each demographic profile in each ZIP Code included in the affected population.

Section 3 provides a detailed description of each of these steps.

Results Overview

Table 1.1 summarizes the nonuse benefit estimates that Veritas developed using its Nonuse Benefits Simulation Model. Table 1.1 presents the benefit estimates for three different regions that Veritas used to evaluate the nonuse benefits of Bayside's entrainment reductions:

1. All the households in Hillsborough County, Florida—the county where Bayside is located
2. All the households in the states included in the Southeast Region of USEPA's Stated Preference Survey
3. All the households in the United States.

Table 1.1 presents the results under two different entrainment sample years and two different discount rates: 3 and 7 percent. The two discount rates are required for evaluating the social costs of entrainment technology alternatives, so we've included them in the Nonuse Benefits Simulation Model to make the present value evaluation of benefits commensurate with the social cost present value calculation. The time period over which the Nonuse Benefits Simulation Model specifies the nonuse benefits to accrue is 2021 to 2054. As the results in Table 1.1 show, the estimated nonuse benefits range from $440 to $45,560.

Table 1.1
Summary of Nonuse Benefits for 100 Percent Entrainment Reduction at Bayside

		Sample Year 1		Sample Year 2	
Discount Rate	Specified Population of Households	Present Value	Annual Value	Present Value	Annual Value
3%	Hillsborough County	$782	$23	$1,552	$46
	USEPA's Southeast Region[a]	$6,947	$204	$13,783	$405
	United States	$22,966	$675	$45,560	$1,340
7%	Hillsborough County	$440	$13	$869	$26
	USEPA's Southeast Region[a]	$3,912	$115	$7,721	$227
	United States	$12,930	$380	$25,522	$751

Notes: [a] The states in USEPA's Southeast Region include Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas, and Virginia.

Report Overview

The following sections provide additional details on the methods Veritas undertook to develop its Nonuse Benefits Simulation Model and the results presented above. Section 2 presents a detailed description on nonuse values, their role in the development of the 2004 and 2014 versions of the 316(b) Rule, the various techniques that USEPA used to evaluate nonuse benefits during the 2004 and 2014 Rule's development, and the reason why we used the chosen technique to develop estimates of the nonuse benefits for Bayside's entrainment reductions. Section 3 presents a detailed description of the methodology Veritas used to develop its Nonuse Benefits Simulation Model to estimate the nonuse benefits associated with impingement and entrainment reductions at Bayside. Section 4 presents references for the citations provided throughout the report, and Appendix A contains the National version of the questionnaire USEPA administered in its stated preference survey.

Background on Nonuse Values

This section describes nonuse values, how they have been evaluated as part of the development of the 2004 and 2014 versions of the 316(b) Rule, the techniques that USEPA has used to develop them, and the implications that the techniques USEPA has used have for developing site-specific estimates of nonuse benefits for reductions in Bayside's impingement and entrainment. The regulatory requirement to consider nonuse values arises in the third component of the Benefits Valuation Study with the rule noting that,

> "The benefits valuation study must include, but is not limited to, the following elements:…(iii) Description of basis for any monetized values assigned to changes in the stock size or harvest levels of commercial and recreational fish or shellfish species, forage fish, and to any other ecosystem or nonuse benefits (122.21(r)(11)(iii), p. 48,448);"

Recreational and commercial benefits from entrainment reductions arise from changes in catch rates and therefore accrue to people who use the affected resource. Nonuse benefits, in comparison, result from changes in values that people may hold for a resource, independent of their use of the resource. These can arise for a number of reasons: they may be happy that other people can use the resource, they may want it to be available for people to use in the future, or they may believe the resource has some inherent right to exist.

Krutilla (1967) presented the original philosophical underpinning for nonuse values, arguing that individuals do not have to be active consumers of unique, irreplaceable resources in order to derive value from the continuing existence of such resources. He wrote that "when the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability are a significant part of the real income of many individuals" (p. 779).

Important components of Krutilla's original concept are that nonuse values are related to the continuing existence of unique resources. Under this framework, common resources suffering from limited injury do not generate significant nonuse values. The economic literature emphasizes the relationship between nonuse values and both the uniqueness of the resource in question and the irreversibility of the loss or injury (Freeman, Herriges, and Kling 2014; Freeman 2003). Freeman (2003) summarizes this relationship as follows:

> …economists have suggested that there are important nonuse values in …preventing the global or local extinction of species and the destruction of unique ecological communities. In contrast, resources such as ordinary streams and lakes or a subpopulation of a widely dispersed wildlife species are not likely to generate significant nonuse values because of the availability of close substitutes (Freeman p. 156).

As Freeman's text indicates, common resources (i.e., resources that are not unique) that do not experience irreversible losses are not likely to generate significant nonuse value.

While experts tend to concur on the existence of nonuse values, they are inherently difficult to observe. As a result, these values are looked upon quite differently from recreational and commercial values. By comparison with use values, there is less agreement among experts about how nonuse values should be measured and the reliability of measurement techniques (Barnthouse, Bingham, and Kinnell 2016).

There are a handful of approaches that have been applied to quantify nonuse values both generally and in the context of impingement and entrainment reductions for supporting the development of various forms of the 316(b) Rule: most notably the rules promulgated in 2004 and 2014. The techniques include non-economic methods referred to as Habitat Replacement Cost (HRC) and Societal Revealed Preference (SRP), a "rule-of-thumb" approach called the Fisher-Raucher approximation, and two approaches that require administering surveys that pose hypothetical questions called Contingent Valuation (CV) and Discrete Choice Experiments (DCE).[17] The following subsections summarize these methods as they've been applied for estimating the nonuse benefits of entrainment reductions and evaluates their applicability for developing nonuse benefits of entrainment reduction at Bayside.

Non-Economic Methods

We refer to Habitat Replacement Cost and Societal Revealed Preference as non-economic methods because they do not attempt to measure society's preferences for changes in ecological services nor economic value. Considering HRC, the costs estimated are the total costs of restoring habitats so that they produce ecological services equivalent to those expected from technological alternatives. These are not benefits, and over the course of USEPA's 316(b) rulemaking, numerous reviewers commented as such. Rather, they are alternative costs for achieving similar objectives. Mitigation approaches, such as stocking and habitat restoration, may achieve similar waterbody-level outcomes as entrainment reductions. However, the cost of such alternatives bears no implicit relationship to the benefits of reducing entrainment. In addition, in its review of the 2004 version of the Rule, the Second Circuit Court rejected restoration as a means for site-specific compliance.

[17] Both CV and DCE can also appropriately be called "Stated Preference" (SP) techniques as they both rely on stated rather than revealed (i.e., by taking fishing trips) preferences. Although DCE is often called SP, here we use the more precise term of DCE. Also, DCE is often referred to as "conjoint analysis" which is a related, but not identical technique.

The underlying reason for this is that measures of economic benefits must be based on the willingness-to-pay (WTP) principle, and HRC is not based on this principle. In many cases, the cost of developing a resource can substantially exceed the resource's value. Although USEPA extensively evaluated HRC during its development of its 2004 Phase II Rule, USEPA ultimately decided that the HRC method should not be used as a means of estimating nonuse benefits due to limitations and uncertainties regarding the application of this methodology (USEPA, 2004, p. 41,625).

The second cost-based methodology considered in USEPA's 316(b) rulemaking is called Societal Revealed Preference (SRP). Rather than using the cost of a hypothetical alternative (as under HRC), SRP uses historical costs under prior government mandates to measure benefits. Like the HRC method, this is a cost-based approach that has no foundation in economics. Accordingly, it is not accepted by economists as a legitimate method of empirical valuation. In fact, the SRP method is a corrupted application of the legitimate revealed preference (RP) method. An essential characteristic of revealed preference analysis, that is not part of SRP, is that willingness to pay is revealed by those who are doing the paying. In contrast, the SRP methodology inappropriately takes the fact that a program exists as evidence that its benefits exceed its costs.

The drawbacks of these methods, with respect to valuation, would seem to indicate that they should not be used for estimating the nonuse values of entrainment reductions. This position is, strictly speaking, correct. However, as the following discussions will describe, the methods that appear at least theoretically capable of quantifying nonuse values are subject to disagreement regarding their reliability and important questions remain about bias in nonuse survey estimates and extrapolation of nonuse survey results. In part because of these difficulties, Natural Resource Damage Assessments and Restoration (NRDAR) evaluations have effectively abandoned nonuse valuation and embraced the Habitat and Resource Equivalency Analysis (HEA and REA) methods which are analytical techniques designed to inform the Habitat Replacement Cost method.[18]

[18] The effective abandonment of nonuse valuation in Natural Resource Damage Assessment and Restoration evaluations and use of Habitat and Resource Equivalency Analysis points out the current quandary with site-specific valuation of changes in ecological services. The best techniques available given the current state of the science are not used because of concerns about their reliability. The technique that is used is a cost-based technique that does not reflect society's values for changes in ecological services but rather the costs required to restore ecological services to the conditions they would have been in but for the presence of a specific environmental impact.

Rule-of-Thumb Method

USEPA has also considered the Fisher-Raucher or "50 percent" rule for assessing nonuse benefits during its rule making. This approach approximates nonuse values at 50 percent of recreational use values. The approximation is derived from a comparison of use and nonuse values for water-quality improvements, where the nonuse values were estimated using the contingent valuation (CV) method (Fisher and Raucher 1984). Applying this "50-percent rule" for entrainment reductions has the great advantage of being simple. However, it is based on CV studies which are subject to questions about their reliability. This rule-of-thumb was based on water quality improvements. There is not good evidence that the ratio of nonuse-to-use benefits from water-quality improvements is similar to that same ratio for environmental improvement from entrainment reductions. In particular, use values from fish often arise from their consumption whereas use values from water quality are typically non-consumptive.

Hypothetical Scenario Survey Methods

Currently, the only conceptually correct methods (i.e., those applying the willingness to pay (WTP) concept), available for estimating nonuse values, are survey-based techniques that ask respondents to value, or choose, natural resource services in a hypothetical context. These are the Contingent Valuation and Discrete Choice survey methods.

Contingent Valuation

The contingent valuation method involves surveying individuals to elicit their WTP for different levels of services.[19] For example, the survey may ask respondents a question such as, "What is the maximum amount you would pay to restore wild salmon runs in the Columbia River Basin?"[20] The responses are analyzed to determine the average WTP for preserving wild salmon runs. This method requires that individuals be able to express their value for changes in the fishery and, furthermore, that their responses to hypothetical questions indicate their actual valuations of the changes described in the questions.

The CV method attempts to establish, through the course of a survey, a hypothetical market where environmental changes can be traded like commodities. Ultimately, the goal of the CV survey is to establish circumstances that represent an exchange of money for the environmental service. Oral or written descriptions, supplemented by visual aids, are used to make the survey informative and realistic.

[19] See Mitchell and Carson (1989), Hausman (1993), and Arrow et al. (1993) for a detailed description of CV.

[20] Natural resource economists have used a variety of question formats. This question is an open-ended format. Alternatives include bidding games, payment cards, and referendum or dichotomous choice. In the dichotomous choice format, respondents are offered a particular payment amount and allowed to accept or reject that amount. See Mitchell and Carson (1989) for a detailed discussion on alternative payment elicitation formats.

The validity and reliability of CV has been questioned because respondents' hypothetical payment for a nonuse service has no behavioral experience to support or test the expressed value. This lack of a linkage between actual behavior and the hypothetical payment makes CV estimates particularly sensitive to variations in survey design, implementation, and analysis.

In addition to this sensitivity, the hypothetical nature of CV makes responses subject to bias. The inclination is for respondents to state that they would pay a higher amount for a good or service than they would actually pay. This problem was recognized by the National Oceanic and Atmospheric Administration (NOAA) when it suggested that CV estimates be treated to the "divide by 2" procedure. That is, to account for hypothetical bias, researchers should divide estimates of WTP from CV by 2.

NOAA's "divide by two" rule has no strong empirical basis, but it did set economists on the task of calibrating hypothetical valuations, by comparing them with values derived from real exchanges, where respondents gave up real money for real goods. Bias from valuation for public goods (such as fisheries) is especially difficult to investigate, however, because hypothetical versus real experiments for public goods are difficult to design.

The value estimate from CV data is typically the average WTP from the survey question. Researchers may model these responses to determine what characteristics of respondents influence their WTP. An important implication is that, in addition to designing the survey, researchers must determine the relevant population for the survey. That is, they must determine "to whom do these results apply?" Identifying this group is important because survey-estimated, WTP estimates must be aggregated over the affected population to determine total WTP. A critical and unresolved consideration is that, by its nature, participating in a survey raises awareness. Previous nonuse value studies have shown that the information treatment included with the questionnaire increases respondents' willingness to pay for the environmental change that is being evaluated (Kinnell et al., 2002). This is a fundamental difference between the surveyed "aware" population and the not-surveyed population that is less aware of the impact, but that difference sometimes makes up the vast majority of the population's willingness-to-pay.

Discrete Choice Experiments

A more sophisticated stated preference technique is discrete choice experiments (DCE). DCE's explicitly recognize that commodities have value because of their attributes. For example, a car has value because of such specific characteristics as size, color, comfort, body style, handling, gas mileage, price, etc. A DCE survey asks respondents to choose among a

series of different alternatives with different levels of attributes and different costs. By analyzing the choices made by respondents, researchers can uncover the underlying preferences for these attributes and respondents' WTP for different attributes or attribute bundles such as environmental programs.

DCE methods have been applied in the fields of environmental and health economics as an alternative to the CV method. For example, the DCE technique has been used to value hunting trips and fishing (Gan and Luzar 1993; Mackenzie 1993; Roe, Boyle, and Teisl 1996), to explain recreation site-choice selection (Adamowicz, Louviere, and Williams 1994), to determine public preferences for siting an industrial facility (Opaluch et al. 1993), and to measure changes in fishery services (Banzhaf, Johnson, and Mathews 2001).[21]

USEPA conducted a DCE to evaluate total (use and nonuse) values for entrainment reductions (USEPA 2012). USEPA selected a total target sample of 2,000 completed surveys across four regions and a national sample. The USEPA allocated these surveys across regions based on an experimental design which presents a set of three hypothetical choices to each respondent. Figure 2.3 presents an example of the choice questions.

As Figure 2.3 shows, the choices presented to respondents are profiles that include a monetary payment and improvement in environmental variables including reductions in I&E, improvements in fish populations, commercial fish populations, and overall aquatic health. Responses to the choice experiment are modeled for a Northeast, Southeast, Inland (containing the Great Lakes), Pacific, and National region using the mixed logit econometric technique. Mix logit is a highly flexible econometric estimation technique that avoids the limitations of the standard conditional logit model by allowing preferences to vary across individuals, unrestricted substitution patterns, and correlation in unobserved factors over time (Train 2009).

Although many environmental variables are insignificant, in all cases the variable representing reductions in I&E is statistically significant. The USEPA approximated survey respondents' willingness to pay (WTP) for a 1% change in fish saved from I&E reductions by conducting simulations for alternative uncertainty distributions of resulting preference coefficients. Ultimately, USEPA estimated that WTP for a 1% reduction in the number of fish impinged and entrained varies between $0.75 and $2.52 per household per year for the four regions surveyed

[21] DCE is also used in numerous nonenvironmental applications. Neenan, Bingham, and Kinnell (2016) use a discrete choice experiment to develop an adoption model of electricity customers' likelihood of choosing new electricity service plans and Bingham, Johnson, and Miller (2001) use a discrete choice experiment to develop an adoption model of patients' likelihood of selecting new pharmaceutical alternatives.

Question 4. Assume that Options A and B would require a different mix of filters and closed cycle cooling in different areas. Assume all types of fish are affected. How would you vote?

Policy Effect NE Waters	Current Situation (No policy)	Option A NE Waters	Option B NE Waters
Commercial Fish Populations (in 3-5 Years)	43% (100% is populations that allow for maximum harvest)	44% (100% is populations that allow for maximum harvest)	45% (100% is populations that allow for maximum harvest)
Fish Populations (all fish) (in 3-5 Years)	31% 100% is populations without human influence)	32% (100% is populations without human influence)	35% (100% is populations without human influence)
Fish Saved per Year (Out of 1.1 billion fish lost in water intakes)	0% No change in status quo	25% 0.3 billion fish saved	50% 0.6 billion fish saved
Condition of Aquatic Ecosystems (in 3-5 Years)	48% (100% is pristine condition)	49% (100% is pristine condition)	50% (100% is pristine condition)
$ Increase in Cost of Living for Your Household	$0 No cost increase	$24 per year ($2 per month)	$36 per year ($3 per month)
HOW WOULD YOU VOTE? (CHOOSE ONE ONLY)	☐ I would vote for NO POLICY	☐ I would vote for OPTION A	☐ I would vote for OPTION B

80

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Figure 2.3: Example of the Choice Question Format in USEPA's Stated-Preference Survey

and averages $1.13 per household per year for the National region (Exhibit II-10 in USEPA 2012).[22]

DCE, such as that conducted by USEPA, has advantages over CV. DCE encourages respondents to explore their preferences for various attribute combinations through a series of choices. The process of explicitly trading off attributes encourages greater respondent introspection than is likely to occur in a traditional CV format. The absence of such introspection has been a major criticism of the validity and reliability of CV estimates (Schkade and Payne 1994). The approach also allows analysts to devise internal consistency checks because respondents provide answers to multiple questions. Having more information from respondents on their relative preferences for the scenarios allows analysts to systematically evaluate whether a respondent's pattern of answers is plausible and consistent with economic theory used to construct social values (Johnson and Bingham 2001). These internal consistency checks are a significant improvement over the rudimentary technique of using general follow-up questions to assess respondents' motives for answers to single CV questions.

Because it provides values for individual components of commodities, as well as for commodities as a whole in a single survey, DCE has general applicability. DCE is frequently used to evaluate the market potential for new goods or services that are being developed and have not yet been brought to market or have only recently been introduced to the market. The large number of such studies that have been conducted have given the technique substantial credibility in the area of new product development and forecasting demand for unfamiliar products (Louviere, Flynn, and Carson 2010).[23] Certain of these are for environmental products that have a "nonuse flavor" such as green electricity (Johnson et al. 1995) or residential solar (EPRI 2017), but others are more traditional goods such as alternative electricity service plans that offer different rate structures (Neenan, Kinnell, Bingham, and Hickman 2016) or new pharmaceutical products (Bingham, Johnson, and Miller 2001)

Despite these advantages, DCE has significant drawbacks for calculating nonuse values. Like CV, it elicits expressed preferences under hypothetical conditions. As a result, the responses are likewise hypothetical, which implies that respondents do not have to make a real dollar commitment as they would in a real-market situation. Experimental evidence demonstrating hypothetical bias in choice experiments has been found by Johansson-Stenman and Svedsäter (2008). Also, like CV, the question of the affected population is critical. DCE

[22] "National" refers to the survey administered to a national sample and is referred to as a region for convenience.
[23] Discrete choice experiments are a subset of conjoint analysis and stated preference techniques. The technical distinction is well-explained in "Discrete Choice Experiments Are Not Conjoint Analysis" (Louviere, Flynn, and Carson 2010).

offers higher potential for connecting WTP to personal characteristics (EPRI 2012b). However, there is currently no solution to the fact that, by nature of them having taken the survey, the surveyed population is fundamentally different from the unsurveyed population (EPRI 2012b). Although there is no study of nonuse values in which these obstacles have been surmounted, recent efforts have proposed novel extensions of typical DCE surveys that propose methods for minimizing bias and extrapolating to the unsurveyed population (Barnthouse, Bingham, and Kinnell 2016).

Considering Quantitative Methods for Estimating Nonuse Benefits for Entrainment Reduction

As this overview of methods indicates, certain approaches that have been proposed for evaluating the nonuse value of entrainment impacts are not consistent with willingness-to-pay, the economic concept of monetary value. Considering the replacement cost and societal revealed preference approaches, there is the potential to entrain species that are recreationally and commercially valuable, forage species, and threatened and endangered species.

Commercial and recreational species are addressed in the valuation of changes in stock, yield, and catch rates of commercially and recreationally valuable species. Forage species are also valued as their contribution to the stock and catch rates of commercially and recreationally harvested species. Any stocking of commercially and recreationally valuable species could be used as information to inform a societal revealed preference approach, but would have issues with evaluating what part of that value is captured by the harvest and consumption of commercial species and the catch of recreational species. Also, lack of stocking of forage species would tend to indicate these species are not emphasized in the SRP approach.

Habitat Equivalency Analysis (HEA) and Resource Equivalency Analysis (REA), techniques that are similar to Habitat Replacement Cost, are implemented under Natural Resource Damage Assessment and Restoration (NOAA 2000) evaluations. It is possible to implement a habitat replacement approach for a reasonable level of effort and these approaches have been applied in entrainment decision making (Veritas Economics 2010). However, it is important to bear in mind that these are cost-based and not value-based estimates.

The Fisher-Raucher 50-percent “rule of thumb” approach is straightforward to implement. However, the approach is based on water quality, as opposed to fishery impacts. Although the approach is based on methods that are conceptually capable of identifying nonuse values, the reliability of these methods is questionable. Bias in the underlying nonuse studies is likely. The appropriate amount of adjustment (following NOAA) is not known. Moreover, the approach is

dated. If the approach were applied, nonuse benefits would simply be half of the estimated recreational benefits.

The USEPA DCE study elicits values from users and nonusers and therefore elicits both use and nonuse values. It is potentially feasible to extract a use/nonuse ratio from this study. However, this has not been attempted and may not be straightforward—users can experience nonuse values and it is not clear how to disentangle them. As described in Barnthouse, Bingham, and Kinnell (2016), an important consideration with nonuse values is the appropriate population to extrapolate over. There is no utility theoretic foundation that allows unaware nonusers to experience welfare increases. Therefore, the process of using and extrapolating the results of USEPA's Stated Preference Survey to the population being considered to hold nonuse values for reductions in Bayside's entrainment has to be considered carefully.

The results from the 2012 Environmental Impacts Awareness survey provides insight into the size of the population that is aware of impingement and entrainment impacts from cooling water intake structures (Kinnell, Bingham, and Hickman 2012). The survey was administered to a representative sample of more than 2,000 United States' residents and asked respondents about their current awareness of environmental impacts, including impacts from power plants (Kinnell, Bingham, and Hickman 2012). The results of the survey indicate that approximately 12 percent of the United States population is aware of aquatic impacts from steam electric plants. These include impacts such as water pollution, thermal discharge, wastewater impacts, and impacts to fish. No respondent specifically mentioned impingement and entrainment, and one percent of respondents mentioned impacts that are related to cooling water intake structures.

While USEPA developed willingness to pay estimates from its stated preference survey, it did not extrapolate those results to the relevant affected population. As the results of the 2012 Environmental Impacts Awareness survey show, given the population's current awareness level of entrainment impacts, careful consideration needs to be undertaken in extrapolating the results of USEPA's stated preference survey to a specific population that is expected to hold reliably measurable nonuse values for entrainment reductions at a specific cooling water intake structure. The following section presents a detailed description of the methods that Veritas has undertaken to use the data from USEPA's stated preference survey to develop estimates of the potential nonuse values for reductions in Bayside's impingement and entrainment.

Methodology

Given the background on nonuse values presented in the previous section, of all the methods that USEPA has used to develop estimates of nonuse benefits from entrainment reductions, its stated preference survey provides the best available approach. This section presents the methodology that Veritas undertook to use the data from USEPA's stated preference survey to develop estimates of the potential nonuse benefits of impingement and entrainment reductions at Bayside. To develop site-specific, nonuse benefit estimates, Veritas developed a Nonuse Benefits Simulation Model (NBSM) that incorporates the best of all the available information and uses the following steps:

1. Collect and compile the data USEPA collected in its stated preference survey;
2. Replicate the econometric models and willingness-to-pay estimates USEPA developed and presented in its 2012 Notice of Data Availability (USEPA 2012);
3. Decompose the willingness-to-pay estimates into individual value categories and identify which categories are recoverable using the parameters estimated from USEPA's stated preference survey;
4. Place the plant's impingement and entrainment impacts in USEPA's study context;
5. Estimate econometric models that identify demographic differences in willingness to pay, collect and compile ZIP-Code level demographic data for the region(s) specified to contain the population holding nonuse values for Bayside's entrainment reductions, and simulate willingness to pay estimate for each region;
6. Adjust the estimates to account for the Survey-Induced Bias present in the willingness-to-pay estimates and the Awareness Bias present in the extrapolation; and
7. Sum and discount the adjusted estimates by demographic profile by ZIP Code.

The following text describes each step.

Step 1 – Collect and Compile USEPA's Stated Preference Survey Data

The first step in developing the Nonuse Benefits Simulation Model is to collect and compile the data from USEPA's stated preference survey. USEPA provided the survey responses and experimental design as part of its Notice of Data Availability (NODA) Related to its Stated Preference Survey (Federal Register V77, N133; June 12, 2012). Veritas collected the data USEPA provided in the NODA and compiled it in the manner necessary to estimate the econometric models that allow recovery of respondents' willingness to pay for impingement and entrainment reductions.

Step 2 – Replicate USEPA's Willingness to Pay Estimates

In the second step, Veritas replicated the econometric models that USEPA estimated from the survey data to develop its estimates of the respondents' willingness to pay for

entrainment reductions. As Figure 2.3 shows, USEPA's Stated Preference Survey presented respondents with three profiles to choose from. Each profile includes a monetary payment and improvements in environmental variables including each of the following:

- **Improvements in commercial fish population from I&E reductions** – Called Commercial Fish Populations in the choice questions and labeled com_fish in the econometric model results;
- **Improvements in fish populations from I&E reductions** – Called Fish Populations in the choice questions and labeled fish_pop in the econometric model results;
- **Reductions in I&E** – Called Fish Saved per Year in the choice question and labeled fish_saved in the econometric model results USEPA presents in the NODA ;
- **Overall aquatic health of the waterbody where the I&E reductions occurred** – Called Condition of Aquatic Ecosystems in the choice questions and labeled aq_cond in the econometric model results; and
- **Cost of the I&E reductions** – Called Increase in Cost of Living for Your Household in the choice questions and labeled Cost in the econometric model results.

USEPA modeled the responses to the choice experiment for a Northeast, Southeast, Inland, and Pacific region using mixed logit techniques (USEPA 2012). USEPA also developed a National level version of the model.[24] USEPA's NODA presents the five best performing models and notes that they are preliminary and do not include all data. Results indicate that the value "fish saved" is statistically significant in all five models, "commercial fish populations" is statistically significant in four of the five models, "fish populations" is statically significant in three of the five models, and "condition of aquatic ecosystems" is statistically significant in two of the five models.[25]

The alternative specific constant (ASC) that represents the status quo (i.e., no new regulation) is not significant in any of the models presented in the NODA. In describing results USEPA interprets statistically significant results on environmental attributes as indicating positive willingness to pay (WTP) for changes in those environmental attributes. Their research memo attributes insignificance on the alternative specific constants as respondents' unwillingness to pay a positive or negative amount for a regulation that has no effects on ecological attributes (USEPA 2012). When discussing the significance of coefficient estimates,

[24] Because the next step in the analysis presents the results of improved econometric models, for brevity, this section does not present the estimated results from USEPA's models, but rather describes the results. See the NODA and USEPA 2012 for a full description of USEPA's estimated econometric models.

[25] The term statistical significance refers to rejecting the null hypothesis that there is no relationship (H_0=0) between changes in each of the independent variables in the model (e.g., fish saved, commercial fish populations, fish populations, etc.) and respondents' willingness to pay for changes in those independent variables. A statistically significant coefficient on fish saved, for example, means that respondents are willing to pay higher amounts for greater amounts of fish saved. The estimated coefficient on fish saved indicates how much more they are willing to pay for a one-percent increase in fish saved holding all other variables in the model constant.

USEPA notes that analogous outcomes are common in ecological choice literature where the substantial majority of choice attributes are statistically significant.

Although many environmental variables are not statistically significant, in all cases Fish Saved Per Year is statistically significant. The USEPA used the statistical significance on the Fish Saved Per Year variable to approximate survey respondents' willingness to pay (WTP) for a 1% change in Fish Saved Per Year by I&E reductions by conducting simulations for alternative uncertainty distributions of resulting preference coefficients. Ultimately, USEPA estimated that respondents' willingness to pay for a 1% reduction in the number of fish impinged and entrained varies between $0.75 and $2.52 per household per year for the four regions surveyed, and averages at $1.13 per household per year for the National model (Exhibit II-10 in USEPA 2012).

Generally speaking, insignificant coefficients on variables in an econometric model of the type USEPA estimated means mixed logit is not the correct specification (Train 2009). Also, ASC's on "status quo" are more often statistically significant than not and are often of a much higher magnitude than other coefficients (Scarpa et al. 2005). Given these results, Veritas developed new models with the survey data to determine if better-performing, mixed logit specifications are available. Veritas started by running the same econometric specifications USEPA presented in the NODA and reproduced USEPA's results so that Veritas' models would be starting from the same estimation point as USEPA. Veritas then developed new econometric models that have more statistically significant variables and greater overall model significance than the NODA models. Veritas' new models identify differences in willingness to pay by the demographic characteristics of respondents and also indicate the potential for survey induced bias in respondents' estimates. Step 3 describes the process and results of Veritas new model estimation.

Step 3 – Decompose Willingness-to-Pay Estimates Into Value Categories

In the fourth step, Veritas decomposes the willingness-to-pay estimates from the estimated econometric model into individual value categories to identify the relationship between the taxonomy of values that society can hold for entrainment reductions and the values that can be recovered from USEPA's stated preference survey. This step allows us to evaluate overlap of values, eliminate double counting, and identify opportunities to calibrate the stated preference results to externally-estimated revealed preference results.

There are generally four categories associated with society's nonuse values for environmental changes:

- Existence Value – the value of simply knowing that a resource exists and will continue to exist regardless of whether the individual ever intends to use it.
- Option Value – the value of maintaining the resource's existence so that the individual has the option to use it in the future
- Bequest Value – the value of making certain that the resource continues to exist in the future so it will be available for future generations, and
- Vicarious Value – the value associated with knowing that other people are using and getting value from the resource.

Option value is a pseudo use value because one is preserving the option of being able to use the resource in the future and is therefore not considered in this evaluation (Freeman, Herriges, and Kling 2014). Bequest value is relevant for something that is likely to have permanent impacts. Because the plants will not continue to operate into perpetuity their impacts are not permanent, and Bequest is therefore not considered in this evaluation. That leaves both Existence and Vicarious values as the relevant nonuse categories to evaluate.

Table 3.3 summarizes the evaluation of the overlap between the components of USEPA's Stated Preference Study and the benefits that will be estimated for Bayside using revealed preference methods for the Benefits Valuation Study. The table is divided into two main components: components of USEPA's Stated Preference Survey on the left and components of a revealed-preference-based evaluation of benefits for a Benefits Valuation Study. The first column lists the evaluated effect of USEPA's stated preference study, and the second column identifies where each of those effects are characterized in the rule. The next three columns identify where and how those effects are quantified using a revealed preference based study of the benefits of entrainment reductions and where a revealed preference study can quantify use and nonuse benefits. As the table shows, a revealed preference based study can quantify the use benefits resulting from aquatic ecosystem changes, recreational and commercial fish population changes, forage fish populations, and fish saved, but it cannot quantify the nonuse benefits of those changes.

Table 3.3
Evaluation of Overlap Between USEPA's Stated Preference Survey and Revealed Preference Methods for Estimating Components of the Benefits Valuation Study

USEPA's Stated Preference Survey		(r)(11) Revealed-Preference-Based Use Study		
Evaluated Effect	Where Effect Characterized in the Rule	Where & How Quantified	Where Use Monetized	Where Nonuse Monetized
Aquatic Ecosystem Conditions	(r)(11)(v-vi)	Not Quantified	(r)(11)(v-vi)	Not Monetized
Recreational and Commercial Fish Populations	(r)(11)(ii)	(r)(11)(ii) Adult Equivalents	(r)(11)(iii)	Not Monetized
Forage Fish Populations	(r)(11)(ii)	(r)(11)(ii) Adult Equivalents from Foregone Production	(r)(11)(iii)	Not Monetized
Fish Saved	(r)(11)(i)	(r)(11)(i) Percent Change with Technology	(r)(11)(iii)	Not Monetized

Given this dynamic, the next component of the value decomposition is to identify where individuals may likely hold nonuse values for each of the evaluated effects in USEPA's stated preference survey and make sure there is no overlap with how they are being estimated by the revealed-preference-based methods. To accomplish this, we first consider the relationships between the change being evaluated from an impingement and entrainment reduction, the value category affected by that change, and the source of values from that change.

Figure 3.2 begins with the example of changes in forage populations. As the figure shows, for the use value component, the source for value comes from the contribution that a change in forage populations contribute to changes in the quality of recreational and commercial fishing. For the nonuse value category of changes in forage populations, people may hold nonuse values for simply knowing that the forage population exists at the level that it would without the plant's entrainment impacts. In the taxonomy of nonuse values, this is the existence value associated with changes to forage populations. However, as figure 3.2 shows, there is also a vicarious value that individuals can have from forage species; it is the vicarious value they get from anglers they know having a higher-quality fishing experience because their catch rate on a given trip is higher with higher forage populations.

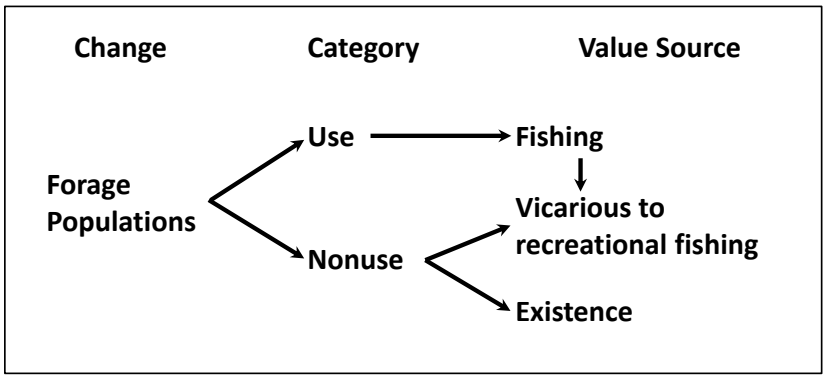


Figure 3.2: Value Decomposition for Changes in Forage Populations

Figure 3.3 shows the decomposition of the values people can have for changes in commercial fish populations. For use values, the benefits accrue to both commercial anglers who have to spend fewer resources to harvest the same or greater levels of commercial fish species and to commercial fish consumers who are able to spend the same or lower amounts to consume greater quantities of the same or higher quality fish. For the nonuse value category, the figure shows that in order for there to be meaningful nonuse values, people would either have to hold a value for other people being able to consume lower priced and/or higher quality commercial fish or have values for the commercial fish stock existing at the level that it would but for the plant's entrainment.

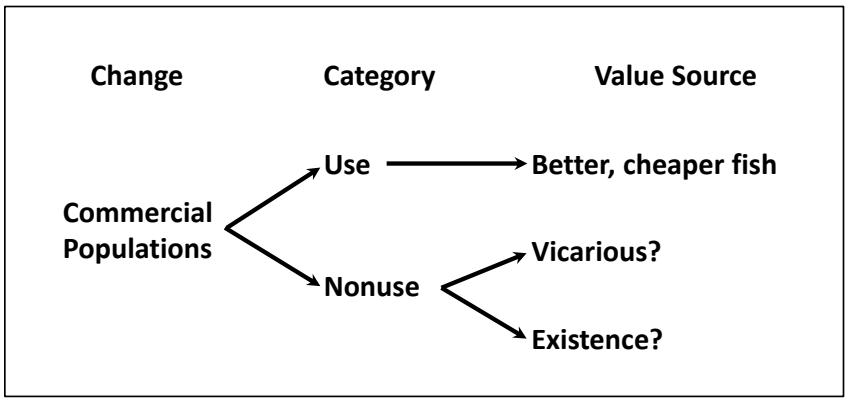


Figure 3.3: Value Decomposition for Commercial Populations

Figure 3.4 shows the decomposition of the values that people can have for changes in recreational fish populations. For use values, the benefits accrue to recreational anglers who have to spend fewer resources to catch more fish per trip than they would with the plant's

continued entrainment. For the nonuse value category, the figure shows that people may hold vicarious values for recreationally caught species (i.e., while they may not fish recreationally themselves, they may get value from knowing that friends, family, or the general public is able to catch more fish than they otherwise would with the plant's continued entrainment). The figure also shows that they may also hold values for the recreational fish stock existing at the level that it would but for the plant's entrainment.

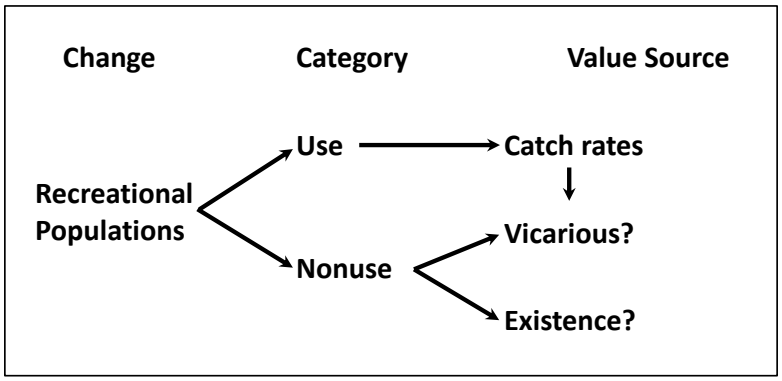


Figure 3.4: Value Decomposition for Recreational Populations

Figure 3.5 shows the value decomposition for the fish saved category in USEPA's Stated Preference Study. As the figure shows there is no use value category for this component of USEPA's study because the use components have been captured by the recreational and commercial changes. This variable focuses only on the nonuse values that people would hold for knowing that the entrainment reduction at the plant has saved a certain percentage of the fish that are lost to cooling water intake structures. The value source for this category of nonuse values is existence value—people's values for knowing that a certain number of fish will be saved from the plant's cooling water intake structures operation regardless of their or others use of those fish.

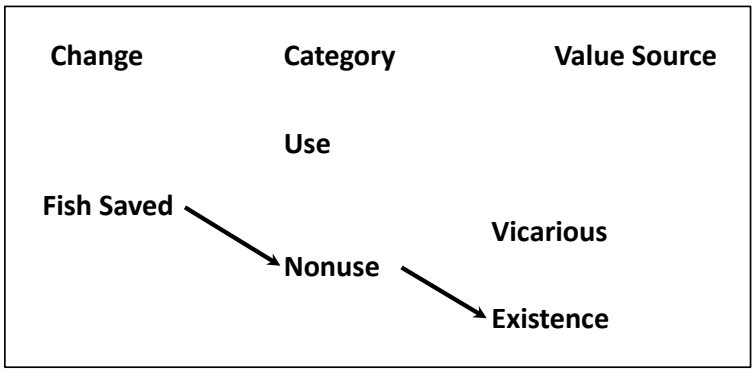


Figure 3.5: Value Decomposition for Fish Saved

These value decompositions identify a number of important implications for assessing nonuse values. The first is that there are opportunities for calibrating and validating the use, and therefore the nonuse value results from USEPA's study, with the revealed preference based estimates. The second is that the most meaningful value pathway that is not evaluated by a revealed preference study is the Fish Saved component of USEPA's study that captures the existence component of nonuse values. While the previous figures identify other potential value pathways, they are either addressed by the revealed preference based use study, their existence is much less certain, or is inconsistent with economic theory. For this reason, the Nonuse Benefits Simulation Model uses the variable on Fish Saved from USEPA's Stated Preference Study to assess the nonuse benefits of entrainment reductions.

Step 4 – Place the Plant's Entrainment Impacts in USEPA's Study Context

Because the Nonuse Benefits Simulation Model uses the Fish Saved variable to assess nonuse values, the plant's entrainment impacts have to be placed into USEPA's study context. This involves specifying the relevant region over which the plant's impacts are going to be evaluated and then placing the plant in the context of the other plants included in that region. The reason this is necessary is that the variable in the econometric model that provides the ability to evaluate the nonuse benefits of entrainment reductions is Fish Saved. As Figures 3.6 through 3.9 show, Fish Saved is in the context of the total fish lost in the cooling water intakes presented for the region where the plant is located (Figures 3.6 and 3.7) or in the nation as a whole (Figure 3.8 and 3.9).

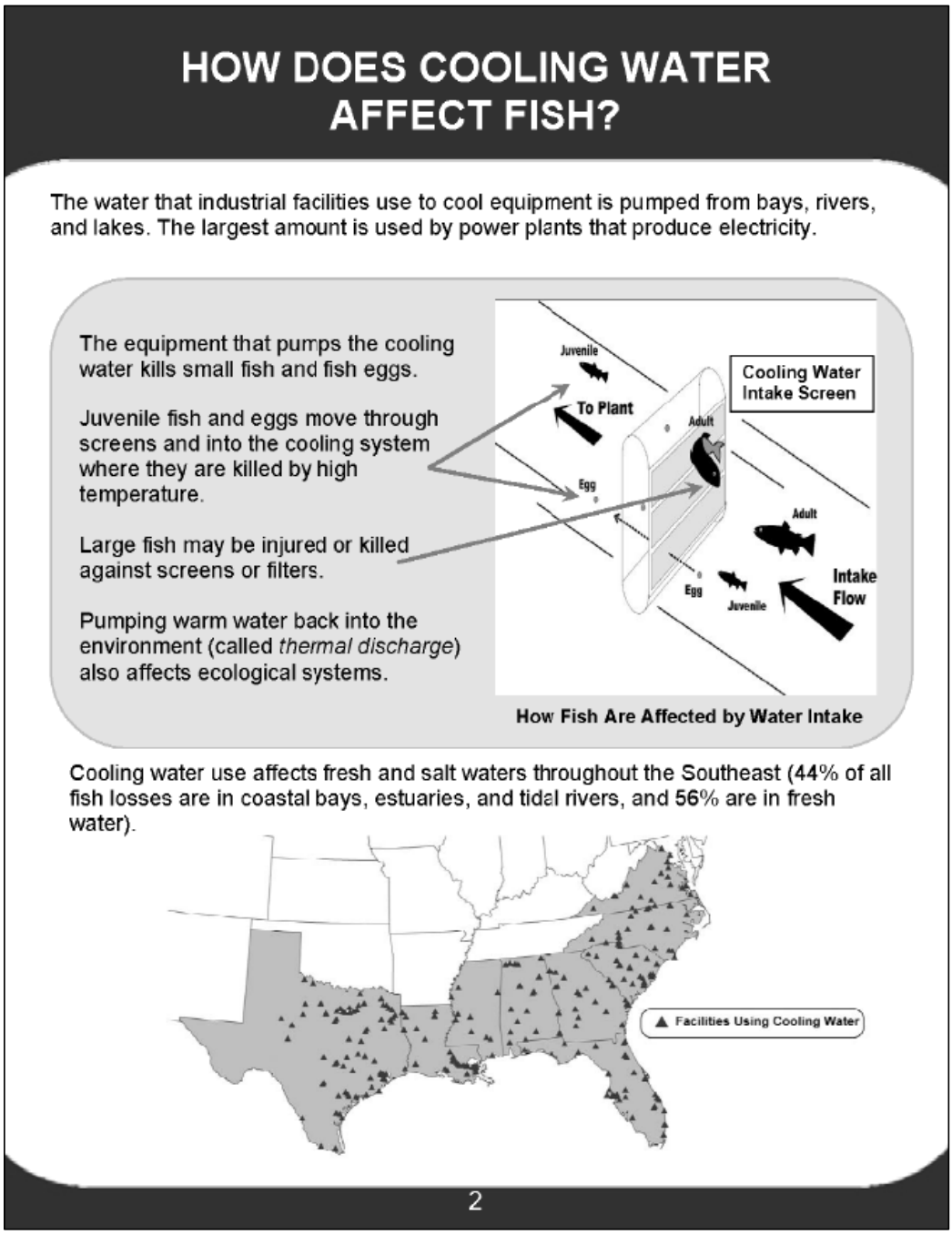


Figure 3.6: Number and Location of Plants in the Northeast Region of the Survey

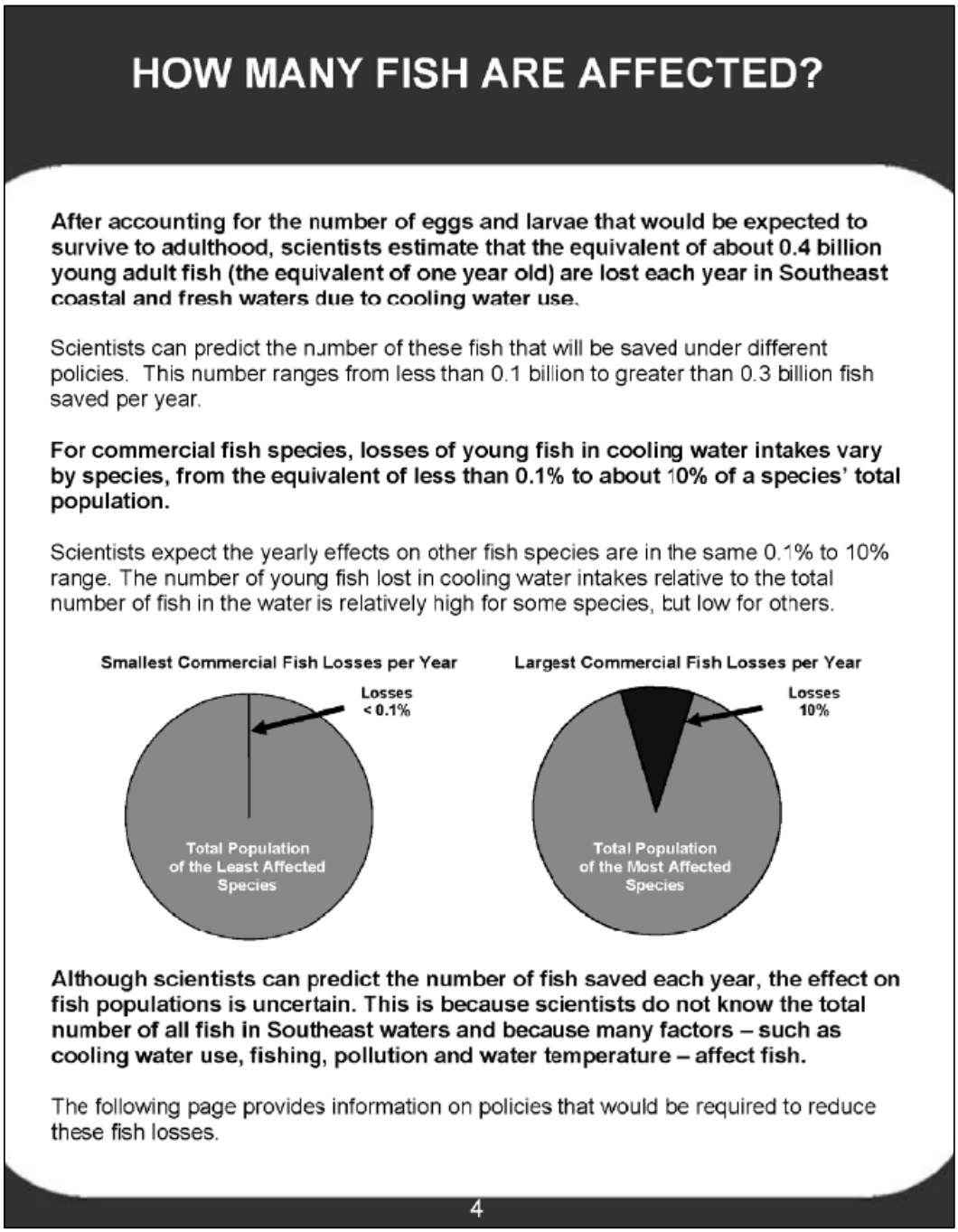


Figure 3.7: Estimated Number of Fish Lost to Cooling Water System Operation in the Southeast Region

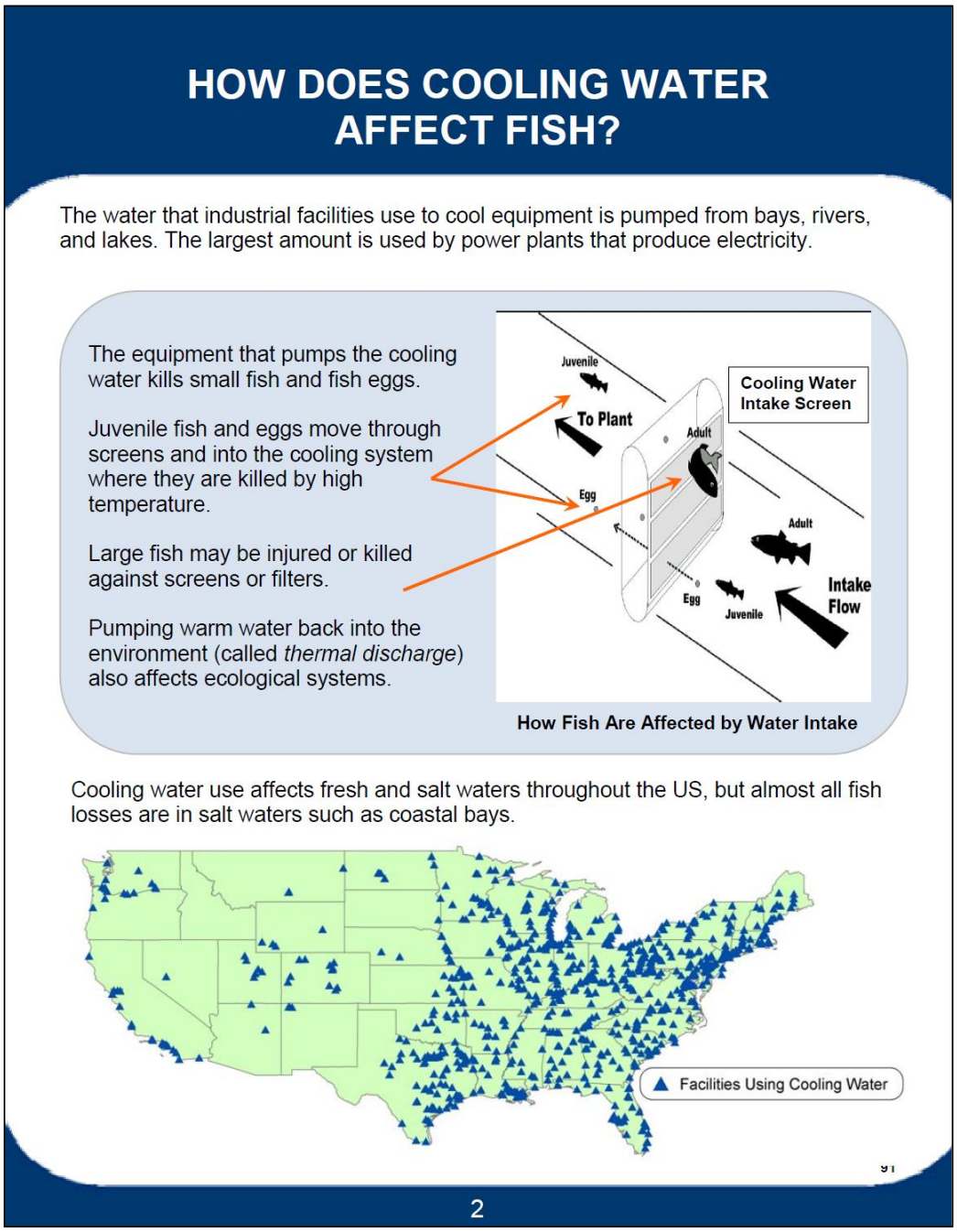


Figure 3.8: Number and Location of Plants in the National Version of the Survey

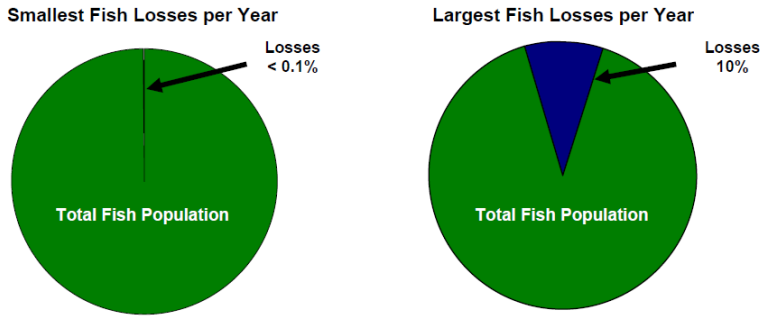
HOW MANY FISH ARE AFFECTED?

After accounting for the number of eggs and larvae that would be expected to survive to adulthood, scientists estimate that the equivalent of about 2.7 billion young adult fish (the equivalent of one year old) are lost each year in U.S. coastal and fresh waters due to cooling water use.

Scientists can predict the number of these fish that will be saved under different policies. This number ranges from 0.7 to 2.6 billion fish saved per year.

For commercial fish species, losses of young fish in cooling water intakes vary by species, from the equivalent of less than 0.1% to about 10% of total populations.

Yearly effects on fish species are between these levels. For example, the number of young fish lost in cooling water intakes relative to the total number of fish in the water is relatively high for some species, but low for others.



Although scientists can predict the number of fish saved each year, the effect on fish populations is uncertain. This is because scientists do not know the total number of all fish in U.S. waters and because many factors – such as cooling water use, fishing, pollution and water temperature – affect fish populations.

The following page provides information on policies that would be required to reduce these fish losses.

4

Figure 3.9: Estimated Number of Fish Lost to Cooling Water System Operation in the United States and the Number of Fish That Would Be Saved by Alternative Technologies

Characterizing the plant's impact relative to all of the other plants' impacts in the specific geographic area covered by USEPA's survey is important because this is the policy variable that the choice questions ask respondents to value with the Fish Saved Variable. As Figure 3.9 shows, in its National version of the survey, USEPA presents that under baseline (status quo) conditions, approximately 2.7 billion young adult fish (i.e., the equivalent adults associated with annual impingement and entrainment estimates) are lost annually in costal and fresh waters from cooling water intake operations. For the Southeast Region (Figure 3.7), USEPA presents respondents with an estimate of 0.4 billion young adult fish lost annually.

To evaluate Bayside's nonuse benefits, the Nonuse Benefits Simulation Model places Bayside's annual equivalent adult estimates (illustrated in Figures 1.1 and 1.3) in the context of the equivalent adult estimates for the Southeast Region. The model then considers the nonuse benefits for three distinct populations:

- Households in Hillsborough County, Florida
- Households in the states included in USEPA's Southeast Region, and
- All households in the United States.

Figures 3.10 through 3.12 illustrate each of these regions.

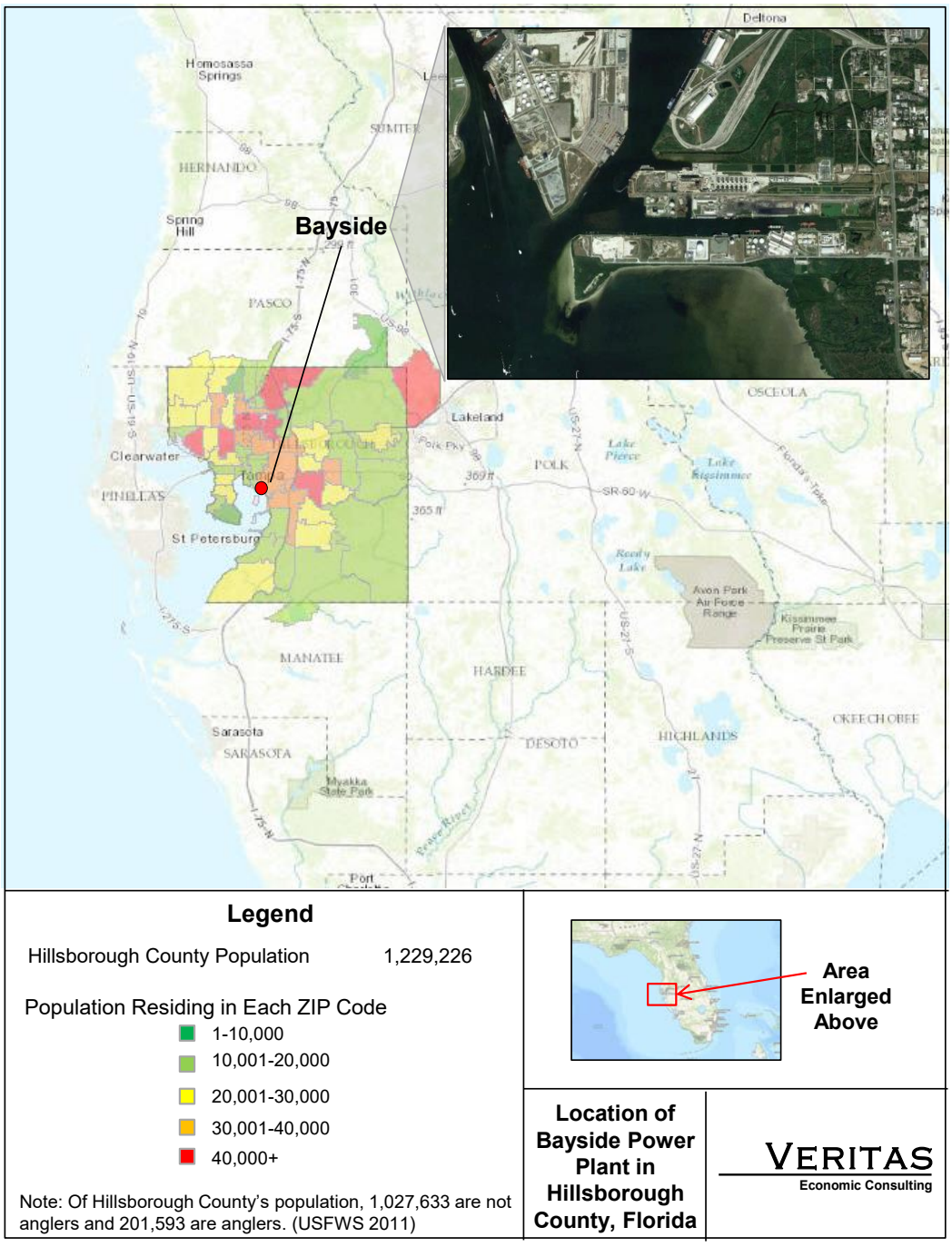
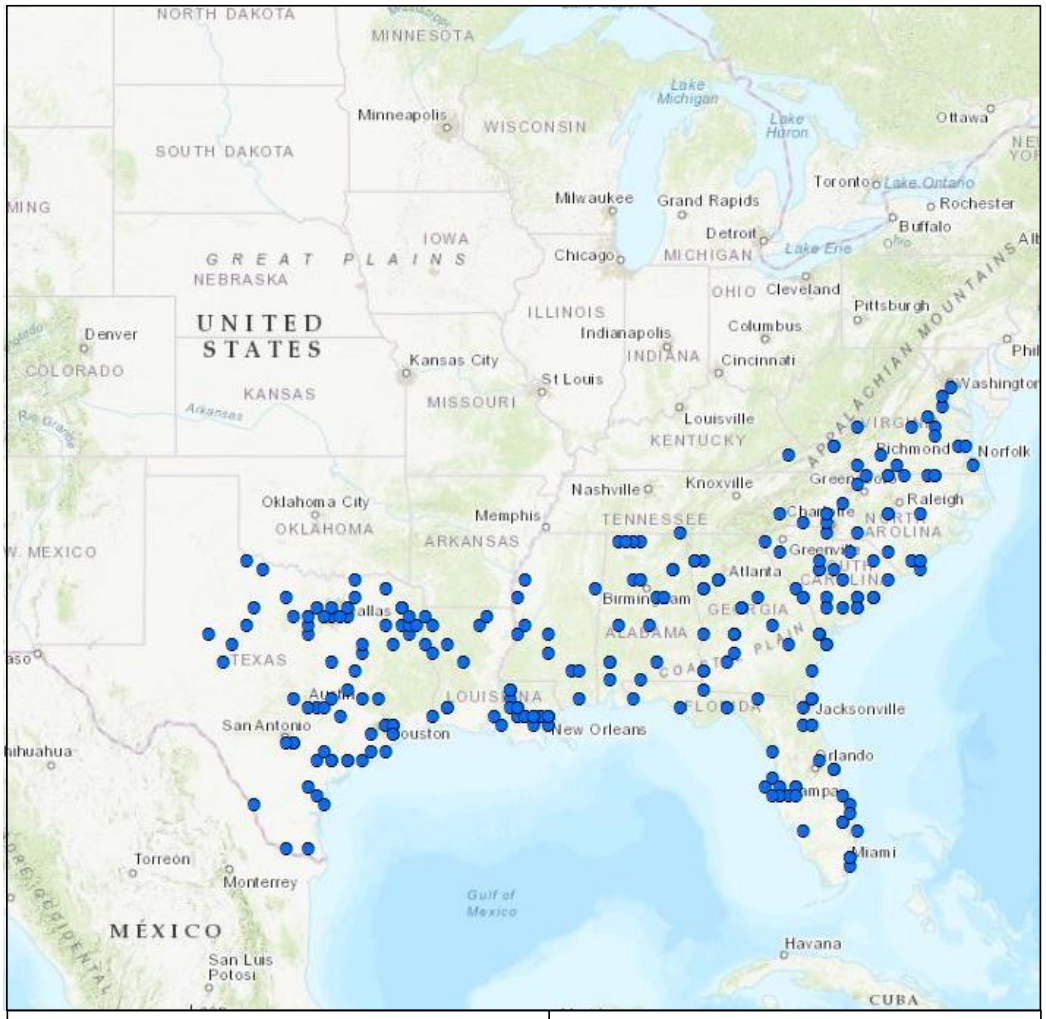


Figure 3.10: Geographic Distribution of the Hillsborough County Population by ZIP Code



Legend	**Location of 316(b)-Regulated Cooling Water Intake Structures Included in the Southeast Region of EPA's Stated Preference Survey**
● Southeast Region Sites with Cooling water Intake Structures Regulated Under the 2014 Rule	VERITAS Economic Consulting

Figure 3.11: Facilities in the Southeast Region of USEPA's Stated Preference Study with Cooling Water Intake Structures



Legend

- National Sites with Cooling Water Intake Structures Regulated Under the 2014 Rule

Location of Sites with Cooling Water Intake Structures Regulated Under the 2014 316(b) Rule and Included in the National Version of EPA's Stated Preference Survey

VERITAS
Economic Consulting

Figure 3.12: Facilities in USEPA's National Stated Preference Survey with Cooling Water Intake Structures

Step 5 – Identify Demographic Differences in Willingness to Pay

There is substantial evidence that awareness of impingement and entrainment impacts is quite low among the general public (Kinnell, Bingham, and Hickman 2012), suggesting that the Stated Preference Survey's results are not applicable to the majority of United States residents. In addition, the econometric models in the NODA do not identify differences in willingness to pay across different demographic profiles. That information is required to extrapolate the survey results to the unsurveyed population. Therefore, in this step, we expand the econometric model evaluation to test for differences in willingness to pay by varying demographics. To test for demographic differences, we developed models that combine USEPA's regional data into one data set for modeling. The results of these combined regional-data models indicate that there are demographic differences in the willingness to pay estimates.

Given a set of preferences held by survey respondents, the experimental design, sampling, and econometric modeling approach of a choice experiment are used together to determine the magnitude and significance of the estimated preference coefficients. Econometric modeling is required to estimate survey respondents' willingness to pay because this value is not directly provided in the choice experiment (i.e., it has to be econometrically recovered from the survey responses) and because respondents are a heterogeneous subset of the general population with specific characteristics and preferences which must be considered when generalizing the results.

For choice experiments such as this one, where the researcher has control over all aspects of the study including attribute ranges, experimental design, and sample size, the expectation is that all of the coefficients are statistically significant. When they are not, it is typically because of some combination of the data modeling technique, experimental design, or sampling (i.e., lack of large sample properties).

Bateman et al. (2002) is a well-established guide to stated preference and economic valuation. In the sampling section, Bateman et al. (2002) notes that "Unfortunately there is no free lunch with respect to obtaining estimates for subgroups. The required sample size increases linearly to a first approximation with the number of subgroups for which separate parameter estimates are required." Bateman et al.'s (2002) reference to subgroups is what we refer to as different demographic groups. To isolate variation in willingness to pay across different demographic groups, we pooled all the regional data to develop one data set. Table 3.4 presents the model results using the single, pooled data set. The number of observations is the total number of choice experiment questions across all regions and respondents. Pooling

the data provides the ability to evaluate deep interactions, which refer to the combination of multiple

Table 3.4
Deeply Interacted Mixed Logit Model Results

Mixed logit results	Number of obs	=	18891
	Number of Cases	=	6297
	Wald chi2(8)	=	2838.52
Log likelihood = -5020.1176	Prob > chi2	=	0.0000

Variable	Coefficient	Standard Error	Z	P>|z|	95% Confidence Interval	
Policy						
cost	-0.031	0.002	-16.89	0.000	-0.035	-0.028
inccomfish	0.001	0.000	1.29	0.197	-0.000	0.001
incfishpop	0.004	0.001	0.04	0.970	-0.001	0.001
incfishsave	0.001	3.710	2.78	0.006	0.000	0.000
incaqcond	0.001	0.001	0.12	0.901	-0.001	0.001
fdhcomfish	-0.015	0.075	-0.20	0.843	-0.163	0.133
fdhfishpop	0.269	0.130	2.07	0.038	0.014	0.524
fdhfishsave	0.022	0.008	2.99	0.003	0.008	0.037
fdhfishaqc~d	0.229	0.123	1.85	0.064	-0.013	0.470
fdlcomfish	0.056	0.049	1.16	0.248	-0.039	0.152
fdlfishpop	0.175	0.078	2.24	0.025	0.022	0.329
fdlfishsave	0.021	0.005	4.43	0.000	0.012	0.031
fdlfishaqc~d	0.102	0.080	1.27	0.204	-0.055	0.258
fndhcomfish	-0.120	0.099	-1.22	0.223	-0.314	0.073
fndhfishpop	0.117	0.157	0.75	0.453	-0.190	0.424
fndhfishsave	0.006	0.011	0.57	0.570	-0.015	0.027
fndhfishaq~d	0.039	0.163	0.24	0.813	-0.281	0.358
fndlcomfish	0.034	0.042	0.81	0.416	-0.048	0.117
mdhfishaqc~d	0.148	0.105	1.41	0.157	-0.057	0.354
mdlcomfish	0.046	0.048	0.96	0.338	-0.048	0.140
mdlfishpop	0.082	0.076	1.08	0.279	-0.066	0.231
mdlfishsave	0.006	0.005	1.32	0.186	-0.003	0.015
mdlfishaqc~d	-0.031	0.077	-0.4	0.688	-0.181	0.119

Table 3.4 continued

Variable	Coefficient	Standard Error	Z	P>|z|	95% Confidence Interval	
mndhcomfish	-0.128	0.072	-1.77	0.077	-0.269	0.014
mndhfishsave	0.001	0.007	0.22	0.828	-0.012	0.015
mndhfishaq~d	0.011	0.116	0.100	0.921	-0.216	0.239
com_fish	0.039	0.029	1.34	0.181	-0.018	0.096
fish_pop	-0.061	0.047	-1.30	0.195	-0.152	0.031
fish_saved	0.009	0.003	3.21	0.001	0.003	0.014
aq_cond	0.108	0.048	2.26	0.024	0.014	0.202
nopolicycon	-2.728	0.303	-9.01	0.000	-3.322	-2.135
SD						
com_fish	-0.129	0.045	-2.87	0.004	-0.216	-0.041
fish_pop	0.118	0.080	1.48	0.138	-0.038	0.275
fish_saved	0.030	0.003	9.75	0.000	0.024	0.036
aq_cond	0.315	0.062	5.09	0.000	0.193	0.436
nopoliycon	7.189	0.447	16.08	0.000	6.313	8.066

factors to identify profiles that resemble people rather than group averages (Gelman 2007).

The pooled data model in Table 3.4 evaluates how eight mutually exclusive groups interacted with each policy variable: combinations of male and female, college degree and no college degree, and high and low income. For example, individual groups include males with no college degree and low income (identified by the variable mndlfishsave for the Fish Saved policy variable) versus females with college degrees and high income (identified by the variable fdhfishsave for the Fish Saved policy variable). Males with no college degree and low income are the omitted category. The coefficient for "fdhfishsave" equaling 0.022 can be interpreted as females with a college degree and high income having a WTP for a one percent increase in fish saved that is $0.71 (0.022/0.031) higher than that of males with no college degree and low income.

As these results indicate, there are important interaction effects occurring at subgroup levels. Therefore, for appropriate extrapolation, willingness to pay should be tied to these deep interactions (i.e., extrapolation of these subgroup-level willingness to pay estimates should be tied to an appropriately estimated number of individuals in that subgroup who are aware of impingement and entrainment impacts). To accomplish this, we collect and compile ZIP Code level demographic data from the US Census for each of the three regions that are evaluated in the Nonuse Benefits Simulation Model: Hillsborough County, the Southeast Region, and the United States. The collected demographic data matches the set of demographic variables from the pooled data econometric model that identifies differences in willingness to pay by demographics. We then use the results from the econometric model to simulate willingness to pay for each demographic group in each region's ZIP Codes.

Step 6 – Adjust the Simulated Estimates to Account for Awareness Bias

One of the results of the pooled data econometric model is significance of the coefficient on the Alternative Specific Constant for the status quo variable (nopolicycon) which indicates that respondents are biased toward selecting either of the two policy options in the questionnaire rather than the status quo, not because they prefer the options, but because they want to select away from the status quo. The implication is that being asked to participate in the survey has influenced their willingness to pay estimate. That is, because they are the representatives of the population who have been selected to evaluate whether they would choose the status quo or one of the two policy options, they want to select away from the status quo and choose one of the policy options. The Nonuse Benefits Simulation Model controls for this effect by using the estimated coefficient on the fish saved and cost variables from the model that includes the statistically significant coefficient on the status quo's alternative specific constant.

The presence of this effect raises another question of how many people in the relevant population have heard of impingement and entrainment. This is an important component in the evaluation because as Johnson et al. (2001) have shown, nonuse values are conditional on people being aware of their presence. The implication being that members of the population cannot hold nonuse values for environmental changes that they are not aware of.

There is no utility theoretic foundation known to Veritas that allows unaware nonusers to experience welfare increases (by comparison, recreational anglers who are unaware of improvements might nevertheless experience catch rate improvements resulting in improved welfare). The results from the 2012 Environmental Impacts Awareness survey provide insight into the size of the aware population. The survey was administered to a representative sample

of more than 2,000 United States' residents, asking them about their current awareness of environmental impacts, including impacts from power plants (Kinnell, Bingham, and Hickman 2012). Figure 3.13 summarizes the results from the survey. As the figure shows more than half of all respondents are unaware of any impacts, and 12% of the United States population is aware of aquatic impacts from steam electric plants. These include impacts such as water pollution, thermal discharge, wastewater impacts, and impacts to fish.

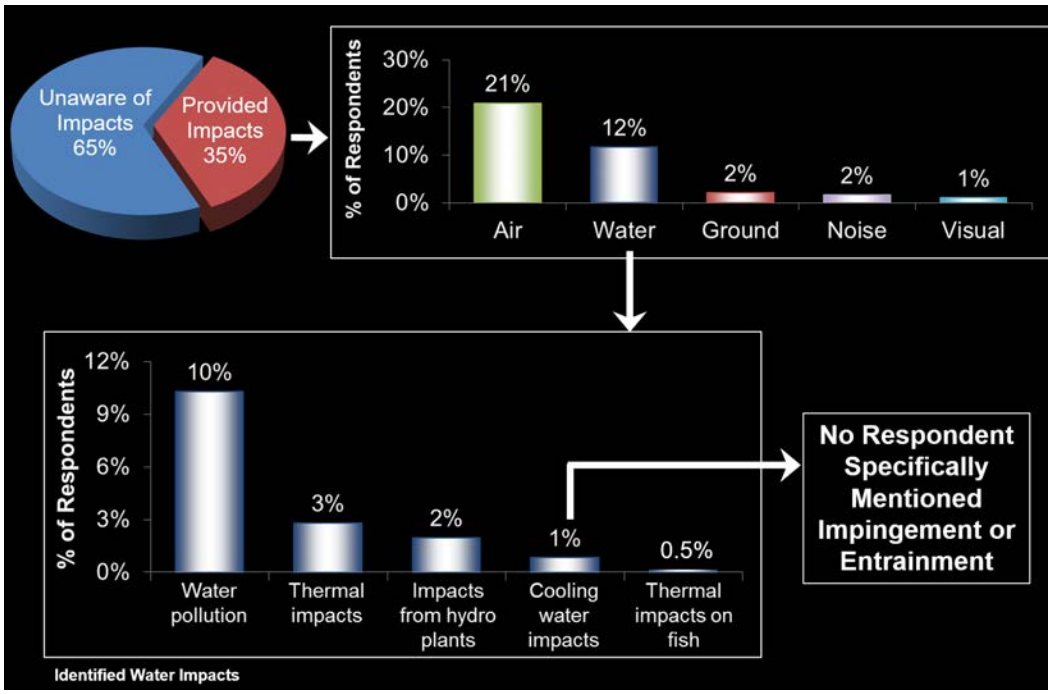


Figure 3.13: Summary of Results from the 2012 Environmental Impacts Awareness Survey

Based on these results, the Nonuse Benefits Simulation Model accounts for population-level awareness and adjusts the simulated results to account for the percentage of the population that is aware of impingement and entrainment. Specifically, the simulation model reduces the amount of the available population that is aware of impingement and entrainment impacts to be represented as the 12 percent of respondents from the survey who mentioned water impacts from power plants. The Nonuse Benefits Simulation Model applies awareness adjustment to the Southeast Region and United States geographic evaluations. Because Bayside is in Hillsborough County, the Nonuse Benefits Simulation Model does not apply the

awareness adjustment to Hillsborough County households, but rather includes all households in the evaluation.

Step 7 – Sum and Discount the Adjusted Estimates by Demographic Profile by ZIP Code

In the last step of the analysis, the Nonuse Benefits Simulation Model sums the adjusted estimates across each of the individual demographic profiles compiled from the US Census for each of the ZIP Codes in the evaluated regions. Because the USEPA's Stated Preference Survey elicits the household's willingness-to-pay for entrainment reductions by year, the Nonuse Benefit Simulation Model has to develop the present value of benefits over the expected lifetime that an entrainment technology would likely be in place at Bayside. To develop these estimates the Nonuse Benefit Simulation Model specifies the schedule for entrainment reduction technologies at Bayside. Table 3.5 presents the timing specifications for each of the feasible technologies.

Table 3.5
Timing Specifications by Feasible Technologies

Entrainment Reducing Technology	Regulatory Documents Submitted	Permitting, Design, Construction & Installation	O&M Costs Begin	Years of Operation
Closed-Cycle Retrofit	2018	2018-2024	2024	20
0.5mm Fine-mesh Ristroph Traveling Screens	2018	2018-2021	2021	23
Variable Speed Pumps	2018	2018-2022	2022	22

Because the technology selection, design, permitting, construction, installation, and operation takes place over many years, the nonuse benefit estimates must be discounted to place the stream of benefits across years into a present value estimate so they can be compared to the present value of the technology's social costs. The rule requires that the social costs be evaluated using two discount rates: 3 and 7 percent. The Nonuse Benefits Simulation Model therefore discounts the stream of benefits using these two discount rates.

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Appendix A
USEPA's Stated Preference Study

Survey of US Households

OMB Control No. 2040-XXXX
Approval expires XX/XX/XX

Fish and Aquatic Habitat

A Survey of US Households



The public reporting and recordkeeping burden for this collection of information is estimated to average 30 minutes per response. Send comments on the Agency's need for this information, the accuracy of the provided burden estimates, and any suggested methods for minimizing respondent burden, including through the use of automated collection techniques to the Director, Collection Strategies Division, U.S. Environmental Protection Agency (2822T), 1200 Pennsylvania Ave., NW, Washington, D.C. 20460. Include the OMB control number in any correspondence. Do not send the completed survey to this address.

HUMAN ACTIVITIES, AQUATIC HABITAT AND FISH

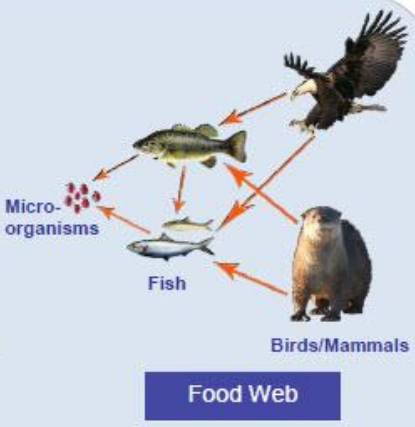
This survey asks for your opinions regarding policies that would affect fish and habitat in the U.S. Your answers will help the government decide which policies will be enacted. Background information in this survey was provided by the National Marine Fisheries Service, U.S. Environmental Protection Agency, U.S. Geological Survey and other state and federal offices.

Northeast fresh and salt waters support billions of fish. These include fish that are used by humans, as well as forage fish that are not used by humans, but serve as food for larger fish, birds, and animals.

Natural factors such as weather have always influenced fish, but in recent years human activities have had an increasing effect.

Activities that affect fish include fishing, pollution, commercial and residential development, and the extraction of cooling water at industrial facilities.

Declines in fish can affect the condition of ecological systems, food webs, and related human uses such as fishing.



Food Web

This survey concerns proposed policies that would reduce fish losses caused by cooling water use by industrial facilities, including factories and power plants. These policies would benefit aquatic ecosystems but would increase the costs of some goods and services you buy, including electricity and common household products.

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1

HOW DOES COOLING WATER AFFECT FISH?

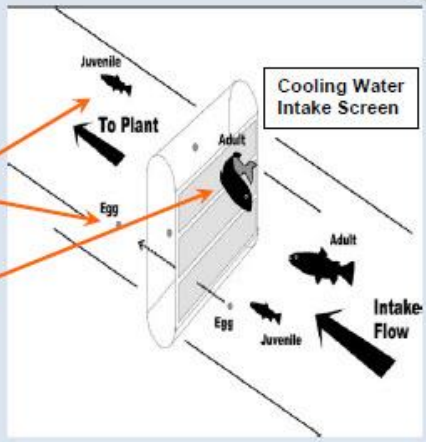
The water that industrial facilities use to cool equipment is pumped from bays, rivers, and lakes. The largest amount is used by power plants that produce electricity.

The equipment that pumps the cooling water kills small fish and fish eggs.

Juvenile fish and eggs move through screens and into the cooling system where they are killed by high temperature.

Large fish may be injured or killed against screens or filters.

Pumping warm water back into the environment (called *thermal discharge*) also affects ecological systems.



How Fish Are Affected by Water Intake

Cooling water use affects fresh and salt waters throughout the US, but almost all fish losses are in salt waters such as coastal bays.



2

WHAT KINDS OF FISH ARE AFFECTED?

Cooling water use is **not** the largest cause of fish loss in most areas (fishing causes greater losses), but has affected some fish populations.

About 1/3 of the fish lost are species caught by commercial and recreational fishermen. Examples include striped bass, flounder, and cod.

The other 2/3 of the fish lost are forage species not caught by humans but are part of the food web. Examples include killifish, silverside, and stickleback.

Question 1. When thinking about how industrial facilities use cooling water, please rate the importance of the following to you. Check one box for each.

	Not Important		Somewhat Important		Very Important
1. Preventing the loss of fish that are caught by humans	☐1	☐2	☐3	☐4	☐5
2. Preventing the loss of fish that are not caught by humans	☐1	☐2	☐3	☐4	☐5
3. Maintaining the ecological health of rivers, lakes and	☐1	☐2	☐3	☐4	☐5
4. Keeping the cost of goods and services low	☐1	☐2	☐3	☐4	☐5
5. Making sure there is enough government regulation of	☐1	☐2	☐3	☐4	☐5
6. Making sure there is not too much government regulation of industry	☐1	☐2	☐3	☐4	☐5

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3

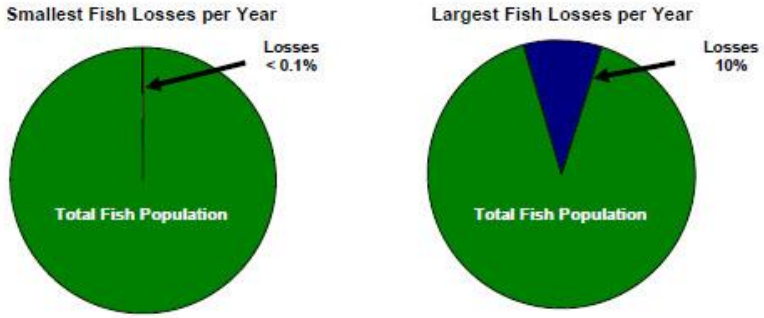
HOW MANY FISH ARE AFFECTED?

After accounting for the number of eggs and larvae that would be expected to survive to adulthood, scientists estimate that the equivalent of about 2.7 billion young adult fish (the equivalent of one year old) are lost each year in U.S. coastal and fresh waters due to cooling water use.

Scientists can predict the number of these fish that will be saved under different policies. This number ranges from 0.7 to 2.6 billion fish saved per year.

For commercial fish species, losses of young fish in cooling water intakes vary by species, from the equivalent of less than 0.1% to about 10% of total populations.

Yearly effects on fish species are between these levels. For example, the number of young fish lost in cooling water intakes relative to the total number of fish in the water is relatively high for some species, but low for others.



Although scientists can predict the number of fish saved each year, the effect on fish populations is uncertain. This is because scientists do not know the total number of all fish in U.S. waters and because many factors – such as cooling water use, fishing, pollution and water temperature – affect fish populations.

The following page provides information on policies that would be required to reduce these fish losses.

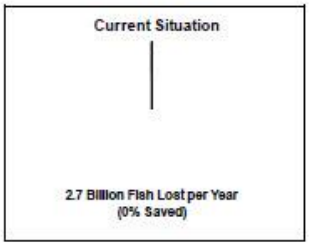
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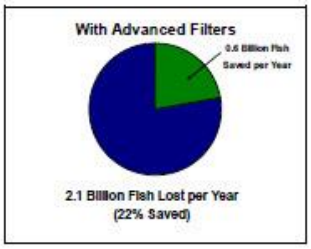
NEW REGULATIONS ARE BEING PROPOSED TO PROTECT FISH

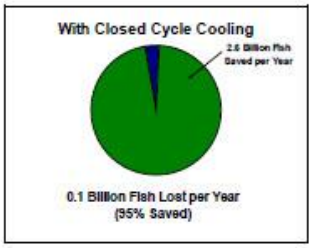
The government is considering policies that would require new measures to protect fish.

One policy would require **advanced filters** that block fish from entering cooling water facilities. Requiring advanced filters could reduce fish losses about 25%.

Another possibility is **closed cycle cooling** that recycles and reuses cooling water, so that less water is needed. Requiring closed cycle cooling could reduce fish losses by 95% and also reduces thermal discharge. However, costs are higher than for advanced filters.







Advanced filters and closed cycle cooling are already in use at many facilities and are proven technologies. **New regulations would require a mix of advanced filters and closed cycle cooling at all facilities—with reductions in fish losses between 25% and 95%.**

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5

HOW IMPORTANT ARE THESE ISSUES TO YOU?

While these policies would reduce fish losses, they would also increase the costs of producing many goods and services — these costs would be passed on to consumers like you.

Question 2. Compared to other issues that the government might address—such as public safety, education and health—how important is protecting aquatic ecosystems to you? Check one box.

	Not Important		Somewhat Important		Very Important
Protecting aquatic ecosystems is	☐1	☐2	☐3	☐4	☐5

The government needs to know whether households are willing to pay the costs of these new policies.

This survey will ask you to compare policies with different effects on cooling water use, fish, and costs to your household. You will be asked to vote for the options you prefer.

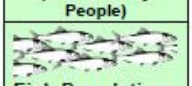
You will also have the opportunity to support the current situation, with no new policies, and no new costs to your household.

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THIS SURVEY IS SIMILAR TO A PUBLIC VOTE

The next part of this survey will ask you to consider different types of policies to protect fish, and indicate how you would vote. Effects of each possible policy will be described using the following scores:

Effect of Policy	What It Means
 Commercial Fish Populations (Fish Used by People)	A score between 0 and 100 showing **the overall health of commercial and recreational fish populations**. Higher scores mean more fish and greater fishing potential. A score of 100 means that these fish populations are at a size that maximizes long-term harvest; 0 means no harvest. **The current score in U.S. waters is 43.**
 Fish Populations (All Fish)	A score between 0 and 100 showing **the estimated size of all fish populations** compared to natural levels without human influence. A score of 100 means that populations are the largest natural size possible; 0 means no fish. **The current score in U.S. waters is 31.**
 Fish Saved (per Year)	A score between 0 and 100 showing the **reduction in young fish lost** because of the new policy. A score of 100 means that no fish are lost in cooling water intakes (all fish are saved). **The current score in U.S. waters is 0;** this represents the status quo with no new policies.
 Condition of Aquatic Ecosystems	A score between 0 to 100 showing **the ecological condition of affected areas**, compared to the most natural waters in the U.S.. The score is determined by many factors including water quality and temperature, the health of aquatic species, and habitat conditions. Higher scores mean the area is more natural. **The current score in U.S. waters is 48.**
$ Cost per Year	How much the policy will **cost your household, in unavoidable price increases for products and services you buy, including electricity and common household products.**

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HOW WOULD YOU RATE THE IMPORTANCE OF THESE EFFECTS?

Question 3. When considering policies that affect how facilities use cooling water, how important to you are effects on each of the following scores? Check one box for each. (For reminders of what the scores mean, please see page 7).

	Not Important				Very Important
1. Effect on commercial fish populations	☐1	☐2	☐3	☐4	☐5
2. Effect on the fish populations (for all fish)	☐1	☐2	☐3	☐4	☐5
3. Effect on fish saved	☐1	☐2	☐3	☐4	☐5
4. Effect on the condition of aquatic ecosystems	☐1	☐2	☐3	☐4	☐5
5. Effect on cost to my household	☐1	☐2	☐3	☐4	☐5

The next questions will ask you to choose between different policy options that would affect fish losses in cooling water systems. You will be given choices and asked to vote for the choice you prefer by checking the appropriate box. Questions will look similar to the sample on the next page.

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SAMPLE QUESTION

Questions will look like the sample below.

Policy Effect	Current Situation (No policy)	Option A	Option B
 Commercial Fish Populations (in 3-5 Years)	53% (100% is populations that allow for maximum harvest)	55% (100% is populations that allow for maximum harvest)	57% (100% is populations that allow for maximum harvest)
 Fish Populations (all fish) (in 3-5 Years)	39% (100% is populations without human influence)	42% (100% is populations without human influence)	42% (100% is populations without human influence)
 Fish Saved per Year (Out of 2.7 billion fish lost in water intakes)	0% No change in status quo	25% 0.7 billion fish saved	50% 1.4 billion fish saved
 Condition of Aquatic Ecosystems (in 3-5 Years)	46% (100% is pristine condition)	46% (100% is pristine condition)	48% (100% is pristine condition)
$ Increase in Cost of Living for Your Household	$0 No cost increase	$24 per year ($2 per month)	$48 per year ($3 per month)
HOW WOULD YOU VOTE? (CHOOSE ONE ONLY)	X I would vote for NO POLICY	X I would vote for OPTION A	X I would vote for OPTION B

If you do not want A or B, check this box

If you prefer Option A, check this box

If you prefer Option B, check this box

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AS YOU VOTE PLEASE REMEMBER

- The map below shows the facilities and areas that would be affected by the proposed policies.
- The policy options (A and B) given to you each require a different mix of advanced filters and closed cycle cooling in different areas, so effects on fish are different.
- You will be shown different questions, with different combinations of technology and different costs
- Depending on the policies chosen, costs to your household could range from $0 per month to a maximum of $6 per month.
- Depending on the type of technology required and other factors, effects on fish and ecosystems may be different—even if the annual reduction in fish losses is similar.
- Consider each pair of policy options separately—do not add them up or compare programs from different pages.
- Scientists expect that effects on the environment and economy not shown explicitly will be small. For example, studies of industry suggest that effects on employment will be close to zero.
- Your votes are important. Answer all questions as if this were a real, binding vote.



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Question 4. Assume that Options A and B would require a different mix of filters and closed cycle cooling in different areas. Assume all types of fish are affected. How would you vote?

Policy Effect US	Current Situation (No policy)	Option A US	Option B US
 Commercial Fish Populations (in 3-5 Years)	53% (100% is populations that allow for maximum harvest)	55% (100% is populations that allow for maximum harvest)	57% (100% is populations that allow for maximum harvest)
 Fish Populations (all fish) (in 3-5 Years)	39% 100% is populations without human influence)	40% (100% is populations without human influence)	43% (100% is populations without human influence)
 Fish Saved per Year (Out of 2.7 billion fish lost in water intakes)	0% No change in status quo	25% 0.7 billion fish saved	50% 1.4 billion fish saved
 Condition of Aquatic Ecosystems (in 3-5 Years)	46% (100% is pristine condition)	47% (100% is pristine condition)	48% (100% is pristine condition)
$ Increase in Cost of Living for Your Household	$0 No cost increase	$24 per year ($2 per month)	$48 per year ($3 per month)
HOW WOULD YOU VOTE? (CHOOSE ONE ONLY)	☐ I would vote for NO POLICY	☐ I would vote for OPTION A	☐ I would vote for OPTION B

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POLICIES COULD REQUIRE DIFFERENT COMBINATIONS OF TECHNOLOGY

Now you will be asked to consider a new set of policy options for U.S. waters. As you vote, please remember—

- Questions 5 and 6 present new sets of policy options. These options require a different mix of technologies in different areas.
- Each question is a separate vote. Questions 5 and 6 cannot be directly compared to each other, or to Question 4.
- Do not add up effects or costs across different questions.
- Policy costs and effects depend on many factors. Saving more fish does not necessarily mean that all effects will improve.

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Question 5. Assume that Options A and B would require a different mix of filters and closed cycle cooling in different areas. Assume all types of fish are affected. How would you vote?

Policy Effect US	Current Situation (No policy)	Option A US	Option B US
 Commercial Fish Populations (in 3-5 Years)	53% (100% is populations that allow for maximum harvest)	55% (100% is populations that allow for maximum harvest)	57% (100% is populations that allow for maximum harvest)
 Fish Populations (all fish) (in 3-5 Years)	39% (100% is populations without human influence)	41% (100% is populations without human influence)	43% (100% is populations without human influence)
 Fish Saved per Year (Out of 2.7 billion fish lost in water intakes)	0% No change in status quo	25% 0.7 billion fish saved	75% 2.0 billion fish saved
 Condition of Aquatic Ecosystems (in 3-5 Years)	46% (100% is pristine condition)	46% (100% is pristine condition)	50% (100% is pristine condition)
$ Increase in Cost of Living for Your Household	$0 No cost increase	$36 per year ($3 per month)	$60 per year ($5 per month)
HOW WOULD YOU VOTE? (CHOOSE ONE ONLY)	☐ I would vote for NO POLICY	☐ I would vote for OPTION A	☐ I would vote for OPTION B

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Question 6. Assume that Options A and B would require a different mix of filters and closed cycle cooling in different areas. Assume all types of fish are affected. How would you vote?

Policy Effect US	Current Situation (No policy)	Option A US	Option B US
 Commercial Fish Populations (in 3-5 Years)	53% (100% is populations that allow for maximum harvest)	60% (100% is populations that allow for maximum harvest)	57% (100% is populations that allow for maximum harvest)
 Fish Populations (all fish) (in 3-5 Years)	39% (100% is populations without human influence)	47% (100% is populations without human influence)	44% (100% is populations without human influence)
 Fish Saved per Year (Out of 2.7 billion fish lost in water intakes)	0% No change in status quo	95% 2.6 billion fish saved	50% 1.4 billion fish saved
 Condition of Aquatic Ecosystems (in 3-5 Years)	46% (100% is pristine condition)	50% (100% is pristine condition)	50% (100% is pristine condition)
$ Increase in Cost of Living for Your Household	$0 No cost increase	$96 per year ($6 per month)	$48 per year ($2 per month)
HOW WOULD YOU VOTE? (CHOOSE ONE ONLY)	☐ I would vote for NO POLICY	☐ I would vote for OPTION A	☐ I would vote for OPTION B

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Question 7. If you **always voted for NO POLICY** in questions 4-6, what was the primary reason? Check one. (Skip this question if you voted for Option A or B in any question above.)

____ The cost to my household was too high
____ Preventing fish losses is not important to me
____ I do not trust the government to fix the problem
____ I would rather spend my money on other things
____ I did not believe the choices were realistic
____ Since the problem was created by private facilities, they should fix it without passing costs on to consumers

Question 8. Indicate how strongly you agree with the following statements about questions 4 - 6 and the information provided. Check one box for each.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The survey provided enough information for me to make informed choices	☐1	☐2	☐3	☐4	☐5
I feel confident about my answers	☐1	☐2	☐3	☐4	☐5
Information in the survey was easy for me to understand	☐1	☐2	☐3	☐4	☐5
Information in the survey was fair and unbiased	☐1	☐2	☐3	☐4	☐5
Questions were easy for me to answer	☐1	☐2	☐3	☐4	☐5
I would vote the same way in an actual public vote	☐1	☐2	☐3	☐4	☐5
The effect of the proposed policies depends on many factors	☐1	☐2	☐3	☐4	☐5
Future ecological conditions are never 100% guaranteed	☐1	☐2	☐3	☐4	☐5

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Question 9. How much did the following factors affect your answers to questions 4 – 6? Check one box for each row.

	Effect on my answers to questions 4-6				
	Very Small Effect		Moderate Effect		Very Large Effect
Wanting to reduce taxes or costs to my household.	☐1	☐2	☐3	☐4	☐5
Wanting to prevent the loss of industrial jobs.	☐1	☐2	☐3	☐4	☐5
Wanting to preserve fish for commercial fishing.	☐1	☐2	☐3	☐4	☐5
Wanting to send a message that all environmental issues are important regardless of cost.	☐1	☐2	☐3	☐4	☐5
Wanting to preserve fish for recreation (fishing, etc.).	☐1	☐2	☐3	☐4	☐5
Wanting to preserve fish to benefit aquatic ecosystems.	☐1	☐2	☐3	☐4	☐5
Wanting to know that fish exist in local lakes, rivers and bays.	☐1	☐2	☐3	☐4	☐5
Wanting to pay my fair share for government programs.	☐1	☐2	☐3	☐4	☐5
Wanting to sustain the competitiveness of US business	☐1	☐2	☐3	☐4	☐5
Wanting to preserve fish as a source of food for people.	☐1	☐2	☐3	☐4	☐5
Wanting to preserve fish and ecosystems for future generations.	☐1	☐2	☐3	☐4	☐5

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Question 10. How many days did you participate in the following during the last year? For trips longer than one day, please count each day separately. Check one box for each row.

	Number of days you did the activity during the past year				
	0	1-5	6-10	11-15	16+
Boating / Canoeing / Kayaking	☐1	☐2	☐3	☐4	☐5
Swimming / Going to the Beach	☐1	☐2	☐3	☐4	☐5
Recreational Fishing (Fresh Water)	☐1	☐2	☐3	☐4	☐5
Recreational Fishing (Salt Water)	☐1	☐2	☐3	☐4	☐5
Shellfishing / Crabbing	☐1	☐2	☐3	☐4	☐5
Scuba Diving / Snorkeling	☐1	☐2	☐3	☐4	☐5

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The following questions ensure that all groups are fairly represented. All answers are anonymous and confidential.

11. What is your age?___ years

12. What is your gender? ❑ Male ❑ Female

13. What is the highest level of education that you have completed?
    - ❑ Less than high school
    - ❑ High school or equivalent
    - ❑ High school + technical school
    - ❑ One or more years of college
    - ❑ Bachelor's Degree
    - ❑ Graduate Degree

14. How many people live in your household? _____

15. How many of these people are 16 years of age or older? ____

16. How many of these people are 6 years of age or younger? ____

17. What is your zip code? _____

18. What town and state do you live in? Town: _____ State:____

19. Are you currently employed? ___Yes _____ No

20. What category comes closest to your total household income?
    - ☐ Less than $10,000
    - ☐ $10,000 to $19,999
    - ☐ $20,000 to $39,999
    - ☐ $40,000 to $59,999
    - ☐ $60,000 to $79,999
    - ☐ $80,000 to $99,999
    - ☐ $100,000 to $249,999
    - ☐ $250,000 or more

21. If you have any comments on this survey, please write them below:

Thank you for your participation in this important survey!

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12.0 40 CFR 122.21(r)(12)—Environmental and Other Impacts Study

12.1 Introduction and Background

12.1.1 Rule Requirement

Bayside consists of two gas-fired combined cycle generation units (1 and 2) and four natural gas fired simple cycle peaking units (3 through 6). The gross summer generation capacity of Unit 1 is 710 MW with 236 MW from the steam turbine and 474 MW from the three combustion turbines. The gross summer generating capacity of Unit 2 is 940 MW with 308 MW from the steam turbine and 632 MW from the four combustion turbines. Units 3 through 6 are 57 MW each. The total gross summer generation capacity of Bayside is therefore 1,878 MW (TECO, 2017a). Cooling water is used only for the steam turbines or steam cycles; therefore, the remainder of this evaluation focuses on the electricity generation and water use associated with the steam cycle at Units 1 and 2. Bayside is situated in Hillsborough County, Florida.

Bayside is regulated under EPA's 2014 rule for existing facilities developed under the 316(b) rule. Bayside's AIF from the Hillsborough Bay is greater than 125 MGD; therefore, the station has to submit information required in the 40 CFR 122.21(r)(12), Non-water Quality Environmental and Other Impacts Study:

(i) Estimates of changes to energy consumption, including but not limited to, auxiliary power consumption and turbine backpressure energy penalty;

(ii) Estimates of air pollutant emissions and of the human health and environmental impacts associated with such emissions;

(iii) Estimates of changes in noise;

(iv) A discussion of impacts to safety, including documentation of the potential for plumes, icing, and availability of emergency cooling water;

(v) A discussion of facility reliability, including but not limited to facility availability, production of steam, impacts to production based on process unit heating or cooling, and reliability due to cooling water availability;

> Significant changes in consumption of water, including a facility-specific comparison of the evaporative losses of both once-through cooling and closed-cycle recirculating systems, and documentation of impacts attributable to changes in water consumption; and,

(vi) A discussion of all reasonable attempts to mitigate each of these factors.

This document discusses the potential impacts that could arise from implementing closed-cycle cooling towers, FMS, alternate water sources or VSPs at Bayside.

12.1.2 Document Organization

This document will evaluate non-water quality and other environmental impacts required for evaluation under the 316(b) rule. The objective of these evaluations is to understand the overall environmental and social impacts associated with implementing an entrainment reduction technology at the station. The 40 CFR 122.21(r)(10) report presents the feasibility and practicality of implementing entrainment reduction technologies and associated costs to the owner and to society. The 40 CFR 122.21(r)(11) report evaluates fisheries benefits. This 40 CFR 122.21(r)(12) report evaluates non-water quality, environmental and other impacts; some of these may be beneficial to society and others may not.

Some potential impacts are readily quantifiable (e.g. energy consumption) but others are difficult to quantify (e.g. impacts to safety). This report describes relevant impacts to the station and surrounding communities and quantifies the impacts where possible.

Each section also includes a discussion on potential mitigation measures and the uncertainties associated with the evaluation.

The remainder of the document is organized as follows:

- Section 12.2 provides a summary of the technologies and operational measures discussed in the 40 CFR Part 122.21(r)(10) report and the technologies retained for impact analysis;
- Section 12.3 provides a discussion of the impacts of retrofitting the existing station with closed-cycle cooling towers;

- Section 12.4 discusses the impacts of a retrofitting the existing intake structure with FMS;
- Section 12.5 discusses the impacts of utilizing alternate water sources, such as onsite water reuse, groundwater, and reclaimed water sources;
- Section 12.6 discusses the impacts of utilizing VSPs; and
- Section 12.7 provides a summary of findings.

12.2 Technologies and Operational Measures in 40 CFR 122.21(r)(10)

Section 12.2.1 lists the technologies evaluated under 40 CFR 122.21(r)(10). Based on that evaluation, technologies that were deemed feasible, practical, or technologies required by regulations to be evaluated in 40 CFR 122.21(r)(12) are listed in Section 12.2.2. This 40 CFR 122.21(r)(12) report focuses on technologies and operational measures listed in Section 12.2.2.

12.2.1 All Technologies and Operational Measures Discussed

Entrainment reduction technologies and operational measures evaluated in the 40 CFR 122.21(r)(10) report are listed below. Sections 12.2.1.1, 12.2.1.2, 12.2.1.3, and 12.2.1.4 list closed-cycle options, fine-mesh options, alternate water sources, and VSPs options, respectively.

12.2.1.1 Closed-cycle Recirculating Systems

- MDCT
- NDCT
- Hybrid cooling towers
- Dry air-cooled condensers

12.2.1.2 FMS

- Permanent installation of 0.5-mm mesh TWS with a TSV of less than 0.5 fps
- Seasonal installation of 0.5-mm mesh TWS
- Permanent installation of 2-mm slot wedge wire screens with a TSV of less than 0.5 fps

12.2.1.3 Alternate Water Sources

- Onsite water reuse
- Reclaimed water sources
- Groundwater sources

12.2.1.4 VSPs

- Install a variable frequency drive on the existing circulating water pump
- Replace existing circulating water pump with a VSP

12.2.2 Practical and Potentially Feasible Technologies and Operational Measures Discussed

The following technologies or operational measures were retained for impact and cost evaluations because they were either deemed feasible and practical for implementation at Bayside or because evaluation was required under the 316(b)rule.

- Mechanical draft cooling towers
- Seasonal installation of 0.5-mm mesh TWS
- VSPs based on replacing the circulating water pumps.

12.3 Closed-cycle Recirculating System

Section 12.3 discusses non-water quality, environmental and other impacts associated with constructing and operating a closed-cycle cooling tower at Bayside. As discussed in the 40 CFR 122.21(r)(10) report, Bayside currently has a once-through cooling system, using water from the Hillsborough Bay. Per the 316(b) rule requirements, this section discusses energy consumption, emissions, noise, safety, facility reliability and the increase in consumptive water use. The organization of each impact evaluation is similar. Each section starts by describing the nature of the impact and how it affects society. The next subsection quantifies the impact after describing the method and data employed for the calculation. Engineering calculations are provided in the appendices. Each impact evaluation includes a discussion on potential mitigation methods and ends with a discussion on uncertainty.

12.3.1 Background on the Area

The magnitude of impacts is often driven by proximity to population centers. It is, therefore, helpful to understand the population density and characteristics surrounding Bayside and served by Bayside.

Bayside is located in Hillsborough County, Florida, near Tampa. Most impacts occur within less than one mile from the station. There is one neighborhood within the one-mile buffer from the station with between 2,001 and 5,000 persons per square mile (Figure 12-1). The remainder of the one-mile buffer area has fewer than 2,000 persons per square mile. Davis Islands, to the northwest of the station, has a population density between 2,000 and 10,000 persons per square mile, and a few pockets with over 10,000 persons per square mile. Davis Islands is approximately 2 miles from the station.

12.3.2 Energy Consumption—40 CFR 122.21(r)(12)(i)

12.3.2.1 Description

There are two forms of energy consumption associated with a closed-cycle cooling tower retrofit at a power plant: parasitic losses and backpressure energy penalty.

Parasitic loss[1] is the energy that is used to operate additional equipment. With a cooling tower retrofit, parasitic losses would occur due to additional pump and fan operation compared to the existing plant. All technologies will likely consume a small quantity of energy by way of additional lighting, signage, and meters, among many other items; however, these are minor usages and will not be quantified. Parasitic losses, where quantified, will be evaluated directly using the horsepower rating of the equipment, and the anticipated hours of operation per year.

[1] Also known as auxiliary load.

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FIGURE 12-1.

POPULATION DENSITY SURROUNDING BAYSIDE POWER STATION (US CENSUS 2014)

Source: HDR, 2017.

Environmental Consulting & Technology, Inc.

Backpressure energy penalty is energy that the power plant is unable to produce because of increases in the condenser backpressure owing to the retrofit. The temperature of once-through cooling water depends on the source water body temperature. The temperature of water from a MDCT depends on the ambient wet bulb temperature and the design of the cooling tower. As shown in Figure 12-2, for a given load on the condenser the backpressure increases as the inlet cooling water temperature increases. During most of the year, the temperature of water from a MDCT is higher than the temperature of water from a once-through system, but there may be short periods of time each year when the reverse is true. This would be particularly true for the Hillsborough Bay during cooler months, where the bay water would remain warm (due to influence from the Gulf of Mexico). It is possible that water from the cooling tower would be cooler than water from the bay. During those short periods, the condenser would be more efficient when cooled with a closed-cycle cooling tower than with once-through cooling water. The turbine's power generation efficiency depends on the quality of exhaust steam, temperature of cooling water, and various other condenser losses. Use of a MDCT, which results in warmer cooling water, reduces the efficiency of the turbine and its capacity to produce electricity, which is referred to as the backpressure energy penalty. While warmer cooling water would erode condenser performance, for as long as the increase in absolute backpressure is less than approximately 6 inches of mercury, condenser performance will not be completely inhibited (Alstrom Power, undated).

This evaluation will estimate energy penalty that would result from retrofitting the existing station with a MDCT using a parametric relationship developed by the U.S. Department of Energy (DOE).

12.3.2.2 Quantification

The parasitic losses for the Bayside MDCT include the operation of fans, booster pumps, makeup water pumps, dilution water pump, lighting, signage, chemical pumps, flow meters, etc.

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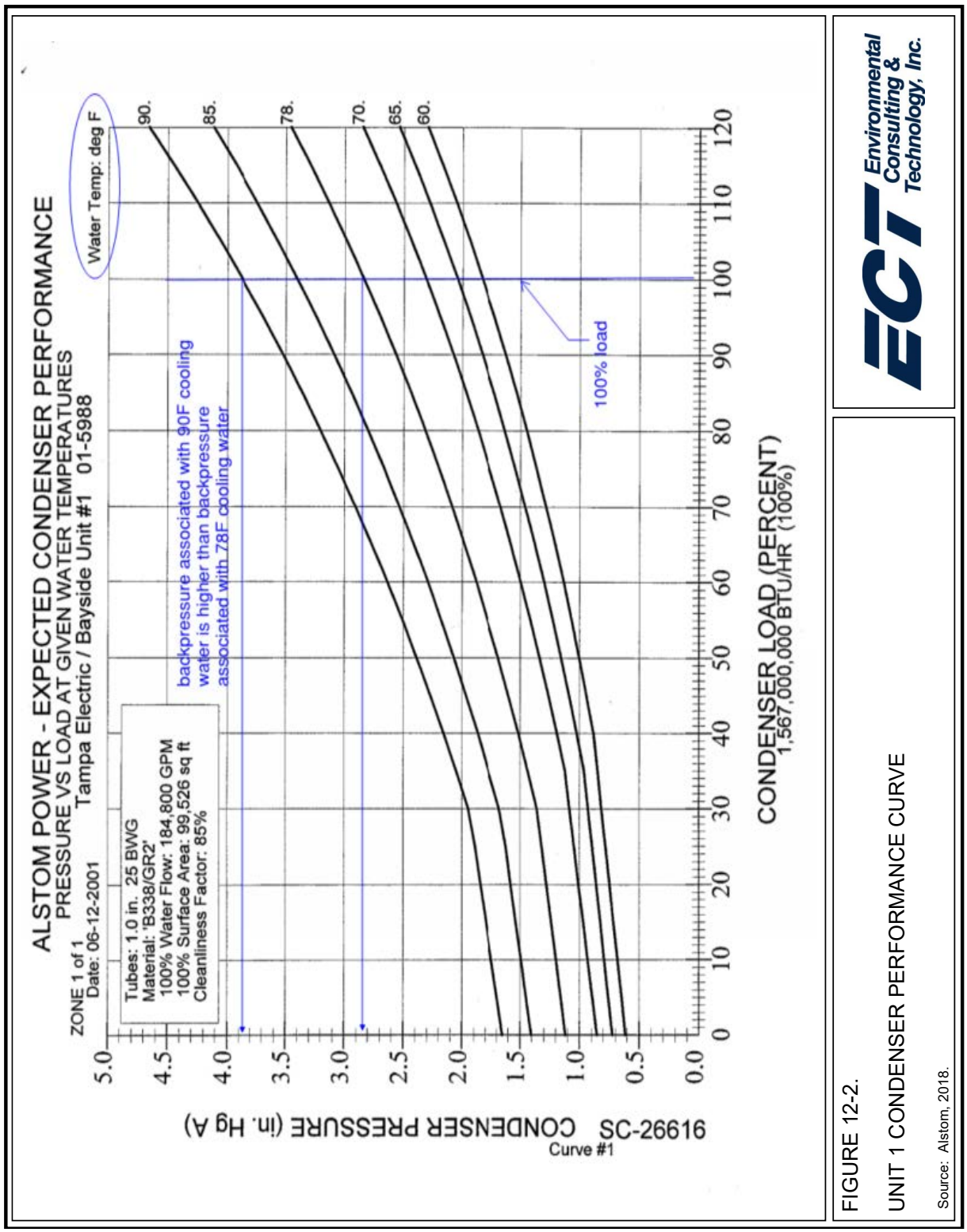


FIGURE 12-2.

UNIT 1 CONDENSER PERFORMANCE CURVE

Source: Alstom, 2018.

The existing cooling system has two circulating water pumps per unit. These pumps will remain in place and will continue to route water from the CWIS to the condensers. Existing pumps provide sufficient head to move water through the current condensing units and through the discharge network, but each generating unit would require additional motive force to route cooling water through the closed-cycle system. The retrofitted system would therefore require additional booster pumps to route water to the cooling towers and makeup water pumps to replenish water lost to the recirculating system due to evaporation, drift, and blowdown. The evaluation assumes that dilution water pumps would be used to meet State of Florida chloride discharge requirements (discussed in the 40 CFR 122.21(r)(10) report).

Large pumps such as circulating water pumps can move large quantities of water, but they cannot develop significant dynamic head. Therefore, it is assumed that four booster pumps, each rated at 46,200 gpm, and another four booster pumps, each rated at 63,000 gpm would route hot water up to the Unit 1 and 2 cooling tower wet decks. Cooling tower booster pump energy consumption was estimated based on conveying water from near the discharge flume to the wet well via a concrete channel and then pumping water from the wet well to the cooling tower deck using pipes[2] – four 4-ft diameter pipes for Unit 1 and four 5-ft diameter pipes for Unit 2. The estimated losses and total dynamic head for the booster pumps are summarized in Table 12-1. Detailed calculations are provided in Appendix 12-A.

Table 12–1. Total Dynamic Head Required of Booster Pumps

	Unit 1	Units 2
Friction head loss (ft)	5.2	4.1
Total minor head loss (ft)	6.4	4.8
Static head for MDCT (ft)	41.0	41.0
Contingency (20%) (ft)	10.5	10.0
Total dynamic head required (ft)	63.1	60.0

Source: HDR, 2017.

[2] Hazen-Williams roughness coefficient of 100.

Similarly, the dynamic head required by the makeup water pump was estimated at 16 ft for Unit 1 and 15 ft for Unit 2; the dilution water pumps would require approximately 21 ft of dynamic head. See Appendix 12-A.

Estimated pump ratings, assuming 85 percent efficient pumps and 90 percent efficient motors are listed in Table 12-2.

Table 12–2. Estimated Pump Ratings

Pump Description	Unit 1 Pump Ratings (hp)	Unit 2 Pump Ratings (hp)
Booster pumps	982	1,312
Makeup water pumps	58	74
Dilution water pumps	119	161

Source: HDR, 2017.

The energy consumption of each cooling tower fan is 250 hp (SPX, 2017), or 4.5 MW for the station, based on the 24 fans associated with all the cooling tower cells. Approximately 1.9 MW is estimated for Unit 1 fans and 2.6 MW for Unit 2 fans.

The total load for operating fans, booster pumps and makeup water pumps is estimated to be approximately 11.6 MW. See Appendix 12-B for detailed calculations. The total energy consumption if the fans, booster pumps, makeup water pumps and dilution water pumps were to operate continuously, would be approximately 101,825 MWhr/year. If Bayside's past utilization rate continues to be representative of future utilization rate (50 percent for Unit 1 and 53 percent for Unit 2) then the total annual energy consumption is estimated to be approximately 52,460 MWhr/year.

The DOE (2002) reported estimates of the energy penalty for a range of condenser temperature rises (ΔTs) and cooling water temperatures when the system water converted from once-through to closed-cycle. Using a ΔT of 17°F, the modeled backpressure energy penalty reduces the plant efficiency by 1 percent on average annually, and by approximately 2.8 percent during maximum wet bulb conditions. The gross energy production of Units 1 and 2 steam turbines are 236 MW

and 308 MW, respectively; therefore, the estimated backpressure energy penalties are 2.3 MW and 2.9 MW as presented in Appendix 12-B.

The hypothetical cooling towers are designed for the 1 percent exceedance of the wet bulb temperature,[3] which means that the cooling towers could be compromised, on average, for 88 hours per year if summer wet bulb temperatures exceed the design wet bulb temperature.[4] Depending on unit load and turbine characteristics, unit performance could be compromised due to the higher cooling water temperature and condenser backpressures. This evaluation assumes that during these highest ambient temperature and humidity conditions, each unit would need to be derated by 20 percent on average. Annual energy loss due to derates is estimated to be 4,135 MWhr/year for Unit 1 and 5,396 MWhr/year for Unit 2. The summary of additional energy consumption and energy losses due to a MDCT retrofit of Units 1 and 2 are provided in Table 12-3 and calculations in Appendix 12-B.

The cumulative annual energy consumption/losses from the addition of MDCTs would therefore be approximately 157 gigawatt-hours (GWhr), if each unit were to operate continuously. Considering the historic capacity utilization of the two units, the total consumption/loss estimated to be approximately 81 GWhr for the station. This is approximately 3.3 percent of the generating capacity of the steam turbines. Because the existing circulating water system would remain in place even after a hypothetical cooling tower retrofit, the energy consumption/losses discussed above represent the increase in energy consumption due to a MDCT retrofit.

As an approximate benchmark, an American household consumes approximately 10.8 MWhr/year of electricity on average (EIA, 2016). The cooling tower retrofit at Bayside would consume the equivalent amount of electricity that could be used to supply approximately 7,027 homes.

[3] Meaning that during a typical year, the wet bulb temperature would be at or lower than the design wet bulb temperature selected.
[4] Ambient data from 2015 were examined to select the warmest 88 hours in the year. The cost of electricity depends on the time of day. Understanding the specific times when the cooling tower would not be fully available is therefore important for assessing costs and benefits.

Table 12–3. Summary of Energy Consumption and Energy Losses Due to Hypothetical MDCT Retrofit

Parameter	Unit 1	Unit 2	Total
Pumps (MW)	3.1	4.1	7.1
Fans (MW)	1.9	2.6	4.5
Total parasitic load	4.9	6.7	11.6
total parasitic load assuming 100 percent operations (MWhr/year)	43,143	58,681	101,825
Total parasitic load assuming historic operations (MWhr/year)	21,593	30,866	52,460
Backpressure energy penalty (MW)	2.3	2.9	5.2
Backpressure energy penalty assuming 100 percent operations (MWhr/year)	19,744	25,767	45,510
Reduction in generation when design wet bulb temperature is exceeded (MWhr/year)	4,135	5,396	9,531
Backpressure energy penalty and derate effects assuming 100 percent operations (MWhr/year)	23,878	31,163	55,041
Backpressure energy penalty and derate effects assuming historic operations (MWhr/year)	11,951	16,392	28,343
Annual maximum parasitic, backpressure energy penalty and derate effects assuming 100 percent operations (MWhr/year)	67,022	89,845	156,866
Annual maximum parasitic, backpressure energy penalty and derate effects assuming historic operations (MWhr/year)	33,544	47,258	80,803

Source: HDR, 2017.

Each unit is assumed to need approximately 4 weeks for the cooling tower tie-in. This evaluation assumes that the hypothetical tie-ins would not happen at the same time. To the extent practicable, the unit that remains online would try to meet the demand placed on Bayside. It is possible that a different power plant may need to provide some of the replacement energy, and such a plant would likely be less efficient than Bayside. This would lead to a slight net increase in emissions during the tie-in period, but that increase would likely be small therefore the tie-in related increases in emissions are not quantified in Section 12.3.2.2.

12.3.2.3 Impact Mitigation Methods—40 CFR 122.21(r)(12)(vii)

Energy consumed by the MDCTs and/or energy not produced by the steam turbines because of the MDCT retrofit, could be replaced by generation available in the larger electricity generation and distribution system. Under this scenario, sources of electricity that would not otherwise be dispatched due to higher price would be activated. Such a strategy would increase the price of power to the consumer and may result in increased air emissions. Alternatively, energy consumed by the MDCTs could be replaced by a variety of potential new generating facilities and may include:

- Constructing a new combined-cycle unit to be operated as needed, and especially during summer months when the combination of higher condenser backpressure energy penalty and derate would reduce the station's output. This option would trigger a series of permitting efforts. This option is not a practical mitigation measure at this time.
- Constructing a solar energy farm. The advantage of this option is that once constructed, it would harness renewable energy. The disadvantage of this option is that its energy production is dependent on the time of day and weather conditions rather than the demand for electricity. This option is not a practical mitigation measure at this time.
- Install several wind turbines. The advantage of this option too is that once constructed, it would harness renewable energy. The disadvantage of this option is that its energy production is dependent on wind condition rather than the demand for electricity. Whether the Tampa area is appropriate for wind turbines is not evaluated here. This option is not a practical mitigation measure at this time.
- Constructing a larger cooling tower. An approach temperature of 5°F is the theoretical minimum that a MDCT can be designed for; 10°F is the practical minimum. The hypothetical Bayside cooling tower has been designed for an approach temperature of

10°F and 99th percentile wet bulb temperature, yet its backpressure energy penalty is high as discussed in Section 12.3.2.2. Making the cooling tower larger still would reduce backpressure energy penalty but would increase the parasitic load as well as the capital costs. Therefore, this is not a practical or sustainable solution.

- Managing the demand for electricity. This would be a long-term effort where consumers are educated to reduce their energy consumption.

While several different methods could potentially be employed to increase electricity production or decrease electricity use to compensate for the increased energy consumption caused by cooling tower operation, none of the above methods appear to be practical due to the lag time and the scale of the new projects. Therefore, this hypothetical design therefore does not propose to incorporate any of these mitigation measures. The price of electricity would likely increase corresponding to the higher demand posed by the operation of cooling towers.

12.3.2.4 Uncertainty

The uncertainties associated with the energy consumption estimate include:

- The lengths of pipes and channels for hot water, makeup water and dilution water were measured on an aerial image with an allowance for potential interferences. Given the age of the station, there would likely be additional buried infrastructure to maneuver when routing pipes and channels that are not accounted for here. If unidentified obstructions cause the pipe lengths to be longer, increased head losses would occur and the energy consumption would be greater. Capital costs would also be greater.
- The backpressure energy penalty was estimated using DOE (2002) modeling of a surrogate site with a similar temperature differential as Bayside, the actual penalty would depend on the current condenser performance and may deviate from this estimate. Several additional feasibility and detailed evaluations would be needed if this station were required to be converted to closed-cycle.
- Parasitic losses assume approximate pipe and pump sizes (that are representative of the Bayside system); the actual in-pipe water velocities may be different and may result in higher or lower parasitic losses.

12.3.3 Air Pollutant Emissions, Environmental Impacts and Human Health—40 CFR 122.21(r)(12)(ii)

12.3.3.1 Description

Air Pollutant Emissions

Implementation of cooling towers at a power plant can increase air emissions in three ways:

- Cooling tower emissions. These are emissions caused by the operation of cooling towers and consist primarily of PM derived from the cooling water;
- Off-site stack emissions during tie-ins-related unit downtime; and
- Off-site and or on-site stack emissions during the operations period to replace the energy lost due to backpressure energy penalty and parasitic uses.

This evaluation assumes that additional or replacement power to compensate for additional energy use or energy loss would be provided from within the TECO fleet. Therefore, TECO emissions factors are used to estimate the hypothetical increase in emissions.

PM Emissions

Operation of cooling towers results in the emission of several trace elements, but the levels of emissions are highly variable depending upon the nature of the source water. PM, driven by the concentration of TDS[5] in the source water body and the cooling tower operating regime, would be an additional source of air emissions from Bayside after the installation of cooling towers. Water chemistry would also impact the quality of cooling tower drift, and thereby PM emissions, but that is assumed to be a lesser issue compared to salts in the Bay water.

Drift droplets resulting from evaporative cooling tower operation contain solids in the form of minerals and organic matter entrained in the cooling water. The water portion of drift droplets exiting the cooling towers evaporate, leaving the remaining solid matter in the air column. These solids range in size based on the cooling water TDS and drift droplet size and they are generically designated as PM. Smaller PM can have a greater impact on human health. PM_{10} refers to PM that is 10 microns[6] or smaller, and $PM_{2.5}$ refers to PM that is 2.5 microns or smaller.

[5] Where TDS concentrations are low, TSS concentration can also impact PM emissions. At Bayside, where water from the Hillsborough Bay would be used for makeup, the concentration of TSS would be one or two orders of magnitude smaller than TDS. Therefore, TSS is not included here.
[6] A micron is a common reference for a micrometer, which is equal to one-millionth (10-6) of a meter.

PM_{10} particles have a larger diameter and are heavier than $PM_{2.5}$ particles. Therefore, compared to $PM_{2.5}$, PM_{10} particle deposition velocity is faster and the deposition distance is shorter.

PM_{10} and $PM_{2.5}$ emissions are regulated. The amount of PM_{10} and $PM_{2.5}$ allowed to be emitted by a facility's air permit is therefore expected to be protective of surrounding communities.

Based on the size and weight of PM, the highest rate of mineral deposition can occur up to approximately 2,500 ft away from a MDCT for freshwater facilities, and up to approximately 3,600 ft away for saline or brackish water facilities (EPRI, 2011). Because saline and brackish waters have a higher TDS, there are more particles being entrained in the exhaust airstream; therefore, PM deposition occurs in a larger area with saline or brackish water (such as from the Hillsborough Bay) compared to freshwater. PM would be carried longer distances during periods of strong winds.

The TDS concentration in the source water body is directly proportional to the TDS concentration in the drift particles: the TDS concentration in drift particles is equal to the TDS concentration in the circulating water system and is estimated as the source water TDS times the COC.

As discussed in the 40 CFR 122.21(r)(10) report, the State of Florida requires that the discharge concentration of chlorides not exceed the receiving water body concentration by more than 10 percent (FAC, 2015). The quality of the blowdown stream depends on the quality of water in the circulating water system and any treatment to remove parameters prior to blowdown. Removing dissolved solids (such as chloride) requires reverse osmosis/thermal/crystallizing-type treatment methods which are rarely employed for blowdown treatment; hence it is reasonable to assume that the chloride or TDS concentration in the blowdown is the same as those parameter concentrations in the circulating water system. As the source water chloride/TDS concentrations increase, the cooling tower would need to be operated at lower COC to modulate the discharge concentrations. The hypothetical MDCT at Bayside are assumed to be operated at 1.3 COC, and the discharge then diluted to achieve 110 percent of Hillsborough Bay chloride concentration.

Stack Emissions

Combustion of fossil fuel produces a range of air pollutants of concern and includes PM, nitrogen oxides (NO_x), sulfur dioxide (SO_2), and carbon dioxide (CO_2). While stack emissions are real, there is significant uncertainty in the emissions rates because the specific composition of each fuel (i.e., the relative abundance of impurities in the fuel) that would be used to generate additional power in the future are unknown. Additionally, many of these pollutants are captured by the various emissions control technologies installed at a fossil-fuel station (Dixon *et al*., 2003). To account for these site-specific factors, the emissions factors used for this evaluation are from the TECO fleet. Modernization of the stations and addition of new generating facilities may cause these emissions to change in the future.

PM is emitted at approximately 50-ft elevation from MDCTs. Because of their emission height and particle weight, dispersion and deposition of PM from MDCTs are relatively local. Combustion units emit PM, NO_x, SO_2, and CO_2 from a height of approximately 300 ft and most emitted particles are positively or neutrally buoyant, and are therefore, carried longer distances than PM emitted from MDCTs. The following sections quantify the potential increases in stack emissions resulting from producing replacement electricity to compensate for generation inefficiencies at Bayside (owing to parasitic load and backpressure energy penalty).

Human Health

Health-related impacts are a function of the change in emissions, dispersion, deposition, human population density relative to the emissions, and the sensitivity of those populations. While increased emissions may have environmental and human health impacts, emissions are regulated by each power plant's emissions permit (Clean Air Act Title V). Emissions standards and allowances are based on the cumulative impacts caused by most emissions sources; therefore, whatever emissions that would be allowed by the station's air permit are expected to be generally protective of surrounding populations.

Environmental Impacts

The corrosive nature of common PM components such as salt and mineral compounds leads to degradation of terrestrial vegetation and man-made objects. Deposition of chloride (Walton *et al.,* 1982) causes damage to automobiles and various metal surfaces, shorting of electrical

equipment, and window marking. These effects typically occur within the facility property (EPRI, 2011). This evaluation therefore located the hypothetical cooling towers sufficient distances away from key station infrastructure (such as substations and switchyards) to mitigate against this impact.

PM emissions on terrestrial vegetation can potentially cause negative impacts both physically and chemically, such as impact leaf growth, impede the plants' ability to intake air, dry out vegetation, and stunt growth (Prajapati, 2012). Much of the potential PM deposition is expected to occur within the station boundary or in the Hillsborough Bay, therefore adverse impacts due to increase PM deposition is low.

12.3.3.2 Quantification

Particulate Matter Emissions from Cooling Towers

Droplets of water that become entrained in the air traveling through the cooling tower are called drift. Drift droplets contain the same types and concentrations of dissolved solids (i.e., sodium, calcium, chlorides, and sulfates) as contained in the water flowing through the cooling tower that can be converted to airborne emissions. Drift droplets also contain organic matter (bacteria, spores, animals [insects], and vegetation) entrained into the towers by the fans (EPRI, 2011). Unless the circulating water is treated (which is very rare), the concentration of solids entrained in cooling tower drift is proportional to the concentration of solids in the circulating water, which, by definition, is the product of the COC of the cooling tower and source water solids concentration.

To reduce drift from cooling towers, drift eliminators are usually incorporated into the tower design to remove water droplets from the exiting air stream. The drift eliminators used in cooling towers rely on inertial separation caused by directional changes while passing through the eliminators. The most efficient drift eliminator currently available can limit the drift rate to 0.0005 percent of the circulating water flow rate.

PM within drift droplets is directly related to the total solids (TS) in the cooling water. The TS is equal to the TSS plus the TDS of the water. The total solids composition of circulating water is the product of the TS concentration in the supplied intake water and the number of times

circulating water is recycled through the system before discharging (i.e., COC).[7] High levels of TS within the cooling water must be controlled to avoid scaling and chemical build up (EPA, 2012). Hillsborough Bay water is assumed to be used for cooling tower makeup; the TDS concentration in the bay range from 8,741 to 28,656 parts per million (ppm) (USGS, 2017), and TSS concentration of approximately 12 ppm (Hillsborough County, 2014). Therefore, the total solids concentration would range between approximately 8,753 to 28,668 ppm. The FAC (2015) constrains the COC; the evaluation assumes 1.3 COC as discussed above. The amount of TS in the circulating water (TSCT) is the product of TS intake concentration and the COC, resulting in a range from 11,379 to 37,268 ppm. See Appendix 12-C for detailed calculations.

The total PM lost is calculated as the product of the cooling water circulation rate per unit (QCT), the drift eliminator efficiency, and TSCT. Drift eliminators act to reduce the amount of drift lost from a cooling tower system by providing multiple airflow direction changes to enhance capture of larger water droplets. At Bayside, QCT is 184,800 gpm and 252,000 gpm for Units 1 and 2 respectively. Total PM emissions rates, assuming a drift rate of 0.0005 percent of the QCT are summarized in Table 12-4.

The magnitude of a specific PM size (PM_{10} and $PM_{2.5}$) lost as drift is influenced by the number and size of drift water droplets produced within the cooling tower. The relative magnitudes of PM_{10} and $PM_{2.5}$ emissions were estimated by incorporating a drift droplet size distribution per SPX (2017). Since drift contains the same TS concentration as the circulating water, the amount of PM per water droplet is directly dependent upon the size, and thus volume of each drift droplet. Following SPX (2017) analysis and the droplet size distribution, PM_{10} represents between 42.6 and 55.2 percent of total PM, and $PM_{2.5}$ represents between 11.7 and 19.1 percent for the range of solids in the circulating water system. The summary of PM_{10} and $PM_{2.5}$ emissions, incorporating Units 1 and 2 capacity factors, are also provided in Table 12-4.

[7] This simplified discussion ignores chemical additional and potential solids settling. It is assumed that added water treatment chemicals will not appreciably increase the overall solids, and that dissolved solids concentration will remain unaffected by physical or chemical treatment that the circulating water would receive.

Table 12–4. Estimated PM Emissions Due to a Cooling Tower Retrofit

PM Emissions	Unit 1	Unit 2	Total
PM (lb/hr)	5.3 to 17.2	7.2 to 23.5	12.4 to 40.8
PM (tpy)	11.5 to 37.8	16.5 to 54.2	28.1 to 92.0
PM_{10} (lb/hr)	2.2 to 9.5	3.06 to 13.0	5.3 to 22.5
PM_{10} (tpy)	4.9 to 20.9	7.0 to 29.9	12.0 to 50.8
$PM_{2.5}$ (lb/hr)	0.61 to 3.30	0.84 to 4.50	1.45 to 7.80
$PM_{2.5}$ (tpy)	1.35 to 7.23	1.93 to 10.4	3.3 to 17.6

Source: HDR, 2017.

PM calculations are provided as Appendix 12-C.

Figure 12-3 shows population densities at various distances from Bayside. The embedded summer wind rose indicates that the predominant wind is from the west and from the east. Progress Village is the nearest population center directly downwind of the station and that is approximately 2 miles to the east of the station. There are several densely populated neighborhoods across the Hillsborough Bay in Tampa approximately 4 miles west of the station. Wind roses for the remainder of the year are shown as Figure 10-11 in the 40 CFR 122.21(r)(10) report. Springtime wind patterns are somewhat similar to summertime wind patterns. The predominant wind direction during the September, October and November months is from the east and northeast. Southern Tampa is the nearest population center, also approximately 4 miles southwest of the station. The predominant wind direction during the December, January and February months is from the east, northeast and north. The nearest downwind populations are approximately 4 miles from the station.

As discussed in Section 12.3.3.1, peak deposition is expected to occur within approximately 3,600 ft from the cooling tower. Major population centers are further away than the anticipated deposition area. While PM emissions would increase due to the operation of cooling towers, impacts on major population centers are expected to be low to none.

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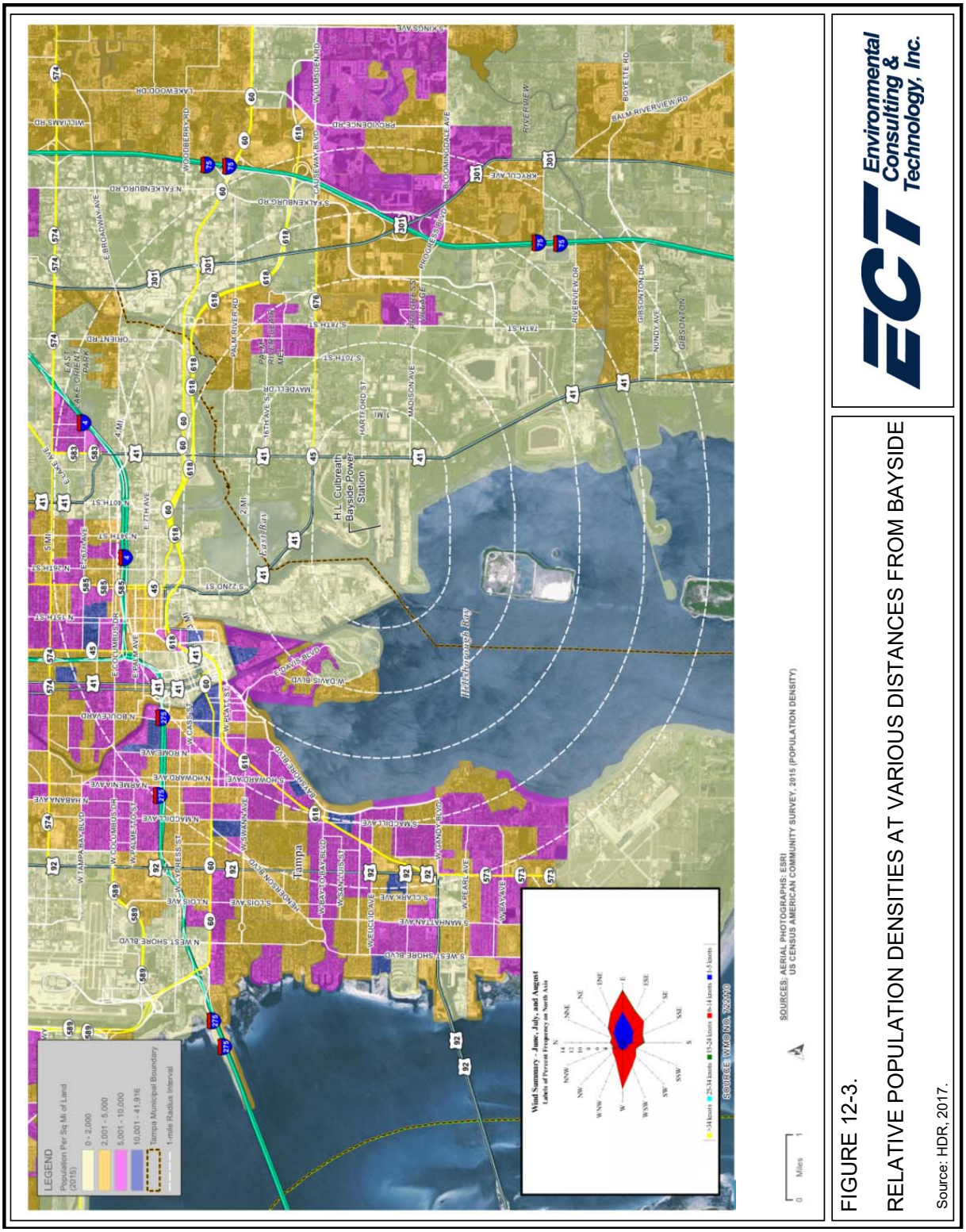


FIGURE 12-3.

RELATIVE POPULATION DENSITIES AT VARIOUS DISTANCES FROM BAYSIDE

Source: HDR, 2017.

CO_2 Emissions

CO_2 production is directly related to energy production at most fossil fuel plants. The recurring energy requirement due to a cooling tower retrofit was estimated in Section 12.3.2.2. The estimated CO_2 increases due to the additional energy consumption and energy losses are summarized in Table 12-5. These estimates show estimated increases for the years 2024 through 2044 from the TECO's Planning & Risk (PaR) production cost model assuming a projected emission rate between 2017 and 2021 of 117 pounds per million British thermal units (lb/MMBtu) (TECO, 2017c).

Table 12–5. Estimated CO_2 Emissions Increases Due to Hypothetical Bayside Cooling Tower

	Average (lb/MMBtu)	Range (lb/MMBtu)
Estimated increases of CO_2 (1,000's pounds/year)	88,205	0 to 118,113

Source: TECO, 2017b.

SO_2 Emissions

The SO_2 estimation method is similar to the CO_2 estimation method, except that it assumes SO_2 (instead of CO_2).

Table 12-6 presents the estimated SO_2 emission increases that would be emitted by the Tampa Electric fleet if a hypothetical cooling tower were required. These estimates show estimated increases for the years 2024 through 2044 from the PaR model assuming a projected emission rate between 2017 and 2021 of 0.0006 lb/MMBtu for Bayside 1 and 2 (steam turbines) and 0.0018 lb/MMBtu for the combustion turbines.

Table 12–6. Estimated SO_2 Emissions Increases Due to Hypothetical Bayside Cooling Tower

	Average (lb/MMBtu)	Range (lb/MMBtu)
Estimated increases of SO_2 (1,000's pounds/year)	0.6	0 to 0.7

Source: TECO, 2017b.

NO_x Emissions

The NO_x estimation method is similar to the CO_2 estimation method, except that it assumes NO_x (instead of CO_2).

Table 12-7 presents the estimated NO_x emission increases that would be emitted due to additional energy generated to compensate for energy consumed or energy lost to the system from operating MDCTs. These estimates show estimated increases for the years 2024 through 2044 from the PaR model assuming a projected emission rate between 2017 and 2021 of 0.013 lb/MMBtu for Bayside 1 and 2 and 0.088 lb/MMBtu for the combustion turbines.

Table 12–7. Estimated NO_x Emissions Increases Due to Hypothetical Bayside Cooling Tower

	Average (lb/MMBtu)	Range (lb/MMBtu)
Estimated increases of NO_x (1,000's lb/yr)	17	0 to 22

Source: TECO, 2017b.

Combustion-related Particulate Matter Emissions

The combustion-related PM estimation method is similar to the CO_2 estimation method, except that it assumes PM (instead of CO_2).

The estimated CO_2 increases due to the additional energy consumption and energy losses are summarized in Table 12-8. These estimates show estimated increases for the years 2024 through 2044 from the PaR model assuming a projected emission rate between 2017 and 2021 of 0.007451 lb/MMBtu, 0.005588 lb/MMBtu, and 0.001863 lb/MMBtu for PM (total), PM (condensable),[8] and PM (filterable),[9] respectively.

[8] Condensable PM is defined as material that is vapor phase at stack conditions, but which condenses and/or reacts upon cooling and dilution in the ambient air to form solid or liquid PM immediately after discharge from the stack.
[9] Filterable PM is defined as particles that are directly emitted by a source as a solid or liquid at stack or release conditions and captured on the filter of a stack test train.

Table 12–8. Estimated Combustion-related PM Emissions Increases Due to Hypothetical Bayside Cooling Tower

	Average (lb/MMBtu)	Range (lb/MMBtu)
Estimated increases of combustion-related PM (1,000's lb/yr)	6	0 to 7.5

Source: TECO, 2017b.

CO_2, SO_2, NO_x, and PM are emitted from the stack about 300 ft above ground level and get carried greater distances than the cooling tower drift. The operation of cooling towers will increase emissions from power plants that generate additional electricity to compensate for parasitic losses, backpressure energy penalty, and derate-related losses. But that increase would be marginal compared to existing emissions by the TECO fleet; all of which are and would be regulated by each station's Clear Air Act Title V permit. Furthermore, the additional emissions would be dispersed widely. Therefore, the potential impacts specifically due to the additional emissions would also be small to none.

12.3.3.3 Impact Mitigation Methods—40 CFR 122.21(r)(12)(vii)

Potential ways to reduce emissions due to a closed-cycle cooling tower may include:

- Implementing the retrofit during periods of low electricity demand. During periods of low electricity demand, there is greater probability that power plants with emissions control technologies would be utilized (during periods of high demand, less efficient power plants are put into service to meet demand). This evaluation assumes that the tie-in outage would be performed outside of the peak demand periods.
- Plan construction and startup such that the outage period is minimized. This evaluation has already minimized the hypothetical outage; therefore, no additional impact mitigation costs are included in this evaluation. This evaluation assumes an aggressive schedule for the cooling tower tie-in to minimize the outage.
- To the extent possible, use electricity from stations that have implemented emissions control technologies. This evaluation assumes that to the extent practicable, replacement/additional energy needed by the hypothetical cooling tower would be

provided by Bayside itself, which has a higher efficiency and lower emissions rates than the average power plant. As such, this aspect is also incorporated into this evaluation.

All the above mitigation measures have already been incorporated into this evaluation.

12.3.3.4 Uncertainty

Potential sources of uncertainty associated with the emissions estimates and costs, including the following:

- These stack emissions estimates assume lost generation would also be made up by Bayside. When one unit is taken offline, the remaining unit may not be able to provide all the replacement energy, and other generating stations may need to provide replacement power. As much as Bayside's future emissions rates are not known, the future emissions rates of stations that might possibly provide replacement power is unknown.
- Additionally, every fleet and regional transmission organization has a particular dispatch order, and that order can change annually, or seasonally in some cases. The dispatch order can also impact the extent of emissions.
- PM and drift are driven by water quality and there is uncertainty in TDS concentrations; the high and low estimates demonstrate this variability. Total solids data was measured seasonally for a two-year period; increasing the duration and frequency of measurements could offer a more detailed estimate of TS dynamics.
- Actual cooling tower tie-ins related downtime at Bayside may be different than the 4 weeks assumed here.
- Changes in regulations that may impact emissions and or costs of trade.
- Actual emissions related impacts depend on locations and sensitivity of receptors (primarily humans in this evaluations). This evaluation looked at current population distributions without regard for their sensitivity. If there is a higher concentration of asthma patients or senior citizens downwind of the fossil plants that produce replacement energy, then the potential health impacts may be greater than discussed here. If the downwind population is healthy then the impacts may be less severe than discussed here.

12.3.4 Noise—40 CFR 122.21(r)(12)(iii)

12.3.4.1 Description

MDCT would add to the noise generated at Bayside. Once hypothetical cooling towers are implemented, falling water and operation of pumps, fans, and other appurtenances will create additional noise that is not currently generated at the station. Pile driving, vehicular traffic, and other construction activity will add to the noise during the construction period. The actual noise level due to a hypothetical retrofit depends on the combination (superimposition) of existing noise level and the noise level due to the hypothetical noise source.

Depending on the sound level of the noise source, noise can be considered an annoyance to those nearby. For the purposes of this report, a noise source is assumed to be any equipment (e.g., falling water, fans, pumps, and related appurtenances) that generates noise at the station; a noise receptor is assumed to be any point of reception (e.g., residential dwellings or business) where extraneous noise and/or vibration are perceived.

Because there are no federal regulations limiting environmental noise levels,[10] the EPA released a document that provided a basis for state and local governments' judgment in setting standards for noise levels (EPA, 1974; EPA, 2014). Noise exposure goals for various locations depend on the noise sensitivities of its surroundings, and areas zoned for residential use usually have more stringent noise exposure limits than industrial or agricultural areas. Similarly, specific institutions, such as places of worship, schools, hotels, hospitals, and libraries, may also have more stringent noise sensitivities and limits.

Noise pollution can generally fall into two groups: acute sound levels that can lead to hearing impairment, and nuisance sounds that impact the wellbeing of surrounding communities. Acute sounds (such as from construction work) are often controlled but nuisance noise may not be.

[10] "Under the Clean Air Act, the EPA administrator established the Office of Noise Abatement and Control (ONAC) to carry out investigations and studies on noise and its effect on the public health and welfare. Through ONAC, the EPA coordinated all Federal noise control activities, but in 1981 the Administration concluded that noise issues were best handled at the State and local level. As a result, ONAC was closed and primary responsibility of addressing noise issues was transferred to State and local governments. However, EPA retains authority to investigate and study noise and its effect, disseminate information to the public regarding noise pollution and its adverse health effects, respond to inquiries on matters related to noise, and evaluate the effectiveness of existing regulations for protecting the public health and welfare, pursuant to the Noise Control Act of 1972 and the Quiet Communities Act of 1978." (EPA, 2017e).

EPA states that a noise level of 55 decibels (dB) is satisfactory in protecting the public health and welfare and does not create an annoyance in most cases[11] (EPA, 2014). The EPC of Hillsborough County regulates noise from industrial and commercial sources in the county through the EPC Ch. 1-10 Noise Pollution Rule. Industrial area sources are limited to 70 dB at all times (Hillsborough County Environmental Protection Commission, 2017).

Should a retrofit project be implemented, it must meet local zoning requirements, which includes the control of noise. Therefore, this evaluation assumes that noise would be mitigated if the project were implemented.

12.3.4.2 Quantification

The quantification of noise levels within and outside the station property would require noise propagation modeling, noise level of each point source, barriers (such as buildings), and atmospheric conditions. These data are not available; therefore, noise propagation modeling will not be performed as a part of this effort but would need to be performed prior to implementing a project.

While noise propagation modeling was not completed, the EPA (2014) states that power plants usually do not result in off-site levels of noise more than 10 A-weighted decibels [dB(A)][12] above background. Table 12-9 lists noise level from common noise sources.

The EPA further states (as cited in SPX, 2009) that stations might expect cooling towers to have a typical noise level of approximately 70 dB approximately 50 ft from the tower (2014). Per the EPC of Hillsborough County, the noise limit is also 70 dB. The 50-ft buffer around each cooling tower would be contained within the site, therefore no additional mitigation measures are needed.

[11] A decibel is a logarithmic unit of base 10 expressing the ratio of two physical quantity values, such as noise.
[12] A dB(A) is a sound level measured with an instrument to account for the relative loudness to a human ear.

Table 12–9. Common Noise Levels

Sound Source	dBA
Military jet, air raid siren	130
Amplified rock music	110
Jet takeoff at 500 meters	100
Freight train at 30 meters	
Train horn at 30 meters	90
Heavy truck at 15 meters	
Busy city street, loud shout	80
Busy traffic intersection	
Highway traffic at 15 meters, train	70
Predominantly industrial area	60
Light car traffic at 15 meters, city or commercial areas or residential areas close to industry	
Background noise in an office	50
Suburban areas with medium-density transportation	
Public library	40
Soft whisper	30
Threshold of hearing	0

Source: Cowan, 1994.

12.3.4.3 Impact Mitigation Methods—40 CFR 122.21(r)(12)(vii)

Based on this preliminary evaluation, additional noise due to cooling towers are expected to occur within Bayside or within the Bay, and the additional noise attenuated to less than 70 dB at and beyond the property line. Therefore, no mitigation measures are needed.

12.3.4.4 Uncertainty

Potential sources of uncertainty associated with the noise evaluation presented above and include the following:

- Many factors can influence the sound perceived by noise receptors. These include topography, line-of-sight, equipment location, and equipment proposed to be installed. Existing noise sources and their specific locations, and the actual sound levels generated through the use of cooling towers and received at off-site receptors are not known at this time. Superimposing cooling tower-related noise over existing noise would increase overall noise level, and potentially increase mitigation costs.

- Noise regulations or guidance, when they exist, limit acute noise. Nuisance noises are more challenging to enforce, and receptors perceive them differently. Long-term exposure to a low-level sound may be perceived as a greater impact than short-term exposure to that same sound level. This impact is real, but difficult to quantify. These nuances were not incorporated into the above evaluation.

12.3.5 Safety—40 CFR 122.21(r)(12)(iv)

12.3.5.1 Description

Per the 316(b) rule at 40 CFR Part 122.21(r)(12)(iv), this section will provide a discussion of impacts to safety, including documentation of the potential for plumes, icing, and availability of emergency cooling water.

Plumes and Fogging

Through evaporation, cooling towers produce a plume, which is an exhaust airstream that is saturated with water vapor. Depending on the atmospheric conditions (typically when it is cold), the plume can condense and become visible as fog. The plume condenses due to the cooler, ambient air not having as much moisture assimilating capacity (SPX, 2012). The plume is typically more visible in the wintertime (in areas that experience winter), when the difference between the cool, ambient atmosphere and the warm exhaust air is the greatest. Although it is cooler in Tampa during the December, January and February months, incidents of fog are infrequent: over the period 2007 through 2016, the Tampa Airport had experienced a total of 155 incidents of fog (WeatherUnderground, 2017), and these events are typically more prevalent in December, January and February.

While plumes and fogging are difficult to forecast objectively, fog and meteorological events (e.g., rain, snow, and thunderstorms) are recorded with other weather data at Water Bureau Army Navy (WBAN) Station 12842, Tampa, FL (Table 12-10). The installation of cooling towers could potentially increase the duration of fog by a few minutes on these days when weather conditions are conducive for fog-forming (EPRI, 2011). A low level of impact is anticipated given the generally low incident rate for fog in and around Tampa.

Table 12–10. Days with Fog Reported 2007 to 2016 at World Meteorological Organization (WMO) Station 722110

Month	Number of Days in Record with Fog Reported	Typical Number of Days in the Month with Fog
January	29	0.9
February	29	1.0
March	7	0.2
April	6	0.2
May	5	0.2
June	7	0.2
July	13	0.4
August	10	0.3
September	7	0.2
October	4	0.1
November	10	0.3
December	28	0.9
Total*	**155**	**5.1**

*Total number of data points between January 2007 and December 2016 is 14,156.

Sources: WMO, 2017.
WeatherUnderground, 2017.

Icing

Icing occurs in freezing weather when moisture from the plume of a cooling tower causes frost or ice crystals to form on nearby surfaces and/or structures. Icing within the station's property boundaries and on adjacent roads, transmission lines, and switchyard can potentially impact the health and safety of the public, as well as the security of the station. However, freezing conditions are rare in Tampa and near Bayside;[13] therefore, icing impacts are also expected to be negligible.

Figure 12-4 shows state and local roadways, bridges and railroads around Bayside. While there are local roads adjacent to the station, major highways are farther away. Therefore, impacts on major roads are also expected to be negligible. A railroad runs into the peninsula and services the Kinder Morgan facility daily; the impact on its operations would need to be evaluated more closely if closed-cycle cooling towers were found to be BTA at Bayside.

[13] The average low temperature is 51.6°F.

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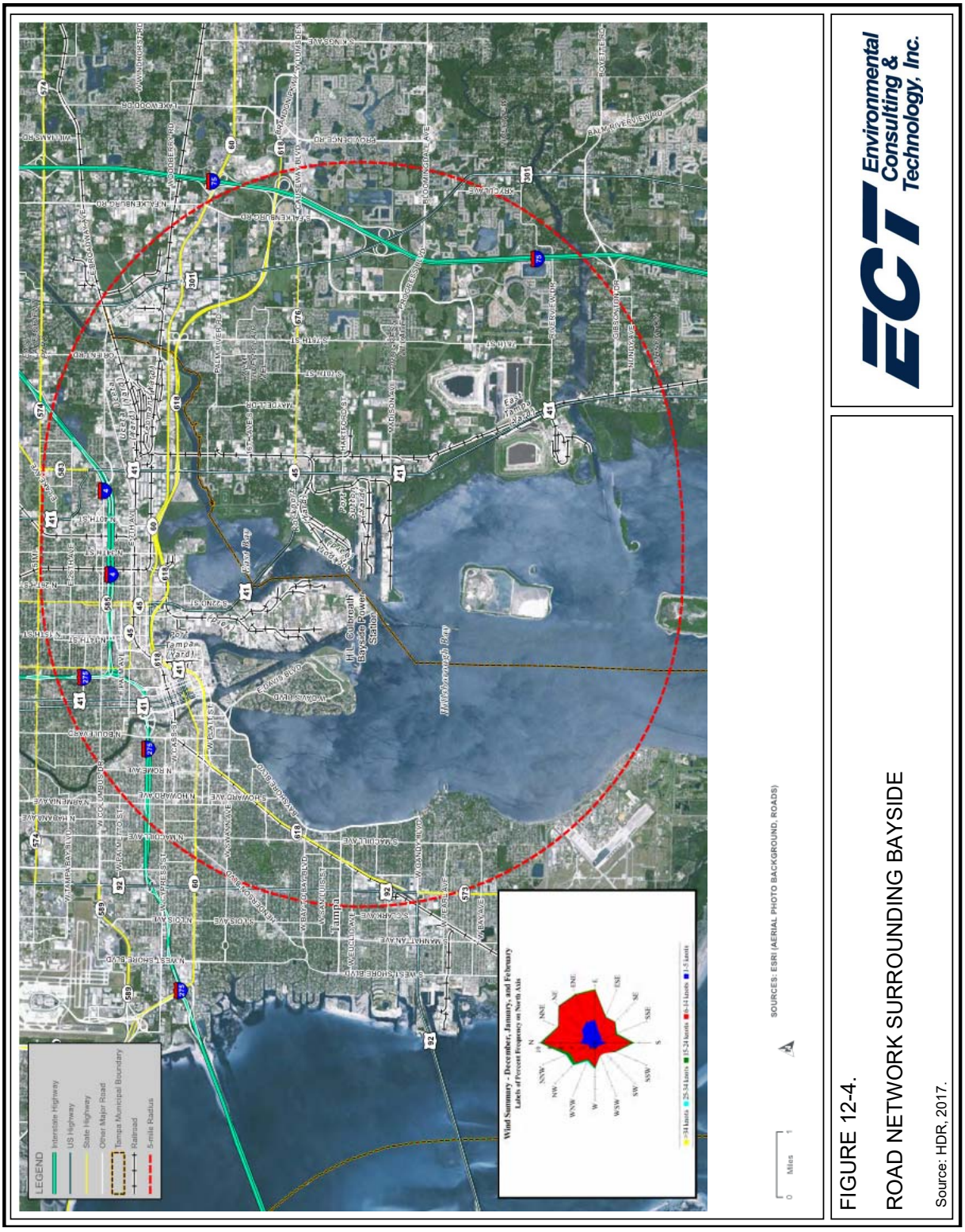


FIGURE 12-4.

ROAD NETWORK SURROUNDING BAYSIDE

Source: HDR, 2017.

Environmental Consulting & Technology, Inc.

While similar to fog in that localized conditions can vary, the possibility for ice can be more easily predicted with forecasted freezing temperatures in the region. Air temperature has been recorded at WBAN Station 12842, Tampa, FL and has been reviewed for days with a recorded minimum temperature of being less than or equal to 32°F (Table 12-11).

The days with freezing temperatures recorded indicate that freezing conditions[14] occurred only in the winter months (January and December).

As with fogging, installation and operation of cooling towers could potentially increase the icing incidents/duration by a few minutes on days when freezing conditions are present (EPRI, 2011) (see Table 12-11).

Table 12–11. Days with a Recorded Freezing Temperature 2007 to 2016 at WBAN Station 12842

Month	Number of Days in Record with a Freezing Temperature	Typical Number of Days in a Year with Freezing
January	7	0.2
February	0	0.0
March	0	0.0
April	0	0.0
May	0	0.0
June	0	0.0
July	0	0.0
August	0	0.0
September	0	0.0
October	0	0.0
November	0	0.0
December	2	0.1
Total*	9	0.3

*Total number of data points between January 2007 and December 2016 is 126,867.

Sources: WMO, 2017.
WeatherUnderground, 2017.

[14] For the purposes of this report, freezing conditions are defined as any period of time when a recorded temperature was at or below the freezing temperature of 32°F.

Emergency Water

The retrofit from a once-through cooled system to a closed-cycle system would not change the station's fire water needs. The forebay may be retrofitted to allow emergency water to flow into the forebay via a bypass gate in case of an emergency and provide sufficient fire water. As such, the cooling tower retrofit would not impact the availability or access to emergency water for Bayside. Therefore, it would not be discussed or evaluated further.

12.3.5.2 Impact Mitigation Methods—40 CFR 122.21(r)(12)(vii)

The likelihood of fog or ice in and around Bayside is low. Therefore, no mitigation measures (e.g., plume abated cooling towers) are anticipated.

12.3.5.3 Uncertainty

The potential sources of uncertainty associated with the safety evaluation presented above include:

- Fog and ice are difficult to predict. Historical data may not necessarily be representative of the future.
- The evaluation was based on large time steps like days and months. But actual unsafe conditions, if they were to occur, can occur within much shorter time spans. If the cooling tower evaluation were progressed further, these safety evaluations would need to be performed at a finer time resolution.

12.3.6 Facility Reliability—40 CFR 122.21(r)(12)(v)

12.3.6.1 Description

Station reliability refers to instances when the station can or cannot produce power when its service areas demands power.

The hypothetical cooling towers used in this evaluation have been designed to the upper 99th percentile wet-bulb temperature obtained from the WMO meteorological data station in Tampa, FL (WMO Station No. 722110), which explicitly means that the cooling tower will not be fully available, on average, for 1 percent of the time. Each year for approximately 88 hours with the highest wet-bulb temperatures the station may need to be derated if the increase in condenser or turbine pressure is significant enough to approach alarm or trip conditions.

Backpressure will vary based on actual wet bulb temperatures. The highest percentile wet bulb temperature occurs during the late afternoons in July and or August. Such conditions typically generate electricity demands that are at their annual peaks. TECO manages its supply to meet anticipated demands, therefore TECO would need to plan for additional generation to compensate for the additional parasitic load and other losses due to the hypothetical cooling towers at Bayside.

12.3.6.2 Quantification

Based on the design parameters, during the average year Bayside would need to derate for approximately 88 hours per year during the warmest and most humid periods. The actual magnitude of the percent reduction in power would depend on actual meteorological conditions including inter-annual variations.

For the purposes of this evaluation, assuming a 20 percent derate for 88 hours per year, amounts to approximately 4.1 GWhr[15] and 5.4 GWhr for Units 1 and 2, respectively, which is approximately 0.2 percent[16] compared to the steam generator capacity. See Appendix 12-B for calculations.

12.3.6.3 Impact Mitigation Methods—40 CFR 122.21(r)(12)(vii)

Designing the cooling tower for the maximum ambient wet bulb temperature (with an allowance for recirculation) would decrease the likelihood of de-rating the station, but such a tower would be significantly costlier to construct and operate and would require a larger footprint. Given that the hypothetical cooling tower assumed for Bayside are MDCTs, the reduction in backpressure energy penalty and derate would be consumed by the additional fans (parasitic losses). Such an assumption has been confirmed by senior Tampa Electric staff who indicated that it is consistent with the company's typical approach to facility design.

[15] Equivalent to the annual power consumption of 385 homes, assuming 10.8 MWhr average consumption reported by EIA (2016). Or 887 homes when both units are considered.
[16] Total derate divided by the station's typical annual production, which incorporates the station's capacity factor. Because the station's capacity factor in summer months is high, it is reasonable to assume Bayside would experience the full impact of the derate.

This evaluation therefore does not assume that the cooling tower would be upsized regarding the criteria presented in 40 CFR 122.21(r)(10).

12.3.6.4 Uncertainty

Uncertainties associated with the reliability evaluation include:

- The conceptual design used the 99th percentile wet bulb temperature which means that the actual wet bulb temperature would exceed the design value approximately 1 percent of the time each year but, in actuality, this is a long-term indicator. There may be some years when the actual wet bulb temperature would not exceed the design value, and other years when it is exceeded far more often. This variability will impact the actual reliability of the station in a given year.
- This evaluation assumes that the demand for electricity would remain approximately the same. If the demand increases or decreases differently from what TECO has planned and forecasted, or if other factors cause several regional power plants to operate differently, the actual impacts could be different than discussed above.

12.3.7 Consumptive Use of Water—40 CFR 122.21(r)(12)(vi)

12.3.7.1 Description

Changes in the consumption of water are primarily attributable to evaporative losses from once-through cooling and closed-cycle recirculating systems.

Evaporation occurs naturally in surface water bodies and is affected by the stored energy in water. Several variables impact surface water evaporation, including incoming solar radiation, ambient water temperatures, and psychrometric[17] and atmospheric conditions at the location. When heated water is discharged to a surface water body, the evaporation rate in the water body is increased because of the added heat (measured in Btu). The increase in evaporation due to the thermal discharge is referred to as forced evaporation and depends directly on the additional heat being routed to the receiving water body. The additional heat added to the water body can be estimated using the temperature differential across the condenser and the condenser water flow rate.

[17] Psychrometrics is the field of study relating to physical and thermodynamic properties of gas-vapor mixtures. Typical psychrometric parameters include dry-bulb, wet-bulb, and dew point temperatures.

Evaporation is also the mechanism utilized by cooling towers to cool water. A small amount of water, compared to a once-through cooling withdrawal, is consumed through evaporation to cool the water circulating through the cooling tower. The flow rate through the cooling tower and the difference in cold and hot water temperatures are the primary functions relating to cooling tower evaporation. Forced evaporation in the water body due to the cooling tower blowdown is small compared to the evaporation from the cooling tower; therefore, it will not be quantified.

12.3.7.2 Quantification

Forced Evaporation

The forced evaporation due to the thermal discharge from once-through facilities has been estimated using the Edinger-Geyer Method.[18] A paper by Edinger and Geyer (1965) presented a consumptive water loss estimation method based on a basic heat budget (Maulbetsch and DiFilippo, 2008; Davis, 1979; EPA, 2008).

In this method, the heat removal rate of circulating water from condensers is a function of the quantity and temperature of the condensed steam and the condenser efficiency (Edinger and Geyer, 1965). The nature of heat removal rate of circulating water allows the quantification of a heat rejection rate.

Heat exchange between a water body and the atmosphere is governed by atmospheric radiation, conduction, convection, and evaporation (Solley *et al.*, 1998). The majority of heat loss from a water body is through evaporation, which is dependent upon the latent heat of evaporation. The forced evaporation rate (Eq. 12-1) induced by a thermal discharge is calculated by multiplying the station's heat rejection rate (Eq. 12-2) by an evaporative loss coefficient. Edinger and Geyer (1965) developed the method to calculate the evaporative loss coefficient (Eq. 12-3). The formulae and variables are included as follows:

$$EE = H_r \times C \qquad \text{Eq. 12-1}$$

[18] The Edinger-Geyer Method terms Forced Evaporation as "in-stream evaporative water loss." The term Forced Evaporation is being used in lieu of the Edinger-Geyer terminology to be consistent within this document.

where: EE = forced evaporation, cubic feet per second (cfs)
Hr = plant's heat rejection rate (Btu/hr)
C = evaporative loss coefficient due to thermal discharge (cfs/10^9 Btu/hr)

$$H_r = \rho \times Q \times c \times \Delta T \qquad \text{Eq. 12-2}$$

where: ρ = density of water (lb_m/ft^3) (approximate value of 62.37 lb_m/ft^3 was used)
Q = circulating water flow rate (cfs)
c = specific heat of water (Btu/lb_m/°F) (approximate value of 1 Btu/lb_m/°F was used)
ΔT = temperature differential across the condenser (°F) (constant for specific generating unit)

$$C = \left(\frac{4{,}450}{\mathrm{L}}\right) \times \frac{\mathrm{B}(\mathrm{K}-15.7)}{(0.26+\mathrm{B})\mathrm{K}} \qquad \text{Eq. 12-3}$$

where: L = latent heat of vaporization, L=1093-0.56T_s
B = slope of saturated water vapor pressure (mmHg/°F)
$\mathrm{B} = 0.255 - 0.0088\mathrm{T} + 0.000204T^2$
K = surface heat exchange coefficient (Btu/ft2/°F)
$\mathrm{K} = 15.7 + (\mathrm{B} + 0.26) \times \mathrm{f(u)}$
T = temperature function
$\mathrm{T} = \frac{1}{2}(T_s + T_d)$
Td = dew point temperature (°F)
Ts = background temperature of receiving water body (°F)
f(u) = function of wind
$\mathrm{f(u)} = 70 + 0.7u^2$
u = wind speed (mph)

This method has been tested and applied at several stations in Pennsylvania that use fresh water. The results have been checked against benchmarks in power industry literature (EPRI, 2011).

The key data used for calculating the plant's heat rejection rate was the circulating water flow rate and condenser temperature rise during a given time interval.

Using Bayside specific input data required for these calculations, forced evaporation has been computed for Bayside for both DIF and AIF conditions. The results of the calculations are provided in Table 12-12.

Table 12–12. Estimated Monthly Forced Evaporation Between July 2012 and April 2017

Month	Design Flow (MGD)		Historic Flow (MGD)	
	Maximum	Average	Maximum	Average
January	5.5	5.2	4.9	4.4
February	5.6	5.3	4.2	3.9
March	6.0	5.7	5.0	3.6
April	6.5	6.2	4.6	4.4
May	6.5	6.4	5.0	4.4
June	6.9	6.7	5.7	5.1
July	6.9	6.8	6.2	5.3
August	6.9	6.8	6.4	5.5
September	6.8	6.7	5.7	4.7
October	6.4	6.3	4.6	4.0
November	6.3	5.7	3.8	3.0
December	6.1	5.6	3.2	2.5

Source: HDR, 2017.

See Appendix 12-D for engineering calculations.

Cooling Tower Evaporation

Wet cooling towers are evaporative-type towers,[19] which utilize evaporation as the primary means of cooling. The cooling tower evaporative water loss as a result of the cooling effect is governed by latent heat transfer and the direct contact of water and air in the tower. This direct contact is designed to expose a maximum amount of water surface to a maximum flow of air for the greatest amount of heat transfer with respect to structural and operational feasibilities (SPX,

[19] Other types of towers include dry towers where heat is transferred directly to the atmosphere through dry surface fins; there is no direct contact between air and water (SPX, 2009). This type of cooling tower was evaluated in Section 10.0 and rejected for Bayside.

2009). Thus, the rate of evaporation (Eq. 12-4) and other water losses can be estimated using the following formulae and variables.[20]

$$E = 0.0008 \times Q_{CT}$$ Eq. 12-4

where: E = rate of evaporation (gpm)
R = condenser range (°F)
Q_{CT} = cooling tower water flow rate (gpm)

Drift is a water loss and occurs as circulating water, in the form of liquid droplets, becomes entrained in the exhaust air stream (SPX, 2009) (Eq. 12-5).

$$D = DE \times Q_{CT}$$ Eq. 12-5

where: D = drift flow rate (gpm)
DE = drift eliminator efficiency (%)

Blowdown is the water discharged from the system to control the concentrations of salts and other impurities in the circulating water and is a function of evaporation, COC, and drift (SPX, 2009) (Eq. 12-6).

$$B = \frac{(E-[\{C-1\}\times D])}{(C-1)}$$ Eq. 12-6

where: B = blowdown flow rate (gpm)
C = Cycles of concentration

Make-up water is the water that is needed to replenish the circulating water due to losses from evaporation, blowdown, and drift.

$$M = E + B + D$$ Eq. 12-7

where: M = makeup flow rate (gpm)

[20] The formulae and variables are detailed in SPX (2009).

Using the previous equations, evaporation from hypothetical cooling towers at Bayside has been estimated and presented in Table 12-13. Evaporation from the cooling tower is approximately 5,906 gpm (8.5 MGD). The makeup water flow rate to the station is approximately 25,591 gpm (36.9 MGD).

Table 12–13. Estimated Hypothetical Cooling Tower Evaporation

Estimated Water Flow Rates		Units	Unit 1	Unit 2	Station Total
Cooling tower evaporation rate	E	gpm	2,498	3,407	5,906
Drift flow rate	D	gpm	0.9	1.3	2.2
Blowdown flow rate	B	gpm	8,326	11,354	19,681
Makeup flow rate	M	gpm	10,827	14,764	25,591
Dilution water flow rate	QD	gpm	16,655	22,711	39,366
Cooling tower evaporation rate	E	MGD	4	5	9
Drift flow rate	D	MGD	0.001	0.002	0.003
Blowdown flow rate	B	MGD	12	16	28
Makeup flow rate	M	MGD	16	21	37
Dilution water flow rate	QD	MGD	24	33	57

Source: HDR, 2017.

See Appendix 12-E for engineering calculations. The cooling tower evaporation is compared against the forced evaporation in the following section.

Change in Consumptive Water Use

Cooling towers, as part of closed-cycle cooling, use evaporation as the main cooling method; therefore, the consumptive use of water is typically higher compared to forced evaporation, as part of once-through cooling. The increase in evaporation due to the closed-cycle retrofit is estimated as the percent increase in evaporation compared to the current forced evaporation rate as shows in Eq. 12-8). Water is also lost to drift but, due to its very low rate relative to evaporation, it is neglected in Eq. 12-8.

$$Increase\ in\ evaporation = \frac{Post{-}retro\ evaporation - forced\ evaporation}{Forced\ evaporation} \times 100 \qquad Eq.\ 12\text{-}8$$

The estimated percent increase in evaporation due to a closed-cycle cooling tower retrofit is presented in Table 12-14. The cooling tower evaporation for Bayside has been estimated to be higher than forced evaporation for all months of the year, with the percent increase ranging from 25 percent (in the summer) to 64 percent (in the winter).

Table 12–14. Percent Difference between Forced Evaporation and Hypothetical Cooling Tower Evaporation under Design Flow Conditions for the Period 2012 through 2017

Month	Forced Evaporation (Design Flow) (MGD)	Evaporation from Cooling Tower (Design Flow) (MGD)	Percent Increase (%)
January	5.2	8.5	64
February	5.3	8.5	60
March	5.7	8.5	49
April	6.2	8.5	37
May	6.4	8.5	33
June	6.7	8.5	26
July	6.8	8.5	25
August	6.8	8.5	25
September	6.7	8.5	27
October	6.3	8.5	34
November	5.7	8.5	49
December	5.6	8.5	52

Source: HDR, 2017.

Percent Reduction of Water Withdrawal

While the utilization of cooling towers would increase evaporation and thereby increase consumptive water use, the total cooling water withdrawn by Bayside would decrease through the use of cooling towers. Table 12-13 provides the estimated makeup water, which is 25,591 gpm (approximately 36.9 MGD) for Bayside.

Because makeup water and dilution water would continue to be withdrawn from Hillsborough Bay, this flow rate is subtracted from the existing once-through flow rate to find the potential reduction in water withdrawal between once-through cooling and closed-cycle recirculating water (Eq. 12-9).

$$Q_R = Q_O - M - Q_D \quad \text{Eq. 12-9}$$

where: Q_R = water withdrawal reduction (gpm)
Q_O = once-through flow rate (gpm)
Q_D = dilution water withdrawal rate (gpm)

The potential reduction in water withdrawal can be expressed as a percent when compared to the once-through flow rate (Eq. 12-10).

$$\text{PR} = \frac{Q_R}{Q_O} \quad \text{Eq. 12-10}$$

where: PR = percent reduction (%)

The hypothetical reduction in water withdrawal rate at Bayside is presented in Table 12-15.

Table 12–15. Estimated Percent Reduction in Water Use

Estimated Reduction		Units	Unit 1	Unit 2	Station Total
Water withdrawal reduction	QR	gpm	157,318	214,525	371,843
Percent reduction in cooling water use	PR	%	85.1	85.1	85.1

Source: HDR, 2017.

The potential reduction in water use by utilizing cooling towers as compared to the existing once-through cooling system would be approximately 85.1% compared to circulating water flows. As discussed in the 40 CFR 122.21(r)(10) report, Bayside uses treated stormwater and wastewater for the station's service water needs or purchases potable water from a water supplier. This evaluation assumed that service water uses and sources would remain unchanged.

12.3.7.3 Impact Mitigation Methods—40 CFR 122.21(r)(12)(vii)

If plume abatement ClearSky™ technologies were used, it is possible that either all or a portion of the water vapor that is condensed and collected could be reused in the system to reduce the total water requirement. However, the volume of water collected through this technology is

anticipated to be only a small portion of the total water withdrawn (SPX, 2016). Therefore, it is not implemented here.

12.3.7.4 Uncertainty

Key uncertainties associated with evaporation are listed below:

- Actual evaporation rates are dependent on psychrometrics and ambient conditions at any given time. Local meteorological conditions can influence evaporation characteristics. Historic meteorological data may not be fully representative of future conditions.
- The forced evaporation estimation method assumed a well-mixed thermal discharge. This evaluation assumed that the Bayside discharge conforms to the characteristics of that assumed in the calculation.

12.4 FMS

12.4.1 Energy Consumption—40 CFR 122.21(r)(12)(i)

12.4.1.1 Description

Fine-mesh TWS consume energy for screen rotation and screen wash pumps. Depending on the screen and pump ratings of the existing system, and the energy ratings of a potential new system, the energy use rate could increase or decrease. Per the discussion in the 40 CFR 122.21(r)(10) report, traveling water screens with 0.5-mm mesh was selected for evaluation purposes under 40 CFR 122.21(r)(11) and (12) at Bayside.

Fine-mesh TWS

The use of fine-mesh TWS with a fish return system would require the continuous operation of screens, a low-pressure screenwash header to gently wash off aquatic organisms and a high-pressure screenwash header to remove debris. Another water source is used to maintain a steady flow of water in the fish trough.

Continuous rotation of screens and continuous use of screenwash pumps could increase energy consumption. Additionally, a decrease in screen opening imposes a greater drag on the screen which further increases energy use. The increased weight of the fish buckets and the water in the fish buckets also increase the weight of the screens, thereby increasing the power needed to

operate the screen motor. Most modern screens have variable speed drives or two-speed drives to rotate the screens fasters when water level sensors measure greater hydraulic head difference across the screen. Faster rotation also increases energy consumption.

12.4.1.2 Quantification

The additional energy consumed through the use of FMS is dependent upon the water quality and anticipated debris loadings at Bayside. The level of debris in the water body is assumed to be directly proportional to screen cleaning requirements, and the screen cleaning requirement is assumed to be directly proportional to the amount of electricity consumed (i.e., through the operation of additional pumps and motors). Therefore, it can be assumed that an increase in debris loading and the need to protect organisms would increase the energy consumed by this alternative.

Table 12-16 summarizes water use by the existing traveling screens and the hypothetical fine mesh traveling screens, and then estimates the increase in energy use should Bayside replace the screens.

12.4.1.3 Impact Mitigation Methods—40 CFR 122.21(r)(12)(vii)

Potential energy use mitigation measures include:

- Continuous screen rotation and use of high- and low-pressure screenwash systems are required by the 316(b) rule and may not be reduced by Bayside.
- The station can reduce energy use by maintaining the screens in good order to minimize operational inefficiencies. This evaluation has assumed that the screens would be maintained regularly, and the maintenance allowance is meant to reflect that effort.
- Additionally, the shutting down pumps and screens whenever the units do not generate would also help reduce energy consumption. There are limitations to this however: circulating flow needs to start several hours before the units are turned on, and to fully purge excess heat the circulators continue to operate for approximately a day after generation ends.

Table 12–16. Increase in Energy Use Due to a Fine-mesh TWS Retrofit

Component	Value	Units
Existing System		
Number of screens	4	
Motor rating of the existing screens	1.5	hp/screen
Low pressure screen wash pump rating	Not applicable	hp/screen
High pressure screen wash pump rating	30	hp/screen
Hours of operation per week	7	hour/week
Current energy usage	0.17	MWhr/week/screen
Total energy use per year	34.40	MWhr/year
IM BTA Option (Coarse-mesh Screens)		
Number of screens	4	
Motor rating of the coarse-mesh screens	15	
hp/screen		
Low pressure screen wash pump rating	Not applicable	hp/screen
Low- and high-pressure screen wash pump rating	35	hp/screen
Hours of operation per week	168	hour/week
Potential energy use upon a coarse-mesh retrofit	6.30	MWhr/week/screen
Total energy use per year (assuming year-long operation)	1,310.40	MWhr/year
Potential Fine-mesh Option		
Number of screens	6	
Motor rating of the FMS	15	hp/screen
Low pressure screen wash pump rating	Not applicable	hp/screen
Low- and high-pressure screen wash pump rating	35	hp/screen
Hours of operation per week	168	hour/week
Potential energy use upon a fine-mesh retrofit	6.30	MWhr/week/screen
Total energy use per year (assuming year-long operation)	1,965.60	MWhr/year
Change in Energy Consumption from Existing Operations		
Increase in energy use per screen per year (assuming year-long operation)	319.00	MWhr/year/screen
Total increase in energy use per year (for Units 1 and 2 combined)	1,931.20	MWhr/year
Change in Energy Consumption from IM BTA Only (year-long operation)		
Increase in energy use per screen per year (assuming year-long operation)	0.00	MWhr/year/screen
Total increase in energy use per year (for Units 1 and 2 combined)	655.20	MWhr/year
Change in Energy Consumption from IM BTA Only (seasonal operation)		
Increase in energy use per screen per year (assuming seasonal operation)	0.00	MWhr/year/screen
Total increase in energy use per year (for Units 1 and 2 combined)*	414.05	MWhr/year

*Total for both units. Because energy use by screens is unrelated to unit MW rating, the assumption is made in subsequent sections that energy use and other dependencies are equally split.

Source: HDR, 2017.

12.4.1.4 Uncertainty

The actual debris and organism loading expected with fine mesh is unknown. Therefore, further evaluation on the amount of debris would be required to assess the actual energy use associated with installing FMS at Bayside.

12.4.2 Air Pollutant Emissions, Environmental Impacts and Human Health—40 CFR 122.21(r)(12)(ii)

12.4.2.1 Description

The continuous operation of screens and high- and low-pressure pumps increase energy consumption, which in turn contributes to increased emissions.

12.4.2.2 Quantification

Annual increase CO_2, NO_x, SO_2, and PM emissions from replacing the existing coarse-mesh screens with FMS is provided in Table 12-17 and has been estimated using methods discussed in Section 12.3.3.

Table 12–17. Increase in Emissions at Bayside Due to Replacing Coarse-mesh with FMS

	Average	Range
Estimated increases of CO_2 (1,000's lb/yr)	675	344 to 774
Estimated increases of SO_2 (1,000's lb/yr)	*	—
Estimated increases of NO_x (1,000's lb/yr)	*	—
Estimated increases of PM (1,000's lb/yr)	*	—

*Too small to be quantified meaningfully.

Source: HDR, 2017.

12.4.2.3 Impact Mitigation Methods—40 CFR 122.21(r)(12)(vii)

Potential mitigation measures for the increase in emissions include:

- As discussed in Section 12.4.1.4, the efficient and as-needed operation of the screen would reduce energy consumption and thereby reduce associated emissions. The potential maintenance effort is included in O&M costs.

- Bayside already employs emissions control technologies and has already converted from coal to gas thereby reducing its emissions rates. No additional mitigation measures are anticipated.

12.4.2.4 Uncertainty

The nature of TECO's generation capacity changes as it is modernized and typically the emissions per unit of energy generated has declined with time. Therefore, future emissions rates would likely be lower than used in these calculations, but specific future emissions rates are unknown.

Actual station generation and emissions depend on market conditions, which are presently unknown with certainty.

12.4.3 Noise—40 CFR 122.21(r)(12)(iii)

Continuous operation of fine-mesh TWS and screenwash pumps would increase the noise level at the cooling water intake structure – albeit marginally – considering that screen motors and screen wash pumps are already in operation at the cooling water intake. The main difference now would be that pump and screen noise would be continuous.

While there would be an increase in noise near the CWIS, it is expected to be negligible and confined to the immediate vicinity of the CWIS. Therefore, noise impacts due to the installation of FMS are not examined further.

12.4.4 Safety—40 CFR 122.21(r)(12)(iv)

Retrofitting the existing cooling water intake structure with fine-mesh TWS is not expected to impact the safe operation of Bayside, or the safety to station personnel and surrounding residents. However, during periods of heavy debris loading, the possibility exists that water would not be able to flow through the screen openings or that the screens would collapse or be structurally damaged under a large differential pressure across screens.

This section will discuss the potential safety issues with clogging, blinding, and fouling of FMS.

12.4.4.1 Description

Under heavy debris loading conditions, clogging of FMS is a possibility. Predominant debris would include seaweed and trash.

Under rare conditions, if screens are blinded, little to no water would enter the CWIS, which could then increase the pressure differential (commonly referred to as "dP" or headloss) across the screen. The screens are designed for some potential clogging. Under blinding conditions, however, the screens may not be able to withstand a large headloss for long periods of time. It is possible that the blinding could either impede flow through the screens so that no water can reach the pumps causing pumps to cavitate or create a buildup of headloss to the point the screens collapse.

The open area of the screens is directly proportional to the TSV (i.e., a smaller open area correlates to a higher velocity). Because blinding and clogging reduces the open area of the screens, the TSV increases.

12.4.4.2 Quantification

The use of FMS could increase the possibility of screen blinding or collapsing which could lead to unsafe and unreliable operating conditions at the station. However, as discussed in Section 12.4.4.4, this evaluation assumes that the screens would be well-maintained and operated. Therefore, safety issues are expected to be minimal.

12.4.4.3 Impact Mitigation Methods—40 CFR 122.21(r)(12)(vii)

This evaluation assumes that the hypothetical FMS at Bayside would be well-maintained and operated. O&M costs reflect this effort. Therefore, no additional mitigation measures are anticipated.

12.4.4.4 Uncertainty

Actual debris loading can vary, and screen operation can get impacted despite best maintenance efforts. Such situations are not incorporated into this evaluation.

12.4.5 Facility Reliability—40 CFR 122.21(r)(12)(v)

Station reliability refers to instances when the station can or cannot produce power when its service areas demands power. If water is unable to flow through the screens or if screens are structurally damaged or collapse due to large differential pressures from clogging and blinding, the station's reliability would be adversely impacted. As discussed in Section 12.4.4.1, malfunction of screens can impact station reliability.

The reliability of FMS may be somewhat lower than the reliability of coarse-mesh screens, and that reduction in reliability translates to the reliability of the station. While this is real, it is expected to be negligible, and therefore not discussed further.

12.4.6 Consumptive Water Use

A hypothetical retrofit from coarse-mesh screens to FMS would not impact the station's consumptive use of water. Therefore, this is not discussed further.

12.5 Alternate Water Sources

The evaluation in the 40 CFR 122.21(r)(10) report found no viable alternate water sources within a 5-mile radius. The following is a brief description of the results of the water source evaluation.

If the use of an alternate water source (whether groundwater or reclaimed water) were viable, then energy consumption would increase owing to additional pumping, and emissions would increase correspondingly. Depending on the station's dependence on the alternate water source and fraction of water provided by the alternate source, the reliability of station operations could also be compromised.

If a freshwater source were used as a potential alternate water source, the commingling of the fresh water with brackish water from the cooling water system would render all the water as brackish. Once discharged to Hillsborough Bay, all the freshwater used would be lost to the freshwater cycle.

12.6 VSPs

12.6.1 Energy Consumption

12.6.1.1 Description

The use of VSPs could potentially decrease energy consumption by pumps because the pumps are meant to be turned down or shutdown depending on the station's generation rate. As discussed in the 40 CFR 122.21(r)(10) report, Bayside's electricity demands (and operating constraints) are such that anticipated hypothetical flow reductions would be between 4 percent and 27 percent. Therefore, water use reductions are expected to be marginal. Per the ITT (2017) quote, the Units 1 and 2 VSPs would be rated at 1,200 hp and 2,000 hp, respectively. The existing pumps are rated at 664 and 905 hp. When operating at full load, the VSPs would use more energy than the existing pumps. Additionally, owing to dust and high summertime temperatures, the drives for the pumps need to be housed in a climate-controlled structure. The ventilation and air conditioning systems would consume additional electricity. The net effect would be an increase in energy use.

12.6.1.2 Quantification

Energy use by the existing system and the hypothetical VSPs are summarized in Table 12-18 and Table 12-19, respectively. Detailed calculations are provided in Appendix 12-F.

Table 12–18. Energy Use by the Existing Pumps

Parameters and Variables	Units of Measure	Unit 1	Unit 2	Total
Power rating per pump	hp	664	905	Not applicable
Total power requirement for pumps	MWhr/year	8,671	11,825	20,496
Total power requirement	MWhr/year	8,671	11,825	20,496

Source: HDR, 2017.

Table 12–19. Energy Use by Hypothetical VSPs

Parameters and Variables	Units of Measure	Unit 1	Unit 2	Total
Power rating per VSP	hp	1,200	2,000	Not applicable
Total power requirement for VSPs	MWhr/year	14,045	23,278	37,323
Total power requirement for HVAC system	MWhr/year	336	392	729
Total power requirements	MWhr/year	14,381	23,670	38,052

Source: HDR, 2017.

Given the relatively small flow reduction change anticipated for Bayside (between 0 and 27 percent, as discussed in the 40 CFR 122.21(r)(10) report), the impact on condenser backpressure energy penalty is assumed to be negligible (Table 12-19 and Table 12-20). As shown in Figure 12-2, backpressure energy penalty increases as the ambient water temperature increases. Reducing the flow through the condenser could potentially influence condenser performance as well. However, this evaluation assumed that the flow through the condenser would be reduced, at most, only to the extent that Bayside generation is reduced (which would be based on the demand for electricity). Per the hypothetical operating rule introduced in the 40 CFR 122.21(r)(10) report, owing to various operational and permitting constraints, the potential reduction in flow anticipated at Bayside is smaller than the potential reduction in unit generation. Therefore, the net effect on condenser backpressure would be negligible.

Table 12–20. Increase in Energy Use from Replacing Existing Pumps with Constant Speed Pumps

Parameters	Units of Measure	Unit 1	Unit 2	Total
Increase in energy use	MWhr/year	5,710	11,846	17,556

Source: HDR, 2017.

12.6.1.3 Impact Mitigation Methods

Introducing control logic that would maximize flow reduction would help reduce energy consumption. Capital costs presented in the 40 CFR 122.21(r)(10) report includes an allowance to develop such logic.

Controlling the air-conditioning system with a thermostat that would maintain the necessary temperature yet not over-cool would also help reduce potential energy consumption.

12.6.1.4 Uncertainty

Key uncertainties include:

- Electricity demand drives the potential reductions in flow. Higher reductions in flow result in lower energy use. Actual future electricity demands are unknown.
- Atmospheric conditions determine the extent of air conditioning needed. Actual future atmospheric conditions are unknown.

12.6.2 Air Pollutant Emissions, Environmental Impacts and Human Health

12.6.2.1 Description

The increase in energy consumption from the hypothetical replacement of the existing circulating water pumps at Bayside with VSPs (including climate control) increases emissions.

12.6.2.2 Quantification

The annual increase in CO_2, NO_x, SO_2, and PM emissions from replacing the existing pumps with VSPs is provided in Table 12-21 and has been estimated using methods discussed in Section 12.3.3.

Table 12–21. Increase in Emissions at Bayside Due to Replacing Existing Pumps with VSPs

	Average	Range
Estimated increases of CO_2 (1,000's lb/yr)	9,797	1,383 to 12,303
Estimated increases of SO_2 (1,000's lb/yr)	0.1	0 to 0.1
Estimated increases of NO_x (1,000's lb/yr)	1.1	0.2 to 1.4
Estimated increases of PM (1,000's lb/yr)	0.6	0.1 to 0.8

Source: HDR, 2017.

12.6.2.3 Impact Mitigation Methods

A robust logic controller that would actuate and control the pumps to follow generation load and system constraints would reduce energy consumption and thereby reduce associated emissions.

Bayside already employs emissions control technologies and has already converted from steam cycle to combined cycle thereby reducing its emissions rates. No additional mitigation measures are anticipated.

12.6.2.4 Uncertainty

The nature of TECO's generation capacity changes as it is modernized and typically the emissions per unit of energy generated has declined with time. Therefore, future emissions rates would likely be lower than those used in these calculations, but specific future emissions rates are unknown.

Actual sources of generation and emissions depend on market conditions, which are forecasted as accurately as possible but may still deviate with future actual demand.

12.6.3 Noise—40 CFR 122.21(r)(12)(iii)

Reduced operation of the pumps would reduce the noise level at the CWIS. The ventilation and air-conditioning system would increase the noise level. Whether the net effect is higher or lower noise, it is expected to be negligible and therefore not discussed further.

12.6.4 Safety

Replacing the existing pumps with VSPs is not expected to impact the safe operation of the station, and therefore is not discussed further.

12.6.5 Facility Reliability

This evaluation assumes that the hypothetical VSPs would be appropriately controlled with a carefully developed and tested logic controller. A key goal of this controller is the maintenance of cooling water supply and facility reliability. Therefore, VSPs are not expected to impact the reliability of the station. However, if the NPDES permit were to specify required flow reductions and constrain the station's use of water and the station's generating capacity, then the permit conditions could impact Bayside's reliability. This evaluation assumes that the permit would not impose constraints on station/pump operations and therefore that the station's reliability would remain unaffected. Were this technology selected, this assumption would need to be validated by the NPDES Director.

12.6.6 Consumptive Water Use

Consumptive use of water would remain unaffected from a hypothetical replacement of the existing circulating water pumps with VSPs.

12.7 Engineering Summary

Table 12-22 provides a summary of the engineering information for each of the entrainment reductions technologies considered for Bayside.

Table 12–22. Summary of Engineering Information

Technology	MDCT	FMS	VSPs
Anticipated year when commissioned	2024	2022	2022
End of life of technology and station	2044	2044	2044
Anticipated outage	Four-week outage for each unit	None; screens to be phased in while station operating	Two weeks for each unit; October 2021
Initial capital costs (in 2017 $ million)	$237	$15.5	$11
Annual O&M costs (in 2017 $ million)	$3.75	$0.35	$1
Number of technology replacements	1 (replace fill in 2034)	Relies on periodic, on-going maintenance costs	Only major maintenance
Net present value (historical current production costs, 3% discount rate)	$399 million	$15 million	$22 million
Energy losses			17,556 MWhr/year
Parasitic losses	52,460 MWhr/year	414 MWhr/year	Negligible
Backpressure energy penalty	45,510 MWhr/year		
Derate when design wet bulb temperature is exceeded	9,531 MWhr/year		
Average increase in stack emissions (1,000's lb/yr)	Yes	Yes, minor	Yes
CO_2	88,205	675	9,797
SO_2	0.6	**	0.1
NO_x	17	**	1.1
PM	6	**	0.6
Emissions from the technology (tpy)			
PM	28.1 to 92.0	0	0
PM_{10}	12.0 to 50.8		
$PM_{2.5}$	3.3 to 17.6		
Increase in noise	Yes, due to fans and cascading water	Negligible	Marginal increase due to HVAC system
Impact on station reliability	Yes, due to 88 hours of CT unavailability and backpressure energy penalty	Potential impacts are mitigated by two sets of screens in series and increased maintenance regime	Only if permit requires specific flow reduction rates at specific times of the year
Increase in consumptive water use	85.1-percent reduction in water withdrawal rate, but increase in water consumption	No change	No change

*Too small to be quantified meaningfully.

Source: HDR, 2017.

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Appendix 12-A

Booster, Makeup, and Dilution Pump Headloss Calculations

Originator:	**Nicholas Thomas, PhD**	4/3/2017
Reviewer:	**Radhika de Silva, PhD, PE**	6/9/2017
Approver:	**Radhika de Silva, PhD, PE**	6/9/2017

Revision No.	Revised by:	Approved by:	Description
0	-	-	-

Calculation Summary:

Pump Requirements	**Unit 1**	**Unit 2**
Number of cooling tower booster pumps:	4	4
Cooling tower booster pump flow rate (gpm):	46,200	63,000
Cooling tower booster pump total dynamic head (ft):	63.1	60.0
Number of makeup water pumps:	1	1
Makeup water pump flow rate (gpm):	10,827	14,764
Makeup water pump total dynamic head (ft):	16.0	14.8
Number of dilution water pumps:	1	1
Dilution water pump flow rate (gpm):	16,655	22,711
Dilution water pump total dynamic head (ft):	21.2	21.0

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System Description:

Bayside Power Station is fossil fuel driven power generation plant consisting of two combined cycle gas turbine generation units (1 & 2) and four natural gas fired peaking units (3 - 6). The gross summer generation capacity of Unit 1 is 710 MW (with 236 MW from the steam turbine and 474 MW from the three combustion turbines). The gross summer generating capacity of Unit 2 is 940 MW (with 308 MW from the steam turbine and 632 MW from the four combustion turbines). Units 3 - 6 are 57 MW each. The total gross summer generation capacity of Bayside is therefore 1,878 MW. Once through cooling water is withdrawn from Hillsborough Bay for cooling the steam turbines associated with Unit 1 and Unit 2.

This evaluation assumes that the cooling water system associated with the steam cycle for Units 1 and 2 would be converted from once-through to closed-cycle. The State of Florida has a 110 percent chloride discharge limit (compared to the receiving waterbody). The evaluation therefore assumes that the cooling towers would be operated at 1.3 cycles of concentration and that the blowdown would be diluted using additional Bay water to achieve the 110 percent discharge limitation.

Calculation Purpose:

Estimate the additional head loss through the cooling water pipe associated with the hypothetical cooling tower retrofit, and size new booster pumps and makeup pumps for the new system.

Calculation Objectives:

1. List the calculation methodology and data required for the calculations.
2. Identify the inputs required for the calculations.
3. Estimate the dynamic head required for the booster pump system.
4. Estimate the dynamic head required for the make-up water system.
5. Estimate the dynamic head required for the dilution water system.
6. Estimate the additional head required for the closed-cycle cooling system.

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Calculation Methodology:

Formula 1

$$H_{Lf} = [\ 10.44 * L * Q^{1.85}\ ] / [\ C^{1.85} * (\ C1 * d\ )^{4.87}\ ]$$

Units: ft

where:

H_{Lf} = Head loss due to pipe wall friction for each new pump/pipe system (ft)
L = Total pipe length per pump (ft)
Q = Flow rate through pipe per pump (gallon per minute (gpm))
C = Hazen-Williams roughness coefficient
d = Pipe diameter (in)
C1 = Conversion factor from feet to inches (in/ft)

Formula 2

$$H_{Lm} = \Sigma k * V^2 / (\ 2 * g\ )$$

Units: ft

where:

H_{Lm} = Minor head loss due to irregularities in each pipe/pump system (ft)
Σk = Sum of minor head loss coefficients which are specified for each head loss feature
V = Flow velocity [$V = Q / (\ \pi * d^2 / 4\ )$] (ft/s)
g = Gravitational acceleration (ft/s^2)

Formula 3

$$H_T = H_{LF} + H_{Lm} + H_S$$

Units: ft

where:

H_T = Total dynamic head required (ft)
H_S = Static head (ft)

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Calculation Inputs:

Parameters and Variables		Measurement Units	Unit 1	Unit 2	Reference/Note
Circulating water flow rate	Q	GPM	184,800	252,000	Note 6
Number of cooling tower booster pumps	N_{Bpump}	-	4	4	Note 3
Make-up pump discharge capacity	Q_M	GPM	10,827	14,764	Note 5
Number of additional make up pumps	N_{Mpump}	-	1	1	As. 2 Note 3
Dilution pump discharge capacity	Q_D	GPM	16,655	22,711	Note 7
Number of dilution pumps	N_{Dpump}	-	1	1	As. 2 Note 3
Pipe length for each booster pump	LB	ft	900	1,200	Note 2
Pipe length for each make-up pump	L_M	ft	100	100	Note 2
Pipe length for each dilution pump	L_D	ft	1500	1500	Note 2
Pipe diameter for each booster pump	d_B	ft	4.0	5.0	Note 1
Pipe diameter for each make-up pump	d_M	ft	2.0	2.5	Note 1
Pipe diameter for each dilution pump	d_D	ft	3.5	4.0	Note 1
Pipe roughness	C	-	100	100	[1]
Gravitational acceleration	g	ft/s^2	32.2	32.2	
Static head for each booster pump	H_{SB}	ft	41.0	41.0	As. 1
Static head for each make-up pump	H_{SM}	ft	10.0	10.0	As. 1
Static head for each dilution pump	H_{SD}	ft	15.0	15.0	As. 1

Intermediate Calculations:

Booster pump discharge capacity	Q_B	GPM	46,200	63,000	As. 2 Note 3
Velocity in each booster pipe	V_B	ft/s	8.2	7.1	Note 1
Velocity in each make-up pipe	V_M	ft/s	7.7	6.7	Note 1
Velocity in each dilution pipe	V_M	ft/s	3.9	4.0	Note 1
Sum of minor head loss coefficients	Σk_B	ft	6.1	6.1	Note 4
Sum of minor head loss coefficients	Σk_M	ft	2.4	2.4	Note 4
Sum of minor head loss coefficients	Σk_D	ft	0.7	0.8	Note 4

Fittings along the cooling water pipeline:

Minor Head Losses		Unit 1		Unit 2	
Description	k	Number	Head loss (ft)	Number	Head loss (ft)
90 Elbow	0.3	10	3.13	10	3.13
Wye	0.2	8	1.67	8	1.67
Entrance loss	0.5	1	0.52	1	0.52
Exit loss	1.0	1	1.04	1	1.04
Total			6.36		6.36

Fittings along the makeup water pipeline:

Minor Head Losses		Unit 1		Unit 2	
Description	k	Number	Head loss (ft)	Number	Head loss (ft)
90 Elbow	0.3	3	0.82	3	0.63
Wye	0.2	0	0.00	0	0.00
Entrance loss	0.5	1	0.46	1	0.35
Exit loss	1.0	1	0.92	1	0.70
Total			2.20		1.67

Fittings along the dilution water pipeline:

Minor Head Losses		Unit 1		Unit 2	
Description	k	Number	Head loss (ft)	Number	Head loss (ft)
90 Elbow	0.3	5	0.35	5	0.38
Wye	0.2	0	0.00	0	0.00
Entrance loss	0.5	1	0.12	1	0.13
Exit loss	1.0	1	0.23	1	0.25
Total			0.69		0.76

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Conversion Factors:

1	foot		=	12 inches
C1 =		12.0	in per ft	

Assumptions:

1. Booster pump static head is based on cooling tower height, and wet well depth.
2. Two booster pumps for each of the two existing once-through cooling pumps.
3. Assume one make-up pump and one dilution water pump per unit, with same efficiency as booster pumps.

Notes:

1. Pipe diameters were selected to maintain a relatively consistent flow velocity within the pipe network.
2. Pipe lengths were estimated based on approximate cooling tower booster pumps, dilution pump and make-up pump locations.
3. Existing cooling system requires two pumps with a per pump capacity of 92,400 gpm, and 126,000 gpm for Unit 1 and Unit 2, respectively.
4. Description of specific minor losses are found in appended tab including elbows, entrance, exit, and wye losses.
5. Required make-up discharge based on evaporation calculations.
6. Circulating water flow rate is divided between each of the cooling tower booster pumps to exchange hot and cold water.
7. Required dilution discharge rate based on flow required to dilute the 130 percent blowdown to 110 percent required by the State of Florida.

References:

[1] Lindeburg, Michael, R., 2003. Environmental Engineering Reference Manual for PE Exam, Second Edition. Professional Publications, Inc.

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Calculations:

1. Estimate the Additional Dynamic Head Required for the Booster Pumps

Formulas Used: 1, 2, 3

Parameters and Variables		Units	Unit 1	Unit 2
Booster Pump Friction Head Loss	H_{Lf}	ft	5.2	4.1
Booster Pump Minor Head Loss	H_{Lm}	ft	6.36	4.84
Booster Pump Total Head Required (with 20 % contingency)	H_T	ft	63.1	60.0

2. Estimate the Additional Head Required for the Make-up Pump System

Formulas Used: 1, 2, 3

Parameters and Variables		Units	Unit 1	Unit 2
Make-up Pump Friction Head Loss	H_{Lf}	ft	1.15	0.69
Make-up Pump Minor Head Loss	H_{Lm}	ft	2.20	1.67
Make-up Pump Total Head Required (with 20% contingency)	H_T	ft	16.0	14.8

3. Estimate the Additional Head Required for the Dilution Pump System

Formulas Used: 1, 2, 3

Parameters and Variables		Units	Unit 1	Unit 2
Dilution Pump Friction Head Loss	H_{Lf}	ft	2.51	2.32
Dilution Pump Minor Head Loss	H_{Lm}	ft	0.16	0.19
Dilution Pump Total Head Required (with 20% contingency)	H_T	ft	21.2	21.0

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Appendix 12-B

Energy Consumption Calculations for Booster, Makeup and Dilution Pumps and MDCT Fans

Originator: **Nicholas Thomas, PhD** 4/3/2017

Reviewer: **Samantha Schneider, EIT** 5/18/2017

Approver: **Radhika de Silva, PhD, PE** 6/9/2017

Revision No.	Revised by:	Approved by:	Description
1	RDS	-	Incorporate derate and dilution water pumps.

Calculation Summary:

Energy Requirement	Unit 1	Unit 2	Total
Pumps (MW):	3.1	4.1	7.1
Fans (MW):	1.9	2.6	4.5
Total Parasitic Load (MW):	4.9	6.7	11.6
Total Parasitic Load assuming 100% Operations (MWhr/year):	43,143	58,681	101,825
Total Parasitic Load assuming Historic Operations (MWhr/year):	21,593	30,866	52,460

Backpressure Energy Penalty (MW):	2.3	2.9	5.2
Backpressure Energy Penalty assuming 100% Operations (MWhr/year):	19,744	25,767	45,510
Derate when design wet bulb temperature is exceeded (MWhr/year):	4,135	5,396	9,531
Backpressure Energy Penalty and Derate Effects assuming 100% Operations (MWHr/year):	23,878	31,163	55,041
Backpressure Energy Penalty and Derate Effects assuming Historic Operations (MWHr/year)	11,951	16,392	28,343

Annual Maximum Parasitic, Backpressure Energy Penalty and Derate Effects Assuming 100% Operations (MWhr/year):	67,022	89,845	156,866
Annual Maximum Parasitic, Backpressure Energy Penalty and Derate Effects Assuming Historic Operations (MWhr/year):	33,544	47,258	80,803

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System Description:

Bayside Power Station is a fossil fuel driven power generation plant consisting of two combined cycle gas turbine generation units (1 & 2) and four natural gas fired peaking units (3 - 6). The gross summer generation capacity of Unit 1 is 710 MW (with 236 MW from the steam turbine and 474 MW from the three combustion turbines). The gross summer generating capacity of Unit 2 is 940 MW (with 308 MW from the steam turbine and 632 MW from the four combustion turbines). Units 3 - 6 are 57 MW each. The total gross summer generation capacity of Bayside is therefore 1,878 MW. Once through cooling water is withdrawn from Hillsborough Bay for cooling the steam turbines associated with Unit 1 and Unit 2.

This evaluation assumes that the cooling water system associated with the steam cycle for Units 1 and 2 would be converted from once-through to closed-cycle (with a mechanical draft cooling tower), which would exert an additional electricity load by way of cooling tower fans, cooling tower booster pumps and makeup water pumps. The State of Florida has a 110 percent chloride discharge limit (compared to the receiving waterbody). The evaluation therefore assumes that the cooling towers would be operated at 1.3 cycles of concentration and that the blowdown would be diluted using additional Bay water to achieve the 110 percent discharge limitation. The dilution water pumps would exert a further energy draw.

Cold water from a cooling tower is typically warmer than water from the Hillsborough Bay, therefore the condenser performance would be lower. This is captured as back pressure energy penalty.

The hypothetical cooling tower are designed for the 99th percentile wet bulb temperature. This evaluation assumes that the station would need to be derated by 20 percent for 88 hours of the year. While this is a reduction is the station's generating capacity, it does not result in additional emissions.

Calculation Purpose:

Estimate the consumptive energy use associated with a hypothetical retrofit of the current once-through cooling system to a closed-cycle cooling system.

Calculation Objectives:

1. List the calculation methodology and data required for the calculations.
2. Identify the inputs required for the calculations.
3. Estimate the parasitic energy losses (energy consumed by fans and pumps).
4. Estimate the backpressure energy penalty and reduction in electricity generation due to summertime derate.

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Calculation Methodology:

Reference:

Formula 1 $P_{Bpump} = [[H_B * Q_B * SG / (3956 * \eta_{pump})] / \eta_{motor}] * N_{Bpump} * C1$ [1]
Units: MW

where:

P_{Bpump} = Power required
Q_B = Booster pump discharge capacity (gallons per minute (gpm))
H_B = Hydraulic head required to circulate water through cooling system (H_m), (ft) Note 1
SG = Specific gravity of cooling water (-) As. 1
η_{pump} = Efficiency of pump converting mechanical energy to water energy (%)
η_{motor} = Efficiency of motor converting electric energy to mechanical energy (%)
N_{Bpump} = Number of booster system pumps required
C1 = Conversion factor from hp to MW (MW/hp)

Formula 2 $P_{Mpump} = [[H_M * Q_M * SG / (3956 * \eta_{pump})] / \eta_{motor}] * N_{Mpump} * C1$
Units: MW

where:

P_{Mpump} = Power required to operate closed-cycle cooling system make up pumps (MW)
Q_M = Make-up pump discharge capacity (gpm)
H_M = Hydraulic head required to circulate water through cooling system (H_m), (ft)
N_{Mpump} = Number of make-up pumps required

Formula 3 $P_{fan} = P_{i,fan} * N_{fan} * C1$
Units: MW

where:

P_{fan} = Power required to operate closed-cycle cooling system fans (MW)
$P_{i, fan}$ = Power required to operate an individual fan (hp) [2]
N_{fan} = Number of cooling system fans required As. 2

Formula 4 $P_{BPEP} = Cgross * \varepsilon_{BPEP}$
Units: MW

where:

P_{BPEP} = Power lost to the backpressure energy penalty (MW) Note 2
C_{gross} = Gross generating capacity of facility (MW)
ε_{BPEP} = Backpressure energy penalty (%) Note 3

Formula 5 $P_{Total} = [P_{Bpump} + P_{Mpump} + P_{fan} + P_{BPEP}] * OP$ As. 3
Units: MWhr

where:

P_{Total} = Total energy loss if the plant were utilized 100 percent of the time with a closed-cycle cooling system in place (MWhr)

OP = Annual operating hours (hr) or 8,760 hours

Formula 6 $P_{OP} = P_{Total} * CUR_5$ As. 3
Units: MWhr

where:

P_{OP} = Total energy loss assuming current capacity utilization extends into future operations as well (MWhr) Note 5
CUR_5 = Five year average capacity utilization rate (%)

Formula 7 $P_{DR} = C_{gross} * DR * Hr_{DR}$ As. 6
Units: MWhr

where:

P_{DR} = Total energy when the design wet bulb temperature is exceeded and the steam turbine needs to be derated
DR = Percent derate (%)

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Calculation Inputs:

Parameters and Variables		Measurement Units	Unit 1	Unit 2	Reference/Note
Booster pump discharge capacity	Q_B	GPM	46,200	63,000	Assumption 4 Note 3
Make-up pump discharge capacity	Q_M	GPM	10,827	14,764	Note 6
Dilution pump discharge capacity	QD	GPM	16,655	22,711	Note 8
Required booster pump head	H_B	ft	63.1	61.8	Note 1
Required make-up pump head	H_M	ft	16.0	14.8	
Required dilution pump head	H_M	ft	21.2	21.0	
Specific gravity of water	SG	-	1.0	1.0	Assumption 1
Pump efficiency	η_{pump}	%	85%	85%	
Pump motor efficiency	η_{motor}	%	90%	90%	
Number of additional booster pumps	N_{Bpump}	-	4	4	Assumption 4 Note 3
Number of additional make up pumps	N_{Mpump}	-	1	1	Assumption 5
Number of additional dilution pumps	N_{Dpump}	-	1	1	Assumption 5
Power required for fan operation	$P_{i,fan}$	hp	250	250	[2]
Number of cooling system fans	N_{fan}	-	10	14	Assumption 2, [2]
Gross generating capacity of the steam turbine	C_{gross}	MW	236	308	[3]
Backpressure energy penalty	ε_{BPEP}	%	1.0%	1.0%	[4], Note 7
Annual maximum operating hours	OP	hr	8,760	8,760	Assumption 3
Average capacity utilization rate	CUR_5	%	50.1%	52.6%	Note 4
Percent derate when the design wet bulb temperature is exceeded	DR	%	20%	20%	Assumption 6
Design wet bulb temperature exceedance		%	1.0%	1.0%	
Number of hours of the year when design wet bulb temperature is exceeded	Hr_{DR}	hr	87.6	87.6	Calc.

Conversion Factors:

1 Megawatt = 1341.02 horsepower
C1 = 7.46E-04 MW per horsepower

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Assumptions:

1. Specific gravity of cooling water is assumed constant.
2. Number of fans equal to number of cooling tower cells (1 fan per cell) per [2].
3. Cooling towers are operated continuously for a given year, unless the unit is in a
4. planned outage.
5. Two booster pumps for each of the two existing once-through cooling pumps.
6. Assume one make-up pump and one dilution pump per unit, with same efficiency
7. as booster pumps.
8. Assume that when the actual ambient wet bulb temperature is greater than the design wet bulb temperature, the station would be derated by 20 percent.

Notes:

1. Total pump head is a summation of expected head loss due to pipe friction, minor losses, and the static head requirement. Where the static head is the sum of wet well depth (10ft pipe below wet well water surface + 3ft of freeboard), and the height to the wet deck of the cooling tower (28 ft). The site is flat, therefore topographical effects are minor.
2. Backpressure energy penalty results from a loss of turbine efficiency due to a reduction in temperature change across the plant condensers. This originates from an increase in cooling water temperature in a closed-cycle cooling system.
3. Existing cooling system requires two pumps with a per pump capacity of 92,400 gpm, and 126,000 gpm for Unit 1 and Unit 2, respectively.
4. Average Plant-specific capacity utilization rate calculated over the 2012 to 2016 period (From R3).
5. Total energy consumption is proportional to the station's capacity utilization rate.
6. Required make-up discharge based on evaporation calculations.
7. Based on [4] for plants in the South.
8. Based on headloss calculations.

References:

[1] Lindeburg, Michael, R., 2003. Environmental Engineering Reference Manual for PE Exam, Second Edition. Professional Publications, Inc.
[2] EvapTech. 2017. Cooling Tower Quote TECO Bayside dated January 23, 2017.
[3] TECO. (2013). Fact Sheet For State of Florida Industrial Wastewater Facility Permit.
[4] United States Department of Energy (DOE). (2002). Energy Penalty Analysis of Possible Cooling Water Intake Structure Requirements on Existing Coal Fired Power Plants.

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Calculations:

1. Estimate Parasitic Power Losses Associate with Auxiliary Loads

Formulas Used: 1, 2, 3

Parameters and Variables		Units	Unit 1	Unit 2	Total
Booster pump power requirement	P_{Bpump}	MW	2.9	3.9	6.8
Make-up pump power requirement	P_{Mpump}	MW	0.04	0.06	0.10
Dilution pump power requirement	P_{Dpump}	MW	0.09	0.12	0.21
Fan power requirement	P_{fan}	MW	1.9	2.6	4.5

2. Estimate Backpressure Energy Penalty Power Loss

Formulas Used: 4

Parameters and Variables		Units	Unit 1	Unit 2	Total
Backpressure energy penalty	P_{BPEP}	MW	2.3	2.9	5.2

3. Estimate Energy Loss during Steam Turbine Derate when Design Wet Bulb Temperature is Exceeded

Formulas Used: 4

Parameters and Variables		Units	Unit 1	Unit 2	Total
Energy loss due to derate	P_{DR}	MWhr	4,135	5,396	9,531

4. Estimate Total Power Loss

Formulas Used: 5, 6

Parameters and Variables		Units	Unit 1	Unit 2	Total
Parasitic and backpressure energy penalty	P_{Total}	MWhr/year	62,887	84,448	147,335
Parasitic and backpressure energy penalty, accounting for capacity utilization	P_{OP}	MWhr/year	31,475	44,420	75,895

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Appendix 12-C

Estimated Particulate Matter Emissions Due to the Operation of Hypothetical Cooling Towers

Originator:	**Nicholas Thomas, PhD**	4/3/2017
Reviewer:	**Radhika de Silva, PhD, PE**	6/9/2017
Approver:	**Radhika de Silva, PhD, PE**	6/9/2017

Revision No.	Revised by:	Approved by:	Description
0	-	-	-

Calculation Summary:

Emission Rate	**Unit 1**	**Unit 2**	**Total**
PM (lb/hr):	5.3 - 17.2	7.2 - 23.5	12.4 - 40.8
PM (tons/year):	11.5 - 37.8	16.5 - 54.2	28.1 - 92.0
PM_{10} (lb/hr):	2.2 - 9.5	3.06 - 13.0	5.3 - 22.5
PM_{10} (tons/year):	4.9 - 20.9	7.0 - 29.9	12.0 - 50.8
$PM_{2.5}$ (lb/hr):	0.61 - 3.30	0.84 - 4.50	1.45 - 7.80
$PM_{2.5}$ (tons/year):	1.35 - 7.23	1.93 - 10.4	3.3 - 17.6

Emission Rate per Cell	**Unit 1**	**Unit 2**	**Average**
PM (lb/hr):	0.53 - 1.23	0.72 - 1.68	0.62 - 1.46
PM (tons/year):	1.15 - 2.70	1.65 - 3.9	1.40 - 3.28
PM_{10} (lb/hr):	0.22 - 0.68	0.31 - 0.93	0.27 - 0.8
PM_{10} (tons/year):	0.49 - 1.49	0.7 - 2.14	0.6 - 1.81
$PM_{2.5}$ (lb/hr):	0.06 - 0.24	0.08 - 0.32	0.07 - 0.28
$PM_{2.5}$ (tons/year):	0.13 - 0.52	0.19 - 0.74	0.16 - 0.63

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System Description:

Bayside Power Station is fossil fuel driven power generation plant consisting of two combined cycle gas turbine generation units (1 & 2) and four natural gas fired peaking units (3 - 6). The gross summer generation capacity of Unit 1 is 710 MW (with 236 MW from the steam turbine and 474 MW from the three combustion turbines). The gross summer generating capacity of Unit 2 is 940 MW (with 308 MW from the steam turbine and 632 MW from the four combustion turbines). Units 3 - 6 are 57 MW each. The total gross summer generation capacity of Bayside is therefore 1,878 MW. Once through cooling water is withdrawn from Hillsborough Bay for cooling the steam turbines associated with Unit 1 and Unit 2.

This evaluation assumes that the cooling water system associated with the steam cycle for Units 1 and 2 would be converted from once-through to closed-cycle. These estimates the additional particulate matter (PM) emissions associated with the onsite cooling tower, assuming that all makeup water will continue to be withdrawn from the Hillsborough Bay.

Calculation Purpose:

Estimate the cooling tower particulate matter emission rate from the hypothetical cooling tower installation.

Calculation Objectives:

1. List the calculation methodology and data required for the calculations.
2. Identify the inputs required for the calculations.
3. Estimate the cooling tower particulate emission rates for total PM, $PM_{2.5}$ and PM_{10}.

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Calculation Methodology:

Reference:

Formula 1 $(TS)_{CT} = (TDS + TSS) * C$ [1], [2]

Units: PPM

where:

$(TS)_{CT}$ = Expected total solids (dissolved and suspended) of the circulating water (PPM)

TDS = Total dissolved solids of the source water (PPM) [3]

TSS = Total suspended solids of the source water (PPM)

C = Cycles of concentration

Formula 2 $E_1 = Q_{CT} * DE * (TS)_{CT} * PM * C1$ [1], [2]

Units: lb/hr

where:

E_1 = Hourly emissions rate of specified particulate matter size PM (lb/hr), $PM_{2.5}$, or PM_{10}

Q_{CT} = Cooling Tower Water Flow rate in gallons per minute (GPM), assumed to be same as condenser cooling water flow rate

DE = Drift eliminator efficiency (%)

PM = Weight percent of specified particulate matter size (%), PM (total particulate matter), $PM_{2.5}$ (particulate matter with a nominal size of less than 2.5 microns), or PM_{10} (particulate matter with a nominal size of less than 10 microns)

C1 = Conversion factor from *GPM*PPM* to *lb/hr*

Formula 3 $E_2 = E_1 * CUR_5 * OP * C2$

Units: tons/year

where:

E_2 = Annual emission rate of specified particulate matter size PM (tons/year), $PM_{2.5}$, or PM_{10}

CUR_5 = Five year average capacity utilization rate (%)

OP = Annual operating hours (hr)

C2 = Conversion factor from *lb/year* to *tons/year*

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Calculation Inputs:

Parameters and Variables		Units	Unit 1	Unit 2	Reference/Note
Water circulation rate (all cells)	Q_{CT}	GPM	184,800	252,000	ssumption 1, [4], [5]
Number of cooling tower cells	n	-	10	14	[6]
Drift eliminator efficiency	DE	%	0.0005%	0.0005%	[6]
Source water total dissolved solids range	TDS	PPM	8,741	8,741	Note 1 & 2, [7]
			28,656	28,656	
Source water total suspended solids	TSS	PPM	12	12	[3]
Cycles of concentration	C	-	1.3	1.3	Assumption 2
Weight percent PM_{10}	PM_{10}	%	55.2%	55.2%	Assumption 3, Note 1, [1]
			42.6%	42.6%	
Weight percent $PM_{2.5}$	$PM_{2.5}$	%	19.1%	19.1%	Assumption 3, Note 1, [1]
			11.7%	11.7%	
Average capacity utilization rate	CUR_5	%	50.1%	52.6%	Note 3
Annual maximum operating hours	OP	hr	8,760	8,760	Assumption 4

Conversion Factors:

1	hour	=	60 minutes
1	PPM	=	1,000,000 parts
1	gallon	=	8.35 pounds
1	ton	=	2,000 pounds

C1 = GPM * PPM x 5.01E-04 = pounds per hour
C2 = pounds x 5.00E-04 = tons

Assumptions:

1. Cooling tower water flow rate is the same as the condenser water flow rate.
2. The evaluation assumes 1.3 cycles of concentration due to brackish water source.
3. PM_{10} and $PM_{2.5}$ are based on TS, water droplet size, and water droplet size distribution.
4. Cooling towers are operated non-stop for a given year.
5. Emission rates are equally distributed amongst all cooling tower cells.
6. If proportion of mass is less than 12%, then the weight % is assumed to related linearly with particle diameter.

Notes:

1. A TDS range of values was used in calculations encompassing the minimum to maximum mean monthly measured values at two locations: 3.3 mi north and 3.9 mi south of the cooling water intake structures per [7] and [8] .
2. TDS concentrations were converted from measured specific conductance.
3. Average Plant-specific capacity utilization rate calculated over the 2012 to 2016 period (From R3).

References:

[1] Reisman, Joel, and Gordon Frisbie. 2002. Calculating realistic PM10 emissions from cooling towers, published by the American Institute of Chemical Engineers.
[2] USEPA AP-42 Section 13.4 Wet Cooling Towers.
[3] Hillsborough County. 2014. Surface Water Quality 2001-2010 for Hillsborough County, Florida, prepared by the Environmental Protection Commission of Hillsborough County.
[4] Tampa Electric Company. (Undated). Bayside Unit #1 Specification 01-5988 Alstom condenser data sheet.
[5] Tampa Electric Company.(Undated). Bayside Unit #2 Alstom condenser data sheet.
[6] EvapTech. 2017. Cooling Tower Quote TECO Bayside dated January 23, 2017.
[7] USGS (2017). National Water Information System, Station ID 02306028, Hillsborough River at Platt Street.
[8] USGS (2017). National Water Information System, Station ID 02301721, Alafia River.

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Calculations:

1. Estimate Total Solids in Circulating Water

Formulas Used: 1, Note 1

Parameters and Variables		Units	Unit 1	Unit 2	Average
Total solids in circulating water range	$(TS)_{CT}$	PPM	11,379	11,379	11,379
			37,268	37,268	37,268

2. Estimate Emission Rates for PM Sizes

Formulas Used: 2, 3, Note 1

Parameters and Variables		Units	Unit 1	Unit 2	Total
Total PM	PM	lb/hr	5.3 - 17.2	7.2 - 23.5	12.4 - 40.8
	PM	tons/year	11.5 - 37.8	16.5 - 54.2	28.1 - 92.0
PM_{10}	PM_{10}	lb/hr	2.2 - 9.5	3.06 - 13.0	5.3 - 22.5
	PM_{10}	tons/year	4.9 - 20.9	7.0 - 29.9	12.0 - 50.8
$PM_{2.5}$	$PM_{2.5}$	lb/hr	0.61 - 3.30	0.84 - 4.50	1.45 - 7.80
	$PM_{2.5}$	tons/year	1.35 - 7.23	1.93 - 10.4	3.3 - 17.6

3. Estimate Emission Rates per Cell

Formulas Used: Assumption 5, Note 1

Parameters and Variables		Units	Unit 1	Unit 2	Average
Total PM	PM	lb/hr	0.53 - 1.23	0.72 - 1.68	0.62 - 1.46
	PM	tons/year	1.15 - 2.70	1.65 - 3.9	1.40 - 3.28
PM_{10}	PM_{10}	lb/hr	0.22 - 0.68	0.31 - 0.93	0.27 - 0.8
	PM_{10}	tons/year	0.49 - 1.49	0.7 - 2.14	0.6 - 1.81
$PM_{2.5}$	$PM_{2.5}$	lb/hr	0.06 - 0.24	0.08 - 0.32	0.07 - 0.28
	$PM_{2.5}$	tons/year	0.13 - 0.52	0.19 - 0.74	0.16 - 0.63

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Appendix 12-D

Estimated Forced Evaporation from Existing Cooling Water System

Originator:	**Nicholas Thomas, PhD**	Date:	4/3/2017
Reviewer:	**Radhika de Silva, PhD, PE**	Date:	6/9/2017
Approver:	**Radhika de Silva, PhD, PE**	Date:	6/9/2017

Revision No.	Revised by:	Approved by:	Description
0	-	-	-

Calculation Summary:

Forced Evaporation between 2012 and 2017				
Month	**Design Flow**		**Actual Flow**	
	Maximum	**Average**	**Maximum**	**Average**
	(MGD)	(MGD)	(MGD)	(MGD)
January	5.5	5.2	4.9	4.4
February	5.6	5.3	4.2	3.9
March	6.0	5.7	5.0	3.6
April	6.5	6.2	4.6	4.4
May	6.5	6.4	5.0	4.4
June	6.9	6.7	5.7	5.1
July	6.9	6.8	6.2	5.3
August	6.9	6.8	6.4	5.5
September	6.8	6.7	5.7	4.7
October	6.4	6.3	4.6	4.0
November	6.3	5.7	3.8	3.0
December	6.1	5.6	3.2	2.5

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System Description:

Bayside Power Station is fossil fuel driven power generation plant consisting of two combined cycle gas turbine generation units (1 & 2) and four natural gas fired peaking units (3 - 6). The gross summer generation capacity of Unit 1 is 710 MW (with 236 MW from the steam turbine and 474 MW from the three combustion turbines). The gross summer generating capacity of Unit 2 is 940 MW (with 308 MW from the steam turbine and 632 MW from the four combustion turbines). Units 3 - 6 are 57 MW each. The total gross summer generation capacity of Bayside is therefore 1,878 MW. Once through cooling water is withdrawn from Hillsborough Bay for cooling the steam turbines associated with Unit 1 and Unit 2.

Calculation Purpose:

Estimate the forced evaporation due to the facility's thermal discharge by using the Edinger-Geyer Method.

Calculation Objectives:

1. List the calculation methodology and data required for the calculations.
2. Identify the inputs required for the calculations.
3. Estimate the waterbody evaporative water loss using the Edinger-Geyer Method for both design and actual flows.

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Calculation Methodology:

Formula 1 $EE = H_r * C * C1$

Units: cubic feet per second (cfs)

where:

EE = Evaporative loss due to thermal discharge, cfs
H_r = Power plant's heat rejection rate, BTU / hr
C = Evaporative loss coefficient, cfs / (10^9 BTU / hr)
C1 = Conversion from million gallons per day (mgd) to cfs

Formula 2 $C = (4450 / L) * (B * (K - 15.7)) / ((0.26 + B) * K) / 10^9$

Units: cfs / (10^9 BTU / hr)

where:

C = Evaporative loss coefficient, cfs / (10^9 BTU / hr)
B = Slope of saturated water vapor pressure, mmHg / °F
K = Surface heat exchange coefficient, BTU / sq. ft / °F
L = Latent heat of vaporization, BTU/lb

Formula 3 $L = 1093 - 0.56 * T_s$

Units: BTU / lb

where:

L = Latent heat of vaporization, BTU/lb
T_s = Background temperature of the receiving waterbody, °F

Formula 4 $B = 0.255 - 0.0088 * T + 0.000204 * T^2$

Units: mmHg / °F

where:

B = Slope of saturated water vapor pressure, mmHg / °F
$T = 1/2 * (T_s + T_d)$
T_d = Dew point temperature, °F

Formula 5 $K = 15.7 + (B + 0.26) * f(u)$

Units: BTU / sq. ft / °F

where:

K = Surface heat exchange coefficient, BTU / sq. ft / °F
B = Slope of saturated water vapor pressure, mmHg / °F
$f(u) = 70 + 0.7 * u^2$
u = wind speed, miles per hour (mph)

Formula 6 $H_r = C2 * \rho * Q * c * \Delta T$

Units: BTU / hr

where:

H_r = Power plant's heat rejection rate, BTU / hr
ρ = density of water, assumed to be 62.37 lb_M / ft^3 for all calculations
c = Specific heat of water, assumed to be 1 BTU / lb_M / °F for all calculations
ΔT = Change in temperature across the condensers, °F
Q = Circulating water flow rate, mgd
C2 = Conversion from mgd to cubic feet per hour

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Calculation Inputs for Unit 1:

Yearly Ambient Meteorological Data and Condenser Information for Unit 1

2012						
Month	Avg. Temp of Receiving Water (T_s)	Avg. Dew Point Temp (T_d)	Avg. Wind Speed (u)	Avg. Condenser Cooling Water (CCW) Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	63.84	50.26	5.10	244.92	16.36	[1,2,3,4]
February	67.11	56.86	6.72	251.80	13.97	[1,2,3,4]
March	73.98	60.03	6.94	251.06	12.92	[1,2,3,4]
April	76.09	59.33	6.93	237.60	13.43	[1,2,3,4]
May	81.33	66.65	6.71	247.65	12.61	[1,2,3,4]
June	82.88	70.27	7.70	248.34	13.72	[1,2,3,4]
July	90.10	72.68	5.06	250.89	14.22	[1,2,3,4]
August	87.63	73.06	5.58	248.50	14.53	[1,2,3,4]
September	85.02	70.53	5.30	250.10	12.95	[1,2,3,4]
October	81.39	64.19	6.58	251.06	12.26	[1,2,3,4]
November	69.56	53.87	5.27	234.96	12.05	[1,2,3,4]
December	65.17	55.13	5.65	251.23	9.08	[1,2,3,4]
2013						
Month	Avg. Temp of Receiving Water (Ts)	Avg. Dew Point Temp (Td)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	66.45	56.35	6.00	251.06	16.36	[1,2,3,4]
February	66.73	53.25	6.89	252.50	13.97	[1,2,3,4]
March	64.68	47.00	7.35	239.16	12.92	[1,2,3,4]
April	75.19	63.87	6.87	250.27	13.43	[1,2,3,4]
May	79.49	63.81	6.65	250.20	12.61	[1,2,3,4]
June	84.65	73.03	6.20	250.80	13.72	[1,2,3,4]
July	84.65	73.06	5.42	246.12	14.22	[1,2,3,4]
August	88.29	73.48	4.77	251.06	14.53	[1,2,3,4]
September	86.54	71.50	5.50	250.98	12.95	[1,2,3,4]
October	81.94	65.26	5.29	249.86	12.26	[1,2,3,4]
November	73.02	60.50	7.50	236.04	12.05	[1,2,3,4]
December	69.51	58.68	6.74	247.48	9.08	[1,2,3,4]
2014						
Month	Avg. Temp of Receiving Water (Ts)	Avg. Dew Point Temp (Td)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	62.91	48.06	7.03	251.91	16.36	[1,2,3,4]
February	66.81	56.68	6.04	249.48	13.97	[1,2,3,4]
March	71.71	55.52	7.42	245.43	12.92	[1,2,3,4]
April	76.44	61.70	7.57	250.98	13.43	[1,2,3,4]
May	82.99	64.74	6.71	247.65	12.61	[1,2,3,4]
June	86.28	69.80	6.40	233.55	13.72	[1,2,3,4]
July	89.05	72.35	5.74	249.69	14.22	[1,2,3,4]
August	89.21	72.74	5.52	250.89	14.53	[1,2,3,4]
September	87.28	71.60	5.30	250.98	12.95	[1,2,3,4]
October	81.69	62.71	5.26	248.67	12.26	[1,2,3,4]
November	69.79	52.13	7.17	249.74	12.05	[1,2,3,4]
December	66.64	55.84	5.52	125.87	9.08	[1,2,3,4]

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Calculation Inputs (cont'd):

2015						
Month	Avg. Temp of Receiving Water (Ts)	Avg. Dew Point Temp (Td)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	66.61	51.94	6.84	240.50	16.90	[1,2,3,4]
February	63.62	48.39	7.79	251.74	16.90	[1,2,3,4]
March	74.82	61.58	7.16	250.89	16.90	[1,2,3,4]
April	82.01	66.70	6.83	159.46	13.46	[1,2,3,4]
May	83.61	65.19	6.32	251.23	13.82	[1,2,3,4]
June	87.41	71.30	5.83	250.98	15.09	[1,2,3,4]
July	89.45	73.16	6.35	247.65	16.09	[1,2,3,4]
August	85.41	74.16	5.77	248.50	16.89	[1,2,3,4]
September	86.67	72.97	5.43	250.98	15.17	[1,2,3,4]
October	81.31	66.03	6.29	186.50	14.58	[1,2,3,4]
November	77.95	65.27	6.77	89.94	12.72	[1,2,3,4]
December	73.14	64.55	7.35	247.31	12.02	[1,2,3,4]
2016						
Month	Avg. Temp of Receiving Water (Ts)	Avg. Dew Point Temp (Td)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	66.46	49.39	7.16	253.10	16.36	[1,2,3,4]
February	65.10	49.59	7.83	214.11	13.97	[1,2,3,4]
March	73.39	60.06	7.61	251.74	12.92	[1,2,3,4]
April	77.84	60.10	7.53	252.03	13.40	[1,2,3,4]
May	83.73	64.90	6.84	250.89	11.39	[1,2,3,4]
June	87.27	73.07	6.53	251.15	12.36	[1,2,3,4]
July	90.71	74.19	5.03	252.08	12.36	[1,2,3,4]
August	88.56	74.52	6.13	251.23	12.16	[1,2,3,4]
September	85.89	73.73	6.07	252.03	10.73	[1,2,3,4]
October	81.27	64.94	7.55	69.32	9.95	[1,2,3,4]
November	72.87	56.17	6.07	0.00	11.38	[1,2,3,4]
December	71.27	58.94	6.48	199.11	6.14	[1,2,3,4]
2017						
Month	Avg. Temp of Receiving Water (Ts)	Avg. Dew Point Temp (Td)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	68.60	55.81	7.10	-	16.36	[1,2,3,4]
February	69.65	57.18	6.96	-	13.97	[1,2,3,4]
March	71.90	54.81	7.58	-	12.92	[1,2,3,4]
April	78.40	67.60	8.00	-	13.43	[1,2,3,4]
May	-	-	-	-	12.61	[1,2,3,4]
June	-	-	-	-	13.72	[1,2,3,4]
July	-	-	-	-	14.22	[1,2,3,4]
August	-	-	-	-	14.53	[1,2,3,4]
September	-	-	-	-	12.95	[1,2,3,4]
October	-	-	-	-	12.26	[1,2,3,4]
November	-	-	-	-	12.05	[1,2,3,4]
December	-	-	-	-	9.08	[1,2,3,4]

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Calculation Inputs (cont'd):

Design Flow:	266	MGD
Density (ρ):	62.37	LB_M / FT^3
Specific Heat of Water (c):	1	BTU / LB_M / °F
Design Temperature Rise:	16.9	°F

Conversions:

1	cubic foot	=	7.481	gallons
1	MG (million gallons)	=	1,000,000	gallons
1	day	=	24	hours
1	hour	=	3600	seconds

C1 = CFS x 0.646 = MGD
C2 = MGD x 5570 = cubic feet per hour

Assumptions:

1. The selection of the nearest meteorological station is reflective of conditions at site.

Notes:

1. Edinger-Geyer Method is an empirical formula developed under Pennsylvania conditions. Authors have evaluated other locations within the United States with success.

References:

[1] NOAA Tidal Observation Station (combination of McKay Bay Entrance and Old Tampa Port), 2012-2017.
[2] Wunderground at the Tampa International Airport, 2012-2017.
[3] Measured Cooling Water Flow 2012-mid 2017.
[4] Temp change across Unit are represented by 2015 and 2016 data.

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Calculations:

1. Monthly Forced Evaporation due to Thermal Discharge at Unit 1

1a. Calculate monthly evaporative loss coefficient (C)

Formulas Used: 2, 3, 4, 5

Given:

Calculate:

2012						
Month	L	T	B	f(u)	K	C
January	1057.25	57.05	0.42	88.18	75.39	2.1E-09
February	1055.42	61.99	0.49	101.65	92.28	2.3E-09
March	1051.57	67.01	0.58	103.67	102.92	2.5E-09
April	1050.39	67.71	0.59	103.65	104.26	2.5E-09
May	1047.45	73.99	0.72	101.51	115.25	2.7E-09
June	1046.59	76.58	0.78	111.50	131.37	2.8E-09
July	1042.54	81.39	0.89	87.95	116.86	2.9E-09
August	1043.93	80.35	0.86	91.80	118.96	2.8E-09
September	1045.39	77.78	0.80	89.66	111.16	2.8E-09
October	1047.42	72.79	0.70	100.31	111.53	2.7E-09
November	1054.05	61.71	0.49	89.42	82.66	2.2E-09
December	1056.51	60.15	0.46	92.31	82.50	2.2E-09
2013						
Month	L	T	B	f(u)	K	C
January	1055.79	61.40	0.48	95.20	86.51	2.2E-09
February	1055.63	59.99	0.46	103.26	90.17	2.2E-09
March	1056.78	55.84	0.40	107.87	86.86	2.1E-09
April	1050.90	69.53	0.63	103.01	107.30	2.6E-09
May	1048.48	71.65	0.67	100.91	109.72	2.6E-09
June	1045.59	78.84	0.83	96.91	121.26	2.8E-09
July	1045.59	78.86	0.83	90.56	114.38	2.8E-09
August	1043.56	80.89	0.88	85.96	113.51	2.8E-09
September	1044.54	79.02	0.83	91.18	115.40	2.8E-09
October	1047.11	73.60	0.71	89.59	102.81	2.6E-09
November	1052.11	66.76	0.58	109.38	107.22	2.5E-09
December	1054.07	64.10	0.53	101.82	96.04	2.4E-09
2014						
Month	L	T	B	f(u)	K	C
January	1057.77	55.49	0.39	104.62	84.20	2.1E-09
February	1055.59	61.74	0.49	95.50	87.26	2.3E-09
March	1052.84	63.61	0.52	108.53	100.43	2.4E-09
April	1050.19	69.07	0.62	110.08	112.62	2.6E-09
May	1046.53	73.87	0.72	101.51	114.98	2.7E-09
June	1044.68	78.04	0.81	98.67	121.35	2.8E-09
July	1043.13	80.70	0.87	93.08	121.20	2.9E-09
August	1043.04	80.98	0.88	91.30	119.79	2.9E-09
September	1044.12	79.44	0.84	89.66	114.62	2.8E-09
October	1047.25	72.20	0.68	89.35	99.96	2.6E-09
November	1053.92	60.96	0.48	105.95	93.75	2.3E-09
December	1055.68	61.24	0.48	91.30	83.37	2.2E-09

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Calculations (cont'd):

2015						
Month	L	T	B	f(u)	K	C
January	1055.70	59.27	0.45	102.74	88.65	2.2E-09
February	1057.37	56.01	0.40	112.43	90.14	2.1E-09
March	1051.10	68.20	0.60	105.90	107.16	2.5E-09
April	1047.07	74.35	0.73	102.69	117.21	2.7E-09
May	1046.18	74.40	0.73	97.98	112.65	2.7E-09
June	1044.05	79.36	0.84	93.82	119.03	2.8E-09
July	1042.91	81.31	0.89	98.27	128.52	2.9E-09
August	1045.17	79.79	0.85	93.34	119.45	2.8E-09
September	1044.46	79.82	0.85	90.66	116.55	2.8E-09
October	1047.47	73.67	0.71	97.70	110.85	2.7E-09
November	1049.35	71.61	0.67	102.05	110.70	2.6E-09
December	1052.04	68.84	0.62	107.87	110.20	2.6E-09
2016						
Month	L	T	B	f(u)	K	C
January	1055.78	57.92	0.43	105.90	88.74	2.2E-09
February	1056.54	57.34	0.42	112.89	92.60	2.2E-09
March	1051.90	66.73	0.58	110.57	108.15	2.5E-09
April	1049.41	68.97	0.62	109.73	112.09	2.6E-09
May	1046.11	74.32	0.73	102.74	117.17	2.7E-09
June	1044.13	80.17	0.86	99.88	127.62	2.9E-09
July	1042.20	82.45	0.92	87.73	118.89	2.9E-09
August	1043.40	81.54	0.89	96.30	126.80	2.9E-09
September	1044.90	79.81	0.85	95.76	122.20	2.8E-09
October	1047.49	73.10	0.70	109.88	121.39	2.7E-09
November	1052.19	64.52	0.54	95.76	91.97	2.4E-09
December	1053.09	65.10	0.55	99.43	95.91	2.4E-09
2017						
Month	L	T	B	f(u)	K	C
January	1054.59	62.20	0.50	105.25	95.37	2.3E-09
February	1054.00	63.41	0.52	103.95	96.50	2.4E-09
March	1052.74	63.35	0.52	110.23	101.26	2.4E-09
April	1049.10	73.00	0.70	114.80	125.87	2.7E-09
May	-	-	-	-	-	-
June	-	-	-	-	-	-
July	-	-	-	-	-	-
August	-	-	-	-	-	-
September	-	-	-	-	-	-
October	-	-	-	-	-	-
November	-	-	-	-	-	-
December	-	-	-	-	-	-

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Calculations (cont'd):

1. Monthly Forced Evaporation due to Thermal Discharge at Unit 1

1b. Calculate monthly heat rejection rate (H_r) and forced evaporation (EE)

Formulas Used: 1, 6

Calculate:

2012				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	1.56E+09	2.07	1.39E+09	1.85
February	1.56E+09	2.31	1.22E+09	1.81
March	1.56E+09	2.50	1.13E+09	1.80
April	1.56E+09	2.53	1.11E+09	1.79
May	1.56E+09	2.72	1.08E+09	1.89
June	1.56E+09	2.83	1.18E+09	2.15
July	1.56E+09	2.89	1.24E+09	2.29
August	1.56E+09	2.87	1.25E+09	2.31
September	1.56E+09	2.79	1.13E+09	2.01
October	1.56E+09	2.68	1.07E+09	1.84
November	1.56E+09	2.25	9.84E+08	1.42
December	1.56E+09	2.21	7.92E+08	1.12
2013				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	1.56E+09	2.27	1.43E+09	2.07
February	1.56E+09	2.25	1.23E+09	1.76
March	1.56E+09	2.11	1.07E+09	1.45
April	1.56E+09	2.58	1.17E+09	1.93
May	1.56E+09	2.65	1.10E+09	1.86
June	1.56E+09	2.85	1.20E+09	2.18
July	1.56E+09	2.82	1.22E+09	2.20
August	1.56E+09	2.86	1.27E+09	2.32
September	1.56E+09	2.83	1.13E+09	2.05
October	1.56E+09	2.66	1.06E+09	1.81
November	1.56E+09	2.51	9.88E+08	1.59
December	1.56E+09	2.39	7.80E+08	1.19
2014				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	1.56E+09	2.08	1.43E+09	1.91
February	1.56E+09	2.28	1.21E+09	1.77
March	1.56E+09	2.40	1.10E+09	1.69
April	1.56E+09	2.59	1.17E+09	1.94
May	1.56E+09	2.72	1.08E+09	1.89
June	1.56E+09	2.84	1.11E+09	2.02
July	1.56E+09	2.89	1.23E+09	2.28
August	1.56E+09	2.89	1.27E+09	2.34
September	1.56E+09	2.84	1.13E+09	2.05
October	1.56E+09	2.62	1.06E+09	1.78
November	1.56E+09	2.30	1.05E+09	1.54
December	1.56E+09	2.24	3.97E+08	0.57

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Calculations (cont'd):

2015				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	1.56E+09	2.22	1.41E+09	2.01
February	1.56E+09	2.13	1.48E+09	2.02
March	1.56E+09	2.55	1.47E+09	2.40
April	1.56E+09	2.74	7.45E+08	1.31
May	1.56E+09	2.73	1.21E+09	2.10
June	1.56E+09	2.85	1.32E+09	2.40
July	1.56E+09	2.93	1.38E+09	2.59
August	1.56E+09	2.86	1.46E+09	2.67
September	1.56E+09	2.85	1.32E+09	2.41
October	1.56E+09	2.70	9.45E+08	1.63
November	1.56E+09	2.65	3.98E+08	0.67
December	1.56E+09	2.58	1.03E+09	1.70
2016				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	1.56E+09	2.18	1.44E+09	2.01
February	1.56E+09	2.18	1.04E+09	1.45
March	1.56E+09	2.52	1.13E+09	1.82
April	1.56E+09	2.59	1.17E+09	1.95
May	1.56E+09	2.74	9.93E+08	1.74
June	1.56E+09	2.90	1.08E+09	2.00
July	1.56E+09	2.92	1.08E+09	2.02
August	1.56E+09	2.92	1.06E+09	1.99
September	1.56E+09	2.87	9.40E+08	1.73
October	1.56E+09	2.73	2.39E+08	0.42
November	1.56E+09	2.39	0.00E+00	0.00
December	1.56E+09	2.42	4.25E+08	0.66
2017				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	1.56E+09	2.34	-	-
February	1.56E+09	2.38	-	-
March	1.56E+09	2.40	-	-
April	1.56E+09	2.73	-	-
May	1.56E+09	-	-	-
June	1.56E+09	-	-	-
July	1.56E+09	-	-	-
August	1.56E+09	-	-	-
September	1.56E+09	-	-	-
October	1.56E+09	-	-	-
November	1.56E+09	-	-	-
December	1.56E+09	-	-	-

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Unit 1 Calculation Summary:

Forced Evaporation between 2012 and 2016				
Month	Design Flow		Actual Flow	
	Maximum	Average	Maximum	Average
	(MGD)	(MGD)	(MGD)	(MGD)
January	2.27	2.16	2.07	1.97
February	2.31	2.23	2.02	1.76
March	2.55	2.42	2.40	1.83
April	2.74	2.61	1.95	1.78
May	2.74	2.71	2.10	1.90
June	2.90	2.85	2.40	2.15
July	2.93	2.89	2.59	2.28
August	2.92	2.88	2.67	2.33
September	2.87	2.84	2.41	2.05
October	2.73	2.68	1.84	1.50
November	2.65	2.42	1.59	1.04
December	2.58	2.37	1.70	1.05

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Calculation Inputs for Unit 2:

Yearly Ambient Meteorological Data and Condenser Information for Unit 2

2012						
Month	Avg. Temp of Receiving Water (T_s)	Avg. Dew Point Temp (T_d)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	63.84	50.26	5.10	342.35	16.36	[1,2,3,4]
February	67.11	56.86	6.72	287.40	13.97	[1,2,3,4]
March	73.98	60.03	6.94	0.00	12.92	[1,2,3,4]
April	76.09	59.33	6.93	326.06	13.43	[1,2,3,4]
May	81.33	66.65	6.71	340.72	12.61	[1,2,3,4]
June	82.88	70.27	7.70	338.16	13.72	[1,2,3,4]
July	90.10	72.68	5.06	342.81	14.22	[1,2,3,4]
August	87.63	73.06	5.58	342.35	14.53	[1,2,3,4]
September	85.02	70.53	5.30	328.56	12.95	[1,2,3,4]
October	81.39	64.19	6.58	337.24	12.26	[1,2,3,4]
November	69.56	53.87	5.27	293.52	12.05	[1,2,3,4]
December	65.17	55.13	5.65	290.09	9.08	[1,2,3,4]
2013						
Month	Avg. Temp of Receiving Water (Ts)	Avg. Dew Point Temp (Td)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	66.45	56.35	6.00	340.95	16.36	[1,2,3,4]
February	66.73	53.25	6.89	344.06	13.97	[1,2,3,4]
March	64.68	47.00	7.35	341.19	12.92	[1,2,3,4]
April	75.19	63.87	6.87	316.25	13.43	[1,2,3,4]
May	79.49	63.81	6.65	249.68	12.61	[1,2,3,4]
June	84.65	73.03	6.20	341.76	13.72	[1,2,3,4]
July	84.65	73.06	5.42	334.92	14.22	[1,2,3,4]
August	88.29	73.48	4.77	341.88	14.53	[1,2,3,4]
September	86.54	71.50	5.50	342.00	12.95	[1,2,3,4]
October	81.94	65.26	5.29	342.35	12.26	[1,2,3,4]
November	73.02	60.50	7.50	323.71	12.05	[1,2,3,4]
December	69.51	58.68	6.74	342.35	9.08	[1,2,3,4]
2014						
Month	Avg. Temp of Receiving Water (Ts)	Avg. Dew Point Temp (Td)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	62.91	48.06	7.03	169.08	16.36	[1,2,3,4]
February	66.81	56.68	6.04	267.94	13.97	[1,2,3,4]
March	71.71	55.52	7.42	328.18	12.92	[1,2,3,4]
April	76.44	61.70	7.57	341.28	13.43	[1,2,3,4]
May	82.99	64.74	6.71	340.49	12.61	[1,2,3,4]
June	86.28	69.80	6.40	343.44	13.72	[1,2,3,4]
July	89.05	72.35	5.74	318.19	14.22	[1,2,3,4]
August	89.21	72.74	5.52	340.95	14.53	[1,2,3,4]
September	87.28	71.60	5.30	336.48	12.95	[1,2,3,4]
October	81.69	62.71	5.26	342.12	12.26	[1,2,3,4]
November	69.79	52.13	7.17	241.68	12.05	[1,2,3,4]
December	66.64	55.84	5.52	342.12	9.08	[1,2,3,4]

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Calculation Inputs (cont'd):

2015						
Month	Avg. Temp of Receiving Water (Ts)	Avg. Dew Point Temp (Td)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	66.61	51.94	6.84	343.74	16.90	[1,2,3,4]
February	63.62	48.39	7.79	271.29	16.90	[1,2,3,4]
March	74.82	61.58	7.16	268.72	16.90	[1,2,3,4]
April	82.01	66.70	6.83	340.80	13.46	[1,2,3,4]
May	83.61	65.19	6.32	342.58	13.82	[1,2,3,4]
June	87.41	71.30	5.83	342.00	15.09	[1,2,3,4]
July	89.45	73.16	6.35	343.97	16.09	[1,2,3,4]
August	85.41	74.16	5.77	343.51	16.89	[1,2,3,4]
September	86.67	72.97	5.43	342.00	15.17	[1,2,3,4]
October	81.31	66.03	6.29	342.58	14.58	[1,2,3,4]
November	77.95	65.27	6.77	307.92	12.72	[1,2,3,4]
December	73.14	64.55	7.35	217.63	12.02	
2016						
Month	Avg. Temp of Receiving Water (Ts)	Avg. Dew Point Temp (Td)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	66.46	49.39	7.16	339.56	16.36	[1,2,3,4]
February	65.10	49.59	7.83	326.23	13.97	[1,2,3,4]
March	73.39	60.06	7.61	232.72	12.92	[1,2,3,4]
April	77.84	60.10	7.53	331.68	13.40	[1,2,3,4]
May	83.73	64.90	6.84	341.19	11.39	[1,2,3,4]
June	87.27	73.07	6.53	342.48	12.36	[1,2,3,4]
July	90.71	74.19	5.03	338.17	12.36	[1,2,3,4]
August	88.56	74.52	6.13	342.35	12.16	[1,2,3,4]
September	85.89	73.73	6.07	233.76	10.73	[1,2,3,4]
October	81.27	64.94	7.55	345.14	9.95	[1,2,3,4]
November	72.87	56.17	6.07	345.12	11.38	[1,2,3,4]
December	71.27	58.94	6.48	343.97	6.14	[1,2,3,4]
2017						
Month	Avg. Temp of Receiving Water (Ts)	Avg. Dew Point Temp (Td)	Avg. Wind Speed (u)	Avg. CCW Flow (Q)	Avg. Change in Temp. Across Unit (ΔT)	Ref.
	°F	°F	MPH	MGD	°F	
January	68.60	55.81	7.10	-	16.36	[1,2,3,4]
February	69.65	57.18	6.96	-	13.97	[1,2,3,4]
March	71.90	54.81	7.58	-	12.92	[1,2,3,4]
April	78.40	67.60	8.00	-	13.43	[1,2,3,4]
May	-	-	-	-	12.61	
June	-	-	-	-	13.72	
July	-	-	-	-	14.22	
August	-	-	-	-	14.53	
September	-	-	-	-	12.95	
October	-	-	-	-	12.26	
November	-	-	-	-	12.05	
December	-	-	-	-	9.08	

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Calculation Inputs (cont'd):

Design Flow:	363	MGD
Density (ρ):	62.37	LB_M / FT^3
Specific Heat of Water (c):	1	BTU / LB_M / °F
Design Temperature Rise:	16.9	°F

Conversions:

1	cubic foot	=	7.481	gallons
1	MG (million gallons)	=	1000000	gallons
1	day	=	24	hours
1	hour	=	3600	seconds

C1 = CFS x 0.646 = MGD
C2 = MGD x 5570 = cubic feet per hour

Assumptions:

1. The selection of the nearest meteorological station is reflective of conditions at site.

Notes:

1. Edinger-Geyer Method is an empirical formula developed under Pennsylvania conditions. Authors have evaluated other locations within the United States with success.

References:

[1] NOAA Tidal Observation Station (combination of McKay Bay Entrance and Old Tampa Port), 2012-2017.
[2] Wunderground at the Tampa International Airport, 2012-2017.
[3] Measured Cooling Water Flow 2012-mid 2017.
[4] Temp change across Unit are represented by 2015 and 2016 data.

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Calculations:

1. Monthly Forced Evaporation due to Thermal Discharge at Unit 2

1a. Calculate monthly evaporative loss coefficient (C)

Formulas Used: 2, 3, 4, 5

Given:

Calculate:

2012						
Month	L	T	B	f(u)	K	C
January	1057.25	57.05	0.42	88.18	75.39	2.1E-09
February	1055.42	61.99	0.49	101.65	92.28	2.3E-09
March	1051.57	67.01	0.58	103.67	102.92	2.5E-09
April	1050.39	67.71	0.59	103.65	104.26	2.5E-09
May	1047.45	73.99	0.72	101.51	115.25	2.7E-09
June	1046.59	76.58	0.78	111.50	131.37	2.8E-09
July	1042.54	81.39	0.89	87.95	116.86	2.9E-09
August	1043.93	80.35	0.86	91.80	118.96	2.8E-09
September	1045.39	77.78	0.80	89.66	111.16	2.8E-09
October	1047.42	72.79	0.70	100.31	111.53	2.7E-09
November	1054.05	61.71	0.49	89.42	82.66	2.2E-09
December	1056.51	60.15	0.46	92.31	82.50	2.2E-09
2013						
Month	L	T	B	f(u)	K	C
January	1055.79	61.40	0.48	95.20	86.51	2.2E-09
February	1055.63	59.99	0.46	103.26	90.17	2.2E-09
March	1056.78	55.84	0.40	107.87	86.86	2.1E-09
April	1050.90	69.53	0.63	103.01	107.30	2.6E-09
May	1048.48	71.65	0.67	100.91	109.72	2.6E-09
June	1045.59	78.84	0.83	96.91	121.26	2.8E-09
July	1045.59	78.86	0.83	90.56	114.38	2.8E-09
August	1043.56	80.89	0.88	85.96	113.51	2.8E-09
September	1044.54	79.02	0.83	91.18	115.40	2.8E-09
October	1047.11	73.60	0.71	89.59	102.81	2.6E-09
November	1052.11	66.76	0.58	109.38	107.22	2.5E-09
December	1054.07	64.10	0.53	101.82	96.04	2.4E-09
2014						
Month	L	T	B	f(u)	K	C
January	1057.77	55.49	0.39	104.62	84.20	2.1E-09
February	1055.59	61.74	0.49	95.50	87.26	2.3E-09
March	1052.84	63.61	0.52	108.53	100.43	2.4E-09
April	1050.19	69.07	0.62	110.08	112.62	2.6E-09
May	1046.53	73.87	0.72	101.51	114.98	2.7E-09
June	1044.68	78.04	0.81	98.67	121.35	2.8E-09
July	1043.13	80.70	0.87	93.08	121.20	2.9E-09
August	1043.04	80.98	0.88	91.30	119.79	2.9E-09
September	1044.12	79.44	0.84	89.66	114.62	2.8E-09
October	1047.25	72.20	0.68	89.35	99.96	2.6E-09
November	1053.92	60.96	0.48	105.95	93.75	2.3E-09
December	1055.68	61.24	0.48	91.30	83.37	2.2E-09

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Calculations (cont'd):

2015						
Month	L	T	B	f(u)	K	C
January	1055.70	59.27	0.45	102.74	88.65	2.2E-09
February	1057.37	56.01	0.40	112.43	90.14	2.1E-09
March	1051.10	68.20	0.60	105.90	107.16	2.5E-09
April	1047.07	74.35	0.73	102.69	117.21	2.7E-09
May	1046.18	74.40	0.73	97.98	112.65	2.7E-09
June	1044.05	79.36	0.84	93.82	119.03	2.8E-09
July	1042.91	81.31	0.89	98.27	128.52	2.9E-09
August	1045.17	79.79	0.85	93.34	119.45	2.8E-09
September	1044.46	79.82	0.85	90.66	116.55	2.8E-09
October	1047.47	73.67	0.71	97.70	110.85	2.7E-09
November	1049.35	71.61	0.67	102.05	110.70	2.6E-09
December	1052.04	68.84	0.62	107.87	110.20	2.6E-09
2016						
Month	L	T	B	f(u)	K	C
January	1055.78	57.92	0.43	105.90	88.74	2.2E-09
February	1056.54	57.34	0.42	112.89	92.60	2.2E-09
March	1051.90	66.73	0.58	110.57	108.15	2.5E-09
April	1049.41	68.97	0.62	109.73	112.09	2.6E-09
May	1046.11	74.32	0.73	102.74	117.17	2.7E-09
June	1044.13	80.17	0.86	99.88	127.62	2.9E-09
July	1042.20	82.45	0.92	87.73	118.89	2.9E-09
August	1043.40	81.54	0.89	96.30	126.80	2.9E-09
September	1044.90	79.81	0.85	95.76	122.20	2.8E-09
October	1047.49	73.10	0.70	109.88	121.39	2.7E-09
November	1052.19	64.52	0.54	95.76	91.97	2.4E-09
December	1053.09	65.10	0.55	99.43	95.91	2.4E-09
2017						
Month	L	T	B	f(u)	K	C
January	1054.59	62.20	0.50	105.25	95.37	2.3E-09
February	1054.00	63.41	0.52	103.95	96.50	2.4E-09
March	1052.74	63.35	0.52	110.23	101.26	2.4E-09
April	1049.10	73.00	0.70	114.80	125.87	2.7E-09
May	-	-	-	-	-	-
June	-	-	-	-	-	-
July	-	-	-	-	-	-
August	-	-	-	-	-	-
September	-	-	-	-	-	-
October	-	-	-	-	-	-
November	-	-	-	-	-	-
December	-	-	-	-	-	-

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Calculations (cont'd):

1. **Monthly Forced Evaporation due to Thermal Discharge at Unit 2**

1b. Calculate monthly heat rejection rate (H_r) and forced evaporation (EE)

Formulas Used: 1, 6

Calculate:

2012				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	2.13E+09	2.83	1.95E+09	2.58
February	2.13E+09	3.16	1.40E+09	2.07
March	2.13E+09	3.41	0.00E+00	0.00
April	2.13E+09	3.45	1.52E+09	2.46
May	2.13E+09	3.71	1.49E+09	2.60
June	2.13E+09	3.86	1.61E+09	2.92
July	2.13E+09	3.94	1.69E+09	3.13
August	2.13E+09	3.92	1.73E+09	3.18
September	2.13E+09	3.80	1.48E+09	2.64
October	2.13E+09	3.66	1.44E+09	2.47
November	2.13E+09	3.07	1.23E+09	1.77
December	2.13E+09	3.01	9.15E+08	1.29
2013				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	2.13E+09	3.09	1.94E+09	2.81
February	2.13E+09	3.07	1.67E+09	2.40
March	2.13E+09	2.88	1.53E+09	2.07
April	2.13E+09	3.52	1.48E+09	2.44
May	2.13E+09	3.61	1.09E+09	1.85
June	2.13E+09	3.88	1.63E+09	2.97
July	2.13E+09	3.85	1.65E+09	2.99
August	2.13E+09	3.90	1.73E+09	3.16
September	2.13E+09	3.86	1.54E+09	2.79
October	2.13E+09	3.63	1.46E+09	2.49
November	2.13E+09	3.43	1.36E+09	2.18
December	2.13E+09	3.26	1.08E+09	1.65
2014				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	2.13E+09	2.84	9.61E+08	1.28
February	2.13E+09	3.11	1.30E+09	1.90
March	2.13E+09	3.27	1.47E+09	2.26
April	2.13E+09	3.54	1.59E+09	2.64
May	2.13E+09	3.71	1.49E+09	2.60
June	2.13E+09	3.87	1.64E+09	2.97
July	2.13E+09	3.94	1.57E+09	2.91
August	2.13E+09	3.94	1.72E+09	3.18
September	2.13E+09	3.87	1.51E+09	2.75
October	2.13E+09	3.57	1.46E+09	2.44
November	2.13E+09	3.13	1.01E+09	1.49
December	2.13E+09	3.06	1.08E+09	1.55

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Calculations (cont'd):

2015				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	2.13E+09	3.03	2.02E+09	2.87
February	2.13E+09	2.91	1.59E+09	2.17
March	2.13E+09	3.48	1.58E+09	2.58
April	2.13E+09	3.74	1.59E+09	2.79
May	2.13E+09	3.72	1.65E+09	2.87
June	2.13E+09	3.89	1.79E+09	3.27
July	2.13E+09	3.99	1.92E+09	3.60
August	2.13E+09	3.90	2.02E+09	3.69
September	2.13E+09	3.89	1.80E+09	3.29
October	2.13E+09	3.68	1.74E+09	3.00
November	2.13E+09	3.61	1.36E+09	2.31
December	2.13E+09	3.51	9.09E+08	1.50
2016				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	2.13E+09	2.98	1.93E+09	2.70
February	2.13E+09	2.98	1.58E+09	2.21
March	2.13E+09	3.43	1.04E+09	1.68
April	2.13E+09	3.54	1.54E+09	2.56
May	2.13E+09	3.74	1.35E+09	2.37
June	2.13E+09	3.95	1.47E+09	2.73
July	2.13E+09	3.98	1.45E+09	2.71
August	2.13E+09	3.99	1.45E+09	2.71
September	2.13E+09	3.92	8.72E+08	1.60
October	2.13E+09	3.72	1.19E+09	2.08
November	2.13E+09	3.25	1.36E+09	2.08
December	2.13E+09	3.30	7.34E+08	1.14
2017				
Month	Design Flow		Actual Flow	
	H_r (BTU/HR)	EE (MGD)	H_r (BTU/HR)	EE (MGD)
January	2.13E+09	3.19	-	-
February	2.13E+09	3.24	-	-
March	2.13E+09	3.27	-	-
April	2.13E+09	3.73	-	-
May	2.13E+09	-	-	-
June	2.13E+09	-	-	-
July	2.13E+09	-	-	-
August	2.13E+09	-	-	-
September	2.13E+09	-	-	-
October	2.13E+09	-	-	-
November	2.13E+09	-	-	-
December	2.13E+09	-	-	-

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Unit 2 Calculation Summary:

Forced Evaporation between 2012 and 2016				
Month	Design Flow		Actual Flow	
	Maximum	Average	Maximum	Average
	(MGD)	(MGD)	(MGD)	(MGD)
January	3.09	2.95	2.87	2.45
February	3.16	3.04	2.40	2.15
March	3.48	3.29	2.58	1.72
April	3.74	3.56	2.79	2.58
May	3.74	3.70	2.87	2.46
June	3.95	3.89	3.27	2.97
July	3.99	3.94	3.60	3.07
August	3.99	3.93	3.69	3.18
September	3.92	3.87	3.29	2.61
October	3.72	3.65	3.00	2.49
November	3.61	3.30	2.31	1.97
December	3.51	3.23	1.65	1.43

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Appendix 12-E

Estimated Evaporation Due to a Hypothetical Cooling Tower

TECO | H.L. Culbreath Bayside Power Station

Revision: 0
Issue Date: 10/13/2017

Appendix 12-E. Estimated Evaporation due to a Hypothetical Cooling Tower

Originator: **Nicholas Thomas, PhD** Date: 4/3/2017

Reviewer: **Samantha Schneider, EIT** Date: 5/18/2017

Approver: **Radhika de Silva, PhD, PE** Date: 6/9/2017

Revision No.	Revised by:	Approved by:	Description
0	-	-	-

Calculation Summary:

	Unit 1	Unit 2	Total
Cooling Tower Evaporation Rate (GPM):	2,498	3,407	5,906
Drift Flow Rate (GPM):	0.9	1.3	2.2
Blowdown Flow Rate (GPM):	8,327	11,356	19,683
Make-up Flow Rate (GPM):	10,827	14,764	25,591
Dilution Water Flow Rate (GPM):	16,655	22,711	39,366
Reduction in Water Withdrawal (GPM:	157,318	214,525	371,843
Percent Reduction in Water Use (%):	85.1%	85.1%	85.1%

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System Description:

Bayside Power Station is fossil fuel driven power generation plant consisting of two combined cycle gas turbine generation units (1 & 2) and four natural gas fired peaking units (3 - 6). The gross summer generation capacity of Unit 1 is 710 MW (with 236 MW from the steam turbine and 474 MW from the three combustion turbines). The gross summer generating capacity of Unit 2 is 940 MW (with 308 MW from the steam turbine and 632 MW from the four combustion turbines). Units 3 - 6 are 57 MW each. The total gross summer generation capacity of Bayside is therefore 1,878 MW. Once through cooling water is withdrawn from Hillsborough Bay for cooling the steam turbines associated with Unit 1 and Unit 2. [5].

Calculation Purpose:

Estimate the cooling tower evaporation from the hypothetical cooling tower installation. In addition, estimate the percent change in cooling water withdrawal rate and evaporative loss rate if the station were converted from once-through cooling to closed-cycle cooling.

Calculation Objectives:

1. List the calculation methodology and data required for the calculations.
2. Identify the inputs required for the calculations.
3. Estimate the cooling tower evaporative water loss.
4. Estimate the percent reduction in water withdrawal rate if the station were retrofitted from once-through cooling to closed-cycle cooling.

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Calculation Methodology:

Reference/Note:

Formula 1 **$E = 0.0008 * R * Q_{CT}$** [1], Assumption 4
Units: GPM

where:

E = Rate of Cooling Tower Evaporation (GPM)
R = Cooling Tower Range (°F), assumed to be the same as the rise in temperature across the condenser, ΔT
Q_{CT} = Cooling Tower Water Flowrate (GPM)

Formula 2 **$D = DE * Q_{CT}$** [1], Assumption 4
Units: GPM

where:

D = Drift Flow Rate (GPM)
DE = Drift Eliminator Efficiency (%)
Q_{CT} = Cooling Tower Water Flowrate (GPM)

Formula 3 **$B = (E - [(C - 1) * D]) / (C - 1)$** [1]
Units: GPM

where:

B = Blowdown Flow Rate (GPM)
E = Rate of Cooling Tower Evaporation (GPM)
C = Cooling Tower Cycles of Concentration

Formula 4 **$M = E + B + D$**
Units: GPM

where:

M = Make-up Flow Rate (GPM)

Formula 5 **$Q_R = Q_O - M$**
Units: GPM

where:

Q_R = Water Withdrawal Reduction (GPM)
Q_O = Once-Through Flow Rate (GPM)

Formula 6 **$PR = Q_R / Q_O$**
Units: %

where:

PR = Percent Reduction in Water Withdrawal Rate (%)

Formula 7 **$B * C + Q_D * 1 = (B + Q_D) * 110\%$**
$Q_D = (C - 110\%) / (110\% - 1) * B$ *Rearranged*

where:

Q_D = Additional dilution water withdrawn to dilute cooling tower blowdown to meet the Florida 110 percent chloride limit

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Calculation Inputs:

Parameters and Variables		Units	Unit 1	Unit 2	Reference/Note
Condenser cooling water flow rate	Q_C	GPM	184,800	252,000	[2], [3]
Condenser temperature rise	ΔT	°F	16.9	16.9	Note 1
Cooling tower range	R	°F	16.9	16.9	Assumption 1
Cooling tower water flow rate	Q_{CT}	GPM	184,800	252,000	Assumption 2
Cycles of concentration	C	-	1.3	1.3	Assumption 3
Florida chloride discharge limit		%	110%	110%	[6]
Drift eliminator efficiency	DE	%	0.0005%	0.0005%	[4]
Once-through flow rate	Q_O	GPM	184,800	252,000	Assumption 4

Assumptions:

1. Cooling tower range is equivalent to the condenser temperature rise.
2. Cooling tower water flow rate is the same as the condenser water flow rate.
3. The evaluation assumes 1.3 cycles of concentration due to brackish water source and Florida chloride discharge limit of 110 percent of receiving water. The evaluation assumes that the discharge would be diluted with additional source water so the blowdown would meet the 110 percent requirement.
4. Once-through flowrate is assumed to be equal to the condenser cooling water flow rate.

Notes:

1. Condenser temperature rise calculated using the unit condenser duty of 1,567,000,000 BTU/hr [2] for Unit 1 and nit condenser duty of 2,130,000,000 BTU/hr [3] for Unit 2.
2. Minor losses of water due to potential leaks, windage, and forced evaporation in the receiving waterbody are not included in these calculations.
3. Per TECO (2016), Bayside Steam Turbine 1 gross Summer Capacity is 236 MW and gross Winter Capacity is 246 MW. Bayside Steam Turbine 2 gross Summer Capacity is 308 MW and gross Winter capacity is 318 MW. Because cooling tower operations are more constrained during the summer than winter, summer capacities are used in the evaluation. Also based on that same Memo, internal plant load throughout the year is approximately 3 MW.

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References:

[1] SPX Cooling Technologies, INC. 2009. Cooling Tower Fundamentals.
[2] Tampa Electric Company. [Undated]. Bayside Unit #1 Specification 01-5988 Alstom condenser data sheet
[3] Tampa Electric Company. [Undated]. Bayside Unit #2 Alstom condenser data sheet
[4] EvapTech. 2017. Cooling Tower Quote TECO Bayside dated January 23, 2017.
[5] Tampa Electric Company (2016). Generating Unit Capability Update Memo from Tom Hernandez (dated July 1, 2016).
[6] Florida Administrative Code (FAC). 2015. Chapter 62-302: Surface Water Quality Standards, Part 62-302.530Table: Surface Water Quality Criteria, Effective May 19, 2015. At https://www.epa.gov/sites/production/files/2014-12/documents/fl_section62-302.pdf.

Calculations:

1. Estimate Cooling Tower Evaporation

Formulas Used: 1, 2, 3, 4

Parameters and Variables		Units	Unit 1	Unit 2	Total
Evaporation rate	E	GPM	2,498	3,407	5,906
Drift flow rate	D	GPM	0.9	1.3	2.2
Blowdown rate	B	GPM	8,327	11,356	19,683
Makeup rate	M	GPM	10,827	14,764	25,591

2. Dilution Water Needed to Meet Florida 110% Chloride Requirement

Formulas Used: 7

Parameters and Variables		Units	Unit 1	Unit 2	Total
Dilution water needed	Q_D	GPM	16,655	22,711	39,366

3. Estimate Percent Reduction in Water Use

Formulas Used: 5, 6

Parameters and Variables		Units	Unit 1	Unit 2	Total
Once-through rate	Q_O	GPM	184,800	252,000	436,800
Makeup rate	M	GPM	10,827	14,764	25,591
Makeup and dilution rate	$M+Q_D$	GPM	27,482	37,475	64,957
Reduction in water withdrawal	Q_R	GPM	157,318	214,525	371,843
Percent reduction in water withdrawal rate	PR	%	85.1%	85.1%	85.1%

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Appendix 12-F

Estimated Energy Use by Existing Pumps and Hypothetical VSPs

Originator:	**Scott Loughery, PE**	6/28/2017
Reviewer:	**Samantha Schneider, EIT**	10/12/2017
Approver:	**Radhika de Silva, PhD, PE**	10/12/2017

Revision No.	Revised by:	Approved by:	Description
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Calculation Summary:

	Unit 1	**Unit 2**	**Total**	
Total Power Requirement for Existing Circulating Water System:	8,671	11,825	**20,496**	MWhr / year
Total Power Requirement for Hypothetical VSP Retrofit:	14,381	23,670	**38,052**	MWhr / year
Annual Increase in Energy Use:	**5,710**	**11,846**	**17,556**	MWhr / year

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System Description:

Bayside Power Station consists of two gas-fired combined cycle generation units (1 & 2) and four natural gas fired simple cycle peaking units (3 - 6). The gross summer generation capacity of Unit 1 is 710 MW (with 236 MW from the steam turbine and 474 MW from the three combustion turbines). The gross summer generating capacity of Unit 2 is 940 MW (with 308 MW from the steam turbine and 632 MW from the four combustion turbines). Units 3 - 6 are 57 MW each. The total gross summer generation capacity of Bayside is therefore 1,878 MW. Once through cooling water is withdrawn from Hillsborough Bay for cooling the steam turbines associated with Unit 1 and Unit 2.

This evaluation assumes that the existing circulating water pumps for Units 1 and 2 would be replaced with variable speed pumps (VSP) that would provide a reduced flow rate to the steam condensers when possible. The approximate energy consumption of the hypothetical variable speed pumping system, which includes new pumps and a new heating, ventilation, and air conditioning (HVAC) system, is compared to the approximate energy usage of the existing constant speed circulating water pumping system.

Calculation Purpose:

Estimate the additional energy consumption by the operation of a variable speed pumping system for the cooling water system at Bayside, which includes new variable speed pumps and a new HVAC system.

Calculation Objectives:

1. List the calculation methodology and data required for the calculations.
2. Provide the inputs required for the calculations.
3. Estimate the additional energy consumption.

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Calculation Methodology:

Formula 1

$$P_{pump} = (TDH_{pump} * Q_{pump} * SG / 3956 * \mu_{pump})$$

where: *Units: hp*

P_{pump} = Power rating for existing circulating water pump (hp)
TDH_{pump} = Total dynamic head for pump (ft)
Q_{pump} = Circulating water pump discharge capacity per pump [gallons per minute (gpm)]
SG = Specific gravity of fluid
μ = Pump efficiency (%)

Formula 2

$$P_{total,pump} = P_{pump} * N_{pump} * OP_{pump} * C1$$

where: *Units: MWhr / year*

$P_{total,pump}$ = Total power requirement for existing circulating water pumps (MWhr / year)
P_{pump} = Power rating for existing pump (hp)
N_{pump} = Number of existing circulating water pumps
OP_{pump} = Operational hours for existing circulating water pumps (hr / year)
C1 = Horsepower to MW conversion factor

Formula 3

$$P_{total,VSP} = P_{VSP} * N_{VSP} * OP_{VSP} * (1 - FR) * C1 * \mu_{VSP}$$

Units: MWhr / year

where:

$P_{total,VSP}$ = Total power requirement for VSPs (MWhr / year)
P_{VSP} = Power rating for VSPs (hp)
N_{VSP} = Number of VSPs
FR = Hypothetical average flow reduction for VSP (%)
OP_{VSP} = Annual operating hours
C1 = Horsepower to MW conversion factor
μ_{VSP} = Motor efficiency (%)

Formula 4

$$P_{total,HVAC} = R_{HVAC} * OP_{HVAC / 1000}$$

where: *Units: MWhr / year*

P_{HVAC} = Total power requirement for HVAC system (MWhr / year)
R_{HVAC} = HVAC Power Rating (kW)
OP_{HVAC} = Operational hours for HVAC system (hr / year)

Formula 5

$$P_{Total} = P_{total,pump} + P_{total,HVAC}$$

Units: MWhr / year

where:

P_{total} = Total power requirement for the existing / hypothetical pumping system (MWhr / year)
$P_{total,pump}$ = Total power requirement for pumps (MWhr / year)
P_{HVAC} = Total power requirement for HVAC system (MWhr / year)

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Calculation Inputs:

Parameters and Variables		Units	Unit 1	Unit 2	Reference/Note
Existing Cooling Water System					
Total Circulating Water Flow Rate	Q_{total}	gpm	184,800	252,000	Ref. 2
Number of Circulating Water Pumps	N_{pump}	-	2	2	Ref. 2
Circulating Water Flow Rate per Pump	Q_{pump}	gpm	92,400	126,000	Ref. 2
Total Dynamic Head per Pump	TDH_{pump}	ft	25	25	
Pump Efficiency	μ_{pump}	%	90%	90%	
Operational Hours	OP_{pump}	hr / year	8,760	8,760	
Hypothetical Cooling Water System with VSPs					
Total Circulating Water Flow Rate	Q_{total}	gpm	184,800	252,000	Ref. 2
Number of Circulating Water Pumps	N_{VSP}	-	2	2	Ref. 2
Circulating Water Flow Rate per Pump	Q_{VSP}	gpm	92,400	126,000	Ref. 2
Motor Rating		HP	1,200	2,000	Ref. 1
Total Dynamic Head per Pump	TDH_{VSP}	ft	40	40	
Motor Efficiency	μ_{VSP}	%	89%	90%	
Operational Hours	OP_{VSP}	hr / year	8,760	8,760	
Average Flow Reduction Achievable	FR	%	20%	20%	Note 1
HVAC Rating		kW	48	56	Ref. 1
HVAC Percentage of Hours Operational		%	80%	80%	Note 2

Conversion Factors and Constants:

1	Megawatt	=	1341.02 horsepower
C1	=	7.46E-04	MW per horsepower
C2	=	2.90E-07	MW per Btu
SG_{ocean_water}	=	1.02	

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Notes:

1. The potential for flow reduction at Bayside is calculated in a separate evaluation.
2. Assume HVAC system is active 80% of the hours in a given day throughout the year.

References:

1. PumpSmart. 2017. ITT Goulds Motor Quotation CP2017-06-19 01 dated July 12, 2017.
2. ECT, Inc. 2017. Clean Water Act 316(b) Compliance Report, Section R3.

Calculations:

1. Total power requirement for the existing circulating water system

Formulas Used: 1, 2, 4, 5

Existing System					
Parameters and Variables		Units of Measure	**Unit 1**	**Unit 2**	**Total**
Power rating per pump	P_{pump}	hp	664	905	n/a
Total power requirement for pumps	$P_{total,pump}$	MWhr / year	8,671	11,825	20,496
Total power requirement	P_{total}	MWhr / year	8,671	11,825	20,496

2. **Total power requirement for the hypothetical VSP circulating water system**

Formulas Used: 3, 4, 5

VSP System					
Parameters and Variables		Units of Measure	**Unit 1**	**Unit 2**	**Total**
Power rating per VSP	P_{VSP}	hp	1200	2000	n/a
Total power requirement for VSPs	$P_{total,VSP}$	MWhr / year	14,045	23,278	37,323
Total power requirement for HVAC system	$P_{total,HVAC}$	MWhr / year	336	392	729
Total power requirement	P_{total}	MWhr / year	14,381	23,670	38,052

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13.0 40 CFR 122.21(r)(13)—Peer Review

In 40 CFR 122.21(r)(13), Peer Review, the regulations state:

> If the application is required to submit studies under paragraphs (r)(10) through (12) of this section, the application must conduct an external peer review of each report to be submitted with the permit application.

Since Bayside is required to submit under paragraphs 40 CFR (r)(10) through (12) due to its DIF being greater than 125 MGD (see Section 10.0), it is also required to conduct an external peer review of each report.

The regulation goes on to state:

> The applicant must select peer reviewers and notify the Director in advance of the peer review. The Director may disapprove of a peer reviewer or require additional peer reviewers. The Director may confer with EPA, Federal, State and Tribal fish and wildlife management agencies with responsibility for fish and wildlife potentially affected by the cooling water intake structure, independent system operators, and state public utility regulatory agencies, to determine which peer review comments must be addressed. The applicant must provide an explanation for any significant reviewer comments not accepted. Peer reviewers must have appropriate qualifications and their names and credential must be included in the peer review report.

This section introduces the peer reviewers, a summary of the peer review process, and the results of peer review.

13.1 Peer Reviewers

Careful consideration was taken when deciding upon the appropriate peer reviewers for this project. Each reviewer, it was felt, must be an expert in their field of study, familiar with the 316(b) process, and available to provide the necessary level of peer review when needed.

As indicated in the request for peer review approval to FDEP dated August 30, 2016, a peer reviewer was chosen for each of the key disciplines necessary to evaluate approaches to entrainment BTA under the 316(b) rule: aquatic ecology, economics, and engineering. The chosen peer reviewers are able to provide expert level assessment and guidance on 316(b)-related issues within their discipline. The chosen peer reviewers are independent of TECO's team of contractors and TECO itself. The peer reviewers chosen to review 40 CFR 122.21(r)(10) through (r)(12) of the Bayside 40 CFR 122.21(r) submission are as follows:

- Jim Cuchens, P.E.—Mr. Cuchens of Cuchens and Associates, Inc. is a retired cooling water systems engineer of nuclear and fossil-fueled steam electric power plants selected to review the 40 CFR 122.21(r)(10) entrainment BTA technologies evaluation and 40 CFR 122.21(r)(12) non-water quality and environmental and other impacts study.
- Steve Layman, Ph.D.—Dr. Layman of Geosyntec Consultants is an aquatic ecologist and fish biologist selected to review the 40 CFR 122.21(r)(11) benefit valuation study.
- Paul Jakus, Ph.D.—Dr. Jakus is professor and Head of the Department of Applied Economics at Utah State University selected to review the 40 CFR 122.21(r)(10) social cost evaluation and the 40 CFR 122.21(r)(11) monetized benefits evaluation.

The resumes of the aforementioned peer reviewers can be found in Appendix 13-A.

13.2 Peer Review Process

Prior to beginning the entrainment BTA process, peer reviewers were identified and approached. On August 30, 2016, FDEP was formally introduced to the peer reviewers selected for Bayside entrainment BTA peer review in writing (Appendix 13-B). On November 7, 2016, verbal approval of the proposed peer reviewers was given and confirmed via email (Appendix 13-C).

TECO, in an attempt to streamline the review of the draft final documents, initiated the peer review during the entrainment BTA plan document development. The entrainment BTA plan was developed to set the framework for how the analysis of entrainment BTA was to be conducted. TECO felt it advantageous to communicate with the peer review team at two points in the process: during the planning of the entrainment BTA effort and following the preparation of the draft submittals under the 316(b) rule. While the review of the draft rule submittals is

clearly suggested by the 316(b) rule, the vetting of the entrainment BTA plan is not required by the 316(b) rule. Despite this, TECO believed it prudent to facilitate early review to have the overall approach benefit from the peer reviewer's perspective and expertise.

Between December 2016 and January 2017, the peer reviewers were presented with the entrainment BTA plan document. With the document, each reviewer was presented with charge questions that queried the peer reviewer's opinion on the assumptions and methodology presented in the entrainment BTA plan. Peer reviewers were provided 30 days to complete their review. One week following the delivery of the entrainment BTA plan document to the peer reviewers, a one-hour conference call was held to address any questions the peer reviewers may have had. Participants of the calls included ECT and the appropriate subconsultants responsible for the various portion of the entrainment BTA analysis (the Team). Following the receipt of the peer reviews of the entrainment BTA plan document, the Team completed a response to comments. As necessary, some back and forth was had to fully address all the comments to the satisfaction of each peer reviewer.

Between September and October 2017, the draft documents 40 CFR 122.21(r)(10) through (r)(12) were provided to the peer reviewers for review. As with the entrainment BTA plan document, charge questions were provided that queried the peer reviewer's opinion on the methodology, results, and assumptions of the analysis on the sections of the draft documents that pertained to them. Again, each reviewer was given 30 days to complete their review.

13.3 Peer Review Results

All peer reviewers responded to the charge questions regarding the entrainment BTA plan document. Mr. Cuchens, in addition to the charge questions responses, provided additional comments in the form of a letter report as did Dr. Jakus. All of the peer review responses to the entrainment BTA plan are provided in Appendix 13-D. The Team made modifications to the plan where appropriate and necessary. For those comments not addressed in the plan documents, an explanation is provided below.

Similarly, all peer reviewer's responses to the charge questions regarding the draft 316(b) documents are provided Appendix 13-E. All questions or comments were addressed as appropriate in the draft document prior to finalization. Those that were not are provided in the following subsections with an explanation as to their omission.

13.3.1 Peer Review Responses of E BTA Plan

The explanation for the responses to the entrainment BTA plan document comments not addressed are as follows.

13.3.1.1 Engineering

General Comment #2—The scope of this study does not include any evaluation of the technical merit and/or economic feasibility of all of the alternative compliance technologies in comparison with the technologies required by the EPA 316(b) rule. Consequently, this 1 study does not make any recommendations and/or conclusions regarding BTA for technologies included. Results of this study are intended to assist the EPA Director in determination of BTA along with any additional evaluations of alternate compliance method(s) and/or technologies and to provide the (EPA) Director with information supporting decisions regarding BTA for the subject generating facilities.

TECO interprets the 316(b)rule as not requiring a conclusion on the BTA technology within 40 CFR 122.21(r)(10) beyond being impractical or infeasible. Final recommendation would only be made after considering the non-water quality and other environmental impacts within 40 CFR 122.21(r)(12) and biological benefits and impacts, and social costs and benefits from 40 CFR 122.21(r)(11) and (12).

Section 6—Non water Quality Environment and Other Impacts Comment #4

Section 6.6, Page 6-7 later states that the 99.6 percent represents approximately 0.4 percent of the time (SPX 2009) or 35 hours per year that the units would be de-rated. This is a presumption conclusion which should be reserved for the final report subject to conclusion of parametrics performed in the study.

Retrofitting a once through cooling system to have closed cycle cooling system would intuitively suggest investigating a cooling tower/system which provides optimum unit performance with minimal degradation.

Use of a tight approach and high wetbulb would provide a cooling tower designed to provide the lowest possible cold water temperature. Use of a large approach temperature at the same

wetbulb would inversely increase performance degradation. As such, any derate of the units will depend on the selected tower design subject to the following:

- *Design Flow (actuals plus margin?)*
- *Wet bulb Temperature (0.4, 1, 2, and 5 percent, etc.; see Tampa FL ASHRAE Data attached)*
- *Approach Temperature (6, 8, 10, and 12°F, etc.)*
- *Design Cold Water Temperature (wet bulb + approach)*
- *Design Range (actual versus design)*

Peer review of the selected tower design in the final study/report will evaluate the merits of design to mitigate performance degradation and associated penalties.

TECO agreed with all of the comments, with the exception of the suggestion to optimize the design parameters. For the purposes of this study, TECO did not read the 316(b) rule as requiring an optimization study nor does TECO believe the costs of doing so are justified by the study requirements in the 316(b) rule. The goal is to develop a feasibly evaluation and preparation of a Class 4 cost estimate for a reasonable configuration of the measure to evaluate whether it should be considered BTA at the facility.

13.3.1.2 Economics

All responses pertaining to the economics analysis of the entrainment BTA plan were addressed.

13.3.1.3 Aquatic Ecology

All responses pertaining to the aquatic ecology analysis of the entrainment BTA plan were addressed.

13.3.2 Peer Review Responses of Entrainment BTA Analysis—40 CFR 122(r)(10) through (12)

13.3.2.1 Engineering

All responses pertaining to the engineering of the entrainment BTA analysis were addressed.

13.3.2.2 Economics

All responses pertaining to the economics of the entrainment BTA analysis were addressed following a revision of the methodology of the nonuse values assessment.

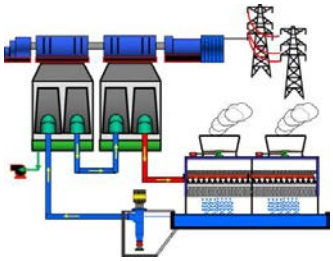
13.3.2.3 Aquatic Ecology

All responses pertaining to the aquatic ecology of the entrainment BTA analysis were addressed.

Appendix 13-A

Peer Reviewers' Resumes

J. W. CUCHENS, P.E.
Principal Consultant / Cooling Systems
B.S., Mechanical Engineering,
Mississippi State University, 1973



EXPERIENCE SUMMARY

Mr. Cuchens has over 42 years of experience in all phases of power plant design, construction and operation with various types of generating units including nuclear, fossil, and co-generation facilities. Engineering experience includes conducting conceptual design studies, equipment design specifications, and procurement/bid evaluations. His experience includes design of major plant equipment including the turbine/thermal cycle equipment, boiler and draft system equipment, and plant cooling system equipment. Experience within the past 39 years has primarily been associated with power plant cooling systems which consist of cooling towers, cooling ponds/lakes, steam-surface and air-cooled condensers, air removal/vacuum systems, auxiliary heat exchangers, cooling water pumps/sumps, service water equipment, and related piping systems. Mr. Cuchens experience also specialized in the development and use of computer simulation models for performance analysis of the cooling systems/components.

RELATED EXPERIENCE

Power Engineering experience involved the optimization of thermal/power island cycle in support of resource forecast modeling (future generation plans) for various types of generation including fossil fuel units; pulverized fluidized bed units; gas fired/combined cycle units; and nuclear units. Mr. Cuchens Power engineering experience supported the development of numerous power generation projects as shown in the project list below.

Steam Cycle / Balance of Plant Design experience includes the development of thermal cycle configurations including feedwater heater and balance of plant equipment configurations. Additional steam cycle engineering experience includes evaluation of turbine design criteria for once-through and closed-loop cooling cycles in establishing guaranteed performance parameters. Additional steam cycle experience includes the evaluation of steam cycle performance constraints and limitations with consideration of equipment design (single pressure, multipressure, etc.) and site specific conditions (climatology, geology, etc.).

Cooling Cycle Design experience includes various types of technical/feasibility studies which became the basis in development of equipment technical specifications, bid evaluations, and applied research of cooling cycle equipment technology. Mr. Cuchens' experience also consisted of design and operating knowledge for various types of cooling cycles including closed loop, once-through, and/or cooling ponds, serving nuclear units, fossil units, and cogeneration units. Mr. Cuchens design experience involved the optimization of the cooling system equipment (towers, pumps, and condensers) for new and/or existing units with consideration of performance, capital cost, and operation and maintenance. His expertise includes development of computer programs for selection of cooling cycle equipment design as well as analysis of equipment and/or plant performance.

J. W. Cuchens, P.E.

Cooling Tower experience includes the design of natural draft and/or mechanical draft cooling towers for numerous power generating facilities. Design experience includes the development of tower design standards for utilization of concrete, wood, and/or fiberglass construction materials for both cross-flow and counter-flow type cooling towers. Cooling tower experience includes consulting services to plant personnel (field inspections, equipment trouble shooting, etc.) in support of operations and maintenance activities. Cooling tower experience includes field testing for development of a system data base for in-depth analysis of tower thermal design and evaluation of vendor proposals. Cooling tower experience includes feasibility studies for modifying and/or upgrading existing towers for enhancing tower performance and reducing operations and maintenance costs. Retrofit experience includes refurbishing existing cooling towers as well as installation of helper cooling towers for supplementing existing tower performance. Mr. Cuchens experience provided enhanced tower/unit performance capability throughout the Southern Electric system.

Condenser Design experience involved the design of both air-cooled and steam surface condensers including single pressure, multi-pressure, single pass, and multi-pass configurations. Mr. Cuchens' experience includes the development of condenser design standards for field erected and modular type condenser construction. Mr. Cuchens provided field inspection/consulting services to plant personnel (tube inspections, air leakage trouble shooting, etc.) in support of operations and maintenance (O&M) and plant outage activities. Mr. Cuchens directed and/or participated in field testing to assess condenser tube cleanliness and overall condenser performance. Mr. Cuchens was responsible for conducting feasibility studies for modifying and/or upgrading condensers to enhance overall system/unit performance. Mr. Cuchens retrofit experience involved numerous re-tubing projects (modular and conventional) as well as condenser waterbox and hotwell replacement.

Circulating Water Pumps/System Design experience includes the engineering design of various types of circulating water pumps and piping systems including mixed-flow vertical can-type pumps and vertical volute type pumps. Mr. Cuchens expertise includes the capability for providing hydraulics analysis for determination of system pumping head requirements as well as the testing and evaluation of pump performance. Pump design experience includes development of pump design standards for closed suction systems as well as open pit sump designs. Mr. Cuchens has been responsible for conducting feasibility studies for modifying and/or upgrading existing pumps for enhancing pump/condenser flow. Retrofit experience includes refurbishing existing pump impellers as well as and installation of new pump rotating assemblies and modification of pump motors. Mr. Cuchens provided guidance in best practices associated with the design of pump sumps based on sump model studies to mitigate vortex issues.

ENVIRONMENTAL PROJECTS & INDUSTRY RELATED EXPERIENCE

EPA 316b Experience **-** Mr. Cuchens has been actively engaged in addressing EPA 316b rule provisions in efforts to integrate industry experience related to best practices in water use/consumption, protection of aquatic species, and application of alternative cooling system technologies which promote and support environmentally compliant and efficient cooling systems. Mr. Cuchens has conducted and/or directed engineering studies in support of compliance with 316b including closed loop cycle conversion, use of treated effluent (greywater) water sources, and/or modified intake systems with fish-friendly traveling water screens.

J. W. Cuchens, P.E.

Anti-Fouling Fill Media Research **-** Film fill media designs used in counter-flow type cooling towers have a tendency to foul or plug under certain water chemistry conditions. Mr. Cuchens has been involved for ~ 20 years in the research and investigation of anti-fouling fill designs for prevention of fouling in counterflow cooling towers. Mr. Cuchens has also been involved in the investigation of the use of surfactants to enhance cross-flow cooling tower performance. The results of these in-situ programs have provided long term reliable cooling tower performance with minimal fouling,

Industry Related Experience & Training

Mr. Cuchens has participated in and authored numerous papers and articles for EPRI Cooling System Conferences, Cooling Technology Conferences, International Water Conferences, Industry Trade Magazines, and Educational Seminars. Mr. Cuchens has conducted numerous training seminars related to cooling tower/condenser technology.

CERTIFICATIONS AND AFFILIATIONS

Registered Professional Engineer In Four States
Alabama PE # 13752; Florida PE # 37709; Georgia PE # 16164; Mississippi PE #09905
American Society of Mechanical Engineers – Member and Committee Representative
Cooling Tower Institute - Board of Directors 1995-2001; 2012-2016 (Current)
Cooling Tower Institute - Vice President 2001, President 2000
Cooling Tower Institute – Engineering Standards & Maintenance Committee - Chairman
ASME - Power Test Code (PTC) 23 – Cooling Tower Test Code - Committee Member
ASME - Power Test Code (PTC) 30 – Air Cooled Condenser Test Code - Committee Member



J. W. Cuchens, P.E.

PROJECT EXPERIENCE (PARTIAL)

The following is a partial experience list of various generation and/or retrofit projects involving cooling system components (Cooling Towers, Condensers, CW Pumps/Sumps, Air Removal Systems, etc.)

Bowen Units 1-4 Cooling Systems W/ Natural Draft Towers - Repack
Scherer Units 1-4 Cooling Systems W/ Natural Draft Towers
Vogtle Units 1 & 2 Cooling Systems W/ Natural Draft Towers – Repair/Refurbish
Vogtle Units 3 & 4 AP1000 Cooling Systems W/ Natural Draft Towers – Under Construction
Millers Units 1 & 2 Cooling Systems W/ Crossflow Natural Draft Tower - Refurbish
Millers Units 3 & 4 Cooling Systems W/ Counterflow Natural Draft Tower - Refurbish
Plant Hatch Nuclear Units 1 – Tower Replacement/Retrofit
Plant Farley Nuclear Units 1 & 2 – Tower Replacement/Retrofit
Crist Steam Plant Units 6 & 7 Cooling Tower Retrofit/Replacement
Watson Steam Plant Unit 5 - Cooling Tower Retrofit/Replacement
Watson Steam Plant Unit 4 – Environmental Cooling Tower – Installation/Repair
Plant Branch Units 1 & 2 – Environmental Cooling Tower
Plant Yates Units 1 - 4 Cooling Tower Retrofit/Closed Loop Conversion
Plant McDonough Units 1 & 2 Cooling Tower Retrofit/Closed Loop Conversion
Combined Cycle (CC) Cooling Systems Experience Including Cooling Towers, Condensers, Cooling Water Pumps, Vacuum Systems, and Related Auxiliaries
- Barry CC Units 6 & 7
- Daniel CC Units 3 & 4
- Wansley CC Units 6 & 7
- Lansing Smith CC Unit 3
- Plant Harris CC Units 1 & 2
- Plant Franklin CC Units 1, 2, & 3
- Plant Theodore Cogeneration Unit
- Olin/Washing County Cogeneration Unit
- McIntosh CC Units 10 & 11
- Plant McDonough CC Units 3, 4, & 5
- Kemper County Integrated Gasified Combined Cycle (IGCC)

Daniel Units 1 & 2 Condenser Retube (Titanium)
Watson Units 4 & 5 Condenser Retube (Titanium)
Crist Units 6 & 7 Condenser Retube (Titanium)
Yates 7 Condenser Retube (Titanium)
Plant Hatch Nuclear Units 1 & 2 Condenser Retube (Titanium)
Gaston Units 1, 2 & 3 Condenser Retube (SeaCure, 90/10 CuNi, & Titanium)
Crist Units 6 CW Pump Replacement/Retrofit
Watson Unit 5 CW Pump Replacement/Retrofit
McIntosh 11 – Cooling Tower On-Line Replacement (Tornado Destruction)t
Crist 6 & 7, Watson 4 & 5 – Cooling Tower Repair - Hurricane Destruction
Miller Units 3 & 4 – On-Line Cooling Tower Fill Replacement

A more comprehensive list can be provided upon request if desired.

October 2009

PAUL MARK JAKUS

Dept. of Applied Economics
3530 Old Main Hill
Utah State University
Logan, UT 84322-3530
(435) 797-2309
Paul.Jakus@usu.edu

Current Position

Professor and Head, Department of Applied Economics, Utah State University (July 2008-present)

Professional Experience

Professor, Department of Economics, Utah State University (July 2003-June 2008)
Associate Professor, Department of Economics, Utah State University (July 2001-June 2003)
Associate Professor, July 1997 – June 2001. Dept. of Agricultural Economics and Rural Sociology, University of Tennessee, Knoxville, TN.
Assistant Professor, February 1992 - June 1997. Dept. of Agricultural Economics and Rural Sociology, University of Tennessee, Knoxville, TN.
Graduate Research Assistant, May 1987 - February 1992. Dept. of Economics and Business, North Carolina State University, Raleigh, NC.
Peace Corps Volunteer, August 1984 - July 1986. The Gambia, West Africa.
Graduate Research Assistant, August 1982 - August 1984. Colorado State University.
Research Assistant, September 1980 - August 1982. University of Nevada, Reno.

Education

Ph.D., North Carolina State University, Economics, 1992
M.S., Colorado State University, Agricultural and Natural Resource Economics, 1984
B.S., University of Nevada, Reno, Agricultural and Natural Resource Economics, 1982

Publications in Refereed Journals

Jakus, Paul M., W. Douglass Shaw, To N. Nguyen, and Mark Walker. 2009. "Risk Perceptions of Arsenic in Tap Water and Consumption of Bottled Water." *Water Resources Research*, 45, W05405, doi:10.1029/2008WR007427.

Swain, Edward B., Paul M. **Jakus**, Glenn Rice, Frank Lupi, Peter Maxson, Joseph Pacyna, Alan Penn, Samuel Spiegel, and Marcello Viega. 2007. "Socioeconomic Consequences of Mercury Use and Pollution." *Ambio*, 36(1):45-61.

Jaenicke, Edward C., R.Wesley Harrison, Kimberly L. Jensen, and Paul M. **Jakus**. 2006. "Follow the Leader: Adoption Behavior in Food Retailers' Decision to Offer Fresh Irradiated Ground

Beef." *Agribusiness: An International J.* 22(4):547-568.

Tiller, Kelly H. and Paul M. **Jakus**. 2005. "Applying the Miceli Model to Explain Cooperation in Municipal Solid Waste Management." *Agricultural and Resource Economics Review*, 34(2):217-225.

Jensen, Kimberly L., Paul M. **Jakus**, Burton C. English and Jamey Menard. 2004. "Consumers' Willingness to Pay for Eco-Certified Wood Products." *J. Agricultural and Applied Economics*, 36(3):617-626.

Jakus, Paul M., Kimberly L. Jensen, and George C. Davis. 2003. "Revenue Impacts of MPP Branded Funds: A Firm Level Analysis." *Agricultural and Resource Economics Review*, 32(2):184-197.

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Jakus, Paul M. and W. Douglass Shaw. 2003. "Perceived Hazard and Product Choice: An Application to Recreational Site Choice." *J. Risk and Uncertainty*, 26(1):77-92.

Caplan, Arthur, Therese C. Grijalva, and Paul M. **Jakus**. 2002. "Waste Not or Want Not: A Contingent Ranking Analysis of Curbside Waste Disposal Options." *Ecological Economics*, 43(2-3):185-197.

Grijalva, Therese A., Robert P. Berrens, Alok Bohara, Paul M. **Jakus**, and W. Douglass Shaw. 2002. "Valuing the Loss of Rock Climbing Access in Wilderness Areas: A National-Level Random Utility Model." *Land Economics*, 78(1):103-120.

Jakus, Paul M., Paula Dowell, and Matthew N. Murray. 2000. "The Effect of Fluctuating Water Levels on Reservoir Fishing." *J. Agricultural and Resource Economics*, 25(2):520-532.

Parsons, George R., Paul M. **Jakus**, and Theodore D. Tomasi. 1999. "A Comparison of Welfare Estimates from Four Models for Linking Seasonal Recreational Trips to Multinomial Logit Models of Site Choice." *J. Environmental Economics and Management*, 38(2):143-157.

Jakus, Paul M., Dimitrios Dadakas, and J. Mark Fly. 1998. "Fish Consumption Advisories: Incorporating Angler-Specific Knowledge, Habits, and Catch Rates in a Site Choice Model." *American J. Agricultural Economics*, 80(5):1019-1024. (Proceedings article)

Jakus, Paul M., J. Mark Fly, Becky Stephens, and Alan Barefield. 1998. "Leasing by Tennessee Hunters." *Proceedings of the Southeastern Association of Fish and Wildlife Agencies*, 52:349-358. (Refereed)

Adams, Barry H., George C. Davis, Kimberly L. Jensen, and Paul M. **Jakus**. 1997. "Priorities and Preferences in the Allocation of MPP Funds to Agribusiness Firms." *American J. Agricultural Economics*, 79(4):1319-1331.

Kelly H. Tiller, Paul M. **Jakus**, and William M. Park. 1997. "Household Willingness to Pay for Dropoff Recycling: A Contingent Valuation Study." *J. Agricultural and Resource Economics*, 22(December):310-320.

Jakus, Paul M., Mark Downing, Mark S. Bevelhimer and J. Mark Fly. 1997. "Do Fish Consumption Advisories Affect Reservoir Anglers' Site Choice?" *Agricultural and Resource Economics Review*, 26(2):198-204.

Jakus, P.M., J. Mark Fly and Becky Stephens. 1997. "Estimating Tennessee Residents' Willingness to Pay for *Teaming with Wildlife.*" *Human Dimensions of Wildlife* 2(3):15-25.

Jakus, Paul M. and W. Douglass Shaw. 1997. "Congestion at Recreation Areas: Empirical Evidence on Perceptions, Mitigating Behavior, and Management Preferences." *J. Environmental Management*, 50(4):389-402.

Jakus, Paul M. and Paul B. Siegel. 1997. "The Effect of Individual and Community Attributes on Residents' Attitudes Toward Tourism-Based Development." *Review of Regional Studies*, 27(1):49-64.

Jakus, Paul M., Kelly H. Tiller and William M. Park. 1997. "Explaining Rural Household Participation in Recycling." *J. Agricultural and Applied Economics*, 29(1):141-148.

Shaw, W. Douglass and Paul M. **Jakus**. 1996. "Travel Cost Demand Models for Rock Climbing." *Agricultural and Resource Economics Review*, 25(4):133-142.

Jakus, Paul M. and W. Douglass Shaw. 1996. "An Empirical Analysis of Rock Climbers' Response to Hazard Warnings." *Risk Analysis*, 16(4):581-586.

Jakus, Paul M., Kelly H. Tiller, and William M. Park. 1996. "Generation of Recyclables by Rural Households." *J. Agricultural and Resource Economics*, 21(1):96-108.

Jakus, Paul M., J. Mark Fly, and J. Larry Wilson. 1996. "Explaining Public Support for Fisheries Management Alternatives." *North American J. of Fisheries Management*, 16:41-48.

Siegel, Paul B. and Paul M. **Jakus**. 1995. "Tourism as a Sustainable Rural Development Strategy: Finding Consensus in Resident Attitudes." *Southern Rural Sociology*, 11(1):17-41.

Jakus, Paul M. 1994. "Averting Behavior in the Presence of Public Spillovers: Household Control of Nuisance Pests." *Land Economics*, 70(3):273-285.

Jakus, Paul M., J. Mark Fly and J. Larry Wilson. 1993. "Activities, Regulatory Preferences and Regulatory Perceptions of Tennessee Anglers." *Proceedings of the Southeastern Association of Fish and Wildlife Agencies*, 47:767-774. (Refereed)

Smith, V. Kerry, Raymond B. Palmquist and Paul M. **Jakus**. 1991. "Combining Farrell Frontier and Hedonic Travel Cost Models for Valuing Estuarine Quality." *Review of Economics and Statistics*, 73(4):694-699.

Miller, Watkins W., Chauncey T.K. Ching, John F. Yanagida and Paul M. **Jakus**. 1985. "Agricultural Water Pollution Control: An Interdisciplinary Approach." *Environmental Management*, 9(1):1-6.

Other Recent Publications

Jakus, Paul M., John C. Bergstrom, Marty Phillips, and Kelly O'Brien. Forthcoming. "Modeling Behavioral Changes in Reservoir Operations in the Tennessee Valley Region." Forthcoming Book chapter in Preference Data for Environmental Valuation, John Whitehead, Ju-chin Huang, and Tim Haab, eds. Routledge.

Jakus, Paul M., Becky Stephens, and J. Mark Fly. 2006. "Temporal Reliability in Contingent Valuation (With a Restrictive Research Budget)." Chapter 11 in Handbook on Contingent Valuation, Anna Alberini and James Kahn, eds. Northampton, MA: Edward Elgar.

Shaw, W. Douglass, Mary Riddell, and Paul M. **Jakus**. 2005. "Valuing Environmental Changes in the Presence of Risk: A Review and Discussion of Some Empirical Issues." Chapter 7 in Folmer, H. and T. Teitenberg (eds.), International Yearbook of Environmental and Resource Economics: A Survey of Current Issues 2005/2006.

Kelly H. Tiller, Paul M. **Jakus**, and William M. Park. 2003. "Household Willingness to Pay for Dropoff Recycling: A Contingent Valuation Study." Book chapter in, T.C. Kinnaman (ed.), The Economics of Residential Solid Waste Management, Ashgate. (Re-print of 1997 *JARE* article)

Jakus, Paul M., Mary Riddel, and W. Douglass Shaw. 2003. "Are Climbers Fools? Modelling Risky Recreation." Chapter 5 in N.D. Hanley, W.D. Shaw, and R. Wright (eds.), The New Economics of Outdoor Recreation, Edward Elgar.

Honors and Awards

J. Agricultural and Resource Economics, Associate Editor, 2003-2006
Society and Natural Resources, Associate Editor, 2003-2005
J. Environmental Economics and Management, Editorial Council, 2001-2003
Water Resources Research, Associate Editor, 1999-2002
Outstanding Referee Citation, *Water Resources Research*, 1998
Western Regional Research Project W-133, President, 1997-98.
Dutch and Marilee Cavender Award for Best Research Publication, University of Tennessee Institute of Agriculture, 1997
J. Agricultural and Applied Economics, Editorial Council, 1996-99
Outstanding Graduate Student Paper, 1991. Southern Association of Agricultural Economics

Geosyntec consultants

Steven R. Layman, Ph.D.

Aquatic Ecology and Fisheries Biology
Clean Water Act Section 316(a)/(b) Compliance
Hydropower Licensing and Compliance
National Environmental Policy Act
Rare, Threatened, and Endangered Species

EDUCATION

Ph.D., Biological Sciences, University of Alabama, Tuscaloosa, 1994
M.S., Ecology, University of Tennessee, Knoxville, 1984
B.S., Biology, Bucknell University, Lewisburg, PA, 1981

DISTINGUISHING QUALIFICATIONS

Dr. Layman is an aquatic ecologist and fish biologist with 25 years' experience leading ecological assessments and managing project delivery for Clean Water Act (CWA) permitting, National Environmental Policy Act (NEPA) review, facility siting and permitting, Federal Energy Regulatory Commission (FERC) hydropower licensing, and Endangered Species Act (ESA) compliance. His distinguishing qualifications related to CWA Section 316(b) include the following:

- Diverse experience evaluating fisheries issues in the power industry, including impingement and entrainment, thermal discharge impacts, upstream and downstream passage of diadromous fish species, environmental flows, water quality, and ESA Section 7 consultation.
- Knowledge of freshwater and estuarine/marine fisheries biology gained through project experience in geographies varying from the upper Midwest to New England, the Ohio River basin, the Southeast, Florida, and the Gulf coast.
- Extensive experience working as part of integrated teams of engineers, scientists, and planners to evaluate the technical feasibility and efficacy of technologies and measures for reducing adverse environmental impact.
- Publication of several peer-reviewed papers on the biology of North American freshwater fishes, including a federally endangered fish species.
- Assistance to the U.S. Fish and Wildlife Service in preparing a recovery plan under the ESA for a federally endangered fish species in Tennessee.
- Previous experience assisting cooling water fisheries research at the University of Georgia's Savannah River Ecology Laboratory at the Savannah River Site.

Geosyntec consultants

REPRESENTATIVE PROJECTS

Clean Water Act Section 316(a)/(b) Compliance

Cooling Water Intake Structure Information for CWA Section 316(b) Compliance, SCANA Services/SCE&G, South Carolina. Currently managing the preparation of 316(b) information submittals under 40 CFR § 122.21(r) for three SCE&G power plants, including V.C. Summer Nuclear Station Unit 1 (cooling water reservoir), Williams Station (reservoir and tidal Cooper River), Urquhart Station (Savannah River) under EPA's final 316(b) regulations for existing facilities. Tasks vary by facility and include area of influence field studies using acoustic Doppler current profiling, and preparing source water physical data, cooling water intake structure data, cooling water system data, source water baseline biological characterization data, entrainment performance studies, and entrainment sampling plans.

Implementation of Cooling Water Intake Structure Plan of Development, Mosaic Fertilizer, LLC, Uncle Sam Plant, Louisiana. Managed the development of 316(b) information submittals under 40 CFR § 122.21(r) for a phosphate fertilizer manufacturing facility located along the lower Mississippi River. Key tasks included preparing source water physical data, cooling water intake structure data, cooling water system data, source water biological characterization data, and assessing impingement mortality and entrainment according to the 316(b) requirements in the Louisiana Pollutant Discharge Elimination System permit for the facility.

CWA 316(a) Thermal Variance Renewal, JEA, St. John's River, Florida. Project director providing oversight and review of two-year evaluation of thermal variance at a coal-fired power plant on the estuarine St. John's River in Florida. Biological Plan of Study included evaluation of the benthic macroinvertebrate assemblages inside and outside of the thermal plume and temperature monitoring for two years.

Cooling Water Intake Structure Assessment and NPDES Permitting Support, Confidential Manufacturer, Massachusetts. For a large manufacturing facility, led an integrated team of engineers, scientists, and natural resource economists in compiling detailed information on the facility's two cooling water intake structures, alternative technologies and operations, and compliance with CWA Section 316(b). Worked closely with plant personnel in evaluating the technical feasibility, efficacy, costs, and social benefits of alternative technologies for reducing fish impingement and entrainment on a tidally influenced river and prepared technical justification to support EPA's determination of best technology available using best professional judgment.

Impingement Mortality Characterization Study, Georgia Power, Plant Mitchell, Georgia. Led development of the Proposal for Information Collection and implementation of impingement mortality sampling for complying with Phase II 316(b) requirements at a Georgia Power existing 170-MW coal-fired generating station along the Flint River. The study included one year of biweekly impingement sampling for estimating calculation baseline, seasonal fish community surveys, and a hydraulic zone of influence study using acoustic Doppler current profiling technology.

Aquatic Habitat Restoration

Supplemental Environmental Impact Statement (SEIS), Mississippi Barrier Island Restoration, U.S. Army Corps of Engineers, Mobile District. Managed the preparation of the preliminary draft SEIS for the U.S. Army Corps of Engineers (USACE) Mobile District to support the Mississippi Coastal Improvements Program Comprehensive Barrier Island Restoration. The proposed restoration activities involved the placement of 22 million cubic yards of sand along the barrier islands of Mississippi Sound. The SEIS assessed impacts to estuarine/marine fisheries, benthic macroinvertebrates, wetlands, and protected species habitat.

Chattahoochee River Aquatic Ecosystem Restoration, U.S. Army Corps of Engineers, Mobile District, Georgia and Alabama. Scoped environmental permitting requirements and associated costs of proposed aquatic ecosystem restoration on the Chattahoochee River. The project involved breaching two FERC-licensed dams to restore 2.3 miles of riverine habitat.

Arkansas River Corridor Master Plan, Tulsa County, Oklahoma. As part of a master plan for the Arkansas River Corridor, assisted Tulsa County in identifying and evaluating potential environmental constraints related to the construction of low-head dams for the purposes of increasing connectivity between the river and surrounding communities, improving habitat for the federally endangered Interior Least Tern, improving the function of the river, and improving recreational opportunities. Led the evaluation of potential project effects to Interior Least Tern nesting and foraging habitat and upstream and downstream passage of highly migratory fish species of interest.

Hydropower Licensing and Fish Entrainment

FERC Hydropower Licensing, Georgia Power, Bartletts Ferry Project, Georgia and Alabama. Managed comprehensive environmental resource studies, consultation, and documentation supporting FERC relicensing of Georgia Power's 173-MW Bartletts Ferry Project on the Chattahoochee River along the Georgia/Alabama border. Led preparation of the Pre-Application Document, FERC-approved Study Plan, eight resource studies, Preliminary Licensing Proposal, and Exhibit E of the license

application, which was filed with FERC in December 2012. Activities included consultation with a diverse interstate group of resource agencies and stakeholders.

Fish Entrainment Evaluation, Louisville Gas and Electric Company, Ohio Falls Hydroelectric Project, Kentucky and Indiana. Developed a literature-based fish entrainment evaluation for relicensing of the Ohio Falls Station on the Ohio River. Applied trends and data from field studies at numerous other sites, including five in the Ohio River basin. Findings satisfied resource agencies that fish entrainment did not pose a substantial threat to the fish community, supported successful agency negotiations, and expedited commencement of the time-critical turbine upgrades.

NEPA Analysis, FERC Hydropower Licensing, Midwestern and Southeastern States. As part of a contractor team, assisted FERC staff in preparing environmental assessments and multiple-project environmental impact statements for 16 hydroelectric projects in Wisconsin, Michigan, New York, South Carolina, and Georgia. Assessed complex fisheries issues related to entrainment and turbine-induced mortality, downstream fish protection, upstream passage, and instream flow needs. Midwestern projects included numerous facilities on tributaries to Lake Michigan (Menominee River, Peshtigo River, Escanaba River), tributaries to Lake Superior (Ontonagon River, Dead River), and on the Wisconsin River in the upper Mississippi River basin.

Ludington Pump Storage Project, FERC, Lake Michigan. Assessed fish entrainment and the effectiveness of using a 2.5-mile-long barrier net at the 1,872-MW Ludington Pumped Storage Project (Lake Michigan) for FERC using site-specific data and literature review. The analysis was part of an environmental assessment evaluating a settlement agreement for proposed permanent fish protection measures at the facility.

Fish Entrainment Evaluation, Duke Energy, Catawba-Wateree Hydroelectric Project, North Carolina and South Carolina. Evaluated potential fish entrainment and turbine-induced mortality at 13 hydroelectric developments for relicensing of Duke Energy's 788-MW Catawba-Wateree Project on the Catawba and Wateree Rivers. Applied trends and data from field studies conducted at over 50 other projects and assessed potential impacts to highly migratory fishes being targeted by agencies for fish passage restoration, including American shad, river herring, striped bass, and federally endangered shortnose sturgeon and Atlantic sturgeon.

Biology Sampling Programs, Multiple Utilities, Multiple States. Designed and led biology sampling programs to support Exhibit E for several hydroelectric projects. Assessed the effects of fluctuating water levels on age and growth of game fish in four Wisconsin River impoundments; directed fisheries sampling on streams and lakes in

Michigan's Upper Peninsula; and managed seasonal studies of fish, wildlife, and botanical resources for a proposed pumped storage facility in Georgia.

Rare, Threatened, and Endangered Species

Tri-State Water Allocation Biological Assessment, U.S. Army Corps of Engineers, Mobile District, Georgia, Alabama, Florida. Led preparation of supporting information for Biological Assessments being prepared by the USACE for ACF and ACT basin water allocation under the ESA. Evaluated distributions of Federally-listed species to identify those most likely to be affected by changes in water management, and assessed the potential for impacts to assist the U.S. Fish and Wildlife Service in making final determinations of potential effect.

Petroleum Pipeline Permitting, Colonial Pipeline Company, Multiple States. Led the analysis of regulatory issues pertaining to threatened and endangered aquatic species (fish, mussels, snails) along a proposed 460-mile petroleum pipeline extending across Louisiana, Mississippi, Alabama, and Georgia. Coordinated surveys conducted by mussel experts at numerous proposed stream crossings in three states, led the analysis of ESA compliance, and prepared related sections of the environmental assessment needed to obtain a Special Use Permit from the U.S. Forest Service.

PROFESSIONAL EXPERIENCE

Geosyntec Consultants, Atlanta, Georgia, 2002-2007, 2012-Present
CH2M HILL, Atlanta, Georgia, 1994-2002, 2007-2012
Dames & Moore, Tallahassee, Florida, 1994
Dames & Moore, Northport, Alabama, 1990-91
Dames & Moore, Atlanta, Georgia, 1985-1989
Savannah River Ecology Laboratory Aiken, South Carolina, 1984-1985

AFFILIATIONS

American Fisheries Society

American Society of Ichthyologists and Herpetologists

REPRESENTATIVE PROFESSIONAL SERVICE

- Moderator for session entitled “Confluence of Emerging Water Regulations on the Electric Power Industry: Clean Water Act Section 316(b) and Steam Electric Effluent Limitations Guidelines” at Air and Waste Management Association Florida Section Conference in Tallahassee, FL, September 2013

- Moderator for session entitled "Fisheries Restoration: Successes and Lessons Learned" at National Hydropower Association 2010 Annual Conference in Washington, D.C.

- Manuscript review for *American Midland Naturalist*, *Journal of Fish Biology*, and *Southeastern Naturalist*

REPRESENTATIVE PUBLICATIONS

Layman, S. R. "Life history of the relict, duskytail darter, *Etheostoma (Catonotus) sp*." in Little River, Tennessee. Copeia 1991(2):47 1-485. 1991.

Layman, S. R. "Life history of the Savannah darter, *Etheostoma fricksium*, in the Savannah River drainage, South Carolina." Copeia 1993:959-968. 1993.

Layman, S. R., and R. L. Mayden. "A new species of the darter subgenus *Doration* (Percidae: *Etheostoma*) from the Caney Fork River system, Tennessee." Copeia 2009:157-170. 2009.

Layman, S. R., and R. L. Mayden. "Morphological diversity and phylogenetics of the darter subgenus *Doration* (Percidae: *Etheostoma*), with descriptions of five new species." Bull. Alabama Mus. Nat. Hist. 22:37-80. 2012.

Appendix 13-B

Proposal of Peer Reviewers to FDEP

ECT Environmental Consulting & Technology, Inc.

August 30, 2016
ECT No. 160430

Marc Harris, P.E.
Environmental Administrator
Power Plant NPDES Permitting
Industrial Wastewater Program
Florida Department of Environmental Protection
Bob Martinez Center
2600 Blair Stone Road
Tallahassee. Florida 32399-2400
Via Email: Marc.Harris@dep.state.fl.us

Re: Proposed Peer Reviewers for Tampa Electric Company's 316(b) Entrainment Assessment

NPDES Numbers:
FL0000817 – Big Bend
FL0000809 – Bayside

Dear Mr. Harris:

Tampa Electric Company (TEC) has begun its compliance efforts required under U.S. Environmental Protection Agency's (EPA's) Section 316(b) existing facilities rule (Rule). A critical part of this effort for facilities withdrawing over 125 million gallons per day (MGD)[1], and the part that represents a critical path for our projects, is the assessment of alternatives to reduce entrainment into the cooling water systems at the regulated plants. The rule at 40 CFR 122.21(r)(9) requires the characterization of the nature of entrainment to support analyses of alternative entrainment mortality control measures as specified at 40 CFR 122.21(r)(10)-(12). This work has already been performed for both of TEC's affected stations. The Rule also requires that the reports prepared under 40 CFR 122.21(r)(10)-(12) be subject to peer review.

The results of the peer review process are to be documented as part of the 316(b) submittals as required at 40 CFR 122.21(r)(13). Importantly, TEC intends to involve peer reviewers as it plans its entrainment analyses, as well as when it completes the draft final reports near the conclusion of the process. We have discussed this approach with you and have also indicated our intention to propose a peer reviewer for each of the key disciplines necessary to evaluate approaches to entrainment best technology available (BTA) under the rule: aquatic biology, economics, and engineering. TEC has begun its 316(b) strategy development and its identification of peer reviewers. As part of the process, TEC seeks Florida Department of Environmental Protection (FDEP) written approval of the three peer reviewers proposed in this letter.

As we have discussed, FDEP considers that the required peer reviewers should be able to provide expert level assessment and guidance on 316(b)-related issues within their discipline. We are confident that our proposed peer reviewers' resumes demonstrate that level of expertise and experience

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[1] Tampa Electric proposes to employ the same peer reviewers at its facilities that employ open cycle cooling and are anticipated to have an actual intake flow of over 125 MGD. Therefore, this letter seeks approval for the proposed peer reviewers in the context of the two plants.

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in their disciplines. Our proposed peer reviewers are also independent of TEC's team of contractors and TEC itself.

We have also discussed with you our belief that, in the context of biology and engineering, peer reviewers with industry experience may provide a more thorough and focused review than a person from academia. In particular, our proposed peer reviewers for biology and engineering have direct experience with the technical and regulatory issues related to entrainment and its mitigation and costing of power facility retrofits, respectively. TEC believes that these individuals will be in a far better position to identify and help rectify potential technical issues with TEC's approach than academics of similar tenure.

For the economics peer reviewer, we have proposed a university professor, Dr. Paul Jakus. Dr. Jakus is a nationally recognized expert in environmental and natural resource economics. He has authored more than 50 publications in top level environmental and resource economics journals, and his research has ranged from evaluating the effects of catch rate changes on angler preferences to operational and technology changes on electricity generators and prices—topics that cover the range of effects that are germane to accurately assessing the social costs and social benefits of alternative entrainment reduction technologies.

Our proposed peer reviewers are presented in three attachments to this letter. In each attachment, we have provided a summary of the peer reviewer's experience relative to needs of the entrainment BTA analysis followed by the individual's resume. Attachment A presents the proposed biological peer reviewer, Dr. Steven Layman. The economics peer reviewer, Dr. Paul Jakus, is presented in Attachment B. Attachment C discusses the credentials of our proposed engineering peer reviewer, James Cuchens, PE.

We hope that you will agree that our proposed peer reviewers will serve as excellent resources for TEC and FDEP during the planning and implementation of the pending entrainment BTA (i.e., the studies defined at 40 CFR 122.21(r)(10)-(12)). If it is helpful to you, we would welcome an opportunity to set up separate conference calls between you and each of the candidates at your convenience to discuss their credentials.

As TEC has a relatively restrictive schedule for its rule-related submittals, we believe that planning the entrainment BTA analysis, including peer review, over the next several months is a critical goal. For this reason, we ask that FDEP respond to our proposal by mid- to late-September of 2016.

Thank you for your attention to this matter. If you have questions or comments, please do not hesitate to contact either one of us.

Sincerely,

ENVIRONMENTAL CONSULTING & TECHNOLOGY, INC.

Mark Gerath
Principal Scientist – Water Resources

Jennifer Mathia
Project Manager

Attachment A: Proposed Peer Reviewer – Biology

Steven Layman, PhD.

Dr. Layman has many years of experience in the disciplines relevant to the biological aspects of the existing facilities 316(b) Rule, including:

- Means of characterizing rates of impingement and entrainment at cooling water intake structures;
- Ecology and fisheries of coastal waters including those in Florida;
- Consideration of the ecological impacts of entrainment and impingement;
- Protection of listed species under both Federal and State authorities, including assessment of potential impacts to listed species and consultation under Section 7 of the Endangered Species Act;
- Assessment of the costs, effectiveness, and operational constraints on technologies intended to mitigate entrainment at cooling water intake structures (CWIS) – critically, this includes assessment of the biological effectiveness of fine mesh screens;
- Working with multi-disciplinary teams to evaluate and implement fisheries protection at CWIS;
- Modeling of fisheries populations, including extrapolation to age-specific losses and production foregone;
- Experience with litigation support on a number of fisheries- and Clean Water Act-related issues;
- The constraints on operation of power plants and other industrial facilities, particularly relative to water use; and
- The goals and requirements of the Section 316(b) Rule.

Consistent with Dr. Layman's experience, TEC believes that the 316(b) process requires that a biological peer reviewer must be able to provide expert analysis and guidance on the following:

- Methods of evaluation of rates of entrainment, including sampling, enumeration, and identification;
- Expertise on the 316(b) Rule, including its goals and requirements procedures;
- The biology of estuaries particularly those in Florida;
- Perspective on the rates and nature of entrainment relative to screening entrainment mitigation technologies and ecosystem impacts;
- Understanding of issues related to State- and Federally-listed species, including the Rule's requirements and procedures/policies of the resource agencies;
- Technologies and operational measures that are available that would reduce rates of entrainment;
- Understanding of the effectiveness of, and constraints on, the candidate technologies and operational measures;
- Assessment of fine mesh screens as a means of reducing entrainment including issues to related to life stage- and species-specific exclusion and survival; and
- Biological expertise that will facilitate estimation of monetized benefits (e.g., issues in modeling Age-1 equivalents, etc.).

As noted above, Dr. Layman has been approved by FDEP and FWC as a peer reviewer for the 316(b)-related issues for another Florida power producer.

ECT Environmental Consulting & Technology, Inc.

Geosyntec consultants

Steven R. Layman, Ph.D.

Aquatic Ecology and Fisheries Biology
Clean Water Act Section 316(a)/(b) Compliance
Hydropower Licensing and Compliance
National Environmental Policy Act
Rare, Threatened, and Endangered Species

EDUCATION

Ph.D., Biological Sciences, University of Alabama, Tuscaloosa, 1994
M.S., Ecology, University of Tennessee, Knoxville, 1984
B.S., Biology, Bucknell University, Lewisburg, PA, 1981

DISTINGUISHING QUALIFICATIONS

Dr. Layman is an aquatic ecologist and fish biologist with 25 years' experience leading ecological assessments and managing project delivery for Clean Water Act (CWA) permitting, National Environmental Policy Act (NEPA) review, facility siting and permitting, Federal Energy Regulatory Commission (FERC) hydropower licensing, and Endangered Species Act (ESA) compliance. His distinguishing qualifications related to CWA Section 316(b) include the following:

- Diverse experience evaluating fisheries issues in the power industry, including impingement and entrainment, thermal discharge impacts, upstream and downstream passage of diadromous fish species, environmental flows, water quality, and ESA Section 7 consultation.
- Knowledge of freshwater and estuarine/marine fisheries biology gained through project experience in geographies varying from the upper Midwest to New England, the Ohio River basin, the Southeast, Florida, and the Gulf coast.
- Extensive experience working as part of integrated teams of engineers, scientists, and planners to evaluate the technical feasibility and efficacy of technologies and measures for reducing adverse environmental impact.
- Publication of several peer-reviewed papers on the biology of North American freshwater fishes, including a federally endangered fish species.
- Assistance to the U.S. Fish and Wildlife Service in preparing a recovery plan under the ESA for a federally endangered fish species in Tennessee.
- Previous experience assisting cooling water fisheries research at the University of Georgia's Savannah River Ecology Laboratory at the Savannah River Site.

Geosyntec consultants

REPRESENTATIVE PROJECTS

Clean Water Act Section 316(a)/(b) Compliance

Cooling Water Intake Structure Information for CWA Section 316(b) Compliance, SCANA Services/SCE&G, South Carolina. Currently managing the preparation of 316(b) information submittals under 40 CFR § 122.21(r) for three SCE&G power plants, including V.C. Summer Nuclear Station Unit 1 (cooling water reservoir), Williams Station (reservoir and tidal Cooper River), Urquhart Station (Savannah River) under EPA's final 316(b) regulations for existing facilities. Tasks vary by facility and include area of influence field studies using acoustic Doppler current profiling, and preparing source water physical data, cooling water intake structure data, cooling water system data, source water baseline biological characterization data, entrainment performance studies, and entrainment sampling plans.

Implementation of Cooling Water Intake Structure Plan of Development, Mosaic Fertilizer, LLC, Uncle Sam Plant, Louisiana. Managed the development of 316(b) information submittals under 40 CFR § 122.21(r) for a phosphate fertilizer manufacturing facility located along the lower Mississippi River. Key tasks included preparing source water physical data, cooling water intake structure data, cooling water system data, source water biological characterization data, and assessing impingement mortality and entrainment according to the 316(b) requirements in the Louisiana Pollutant Discharge Elimination System permit for the facility.

CWA 316(a) Thermal Variance Renewal, JEA, St. John's River, Florida. Project director providing oversight and review of two-year evaluation of thermal variance at a coal-fired power plant on the estuarine St. John's River in Florida. Biological Plan of Study included evaluation of the benthic macroinvertebrate assemblages inside and outside of the thermal plume and temperature monitoring for two years.

Cooling Water Intake Structure Assessment and NPDES Permitting Support, Confidential Manufacturer, Massachusetts. For a large manufacturing facility, led an integrated team of engineers, scientists, and natural resource economists in compiling detailed information on the facility's two cooling water intake structures, alternative technologies and operations, and compliance with CWA Section 316(b). Worked closely with plant personnel in evaluating the technical feasibility, efficacy, costs, and social benefits of alternative technologies for reducing fish impingement and entrainment on a tidally influenced river and prepared technical justification to support EPA's determination of best technology available using best professional judgment.

Impingement Mortality Characterization Study, Georgia Power, Plant Mitchell, Georgia. Led development of the Proposal for Information Collection and implementation of impingement mortality sampling for complying with Phase II 316(b) requirements at a Georgia Power existing 170-MW coal-fired generating station along the Flint River. The study included one year of biweekly impingement sampling for estimating calculation baseline, seasonal fish community surveys, and a hydraulic zone of influence study using acoustic Doppler current profiling technology.

Aquatic Habitat Restoration

Supplemental Environmental Impact Statement (SEIS), Mississippi Barrier Island Restoration, U.S. Army Corps of Engineers, Mobile District. Managed the preparation of the preliminary draft SEIS for the U.S. Army Corps of Engineers (USACE) Mobile District to support the Mississippi Coastal Improvements Program Comprehensive Barrier Island Restoration. The proposed restoration activities involved the placement of 22 million cubic yards of sand along the barrier islands of Mississippi Sound. The SEIS assessed impacts to estuarine/marine fisheries, benthic macroinvertebrates, wetlands, and protected species habitat.

Chattahoochee River Aquatic Ecosystem Restoration, U.S. Army Corps of Engineers, Mobile District, Georgia and Alabama. Scoped environmental permitting requirements and associated costs of proposed aquatic ecosystem restoration on the Chattahoochee River. The project involved breaching two FERC-licensed dams to restore 2.3 miles of riverine habitat.

Arkansas River Corridor Master Plan, Tulsa County, Oklahoma. As part of a master plan for the Arkansas River Corridor, assisted Tulsa County in identifying and evaluating potential environmental constraints related to the construction of low-head dams for the purposes of increasing connectivity between the river and surrounding communities, improving habitat for the federally endangered Interior Least Tern, improving the function of the river, and improving recreational opportunities. Led the evaluation of potential project effects to Interior Least Tern nesting and foraging habitat and upstream and downstream passage of highly migratory fish species of interest.

Hydropower Licensing and Fish Entrainment

FERC Hydropower Licensing, Georgia Power, Bartletts Ferry Project, Georgia and Alabama. Managed comprehensive environmental resource studies, consultation, and documentation supporting FERC relicensing of Georgia Power's 173-MW Bartletts Ferry Project on the Chattahoochee River along the Georgia/Alabama border. Led preparation of the Pre-Application Document, FERC-approved Study Plan, eight resource studies, Preliminary Licensing Proposal, and Exhibit E of the license

application, which was filed with FERC in December 2012. Activities included consultation with a diverse interstate group of resource agencies and stakeholders.

Fish Entrainment Evaluation, Louisville Gas and Electric Company, Ohio Falls Hydroelectric Project, Kentucky and Indiana. Developed a literature-based fish entrainment evaluation for relicensing of the Ohio Falls Station on the Ohio River. Applied trends and data from field studies at numerous other sites, including five in the Ohio River basin. Findings satisfied resource agencies that fish entrainment did not pose a substantial threat to the fish community, supported successful agency negotiations, and expedited commencement of the time-critical turbine upgrades.

NEPA Analysis, FERC Hydropower Licensing, Midwestern and Southeastern States. As part of a contractor team, assisted FERC staff in preparing environmental assessments and multiple-project environmental impact statements for 16 hydroelectric projects in Wisconsin, Michigan, New York, South Carolina, and Georgia. Assessed complex fisheries issues related to entrainment and turbine-induced mortality, downstream fish protection, upstream passage, and instream flow needs. Midwestern projects included numerous facilities on tributaries to Lake Michigan (Menominee River, Peshtigo River, Escanaba River), tributaries to Lake Superior (Ontonagon River, Dead River), and on the Wisconsin River in the upper Mississippi River basin.

Ludington Pump Storage Project, FERC, Lake Michigan. Assessed fish entrainment and the effectiveness of using a 2.5-mile-long barrier net at the 1,872-MW Ludington Pumped Storage Project (Lake Michigan) for FERC using site-specific data and literature review. The analysis was part of an environmental assessment evaluating a settlement agreement for proposed permanent fish protection measures at the facility.

Fish Entrainment Evaluation, Duke Energy, Catawba-Wateree Hydroelectric Project, North Carolina and South Carolina. Evaluated potential fish entrainment and turbine-induced mortality at 13 hydroelectric developments for relicensing of Duke Energy's 788-MW Catawba-Wateree Project on the Catawba and Wateree Rivers. Applied trends and data from field studies conducted at over 50 other projects and assessed potential impacts to highly migratory fishes being targeted by agencies for fish passage restoration, including American shad, river herring, striped bass, and federally endangered shortnose sturgeon and Atlantic sturgeon.

Biology Sampling Programs, Multiple Utilities, Multiple States. Designed and led biology sampling programs to support Exhibit E for several hydroelectric projects. Assessed the effects of fluctuating water levels on age and growth of game fish in four Wisconsin River impoundments; directed fisheries sampling on streams and lakes in

Michigan's Upper Peninsula; and managed seasonal studies of fish, wildlife, and botanical resources for a proposed pumped storage facility in Georgia.

Rare, Threatened, and Endangered Species

Tri-State Water Allocation Biological Assessment, U.S. Army Corps of Engineers, Mobile District, Georgia, Alabama, Florida. Led preparation of supporting information for Biological Assessments being prepared by the USACE for ACF and ACT basin water allocation under the ESA. Evaluated distributions of Federally-listed species to identify those most likely to be affected by changes in water management, and assessed the potential for impacts to assist the U.S. Fish and Wildlife Service in making final determinations of potential effect.

Petroleum Pipeline Permitting, Colonial Pipeline Company, Multiple States. Led the analysis of regulatory issues pertaining to threatened and endangered aquatic species (fish, mussels, snails) along a proposed 460-mile petroleum pipeline extending across Louisiana, Mississippi, Alabama, and Georgia. Coordinated surveys conducted by mussel experts at numerous proposed stream crossings in three states, led the analysis of ESA compliance, and prepared related sections of the environmental assessment needed to obtain a Special Use Permit from the U.S. Forest Service.

PROFESSIONAL EXPERIENCE

Geosyntec Consultants, Atlanta, Georgia, 2002-2007, 2012-Present
CH2M HILL, Atlanta, Georgia, 1994-2002, 2007-2012
Dames & Moore, Tallahassee, Florida, 1994
Dames & Moore, Northport, Alabama, 1990-91
Dames & Moore, Atlanta, Georgia, 1985-1989
Savannah River Ecology Laboratory Aiken, South Carolina, 1984-1985

AFFILIATIONS

American Fisheries Society

American Society of Ichthyologists and Herpetologists

REPRESENTATIVE PROFESSIONAL SERVICE

- Moderator for session entitled “Confluence of Emerging Water Regulations on the Electric Power Industry: Clean Water Act Section 316(b) and Steam Electric Effluent Limitations Guidelines” at Air and Waste Management Association Florida Section Conference in Tallahassee, FL, September 2013

- Moderator for session entitled "Fisheries Restoration: Successes and Lessons Learned" at National Hydropower Association 2010 Annual Conference in Washington, D.C.

- Manuscript review for *American Midland Naturalist*, *Journal of Fish Biology*, and *Southeastern Naturalist*

REPRESENTATIVE PUBLICATIONS

Layman, S. R. "Life history of the relict, duskytail darter, *Etheostoma (Catonotus) sp*." in Little River, Tennessee. Copeia 1991(2):47 1-485. 1991.

Layman, S. R. "Life history of the Savannah darter, *Etheostoma fricksium*, in the Savannah River drainage, South Carolina." Copeia 1993:959-968. 1993.

Layman, S. R., and R. L. Mayden. "A new species of the darter subgenus *Doration* (Percidae: *Etheostoma*) from the Caney Fork River system, Tennessee." Copeia 2009:157-170. 2009.

Layman, S. R., and R. L. Mayden. "Morphological diversity and phylogenetics of the darter subgenus *Doration* (Percidae: *Etheostoma*), with descriptions of five new species." Bull. Alabama Mus. Nat. Hist. 22:37-80. 2012.

Attachment B: Proposed Peer Reviewer – Economics

Dr. Jakus has more than 25 years of experience in conducting research on various environmental and natural resource economics topics including those that will be most relevant to assessing the social costs and social benefits of alternative entrainment reduction technologies. He has authored more than 50 peer-reviewed publications in top rated environmental and natural resource economics journals including the *Journal of Environmental Economics and Management, Agricultural and Resource Economics Review, Ecological Economics, Land Economics, Review of Economics and Statistics, Journal of Agricultural and Resource Economics, Risk Analysis, Environmental Management,* and the *North American Journal of Fisheries Management.* He has also authored book chapters in Preference Data for Environmental Valuation, Handbook on Contingent Valuation, The New Economics of Outdoor Recreation, and International Yearbook of Environmental and Resource Economics: A Survey of Current Issues.

Examples of Dr. Jakus relevant experience include

- Developing random utility maximization models to assess the impacts of changes in catch rates on angler preferences and wellbeing.
- Evaluating the effect of fluctuating water levels on angler and recreator wellbeing.
- Evaluating the effect of fisheries management alternatives on angler and societal wellbeing
- Assessing the effects of technology changes on power producers, electricity prices, and consumer wellbeing.
- Evaluating changes in estuarine water quality on societal wellbeing.
- Evaluating changes in housing attributes on property values.
- Evaluating the effect of risk changes and health states on societal wellbeing.
- Linking ecological and economic data to estimate the value of water quality improvements.
- Conducting stated preference surveys that assess the role of nonuse values in benefit-cost analyses.

Consistent with Dr. Jakus' experience, TEC believes that the 316(b) process requires that an economics peer reviewer be able to provide expert analysis and guidance on the following:

- All facets of benefits analysis including
  - the bioeconomic relationship between reductions in entrainment, changes in fish stocks, changes in recreational and commercial yield, changes in recreational and commercial catch, and changes in recreational and commercial benefits
  - the use and challenges of stated preference techniques to develop reliable estimates of nonuse values
- All facets of social cost analysis to evaluate the effects of price and environmental changes on social wellbeing.
- The use of benefits transfer to apply existing information from the literature to assess the social benefits and social costs of entrainment reduction technologies at the site-specific level.
- The use of Benefit-Cost Analysis to compare the social costs of individual entrainment reduction technologies to their social benefits.
- Using scenario and sensitivity analysis to assess the uncertainty of benefits and costs.

ECT Environmental Consulting & Technology, Inc.

October 2009

PAUL MARK JAKUS

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Current Position

Professor and Head, Department of Applied Economics, Utah State University (July 2008-present)

Professional Experience

Professor, Department of Economics, Utah State University (July 2003-June 2008)
Associate Professor, Department of Economics, Utah State University (July 2001-June 2003)
Associate Professor, July 1997 – June 2001. Dept. of Agricultural Economics and Rural Sociology, University of Tennessee, Knoxville, TN.
Assistant Professor, February 1992 - June 1997. Dept. of Agricultural Economics and Rural Sociology, University of Tennessee, Knoxville, TN.
Graduate Research Assistant, May 1987 - February 1992. Dept. of Economics and Business, North Carolina State University, Raleigh, NC.
Peace Corps Volunteer, August 1984 - July 1986. The Gambia, West Africa.
Graduate Research Assistant, August 1982 - August 1984. Colorado State University.
Research Assistant, September 1980 - August 1982. University of Nevada, Reno.

Education

Ph.D., North Carolina State University, Economics, 1992
M.S., Colorado State University, Agricultural and Natural Resource Economics, 1984
B.S., University of Nevada, Reno, Agricultural and Natural Resource Economics, 1982

Publications in Refereed Journals

Jakus, Paul M., W. Douglass Shaw, To N. Nguyen, and Mark Walker. 2009. "Risk Perceptions of Arsenic in Tap Water and Consumption of Bottled Water." *Water Resources Research*, 45, W05405, doi:10.1029/2008WR007427.

Swain, Edward B., Paul M. **Jakus**, Glenn Rice, Frank Lupi, Peter Maxson, Joseph Pacyna, Alan Penn, Samuel Spiegel, and Marcello Viega. 2007. "Socioeconomic Consequences of Mercury Use and Pollution." *Ambio*, 36(1):45-61.

Jaenicke, Edward C., R.Wesley Harrison, Kimberly L. Jensen, and Paul M. **Jakus**. 2006. "Follow the Leader: Adoption Behavior in Food Retailers' Decision to Offer Fresh Irradiated Ground

Beef." *Agribusiness: An International J.* 22(4):547-568.

Tiller, Kelly H. and Paul M. **Jakus**. 2005. "Applying the Miceli Model to Explain Cooperation in Municipal Solid Waste Management." *Agricultural and Resource Economics Review*, 34(2):217-225.

Jensen, Kimberly L., Paul M. **Jakus**, Burton C. English and Jamey Menard. 2004. "Consumers' Willingness to Pay for Eco-Certified Wood Products." *J. Agricultural and Applied Economics*, 36(3):617-626.

Jakus, Paul M., Kimberly L. Jensen, and George C. Davis. 2003. "Revenue Impacts of MPP Branded Funds: A Firm Level Analysis." *Agricultural and Resource Economics Review*, 32(2):184-197.

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Jakus, Paul M. and W. Douglass Shaw. 2003. "Perceived Hazard and Product Choice: An Application to Recreational Site Choice." *J. Risk and Uncertainty*, 26(1):77-92.

Caplan, Arthur, Therese C. Grijalva, and Paul M. **Jakus**. 2002. "Waste Not or Want Not: A Contingent Ranking Analysis of Curbside Waste Disposal Options." *Ecological Economics*, 43(2-3):185-197.

Grijalva, Therese A., Robert P. Berrens, Alok Bohara, Paul M. **Jakus**, and W. Douglass Shaw. 2002. "Valuing the Loss of Rock Climbing Access in Wilderness Areas: A National-Level Random Utility Model." *Land Economics*, 78(1):103-120.

Jakus, Paul M., Paula Dowell, and Matthew N. Murray. 2000. "The Effect of Fluctuating Water Levels on Reservoir Fishing." *J. Agricultural and Resource Economics*, 25(2):520-532.

Parsons, George R., Paul M. **Jakus**, and Theodore D. Tomasi. 1999. "A Comparison of Welfare Estimates from Four Models for Linking Seasonal Recreational Trips to Multinomial Logit Models of Site Choice." *J. Environmental Economics and Management*, 38(2):143-157.

Jakus, Paul M., Dimitrios Dadakas, and J. Mark Fly. 1998. "Fish Consumption Advisories: Incorporating Angler-Specific Knowledge, Habits, and Catch Rates in a Site Choice Model." *American J. Agricultural Economics*, 80(5):1019-1024. (Proceedings article)

Jakus, Paul M., J. Mark Fly, Becky Stephens, and Alan Barefield. 1998. "Leasing by Tennessee Hunters." *Proceedings of the Southeastern Association of Fish and Wildlife Agencies*, 52:349-358. (Refereed)

Adams, Barry H., George C. Davis, Kimberly L. Jensen, and Paul M. **Jakus**. 1997. "Priorities and Preferences in the Allocation of MPP Funds to Agribusiness Firms." *American J. Agricultural Economics*, 79(4):1319-1331.

Kelly H. Tiller, Paul M. **Jakus**, and William M. Park. 1997. "Household Willingness to Pay for Dropoff Recycling: A Contingent Valuation Study." *J. Agricultural and Resource Economics*, 22(December):310-320.

Jakus, Paul M., Mark Downing, Mark S. Bevelhimer and J. Mark Fly. 1997. "Do Fish Consumption Advisories Affect Reservoir Anglers' Site Choice?" *Agricultural and Resource Economics Review*, 26(2):198-204.

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Jakus, Paul M., Kelly H. Tiller and William M. Park. 1997. "Explaining Rural Household Participation in Recycling." *J. Agricultural and Applied Economics*, 29(1):141-148.

Shaw, W. Douglass and Paul M. **Jakus**. 1996. "Travel Cost Demand Models for Rock Climbing." *Agricultural and Resource Economics Review*, 25(4):133-142.

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Siegel, Paul B. and Paul M. **Jakus**. 1995. "Tourism as a Sustainable Rural Development Strategy: Finding Consensus in Resident Attitudes." *Southern Rural Sociology*, 11(1):17-41.

Jakus, Paul M. 1994. "Averting Behavior in the Presence of Public Spillovers: Household Control of Nuisance Pests." *Land Economics*, 70(3):273-285.

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Smith, V. Kerry, Raymond B. Palmquist and Paul M. **Jakus**. 1991. "Combining Farrell Frontier and Hedonic Travel Cost Models for Valuing Estuarine Quality." *Review of Economics and Statistics*, 73(4):694-699.

Miller, Watkins W., Chauncey T.K. Ching, John F. Yanagida and Paul M. **Jakus**. 1985. "Agricultural Water Pollution Control: An Interdisciplinary Approach." *Environmental Management*, 9(1):1-6.

Other Recent Publications

Jakus, Paul M., John C. Bergstrom, Marty Phillips, and Kelly O'Brien. Forthcoming. "Modeling Behavioral Changes in Reservoir Operations in the Tennessee Valley Region." Forthcoming Book chapter in Preference Data for Environmental Valuation, John Whitehead, Ju-chin Huang, and Tim Haab, eds. Routledge.

Jakus, Paul M., Becky Stephens, and J. Mark Fly. 2006. "Temporal Reliability in Contingent Valuation (With a Restrictive Research Budget)." Chapter 11 in Handbook on Contingent Valuation, Anna Alberini and James Kahn, eds. Northampton, MA: Edward Elgar.

Shaw, W. Douglass, Mary Riddell, and Paul M. **Jakus**. 2005. "Valuing Environmental Changes in the Presence of Risk: A Review and Discussion of Some Empirical Issues." Chapter 7 in Folmer, H. and T. Teitenberg (eds.), International Yearbook of Environmental and Resource Economics: A Survey of Current Issues 2005/2006.

Kelly H. Tiller, Paul M. **Jakus**, and William M. Park. 2003. "Household Willingness to Pay for Dropoff Recycling: A Contingent Valuation Study." Book chapter in, T.C. Kinnaman (ed.), The Economics of Residential Solid Waste Management, Ashgate. (Re-print of 1997 *JARE* article)

Jakus, Paul M., Mary Riddel, and W. Douglass Shaw. 2003. "Are Climbers Fools? Modelling Risky Recreation." Chapter 5 in N.D. Hanley, W.D. Shaw, and R. Wright (eds.), The New Economics of Outdoor Recreation, Edward Elgar.

Honors and Awards

J. Agricultural and Resource Economics, Associate Editor, 2003-2006
Society and Natural Resources, Associate Editor, 2003-2005
J. Environmental Economics and Management, Editorial Council, 2001-2003
Water Resources Research, Associate Editor, 1999-2002
Outstanding Referee Citation, *Water Resources Research*, 1998
Western Regional Research Project W-133, President, 1997-98.
Dutch and Marilee Cavender Award for Best Research Publication, University of Tennessee Institute of Agriculture, 1997
J. Agricultural and Applied Economics, Editorial Council, 1996-99
Outstanding Graduate Student Paper, 1991. Southern Association of Agricultural Economics

Attachment C: Proposed Peer Reviewer – Engineering

Mr. James W. Cuchens, PE

Mr. James Cuchens has over 40 years of experience with cooling water systems engineering, balance-of-plant modification, construction and operations at nuclear and fossil-fueled steam electric power plants. Prior to his retirement from a major utility his work included:

- Conceptual design studies, design evaluations, preparing equipment specifications, and procurement/bid evaluations.
- Design of major plant equipment including the turbine/thermal cycle equipment, boiler and draft system equipment, and plant cooling system equipment.
- Evaluating or performing design modifications of cooling towers, cooling ponds/lakes, steam-surface and air-cooled condensers, air removal/vacuum systems, auxiliary heat exchangers, cooling water pumps/sumps, service water equipment, and related piping systems.
- Development and use of computer simulation models for performance analysis of the cooling systems/components.
- The design of natural draft and/or mechanical draft cooling towers for numerous power generating facilities; implementing field tests to evaluate tower thermal designs; performing feasibility studies for modifying and/or upgrading existing towers for enhancing tower performance and reducing operations and maintenance costs.
- Performing cooling system retrofits such as refurbishing existing cooling towers as well as installing helper cooling towers for supplementing existing tower performance; performing or participating in condenser re-tubing projects (modular and conventional) as well as condenser waterbox and hotwell replacement.
- Development of condenser design standards for field erected and modular type condenser construction; conducting feasibility studies for modifying and/or upgrading condensers to enhance overall system/unit performance.
- Design of various types of circulating water pumps and piping systems including mixed-flow vertical can-type pumps and vertical volute type pumps; performing hydraulics analyses.
- Conducting or directing engineering studies in support of compliance with CWA 316(b) including conversion to closed-cycle cooling, use of treated effluent (greywater) water sources, and/or modified intake systems with fish-friendly traveling water screens.
- Serving as the Vice President, President and on the Board of Directors of the Cooling Tower Institute.

  Mr. Cuchens is a registered Professional Engineering in the state of Florida and in three other states.

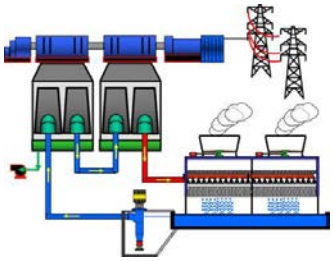
TEC believes that Mr. Cuchen's experience will allow him to effectively peer review the following engineering aspects in 122.21(r)(10) and 122.21(r)(12):

- Technical feasibility of retrofitting existing once-through cooled systems with closed-cycle recirculating cooling towers with consideration for sizing of new towers, locating them

appropriately onsite, offsite or in repurposed sections of the site; evaluating balance of plant modifications needed; and cost of the new equipment and retrofits to the balance-of-plant.

- Technical feasibility of retrofitting the existing coarse-mesh cooling water intake structures with fine-mesh or fine-slot screens; retrofits needed to the balance of system, particularly the circulating water pumps; and the cost of retrofit.
- Technical feasibility of routing alternate water sources and reusing existing water streams in order to reduce cooling water withdrawal from the surface water source.
- Changes in energy consumption due a retrofit.
- Air pollutant emissions, their impacts, and mitigation measures.
- Changes in noise and mitigation measures.
- Impacts on safety and measures to improve safety.
- Impact on facility reliability and cooling water reliability.
- Changes to consumption of water, and mitigation measures.

J. W. CUCHENS, P.E.
Principal Consultant / Cooling Systems
B.S., Mechanical Engineering,
Mississippi State University, 1973



EXPERIENCE SUMMARY

Mr. Cuchens has over 42 years of experience in all phases of power plant design, construction and operation with various types of generating units including nuclear, fossil, and co-generation facilities. Engineering experience includes conducting conceptual design studies, equipment design specifications, and procurement/bid evaluations. His experience includes design of major plant equipment including the turbine/thermal cycle equipment, boiler and draft system equipment, and plant cooling system equipment. Experience within the past 39 years has primarily been associated with power plant cooling systems which consist of cooling towers, cooling ponds/lakes, steam-surface and air-cooled condensers, air removal/vacuum systems, auxiliary heat exchangers, cooling water pumps/sumps, service water equipment, and related piping systems. Mr. Cuchens experience also specialized in the development and use of computer simulation models for performance analysis of the cooling systems/components.

RELATED EXPERIENCE

Power Engineering experience involved the optimization of thermal/power island cycle in support of resource forecast modeling (future generation plans) for various types of generation including fossil fuel units; pulverized fluidized bed units; gas fired/combined cycle units; and nuclear units. Mr. Cuchens Power engineering experience supported the development of numerous power generation projects as shown in the project list below.

Steam Cycle / Balance of Plant Design experience includes the development of thermal cycle configurations including feedwater heater and balance of plant equipment configurations. Additional steam cycle engineering experience includes evaluation of turbine design criteria for once-through and closed-loop cooling cycles in establishing guaranteed performance parameters. Additional steam cycle experience includes the evaluation of steam cycle performance constraints and limitations with consideration of equipment design (single pressure, multipressure, etc.) and site specific conditions (climatology, geology, etc.).

Cooling Cycle Design experience includes various types of technical/feasibility studies which became the basis in development of equipment technical specifications, bid evaluations, and applied research of cooling cycle equipment technology. Mr. Cuchens' experience also consisted of design and operating knowledge for various types of cooling cycles including closed loop, once-through, and/or cooling ponds, serving nuclear units, fossil units, and cogeneration units. Mr. Cuchens design experience involved the optimization of the cooling system equipment (towers, pumps, and condensers) for new and/or existing units with consideration of performance, capital cost, and operation and maintenance. His expertise includes development of computer programs for selection of cooling cycle equipment design as well as analysis of equipment and/or plant performance.

J. W. Cuchens, P.E.

Cooling Tower experience includes the design of natural draft and/or mechanical draft cooling towers for numerous power generating facilities. Design experience includes the development of tower design standards for utilization of concrete, wood, and/or fiberglass construction materials for both cross-flow and counter-flow type cooling towers. Cooling tower experience includes consulting services to plant personnel (field inspections, equipment trouble shooting, etc.) in support of operations and maintenance activities. Cooling tower experience includes field testing for development of a system data base for in-depth analysis of tower thermal design and evaluation of vendor proposals. Cooling tower experience includes feasibility studies for modifying and/or upgrading existing towers for enhancing tower performance and reducing operations and maintenance costs. Retrofit experience includes refurbishing existing cooling towers as well as installation of helper cooling towers for supplementing existing tower performance. Mr. Cuchens experience provided enhanced tower/unit performance capability throughout the Southern Electric system.

Condenser Design experience involved the design of both air-cooled and steam surface condensers including single pressure, multi-pressure, single pass, and multi-pass configurations. Mr. Cuchens' experience includes the development of condenser design standards for field erected and modular type condenser construction. Mr. Cuchens provided field inspection/consulting services to plant personnel (tube inspections, air leakage trouble shooting, etc.) in support of operations and maintenance (O&M) and plant outage activities. Mr. Cuchens directed and/or participated in field testing to assess condenser tube cleanliness and overall condenser performance. Mr. Cuchens was responsible for conducting feasibility studies for modifying and/or upgrading condensers to enhance overall system/unit performance. Mr. Cuchens retrofit experience involved numerous re-tubing projects (modular and conventional) as well as condenser waterbox and hotwell replacement.

Circulating Water Pumps/System Design experience includes the engineering design of various types of circulating water pumps and piping systems including mixed-flow vertical can-type pumps and vertical volute type pumps. Mr. Cuchens expertise includes the capability for providing hydraulics analysis for determination of system pumping head requirements as well as the testing and evaluation of pump performance. Pump design experience includes development of pump design standards for closed suction systems as well as open pit sump designs. Mr. Cuchens has been responsible for conducting feasibility studies for modifying and/or upgrading existing pumps for enhancing pump/condenser flow. Retrofit experience includes refurbishing existing pump impellers as well as and installation of new pump rotating assemblies and modification of pump motors. Mr. Cuchens provided guidance in best practices associated with the design of pump sumps based on sump model studies to mitigate vortex issues.

ENVIRONMENTAL PROJECTS & INDUSTRY RELATED EXPERIENCE

EPA 316b Experience **-** Mr. Cuchens has been actively engaged in addressing EPA 316b rule provisions in efforts to integrate industry experience related to best practices in water use/consumption, protection of aquatic species, and application of alternative cooling system technologies which promote and support environmentally compliant and efficient cooling systems. Mr. Cuchens has conducted and/or directed engineering studies in support of compliance with 316b including closed loop cycle conversion, use of treated effluent (greywater) water sources, and/or modified intake systems with fish-friendly traveling water screens.

J. W. Cuchens, P.E.

Anti-Fouling Fill Media Research **-** Film fill media designs used in counter-flow type cooling towers have a tendency to foul or plug under certain water chemistry conditions. Mr. Cuchens has been involved for ~ 20 years in the research and investigation of anti-fouling fill designs for prevention of fouling in counterflow cooling towers. Mr. Cuchens has also been involved in the investigation of the use of surfactants to enhance cross-flow cooling tower performance. The results of these in-situ programs have provided long term reliable cooling tower performance with minimal fouling,

Industry Related Experience & Training

Mr. Cuchens has participated in and authored numerous papers and articles for EPRI Cooling System Conferences, Cooling Technology Conferences, International Water Conferences, Industry Trade Magazines, and Educational Seminars. Mr. Cuchens has conducted numerous training seminars related to cooling tower/condenser technology.

CERTIFICATIONS AND AFFILIATIONS

Registered Professional Engineer In Four States
Alabama PE # 13752; Florida PE # 37709; Georgia PE # 16164; Mississippi PE #09905
American Society of Mechanical Engineers – Member and Committee Representative
Cooling Tower Institute - Board of Directors 1995-2001; 2012-2016 (Current)
Cooling Tower Institute - Vice President 2001, President 2000
Cooling Tower Institute – Engineering Standards & Maintenance Committee - Chairman
ASME - Power Test Code (PTC) 23 – Cooling Tower Test Code - Committee Member
ASME - Power Test Code (PTC) 30 – Air Cooled Condenser Test Code - Committee Member



J. W. Cuchens, P.E.

PROJECT EXPERIENCE (PARTIAL)

The following is a partial experience list of various generation and/or retrofit projects involving cooling system components (Cooling Towers, Condensers, CW Pumps/Sumps, Air Removal Systems, etc.)

Bowen Units 1-4 Cooling Systems W/ Natural Draft Towers - Repack
Scherer Units 1-4 Cooling Systems W/ Natural Draft Towers
Vogtle Units 1 & 2 Cooling Systems W/ Natural Draft Towers – Repair/Refurbish
Vogtle Units 3 & 4 AP1000 Cooling Systems W/ Natural Draft Towers – Under Construction
Millers Units 1 & 2 Cooling Systems W/ Crossflow Natural Draft Tower - Refurbish
Millers Units 3 & 4 Cooling Systems W/ Counterflow Natural Draft Tower - Refurbish
Plant Hatch Nuclear Units 1 – Tower Replacement/Retrofit
Plant Farley Nuclear Units 1 & 2 – Tower Replacement/Retrofit
Crist Steam Plant Units 6 & 7 Cooling Tower Retrofit/Replacement
Watson Steam Plant Unit 5 - Cooling Tower Retrofit/Replacement
Watson Steam Plant Unit 4 – Environmental Cooling Tower – Installation/Repair
Plant Branch Units 1 & 2 – Environmental Cooling Tower
Plant Yates Units 1 - 4 Cooling Tower Retrofit/Closed Loop Conversion
Plant McDonough Units 1 & 2 Cooling Tower Retrofit/Closed Loop Conversion
Combined Cycle (CC) Cooling Systems Experience Including Cooling Towers, Condensers, Cooling Water Pumps, Vacuum Systems, and Related Auxiliaries
- Barry CC Units 6 & 7
- Daniel CC Units 3 & 4
- Wansley CC Units 6 & 7
- Lansing Smith CC Unit 3
- Plant Harris CC Units 1 & 2
- Plant Franklin CC Units 1, 2, & 3
- Plant Theodore Cogeneration Unit
- Olin/Washing County Cogeneration Unit
- McIntosh CC Units 10 & 11
- Plant McDonough CC Units 3, 4, & 5
- Kemper County Integrated Gasified Combined Cycle (IGCC)

Daniel Units 1 & 2 Condenser Retube (Titanium)
Watson Units 4 & 5 Condenser Retube (Titanium)
Crist Units 6 & 7 Condenser Retube (Titanium)
Yates 7 Condenser Retube (Titanium)
Plant Hatch Nuclear Units 1 & 2 Condenser Retube (Titanium)
Gaston Units 1, 2 & 3 Condenser Retube (SeaCure, 90/10 CuNi, & Titanium)
Crist Units 6 CW Pump Replacement/Retrofit
Watson Unit 5 CW Pump Replacement/Retrofit
McIntosh 11 – Cooling Tower On-Line Replacement (Tornado Destruction)t
Crist 6 & 7, Watson 4 & 5 – Cooling Tower Repair - Hurricane Destruction
Miller Units 3 & 4 – On-Line Cooling Tower Fill Replacement

A more comprehensive list can be provided upon request if desired.

Appendix 13-C

Email to FDEP Confirming Verbal Approval of Peer Reviewers

From: Mark Gerath
To: marc.harris@dep.state.fl.us
Cc: Butler, Amy M.; Stephen Cibik; Jennifer Mathia; de Silva, Radhika
Subject: Tampa Electric Peer Review Approval
Date: Monday, November 07, 2016 5:15:33 PM

Marc,

Thanks very much for your time this afternoon. Based on our call this afternoon, I understand that Tampa Electric's proposal for peer reviewers of August 30, 2016 is approved. Therefore, Tampa Electric will proceed with Dr. Steven Layman, Dr. Paul Jakus, and Mr. Jim Cuchens, PE as the biology, economics, and engineering peer reviewers, respectively.

I do want to clarify one point on our call. Mr. Cuchens is retired from Southern Company where he was a manager of their design group including nuclear facilities. I understand that he is a contractor to Gulf Power, a Southern Company subsidiary, including supporting that company with Section 316(b) work. Please let me know if this relationship is of concern to you, we do not believe that it is a concern to us. Please do not hesitate to call me if you would like to discuss Mr. Cuchens's background or any other aspect of the peer review.

I also left Jason Rueter of NMFS a voice mail and will follow up with him tomorrow if I don't hear from him.

Thanks,

Mark Gerath
Principal Scientist – Water Resources
Environmental Consulting & Technology, Inc.
1740 Massachusetts Avenue|Boxborough, MA 01719
978-263-3335 (Office)|978-337-5935 (Mobile)
mgerath@ectinc.com | www.ectinc.com

Appendix 13-D

Peer Reviewer Responses to Entrainment BTA Plan Document

Charge Questions

Engineering Peer Reviewer

J.W. Cuchens, P.E.

The following are the charge questions for the engineering peer reviewer. The focus of these questions is with regard to adequacy of the Plan to execute the reports under 40 CFR 122.21(r)(10) and (12) (https://www.gpo.gov/fdsys/pkg/FR-2014-08-15/pdf/2014-12164.pdf ; see pp. 48427-48428, pp. 129 and 130 of the PDF file).

Please check 'Yes' or 'No' to each question. We welcome comments for categories you check 'Yes' and we request comments for categories you check 'No'.

Question Number	§122.21(r)(10),(12)	Response	Comments (if any)
Cooling Tower Evaluation			
1)	Does the approach for sizing and siting cooling towers presented in Section 4 take into consideration key design parameters?	√ Yes/No	See attached
2)	Is the conceptual design approach presented in Section 4 consistent with industry standards?	√ Yes/No	See attached
3)	Is the level of cooling tower design presented in Section 4 sufficient for developing a +50%/-30% cost estimate?	√ Yes/No	See attached
4)	Are the key cooling tower-related impacts discussed in Section 6 consistent with the requirements in 122.21(r)(12)?	√ Yes/No	See attached
5)	Is the approach presented for each impact evaluation (emissions, energy consumption, noise, safety, reliability and consumptive water use) sufficient for the purposes of 316(b) evaluations?	√ Yes/No	See attached
Fine mesh screen evaluation			
6)	Does the approach in Section 4 include a sufficient variety of fine mesh screen options/configurations to meet the requirements in 122.21(r)(10)?	√ Yes/No	See attached

7)	For the fine slot wedgewire screens, does the approach in Section 4 consider key design parameters that should be included in concept design?	√Yes/No	See attached
8)	Is the level of design proposed in Section 4 for fine mesh traveling screens and fine slot wedgewire screens sufficient?	√Yes/No	See attached
9)	Does Section 6 sufficiently clarify impacts associated with a fine mesh retrofit? If so, is it reasonable to not evaluate some impacts for fine mesh screens (e.g. consumptive water use)? If the impact evaluation for fine mesh screens needs to be expanded, please clarify which other impacts that should be evaluated?	√Yes/No	See attached
Alternate Water Sources			
10)	Does the approach in Section 4 consider all reasonable alternate cooling water sources? If not, suggest others.	√Yes/No	See attached
11)	Does Section 6 sufficiently clarify impacts associated with using alternate water sources? If so, it is reasonable to not evaluate some impacts for alternate water sources (e.g. consumptive water use)? If the impact evaluation for alternate water sources needs to be expanded, please clarify which other impacts that should be evaluated?	√Yes/No	See attached
General			
12)	Does the approach presented in Section 6 include all the non-water quality impacts that are required to be evaluated in 122.21(r)(12)? If not, clarify which ones are missing.	√Yes/No	See attached
13)	Does the approach presented in Section 4 for evaluating cooling tower retrofits, fine mesh screen retrofits or use alternate water sources (the narrative and the matrices) clarify data inputs and interface points with other disciplines? Does the approach presented seem appropriate and practical? If not, clarify how the approach should be modified.	√Yes/No	See attached

14)	Based on information presented, does it seem that this approach will facilitate a feasibility evaluation that is adequate for the purposes of 122.21(r)(10) and to inform a NPDES Permit Director on which technologies may or may not be feasible at each station?	√Yes/No	See attached
15)	Does the approach presented in Section 4 evaluate key cost components that should be evaluated? If not, clarify which cost components are missing. If this approach includes key cost components, does it seem that the cost evaluation can provide a +50%/-30% cost estimate?	√Yes/No	See attached
16)	If you responded in the affirmative to all of the questions above, do you conclude that the proposed Plan is adequate to address the engineering aspects of the Rule's requirements at 40 CFR 122.21(r)(10) and (12)?	√Yes/No	See attached

1

2

3

PLANNING DOCUMENT PEER REVIEW – COMMENTS
J. W CIUCHNES, P.E.

SCOPE AND OBJECTIVE

The scope of this report is to provide a peer review of the Planning Document to address requirements of EPA 316(b) 40 CFR 122.21 r(10), (11), & (12) as described below:

r(10) *Comprehensive Technical Feasibility and Cost Evaluation Study.*
r(11) *Benefits Valuation Study.*
r(12) *Non-water Quality Environmental and Other Impacts Study.*
r(13) Peer Review of 40 CFR 122.21 r(10), (11), & (12) submittals

The primary focus of the author will be to address compliance with 40 CFR 122.21® (10), *Comprehensive Technical Feasibility and Cost Evaluation Study.*

The objective of this peer review is to provide an objective review and critique of the proposed plan to address the above requirements.

Author: No responses needed.

GENERAL COMMENTS

The requirements for the Technical Feasibility Study includes the assessment of technical feasibility (viability) and the associated costs (economics) for implementation of various compliance technologies required by 316(b) r(10).

There are numerous other compliance alternatives and/or technologies which may offer additional guidance for site specific BTA. These compliance alternatives would need to be examined in comparison with technologies considered in this study to render a more comprehensive and indiscriminate analysis of BTA for the subject generating facilities.

Author: During initial planning stages, TECO discussed with Florida Department of Environmental Protection (FDEP) the need to evaluate additional technologies, and FDEP clarified that such an evaluation was not needed. Their decision was likely based on historical understanding of the stations and knowing that other entrainment reduction technologies are not practical at these two stations.
We understand the Peer Reviewer's suggestion for a broader entrainment reduction technology evaluation, for the completeness of the feasibility report. We propose therefore to present a matrix and perform a brief evaluation of entrainment reduction technologies not directly required by the rule.

The scope of this study does not include any evaluation of the technical merit and/or economic feasibility of all of the alternative compliance technologies in comparison with

the technologies required by the EPA 316(b) rule. Consequently, this study does not make any recommendations and/or conclusions regarding BTA for technologies included. Results of this study are intended to assist the EPA Director in determination of BTA along with any additional evaluations of alternate compliance method(s) and/or technologies and to provide the (EPA) Director with information supporting decisions regarding BTA for the subject generating facilities.

Author: Regarding the scope of study (page 5, Lines 31-32), see previous response regarding an evaluation, in matrix form, of additional entrainment reduction technologies beyond those required by the rule.

Regarding recommendations and conclusions of BTA technologies within the 122.21(r)(10) report (page 6, lines 4), we read the rule as requiring 122.21(r)(10) report to evaluate entrainment reduction technologies for their feasibility and cost of implementation. If the technology is infeasible or impractical, then we will state that clearly but our intention is still to estimate costs for a representative approach to each technology. In any case, feasibility of a technology alone would not mean that it would necessarily be recommended.

122.21(r)(11) report would evaluate the benefits of implementing entrainment reduction technologies; and 122.21(r)(12) would evaluate non-water quality and other environmental impacts. The conclusions/recommendations on technology implementation would need to weigh engineering feasibility (from 122.21(r)(10)), biological benefits (from 122.21(r)(11)), impacts (from 122.21(r)(12)), and social costs and benefits (from 122.21(r)(10)-(12)). The 122.21(r)(10) report alone should not draw conclusions on the BTA technology (unless infeasible/impractical).

SECTION 3 – OVERVIEW OF PLANTS

Comment 1

Table 3-1 Bayside Plant Information, Page 3-2, Design Intake Flows depicted as flow velocities (FPS) rather than volumes (MGD).

Author: This will be corrected.

Intake Velocities for Bayside CWIS 1 & 2 referenced were from 2005 PIC design values, Are these design values, actual values, or calculated/estimated values? Are these values coincident with any of the flow data presented (design or actual) reflected in the table ?

Author: Per language in the rule about design intake flow, “design intake velocity” refers to the through-screen velocity corresponding to the design intake flow rate and lowest water depth. For the purposes of this evaluation, we will use nameplate ratings of pumps when calculating the design intake flow.

Description of Intake(s) – Difficult to assess which CWIS serves which units and quantity of TWS associated with number of bays/pumps, etc.

CWIS 1 – No. of Units/Pumps/Bays ?
No. of Dual-Flow (double entry ?) Traveling Water Screens (TWS)
Do all TWS have 0.375 Mesh Screens ?
Are all TWS same design/capacity ?
CWIS 2 – No. of Units/Pumps/Bays ?
No. of Dual-Flow (double entry ?) Traveling Water Screens (TWS)
Do all TWS have 0.375 Mesh Screens ?
Are all TWS same design/capacity ?

Author: Flow rates associated with each unit, including numbers of pumps associated with each unit, pump ratings, number and types of screens, mesh sizes, etc. will be presented in the 122.21(r)(3) report. The subset of information relevant to the screen evaluation will be repeated in 122.21(r)(10).

Description states that repowered Units 1&2 use bays for Intakes on Units 5 & 6 but also states Units 1-4 have been demolished. Units 1 & 2 obviously don't use any bays/intakes if demolished. As such, I would assume that Units 5 & 6 probably utilize intake bays originally intended for Units 1-4 but not clear.

Author: This information will be presented in the 122.21(r)(3) report.

Comment 2

Source Water Body – Page 3-5 states that the source of water is from the Tampa Bay. Are there any additional sources of water which influence the water volume, quality, and biology of Tampa Bay (tidal Influence, rivers, streams, etc.)?

Author: This information will be presented in the 122.21(r)(2) and (4) reports. The subset of information relevant to the cooling tower, fine-mesh screens, alternate water sources, VFDs, etc. will be repeated in 122.21(r)(10).

Comment 3

Table 3-3 Big Bend Plant Information, Page 3-8, - Design Intake Flows correctly depicted as volumes (MGD), not velocities (FPS).

Description included comment that Units 3&4 are required to utilize seasonal FMS. What is mesh size of seasonal FMS ? What are intake velocities during use of FMS on CWIS (704.5 MGD <>~ 490,000 GPM).

Author: A second set of screens (not overlays) with fine-mesh (1-mm) are installed in series during months with higher entrainment rates.

Mesh sizes associated with the coarse-mesh and fine-mesh screens, the months when they are in use, through-screen velocities associated with each set of screens will be presented in the 122.21(r)(3) report. The subset of information relevant to the screen evaluation will be repeated in 122.21(r)(10), and the through-screen velocity will be carefully evaluated when assessing feasibility.

Description of Intake(s) - There is no description of permanent intake traveling water screens on either CWIS 1 or CWIS 2 other than seasonal FMS. This would suggest no other screens are used/present except for seasonal FMS. I would however assume that CWIS 1 & 2 have some sort of traveling water screens or other screening system (quantity/mesh/number ?) – please verify/clarify.

Author: Both intakes at Big Bend employ coarse-mesh traveling water screens all year. The Unit 3&4 intake installs seasonal FMS in series, upstream of the coarse-mesh screens; coarse-mesh screens remain in place even when the FMS are installed.

Is there a debris removal system, if any (i.e. no trash racks or skimmer system stated for Bayside Units).

Author: Bayside also employs coarse-mesh traveling water screens and has a debris removal system. The 122.21(r)(3) report will provide details of the existing debris and aquatic organism return systems, trash racks, cleaning systems, etc. The subset of relevant information will be included in 122.21(r)(10), and potential/hypothetical enhancements to the debris and or organism return system will be discussed in 122.21(r)(10).

Are Intake Velocities for Big Bend referenced from 2005 PIC design values, actual values, or calculated values. Are these values coincident with design flows or actual intake flows reflected in Table 3-3 ?

Author: As noted under Bayside, per language in the rule, “design intake velocity” refers to the through-screen velocity calculated using the design intake flow rate and lowest water depth.

SECTION 4 – COMPREHENSIVE TECHNICAL FEASIBILITY & COST EVAL STUDY

Comment 1

Section 4.2 Feasibility Evaluation – Page 4-2 states the comprehensive technical evaluate ion will include closed cycle cooling (CCC), FMS and alternate water sources as required by the rule.

The rule requirements include "*providing a description of all technologies and operational measures considered (including alternative designs of closed- cycle recirculating systems such as natural draft cooling towers, mechanical draft cooling towers, hybrid designs, and compact or multi-cell arrangements*". Does the matrix of alternative cooling tower technologies that will be examined and the associated pros/cons (cost, performance, real estate, station service, water use, emissions, etc.) include but not limited to the following?

Counterflow Mechanical Draft
Crossflow Mechanical Draft
Hyperbolic Natural Draft
Hybrid Mechanical Draft (plume abated)
Dry/Air Cooling (direct/indirect)

Author: The matrix will first examine mechanical draft, natural draft, hybrid and air-cooled condensers, and select the type of tower to be evaluated in greater detail based on site-specific factors. Our general strategy will be to consider the most feasible and lower costs option lest we be considered to select an option that needlessly increases estimated costs as a means of biasing the analysis. Counter-flow and cross-flow mechanical draft towers operate differently and have different footprints, however their feasibility criteria are similar. Therefore counter-flow and cross-flow towers will not be evaluated separately.

Comment 2

Section 4.2.1 Cooling Tower Feasibility Evaluation – Page 4-2 states the cooling tower design will be based on design flow rates and design ΔT (temperature rise/heat load). What is the a reason why actual flows and ΔT are not being used ? The study results are being compared to the modifications of the configuration and capability of existing plant/units. EPA does not mandate use of either design and/or actual data in conducting the technical feasibility study. However, if actual data exist, the use of design data may not reflect true differentials in either performance and/or compliance costs.

Author: Per language in the rule, the design intake flow is the maximum intake rate. The cooling tower evaluation will be performed for the maximum heat load and flow of the condenser. Actual heat loads and flows at each station in recent years may be lower than the maximum, but the station wishes to be permitted for the full capacity. Hence the hypothetical cooling towers in this evaluation will be sized for the maximum heat load.

The intent of the 122.21(r)(10) evaluation is to assess feasibility and cost of implementing entrainment reduction technologies using a conceptual level design. Once a specific technology is selected, the stations will perform further evaluations with additional site-specific information. While it is possible that the actual heat loads and actual flow could be higher than the nameplate values used in the 122.21(r)(10) evaluation, the differential is not expected to change the outcome of the study.

Design weather data are statistically based on certain percentages of exceedance (i.e. 1.0, 5.0, 10% of seasonal hours) Cooling tower design wetbulb are often reflected as an ASHRAE seasonal exceedance values which by definition reflects a percentage of time that the wetbulb will be exceeded during that season.

For example, a 1 % summer exceedance wetbulb represents the amount of time that the wetbulb will be exceeded during the months of June, July, August and September which is approximately 30 hours. A 0.5 1 % summer exceedance wetbulb represents the amount of time that the wetbulb will be exceeded during the months of June, July, August and September which is approximately 15 hours.

Section 4.2.1 Cooling Tower Feasibility Evaluation – Page 4-2 states the cooling tower will be designed to the 99.6th percentile. Section 6.6, Page 6-7 later states that the 99.6% represents approximately 0.4 % of the time (SPX 2009) or 35 hours per year that the units would be derated. Does this agree with ASHRAE summer exceedance criteria/data ? (see attached ASHRAE Tampa FL data attached.)

Author: Thank you for the ASHRAE datasheet. We believe that the datasets that we used conform well to the ASHRAE summaries. For example, the 99.6th percentile wet bulb temperature is based on an annual basis. 0.4% x 8,760 hours = 35 hours. The highest wet bulb periods occur in the summer and early fall. 1% of summer exceedance (30 hours) is similar in duration to the 0.4% of annual exceedance. We are evaluating our access to ASHRAE information. If available to us, we may use ASHRAE datasheets. However, we do not anticipate the outcome of the evaluations to change based on WMO or ASHRAE data because the data are consistent.

Comment 3

Section 4.2.1 Cooling Tower Feasibility Evaluation – Page 4-3 states that service water (SW) systems will continue in a once through mode. What is the basis for this design assumption/criteria ? While it may have potential benefits, EPA has not endorsed or advocated exclusion of service water from closed cycle cooling system conversion. Depending on CCC system design, there may be significant benefits for including SW in the closed cycle cooling system.

What is the current configuration of service water system for units/plants being studied ? Is service water provided from independent SW pumps at the CWIS or from discharge of the main cooling water pumps ?. If SW pumps are located at the CWIS, this information should be included in the plant CWIS system description. If service water is provided

from the discharge of the main cooling/circulating water pumps, what is the proposed plan for a new CWIS to accommodate independent service water pumps.

Author: We agree that the EPA does not require or reject the inclusion of service water in the closed-cycle system. We have, since writing the study plan, reconsidered the handling of service water. If inclusion of service water further reduces the cycles of concentration or somehow reduces the feasibility of implementing cooling towers, then service water will be kept separate. Otherwise, the evaluation will assume that the service water can be incorporated into the closed-cycle system. The stations are unable to provide the heat loads associated with service water flows. For the purposes of the evaluation we will assume that the ΔT of the service water is the same as the average ΔT of the unit it is associated with.

Comment 4

Section 4.2.1 Cooling Tower Feasibility Evaluation – Page 4-3 states that if the condenser temperature rises (ΔT) are different for individual units, the cooling towers will be dedicated to different generating units. This would require segregated piping systems for each unit. Is there a reason why the towers for all units should not be the same that would allow flexibility in modulation of tower operation to maximize performance ? Designing the cooling tower for a low approach temperature at 1% wetbulb and the highest ΔT would provide cooler water for all unit(s). This would also provide reduced O&M with all towers/cells having identical interchangeable mechanical/electrical components.

Author: For the purposes of this evaluation, we will assume that each unit would be dedicated to a cooling tower. Per the peer reviewer's input, we will also note that the pipes will be cross-connected so that one unit can use the cooling tower of another unit. When the ΔTs are different, a unit may experience a performance advantage or disadvantage when "cross-connected". Considering that operations in cross-connected mode would happen infrequently, we believe that this is an acceptable approach.

Anyhow, the ΔTs of the different units at Bayside and Big Bend are same/similar. Therefore, the hypothetical cooling towers will have the same ranges.

Comment 5

Section 4.2.1 Cooling Tower Feasibility Evaluation Page 4-3 states that "*if the closed cycle cooling system pressure exceeds the condenser pressure rating, then closed cycle retrofit would be considered unfeasible/unpractical*". I would concur with this conclusion if and only if the use of booster pumps **or** modification of the condenser and piping network is not an option. Otherwise, it is NOT a show stopper and should be considered.

The condenser and piping systems on once through cooling systems typically have a low head/pressure design. The use of a cooling tower will require higher head/pressure system hydraulics. The use of booster pumps would obviously allow continued use of the existing low head cooling water pumps and existing condenser. However, this section further states that *"inclusion of another pump sump (wet wells) for booster pumps is also impractical due to large new wet well needed"*.
Based on the above "planning document" conclusions, closed cycle cooling is impractical/unfeasible and apparently should not be considered. There are multiple methods for modifying the condenser and/or piping system. The primary pressure components of the condenser includes the waterboxes and piping network. If booster pumps are not considered, then replacing the waterboxes and installing liners inside the existing piping should then be considered. These modifications has been performed on previous retrofit CCC system conversions.

Author: We agree, and will modify our approach accordingly. Where the condenser pressure rating is lower than the pressure imposed by the closed-cycle system, this evaluation will assume that booster pumps would be used to pump water from the condensers to the top of the cooling towers. Water will be returned to the condensers using the existing circulating pumps so that the pressure on the condensers remain the same as when in once-through.
Because the existing cooling water pipes and waterboxes will continue to experience the same pressures as they do in the current once-through mode, the evaluation will not assume that the pipes and waterboxes will be lined.

In summary, the options that should be considered impractical are those which are *"show stoppers"* (not physically do-able) even though the remaining options present significant challenges and/or expense, The basis for options to be classified as should be included in the body of the main report.

Retrofitting an open loop cooling system for closed cycle cooling (CCC) will require inclusion of site specific considerations including but not limited to water resources, number/type of generating units, available real estate, impact on environment, and piping/hydraulics configuration. While it is generally recognized that almost any retrofit project can probably be accomplished (technically) *with sufficient financial resources*, implementation without due diligence in consideration of industry standards/experience, design practices, and/or proven technologies does not constitute economic viability.

Author: We agree. We also note that being able to accomplish a potential retrofit with sufficient financial resources does not necessarily indicate that the costs would be justified by the outcome nor that Tampa Electric would be justified in spending those costs (as those costs would mostly be passed on to their customer base). For this reason, and others, we intend to provide a Class 4 costing effort for a reasonable representative for each technology required by the rule.

Comment 6

Section 4.2.1 Cooling Tower Feasibility Evaluation Page 4-4 states that "*per Florida requirements, the maximum cycles of concentration (COC) will be 1.1"* for the closed cycle cooling system.

A once through cooling system has a COC of 1.0. As such, tower makeup and blowdown flow requirements while operating with a COC of 1.1 would closely approximate once through cooling. Due to the relatively large volume of makeup water with 1.1 COC, this could trigger mandatory intake screening of tower makeup.

The minimum cycles of concentration permissible for any unit with a closed cycle cooling system is usually dictated by the resource water quality (Tampa Bay) and water chemistry controls (chemical treatment) necessary to maintain optimum water quality.

Please provide a copy of Florida's requirement for a 1.1 COC and include a comment regarding the potential need for additional pumping/CWIS cost associated with the magnitude of tower makeup and/or dilution water necessary for compliance with this requirement.

Author: We agree that 1.1 cycles of concentration will not reduce water withdrawal rate as much as a system operated at higher cycles of concentration. In Florida, the chloride concentration in the discharge cannot be greater than 110% of the receiving waterbody chloride concentration. If the discharge is so amenable, it may be feasible to run the system at higher cycles (while preventing corrosion and scaling) and dilute the discharge (if there is space/time for sufficient mixing. We like to discuss this approach with you further.
Per our discussion on 2/9/17, we will assume 1.3 cycles of concentration for the cooling tower design and operation, and also assume that the blowdown would diluted so that the chloride concentration would not exceed 110% of the makeup water chloride concentration. Per §125.92(e) dilution water will be considered to be a type of cooling water.

Comment 7

Section 4.2.2 FMS Feasibility Evaluation Page 4-4 states that "*0.5 mm mesh screens will be evaluated for both Tampa Electric facilities and finer mesh screens would not be evaluated"*. Since 0.5 mm is ¼ the size of 2.0 mm mesh screens (as required by the rule), I concur that there would be no apparent reasoning for evaluating finer mesh screens.

Author: No response needed.

This section also stated that wedge-wire screening system would not be evaluated due to water depth, limited space and/or lack of sweeping velocity (inside the intake canal),

Wedge Wire Screen (WWS) systems should be located such that the water velocity across the screen provides a sheer/sweeping flow with a minimum current of 1.0 fps to reduce impingement of organisms as well as minimize debris entrainment and/or fouling. Water flow through the CWWS and its effectiveness will be largely dependent on the blockage factor (% of surface area impacted by debris accumulation on the surface of the screens). Silt accumulation can also create a blockage resulting in reduced screen flow/effectiveness. Debris buildup can be periodically dislodged and removed from the WWS surfaces by utilizing an airburst system. However, without a sweeping current, the dislodged debris could resettle on the screen surface.

While implementation of a WWS system would appear impractical, the study should include sufficient information to substantiate the basis for exclusion (not the plan). As such I would expect the report to include technical information reflecting the magnitude of the system (number of WWS). Obviously this may require sizing a WWS system utilizing multiple small diameter (4 to 6 ft.) screens located relatively close to shore (or in a potentially dredged inlet – see illustration below). Such evidence would provide supporting evidence that WWS is not a viable (do-able) compliance technology.

Author: We agree. The evaluation will include a discussion of wedgewire screens, their design and operation criteria (such as those listed by the peer reviewer above). Based on previous evaluations at this facility, we expect that this evaluation will conclude that wedgewire screens are infeasible at these two stations.



Comment 8

Section 4.2.2 FMS Feasibility Evaluation Page 4-5 includes a discussion of various course3 mesh and FMS options. I did not see an option which included installation of additional FMS which would provide the same TSV (& ΔP) as the existing intake structure with 3/8" mesh screens. One option discussed installation of additional FMS that would result in "reasonable" TSV. I would question what is considered as "reasonable" TSV which obviously is at the discretion of the EPA to qualify (0.5 FPS TSV is referenced in the rule).

Author: The evaluation will consider an 'intake expansion', meaning that one of the FMS scenarios will assume that additional FMS will be used to manage the through-screen velocity. It is unlikely that the new system would be designed to achieve 0.5 fps through-screen velocity because this design condition would result in a very large intake. We are very likely to pattern any expanded intakes after the seasonally-employed intakes at Big Bend Units 3 and 4. For example, these intakes have an "approach velocity" of 0.7 fps. The engineers will work with biologists to identify the through-screen velocity that would be large enough to reduce intake size, but small enough to be protective of impingeable organisms (converts in this case). If that evaluation determines that 0.5 fps is in fact the appropriate velocity, the hypothetical system would be designed for that velocity.

The option to expanding the intake structure included stated the importance to address hydraulic issues. Every single option considered has hydraulic implications which can potentially result in unit de-rate equal due to decreased pump head. If the existing pumps are subject to cavitation, then it may be necessary to include cost for replacements pumps/motors/switchgear and/or modifications to the pumps/structure. The consequence of may include replacing pump/motor, evaluation of screening options should include a fouling factor at low tide and the consequential reduction in pump flow here was also mention of the

Author: Agreed and these considerations will be included.

Comment 9

Section 4.2.2 FMS Feasibility Evaluation Page 4-6 list FMS feasibility criteria. The evaluation of screening options should include a screen fouling factor at low tide. Previous drafts of the EPA rule mandated inclusion of a screen fouling factor which has since been removed in the current version. As such, it is at the discretion of the owner/engineer conducting the study to include such subject to site specific operating experience. It has been stated that the subject plants/units have considerable debris issues which should be addressed in the conceptual design for any FMS option.

Author: We agree. In the event that we target a specific through screen velocity, the evaluation will include a 15% fouling factor to account for potential fouling (this value is consistent with previous rules).

Comment 10 – Alternative Water Source for Cooling Water

Section 4.2.3 FMS Feasibility Evaluation, Page 4-6 discussed investigation of alternative water sources and associated issues including pipeline design/layout, etc.

Is this evaluation considering quantities needed for total plant cooling water and/or quantities needed for service water and cooling tower makeup ?

Author: Per the rule, the evaluation will consider water flow quantities needed for once-through cooling.

Even if sufficient quantities are available, the cost for supplying large volumes of cooling water through developed areas of Tampa, FL in the quantities needed are anticipated to be substantial, especially with inclusion of additional pumping stations/structures, piping systems, and parasitic/energy cost requirements. Construction of pipelines to the plant is anticipated to incur additional cost associated with permits associated with right of way/access provisions from the source to the plant(s). The use of alternate water sources in the quantities necessary may also require additional cost for compliance with federal,

state, and local/regional environmental laws/regulations. Use of treated wastewater may also require additional treatment considerations/costs of water discharges.

Author: We agree.

Comment 11 – Feasibility of Other Alternative Technologies

Section 4.2.4 Feasibility of Alternative Technologies – Consideration of VFD drives for cooling water pumps will be examined if deemed feasible and/or practical.

The use of variable frequency drives suggest the variable operation of cooling water pumps. Reducing cooling water flow at any time at any load has a consequential performance penalty. Condenser performance is more sensitive to incremental flow than incremental cooling water temperatures. Reducing condenser flow at any load, increases condenser backpressure which in turn decreases unit efficiency/performance (Kw & Heat Rate). Consequently, the use of VFD for reduced/partial flow operations is anticipated to incur performance penalties.

Author: We agree.

It is anticipated that the existing cooling water pumps are mixed flow vertical turbine-type pumps. These type of pumps have a unique performance curve (head/flow) which necessitate avoidance of certain regions to avoid potentially surging/cavitation.

Prior to consideration of VFD drives, a thorough examination of the pump design should be conducted to assess the technical viability of variable speed operation of the large cooling water pumps/motors.

Author: We agree.

Comment 12 – Cost Evaluations

Section 4.3.1, Page 4-8 through 4-9 includes a discussion on Capital Costs – Does this cost include potential costs to address interferences and/or resolution of such. The electrical costs may also need to include potential costs for upgrading switchgear to accommodate additional electrical loads subject to existing bus-bar capacity/limitations. A bus-bar study is probably been performed to provide/assess exiting system capabilities.

Author: The cost evaluation will include electrical components and the cost of bringing power to where new equipment is hypothetically located. The Class 4 estimate will not evaluate interferences or perform a bus-bar study. These issues will be discussed as uncertainties that could increase the cost of potential retrofits.

Comment 13 – Assessment of Energy Penalties

Section 4.3.2.2, Page 4-13 through 4-18 includes a discussion of the methodologies for assessing energy penalties which include reference to EPRI data and/or equations.

The information included in the plan (per EPRI) is obviously generic and in general, reflects basic cooling system fundamentals which however do not reflect site specifics. As such, it is not an intent to develop and/or use empirical cooling system models for each unit/plant (condenser, cooling water pumps, cooling towers, turbine generator/exhaust pressure, etc.) to assess differentials in unit performance capacity. The use of empirical cooling system models can potentially enhance results due to simulation of actual/existing unit performance with inclusion of available operating data. The use of EPRI data will provide trending (typical) valuations which may not coincide with site/unit specific empirical models.

In summary, the key to performance/energy penalty assessment will be to fairly assess differentials in performance capabilities (not absolutes) for the various options and/or technologies being evaluated which will be reviewed upon completion of the draft report.

Author: We assume that you meant to refer to the Department of Energy 2002 report when you mentioned EPRI above.

We agree that the DOE information is somewhat generic and that the use of an empirical cooling system model would result in more accurate results but at considerably higher study costs. For the purposes of this study, which aims to present a 10-15 percent design and a Class 4 cost estimate, we believe that the somewhat generic DOE energy penalty information will be sufficient.

SECTION 6 – NON WATER QUALITY ENVIRONMENT & OTHER IMPACTS

Comment 1

Section 6.2, Page 6-2 states that most of the year, the temperature of water from the closed cycle cooling water system is higher than temperature of water from a once through system, but there are short periods of time each year when the reverse is true. This statement is potentially true/false dependent on the selected tower design. A more stringent tower design (i.e. 80ºF wetbulb, 7ºF approach, 87ºF cold water temperature & 20ºF range), may potentially reverse this trend since actual summer water temperatures from the shallow Tampa Bay may approach and/or exceeded 87ºF on occasion. The CWT from cooling towers may also be lower than water temperatures from Tampa Bay during winter/spring/fall seasonal temperatures. Consequently, a more stringent tower design could potentially provide comparable generation/performance capabilities. The cost for enhanced incremental tower design is anticipated to be minimal compared to the benefits. A more conservative/stringent tower design may also offset the requirement to

segregate service water from the closed cycle cooling water system, thus avoiding additional service water pumps/structure/piping costs. In any event, it should not require much effort to consider enhanced tower performance options.

Author: Per peer reviewer input, the evaluation will consider a 7°F approach (assuming that the vendors will provide a quote for this approach).

Comment 2

Section 6.3, Page 6-3 states that emissions from the tower will be evaluated under the umbrella of PM_{10} particulate matter. The quantity of suspended and dissolved solids discharged from the fan stacks as PM_{10} particulate matter will be substantial (tons/year). The area (target zone) impacted from dispersion of emissions/particulate is subject to tower location, proximity and wind conditions. The plume emissions will be highly corrosive in nature due to the chemistry of Tampa Bay water containing high levels of chlorides (salts). Since the emissions will not be modeled, it may be prudent to simply advise the customer of the potential dispersion area (target zone) subject to enhanced corrosion and/or deposition of suspended particulate (i.e. overlaying the potential emissions target zone on the cooling tower/site general arrangement). The figures at the end of this report show potential dispersion/target zone for particulate emissions from the cooling tower for any wind direction. Location of cooling towers to mitigate plume dispersion on electrical switchyard/components is a key consideration in the power industry (especially corrosive tower plumes).

Author: Understood, and thank you for the figure. We will include a simple figure showing the more likely impact direction.

Comment 3

Section 6.5, Page 6-6 states that cooling tower plume can be a safety factor. I would concur dependent upon proximity to 1) climitalogical data indicating percentage of time for fogging potential, 2) proximity to major highway, residential/business areas, predominant wind direction/wind rose data, and 4) cooling tower design (velocity recovery fan stacks, wind-wall diversion, etc.). A plume study would identify prominent concerns subject to the design and location of the selected tower.

Author: We concur with the issues described and will discuss these factors for each site and the anticipated locations and design of the cooling towers. We do not plan to perform a quantitative model of the cooling tower plumes.

The emissions from the cooling tower using brackish/salt water may be highly corrosive (due to levels of salts/chlorides). It is assumed that the cooling tower design will

incorporate drift eliminators design for a 0.0005% drift rate to mitigate as much particulate (suspended/dissolved solids) emissions as possible. Emissions from the cooling tower could be a significant safety factor with regards to corrosion and/or influences on external electrical components, especially the switchyard and unpredictable impacts on switchgear which translates to potential loss of emergency power.

Author: We agree.

Use of fine mesh screens is not anticipated to present a significant safety factor unless excessive debris occurrence triggers pump cavitation/shutdown and subsequent loss of emergency power. What provisions are included to address debris removal with use of FMS ?

Author: Continuous rotation, continuous cleaning, high- and low-pressure washes, and debris troughs will be assumed and incorporated into the design to address debris.

Comment 4

Section 6.6, Page 6-7 later states that the 99.6% represents approximately 0.4 % of the time (SPX 2009) or 35 hours per year that the units would be de-rated. This is a presumption conclusion which should be reserved for the final report subject to conclusion of parametrics performed in the study.

Retrofitting a once through cooling system to have closed cycle cooling system would intuitively suggest investigating a cooling tower/system which provides optimum unit performance with minimal degradation.

Use of a tight approach and high wetbulb would provide a cooling tower designed to provide the lowest possible cold water temperature. Use of a large approach temperature at the same wetbulb would inversely increase performance degradation. As such, any de-rate of the units will depend on the selected tower design subject to the following:

Design Flow (actuals plus margin ?
Wetbulb Temperature (0.4%, 1%, 2%, 5%, etc - See Tampa FL ASHRAE Data attached)
Approach Temperature (6ºF, 8 ºF , 10 ºF, 12 ºF, etc.)
Design Cold Water Temperature (wetbulb + approach)
Design Range (actual versus design)

Peer review of the selected tower design in the final study/report will evaluate the merits of design to mitigate performance degradation and associated penalties.

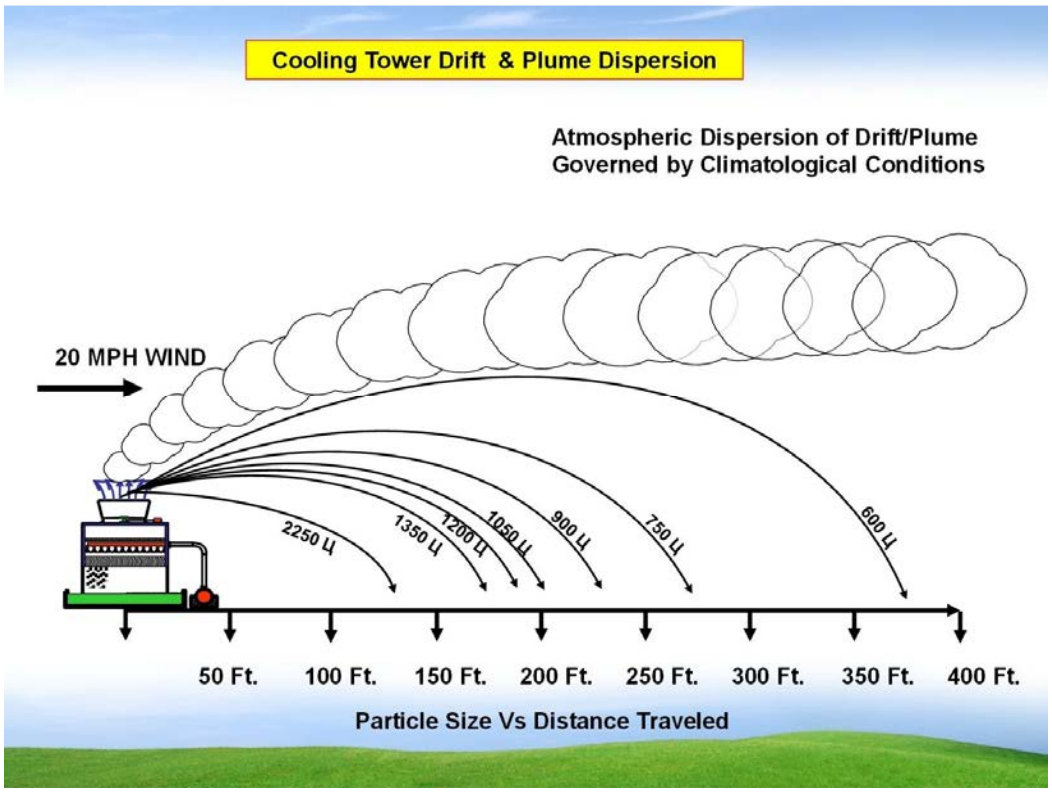
Author: We agree with all of the above, except the suggestion to optimize the design parameters. For the purposes of this study, we did not read the rule as requiring an optimization study nor do we believe that the costs of doing so are justified by the study requirements in the rule. We agree that our approach may results in a sub-optimal cooling tower. The goal is to develop a feasibility

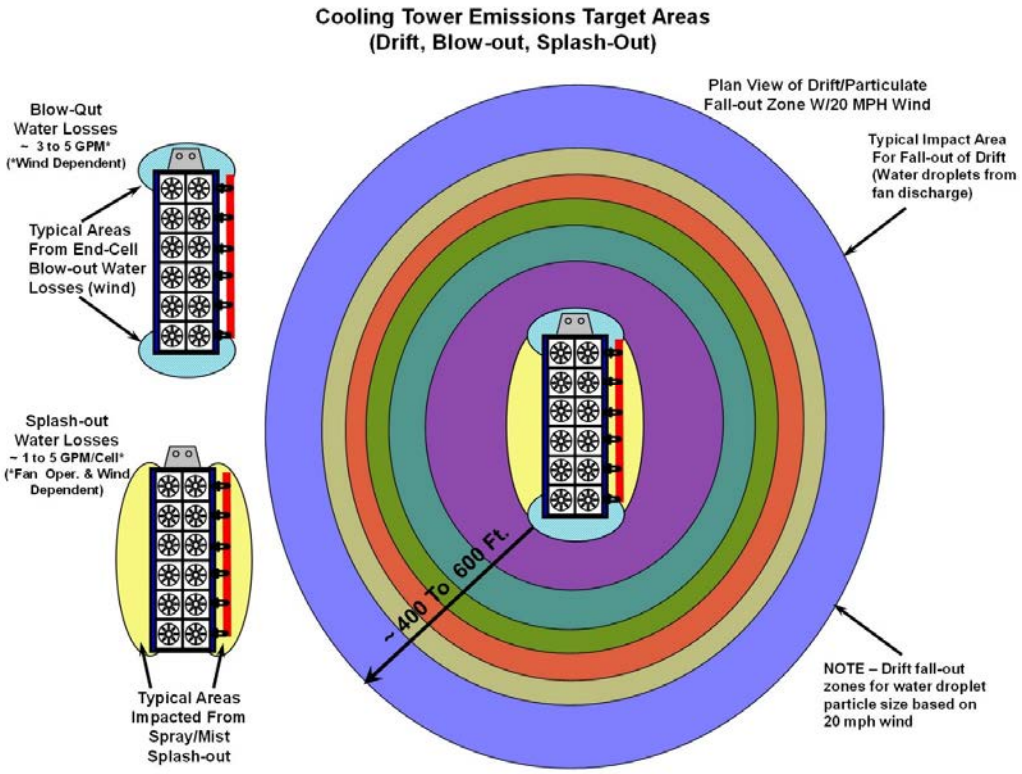
evaluation and prepare a Class 4 cost estimate. While we agree that optimizing design parameters could potentially decrease life-cycle costs, we do not believe that optimized design criteria would cause the cost estimate to stray outside Class 4 accuracy or change the feasibility/practicality determination.
Per our discussion on 2/9/17, for the purposes of the feasibility and cost evaluation for 316(b), we will not optimize the design parameters. We will clarify in the reports that if the BTA determination is closed-cycle cooling that the station would need to reopen the cooling tower analysis and would need to re-evaluate the most suitable suite of design parameters to use.

Comment 5

Section 6.7, Page 6-7 & 6-8 states that water consumption associated with forced evaporation due to added heat load will be calculated for the once through cooling systems. At what average unit load (capacity factor) will be used to assess incremental forced evaporation from Tampa Bay ?. Will the same unit load/capacity factor be used to assess annual/average cooling tower system consumptive losses ?

Author: Because evaporation would be driven by the thermal discharge rate, forced evaporation and cooling tower evaporation will be estimated for full plant operation and also assuming that the same capacity utilization continues out into the future, using the design intake flow (as defined in the rule).


Cooling Tower Drift & Plume Dispersion
Atmospheric Dispersion of Drift/Plume
Governed by Climatological Conditions
20 MPH WIND
2250 Ft
1350 Ft
1200 Ft
1050 Ft
900 Ft
750 Ft
600 Ft
50 Ft.
100 Ft.
150 Ft.
200 Ft.
250 Ft.
300 Ft.
350 Ft.
400 Ft.
Particle Size Vs Distance Traveled


Cooling Tower Emissions Target Areas
(Drift, Blow-out, Splash-Out)
Blow-Qut
Water Losses
~ 3 to 5 GPM*
(*Wind Dependent)
Typical Areas
From End-Cell
Blow-out Water
Losses (wind)
Splash-out
Water Losses
~ 1 to 5 GPM/Cell*
(*Fan Oper. & Wind
Dependent)
Typical Areas
Impacted From
Spray/Mist
Splash-out
Plan View of Drift/Particulate
Fall-out Zone W/20 MPH Wind
Typical Impact Area
For Fall-out of Drift
(Water droplets from
fan discharge)
~ 400 To 600 Ft.
NOTE – Drift fall-out
zones for water droplet
particle size based on
20 mph wind

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TAMPA INTERNATIONAL AP, FL, USA

WMO#: 722110

Lat: 27.96N Long: 82.54W Elev: 10 StdP: 14.69 Time Zone: -5.00 (NAE) Period: 82-06 WBAN: 12842

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
1	38.4	42.5	23.0	17.3	45.3	28.4	22.4	49.4	20.8	58.1	18.8	58.5	6.2	10

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
8	14.2	92.4	77.4	91.3	77.3	90.3	77.2	80.5	87.9	79.9	87.6	79.2	87.0	8.6	260

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours
0.4%			1%			2%			0.4%		1%		2%		8 to 4 &
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	55/69
78.4	147.7	84.8	77.5	143.2	84.0	76.9	140.3	83.5	44.0	87.9	43.2	87.5	42.5	86.9	539

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%	WB	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
18.1	16.2	14.2	86.7	30.8	95.0	5.3	1.4	27.0	96.1	23.8	96.9	20.8	97.7	17.0	98.7

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours		Tavg	73.2	61.0	63.6	67.2	71.5	78.0	81.7	82.6	82.7	81.2	75.7	69.2	63.1
		Sd		8.23	7.31	6.73	5.37	3.77	2.50	1.98	1.92	2.44	5.07	6.53	8.37
		HDD50	26	12	4	1	0	0	0	0	0	0	0	0	9
		HDD65	528	177	103	58	13	0	0	0	0	0	4	37	136
		CDD50	8489	352	386	535	646	868	951	1011	1015	936	795	577	417
		CDD65	3517	52	65	127	209	404	501	546	550	486	334	164	79
		CDH74	31381	187	265	685	1428	3673	5107	5793	5819	4621	2546	923	334
		CDH80	11071	11	21	86	319	1310	2013	2342	2334	1740	720	146	29
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		81.5	82.5	84.6	88.1	92.9	93.8	93.6	93.5	92.6	90.1	85.9	83.0
		MCWB		69.9	69.4	70.9	72.5	74.5	77.1	78.0	78.5	77.0	75.8	73.3	71.8
	2%	DB		78.5	79.9	82.4	85.6	90.3	91.7	91.9	92.0	91.0	87.9	83.5	80.4
		MCWB		68.8	68.7	70.1	71.4	74.2	76.7	77.9	78.3	76.9	75.4	72.6	70.2
	5%	DB		76.0	77.5	80.4	83.7	88.4	90.2	90.6	90.8	89.8	86.2	81.7	78.1
		MCWB		67.6	67.8	69.2	71.0	73.8	76.8	77.9	78.3	76.8	74.6	71.4	69.2
	10%	DB		73.0	74.7	78.2	81.6	86.6	88.7	89.2	89.5	88.3	84.3	79.6	75.2
		MCWB		66.5	66.3	68.1	69.7	73.1	76.6	78.0	78.3	76.7	73.7	70.1	68.1
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		73.0	72.8	75.3	76.4	78.4	80.5	81.6	82.1	80.5	79.0	76.4	74.5
		MCDB		78.0	78.9	80.3	83.2	86.9	88.1	88.5	89.4	87.1	84.9	81.3	79.0
	2%	WB		71.0	71.2	73.4	75.0	77.3	79.5	80.4	80.5	79.6	77.9	75.1	72.7
		MCDB		75.5	76.4	78.7	81.2	85.6	87.7	87.8	88.2	86.9	84.0	80.2	77.1
	5%	WB		69.5	69.7	72.0	73.5	76.3	78.5	79.6	79.9	78.7	76.9	73.7	71.1
		MCDB		73.6	74.4	76.9	80.0	84.2	86.5	87.5	87.9	85.9	82.8	78.6	75.4
	10%	WB		67.9	68.4	70.4	72.2	75.3	77.9	78.8	79.1	78.0	75.8	72.4	69.4
		MCDB		71.6	72.8	75.4	78.5	83.0	85.8	86.6	86.9	85.1	81.5	77.2	73.9
Mean Daily Temperature Range		MDBR		18.2	17.9	17.9	17.9	17.5	14.8	14.3	14.2	14.5	16.2	17.3	17.7
	5% DB	MCDBR		17.7	18.3	18.6	18.7	18.4	16.4	15.8	15.8	16.3	16.1	16.9	17.0
		MCWBR		9.6	9.1	8.8	7.9	6.8	6.2	6.2	6.1	5.8	6.3	7.9	8.5
	5% WB	MCDBR		14.7	14.9	14.6	15.3	15.7	14.2	14.1	14.0	14.2	13.7	14.4	14.3
		MCWBR		9.3	8.9	8.9	7.9	6.9	6.2	6.5	6.4	6.0	6.3	8.3	8.8
Clear Sky Solar Irradiance		taub		0.344	0.364	0.391	0.403	0.470	0.473	0.509	0.493	0.445	0.398	0.360	0.346
		taud		2.531	2.403	2.271	2.272	2.029	2.070	1.950	2.010	2.190	2.356	2.488	2.512
		Ebn,noon		286	288	285	284	264	261	252	255	265	273	278	280
		Edh,noon		30	36	43	43	55	53	60	56	45	37	31	29

CDDn Cooling degree-days base n°F, °F-day
CDHn Cooling degree-hours base n°F, °F-hour
DB Dry bulb temperature, °F
DP Dew point temperature, °F
Ebn,noon } Clear sky beam normal and diffuse hori-
Edh,noon } zontal irradiances at solar noon, Btu/h/ft2
Elev Elevation, ft
Enth Enthalpy, Btu/lb
HDDn Heating degree-days base n°F, °F-day
Hours 8/4 & 55/69 Number of hours between 8 a.m. and 4 p.m with DB between 55 and 69 °F
HR Humidity ratio, grains of moisture per lb of dry air
Lat Latitude, °
Long Longitude, °
MCDB Mean coincident dry bulb temperature, °F
MCDBR Mean coincident dry bulb temp. range, °F
MCDP Mean coincident dew point temperature, °F
MCWB Mean coincident wet bulb temperature, °F
MCWBR Mean coincident wet bulb temp. range, °F
MCWS Mean coincident wind speed, mph
MDBR Mean dry bulb temp. range, °F
PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East
Period Years used to calculate the design conditions
Sd Standard deviation of daily average temperature, °F
StdP Standard pressure at station elevation, psi
taub Clear sky optical depth for beam irradiance
taud Clear sky optical depth for diffuse irradiance
Tavg Average temperature, °F
Time Zone Hours ahead or behind UTC, and time zone code
WB Wet bulb temperature, °F
WBAN Weather Bureau Army Navy number
WMO# World Meteorological Organization number
WS Wind speed, mph

40 CFR 122.21(r) (10),(11) & (12) REQUIREMENTS SUMMARY

r(10) ***Comprehensive Technical Feasibility and Cost Evaluation Study***

An engineering study of the technical feasibility and incremental costs of candidate entrainment control technologies. In addition, the study must include the following:

(i) *Technical feasibility.* An evaluation of the technical feasibility of closed- cycle recirculating systems as defined at 40 CFR 125.92(c), fine mesh screens with a mesh size of 2 millimeters or smaller, and water reuse or alternate sources of cooling water. In addition, this study must include:

(A) A description of all technologies and operational measures considered (including alternative designs of closed- cycle recirculating systems such as natural draft cooling towers, mechanical draft cooling towers, hybrid designs, and compact or multi-cell arrangements);

(B) A discussion of land availability, including an evaluation of adjacent land and acres potentially available due to generating unit retirements, production unit retirements, other buildings and equipment retirements, and potential for repurposing of areas devoted to ponds, coal piles, rail yards, transmission yards, and parking lots;

(C) A discussion of available sources of process water, grey water, waste water, reclaimed water, or other waters of appropriate quantity and quality for use as some or all of the cooling water needs of the facility; and

(D) Documentation of factors other than cost that may make a candidate technology impractical or infeasible for further evaluation.

(ii) *Other entrainment control technologies.* An evaluation of additional technologies for reducing entrainment may be required by the Director.

(iii) *Cost evaluations.* The study must include engineering cost estimates of all technologies considered in paragraphs (r)(10)(i) and (ii) of this section. Facility costs must also be adjusted to estimate social costs. All costs must be presented as the net present value (NPV) and the corresponding annual value. Costs must be clearly labeled as compliance costs or social costs. The applicant must separately discuss facility level compliance costs and social costs, and provide documentation as follows:

(A) Compliance costs are calculated as after-tax, while social costs are calculated as pre-tax. Compliance costs include the facility's administrative costs, including costs of permit application, while the social cost adjustment includes the Director's

administrative costs. Any outages, downtime, or other impacts to facility net revenue, are included in compliance costs, while only that portion of lost net revenue that does not accrue to other producers can be included in social costs. Social costs must also be discounted using social discount rates of 3 percent and 7 percent. Assumptions regarding depreciation schedules, tax rates, interest rates, discount rates and related assumptions must be identified;

(B) Costs and explanation of any additional facility modifications necessary to support construction and operation of technologies considered in paragraphs (r)(10)(i) and (ii) of this section, including but not limited to relocation of existing buildings or equipment, reinforcement or upgrading of existing equipment, and additional construction and operating permits. Assumptions regarding depreciation schedules, interest rates, discount rates, useful life of the technology considered, and any related assumptions must be identified; and

(C) Costs and explanation for addressing any non-water quality environmental and other impacts identified in paragraph (r)(12) of this section. The cost evaluation must include a discussion of all reasonable attempts to mitigate each of these impacts.

r(11) ***Benefits Valuation Study Requirements.***

An evaluation of the benefits of the candidate entrainment reduction technologies and operational measures evaluated in paragraph (r)(10) of this section including using the Entrainment Characterization Study completed in paragraph (r)(9) of this section. Each category of benefits must be described narratively, and when possible, benefits should be quantified in physical or biological units and monetized using appropriate economic valuation methods. The benefits valuation study must include, but is not limited to, the following elements:

(i) Incremental changes in the numbers of individual fish and shellfish lost due to impingement mortality and entrainment as defined in 40 CFR 125.92, for all life stages of each exposed species;

(ii) Description of basis for any estimates of changes in the stock sizes or harvest levels of commercial and recreational fish or shellfish species or forage fish species;

(iii) Description of basis for any monetized values assigned to changes in the stock size or harvest levels of commercial and recreational fish or shellfish species, forage fish, and to any other ecosystem or non use benefits;

(iv) A discussion of mitigation efforts completed prior to October 14, 2014 including how long they have been in effect and how effective they have been;

(v) Discussion, with quantification and monetization, where possible, of any other benefits expected to accrue to the environment and local communities, including but not limited to improvements for mammals, birds, and other organisms and aquatic habitats;

(vi) Discussion, with quantification and monetization, where possible, of any benefits expected to result from any reductions in thermal discharges from entrainment technologies.

r(12) ***Non-water Quality Environmental and Other Impacts Study.***

a detailed facility-specific discussion of the changes in non-water quality environmental and other impacts attributed to each technology and operational measure considered in paragraph (r)(10) of this section, including both impacts increased and impacts decreased. The study must include the following:

(i) Estimates of changes to energy consumption, including but not limited to auxiliary power consumption and turbine backpressure energy penalty;

(ii) Estimates of air pollutant emissions and of the human health and environmental impacts associated with such emissions;

(iii) Estimates of changes in noise;

(iv) A discussion of impacts to safety, including documentation of the potential for plumes, icing, and availability of emergency cooling water;

(v) A discussion of facility reliability, including but not limited to facility availability, production of steam, impacts to production based on process unit heating or cooling, and reliability due to cooling water availability;

(vi) Significant changes in consumption of water, including a facility-specific comparison of the evaporative losses of both once-through cooling and closed-cycle recirculating systems, and documentation of impacts attributable to changes in water consumption; and

(vii) A discussion of all reasonable attempts to mitigate each of these factors.

r(13) Peer Review

Studies submitted under paragraphs (r)(10) through (12) must include an external peer review of each report to be submitted with the permit application. The applicant must select peer reviewers and notify the Director in advance of the peer review. The Director may disapprove of a peer reviewer or require additional peer reviewers. The Director may confer with EPA, Federal, State and Tribal fish and wildlife management agencies with responsibility for fish and wildlife potentially affected by the cooling water intake structure, independent system operators, and state public utility regulatory agencies, to determine which peer review comments must be addressed. The applicant must provide an explanation for any significant reviewer comments not accepted. Peer reviewers must have appropriate qualifications and their names and credentials must be included in the peer review report.

Charge Questions

Economics Peer Reviewer

The following are the charge questions for the economics peer reviewer. The focus of these questions is with regard to adequacy of the plan to execute the reports under 40 CFR 122.21(r)(10), (11), and (12) (https://www.gpo.gov/fdsys/pkg/FR-2014-08-15/pdf/2014-12164.pdf ; see pp. 48427-48428, pp. 129 and 130 of the PDF file).

Question Number	§122.21(r)(10), (11), (12)	Response	Comments (if any)	*Tampa Electric Company's Response 02/02/17*
1)	Does the information provided in the Peer Review Plan provide detail sufficient to allow you to comment on the general appropriateness of the approach and methods to be applied?	Yes		*Tampa Electric Company acknowledges the response and will not change the study approach.*
2)	Are there any other economic analyses that you suggest the Peer Review Plan consider or that require separate study plan(s) to clarify the approach?	No		*Tampa Electric Company acknowledges the response and will not change the study approach.*
3)	Does the Peer Review Plan target quantification and monetization of benefits where they may be reasonably achieved?	Yes		*Tampa Electric Company acknowledges the response and will not change the study approach.*
4)	Is there any literature including that outside of economics literatures that you think should be considered during execution of the work directed by the Peer Review Plan? To which study(s) do you suggest they should apply?	No		*Tampa Electric Company acknowledges the response and will not change the study approach.*
5)	Do you have any other comments that you think relevant to clarifying and/or improving this Peer Review Plan?	Yes	1) Page 5-8, Figure 5-1. As stated during the phone call, this figure was jam-packed with information, and some of the detail was lost.	*Tampa Electric Company acknowledges the comments and will make the*

			The data generated from the live return model is crucial to the economic models described later in the chapter. Please make sure that the final document provides added clarity to the model. 2) Much of the economic modeling will be dependent upon assumed values for engineering, biological, and economic parameters. I raised this question during the phone call and was told that sensitivity analysis—especially with regard to biological models—can be very challenging. That's fine, but I would encourage the study teams to identify the key variables driving the results at all points in the modeling. 3) I looked at the Bingham et al. NAJFM (2011) paper on urban angling and the model seems quite appropriate for function transfer despite its application to anglers in the northeastern U.S. It is quite fortunate to have this paper as I was unable to find any "urban" alternatives to this model; still the economics study steam should all keep their eyes open just in case something else appears in the coming months. I see no reference to fishing models conducted in Florida that may be used as part of the calibration procedure. For example, Frank Bell had a couple of TCM papers back in the 1990s, and there is at least one gray literature RUM model for Tampa Bay by Green, Moss, and Spreen (see the abstract in AJAE Dec 1996, p 1414.) The paper is listed on AgEconSearch, but for some reason is not available for download. The error message suggests that you contact the AgEconSearch site admin…or you could just contact Charlie Moss directly.	*following changes to its approach as follows:* *1) The appropriate (r) reports will provide a thorough description of the live return model so that there is no confusion as to what steps were taken to arrive at the final number of EN losses.* *2) Careful attention will be given when describing the key variables used in the modelling and what impact these variables have on the final results. A qualitative discussion on how the key variables affect the final results will be provided. No sensitivity analysis will be conducted.* *3) Prior to completing the recreational use losses model, a review will be conducted of the current literature for models that may be appropriate for the conditions at Bayside/Big Bend.*

Steven R. Layman, Ph.D.

Biology Peer Reviewer Charge Questions and Responses

Clean Water Act Section 316(b) Planning Document to Support Peer Review of 40 CFR 122.21(r) (10), (11), and (12); Big Bend and Bayside Power Stations

The following are the charge questions for the biological peer reviewer. The focus of these questions is with regard to adequacy of the Plan to execute the reports under 40 CFR 122.21(r)(10) and (11) (https://www.gpo.gov/fdsys/pkg/FR-2014-08-15/pdf/2014-12164.pdf; see pp. 48427- 48428, pp. 129 and 130 of the PDF file). It should be noted that use of the entrainment characterization data collected under Phase II at Big Bend and Bayside have been approved by FDEP and FWC.

Question Number	§122.21(r)(11)	Response	Comments (if any)	*Tampa Electric Company's Response 01/30/17*
1)	Is the consideration of biological efficacy (i.e., reductions in IM and EM) of different EM technologies adequate for the Rule's goals (i.e., they are accurate within the needs of the effort or are conservative)?	**Yes**	The consideration of biological efficacy of alternative EM technologies is adequate for the purposes of the Rule because: (1) the approach applies each year of biological sampling data separately to assess inter-annual variation in entrainment and impingement losses; (2) efficacy will be evaluated against the baseline condition by species/species group, life stage, and year; (3) IM and EM will be reduced proportionally with flow for flow- reduction technologies, consistent with EPA rationale in the Rule; (4) the efficacy of fine mesh screens (FMS) will be based on site-specific studies at Big Bend on exclusion of entrainable organisms and post- exclusion survival; these data will	*Tampa Electric Company acknowledges the comments and will make the following changes to its approach to accessing the biological effectiveness of EM technologies:* *1) We will include a discussion of the uncertainty regarding key assumptions in the analysis.*

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Question Number	§122.21(r)(11)	Response	Comments (if any)	*Tampa Electric Company's Response 01/30/17*
			also be representative of many of the same or closely related taxa at Bayside Station on the same source waterbody (Hillsborough Bay); for example, species of drum (Sciaenidae) and egg life stages numerically dominated entrainment samples at both facilities according to the summaries provided in Tables 3-1 and 3-3; (5) entrained organisms will be assumed to experience 100-percent mortality as required by the Rule; and (6) assumptions made where published studies and data are lacking to inform estimates tend to be conservative on the side of overstating social benefits (potentially weighing in favor of technology selection). The uncertainty surrounding conservative assumptions used in evaluating the efficacy of FMS (Section 5.3.2) (e.g., no increase in the rate of impingement for FMS) should be discussed and evaluated in the study reports, including updated literature review and using sensitivity analysis where appropriate. This will help to determine what effects uncertainties may have on the confidence of the social benefits estimate when comparing the efficacy of FMS to a closed-cycle cooling and other EM reduction technologies.	

Question Number	§122.21(r)(11)	Response	Comments (if any)	*Tampa Electric Company's Response 01/30/17*
1a)	Is the approach to estimating the baseline losses (i.e., definition of organisms of interest, estimation of absolute losses, accounting for prior mitigation measures) appropriate and consistent with the goals of the rule?	**Yes**	The approach will use site-specific data on intra- and inter-annual variation in entrainment and impingement rates and actual intake flow to estimate total annual baseline losses by species and life stage (Section 5.2). To support biological modeling for benefits valuation, taxa may be grouped or parameters of exclusion and survival may be extrapolated to rarely entrained/impinged organisms of interest by using surrogate species. The analysis will include dominant taxa by number and biomass, recreationally important species, listed species, and commercially	*Tampa Electric Company acknowledges the comment and will provide a thorough description of the FMS design and use in the appropriate (r) reports.*
			harvested species, with all other taxa being treated as forage. Unit closures are identified in Section 5.6 as the primary mitigation effort completed at these facilities prior to the effective date of the 316(b) rule; however, FMS technology has been in seasonal operation at Big Bend Units 3 and 4 since the 1980s. I recommend that the plan be modified to more clearly describe when FMS technology was installed at Big Bend Units 3 and 4 (e.g., in Table 3-3) and how the long-time use of FMS for mitigating entrainment losses will be considered in the benefits valuation (Section 5.6).	

Question Number	§122.21(r)(11)	Response	Comments (if any)	*Tampa Electric Company's Response 01/30/17*
1b)	The assumption that reductions in IM and EM are directly proportion to reductions in intake flow is consistent with the basis of the Rule. Is it a reasonable approximation in combination with narrative comments (e.g., commenting on increases and decreases in through-screen velocity relative to changes in IM)?	**Yes**	Combining with a narrative approach is appropriate, for example, to more fully characterize and qualify the impingement reduction benefits of cooling towers. For example, reducing intake flow below the level which achieves a through-screen velocity of 0.5 feet per second would not necessarily result in further incremental impingement reduction benefits (regardless of flow volume) because the majority of healthy, impingeable-size fish can avoid becoming impinged below this velocity threshold.	*Tampa Electric Company acknowledges the comment and will not change the study approach in response.*
1c)	Is the approach to estimating rates of exclusion by FMS reasonable?	**Yes**	The approach is reasonable because it applies site-specific study data for 0.5-mm mesh FMS from Big Bend Units 3 and 4 to both facilities. Big Bend and Bayside are located only 8 miles apart on the east shore of Hillsborough Bay and share similar numerically dominant taxa (e.g., drum species) and life-stage composition (eggs were over 90 percent of total) in entrainment samples. In its Technical Development Document for the final 316(b) rule, EPA (2014) described Big Bend as the most significant example of long-term use of FMS. EPRI (2010; Laboratory Evaluation of Fine-Mesh Traveling Water Screens) reviewed and characterized the Big Bend FMS screen investigations from the 1980s as presenting a comprehensive performance and efficiency evaluation. However, because data were limited to 10 selected representative species (6 fish, 4 invertebrates) and two of the fish	*Tampa Electric Company acknowledges the comment and the recommendation conforms to its plan for the EM BTA assessment.*

Question Number	§122.21(r)(11)	Response	Comments (if any)	*Tampa Electric Company's Response 01/30/17*
			families represented include species considered fragile with respect to impingement (Clupeidae, Engraulidae) (§125.92(m)), EPRI suggested that the survival estimates may be a conservative indicator of the screen performance. Hence, I recommend that the analysis described in Section 5.3.2 also provide an updated literature review of potentially relevant FMS investigations at other facilities on estuarine source waterbodies, if any, and discuss how those data may further inform assumptions and/or survival estimates used for organisms of interest at Big Bend and Bayside.	
1d)	Is the approach to estimating the rate of live return of excluded organisms based on the empirical, site-specific data reasonable?	**Yes**	The approach is reasonable because it applies site-specific study data from Big Bend to Bayside. In addition to being on the same waterbody and entraining similar numerically dominant taxa and life stages, the facilities have similar overall site layouts with respect to orientation of the intake and discharge canals on Hillsborough Bay and distances that a return system would need to traverse to the discharge point (Figures 3-1 and 3-2). Thus, post-exclusion survival at Big Bend should be reasonably representative of that which would be expected at Bayside with the use of 0.5-mm FMS and an organism return system.	*Tampa Electric Company acknowledges the comment and will not change the study approach in response.*

Question Number	§122.21(r)(11)	Response	Comments (if any)	*Tampa Electric Company's Response 01/30/17*
1e)	Does the approach adequately consider the types and abundances of various species and appropriately evaluate the taxa-specific rates of protection that the technology/measure would provide?	**Yes**	The approach considers organisms of interest inclusive of the variety of species entrained, tabulates total annual entrainment separately by sampling year as counts of each identified taxon and observed life stage, and applies site-specific data from Big Bend to both facilities for estimating exclusion and post- exclusion survival.	*Tampa Electric Company acknowledges the comment and will not change the study approach in response.*
2)	Does the approach adequately address the need to estimate changes in fish stocks and harvest based on reductions in IM and EM?	**Yes**	The methods and approach proposed are consistent with those used by EPA in the rulemaking process and are appropriate for calculating the economic value of total forgone yield. The models will be run for each year of losses and supported by a narrative discussion of the model assumptions and uncertainties.	*Tampa Electric Company acknowledges the comment and will not change the study approach in response.*
3)	Is a narrative based on ecological reasoning sufficient to support estimation of "benefits likely to accrue to the environment	**Yes**	The proposed approach to evaluating potential changes in populations of birds and other wildlife and to aquatic systems, and estimating their use and non-use benefits seems reasonable.	*Tampa Electric Company acknowledges the comment and will not change the study approach in response.*
4)	Is a narrative including discussion of thermal limitations and thermal impact assessment sufficient to present "benefits from any reductions in thermal discharges from	**Yes**	The analysis should consider any prior 316(a) demonstrations or related studies conducted at the facilities and other relevant site-specific factors, including the depth and tidal influence in the source waterbody, other heat loads, and the fish assemblage nearby.	*Tampa Electric Company acknowledges the comment and the recommendation conforms to its plan for the EM BTA assessment.*

Question Number	§122.21(r)(11)	Response	Comments (if any)	*Tampa Electric Company's Response 01/30/17*
5)	If you responded in the affirmative to all of the questions above, do you conclude that the proposed Plan is adequate to address the biological aspects of the Rule's requirements at 40	**Yes**	I recommend revisions to the EM BTA Plan to address the comments made in Response 1 concerning uncertainty, Response 1a concerning prior mitigation efforts, and Response 1c concerning updated literature review on FMS efficacy.	*Tampa Electric Company acknowledges the comment and will modify its approach as described above.*

Appendix 13-E

Peer Reviewer Responses to Entrainment BTA Draft Documents

Charge to the Engineer

For Peer Review required by CWA §316(b)

Tampa Electric Company

Bayside Generating Station

This Charge is presented in the following three parts:

Part 1 - Logistical Information

Part 2 - The requirements of the §122.21(r)(10) and (12) Reports, as presented in the Rule

Part 3 - Charge Questions to be completed and returned

Part 1 - Logistical Information for the Engineering Peer Reviewer

Tampa Electric Company (TECO) requests you to review and comment on the following documents in accordance with this Charge:

- *Engineering Feasibility and Facility Costing Sections of the Technology Feasibility and Cost Evaluation (122.21(r)(10)). The information on the estimation of social costs will be reviewed by others and the Engineering Peer Reviewer is not asked to review those sections.*
- *Non-water Quality Environmental and Other Impacts (122.21(r)(12))*

Review of these documents by an expert such as yourself is required by the U.S. Environmental Protection Agency's (EPA's) 2014 §316(b) Rule ("the Rule").

We have made several assumptions when preparing §122.21(r)(10) - (12), and they are documented in the reports. We have collated key assumptions into a separate document and are providing that also to you.

Part 2 of this collection reiterates the Rule requirements for §122.21(r)(10) and (12). These two sections cover both engineering and resource economics requirements. You are being requested to review and comment on the engineering sections only and, therefore, the reports provided herewith do not include the resource economics sections, but you can see the placeholders for those sections. Rule requirements provided as Part 2 grey-out economics requirements.

Part 3 includes a list of questions (Charge Questions) that we ask that you respond to. Your responses to these questions constitute your only deliverable back to Ms. Mathia, see below. A Microsoft Word version of this table is provided to support the development of your response.

We request that you complete your review and respond to the Charge Questions provided as Part 3 of this compendium by October 20, 2017, and return your responses to Jennifer Mathia and Radhika de Silva.

If you have questions or need clarification, please contact Ms. Mathia at jmathia@ectinc.com or Radhika deSilva at Radhika.deSilva@hdrinc.com.

TECO sincerely appreciates your prompt attention to this very important task.

Part 2 - The requirements of the §122.21(r)(10)-(12) Reports

The following excerpts are from the Final Rule[1].

§122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study

(Federal Register / Vol. 79, No. 158 / Friday, August 15, 2014 / Rules Regulations, Pages 48427-48428)

The owner or operator of an existing facility that withdraws greater than 125 mgd AIF must develop for submission to the Director an engineering study of the technical feasibility and incremental costs of candidate entrainment control technologies. In addition, the study must include the following: (i) *Technical feasibility.* An evaluation of the technical feasibility of closed cycle recirculating systems as defined at 40 CFR 125.92(c), fine mesh screens with a mesh size of 2 millimeters or smaller, and water reuse or alternate sources of cooling water. In addition, this study must include: (A) A description of all technologies and operational measures considered (including alternative designs of closed cycle recirculating systems such as natural draft cooling towers, mechanical draft cooling towers, hybrid designs, and compact or multi-cell arrangements); (B) A discussion of land availability, including an evaluation of adjacent land and acres potentially available due to generating unit retirements, production unit retirements, other buildings and equipment retirements, and potential for repurposing of areas devoted to ponds, coal piles, rail yards, transmission yards, and parking lots; (C) A discussion of available sources of process water, grey water, waste water, reclaimed water, or other waters of appropriate quantity and quality for use as some or all of the cooling water needs of the facility; and (D) Documentation of factors other than cost that may make a candidate technology impractical or infeasible for further evaluation. (ii) *Other entrainment control technologies.* An evaluation of additional technologies for reducing entrainment may be required by the Director. (iii) *Cost evaluations.* The study must include engineering cost estimates of all technologies considered in paragraphs (r)(10)(i) and (ii) of this section. Facility costs must also be adjusted to estimate social costs. All costs must be presented as the net present value (NPV) and the corresponding annual value. Costs must be clearly labeled as compliance costs or social costs. The applicant must separately discuss facility level compliance costs and social costs, and provide documentation as follows: (A) Compliance costs are calculated as after-tax, while social costs are calculated as pre-tax. Compliance costs include the facility's administrative costs, including costs of permit application, while the social cost adjustment includes the Director's administrative costs. Any outages, downtime, or other impacts to facility net revenue, are included in compliance costs, while only that portion of lost net revenue that does not accrue to other producers can be included in social costs. Social costs must also be discounted using social discount rates of 3 percent and 7 percent. Assumptions regarding depreciation schedules, tax rates, interest rates, discount rates and related assumptions must be identified; (B) Costs and explanation of any additional facility modifications necessary to support construction and operation of technologies considered in paragraphs (r)(10)(i) and (ii) of this section, including but not limited to relocation of existing buildings or equipment, reinforcement or upgrading of existing equipment, and additional construction and operating permits. Assumptions regarding depreciation schedules, interest rates, discount rates, useful life of the technology considered, and any related assumptions must be identified; and (C) Costs and explanation for addressing any non-water quality environmental and other impacts identified in paragraph (r)(12) of this section. The cost evaluation must include a discussion of all reasonable attempts to mitigate each of these impacts.

[1] https://www.gpo.gov/fdsys/pkg/FR-2014-08-15/pdf/2014-12164.pdf

§122.21(r)(12) Non-water Quality Environmental and Other Impacts Study

(Federal Register / Vol. 79, No. 158 / Friday, August 15, 2014 / Rules Regulations, Page 48428)

The owner or operator of an existing facility that withdraws greater than 125 mgd AIF must develop for submission to the Director a detailed facility-specific discussion of the changes in non-water quality environmental and other impacts attributed to each technology and operational measure considered in paragraph (r)(10) of this section, including both impacts increased and impacts decreased. The study must include the following: (i) Estimates of changes to energy consumption, including but not limited to auxiliary power consumption and turbine backpressure energy penalty; (ii) Estimates of air pollutant emissions and of the human health and environmental impacts associated with such emissions; (iii) Estimates of changes in noise; (iv) A discussion of impacts to safety, including documentation of the potential for plumes, icing, and availability of emergency cooling water; (v) A discussion of facility reliability, including but not limited to facility availability, production of steam, impacts to production based on process unit heating or cooling, and reliability due to cooling water availability; (vi) Significant changes in consumption of water, including a facility-specific comparison of the evaporative losses of both once-through cooling and closed-cycle recirculating systems, and documentation of impacts attributable to changes in water consumption; and (vii) A discussion of all reasonable attempts to mitigate each of these factors.

Charge Questions to the Engineering Peer Reviewer

You are provided the following questions in Microsoft Word format as well. We request that you please respond within the Microsoft Word document and return it to Ms. Mathia.

Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
1)	Does 122.21(r)(10) clarify the size and nature of the system being evaluated – the location of the station, the number of units, the flow rates associated with each unit, the existing intake structure, the fundamentals of the existing cooling system?	Yes	The facility description clearly details specifics including number of units, cooling water flows, heat loads, existing intake structures and condenser/cooling water components. Fundamentals of the cooling system and various components were clearly described to provide a full awareness and knowledge of the existing facility.	No further action needed.	Agreed
2)	Does the document consider the range of entrainment control measures required by the Rule?	Yes	The feasibility study includes a comprehensive discussion of compliance technologies including wet/dry alternatives as required by the rule.	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
			Closed-Cycle Cooling Evaluation		
3)	The Rule requires that all cooling tower types be evaluated. The report did a simple review of all cooling tower types and selected the least cost option from the potentially feasible types for additional evaluation. Were the justifications provided to eliminate other cooling towers reasonable?	Yes	The report included consideration for all types of cooling tower technologies and detailed comparisons of options with associated costs. The report included adequate and relative information in justification of technologies not evaluated. Justifications were based on valid technical merit and/or cost considerations to establish viability and/or economic sensibility.	No further action needed.	Agreed
4)	Does the closed-cycle system evaluation incorporate site-specific meteorological and water quality conditions, and the facility's condenser water flow rate and temperature differential?	Yes	Site meteorological data was used to determine appropriate design wetbulb conditions for optimizing the cooling tower performance. Site specific wind rose data was used in determining appropriate cooling orientation and proximity to existing structures & switchyard with regard to tower emissions and plume. The full load condenser design flow rates, heat loads, and ΔT served as the basis for closed cycle cooling. Operating data was examined for comparison to ensure applicable design basis.	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
5)	Does it consider all practicable locations for the new cooling towers?	Yes	Multiple tower locations for Units 1&2 were considered/examined for potential use. Each location was evaluated based on constructability, proximity, site orientation, access for laydown/maintenance, pipe routing, and performance. The site selections for Units 1 & 2 were considered the best solutions with consideration to space requirements, orientation, and overall performance, while minimizing impact on existing plant facilities, and installed costs.	No further action needed.	Agreed
6)	Did the conceptual design size the hot and cold water pipes and tunnels appropriately and route them between the cooling towers and condensers? Did the pipeline routes consider existing buried and overhead infrastructure to the extent appropriate for the concept design?	Yes	Adequate information was provided (and reviewed/confirmed) to assess that proper engineering practices and hydraulic standards were implement in sizing of pipelines (hot & cold legs) as required for retrofitting the new closed cycle cooling (CCC) system. Routes for piping modifications included considerations of any existing and/or identified underground interferences which may preclude viability of conceptual design.	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
7)	The report presents the major cost components included in the final capital cost. The report aims to develop a +50% / -30% cost estimate. Are the major cost components reasonable for developing a +50% / -30% estimate?	Yes	The cost estimates reviewed were in sufficient detail to confirm they were 1) comprehensive, 2) reasonable to reflect components for design basis and 3) within accuracy of targeted initiatives. The only exception was the CCC system cooling tower retrofit cost estimate. Cost estimated included did not reflect estimates for the major system components.	The report has been revised to include the breakout of costs for major components.	Agreed
8)	Are the costs presented reasonable for this location and work? If not, how are they not?	Yes	Costs included represent the location of work with the targeted level of accuracy for the CCC system retrofit work scope as detailed in the report.	No further action needed.	Agreed
9)	Is the level of accuracy or uncertainty presented appropriately? List key uncertainties or inaccuracies that should be specifically discussed.	Yes	The level of engineering detail was sufficient to identify essential work scope for development of cost estimates at the level of accuracy required. Uncertainties include potential interferences not known/identified, potential additional electrical scope based on detailed bus-bar studies, and impact on unit operations from a more comprehensive performance study& outage requirements.	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
10)	Does the report discuss O&M measures and associated costs to the extent required in §122.21(r)(10) and provide a reasonable estimate of facility costs?	Yes	The report included comprehensive O&M considerations including but not limited to maintenance of mechanical components, outage PM maintenance, and operating costs such as chemical treatment and annual maintenance.	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
11)	Considering the technology's proven ability to perform at facilities of similar size and site conditions, the ability of the facility to operate (generate electricity) reliably, and the ability to obtain all necessary permits for installation and operation of the technology, can it be concluded that closed-cycle cooling towers are technically feasible ("can you retrofit"?) and practical ("does it make sense to retrofit"?) for this facility? If not, why not?	Yes	I would agree that closed cycle cooling system (CCC) technology is proven and could support the ability of this facility to generate electricity at some level of proficiency. However, the feasibility of a CCC system with a cooling tower is dependent on site specific considerations rather than CCC proven technology. Such considerations as discussed in the report dictate whether CCC would be practical (do- able), and/or economically viable. Implementation of a CCC retrofit system can be accomplished (do-able) at almost any facility if capital resources are unlimited. This would not however, conclude that spending vast amounts of capital for retrofitting a CCC system would be either prudent and/or viability. The conceptual design of the CCC system presented in the study is a "do-able" concept which would support conclusion that it is a viable technical alternative. The economic feasibility for retrofitting the CCC system would be subject to results in comparison with other "do-able" compliance alternatives. The reports contains a fair assessment of CCC cost for assessment of feasibility in comparison with other options presented.	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
12A)	Considering the durations needed for NPDES permit issuance, technology design, obtain construction permits, equipment procurement, bidding, construction/installation and potential time of year restrictions on construction, is the project schedule presented for closed-cycle cooling towers reasonable and realistic? If not, why not?	Yes	Based on the level of details in the report, I would consider the preliminary construction schedule for implementation of retrofitting a CCC system to be reliably accurate for the design, procurement, installation, and tie-in with existing facility. The schedule for obtaining the various permits has the highest level of subjectivity but is still representative of actual project experience. The time of year of construction presents some level of schedule variation but since the project is in Florida (versus Minnesota), the seasonal impact on schedule deviation would be minimal.	No further action needed.	Agreed
12B)	Were all impacts required to be identified by 40 CFR §122.21(r)(12) appropriately identified and described? If not, list the impacts that need further consideration and nature of additional consideration. Were all reasonable attempts to mitigate each of these impacts discussed to the extent required in §122.21(r)(12)? If not, list impacts that need additional mitigation measures and nature of those mitigation measures.	Yes	The impacts of CCC installation were adequately identified and described including the potential need for further consideration of mitigation alternatives. The report included recommendations for additional requirements to properly address potential impacts associated with the design, construction and operation of CCC system (i.e. noise attenuation, plume abatement study, detailed performance analysis, etc.).	No further action needed.	Agreed

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Charge to the Engineering Peer Reviewer

13)	Are the methods employed to assess energy penalty (auxiliary load), backpressure energy penalty, and downtime-related energy loss reasonable for the purposes of the 122.21(r)(10) requirements?	Yes	The method employed for assessing differential in auxiliary power requirements (station service loads) for the CCC system adequately included consideration of fan power and pumping energy requirements. The method for assessing unit performance differentials (Δ in condenser backpressures) included use of a surrogate unit model for "approximation" of potential unit performance capabilities. A more detailed performance analysis/study using site specific unit data is anticipated to yield similar results and/or quantitative magnitudes. Downtime costs (outage & load cuts) associated with implementation and operation will be estimated/assessed by Tampa Electric. The preclusion that tower capacity may inhibit unit capability 1% of during summer is speculative without a more detailed performance study and models of existing site power cycle.	The report has been revised to clarify that the condenser performance/efficiency would erode as the cooling water temperature increases, but generally, if the increase in backpressure is less than approximately 6 inches mercury (absolute) the condenser would not be completely impeded. Added a footnote clarifying that 2015 ambient data was examined to select the warmest 88 hours in the year. The cost of electricity would depend on the specific hours in the day. Understanding the specific times when the cooling tower would not be fully available is therefore important. Revised report to clarify that during cooler weather, condenser efficiency may be greater when cooled with a closed-cycle cooling tower than when using once-through cooling with water from the Bay. Clarified that additional feasibility and detailed evaluation would be needed if detailed design were undertaken.	Agreed

Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
14)	Are the methods used to assess increase in emissions loss reasonable for the purposes of the 122.21(r)(10) requirements?	Yes	The report discusses emissions from the cooling towers included drift and associated contaminants. The report quantifies a range of PM10 emissions and potential impact based on variations of water chemistry which is considered representative of actual variations in water chemistry analysis and levels of constituents.	Revised report to clarify that in marine environment solids content is driven by 'salts'. While chemicals will impact water chemistry and PM emissions, that impact smaller compared to Bay water quality. No further action needed.	Agreed
15)	Are the methods used to assess the increase in evaporation reasonable for the purposes of the 122.21(r)(10) requirements?	Yes	The method for assessing evaporation for the existing once through cooling system included modeling the zone of influence from the discharge in Tampa Bay. Results are based on a significant number of assumptions variables which provided a reasonable estimate for evaporation. Cooling tower evaporation was based on basic fundamental heat transfer for latent heat of evaporation applicable to cooling tower technology. This is a common methodology used for assessing evaporation, makeup, and blowdown for various cycles of concentration. A typical computation for estimating evaporation, makeup and blowdown is attached at the end of this review.	No further action needed.	Agreed

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Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
16)	Are the discussions on noise, safety, facility reliability associated with cooling towers reasonable for the purposes of the 122.21(r)(10) requirements?	Yes	The report contained appropriate discussions on cooling tower noise (fans and falling water), tower safety, and facility reliability as required by 122.21(r)(10).	No further action needed.	Agreed
			Fine-Mesh Screens Evaluation		
17)	Does the evaluation of fine mesh screens adequately consider alternative fine mesh screen configurations?	Yes	122.21(r)(10) requires consideration of ≤ 2 mm fine mesh screens. The report included consideration of using 0.5mm fine mesh screens which is considerable smaller than the 2 mm requirements. As such, it is assumed that the use of 0.5mm would was considered adequate to meet the intent of 122.21(r)(10) requirements. Alternative screen configurations were also discussed/examined.	No further action needed.	Agreed
18)	Does the fine-mesh screen evaluation consider the facility's intake rate and location; water quality; size of the source waterbody; and potential for biofouling when selecting, sizing and locating the screens?	Yes	The design of the existing intake, screening system, flow rates, and associated velocities were adequately considered in design considerations of new screening alternatives. The waterbody (Tampa Bay) and associated water chemistry water was considered with regard to corrosion, depth, sedimentation, and implication of biofouling of susceptible screening components.	No further action needed.	Agreed

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Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
19)	Are the site and construction constraints presented valid and reasonable for the fine-mesh screen retrofit project discussed?	Yes	The modification of existing structures as well as the construction/installation of new fine mesh screens adequately included consideration of impact on existing waterbody and any potential constraints.	No further action needed.	Agreed
20)	Do the fine-mesh screen costs consider site characteristics such as geotechnical constraints, earth moving requirements, work on/near water aspects, screen cleaning and maintenance, and system reliability?	Yes	Geotechnical constraints are also considered construction constraints as discussed in the previous comments. The report did include consideration for essential screen cleaning/maintenance as well as any geotechnical/construction issues/constraints associated with construction of pilings and new structures/screens in the intake canal.	No further action needed.	Agreed

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Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
21)	The report presents the major cost components included in the final capital cost and estimates of incremental operation/maintenance costs. Are the major cost components reasonable for the scope of work in 122.1(r)(10) and location of facility?	Yes	The cost estimates for the fine mesh screening option included consideration of capital costs, O&M costs, and associated identified construction costs. Cost estimated included reasonable estimates for the major system components. The report included discussion incremental service and/or operation of fine mesh screening systems as a function of unit operations and seasonal withdraw for optimization of performance and compliance.	No further action needed.	Agreed
22)	Are there additional considerations that should be incorporated into the fine mesh screen evaluation? If so, please list them in the comments sections.	No	The report adequately included evaluation of fine mesh screens as required by 122.1(r)(10)(12).	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
23)	Were all impacts required to be identified by 40 CFR §122.21(r)(12) appropriately identified and described? If not, list the impacts that need further consideration and nature of additional consideration. Were all reasonable attempts to mitigate each of these impacts discussed to the extent required in §122.21(r)(12)? If not, list impacts that need additional mitigation measures and nature of those mitigation measures.	Yes	The impacts were adequately identified and described including the potential need for further consideration of mitigation alternatives. The report included recommendations for additional requirements to properly address potential impacts associated with the design and/or construction and operation of fine mesh screens (i.e. hydraulic model study of intake structure/pump sump, etc.).	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
24)	Considering the technology's proven ability to perform at facilities of similar size and site conditions, the ability of the facility to operate (generate electricity) reliably, and the ability to obtain all necessary permits for installation and operation of the technology, can it be concluded that the fine-mesh screens are technically feasible ("can you retrofit"?) and practical ("does it make sense to retrofit"?) for this facility? If not, why not?	Yes	Based on proven experience with fine mesh screens at a similar site with similar water chemistry, I would conclude that the use of fine mesh screens is both technically viable and economically feasible as conceptualized in the report. The conceptual design in considered as a "do-able" compliance alternative which warrants further consideration as a compliance alternative for this facility.	No further action needed.	Agreed
25)	Considering the durations needed for NPDES permit issuance, technology design, obtain construction permits, equipment procurement, bidding, construction/installation and potential time of year restrictions on construction, is the fine mesh project schedule presented reasonable and realistic? If not, why not?	Yes	Based on the level of details in the report, I would consider the preliminary construction schedule for implementation of fine mesh screens to be relatively accurate with regard to design, procurement, installation, etc. The schedule for obtaining the various permits has the highest level of subjectivity but is still representative of actual project experience. The time of year of construction presents some level of schedule variation but since the project is in Florida (versus Minnesota), the seasonal impact on schedule deviation would be minimal.	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
26)	Are the methods employed to assess energy penalty (auxiliary load) reasonable for the purposes of the 122.21(r)(10) requirements?	Yes	See Questions 13/26 - The method employed were considered technically correct to assess the differential in auxiliary power (station service loads) for options considered. A more detailed design study is anticipated to yield similar results.	No further action needed.	Agreed
27)	Does the peer reviewer agree that evaporation rates would remain unaffected due to a fine mesh screen retrofit?	Yes	Evaporation rates are a function of heat load and ambient conditions which are not factors germane to the functionality of fine (or coarse) mesh screen functionality.	No further action needed.	Agreed
28)	Are the discussions on noise, safety, facility reliability associated with fine mesh screens reasonable for the purposes of the 122.21(r)(10) requirements?	Yes	There was reasonable discussion on fine mesh screen noise/safety which I considered sufficient since the report did a thorough job of assessing more pertinent issues such as screen ΔP, performance impact performance, and screen effectiveness to ensure plant reliability.	No further action needed.	Agreed

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Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
			Alternate Water Sources		
29)	The evaluation looked at onsite service water, groundwater and reclaimed water, but found that none was viable based on volume, reliability, and proximity as replacement or supplemental sources. Do you agree with this finding? If not, which of these water sources is viable at this Station and why?	Yes	Yes, the sheer volume of water required eliminates ground onsite water. Ground water is not a consistent, dependable reliable source to ensure stability of unit operations and/or performance. Adequate quantities of reclaimed water is also not available and/or in close proximity to be considered as a viable economic alternative water source. The report did a thorough examination of alternate water resources within a wide boundary from the plant site.	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
			Variable Speed Pumps		
30)	122.21(r)(10) examined historical generation, flow and temperature data to assess viability of variable speed pumps at this Station. Is the hypothetical variable speed pump operating rule developed sufficient for the purposes of evaluating the technology under the Rule? If not, what else should be evaluated? Would the evaluation of additional parameters find that variable speed pumps are appropriate and practical at this Station?	Yes	The theoretical operating rule used is considered a viable method for evaluating variable speed pump operation. I would agree with the results which concluded that it variable speed pumps is not a practical/viable alternative for this site. With regard to additional parameters that should be considered, the report did acknowledge unit performance degradation associated with flow reductions which would further enhance the conclusion presented.	Revised report to clarify that larger flow reductions (which are meaningful for entrainment reduction) could impede condenser performance and or reduce hydraulic stability.	Agreed

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Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
31)	Does the peer reviewer agree that committed reductions in flow associated with use of VSPs is not feasible given the need for the power plant to respond to electricity demand?	Yes	I would agree that the use of variable speed cooling water pumps is not a viable and/or feasible alternative for several reasons. Reduction of flow (as a means of environmental compliance) is counterintuitive to the fundamental initiative of efficient power generation. Condenser/turbine performance (generation capability) is highly sensitive and/or dependent on the volume of cooling water to flow (more sensitive than cooling water temperature). As such, reducing flow would consequently reduce unit performance capability and consequently reduce plant/cycle efficiency. The use of variable speed pumps is not anticipated to be a viable option for any generation facility which is required to operate to meet variable electricity demand loads.	No further action needed.	Agreed

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Peer Reviewer Name:	Jim Cuchens, PE	Facility Name:	TECO Bayside Generating Station		
Question Number	**§122.21(r)(10),(12)**	**Response**	**Comments (if any)**	**HDR Responses**	**Peer Reviewer Acceptance / Rejection of Revision**
32)	Based on historic data presented in the report, do variable speed pumps appear to be an efficacious entrainment reduction technology at this station?	Yes	The demand for generation is dependent on various factors including but not limited to industry/commercial business, climatology (weather), and population/residential use. These factors govern the demand for generation which can fluctuate somewhat rapidly. Utilizes strive to provide stable, dependable, generation capacity capable of meeting the demand efficiently without hindrance. As such, I would not consider variable speed CW pumps as a viable compliance technology at this or any station that intends to operate reliable for meeting changing load demand. See previous comments concerning technical viability.	No further action needed.	Agreed

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Draft Charge Questions for Tampa Electric Company's Bayside Generating Station

Submitted to:

ECT

Prepared by:

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October 13, 2017

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Below are draft charge questions for Paul Jakus to respond to in his review of the social-cost component of the *Comprehensive Technical Feasibility and Cost Evaluation Study* (*§122.21(r)(10))* and the *Benefits Valuation Study* (*§122.21(r)(11))*. The questions are intended to ensure that the analysis and results cover the scope required for the social-cost component of the *Comprehensive Technical Feasibility and Cost Evaluation Study* and the economic portion of the *Benefits Valuation Study*.

The questions are also intended to ensure that the information provided is deemed both reasonable and adequate for making the entrainment BTA determination by the NPDES permitting authority. To be deemed "reasonable" the information should:

- have used an appropriate approach or methodology,
- be technically sound in terms of the science and any analytical methods used, and
- produce results supported by the analysis and available data.

To be deemed "adequate" the information should:

- have an adequate description of the methods used in the evaluation,
- have a sufficient discussion of the evaluation results to understand the impact on the design, benefits, technology, non-water quality environmental or other impacts being evaluated, and
- provide additional supporting materials (tables, figures, references and appendices) sufficient to understand and support the evaluation.

If Paul deems the evaluation of a topic to be either unreasonable or inadequate, he should provide specific comments that will allow the facility to address the issue of concern. For questions with Yes/No answers, we request that he support his answers and describe his reasoning behind his answers.

Question Number	§122.21(r)(10)	Response	Comments (if any)
1)	If Bayside were to be retrofitted with closed-cycle cooling, fine mesh modified travelling screens, or variable speed pumps, the social costs can vary depending on the facility's location, it's role in the relevant power system market, and the nature and use of adjacent land (i.e., urban, suburban, rural/agricultural, native vegetation or parkland).		
1a)	Was the list of social impacts considered reasonable?	Yes	
1b)	Were the methods used to quantify and/or monetize the social costs of these impacts appropriate?	Yes	
1c)	Were the social costs adequately quantified and/or monetized for the facility?	Yes	
2)	Were the social costs presented as both a present value (PV) and annual value and were the methods used to generate these estimates reasonable and adequate?	Yes	
3)	In your professional opinion, do you think the information provided is both reasonable and adequate for the National Pollution Discharge Elimination System (NPDES) permitting authority to make the entrainment BTA determination?	Yes	

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Question Number	§122.21(r)(11)	Response	Comments (if any)
1)	Are the methods, analysis, and discussion of the monetization of the recreational, commercial, and nonuse benefits reasonable and adequate?	Provisional Yes	Please see my attached comments. I have questions regarding the procedures used to estimate recreation and nonuse benefits.
2)	In your professional opinion, do you think the information provided is both reasonable and adequate for the NPDES permitting authority to make the entrainment BTA determination?	Provisional Yes	See above, and my comments

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Peer Reviewer Response to Draft r(10) and r(11) studies

Economics, Veritas r(10) study (planned Appendix 10-A of the r(10) report): Received November 21, 2017

1. Baseline effects in the power system reflect the 2016 calendar year (p. 24 of Appendix 10-A prepared by Veritas Economics) for both baseline load (Figures 5 through 7) and prices (Figure 8). How does 2016 compare to a "normal year" for power generation and prices?

Edits have been made to the text to indicate that 2016 is a typical year for the facility.

2. Table 1 of the recreation effects of the cooling tower (p. 40) are not placed in context. How loud are the towers? At what rate does noise decay? Given a decay rate and an initial decibel level, that would let the reader know the range at which we should be concerned about noise effects. The current document simply asserts that noise is not a problem (pp. 40-41).

The text has been modified to provide clarity in regard to the noise impacts.

3. The six mile radius for viewshed effects is a nice compromise of what others have done (p. 41), especially in Florida where the viewing conditions in a high humidity environment are less than ideal.

No action needed.

4. The Pythagorean Theorem in footnote 5 (p. 42) as used to calculate the distance from which a plume can be seen is incorrect. Where d is distance, R is the radius of the earth, and h is the height of the plume, the correct formula is $d = [(R+h)^2 - R^2]^{0.5}$. An even simpler version is

   d=(2*R*h)0.5. (A minor point, yes, but that formula just seemed so 'off' that I looked it up.)

The correction has been made in the text.

5. P. 45, paragraph 2. Plume frequency will vary by region, so use of the EPRI estimate for a representative southeastern power plant (1.1% of days) is reasonable. That said, the authors rely upon EPRI documents for a 1.8% diminution of recreation values due to a plume. Please provide a bit of the rationale behind this percentage. On what did EPRI base this estimate? EPRI reports are not publicly available, so the reader must rely upon the authors to explain why 1.8%

is justified. This is especially important because the same 1.8% is asserted as a property value effect (p. 55). Why should plume effects be the same for both recreation and property value?

Text has been added to provide clarity in how 1.8% was determined.

6. The book by Freeman (2003) (p.52) has been updated as Freemen, Herriges and Kling (2014).

The reference has been updated as suggested.

7. Typo p. 30, VOM, not WOM.

The correction has been made.

ECT Draft of r(10) document

1. Why does Table 10-15 (and the text on 10-77) use an electricity cost of $50/MWh while page 10-19 references a cost a cost of $37/MWh? Same question for page 10-152, last paragraph.

All facility costs have been updated to 37$/MWh with the exception of the social costs which use the power system model for energy costs.

2. Technical question for the interest rate used, page 10-114: Should the facility costs use the same interest rate(s) as the social cost discount rate(s)? Does the final rule provide guidance?

The rule specifies that for social costs, a discount rate of 3% and 7% must be applied. The interest rate of the facility costs will vary with location.

3. Typos

   a. p. 10-51 top Section 4.5 and Table 4-2

   b. p. 10-63, first paragraph, Waters [of] the United States

   c. p. 10-66, Location E, “arcing” instead of “arching”?

All errors have been remedied.

Economics, Veritas r(11) study (planned Appendix 11-G of the r(11) report)

Introductory note: this document read as if I was peeling away layers of an onion. I'd have a question about what I was reading in Section 1. This question was then partially answered in Section 2, or perhaps in Section 3. Then even more details were provided in one of the appendices. Hence, I have arranged my comments by topic rather than the sequence of the report.

Recreation Modeling

1. Recreation benefits are based on a calibrated function transfer using Bingham et al. (2011) model for an urban estuary in New Jersey. The model is appropriate and, as far as I can tell, the most recently published, applicable study. That said, Greene et al. (*Marine Resource Econ*, 1997) have a RUM for precisely the study region (Tampa Bay and its environs). Given if geographic specificity, be sure to place the benefit transfer per trip CS estimates (about $43 per trip—I calculated this; why not just say what it is?) in context with Greene et al.

The following has been added as a footnote to address the comment: "While Bingham et al., (2011) is the most recently published applicable study for this site-calibrated benefits transfer, Greene, Moss, and Spreen (1997) present the results of a random utility maximization based model of angler preferences in Tampa Bay. The analysis uses Bingham et al. (2011) because its modeled catch rates are species-group specific, it accounts for the impact of urban characteristics, and is estimated using a repeated nested logit specification that evaluates ocean, estuarine, and freshwater trips. Comparing the two studies, the results from Bingham et al. (2011) estimate a per trip value of approximately $42 (2011$ - 1/0.024) per trip and Greene, Moss, and Spreen (1997) estimates a per trip value of approximately $2.48 (1997$ - 1/.404). "

2. Page 32, step #3. The number of trips is fixed due to the repeated nested logit (RNL) RUM model?

Yes, it is.

3. Figure 1-6 is incomplete, as are numerous other versions of this figure (Figure 3-1,.

The extra copies of the figure have been deleted and the figure itself has been updated to show all the sites and counties included.

4. I am confused about the number of sites included in the calibrated BT model. Exactly how many sites are included? Three sites are affected directly by Bayside (Table 3.3). Somewhere the text notes there are 236 sites (I actually can't this in the text but it's in my notes) but Tables 3.4 and 3.5 imply there are only 10 additional sites. To further confuse the

matter, Appendix B shows 211 sites, if my count is correct. Why show the "conditions" for only these ten sites and not (presumably) the other 200 or so, especially when the variables that describe the conditions differ across the two tables. Further, I'm not sure how the conditions reported in these tables fit into the parameters of the Bingham et al. (2011) model.

Edits have been made to the text that clarify the concern and reconcile the numerical citations. Edits have also been made to refer the reader to the appendix. Tables 3.4 and 3.5 have been deleted as redundant with the appendix, which is complete.

5. Are some sites combined into a single site (e.g., Ballast Point appears as a pier and a ramp in Appendix B), or kept as separate sites?

If there were multiplied fishing points within the same recreational site, they were combined. Appendix B has been updated to show the combined information for each site.

6. I don't really understand how the Bingham model was calibrated.

    a. Were all three levels of the model used? At the top level (participation) were zonal averages used for things like age, boat ownership, fishing licenses, etc.?

    b. I'm left to guess exactly how the calibration was performed. Here goes:

        i. The total recreation trips to the 236 (?) sites was known. This represents the aggregate trips to be allocated by the RNL, and establishes known (baseline) visitation probabilities (proportion of total) for each site. These probabilities are those against which the transferred model is to be calibrated.

        ii. Known RHS values for TC, catch rates, etc. were combined with the Bingham parameters to get a first cut at predicted visitation probabilities, which did NOT result in a the observed allocation of trips across sites (i.e., the probabilities are off)

        iii. Probabilities were matched to the known (baseline) by using site-specific constants.

During the conference call with Paul Jakus, Veritas explained that the model was calibrated on the site choice component.

7. Page 42, last full paragraph. Again, here it sounds like you're only using three sites in the model.

For the baseline fishery, only the three sites presented in Table 3.2 were used to calibrate the model as these were the sites located within Hillsborough Bay.

Nonuse Values

1. Upper and lower bounds on nonuse value estimates are based on the 12% of the population who said they were aware of water impacts from power plants, or the 1% of people who said they were aware of cooling water impacts (p. 135). The implication is that existence value for cooling water issues is zero if someone doesn't know about them. Fair enough. But the text also claims that the negative and significant ASC represents a biased movement away from the status quo, where the bias results from becoming aware of cooling water issues via the EPA survey. That is, if we judge that you've become aware of the issue only because of the survey, then we have 'induced' your value and must adjust any existence value downward. So, we're going to set your value at zero if you don't know about cooling water problems, and we'll also scale the values downward if our econometric model suggests we don't like the way you learned about them. Yes, a statistically significant Status Quo ASC means that respondents may have focused on something other the choice attributes included in the survey, but adjusting implied values upward or downward in response to a coefficient we don't care for is excessively arbitrary. Can you point to any literature that suggests adjustment associated with a statistically significant SQ ASC?

2. Table 1-6 (p.23); why would total nonuse value (NUV) get smaller as the extent of the market gets larger?

    a. If we're achieving a 100% entrainment reduction at Bayside and its aggregate NUV when adding up over all the households in Hillsborough county is $28,480, why would the aggregate value for the entire southeastern U.S. be less than $28,480? Even if everyone outside of Hillsborough county had $0 NUV, aggregate NUV is still $28,480.

    b. The text on page 127 makes it appear that the good being valued is changing from [entrainment at Bayside] to [entrainment at all southeastern plants] to [entrainment at all U.S. power plants]. If so, this completely changes the scenario from WTP for reduced entrainment at one plant to WTP for that one plant when we're also reducing entrainment at every other plant in the country. Yes, under those conditions WTP for Bayside should fall (reach a minimum, actually) but the focus of this study is on Bayside, so why do that? We also know that 100% entrainment reduction is NOT going to happen at Bayside or anywhere else, so this approach to estimating NUVs seems odd.

c. If the interpretation in part (b) is correct and you want to argue that 316(b) will apply to all power plants in the US, then why doesn't the analysis of, say, recreation benefits, make the same assumption? That is, why not improve game species catch rates at every other site in the model that may be affect by a power plant governed by 316(b)? You don't do this (and I think that's right), so you'll have to make a compelling argument that your should do this for NUV.

3. Figures 3.11 and 3.12 are incomplete.

Following our conference call on November 21, 2017, Veritas revised the nonuse values analysis and methodology to reflect the edits as suggested and a revised version was sent to Paul Jakus on January 25, 2018. Paul Jakus reviewed the revised version and had some additional questions that ECT, Veritas, and Dr. Jakus discussed on February 2, 2018. Specifically, Dr. Jakus pointed out that while most of the document has exemplary clarity, the text on the NUV aggregation procedure is missing some important information. Dr. Jakus provided the following statements about what he thought those additional details were:

1. Using the EPA data, Veritas estimated the "deep interactions" model, in which NUV varies by gender, education, and income. For each demographic group, NUV is estimated for one percent of fish saved.
2. The text never states how many fish are saved by the new I&M technologies; while that figure may appear elsewhere in the Bayside documents, it should be re-iterated here. That said, the change in # fish killed (i.e., fish saved) converted to a percentage of baseline mortality for the plant. NUVs, by HH type, are calculated for fish saved at Bayside.
3. The values in Table 1.1 are on a per HH basis, so I'm guessing that the characteristics of the Head of HH were used to calculate the number of HH, by type of HH and zip code, to which to assign a specific NUV.
4. In Hillsborough, 100% of HH were used for the aggregation; in the Southeast and the nation, the 12% adjustment was made.

He noted that if this procedure is correct, the reader could be helped by providing some key information: (a) the number of fish saved at the power plant, (b) the value per HH by type, and (c) the number of HH, by type, in each aggregation region. He also noted that no WTP decay function was use when aggregating to the Southeast or nation.

During the February 2, 2018 conference call, Veritas communicated that Dr. Jakus was correct with the previous four points in the NUV aggregation and stated they would add additional detail to the NUV report

to incorporate the additional detail.

Miscellaneous/Typos

1. Based on a comparison of Figures 1-1 through 1-3, I'm guessing that you have used a simple 40:1 ratio between forage biomass and game species biomass. True? Just say what it is rather than use a hypothetical example (p. 7, top).

No, a simple ratio was not used. The values of commercial to recreational biomass are based upon the biological modelling results presented in (r)(11) which follow the trophic transfer of forage biomass to commercial biomass.

2. Page 27, first paragraph. The second sentence references a proposed rule; shouldn't the reference be to the final rule?

This sentence is referencing the language of the rule presented in 2011. While the option of a decision by the Director on a cost/benefit basis is incorporated into the final rule, the language differs and does not provide the same level of clarify as what was provided in 2011 draft rule document. Therefore, the 2011 reference was thought most useful for the purposes of this report.

3. Page 27, footnote #2: Is the Barnthouse (2013) reference actually the 2016 paper?

The reference to Barnthouse (2013) has been added.

4. Page 34, footnote 5, second sentence. Repeated words make it awkward.

The repeated words have been removed.

5. Page 43, Table 3.6: I think there's a typo with the 2016 value of ladyfish.

There is no typo. Ladyfish landings were indeed that high in 2016.

6. Impingement densities for 2005 are matched with 2015 intake flows, and 2006 impingements are matched with 2016 AIF. Why not 2005/2016 and 2006/2015? If impingement is related to intake flows.

The comment refers to impingement but the potential issue (i.e., using observed densities, number of organisms per water volume collected) is also relevant to entrainment. 2015 and 2016 represent typical operational years for Bayside. Applying the 2005 data to 2015 flow and 2006 data to 2016 flows was merely done out of convenience and to maintain chronology. Organism densities (number per volume) varied greatly between the two years which is why the numbers between the two sample years differ so substantially. The actual flow rates in the two years is of less importance.

ECT Draft of r(11) document

1. Throughout the text are references to section #s that do not correspond to any section # appearing in the report.

These references refer to sections of the report that will exist once the entire document is put together ((r)(2) through (r)(13)).

2. Page 11-45. Veritas (2017) does not appear in references.

The reference has been added.

3. Page 11-47, top. Anseriformes misspelled.

The correction has been made.

4. P. 11-49, near bottom. Wrong year for Bingham reference.

The correction has been made.

5. Page 11-50, first two paragraphs repeat text verbatim from page 11-40.

The repeated paragraphs have been deleted.

6. Page 11-53. Figure 11-3 is incomplete.

This figure has been updated to be complete.

7. Page 11-56, top. Missing Table #? Should Hernando county be included?

Yes, the correction has been made.

8. Page 11-58. The 2016 value for ladyfish is probably a typo.

The value for ladyfish is checked and is correct.

9. Page 11-88. Thanks for the discussion of uncertainty and Table 11-38!

Comment acknowledged.

Steven R. Layman, Ph.D.

Biology Peer Reviewer Charge Questions and Responses
Clean Water Act Section 316(b) Peer Review of 40 CFR 122.21(r) (10) and (11) – Entrainment BTA Assessment
Bayside Power Station

The following are the charge questions for the biological peer reviewer to address following review of the draft final documents prepared under 40 CFR 122.21(r)(10) and (11) (https://www.gpo.gov/fdsys/pkg/FR-2014-08-15/pdf/2014-12164.pdf; see pp. 48427- 48428, pp. 129 and 130 of the PDF file). It should be noted that use of the entrainment characterization data collected under Phase II at Big Bend and Bayside have been approved by FDEP and FWC. This review of the draft final documents follows the presentation of a study plan to the peer reviewers, the peer reviewer's provision of comments, and Tampa Electric's provision of responses in January 2017.

The questions are also intended to ensure that the information provided is deemed both reasonable and adequate for making the entrainment BTA determination by the NPDES permitting authority. To be deemed "reasonable" the information should:

- have used an appropriate approach or methodology,
- be technically sound, and
- produce results supported by the analysis and available data.

To be deemed "adequate" the information should:

- have an adequate description of the methods used in the evaluation,
- have a sufficient discussion of the evaluation results to understand their implications for the conceptual design and likely benefits of the entrainment measures, and
- provide additional supporting materials (tables, figures, references and appendices) sufficient to understand and support the evaluation.

If the biological peer reviewer deems the evaluation of a topic to be either unreasonable or inadequate, they should provide specific comments that will allow the facility to address the issue of concern.

Question Number	122.21(r)(10)	Response	Comments (if any)	Response to comments	Accept/Reject Revision
1)	Is the discussion of fine mesh screen technologies adequate and reasonable to support the conclusions reached?	Yes	The discussion is adequate and reasonable given the thorough descriptions of the alternative intake configurations that would be required for each technology, the low estimated tidal velocity relative to sweeping currents for cleaning wedgewire screens, and the evidence derived from the current successful application of FMS technology at the Big Bend station.	No response needed.	
2)	Is the relationship between potential EM BTA approaches and IM BTA properly considered?	Yes	The analysis of fine mesh screens clearly makes important distinctions between those aspects of technology design that would address IM BTA requirements and those that would address EM BTA requirements. For instance, FMS alternatives were evaluated that would address the IM BTA requirements by either reducing through- screen velocity to 0.5 feet per second (fps) or less, or through the use of fish-friendly modified traveling screens if the through-screen velocity would be greater than 0.5 fps.	No response needed.	

Question Number	122.21(r)(11)	Response	Comments (if any)	Response to comments	Accept/Reject Revision
1)	Are the methods, analysis, and discussion of the characterization of the recreational and commercial biological effects reasonable and adequate?	Yes	I find the methods, analysis, and discussion of the recreational and commercial biological effects to be reasonable and adequate. The analysis applies relevant data for entrainment of non- commercial/recreational (C/R) shellfish from the Bartow station as well as FMS exclusion and post-exclusion survival studies from the Big Bend station. Both stations are located on the same source waterbody (Tampa Bay). The analysis considers the potential contribution of forage shellfish entrainment at Bayside based on the known entrainment of non-C/R shellfish at the nearby Bartow station, and necessarily applies life-history data from surrogate fish and shellfish in a reasonable manner to account for all entrained organisms in the benefits analysis. In addition, biological uncertainties are appropriately considered and discussed in a matrix describing 12 categories of input to the benefits valuation. My review comments deal mainly with describing more clearly in the final report: how non- C/R shellfish were treated throughout the analysis; supporting justification for certain approaches and assumptions used; and how uncertainties may compound in the analysis and affect the social benefits estimates and comparisons between technologies. I recommend revisions to the final report that consider and address the biological peer review comments and questions that follow: **Definition of Baseline Losses (Section 11.2.1.1), Entrainment:**	No response needed.	
			This section describes that non-C/R shellfish should be included in the assessment of the potential benefits of each candidate technology because they may serve as forage, but no examples are cited. What were some of the non-C/R taxa that could serve as forage and how might they compare to the fish forage base in terms of significance to commercial and recreational fisheries? Although the requirements for the Benefits Valuation Study at 40 CFR §122.21(r)(11) do not preclude the analysis of non-C/R shellfish as forage, they refer specifically to forage fish species in terms of the indirect benefits to changes in the stock sizes or harvest levels of commercial or recreational fish or shellfish species. Because applying non-C/R shellfish data from Bartow substantially increases the annual entrainment estimates at Bayside, I suggest citing a few examples from the scientific literature as evidence of the potential importance of non- C/R shellfish as forage for commercially and recreationally important species occurring in Tampa Bay, such as for species of Sciaenidae (drums/croakers).	Appendix 11-F provides the life history and feeding habits of the surrogate species used. The majority of the species include small crustaceans as a food source, if not the dominant food source. As stated in Section 11.3, the unknown shellfish from the Bartow data were distributed across the surrogate taxa of brachyuran crabs, anomuran crabs, and caridean shrimp using proportions observed in at Bartow, the literature, and surrounding facilities. The report has been modified to provide clarity in this regard as follows: "The Bartow data was collected under the Phase II rule and included the enumeration of both forage and C/R shellfish species as described in the IM&E Characterization Report (Golder, 2008). The non-C/R shellfish taxa includes mud crabs (Xanthoidea), pea crabs (Pinnnotheroidea), and porcelain crabs (Porcellanidae). These groups comprised of 98 percent of entrained organisms at Bartow which illustrates their importance to the characterization of the entrainment effects at Bayside."	Accept
			From Table 11-1, 95% of the shellfish taxa in samples at Bartow were “other invertebrates”. Do you mean that these other invertebrates were other shellfish (i.e., limited to crustaceans and mollusks) and that they could not be identified to family or below? If so, I suggest clarifying that they were “other shellfish,” because it would not be appropriate to include other invertebrates that were not shellfish. Also, can you reasonably ascertain from the available data that these other shellfish did not include barnacles, green mussels, or other nuisance species? The definition of “all life stages of fish and shellfish” at 40 CFR §125.92(b) excludes certain nuisance species such as these.	The "other invertebrates" are indeed "other shellfish" and none is a nuisance species as suggested in the comment. The report has been modified accordingly.	Accept
			The last paragraph on p. 11-12 states that the entrained C/R shellfish species (blue crab and stone crab) observed at Bayside make up 4.03% of the taxa observed at Bartow. It appears in Table 11-1 that these two taxa comprise 3.91% of the taxa observed at Bartow. Clarification is needed on how 4.03% was obtained from Table 11-1.	The difference between the two cited percentages is that the higher value includes Callinectes spp. while the lower is only blue crab. The report has been modified as "...the entrained C/R shellfish species (*Callinectes* spp. and stone crab) observed at Bayside make up 4.03% of the taxa	Accept
			In the first, partial sentence at the top of p. 11-13, the closed parenthesis mark needs to be moved from the end of the sentence to follow the numeral 2 of “sample year 2”.	The correction has been made in the report.	Accept

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Question Number	122.21(r)(11)	Response	Comments (if any)	Response to comments	Accept/Reject Revision
1) cont…	Are the methods, analysis, and discussion of the characterization of the recreational and commercial biological effects reasonable and adequate?	Yes	**Fine Mesh Screens (Section 11.2.1.3), Entrainment Reduction:** How were rates of exclusion and survival applied to the non-C/R shellfish taxa that were extrapolated from Bartow to Bayside? Were non-C/R taxa of similar small size represented in the Big Bend FMS study? Since the majority of non-C/R shellfish (from Bartow) could not be identified to family, were the average shellfish exclusion and survivability rates applied? It appears from Table 11-1 that about half of the non-C/R shellfish from Bartow were pro yolk-sac larvae, while most of the shellfish tested at Big Bend were postlarvae (Table 11-3) and presumably larger. I suggest adding an explanation as to how rates of exclusion and survival were applied to non-C/R shellfish taxa, the assumptions made, and how conservative they may be regarding the estimation of social benefits. It would also be appropriate to add further discussion about uncertainties of these assumptions to Table 11-38 (Uncertainties of benefits valuation study) under the topic "Consideration of Forage Shellfish."	When applying the rates of exlcusion and survival to shellfish, the Big Bend study values were applied to the observed entrainment densities of *Callinectes* spp. and stone crab. The reduced numbers were again set to 4.03% to get the total shellfish count. As with the baseline case, this FMS impacted total count, was then spread across the shellifsh taxa using the cumulative proportion for C/R taxa observed at Bartow. The report has been modified to include this description of the methodology applied for forage shellfish under the FMS scenario: "When considering the exclusion efficiency and survival of the forage shellfish, the exclusion efficiency and survival of *Callinectes* spp. and stone crab was first applied to the observed entrainment numbers at Bayside. This reduced number was then set to 4.03% of shellfish taxa and carried through as described above in Section 11.2.1.1. " In Table 11-3, there was an error in that the post-larvae shellfish column should have been labeled zoea, while the prolarvae were the megalop larvae values. The correction has been made in the report. No changes in calculations was needed since this was restricted to an error in the presentation of the data in the body of the report. This translates into the correlation of the lifestages of Big Bend and Bartow shellfish species with the majority of the shellfish entrained being in the zoea stage (pro larvae) A brief discussion of the uncertainties surrounding this methodology has been provided in Table 11-38 as suggested.	Accept
			Basis for Any Estimates of Changes in Stock Size or Harvest Levels (Section 11.2.2): It seems reasonable to identify age of entry to the fishery as the age at which at least 50% of the lifestage are exploited by a C/R fishery but some further explanation as to why this approach was used is warranted. Is it because this approach seeks to achieve a balance between the potential to overestimate and the potential to underestimate adult equivalency? A clearer explanation in the text would be helpful relative to the uncertainties in this type of modeling. Table 11-6 (Biological model surrogate taxa life history parameters) summarizes the life history parameters used to determine the age at which at least 50% of the lifestage are exploited but it's unclear how the equivalent adult age is interpreted from the values in the table; for example, for age 3 being the equivalent adult age for Sciaenidae. Clarification is needed in the footnotes of the table as to how total stage mortality and fishing mortality were used to calculate when at least 50% of the lifestage was exploited by the fishery.	The report has been modified to include a description for each C/R chosen age of equivalence to provide greater transparency in the choices made.	Accept
			It becomes evident in this section that tables are being cited out of order in the text. For example, Tables 11-6 and 11-7 are cited before Table 11-5. This occurs elsewhere and is a global issue that needs to be addressed in the final report.	The citations have been corrected in the report.	Accept
			I understand from the second paragraph in this section that surrogate taxa were used for identified taxa for which life history parameters were not available and for unknown shellfish, and that all organisms were accounted for in the benefits analysis. However, I find this overall discussion to be confusing. Why are unknown invertebrates of unknown life stages being discussed in the context of calculating equivalent adults of C/R taxa, or does this discussion also refer to production foregone modeling? I had trouble following the descriptions of how the annual counts of unknown taxa and unknown life stage numbers were treated using the surrogate taxa. I recommend reworking this discussion to identify that surrogate taxa were used for both EA and PF modeling, and to more clearly describe how unknown taxa were assigned to surrogates, how the annualized counts of unknown taxa were distributed among life stages using surrogate data, how biomass and trophic levels were applied, and the assumptions made.	The text has been modified to provide further transparency as to the methodology employed when applying surrogates.	Accept
			Paragraph 3 in this section refers to foregone production of biomass being calculated using Rago's model but up to this point there has been little mention of how biomass was estimated for unknown shellfish of unknown life stages. I suggest providing further description in this section of how biomass was estimated using surrogates and assumptions made, especially for unknown taxa and unknown life stages, which comprise a substantial proportion of estimated shellfish entrainment and were included specifically for their potential contribution to the forage base.	The following has been added to the paragraph referenced: "The biomass of unknown taxa was accounted for through the distribution of their counts across the other surrogate taxa as described above."	Accept; suggest referencing Table 11-5 for biomass data, as appropriate.

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Question Number	122.21(r)(11)	Response	Comments (if any)	Response to comments	Accept/Reject Revision
1) cont…	Are the methods, analysis, and discussion of the characterization of the recreational and commercial biological effects reasonable and adequate?	Yes	Paragraph 6 in this section describes that production foregone of forage fish and shellfish was transferred to Sciaenidae (drums/croakers) based on their observed occurrence within entrainment and impingement samples and because there is a fishery for Sciaenidae within Hillsborough County. I suggest strengthening your justification for using Sciaenidae by describing what proportion of entrainment and impingement was comprised by this taxon, and how it compared with other C/R taxa in relative abundance in entrainment and impingement samples, referring to the Appendix 11-A tables of annualized counts. It would also be helpful to briefly describe the size or relative importance of the Sciaenidae fishery in Hillsborough County compared to fisheries for other C/R taxa. I suggest bringing some of the reference citations forward from Table 11-38 (e.g., Golder, 2009; FWC, 2017), as appropriate.	The text has been modified to reference the relative abundancy of Sciaenidae in the entrainment and impingement samples as well as in relation to the C/R fishery within Hillsborough Bay.	Accept
			What assumptions were made in applying the trophic levels of surrogate taxa to the unknown non-C/R shellfish taxa, what level of uncertainty was involved, and how conservative were the assumptions in representing the importance of unknown shellfish taxa in the forage base? A brief discussion here or in Section 11.5 (Table 11-38) would be appropriate.	As per the edits to the description of the methodology of accounting for the forage shellfish, unknown forage C/R shellfish taxa are defined as anomura crabs, brachyuran crabs, and caridea shrimp. Their corresponding trophic levels are defined by theseararoundus.org similar to the other taxa used in the model. A brief description will be included in Table 11-38 (now Table 11-37).	Accept
			The last paragraph of this section consists of a single sentence referring to Section 11.2.2 (which is this same section) on how counts of individual organisms were converted to biomass of C/R taxa. To avoid confusion, I suggest revising the paragraph to be more descriptive of the specific procedure being referred to from the preceding paragraphs.	The reference to the section was deleted in the report and replaced with a description of how the projections were completed.	Accept
			Recreational Benefits (Section 11.2.3.1), Random Utility Analysis: Paragraph 2 repeats the following sentence from Paragraph 1 in this same section: "The EPA endorsed the use of RUMs for 316(b) applications…" To eliminate redundancy, the sentence should be deleted from either Paragraph 1 or 2.	The second reference has been deleted.	Accept
			On pages 11-40 and 11-41, under the subsection entitled "1. Select the angling preference function from the best available RUM study," the last three paragraphs of the subsection (beginning with "The model output is a coefficient for each site characteristic…) and Table 11-8 are repeated in Section 11.3.1.1 (Angler Preferences). Table 11-10 on page 11-49 is a repeat of Table 11-8. To eliminate redundancy, the three paragraphs and table should be deleted from one of these sections, and tables renumbered accordingly.	The second reference has been deleted	Accept
			Angler Participation: Population Size and Annual Fishing Trips (Section 11.3.1.2): It would be helpful if this section referenced Figure 11-3 showing the affected and substitute sites. Also, the legend in Figure 11-3 needs to be completed to define what the symbols mean.	Reference to Figure 11-3 has been added in the report. Figure 11-3 has been modified to complete the legend (in progress)	Accept
			Technology-specific Findings (Section 11.4): It becomes evident throughout this section that table and figure numbers are out of order. To avoid confusion, the numbering of tables and figures should be corrected in the final report.	Tables and figures have been references accurately.	Accept
			Any Monetized Value of Changes in Stocks and Harvest (Section 11.4.1.3), Valuing Changes in Commercial Yield: The first sentence in the second paragraph of this subsection (p. 11-61) refers to "…changes in the recreational stock…" but this subsection is about commercial yield. It appears the paragraph was copied from the previous section on recreational yield. This occurs again under subsections entitled "Valuing Changes in Commercial Yield" on page 11-70 (Section 11.4.2.3), page 11-75 (Section 11.4.3.3), and page 11-79 (Section 11.4.4.3).	The report has been corrected	Accept
			Section 11.4.1.3, page 11-60: The third paragraph refers to Figure 11-4 in illustrating how the benefits to fishery yield would be realized over the project life of Bayside but does not describe what factors drive the shape of the curve. The methods in Section 11.2.2 (pages 11- 27 and 11-28) briefly describe that dynamic Leslie matrix models were used to simulate numbers and biomass forward until they reach estimates of equivalent adults. Because there are many figures in Section 11.4 that depict the change in benefits over the life of the technology, it would be helpful if the first reference to these figures described the overall shape of the benefits curve – why does it increase gradually over several years, levels off, and then gradually decrease? I suggest providing such a description for Figure 11-4 that would then apply generally to the benefits curves in the other figures.	A description to the methodology employed has been provided in Section 11.2.2. This addition describes the rise and decay of the EAs at the beginning technologies use and at the end of the facility life, respectively. A reference to this description has been provided in Section 11.4.1.3 relating to the figures mentioned.	Accept

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Question Number	122.21(r)(11)	Response	Comments (if any)	Response to comments	Accept/Reject Revision
1) cont…	Are the methods, analysis, and discussion of the characterization of the recreational and commercial biological effects reasonable and adequate?	Yes	**Discussion of Uncertainty (Section 11.5):** This section, especially Table 11-38, is very helpful in better understanding sources of uncertainty in the benefits valuation. I recommend adding further discussion of the uncertainties associated with the analysis of forage shellfish, particularly the unknown invertebrates which comprised a substantial proportion of the Bartow shellfish entrainment sample. What levels of uncertainty were involved in assuming their importance in the forage base of C/R fish and shellfish species, and in applying biomass and trophic levels from surrogate taxa to unknown taxa? Would there be any differential effect of these uncertainties on estimated social benefits for the entrainment reduction technologies evaluated, or would they apply equally to all technologies? What would be the effect on the analysis of excluding non-C/R shellfish from the forage base; would it change the relative performance of the evaluated technologies in terms of social benefits or only reduce the magnitude of the social benefits?	A description regarding the uncertainties associated with the application of the forage shellfish species and how they were handled has been included in Table 11-38 (now Table 11-37).	Accept
			I also suggest including in Table 11-38 further discussion of the uncertainty associated with applying surrogate shellfish FMS exclusion and survivability rates to non-C/R shellfish. About half of the non-C/R shellfish from Bartow were pro yolk-sac larvae, while most of the shellfish tested at Big Bend were postlarvae, presumably larger, and would be expected to exhibit higher post-exclusion survival rates. How conservative were the assumptions, and would they tend to contribute to an overestimate of social benefits?	A description regarding the uncertainties associated with the application of the FMS exclusion and survival rates to forage shellfish species and how they were handled has been included in Table 11-38 (now Table 11-37).	Accept
			Are there any concluding observations about uncertainty and the comparison of social benefits between technologies that can be made in Section 11.5? For which technologies if any would biological uncertainties and conservative assumptions tend to compound the most, potentially contributing to overestimates of social benefits to a greater degree than for other technologies? It seems that uncertainties could compound for FMS because of the added analysis of exclusion and post-exclusion survival. How significant might the implications be if any to comparing the social benefits between technologies?	A brief description regarding the cumulative effects of the uncertainties is provided in Section 11.5.1 as follows: "A number of areas of uncertainty have been described in Table 11 37. Independently, these uncertainties may not have a large impact on the final social costs and benefits. However, when combined, they have the potential to become additive and possibly (though unlikely in most circumstances) change the results of the assessment. Furthermore, the cumulative effects for one technology (FMS) may be greater than others since that technology has more assumptions associated with it (exclusion and survival parameters) or the assumptions (addition of forage shellfish which have a larger exclusions efficiency and post exclusion survival than finfish) affect that technology more than others. The largest perceived impact is associated with the addition of forage shellfish. It is possible, that if this step was not taken, the social benefit of FMS may be lower than that of VSPs since the entrainment was made to be dominated by forage shellfish and they experience the greatest survival as compared to fish. However, this would not change the recommendations presented regarding EM BTA. Every effort was made to recognize, process, and choose the appropriate value for the assessment using best professional judgement. As with the changes in social preference noted above, following the submittal of this report new information, understanding, and studies may become available that would change the values chosen in Table 11-37. However, the decisions made for this assessment were carefully considered and vetted by the team and others and represent the best professional judgement at the time of writing this report."	Accept
			In Table 11-38, for “Consideration of FMS Exclusion and Post- Exclusion Survival,” in the first column, the sentence beginning “There is also a literature on rates…” is missing one or more words and needs to be completed.	The sentence has been corrected to: "There is also a literature on rates of exclusion and/or survival at other facilities and laboratory settings."	Accept
2)	In your professional opinion, do you think the information provided is both reasonable and adequate to support the decision for the entrainment BTA determination by NPDES permitting authority?	Yes	In my professional opinion, after addressing my review comments and questions for clarifying and improving certain aspects of the presentation of the analysis, the biological information developed for the benefits valuation is reasonable and adequate to support an entrainment BTA determination.	No response needed.	

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5. Please refer to page 4, paragraph 7 of the petition. Please provide the date TECO anticipates DEP approval of the Bayside Station National Pollutant Discharge Elimination System ("NPDES") permit.

A. Tampa Electric has provided all information requested by the FDEP with respect to this NPDES permit renewal. At this time, Tampa Electric cannot provide a date on which FDEP will approve the permit; however, the NPDES permit renewal approval is not required before construction can commence.

6. Please refer to page 4, paragraph 8 of the petition, for the following questions.

a. Please explain when TECO expects to both solicit and receive bids for construction.

b. Please explain if the NPDES permit approval is required before construction can commence.

A. a. Tampa Electric expects to solicit bids for construction in the first quarter of 2022.

b. FDEP confirmed in its meeting with the company on February 16, 2021, that NPDES permit renewal approval is not required before construction can commence. After construction, the selected compliance method of modified traveling screens and fish return is subject to an optimization study to validate that impingement mortality has been adequately minimized as described at 40 CFR 122.21(r)(6)(i).

7. Please refer to page 5, paragraph 11 of the petition, for the following questions.

a. Please provide the estimated construction start date and in-service date.

b. Please explain how the estimated costs were determined.

A. a. Construction is expected to begin in the third quarter of 2022. The equipment for Unit 1 will be in service in the fourth quarter of 2022, and the equipment for Unit 2 is expected to be in service in the fourth quarter of 2023.

b. The estimated cost was developed in 2020 using actual costs from a similar 316(b) project. Labor costs from central Florida were used with budgetary quotes on the major equipment such as the fish friendly traveling screens. A draft layout of the fish return system was created, and material requirements were estimated.