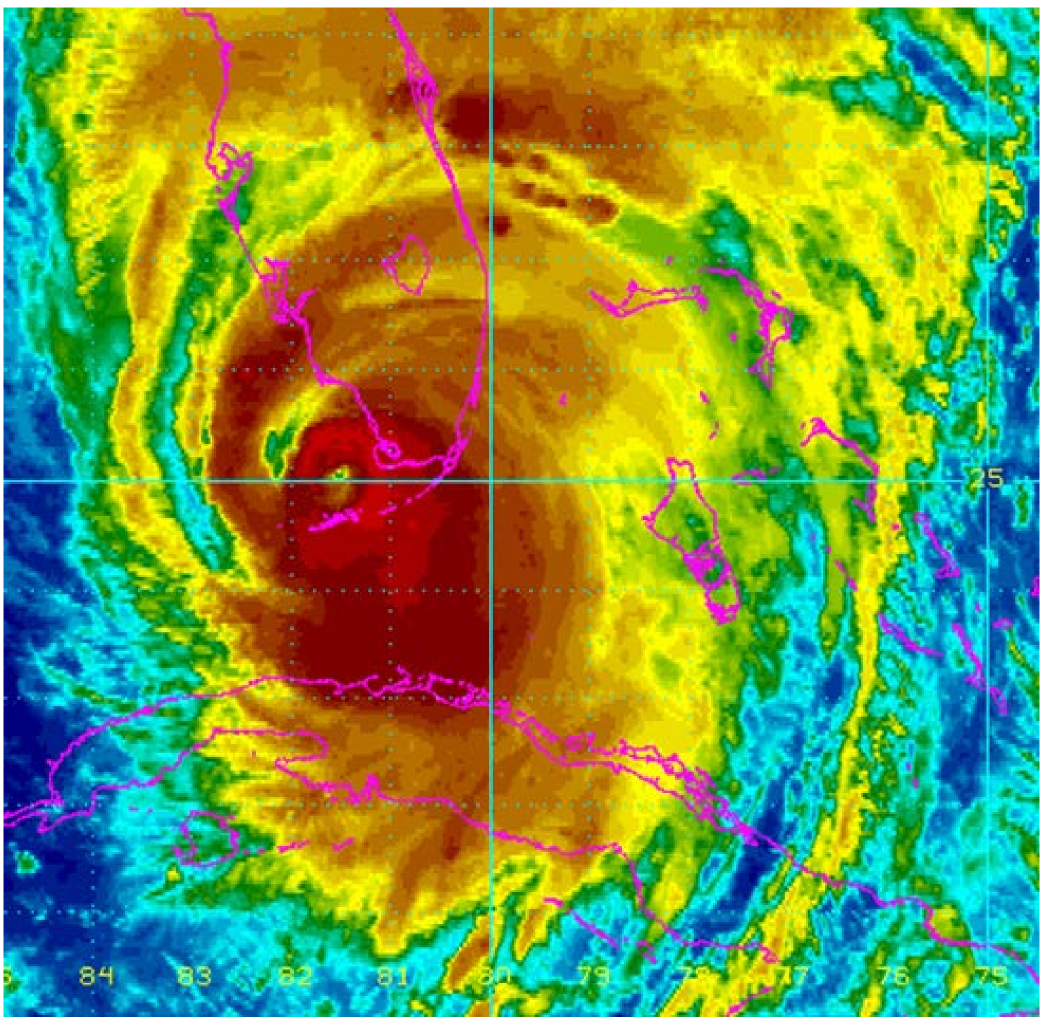
# Power Delivery Performance

## Hurricane Irma

**Storm Date: September 9, 2017**

**Report Date: April 19, 2018**



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# General

This is the Power Delivery Performance Report for Hurricane Irma. The purpose of this report is to give an overview of the performance and generalized assessment of the system with specific case studies describing conditions, damage, and system performance.

# Executive Summary

On Sunday September 10, 2017, Hurricane Irma made two landfalls in Florida; once in the Keys as a Category 4 hurricane and the second time in Southwest Florida on Marco Island in Collier County as a Category 3 hurricane. Hurricane Irma also generated 21 confirmed tornadoes in the Florida Peninsula. Irma impacted all 35 counties across the 27,000 square miles of FPL's service territory causing outages for 4.4 million or 90% of FPL customers. Hurricane Irma was an unprecedented storm by almost every measure -- size, destructive power and slow movement. The powerful storm spawned tornadoes, uprooted large trees, transformed roads into rivers, flooded isolated areas, and tore roofs off homes and businesses.

The investments in the FPL Grid since 2006 have made it more storm resilient. During Hurricane Irma, Transmission and Distribution Hardening and Smart Grid worked together to reduce the severity, amount of damage, and improve situational awareness.

The results: 50% of Customers restored in one day, 75% in three days, 95% in seven days and 100% in ten days. Average customer outage was 2.1 days for Irma compared to 5.4 days for Wilma

**FPL Transmission System** performed well in Irma. It is a testament to the benefits of hardening improvements that only 5 poles failed (1 wood pole on the Bulk Electric System and 4 wood poles on a 69KV circuit.) West Area, where the storm made landfall, has no transmission wood structures and had 0 pole failures. 127 Transmission lines tripped and 92 Substations went out. Substations were back in service in one day compared to 5 days in Wilma. 86 of the 92 Substations were out due to transmission outages, 4 for equipment damage and 2 were proactively deenergized due to flooding. Protective relay systems and Breakers were called on to clear 150 short circuit events and had only 2 mis-operations (1.3%). This is well below the 8% NERC average.

**FPL Distribution System** performed well in Irma and demonstrated that the investments in the Distribution Feeder Hardening Program, Pole Inspection Program (PIP) and Smart Grid are providing benefits. The system performed as designed and greatly helped to reduce severe damage, duration of restoration and provide the ability for the grid to self- heal. These investments were key to the speed of storm restoration.

**Distribution Pole Damage** was primarily due to fallen trees. 40% of total pole damage was in the west area where the storm made landfall and the ground was already saturated by severe rainfall before the storm. Southwest Florida had received record rainfall (16") less than 2 weeks before Irma which contributed to trees uprooting and poles leaning. Dade area had 30% of total pole damage which was primarily due to fallen non-native trees that are less storm resilient. Also, some areas in Dade choose to not follow the right tree, right place program which resulted in trees falling into poles and lines.

**Hardened Feeder** design philosophy to reduce restoration times by minimizing the number of pole failures during extreme wind and weather events was tested in Irma. During Irma, Hardened Feeders poles performed 10X better, required 50% less work to restore and had significantly fewer outages compared to non-Hardened Feeders demonstrating the benefits of hardening.

**Non-Hardened Feeder** performance and restoration benefitted from the Pole Inspection Program (PIP) which has resulted in the replacement of over 80,000 poles and reinforcement of over nearly 50,000 poles since the inspection program began in 2006.

**Overhead Lateral** outage rate was 4.7X greater than the Overhead Feeders outage rate with a failure every 1.2 miles of Overhead Lateral compared to every 5 miles of Overhead Feeders. Restoration of these Laterals is generally more difficult as many are in the rear of our customer's residential properties. That said, 24% of Overhead Laterals had damage that caused an outage. Underground Laterals performed 6.6X better than Overhead Laterals. Lateral Undergrounding part of the system, to alleviate restoration challenges related to significant access and vegetation issues, should be considered as a next step for grid hardening.

**Smart Grid** provided benefits that did not exist in 2004-2005 storm season. 546,000 Customer interruptions were prevented by self-healing of the grid during the storm.

Hurrican Irma approaching Cuba and the Florida Peninsula.

# Hurricane Irma Quick Stats

**Meteorology**

- Landfall in the Florida Keys as a CAT 4 Sunday 9:10 AM, September 10, 2017
- Second landfall in Marco Island as a CAT 3 at 3:35 PM, September 10, 2017
- Maximum sustained winds of 130 mph in Naples area, gusts to Hurricane strength throughout the east coast
- 21 tornadoes confirmed in the Florida Peninsula
- Rainfall of up to 21.66 inches, which was 3 to 5 times more than Wilma
- Southwest Florida was saturated and had flooding only a couple of weeks before Irma
- Widespread flooding in various areas throughout the state
- The path around the peninsula and relatively slow forward speed caused tropical storm force wind durations near 24 hours over parts of the FPL territory
- 4.3 Cyclone Damage Potential Index is higher than Wilma (2.6) and higher than any hurricane since Andrew

**Vegetation**

West area saturated with record breaking rainfall two weeks before Irma made landfall plus Irma impact led to significantly higher tree uprooting. Dade and East areas have a higher % of non-native trees that are less storm resilient

- **Tree Failure causes**
    - Up-rooting /Broken Trunks 57%
    - Broken Limbs 43%

| Tree Damage | Native | Non-Native |
|---|---|---|
| Dade | 20% | 80% |
| East | 30% | 70% |
| West | 55% | 45% |
| North | 70% | 30% |

**Distribution System Performance**

- **Feeders Out 2,286 170K CMH**
    - UG 85
    - Hardened 592
    - Non-Hardened 1,609

    Excludes outages caused by Transmission and Substation

- **Laterals Out 24,108 871K CMH**
    - OH 20,341
    - UG 3,767
    - Underground performed 6.6X better than Overhead

    *Excludes outages caused by Feeder, Transmission and Substation*

- **Overhead Feeder To Lateral Comparison:**
  - **Overhead Feeders performed 4.7X better than Overhead Laterals.**
    - OH Feeders had an outage every 5 miles while OH Laterals had an outage every 1.2 miles
    - **OH Feeders required 1 hour CMH to an average of 5 hours CMH for OH Laterals.** The total CMH estimate for Irma is 170K CMH for Overhead Feeders and 871K for Overhead Laterals

- **Distribution Transformers**
  Single phase pad mount transformers for Underground Systems performed 3.5X better than aerial transformers for Overhead systems. This further hi-lites the difference of Underground Systems vs. Overhead in a major storm.

| | | |
|---|---|---|
| • **Poles Down *** | **2860** | **(Feeder, Lateral, Service, Telephone)** |
| o Hardened Feeder | 26 | (0.02%) |
| o Non-Hardened Feeder, Lateral,Service,Telephone | 2,834 | (0.20%) |

** Poles replaced to restore power*

- **Smart Grid**
  Automatic Feeders Switch (AFS) teams operated to avoid 546,000 Customer Interruptions

**Hardened Feeder Performance**

Hardened Feeders demonstrated significantly better performance. The primary objective of hardening is to reduce restoration times by minimizing the number of pole failures during extreme wind weather events.

- **Hardened Feeders performed better than non-Hardened Feeders**
  - Pole Failure Rate 10x better
  - CMH to Restore 2x better
  - Outages 1.19x better

**Transmission and Substation System Performance**

| | | |
|---|---|---|
| • **Transmission Out** | **215 line sections** | |
| • **Transmission Poles Down** | **5** | |
| o BES (Bulk Electric System) | 1 | (wood, non-hardened) |
| o Non-BES (69kV) | 4 | (wood, non-hardened) |
| • **Substations Out** | **92** | |
| o Transmission outages | 86 | |
| o Substation Equipment | 4 | |
| o Flooded | 2 | (proactively deenergized) |

**Other**

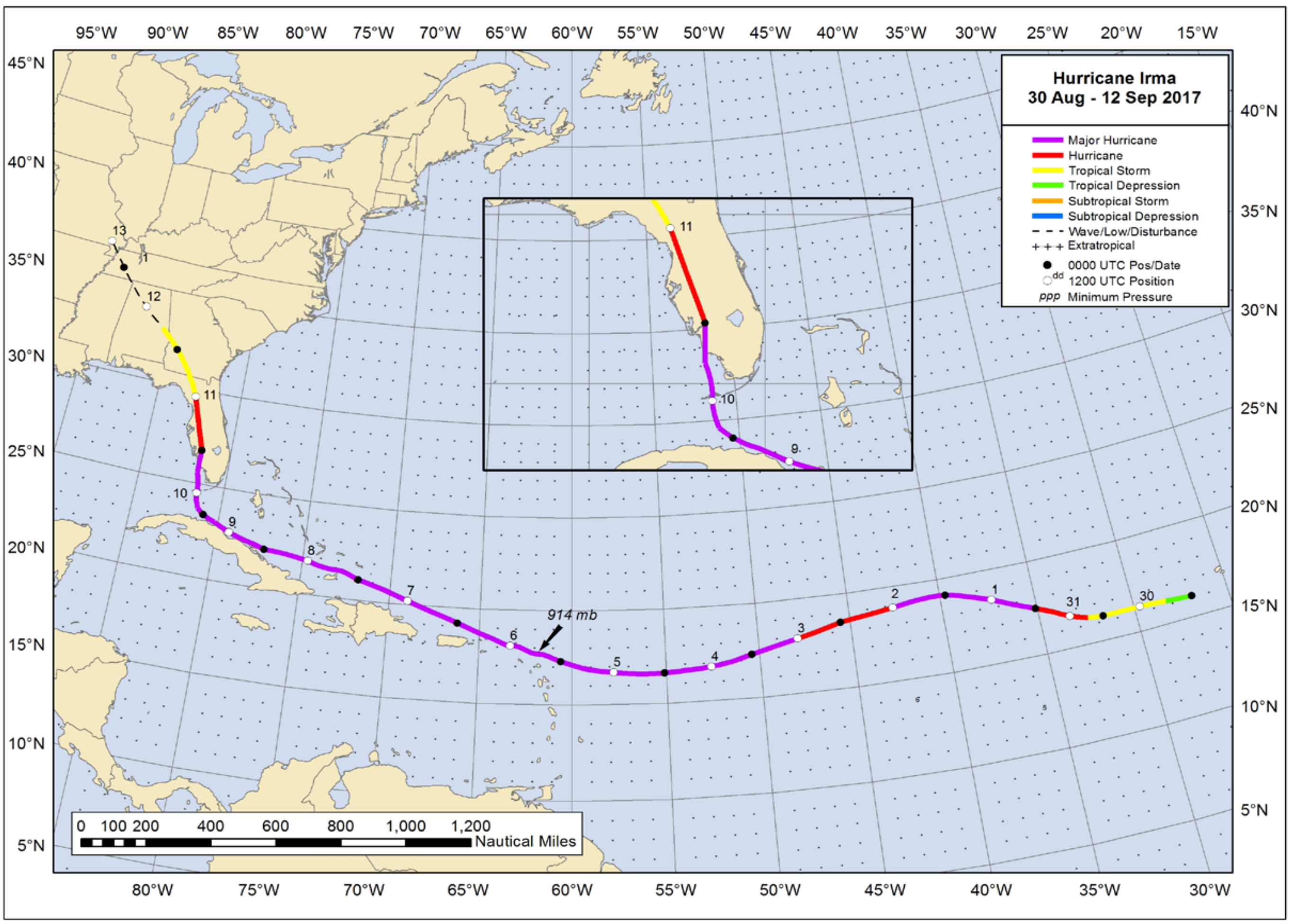
| | |
|---|---|
| • Injuries OSHA | 9 |
| • Injuries / 200,000 CMH | 2.35 |
| • Forensics Teams Deployed | 42 personnel (trans., sub, dist.) |

# Storm Characteristics and Weather

Hurricane Irma began to directly affect South Florida early in the morning on September 9, 2017. As Hurricane Irma traveled north through the state, it continued to impact customers into the evening on September 11. Due to its size and path, Hurricane Irma impacted all 35 counties across FPL's 27,000 square-mile service territory. The National Hurricane Center's preliminary report estimates that parts of FPL's service area experienced hurricane-force winds as high as 142 miles per hour and rainfall totaling as much as 21.66 inches.

Hurricane Irma was an unprecedented storm by almost every measure -- size, destructive power and slow movement. The powerful storm spawned tornadoes, uprooted large trees, transformed roads into rivers, flooded isolated areas, and tore roofs off homes and businesses. FPL brought in twice as many tree trimming crews to support the Irma restoration effort compared with Hurricane Wilma in 2005.

### Actual Storm Path




Best track positions for Hurricane Irma, 30 August–12 September 2017 (Source NHC)

## Storm Surge

Examples of storm surge caused by Hurricane Irma across Florida.

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**Storm Surge Summaries (Source NHC)**

COLLIER COUNTY**:** Highest inundation in Chokoloskee of 6-8 feet at waterfront, approximately 8 feet above mean higher high water (MHHW), with 3-5 feet across most of island. In Everglades City, maximum 6 feet of inundation at Everglades National Park Gulf Visitor Center, with 2-4 feet across the town and as high as 5 feet in a few areas. In Marco Island there was 2-4 feet inundation mainly on South and East parts of Island with less than half mile inland penetration. In Naples there was 3-4 feet inundation along Gulf water-front within 1 block of beach, with less than half mile inland penetration. Highest inundation values were noted in Vanderbilt Beach as well as South of Naples Pier. Along Naples Bay, inundation of 1-2 feet on West side of bay just South of Tamiami Trail, resulting in about 2-3 feet above MHHW. The National Ocean Service (NOS) tide gauge at Naples measured a water level of 4.25 feet MHHW. USGS storm tide sensors in Naples and at Delnor-Wiggins State Park near Naples Park measured water levels of 5.06 feet NAVD88 (4.5 feet MHHW) and 3.90 feet NAVD88 (3.4 feet MHHW), respectively.

LEE COUNTY**:** The gauge at Ft. Myers on the Caloosahatchee River recorded a water level of 3.28 feet MHHW. In Bonita Springs USGS Survey indicated surge of 4.64 feet. up the reaches of the Imperial River.

DESOTO COUNTY**:** Inundation of up to 6 feet along the Peace River near Arcadia from surge and rain.

DADE COUNTY: The combined effect of storm surge and the tide produced maximum inundation levels of 4 to 6 feet above ground level for portions of Miami-Dade County in southeastern Florida, especially along Biscayne Bay. A USGS storm tide sensor at Matheson Hammock Park in Miami measured a peak water level of 5.75 feet NAVD88 (5.6 feet MHHW), consistent with a high water mark of 5.1 feet above ground level which was surveyed in the park. The NOS tide gauge on Virginia Key recorded a peak water level of 3.7 feet MHHW. Lesser inundation occurred North of downtown Miami and along Atlantic oceanfront.

BROWARD COUNTY: 2-3 feet inundation along the barrier island from Ft. Lauderdale Beach South. Tidal overwash reported in Ft. Lauderdale on A1A and adjacent streets. Inland penetration was less than half a mile.

PALM BEACH to INDIAN RIVER COUNTIES: A storm tide sensor along the Intracoastal Waterway in Boca Raton recorded a wave-filtered water level of 3.05 feet NAVD88 (2.7 feet MHHW), and the NOS tide gauge at Lake Worth measured a peak water level of 1.5 feet MHHW. Farther north, maximum inundation levels of 1 to 3 feet above ground level occurred across coastal sections of Martin, St. Lucie, Indian River, and southern Brevard Counties.

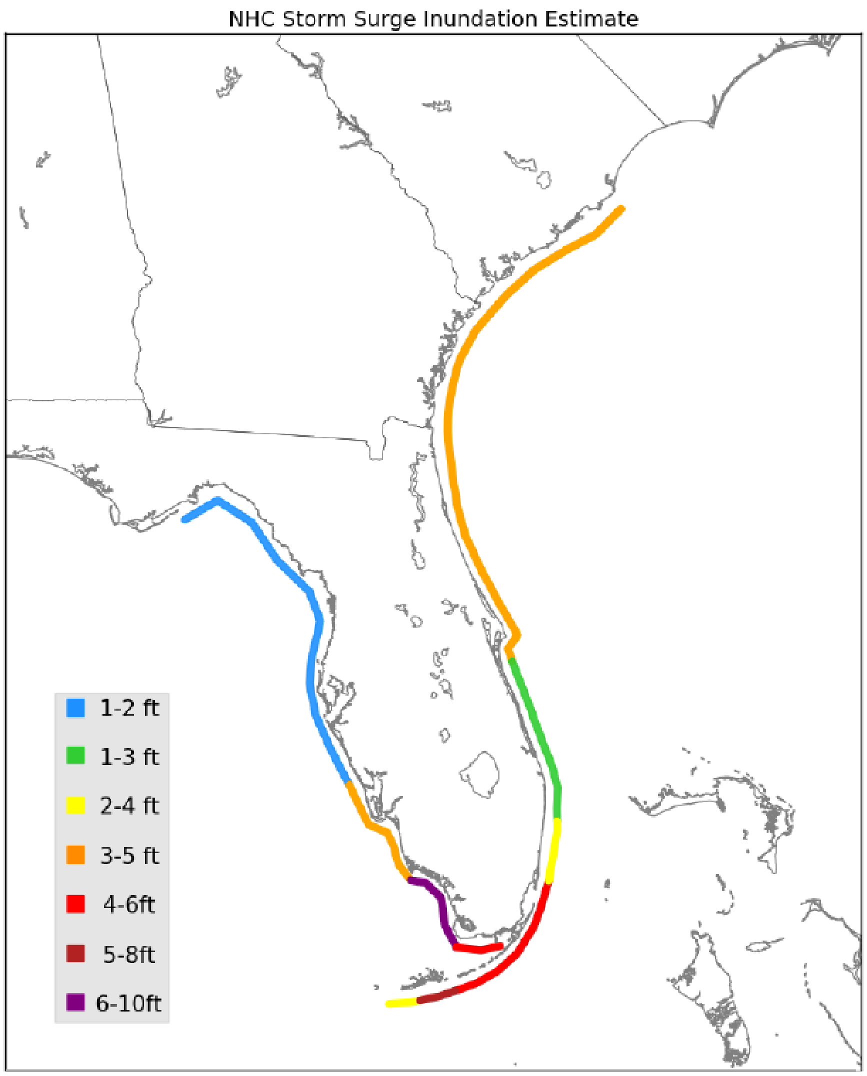
BREVARD COUNTY: A maximum of 3 to 5 feet of inundation above ground level occurred from Cape Canaveral northward to the Florida-Georgia border. The NOS tide gauge on Trident Pier at Port Canaveral measured a peak water level of 4.2 feet MHHW.

VOLUSIA COUNTY: A USGS storm tide sensor at Ormand Beach recorded a water level of 4.37 feet NAVD88 (4.5 feet MHHW).

<u>ST. JOHNS COUNTY:</u> Durbin Creek reported a storm surge over 5 feet and 4.7 feet at Racy Creek. A storm tide sensor on the Matanzas River south of St. Augustine recorded a wave-filtered water level of 6.65 feet NAVD88 (4.8 feet MHHW), and the USGS surveyed several high water marks of 2 to 4 feet above ground level in that area. The highest was a mark of 3.3 feet above ground level near Vilano Beach.

<u>DUVAL COUNTY:</u> A storm surge of nearly 6 feet was recorded along the St. John's River and several surrounding rivers and creeks. Along the coast of extreme northeastern Florida, a storm tide sensor at Jacksonville Beach recorded a wave-filtered water level of 6.55 feet NAVD88 (4.1 feet MHHW).

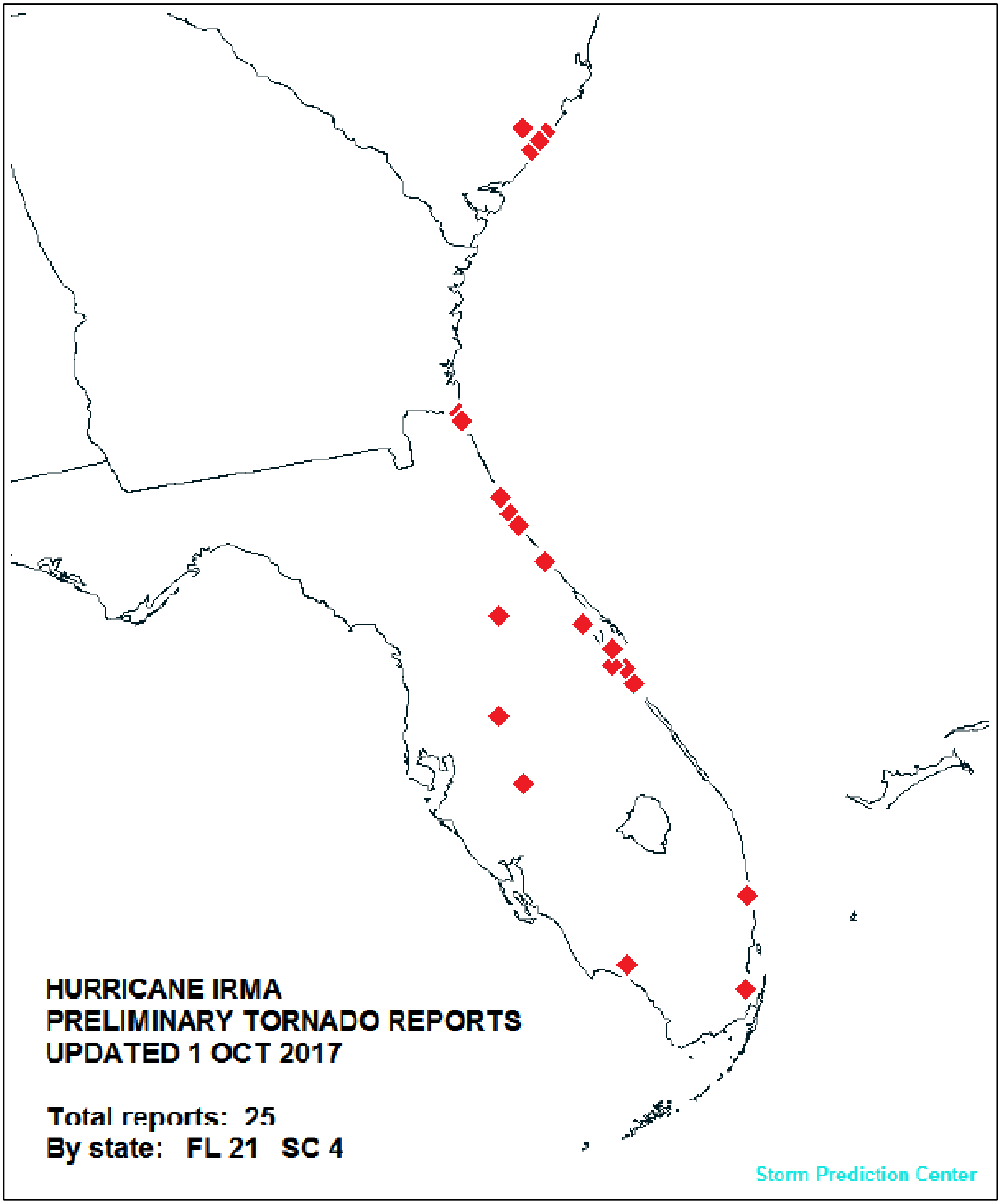
<u>NASSAU COUNTY:</u> A storm surge up to 7.78 feet was recorded along Fernandina Beach. In addition, the NOS gauges at Mayport (Bar Pilots Dock) and Fernandina Beach both measured peak water levels of 3.6 feet MHHW.




Analyzed storm surge inundation (feet above ground level) along the coasts of Florida, Georgia, and South Carolina from Hurricane Irma. Image courtesy of the NHC Storm Surge Unit.

**Tornadoes**

Twenty-one tornadoes were reported in the Florida Peninsula.



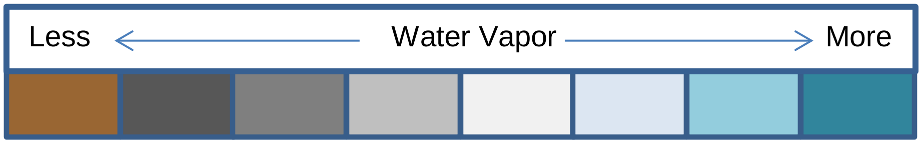

Map of tornado reports from Hurricane Irma. Courtesy of NOAA's Storm Prediction Center.

## Water Vapor

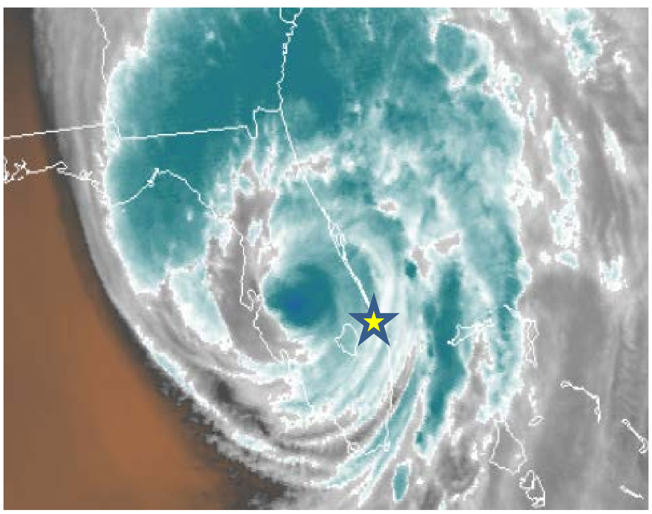
Color water vapor images taken from NOAA's GOES Satellite* shows a dry slot coming across the St. Lucie Site (designated by star) after the eye had passed north of the plant which caused significant insulator contamination**. This was typical for several locations along the East coast.

* ftp://ftp.nnvl.noaa.gov/GOES/color_WV/

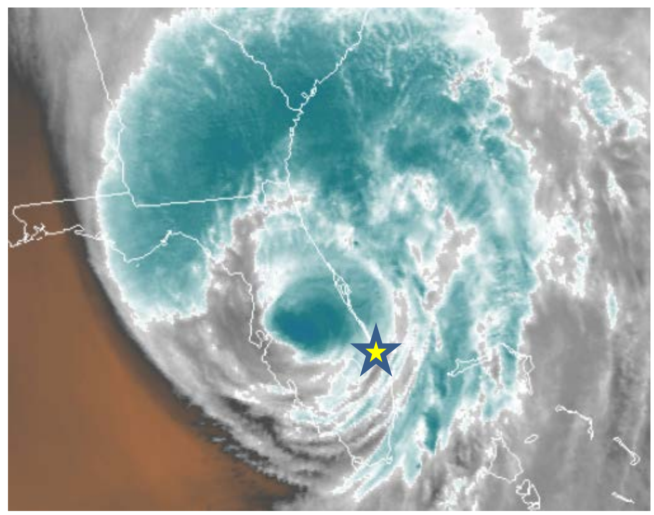
** Insulator Contamination Case Study on page 34



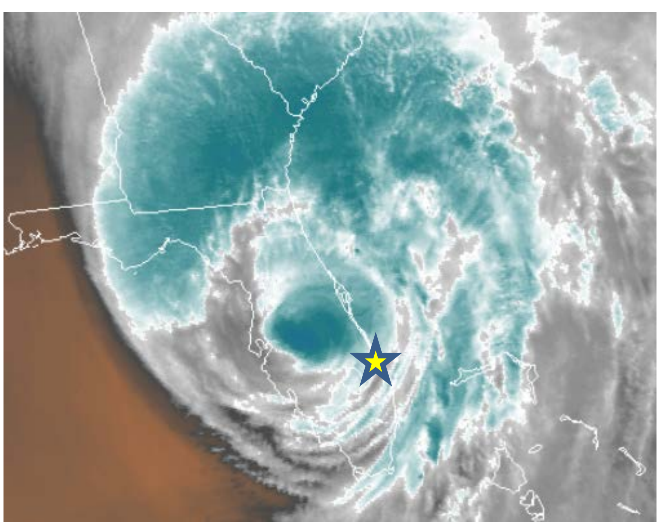

9/11/17 at 12:45AM



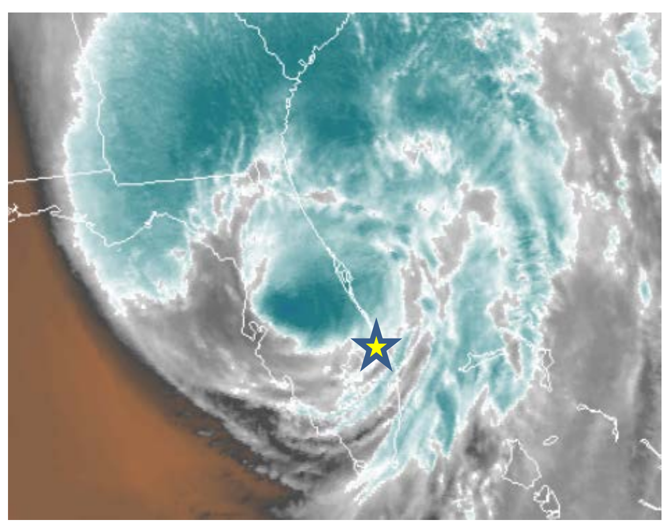
9/11/17 at 01:44AM



9/11/17 at 02:16AM



9/11/17 at 04:14AM





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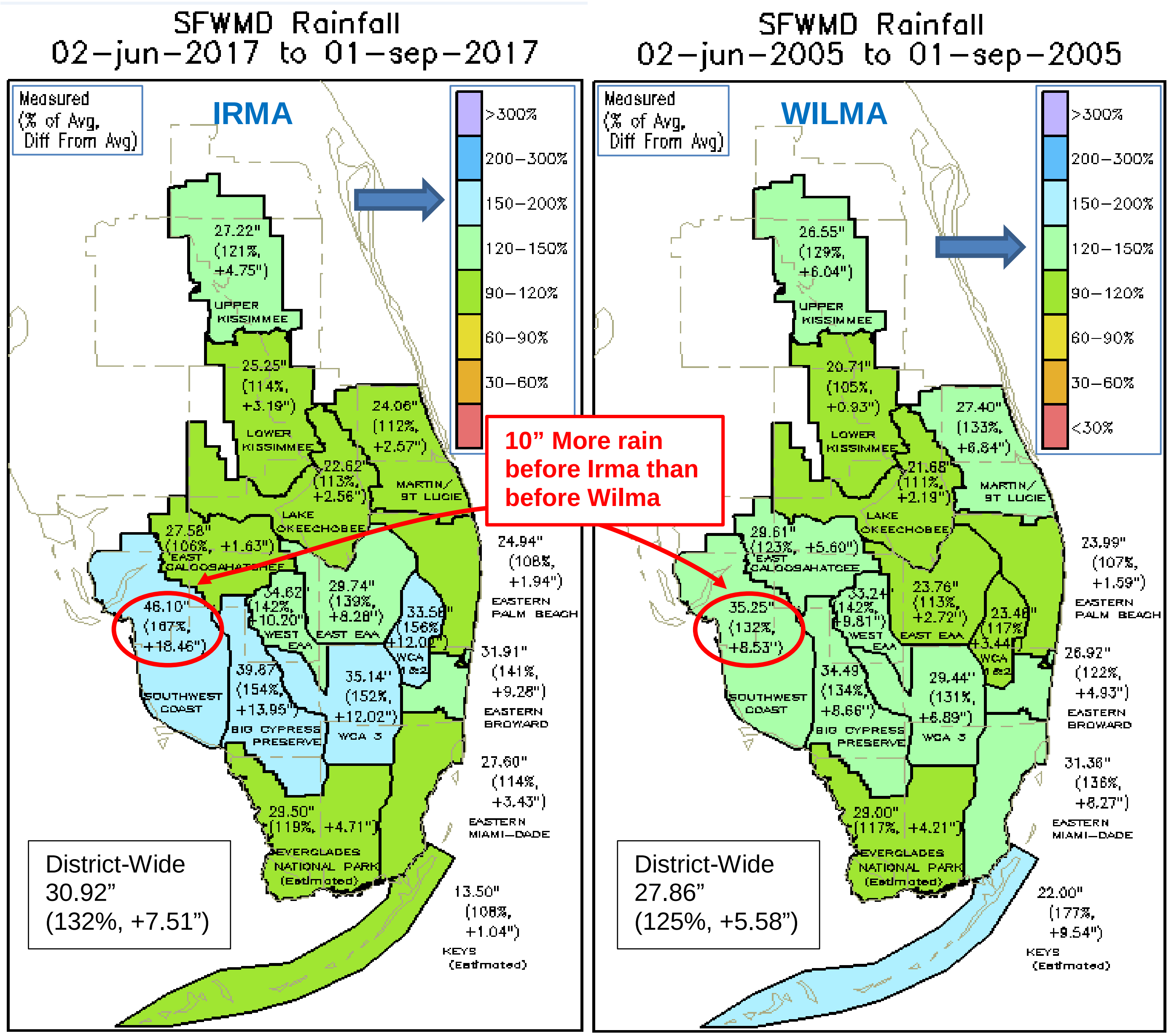
## Rainfall

### Rainfall Pre-Storm per SFWMD (South Florida Water Management District)

In general, more rain fell (~ 3") for the entire district from Irma (2017) as compared to Wilma (2005); however, in specific regions the rainfall was as much as 10" more from Irma as compared to Wilma. Also, note that the light blue sections designate that rainfall was 150%-200% above average. Significant wet soil conditions pre-storm combined with the slow moving Irma storm caused significantly more uprooting of vegetation.

| County / Region | Irma | Wilma | Difference | Circle Color |
|---|---|---|---|---|
| Southwest Coast | 46.10 | 35.25 | 10.85 | Red |
| SW Palm Beach & NW Broward | 33.58 | 23.48 | 10.10 | Purple |



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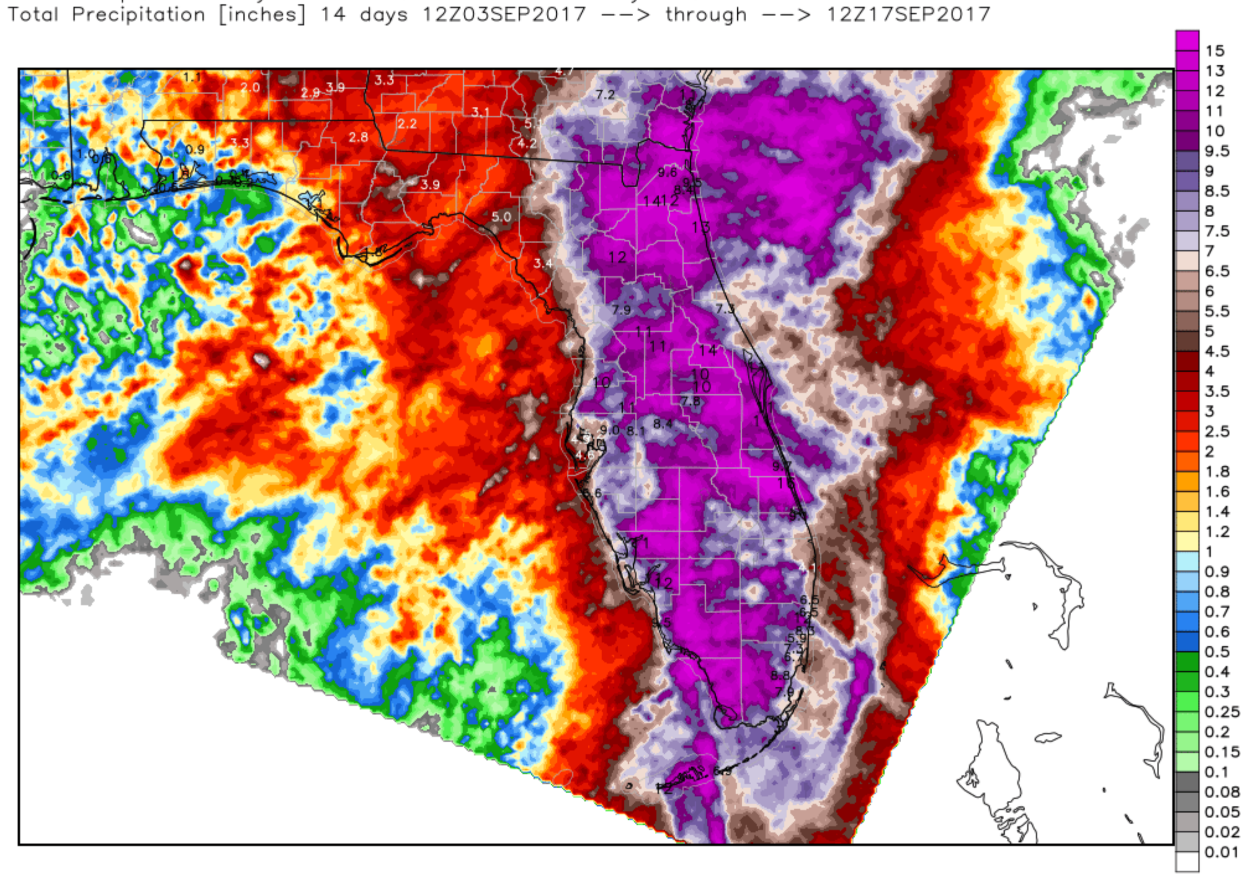
## Rainfall Pre-Storm

- The three day period between Aug. 25 and Aug. 27 produced over 16 inches of rain in Southwest Florida which was well above the all-time record (9.8 inches.)

Picture of Southwest Florida on August 28, 2017 2 weeks before IRMA. Source: Kinfay Moroti/news-press.com

## Rainfall 14 day Precipitation Centered on Storm Landfall



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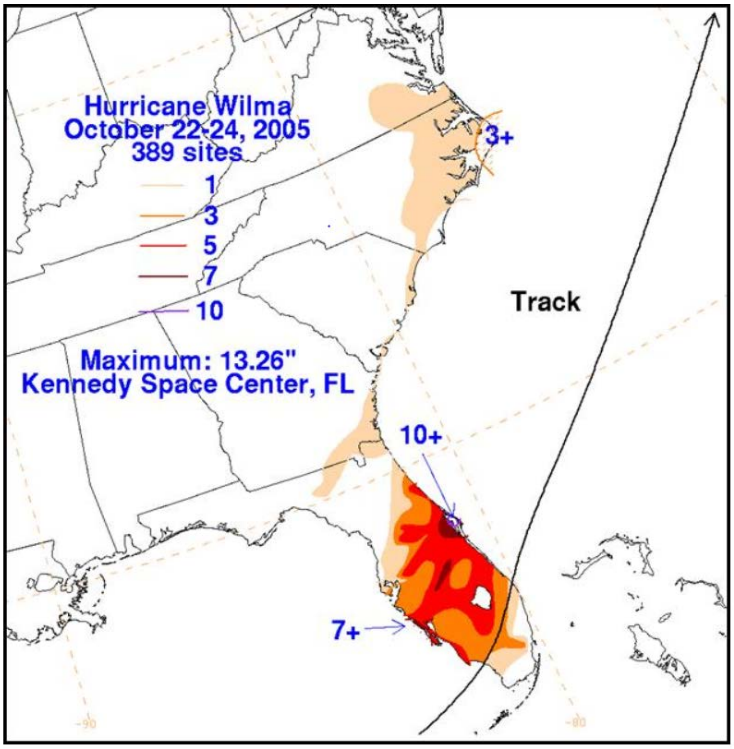
## Actual Storm Rainfall over a 3-Day Span

- Irma experienced 3 to 5 times more rain as compared to Wilma

## Wilma Rainfall was 3-7 inches




urricane Wilma storm total rainfall map (22-24 October 2005), constructed using data provided by NWS River Forecast Cen
nage courtesy of NOAA/NWS/Hydrometeorological Prediction Center).

## Irma Rainfall was 12-15 inches

# Vegetation Impacts

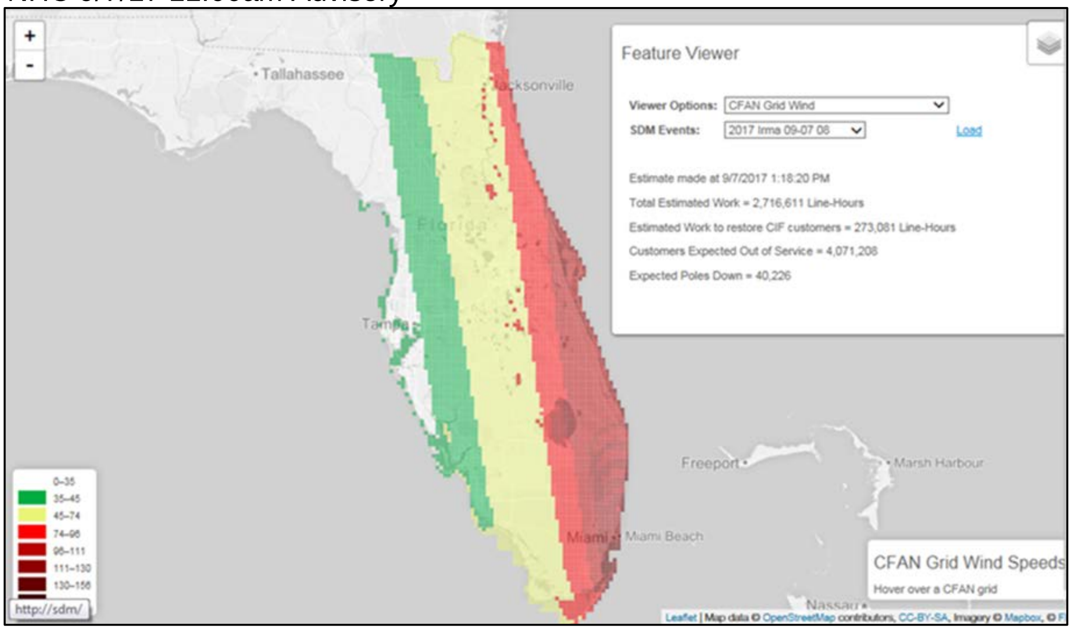
- Vegetation section starting on page 89 with detailed analysis

Vegetation outside of ROW toppling into Overhead Circuits was common.

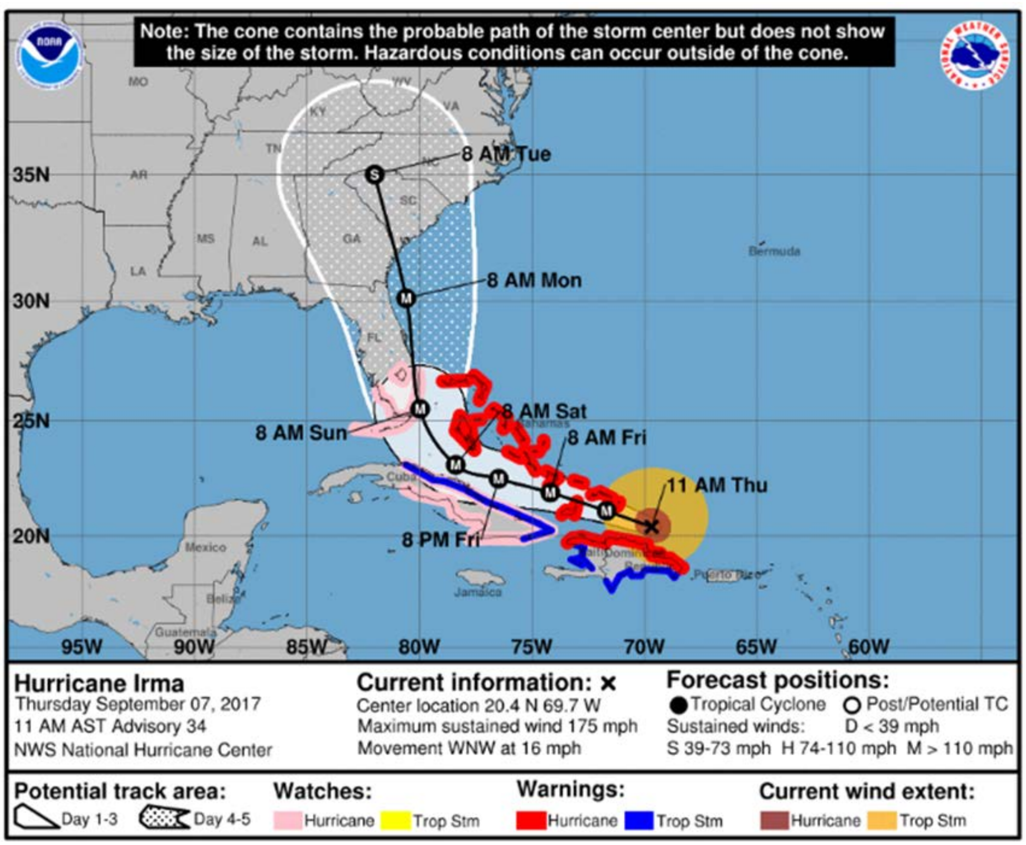
# Pre-Landfall Storm Path

## 72 Hour Pre-Landfall

NHC 9/7/17 11:00am Advisory




NHC Track 9/7/17 11:00am Advisory



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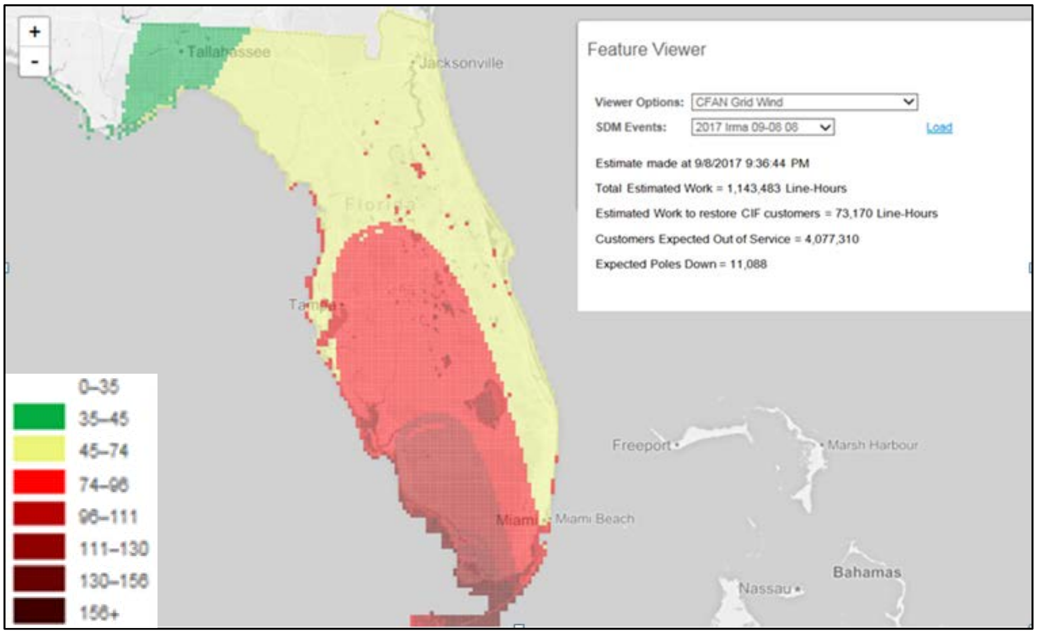
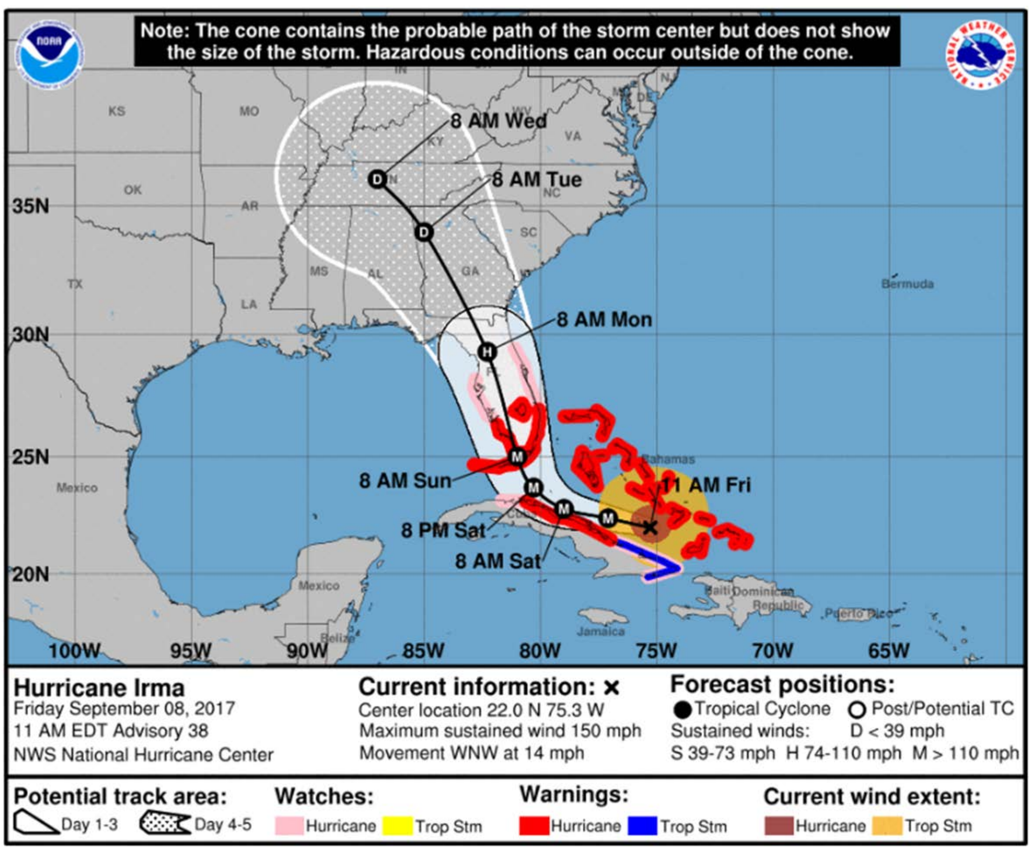
## 48 Hour Pre-Landfall

NHC 9/8/17 11:00am Advisory

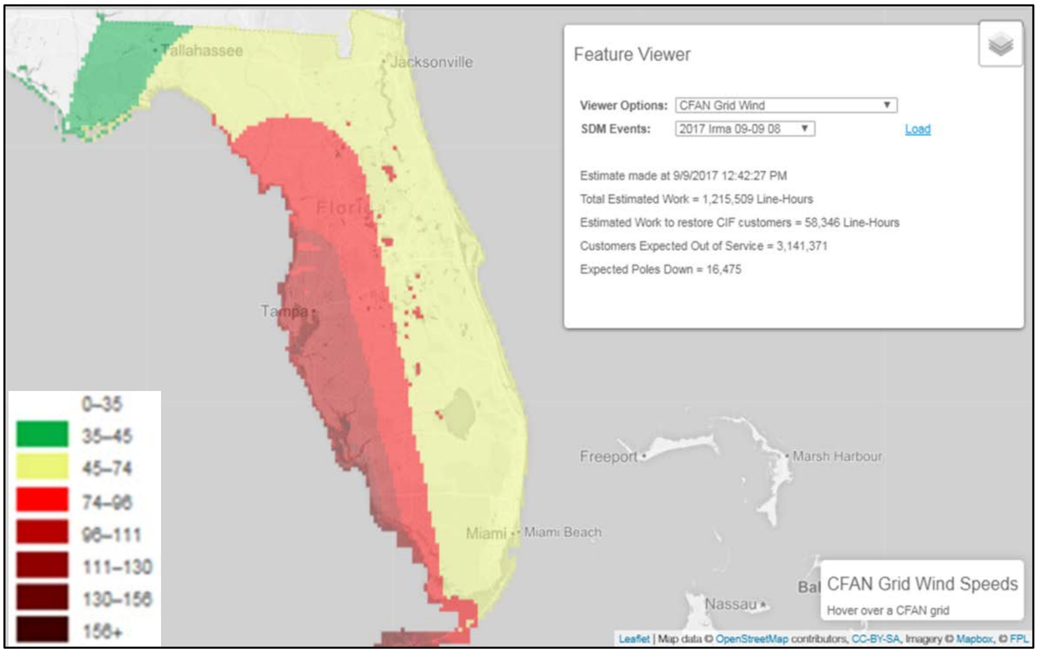



NHC Track 9/8/17 11:00am Advisory

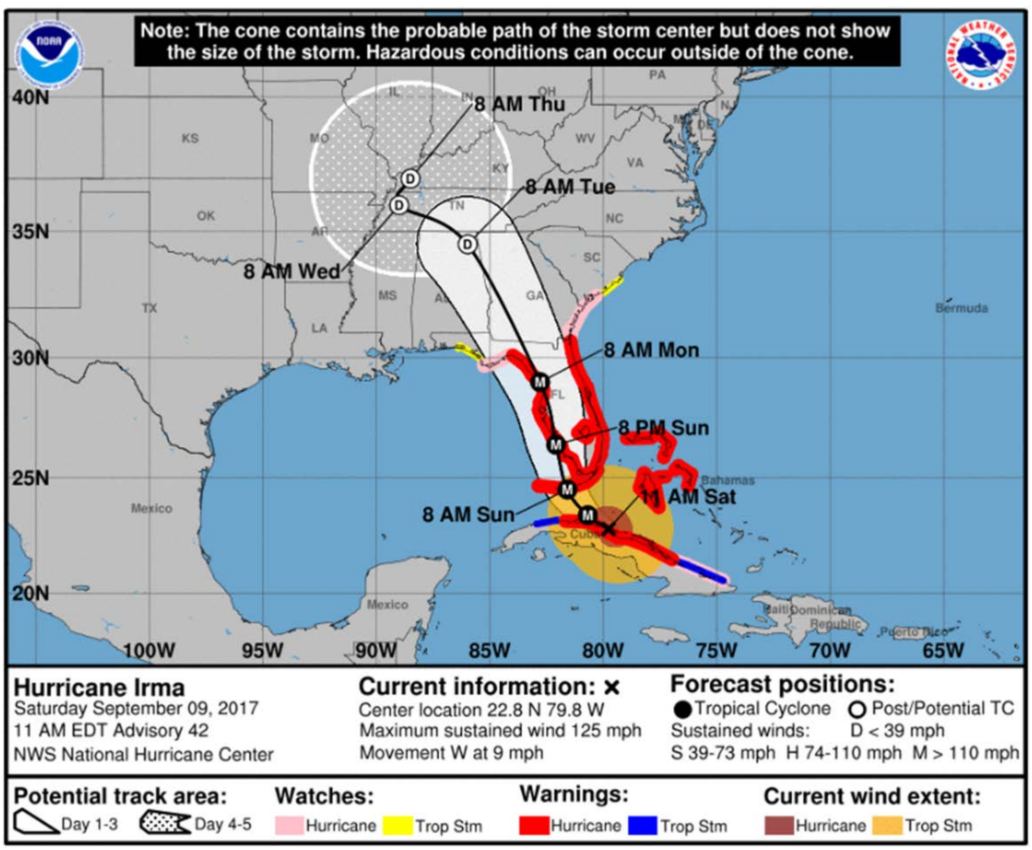


## 24 Hour Pre-Landfall

NHC 9/9/17 11:00am Advisory




NHC Track 9/9/17 11:00am Advisory



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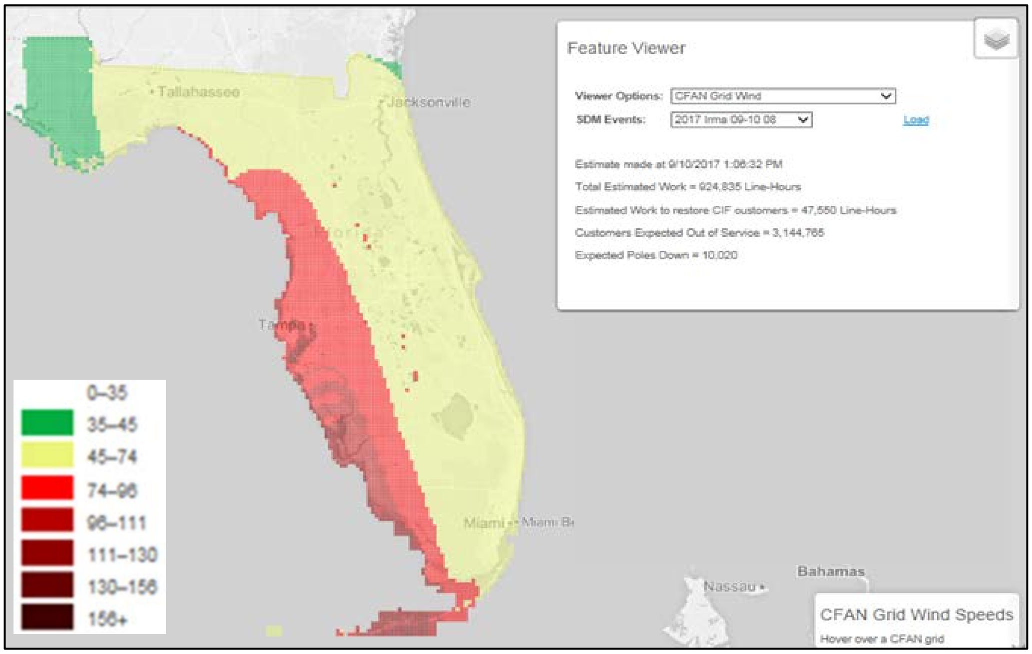
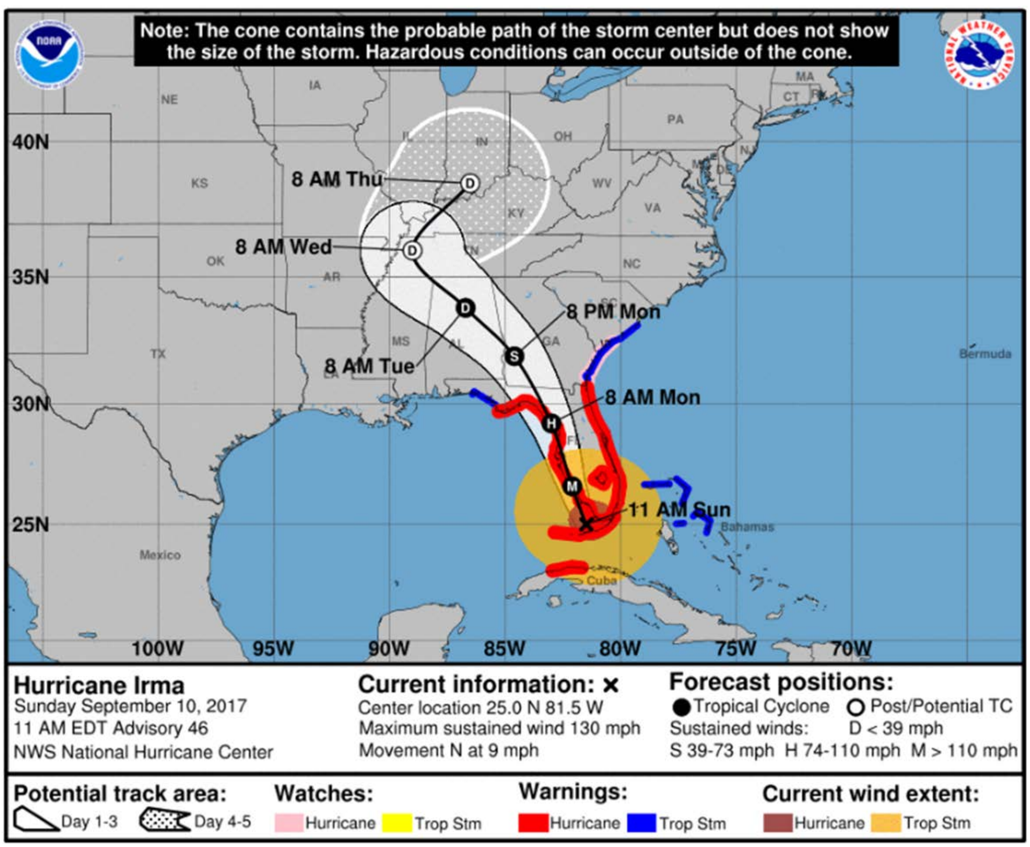
## Final Hour Pre-Landfall

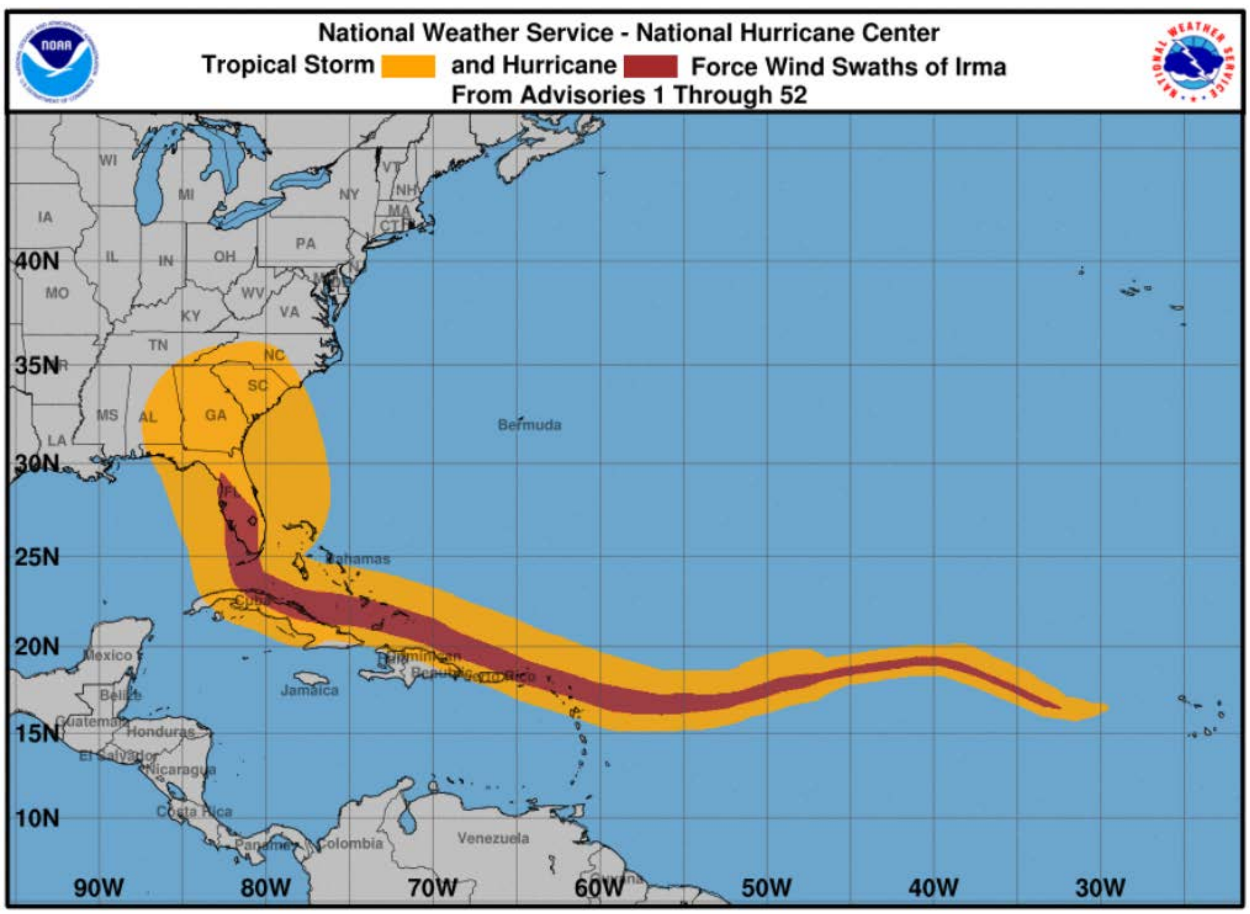
NHC 9/10/17 11:00am Advisory




NHC Track 9/10/17 11:00am Advisory



## Actual Storm Path (Source: NHC)

# Transmission and Substation Performance

## Summary

Overall, the Transmission System performed well during the storm event. Equipment and conductor damage was minimal. ***Duration of outages was approximately 1 day*.**

**Transmission lines out: 127**

- Voltage class 7 -69kV, 26 -115kV, 58 -138kV, 35 -230kV, 1-500kV

**Transmission line sections out: 215**

- Voltage class 14 -69kV, 69 -115kV, 90-138kV, 41 -230kV, 1-500kV

**Substations out: 92**

- 86 due to transmission line outage
- 2 were de-energized proactively due to flooding (St. Augustine and South Daytona)
- 4 due to Substation equipment damage (Delta, Haulover, Lighthouse and Memorial)

**Protection System Performance:**

- There were 150 transmission relay events and 2 mis-operation for a 1.3% mis-operation rate (NERC goal is 8.0%, FPL 12 month average is 4.8%)
- Calculation based on NERC PRC-004

**Major Equipment Damage:**

**Transmission Lines and Substations**

- Replace 4 structures on Sweatt to Sweatt Tap line section on the Okeechobee to Sherman #1 69kV line
- Replace 1 structure on the Deland to Putnam 115kV line
- HV breakers 2 (1-230kV and 1- 138kV)
- Repair 5 cross braces

**Distribution Substations**

- Power Transformers 7
  - o 1-230/23kV, 2-138/13.8kV, 4-138/13.8kV TCUL
- Medium Voltage (MV) Breakers 38
  - o 34-13.8kV feeder, 3-23kV feeder, 1-13.8kV bus breaker
- Regulators 18
  - o 11- 13.8kV, 7-23kV
- Surge Arrestors 20
  - o HV Transformers 17 (4-230kV, 14-138kV)
  - o Line Arrestors 3 (2-230kV, 1-138kV)
- Transformer Bushings 7 (replace in sets of 3):
  - o HV- 2 (6 units 138kV)
  - o LV -5 (15 units 13.8kV)
- Battery Bank -1
- Relay Roof – 1 (Basscreek)
- Flooded Substations – 2 (St Augustine and South Daytona)

# Transmission Line Performance

Overall Transmission Performance was good during the storm event. Equipment and conductor damage was minimal. All lines were patrolled after the storm

**Transmission System Performance**

- 127 out of 523 Transmission lines experienced 150 Relay Operations
- 215 out of 1241 Line Sections out

**Damage / Component Failures**

- 5 poles down on 2 line sections
- 5 Cross braces repaired
- 28 structures with phases down
    - 27 due to trees
    - 1 due to insulator failure
- 3 OHGW failures
- 6 spans replaced

**Causes**

- Most of these outages were caused by vegetation and some by wind-blown debris
- Thirteen Underground line sections were isolated due to contamination at the substation line terminals
- 2 line sections de-energized to isolate St. Augustine substation due to flooding
- 2 line sections de-energized to isolate S. Daytona substation due to flooding

Structure 55R13A – Broken insulator

Structure 112R1 - Wire down due to vegetation



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## Case Study: 5 Transmission Poles Down – All Wood

### Deland-Putnam 115kV - One Wood Transmission Structure

- One single pole wood structure (75G3) was replaced on the Deland-Putnam 115kV [0091] Line, Satsuma Tap-Putnam Tap Section.
  - The poles were inspected in 2017. The pole was reported as Level 4 condition (replacement not required).
- Winds in the area were reported to be 61-80 mph gusts or higher
- An approximately 80 foot tall slash pine tree was reported to have fallen on the transmission line; the impact caused this pole to fail.

### Okeechobee-Sherman #1 69kV – Sweatt Tap - Four Wood Structures

Four Non-BES single pole wood structures with distribution underbuilt (73K13, 74K1, 76K8, and 81K8) were replaced on the Okeechobee-Sherman #1 69kV [0274] Line, John C. Eisinger Tap-Sweatt Tap 2 (Tap) Section.

- There were 3 separate failure locations
- All of the poles were inspected in June 2017 and 2 of the 4 poles were identified for replacement in 2018/2019
  - Structure 74K1 was identified for replacement bringing down an adjacent structure 73K13. Deterioration was noticed with 1" of shell remaining on structure 74K1 at groundline.
  - Structure 76K8 was identified for replacement came down alone.
  - Structure 81K8 was identified as a level 4 (replacement not required) from inspection.

Pole Replacement of Structure 75G3 (115KV line in North area)

# Substation Performance

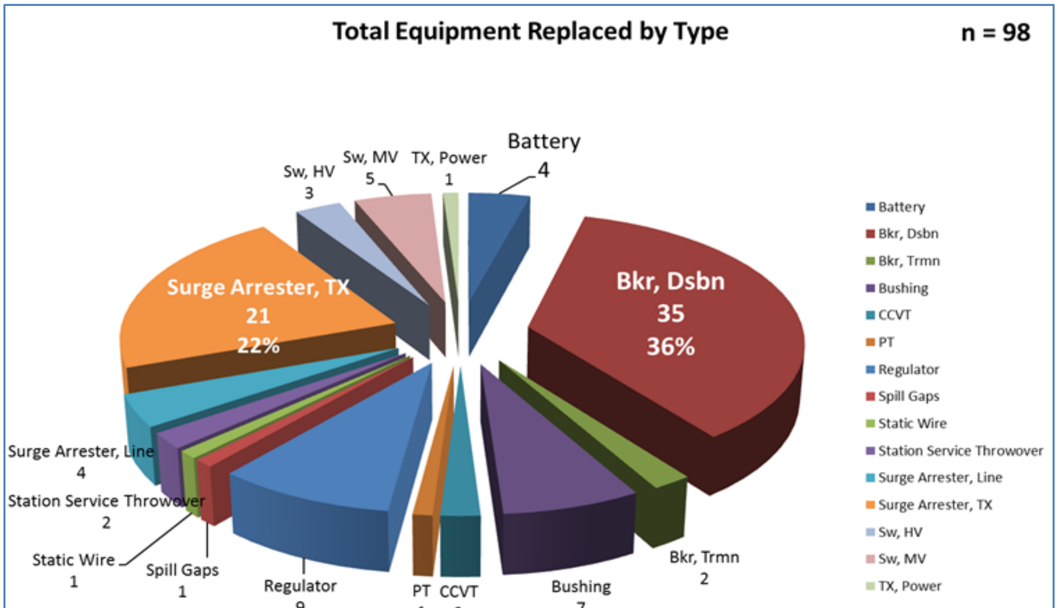
Overall Substation Performance was good during the storm event with all substations being partially energized by 9/12/2017 and fully energized on 9/13/2017 by 9:57AM on.

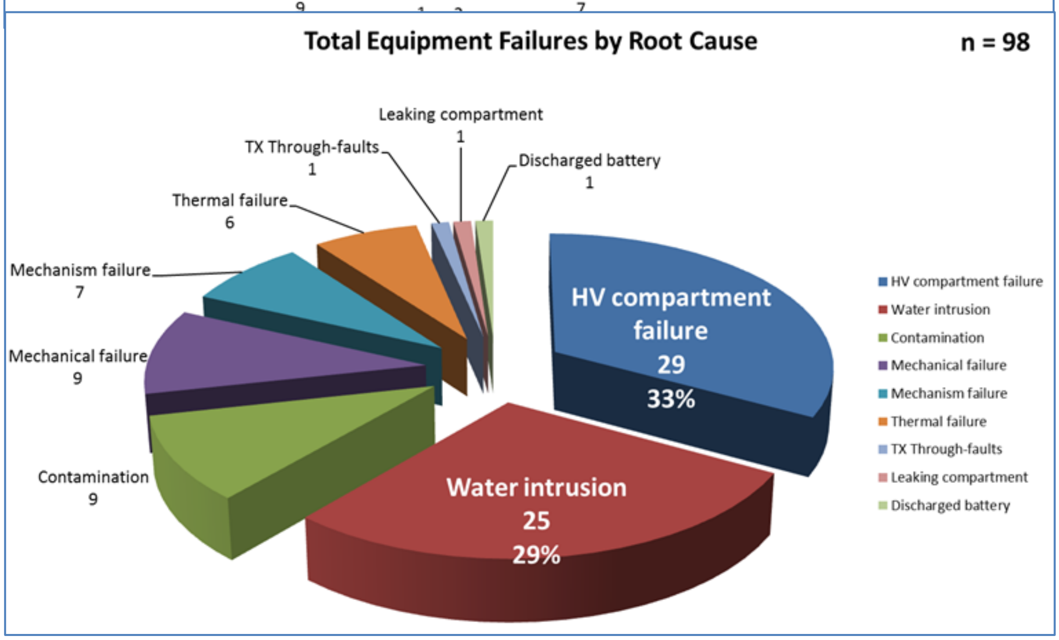
- 92 Distribution Substations out of 607 total Substations were out
  - 86 for due to Transmission outages
  - 2 were deenergized proactively for flooding (St. Augustine and South Daytona)
  - 4 for Substation Equipment issues (Delta, Haulover, Lighthouse and Memorial)
- 150 BES Relay Operations with two relay mis-operations (1.3 % mis-operations)
- Substation Communications lost
  - TELCO: 135 stations
  - Wireless: 11 stations
  - Both wired and wireless: 6 stations
- 98 locations of equipment damage
  - 60% of damage was failed surge arrestors and feeder breakers
- Two flooded substations that were proactively de-energized.
  - St. Augustine and South Daytona
  - The flood monitoring system and response process performed as expected and in a fashion to minimize damage and speed restoration.
- System protection operated as expected.
  - One breaker event was reported.
- Substation communications were lost at 135 stations and 11 stations lost wireless communications.
- 1 station experienced battery loss due to extended outage.
- No mobile equipment was deployed during this hurricane.

Post Storm Events

- A number of events continued to occur post storm. This included breakers, bushings, surge arresters and battery bank failures after initial energization.
- In addition, post storm failures were due to internal contamination presumably from wind-blown salt water and contamination given the orientation of the storm when it came on-shore.
- The North-East quadrant of the storm (aka the “dirty side”) impacted most of the FPL territory contributing to the contamination damage.

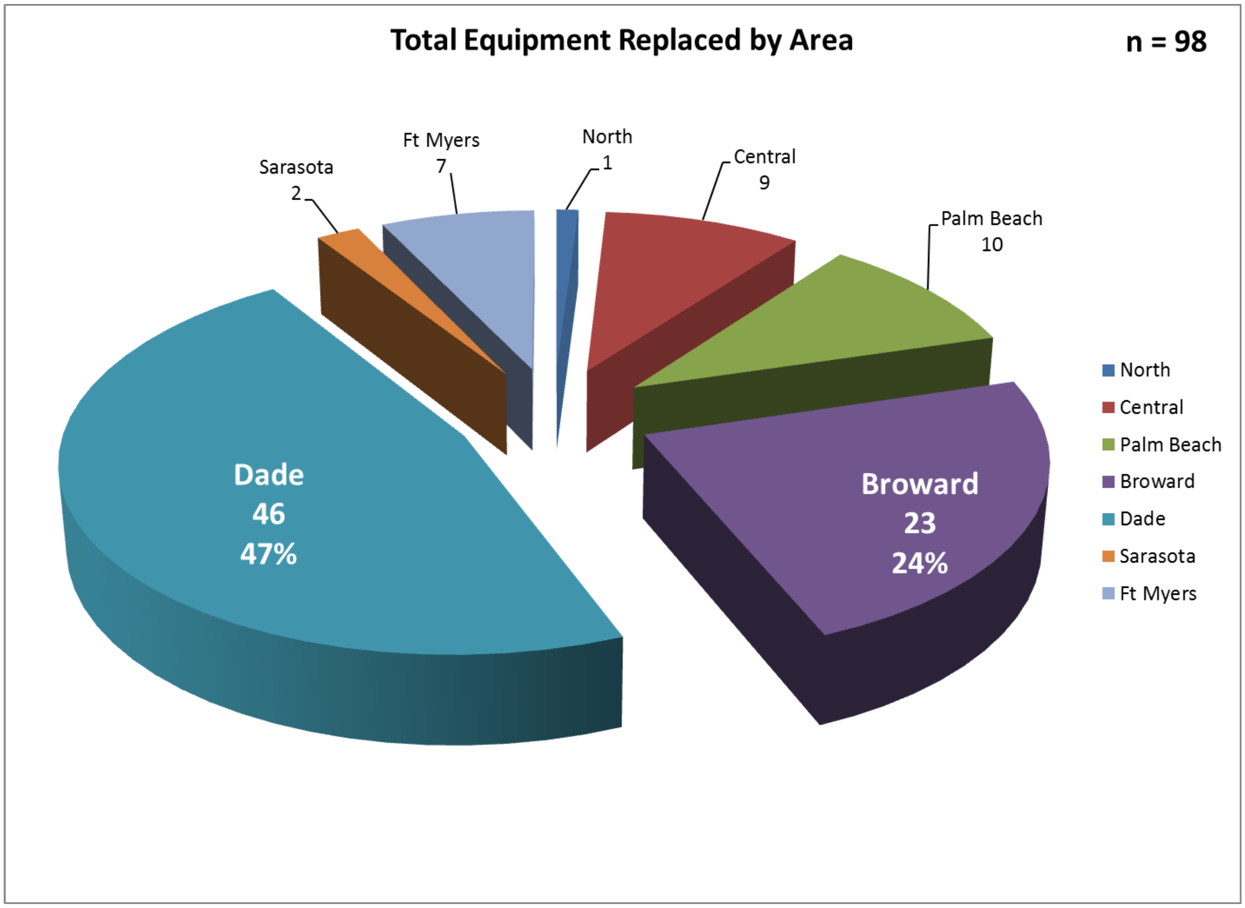
## Substation Equipment Performance "Replacement by Type" and "Failures by Root Cause"




Equipment failures were dominated by feeder breaker failures during the storm and surge arrester failure post event. Most of the failures of the feeder breakers were a result of the High Voltage (HV) compartments flashing from water intrusion due to wind-blown rain. The surge arrester failures appear to be a latent failure mode with water intrusion and/or contamination due to the storm the most likely root cause of the failures occurring post storm after energization.

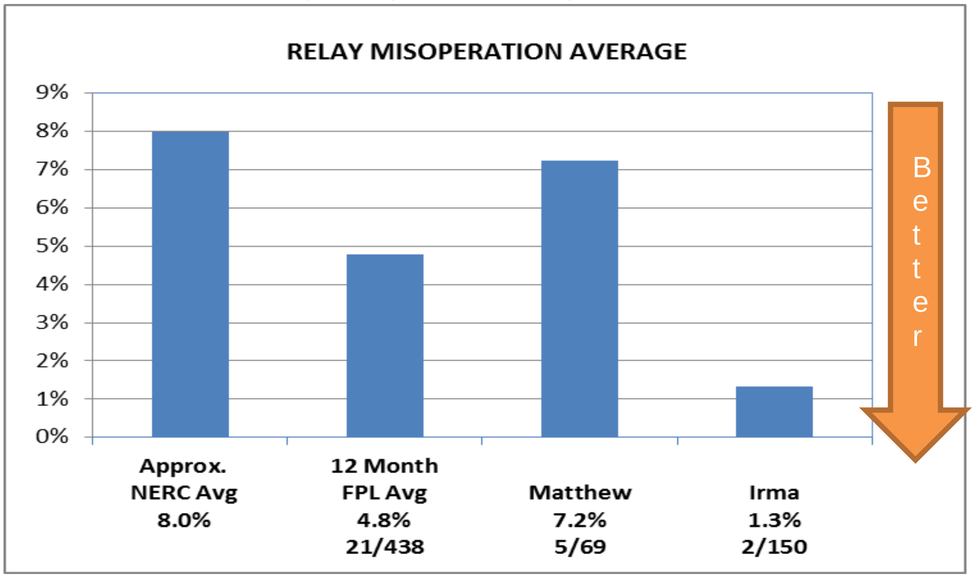
**Substation Performance "Replacements by Area"**




Substation performance by area was dominated by a significant impact to substations in the SE region of Florida. The importance of this impact resulted from the course of the storm as well as the duration of the event.

# Protective Relay Performance

Relay Misoperation Comparisons




* A Relay Mis-operation is a failure to trip or tripping unnecessarily further defined by NERC PRC-004

| Relay Misoperation Details for Irms | |
|---|---|
| **Date Time** | **Event Description of Relay Misoperation** |
| 9/10/2017 3:04:52 PM | Ft Myers terminal of the Alico - Ft Myers #1 138kV line tripped for a Cph-Gnd fault on the Alico – Ft Myers #2 138kV line. Investigation is underway. |
| 9/11/2017 9:54:04 AM | The Seminole terminal of the Putnam – Seminole 230kV line tripped for a B-C phase fault on the Korona – Putnam 230kV line. Seminole relay records indicated a pilot trip and no carrier received. Investigation at Putnam identified a failed power supply and an intermittent failure on the filter card of the RFL carrier set. This condition prevented the carrier blocking signal from being sent. |

# De-Energized Distribution Substations

92 Substations were de-energized. Below is a list of Substations, locations, and times.

| Site | Date Deenergized (MM/DD/YYYY) | Area |
|---|---|---|
| Fairmont | 9/10/2017 10:24 | Broward |
| Jacaranda | 9/10/2017 18:17 | |
| Moffett | 9/10/2017 12:22 | |
| Motorola | 9/10/2017 18:17 | |
| Pembroke | 9/10/2017 11:02 | |
| Pinehurst | 9/10/2017 8:49 | |
| Springtree | 9/10/2017 18:17 | |
| Aventura | 9/10/2017 12:22 | Dade |
| Buena Vista | 9/10/2017 11:20 | |
| Dade Distribution | 9/11/2017 14:13 | |
| Deauville | 9/10/2017 8:05 | |
| Haulover | 9/10/2017 10:18 | |
| Indian Creek | 9/10/2017 13:32 | |
| Key Biscayne | 9/10/2017 12:32 | |
| Killian | 9/11/2017 19:25 | |
| Latin Quarter | 9/10/2017 11:56 | |
| Memorial | 9/10/2017 13:17 | |
| Normandy Beach | 9/10/2017 14:56 | |
| Overtown | 9/10/2017 12:49 | |
| Virginia Key | 9/10/2017 12:32 | |
| Weston Village | 9/10/2017 14:46 | |
| Belle Meade | 9/10/2017 15:47 | West |
| Bonita Springs | 9/10/2017 17:43 | |
| Capri | 9/10/2017 16:02 | |
| Gladiolus | 9/10/2017 17:52 | |
| Imperial | 9/10/2017 17:43 | |
| Iona | 9/10/2017 17:52 | |
| Orangetree | 9/10/2017 16:21 | |
| Naples | 9/10/2017 12:43 | |
| Rattlesnake | 9/10/2017 16:02 | |
| San Carlos | 9/10/2017 13:16 | |
| Summit | 9/10/2017 16:21 | |
| Belvedere | 9/11/2017 0:09 | Palm Beach |
| Belle Glade | 9/10/2017 15:05 | |
| Congress | 9/10/2017 17:05 | |
| Deltrail | 9/10/2017 16:01 | |
| Hamlet | 9/10/2017 16:17 | |
| Hillcrest | 9/10/2017 17:05 | |
| Inlet | 9/10/2017 23:06 | |
| Juno Beach | 9/10/2017 23:06 | |
| Lake Park | 9/10/2017 23:06 | |
| Lantana | 9/11/2017 8:23 | |
| Norton | 9/10/2017 17:05 | |
| Oscemill | 9/11/2017 21:44 | |
| Quantum | 9/11/2017 8:23 | |

| Site | Date Deenergized (MM/DD/YYYY) | Area |
|---|---|---|
| 624a | 9/11/2017 1:42 | East |
| Aurora | 9/11/2017 1:01 | |
| Banana River | 9/10/2017 23:58 | |
| Brighton | 9/10/2017 12:22 | |
| Cocoa | 9/11/2017 1:44 | |
| Cocoa Beach | 9/11/2017 22:51 | |
| Delta | 9/11/2017 1:42 | |
| Eau Gallie | 9/11/2017 0:33 | |
| Hibiscus | 9/11/2017 1:01 | |
| Holland Park | 9/10/2017 22:56 | |
| Hutchinson Island | 9/10/2017 22:40 | |
| Indialantic | 9/11/2017 1:13 | |
| Indian Harbor | 9/11/2017 1:13 | |
| Lighthouse | 9/11/2017 0:54 | |
| Mars | 9/11/2017 4:48 | |
| Merritt | 9/11/2017 1:22 | |
| Minuteman | 9/10/2017 23:58 | |
| North Cape | 9/11/2017 9:37 | |
| Orsino | 9/11/2017 4:48 | |
| Patrick | 9/11/2017 1:13 | |
| Rockledge | 9/11/2017 1:44 | |
| Satellite | 9/11/2017 1:13 | |
| Slag | 9/12/2017 2:07 | |
| South Cape | 9/12/2017 0:48 | |
| Suntree | 9/11/2017 1:39 | |
| Sweatt | 9/10/2017 17:22 | |
| Sykes Creek | 9/11/2017 1:22 | |
| Tropicana | 9/12/2017 2:07 | |
| Windover | 9/11/2017 1:39 | |
| Columbia | 9/11/2017 5:59 | North |
| Como | 9/11/2017 0:35 | |
| Crescent City | 9/11/2017 23:43 | |
| Deland Dist | 9/10/2017 22:19 | |
| Durbin | 9/11/2017 5:46 | |
| Elkton | 9/11/2017 10:41 | |
| Gumswamp | 9/11/2017 5:59 | |
| Hastings | 9/11/2017 6:03 | |
| Kacie | 9/11/2017 6:03 | |
| Lake Butler | 9/11/2017 5:58 | |
| Live Oak | 9/11/2017 4:26 | |
| Nash | 9/11/2017 5:59 | |
| Price | 9/11/2017 5:58 | |
| South Daytona | 9/11/2017 2:02 | |
| St Augustine | 9/11/2017 1:08 | |
| Tolomato | 9/11/2017 5:46 | |
| Wellborn | 9/11/2017 4:26 | |
| Wiremill | 9/11/2017 5:59 | |

**Case Study: De-Energized Substation Battery Voltage Monitoring**

Battery performance is a concern when substations are deenergized for extended periods of time and lose multiple sources of AC station service used to charge the batteries. To manage the risk of batteries discharging below recoverable levels, battery voltage monitoring was performed from the PDDC on a periodic basis and logged. See table below.

During the first day, when the 92 substations were out of power, monitoring substation battery power is critical. Batteries power the breakers and protection equipment on the grid and allow remote opening and closing of breakers to restore the grid. Situational awareness of battery voltage to know how close a station was to having a significant backup power issue, provides information to Substation Rapid Responder teams which helps prioritize order of stations to visit.

This was a significant issue in Wilma in 2005, but thanks to remote monitoring, it was a not an issue in Irma.

| | | | | | *Battery Voltage Readings from SEL Relays via PDDC* | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Station | Area | Charger Off at Time | Charger Off at Date | Battery Voltage Alarm | 6:00 | 11:00 | 12:30 | 15:00 | 17:00 |
| Deauville | Dade | 8:00 | 10-Sep | 8:06 | 118.3 | n/a | n/a | n/a | n/a |
| Pembroke | Broward | 11:05 | 10-Sep | 11:05 | 118.9 | 125.8 | 127.4 | 128.7 | |
| Overtown | Dade | 12:49 | 10-Sep | 20:22 | 117.7 | 115.32 | 123.52 | 124.99 | |
| Brighton | Central | 19:31 | 10-Sep | 19:38 | 124.5 | 124.1 | n/a | n/a | n/a |
| Minuteman | Central | 21:16 | 10-Sep | 21:18 | 119.1 | n/a | n/a | n/a | |
| Deland | North | 22:13 | 10-Sep | 22:17 | 119.5 | 119.2 | 126.0 | 128.7 | |
| Cocoa Beach | Central | 22:45 | 10-Sep | 2:03 | 121.6 | 120.3 | 126.0 | 128.8 | |
| Sykes Creek | Central | 0:15 | 11-Sep | 0:18 | 113.6 | 122.6 | 125.2 | 126.9 | |
| Banana River | Central | | | 0:17 | 122.7 | 122.5 | 128.6 | 133.3 | |
| St Augustine | North | 1:12 | 11-Sep | 1:59 | 122.3 | 132.1 | 133.1 | | 133.3 |

Example of Substation Battery Voltage Readings taken during Irma while substation had no off-site AC power source. Monitoring substation battery voltage remotely from the PDDC helped to manage the priority of response to substation outages

## Case Study: Insulator Contamination at St. Lucie

The likelihood of flashover is a function of the level of contamination building up along with weather conditions that produce dew or slight moisture to form on the insulation. FPL transmission rates insulator contamination levels based on the ESDD (Equivalent Salt Deposit Density) scale of 0 – 20. (Greater than 10 is at high risk for a flashover). Atmospheric conditions consisting of extended durations without adequate rain and exposure to winds from the sea or dust from nearby construction can lead to contamination build up. When these conditions change to allow moisture to accumulate on the insulator surface arcing and scintillations begin to erupt across the insulators.

**Normal Operations (non-storm conditions)**

- Monitoring of leakage current across insulators generally displays around 0.8 to 2.5 mA
- Level 10 and below on ESDD scale is considered to be a lower risk for flash over.
- Dry Salt on insulation does not create an immediate threat, however can represent a contamination exposure during early morning dew or a light rain.

**Tropical Storm / Hurricane conditions**

- Leakage currents will jump way up within close proximity to the coastline or other forms of atmospheric contamination.
- Contamination potential increases due to Florida’s flat geography, higher storm winds and turbulent ocean waters blowing salt mist across the FPL system.
- At around 3 mA FPL monitors for contamination problems
- Level 10 and above on ESDD scale is considered to be a higher risk for flash over.
- Wet (liquefied) salt becomes an electrolyte and can cause insulation to flash

Although the Contamination Withstands Tools and Processes are effective for long term buildup of sea salt, there is little that can be done, from a process perspective, for sudden buildup events like hurricanes. In this event we went from a FPL scale of 0 (clean) just prior to storm to a FPL scale 20 (Very Heavy) in a matter of minutes/hours.

Strong evidence demonstrates that this may have been the most severe contamination event at St Lucie switchyard. Even the insulation on the transmission line towers outside of the station was experiencing scintillations. In addition, contamination assessment in early morning hours confirmed that most of the energized insulation was experiencing extreme scintillations. Unlike Hurricane Jeanne and Francis during Hurricane Irma there was no natural cleaning from rain on the back side of the storm.

Every early morning assessment 9/11 – 9/18 continued to demonstrate that the insulation contamination level was heavy. It was not until after the rain on the night of 9/18 that the insulation was effectively cleaned and transmission declared a rain wash base on the results of the early morning assessment of 9/19.

Along with the St Lucie switchyard and Hutchinson Island FPL experienced approximately 25 contamination flash overs along the east coast of Florida.

The initial St. Lucie station conditions were wet but drying insulation with still fairly high wind speeds. Scintillations were observed on all energized, 230kV breakers, Capacitive Coupled Voltage Transformers (CCVTs), and high tension pull-off insulators. Scintillations were running almost the entire length of the insulation and it is likely that the high winds were extinguishing the arcs before they could flash over.

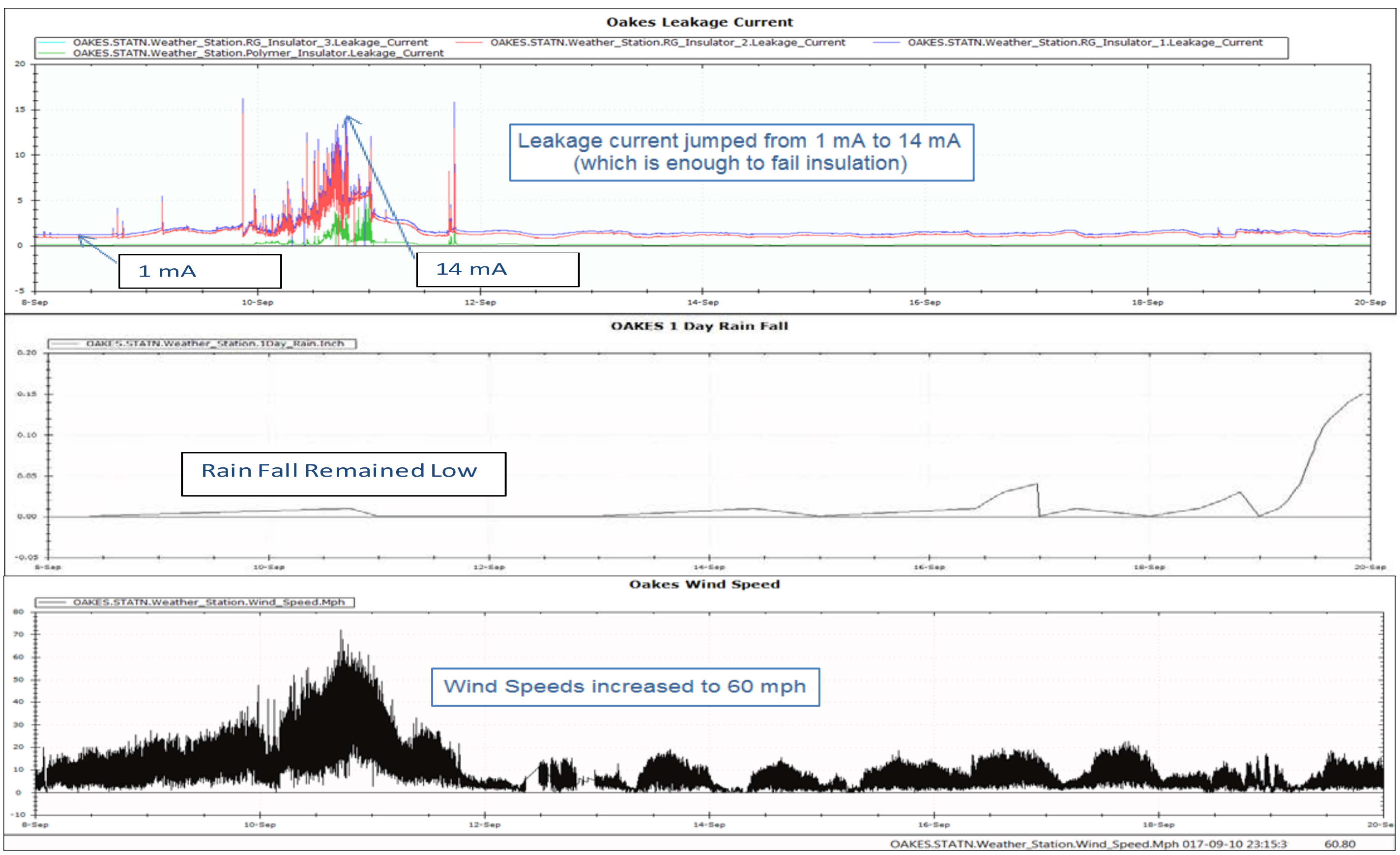
Due to St. Lucie Switchyard proximity to the sea or otherwise exposure to strong winds from the sea, efforts have been made to improve the St. Lucie insulation contamination withstand capability. Because of these improvements St. Lucie switchyard insulation has successfully operated during heavy contamination levels of 11-16 on the FPL ESDD scale. Based off this operational experience we can conclude the contamination levels immediately post-storm were very high or at a level of 17-20 on the FPL ESDD scale.

**The following equipment was out of service:**

- Hutchinson Island #1 feed
- Hutchinson Island #2 feed
- Leakage current detector insulators (out from the loss of Hutchinson Island # 2)
- East 230kV bus
- Turnpike 230kV line (switched out by dispatcher for voltage control)
- 1B & 2B startup feed (out from loss of Hutchinson Island #1 and loss of East bus)

**Key Points:**

- All protective relay schemes operated as designed
- The insulation performed as expected based on the "Very Heavy" level of contamination
- crews were prompt and deliberate in the insulation cleaning
- Actual washing duration was better than or at target scheduled duration
- The insulation that was not cleaned performed well when the rain wash finally moved in, which is evidence that the insulation strategy is effective.




Above shows high winds and little or no rainfall caused contamination and increased leakage current to damaging levels.

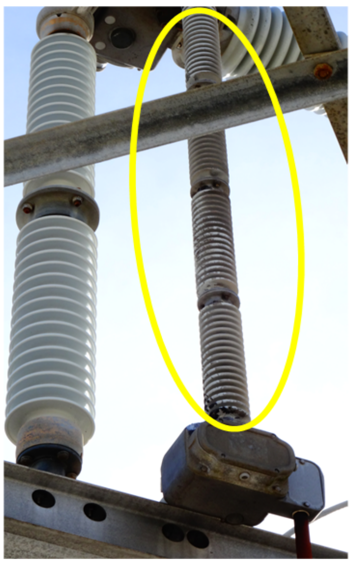


FPL 000035
20180049-EI

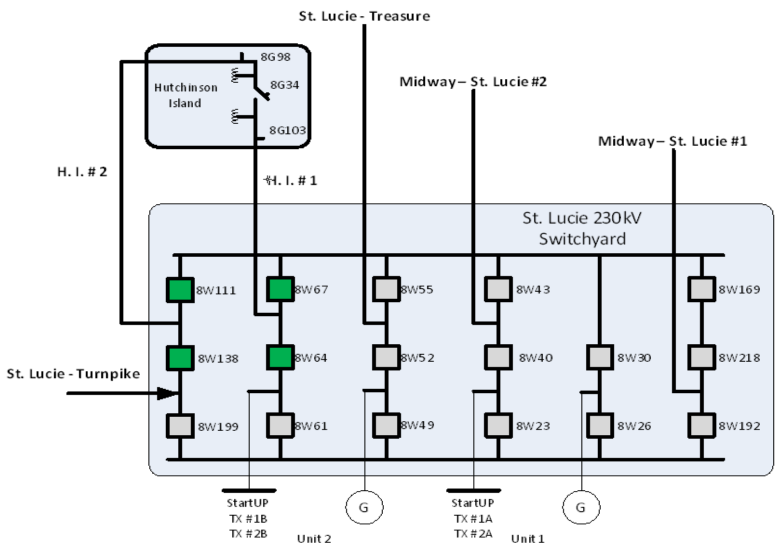
## Specific Event during the Storm – Hutchinson Island

Hutchinson Island #2 line terminal trips for a B-Phase fault on the 8F10 switch in Hutchinson Island. The switch was found in the closed position with flash marks across the shunt trip insulator on the B-Phase. The protective relays and the transmission breakers in the St. Lucie station operated as designed and de-energized the high voltage line and the feed to the transformer from the St. Lucie switchyard.

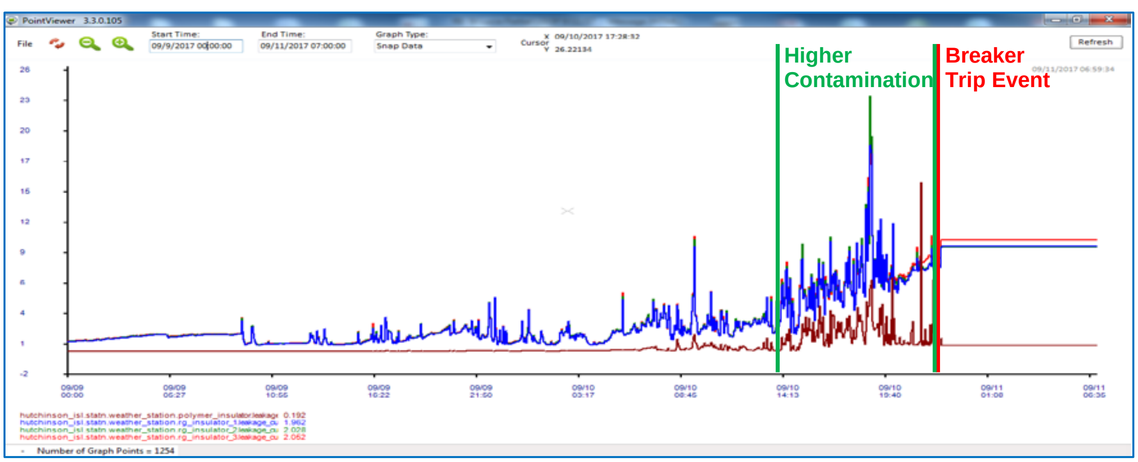
Data from the remote contamination monitor shows the pre-storm leakage current and the increase in leakage current as the storm winds blow salt contaminants onto the test insulators. The vertically mounted RG insulators measured 1.2 mA of leakage current pre-storm with the highest level of 31.2 mA achieved prior to the monitor being de-energized. The horizontally mounted polymer insulator had a similar increase signature starting at 0.18 mA and reached a maximum high of 25.2 mA. This data confirmed that the insulation system was clean pre-storm and the buildup was seen as the storm moved across the stations. The test insulators were de-energized and stopped supplying data when the Hutchinson Island #2 line was de-energized.



Contamination damage on F-switch




One-line showing Hutchenson Island breaker open




High contamination monitor reading correlates to time of breaker trip event.



FPL 000036
20180049-EI

# Substation Flooding

Early substation flooding predictions were derived from NOAA SLOSH model runs using the predicted wind speed and direction.

Once National Hurricane Center storm specific storm surge predictions were issued substation flood damage was predicted by using 50% chance of exceedance inundation levels.

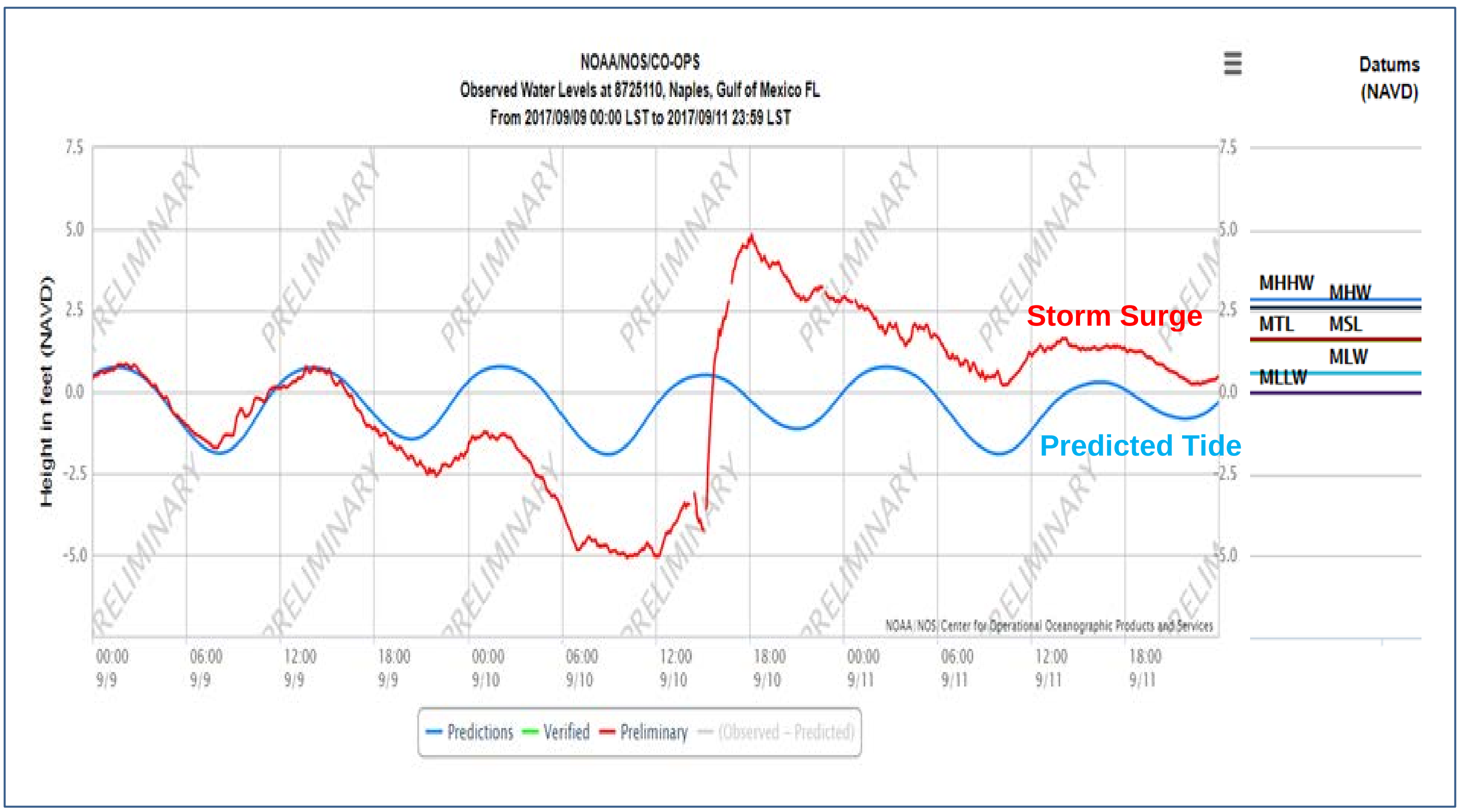
Post storm 5 substations were determined to be impacted by storm surge and 4 were impacted by rain event flooding with standing water.

Two substations set off emergency flood alarms and were pro-actively de-energized to prevent equipment damage:

- St. Augustine
- South Daytona

Only St. Augustine substation had damaged equipment related to flooding.

Utilizing the 50 percent exceedance prevented over prediction of impacted substation. However Irma path and intensity changed with each forecast and after landfall limiting the validity of the pre-landfall predictions.



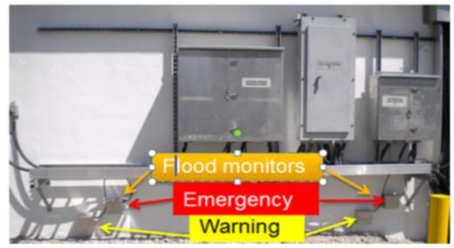

Surge peaked in a few hours and receded in more than one day. (Source: NOAA Tidal Gauge at Naples)



FPL 000037
20180049-EI

## Substation Flooding Analysis

- 32 Stations of the 600 plus substations were at risk of flooding.
- **<u>6 Substations were impacted with flood waters</u>**
  - 3 water did not reach the flood alarm levels
    - Corkscrew, Ft. Myers and Lewis
  - 1 reached the first level "Warning" alarm
    - Pine Ridge
  - 2 reached the first and second level alarms,
    - "Warning" and "Emergency"
    - St. Augustine and South Daytona
    - Both were proactively deenergized.




**SUBSTATION FLOODING RESULTS - HURRICANE IRMA**

| Substation | Area | Station Type | Wind Hardened | Cameras | Irma - NOAA Storm Predicted Surge Innundation (P50 from 11AM 9/9) (feet) | Irma - Substation Actual Impact | Irma Type | Irma Water Level Above Yard (feet) | Irma Water Level Above Vault Finish Floor (feet) | Relay Vault Storm Surge Hardened | Flood Monitors | Received Flood Monitor Warning Alarm? | De-Energized due to Flood monitors | Station Recommended for Storm Flood Mitigation (e.g. Sandbags) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South Daytona | North | D | 1 | 1 | None Predicted | Yes | Surge | 0.53 | 0.46 |  | 1 | Y | Y |  |
| Ft Myers Plant | Ft Myers | T | 1 | 1 | 0-2 | Yes | Rain | 0.60 | 0.00 | 1 | 1 |  |  | N |
| Corkscrew | Ft Myers | D |  |  | None Predicted | Yes | Rain | 0.65 | 0.00 |  | 1 |  |  |  |
| Pine Ridge | Ft Myers | D | 1 | 1 | 0-2 | Yes | Rain | 0.72 | 0.01 (small puddle) |  | 1 | Y |  |  |
| Lewis | North | D | 1 |  | None Predicted | Yes | Surge | 1.13 | 0.00 |  | 1 |  |  |  |
| St Augustine | North | D | 1 |  | 3-5 | Yes | Surge | 2.51 | 0.38 (Did not enter Vault) | 1 | 1 | Y | Y |  |
| Alligator | Ft Myers | D | 1 | 1 | 2-3 | No |  |  |  |  | 1 |  |  | Y |
| Buckeye | Sarasota | D | 1 |  |  |  |  |  |  |  | 1 |  |  | Y |
| C5 | Central | T | 1 |  |  |  |  |  |  |  | 1 |  |  | Y |
| Cocoplum | Sarasota | D | 1 | 1 |  |  |  |  |  |  | 1 |  |  | Y |
| Dania | Broward | D | 1 | 1 |  |  |  |  |  |  | 1 |  |  | Y |
| Edison | Ft Myers | D | 1 |  | 2-3 | No |  |  |  |  | 1 |  |  | Y |
| Franklin | Sarasota | D | 1 |  |  |  |  |  |  |  | 1 |  |  | Y |
| Ft Myers | Ft Myers | D | 1 |  |  |  |  |  |  |  | 1 |  |  | Y |
| Gladiolus | Ft Myers | D | 1 |  | 3-5 | No |  |  |  |  | 1 |  |  | Y |
| Homestead | Dade | D | 1 | 1 |  |  |  |  |  |  | 1 |  |  | Y |
| Indian Creek | Dade | T&D | 1 | 1 |  |  |  |  |  |  | 1 |  |  | Y |
| Iona | Ft Myers | D | 1 | 1 | 7-9 | No |  |  |  | 1 | 1 |  |  | N |
| Key Biscayne | Dade | D | 1 | 1 |  |  |  |  |  |  | 1 |  |  | Y |
| Knowlton | Dade | D | 1 | 1 |  |  |  |  |  |  | 1 |  |  | Y |
| McGregor | Dade | D | 1 | 1 |  |  |  |  |  | 1 | 1 |  |  | Y |
| Murdock | Sarasota | D | 1 | 1 |  |  |  |  |  |  | 1 |  |  | Y |
| Naples | Ft Myers | T&D | 1 |  | 0 close to 5-7 | No |  |  |  | 1 | 1 |  |  | N |
| Natural Bridge | Dade | D | 1 | 1 |  |  |  |  |  |  | 1 |  |  | Y |
| Notre Dame | Ft Myers | D | 1 |  |  |  |  |  |  |  | 1 |  |  | Y |
| Payne | Sarasota | D | 1 | 1 | 2-3 | No |  |  |  | 1 | 1 |  |  | N |
| Rotonda | Sarasota | D | 1 |  |  |  |  |  |  |  | 1 |  |  | Y |
| Snapper Creek | Dade | D | 1 | 1 |  |  |  |  |  |  | 1 |  |  | Y |
| Tice | Ft Myers | D |  |  | 0-2 | No |  |  |  |  | 1 |  |  | Y |
| Whispering Pines | Dade | D | 1 | 1 |  |  |  |  |  |  | 1 |  |  | Y |
| Belle Meade | Ft Myers | D | 1 |  | 9-11 | No |  |  |  | 1 | 1 |  |  | N |

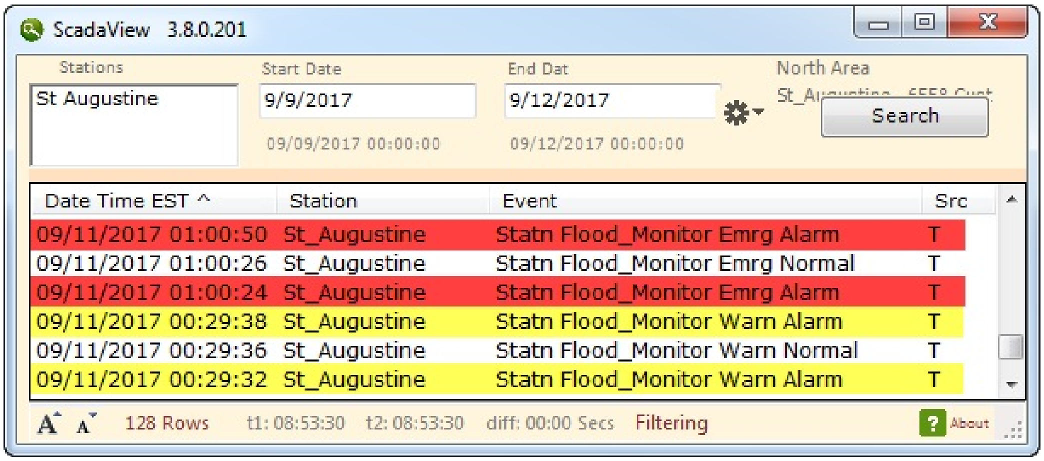
| | |
|---|---|
| Yellow | Flood water near equipment |
| Red | Flood water impacted equipment |
| Blue | Recommended flood hardening impovements |

**Case Study - St. Augustine Flooding**

Station flood monitor warning alarmed at 12:26 am on 9/11

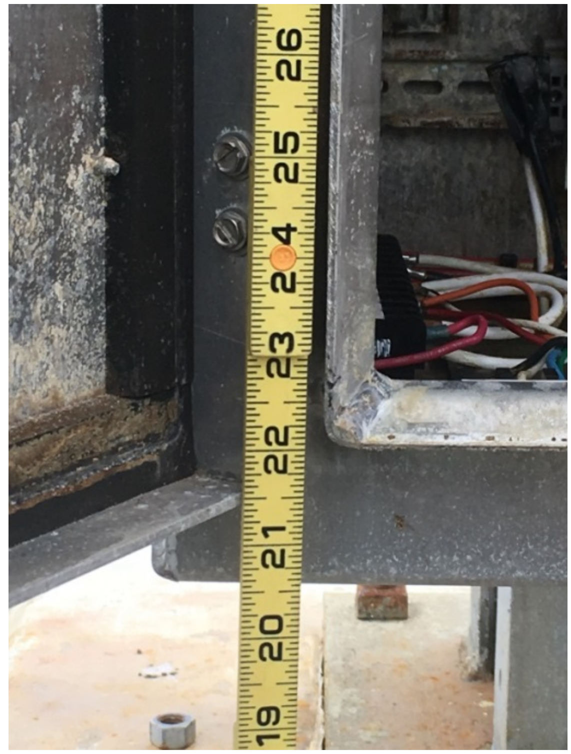
Station flood monitor emergency alarmed shortly after at 1:00 am

Both outdoor flood monitor alarms cleared at 8:53 pm

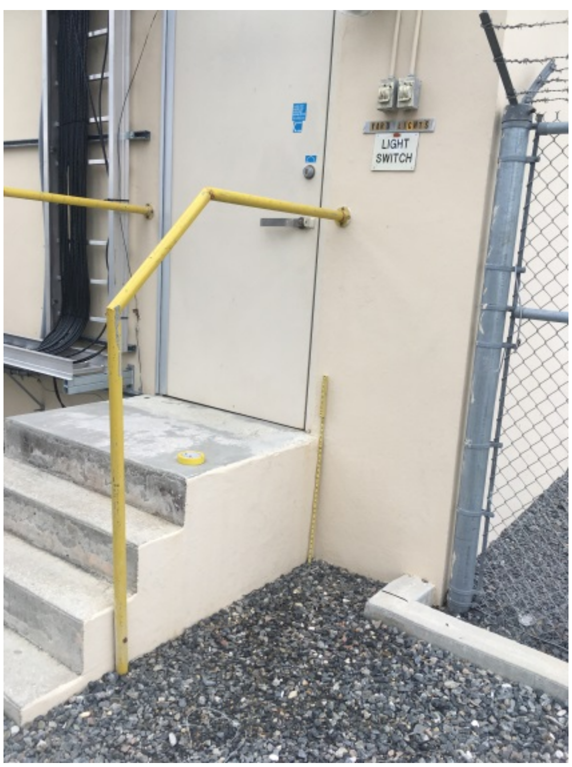



Alarm log for St. Augustine Substation

St. Augustine Substation

Feeder Breakers with water intrusion




Fault bus CT's were submerged throughout entire substation

Examples of St. Augustine Substation motor operator impacted by storm surge





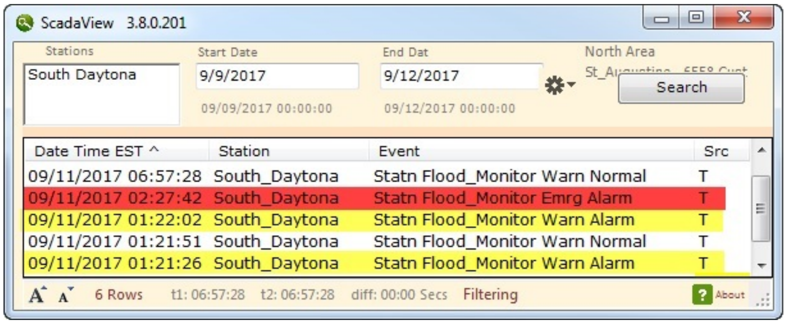
FPL 000041
20180049-EI

## Case Study - South Daytona Flooding

Station flood monitor warning alarm set off at 1:21 am on 9/11

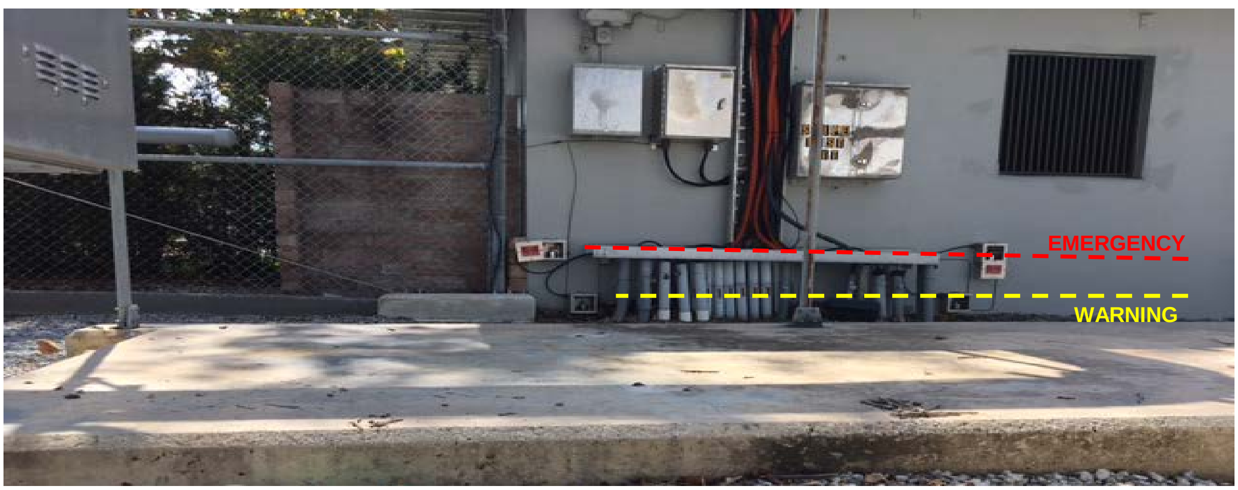
Station flood monitor emergency alarm set off at 2:27 am

Both outdoor flood monitor alarms cleared at 6:57 pm




| Date Time EST | Station | Event | Src |
|---|---|---|---|
| 09/11/2017 06:57:28 | South_Daytona | Statn Flood_Monitor Warn Normal | T |
| 09/11/2017 02:27:42 | South_Daytona | Statn Flood_Monitor Emrg Alarm | T |
| 09/11/2017 01:22:02 | South_Daytona | Statn Flood_Monitor Warn Alarm | T |
| 09/11/2017 01:21:51 | South_Daytona | Statn Flood_Monitor Warn Normal | T |
| 09/11/2017 01:21:26 | South_Daytona | Statn Flood_Monitor Warn Alarm | T |

Alarm log for South Daytona Substation



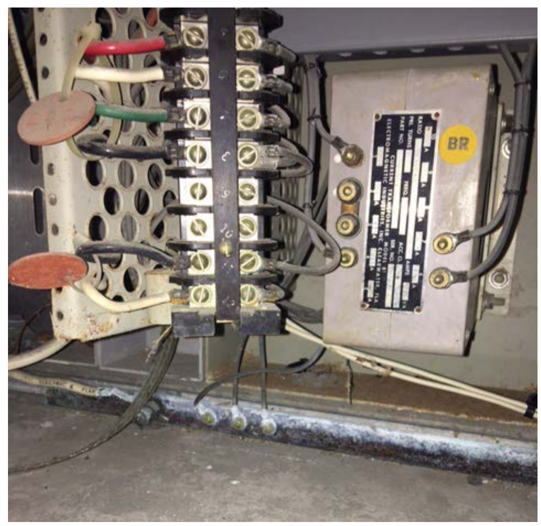



South Daytona Substation and Flood Warning Monitors



FPL 000042
20180049-EI

Examples of South Daytona SubstationDamage inside the vault




Flood waters reached 5 1/2” on the inside of the relay vault and affected ground bus and some connections



FPL 000043
20180049-EI

**Case Study – Pine Ridge Flooding**

Pine Ridge station order of events

- Flood monitor warning alarmed at 5:13PM on 09/10*
- Both outdoor flood monitor alarms cleared at 5:18PM
- Rain Flooding .72 Ft. above average yard grade

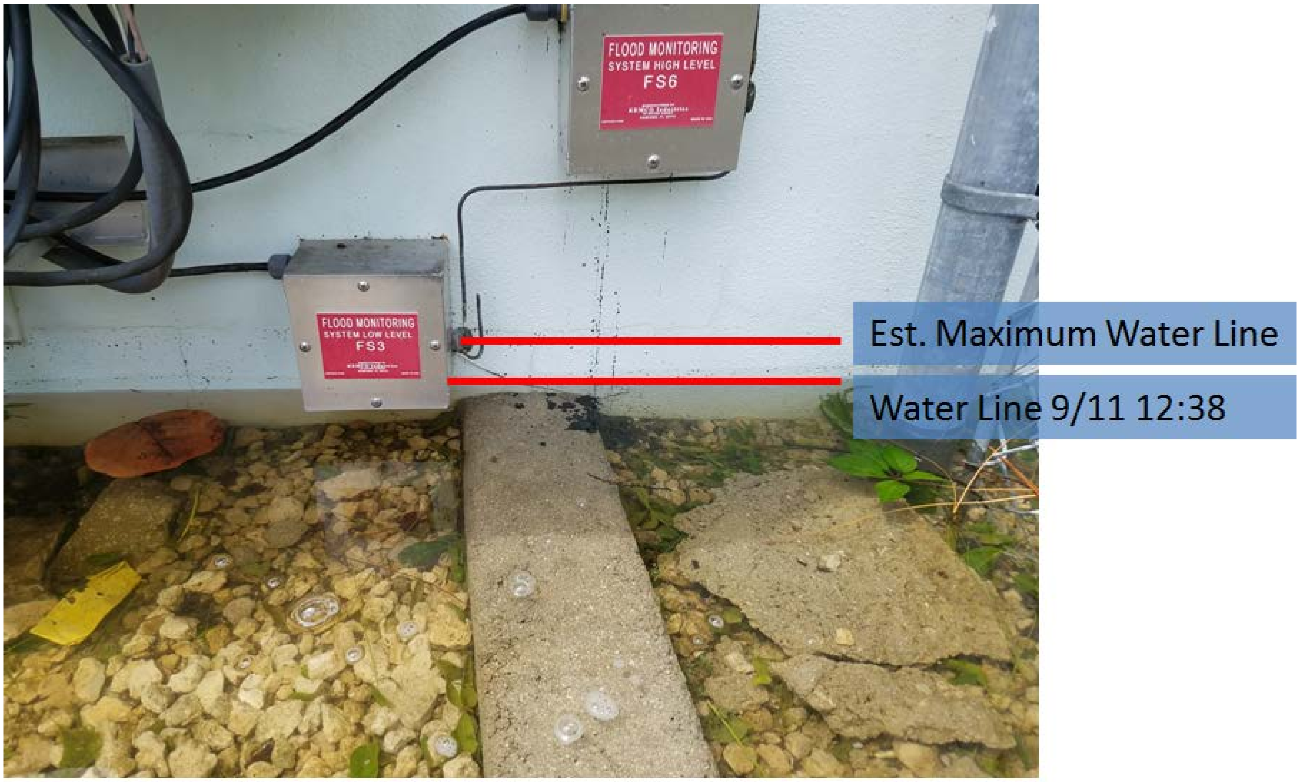
* Only first level “warning” alarm asserted and second level “emergency” alarm did not assert; therefore, station was not deenergized.

Relay vault does not have flood doors, which allowed flooding to occur inside vault

- Rain Flooding .01 Ft. above Relay Vault small puddle on floor.

Pine Ridge Substation rain event flooding

Examples of Pine Ridge Substation




Pine Ridge Substation Flood Monitoring

Pine Ridge Substation Flooding

**Case Study – Corkscrew Flooding**

Corkscrew Sub and Corkscrew Access drive (patrol road) flooded, including surrounding area and adjacent subdivision, however homes seems to be above flood levels.

- Flood waters from adjacent property impacted FPL property
- P&C van became stuck on Access drive attempting to access the substation
- Substation was only accessible by off road vehicles
- Rain flooding reported to be 1.5 Ft. to 2 Ft. above access drive.
- Rain flooding inside substation is 0.65 Ft. above average yard grade
- Relay vault does not have flood doors
- Rain flooding did not enter Relay Vault

Corkscrew Substation Rain Event Flooding

Corkscrew Access Drive

**Case Study – Substation Fence and Gate Damage**

A total of 48 substations sustained physical facility damage during Hurricane Irma. Below is the breakdown of the types of components impacted.

| Facility Component | Qty |
|---|---|
| Building Exterior | 1 |
| Roof Air Extractors | 4 |
| Overhead Door | 2 |
| Decorative Sliding Gate | 2 |
| Substation Fence Damage | 37 |
| Swing Gate | 4 |
| Vault Door | 1 |
| Property Fence | 2 |

Note that some substations had more than one type of component impacted. Below are examples of physical damage.

Indian Creek Substation – Roof Exhaust Fan

Watkins Substation – Louver Screen

Crystal River Substation – Fence

Watkins Substation – Roof Exhaust Fan


Natural Bridge Substation – Gate


Watkins Substation – Overhead Door

Watkins Substation – Overhead Door

**Case Study – Belle Meade LCEC Shed Damaged Substation Equipment**

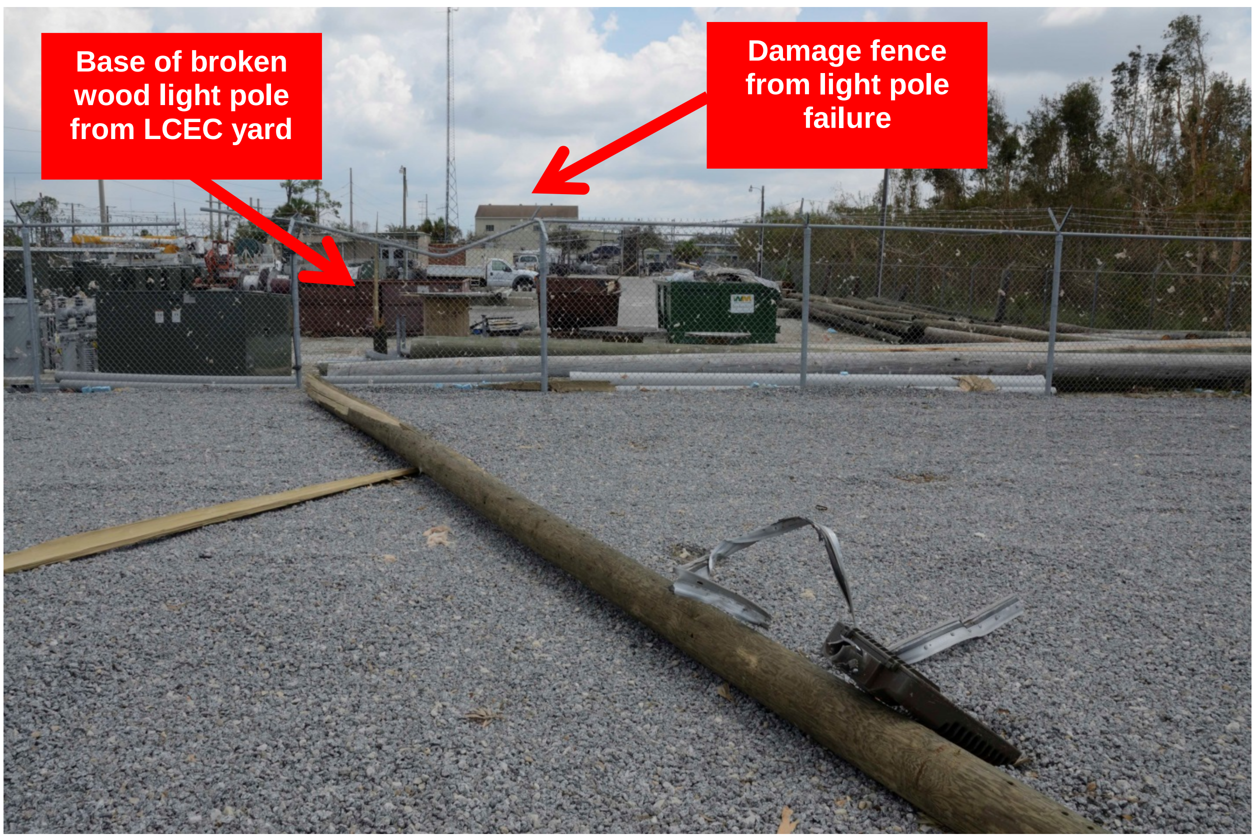
No evidence of flooding in station and no flood monitor alarm. Capri Sub did have evidence of flooding, so there may have been flooding in Belle Meade with no evidence found.

Large debris found in substation (part of shed and wood light pole from LCEC yard).

Current design, 150mph-gust-wind-designed fence partially damaged in areas due to flying debris and failing LCEC wood light pole.

Switch jumper was damaged/disconnected due to debris from LCEC.

Station and fence performed well even with the large debris impact. Station and fence were designed to FPL current design criteria.

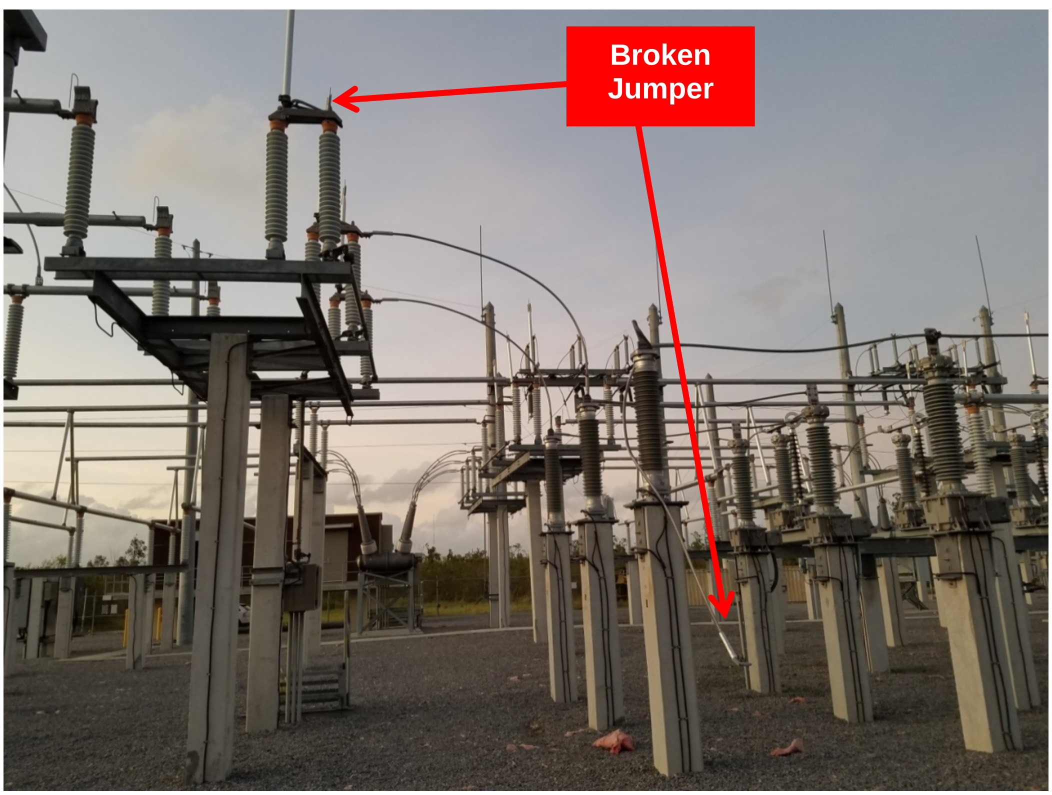



Belle Meade Substation (Looking East) adjacent to LCEC yard (Lee County Electric Coop)


Belle Meade Substation (Looking West)


Belle Meade Substation (Looking West)


Belle Meade Substation (Looking East)




Belle Meade Substation

# Distribution Substation Transformers Experiencing Through Fault Levels

As the effects of Irma were impacting our system, the grid experienced several thousand system wide faults. The faults created excessive mechanical wear on our breakers and switches and the impact on the overall grid was substantial. The long term effects are especially impactful to our fleet transformers.

FPL had 452 transformers that experienced more than 20 faults throughout the duration of Irma's impact to our service territory. Typically, transformers see one or two faults per year and are designed to withstand the thermal stresses and mechanical forces that are produced when a fault occurs, but repeated frequent faults can adversely affect the transformer's capabilities.

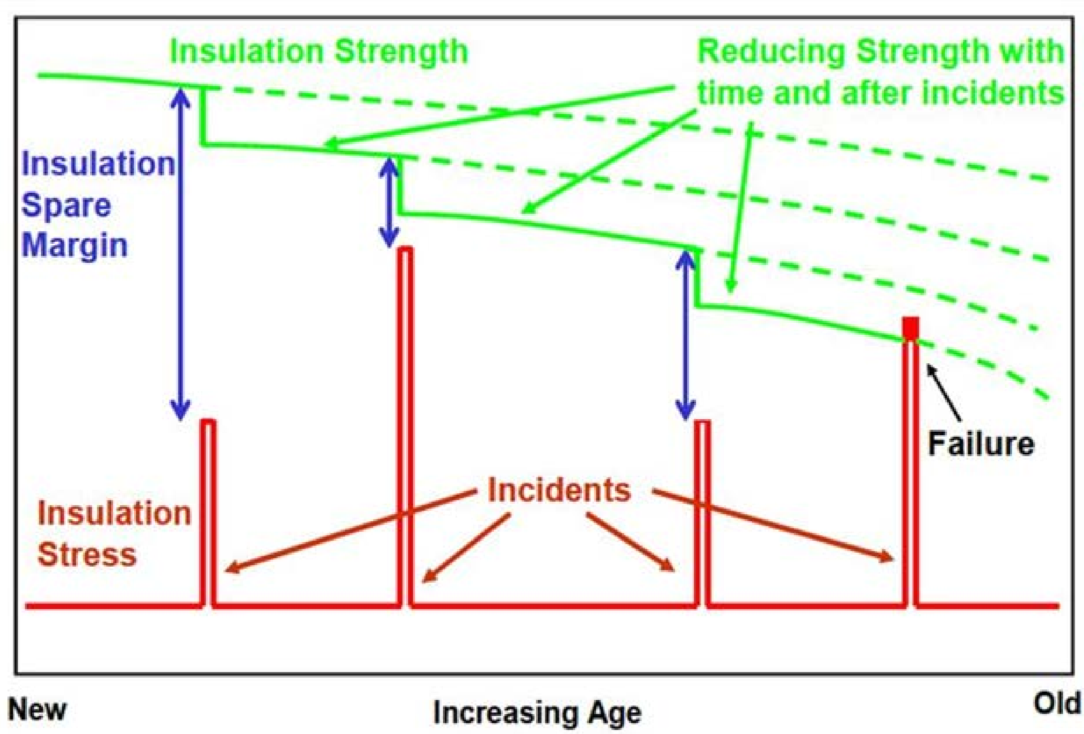
In addition, a subset of these 452 transformers experienced through faults with high fault currents exceeding 600A as wind driven rain and contamination circumvented the fault current limiting reactors installed to mitigate the fault levels.

2 transformers failed; one at Crystal and one at Mallard. See details on following pages. Below is a list of 15 transformers that experienced several successive high fault levels in excess of 7,000A. These transformers passed a Kelman oil test before being placed back in service. This data is included into the transformers risk profile:

| Substation | Transformer |
|---|---|
| 40th St. | T-0962 |
| Haulover | T-0097 |
| Haulover | T-0966 |
| Indian Creek | T-0964 |
| Indian Creek | T-0967 |
| Market | T-3176 |
| Market | T-3207 |
| Miami Bch | T-1742 |
| Miami Bch | T-2266 |
| Miami Bch | T-2529 |
| Normandy Bch | T-0965 |
| Normandy Bch | T-1346 |
| Railway | T-2772 |
| Venetian | T-0742 |
| Venetian | T-0968 |

## Damaging Effects of Faults

- Well-designed transformers are built to withstand a through-fault which is usually around 6 or 7 times the rated current.
- When a fault occurs, the windings and clamping structure are subjected to mechanical and thermal stresses.
    - The mechanical stresses are a function of the electro-magnetic forces from the current and are proportional to the current magnitude squared.
    - The thermal stresses are also a function of the current magnitude squared.
- Transformers are not designed to withstand numerous faults, especially during a short time period.
    - The mechanical forces act to compress winding spacers and loosen clamping which weakens the transformer's ability to withstand future faults
    - Thermal stresses are significantly increased when multiple faults occur in a short time because the windings do not have sufficient time to cool back down between faults. This will accelerate the insulation aging or permanently damage the insulation, leading to electrical failure.
- All of the transformers that had significant number of high current faults during the storm have reduced fault withstand capability as a result of the cumulative mechanical and thermal stresses from the faults
- This graph illustrates the reduction in insulation strength due to stresses from multiple fault incidents.

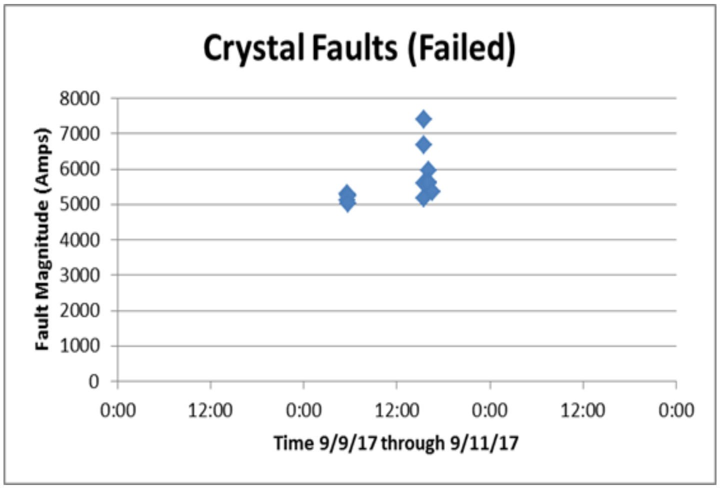


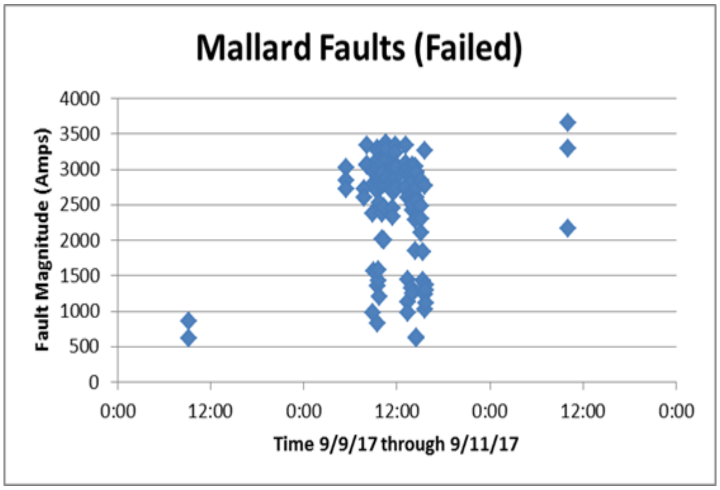

A conceptual failure model proposed by CIGRE WG 12.18 [7,8]

**Case Study: Analysis of Failed Transformers**

Faults create thermal and mechanical stresses. All of the Transformers at Crystal and Mallard had significant number of high current faults during the storm and failed due to their reduced fault withstand capability as a result of the cumulative mechanical and thermal stresses from the faults

| | Crystal | Mallard |
|---|---|---|
| Total $I^2t$ $A^2$seconds | 3,400,249 | 5,669,606 |
| Times the cumulative thermal energy that the transformers were each designed to withstand, assuming equal stress on each of the transformers | 3.4 | 3.9 |



# Distribution Performance

Distribution System performed well in Irma and demonstrated the investments in the Distribution Hardening Program, Pole Inspection Program (PIP) and Smart Grid have helped reduce the number and severity of outages during Hurricane Irma. This was key to improved speed of restoration.

**Pole Summary**

- Hardened Feeder Poles Down 26 (0.02%)
- Non-Hardened Poles Down 2,834 (0.20%)
- Poles Down 2860 (Feeder, Lateral, Service, Telephone)
  - Poles replaced during restoration
- Pole damage was primarily due to fallen trees
- Flooding and debris caused issues to a much lesser degree
- Overall pole performance was significantly better than previous storms

**Hardened vs non-Hardened Feeder Performance Summary**

| | non-Hardened | Hardened | Improvement |
|---|---|---|---|
| Pole Failure Rate | 0.20% | 0.02% | 10 X Better |
| CMH to Restore | 105 | 52 | 2 X Better |
| Feeders Out | 82% | 69% | 1.19 X Better |

| Feeder Summary | Affected | % Affected |
|---|---|---|
| • **Feeders Out** | **2,286** | **70%** |
| o UG | 85 | 19% |
| o Hardened | 592 | 69% |
| o Non-Hardened | 1,609 | 82% |

*Excludes outages caused by Transmission and Substation*

**Hardened Feeder Summary**

- 26 Hardened Feeder Poles were down out of 124,518 hardened poles on 859 Hardened Feeders.
- Hardened Feeders performed 1.19 times better than non-Hardened Feeders
- The primary objective of hardening is to reduce restoration times by minimizing the number of pole failures during extreme wind weather events.
- Hardened Feeders took half as much time to restore than non-Hardened Feeders
- On average Hardened Feeders had 13 damage findings vs. 18 damage findings on non-Hardened Feeders

| Lateral Summary | Affected | % Affected |
|---|---|---|
| • **Laterals Out** | **24,108** | **13%** |
| o OH | 20,341 | 24% |
| o UG | 3,767 | 4% |

- Underground Laterals perform 6.6X times better than Overhead Laterals.
- Overhead Laterals averaged an outage every 1.1mile vs. Overhead Feeders averaged and outage every 5.3 miles.
- Vegetation is leading cause of Overhead Lateral outages
- Flooding or vegetation(roots) are leading cause for Underground outages
- Excludes outages caused by Feeder, Substation or Transmission outages

**Smart Grid Summary**

- Self-Healing AFS (Automated Feeder Switch) operations avoided 546,000 Customer Interruptions during the storm.

Hurricane Irma hits Biscayne Bay in Miami on Sept. 10, 2017. Wilfredo Lee – AP

# Pole Performance

Distribution Poles performed well in Irma. Hardened poles performed 10-times better than non-hardened poles and Non-Hardened poles performed better than previous storms. Fewer total poles replaced and shorter time to restore show that the system performs better for storm.

40% of pole failures were in the West area. In addition to Irma's impact, this area experienced record rainfall of over 16 inches in 3 days just 2 weeks before Irma. This combined with Hurricane Irma's impact led to a high uprooting of trees which was a main cause of pole failures.

- 26 Hardened Feeder poles down
    - Zero hardened concrete poles down
- 2860 Total poles replaced to restore power

**Hardening Pole Programs**

- Storm Hardening Plan: 124,518 poles have been hardened
- Pole Inspection Program: Inspection of Feeder and Lateral poles resulted in replacement of over 80,000 poles and reinforcement of nearly 50,000

| Region | FPL Concrete | FPL Wood | FPL Total | Tele-phone | Total Poles | Broken + Down in ESDA | Total Poles to Restore | Pole Failure Rate |
|---|---|---|---|---|---|---|---|---|
| Broward | 24,289 | 76,817 | 101,106 | 46,206 | 147,312 | 104 | 148 | 0.10% |
| Dade | 27,554 | 120,441 | 147,995 | 60,961 | 208,956 | 649 | 828 | 0.40% |
| East | 16,430 | 128,970 | 145,400 | 42,719 | 188,119 | 226 | 285 | 0.15% |
| North | 23,556 | 434,659 | 458,215 | 75,113 | 533,328 | 300 | 507 | 0.10% |
| West | 13,317 | 302,309 | 315,626 | 7,000 | 322,626 | 822 | 1,092 | 0.34% |
| Total | 105,146 | 1,063,196 | 1,168,342 | 231,999 | 1,400,341 | 2,101 | 2,860 | 0.20% |

| Distribution Pole Failure % | | | |
|---|---|---|---|
| Pole Type | Failures | Total # of Poles | Failure Rate |
| Hardened Feeders | 26 | 124,518 | 0.02% |
| non-Hardened Feeder | 585 | 286,482 | 0.20% |
| Telephone | 511 * | 231,000 | N/A |
| Lateral / Service | 1,738 | 758,341 | 0.22% |
| Overall | 2,860 | 1,400,341 | 0.20% |

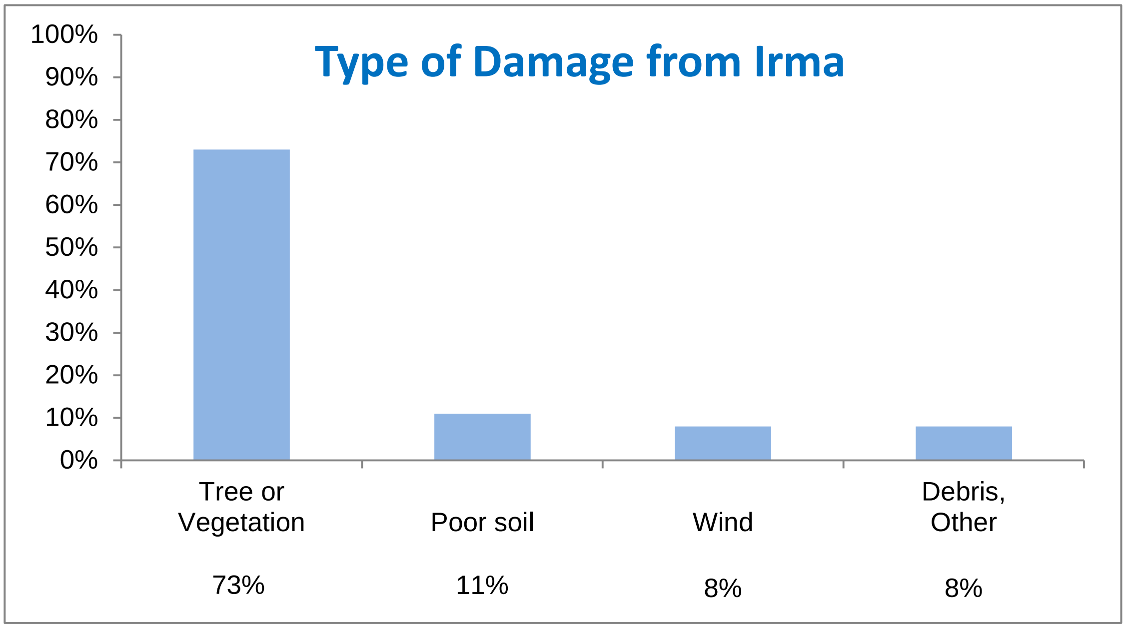
* Telephone Company Poles replaced by FPL

**Extrapolation Assumptions below**

1. Includes all poles reported in ESDA as broken or down which includes Feeders, Laterals, Service, and Telephone.
2. Feeder Outage Duration < 24 hours excluded - Assumed no poles down or broken
3. Extrapolate to population based on sample size for the area

## General Pole Performance by Failure Type

Survey of 33 Forensic Patrollers for Hurricane Irma. Damage was based on information from patrols and pictures were used to verify accurate categorization.



## Hardened vs non-Hardened Pole Performance

The investments in the distribution hardening program, pole inspection program (PIP) and smart grid have helped reduce the number and severity of outages during hurricane Irma.

The severity of damage was minimized and the speed of restoration was faster due to the efforts of the hardening programs that FPL has employed.

FPL's total pole down/broken count for Irma is 2,860 with only 26 being Hardened Poles. Pole damage was primarily due to fallen trees. Flooding and debris caused issues to a much lesser degree. This performance is significantly better than previous storms.

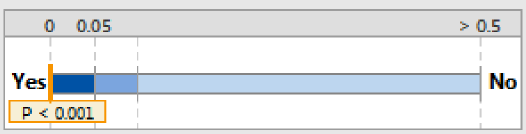
| Distribution Pole Failure % | | | |
|---|---|---|---|
| Pole Types | Failures | Total # of Poles | Failure Rate |
| Hardened Feeder | 26 | 124,518 | 0.02% |
| non-Hardened Feeder | 585 | 286,482 | 0.20% |

Hardening Works

Data shows there was a statistical difference in performance between Hardened and non-Hardened Feeder outages since the p-value <.05.
Analysis that showsthe defect rate of non-Hardened and Hardened Feeder poles is significantly different.

### 2-Sample % Defective Test for non-Hardened vs Hardened
Summary Report

Do the % defectives differ?




The % defective of non-Hardened is significantly different from the % defective of Hardened ($p < 0.05$).

Individual Samples

| Statistics | non-Hardened | Hardened |
|---|---|---|
| Total number tested | 286482 | 124518 |
| Number of defectives | 585 | 26 |
| % Defective | 0.20 | 0.02 |
| 95% CI | (0.19, 0.22) | (0.01, 0.03) |

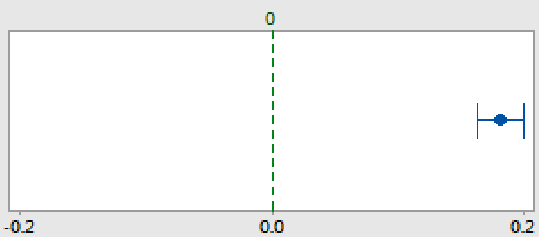
Difference Between Samples

| Statistics | *Difference |
|---|---|
| Difference | 0.18 |
| 95% CI | (0.16, 0.20) |

*Difference = non-Hardened - Hardened

95% CI for the Difference

Is the entire interval above or below zero?




Comments

- Test: You can conclude that the % defective differs at the 0.05 level of significance.
- CI: Quantifies the uncertainty associated with estimating the difference from sample data. You can be 95% confident that the true difference is between 0.16% and 0.20%.

## Hardened Pole Failure Analysis

- 26 Hardened Feeder poles (all wood) were down or broken out of the 859 Hardened Feeders
- This is a 0.02% failure rate compared to 0.2% for all poles
- 9 Trees, 9 Poor Soil and possibly a set depth issue, 3 cascade, 5 other

**Hardened Pole Failure Analysis (from ESDA)**

| Feeder | Substation | Official Hardening Date | Region | Poles Down | Poles Broken | Poles Leaning | Comments | Cause - Tree | Cause - Debris | Cause - Wind | Cause - Soil/Fnd | Cause - Other/ unknown such as defect, deterioration, pole fire, overloaded, poor guying | Cause - Secondary Failure (Cascade) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 503564 | ALLIGATOR | 3/31/2015 | West | | 2 | | Tree | 2 | | | | | |
| 504061 | CAPRI | 9/23/2016 | West | 1 | | 11 | Debris and micro extreme wind event in trailer park | | 1 | | | | |
| 503261 | COCOPLUM | 6/30/2015 | West | | 1 | | Pole broken 10' from the ground. Not cause for outage, no obvious cause for outage beyond wind. Likely pre-existing material defect in pole. | | | | | 1 | |
| 500765 | ENGLEWOOD | 5/31/2009 | West | | 2 | | Tree broke tops of 2 poles | 2 | | | | | |
| 508463 | GATEWAY | 6/30/2014 | West | | 1 | | Pole Fire damaged top of pole | | | | | 1 | |
| 560166 | METRO | 9/24/2010 | West | | 1 | | Tree came down on line | 1 | | | | | |
| 507761 | RATTLESNAKE | 11/12/2009 | West | | 1 | | Pole broken 3-6' from the ground, normally open ScadaMate switch | | | | | 1 | |
| 102361 | TERRY | 5/1/2014 | West | 9 | | 9 | Potentially Shallow set depths and extreme saturated soil conditions lead to failures (9 additional poles leaning) | | | | 9 | | |
| 800432 | LIVE OAK | 9/24/2009 | North | | 1 | | Live Oak tree on adjacent span fell on phone trunk snapping pole | 1 | | | | | |
| 300633 | MATANZAS | 12/21/2013 | North | | 1 | | Tree damage - tornado in area | 1 | | | | | |
| 102532 | ST JOE | 1/6/2015 | North | | 1 | | Two trees on feeder | 1 | | | | | |
| 508362 | BELLE GLADE | 12/19/2008 | EAST | | 4 | | Failure of one pole caused cascade of 3 other broken poles. Poles broken from the cascade snapped 0 to 10 ft above grade. | | | | | 1 | 3 |
| 400934 | COCONUT GROVE | 10/25/2007 | Dade | | 1 | | Large tree fell directly onto pole causing it to break | 1 | | | | | |
| **Totals** | | | | 10 | 16 | 20 | | 9 | 1 | 0 | 9 | 4 | 3 |
| | | | | **26** | | | | **26** | | | | | |

**Telephone Pole Performance**

- ESDA data of Telephone pole failure rate.
- Poles owned by Telephone companies and with FPL facilities.
- Telephone poles replaced by FPL

| Region | Total Poles Extrapolated from Patrolled | Telephone Pole Replaced | % Telephone Pole Replaced |
|---|---|---|---|
| Broward | 148 | 50 | |
| Dade | 828 | 282 | |
| East | 285 | 71 | |
| North | 507 | 86 | |
| West | 1092 | 22 | |
| **Total** | **2860** | **511** | **18%** |

| **Total w/o West** | **1768** | **489** | **28%** |
|---|---|---|---|
| Total without the west region is calculated for comparison reasons due to the low number of Telephone poles. | | | |

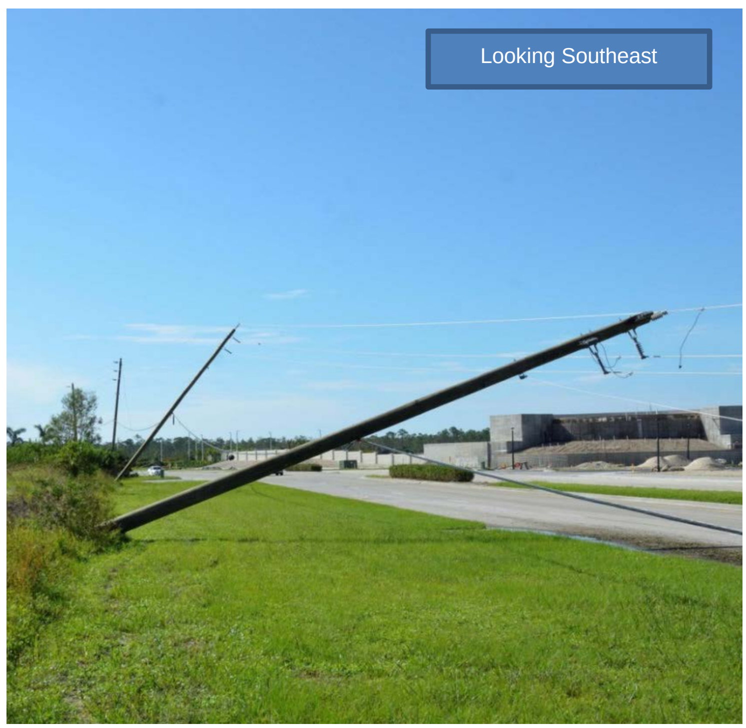
**Case Study – Terry 508362 - Side Guying Failed Causing Leaning Poles**

Nine hardened FPL wood poles with foreign attachments leaned or were laid over on the Terry 508362 Feeder.

The area experienced wind speeds in the range of 81-100 mph gust wind speeds. These poles were designed to 130mph wind gusts given the date of the hardening project.

It was reported that the heavy rain in the weeks prior to the storm had left the soil fully saturated which also reduces the foundation capacity. Also, the poles appear to have been set shallow.

The anchors on the structure at the northern end of the failure pulled out of the soil. The anchors were set in a berm with a small pond behind. No extensions were utilized on the anchors. The shallow installation depth into a berm would significantly reduce the holding capacity of the anchor particularly in saturation soil.

**Case Study – Capri 504061 – Leaning and Down Poles due to Trailer Park Debris**

11 FPL Hardened Feeder poles (10 wood, 1 concrete) with foreign attachments were leaning and 1 pole (wood) was down on the Capri 504061 Feeder due to high winds and debris from the adjacent trailer park.

The area experienced wind speeds in the range of 81-130 mph gust wind speeds. These poles were designed to 145mph wind gusts given the date of the hardening project.

The poles leaned over when impacted by debris from the trailer park. Debris seemed to be from structures immediately adjacent to the line.

The soil is soft in the area. There is a small ditch next to the poles and there may be a layer of muck that would decrease the effective setting depth.

There is evidence of potential areas of enhanced wind events from the drone investigation, but the areas of impact have such small impact areas (less than 300 feet in most locations of this area), the manufactured homes and the additions that are made to them are so susceptible to damage in high wind, and the gusts from the hurricane force winds themselves are so powerful that it is difficult to be definitive here.

No poles broke and all were able to be straightened and reset. Cross-arms, wires, and equipment were damaged and would need to be replaced.

Pole down with transformer in West area due to trailer park debris

Debris wrapped around pole in line.

Insulator tie and failed splice. Below: ALS out of support and on ground

View of leaning poles

Base of leaning concrete pole

Leaning concrete pole

Area of concentrated damage, looking west.


Looking northwest through the trailer park toward the feeder


Indications of enhanced wind activity

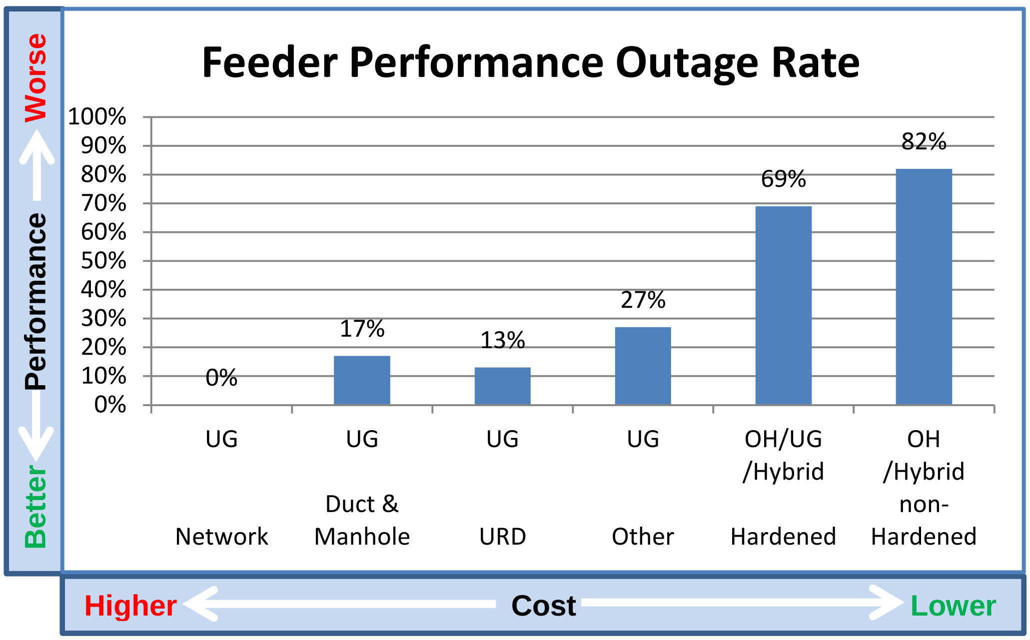
Looking south along feeder.

# Feeder Performance

Underground Feeders performed better than Overhead Feeders. Hybrid Feeders performed similar to Overhead Feeders because Hybrid Feeders are a combination of OH and UG.

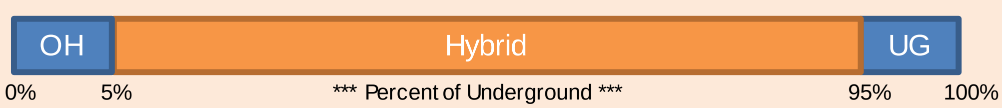
**Feeder Performance by Feeder Type**

| Feeder | Type | Affected | Population | % Affected |
|---|---|---|---|---|
| UG | Network | 0 | 11 | 0% |
| UG | Duct / Manhole | 54 | 314 | 17% |
| UG | Other | 23 | 85 | 27% |
| UG | URD | 8 | 60 | 13% |
| OH / UG / Hybrid | Hardened | 592 | 859 | 69% |
| OH / Hybrid | non-Hardened | 1,609 | 1,958 | 82% |
| Total | | 2,286 | 3,287 | 70% |




Notes: - Excludes Transmission and Substation Outages
- OH Hardened Feeder includes OH-to-UG conversions as a part of Hardening
- Source is Carver Data on 9/22/17 at 7:00 am

UG Feeder → Combination of feeder and lateral miles > = 95% UG
OH Feeder → Combination of feeder and lateral miles < = 5% UG
Hybrid Feeder → Combination of feeder and lateral miles between 5% - 95% UG




Definition of Purely Overhead (OH), Purely Underground(UG) and Hybrid Feeders

**Hardened vs non-Hardened Feeder Performance**

Hardened Feeders performed better than non-Hardened Feeders during Hurricane Irma

- While Hardened Feeders make up 26% of the Feeder population, Hardened Feeders sustained less pole damage accounting for only 0.9%( 26 out of 2860) of the poles down or broken
- Based on less damage sustained, Hardened Feeders took 50% less resource-time to restore than non-Hardened Feeders
- Hardened Feeders performed 1.19 times better than non-Hardened Feeders
- Primary cause of pole failures and feeder outages was due to vegetation
- Forensic teams inspected all poles from the 859 Hardened Feeders
- Based on the assessment of outage performance Hardened Feeders performed 1.19 times better than non-Hardened Feeders

$$\text{Hardened Feeder Performance Ratio} = \frac{\text{Number of Non-Hardened Feeders Out*}}{\text{Total Number of Non- Hardened Feeders}} \text{ to } \frac{\text{Number of Hardened Feeders Out*}}{\text{Total Number of Hardened Feeders}}$$

* Affected = Feeders out at least one time

$$\frac{1{,}609 / 1{,}958}{592 / 859} = \frac{.82}{.69} = 1.19 \text{ X Better}$$

Hardened Feeders Performed 1.19 Times Better Than Non-Hardened Feeders

Hardened vs non-Hardened Average Time to Restore

Hardened Feeders have performed better both on outages and damage, thus we are seeing that they take half the time to restore. An assessment of Construction Man Hours (CMH) was performed to convey the benefits of Feeder Hardening.

Approach:

1. A survey was conducted of 100+ Irma Production Leads to assess the CMH associated with major work types for the storm
2. Electric Storm Damage Assessment (ESDA) data was utilized to characterize the major types of damage on Feeders impacted
3. Merging the CMH survey results to actual damage reported provides an estimate of the CMH required to restore major work on Hardened Feeders (52 CMH) vs. non-Hardened Feeders (105 CMH)

| Damage | ESDA Conditions per Feeder | | CMH to Resolve each Condition | Estimated CMH to Restore | |
|---|---|---|---|---|---|
| | Hardened Feeder | non-Hard Feeder | | Hardened Feeder | non-Hard Feeder |
| Transformer | 1.19 | 1.77 | 3 | 3.6 | 5.3 |
| Wire | 2.07 | 4.05 | 11.3 | 23.4 | 45.8 |
| Pole Leaning | 0.47 | 0.75 | 14.1 | 6.6 | 10.5 |
| Pole Down / Broken | 0.04 | 0.94 | 18.1 | 0.7 | 17 |
| Tree | 1.51 | 2.17 | 11.9 | 17.9 | 25.9 |
| Total | 5.27 | 9.68 | | 52.2 | 104.5 |

**½ the time to restore**

- Capacitor, customer, fuse, unclassified pole, and recloser conditions for feeders in ESDA are not considered major work categories to restore the feeder and thus no CMH was assigned
- Half of non-broken poles were replaced; half were reset. Thus an average of pole leaning CMH and pole broken CMH were used
- Counts of Hardened poles down & broken is per Forensics analysis. All other data sources are ESDA (non-Forensics) on 9/20/17 7AM

Examples of Hardened and non-Hardened Feeders

**Hardened Feeder**

- Wires down, but not the poles will result in quicker restoration.
- Boca Raton Area

**Non-Hardened Feeder (independent of the above Hardened Feeder)**

- Leaning poles due to soft / saturated ground
- Carlstrom 5961 (Ft.Myers / Arcadia Area)

## Case Study – Hardened vs non-Hardened Poles within a mile

The comparisons used for this analysis are from a Hardened section of Feeder to a non-Hardened section of Feeder that are less than a mile apart.

This Feeder was Hardened up to a recloser, and not beyond, due to planning recommendations, and experienced a variety of damage including wind and vegetation. This line is located in southern Miami.

Newton 810366

**Hardened:**

- No poles down.
- The only wires down were due to a massive tree
- However, this leaning tree did not bring down poles

**Non-Hardened:**

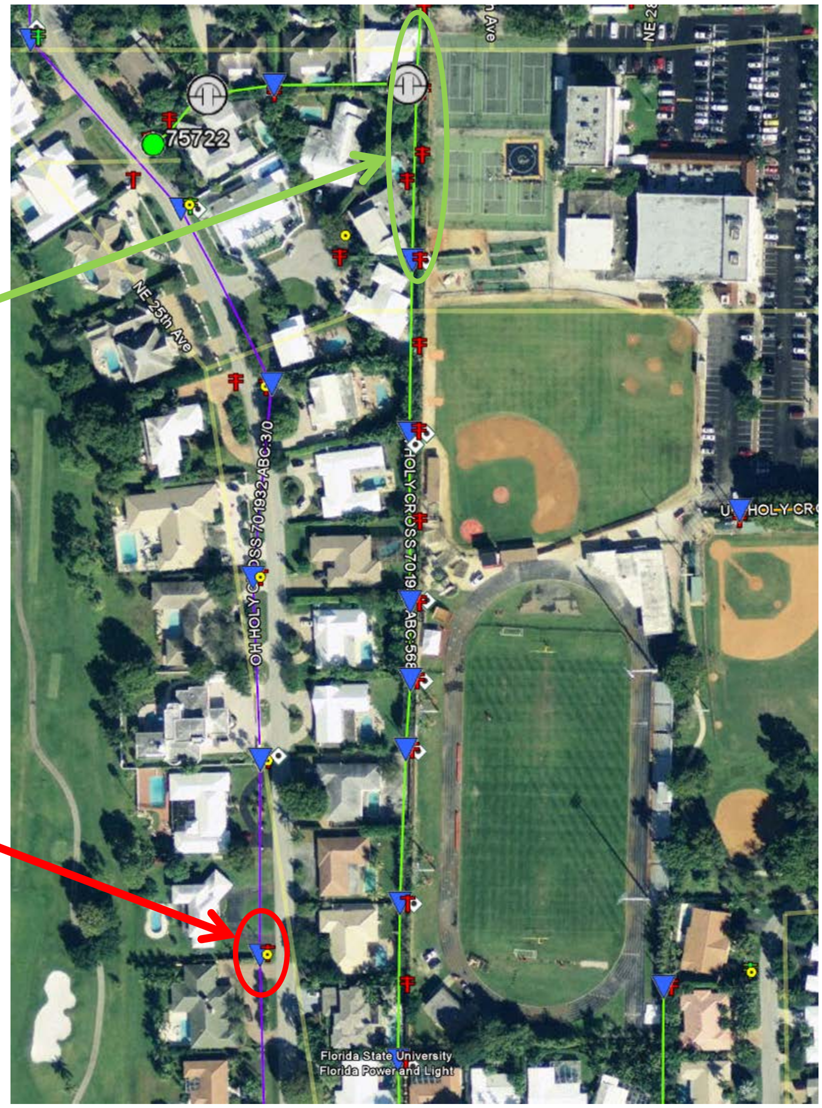
- Feeder behind the OCR had three broken poles shown below due to wind
- Two stub poles are all that remain and the rest of the poles and wires were behind the berm across the canal

<u>Holy Cross 701937</u>

Below is an example of two pole lines that are running parallel and separated by a couple of lots in Ft. Lauderdale. It appears that the primary damage was from wind.

**Hardened** (Holy Cross 701937):

- Slightly leaning in rear of due to wind




**Non-Hardened** (Sample 701932):

- Broken pole

<u>Labelle 502463</u>

Below is a good example of a Hardened wood pole line section compared to a non-Hardened wood pole line section. This pole line is on the West coast just west of Labelle which was a few miles east of where the eye passed. Wind seemed to be the primary cause, as neither section appeared to be related to vegetation or debris.

**Non-Hardened** (Labelle 502463 – East of SW# 20714)

- Pole line leaning significantly as well as another section that had 2 broken poles. This section of Feeder was not Hardened
- Poles appeared to be 45'/5 or 45'/4 poles, but could not identify pole brand

Broken →


Leaning →

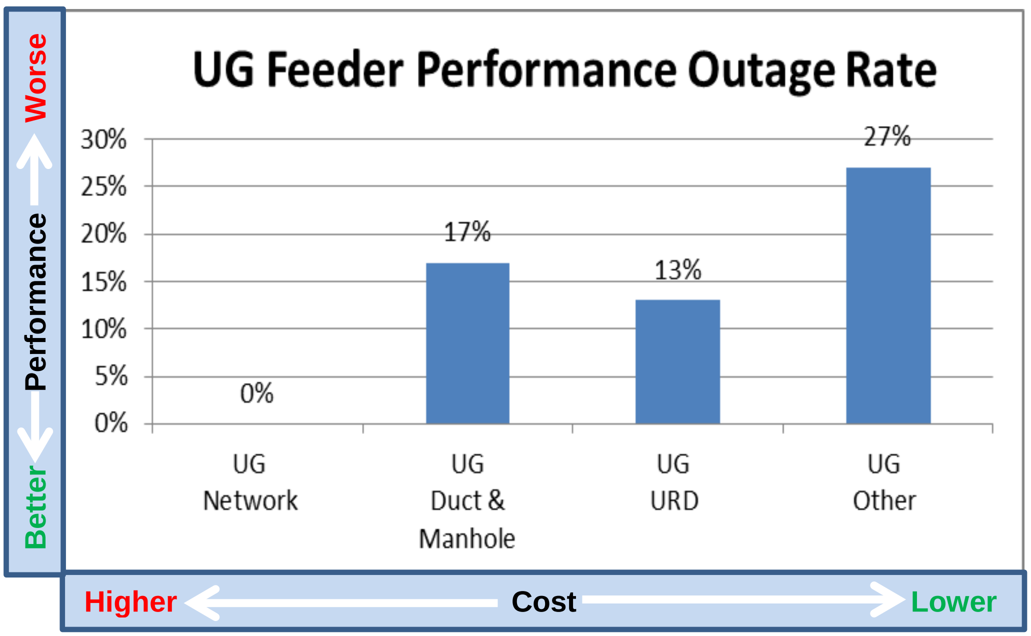
**Hardened (**Alva Feeder 504761 – West of switch number 20714)

- Section of wood hardened poles that were unaffected by the storm. These poles were not leaning and showed no signs of any damage.


# Underground Feeder Performance

Impacts to Undergound Feeder performance is generally proportional to the cost and type of the Underground design

| Feeder | Type | Affected | Population | % Affected |
|---|---|---|---|---|
| UG | Duct / Manhole | 54 | 314 | 17% |
| UG | Other | 23 | 85 | 27% |
| UG | URD | 8 | 60 | 13% |
| Total | | 85 | 459 | 19% |




Notes: - Excludes Transmission and Substation Outages
- Source is Carver Data on 9/22/17 at 7:00 am

# Lateral Performance

Underground Laterals performed better than Overhead Laterals during Hurricane Irma.

- While UG Laterals make up 55% of the Lateral population, UG Laterals sustained less outages accounting for only 3.6% of the Laterals out
- Based on the assessment of outage performance UG Laterals performed 5.6 times better than OH Laterals.
- Lateral outages do not include outages caused by Feeder, Substation or Transmission

| Laterals Out | Affected | Population | % Affected |
|---|---|---|---|
| OH | 20,341 | 84,574 | 24% |
| UG | 3,767 | 103,384 | 4% |
| Total | 24,108 | 187,958 | 13% |

$$\frac{\mathbf{20{,}341 / 84{,}574}}{\mathbf{3{,}767 / 103{,}384}} = \frac{\mathbf{.24}}{\mathbf{.04}} = \mathbf{6.6}$$

**Underground Laterals performed 6.6X better than Overhead Laterals**

$$\text{UG Lateral Performance Ratio} = \frac{\text{Number of OH Laterals Out*}}{\text{Total Number of OH Laterals}} \text{ to } \frac{\text{Number UG Laterals Out*}}{\text{Total Number of UG Laterals}}$$

* Affected = Laterals out at least one time

Laterals Out from Tickets and from Storm Control (SC) Laterals from Patrols

| Lateral Type | Lateral Out |
|---|---|
| SCL | 18,074 |
| SCLU | 3,433 |
| LAT | 2,267 |
| LATU | 334 |
| **Total** | **24,108** |

Overhead Laterals = SCL + LAT
Underground Laterals = SCLU +LATU

# Distribution Transformer Performance

Single phase pad mount transformers for Underground systems performed 3.5X better than Aerial transformers on Overhead Systems

Transformer Inspection at CRS

- There are over 930,000 distribution transformers in service:
  - 605,000 aerial transformers
  - 255,000 single phase pad mounted transformers
  - 46,000 three phase pad mounted transformers
- According to Inventory Services approximate net issues for storm Irma were as follows:
  - 4033 aerial transformers = 0.667% failure rate
  - 481 single phase pads = 0.189% failure Rate
  - Therefore UG performed 3.5X better than OH transformers
    - (0.667/0/189)=3.5X
- Mostly Aerial distribution transformers were impacted by Hurricane Irma. Much less Underground transformer damage has been reported and observed.

Inspection at CRS**:**

- The observed aerial transformers mainly fall in two categories:
  - Broken insulator/bushings due to trees and flying objects
  - Extensive physical deformation due to impact or fall due to broken pole

**Broken bushings**

**Bent frames**

- It is estimated by Inventory Services that approximately 4000 aerial transformers were issued due to damage caused by trees, flying objects, or damaged as a result of falling with the broken pole in which they were installed.

Underground Transformers (Single and Three Phase Pads):

- Thirty 3-phase pads with corresponding dates that could be associated with Hurricane Irma. No Physical observation on 2 while 1 had a primary bushing damage suggesting possible cable pulled by uprooted tree/falling riser pole.

- Less than 30 single phase pads with corresponding dates that could be associated with Hurricane Irma. No outside observations on them other than some rust and one unit had been physically hit by debris. We were not able to open them due to how they are stored next to each other and banded closed. Most of them were drained by environmental prior to shipping as is customary.

- It is estimated by Inventory Services that approximately 500 Underground transformers were issue due to Storm Irma. Less number of Underground transformers were observed at CRS and issued postulating that the hurricane did not cause as significant damage to the Underground transformers as to the Overhead.

Transformer Interruptions

| | TX Total | OH TX | UG TX |
|---|---|---|---|
| Interruptions | 10,594 | 8,061 | 2,533 |

Padmounted Transformer Analysis

The primary damage was due to:

- Flooding
- Up-rooted trees
- Debris falling onto equipment

Percentage of UGTX failures on Hybrid vs. UG Feeders

- The % Outages of UGTX on UG Feeders (0.34%) is better than the % outages of UGTX on Hybrid Feeders (0.78%)
- Source Carver Report

| % of UGTX Failures | Hybrid | UG |
|---|---|---|
| Outages | 2,303 | 43 |
| System | 294,652 | 12,619 |
| % Outage | 0.78% | 0.34% |

Percentage of UGTX failures on 23KV vs. 13KV

- The % Outages of UGTX on 23KV (0.5%) is better than the % outages of UGTX on 13KV (1.2%)
- Source Device File

| % of UGTX Failures | 13KV | 23KV |
|---|---|---|
| UGTX Outages | 1,558 | 799 |
| UGTX System | 133,325 | 175,657 |
| % Outage | 1.20% | 0.50% |

Underground facilities were also impacted by vegetation

Before Restoration

After Restoration

# Pad-Mounted Switch Performance

Pad Mounted Switches

- There were minimal pad-mount switch failures related to the storm
- Information based on teams reviewing trouble tickets, materials that were issued, and reports from the areas
- No failed switches were sent to the Reliability Assurance Center for RCA (Root Cause Analysis)

# Case Study – Miami Network

The Miami Network performed well with no breaker operations during Hurricane Irma.

The Miami Network is an Underground electrical network that assures service continuity in 120/208 and 277/480 volt Y connected secondary network systems. These systems, in either distributed grid or spot network form, are commonly used in such areas of high load density as metropolitan and suburban business districts.

Streets of downtown Miami

The FPL downtown Miami Network System consists of :

- 11 dedicated primary Network Circuits (Feeders)
- 104 transformers in 32 vaults
    - o Each transformers with its own protector
    - o Fire protection systems in all 480/277 Spot Network vaults.

| TRANSFORMER SIZE | TRANSFORMER QTY | VAULTS QTY | BELOW GRADE QTY |
|---|---|---|---|
| 208/120 | 45 | 18 | 10 |
| 480/277 | 74 | 15 | 0 |
| Total | 104 | 32 | 10 |

After seeing the impact of Superstorm Sandy, much of the equipment that was not already submersible has been changed out to be submersible. Many of the sidewalk vaults are being eliminated.

Downtown Miami experienced surface flooding from hurricane tidal surge impacts, which were generally reported east of NE 2nd Avenue, from the Edgewater area south to SE 15th Road. The flood heights were reported to reach roughly 2 feet above existing grade in some areas. Guided by the news reports, areas within this zone were visually inspected to determine a more detailed delineation of the flooding extent and whether Distribution Network and ground equipment in these select areas experienced flooding. The estimated limits of surface flooding from this assessment, along with visual evidence of flood intrusion into the Distribution equipment are shown in **Exhibit 1**.

Sixteen of 34 Network locations provided by Distribution were observed as shown in **Exhibit 2**. In most cases, the specific location was not accessible but the area was observed for evidence of surrounding flooding and noted. Three of these locations had evidence of roughly 2 feet flood height above the road elevation outside the Network equipment location.

Of the above-ground Distribution equipment locations observed in select areas north of the Miami River, three of these locations are assumed to have experienced flooding ranging from 12” to 18” of depth. These locations are shown in **Exhibit 1**. South of the Miami River, vault locations in buildings were inaccessible, but flooding estimations were made.

**Case Study – Miami Network**

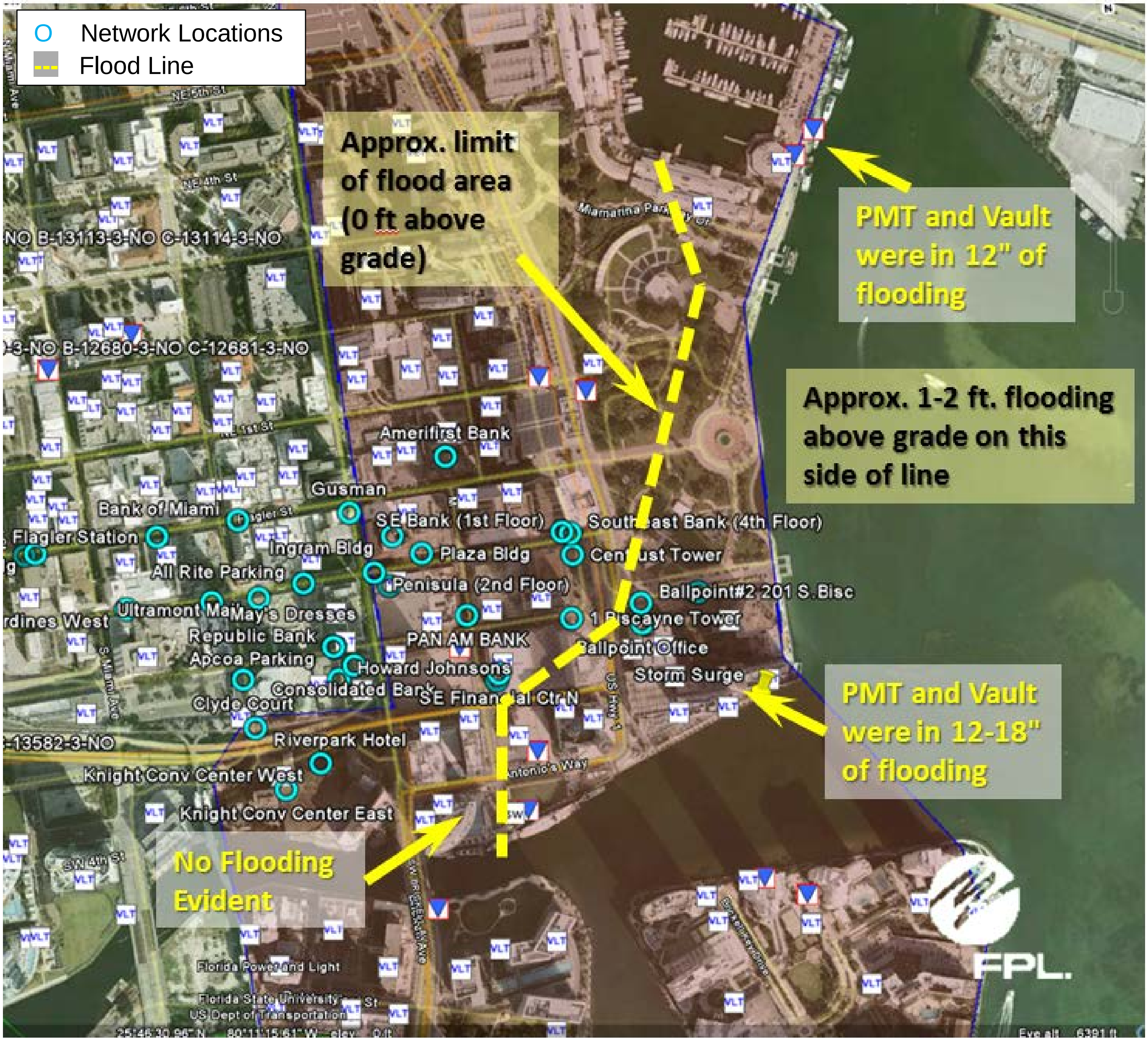



Exhibit 1: Flood intrusion into the Distribution Equipment in Miami

## Case Study – Miami Network

| GRID | NAME | VAULT # | ADDRESS | SUBMERSIBLE (3/3/14) | LOCATION FOUND (ACCESSIBLE) | SURROUNDINGS AREA FLOODED (APPARENT) | APPROX. FLOOD HEIGHT ABOVE GRADE |
|---|---|---|---|---|---|---|---|
| Main 208V | Knight Conv Center West | C4 | 400 SE 2 AVE (R/0) | No | YES (inside alleyway) | No | NA |
| Main 208V | Plaza Bldg | C25 | 245 SE 1 ST (ALLEY) | Yes | No (alleyway gate close) | No | NA |
| Main 208V | Ingram Bldg | C28 | 25 SE 2 AVE. - MEZZANINE | 2 Yes, 2 No | Not Accessible | No | NA |
| Main 208V | Peninsula Federal | C43 | 200 SE 1 ST | Yes | Not Accessible | No | NA |
| Main 208V | Riverpark Hotel | C51 | 321 SE 1 AVE (N SIDE) | Yes | Yes | No | NA |
| Main 208V | PAN AM BANK | T10 | 180 SE 3RD AVE | Yes | Not Accessible | No | NA |
| Main 480V | Knight Conv Center East | C5 | 400 SE 2 AVE (LOADING DOCK) | | Yes (in loading dock) | No | NA |
| Main 480V | Centrust Tower | C50 | 151 SE 3 ST | No | Not Accessible | No | NA |
| Main 480V | Hotel Intercontinental | C58 | 150 CHOPIN PLAZA | Yes | Yes (more that 4 feet above grade) | Yes | 1 to 2 feet |
| Main 480V | Ballpoint Office | C59 | 100 CHOPIN PLAZA | 2 Yes, 4 No | Not Accessible | Yes | 1 to 2 feet |
| Main 480V | SE Financial Ctr N | C61 | 325 SE 3RD ST (SW Corner of Bldg) | No | Not Accessible | No | NA |
| Main 480V | SE Financial Ctr S | C62 | 325 SE 3RD AVE. | No | Not Accessible | No | NA |
| Main 480V | SE Bank (1st Floor) | C65 | 100 SE 1 ST (100 S. BISCAYNE BLVD) | No | Not Accessible | No | NA |
| Main 480V | Ballpoint#2 201 S.Bisc | C66 | 201 S. Biscayne | No | Not Accessible | Yes | 1 to 2 feet |

**Exhibit 2: Network locations in Miami**

## Case Study – Miami Network

- Examples of Brickell Ave and the Financial District


Source: From Miami Herald

Image from https://www.youtube.com/watch?v=rDY_VQrCC1o

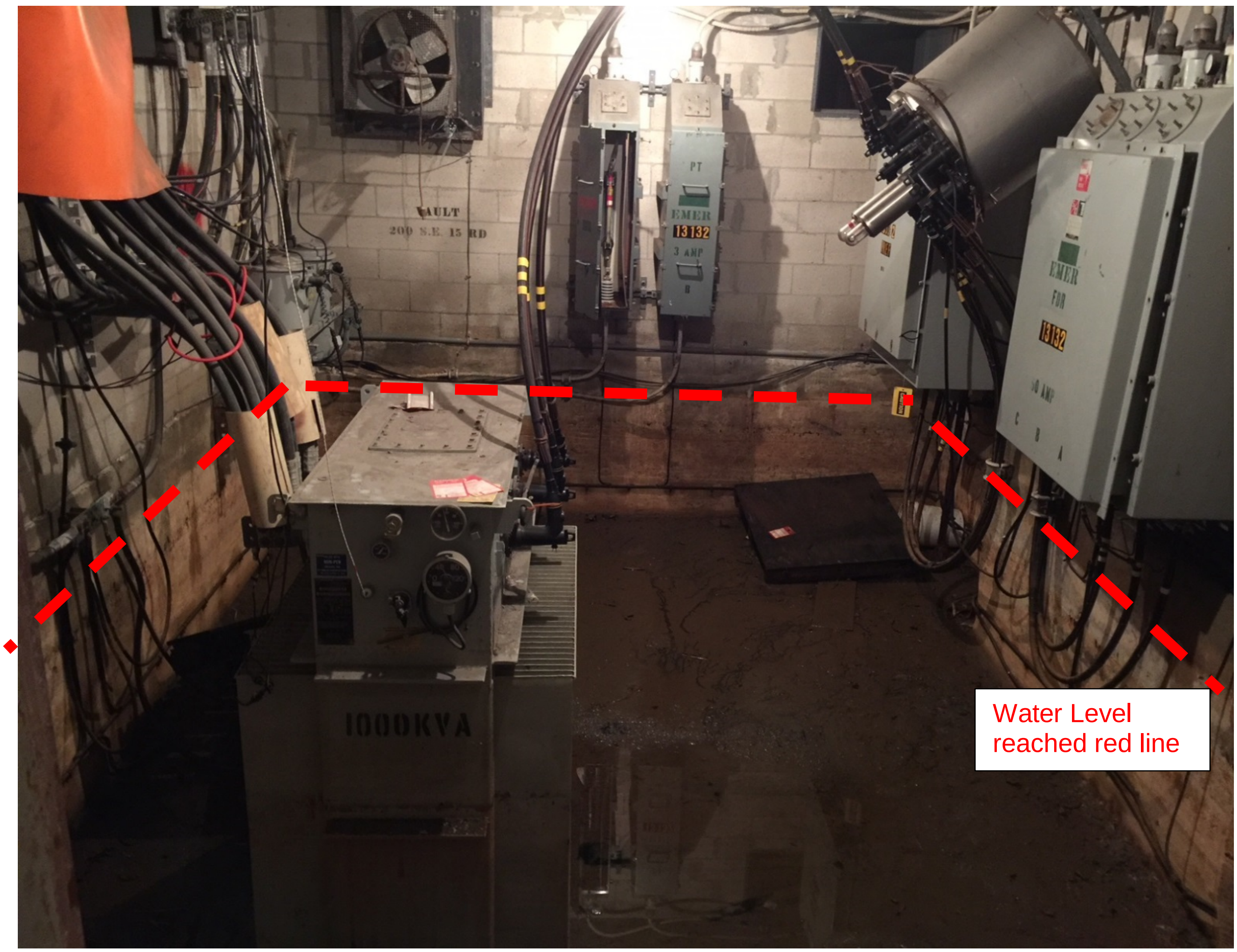
Image from https://www.youtube.com/watch?v=rDY_VQrCC1o

2’ deep at SE 12th St & Brickell Ave (Mike Seidel Twitter Feed)

Waves crash at mouth of Miami River at Biscayne Bay (AP)

### Case Study – Miami Network

Below is one of the vaults after the water was pumped out (200 SE 15th Road, 8VC13102.) It is the vault for Brickell Harbour, which is a subgrade vault. The water level (noted by the red line) never reached the spades of the transformer nor the bottom of the fuse cabinets, so it remained in service. Actually, none of the flooded network vaults lost power because of Hurricane Irma.




Subgrade Vault for Brickell Harbour

# Smart Grid

**AFS (Automated Feeder Switch)**

Automatic Feeder Switches (AFS) isolate, transfer load, interrupt faults and have pulse close capabilities. They automatically reroute electricity to reduce the amount of customers affected when an adverse condition affects the power lines.

AFS Performance:

- 546K Customer Interruptions avoided during the storm

AFS device availability was reduced to 33% at the peak of the storm. This occurred naturally through:

- Lost communications due to loss of power
- Damage to switches
- Switches reconfigured in the field

Note the lower effectiveness of the AFS in the West Management Area was due to implementing the Storm process which disables AFS team operations for winds greater than 74mph. The process includes:

1) Determining areas in which sustained winds will be greater than 74mph
    a. West Management Area was the area identified
2) Disabling of “Normal Open” switches in those areas to avoid automatic throw-over to alternate feeder.

There were around 250 AFS’s that showed offline or “Not Available” after the storm.

- Power Quality patrolled approximately 2,500 AFS’s on patrol sweeps.

There were 26 failed AFS’s that needed to be replaced

- Over half had physical damage and the rest are other mechanical and/or relay issues

**AFS Team Success Rate**

| Management Areas | CI Avoided | CI on Original Feeder Tickets | Feeder Tickets w/ CI Avoided | # of AFS Feeder tickets | Success Rate |
|---|---|---|---|---|---|
| East | 171337 | 822461 | 158 | 405 | 39% |
| BR | 55414 | 261726 | 46 | 116 | 40% |
| GS | 30967 | 159998 | 28 | 82 | 34% |
| PM | 27206 | 117595 | 30 | 62 | 48% |
| WB | 29191 | 150918 | 29 | 78 | 37% |
| WG | 28559 | 132224 | 25 | 67 | 37% |
| North | 157043 | 685010 | 145 | 369 | 39% |
| BV | 49547 | 198825 | 49 | 106 | 46% |
| CF | 46151 | 205100 | 41 | 115 | 36% |
| NF | 25783 | 100924 | 24 | 55 | 44% |
| TC | 35562 | 180161 | 31 | 93 | 33% |
| South | 110753 | 601079 | 124 | 353 | 35% |
| CE | 22072 | 138108 | 28 | 80 | 35% |
| ND | 18297 | 103835 | 21 | 64 | 33% |
| SD | 33507 | 189504 | 41 | 120 | 34% |
| WD | 36877 | 169632 | 34 | 89 | 38% |
| West | 107165 | 653774 | 71 | 241 | 29% |
| MS | 42448 | 194374 | 29 | 81 | 36% |
| NA | 37058 | 295988 | 23 | 98 | 23% |
| TB | 27659 | 163412 | 19 | 62 | 31% |
| Grand Total | 546298 | 2762324 | 498 | 1368 | 36% |

Naples is where the storm made landfall

Success Rate indicates self-healing from primary circuits to backup circuit

## ALS (Automated Lateral Switch)

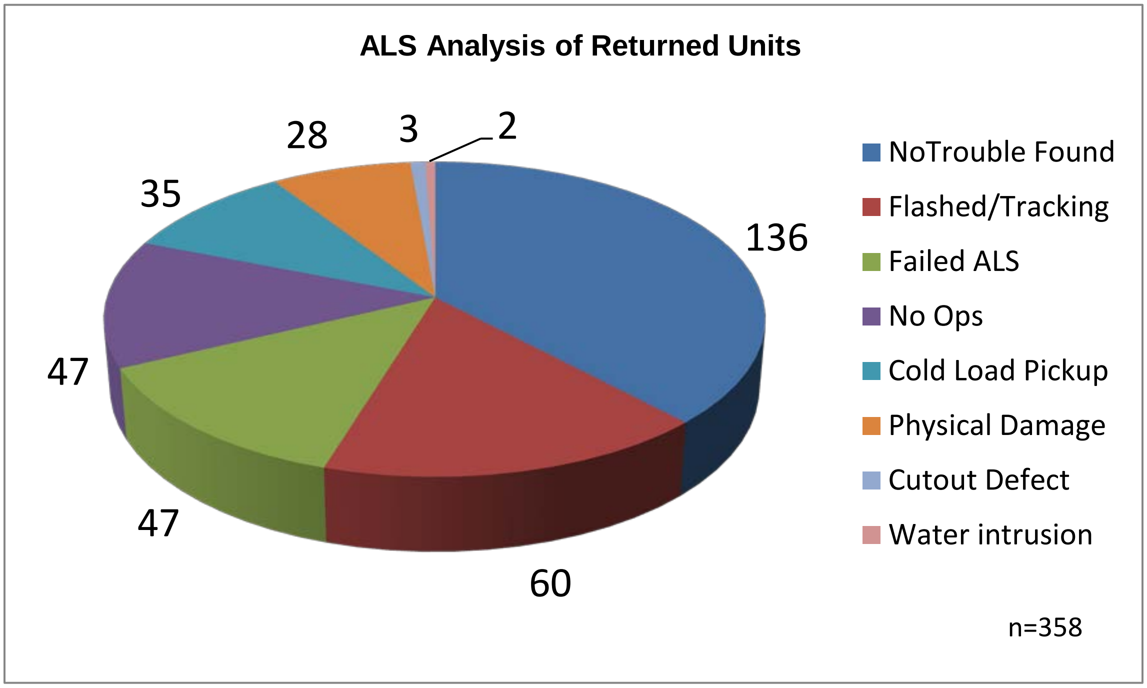
Automatic Lateral Switches (ALS) clear temporary faults, provides enhanced protection and coordination. During storm events with extreme winds for extended period of time, ALS performance is similar to a fuse.

### ALS Forensics

- Over 60% of ALS that were returned were operational

### ALS Analysis : 358 units

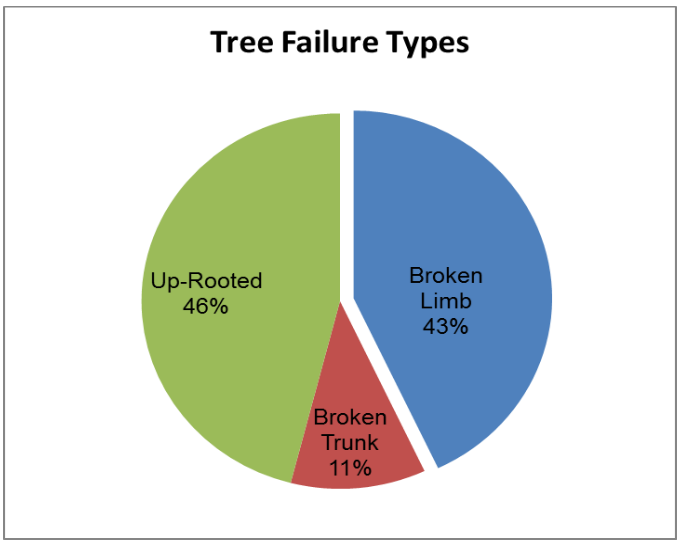
- 136 No Trouble Found
- 60 units were flashed or had evidence of tracking - most were operational
- 47 true failures
- 35 units returned due to cold load pickup concerns - operational
- 28 units had physical damage

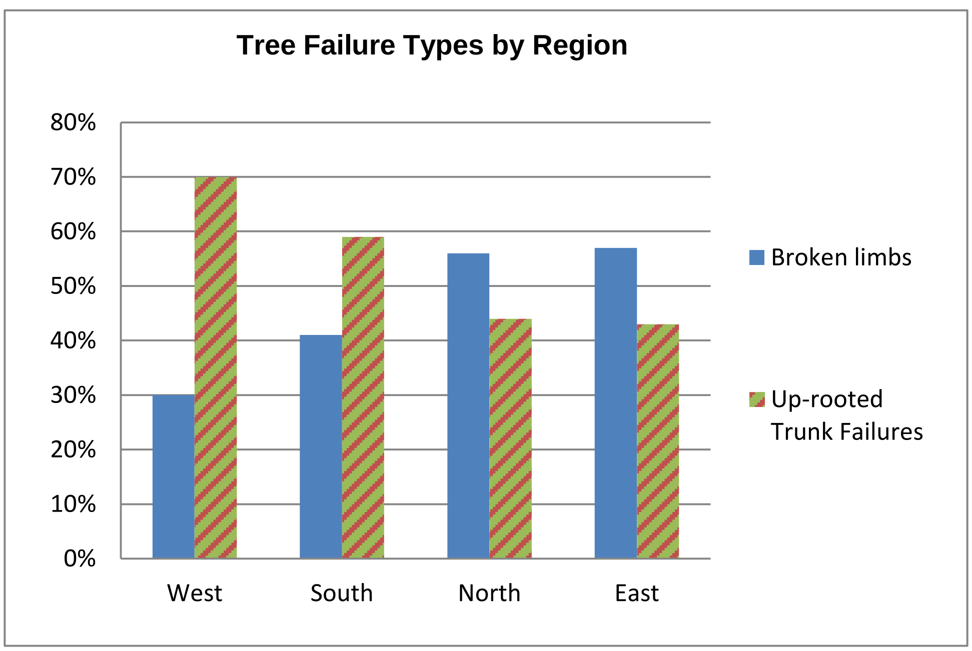


# Vegetation

**Overview - Vegetation was the leading cause of pole and wire damage**

- 57% of tree failures were caused by up-rooting trees or trunk failures falling into overhead facilities
- The remaining 43% of tree failures were due to broken limbs
- Additional trimming by FPL or shorter vegetation trimming cycles would not have made a significant impact to the system performance since the majority of damage was caused by uprooted trees, broken trunks and broken limbs that fell into the lines from outside of right-of-way.
- Over 6,000 reports were reviewed in ESDA (Electric Storm Damage Assessment) and 1,700 of these observations were referred to arborists to classify.



## Tree Characteristics

Native Trees
- Oak – Typically storm resilient unless they are older and larger
- Pine – Older trees are significantly less storm resilient

Non-Native and Exotic Trees
- Ficus - Dense foliage creating increased wind resistance and shallow root system
- Australian pine – Less flexible limbs, shallow root systems, low survival rates due to storms
- Melaleuca – Less flexible limbs, shallow root systems, low survival rates due to storms
- Palm – More storm resilient, however typically shed palm fronds
- Mango – Large non-native fruit tree with low wind resistance
- Acacia – Tall tree prone to large branch failure

Damage due to larger tree size based on ESDA observations
- Generally less storm resilient
- Large trees outside Right-of-Way fell into FPL facilities
- Downed larger trees require special equipment and additional time for clean up
- Downed larger trees blocked access and delayed restoration

Damage due to tree location based on ESDA observations
- In many cases Right Tree Right Place (RTRP) guidelines not followed
- Large trees outside Right-of-Way fell into FPL facilities

Damage due to Ground Conditions based on ESDA observations
- Saturated ground reduced soil friction and root holding ability

ESDA App (Electronic Storm Data Assessment) is the mobile data collection tool that FPL used to capture damage on storm patrols.

University of Florida Study Wind and Trees: Lessons learned from Hurricanes published by UF Institute of Food and Agriculture Sciences (IFSA) show that native trees typically fair better than non-Native trees in South Florida during storm.

**Tree and Vegetation Damage Patrol Observations and Analysis**
(Data collected from ESDA)

| Observation | Dade | East | North | West |
|---|---|---|---|---|
| % of tree damage For Native and non-Native trees | Native 20%<br>Non-Native 80% | Native 30%<br>Non-Native 70% | Native 70%<br>Non-Native 30% | Native 55%<br>Non-Native 45% |
| % of tree damage by tree type | Ficus 23%<br>Palm 10%<br>Aust. Pine 9%<br>Black Olive 7%<br>Oak 6%<br>Avocado 5%<br>Mango 5%<br>Bischofia 4%<br>Royal Poin. 3%<br>Bean Tree 3%<br>H.K. Orchid 3%<br>Vine 3%<br>Other 20% | Ficus 24%<br>Aust. Pine 13%<br>Oak 11%<br>Palm 7%<br>Melaleuca 6%<br>Pine 6%<br>Back Olive 4%<br>Brazi.Pepper 4%<br>Acacia 2%<br>Java Plum 2%<br>Vine 2%<br>Other 18% | Oak 43%<br>Pine 21%<br>Palm 8%<br>Hardwood 5%<br>Aust. Pine 5%<br>Other 19% | Pine 30%<br>Oak 16%<br>Ficus 9%<br>Palm 7%<br>Melalueca 6%<br>Acacia 5%<br>Aust. Pine 5%<br>Carrotwood 4%<br>Other 19% |
| | | | | |
| Primary damage | Up-rooted trees and broken trunks | Broken Limbs | Broken Limbs | Up-rooted trees and broken trunks |
| % of primary damage | 59% | 57% | 56% | 70% |
| | | | | |
| Secondary damage | Broken Limbs | Up-rooted trees and broken trunks | Up-rooted trees and broken trunks | Broken Limbs |
| % of secondary damage | 41% | 43% | 44% | 30% |
| | | | | |
| Ground Condition | Saturated | | | Saturated |
| General Comments | Access was an issue due to large number of exotics which are less storm resilient | Higher percentage of non-native and exotics are less storm resilient | Larger and older trees which are typically less storm resilient | Larger and older trees which are typically less storm resilient, High winds and saturated soil caused storm resilient trees to fail such as palms |

## Examples of Vegetation Damage in Dade Area

## Examples of Vegetation Damage in East Area

## Examples of Vegetation Damage in North Area

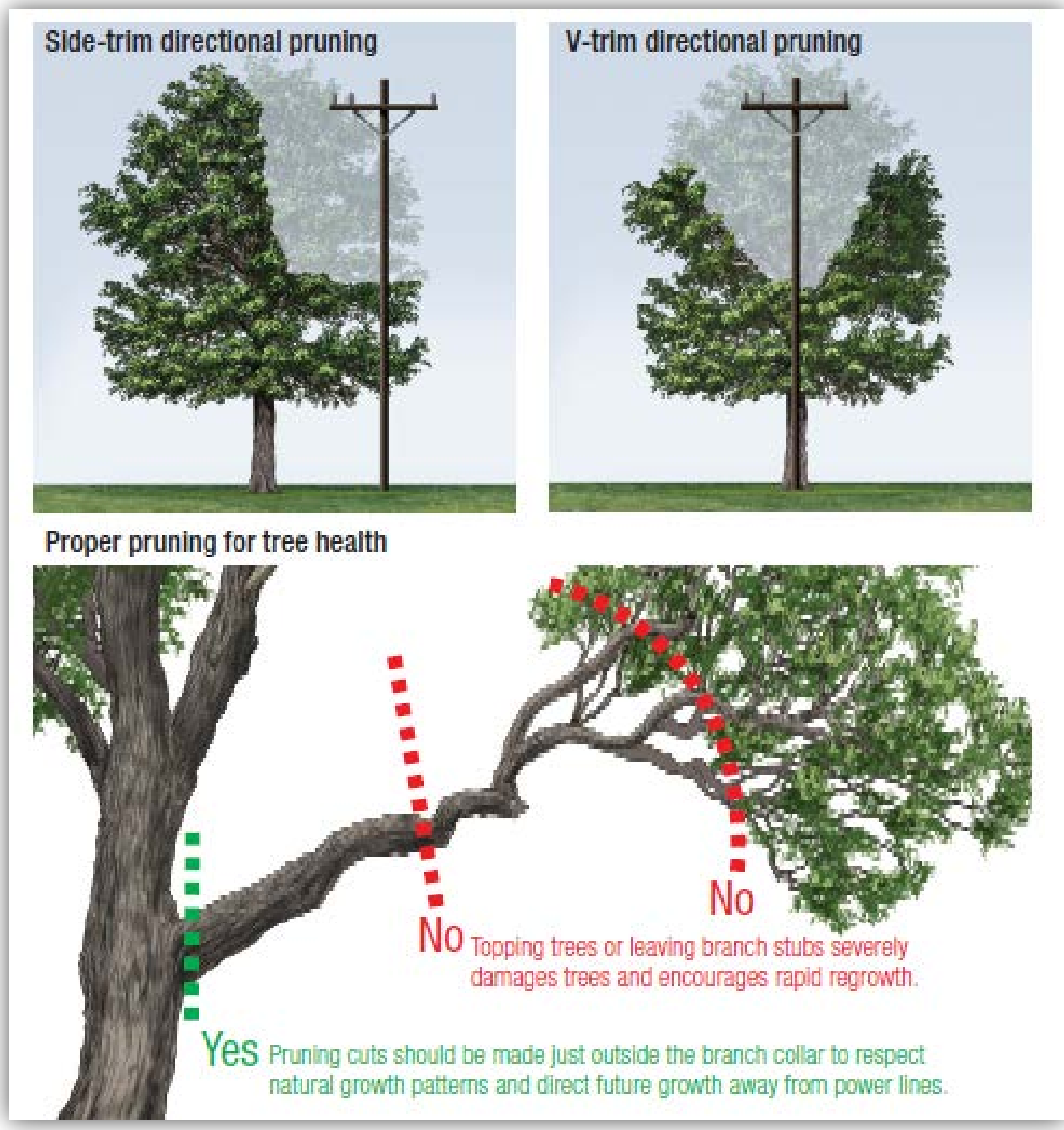
## Examples of Vegetation Damage in West Area

## Vegetation Trimming Guidelines - Specifications and Guidelines for Clearances

*Planting the Right Tree in the Right Place (RTRP) reduces pruning requirements*

**However, when we need to trim, we follow all industry guidelines**

- **Directional pruning:**
    - Removes limbs growing towards the conductors
    - Trains the tree to grow away from the facilities
    - Removes limbs at natural detachment points, or laterals, to help facilitate sealing to prevent decay
- **Removal:**
    - Necessary if pruning cannot be maintained
    - Palms



## Case Study – High Density Foliage areas in South Florida "Rear-of-Service"

Existing Conditions and Limitations

- Many large trees are in close proximity to utility lines and outside rights-of-way and easements
    - Wrong tree planted in the wrong place (including new and young trees)
    - Many non-native trees have less wind resistance and break or blow over in high winds
- Some communities have advised that "Right Tree Right Place" (RTRP) does not meet the characteristics of the city.
- Pressure from some communities on FPL to perform minimal trimming so it does not impact aesthetics.

<u>Possible Solutions</u>

- Adopt ordinances that support keeping vegetation away from utilities
- Cities should have strategy to maintain trees for storm (thin out tree for storm resilience)
- Plant only right tree right place (RTRP)
- Partner with customers and municipalities to identify trees in need of removal or relocation that are wrong tree wrong place

## Case Study – Coral Gables

The city has a long history focused on aesthetics, tree lined streets, and green spaces which has resulted in many large canopy trees adjacent to power lines in easements. During storm, large mature banyan trees topple over and crash into facilities from far beyond the FPL line clearing trim zone. At the start of restoration, many line trimming crews were initially clearing trees to allow for access to roads and FPL facilities. The city's vision continues to have tree lined streets with high tree density around utilities (e.g., the Tree Succession Plan).

**Recommendations:**

- Prior Lessons Learned from the 2004 and 2005 storm seasons, older trees are more likely to fail in hurricanes and over-mature trees should be removed and replaced by new trees. Source: "Wind and Trees: Lessons Learned from Hurricanes" published by UF Institute of Food and Agriculture Sciences (IFSA).
- Follow Right Tree Right place guidelines and stop actively planting large canopy trees adjacent to power lines.
- Adopt ordinances that support keeping vegetation away from utilities

Pictures above: Large, mature ficus trees topple over due to massive tree canopy with shallow root systems

Pictures to the right: Young canopy trees (i.e. oak) and palms planted in the wrong place and will impact facilities in the future

**Case Study – West Florida**

Tree failure in West Florida included many large older trees, which studies have shown are less storm resilient. Large trees may require specialized equipment to remove, slowing restoration. High wind and saturated soil may have contributed to high rate of tree failure, as even more wind resistant trees such as palms were more likely to fail.

**Recommendations:**

- Prior Lessons Learned from the 2004 and 2005 storm seasons, older trees are more likely to fail in hurricanes and over-mature trees should be removed and replaced by new trees. Source: “Wind and Trees: Lessons Learned from Hurricanes” published by UF Institute of Food and Agriculture Sciences (IFSA).
- Follow Right Tree Right place guidelines and stop actively planting large canopy trees adjacent to power lines.
- Adopt ordinances that support keeping vegetation away from utilities

Large trees and palms topple over onto from outside the utility trim zone

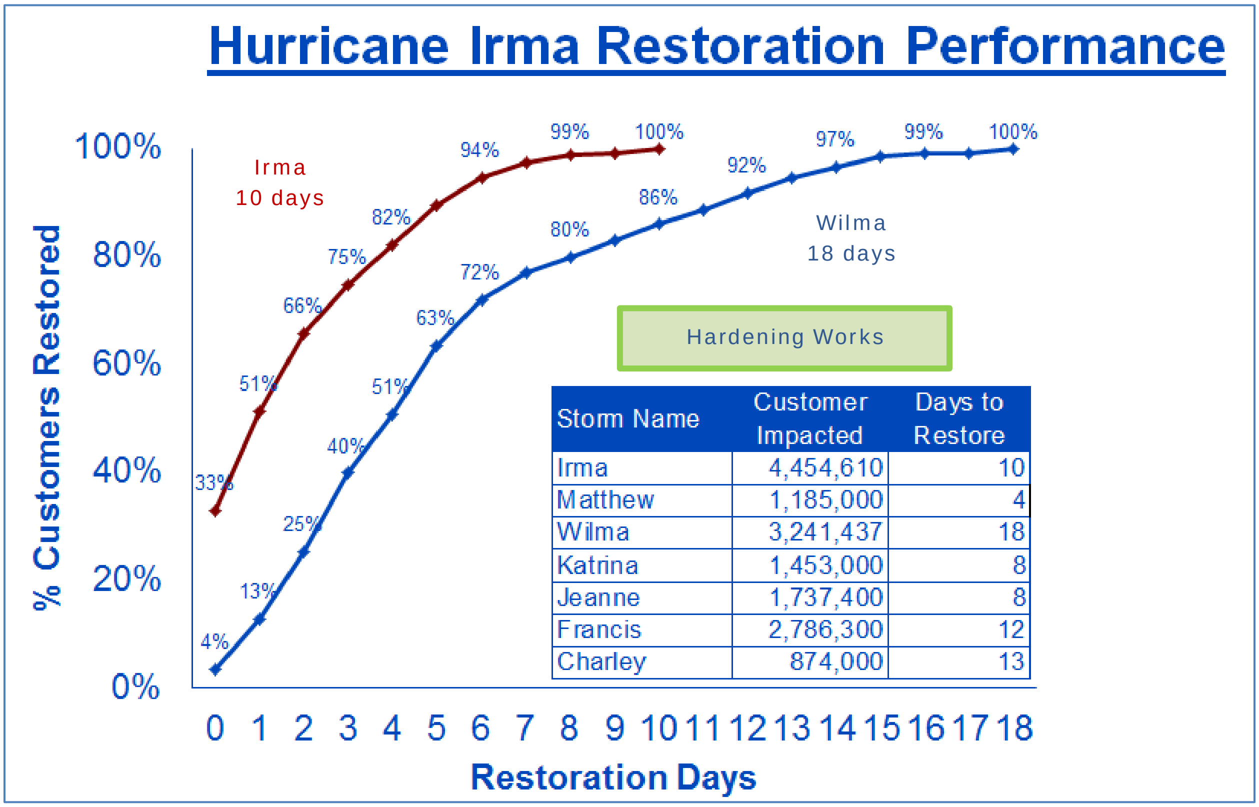
Trimming crews use a crane to remove large tree from utility lines

# Restoration and Storm Comparisons

### FPL Restoration Milestones

| Restoration Milestones | |
|---|---|
| 1M restored | 3PM, Monday 9/11 Day 0 |
| 2M | 6PM, Tuesday 9/12 Day 1 |
| 3M | 4AM,Thursday 9/14 Day 3 |
| 4M | 7AM, Sunday 9/17 Day 6 |

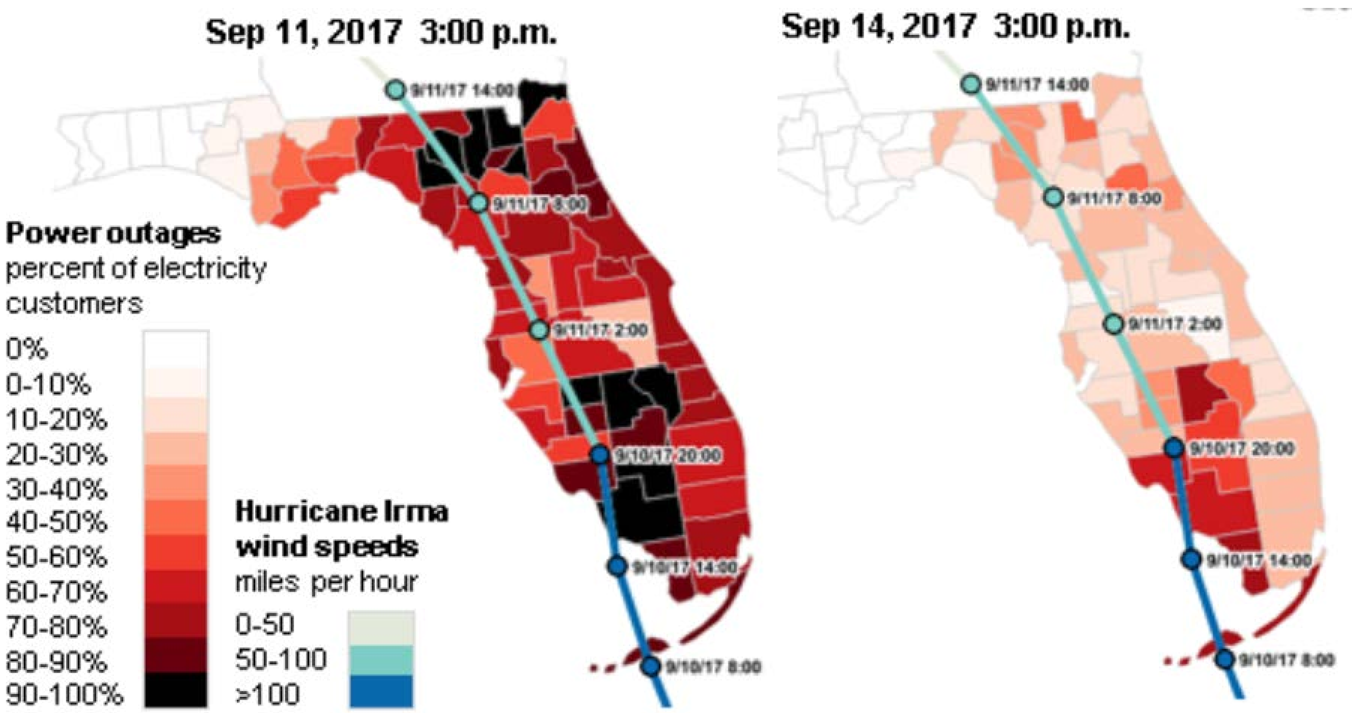
### FPL Restoration comparing Irma to Wilma

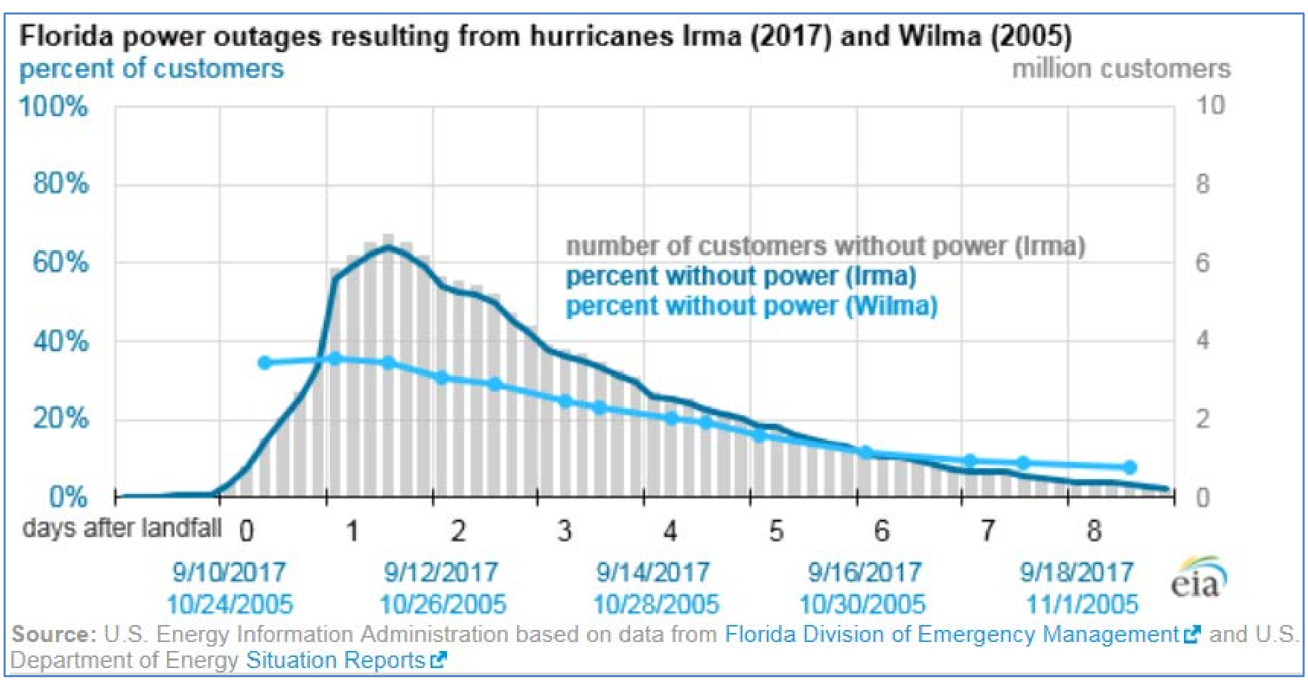


## Restoration and Outages by County (All Utilities)

Although the percentage of Florida customers without power during Irma was higher than during Wilma, the rate of electric service restoration has been more rapid.

**Source:** U.S. Energy Information Administration based on data from Florida Division of Emergency Management and NOAA National Hurricane Center
**https://www.eia.gov/todayinenergy/detail.php?id=32992**



## FPL Restoration Hurricane Wilma vs. Irma


Hurricane Wilma, 2005 Hurricane Irma, 2017

| | Hurricane Wilma, 2005 | Hurricane Irma, 2017 |
|---|---|---|
| Saffir-Simpson Scale | Category 3 | Category 4 |
| Maximum sustained winds in Florida | 120 mph | 130 mph |
| Cyclone damage potential index* | 2.8 | 4.3 |
| | | |
| FPL counties impacted | 21 | 35 |
| Customer impacted | 3.2 million | 4.4 million |
| % of FPL customers | 75% | 90% |
| | | |
| Poles damaged* | 12,419 | 4,561 |
| | | |
| Sub-stations de-energized | 241 | 92 |
| | | |
| Sub-stations restored | 5 days | 1 day |
| | | |
| Customer restoration | 18 days | 10 days |
| | | |
| 50% of customers restored | 5 days | 1 day |
| 75% of customers restored | 8 days | 3 days |
| 95% of customers restored | 15 days | 7 days |
| | | |
| Average customer outage | 5.4 days | 2.1 days |

*Irma and Wilma pole counts represent the poles replaced during restoration and follow up work. Irma number is preliminary as follow up work is ongoing

**Transmission and Substation Storm Comparison (Wilma vs. Irma)**

| | Wilma | Irma | % Improvement |
|---|---|---|---|
| Substations Out | 241 | 92 | 62% |
| Substations Out due to Lines | 227 | 86 | 62% |
| Transmission Line Sections Out | 345 | 215 | 38% |
| Transmission Line Sections with work required | 117 | 48 | 59% |
| Tree | 22 | 29 | -32% |
| OHGW | 58 | 6 | 90% |
| Transmission Structures | 100 | 5 | 95% |
| 500KV Structures | 30 | 0 | 100% |
| Debris | 49 | 3 | 94% |
| Contamination | 0 | 1 | |
| Foreign Substation | 0 | 1 | |
| Station Arrestor | 0 | 1 | |
| Cross Arms | 7 | 0 | 100% |
| Insulators Replaced (Structures) | 101 | 28 | 72% |
| Ceramic Posts (CPOC) | 68 | 0 | 100% |
| Ceramic Suspension | 14 | 7 | 50% |
| Polymer Post | 6 | 17 | -183% |
| Polymer Suspension | 13 | 4 | 69% |

Source:
Wilma info - Wilma T&S PPT
Irma – TSCC Storm Central

### Distribution Storm Comparison (Irma vs. Wilma)

| Distribution Impacts | Irma | Wilma | % Change |
|---|---|---|---|
| Distribution Poles * | 4,561 | 12,419 | 63% |
| AFS CI Avoided | 546,000 | 0 | |
| Counties Affected | 35 | 21 | |
| Miles of Wire | 1,300 | 1,016 | -28% |
| Transformers | 4,596 | 6,330 | 27% |

***** Irma and Wilma pole counts 4,561 and 12,419 respectively represent the poles replaced during restoration and follow up work. Irma number is preliminary as follow-up work is ongoing. Irma poles replaced during restoration is 2860. The comparable figure for poles replaced during restoration for Wilma is not available, as FPL did not track or maintain this information prior to or at the time of Hurricane Wilma.

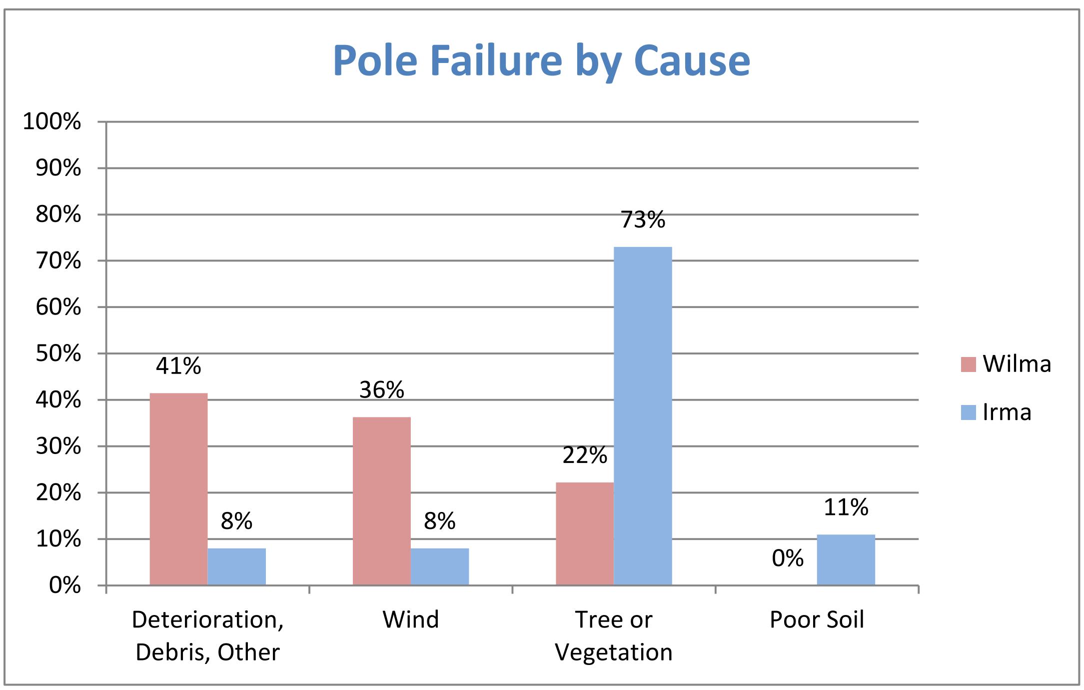
### Distribution Storm Comparison (Last 6 Largest Storms)

| | Charley | Frances | Jeanne | Wilma | Matthew | Irma |
|---|---|---|---|---|---|---|
| Customers Interrupted | 874 K | 2,786 K | 1,737 K | 3,241K | 1,185K | 4,455 K |
| Pole Counts | 6,878 | 3,757 | 2,227 | 12,419 | 656 | 4,561* |

*Preliminary

Primary Pole Failure

- Irma - Vegetation and Poor Soil Conditions (84%)
- Wilma - Wind and Pole Deterioration (77%)






FPL 000104
20180049-EI

# Other


# Forensics

### Data Collection Findings / Number of Patrols (using ESDA app unless noted)

- Drive-in (Did not use ESDA App) 183 Findings / 129 Patrols
- RPA (Rapid Patrol Assessment)* 26,340 Findings / 1527 Patrols
  * Paper Patrols converted to ESDA
- ALP (Advanced Lateral Patrol) 11,087 Findings / 714 Patrols
- Forensic 601 Findings / 522 Patrols

### Background and Philosophy

FPL's Storm Forensic Organization was formed after the 2004-2005 active storm seasons to help evaluate Distribution infrastructure performance during extreme wind weather events. The data collected serves to meet FPL commitments to the FPSC which include annual summary reporting of infrastructure performance during hurricane events.

The field forensic teams were created to investigate affected areas and collect damage information to analyze performance of:

- Hardened Feeders
- Overhead Feeders
- Overhead vs. Underground Laterals

Note: Forensic investigations exclude locations under safety, property damage or other special investigation teams

### Irma Activation

Based on the projected path and intensity of Irma the Forensics Team was pre-activated, but not pre-positioned. As the storm passed from the Southwest to the North, the teams were deployed as conditions improved and were acceptable to begin patrol.

### ESDA

Since communications were not down, FPL incorporated the use of the ESDA (Emergency Storm Damage Assessment) App on their smart device to collect data on the impacted Hardened Feeders.

- For the first time, patrollers completed over 34,000 damage assessments digitally, drastically reducing the time it takes to understand damage and deploy the right resources
- On one day, we had just under 800 concurrent users
- All Hardened Feeders impacted, that were not related to substation or transmission outages, were patrolled using ESDA

## Hardened Feeders

The primary objective of hardening is to reduce restoration times by minimizing the number of pole failures during extreme wind weather events. Pole failures typically lead to extended restoration times and longer outages. As a result, FPL forensic investigators use pole failure rates as the primary measurement criteria to evaluate performance of Hardened vs. non-Hardened Feeders within the impacted areas. Feeder field forensic data was collected to conduct root cause analysis and failure mode of previously Hardened Feeders that locked out during the storm. All calculations are based on field data collected from ESDA patrols.

## Overhead Feeders

Investigation of selected Overhead Feeders impacted by extreme wind events is an annual reporting requirement to the FPSC. Inspection locations are defined based on selected routes within the path of the storm. The objective of inspections is to collect sample data on selected Feeder locations in order to evaluate infrastructure performance during extreme wind events. Field data from ESDA patrols, TCMS and other sources will be utilized.

## Overhead vs. Underground Performance

The investigation and performance of Overhead vs. Underground infrastructure during extreme wind events is an annual reporting requirement to the FPSC. Forensic investigators examine selected Underground or Overhead Lateral facilities that were affected within the path of the storm. The objective of these inspections is to collect sample data from Overhead or Underground damage locations in order to evaluate and compare infrastructure performance of Overhead and Underground facilities during extreme wind event. Field data from ESDA patrols, TCMS and other sources will be utilized.

## Defining Storm Affected Areas

The emergency preparedness department performs the storm tracking activities from forecast to actual storm path. This information is available to the GIS group Technology Coordinator and is used to identify the storm affected area. Prior to a storm event, the Forensic Leads and the Technology Coordinator will be in close contact to execute the below plan based on the latest possible forecast or pre-storm plan. After the storm has passed, the Forensics Team executes the pre-storm plan unless the actual event was significantly different, at which time a new plan based on the actual storm path will be developed.

**Irma affected FPL's entire service area including:**

<u>Southeast Areas:</u>

| | | |
|---|---|---|
| Central Dade | North Dade | South Dade |
| West Dade | Central Broward | North Broward |
| South Broward | Boca Raton | West Palm |

<u>North Management Areas:</u>

| | | |
|---|---|---|
| Treasure Coast | Brevard | Central Florida |
| North Florida | | |

<u>West Management Areas:</u>

| | | |
|---|---|---|
| Manasota | Naples | Toledo Blade |

## Smart Grid Forensics (Pre Storm)

**Objective:**

1. Assess storm impacts to DA (Distribution Automation) Smart Grid equipment
2. Support restore of DA Smart Grid equipment after power has been restored

**72 Hour Pre-Storm Checklist**

- Activate field smart grid forensics team & confirm ability to travel. Update PREPS
- Notify contractors of storm efforts; Develop preliminary Forensics resource capabilities
    - S&C: Contact S&C – request full roster (name, contact info, employee id, vehicle # & type, qualification/title, years of employment).
- Contact Design &Standards for any available secondary support & time frame of availability
- Check equipment (laptops)
- Verify Storm Safety and Current Stock levels
- Verify DA battery stocks with Power Quality
- Review M&S Number Lists

**48 Hour Pre-Storm Checklist**

- Identify Work location for team & secure access: Service Center for team to check-in post storm. Confirm with Forensics Team Leader
- Coordinate logistics (hotel, car rental)
- Take System Status Snapshot
    - AFS Availability
        - How many units are installed but not in service
        - Availability of not in EDNA data historian
    - FCI
        - How many units are installed but not in-service
    - Vault Monitor
    - Capacitor Controller
    - Transformer Monitors
    - TripSavers
- Establish number and list of devices within the storm path

**24 Hour Pre-Storm Checklist**

1. Contact Smart Grid Forensics team to confirm work location
2. Set up information line for post storm reporting
3. Contact S&C to confirm meeting locations
4. Establish number and list of devices within the storm path

## Smart Grid Forensics (Post Storm)

**Post Storm 36 hr AFS IntelliRupter Visual and Operational Check.**

**Storm Name**_________________________________ **Test Date**___________________

**Switch Number** ______________________________

**Substation**___________________________________

**Feeder**_______________________________________

Verify if item #2 activities can be performed if switch is under Storm Feeder Control instead of Control Center Control.

1. **Perform Visual Check of IntelliRupter**
   - 1.1. IR Base Free of Damage or Flash Marks
     - 1.1.1. Manual Controls Undamaged (Open/Close, RC-Off and Ground Trip Block Levers)
     - 1.1.2. Visual Disconnect (Air Break) Control Rocker Arm and Support Undamaged or Showing Flash Marks
   - 1.2. Control & Communication Modules Properly Installed (Arrow Orientation and Properly Seated)
     - 1.2.1. Control Module Status light indicating normal (On for .5 seconds every 30 seconds)
   - 1.3. Phase Interrupters Undamaged or Showing Flash Marks
   - 1.4. Semaphores Undamaged
   - 1.5. Antennae Present and Undamaged
   - 1.6. Integral Power Modules (IPM's) Undamaged or Showing Flash Marks
   - 1.7. Arresters & Arrester Leads Undamaged and Properly Connected.
   - 1.8. Ground connection present to closest pole ground.
   - 1.9. Pole Top Position Crossarm, Insulators, By-Pass Switches and other Primary Hardware Undamaged or Showing Flash Marks.

2. **Perform Limited Operational Check of IntelliRupter**
   - 2.1. Call Control Center to notify them of testing at the location.
   - 2.2. Provide CC Desk Operator Substation, Feeder and Switch # to be tested
   - 2.3. Is switch being scanned?
   - 2.4. If yes go to step 2.6
   - 2.5. If No, Switch Should Be Bypassed and Referred To PQ TCMS AFS Screens.
   - 2.6. Verify Current IntelliRupter Status with Control Center
     - 2.6.1. IntelliRupter Position : Open/Ready _________ Closed ___________ Open/Locked
     - 2.6.2. Air Break (Disconnect) : Open _________ or Closed ___________
     - 2.6.3. Auto Op: Enabled __________ or Disable __________
     - 2.6.4. RC: ON or OFF (**RC-ON = HLT is OFF; RC-OFF = HLT is ON**)
     - 2.6.5. Display Voltages per Phase to be within +/_ 2 Volts of IT-II remote values
     - 2.6.6. Verify Team Status
   - 2.7. If SCADA display does not match IntelliRupter, Switch Should Be Bypassed and Referred To PQ.
   - 2.8. Have Control Center Operator Verify Remote Control by
     - 2.8.1. Execute Auto Op Command, Wait for Confirmation, and RTN to position Found
     - 2.8.2. Execute RC Command, Wait for Confirmation, and RTN to position Found
     - 2.8.3. If Either 2.8.1 or 2.8.2 Control Tests Fail, Switch Should Be Bypassed and Referred To PQ.
   - 2.9. If no alarms or abnormal conditions, clear manual override with dispatcher.

SCC Tester___________________________________ CC Operator ___________________________________

Please provide a copy of completed form to Storm Forensics Team Manager.

# Distribution Hardening Programs

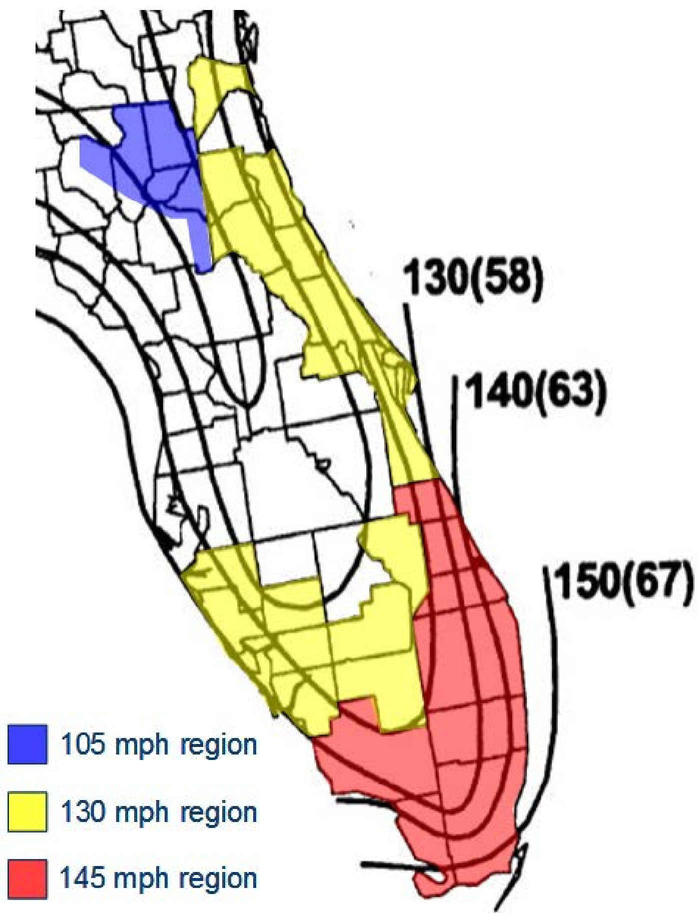
### Storm Hardening Plan

- The Storm Hardening Plan started in 2006 with 124,128 poles having been hardened though September 2016.
- FPL's Storm Hardening Plan is filed with the PSC.

### PIP (Pole Inspection Program)

- The Pole Inspection Program started in 2006 and FPL has:
    - Replaced 79,931 as of 2016 (82,132 as of 2017)
    - Reinforced 47,247 as of 2016 (50,939 as of 2017)
- FPL's Pole Inspection Program is filed with the PSC.

### Distribution Design Gust Wind Speeds



# Definitions / Acronyms

**Affected** - include only one interruption per device (feeder, lateral, transformer, etc) if the device goes out multiple times

**ALS** – Automated Lateral Switch

**AFS** – Automated Feeder Switch

**Broken or Downed Pole** – Cannot carry electricity

**Customers Affected -** Customers that experienced an outage

**CI** - Customers Impacted which are customers that may have gone out more than once or nested outages.

**CI Avoided** – Customer Interruptions Avoided

**CMH** – Construction Man Hours (Labor)

**DA** – Distribution Automation

**D&S** – Design and Standards which coordinate the forensic operations and forensic patrols

**ESDA -** Electric Storm Damage Assessment is a mobile app and primary tool that facilitated the collection and characterization of the major types of damage on the Distribution system.

**Hybrid Feeder** - Combination of Feeder and Lateral miles between 5% - 95% UG

**Interruptions** - Total number of customer outages

**Mean Higher High Water (MHHW)** – An average of higher high water heights over time. Numbers are reported as the value above that regions value.

**NHC** – National Hurricane Center

**NOS** – National Ocean Service

**OH Feeder** - Combination of Feeder and Lateral miles < = 5% UG

**RCA** – Root Cause Analysis

**UG Feeder** - Combination of Feeder and Lateral miles > = 95% UG