ORIGINAL

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

DOCKET NO. 060038-EI
FLORIDA POWER & LIGHT COMPANY

IN RE: FLORIDA POWER & LIGHT COMPANY'S PETITION FOR ISSUANCE OF A STORM RECOVERY FINANCING ORDER

CMP ______
COM ______
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OTH ______

JANUARY 13, 2006

DIRECT TESTIMONY & EXHIBITS OF:

RICHARD E. BROWN

DOCUMENT NUMBER-DATE
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FPSC-COMMISSION CLERK

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

FLORIDA POWER & LIGHT COMPANY

DIRECT TESTIMONY OF RICHARD E. BROWN

DOCKET NO. XXXXXX-EI

JANUARY 13, 2005

Q. Please state your name and business address.

A. My name is Richard E. Brown. My business address is KEMA Inc., 3801 Lake Boone Trail, Suite 200, Raleigh, NC 27607.

Q. By whom are you employed and what is your position?

A. My employer is KEMA, Inc., where I am a Senior Principal Consultant focusing in the areas of utility asset management and reliability. I also lead the Asset Management and Performance team. KEMA is an international consulting firm providing independent technical and management consulting, testing, inspections, certification, and training services to more than five hundred electric industry clients in over seventy countries. Headquartered in Arnhem, the Netherlands, with subsidiaries worldwide, KEMA employs more than fifteen hundred full-time professionals and leading experts in nearly all aspects of the electric industry.

Q. Please describe your educational background and business experience.

A. I received a BSEE, MSEE, and PhD degree from the University of Washington (Seattle, WA) in 1991, 1993, and 1996, respectively. I received an MBA from the University of North Carolina (Chapel Hill, NC) in 2003.

From 1991 to 1993 I worked as an Electrical Engineer at Sverdrup Corporation (now Jacobs Engineering) performing design work for electric distribution systems. Responsibilities included engineering design of medium voltage and low voltage electrical systems for industrial facilities, institutional facilities, and public works. Typical work included design, value engineering, specification writing, construction document generation, and construction support.

From 1994 to 1996 I worked as a teaching and research assistant for the University of Washington while attending graduate school. My research was in the area of distribution system reliability assessment and design optimization. In addition to research, I served as a teaching assistant for various power systems and controls courses at the undergraduate and graduate level.

From 1996 to 2003 I worked for ABB Inc. in various roles. From 1996 to 1999 I was a Senior Engineer in the corporate research department with responsibilities of research, product development, consulting, project management, business development, and teaching workshops. From 1999 to 2001 I was a Principal Engineer for the Distribution Solutions group with the goal of providing customers with complete solutions based on functional requirements including design, build, own, operate, maintain, guarantee, and finance. From 2001 to 2003 I was the Director of Technology for the Consulting business with the responsibility for research and development of algorithms and software tools.

From May of 2003 to the present, I have been a Senior Principal Consultant for KEMA Inc. As a charter member of the T&D Consulting division in the US, my role is to provide management and technical consulting services in the areas of distribution reliability and asset management, which includes issues related to aging infrastructure.

I have authored or co-authored more than seventy papers and articles on the topics of distribution reliability and asset management. I am also author of the book *Electric Power Distribution Reliability* (Marcel Dekker, 2002), and have contributed to the book *The Electric Power Engineering Handbook* (CRC Press, 2001). I am a senior member of the Institute for Electrical and Electronics Engineers (IEEE), and chair its working group on Distribution Planning and Implementation. I was the recipient of the IEEE Walter Fee Outstanding Young Engineer Award in 2003, which is issued by the IEEE Power Engineering Society. I am registered by the state of North Carolina as a Professional Engineer in Electrical Engineering.

Q. Are you sponsoring an exhibit in this case?

A. Yes, it is comprised of the following document:

Document No. REB-1- "Technical Report: Post Hurricane Wilma Engineering Analysis"

PURPOSE AND SUMMARY

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to present the results of KEMA's independent analyses of the FPL infrastructure performance during Hurricane Wilma, which assesses whether FPL transmission, substation, and distribution facilities performed appropriately.

Q. Please briefly describe the analyses performed for FPL.

A. KEMA has examined the performance of FPL facilities during Hurricane Wilma in an attempt to better understand whether transmission and distribution structures performed appropriately. This includes analyses on the following topics: distribution design standards; quality systems and processes related to distribution poles; inspection and maintenance practices related to distribution poles; transmission system performance during Wilma; substation performance during Wilma; and distribution system performance during Wilma. KEMA also performed an industry survey related to these topics, and had the strength of Wilma reviewed by a hurricane expert.

Q. Please summarize the results of your analyses.

A. Hurricane Wilma caused extensive damage to the infrastructure of Florida Power & Light Company (FPL). This damage included more than ten thousand distribution poles and nearly one hundred transmission structures. In all, Wilma resulted in more than three million customer accounts losing electrical service. FPL has retained KEMA to examine the performance of FPL facilities during

Wilma in an attempt to better understand whether transmission and distribution structures performed appropriately.

KEMA's investigation concludes that the power delivery system of FPL is designed to meet or exceed all required safety standards, and, during Wilma, performed as expected and in accordance with FPL standards. These results are based on an extensive assessment including standards, quality systems, maintenance practices, transmission performance, substation performance, and distribution performance. These results are further supported by an industry benchmark survey covering these topics, and a review on the strength of Wilma by an independent hurricane expert. Summary results for these issues are now provided.

Distribution Standards. FPL distribution standards as described in the Distribution Engineering Reference Manual (DERM) meet or exceed the requirements of National Electrical Safety Code (NESC), which requires distribution poles to be designed based on a minimum of 60 mph wind speeds. In fact, FPL requires that most poles be designed to the highest NESC requirement, which is 50% stronger than NESC minimum requirements. The NESC has requirements related to extreme wind conditions, but these requirements are only for structures over sixty feet in height, which rarely apply to distribution structures.

Quality Processes. The quality systems and processes of FPL and key suppliers are sufficient to reasonably ensure that procured distribution poles, both wood and concrete, meet national standards and FPL specifications. Further, the quality systems of the FPL pole inspection and treatment vendor are such that it is reasonably ensured that inspected wood poles requiring treatment or replacement are identified as such.

Pole Maintenance. FPL distribution pole performance during non-hurricane conditions is good, and non-hurricane pole failures cause virtually no customer interruptions. FPL has two systematic programs related to pole inspections: (1) a Thermovision program that visually inspects all main-trunk feeder poles at least every five years, and (2) a more targeted wood-pole inspection and treatment program that is smaller in scope and focuses on specific areas of the FPL system. FPL crews are also required to perform a safety inspection on a pole before performing work on the pole. These inspections will not systematically address each pole, but KEMA estimates that this will effectively test between 80% and 90% of all branch-line laterals over a fifteen year period.

Transmission Performance. FPL's transmission lines are designed in accordance with the NESC, including extreme wind requirements, applicable at the time of design. For transmission structural damage that occurred during Wilma on less-than 500-kV lines, most occurred on single-pole unguyed wood structures. These facilities met the required design codes at the time of installation, but differ from current designs in place now at FPL. This was the primary contributing factor for these failures. Only one 500-kV transmission line experienced damage during Wilma. This particular line had 30 tower failures. The major contributing factor for these tower failures was the installation guidelines for manual tightening of crossbrace bolts, per industry standard practice, which is insufficient and led to the loosening of crossbrace bolts in several locations.

Substation Performance. FPL designs its substations according to extreme wind criteria. The FPL substation performance during Wilma was acceptable, and structural damage to substations was minor. Although FPL experienced outages on 241 substations during Wilma, most were due to the outage of transmission lines serving these stations; only 8 required equipment repair before being reenergized. With some minor exceptions, there was no discernible pattern of equipment failure that indicates a design or maintenance concern.

Weather Assessment. Wilma was a strong storm, and its path affected a large percentage of the FPL system. As opposed to many statements by the media, Wilma was a Category 3 hurricane when it made landfall at the Southwest coast of Florida traveling to the Northeast. It transitioned into a Category 2 hurricane while passing over Florida and left the state as a Category 2 hurricane. The maximum 1-minute sustained wind speed (as reported by Unisys) as Wilma crossed Florida was 127 mph, which comes close to a Category 4 hurricane. In comparison, Katrina had a maximum sustained wind speed of 81 mph while crossing Florida (also reported by Unisys).

Distribution Performance. FPL pole performance during non-hurricane conditions is good. Distribution pole performance during Wilma is known to be acceptable, since FPL gathered extensive forensic data on Wilma pole failures. Based on this data, the following conclusions are drawn: (1) wind was the predominant root cause of pole breakage, (2) many failures involved multiple CCA main-trunk feeder poles where one pole breaks first and takes down a series of adjacent poles, and (3) the number of failures involving creosote poles was relatively small, with these failures mainly being due to falling trees and the presence of deterioration. During Wilma, pole breakage was about 1.5% of the total amount of poles exposed to hurricane wind speeds. This pole breakage ratio is in line with past hurricane pole performance after correcting for hurricane severity. For comparison: Katrina (2005) was the weakest recent hurricane at Category 1, and only had a 0.3% pole failure rate. Frances (2004) was Category 2, and had a 0.9% pole failure rate. Wilma (2005) was Category 2 to Category 3, and had a 1.5% pole failure rate. Charley (2005) was Category 3 to Category 4, and had a 3.1% pole failure rate. Andrew (1992) was Category 5, and had a 10.1% pole failure rate.

Industry Benchmark Survey. KEMA received survey responses from 9 companies (not including FPL) with answers to questions relating to standards, maintenance, and hurricane performance. Based on these responses, the following conclusions are made: (1) FPL designs and constructs distribution facilities to a more stringent standard than most other companies, (2) none of the companies are required by their regulatory authority to place facilities underground in response to storm damage, and (3) most of the responding companies have a systematic pole inspection and treatment program in place with inspection cycles ranging from 10 to 15 years for poles older than a certain age.

Q. Overall, describe how FPL's infrastructure performed during Hurricane Wilma.

A. The transmission, substation, and distribution systems of FPL are designed to meet or exceed all required safety standards, and, during Wilma, performed as expected and in accordance with FPL standards. This conclusion is based on an extensive assessment including standards, quality systems, maintenance practices, transmission performance, substation performance, and distribution performance. These results are supported by an industry benchmark survey covering these topics, and a review of the strength of Hurricane Wilma by an independent weather expert.

CONCLUSION

Q. Does this conclude your direct testimony?

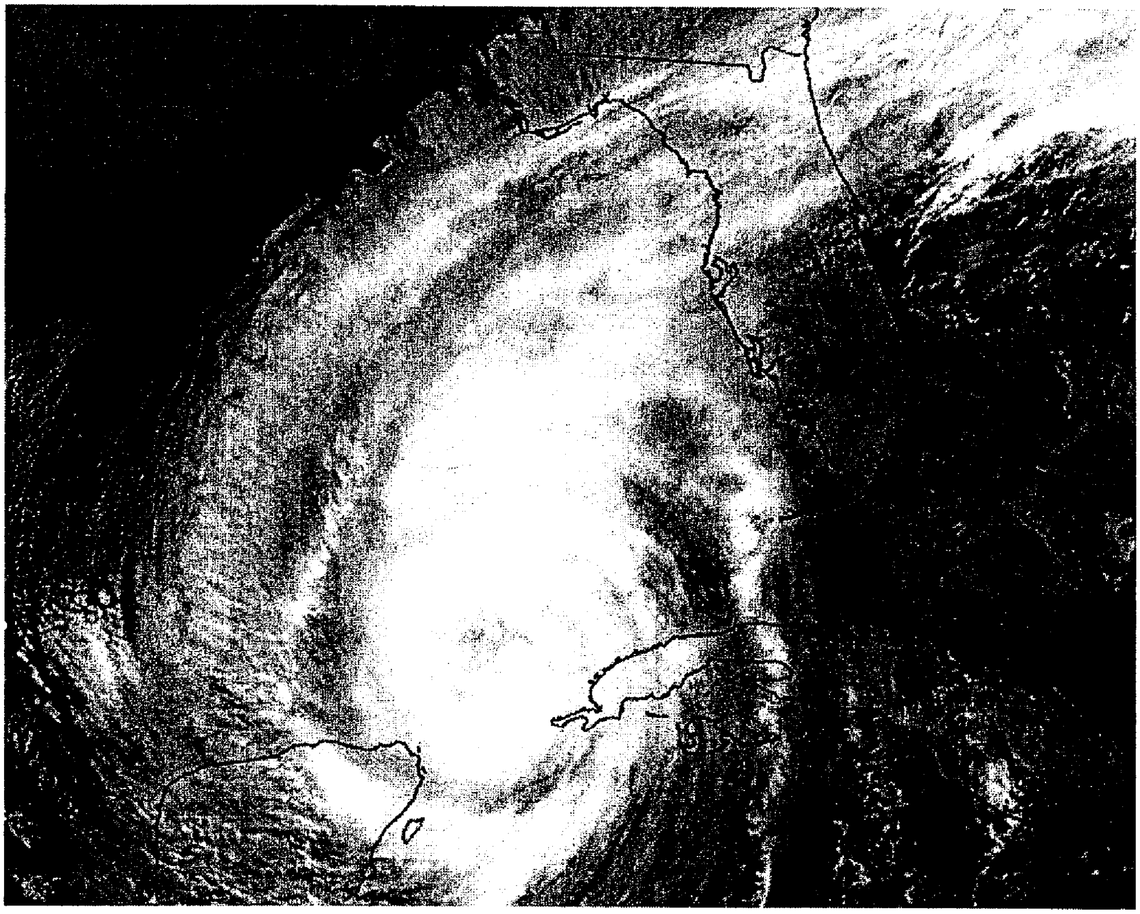
A. Yes.

Docket No. XXXXXX-EI
Richard E. Brown, Exh No. ___
Document No. REB-1
Technical Report: Post Hurricane
Wilma Engineering Analysis

[SEE ATTACHED]

Technical Report:
Post Hurricane Wilma Engineering Analysis

FINAL REPORT



Prepared by: KEMA Inc.

Prepared for: Florida Power & Light Company

KEMA Project 05-349

January 12th 2006

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Executive Summary

Hurricane Wilma caused extensive damage to the infrastructure of Florida Power & Light Company (FPL). This damage included more than ten thousand distribution poles and nearly one hundred transmission structures. In all, Wilma resulted in more than three million customer accounts losing electrical service. FPL has retained KEMA to examine the performance of FPL facilities during Wilma in an attempt to better understand whether transmission and distribution structures performed appropriately.

KEMA's investigation concludes that the transmission, substation, and distribution systems of FPL is designed to meet or exceed all required safety standards, and, during Wilma, performed as expected and in accordance with FPL standards. These results are based on an extensive assessment including standards, quality systems, maintenance practices, transmission performance, substation performance, and distribution performance. These results are further supported by an industry benchmark survey covering these topics, and a review on the strength of Wilma by an independent hurricane expert. Summary results for these issues are now provided.

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Table A. Distribution Pole Failures During Past Hurricanes.

Year	Name	Poles exposed to 74+ mph wind speeds	Poles issued by FPL during restoration	% of exposed poles that failed	Hurricane category
2005	Katrina	343,200	1,086	0.3%	1
2004	Frances	397,134	3,757	0.9%	2
2005	Wilma	773,700	11,371	1.5%	2-3
2004	Charley	222,666	6,878	3.1%	3-4
1992	Andrew	203,500	20,580	10.1%	5

Note: The number of poles in Table A includes all poles with FPL equipment, including poles not owned by FPL.

Distribution Performance. FPL pole performance during non-hurricane conditions is good. Distribution pole performance during Wilma is known to be acceptable, since FPL gathered extensive forensic data on Wilma pole failures. Based on this data, the following conclusions are drawn: (1) wind was the predominant root cause of pole breakage, (2) many failures involved multiple CCA feeder poles where one pole breaks first and takes down a series of adjacent poles, and (3) the number of failures involving creosote poles was relatively small, with these failures mainly being due to falling trees and the presence of deterioration. During Wilma, pole breakage was about 1.5% of the total amount of poles exposed to hurricane wind speeds. This pole breakage ratio is in line with past hurricane pole performance after correcting for hurricane severity (see Table A). Katrina was the weakest recent hurricane at Category 1, and only had a 0.3% pole failure rate. Wilma was Category 2 to Category 3, and had a 1.5% pole failure rate. Andrew was Category 5, and had a 10.1% pole failure rate.

Industry Benchmark Survey. KEMA received survey responses from 9 companies (not including FPL) with answers to questions relating to standards, maintenance, and hurricane performance. Based on these responses, the following conclusions are made: (1) FPL designs and constructs distribution facilities to a more stringent standard than most other companies, (2) none of the companies are required by their regulatory authority to place facilities underground in response to storm damage, and (3) most of the responding companies have a systematic pole inspection and treatment program in place with inspection cycles ranging from 10 to 15 years for poles older than a certain age.

Based upon the analyses contained in this report, KEMA is in the process of developing specific recommendations for FPL's consideration with respect to potentially improving the future hurricane performance of FPL's transmission, substation, and distribution systems. KEMA is also developing additional points for FPL's consideration concerning the possible additional "hardening" of its distribution system. It should be emphasized that most distribution structures are not required by code to do this. However, it is worth considering the possibility of using criteria exceeding minimum code standards in an effort to reduce the extent of damage that can be expected during extreme wind conditions. This is especially true if the present time is the start of a long cycle of increased hurricane activity.

Table of Contents

Table of Contents (cont.)

1 Introduction

Hurricane Wilma caused extensive damage to the infrastructure of Florida Power & Light Company (FPL). This damage included more than ten thousand distribution poles and nearly one hundred transmission structures. In all Hurricane Wilma resulted in more than three million customer accounts losing electrical service.

Due in part to the extensive damage experienced during Hurricane Wilma, FPL has retained KEMA to examine the performance of FPL facilities during Hurricane Wilma in an attempt to better understand whether transmission and distribution structures performed appropriately. This includes aspects of standards assessment, forensic analysis, weather analysis, quality assessment, and benchmarking. The report is organized as follows:

Section 2: Distribution Standards Assessment. This section assesses the FPL current distribution standards to validate compliance to strength and loading criteria as defined by the National Electrical Safety Code (NESC). In addition, this section reviews calculations as shown in FPL's Distribution Engineering Reference Manual (DERM). The intent of this section is to validate the FPL standards with regards to (1) minimum safety requirements, (2) normal system performance, and (3) extreme wind conditions.

Section 3: Quality Process Assessment. This section reviews the quality systems of (1) FPL purchasing and product engineering, (2) Osmose Utilities Services, (3) Pre-Cast Specialties, and (4) Langdale Forrest Products. The intent is to understand whether quality systems are sufficient to ensure that distribution wood and concrete poles meet national standards and Florida Power & Light specifications

Section 4: Pole Maintenance Assessment. This section assesses inspection and maintenance programs for distribution poles in the FPL system. This includes (1) the thermovision program, (2) the Osmose inspection and maintenance program, (3) other pole "touchpoints" afforded by daily work activities.

Section 5: Transmission Forensic Analysis. This section assesses the transmission structure failures that occurred during Wilma in an attempt to establish whether FPL's designs meet the requirements of the National Electrical Safety Code (NESC).

Section 6: Substation Forensic Analysis. This section reviews the substation design standards at FPL for compliance with applicable codes and safety standards and for adherence to accepted industry practices. The intent is to validate the FPL standards with regards to (1) minimum safety requirements, (2) normal system performance, and (3) extreme wind conditions. This section also reviews the FPL maintenance practices and procedures for substations with regards to completeness, timeliness, procedures for issues discovered in routine inspections and compliance with the established schedule. Also included is a review of the substation damage experienced during Hurricane Wilma and an examination of the maintenance records of major equipment that failed (breakers, transformers).

Section 7: Distribution Forensic Analysis. This section outlines the results of a thorough data inventory, collection, review and analysis effort in order better understand the distribution pole breakages during Hurricane Wilma. Pole performance during normal conditions are compared to storm conditions and several past hurricanes are compared. Findings with respect to number of breakages, breakage rates, root causes, likely scenarios and explanations are generated together with geographical maps, thematically overlaying and representing different data sets. An integral interpretation of the findings together with the findings from other investigation efforts within this engineering analysis, such as the standards review and maintenance assessment, are reported.

Section 8: Industry Benchmark Survey. As part of the review of FPL standards and practices for engineering design, construction and pole maintenance, an industry practices survey was initiated. This survey was targeted at electric utilities in the southeastern USA with significant hurricane exposure and recent hurricane damage experience. The overall purpose of the survey was to sample the engineering, construction and maintenance practices of other companies in an effort to learn how FPL practices compare and to learn of any practices that could be considered by FPL for improvement of their operations. This section describes the results of the survey.

The report ends with high-level conclusions about the FPL system with regards to hurricane performance.

2 Distribution Standards Assessment

This section assesses the FPL current distribution standards to validate compliance to strength and loading criteria as defined by the National Electrical Safety Code (NESC). In addition, this section reviews calculations as shown in FPL's Distribution Engineering Reference Manual (DERM). The intent of this section is to validate the FPL standards with regards to (1) minimum safety requirements, (2) normal system performance, and (3) extreme wind conditions.

2.1 Summary of Findings

FPL distribution standards as described in the Distribution Engineering Reference Manual (DERM) meet or exceed the requirements of National Electrical Safety Code (NESC), which requires distribution poles to be designed based on a minimum of sixty mph wind speeds. In fact, FPL requires that most poles be sized so that they are 50% stronger than NESC minimums. The NESC has requirements related to extreme wind conditions, but these requirements are only for structures over sixty feet in height, which rarely apply to distribution structures.

Both the NESC and the FPL distribution standards distinguish between pole strength requirements at installation and pole strength requirements at replacement. Older versions of the NESC are vague, but the 2002 version is clear that the strength differences exist to allow for pole strength deterioration over time. In this respect, DERM requirements are in accordance with NESC. As a result, certain poles are likely to have less strength than the intention of the DERM (although still meeting NESC requirements). This is primarily because attachments are sometimes added to existing poles without ensuring that this additional loading meets all of the criteria that would be required if it were a new installation.

<u>**Key Findings**</u>

- FPL meets or exceeds NESC pole strength requirements
- In most cases, current FPL standards require poles that are 50% stronger than minimum NESC requirements.
- FPL is inconsistent in application of its loading calculations, which may result in certain poles being loaded more heavily than intended by the DERM (although still meeting NESC requirements), because of attachments.

2.2 Overview of NESC Requirements

The governing safety standard for distribution pole strength is the National Electrical Safety Code (NESC). This document is intended to provide minimum design criteria to ensure public safety. It is not intended to be a design manual, nor is it intended to address issues other than public safety. A pole meeting the NESC requirements can be considered safe, but may or may not be desirable from an economic or reliability perspective.

The NESC defines three different grades of safety requirements depending upon the public safety issues related to a particular installation. These are termed Grade B, Grade C, and Grade N, with Grade B being the highest requirement. In general, the NESC requires distribution structures to meet Grade C construction except when crossing railroad tracks or limited-access highways (these require Grade B construction).

According to the NESC, a structure must be able to withstand loading due to combined ice buildup and wind (the ice is both heavy and provides more area for the wind to affect). The NESC divides the US into three loading districts termed heavy, medium, and light (see Figure 2-1). Florida is completely located within the light loading district.

The NESC also requires certain structures to be designed to withstand extreme wind speeds. The extreme wind speed criteria of the NESC changed in 2002, and is now based on 3-second gust speeds (see Figure 2-2). Parts of Florida are located within the most severe extreme wind conditions in the United States, with 3-second gust criteria reaching 145 mph. It is important to note that only structures taller than sixty feet must meet this extreme wind criteria. Most distribution structures do not fall into this category.

A summary of important NESC points as they relate to the situation at FPL is now provided:

Summary of NESC Requirements for Distribution Poles

- Grade C construction is required for most distribution structures
- According to the NESC, distribution structures in Florida must be designed for sixty mph winds with no ice build up.
- Florida is in the most severe region for extreme wind loading. However, distribution structures are not required by the NESC to withstand these extreme winds.

The NESC specifies the required strength of structures based on grade of construction and loading conditions. Criteria based on combined wind and ice loading is specified in Section 250B. Criteria based on extreme wind loading is specified in Section 250C. Each of these sections uses an "overload" factor, which is essentially a safety factor that results in added strength. The NESC also allows for deterioration of structure strength, resulting in a specified strength for "initial installation" and a separate specified strength for "at replacement." Engineered materials like concrete are assumed to not lose strength over time, and therefore only have one specified strength.

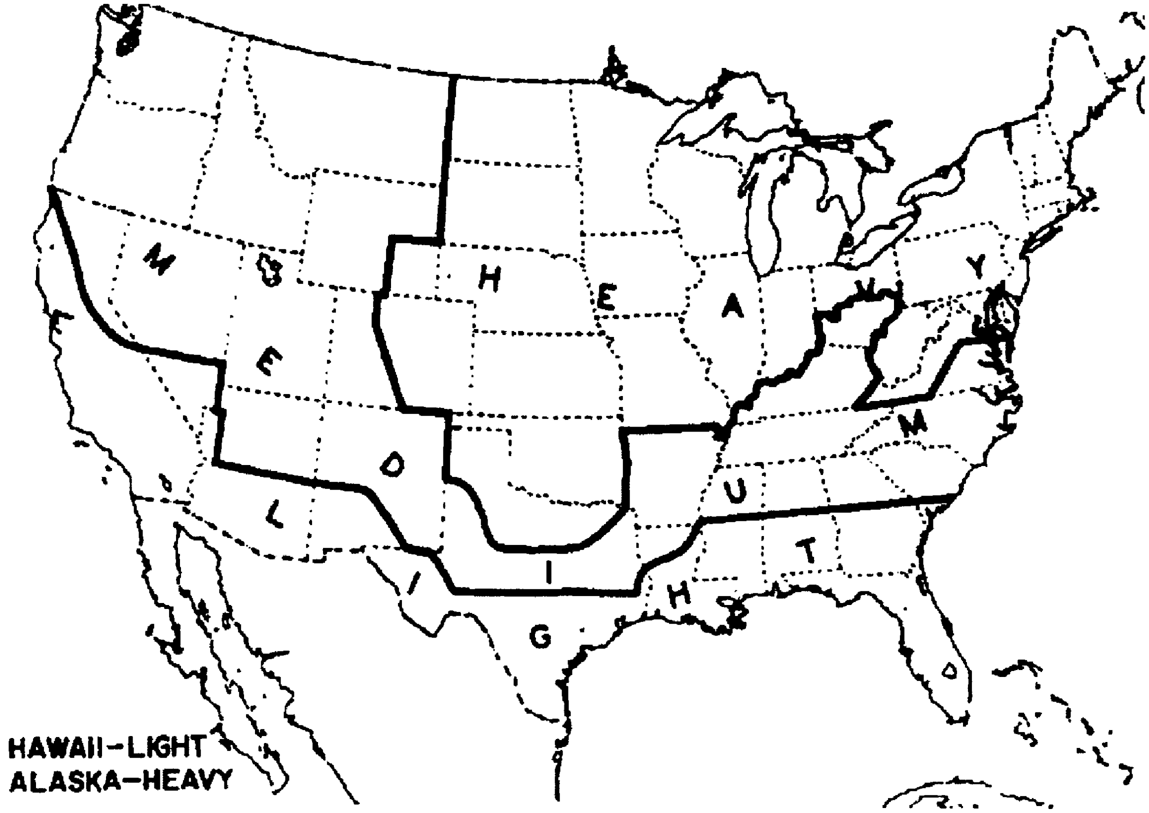
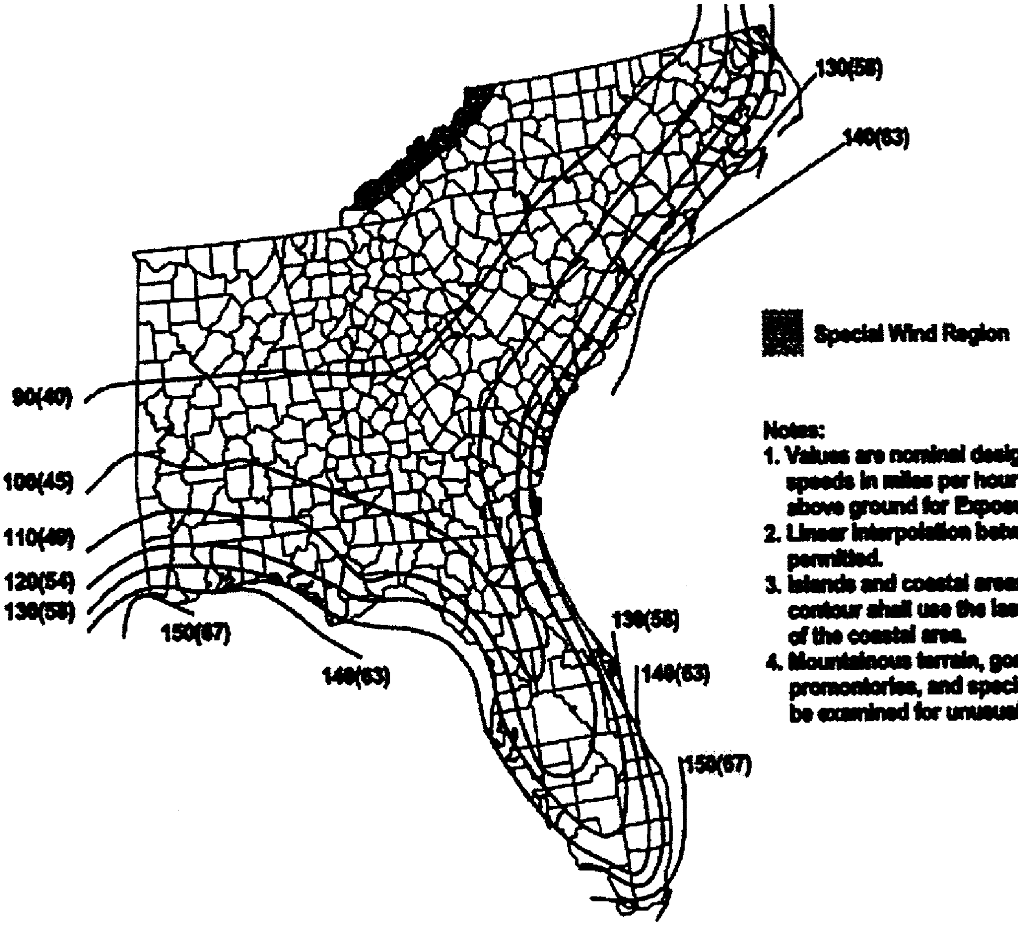


Figure 2-1. Combined Ice and Wind Loading Map (NESC Figure 250-1)



Notes:

1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure C category.
2. Linear interpolation between wind contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.

Figure 2-2. Southeastern U.S. Hurricane Wind Speeds (NESC Figure 250-1)

Table 2-1. Relative Strengths of Various NESC Design Criteria

	250B Grade C	250B Grade B	250C Grade B&C
Wood at Installation			
Wind Speed (mph)	60	60	145
Overload Factor	2.67	4.00	1.33
Relative Strength	1.00	1.50	2.91
Wood at Replacement			
Wind Speed (mph)	60	60	145
Overload Factor	1.33	2.67	1.00
Relative Strength	0.50	1.00	2.19
Concrete			
Wind	60	60	145
Overload Factor	2.20	2.50	1.00
Relative Strength	0.82	0.94	2.19

The force that wind exerts on a pole is proportional to the square of wind speed. This means that 120-mph winds exert four times more force than 60-mph winds. Using this relationship, relative strengths for different design criteria can be computed (these do not appear in the NESC). In this case, Grade C construction with light combined ice and wind loading is assumed to have a relative strength of 1. This is the NESC requirement for new FPL wood distribution poles in most cases. Relative strengths of other design criteria are shown in Table 2-1.

Table 2-1 shows the relative strength requirements of different NESC scenarios. As stated before, FPL is required to meet requirements for 250B Grade C for most distribution applications. For railway and freeway crossings, 250B Grade B applies and pole strength must be 50% greater (relative strength of 1.5). For structures taller than sixty feet in height, 250C applies and poles must be nearly three times as strong (relative strength of 2.91).

Wood poles will naturally degrade in strength over time due to wood deterioration and other factors. The NESC accounts for this deterioration by specifying the overload factor to be used to determine when pole replacement is required. For example, the 250B Grade C overload factor is 2.67 for initial installation, but is 1.33 at replacement. This implies that a fully loaded wood pole can lose 50% of its initial strength before replacement is required. At minimum replacement strength, Grade B construction is twice as strong as Grade C construction, and 250C construction is more than four times as strong.

2.3 Review of FPL Design Standards

Wood distribution poles must be specified based on height and strength. Generally, height is specified in feet, and strength is specified by an ANSI pole class. ANSI pole classes used for distribution are as follows (from weakest to strongest): 7, 6, 5, 4, 3, 2, 1, H1, H2, H3, H4, H5, H6, H7, H8, H9, H10. For example, a 45' distribution pole of Class 3 would be referred to as a 45/3 pole. Common poles for distribution application are from 30' to 50' in height and from Class 5 to Class 2 in strength.

Pole selection criteria for FPL is based on the Distribution Engineering Reference Manual (DERM). The DERM provides sample calculations based on NESC requirements, and then provides a large number of tables from which pole class can be determined. The remainder of this section now discusses how the present version of the DERM (December 2004 Edition) relates to the NESC.

2.3.1 Grade B and Grade C Construction

Prior to 1993, the practice at FPL was to build all distribution poles to Grade B construction, even though the NESC only requires Grade C construction for most distribution poles. The implication is that FPL distribution poles are 50% stronger than the required NESC minimum. FPL chose these design guidelines since it did not feel that the loading criteria in the NESC relevant to Florida (light combined ice and wind loading) adequately considered exposure to high winds during tropical storms and hurricanes.

Based on an internal FPL study of historical hurricane patterns, in 1993, FPL decided to allow Grade C construction in parts of its service territory considered less likely to encounter extreme wind conditions. During this time, the following areas were still required to build to Grade B: Monroe County, Dade County, Broward County, and the coastal areas of Palm Beach County and Martin County (see Figure 2-3). This is the requirement that presently exists in the DERM.

The January/February 2005 issue (No. 167) of the FPL internal publication "The Distribution Line," states the following, "As a reminder, design all of your jobs to Grade B Construction in all of FPL's Territory. In Late 2003, we began reviewing our previous practice of using Grade C in parts of our Territory and Grade B in other areas. By mid year 2004, the decision was made to use all Grade B Construction."

Therefore, the present design standard of FPL is for all distribution poles to be designed to Grade B, even though this is not currently reflected in the DERM. From 1993 to 2004, Grade C was allowed in areas serving about 42% of all customer accounts (customer connections in this area prior to 1993 were built to Grade B construction). Even though Grade C construction was allowed, it is uncertain as to the extent of poles that conform to only Grade C. An audit described in the FPL internal document "Grade B and Grade C Construction" showed that 12 out of 14 field inspected sites met Grade B standards even though FPL required only Grade C. Further analysis in this document makes the argument that Grade B construction is cost-effective.

To sum up the above discussion, FPL standards have always met or exceeded NESC requirements, and a large percentage of poles are at least 50% stronger than required according to the NESC minimum.

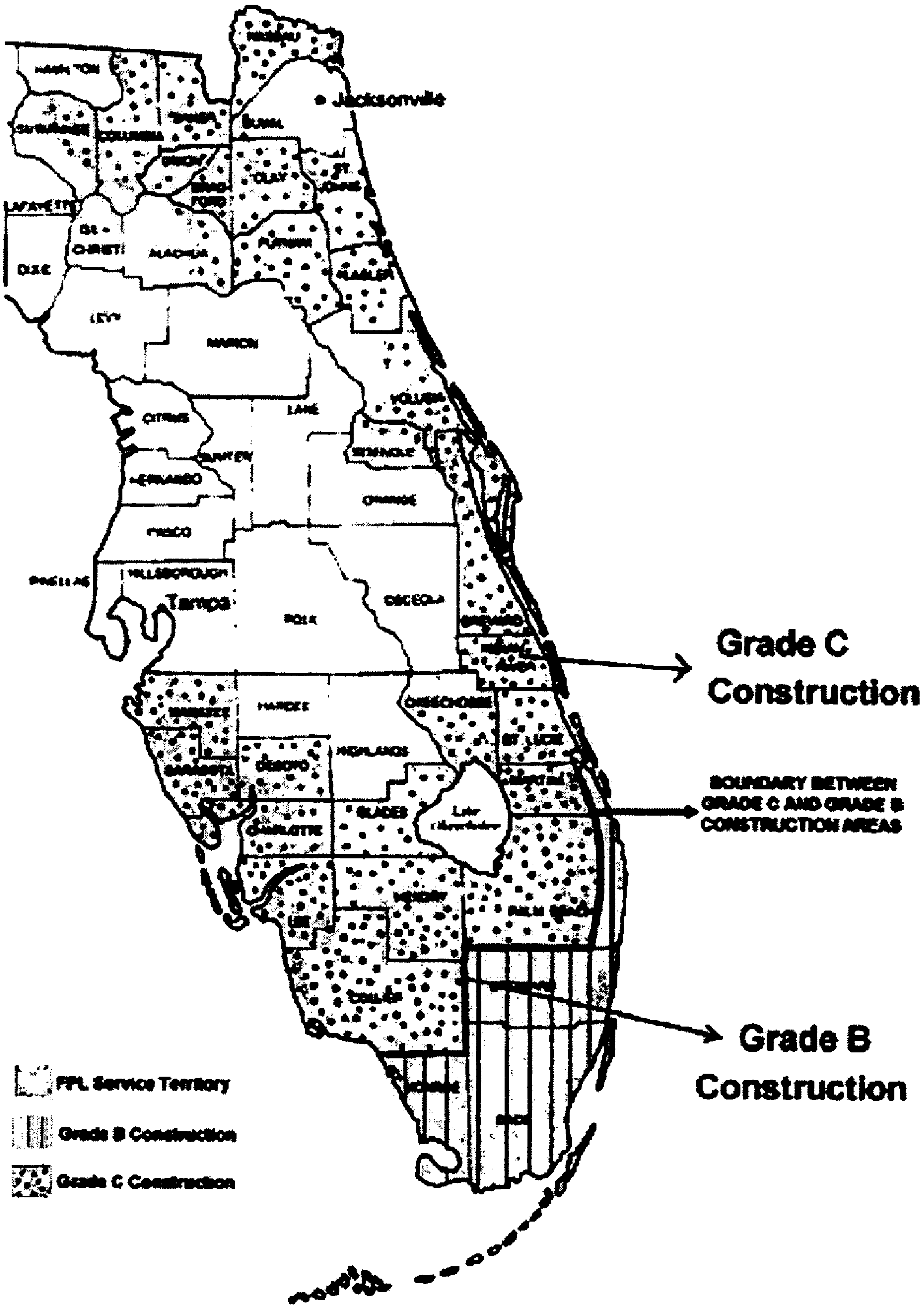


Figure 2-3. Map showing FPL grade of construction requirements (DERM Figure 2) from 1993 to 2004. Outside of these years, FPL specifies Grade B for the entire service territory.

2.3.2 Initial Installation, Replacement, and Attachments

When discussing design specifications, the DERM only references the overload factors related to initial installation. However, tables showing allowable transverse pole loading (Table A-3 and A-4) have values related to both initial installation and before replacement. When applying these tables, the DERM states:

> DERM: "Existing wood poles may be loaded to higher values [than initial installation values] shown in TABLE A-3 and A-4 prior to replacement. These values, however, are based upon full remaining strength of the pole; they must be reduced to compensate for any deterioration."

This statement is confusing when compared the requirements of the NESC, since it implies that additional load can be placed on an existing structure as long as the "at replacement" overload factors are not exceeded. The NESC requires that pole loading always be limited by the "when installed" values, assuming that the pole is not deteriorated. The lower overload factors dictated by the "at replacement" values are completely reserved for pole weakening due to deterioration. Specifically, the NESC states:

> NESC: "When structure strength deteriorates to the level of the loads multiplied by the overload factors required at replacement, the structure shall be replaced or rehabilitated. If a structure is replaced, it shall meet the 'when installed' overload factors at replacement."

This discrepancy between the DERM and the NESC is important when additional equipment is installed on poles after initial installation. If additional equipment needs to be placed on a pole, it is the general practice in FPL today to not upgrade the pole unless the "at replacement" overload factor is violated. Table 2-1 shows that loading a Grade B wood pole to its "at replacement" level reduces its relative strength from 1.5 to 1.0, which is precisely the same strength of Grade C construction for initial installation. Therefore, the DERM still ensures that NESC minimum standards are met, but does not ensure that Grade B is met for poles that have increased their loading after initial installation.

Treatment of initial versus replacement overload factors is further complicated by foreign attachments such as telephone and cable television. The DERM does a good job explaining pole loading with regards to attachments, but is not specific with regards to application. Consider a new feeder that is being designed. FPL notifies other utilities and requests a description of expected attachments. If descriptions are provided, FPL can specify its poles accordingly. If a description is not provided, it is not clear whether FPL should still size poles for likely attachments, or should size poles assuming no future attachments. The issue is not one of safety, but of consistency. The current FPL processes could potentially result in parts of the system that are much stronger than others simply due to the manner in which the DERM is interpreted.

The above-described issues raise a small concern with regards to the Grade C poles installed between 1993 and 2004. If many situations happen to exist simultaneously for one-or-more of these poles, there is the unlikely possibility that they might violate the "at replacement" overloads values specified in the NESC. For example, consider a hypothetical situation where a wood pole (1) just meets Grade C criteria at initial installation, (2) attachments are later added that bring the wood pole overload factor near to the "at replacement" value, and (3) becomes weaker due to deterioration. This situation would be unacceptable based on NESC criteria. This is unlikely to presently exist. This is due to the following reasons: (1) most poles required to meet Grade C construction were stronger than required, often meeting Grade B, and (2) all FPL poles required to meet Grade C construction are of an age and vintage (less than thirty years old and CCA treated) that have not shown signs of deterioration.

2.3.3 Wind Speed Calculations

The DERM does not provide guidance on how to calculate required pole strength for extreme wind conditions. The DERM does, however, calculate estimated wind speeds that would approach the limits of the strength of Grade B and Grade C construction. The DERM states that, "the calculated wind velocity for Grade B is 118.6 mph and 96.9 mph for Grade C. Referring to [Figure 2-4 on the next page] the 1997 edition of the NESC book, the State of Florida can experience basic wind speeds between 90 and 110 mph."

It must be understood that the NESC defines the wind design criteria for light loading areas (Fig. 2-1) to be 60 mph, not 118.6 or 96.9 mph. The DERM effectively computes the ability of Grade B and Grade C poles to withstand high winds assuming that the overload factor is reduced to 1.0 instead of 4.0 for Grade B and 2.67 for Grade C. This approach must be modified to derive an effective extreme wind rating according to the NESC, since new wood structures designed for extreme wind speeds require an overload factor of 1.33.

Using an overload factor of 1.33 for extreme wind conditions yields the following extreme wind ratings for Grade B and Grade C construction.

Table 2-2. Equivalent Extreme Wind Ratings for Wood Grade B and Grade C Construction

	Grade B	Grade C
Base Wind Speed (mph)	60	60
Base Overload Factor	4.00	2.67
Extreme Wind Overload Factor for Wood Structures	1.33	1.33
Extreme Wind Rating (mph)	104	85

According to the 2002 version of the NESC, these ratings correspond to 3-second gust speeds, which are considerably higher that the wind speeds shown in the 1997 edition of the NESC. For example, Grade B construction meets the criteria for extreme wind loading of 104 mph, but certain parts of the FPL service territory have extreme wind design criteria of 145 mph.

Of course, most distribution poles are not required to be designed for extreme winds according to the NESC. The exception is that distribution poles that extend more than 60' above the groundline are required to be designed for extreme winds, and the DERM does not give guidance on how these calculations should be performed, but gives guidance on how to obtain the information. These types of structure are designed by qualified engineers on specific applications.

The NESC has a strange requirement that all structures (even those that do not extend more than 60' above the groundline) must be designed to withstand extreme wind loading conditions assuming that no conductors are attached to the structure. This is not typically a relevant criterion, since the wind forces on conductors are typically large when compared to the wind forces on the pole.

Consider a 45/2 pole set 7' deep with the ability to withstand a force of 145,000 ft-lbs. The wind force on this pole at 60 mph is less than 6000 ft-lbs. With a safety factor of 4, wind force on the pole is using up less than 24,000 ft-lbs out of an available 145,000 ft-lbs. Now consider worst-case wind speeds of 145 mph, which exerts a force of about 34,400 ft-lbs on the pole. This is a large force to be sure, but with an overload factor of 1.33, the extreme wind force still only using up less than 46,000 ft-lbs out of an available 145,000 ft-lbs.

Since a 45/2 pole is relatively large, it is worth investigating something smaller. Consider a 30/6 pole with a 5.5' setting depth with maximum stress assumed to be at the groundline. For this situation, groundline circumference is 25.2" and the maximum withstand force is 33,800 ft-lbs. Wind speeds of 145 mph will exerts a force of about 8260 ft-lbs on the pole. With an overload factor of 1.33, the extreme wind force uses up about 11,000 ft-lb, which is similar in percentage to the 45/2 pole previously considered. Since this criteria of the NESC will never impact wood pole sizing, calculations do not need to be performed for structures extending less than 60' above the ground.

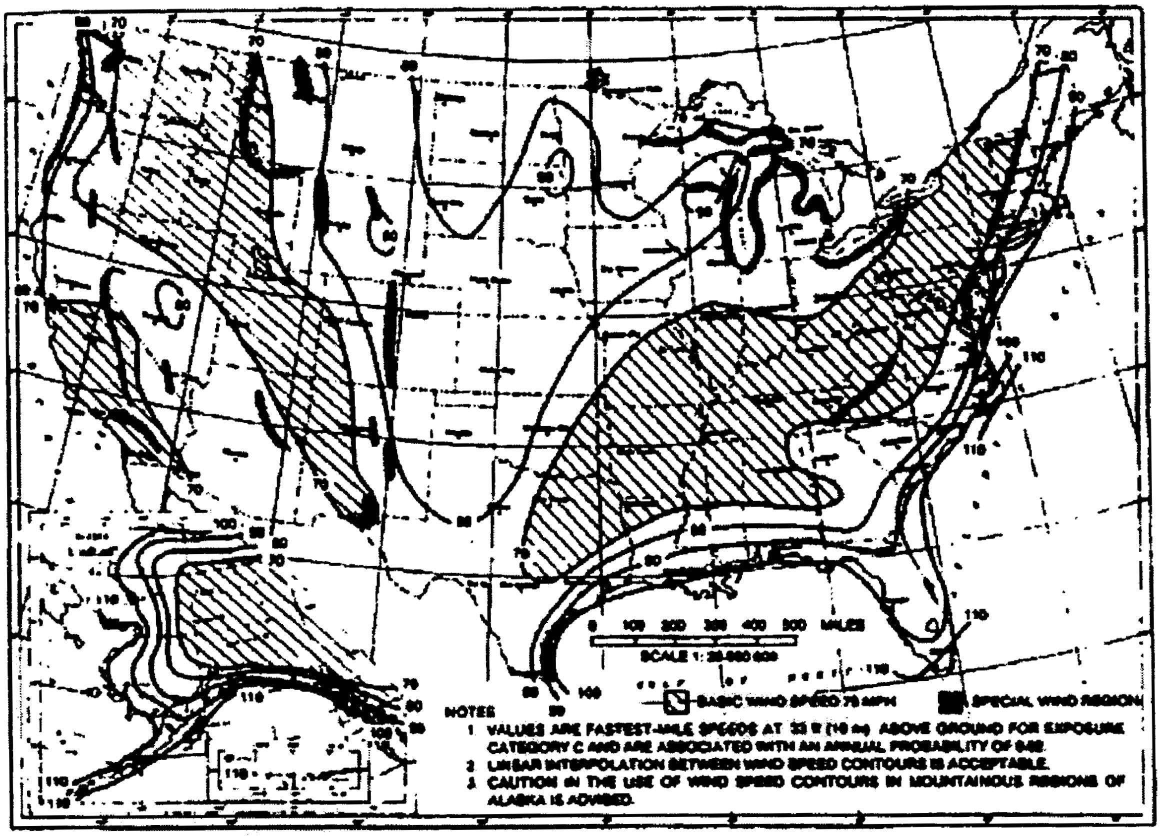


Figure 2-4. DERM Wind Speed Map Based on Old NESC Data (DERM Figure 1)

2.3.4 The "Fixity Point" Assumption

Pole strength calculations require that the location of maximum fiber stress be identified. Typical engineering references assume that this location is at the ground line. Exceptions are made for very tall poles, where the maximum stress may occur somewhat above the ground line. However, the *Standard Handbook for Electrical Engineers* states, "Usually decay is greatest at the ground line, and as the pole ages, its ground-line circumference is reduced to make it the point of greatest fiber stress."

The DERM assumes that the point of greatest fiber stress occurs below the ground line at a point one-third the distance from the ground line to the base of the pole (see Figure 2-5). This point is referred to as the "fixity point."

As a practical matter, FPL distribution poles have shown to nearly always break at or above the ground line. Actual calculations will typically not differ substantially whether using the fixity point or ground line, but FPL should further investigate this issue.

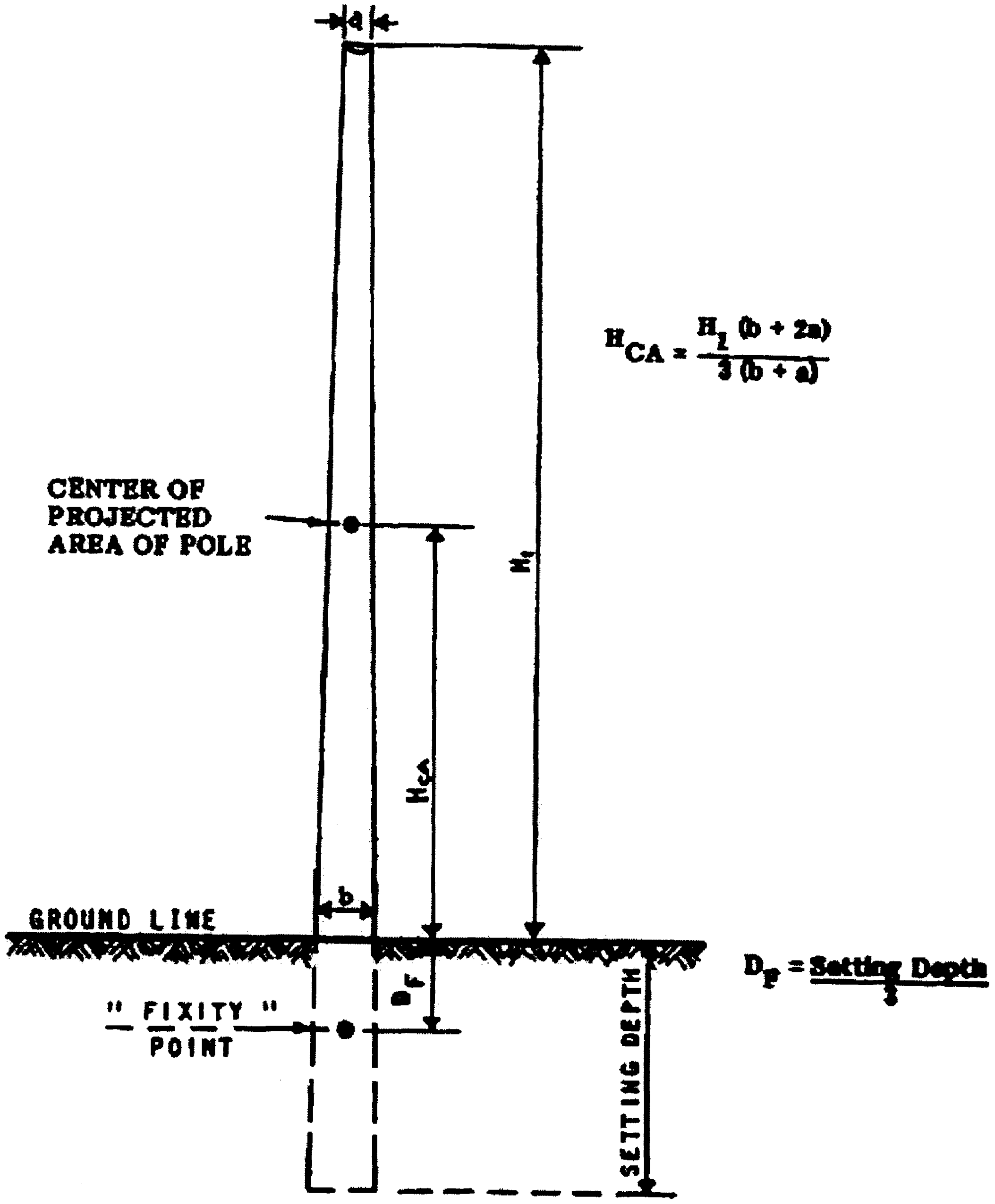


Figure 2-5. Dimensions Used in Calculating Wind Load on Poles (DERM Figure 3)

2.4 DERM Calculations

DERM Section 4.2.2 has several example calculations. It is important that these calculations be correct, since engineers will typically use example problems as a template when performing calculations for themselves. This section checks these example calculations for accuracy and correctness.

Example Wood Pole Strength Calculation (DERM 4.2.2, Page 10)

This calculation is correct. Small comments include:

- When calculating the diameter at 38' below the pole top, a circumference of 40.1" is first cited, but then the value of 40.5" is used for the calculation.
- When M_p is computed, the final result is preceded by a plus sign (+) instead of an equal sign (=)

Example Concrete Pole Strength Calculation (DERM 4.2.2, Page 10)

This calculation is correct. Small comments include:

- When the area of the pole face is computed, the value 38' is written as 3'8.
- This example uses a 7' setting depth for height calculations, but an implied 8' setting depth for groundline width calculations. A 7' setting depth results in a groundline width of 15.67", but an 8' setting depth results in a groundline width of 15.33".
- Wind pressure is calculated at the "fixity" point, but the pole strength is calculated at the ground line as shown on Page 6 (assumes an 8' setting depth).

Wind Loading Calculations: Example A (DERM 4.2.2, Page 12)

This calculation is correct.

Wind Loading Calculations: Example B (DERM 4.2.2, Page 13)

This calculation is correct.

Wind Loading Calculations: Example C (DERM 4.2.2, Page 14)

This calculation is correct. Small comments include:

- The figure shows a cable TV wire that is not used in the calculations.
- The force associated with a 4" riser shield according to Table A-2 is 4 lbs per foot above grade. The calculation uses 3.2 lbs per foot above grade. This number corresponds to a 4" riser conduit in Table A-2.
- In the last equation, the fixity value of 2.33' is written as 2.3'3.

Wind Loading Calculations: Example D (DERM 4.2.2, Page 15)

- This calculation is correct.

3 Quality Process Assessment

In order to determine the effectiveness of the Florida Power & Light Quality Management System to assure the quality of distribution poles and pole maintenance, KEMA reviewed the FPL purchasing and product engineering policies, procedures and specifications. Contracts were reviewed to assure that the purchase orders tied the product requirements back to national standards and Florida Power & Light specifications.

Field trips were conducted to audit and examine how the FPL subcontractors met the requirements of the National Standards and FPL specifications. The following subcontractors were audited:

1. Osmose Utilities Services, Inc.
   502 71st Street NW
   Bradenton, FL 34209
   (Audit conducted in the field at Titusville, FL)

2. Pre-Cast Specialties, Inc.
   1380 N.E. 48th Street
   Pompano Beach, FL 33064

3. Langdale Forrest Products Co.
   1202 Madison Highway
   Valdosta, GA 31603

3.1 Summary of Findings

The quality systems and processes of FPL and key suppliers is sufficient to reasonably ensure that procured distribution poles, both wood and concrete, meet National Standards and Florida Power & Light specifications. Further, the quality systems of Osmose are such that it is reasonably ensured that inspected wood poles requiring treatment or replacement are identified as such.

3.2 Audit: FPL Purchasing and Product Engineering

3.2.1 Participants

The following employees were involved:

Name	Position/Department	Company
Scott Stephens	Product Engineer	FPL
Deborah Wanser	Materials Sourcing	FPL
Albert Egreczky	Quality System Auditor	KEMA

Where necessary, other employees provided additional explanations.

3.2.2 Process Description

FPL has a robust purchasing and contract management system that is managed on the company intranet. The purchasing department and product engineers act as a team to assure that FPL gets the products that meet their requirements. Product Engineering develops the specification and the purchasing department develops the purchase order or contract to provide the product in accordance with the specification.

Florida Power & Light evaluates and selects its suppliers on their ability to supply product in accordance with FPL requirements. Criteria for the selection and evaluation have been established. For the CCA wood pole manufacturers, FPL visits the vendor manufacturing sites and evaluates the vendor against an FPL checklist prepared by the product engineer. The FPL product engineer investigates things such as grading, framing, drying, treating, storage, handling and records management. Records of the results of the evaluations are maintained as part of that contract documentation. The purchase order or contract identifies specifics such as quantity, type, length, treatment, delivery location, FPL specification, etc.

The organization has established and implemented inspection or other activities to ensure that purchased product meets specified purchase requirements. FPL has included the right to perform product verification at the supplier's premises in their contract. The auditor reviewed inspection records for Langdale Forrest Products Co., the current supplier of CCA treated Southern Yellow Pine Distribution Poles, from July 2004 through October 2005 and found them to be in order.

There have been no Unsatisfactory Performance Reports (UPRs) issued to the Wood Pole manufacturer for inadequacy of product or service.

3.2.3 Reviewed Documents

- FPL Purchasing Procedure #705 – Purchasing Materials and Services Policy and Requirements
- FPL Purchasing Procedure Pro7 – Records Management
- FPL CCA Pole Plant Audit Check Sheet
- Langdale Forrest Products – File No. 46002265 (Supplier of Southern Yellow Pine CCA Treated Distribution Wood Poles)
- Contract 4600002265 - Langdale Forrest Products
- Supplier Profile Form – Langdale Forrest Products
- Contract File Contract Checklist – Contract 4600002265 Langdale Forrest Products

- Langdale Forrest Products Inspection and Treatment reports July 2004 – October 12005.
- FPL Specification1-8.0 Rev. 8 – Southern Yellow Pine CCA Treated Distribution Wood Poles
- FPL Specification 1-8.1 Rev. 3 – Pole inspection & Treatment Specification
- FPL Specification 1-8.2 Rev. 2, 8/17/05 – Pole Reinforcing
- FPL Specification 1-4.0 Rev. 8, 5/16/96 – Square Prestressed Concrete Distribution Poles

3.2.4 Conclusions

The process described above was found to satisfy the requirements of applicable FPL Purchasing Procedures and accepted practices for Quality Management Systems.

3.3 Audit: Osmose Pole Inspection, Treatment and Reinforcing

3.3.1 Participants

The following employees were involved:

Name	Position/Department	Company
Luis Gutierrez	Reliability Program Engineer	FPL
John Tessieri	District Manager	Osmose
David Grow	Supervisor	Osmose
Richard "Shane" Doris	Pole Inspector	Osmose
Lloyd Jackson	Excavator/Crew Member	Osmose
Joel Rampersad	Foreman	Osmose
Jonathan Hutchinson	Pole Inspector	Osmose
Justin "Blake" Mitchell	Pole Treatment Specialist	Osmose
Albert Egreczky	Quality System Lead Auditor	KEMA

Where necessary, other employees provided additional explanations.

3.3.2 Process Description

FPL is currently using Osmose Utilities Services Inc to provide inspection, treatment and reinforcing of wood poles in their system. They are focusing on the distribution areas where there is the highest concentration of creosote treated utility poles. FPL stopped purchasing creosote treated poles in 1978. FPL has been purchasing chromated copper arsenate (CCA) impregnated poles since 1978. The CCA treated poles have a stated service life of 65 years.

In 1998 an inspection program was instituted to inspect, treat and reinforce the wood poles in the system. Since then approximately 31,131 poles have been inspected by Osmose primarily in Northern Florida and West Palm Beach area.

The Auditor observed two separate crews to assure that the different crews in the area were following FPL specifications. The Osmose crews consisted of a supervisor, foreman, excavator, inspector, and treatment specialist. The excavator performs a visual inspection of the pole before approaching the pole. The inspection includes original treatment, circumference, pole age, height, class, and any physical damage to the pole. In addition, the excavator looks for obvious conditions that may appear to be improper such as slack guy wires, slack overhead conductors, broken insulators, etc.

Earth is removed to a depth of 18 inches making sure not to damage ground wires or other utilities in the immediate area. If there is obstruction around the pole it is excavated in a manner as to permit the inspection and treatment of as much of the pole as possible.

The inspector performs a sounding of the pole with a hammer. This is done from below the ground line to approximately six feet above the ground line. If there is evidence of possible decay, boring with a 3/8" diameter bore is done and a shell gage is used to determine the extent of the void or decay.

The pole inspector collects the following data which is placed in a database for FPL: 1) Pole location, by street address or other means, 2) GPS coordinates, 3) Pole brand date month and year, 4) Pole length and class, 5) Species of wood, 6) Original treatment, 7) Pole supplier, 8) FPL grid number if available, 9) Ground line circumference, 10) Condition of pole above ground line, 11) Condition of attachments, 12) Last year inspected, 13) Last year treated, 14) Decay this cycle, 15) Evaluations, 16) Work performed.

Poles are evaluated for treatment and reinforcement in accordance with FPL Specification 1-8.1 Rev 3 dated 9/19/2005 and FPL Specification 1-8.2 Rev 2 Dated 8/17/05 respectively. A tag is placed on the pole facing the street indicating status and treatment to be performed.

The Osmose treatment specialist performs the treatment of the wood pole. All poles not rejected are covered from 18 inches below the ground to 2 inches above the ground line with "Osmose Copper Plastic Treatment" in accordance with the manufacturer's recommendations. All poles that are not rejected in accordance with FPL Specification 1-8.1 Rev 3 dated 9/19/2005 that contain decay pockets are treated with "Woodfume" in accordance with the manufacturers recommendations. All holes are plugged with threaded removable plugs.

After treatment the treatment specialist places a protective wrapping around the pole starting 3 inches above the ground line. The excavation is refilled and tamped to a point 3 inches above the ground line. The treatment specialist then places a treatment tag on the pole indicating what was done to the pole. Poles that are rejected are placed on a priority schedule or on a non-priority schedule determined by the overall condition of the pole.

3.3.3 Reviewed Documents

- FPL Specification 1-8.1 Rev 3 Dated 9/19/05 – Pole Inspection & Treatment Specification
- FPL Specification 1-8.2 Rev 2 Dated 8/17/2005 - Pole Reinforcing
- David Grow - FL State Pesticide license No. CM12759 Exp: 03/2006
- Osmose Pole Inspection & Maintenance Records March 1998 – December 2004
- Observed pole inspection, evaluation, tagging and treatment at the following locations:
- NW Corner Palmetto & Olive, Titusville, FL
- SE Corner Palmetto & Olive, Titusville, FL
- SE Corner Pine & Canaveral, Titusville, FL
- NE Corner Pine & Canaveral, Titusville, FL

3.3.4 Conclusions

The process described above was found to satisfy the requirements of applicable FPL Specifications and accepted practices for Quality Management Systems.

3.4 Audit: Pre-Cast Concrete Distribution Poles

3.4.1 Participants

The following employees were involved:

Name	Position/Department	Company
Fred Cianelli	President	Pre-Cast Specialties
Scott Stephens	Product Engineer	FPL
Richard Osborn	Product Engineer	FPL
Albert Egreczky	Quality Systems Lead Auditor	KEMA

Where necessary, other employees provided additional explanations.

3.4.2 Process Description

Pre Cast Specialties, Inc. (PCS) provides FPL with statically cast square pre-stressed concrete distribution poles to be used in their overhead distribution system. These poles are manufactured at PCS's manufacturing facility at 1380 NE 48th Street, Pompano Beach, Florida.

PCS has provided FPL with detailed working drawings, load vs. deflections, ultimate torque curves and estimated weight for their pole types identified in FPL specification 1-4.0 Rev 8 dated 5/16/96. All embedded steel, both pre-stresses and spiraling has a minimum of 1 inch of concrete cover. Steel strand used to pre-stress the concrete is not tensioned above 70% of the rated ultimate strength. All pre-stressed strand is burned back one inch and filled and sealed with grout of the same composition as the pole. All poles are grounded with a #6 AWG copper wire in accordance with drawings showing the pole type.

All poles are clearly marked with a brand mark to identify the manufacturer, month and year of manufacture and type and length. Type and length are also marked on the pole butt. Holes are drilled in the pole in accordance with pole type after the concrete has cured.

Poles are manufactured using the following process: 1) Strip previous days production, 2) Clean and apply concrete release agent to pole form. 3) Place top and bottom headers, 4) Place structural steel in pole form, 5) Thread and anchor pre-stress cable. 6) Pull cable to pre-stress value, 7) Tie structural steel off to pre-stress cable, 8) Place dormant strand and tie off to pre-stressed cable, 9) Place and attach ground wire, 10) Pour, vibrate and float concrete into the form. 11) After concrete has reached proper strength (determined by strength testing) release pre-stressed cable and remove pole from form.

The Hercules Power pre-stressing machines used to pre-stress the cable is in the calibration system and is calibrated by Southern Calibration and Service. All machines were calibrated on 11/15/05 and scheduled for recalibration on 5/15/06.

An American Concrete Institute (ACI) certified technician using a Baldwin 300K stress-testing machine that is calibrated by Southern Calibration Services performs concrete strength tests. The Baldwin 300K was calibrated on 2/16/2005 and found to be within a tolerance of 1%.

The auditor observed a concrete compression test performed by Luis Escobar on FPL test sample done on 12/6/05. The test showed that the sample exceeded the release requirements of 3500 psi. In addition, the auditor reviewed results of tests for FPL poles performed on 12/1/05, 12/2/05 and 12/5/05. All tests reviewed met specification.

3.4.3 Reviewed Documents

- FPL Specification No. 1-4.0 Rev 8 Dates 0/16/96
- FPL release against PO 4500202397, Contract 4600002268, 70 poles, PLE, STD, CNC, 45', III-G, WT2.6K#, 45' LG, Prestressed concrete 4380lb
- Baldwin 300K Compression Testing Machine Serial No. 513255 Calibration Certificate 22123
- Hercules "B" Single Strand Tensioning System Serial No. 319890- Calibration Cert.
- Hercules "B" Single Strand Tensioning System Serial No. 314703 – Calibration Cert.
- Hercules "B" Single Strand Tensioning System Serial No. 57160 – Calibration Cert.
- Observed concrete compression test for FPL cast 12/06/05
- Compression Test Records FPL for 12/01/05, 12/02/05, 12/05/05
- Working drawings, load vs. deflections, ultimate torque curves and estimated weight for Type III-H utility Pole – 9" Tip

3.4.4 Conclusions

The process described above was found to satisfy the requirements of applicable FPL Specifications and accepted practices for Quality Management Systems.

3.5 Audit: Langdale Wood Poles

3.5.1 Participants

The following employees were involved:

Name	Position/Department	Company
Jim Hickman	Technical Director	Langdale
Hugh Rowe	Sales Manager	Langdale
William Browning	Production Manager	Langdale
Robert Parish	QA/QC Field Inspector	Langdale
Bill Berry	CCA Treatment Operator	Langdale
Scott Stephens	Product Engineer	FPL
Richard Osborn	Product Engineer	FPL
Albert Egreczky	Quality Systems Lead Auditor	KEMA

Where necessary, other employees provided additional explanations.

3.5.2 Process Description

Langdale Forrest Products Co. (LFP) provides FPL with CCA treated southern yellow pine distribution wood poles to be used in their overhead distribution system. These poles are manufactured at Langdale Forrest Products Co.'s facility at 1202 Madison Highway, Valdosta, GA.

All poles used in the manufacture are Southern Yellow Pine poles conforming to ANSI standard 05.1-2002. An operator manually selects distribution poles after the poles are trimmed and debarked. The poles are then dried to approximately 25% moisture content and framed (holes drilled for attachments). After the framing the poles go through a final inspection prior to CCA treatment. A certified pole inspector performs this inspection. The inspector inspects the poles for any signs of: compression wood, red heart wood, excessive knots, shakes, splits, through checks, scars or low density. Inspection status is marked with a hammer on the top of the pole. This inspection is recorded and forwarded to FPL as part of a monthly White Pole Inspection and Treating Report. If any defects are observed the poles are rejected and removed to another area.

Poles are then branded to include the following information: the supplier trademark, the plant location, code letters denoting pole species, preservative and amount of retention, the month and year of treatment, the pole class and length, and the designation "FPL Co."

The poles are treated by the full length, full cell pressure process in accordance with AWPA Standards C1-2003 and C4-2003 in charge lots using Chromated Copper Arsenate (CCA) Type "C" which conforms to American Wood-Preservers Association (AWPA) Standard P5-2004. The treatment must achieve an average retention of 0.60 pounds of CCA per cubic foot of wood treated. Penetration must be 3.5 inches or 90% of the sapwood.

After the poles are treated the Quality Manager samples the poles to determine penetration and retention. The retention sample is taken from wood plugs removed from the poles. The assay sample is taken from ½ inches to 2 inches from the surface of the pole. The sample is pulverized and x-ray spectroscopy tested to meet the average retention of 0.6 lbs/ft^3 of wood treated. Penetration is determined visually from the initial plug sample. The sampling record is stapled to the treatment sheet and kept in the quality lab for a period of seven years.

The auditor and product engineers from FPL witnessed white pole sampling for FPL poles framed on 12/07/05 and X-Ray spectroscopy sampling of FPL charge 15604 dated 12/06/05. The initial X-Ray spectroscopy result was low but on subsequent sampling of the same lot the average retention was .63lbs/cuft.

The quality manager calibrates the Asoma X-ray spectrograph and Oxford Lab X3000 X-Ray spectrograph against a known sample SUM128B-F147/04 provided with the Oxford Lab equipment.

3.5.3 Reviewed Documents

- FPL Specification1-8.0 Rev. 8 – Southern Yellow Pine CCA Treated Distribution Wood Poles
- ANSI Standard 05.01-2002 – Specifications and Dimensions
- AWPA Standard P5-04 Standard for Waterborne Preservatives
- AWPA Standard A-9 Standard method for analysis of Treated Wood and Treating Solutions by X-Ray Spectroscopy
- AWPA Standard C4-03 Poles – Preservative Treatments by Pressure Processes
- Langdale Quality Control Program (LQC)
- FPL CCA Pole Plant Audit Check Sheet
- Langdale Forrest Products Inspection and Treatment reports for FPL July 2004 – October 2005.
- FPL Charge Record 15549 Dated 11/22/05 -.82lbs/cuft
- FPL Charge Record 15604 Dated 12/06/05 -.63lbs/cuft

3.5.4 Conclusions

The process described above was found to satisfy the requirements of applicable FPL Specifications and accepted practices for Quality Management Systems.

4 Pole Maintenance Assessment

This section assesses inspection and maintenance programs for distribution poles in the FPL system. This includes (1) the thermovision program, (2) the Osmose inspection and maintenance program, (3) other pole "touchpoints" afforded by daily work activities.

4.1 Summary of Findings

FPL distribution pole performance during non-hurricane conditions is good, and non-hurricane pole failures have virtually no contribution to customer interruptions. FPL has two systematic programs related to pole inspections: (1) a Thermovision program that visually inspects all main-trunk feeder poles at least every five years, and (2) a wood-pole inspection and treatment program that is small in scope and focuses on specific areas of the FPL system. FPL crews are also required to perform a safety inspection on a pole before performing work on the pole. These inspections will not systematically address each pole, but KEMA estimates that this will effectively test between 80% and 90% of all branch-line laterals over a fifteen year period. Most utilities do not have a systematic inspection program for all poles, but do have a systematic inspection program for all wood poles older than a specified year (for deterioration) on a ten to fifteen year cycle.

FPL has two systematic programs for inspection and/or treatment of poles: the Thermovision program, and the Osmose program. As part of FPL's company-wide equipment reliability program at least from 1998, the Thermovision program includes a visual inspection of all feeder poles, including any third-party poles, running at cycles of 4.6 years and 2.5 years for 23-kV and 13-kV feeders, respectively Although the primary focus on this program is not pole inspection, each pole is visually examined for obvious signs of physical damage or deterioration. The Osmose program performs a detailed inspection of pole with a specific emphasis on wood deterioration and structural integrity. All three pole types are included in both programs – creosote (CSY), CCA and Penta.

FPL examines both FPL-owned and non-FPL-owned poles in its pole inspection programs. In the case of non-FPL-owned specifically, results regarding these poles are always passed on to the pole owner. However, FPL does not always know the final remedies undertaken by the pole owners. No process is in place to track what third parties do to the poles determined by FPL inspection to need attention.

In August 2005, FPL made a decision to focus its 2006 inspection and maintenance program on creosote poles. The initial geographic focus being the Brevard and Treasure Coast Management Areas. Osmose just completed the first phase of this 2006 program – within the Brevard Area – at the end of 2005. Results so far indicate that out of 1620 poles inspected, 18% require either bracing or replacement (15% for FPL poles, and 24% for non-FPL poles). These rates are substantially higher than the industry survey results of 5%, but may be high since FPL is specifically targeting areas with older pole populations.

In addition to formal inspection programs, FPL poles are regularly inspected by crews required to perform work on the poles such as overhead service connects, disconnects, feeder reconfiguration, customer service requests, streetlight trouble tickets, overhead work trouble tickets, and overhead work requests. These "pole touchpoints" totaled about 199,000 in 2004. (This number of touchpoints excludes storm-related services, and each pole touchpoint may not be for a unique pole.) Adding all these pole touchpoints with those from Thermovision and Osmose programs results in about 280,000 pole inspections per year. Making certain assumptions, KEMA estimates that this activity level will result in between 80% and 90% of lateral poles being visually examined over a fifteen year period.

Key Findings

- FPL distribution pole performance during non-hurricane conditions is good, and non-hurricane pole failures have virtually no contribution to customer interruptions.
- FPL has two formal inspection programs: Thermovision and Osmose. Both of these programs examine both FPL poles and non-FPL poles.
- Thermovision includes a visual inspection of main-trunk feeder poles, which are on an aggressive cycle ranging from 2.5 to 4.6 years. However, the primary focus of Thermovision is not pole deterioration, and this program does not include branch laterals.
- Presently the Osmose program is very small in scope.
- In addition to formal inspection programs, FPL poles are regularly inspected by crews required to perform work on the poles. It is estimated that these "touchpoints" will look at between 80% and 90% of all lateral poles over a typical fifteen year period.
- FPL does not have a systematic test-and-treat program for its older distribution wood pole population.

4.2 Thermovision Program

The Thermovision Program is a reliability program administered by FPL in-house. It has been in existence since 1998. It involves infrared inspection of electrical equipment along the overhead distribution feeders and visual inspection of poles and other equipment along the feeders. This program does not cover the laterals.

Each year FPL inspects about 600 feeders, including any third-party poles, running at cycles of 4.6 years and 2.5 years for 23-kV and 13-kV feeders, respectively. Although the primary focus on this program is not pole inspection, each pole is visually examined for obvious signs of physical damage or deterioration.

For the poles, the visual inspections reveal whether there are broken, cracked or severely deteriorated cross-arms, split pole tops, or conditions that would call for pole replacement – the definition of "defective poles" in this process. The FPL system contains 471 distribution substations with a total of 2920 feeders emanating from these substations. The feeders are broken down into the following for the three voltage levels [3]:

Voltage	# of Feeders
4 kV	3
13 kV	2141
23 kV	776

Table 4-1, shows the visual inspection program's result on wood poles along feeders for the entire system. It shows that the average percentage of feeder poles inspected by Thermovision that are defective is 0.52%. This calculation is based on the assumption that on average each feeder has 113 poles [4].

It should be noted that the visual inspection also covers the third-party poles. FPL passes the information on any third-party poles that need replacement or bracing to the third parties. However, FPL does not track what remedial actions, if any, the third parties have taken. There is no formal process in place to allow such tracking.

Table 4-1. Feeder Pole Defective Rates from Thermovision Program over 1998-2005.

Area	# Inspected	# Defective	Inspection Defective Rate
Boca Raton	45,007	123	0.27%
Brevard	29,730	188	0.63%
Dade County	150,927	969	0.64%
Central Florida	33,352	171	0.51%
Gulfcoast	36,305	81	0.22%
Manasota	24,439	81	0.33%
North Florida	30,389	134	0.44%
Pompano	38,286	94	0.25%
Toledo Blade	15,286	60	0.39%
Treasure Coast	32,831	133	0.41%
West Palm Beach	44,388	431	0.97%
Total	**480,940**	**2,465**	**0.52%**

* Computed using data from [1] and [2]

4.3 Osmose Pole Inspection and Treatment Program

FPL has a targeted program for inspecting and treating wood poles. By outsourcing to Osmose, a vendor specializing in wood pole inspection and maintenance, FPL is able to identify wood poles in targeted areas that require treatment, bracing or replacement. The inspection process involves visual inspection, excavation, and sounding. Boring is performed if deemed appropriate. Should the need for remedial treatment arise, Osmose applies the appropriate treatment (e.g., COP-R-plastic, WoodFUME). Should the need for replacement or bracing arise, FPL schedules work orders to restore or replace those poles (e.g., C-Truss, fiber wrap).

From 1999 through 2004, FPL has focused Osmose poles inspections on specific areas based on the company's belief that these areas presented the most potential with regards to pole deterioration. When directed to an area by FPL, Osmose inspects both FPL-owned and third-party-owned poles. When third-party poles are found to require treatment, bracing, or replacement, this information is passed on to those third parties. However, as in the case of Thermovision program, FPL does not have a formal process to track the actions, if any, that third parties take with regards to those poles.

The data from 1999 through 2004 shows that the pole defective rate (i.e., poles that require bracing and/or replacement) for the North Florida and Palm Beach areas run at 4.6% and 6.9%, respectively [5, 6, 7, 8]. If the data for both areas are combined, as in Table 4-2, it is shown that the combined areas have a pole defective rate of 5.63%. The bracing rate is 2.80% and replacement rate 2.82% (versus 2% and 3%, respectively, from the industry survey).

Table 4-2. Pole Defective Rates for Poles Inspected in North Florida and Palm Beach Management Areas*

Total # of poles inspected from 1998 - 2004	81,131
Total # of bracings	2,275
Total # of replacements	2,289
Total # Defective	4,564
Bracing Rate	2.80%
Replacement Rate	2.82%
Structurally Defective Rate	5.63%

* Computed using data from [5,6,7,8]. It must be remembered that poles selected to be inspected are those in areas with older pole populations. Therefore, the defective rate shown in this table is not representative of the entire FPL pole population.

Osmose data suggests that creosote poles have a higher pole defective rate than the other pole types (CCA and Penta). Thus despite the absence of statistically exacting data, FPL decided to monitor creosote poles more closely. Therefore, as of August 2005, FPL concentrated its resources on creosote poles. About 1600 creosote poles were inspected for Brevard Area in 2005, and a similar number for the Treasure Coast Area is scheduled for next year.

The results from Brevard Area so far have validated the company's decision to concentrate on creosote poles. Table 4-3 shows the Brevard results [9, 10].

Table 4-3. Creosote Pole Inspection Results from Brevard Area by Osmose in 2005

	FPL	Non-FPL	Total
Inspections	1,133	487	1620
% of total	70%	30%	
Brace	79	73	152
Replace	91	42	133
% Brace	7%	15%	9%
% Replace	8%	9%	8%
Total Defect Rate	15%	24%	18%

Pole defective rates vary by Management Areas. In this case, the creosote poles in Brevard Area display a higher defective rate when compared with the other two areas. However, the data is not readily amenable to analyses that could ascertain whether this higher rate is primarily due to the creosote poles or due to some other factor. Nor is it easy to extrapolate the results for the entire population of poles in the FPL system.

This inability to make conclusions on the condition of different types of poles for the entire system is due to the lack of a comprehensive database on the vintage, pole type, repair record, and condition of poles in each location. The current inspection program is not designed to collect data on the entire population of poles. Such a database would provide a tool for a more effective maintenance program for managing the pole population.

4.4 Other Pole Touchpoints

As part of its routine engineering jobs to serve customers, FPL also has many opportunities to inspect distribution poles. Such jobs include connecting and disconnecting overhead services, repair and/or replacement of devices on poles (e.g., bushings, connectors and lightning arrestors), streetlight repairs, and responses to trouble calls (excluding storms). Each of these jobs affords the opportunity to inspect the poles. Should there be any safety concerns or poor pole conditions, the technician or engineers would so note the condition on a Hazard Assessment form and pass that information on to the area supervisor. The technician or field crew may also prepare a Crew Turndown Request form should it be decided that the pole is unfit for executing the original job request.

For FPL, all these daily pole activities add up to 199,068 opportunities of "touching" and visually inspecting the poles in 2004 [10]. If we add the average number of inspections for Thermovision and Osmose programs – about 69,000 poles and 12,000 poles, respectively – to these touchpoints, FPL actually "touches" about 280,000 poles per year on the average. For a population of about 1.3 million poles in the system [11], FPL would have completed examining all the poles, both FPL-owned and third party-owned, in 4.9 years. This assumes that the same pole is not "touched" more than once over this period.

It is of interest to examine the likelihood of a pole not being inspected for a long period of time. Each feeder pole is systematically examined by the Thermovision program at least every five years. To examine laterals, several assumptions must be made. First, it is assumed that 65% of all poles are lateral poles (845,000 total). Second, it is assumed that touchpoint activity is twice as frequent on a typical feeder pole when compared to a typical lateral pole (due to more attached equipment, more frequent relocations, etc.). Third, it is assumed that each touchpoint examines a single pole. Last, it is assumed that touchpoint activity follows a Poisson process, meaning that the likelihood of being touched is constant and does not depend upon past activity.

With these assumptions, there are about 95,848 touchpoints per year on lateral poles, which implies a "touchpoint rate" of 11.34% per year. For a Poisson process, this means that the probability of a pole not being touched in a given year is equal to $e^{-0.1134}$ = 89.28%. It is then straightforward to compute the probability of a pole not being touched in consecutive years. A graph of these probabilities is shown in Figure 4-4.

Figure 4-4 shows that, for the above assumptions, about 32% of poles will not be inspected over a ten-year period, and about 18% of poles will not be inspected over a fifteen-year period. If it is assumed that each lateral touchpoint involves an average of two poles instead of one pole (due to crews inspecting adjacent structures), about 10% of poles will not be inspected over a ten-year period, and about 3.3% of poles will not be inspected over a fifteen-year period. Considering the uncertainty of assumptions in this calculation, KEMA feels that between 80% and 90% of all lateral poles will be inspected over a 15-year period.

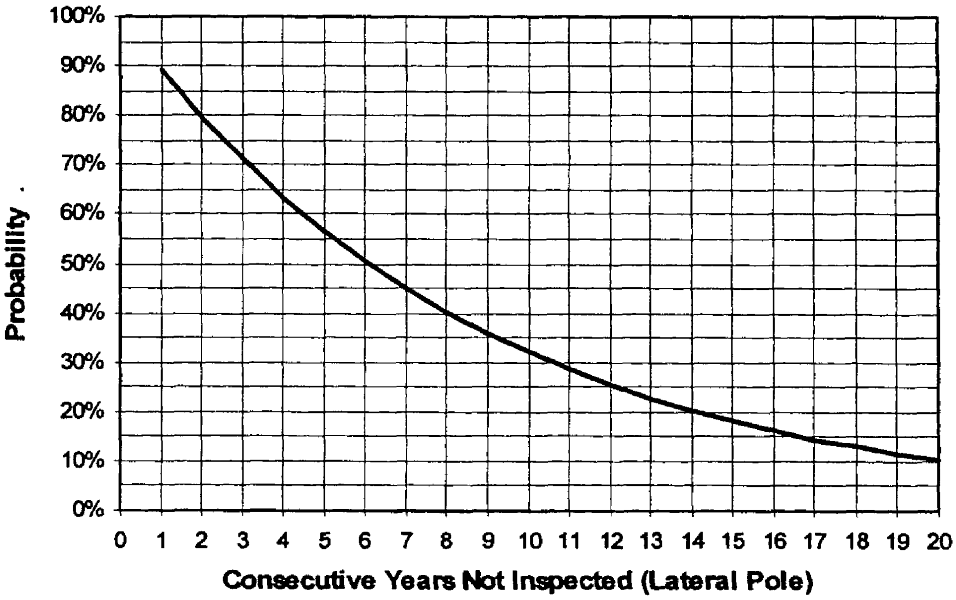


Figure 4-4. Probability of Lateral Poles Not Being Inspected for Multiple Consecutive Years.

4.5 References

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8. Inspection by Areas 1999 - 2005 Updated.jpg, a summary of results for Osmose pole inspection program from 1999 through 2005.
9. Osmose Data for Brevard for 2006 in 2005_120305 from Luis.xls, a spreadsheet of inspection results on creosote poles in Brevard County, conducted by Osmose in the last quarter of 2005.
10. Number of Poles Visited During Normal Work in 2004 Revised 12-14-05.xls, a compilation of the number of pole touchpoints in the year 2004.
11. Pole population statistics, furnished by Scott Stephens, December 2005.

5 Transmission Forensic Analysis

This section analyzes the performance of FPL's transmission system during Hurricane Wilma. The intent of this section is to (1) analyze the failures, and (2) to establish whether FPL's designs meet the requirements of the National Electrical Safety Code (NESC).

At the time this report was written, all damaged transmission structures had been repaired or removed. The forensic data for this report was obtained from FPL. A site visit of several of the failure locations was performed on December 14, 2005.

5.1 Summary of Findings

FPL's transmission lines are designed in accordance with the requirements form the NESC, including extreme wind requirements, applicable at the time of design.

Hurricane Wilma was a significant event that caused a number of failures in FPL's transmission system. Many failures were relatively minor and were repaired shortly after initial discovery. The exact wind speed during Hurricane Wilma is not known, but transmission structural damage indicates that Wilma was a Category 2 storm or stronger. This agrees with the KEMA weather analysis that shows that Wilma was Category 2 to Category 3.

Transmission Lines Less than 500 kV

Four significant failures occurred on transmission lines of voltage levels less than 500 kV. For three of these failures, even though they met the required design at the time of installation, they did not meet the current design criteria implemented at FPL. Two failures were in an area where FPL intended to relocate the transmission lines, but which were hit by the storm before this relocation was implemented. The fourth significant event was mainly due to the 500-kV Conservation–Corbett line falling on top of lower voltage structures.

Prior to Wilma, FPL was implementing a number of improvements to the transmission system, and continues these improvement efforts:

- Most new transmission structures are round spun concrete poles
- Increased setting depths for new poles
- Installation of polymer post insulators instead of ceramic post insulators
- Relocation of transmission lines in areas prone to wind acceleration

Conservation–Corbett 500 kV Transmission Line

The only 500-kV transmission line that experienced structural failures during Wilma was the Conservation–Corbett transmission line. Several 500-kV transmission lines are in the vicinity of the Conservation–Corbett line, but did not experience failures during Wilma.

Thirty structures of the Conservation–Corbett 500-kV transmission line failed completely during Wilma. Three issues were found that may have initiated the failure and/or contributed to the cascading effect:

- At the time of installation the installation guidelines was to hand-tighten bolts. This was insufficient and played a role in loosening of bolts in certain cases. This very likely was a major contribution to the cascading failure of 28 structures.
- One foundation failed. This may have initiated part of the cascading failure of 28 structures or contributed to the cascading effect.
- Conductor breakage occurred in many places along the cascading failure of 28 structures. One failure appeared to be a pure tensile failure. This failure could have contributed to the cascading effect and may have initiated part of the failure.

5.2 Forensic Data

Hurricane Wilma caused 345 transmission line sections to be out of service (out of a total of 924 sections). 228 sections were restored after completion of the initial assessment. The remaining 117 sections required work at structure locations as shown in Table 5-1:

Table 5-1. Required Work at Transmission Structure Locations*

Failure	Number of Locations
Insulators	101
Structures	100
Overhead Ground Wire	58
Debris	49
Trees	22
Crossarms	7

* FPL has more than 68,000 transmission structure locations.

This report focuses on the structure failures. The impact of the other failure types is less significant than the failure of complete structures. Brief comments on these other failure modes is now provided.

Ceramic Insulators. The insulator failures were mainly failures of ceramic post type insulators (68 out of 101 incidents). Failure of this type of insulator generally occurred as a result of debris or trees hitting the ceramic posts leading to breakage of the post insulator. The vulnerability of these insulators to this kind of impact has led to FPL's policy of not using them anymore. The ceramic post insulators are gradually being replaced by composite insulators.

Polymer Insulators. Thirteen polymer suspension insulators failed. Eleven of these polymer suspension failures were a result of the Conservation–Corbett 500-kV transmission line falling on top of the Alva–Corbett 230-kV transmission line.

Debris and Trees. Damage as a result of debris is generally outside of FPL's control. The damage by trees was a result of trees and branches located outside FPL's right of way hitting the transmission lines, and was therefore also outside of FPL's control.

Overhead Ground Wire and Crossarms. Not much information is available on the overhead ground wire failures and cross-arm failures. However, but these can be considered to be minor events

Structures. Thirty steel structures were damaged on the Conservation–Corbett 500-kV transmission line. Other significant events on non-500 kV transmission lines were:

- 26 structures on the South Bay – Belle Glade Section of the South Bay – Bryant 69 kV transmission line
- 10 structures on the Port Mayaca - Bryant Section of the Martin – Bryant 69 kV transmission line
- 6 structures on the Bryant – Pahokee Section of the South Bay – Bryant 69 kV transmission line
- 6 structures on the Alva – Corbett 230 kV transmission line

Other failed structures were single structure events or two adjacent structures, of which limited data is available.

5.3 Standards

The Florida Statute Section 366.04 requires that the National Electrical Safety Code (NESC) be followed for the design of transmission lines.

FPL also follows the American Society of Civil Engineers (ASCE) structural design standards for transmission lines:

- Minimum Design loads for Buildings & Other Structures – ANSI-7
- No. 74 Guidelines for Electrical Transmission Line Structural Loading
- No. 72 Design of Steel Transmission Pole Structures
- No. 91 Design of guyed Electrical Transmission Structures

FPL's existing transmission lines were designed in accordance with the standards applicable at the time of design.

5.4 Maintenance

FPL's maintenance program for transmission lines consists of climbing inspections, visual inspections and special assessments.

The transmission line sections are on a 3-, 4- or 8-year inspection cycle. The frequency of inspection depend on several factors including the type of components in the section. The 500-kV weathering steel transmission lines are on a 4-year 10% sample inspection cycle.

The inspections are carried out based on the methods and criteria described in FPL document "Power Systems Overhead Transmission Inspection Criteria Training." This document is a comprehensive manual and includes inspection methods, characteristics of ageing mechanisms and criteria for assessment. Annual refreshment training is conducted for the inspectors.

The inspection results are entered into FPL Transmission/Substation's asset management system (Orion). The condition assessment follow-up work is generated by Orion.

In general, FPL is currently implementing the following improvements on its transmission lines:

- For transmission voltages other than 500 kV, the majority of new structures are round spun concrete poles with polymer post insulators. In some instances, replacement of existing structures or parts of existing structures is on a like-for-like basis, based on an economic analysis.
- For unguyed single pole wooden structures, FPL used to follow industry standard practice for setting depth, which is equal to 10% of the pole length plus 2 feet. This practice is not followed anymore by FPL for new transmission poles, even though it is still an industry standard practice. New poles are installed at setting depths determined from Broms' equation.
- Ceramic post insulators are not installed anymore. Polymer post insulators are installed instead.
- FPL has carried out relocation projects to move parts of transmission lines away from unfavorable locations. FPL intends to carry out more relocation projects in the near future.

5.5 Transmission Lines Less Than 500 kV

The four significant events on transmission lines less than 500 kV were the following:

- 26 structures on the South Bay–Belle Glade Section of the South Bay–Bryant 69-kV transmission line
- 10 structures on the Port Mayaca–Bryant Section of the Martin–Bryant 69-kV transmission line
- 6 structures on the Bryant–Pahokee Section of the South Bay–Bryant 69-kV transmission line
- 6 structures on the Alva–Corbett 230 kV transmission line

These events are now discussed in the following sections.

5.5.1 South Bay–Belle Glade

On the South Bay–Belle Glade Section of the South Bay–Bryant 69-kV transmission line, 21 structures failed south of corner structure 66P15. These structures were mostly unguyed single wooden poles. Some structures had been replaced by light-duty spun concrete poles during regular maintenance. This transmission line runs roughly north-south at the location of the failures, and the structures failed in the transverse direction to the west. The line runs parallel to an elevated road. The surrounding country is flat with hardly any obstacles in the vicinity of the transmission line. Many of these failures were a result of foundation failures, which likely led to cascading effects that bought down additional structures.

Five structures failed 0.5 mile further south along the same elevated road. The wind direction changed as Hurricane Wilma passed through this area and these structures failed in the transverse direction to the east. The failure of these five structures was most likely initiated by debris hitting the conductor. FPL found evidence of debris in the conductor after the storm. In the direct vicinity of the location a lot of debris was present from facilities along the road. Cascading effects likely brought more structures down.

Since Wilma, FPL has strengthened this section of transmission line by replacing the whole length of the line running parallel to the elevated road with round spun concrete poles with polymer post insulators.

5.5.2 Port Mayaca–Bryant and Bryant–Pahokee

On the Port Mayaca–Bryant transmission line, a set of ten consecutive structures failed. Nearby on the Bryant–Pahokee transmission line, another set of six consecutive structures failed. Both of these locations were directly behind the Herbert Hoover Dike of Lake Okeechobee. The structures were mostly unguyed single wooden poles. Some structures had been replaced by light-duty spun concrete poles during regular maintenance. The transmission lines run roughly north-south here and the structures failed in the transverse direction to the east.

The exact wind load in this area during Hurricane Wilma is not known. However, the water surface of Lake Okeechobee will have caused the wind load on the structures directly behind the dike to be relatively high. Based on structural damage, it is estimated that the storm strength at this was Category 2 at this location. This is based on observed wind loads approximately of the strength that the unguyed single wooden pole structures could withstand.

FPL had previously recognized the unfavorable location of these sections of these transmission lines. During the 2004 storms, structures failed in the same area. After the 2004 damage, parts of the transmission lines were relocated 300 feet east where a new right-of-way was obtained. This relocated part of the transmission line now consists of round spun concrete poles and performed well during the 2005 storms.

The parts of the transmission lines for which no new right-of-way could be obtained were rebuilt in the original location. The Wilma damage occurred along these parts of the lines. It is not possible to erect round spun concrete poles with additional set depth in the present location, as this may affect the integrity of the dike.

5.5.3 Alva–Corbett

During Wilma, the Conservation–Corbett 500-kV transmission line collapsed on top of the Alva–Corbett 230-kV transmission line. Eleven polymer suspension insulators broke as a result of this impact. Further, four structures in the affected 10-mile section were damaged as well. The failure of these structures does not show any regular pattern, but it is likely that the damage was caused by the impact of the 500-kV line landing on the 230-kV line.

Two structures failed outside the 10-mile section affected by the 500-kV line collapse. These two single failures can be considered minor events.

5.6 Conservation–Corbett

5.6.1 Bolts and Cross-Bracing

Two individual structures on the Conservation–Corbett 500-kV transmission line failed (16Z51 and 16Z139). At structure 16Z51, the west leg was not supported by the cross-brace as a result of a missing bolt, and this leg buckled. At structure 16Z139 both legs buckled.

In all, 28 structures (16Z186 to 16Z213) failed in cascading style during this event. At the time of installation, the installation guidelines was to manually tighten crossbrace bolts. This was insufficient and played a role in loosening of bolts in certain cases. Loose and/or missing crossbrace bolts were discovered on several structures after the failures. This significantly reduced the transverse capacity of the structures because of the impact to the cross-brace and was most likely a major contribution to the cascading event.

5.6.2 Foundations

One foundation failure on the Conservation–Corbett 500-kV transmission line occurred during hurricane Wilma. This foundation failure may have initiated part of the failure of the 28 structures or may have contributed to the cascading effect of the failure.

The foundation failure should not have occurred. FPL investigations concluded that the foundation was installed incorrectly. As only one foundation failure occurred, this particular failure can be viewed as idiosyncratic. At this stage, there is no reason to assume that more foundations in the transmission line are not reliable.

5.6.3 Conductors

Several conductor failures on the Conservation–Corbett 500-kV transmission line occurred during hurricane Wilma. Most of these failures probably occurred after structural failures occurred, and were not initiating events themselves. The conductors were probably damaged as a result of hitting the structure (or the structure hitting the conductor) during failure of the structure.

FPL found one instance (at structure 16Z207) where the conductor failure appeared to be a tensile failure. It is difficult from the available information to determine whether this conductor failure initiated the failure of 28 structures (e.g., the conductor failure resulted in excessive torsional forces on the tower, which resulted in tower failure, which then led to more cascading failures). In any case, the relatively high conductor stringing tension may have contributed to the conductor failures.

The relatively high stringing tension on the Conservation–Corbett transmission line is a potential cause of Aeolian vibration. In 1998, vibration problems were experienced on this transmission line. Vibration monitoring equipment was installed in the line for several months. It was found that movement of at least 20 mm occurred. At the same time clamps were inspected and, in approximately 45% of the inspected clamps, damage as a result of vibrations was found.

After the vibration measurements were carried out in 1998, one vibration damper ("dog bone design") was installed per conductor per span. Further, the existing clamps were replaced with armor grip suspension clamps.

In 1999, vibration monitoring equipment was installed again. The movement was now reduced to approximately 4 mm. As an extra precaution, a second vibration damper (also a "dog bone design") was installed per conductor per span.

After the 2005 Wilma failures, a number of AGS clamps were inspected for vibration damage. Only two clamps were found with associated damage, with only one broken strand in each case. It is not known when this damage occurred. It appears that the vibration dampers and AGS clamps installed in 1998 and 1999 reduced the vibrations to such extent that no further conductor damage has occurred as a result of vibrations, implying that the above-mentioned damage occurred before this time.

A significant number of the original spacer dampers failed during Hurricane Wilma, implying that these original spacer dampers may not be suitable for Hurricane conditions.

5.6.4 Cross-Bracing

The design of the connection of the cross-brace and the pole for the Conservation–Corbett transmission line was changed in comparison with the design of other 500-kV transmission structures constructed earlier. In the earlier design, the plate at the end of the cross-brace was placed between two plates forming part of the pole. Tightening of the bolt through the plates was simpler in this design. The bolt was only loaded with a shear force and the design allowed rotating of the cross-brace around the bolt. This rotation ensures that the cross-brace is only loaded purely on tensile or on compression. It should be noted that both connection designs are common practice in the industry.

In the design of the Conservation–Corbett 500-kV transmission line, the plate at the end of the cross-brace is connected to one plate forming part of the pole. The two plates are connected by a single bolt and nut, without washers, locking devices etc. Manual tightening of the bolt is potentially difficult, especially if there is a small offset between the plate and cross-brace. In this case, tightening of the bolt will only be possible if at the same time this offset is corrected. Given the size of the structure, this will be difficult to accomplish manually. In the current retrofit, FPL is applying approximately 4,600 ft-lb of torque to fasten the connection. Any movement in the structure, either as a result of conductor-induced vibrations, or movement of the structure as a result of the wind, can lead to loosening of the bolt in this connection. The specification for construction of the transmission line from 1996 specifies that these bolts be tightened snug-tight plus 1/6 of a turn. This is in fact an insufficient specification given the design of the connection.

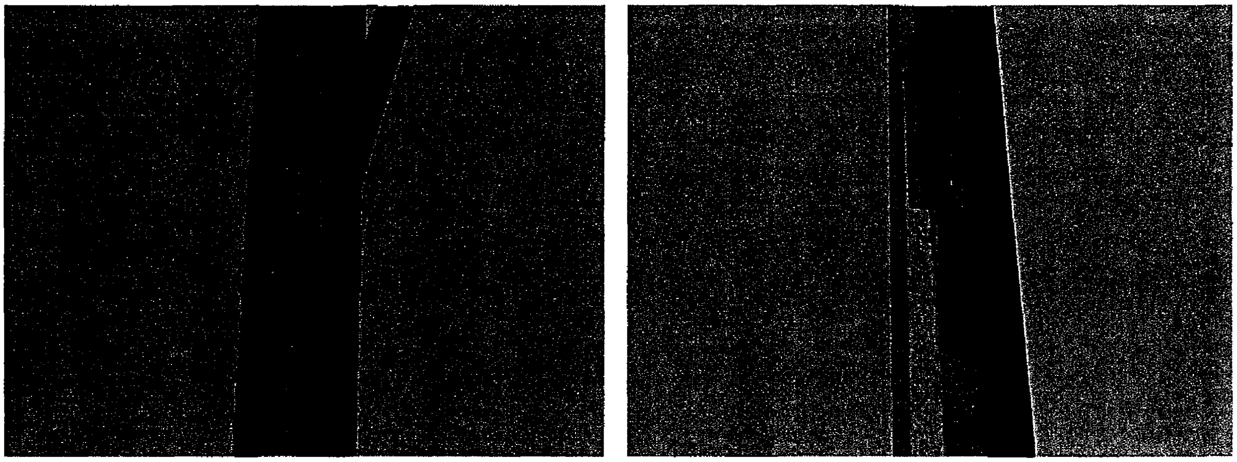


Figure 5-2. Older (left) and new (right) design of cross-brace connection

In 1998, some crossbrace bolts were found to be loose or missing. The exact actions to rectify the loose and missing bolts in 1998 is not known, but action was taken to fix this. Since manual tightening was used, it appears that some of the tightened crossbrace bolt subsequently became loose again.

There is no record that it was known before the 2005 storms that bolts were loose or missing. There is no inspection record data in the spreadsheet from Orion of the structures that failed. It is therefore not known when the failed structures were inspected last. The 500-kV transmission lines are inspected on a 4-year 10% sample inspection. Possibly this frequency was insufficient on this particular line to observe and rectify bolt problems.

During the site visit it was observed that several foundation bolts of the Conservation–Corbett 500-kV transmission line were loose. Foundation bolts on other 500-kV transmission lines appeared to be welded to the base plate. It cannot be established definitively, but this situation may have been a been a contributing factor to cascading failures.

5.7 Conclusions

FPL's transmission lines are designed in accordance with the requirements form the NESC, including extreme wind requirements, applicable at the time of design.

Hurricane Wilma was a significant event that caused a number of failures in FPL's transmission system. Many failures were relatively minor and were repaired shortly after initial discovery. The exact wind speed during Hurricane Wilma is not known, but transmission structural damage indicates that Wilma was a Category 2 storm or stronger. This agrees with the KEMA weather analysis that shows that Wilma was Category 2 to Category 3.

Transmission issues can be categorized based on damage that occurred on less-than 500-kV transmission lines, and damage that occurred on 500-kV transmission lines.

For transmission structural damage that occurred during Wilma on less-than 500-kV lines, most occurred on single-pole unguyed wood structures. These facilities met the required design codes at the time of installation, but differ from current designs being implemented at FPL. This was the primary contributing factor for these failures.

Only one 500-kV transmission line experienced structural damage during Wilma, but this particular line had 30 tower failures. The major contributing factor for these tower failures was the installation guidelines for manual tightening of crossbrace bolts, which is insufficient and led to the loosening of crossbrace bolts in certain cases.

6 Substation Forensic Analysis

This section reviews the substation design standards at FPL for compliance with applicable codes and safety standards and for adherence to accepted industry practices. The intent is to validate the FPL standards with regards to (1) minimum safety requirements, (2) normal system performance, and (3) extreme wind conditions.

This section also reviews the FPL maintenance practices and procedures for substations with regards to completeness, timeliness, procedures for issues discovered in routine inspections and compliance with the established schedule. Also included is a review of the substation damage experienced during Hurricane Wilma and an examination of the maintenance records of major equipment that failed (breakers, transformers).

6.1 Summary of Findings

FPL designs its substations according to extreme wind criteria. The FPL substation performance during Wilma was acceptable, and structural damage to substations was minor. Although FPL experienced outages on 241 substations during Wilma, most were due to the outage of transmission lines serving these stations; only 8 required equipment repair before being reenergized. With some minor exceptions, there was no discernible pattern of equipment failure that indicates a design or maintenance concern.

6.2 Forensic Data

6.2.1 Levels of repair required

As a result of Hurricane Wilma, FPL experienced outages at 241 substations across the system. Six of these stations are classified as transmission substations with the remaining 235 classified as distribution substations. Review of data and damage assessment records revealed the following:

- 227 of the 235 distribution substations were out of service because transmission lines feeding the substations were out of service.
- 8 substations required equipment replacement or repair before being reenergized.
- Some stations required major equipment repair or replacement but, because of equipment redundancy in the substation, were capable of being reenergized when transmission service was available.
- Structural damage to substations was minor as a result of Hurricane Wilma.
- With some minor exception, no discernible pattern of equipment failure that could indicate a design or maintenance concern is evident in the substation damage assessment records.

Substation damage due to Hurricane Wilma can be categorized as follows:

- Severe:	Major repair or equipment replacement required; station not available.
- Moderate:	Major repair or equipment replacement required; station available through redundant equipment or capacity.
- Midlevel:	Some equipment replacement required; station available.

Damage assessment and repair records from Hurricane Wilma show that eight substations experience severe damage; eight stations experienced moderate damage; and forty-five stations had midlevel repairs required. Figure 6-1 illustrates the location of the substations in each of the above categories. Coincidence of location of substations requiring repair and high pole failure rates is evident in the graphic. The pole failure rate data is explained in detail in Section 7 of this report.

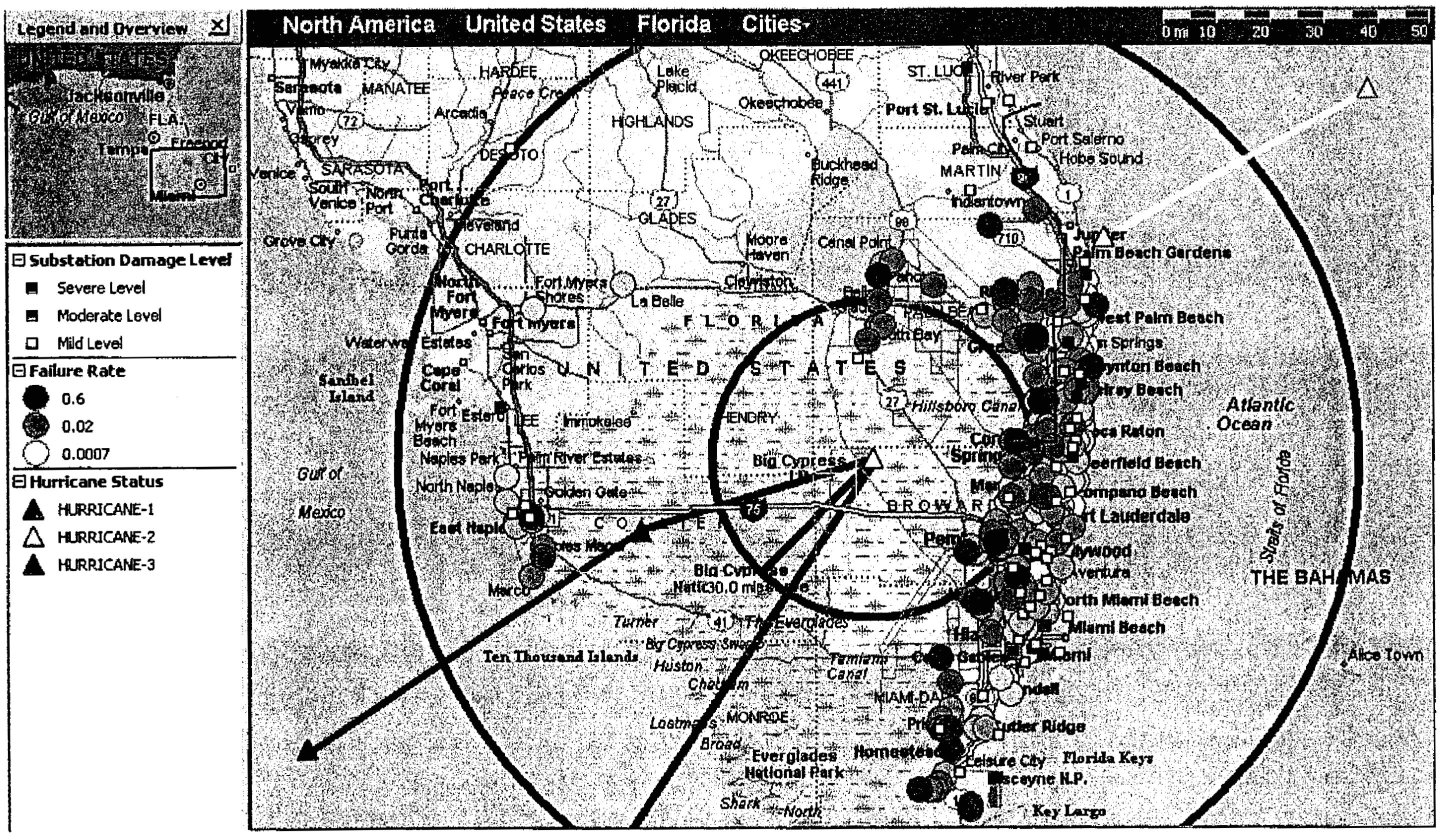
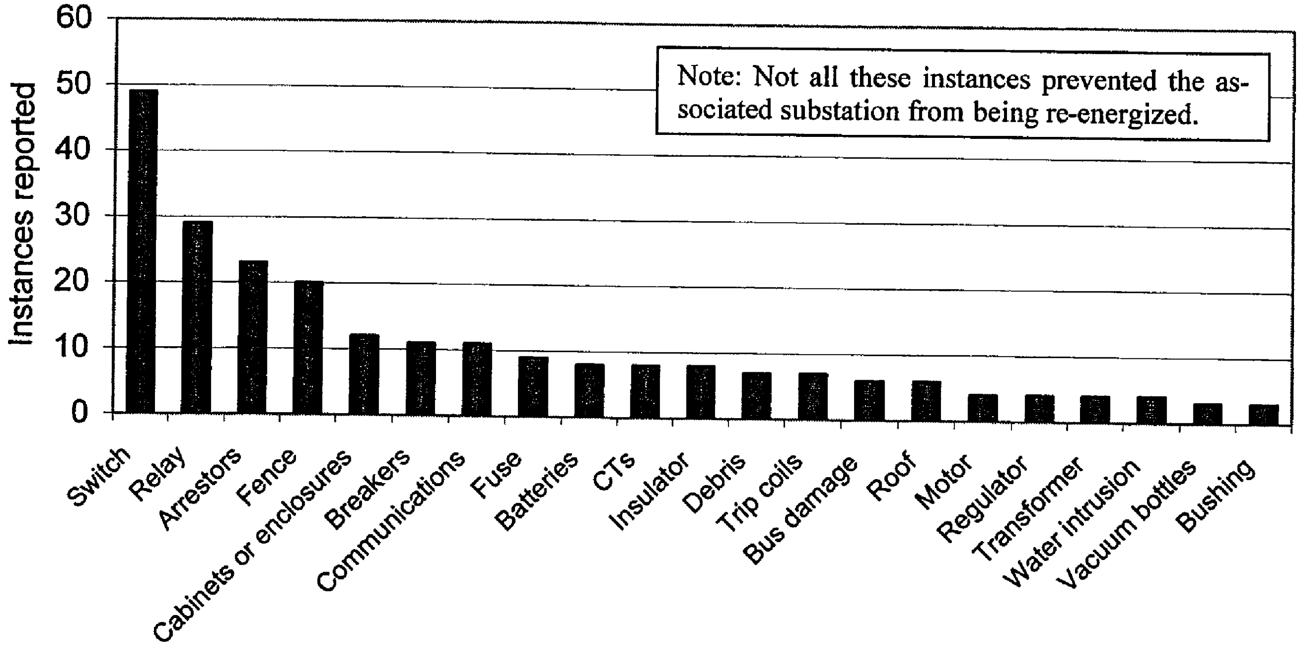


Figure 6-1. Location of substations requiring equipment replacement.

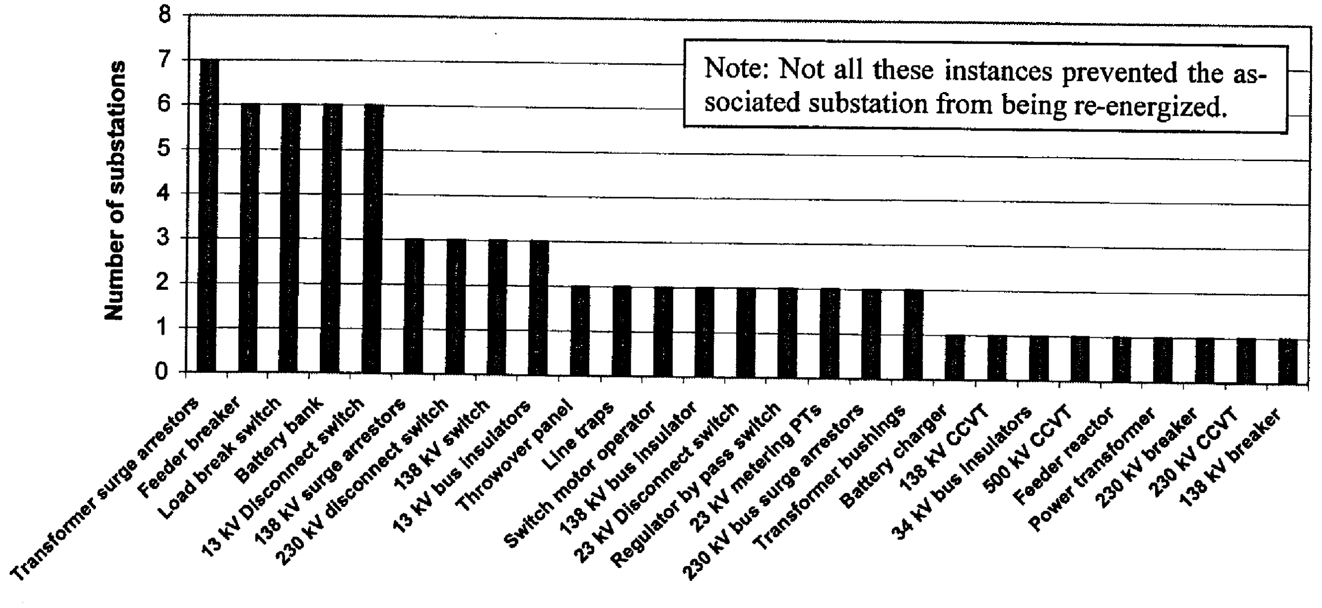
6.2.2 Substation Assessments

Data provided by FPL indicates a total of 364 substations were inspected for damage following the storm. As outlined in the previous section, 61 of those substations required some level of equipment replacement. The remaining 303 substations were reported to have varying levels of minor damage that required some on-site repairs of equipment or systems or no damage at all. The types of equipment noted for repair at all substations inspected and the number of incidences noted for each category are detailed in Figure 6-2. For those substations where equipment repair or replacement was required, the categories of equipment were distributed as shown in Figure 6-3.



Note: Not all these instances prevented the associated substation from being re-energized.

Figure 6-2. Types of substation equipment requiring repair or replacement after Wilma.



Note: Not all these instances prevented the associated substation from being re-energized.

Figure 6-3. Substation Equipment requiring repair of replacement after Wilma.

6.3 Maintenance

Routine substation maintenance at FPL consists of the following activities:

- Quarterly substation condition assessment for all substations.
  This assessment consists of a visual inspection of the substation for any noticeable issues which are in turned corrected or submitted to the appropriate personnel for follow up maintenance. The FPL "Substation Reliability Work Planning/Exposure Identification Program" documentation serves as the procedural guideline for the substation inspection program. This document, used both as a training aid and an inspection guide, provides detailed pictorial information on what to look for in particular equipment or areas of a substation and the procedures to follow to ensure proper maintenance or attention to items noted.

- Semiannual thermographic inspection of substations.
  These inspections are typically done before the end of May each year and again in the late summer or fall, after the system summer peak load has been experienced. Thermographic surveys are also conducted after major storms to examine equipment for damage not visible through visual inspections.

- Transformer gas analysis.
  Dissolved gas analysis (DGA) on transformers is performed at least annually. Any transformers that have experienced major problems due to normal operations or storm conditions are also subject to other tests such as power factor, transformer turns ratio (TTR), more frequent DGA, etc. Detailed records by unit are maintained and used for individual unit trend analysis.

- Station check operational testing.
  This is an annual functional test of protection equipment in the substation. Transformer protective equipment and bus tie breakers are included in this testing.

FPL used reliability centered maintenance (RCM) practices to set schedules and cycles for planned maintenance on much of their substation equipment. The RCM practice used information from condition assessment, equipment events, manufacturers bulletins and other inputs to determine the optimum cycle time for planned maintenance.

7 Distribution Forensic Analysis

This section outlines the result of a thorough data inventory, collection, review and analysis effort in order to better understand the distribution pole breakages during Hurricane Wilma. Pole performance during normal conditions has been compared to storm conditions and several past hurricanes have been compared. Findings with respect to the number of breakages, breakage rates, root causes, likely scenarios and explanations have been generated together with geographical maps, thematically overlaying and representing different data sets. An integral interpretation of the findings together with the findings from other investigation efforts within this engineering analysis, such as the standards review and maintenance assessment, will be reported.

7.1 Summary of Findings

- The forensic data as gathered by FPL staff during the restoration of Hurricane Wilma damage was very useful for engineering analysis. Specific additions to this forensic study and data collection process together with improved accuracy in the pole population data would enable more specific and targeted engineering solutions.
- Wind is the predominant root cause of pole breakage based on analysis of the forensic data collected after Hurricane Wilma.
- Wilma was a Category 3 hurricane, later transitioning into Category 2, with greater impact than Hurricane Katrina, which was Category 1, when covering FPL's service territory. Hurricane Wilma's force and the impacted area resulted in a five-times higher pole breakage versus exposure ratio.
- Wilma traveled from West to East over Florida. When Wilma reached the western part of the Tri-County Area (Palm Beach, Miami-Dade, and Broward), it affected many feeders in open areas with relatively young CCA type poles. Most of the pole breakages in this area were caused by wind only. Over 85% of these incidences were most likely multiple breakages where one pole breaks first and takes down a series of other poles.
- Subsequently, Wilma transitioned to a Category 2 hurricane and moved into the eastern part of the Tri-County Area, which has many older Creosote type poles. The relatively small amount of pole breakages in this area was mainly due to (1) falling trees and (2) creosote feeder poles with some levels of deterioration.
- FPL pole performance during non-hurricane conditions is good. Distribution pole performance during Wilma is known to be acceptable, since FPL gathered extensive forensic data on Wilma pole failures. During Wilma, the FPL pole breakage was below 1.5% of the total amount of FPL owned poles exposed to hurricane wind speeds. This pole breakage ratio is in line with past hurricane pole performance, correcting for hurricane severity.

7.2 Available Data

7.2.1 Pole Population Data

In order to assess the impact of the hurricane, the ratio of broken poles versus exposed poles, and to evaluate potential root causes and scenario's we have made significant effort to collect information pertaining to pole location, type, vintage, class and height. The following resources have been evaluated:

Accounting records, being the most accurate data source when it comes to amounts, material (not type), height and vintages, has been processed and used. It should be noted that vintage data for retired poles is processed according to the Iowa curve method (based on pole retirement work orders issued during normal operations and the total number of poles issued during hurricane conditions). Location and type are not available.

Table 7-1. Total FPL pole population by type from accounting data

Type	FPL Owned
CCA	716,911
Creosote	307,002
Concrete	65,655
Total	1,089,568

A Geographic Information System, MapFrame, was available to add the location and class information. The audited MapFrame data for Palm Beach county has been evaluated but can not be consolidated with accounting numbers, potentially due to pole ownership and area (county versus management area) issues. The data has been reviewed closely but has been dismissed for further use based on its limited area coverage (Palm Beach County only) and limited accuracy. The limited accuracy appears from the following table where the audited MapFrame data are compared to property accounting records. The percentage of FPL owned feeder poles in the system should be approximately 35%, as verbally reported by FPL.

Table 7-2. Feeder pole percentage by ownership in Palm Beach County

	FPL	Third Party	Total
Feeder pole population in MapFrame (filtered Palm Beach management area to obtain Palm Beach county)	56,635	6,590	63,225
Population in property accounting	118,086	41,884	159,970
% of feeder poles in Palm Beach county	47.96%	15.73%	39.52%

FPL performs a pole attachment audit on a 5-year basis covering the entire service area. The data has been received and covers location, height and ownership of approximately 820,000 FPL owned poles with attachments. Vintage, type and class information is not available. Based on these unavailable data points and the fact that poles without attachments are not covered by audits, KEMA has not used this data file for further analysis and graphical representation.

FPL has commercially available storm damage prediction software named Hurrtrak. The input file for this modeling software contains equipment density per geographic area (1 square mile area). The construction grade per area is also provided. Although the data contains both FPL owned and third party owned poles, the totals add up to 1.03 million poles instead of 1.09 million poles plus the approximately 0.23 million third party owned poles. The pole density per area has been extracted for failure rate calculations and geographic representation.

Going forward with the accounting data as accurate data pertaining to actual numbers of poles per county and Hurrtrak data for location, the following data comparison tells us that the Hurrtrak data is accurate for the total affected area but shows approximately 20% more poles in the Tri-county area. The failure rates that will be derived from this data in a later stage will therefore be lower than actual failure rates. However, the failure rates are used only for comparison between areas, root causes, pole types and circuit types as well as a Wilma versus Katrina comparison. Both will use the same Hurrtrak data and result in identical deviations.

Table 7-3. FPL pole population in nine counties affected by Wilma with poles issued

County	# Concrete Poles (Accounting)	# Wood Poles (Accounting)	Total (Accounting)	Total (Hurrtrak)
BREVARD	3,640	117,602	121,242	93,311
BROWARD	18,181	82,379	100,560	161,258
CHARLOTTE	1,313	47,829	49,142	46,927
SARASOTA	1,452	59,293	60,745	51,167
DADE	18,217	125,086	143,303	107,256
LEE	2,671	66,350	69,021	37,699
PALM BEACH	7,961	110,125	118,086	152,025
ST. LUCIE	2,449	44,454	46,903	56,441
VOLUSIA	1,430	55,744	57,174	43,506
Total	57,314	708,862	766,176	749,590

Table 7-4. FPL owned pole population in the Tri-county area (Broward, Dade and Palm Beach)

County	# Concrete Poles (Accounting)	# Wood Poles (Accounting)	Total (Accounting)	Total (Hurrtrak)
BROWARD	18,181	82,379	100,560	161,258
DADE	18,217	125,086	143,303	107,256
PALM BEACH	7,961	110,125	118,086	152,025
Total	44,359	317,590	361,949	420,539

Figures 7-1 and 7-2 show the wood pole and concrete pole vintages, respectively, before Hurricane Wilma. The spike in 1993 records for wood poles can be explained by 20,580 replacement poles needed for broken poles caused by Category 5 hurricane Andrew in 1992. The years 1977 and 1978 are low on remaining poles, preceding a spike in 1979. These low volumes have been confirmed by pole installation records from procurement. It can be seen from both figures that FPL's recent pole expansion is decreasing, most likely due to new services being connected through underground systems.

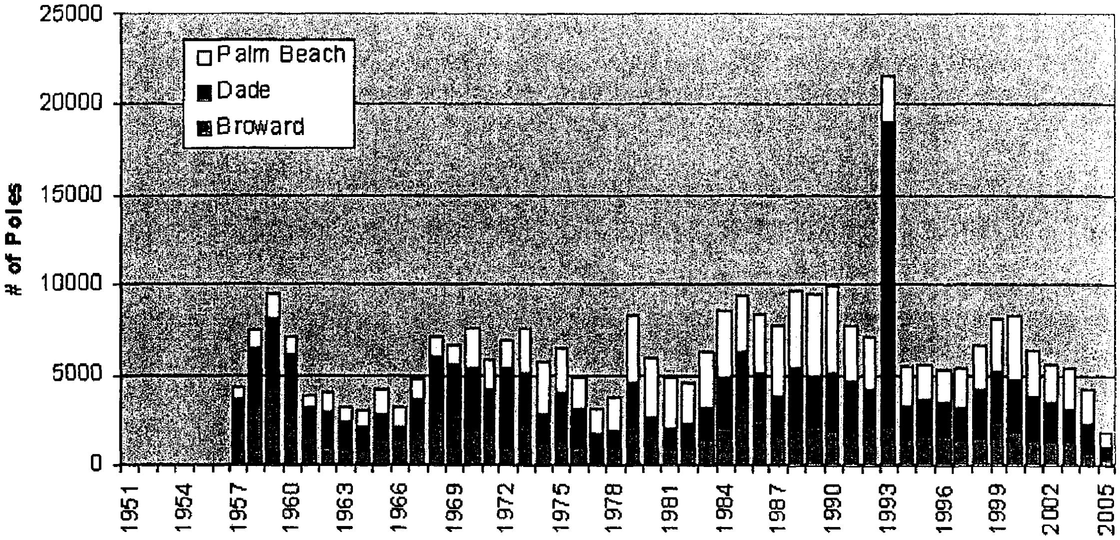


Figure 7-1. Wood pole population versus vintage for the Tri-county per accounting data

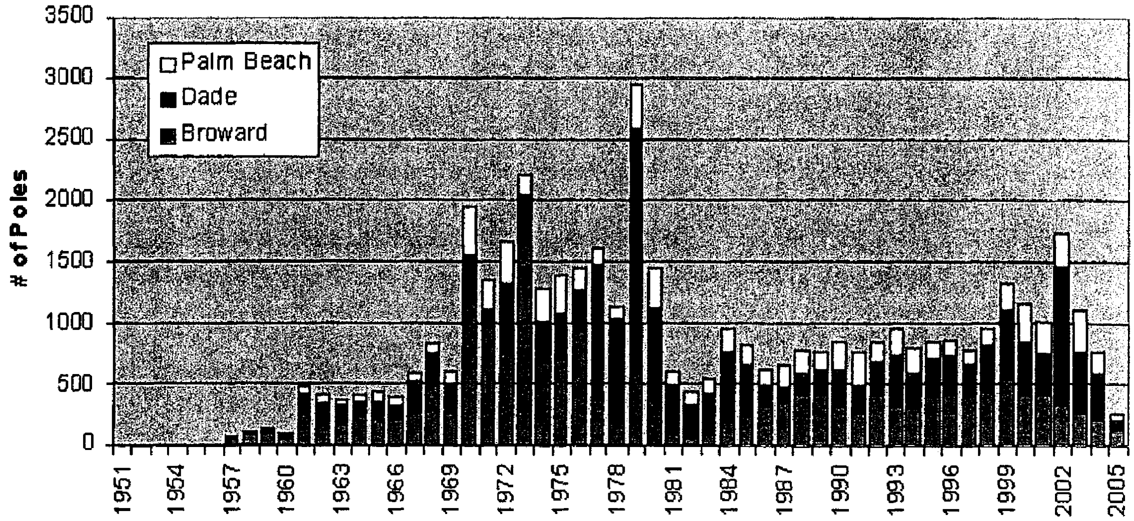


Figure 7-2. Concrete pole population versus vintage for the Tri-county per accounting data

7.2.2 Normal operations

Since October 2003, FPL has maintained report cards to monitor equipment and system performance during normal operations. From these report cards we derived the following:

The 12-month rolling average of known feeder pole caused outages trends up from 10 interruptions per year at the end of 2003 to approximately 40 as of September 2005. Most of these pole related interruptions are caused by fire from dielectric tracking. Deterioration caused feeder pole outages are constant between May 2003 and September 2005 with a 12-month rolling average of approximately 4 outages.

The 12-month rolling average of all feeder and lateral pole caused outages trends up from approximately 57 interruptions in October 2003 to 146 in September 2005. There is no cause data available other than the above-mentioned feeder pole cause data.

The 12-month rolling average of poles issued during normal operating conditions (excluding capital work for new services) is slightly trending down from approximately 13,000 at the end of 2003 to 12,000 as of September 2005. Taking into account a total FPL-owned population of approximately 1.09 million poles, this results in a maximum pole replacement rate trending down from 1.2% to 1.0%. Typical reasons for pole replacement include relocations due to road widenings and re-conductoring due to capacity expansion projects.

7.2.3 Weather Data

As opposed to many statements by the media, Wilma was a Category 3 hurricane when it made landfall at the Southwest coast of Florida traveling to the Northeast. It transitioned into a Category 2 hurricane just over land and left the state as a Category 2 hurricane.

Quote from the National Oceanic and Atmospheric Administration (NOAA) regarding Hurricane Wilma:

> "THE HURRICANE STRENGTHENED AS IT APPROACHED THE SOUTHWEST FLORIDA COAST...AND IT MADE LANDFALL NEAR CAPE ROMANO ON 24 OCTOBER WITH CATEGORY 3 INTENSITY. THE SYSTEM CONTINUED TO ACCELERATE NORTHEASTWARD...CROSSING FLORIDA IN LESS THAN 5 HOURS. WILMA MOVED INTO THE ATLANTIC JUST TO THE NORTH OF PALM BEACH AS A CATEGORY 2 HURRICANE. IT REGAINED CATEGORY 3 STATUS JUST OFF THE CENTRAL EAST COAST OF FLORIDA..."

The maximum 1-minute sustained wind speed over the duration that the storm crossed Florida as reported by Unisys on their website was 110 knots (127 mph). This comes close to a Category 4 hurricane, as defined by the generally applied Saffir-Simpson scale. For comparison, Katrina had a maximum sustained wind speed of 70 knots (81 mph), according to the same source. This is low in the Category 1 range of the Saffir-Simpson scale.

Peak gusts as read from yet unofficial NOAA weather reports are as follows:

Hurricane Wilma:
West Palm Beach (PBI) 88 knots (ASOS, Automated Surfaces Observing System)
Miami Dade 107 knots (C-MAN, Coastal Marine automated network)
Collier 101 knots (Mesonet)
Broward 104 knots (Unofficial)

The available preliminary weather data for Hurricane Wilma has been reviewed by meteorologist and hurricane expert Dr. T.N. Krishnamurti from Florida State University, department of meteorology (see Appendix B for Dr. Krishnamurti's full report). The influence of tornadoes and rain bands within the hurricane area and the height of wind speed measurement has been evaluated. The reported wind speeds in the Tri-county area are not influenced by the reported four tornadoes as their locations are outside this area under investigation. The stronger winds were recorded by instruments located at a height of 60 ft. Wind speeds measured at a 60 ft height are typically higher than surface wind speeds. The North-East section of the storm carried the heaviest rains and strongest winds, traversed the counties Palm Beach (south section), Broward and Dade. With the front side typically being the strongest, it must also be noted that Palm Beach county is the area affected most by the back side of the hurricane. This is confirmed by the following unofficial measurement.

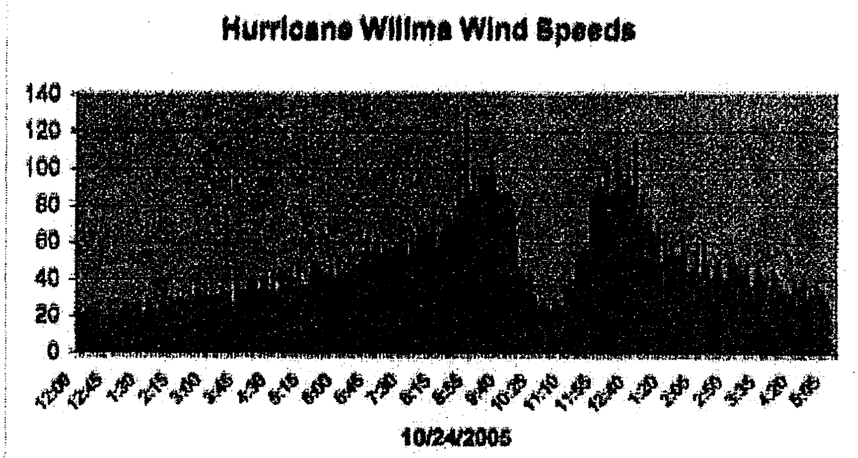


Photo courtesy of the city of Palm Beach Gardens
A graphs shows wind speeds from Hurricane Wilma, measured during the storm at the city Emergency Operations Center. Shortly before the arrival of the eyewall, winds were measured at 129 mph.

Figure 7-3. Hurricane Wilma wind speeds as measured in Palm Beach County, courtesy of the city of Palm Beach Gardens.

The expert review confirmed that the preliminary NOAA data is reliable and confirms the areas with most damage and above statements with respect to the hurricane category.

Katrina, on the other hand, made landfall at the Southeast coast as a Category 1 hurricane, left the state as a tropical storm, before picking up force, eventually becoming a Category 5 hurricane over the Gulf of Mexico. It is important to notice that Katrina and Wilma traveled in opposite direction while traversing Florida.

Hurricane Katrina:
Broward (FLL) 71 knots (ASOS)
Miami Dade 68 knots (C-MAN)
Miami Dade 81 knots (Mesonet)
Miami Dade 84 knots (Unofficial)

It should be noticed that 153 concrete poles broke during Hurricane Wilma. As opposed to the concrete pole breakages during Hurricane Katrina (all caused by falling trees), more than half of the concrete pole breakages during Wilma were caused by wind only.

7.2.4 Pole performance during hurricanes

Actual pole breakage data by county is based on records of poles issued during the hurricanes by FPL. As FPL can replace both FPL and third party broken poles during hurricane restoration, this data needs to be interpreted carefully against forensic and population data.

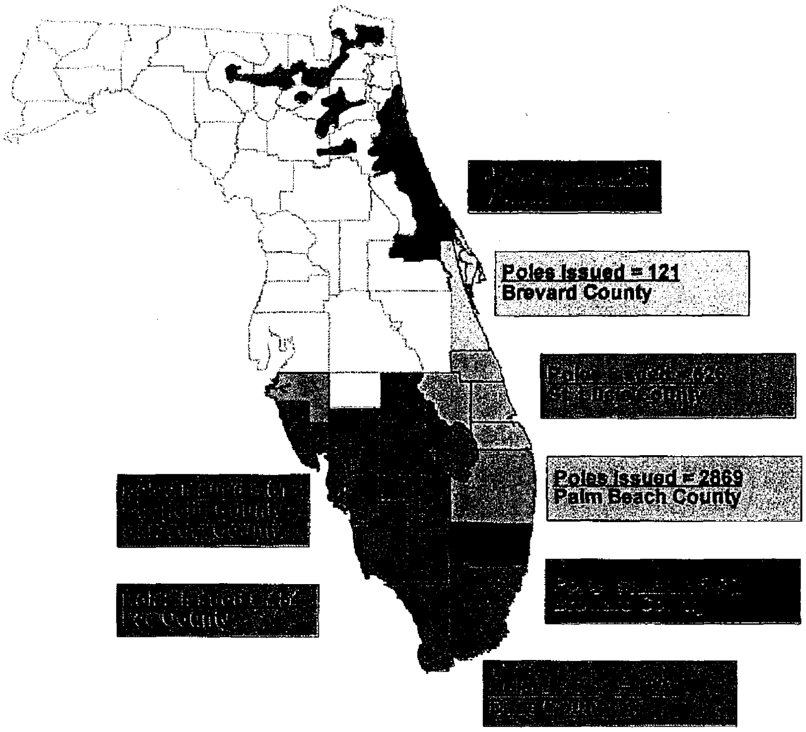


Figure 7-4. Total counts of distribution poles issued by county during Hurricane Wilma

Table 7-5. Wilma total pole failure rate by county for counties with poles issued (including both FPL and third party poles)

County	FPL Pole Population	Third party Population	Total Pole Population	# poles issued	Failure rate	Wind speeds (knots)
BREVARD	121,242	21,651	142,893	121	0.08%	42
BROWARD	100,560	39,623	140,183	5,432	3.87%	72
CHARLOTTE & SARASOTA	109,887	0	109,887	61	0.06%	45
DADE	143,303	59,747	203,050	1,875	0.92%	74
LEE	69,021	0	69,021	454	0.66%	54
PALM BEACH	118,086	41,884	159,970	2,869	1.79%	71
ST. LUCIE	46,903	24,203	71,106	526	0.74%	45
VOLUSIA	57,174	10,843	68,017	33	0.05%	25
Total	766,176	197,951	964,127	11,371	1.18%	

Table 7-6. Comparison of past hurricane pole performance (including both FPL and third party poles)

Year	Name	Number of poles exposed to 74+ mph wind speeds	Poles issued	% of exposed poles that failed	Hurricane Category
1992	Andrew	203,500	20,580	10.1%	5
2004	Charley	222,666	6,878	3.1%	3-4
2004	Frances	397,134	3,757	0.9%	2
2004	Jeanne	455,302	2,227	0.5%	2-3
2005	Katrina	343,200	1,086	0.3%	1
2005	Wilma	773,700	11,371	1.5%	2-3

Table 7-5 correlates the maximum one-minute sustained wind speeds with the pole failure rate by county. It is assumed that poles issued represent poles broken in the same county. This table confirms that the number of poles issued correlates well with the maximum one-minute sustained wind speeds, as expected, keeping in the mind that the number of poles issued in a certain county does not necessarily represent the actual number of pole breakages in that county. The table also indicates that the counties Broward, Palm Beach and Dade are affected most by Hurricane Wilma and particularly in that order ranked by failure rate.

Table 7-6 shows the relationship between pole failure rates and hurricane severity. This is done by dividing the number of poles issued during storm restoration by the total number of poles exposed to hurricane force winds. As can be seen in Table 7-6, pole failure rates correspond closely to hurricane category. For example, Katrina was the weakest recent hurricane at Category 1, and only had a 0.3% pole failure rate. Wilma was Category 2 to Category 3, and had a 1.5% pole failure rate. Andrew was Category 5, and had a 10.1% pole failure rate.

The only anomaly in Table 7-6 is Jeanne, which shows an unexpected low pole failure rate of 0.5%. Jeanne, however, affected the same area as hurricane Frances, shortly after Frances, and traveled in the same direction as Frances. In effect, Frances did most of the "Category 2 damage" in this area and only left Jeanne with the opportunity to do "Category 3 damage". If Frances and Jeanne are considered as a single event and their failure rates are added, the results are an equivalent Frances/Jeanne hurricane of Category 2 to Category 3, with a 1.4% pole failure rate. This corresponds very closely to Wilma statistics.

7.2.5 Forensic data

Assumptions that KEMA made processing and interpreting the FPL forensic data on the pole sampling and established root causes of pole breakages:

- FPL verbally confirms that the forensic studies have been based on a balanced geographic survey of the Tri-county area and, to some extent, Collier County. The exact routes, locations and areas have not been established other than where actual poles have been examined.
- FPL verbally confirms that the total pole breakage ratio between feeder poles and lateral poles is about 45/55%.
- FPL verbally confirms that there is an approximate feeder pole versus lateral pole ratio of 35/65% in the system. Among these, as a result of a variety of reasons, creosote poles are mostly found on lateral circuits (80%) and CCA poles divide 55% / 45% over lateral and feeder circuits.
- FPL verbally confirms that assignment of root causes is a personal judgment call irrespective of the pole ownership.

Wilma forensic broken pole investigation yielded 1742 records versus a total amount of broken poles of approximately 11,371 (15%). This sample size is sufficient for statistical analysis resulting in a 95% confidence level and range of 2.2%. This means that conclusions from statistical analysis of this sample yields results in a range plus or minus 2.2% with 95% certainty.

Katrina forensic broken pole investigation resulted in 157 records (no direction recorded) versus a total amount of broken poles of approximately 1086 (15%). The same confidence level and range are established with this sample size.

7.3 Analysis and findings

Pole breakage and contributing factors

From the received FPL forensic data, as the first analysis, a statistical analysis on contributing factors has been performed. It must be noted that these contributing factors are all subjected to the primary root cause being wind (wind only). It is unlikely that poles would break had the strong wind not occurred in the first place. Table 7-7 lists statistics of different contributing factors categorized by circuit type. Table 7-8, an expansion of Table 7-7, lists statistics of different contributing factors categorized by circuit type and pole type.

Table 7-7. FPL owned pole breakage; contributing factor comparison between Wilma and Katrina by circuit type.

Wilma Contributing Factors to Pole Failures						
Type	**Wind Only**	**Possible Design Overload**	**Tree**	**Presence of Deterioration**	**Other**	**Total**
Feeder	558	45	140	67	33	843
	66%	5%	17%	8%	4%	100%
Lateral	13	1	36	51	8	109
	12%	1%	33%	47%	7%	100%
Katrina Contributing Factors to Pole Failures						
Type	**Wind Only**	**Possible Design Overload**	**Tree**	**Presence of Deterioration**	**Other**	**Total**
Feeder	4	12	14	13	2	45
	9%	27%	31%	29%	4%	100%
Lateral	0	0	27	9	1	37
	0%	0%	73%	24%	3%	100%

Table 7-8. FPL owned pole breakage; root cause comparison between Wilma and Katrina by circuit type and pole type

Wilma						
Type	**Wind Only**	**Possible Design Overload**	**Tree**	**Presence of Deterioration**	**Other**	**Total**
Creosote Feeder	64	10	22	64	2	162
	40%	6%	14%	40%	0%	100%
Creosote Lateral	7	1	27	49	5	89
	8%	1%	30%	55%	6%	100%
CCA Feeder	446	33	83	3	20	585
	76%	6%	14%	1%	3%	100%
CCA Lateral	4	0	9	2	2	17
	24%	0%	53%	12%	11%	100%
Concrete Feeder	48	2	35	0	11	96
	50%	2%	36%	0%	12%	100%
Concrete Lateral	2	0	0	0	1	3
	67%	0%	0%	0%	33%	0%
Katrina						
Type	**Wind Only**	**Possible Design Overload**	**Tree**	**Presence of Deterioration**	**Other**	**Total**
Creosote Feeder	1	1	7	13	0	22
	5%	5%	32%	59%	0%	100%
Creosote Lateral	0	0	21	9	0	30
	0%	0%	70%	30%	0%	100%
CCA Feeder	3	11	5	0	2	21
	14%	52%	24%	0%	10%	100%
CCA Lateral	0	0	6	0	1	7
	0%	0%	86%	0%	14%	100%
Concrete Feeder	0	0	2	0	0	2
	0%	0%	100%	0%	0%	100%

These two tables show us the differences between the two hurricanes. Whereas Hurricane Katrina caused many more tree related pole breakages, Hurricane Wilma broke more poles without any indication of presence of deterioration or falling trees. In either hurricane, possible design overload is not identified as the most significant contributing factor. It is noted that the percentage of breakage with possible design overload for CCA feeder poles is estimated at 52%, for Hurricane Katrina. Examination of data, leads KEMA to believe that this number may be relatively high because wind only is relatively low. Potentially, the 11 judgments for possible design overload could be personal judgments from a small group of inspectors.

The tables reflect two additional failure characteristics. First, falling trees affected lateral poles much more than feeder poles. Second, the presence of deterioration as a contributing factor mostly occurred with creosote poles.

Pole failure rates by pole type

In this section, pole failure rates are derived to compare breakage patterns among pole types and circuit types. Failure rates, the ratio of pole breakages against the total number of poles exposed, provides more insight into the actual behavior of the system than absolute numbers of breakages.

As mentioned in Section 7.2.5, the percentage of FPL owned pole breakages (versus third party owned pole breakages) in the investigated sample is assumed to represent the percentage of poles issued to replace FPL owned broken poles. Table 7-9 presents these percentages for the Tri-county area derived from forensic data.

Table 7-9. Percentage of FPL owned pole breakages in total pole breakages during Wilma (Excluding 1 pole breakage without owner information and 23 pole breakages in Collier County)

	Broward	Dade	Palm Beach	Total
FPL pole breakage	262	234	460	956
Third party pole breakage	374	200	188	762
Total pole breakage	636	434	648	1718
% of FPL pole breakages	41.19%	53.92%	70.99%	55.65%

Based on the percentage of FPL pole breakages from Table 7-9, total number of poles issued during Hurricane Wilma and the total pole population by county from Table 7-4, the FPL pole failure rates for each of the three counties are derived and provided in Table 7-10.

Table 7-10. FPL owned pole failure rate in the Tri-county area

County	FPL pole population	# of FPL broken poles	FPL pole failure rate
BROWARD	100,560	2,238	2.23%
DADE	143,303	1,011	0.71%
PALM BEACH	118,086	2,037	1.72%
Total	361,950	5,286	1.46%

These failure rates agree with preliminary weather data. The areas most affected by Hurricane Wilma are Broward County with most likely the highest wind speeds and Palm Beach suffering a strong back side of the storm.

As verbally verified by FPL, among the total poles issued during Hurricane Wilma restoration, 45% were issued to replace broken feeder poles and 55% were issued to replace the broken lateral poles (assumption listed in section 7.2.5). However, the ratio of feeder pole versus lateral pole breakages in the forensic data of Hurricane Wilma is approximately 70% vs. 30%. Therefore, in order to match this ratio in the forensic data with total breakage population, the forensic failure data needs to be adjusted for correct interpretation. The lateral pole breakage data was multiplied by 2.85, while keeping the feeder pole breakage data unchanged. This process was also applied to Hurricane Katrina forensic data using a multiplier 2.3. This multiplier is based on a ratio of 70% / 30% lateral versus feeder pole issues and 50% / 50% feeder pole versus lateral pole breakages.

A sample size of 1154 FPL owned pole breakages for Hurricane Wilma is obtained after adjusting pole breakage ratio between laterals and feeders. Compared to the total 5286 poles issued to replace FPL owned broken poles, a multiplier of 4.6 is applied to each sample data to match total pole breakage counts. The same process is applied to the sample statistics of Hurricane Katrina with a multiplier of 3.9 (132 pole breakages versus 520 poles issued to replace FPL owned poles during the restoration). The final adjusted statistics for both Hurricane Wilma and Hurricane Katrina amount to 5286 and 520 FPL-owned broken poles, respectively.

As addressed in Section 7.2.5, the ratio of creosote poles over lateral circuits and feeder circuits is not the same for CCA poles. Based on the assumption listed in Section 7.2.5 and the fact that creosote poles date from before 1978 and CCA pole were installed during and after 1978, the pole population by circuit type and pole type for the Tri-county area was derived based on the accounting data. This distribution before Hurricane Katrina was assumed to be identical, considering that relative small amount of broken poles during this hurricane.

Combining the numbers from Table 7-3 and 7-4 with the distribution described above, the pole failure rates by circuit type and pole type for Hurricane Wilma and Hurricane Katrina were calculated and listed in Table 7-11.

Table 7-11. Adjusted FPL-owned pole failure rates by circuit type, pole type and contributing factor

Wilma

Type	Wind Only	Possible Design Overload	Tree	Presence of Deterioration	Others	Total
Creosote Feeder	1.26%	0.20%	0.43%	1.26%	0.04%	3.19%
Creosote Lateral	0.10%	0.01%	0.38%	0.69%	0.07%	1.25%
CCA Feeder	2.26%	0.17%	0.42%	0.02%	0.10%	2.96%
CCA Lateral	0.05%	0.00%	0.11%	0.02%	0.02%	0.20%
Wood pole total	0.78%	0.07%	0.30%	0.31%	0.06%	1.51%
Concrete Poles	0.55%	0.02%	0.36%	0.00%	0.14%	1.08%
Total	0.75%	0.06%	0.31%	0.27%	0.07%	1.46%

Katrina

Type	Wind Only	Possible Design Overload	Tree	Presence of Deterioration	Others	Total
Creosote Feeder	0.02%	0.02%	0.12%	0.22%	0.00%	0.37%
Creosote Lateral	0.00%	0.00%	0.20%	0.09%	0.00%	0.29%
CCA Feeder	0.01%	0.05%	0.02%	0.00%	0.01%	0.09%
CCA Lateral	0.00%	0.00%	0.05%	0.00%	0.01%	0.06%
Wood pole total	0.00%	0.01%	0.09%	0.04%	0.01%	0.16%
Concrete Poles	0.00%	0.00%	0.02%	0.00%	0.02%	0.04%
Total	0.00%	0.01%	0.08%	0.04%	0.01%	0.14%

This table shows a slightly different aspect than when considering only absolute numbers of failure records. It confirms that during Hurricane Wilma the pole failure rates were highest due to breakages caused by wind only. Creosote feeder poles showed the highest failure rate, closely followed by CCA feeder poles. Whereas CCA feeder poles mainly broke due to wind only, creosote feeders poles broke mainly due to wind only and/or wind with the contributing factor of deterioration. Creosote lateral poles showed lower failure rates compared to creosote feeder poles, and mostly broke due to either a combination of wind and deterioration or a combination of wind and trees. The failure rates of concrete poles during Hurricane Wilma are relatively high with breakages caused by falling trees and wind only.

Pole breakage during Hurricane Katrina affected mostly creosote feeder poles and creosote lateral poles. The cause of these failures tended to be wind plus the contributing factors of deterioration and falling trees.

Pole failure rates by location

The next analysis will investigate geographical attributes of the forensic data and the derived failure rates. The following set of geographical representations of the FPL service territory affected by hurricane Wilma, show the pole breakage incidents by location and the (non adjusted) pole failure rates by location. The wind speed data in selected locations comes from preliminary NOAA reports, with the actual path, category and effective area information coming from Unisys weather data.

The failure rates are the pole breakages, the geographically mapped forensic data points in all Hurrtrak areas, divided by the population in each area. The pole breakage incident rates are identical to the failure rates, with collapsed multiple failures at a single location (i.e. multiple failures represent one actual failure). The age distribution of broken poles represents the average age of the investigated broken poles in each area. All data points pertain to FPL owned poles. As the failure rates are not adjusted, these values should be used only for geographic comparison. One graphic on the impact of Hurricane Katrina has been added for comparison.

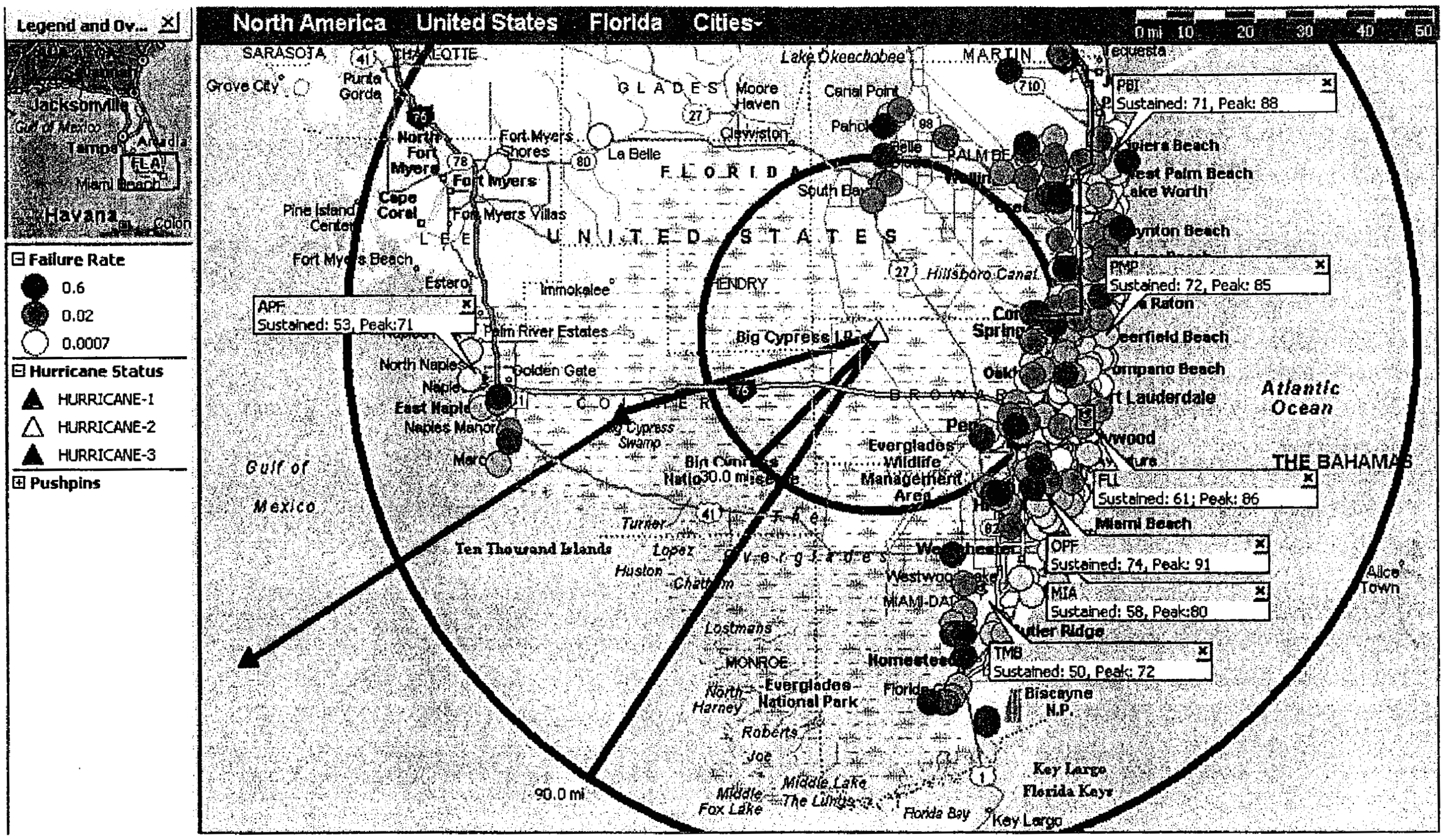


Figure 7-5. Pole failure rate for Hurricane Wilma

From this graphic it becomes apparent that the failure rates are highest at the west side of the Tri-County area. This corresponds with open areas. These places also coincide with the eye wall (red circle) at the last moment the hurricane had a Category 3 classification. Red represents the category 3 path and eye wall, yellow the Category 2 path and blue represents the area affected by hurricane force winds.

The dark blue line coming North-South in Palm Beach represents the grade B and C construction division, with Grade B construction towards the east of this division line.

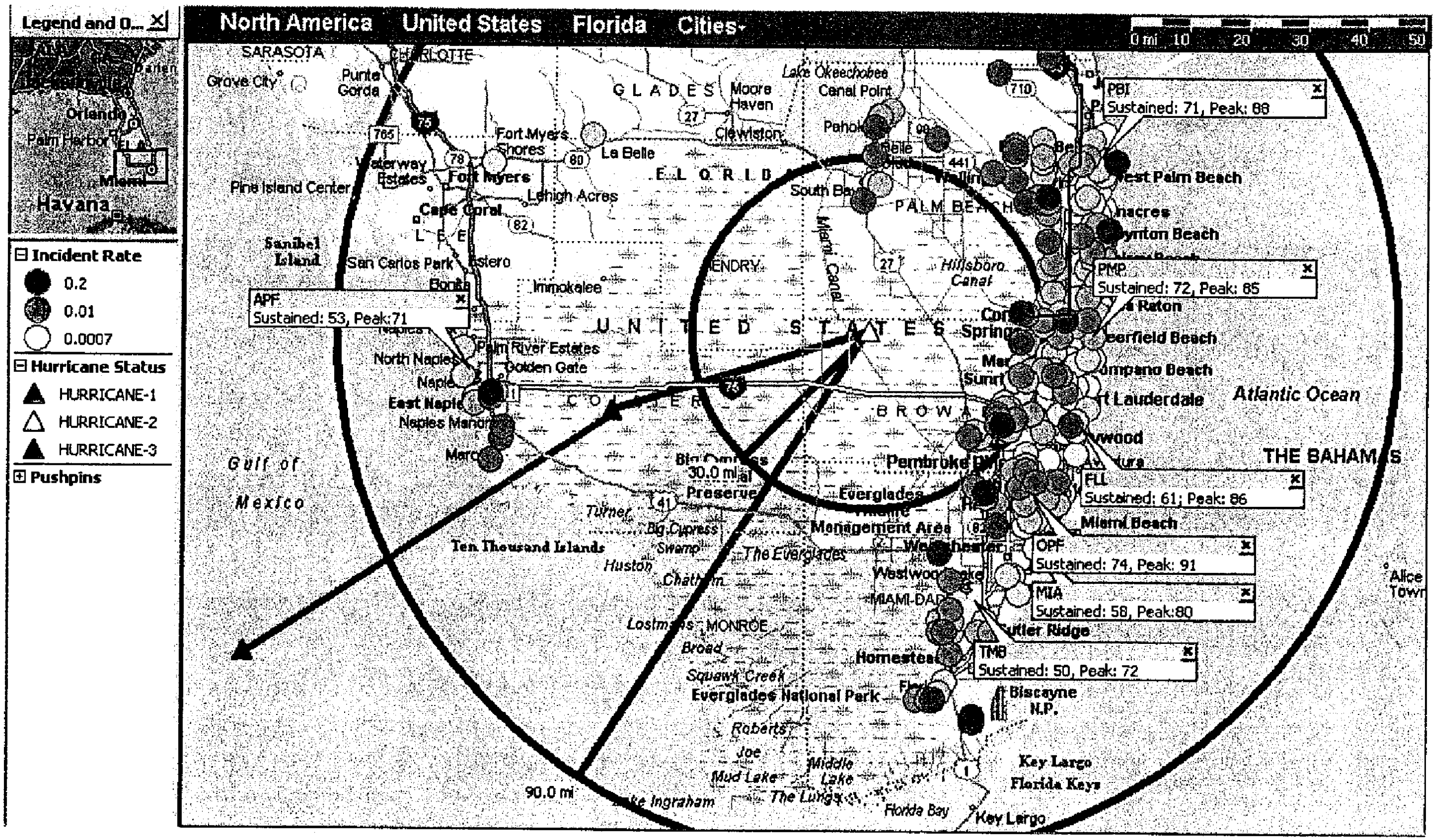


Figure 7-6. Pole breakage incident rate for Hurricane Wilma

This graphic has been produced to ensure proper interpretation of multiple failures. It was expected that the substantial amount of multiple failures, exceeding 85% of the recorded failures, could affect the analysis in general and geographic mapping in particular. However, this graphic with all multiple failures collapsed into single failures, shows similar results as the former graphic.

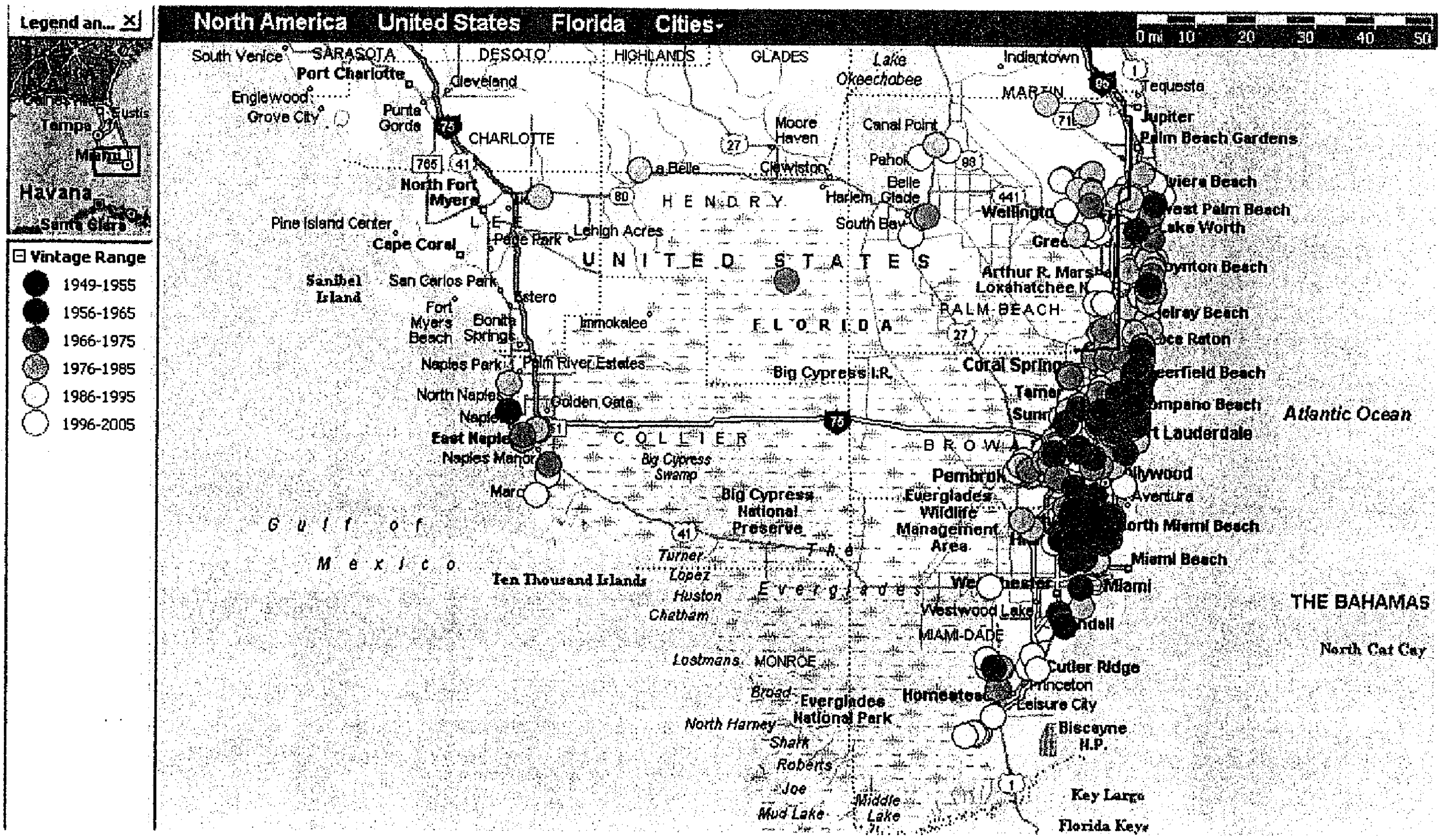


Figure 7-7. Age distribution of broken poles for Hurricane Wilma

This graphic shows opposite results compared to the former two graphics; where the failure rates are lowest the average age of the broken poles is highest and vice versa. It must be emphasized that these ages are the ages of broken poles and not general average pole ages. As Hurrtrak does not have age information, this general age versus area graphic can not be produced.

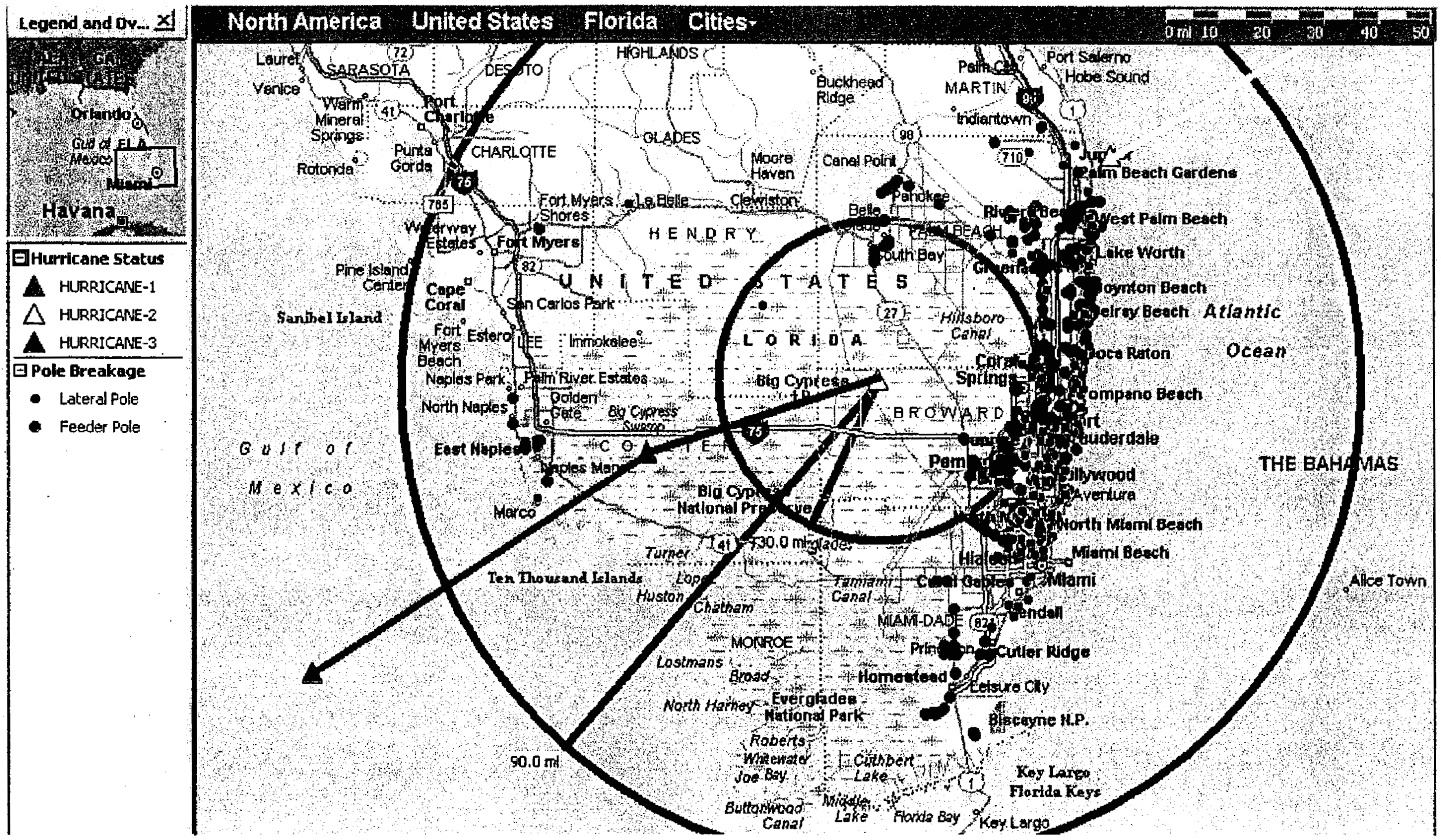


Figure 7-8. Lateral versus feeder pole breakages for Hurricane Wilma

This graphic shows a clear distinction in the investigated area where mostly feeder poles broke and where mostly lateral poles broke during Wilma. The majority of the feeder pole breakages coincide with the areas of higher failure rates and younger poles, except for the East coast of Palm Beach County. This finding triggers two further analyses; one focused on pole breakages for vintages between 1993 and 2004 (to verify potential construct grade effects – parts of Palm Beach allowed grade C construction during this period), the other focused on pole type differences.

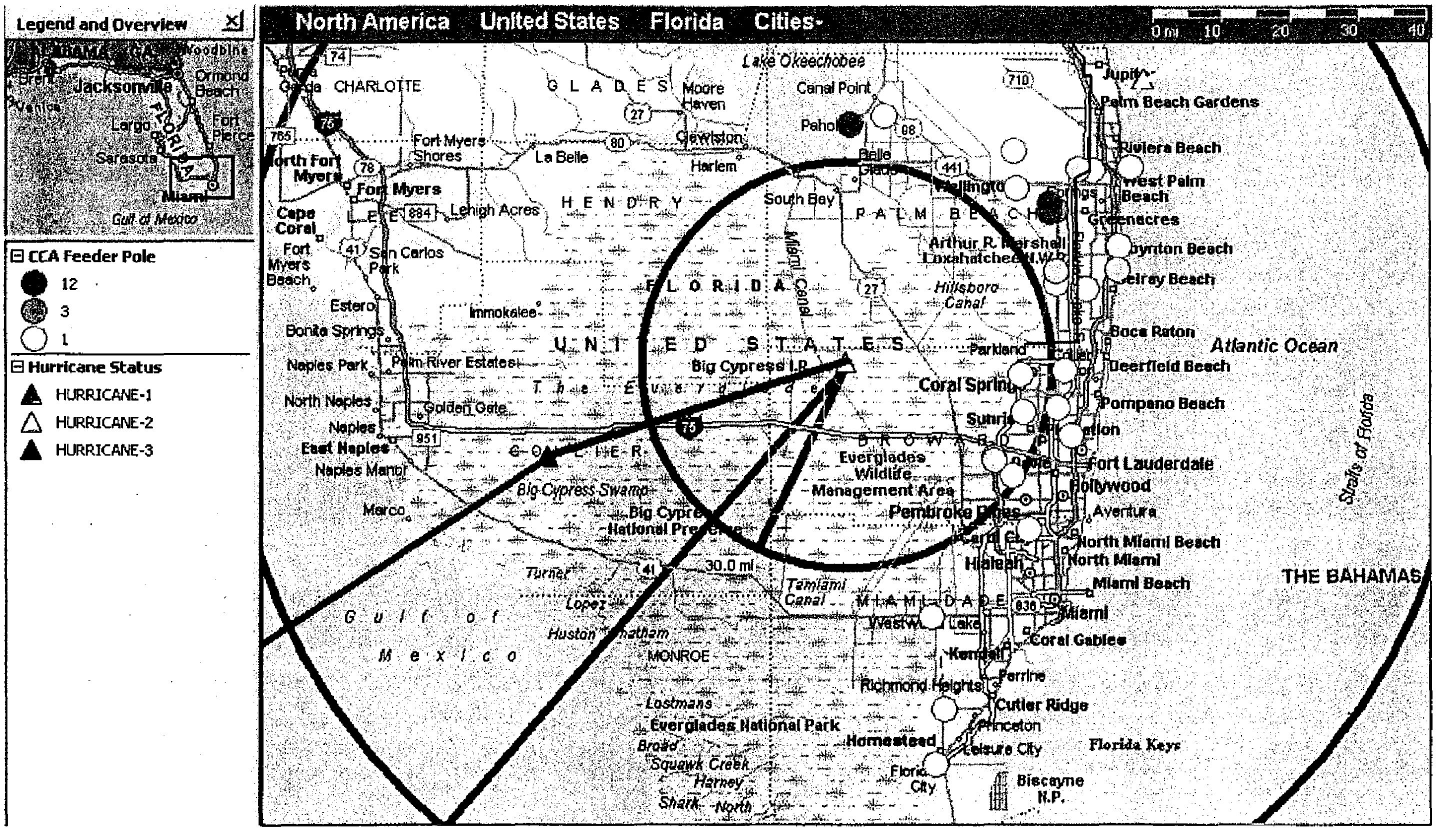


Figure 7-9 Pole breakages for pole vintages between 1993 to 2004

As lateral pole breakages were only found for vintages before 1990, these filtered pole breakages between 1993 and 2002 only included CCA feeder poles. Two concrete feeder pole breakages were recorded in Broward County but have been excluded from this map. Failure rates can not be produced for this aspect as the Hurrtrak data does not provide age data.

Firstly, it can be stated that amount of pole breakages for vintages between 1993 and 2004 was low. Secondly, in Palm Beach County there is some raised level of related incidences potentially indicating a minor construction grade issue. However, the dark green clustered area involved three nearby failures. The three incident locations have multiple breakages that are all caused by wind only. Half of these circuits were double circuits. Most poles had cross-arm construction and half of them fell to the east and half of them fell to the west (all having a North-South orientation). Most of these poles were class 2 poles.

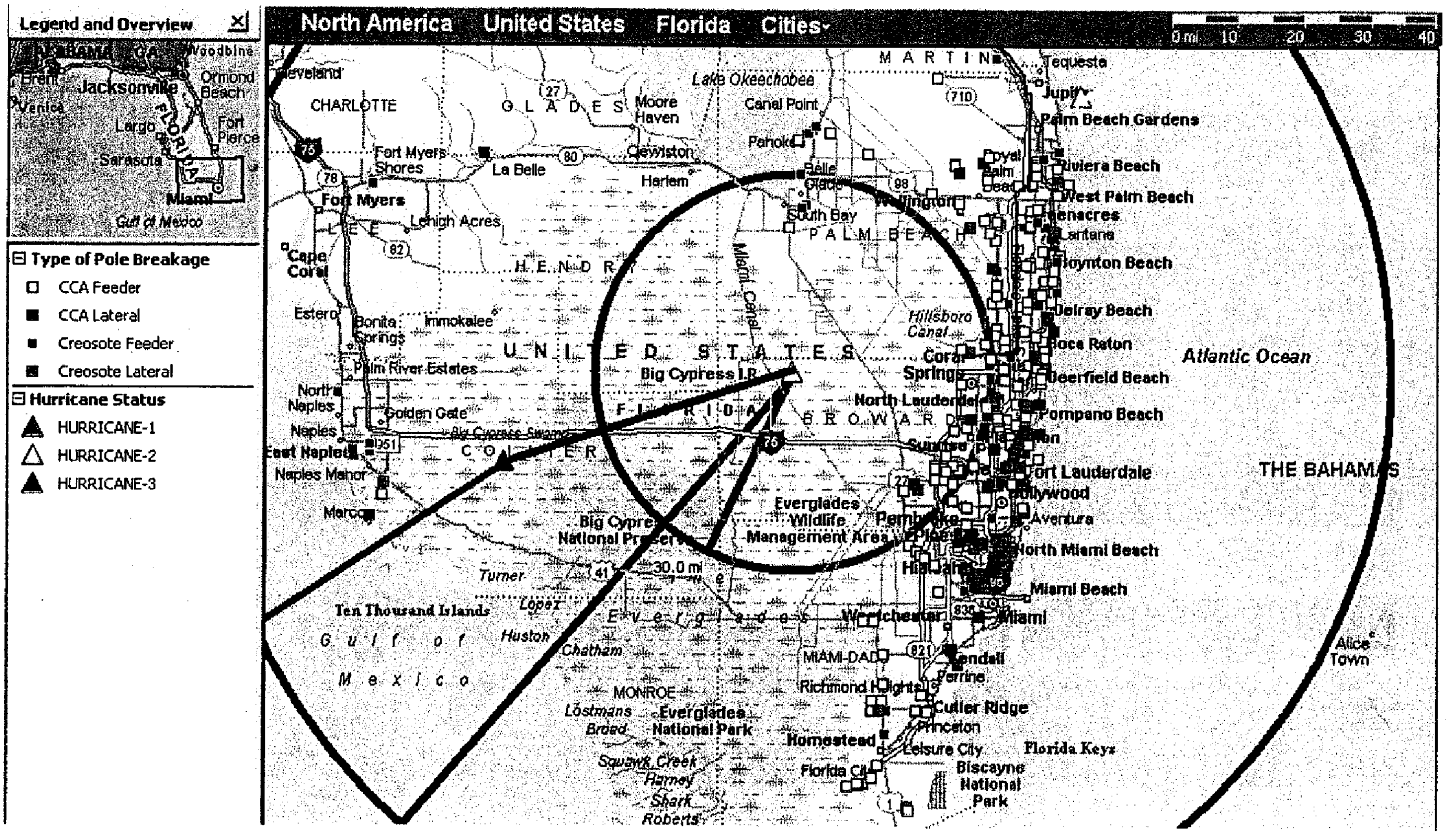


Figure 7-10 Pole breakage by feeder, lateral and pole type

This graphic confirms the findings above with respect to feeder and lateral pole breakages. The graphic adds the fact that most feeder pole breakages involve CCA type poles and lateral pole breakages involve Creosote type poles.

Many CCA feeder poles broke on the East coast of Palm Beach. However, these incidences result in low failure rates as the populations are high in this area. Further investigation revealed that the predominant root cause in this area was wind only, whereas falling trees prevail in the other coastal areas of Broward and Dade counties. From this analysis, is likely that Palm Beach County was hit hardest by the back side of the hurricane.

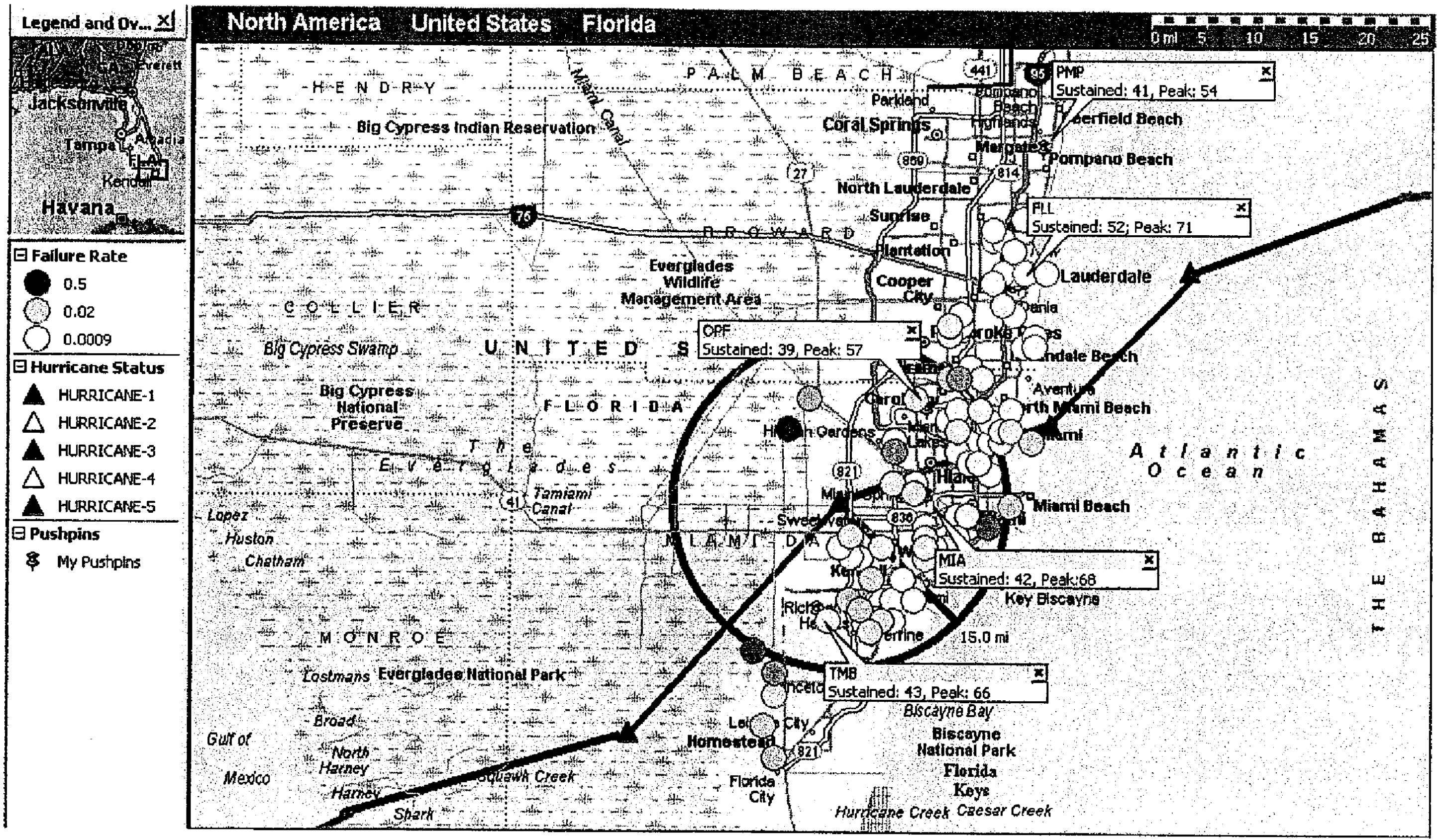


Figure 7-11 Pole failure rate for Hurricane Katrina

The geographic representation of pole failure rates for Katrina shows a much more equal impact over the affected area compared to Wilma. This hurricane had different attributes such as traveling direction, wind speeds and resulted in different pole breakage behavior such as higher impact of falling trees, as has been investigated and reported before.

Pole failure rates by vintage

As the next step in the investigation, we focus on the failure rates as a function of the pole vintage, by root cause and county. All presented failure rates are adjusted to incorporate for the effect of sample size versus total failed population and the sample size without vintage data. Note that the effect of the availability of age data, typically being available for younger poles and less for older poles, has not been corrected for. However, it has been verified that the records with blank vintage data contains both CCA and creosote poles to an equal extent.

Table 7-15. Percentage of FPL owned pole breakage records with vintage data

With vintage data	Broward	Dade	Palm Beach	Total
Yes	179	146	334	659
No	83	88	126	297
Total	262	234	460	956
% of poles with vintage data	68.32%	62.39%	72.61%	68.93%

The forensic data had vintage data for approximately 69% of the records of the investigated FPL owned broken pole population (feeder plus laterals). Furthermore, we take the percentage of investigated versus total pole breakage into account (Table 7-16).

Table 7-16. Percentage of investigated versus non-investigated FPL owned pole breakages

FPL pole breakage	Broward	Dade	Palm Beach	Total
Investigated	262	234	460	956
Total broken	2,238	1,011	2,037	5286
% of investigated FPL pole breakages	11.71%	23.15%	22.58%	18.09%

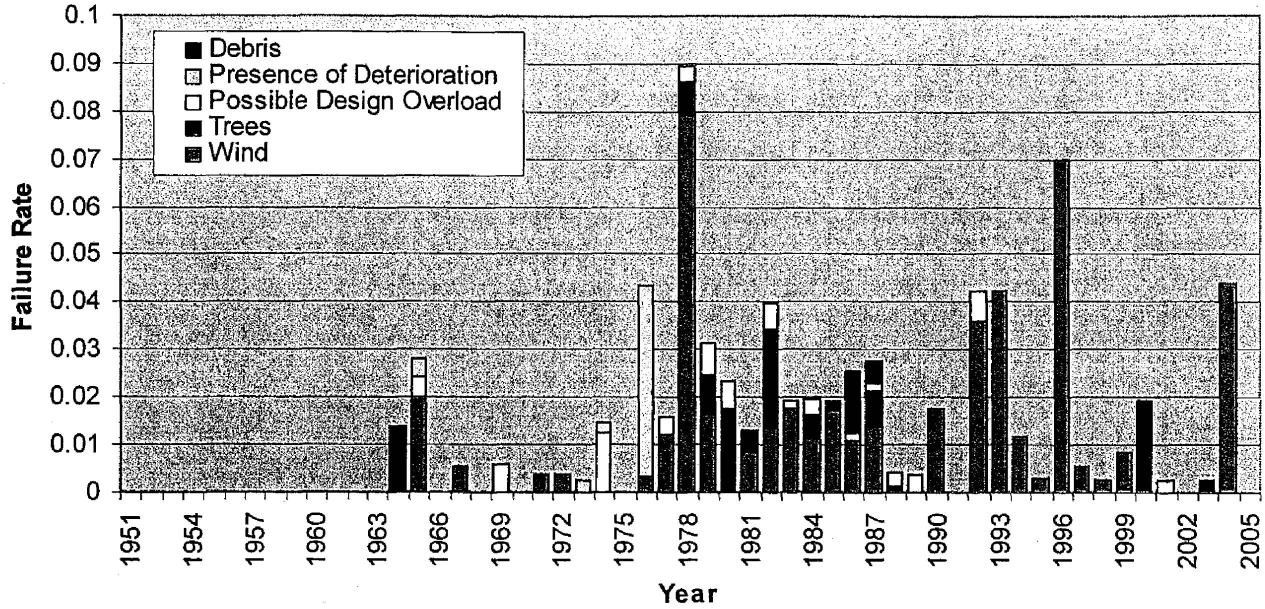


Figure 7-12. FPL owned wood pole failure rates (adjusted) by contributing factor in Palm Beach County

Failure records indicating vintages earlier than 1958 were discarded for this evaluation because the necessary population data was not available from accounting records. The year 1965 shows a relatively high failure rate because many investigated poles that did not have a recognizable age stamp, had been clustered into the age representing the surrounding area. The year 1978 shows a higher failure rate because of an abnormal ratio of 1978 vintage poles as per property accounting (refer to Figure 7-2) and many failed poles of this vintage. As the low balance of 1978 poles has been confirmed, this may indicate that this should be further investigated. Also the relative high failure rates for vintages between 1979 and 1987 also warrant potential further investigation. The relatively high failure rate of 1976, with large contribution of presence of deterioration, goes unexplained. Lastly, the increased failure rate of the year 1996 can be explained by a large multiple failure giving rise to a high failure rate (mostly class 2 poles involved).

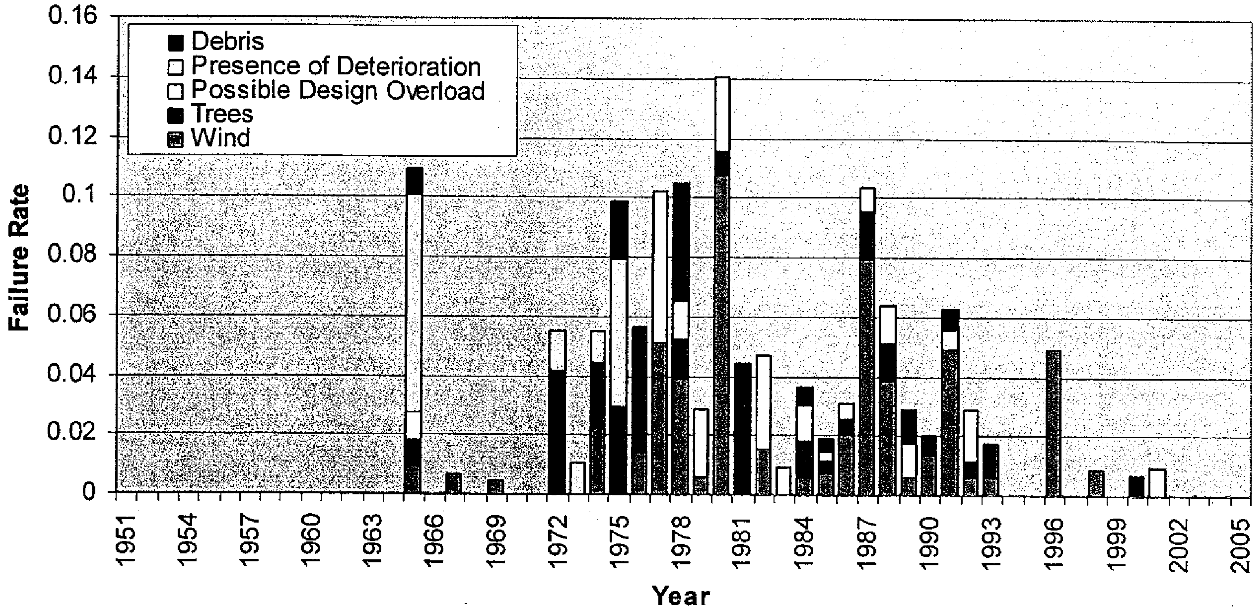


Figure 7-13. FPL owned wood pole failure rate (adjusted) by contributing factor in Broward County

Different from the other two counties, the pattern for Broward County shows a higher failure rate for 1980 instead of 1978 and more pronounced failure rates with presence of deterioration as a contributing factor for poles before 1976.

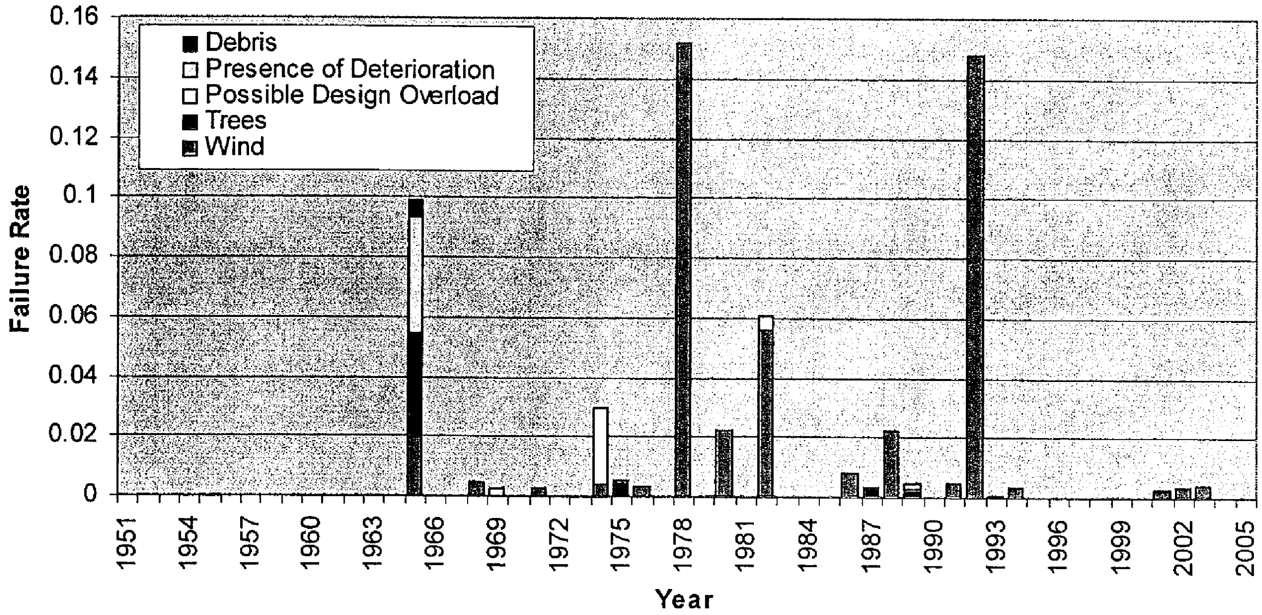


Figure 7-14. FPL owned wood pole failure rate (adjusted) by contributing factor in Dade County

The high failure rates of 1965 and 1978 are identical to the explanations provided for Palm Beach County. The high failure rate of 1992 indicates the potential influence of poles replaced due to hurricane Andrew; it could also be that these poles are simply in vulnerable areas. Mostly class 3 and 4 poles were involved in the 1992 failure records for Dade County. Further investigation revealed that the 1978 and 1992 failure rates were especially high due to multiple breaks.

From the above three graphs it can be seen that for vintages after 1978 (i.e. CCA type poles), the failure rates are mostly comprising breaks due to wind only.

Compared to other counties, Broward County shows the highest failure rates in general, corresponding to the findings in Table 7-10, and Palm Beach shows the highest failure rates for poles with recent vintages (after 1992).

It was not possible to generate failure rates per pole class or feeder versus lateral, as the accounting data does not provide for pole class information. The following graph shows the unadjusted failure rates by pole height (with pole height being extracted from the accounting data).

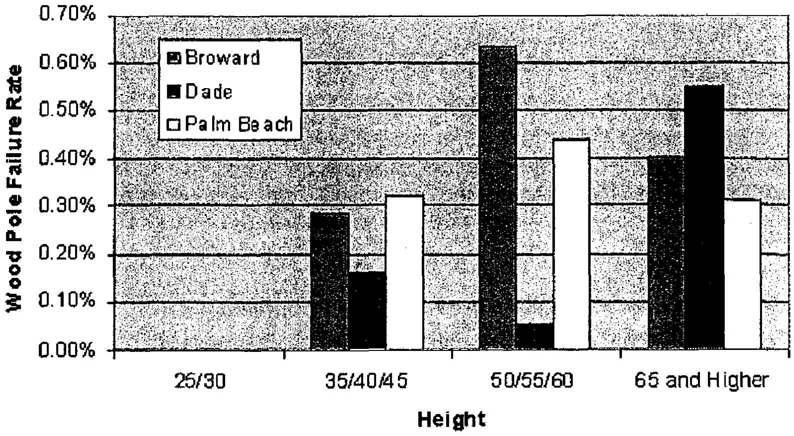


Figure 7-15. FPL owned wood pole failure rates (not adjusted) by height and county.

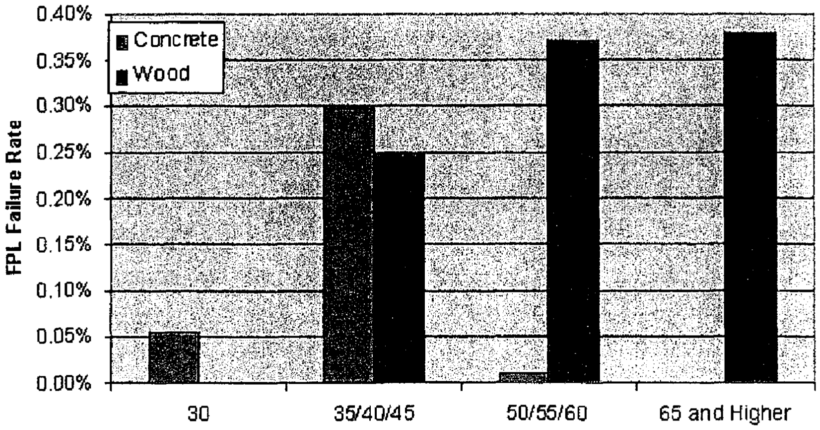


Figure 7-16. FPL owned wood pole and concrete pole failure rates (not adjusted) by height in the Tri-county area.

The next two graphs show the same information for concrete pole failures in Palm Beach and Broward counties. Note that there were no failure records related to concrete poles in Dade County.

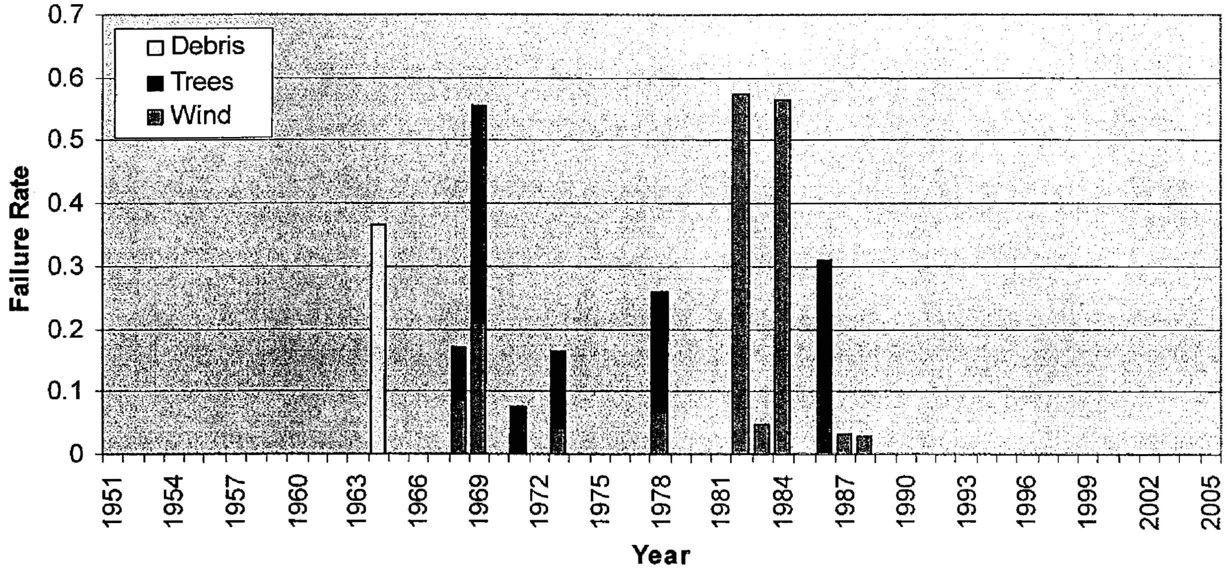


Figure 7-17. FPL owned concrete pole failure rate (adjusted) by contributing factor in Palm Beach County

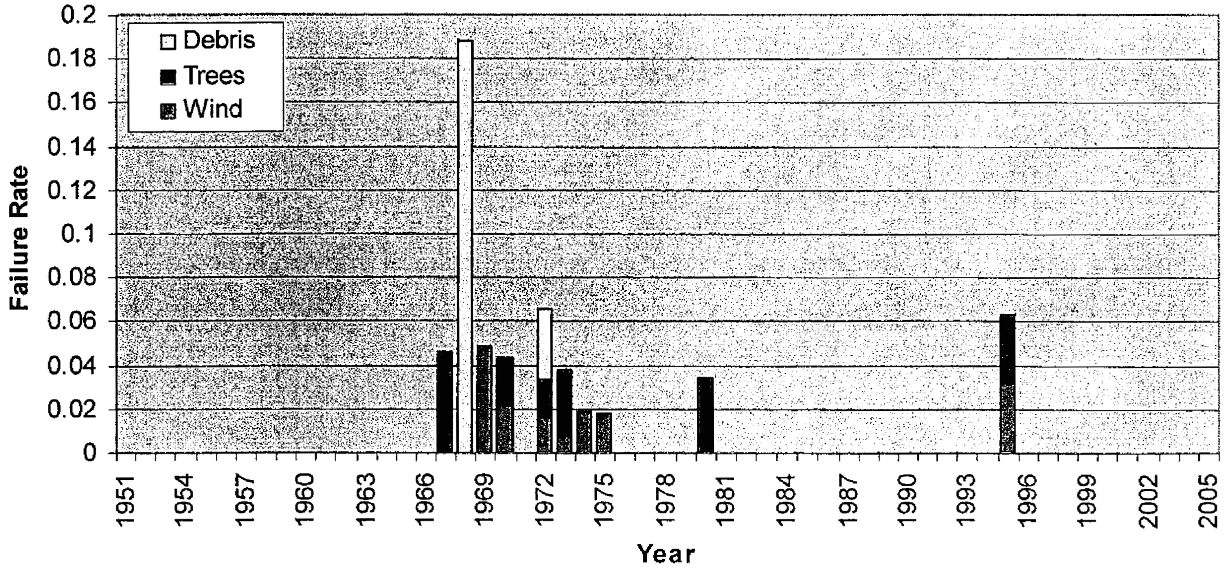


Figure 7-18. FPL owned concrete pole failure rate (adjusted) by contributing factor in Broward County

Here we note a specific pattern of higher failure rates for a selected set of vintages, especially for older vintages (before 1990), with high impact of wind only.

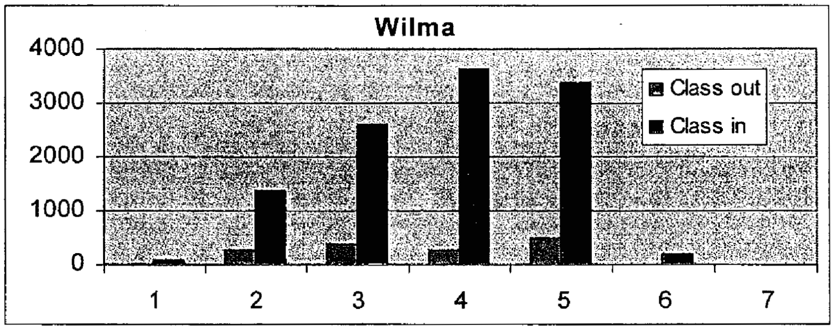
Pole replacements by class

The last step in the forensic data analysis relates the forensic data to pole replacement records during the hurricanes Wilma and Katrina.

From the poles issued data and the forensic data files, the following "class-in versus class-out" analysis can be performed. The data pertaining to "class-out" has not been adjusted to the entire population.

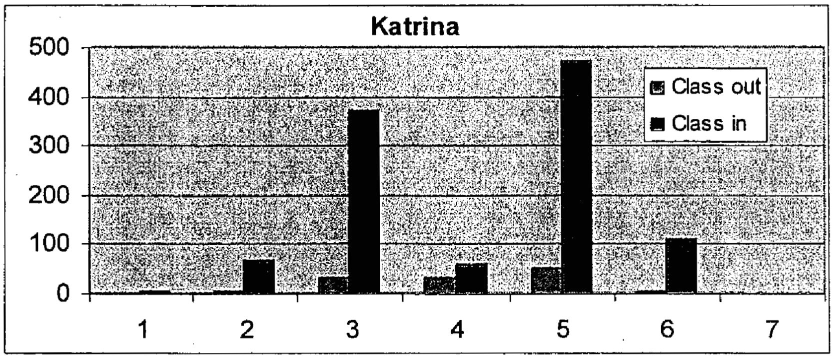
Wilma Wood poles (3 counties)

Class	# out	# in
1	8	62
2	248	1,358
3	365	2,598
4	241	3,631
5	478	3,379
6	7	185
Mean	3.71	3.84



Katrina Wood poles (2 counties)

Class	# out	# in
1	0	2
2	5	66
3	31	370
4	32	58
5	50	471
6	3	108
Mean	4.12	4.17



It can be seen that the mean values for poles out (broken poles) and poles in (replacements) differs only slightly but in both cases increases. This means that on average the system gets slightly weaker compared to the situation before these two storms. The class 6 poles installed after Hurricane Katrina were all 30-foot poles.

7.4 Integral analysis and interpretation

Wind is the predominant root cause of pole breakage based on analysis of the forensic data collected after Hurricane Wilma. Creosote feeder poles showed the highest failure rate, closely followed by CCA feeder poles. Whereas CCA feeder poles mainly broke due to wind only, creosote feeder poles broke due to wind only and the contributing factor of presence of deterioration. Creosote lateral poles showed lower failure rates compared to creosote feeder poles and mostly broke due to wind with the contributing factors of presence of deterioration and falling trees. Failure rates of concrete poles during Hurricane Wilma are relatively high with breakages caused by falling trees and wind only. Compared to concrete pole breakage during Hurricane Katrina (mostly caused by debris and falling trees) this is indicative for the high wind speeds during Hurricane Wilma.

The counties and areas with highest pole failure rates coincide with the areas with the highest wind speeds (or correlation with heavy rainfall) and are bordering open areas in the path of Hurricane Wilma.

Pole breakage during Hurricane Katrina happened mainly to creosote poles. The predominant contributing factors were falling trees breaking both creosote lateral and feeder poles, followed by presence of deterioration of creosote feeder poles.

Design overload is not a major contributor to poles breaking during Hurricane Wilma. Focusing on the 53 FPL owned poles broken with the suspicion of design overload as a contributing factor, most of these were multiple breaks investigated by one inspector. Further analysis yielded the following additional information: whereas generally all structure types were involved in the total amount of investigated pole breakages, these breakages specifically involved cross arm structures on feeder poles. The span length was about average but these breaks correlated highly to a relatively high number of attachments (3-4). Only 30 out of the 956 FPL owned pole breakages belonged to double circuits.

Katrina had a more substantial percentage of breakages with possible design overload as a contributing factor. Many of these breakages were multiple breakages with a smaller influence of the number of attachments (1-2).

Katrina caused few pole breakages of vintages between 1993 and 2005. As Wilma took a lot more CCA poles out by wind only than Katrina, the question arises whether Katrina conditioned these poles and Wilma took them out. Most of the pole breakages during Katrina were from vintages 1978 and 1992 and Dade County, the primary area affected. During Wilma, however, there were not many poles affected with recent vintages with most of them being in Palm Beach County (not affected by Katrina), thereby rejecting this conditioning scenario.

Compared to other counties, Broward County shows the highest failure rates in general and Palm Beach shows the highest failure rates for poles with recent vintages (after 1992). Most of these recent vintage pole breakages were caused by wind only and involved class 2 poles, which likely complied with grade B construction standards. Also, when considering pole vintages between 1993 and 2004, pole breakages are equally spread over the Tri-county area. These findings virtually eliminate the potential grade C construction as a contributing factor.

As there were only a few preventable tree related pole breakages (3 in total), this is not an issue that needs consideration for improvement. Wind was the predominant root cause of pole breakage in general and tree breakage causing pole breakage in particular.

There is a suspicion by some that CCA type pole are somehow more brittle than other pole types and therefore more prone to breakage during severe storms. The following table provides information on wind speed versus pole breakages and percentage of contribution by the causes wind only and contributing factor "presence of deterioration".

Table 7-17. Contributing factors versus wind speed for Hurricane Wilma

Max Wind (MPH)	Circuit Type	Wind Only	% Wind Only	Presence of deterioration	% Presence of Deterioration	Grand Total
	Lateral	11	15	33	46	71
115	Feeder	358	70	42	8	511
	Total	369	63	75	13	582
	Lateral	4	13	15	50	30
121	Feeder	242	76	21	7	318
	Total	246	71	36	10	348
Grand Total		615	66	111	12	930

Table 7-18. Contributing factors versus wind speed for Hurricane Katrina

Max Wind (MPH)	Circuit Type	Wind Only	% Wind Only	Presence of deterioration	% Presence of Deterioration	Grand Total
	Lateral	0	0	6	23	26
Low (70-)	Feeder	4	17	9	38	24
	Total	4	8	15	30	50
	Lateral	0	0	3	25	12
High (70+)	Feeder	12	52	4	17	23
	Total	12	34	7	20	35
Grand Total		16	19	22	26	85

From this data, it becomes obvious that wind speed does not correlate with increased contribution of deterioration for lateral poles nor for feeder poles. This may be explained by deterioration requiring a just certain (low) threshold level of wind force to be applied for breakage. However, increased wind speed does correlate with increased contribution of wind as cause for feeder poles and not for lateral poles. This may be caused by the predominant CCA types of poles in the feeder circuits and the fact that lateral circuits are more shielded (resulting in a higher impact of trees as a contributing factor). Which one of these two is decisive and to what extent this relates to CCA type poles being brittle and easier to break during severe storms has been further investigated by extending the above analysis distinguishing pole type. The results showed that both CCA and creosote feeder poles correlated positively and with similar coefficients. This tells us that a different pole type as an alternative engineering solution is not to be recommended and that brittleness of CCA poles, if any, is not a decisive factor.

The highest wind speeds are typically recorded to the south of the path (wind speeds plus movement of the system) for an eastwards traveling storm in the Northern hemisphere. For a westwards traveling storm this will be to the north of the path. Consequently, it can be expected that Hurricane Wilma had strongest storms to the south of its path and Hurricane Katrina to the north of its path. The following graph shows circuit orientation and the falling direction of broken poles.

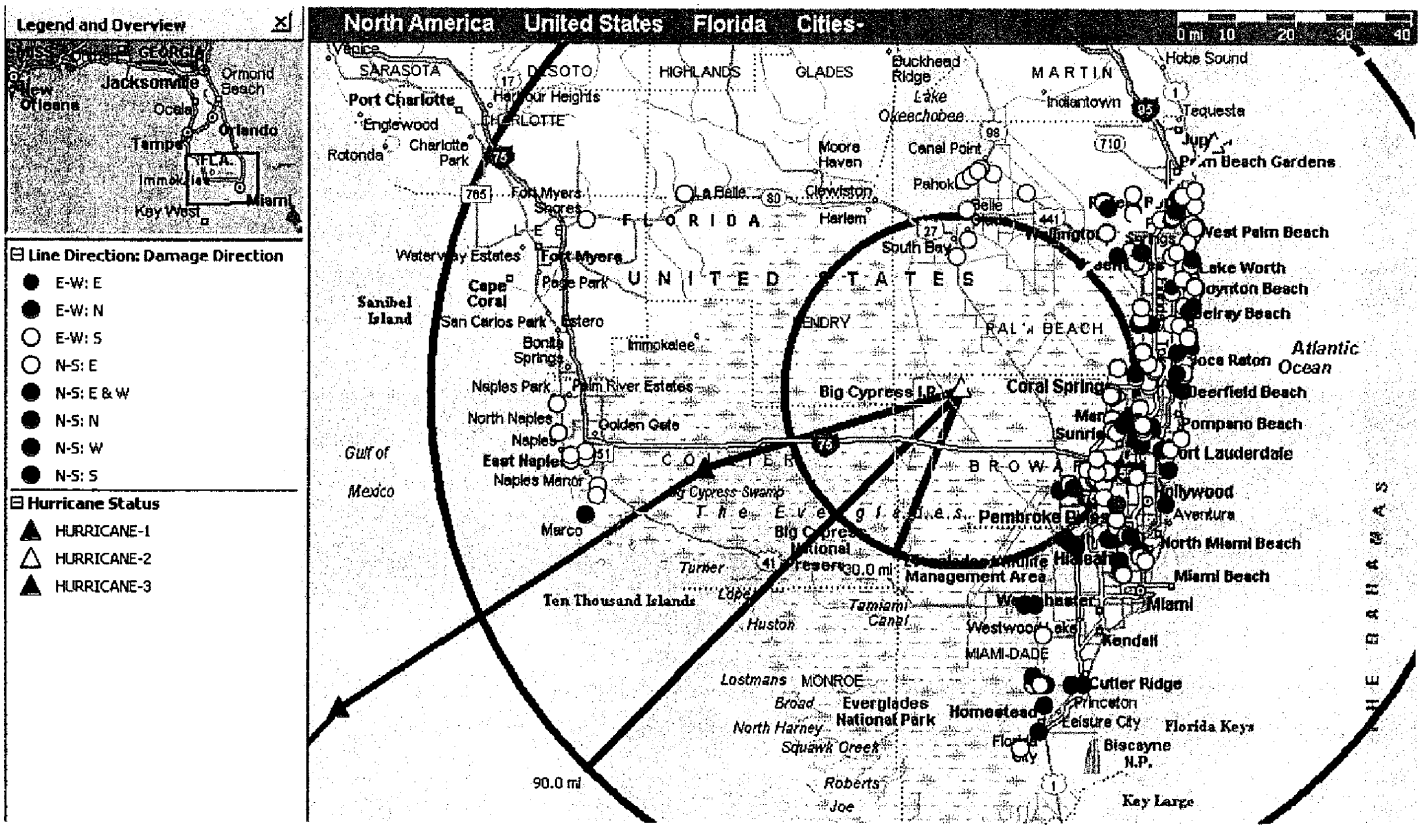


Figure 7-19. Circuit orientation and direction of falling poles for Hurricane Wilma

This graph shows an obvious pattern of abundant East-West circuit orientation with poles falling to the North, in the Southern area (Dade) and North-South circuit orientation with poles falling to the West and East, in the Northern area (Palm Beach and Broward). This pattern can be explained by the wind directions alone for the Southern area and a combination of wind directions, changing wind direction in the path of the eye wall, and majority of circuit orientation in the Northern area.

The North-South oriented circuits falling quasi randomly to the East and West, could indicate a failure mechanism where the front side of the storm either breaks or conditions the poles and the back side of the storm takes out the conditioned poles. Such poles could lean and get smashed back by the back side of the storm, breaking the pole upon sudden impact. This could explain the number of CCA feeder poles broken by wind only on the East side of Palm Beach County (refer to Figure 7-10), most affected by the back side of Hurricane Wilma. The East-West oriented circuits falling to the North (red dots), show failures that are difficult to prevent as the wind comes through shielded areas (South to North). An extended root cause analysis during the forensic study may have supported targeted engineering solutions in this area.

7.5 Conclusions

With the forensic data received and assumptions made as described in this chapter, the following conclusions, based on statistical analysis sufficient to perform root cause analysis and to direct engineering solutions, can be drawn. The sample size was sufficient to guarantee results in a range plus or minus 2.2% with 95% certainty. The larger uncertainties are due to deviations in pole population data, assuming the accounting data correct, the Hurrtrak data has a minimum of 5% deviation from accounting data for the entire system and differences up to 60% for one county in the Tri-county area. This disables interpretation of the absolute failure rate numbers whenever geographically represented. However, these relative failure rate maps still show differences that provide substantial conclusions that can be used as the basis for further analysis.

Wind is the predominant root cause of pole breakage based on analysis of the forensic data collected after Hurricane Wilma.

Wilma was a hurricane Category 3, later transitioning into Category 2, with greater impact than hurricane Category 1 Katrina when covering FPL's service territory. Hurricane Wilma's force and the impacted area resulted in a 5 times higher pole breakage versus exposure ratio.

Wilma traveled from West to East over Florida, affecting the western part of the Tri-County Area. This area has feeders in open locations with relatively young CCA type poles. Most of the pole breakages in this area were caused by wind only. Over 85% of these incidences were most likely multiple breakages where one pole breaks first and takes down a series of other poles. Subsequently, Wilma lost strength and transitioned to a Category 2 hurricane, moving towards the East Coast that has older lateral Creosote type poles. The relatively small amount of pole breakages in these areas was mainly due to falling trees and creosote feeder poles with presence of some level of deterioration. The unexplained items are the block of vintages between 1978 and 1987 that show higher failure rates in Palm Beach and, possibly related, the relatively large amount of CCA feeder pole breaking at the coast side of Palm Beach County. This may need further investigation.

This engineering analysis showed that most other relevant pole break scenarios were of minor importance. Possible design overload due to double circuits or attachments, weakening of poles by Hurricane Katrina with Wilma taking them out, the potential construction grade C issue in Palm Beach County and potential brittleness of CCA poles all have been evaluated without evidence of substantial contribution to the number of pole breakages.

Katrina traveled in opposite direction from East to West, affecting the older Creosote pole areas first and hardest. Most of the pole breakages were due to falling trees. Although possible design overload and presence of deterioration of feeder poles played a more substantial role than for the breakages during Hurricane Wilma, the total number of pole breakages was less, as can be expected from the lower hurricane force.

During Hurricane Wilma, the pole breakage was below 1.5% of the total amount of poles exposed to hurricane wind speeds. This pole performance is consistent with FPL pole performance during other hurricanes; only hurricane Andrew and hurricane Charley had higher ratios relative to their higher wind speeds.

8 Industry Benchmark Survey

As part of the review of FPL standards and practices for engineering design, construction and pole maintenance, an industry practices survey was initiated. This survey was targeted at electric utilities in the southeastern USA with significant hurricane exposure and recent hurricane damage experience. The overall purpose of the survey was to sample the engineering, construction and maintenance practices of other companies in an effort to learn how FPL practices compare and to learn of any practices that could be considered by FPL for improvement of their operations.

8.1 Summary of Findings

- KEMA issued surveys to 21 companies including a municipal utility, a rural cooperative utility, Caribbean region utilities, a Pacific area utility, and investor-owned companies throughout the southeastern and mid-Atlantic states. Responses from individual companies and utility holding companies representing multiple operating companies were received.

- The survey responses indicate that FPL engineers, designs and constructs distribution facilities to a more stringent standard than most other companies. Of companies responding, only one other utility routinely builds to NESC Grade B construction standards, which is the norm for FPL. All companies are compliant with NESC standards and in many cases, exceed the NESC Light Loading District criteria which applies to many of the responding companies.

- Few companies are using the current extreme wind loading criteria found in the NESC. The requirement of structures taller than sixty feet to be designed to extreme wind conditions is generally observed by all, with some exceptions, based on local conditions.

- Joint use attachments are commonly allowed for in pole loading design calculations with some companies performing site-specific calculations as part of the request process for foreign utility attachments.

- None of the companies are required by their regulatory authority to place facilities underground in response to storm damage. There is some mention, however, of regulatory requests for overhead-versus-underground cost comparisons following the storm season of 2005. One company reports placing facilities underground as risk mitigation in isolated cases where extensive storm damage is highly likely.

- All but one of the responding companies besides FPL have an active pole inspection and treatment program in place for older poles with an inspection cycle of 10 to 15 years. The inspections are targeted at creosote or penta pole populations, as the CCA population is not regarded as a risk at this time. Actual inspection results indicate that maintaining the target cycle is difficult and is budget dependent.

Detailed information by survey topic area appears in the following sections. FPL responses are not included in these summaries. The full, detailed results of the survey are found in Appendix A.

8.2 Engineering Design and Construction Standards

Design standards and practices:

- All respondents design to NESC criteria for light loading or medium loading district based on location.
- All report some cases where minimum NESC requirements are exceeded; however, it is on an exception basis. One company has adopted a standard pole height/pole class combination.
- Only one responding utility uses Grade B construction as the standard.
- Extreme wind loading criteria is not generally used for structures below 60 feet. There are individual exceptions based on specific application.
- Use of ground line as fulcrum point for loading calculations is accepted practice. Use of automated programs to determine critical section structure and general sizing calculations is increasing with O-Calc, Pole Foreman, and LD Pro cited as examples.
- Use of pole set depth of 10% + 2 is accepted standard by all with variation for soil conditions.

Joint use attachments:

- Most allow for joint use attachments in their standard pole loading criteria. One company makes allowance only if it is known that attachments will be made.
- In most cases a general loading allowance is applied for future joint use and then checked when actual loading information is obtained or attachment is installed.
- All respondents report an audit procedure for joint use attachments but vary widely on the extent of engineering compliance that is included in the audits or inventories. No "best practice" for auditing unauthorized or non-compliant attachments was noted.
- When placing facilities on poles owned by others, the electric utility loading standards are used, sometimes requiring pole change-outs. One company reports they do not attach to poles owned by others.

Storm data and impacts:

- No respondents report being mandated to place facilities underground as a result of storm damage. One company reports current request for underground and overhead cost comparisons by their regulator in response to 2005 storms.
- Some effort to collect data on storm damage for analysis is conducted by two utilities. The data collection appears to be more in the area of outage records than true forensic analysis of damage.
- One company reports an automated outage record system used in the field by engineering personnel to collect damage information. Program includes recording format with drop down selections for data to be recorded. Program runs on company intranet and can produce various reports for analysis.
- Data collected in preceding example is sent to the affected standards engineer for review and analysis.

8.3 Pole Inspection and Maintenance

Pole population characteristics:

- The number of poles by responding companies ranged from 4.8 million (total for all operating companies within large holding entity) to 140,000 at a cooperative. The average number of poles for IOUs reporting was 1.0 million.
- Pole population consists of 95% wood poles, with remaining poles primarily concrete.
- 41% of poles are creosote treated; 32% are CCA; and 27% are penta.
- The estimated average age of the population ranges from 18 years to 35 years. The median average age is 25.2 years.

Inspection and treatment programs:

- 80% of respondents have an active inspect and treat program for wood poles. Programs are administered in-house with work performed by contractors.
- A 10 to 15 year inspection cycle for older poles is reported with most companies targeting 10 years. One company reports a 10-year cycle for poles in service 18 or more years. In the coastal regions served by this company the in-service age for inspection begins at 10 years.
- Percent poles inspected in each of the last five years ranged from 0% to 12.5%. Several companies reported inspection cycles driven by available budget from year to year.
- All respondents are treating only creosote poles at this time.

Pole treatment and reinforcement:

- Type of treatment varies by company but all treatments are standard within the industry. They include copper naphthenate, sodium fluoride, methyl ethyl isothiocyanate, wood fume, and oil & water borne preservative pastes.
- 90% of companies are reinforcing poles in service. All use a steel strut or C-truss with one company using a laminated wood brace also.
- Cost of pole reinforcement as a percent of new pole installation ranges from 18% to 33%. One company reports that they will go to a maximum of 80% of new pole installation cost.
- Approximately 2% of poles inspected are reinforced; approximately 3% of poles inspected are replaced.
- The percent of poles replaced as part of day-to-day operations (outside the inspection program) was reported at less than one percent.
- Outages per year due to pole failures ranged from 500 to 20 among companies that track the statistic. Average was approximately 230.

Pole quality control:

- 90% of respondents report using independent or 3rd party inspectors as part of quality control process for poles.
- One company reports 100% inspection of poles over 35 feet in length.

9 Conclusions

KEMA's investigation concludes that the transmission, substation, and distribution systems of FPL is designed to meet or exceed all required safety standards, and, during Wilma, performed as expected and in accordance with FPL standards. This conclusion is based on an extensive assessment including standards, quality systems, maintenance practices, transmission performance, substation performance, and distribution performance. These results are further supported by an industry benchmark survey covering these topics, and a review of the strength of Wilma by an independent weather expert. Specific conclusions on these issues are now provided.

Distribution Standards

FPL distribution standards as described in the Distribution Engineering Reference Manual (DERM) meet or exceed the requirements of National Electrical Safety Code (NESC), which requires distribution poles to be designed based on a minimum of 60 mph wind speeds. In fact, FPL requires that most poles be designed to the highest NESC requirement, which is 50% stronger than NESC minimum requirements. The NESC has requirements related to extreme wind conditions, but these requirements are only for structures over sixty feet in height, which rarely apply to distribution structures.

Quality Processes

The quality systems and processes of FPL and key suppliers are sufficient to reasonably ensure that procured distribution poles, both wood and concrete, meet national standards and FPL specifications. Further, the quality systems of the FPL pole inspection and treatment vendor are such that it is reasonably ensured that inspected wood poles requiring treatment or replacement are identified as such.

Pole Maintenance

FPL distribution pole performance during non-hurricane conditions is good, and non-hurricane pole failures cause virtually no customer interruptions. FPL has two systematic programs related to pole inspections: (1) a Thermovision program that visually inspects all main-trunk feeder poles at least every five years, and (2) a more targeted wood-pole inspection and treatment program that is smaller in scope and focuses on specific areas of the FPL system. FPL crews are also required to perform a safety inspection on a pole before performing work on the pole. These inspections will not systematically address each pole, but KEMA estimates that this will effectively test between 80% and 90% of all branch-line laterals over a fifteen year period.

Transmission Performance

The transmission lines of FPL are designed in accordance with the NESC, including extreme wind requirements, applicable at the time of design. For transmission structural damage that occurred during Wilma on less than 500-kV lines, most occurred on single-pole unguyed wood structures. These facilities met the required design codes at the time of installation, but differ from current designs being implemented at FPL. This was the primary contributing factor for these failures. Only one 500-kV transmission line experienced structural damage during Wilma, but this particular line had 30 tower failures. The major contributing factor for these tower failures was the installation guidelines for manual tightening of crossbrace bolts as per industry standard practice, which is insufficient and led to the loosening of crossbrace bolts at several locations.

Substation Performance

FPL designs its substations according to extreme wind criteria. The FPL substation performance during Wilma was acceptable, and structural damage to substations was minor. Although FPL experienced outages on 241 substations during Wilma, most were due to the outage of transmission lines serving these stations; only 8 required equipment repair before being reenergized. With some minor exceptions, there was no discernible pattern of equipment failure that indicates a design or maintenance concern.

Weather Assessment

Wilma was a strong storm, and its path affected a large percentage of the FPL system. As opposed to many statements by the media, Wilma was a Category 3 hurricane when it made landfall at the Southwest coast of Florida traveling to the Northeast. It transitioned into a Category 2 hurricane while passing over Florida and left the state as a Category 2 hurricane. The maximum 1-minute sustained wind speed (as reported by Unisys) as Wilma crossed Florida was 127 mph, which comes close to a Category 4 hurricane. In comparison, Katrina had a maximum sustained wind speed of 81 mph while crossing Florida (also reported by Unisys).

Distribution Performance

FPL pole performance during non-hurricane conditions is good. Distribution pole performance during Wilma is known to be acceptable, since FPL gathered extensive forensic data on Wilma pole failures. Based on this data, the following conclusions are drawn: (1) wind was the predominant root cause of pole breakage, (2) many failures involved multiple CCA feeder poles where one pole breaks first and takes down a series of adjacent poles, and (3) the number of failures involving creosote poles was relatively small, with these failures mainly being due to falling trees and the presence of deterioration. During Wilma, pole breakage was about 1.5% of the total amount of poles exposed to hurricane wind speeds. This pole breakage ratio is in line with past FPL hurricane pole performance after correcting for hurricane severity. For comparison: Katrina (2005) was the weakest recent hurricane at Category 1, and only had a 0.3% pole failure rate. Frances (2004) was Category 2, and had a 0.9% pole failure rate. Wilma (2005) was Category 2 to Category 3, and had a 1.5% pole failure rate. Charley (2005) was Category 3 to Category 4, and had a 3.1% pole failure rate. Andrew (1992) was Category 5, and had a 10.1% pole failure rate.

Industry Benchmark Survey

KEMA received survey responses from 9 companies (not including FPL) with answers to questions relating to standards, maintenance, and hurricane performance. Based on these responses, the following conclusions are made: (1) FPL designs and constructs distribution facilities to a more stringent standard than most other companies, (2) none of the companies are required by their regulatory authority to place facilities underground in response to storm damage, and (3) most of the responding companies have a systematic pole inspection and treatment program in place with inspection cycles ranging from 10 to 15 years for poles older than a certain age.

Based upon the analyses contained in this report, KEMA is in the process of developing specific recommendations for FPL's consideration with respect to potentially improving the future hurricane performance of FPL's transmission, substation, and distribution systems. KEMA is also developing additional points for FPL's consideration concerning the possible additional "hardening" of its distribution system. It should be emphasized that most distribution structures are not required by code to do this. However, it is worth considering the possibility of using criteria exceeding minimum code standards in an effort to reduce the extent of damage that can be expected during extreme wind conditions. This is especially true if the present time is the start of a long cycle of increased hurricane activity.

Appendix A: Survey Instrument

This section provides detailed survey responses that provide the basis for Section 8. The cover letter that was sent with the surveys is first provided. Next, the specific questions in the survey are listed, along with the answers received from each participant (not all respondents provided answers to all questions).

<u>**Cover letter sent with survey:**</u>

KEMA T&D Consulting is conducting a survey of practices used in distribution line design and construction, storm damage analysis, and pole inspection and maintenance among electric utilities in areas prone to wind damage from large storms. This survey is sponsored by FPL in the interest of comparing practices among utilities with significant storm or hurricane exposure.

KEMA will not identify the responses to the individual questions by company; however, a list of the companies responding to the overall survey will be included in the summary report. If a company prefers not to be named, please indicate that and your request will be honored. All respondents will receive a summary report of the findings of this survey. This survey is being sent to approximately 25 IOUs, Municipals, and Coops in the US and Caribbean.

Please respond to the questions to the best of your knowledge based on your company practices and operating history. A KEMA consultant may call to clarify answers to ensure full understanding of the intended response.

Your attention to this survey prior to December 16, 2005 will be appreciated.

Please contact me with any questions and return the survey to the e-mail address below.

Thank you.

Bill Snyder
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Design and construction standards:

1. **What design criteria are used for your distribution structures?**
   - Standard construction units for each voltage class based originally on REA specs. They have been modified to fit our needs and comply with code changes. Elected to use one pole class for each pole height sized to meet most conditions.
   - Standard is Light Loading District—Grade B.
   - Our design criteria meets or exceeds the requirements of the NESC.
   - Adhere to the requirements of the NESC.
   - NESC safety criteria.
   - Our design criteria is based on NESC requirements. Mainly based on maximum allowable span lengths due to conductor sag. The poles kept in stock allow for the installation of typical equipment, such as transformers, and guying based on certain criteria. When large equipment is installed or special guying requirements are involved, we use a computer program to determine the stresses on the pole.

2. **Do you exceed the requirements of the NESC? (for example, do you use Grade B construction in areas other than ones required by NESC?)**
   - No.
   - Yes, use Grade B in Grade C areas.
   - Yes, in some locations we specify additional strength and/or clearance.
   - Due to material consolidation, standardization of design, state and local requirements, designs often exceed the minimum requirements of the NESC. Examples such as railroad crossings may be designed to "C" construction.
   - Use Grade B for railroad and controlled access highway crossings.
   - Typically, we use Grade C when allowed and Grade B where required.

3. **Does the design criteria vary in high wind exposure areas of the system? Describe variation.**
   - No.
   - Standard is Grade B. Reviewing potential changes of NESC Extreme Wind requirements. Also, reviewing in light of annual hurricane cycle.
   - We do not vary from NESC requirements for high wind loading.
   - High wind areas typically exist in the coastal areas. Due to the compactness of the developments in these areas, overhead line spacing is typically very short. Applying our standard NESC loading designs (for much longer spans) in these areas results in lines that far exceed the minimum NESC loading requirements.
   - No.
   - High wind only changes our design when the structure, or anything supported by the structure exceeds 60 feet above ground or water.

4. **NESC Rule 250-C requires extreme wind load calculations for facilities that exceed 60 feet above ground or water level. Do you apply extreme wind loading to any facilities below 60 feet?**
    - No.
    - Not currently. Grade B result with OCF's approximate to 130 mph.
    - We follow the NESC requirements for high wind loading.
    - Yes.
    - No.
    - No.

    If yes, what are the determining criteria for use of extreme wind loading?
    - NESC Rule 261A1c and 261A2f are applied to street and area light poles served from underground lines.

5. **For wind loading calculations, do you use ground line as fulcrum point? If no, what is used?**
    - Yes.
    - For practical application we use ground line as the fulcrum point rather than the technical/theoretical point.
    - We determine the critical section of the structure and use it as the fulcrum point.
    - Yes.
    - Strength of entire structure is compared to the moment load.
    - No. When a loading calculation is performed, all forces (wind, guying, angles, etc.) are taken into account. The pole is divided into segments and the total moment is calculated at the bottom of each section, and then compared to the calculated strength based on the parameters of the pole at each section.

6. **What significant changes in distribution line design standards have been made in the last 3 years, if any? (for example, pole class or type, framing, conductor size)**
    - None.
    - Have changed primary conductor types – acsraw to aaac. Have included tree wire and insulated aerial cable applications.
    - No significant changes have been made to affect the clearances or mechanical strength requirements.
    - None.
    - None.
    - None.

7. **Does design standard for a new pole allow for foreign or joint-use attachments in the loading criteria?**
    - Nominal attachments are taken into account.
    - Have a designated "standard" pole height/class with pre-drilled holes for joint users. All attachments require request process for confirmation of structure loading and clearances.
    - Yes, if joint use is planned for the new pole.
    - Yes.
    - Yes.
    - Yes.

8. **Is the joint-use attachment consideration a general load allowance or a specific calculation?**
   - Standard units use general load allowance. For unusual attachments, use O-Calc or Pole Foreman.
   - Specific calculation.
   - Generally, we know the specific information on the planned attachments. If not, we use a general load allowance. Then once we know the specifics we check to make sure the pole is adequate.
   - General load allowances.
   - General allowance.
   - Typically a general load is used. If specifics are known, the information is used for the calculation.

9. **How are joint-use attachments controlled in the field to address unauthorized or non-standard attachments?**
   - No formal controls. Found in the field by linemen.
   - Normal observation/confirmation. Contract stipulations allow periodic audits with penalties for unauthorized attachments.
   - We perform periodic inventories and inspect join use attachments as part of the inventory.
   - Currently do not have dedicated resources auditing existing poles for unauthorized attachments. For non-standard attachments a post installation inspection is performed.
   - Random audits.
   - Local monitoring and state-wide permit process. Joint use attachment count every 5 years.

10. **Do you audit or inspect joint attachments for engineering standards compliance?**
    - No.
    - Require detailed information as to cable size/tension, as well as clearance information relative to existing facilities. Used to aid in engineering analysis. Also, during periodic attachment audits, compliance to NESC, etc. is included.
    - Yes.
    - Yes, permitted joint use attachments receive a post installation inspection.
    - Yes.
    - A post inspection is performed.

11. **What pole depth calculation or standard is used for setting poles? (by pole type: wood, concrete, other)**
    - Use standard 10%+2 feet up to 10 foot max for wood poles and other standard poles. For special poles the depth is determined using computer programs.
    - Standard is 10% + 2 feet.
    - For wood poles in normal soil the setting depth is 10% of the pole length plus two feet.
    - The standard 10% plus 2 is the norm. There are variations for clay, marsh and rock.
    - Wood: 10% + 2 feet.
    - Wood: follow ANSI; Concrete: most concrete poles are engineered for a specific loading requirement. Use some generic concrete poles and standard pole setting depths are used.

12. Describe a standard feeder pole configuration on your system:

- Voltage: 13.2 kV
  Framing: 8' crossarm, center phase on pole top pin. Neutral 7' below crossarm.
  Pole: 40' class 4 wood, CCA
  Conductor: 336.4 kcmil ACSR Linnet with 4/0 neutral
- Voltage: 14.4/24.9 kV
  Framing: Horizontal crossarm construction
  Pole: 40-3 wood
  Conductor: 336.4, 26/7 Al with 4/0 Al neutral
- Voltage: 12.47 kV
  Framing: Wood crossarm
  Pole: Wood, 40 foot class 4
  Conductor: 556.6 kcmil Al 19 strand bare Dahlia
- Voltage: 15 and 25 kV
  Framing: Vertical, armless delta, and crossarm.
  Pole: 40 to 45 foot, class 3, 4, and 5; CCA.
  Conductor: 477 AAC and 795 AAC
- Voltage: 15 and 25 kV
  Framing: Vertical (phase over phase), delta, crossarm.
  Pole: CCA 40 and 45 feet, class 3, 4, 5.
  Conductor: 336 AAC and 795 AAC.
- Voltage: 4, 12 and 24 kV
  Framing: Wood crossarm
  Pole: Wood, 40 feet, class 5
  Conductor: 2 ACSR, 1/0 ACSR, 336 AAC, 556 AAC
- Voltage: 12.47 or 25 kV
  Framing: Horizontal or vertical
  Pole: Wood, class is dependent on height and construction
  Conductor: 1/0 ACSR to 397 ACSR (some 750 AAC)

13. Has your company been directed by regulatory authority to place distribution facilities underground to lessen storm damage exposure?

- No, but after recent hurricane season they have requested cost comparisons.
- Not to current knowledge.
- No.
- No.
- No.
- No.
- No.

14. Has your company, on its own initiative, placed facilities underground in response to previous storm damage or to lessen future storm damage exposure?

- No.
- In a few isolated cases. Some currently under review process.
- No.
- No.
- No.
- No.
- No.

15. If your company attaches to poles owned by other utilities, is the design standard the same as on your own poles? How is this monitored?

- We use our standard construction on poles owned by others as much as possible. Facilities are installed by company crews or contractors under supervision of company personnel.
- We do not attach to poles of other utilities.
- Yes. We request the pole(s) be changed if necessary to meet our requirements. Agreements require all parties to maintain attachments at least to the minimum NESC requirements.
- Generally yes. An analysis may be done using a computer program for structural loading.
- Yes, through field audits.
- Yes. Same calculations are performed as for our poles. Normal when we attach to another company's pole, that pole has to be replaced. We inform the other company of class and height we require.

16. How often does your company conduct a design standard review based on failure data or other performance data?

- When a new construction type is developed, these criteria are considered, however, we don't usually conduct design reviews after that.
- Monitor changes in code etc. which affect design requirements. Failure/performance analysis routine to reported failures.
- Have established schedule for design standard review. We review each standard at least once every five years. We also continuously monitor our material and equipment failures and outage event trends. Analysis of this data can lead to review of design standards to address identified issues.
- A design review is conducted after each revision of the NESC to ensure present conformance to the new edition. If a significant event occurs (unusual pole failure), we may run a computer analysis.
- Routinely throughout the calendar year.
- As needed, based on unusual incidents.

Storm damage analysis:

1. **Do you have an established procedure for gathering data on storm related damage for purpose of evaluating material performance and design standards?**
    - No.
    - In accordance with Emergency Restoration Plan data is collected for a number of reasons (severity of storm dictates level of data gathered). Feedback specific to evaluation of material/design standards is less formalized but we do try to review and learn from each occurrence.
    - Yes, but it is difficult to get complete data reported when crews are working on service restoration following major storm events.
    - No. Damage assessment is done on all lines after a major storm. The data is stored in a computerized database. Location of damage, feeder or tap line, number of trees on line, number of broken poles, spans of primary down, spans of secondary/service down, transformers damaged. A comment section is also provided to capture size of trees, pole height and class, size of transformer, etc. The data is primarily used for outage restoration assessment and not to evaluate material performance.
    - No.
    - No.

2. **If yes, what data is collected?**
    - N/A.
    - Compatible units damaged by the storm which allows identification of material item types, etc.
    - The location, a description of the failed equipment and/or damaged equipment, the catalog number, the manufacturer, the stock number, the rated voltage, the description of failure or event, the contact person with location and phone number for more information, the date installed, the date of manufacture, and the outage management system report number.
    - Detailed in #1 above.
    - N/A.
    - N/A.

3. **How is the data collected?**
    - N/A.
    - Dependent upon escalation of restoration plan, data collected through normal material transaction process, specific report by operations personnel or through field assessment by engineering personnel.
    - The person initiating the report uses a graphical user interface to an electronic database program running on the company intranet. The program has drop down selections for many entries to facilitate data entry.
    - Two person teams using data sheets, marking up maps and/or use of lap tops with mapping software and GPS.
    - N/A.
    - N/A.

4. **How is data used for review and analysis?**
   - N/A.
   - Cursory review of failed items unless specific concerns or observations identified.
   - A copy of each failure report is e-mailed to the standards team member for follow up. In addition, special ad hoc reports can be produced for trending and in depth analysis.
   - The primary purpose of gathering data immediately after a storm is to estimate the number of crews and material that will be needed to restore service. A secondary use is to analyze data later for system design weaknesses that should be investigated. The data from storms that occurred in 2004 did not uncover any design weaknesses/trends that should be investigated.
   - N/A.
   - N/A.

5. **Have any design changes been made as a result of storm damage analysis? If yes, please describe.**
   - No.
   - Consideration of mitigation in high risk areas of overhead facilities conversion to underground.
   - No design changes have been made in the last three years.
   - No.
   - No.
   - We have instructed our construction forces and inspectors to ensure correct guy lead lengths and numbers of guys/anchors. We monitor tree damage to optimize clearing cycles.

Pole standards, inspection, and maintenance:

1. **What is total distribution pole population?**
   - Approximately 400,000 including service poles.
   - Approximately 140,000.
   - Approximately 4,800,000.
   - 1.1 million
   - 1.0 million
   - 2.2 million
   - 1.2 million

2. **Percent of total population that are wood? Concrete? Other?**
   - Wood 98%, concrete 1%, other 1%
   - Wood 91% , concrete 9%
   - Wood >99%
   - Wood 91.5%, concrete 0.1%, other 8.5%.
   - Wood 70%, concrete 30%, other <1%.
   - Wood 99.99%
   - Wood 96.8%, concrete 0.07%, other 3.13%

3. **What is the wood pole population by type of pole treatment?**
    - Creosote 85%, CCA 15%
    - Do not track by type of treatment.
    - Creosote 5%, CCA 35%, Penta 60%.
    - Creosote 58%, CCA 42%.
    - Creosote 60%, CCA 40%.
    - Creosote 85%, CCA 15%
    - Creosote 57.7%, CCA 41.2%, other 0.8% (some are Penta)

4. **Average age of population?**
    - 35 years.
    - 18.4 years.
    - 27 years.
    - 21 years.
    - Unknown.
    - 24 years.
    - 25.9 years.

5. **Does your regulatory authority require a distribution pole inspection program?**
    - No.
    - Requires inspection of "plant" based on utility experience. Not specific to pole inspection.
    - Yes.
    - To the extent required by NESC inspection requirements.
    - Require adherence to NESC which requires inspection.
    - No.
    - No.

6. **Do you have an active pole inspection and treatment program?**
    - No.
    - No formal program. Poles checked when performing routine system maintenance.
    - Yes.
    - Yes.
    - Yes.
    - Yes.
    - Yes.

7. **Is your program administered by in-house personnel or outside contractors?**
    - N/A.
    - N/A.
    - Outside contractors.
    - Administered in house, performed by contractors.
    - Administered in house, performed by contractors.
    - Outside contractors. Different contractors for inspection and reinforcement.
    - Contractors exclusively.

8. **What is the pole inspection cycle on your system?**
   - N/A.
   - N/A.
   - Once every 10 years for all poles that have been in service for 18 years or longer. For several areas where conditions are more prone to early decay, such as coastal areas, the in-service age of 10 years is used instead of 18 years.
   - 10 years is the target cycle.
   - 10 years.
   - 12 years.
   - 10 years.

9. **What percentage of pole population has been inspected in each of last five years?**
   - 3%
   - N/A.
   - Inspect about 8% of our wood pole population each year.
   - 63% total for an average of 12.5% per year.
   - 35% total for an average of 7% per year.
   - 8%.
   - 10% per year average.

10. **What minimum pole shell thickness is required to remain in service?**
    - 2" depending on pole circumference.
    - Follow NESC replacement requirements.
    - The minimum pole shell thickness required to remain in service varies depending upon the location and extent of the decay. We perform calculations based upon the mechanical loading on the pole and the characteristics of the remaining good wood.
    - Replace based on remaining strength of the pole using the remaining effective circumference as a factor in calculating the remaining pole strength.
    - Don't replace solely on shell thickness. Calculate strength based on circumference, shell thickness, etc.
    - Per NESC, any pole found to be less than 66% of original strength must have remediation. This remediation is in the form of either reinforcement or replacement.
    - 2" to be considered for reinforcement at either 15" or 26" above ground line and no voids above the 5' level.

11. **What treatment compound or methods are used?**
    - Copper naphthenate
    - None.
    - Use a fumigant for internal decay pockets and inject a liquid preservative treatment into any cavities.
    - Sodium fluoride & copper naphthalene external; methyl ethyl isothiocyanate internal.
    - For external applications, an oil and water borne preservative paste is used. A " wood fume" is used when an external paste cannot be used. Copper naphthalene is used for termite damage.
    - Sound and Probe, Treat with Copper-Boron Rods
    - External - COP-R-PLASTIC wood preserving compound; fumigant - MITC-FUME; internal voids, hollow heart – COP-R-NAP.

12. Does treatment compound or method vary by pole type (creosote, cca, penta, etc.)? If so, what treatment or method is used for each type of pole?
- No.
- N/A.
- The same method of inspection and treatment is used for both penta and creosote treated poles. We have not found it necessary to perform ground line inspection and treatment of CCA treated poles.
- Currently treating only creosote poles. The CCA poles are not old enough to need treatment.
- Treating creosote poles only.
- No variation.
- No but we do conditional inspection and treatment, meaning we do not fully excavate at this time, any CCA poles unless we have signs of decay from visual, sounding or boring.

13. Does your company reinforce poles in service?
- Yes.
- No.
- Yes.
- Yes.
- Yes.
- Yes.
- Yes.

14. What reinforcement method is used?
- C-truss
- N/A.
- Use both metal and laminated wood re-enforcers that are banded to the pole.
- Steel brace.
- Steel brace/strut.
- Groundline steel plates (C Truss)
- C-Truss.

15. What is estimated cost of pole reinforcement as percentage of cost of pole replacement?
- 25%
- N/A.
- Up to a maximum of 80%.
- 33%
- 19%
- 36%
- 25%.

16. What percent of poles inspected are: Treated? Reinforced? Replaced?
- Treated 84%, reinforced 0%, replaced 3.5%
- N/A.
- Treated 26%, reinforced 2%, replaced 3%.
- Treated 50%, reinforced 0.7%, replaced 2.25%.
- Treated 26%, reinforced 1.5%, replaced 2.6%.
- Treated 0.7%, reinforced 0.8%, replaced 0.6%.
- Treated 15%, reinforced 0.5%, replaced 0.7%.

17. What percent of wood pole population is replaced annually outside of formal pole inspection and treatment program? (for example, poles changed as result of everyday inspection or work by local line crews).
- <1%
- Not statistically tracked.
- <1%.
- <1%
- <1%.
- 0.065%
- Unknown, estimate 0.5%.

18. How many pole related outages do you experience annually that are non-storm related? (outages due to pole failure only—not caused by trees, cars, etc.)
- Approx. 20.
- Not tracked. Believed to be rare occurrence.
- About 430 and the trend has been to have decreasing numbers of failures each year.
- Approx. 100.
- 100
- 38 in last 12 months
- 1 or 2 per year.

19. What quality assurance processes are used in examining wood poles purchased from vendors?
- 3rd party inspection.
- Via stipulations as may be provided in purchase orders.
- Hire independent inspectors and monitor the quality of the poles we receive.
- Independent inspection.
- Independent inspection.
- Vendor QA inspections; vendor alliances.
- Have in-house inspector that oversees program.

20. Do you use independent inspectors to inspect poles or pole vendor processes?
- Yes.
- No.
- Yes.
- Yes. Independent inspectors are used at the vendor's facility.
- Yes.
- No.
- In-house inspector for 80% and use independent inspectors for 20%.

Appendix B: Weather Assessment

As performed by:
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AN ANALYSIS OF HURRICANE WILMA WIND INTENSITIES

This report carries an analysis of the data presented by the NHC and the supplementary information provided by KEMA (from their assessment). The major question relates to the official intensity of Hurricane Wilma as it impacted the southeast coastal area of Florida on October 24, 2005. The NHC's official stand of a Category 3 hurricane (winds in the range of 96 to 113 knots) was contrary to the media's statement of a Category 1 hurricane (winds in the range of 64 to 82 knots). However, the damage surveyed in counties such as Brevard, Indian River, Collier, Broward and Miami-Dade supports the NHC with a Category 3 hurricane.

Was Wilma a Category 1 hurricane?

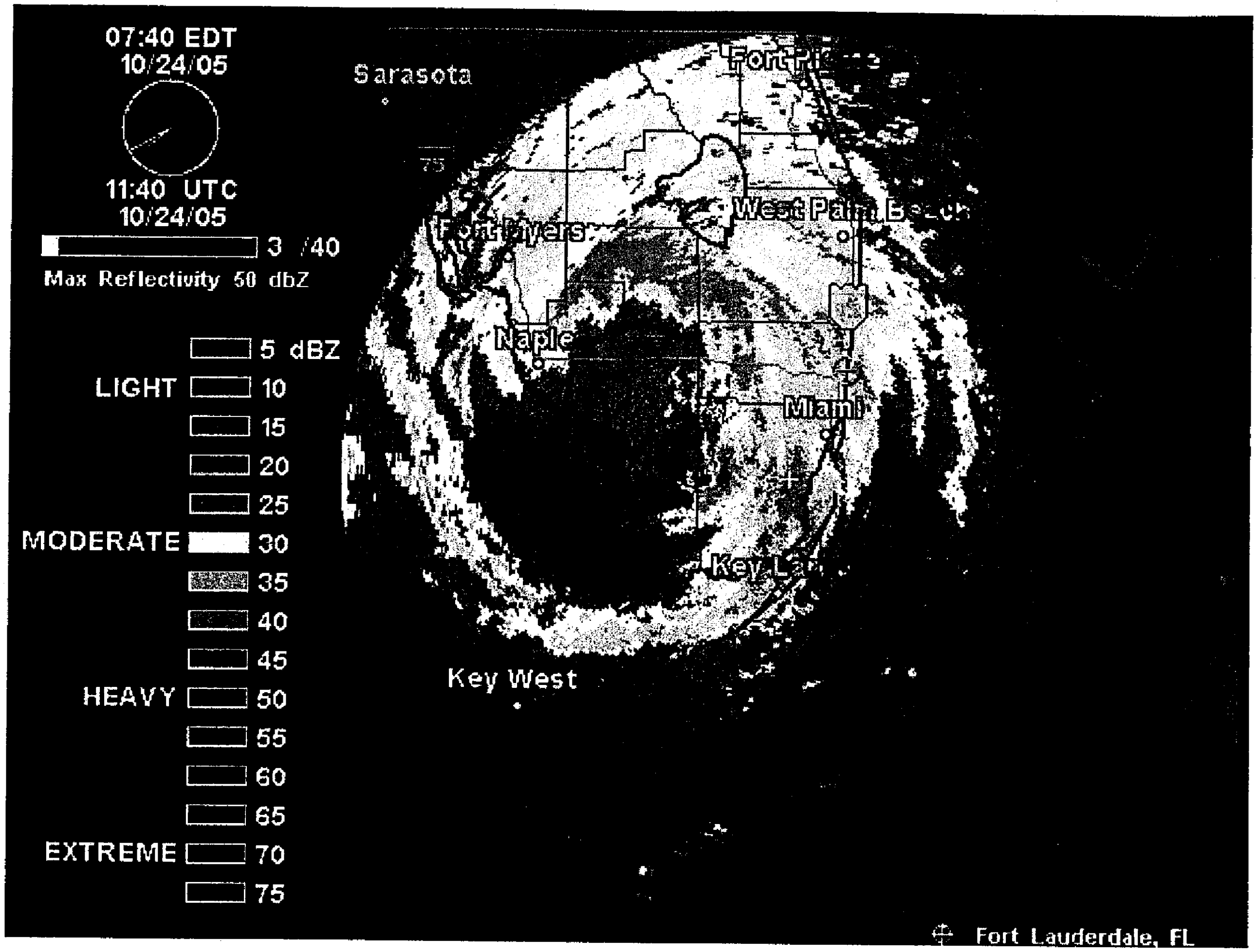
Your tables carry the following types of wind reports:

Tower LC39B (28.60 N 80.60W at 60 ft AGL)
Highest sustained-56 kts 10/24/05 1640Z
Highest gust-82 kts 10/24/05 1530Z (borderline Category 2 intensity)
Palm Beach County (Jonathan Dickinson Missile Tracking Annex)
Highest sustained- 71 kts 10/24/05 1310Z
Highest gust-98 kts 10/24/05 1314Z (Category 3 intensity)
Martin County (Stuart Skywarn Spotter 27.13N 80.20W)
Highest gust-94 kts 10/24/05 1419Z (Category 2 intensity)
Martin County (Vessel on South Fork of St. Lucie River; Boat mast anemometer 35 ft above sea level)
Highest gust-116 kts 10/24/05 (Category 4 intensity)
Lake Okeechobee L006 (SFWMD)
Highest sustained-90 kts 10/24/05 1430Z (Category 2 intensity)
Collier County (FCMP)
Peak gust-101 kts 10/24/05 1311Z (Category 3)
Miami-Dade (CHKF1)
Peak gust-98 kts 10/24/05 1235Z (Category 3)

From these tables we note that strong winds occurred largely when Hurricane Wilma was sweeping across south Florida. Only a few sites reported Category 3 winds. There is of course the issue of whether these strong winds were related to tornadoes. It is most likely that a rain band at the surface will see heavy rains and an associated surface squall line feature with strong gusts. Such gusts are very regular at the time of the passage of very heavy rains. Here one should in fact see some large differences between 3 minute averaged winds and a 3 second winds. Within the data there were some towers as well as elevated instruments recording wind speeds. It is important to note that these towers can overestimate the intensity of wind gusts. They can easily carry the winds a category higher than the reported winds. Some of the stronger winds were seen from the Ruscher Mesonet instruments and NASA towers. Those were not the conventional surface/2 meter wind reports. The wind sensors were located at a height of 60 ft on these towers. Surface winds tend to be smaller than those at 60 ft. These tower winds, however, are much more relevant to the damage. Winds at 60 ft and above exceeding speeds of about 85 kts could be detrimental to any tall buildings as windows could be broken and structural damage could occur from any debris or falling trees.

Radar Loops

We attach a radar loop of Hurricane Wilma as it traversed across Florida. This is the most important section of the analysis as it verifies the data provided by KEMA and allows for the explanation of damage. Please note the very intense rain band to the north of the hurricane before it makes landfall. This band revolves counterclockwise and causes heavy rain and related strong wind squalls (some of which may not have been directly observed). This part of the mesoscale strong winds history must be clearly related to Hurricane Wilma where we can isolate those features from the tornadoes that were spotted. This suggests that winds stronger than reported occurred in regions with the most severe damage. These counties are as follows: Brevard, Volusia, Indian River, St. Lucie, Okeechobee, and Osceola. This band carried very heavy rains (~5 to 6 inches) which was clearly evident in some of the precipitation data provided by KEMA for the aforementioned areas. Therefore, the radar loop suggests that a Category 2 could have easily escaped direct observation. These are areas for further research. The radar strongly suggests a strong rain band passage-possibly with related strong Category 2 winds and the resulting damage of the areas mentioned. Also, note that the northeast section of the storm traversed over the counties of Collier, Broward, and Miami-Dade as the storm crossed into the Atlantic. This section of all hurricanes contains the heaviest rain and the strongest winds. Therefore, in accordance with the data provided we can verify that these counties had the strongest winds as well as the heaviest rains. Thus explaining the extent of the damage in these locations.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LIGHT 10
15
20
25
MODERATE 30
35
40
45
HEAVY 50
55
60
65
EXTREME 70
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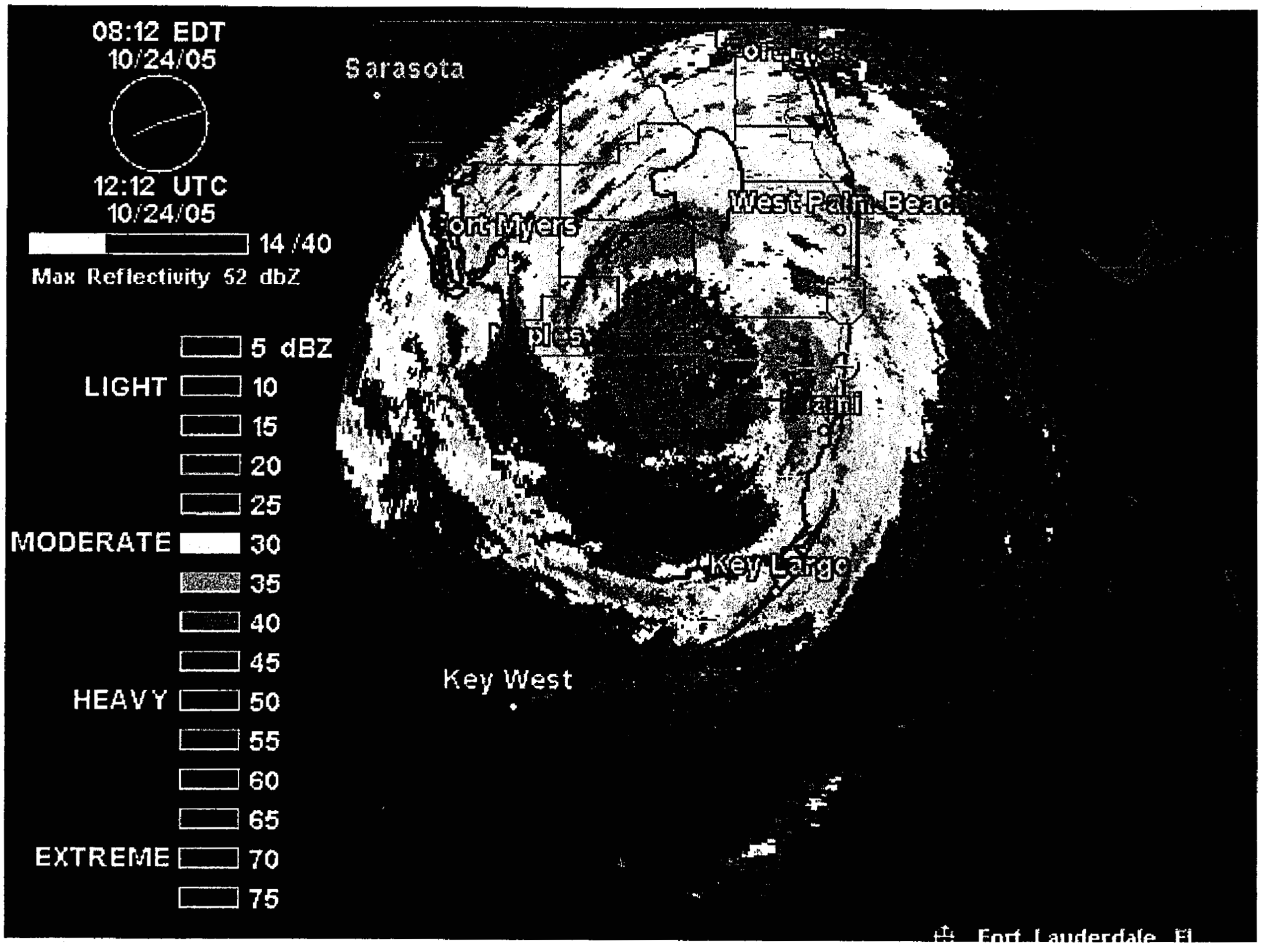
Fort Pierce
75
Fort Myers
West Palm Beach
Naples
Miami
Key Largo
Key West
Fort Lauderdale, FL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5 dBZ
LIGHT 10
15
20
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MODERATE 30
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HEAVY 50
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EXTREME 70
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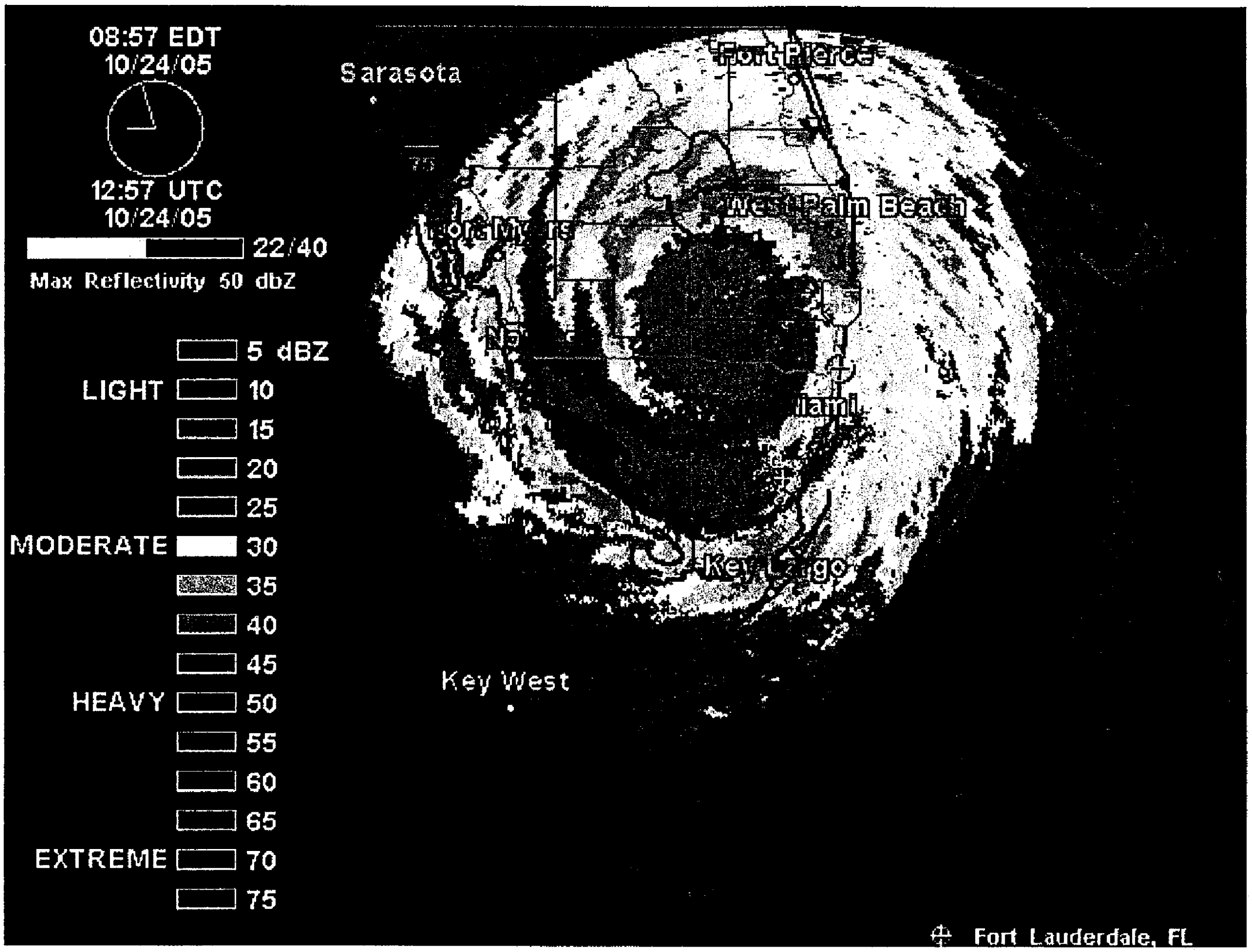
Sarasota
Fort Myers
West Palm Beach
Naples
Miami
Key Largo
Key West
Fort Lauderdale, Fl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MODERATE 30
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HEAVY 50
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EXTREME 70
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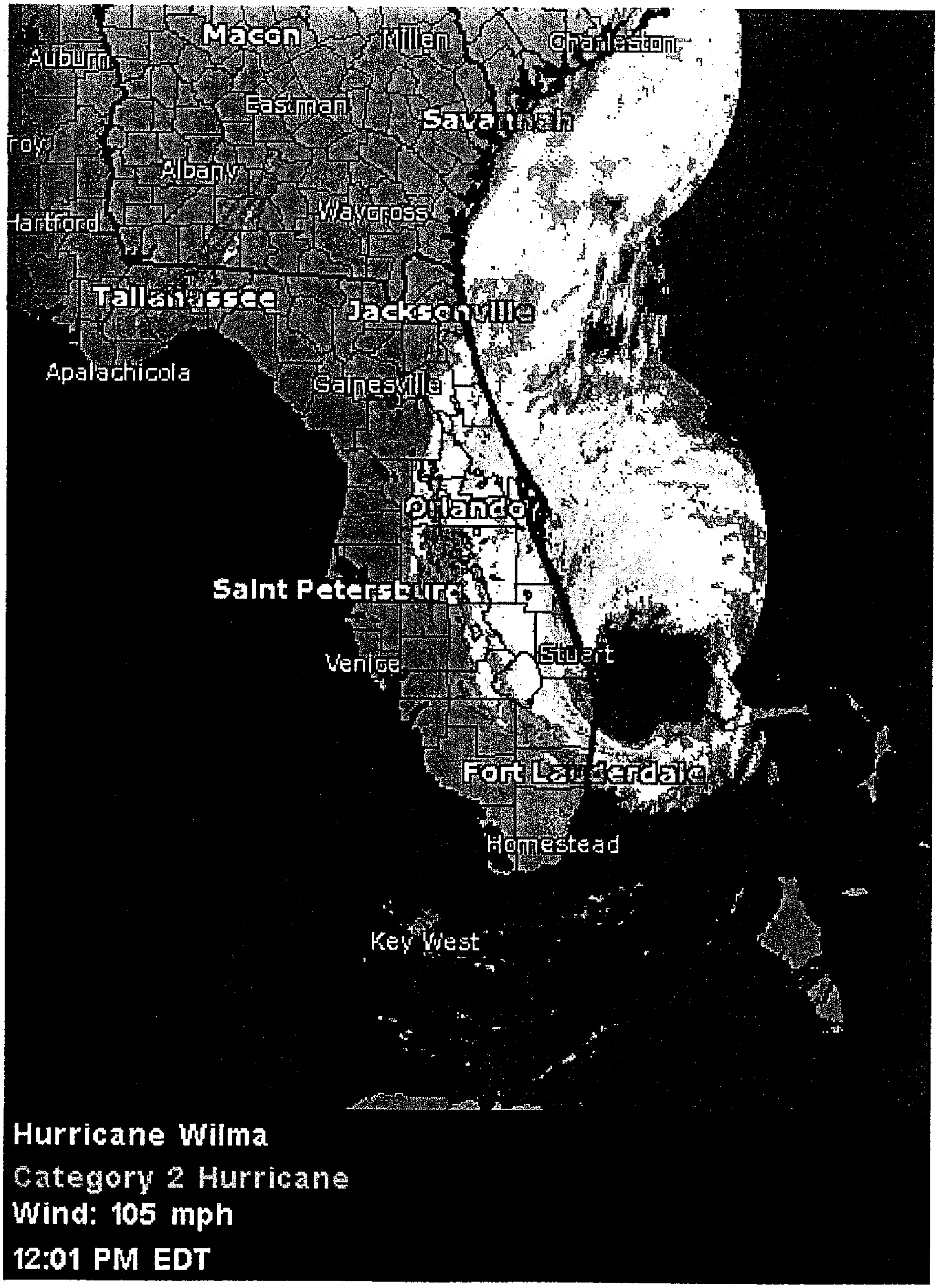
Fort Pierce
West Palm Beach
Fort Myers
Miami
Key Largo
Key West
Fort Lauderdale, FL


Macon
Millen
Charleston
Auburn
Eastman
Savannah
roy
Albany
Hartford
Waycross
Tallahassee
Jacksonville
Apalachicola
Gainesville
Orlando
Saint Petersburg
Stuart
Venice
Fort Lauderdale
Homestead
Key West
Hurricane Wilma
Category 2 Hurricane
Wind: 105 mph
12:01 PM EDT

Tornado Outbreaks, Tornado Winds vs. Hurricane Winds

During the passage of Wilma across south Florida the outer rain band of Wilma carried no less than four tornadoes. The tornado circulation (especially for an F0 to F1 tornado) carries maximum winds in the range of less than 73 mph to 112 mph. In essence, an F1 tornado at maximum wind speed of 112 mph is equivalent to a Category 3 hurricane. Having two weather systems, tornadoes and a hurricane over the same general region begs the question: should one identify all strong winds as those belonging to Hurricane Wilma. The tradition of the National Hurricane Center has been to separate the hurricane's strong wind circulation (about the center of the hurricane) from those of any tornadoes the hurricane might spawn. Given that, we need to sort out all strong winds that could be identified with the tornadoes as a separate entity. The following is a chronology of the tornadoes.

10/23/05 2030 – The first tornado was an F0 tornado (winds less than 73 mph). It formed in North Rockledge and moved across the Intracoastal Waterway into North Merritt Island destroying power transformers.

10/24/05 0630 – The second tornado was an F1 tornado (winds from 73 to 112 mph). It was observed by a fire and rescue team moving northwest from the intersection of US 41 and state road 29. It split a power pole in half and caused minor structural damage to homes and uprooted many large trees.

10/24/05 0635 – The third tornado was also an F1 tornado. It formed 3 miles north of the Sebastian Inlet and destroyed a house. The same tornado weakened to an F0 as it moved northwest into Palm Bay briefly. Witnesses say they saw the tornado strike power transformers.

10/24/05 0650 – The fourth tornado was another F1 tornado that touched down in West Melbourne destroying an apartment roof, three cars, and blew down fences and trees.

The scale of the tornadoes is very small and it was not sighted at many places, hence we can rule out the larger influence of strong winds for the tornadoes. However, the associated tornado cyclone and related squall system must have had a larger influence.

Big Damage Areas

There was clearly more damage from the passage of Wilma compared to that from Katrina over the south and central portions of Florida. The damage survey especially over Coconut Grove, Miami Beach, Biscayne Blvd., and Miami central was clearly much larger from Wilma than Katrina. Wilma's track passed closer to these regions where as that of Katrina was clearly farther south. There is a need to carry out a more detailed estimate analysis of Wilma's winds for this damage survey. It is possible that the gust structure of Wilma in the lowest few hundred feet carried rather strong winds. This needs to be evaluated from the 3-second winds. Several strong wind reports from the previous table show that these strong winds were located away from the tornadic areas and occurred after the tornadoes had diminished. This suggests the possibility of very strong gusts. This is a little reminiscent of Hurricane Kate of 1985, whose eye passed over Tallahassee as a Category 1 storm. The wind gust structure of Kate notably carried many

Category 2 features. No less than 5000 trees fell in Leon county during the passage of this Category 1 storm. Wind gusts although not long lasting can still create a large amount of damage. One can also note that gusts are not accounted for when determining the strength of a hurricane.

Data Analysis

The data provided by KEMA was credible and contained all the necessary information to answer all of their questions. The data contained several different wind measurements from various instruments and at various heights. This allows us to examine the storm from every angle and at every level. That type of data also allows for verification. With different wind instruments in the same area we can easily determine which instruments and measurements were accurate and which were not. However, there was an insufficiency in the wind data. All the wind data obtained and provided by KEMA occurred after the landfall of Wilma. It would have been even more helpful to provide wind data at landfall in order to more accurately determine Wilma's strength at landfall and throughout its passage over Florida. The tornado reports were also very helpful. This information aided in creating a relationship between the location of a rain band and the occurrence of tornadoes. With this data one can create an explanation for a majority of the damage in those cities where tornadoes occurred. The tornado reports assist in the separation of tornadic winds from hurricane winds so that the damage can be better assessed. Lastly, the rainfall amounts were essential when trying to pinpoint the location of the rain bands as well as the areas of the storm that carried the heaviest rains. This allows for the explanation of the location of severe damage. Typically where the heavier rains are within the storm and where the rain bands are located there are generally stronger winds leading to more damage. Thus explaining the intense damage in the counties previously mentioned.

Summary of Evaluation

Based on the above findings we provide the following assessment:

Was Wilma a Category 1 hurricane?

It is evident from the data provided by KEMA that Wilma was indeed stronger than a Category 1. Winds were recorded throughout its passage that exceeded Category 1 strength. The damage also suggests that stronger winds occurred.

How good is the NOAA data?

The NOAA data is credible and useful. However, the data does lack information on the landfall of Wilma. All the wind data reported occurred an hour or more after landfall along the southwest coast of Florida. This data would have been helpful when determining the strength of Wilma at landfall. The radar loop has proven to be even more helpful especially concerning the landfall of Wilma. The radar provided enough data to determine the intensity of the storm as well as verify locations with strong gusts and tornadoes.

Was Katrina stronger than Wilma?

It is evident from the damage reports provided by KEMA that Wilma was indeed stronger than Katrina. This can be shown from the insurance claims for both storms. Wilma prompted 750,000 claims totaling $6.1 billion. In contrast, Katrina, a Category 1 storm in South Florida, generated 110,000 claims in the state, totaling $468 million. Therefore, it is quite evident that Wilma was significantly stronger than Katrina in South Florida.

3-second gust speed vs. NOAA data

The NOAA wind data provided are two-minute averages. Three-second gust speeds can cause significant damage and should notably be accounted for. A two-minute wind average is going to be significantly smaller than a three-second gusts. Within a two-minute average a strong three-second gust can occur but it is averaged in with weaker wind speeds thus not accounting for its strength. Three-second gusts data could have better explained severe damage.

Geospatial Issues

Downbursts were not being mentioned anywhere during the passage of Wilma over South Florida. The scale of the damage seems somewhat inconsistent compared to the normal smaller size of downbursts in squall systems. The damaging winds spread over several counties making it a less likely possibility. However, much of the damage that occurred in various counties can be attributed to the tornadoes that were spawned from the rain bands. These tornadoes had the strength and wind speeds of a Category 3 storm and were capable of severe damage. The locations of these tornadoes are provided in an attachment. There were no other geospatial issues noted.

Appendix C: Key Contributors

This report is the result of a team effort including KEMA consultant, an independent weather expert, survey participants, and FPL employees. Material contributions by non-FPL employees were made by the following people:

KEMA Contributors

- Dr. Richard E. Brown (project manager, distribution standards)
- Dr. Gerard Cliteur (distribution forensics)
- Ms. Yujia Zhou (distribution forensics)
- Dr. M.L. Chan (pole inspection and maintenance)
- Mr. Bill Snyder (substations, industry survey)
- Mr. Donald Seay (substations)
- Mr. Andries van der Wal (transmission)
- Mr. Albert Egreczky (quality)

Non-KEMA Contributors

- Dr. T. N. Krishnamurti (weather)