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February 8, 2018

**VIA: ELECTRONIC FILING**

Ms. Carlotta S. Stauffer
Commission Clerk
Florida Public Service Commission
2540 Shumard Oak Boulevard
Tallahassee, Florida 32399-0850

Re: Docket No. 20170215-EU – Review of electric utility hurricane preparedness and restoration actions

Dear Ms. Stauffer:

This will follow up Tampa Electric Company's response to Staff's Second Data Request, Request No. 2, in which the company indicated that it would follow up its response to that Data Request with a supplement including the completed forensic analysis by an independent third party contractor to determine the performance of the company's system during Hurricane Irma. Attached is a copy of the completed forensic analysis.

Thank you for your assistance in connection with this matter.

Sincerely,

James D. Beasley

JDB/pp
Attachment

DNV·GL

POST STORM FORENSICS ANALYSIS

# Forensics Analysis of Hurricane Irma Data

Tampa Electric

**Report No.:** 1, Rev. 12
**Document No.:** Final
**Date:** February 2, 2018

| | | |
|---|---|---|
| Project name: | Post Storm Forensics Analysis | KEMA, Inc. |
| Report title: | Forensics Analysis of Hurricane Irma Data | Energy Advisory |
| Customer: | Tampa Electric | [Office Post 1] |
| Customer contact: | Dave W. Johnson | [Office Post 2] |
| Date of issue: | February 2, 2018 | [Office Post 3] |
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Applicable contract(s) governing the provision of this Report: R-40091

Objective:

| Prepared by: | Verified by: | Approved by: |
|---|---|---|
| Milton Omoto<br>Head of Section | Clay Tutaj<br>Emergency Planning Consultant | Milton Omoto<br>Head of Section |



DNV GL Distribution:

☐Unrestricted distribution (internal and external)

☐Unrestricted distribution within DNV GL Group

☐Unrestricted distribution within DNV GL contracting party

☒ No distribution (confidential)

| Rev. No. | Date | Reason for Issue | Prepared by | Verified by | Approved by |
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| 0 | 20170918 | Work in Progress | | | |
| 1 | 20171011 | Formatted Version | | | |
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| 4 | 20171013 | Revised with TECO Comments | | | |
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| 10 | 20180119 | Updated per TECO Request | | | |
| 11 | 20180131 | Updated per TECO Request | | | |
| 12 | 20180202 | Revised to Correct Errors | | | |

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## Appendices



## List of exhibits

# 1 EXECUTIVE SUMMARY

This report documents a forensics analysis performed on a representative sample of data collected on storm impacted and damaged energy delivery poles, structures, and equipment caused by the effects of Hurricane Irma. It is an independent analysis performed by KEMA DNV GL (hereafter DNV GL) for Tampa Electric Company (hereafter TECO). DNV GL has strived to provide a balanced report that includes results of impacted and damaged assets collected, a root cause analysis of asset failures, and the correlation of available weather data to specific geographic areas to observed effects.

## 1.1 Approach to Data Collection

The information sources used by DNV GL for this forensics analysis was provided by Osmose Utilities Services, Inc. Immediately after the storm passed TECO's service area, DNV GL identified one square mile map grids for Osmose personnel to conduct surveys of impacted and damaged poles, structures, conductors, and equipment. The grid samples were selected based on factors such as wind strength and pattern, geography, customer outages, class and material type of distribution poles and transmission structures, and density of assets within the area.

Osmose then provided these map grids for assignment to field personnel, who then conducted the survey and collected required data once it was safe for their personnel to do so. This data was made available on the Osmose FTP site for access by DNV GL.

## 1.2 Forensics Data Analysis Methodology

DNV GL used available data that was immediately available after the event, including TECO provided distribution pole and transmission structure data, Osmose collected field data, and available public data from the National Oceanic and Atmospheric Administration (NOAA). Statistical analysis was performed on the collected field data and correlated to TECO pole and structure data. Survey data was then correlated to weather data, primarily wind speed. Finally, wind speed to infrastructure affected and failure probability (including broken poles, broken cross arms, wires down) was defined for this specific storm event and extrapolated to the entire TECO service area.

## 1.3 Root Cause Analysis Conclusion

Based on root cause analysis of data, the following conclusions are drawn:

- Damage categories include broken poles, conductor (wire down) and cross arm broken
- The impacted pole category includes leaning poles
- Pole damage (broken) was predominately due to wind damage and wind borne debris
- There was no transmission structure damage; three leaning structures were reported
- Conductor damage was generally due to debris hitting the conductor and/or hitting and breaking cross arms
- Total infrastructure impacted rates for all affected categories range from 0.06% to 7.69% within the survey areas only
- Extrapolated survey data to the entire TECO service area was made to show the probable effects of storm caused impacts and damage; however, this extrapolation is statistically biased in that only heavily impacted areas were surveyed

Contributing factors for damage potentially include wind speed, tree hitting pole and/or conductor, debris hitting pole, cross arm and/or conductor, pole age and storm surge.

## 1.4 Definitions

The following definitions were used by DNV GL in this analysis:

Impacted Infrastructure. This term is used to classify all poles or structures, leaning or broken that may or may not have been affected from the storm; TECO does not consider leaning structures to be damaged

Broken Pole. Poles that failed as a result of the storm.

Damaged Conductor. Wires down.

Broken Cross Arm. Damaged cross arms that required repair/replacement.

## 1.5 Disclaimer

The forensics data analysis performed as part of this post storm assessment is based on the information provided by Osmose, TECO and publicly available data. DNV GL did not conduct field measurements at TECO's service areas and therefore cannot accept liability for the accuracy of the data supplied to it.

# 2 INTRODUCTION

## 2.1 Background of Event

Hurricane Irma, an extremely powerful and catastrophic Cape Verde type hurricane, made landfall in Cudjoe Key, Florida at 13:10 UTC on September 9, 2017 with maximum sustained winds of 130 mph. It weakened into a category 2 once inland. It approached the Tampa area at approximately 0100 hour on September 11, 2017 as a category 1 or less storm.

In anticipation of the hurricane, TECO notified DNV GL on Friday, September 8, 2017, to standby should they desire to activate the forensics data analysis contract, which is based on the intensity of an anticipated storm. To prepare for the event, DNV GL tracked the hurricane's progress through Southern and Central Florida over the weekend. DNV GL was notified by TECO on Monday, September 11, 2017 that they would activate the contract and for DNV GL to begin performing analysis of areas where most probable damage impact would exist based on reported weather patterns.

## 2.2 Scope of this Assessment

This report documents the approach, methodology, and results of the storm forensics data analysis performed by DNV GL. The work scope for this assessment is to perform forensics analysis on a representative sample of data collected by Osmose Utilities, Inc., under contract to TECO. DNV GL defined the geographic areas for Osmose to perform field surveys for data collection. Data collected included storm impacted and damaged poles and structures, conductor, and equipment. DNV GL then performed analysis of this data including determining the root cause of asset failures.

Specifically, DNV GL performed the following contractual work:

- Analyze storm pattern to identify areas of most probable impact and damage
- Identify the grids for field surveys
- Analyze field survey data of storm damaged and impacted assets
- Correlate available weather data and geographical areas to observed failures
- Perform a root cause analysis on damaged assets
- Document work and results of the data analysis in a report

# 3 APPROACH AND METHODOLOGY

The storm data collection and analysis process is highlighted in the flow below.


## 3.1 Pre-Storm Analysis

A pre-storm analysis was performed to assess the direction and intensity of the storm and to correlate this information to TECO service areas to determine the most probable damaged areas. These activities include:

- TECO activates forensics data analysis contract
- Track the path and intensity of Hurricane Irma and relate to TECO's service area
- Determine the most probable areas of damage to the electric delivery infrastructure

Once TECO activated the storm forensics data analysis contract, DNV GL tracked the path and intensity of Hurricane Irma using the National Oceanic and Atmospheric Administration's (NOAA) web site (Figure 3-1). Storm information was then correlated to TECO service areas to determine areas for data collection.

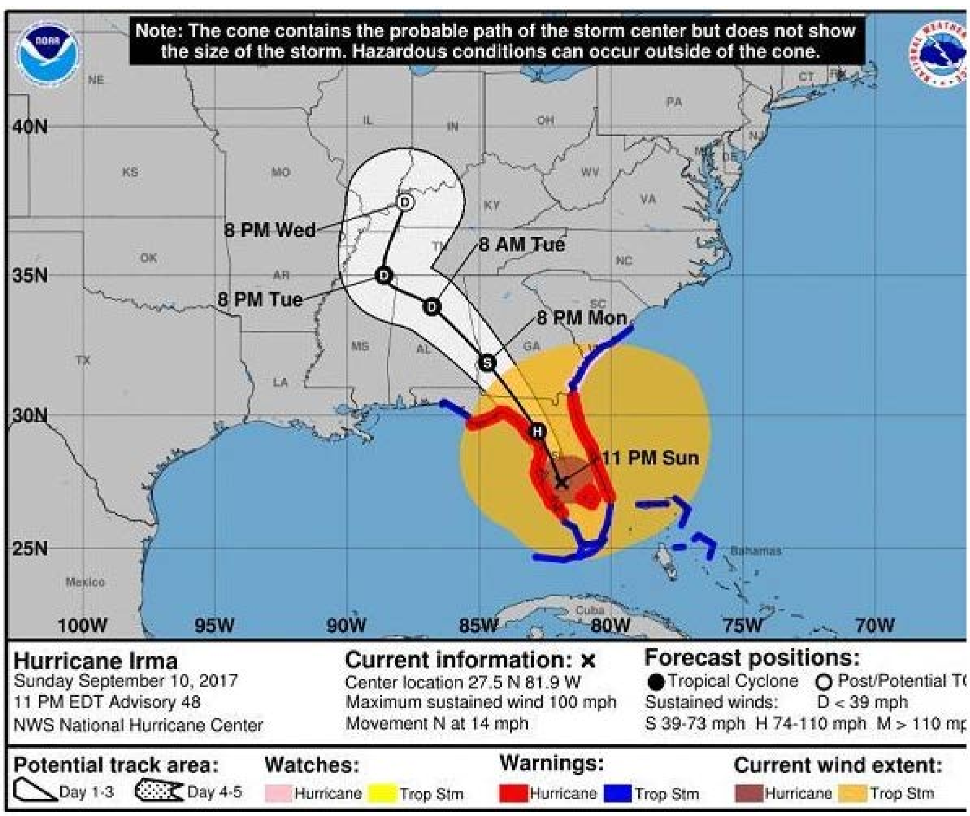


**Figure 3-1 Hurricane Irma Predicted Path and Severity**

## 3.2 Post Storm Data Collection

TECO provided DNV GL with pole and structure data for their entire service area. This data was combined with the pre-storm analysis information to perform the following activities:

- Define one-mile square map grids for areas of field surveys
- Assign these map grids to Osmose to conduct the field surveys
- Osmose then performed the field survey and data collection

DNV GL defined the survey areas for field data collection based on TECO service areas (Figure 3-2), interpolated maximum wind speed (Figure 3-3), interpolated wind gusts (Figure 3-4), outage information (Figure 3-5) and pole density data (Figure 3-6). TECO determined that the Winter Haven service area reportedly experienced Category 1 severity and was a priority survey area. The other service areas sustained tropical storm wind intensity. The survey had to be performed in a timely manner before significant restoration activities began. Only above ground assets were surveyed and no survey was conducted on substations or underground facilities.

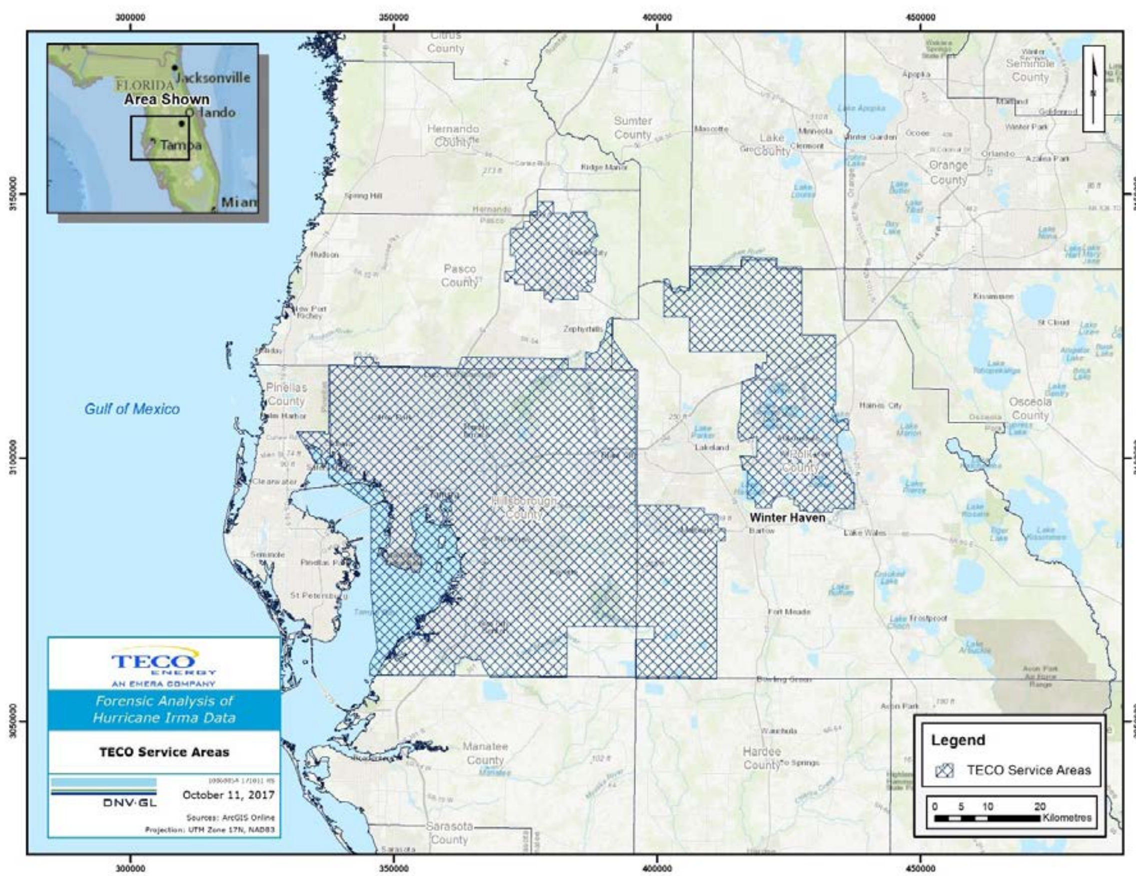


**Figure 3-2 TECO Service Area Map**

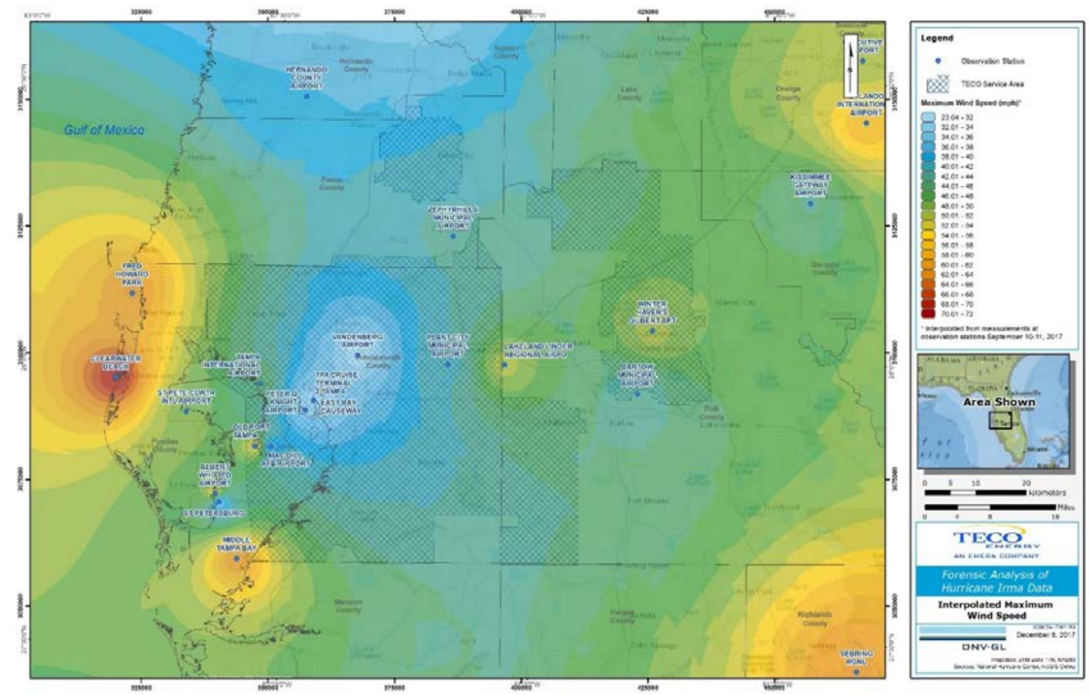


**Figure 3-3 Interpolated Wind Speed**

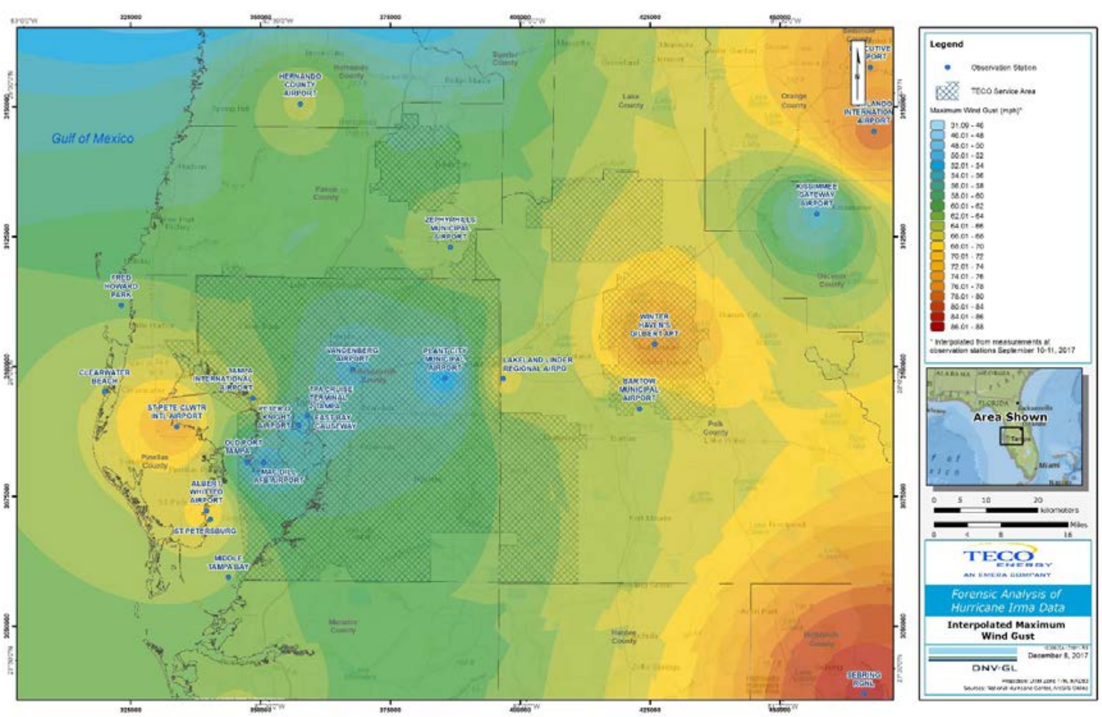


**Figure 3-4 Interpolated Wind Gust**

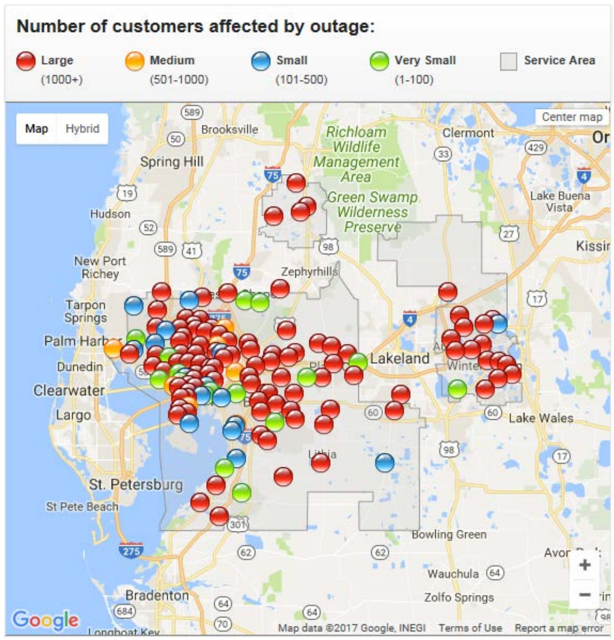


**Figure 3-5 Outage Map Example at 0930 Hour 09/11/2017**

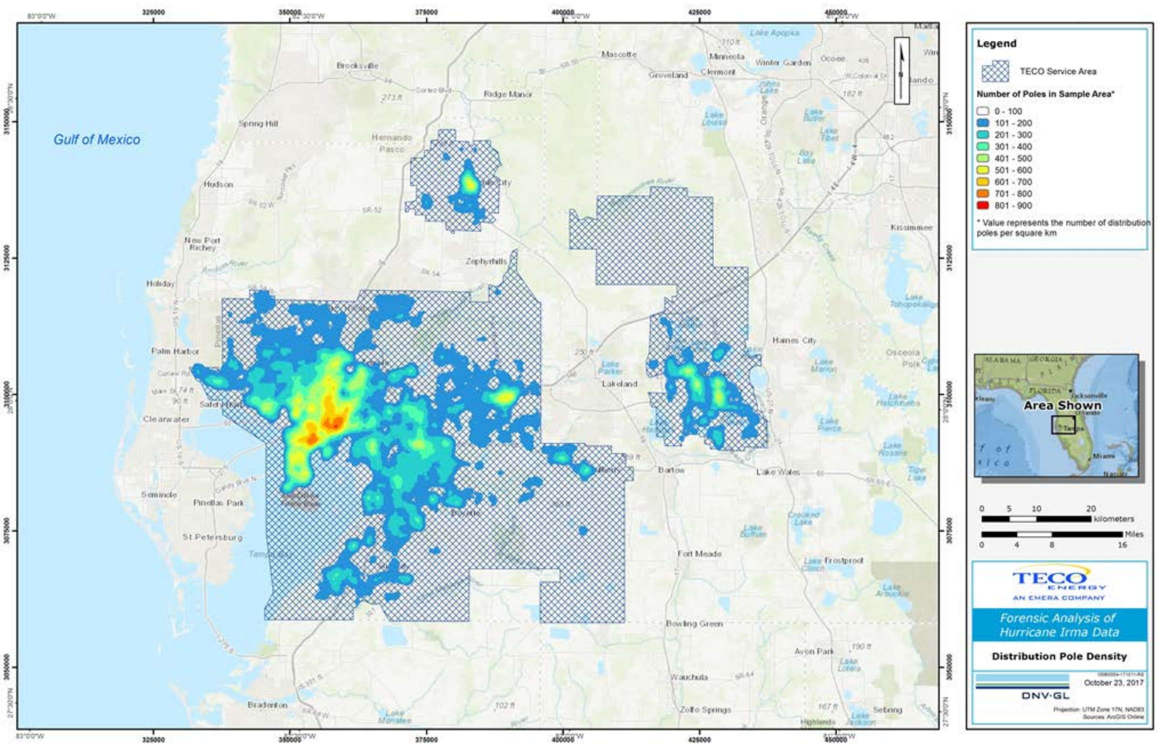


**Figure 3-6 Distribution Pole Density**

Osmose personnel performed the field survey based on the defined grids to identify and collect impacted and damage information to energy delivery poles, structures, conductors, and equipment. This information was uploaded from their field collection devices to an Osmose FTP site for access and processing by DNV GL.

The categories of reported impact, damage and quantities are listed below.

- Conductor Down 62
- Cross Arm Broken 4
- Broken Pole 9
- Leaning Pole 32
- Other 15

## 3.3 Forensics Analysis

DNV GL then performed analysis on the collected damage data. The following steps were followed:

- Review field survey data collected
- Analyze and summarize impact and damage report data
- Determine failure rate by map grid
- Determine potential damage contributing factors

The forensics analysis (Section 4 of this report) correlated collected impact and damage data to service areas and most likely contributing factors for pole and infrastructure related damage.

## 3.4 Correlation of Weather Data to Damage

Available weather data immediately after the storm was then correlated to survey data as follows:

- Obtain available NOAA weather data
- Extrapolate wind speed and correlate to geography
- Perform root cause analysis
- Determine pole failure probability to wind speed
- Extrapolate data to TECO service area

Results of this correlation were to define the post-storm wind path and speed (Figure 3-7) based on the predicted path for Hurricane Irma based on weather data available on public sources at that time.

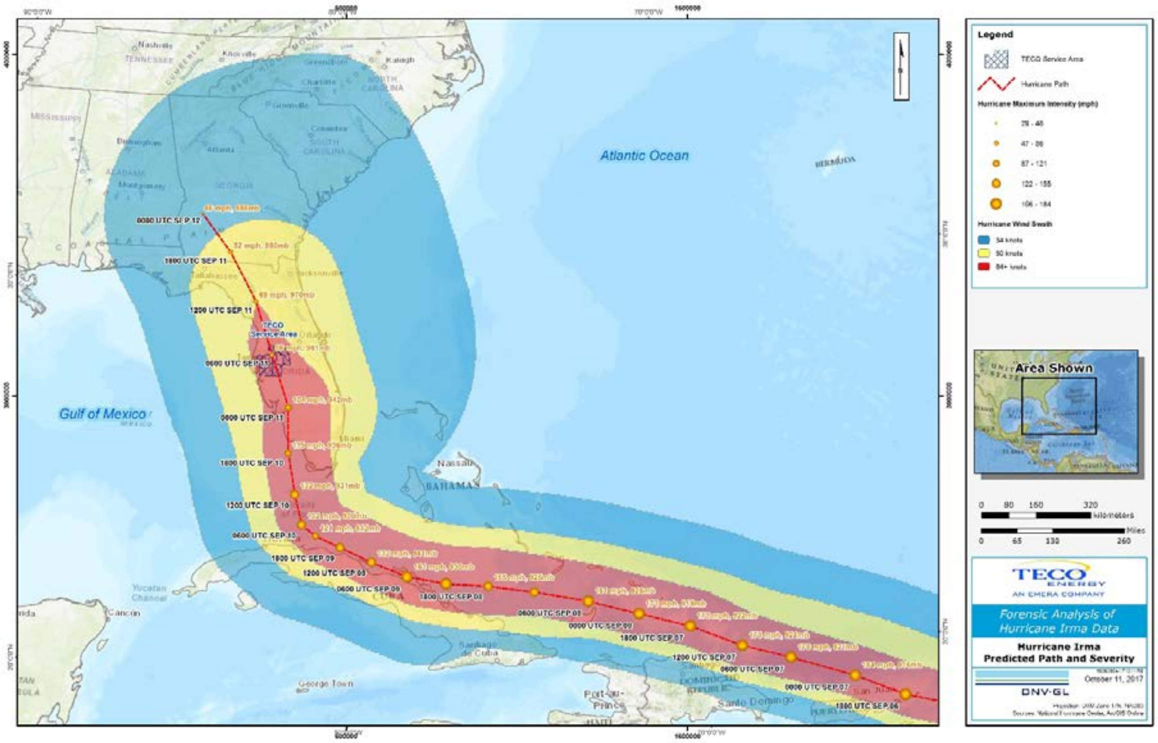


**Figure 3-7 Wind Path and Severity**

Several months after the storm event elapsed, TECO provided DNV GL with wind gust data from their weather contractor. The provided StormGeo data enabled DNV GL to further develop a map of maximum wind gusts, illustrated in Figure 3-8 and maximum wind speed, illustrated in Figure 3-9. Data from a total of 94 stations were provided by TECO. These covered the entire State of Florida. DNV GL used this data to develop the interpolated maps shown in Figures 3-3, 3-4, 3-8 and 3-9. However, DNV GL only used data from the 11 stations related to TECO service areas for the forensics data analysis and extrapolation analysis. The data that was immediately available after the storm was used to calculate the average maximum wind gust for each service area grid cell (distance of service area from station location). Wind gust data showed slower wind pockets near Tampa and higher wind gusts near Winter Haven.

Please see section 5.3 of this report for an explanation of extrapolation versus interpolation techniques.

Note that maximum wind gust StormGeo data for the 11 stations are the same stations as those used initially by DNV GL for sustained wind speed data. Table 5-3 lists these 11 stations.

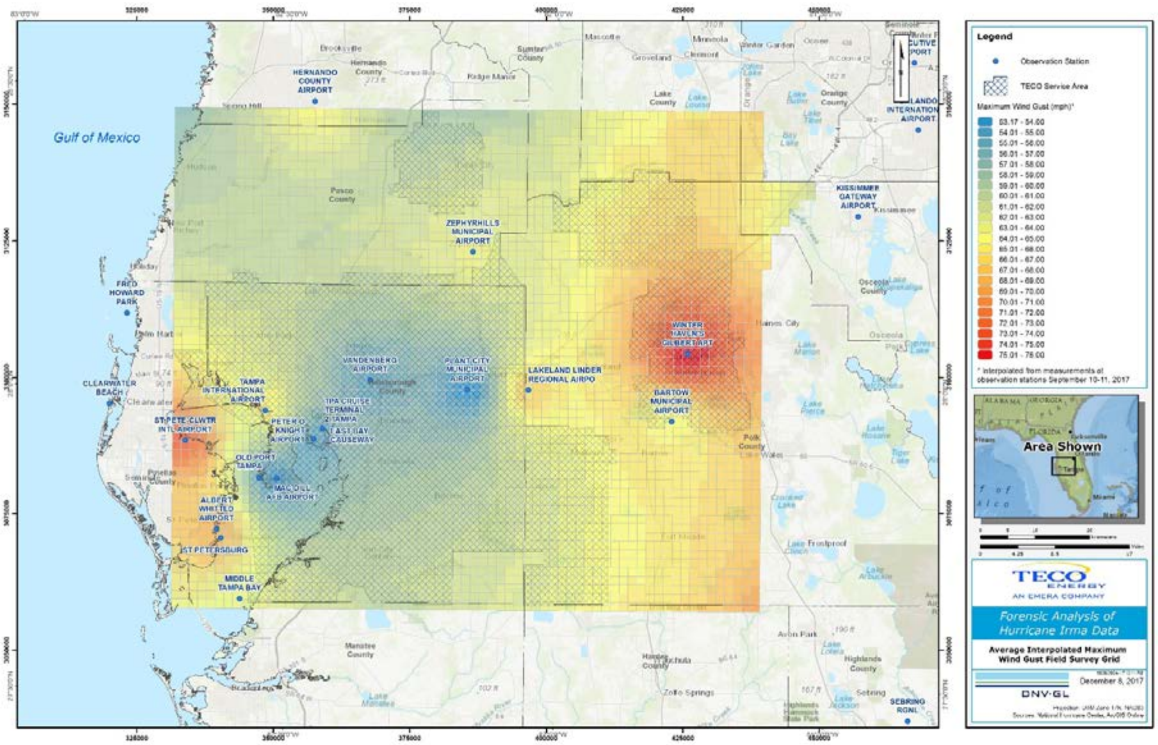


**Figure 3-8 Interpolated Maximum Wind Gusts**

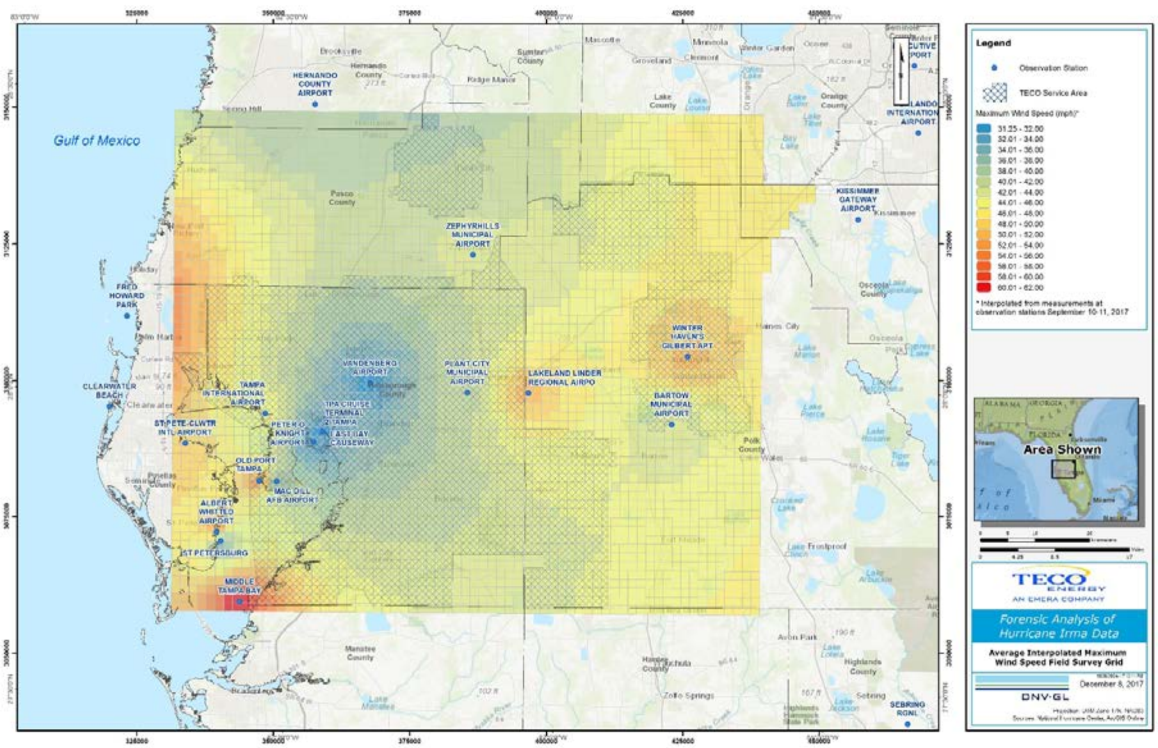


**Figure 3-9 Interpolated Maximum Wind Speed**

The probability of failure is graphically shown in Figure 3-10. This Damage and Failure Probability map clearly showed the potential damage areas and severity. This map is based on sustained wind data and not maximum wind gust data. Reported field survey failures collected by Osmose were then related to the entire TECO service area. Impacts and failures associated to pole and type were determined, using poles as the reference for damages and include pole, conductor and cross arm damages. Finally, root cause analysis of contributing factors of damage cause was performed.

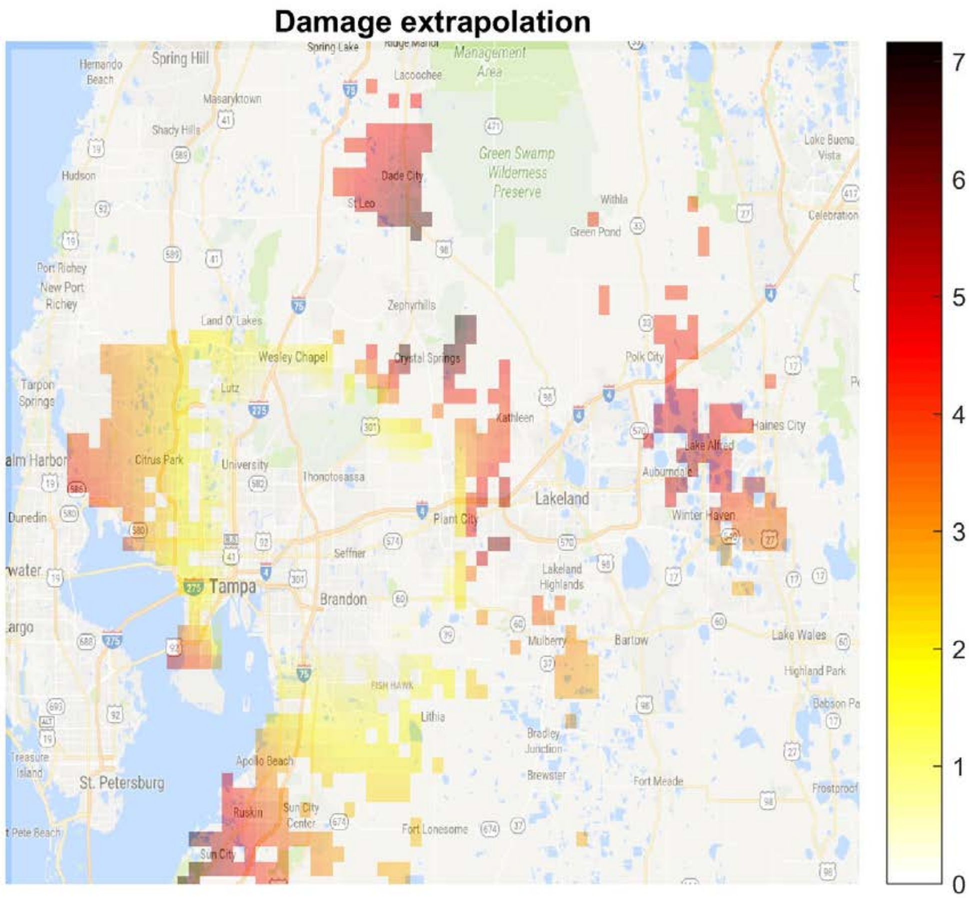


**Figure 3-10 Damage and Impacted Probability**

Based on the wind path and severity (Figure 3-7), and the extrapolated sustained wind speed data for each grid zone in the TECO service area, a probability for damage was found for each grid zone of the TECO service area. This is illustrated above in Figure 3-10. The scale is in percentage.

# 4 FORENSICS DATA ANALYSIS

DNV GL performed a thorough data review and analysis of available data to better understand impact and damage to the TECO energy delivery infrastructure caused by Hurricane Irma. Findings with respect to the number of breakages, breakage rates, root causes, and explanations have been generated together with geographical maps and documented in this report.

## 4.1 Available Data

To assess the impact of the hurricane to TECO's energy delivery system, the ratio of damage information collected from the Osmose field survey versus exposed poles and structures was evaluated for potential root causes. Significant effort was made to evaluate available information pertaining to pole type, class, location, and other attributes. This information was used to analyze and categorize all damage types.

## 4.2 Distribution Pole Population Data

Pole record data provided by TECO, being the most accurate data source when it comes to amounts, material and class, was processed and used for this analysis and serve as the reference point for resulting storm impact and damages.

Table 4-1 gives a summary of the pole population by material type in the TECO area.

**Table 4-1 Total pole population by material type**

| Type | Number of poles |
|---|---|
| Wood | 302,847 |
| Concrete | 20,863 |
| Aluminium | 7,360 |
| Fiberglass | 8,848 |
| Iron | 401 |
| Steel | 327 |
| Other | 93,320 |
| **Total** | **433,966** |

As shown in the table, and illustrated in Figure 4-1, about 69% percent of the poles in the TECO are made from wood, while concrete poles make about 5% of the total population.

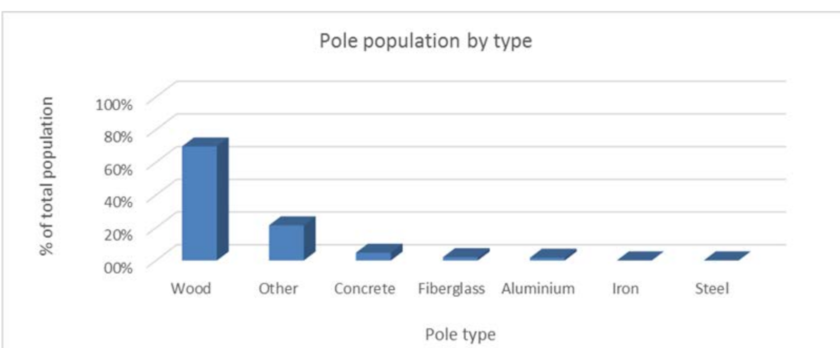


**Figure 4-1 Graph of Pole Population by Material Type**

Furthermore, the population of wooden poles is divided into different classes, as shown in Table 4-2.

**Table 4-2 Classification of total TECO wooden poles**

| | Class 0 | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Class 6 | Class H2 |
|---|---|---|---|---|---|---|---|---|
| Wood poles | 1 | 9761 | 27710 | 7146 | 175947 | 1540 | 80631 | 1 |
| % of wood poles | 0.0% | 3.2% | 9.1% | 2.4% | 58.1% | 0.5% | 26.6% | 0.0% |

These poles are distributed mostly in the Tampa area, but the TECO service area includes areas outside of the immediate Tampa location, such as Winter Haven, as illustrated by Figure 4-2. This figure shows pole density throughout the area of TECO. The scale indicates the number of poles present in a specific area.

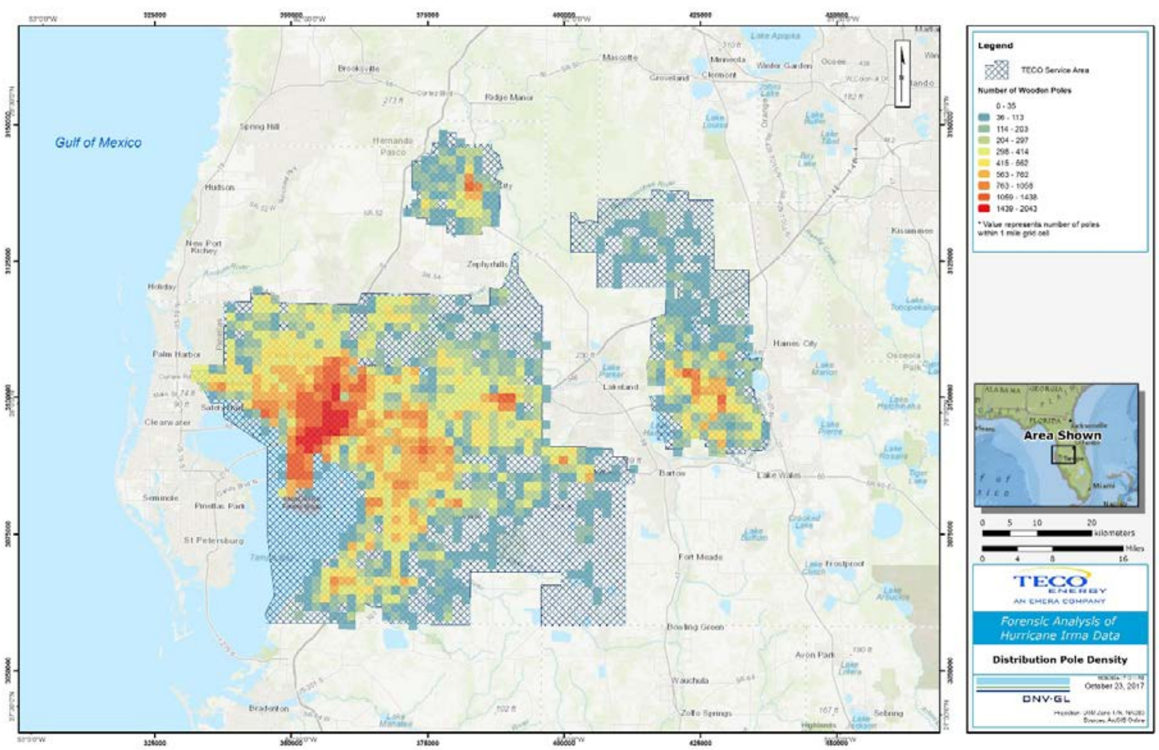


**Figure 4-2 Total TECO Distribution Pole Density Map**

## 4.3 Transmission Structure Population Data

Transmission structure density for the TECO service area is shown in Figure 4-3.

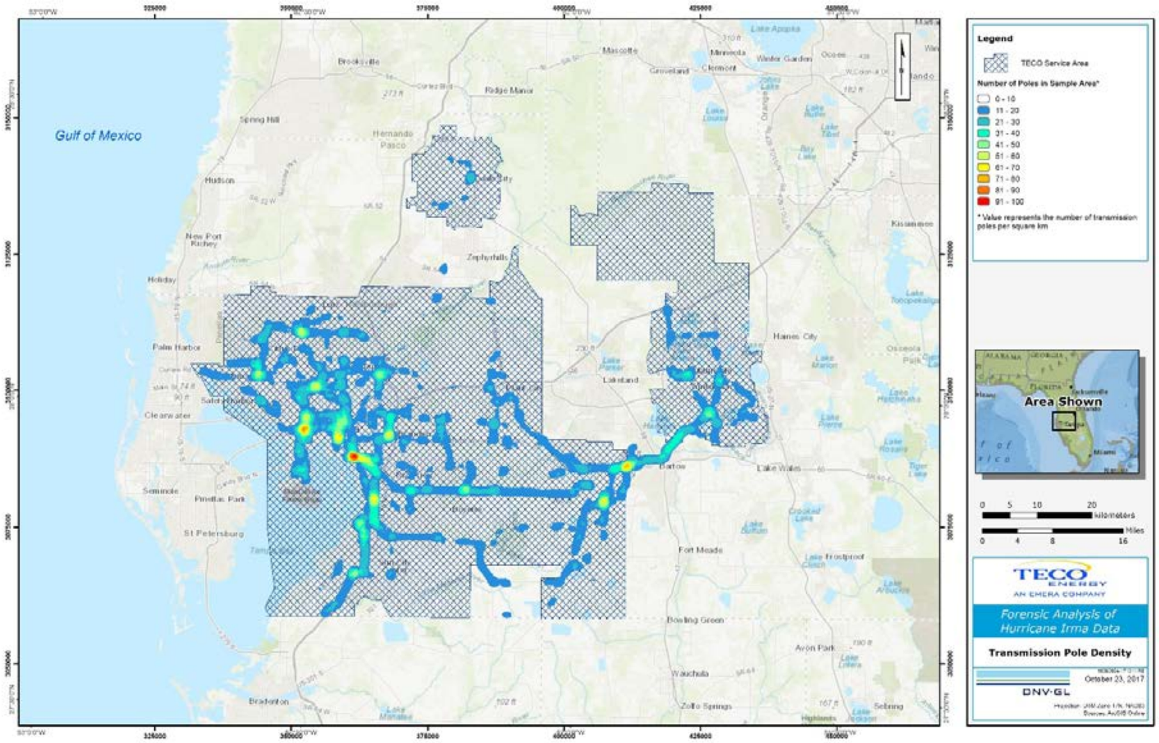


**Figure 4-3 Transmission Structure Density**

Table 4-33 provides failure rates for transmission structure related impact.

**Table 4-3 Failure rates by transmission structures per survey data**

| Grid codes | Zone type | Total Structure Population | Num. Damage reported | Failure rate |
|---|---|---|---|---|
| 17-24 | Urban | 77 | 0 | 0.00% |
| 17-25 | Rural | 23 | 0 | 0.00% |
| 17-29 | Urban | 54 | 0 | 0.00% |
| 31-26 | Urban | 24 | 0 | 0.00% |
| 36-27 | Urban | 0 | 0 | 0.00% |
| 37-27 | Rural | 11 | 0 | 0.00% |
| 38-27 | Urban | 0 | 0 | 0.00% |
| 56-29 | Urban | 52 | 0 | 0.00% |
| 57-23 | Rural | 63 | 1 | 1.59% |
| 57-28 | Rural | 3 | 0 | 0.00% |
| 59-25 | Urban | 48 | 0 | 0.00% |
| 60-28 | Urban | 26 | 2 | 7.69% |

Since the survey data for transmission related damage was only 3 in the sample of collected data, this was not used in the analysis due to the small sample size. All three transmission related damages were reported as leaning structure with no actual breakage of the structure itself.

## 4.4 Damage Report Data

Post storm, TECO investigated impact and damage to their energy delivery infrastructure using Osmose Utilities Service. In total, 123 reports where collected from a survey that covered about 1% of the TECO geographic service area by map grid. More details about the reported damage from collected data is provided in Table 4-4. The impact and damage categories include poles (leaning or broken), conductor (wire down), cross arm damage, and “other.” The other category includes miscellaneous impact or damage to service poles, lighting poles, and so on.

In the table, impact and damages are related only to distribution poles because that was the reference source used (pole ID) and how damages were catalogued. In addition, leaning poles were included in the analysis as impacted. While TECO does not consider leaning poles to be a damage category, these impacted poles were included because some may have resulted from the storm. DNV GL understands that leaning poles reported to be 20º or even 30º from vertical may have existed prior to the storm and may or may not be the result of storm winds. However, there were several leaning poles reported that had greater angles of lean, and it was decided to include all leaning poles in the analysis.

In summary, it is observed that the failure rates for all impacted categories within the sample population ranged from 0.06% to 7.69% for distribution assets. Note that this failure rate is only within the sampled survey areas, and these sampled areas most likely sustained greater damage than other areas. This damage percentage range cannot be extrapolated to the entire TECO service area. This failure rate relates to all categories of damage including leaning poles. Actual pole damage (breakage) was low, even in the surveyed areas.

**Table 4-4 Failure rates by distribution pole per survey data**

| Grid Codes | Zone Type | Total Pole Population | Total Impacted Poles (leaning and damaged) | Total Impacted Rate | Pole Damage (breakage) | | Leaning Poles | | Conductor Damage (wire down) | | Damaged Cross Arm | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Number of Damaged Poles | Failure Rate | Number of Leaning | Leaning Rate | Number of Damage | Failure Rate | Number of Damage | Failure Rate | Number of Damage | Failure Rate |
| 17-24 | Urban | 1812 | 1 | 0.06% | 0 | 0.00% | 0 | 0.00% | 1 | 0.06% | 0 | 0.00% | 0 | 0.00% |
| 17-25 | Rural | 1640 | 1 | 0.06% | 0 | 0.00% | 0 | 0.00% | 1 | 0.06% | 0 | 0.00% | 0 | 0.00% |
| 17-29 | Urban | 1154 | 2 | 0.17% | 0 | 0.00% | 0 | 0.00% | 1 | 0.09% | 1 | 0.09% | 0 | 0.00% |
| 31-26 | Urban | 384 | 3 | 0.78% | 0 | 0.00% | 0 | 0.00% | 3 | 0.78% | 0 | 0.00% | 0 | 0.00% |
| 36-27 | Urban | 1238 | 18 | 1.45% | 3 | 0.24% | 1 | 0.08% | 13 | 1.05% | 0 | 0.00% | 1 | 0.08% |
| 37-27 | Rural | 1432 | 12 | 0.84% | 1 | 0.07% | 2 | 0.14% | 6 | 0.42% | 2 | 0.14% | 1 | 0.07% |
| 38-27 | Urban | 533 | 4 | 0.75% | 0 | 0.00% | 0 | 0.00% | 3 | 0.56% | 0 | 0.00% | 1 | 0.19% |
| 56-29 | Urban | 306 | 4 | 1.31% | 1 | 0.33% | 1 | 0.33% | 2 | 0.65% | 0 | 0.00% | 0 | 0.00% |
| 57-23 | Rural | 234 | 18 | 7.69% | 2 | 0.85% | 12 | 5.13% | 1 | 0.43% | 0 | 0.00% | 3 | 1.28% |
| 57-28 | Rural | 302 | 13 | 4.30% | 0 | 0.00% | 6 | 1.99% | 7 | 2.32% | 0 | 0.00% | 0 | 0.00% |
| 59-25 | Urban | 273 | 15 | 5.49% | 0 | 0.00% | 2 | 0.73% | 3 | 1.10% | 0 | 0.00% | 10 | 3.66% |
| 60-28 | Urban | 681 | 29 | 4.26% | 2 | 0.29% | 5 | 0.73% | 21 | 3.08% | 1 | 0.15% | 0 | 0.00% |

Additionally, Table 4-5 shows the distribution of impacted and failure rates related to distribution wooden poles only, according to pole class in the grid areas surveyed. As shown, poles class 2 and 4 show the highest related failure rate. Note again that these impacted rates include pole damage (broken), pole leaning, damaged conductor (line down), and damaged cross arm, whereas damaged rates do not include leaning poles.

**Table 4-5 Failure and impacted rates of wooden poles per class in the grid zones with records**

| | Class 0 | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Class 6 | Class H2 | No Class |
|---|---|---|---|---|---|---|---|---|---|
| All Wooden Poles | 0 | 243 | 460 | 268 | 4803 | 32 | 2427 | 0 | 2 |
| Impacted Wooden Poles | 0 | 1 | 7 | 3 | 75 | 0 | 16 | 0 | 0 |
| % Impacted of Sample | 0.00% | 0.41% | 1.52% | 1.12% | 1.56% | 0.0% | 0.66% | 0.00% | 0.00% |
| Damaged Wood Poles | 0 | 0 | 3 | 3 | 44 | 0 | 11 | 0 | 0 |
| % Damaged of Sample | 0.00% | 0.00% | 0.67% | 1.12% | 0.92% | 0.00% | 0.45% | 0.00% | 0.00% |

Finally, Table 4-6 shows the damage and impacts to distribution according to their root cause (as given by the field survey reports). Damage and impacts are related to feeder, lateral, other (service) and material. As the table shows, trees and wind were the main cause for infrastructure damage and impact in the TECO service area.

**Table 4-6 TECO damaged and impacted contributing factor comparison by circuit and pole type**

| Type | Material | Wind Only | Tree (+wind) | Debris (+wind) | Decay (+ wind) | Storm Surge (+ wind) | Total |
|---|---|---|---|---|---|---|---|
| **Feeder** | | **12** | **12** | **3** | **2** | **3** | **32** |
| | | 38% | 38% | 9% | 6% | 9% | |
| | Wood | 12 | 8 | 3 | 1 | 3 | 27 |
| | | 44% | 30% | 11% | 4% | 11% | |
| | Concrete | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 0% | 0% | 0% | 0% | 0% | |
| | Unknown | 0 | 4 | 0 | 1 | 0 | 5 |
| | | 0% | 80% | 0% | 20% | 0% | |
| **Lateral** | | **7** | **69** | **3** | **1** | **3** | **83** |
| | | 8% | 83% | 4% | 1% | 4% | |
| | Wood | 7 | 58 | 3 | 0 | 3 | 71 |
| | | 10% | 82% | 4% | 0% | 4% | |
| | Concrete | 0 | 2 | 0 | 0 | 0 | 2 |
| | | 0% | 100% | 0% | 0% | 0% | |
| | Unknown | 0 | 9 | 0 | 1 | 0 | 10 |
| | | 0% | 90% | 0% | 10% | 0% | |
| **Other** | | **1** | **4** | **0** | **0** | **0** | **5** |
| | | 20% | 80% | 0% | 0% | 0% | |
| | Wood | 1 | 3 | 0 | 0 | 0 | 4 |
| | | 25% | 75% | 0% | 0% | 0% | |
| | Concrete | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 0% | 0% | 0% | 0% | 0% | |
| | Unknown | 0 | 1 | 0 | 0 | 0 | 1 |
| | | 0% | 100% | 0% | 0% | 0% | |

**Table 4-7 TECO damage contributing factor comparison by damage type**

| Material | Wind Only | Tree (+wind) | Debris (+wind) | Decay (+ wind) | Storm Surge (+ wind) | Total |
|---|---|---|---|---|---|---|
| | **20** | **85** | **6** | **3** | **6** | **120** |
| Pole Broken | 0 | 8 | 0 | 1 | 0 | **9** |
| | 0.00% | 88.89% | 0.00% | 11.11% | 0.00% | |
| Pole Leaning | 14 | 10 | 0 | 0 | 5 | **29** |
| | 48.28% | 34.48% | 0.00% | 0.00% | 17.24% | |
| Conductor Down | 3 | 52 | 6 | 0 | 1 | **62** |
| | 4.84% | 83.87% | 9.68% | 0.00% | 1.61% | |
| Cross Arm Broken | 1 | 2 | 0 | 1 | 0 | **4** |
| | 25.00% | 50.00% | 0.00% | 25.00% | 0.00% | |
| Other | 2 | 13 | 0 | 1 | 0 | **16** |
| | 12.50% | 81.25% | 0.00% | 6.25% | 0.00% | |

**Table 4-8 Number of damaged and impacted poles per grid zone type in the sample**

| Type of grid zone | #all poles | #damaged | Failure rate% |
|---|---|---|---|
| **rural** | 3608 | 44 | 1.22% |
| **urban** | 6381 | 76 | 1.19% |

Damage to distribution pole material type (wood, concrete) in this table is inclusive of pole breakage, pole leaning, conductor damage (wire down) and broken cross arm, not just pole damage. The tables are relevant to distribution poles only.

## 4.5 Confidence level

Hurricane Irma post storm forensic analysis resulted in 123 survey records of damage versus a total amount of approximately 433,966 poles and structures within TECO's service areas. This amounts to a sample size of 0.02%. This sample size is generally sufficient for statistical analysis resulting in a 99% confidence level and range of 11.77%. This means that conclusions from statistical analysis of this sample yields results in a range plus or minus 11.77% with 99% certainty.

# 5 DAMAGE EXTRAPOLATION ANALYSIS

## 5.1 Description of Map Grid Zones

The TECO service area is divided into 1,545 map grid areas. These areas can be further divided into urban and rural, as shown in the following Table 5-1.

**Table 5-1 TECO grid zones per population density**

| Type | Number of grid zones | Percentage of total |
|---|---|---|
| Urban | 493 | 32% |
| Rural | 1052 | 68% |
| **Total** | **1545** | |

Additionally, Table 5-2 shows the distribution of poles and structures related to urban or rural.

**Table 5-2 TECO distribution poles and transmission structures per grid zone type**

| Type | Urban | Rural |
|---|---|---|
| Transmission structures | 11420 | 13896 |
| Distribution poles | 238777 | 195189 |

## 5.2 Weather Data

Weather information, including sustained wind speed, wind direction and pressure, was obtained from the National Oceanic and Atmospheric Administration (NOAA) for 11 meteorological stations across 3 counties in the Tampa geographic area, for the month of September 2017. These stations are listed below in the following table.

**Table 5-3 List of the stations where wind speed data were extracted**

| | Station name |
|---|---|
| 1. | ST PETERSBURG ALBERT WHITTED AIRPORT FL US |
| 2. | ST PETERSBURG CLEARWATER INTERNATIONAL AIRPORT FL US |
| 3. | MACDILL AFB FL US |
| 4. | TAMPA INTERNATIONAL AIRPORT FL US |
| 5. | TAMPA PETER O KNIGHT AIRPORT FL US |
| 6. | TAMPA VANDENBERG AIRPORT FL US |
| 7. | PLANT CITY MUNICIPAL AIRPORT FL US |
| 8. | ZEPHYRHILLS MUNICIPAL AIRPORT FL US |
| 9. | LAKELAND LINDER REGIONAL AIRPORT FL US |
| 10. | WINTER HAVEN GILBERT AIRPORT FL US |
| 11. | BARTOW MUNICIPAL AIRPORT FL US |

## 5.3 Interpolation vs. Extrapolation

A key to this forensics data analysis is to note the difference between interpretation and extrapolation. Interpolation is used when estimating between multiple known values, in the case of this analysis, the estimation of wind speeds and wind gusts. Extrapolation is used to make an estimate based on a sequence of facts, in this case the estimation of pole damage based on observed wind speeds.

What DNV GL did to estimate wind speeds was to interpolate. To produce the interpolated maps for this report (Figures 3-4, 3-8 and 3-9), the maximum wind speed and maximum wind gust at each of the 94 observation stations over September 10-11, 2017 was used. This data was provided by TECO. The interpolation for each variable was conducted using inverse distance weighting (IDW) to predict the values between multiple sets of points. In this technique, the measured values closest to the prediction location have more influence on the predicted value than those farther away. IDW assumes that each measured point has a local influence that diminished with distance. It gives greater weights to points closest to the prediction location, and the weights diminish as a function of distance. This technique does have limitations as it only considers distance to the measured location and does not consider local topography which can greatly influences wind speeds

Extrapolation makes an estimate by extending out a known sequence based on some facts, while interpolation is estimate between multiple known values. For the forensics data analysis performed by DNV GL that follows, a data extrapolation technique was applied using maximum sustained wind data collected from the 11 stations only since maximum wind gust data was not available at the time these calculations were made. This data was used to estimate the wind speed at each grid zone of the TECO service area and considered the distance of each grid zone from each of the 11 monitoring stations as well as the wind contribution from all the 11 station locations.

DNV GL used the best publicly available source for wind speed and direction immediately after the storm. For wind extrapolation, DNV GL's approach used squared distance weighted:

$$u = \frac{\left(\frac{u1}{r1^2} + \frac{u2}{r2^2} + \frac{u3}{r3^2} + \frac{u4}{r4^2}\right)}{\left(\frac{1}{r1^2} + \frac{1}{r2^2} + \frac{1}{r3^2} + \frac{1}{r4^2}\right)}$$

## 5.4 Analysis Assumptions

In order to make sense of available data, extrapolation was performed for the failure analysis. To extrapolate the pole failure rates due to Irma, DNV GL used the following assumptions:

1. Each TECO grid area is of one type, i.e., either Rural or Urban; however, there was no correlation of damage due to failures being in either Rural or Urban geographic area classifications;
2. Wind speed data: the maximum wind speed values recorded during the day of Hurricane Irma at the 11 climate stations were considered in the analysis;

3. The Osmose field survey concentrated on high probability of damage areas, such as the Winter Haven service area and areas East of the Tampa metro area;
4. For the extrapolation of damage reported, the wind speed levels were matched with the average values of the corresponding failure noticed in the grid zones based on field survey data. No urban/rural or pole population data were considered;
5. For the root-cause analysis, the 2 contributing factors for each record (reported impact or damage related to pole) were merged into one per the following table, without considering the order (factor 1, factor 2). Again, the damage root cause includes pole damage (breakage), impacted pole (leaning), damaged conductor (wire down), and damaged cross arm.

**Table 5-4 Damage root cause**

| Root cause reported | Contributing factor 1 | Contributing factor 2 |
|---|---|---|
| Only wind | Wind | Wind |
| | Wind | Other |
| Tree | Tree | Tree |
| | Tree | Wind |
| Debris | Debris | Wind |
| Decay | Decay | Wind |
| | Decay | Other |
| Storm surge | Storm surge | Wind |

## 5.5 Results of Extrapolation

The extrapolation of damaged distribution infrastructure for the entire TECO service area was performed by taking into consideration the wind speeds of each TECO map grid zone, which were also extrapolated as described earlier. The map grid zone pole population or density could be also used but with the data available, a reasonable match could not be made. For the extrapolation of the reported impact and damages, the following wind speed-failure rate curve, Figure 5-1, was considered.

Note again that the extrapolated data is statistically biased because the collected sample data concentrated on potentially high damage area. In reality, other (non-surveyed) service areas did not sustain as extensive impact or damage.

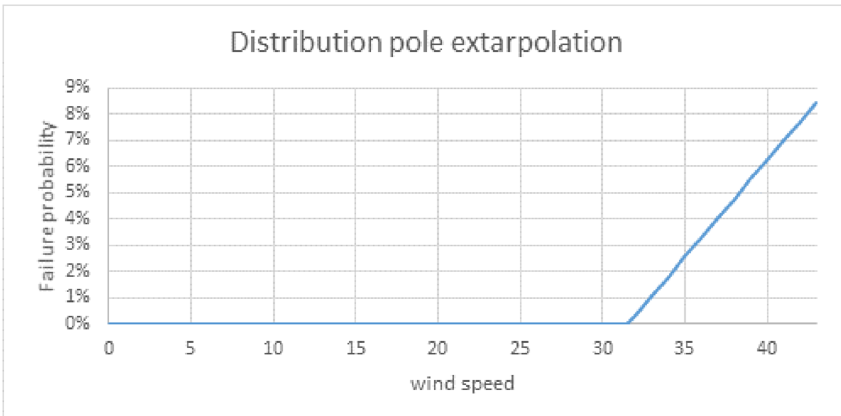


**Figure 5-1 Sustained Wind Speed vs. Failure Probability Curve**

Based on this speed-failure rate curve, and the extrapolated wind speed data for each map grid zone in the TECO service area, a probability for impact and damage (combined) is found for each grid zone in the service area. This is illustrated by Figure 5-2. The scale is in the number of damages used as the base reference.

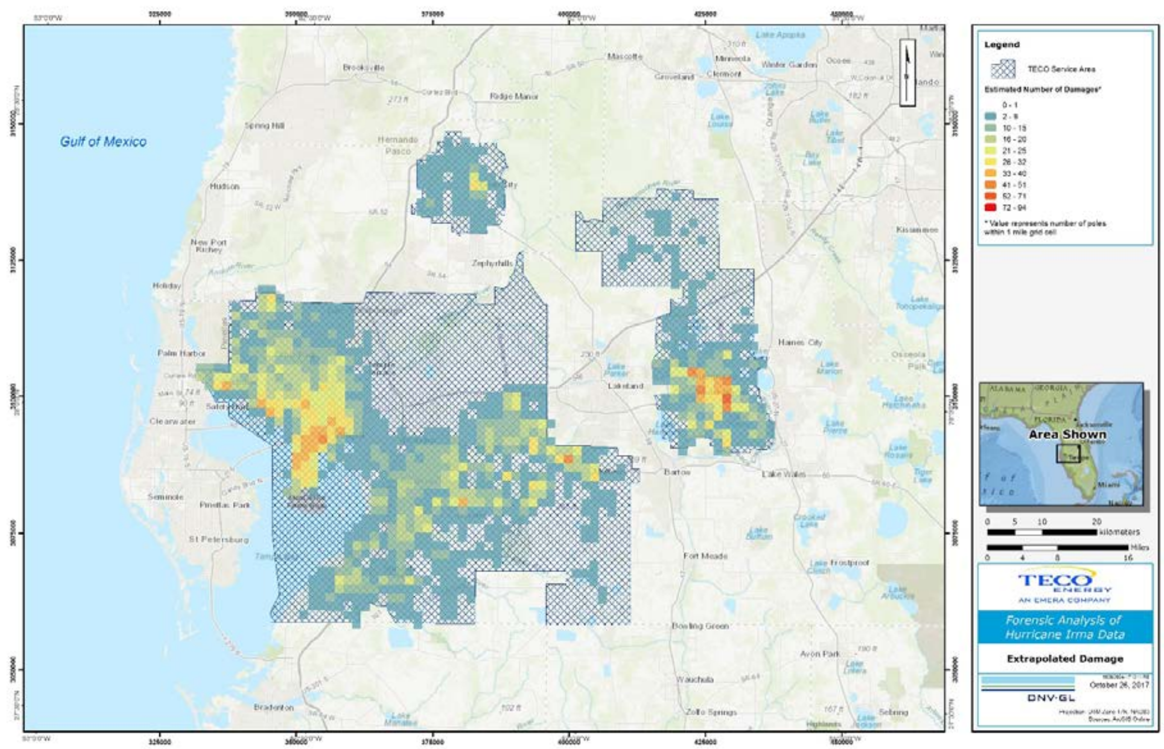


**Figure 5-2 Extrapolated TECO Damages to the Entire Service Area**

The figure shows that the most severe damage probability occurred in the areas surveyed by Osmose. Again, care must be taken in assuming that areas outside of the surveyed service areas sustained similar damage. In reality, less damage was sustained in these non-surveyed areas.

## 5.6 Urban versus Rural Analysis

DNV GL categorized map grids based on urban or rural to determine whether greater or less dense energy delivery infrastructure had an impact on potential storm impact and damage. Figure 5-3 is a graphic representation of urban versus rural geographic representation. The grids correspond to TECO map grid and classifications were determined based off the 2011 National Landcover Database.

No statistical correlation was found between impact or damage reported to urban or rural classifications.

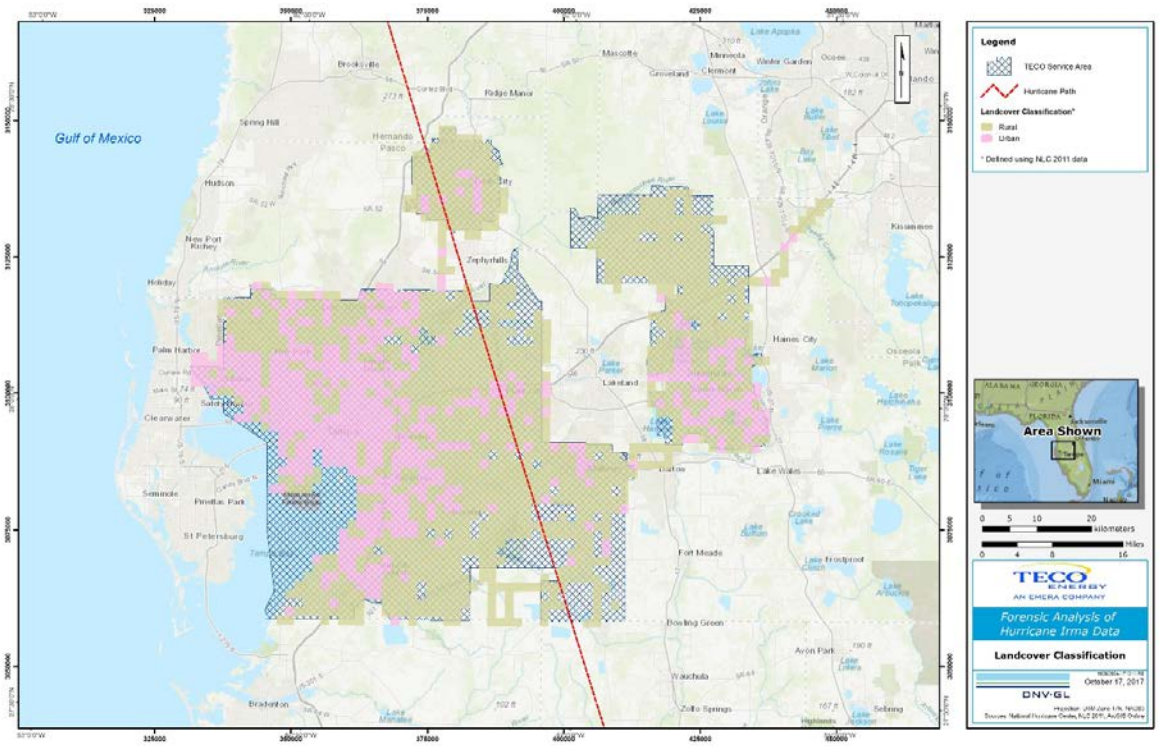


**Figure 5-3 Land Cover Classification**

## 5.7 Forensics Data Analysis Conclusion

During a major storm event, such as Hurricane Irma, wind is the primary factor in distribution pole and transmission structure caused impacts and failure. Severe wind speed and wind gusts stresses poles and cross arms. Debris hitting poles, conductors and cross arms result in infrastructure damage. Damage resulting from windborne debris is generally outside of TECO's control. Pole damage by debris is a result of trees and branches, many times located outside TECO's right of way, hitting distribution and transmission lines.

Damage to conductors are due primarily to pole damage (broken) and conductors hit directly by windborne debris resulting in cross arm failure and wires down, and is therefore also outside of TECO's control. Insulator failures are mainly a result of debris or trees hitting conductors, leading to breakage of the post insulator.

Of the field damage survey data collected, only three transmission related structures were found impacted (leaning, not damaged).

Based on data analyzed, the TECO service area experienced 2.7% impact to their distribution grid assets. This is based on the field survey conducted within anticipated high damage areas which was then extrapolated to the entire service area. Since the survey was not conducted in a statistically random pattern across the TECO service areas, but concentrated on most high probable damaged areas, this figure is high and actual infrastructure impact and damage results were much less across the entire TECO service area. Further, there is no correlation to geographic classification of urban or rural on impact or damage results.

Overall, in DNV GL's experience with post storm forensics analysis, this is a low damage count, and the TECO distribution and transmission energy delivery infrastructure fared well during this major storm event.

## APPENDIX A TECO POLE IMPACT RATE PER GRID ZONE

Please refer to separate Excel workbook “Derived Extrapolation Data per Map Zones.”

Note that the impact rates listed in this Spreadsheet apply only to the grid zones that were surveyed.

# APPENDIX B TECO IMPACT PER POLE TYPE IN THE RECORDS

**Table B- 1 TECO distribution impacted and pole failures, related to pole type in the grid zones where damages were collected by Osmose**

| Grid codes | Total | | | | Wood | | Concrete | | Unknown* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Zone density | # poles | # of reported impacted | Impacted rate % | # pole | # mpacted | # pole | # impacted | # poles | # impacted |
| 17-24 | Urban | 1812 | 1 | 0.06% | 1351 | 1 | 14 | 0 | 387 | 0 |
| 17-25 | Rural | 1640 | 1 | 0.06% | 1496 | 1 | 37 | 0 | 107 | 0 |
| 17-29 | Urban | 1154 | 2 | 0.17% | 961 | 2 | 20 | 0 | 170 | 0 |
| 31-26 | Urban | 384 | 3 | 0.78% | 377 | 2 | 0 | 0 | 7 | 1 |
| 36-27 | Urban | 1238 | 18 | 1.45% | 986 | 17 | 158 | 0 | 70 | 1 |
| 37-27 | Rural | 1432 | 12 | 0.84% | 1196 | 11 | 108 | 0 | 123 | 1 |
| 38-27 | Urban | 533 | 4 | 0.75% | 372 | 4 | 39 | 0 | 121 | 0 |
| 56-29 | Urban | 306 | 4 | 1.31% | 271 | 3 | 12 | 0 | 21 | 1 |
| 57-23 | Rural | 234 | 18 | 7.69% | 218 | 16 | 0 | 0 | 16 | 2 |
| 57-28 | Rural | 302 | 13 | 4.30% | 268 | 8 | 9 | 0 | 25 | 5 |
| 59-25 | Urban | 273 | 15 | 5.49% | 237 | 15 | 1 | 0 | 35 | 0 |
| 60-28 | Urban | 681 | 29 | 4.26% | 502 | 22 | 124 | 2 | 45 | 5 |
| | | 9989 | 120 | 1.20% | 8235 | 102 | 522 | 2 | 1127 | 16 |

**Notes:**

*Impact counts in this table B-1 include pole damage (breakage), leaning (impacted), conductor damage (wire down), and damaged cross arm. Poles are used as a reference to report these damage types. These failure rates apply only within the grid zones that were surveyed.*

*Unknown column are poles of unknown material. In the TECO Distribution Poles.xlsx Spreadsheet, these are the poles with no material type listed.

# APPENDIX C TECO DAMAGE PER POLE TYPE IN THE RECORDS

**Table C- 1 TECO distribution pole damage only failures, related to pole type in the grid zones where data were collected by Osmose**

| Grid codes | Total | | | | Wood | | Concrete | | Unknown* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Zone density | # poles | # of Reported Damaged | Failure rate % | # pole | # Damaged | # pole | # Damaged | # poles | # Damaged |
| 17-24 | Urban | 1812 | 1 | 0.06% | 1351 | 1 | 14 | 0 | 387 | 0 |
| 17-25 | Rural | 1640 | 1 | 0.06% | 1496 | 1 | 37 | 0 | 107 | 0 |
| 17-29 | Urban | 1154 | 2 | 0.17% | 961 | 2 | 20 | 0 | 170 | 0 |
| 31-26 | Urban | 384 | 3 | 0.78% | 377 | 2 | 0 | 0 | 7 | 1 |
| 36-27 | Urban | 1238 | 17 | 1.37% | 986 | 16 | 158 | 0 | 70 | 1 |
| 37-27 | Rural | 1432 | 10 | 0.70% | 1196 | 9 | 108 | 0 | 123 | 1 |
| 38-27 | Urban | 533 | 4 | 0.75% | 372 | 4 | 39 | 0 | 121 | 0 |
| 56-29 | Urban | 306 | 3 | 0.98% | 271 | 3 | 12 | 0 | 21 | 0 |
| 57-23 | Rural | 234 | 6 | 2.56% | 218 | 4 | 0 | 0 | 16 | 2 |
| 57-28 | Rural | 302 | 7 | 2.32% | 268 | 2 | 9 | 0 | 25 | 5 |
| 59-25 | Urban | 273 | 13 | 4.76% | 237 | 13 | 1 | 0 | 35 | 0 |
| 60-28 | Urban | 681 | 24 | 3.52% | 502 | 19 | 124 | 0 | 45 | 5 |
| | | 9989 | 91 | 0.91% | 8235 | 76 | 522 | 0 | 1127 | 15 |

**Notes:**

*Damaged counts in this table C-1 include pole damage (breakage), conductor damage (wire down), and damaged cross arm but no leaning poles. Poles are used as a reference to report these damage types. These failure rates apply only within the grid zones that were surveyed.*

*Unknown column are poles of unknown material. In the TECO Distribution Poles.xlsx Spreadsheet, these are the poles with no material type listed.

## About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our professionals are dedicated to helping our customers make the world safer, smarter and greener.