EVALUATION OF SANITARY SEWER OVERFLOWS AND UNPERMITTED DISCHARGES ASSOCIATED WITH HURRICANES HERMINE & MATTHEW

JANUARY 6, 2017

RS&H

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EXECUTIVE SUMMARY

Between August 31 and October 15, 2016, several areas of the state were impacted by hurricane conditions and extreme weather events. These conditions tested the tenacity of Florida's wastewater infrastructure and several systems yielded under the pressure; most notably in the Tampa Bay Area and in Northeast Florida. These system failures resulted in Sanitary Sewer Overflows (SSOs) of approximately 250 million gallons. In response to these conditions, Governor Rick Scott directed the Florida Department of Environmental Protection (FDEP) to evaluate the overflows, determine the underlying causes, and work with wastewater utilities to identify solutions that will help minimize overflows during hurricanes and extreme weather events.

On November 7, 2016, RS&H Inc. was authorized to assess the storm conditions that precipitated the SSOs and evaluate select SSOs, including the utilities where they occurred and the failure modes that led to the SSOs. Once failure modes were identified, Emergency Response Plans were reviewed along with industry guidelines relative to the failure modes. Additional Best Management Practices (BMP) were identified by benchmarking extreme weather BMPs implemented by Atlantic and Gulf Coast communities recently impacted by extreme weather events. Each of the failure modes were detailed and solutions were provided based upon industry guidelines, benchmarking and professional experience.

The 26 SSOs evaluated represent approximately 212 million gallons. These SSOs occurred in seven utilities including:

- City of St. Petersburg
- City of Gulfport
- City of Largo
- Pinellas County Utilities
- City of Clearwater
- JEA
- City of St. Augustine

Interviews with each of the utilities and subsequent conversations provided significant detail for this effort. The study would not have been possible without their active participation.

In descending order of occurrence the failure modes responsible for these SSOs were as follows:

- Power loss and/or interruption
- Infiltration & Inflow
- Flooding/Inundation
- Wastewater Treatment Plant Anomalies
- Force main failure
- Pump failure

The type of failure mode experienced in a community was driven by the type of storm event. Hurricane Hermine, which impacted the Tampa Bay area, produced rainfalls approaching the 25-year recurrence interval in concert with a prolonged 33-hour tidal surge. This storm resulted in SSO failure modes of I&I, Wastewater Treatment Plant Anomalies and Pump Failure. In Northeast Florida, Hurricane Matthew's

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sustained winds and tidal surge were responsible for all of the Power Loss and/or Interruption, Flooding/Inundation and the one Force Main failure.

Technical solutions ranging from activation of emergency generators before power outage is expected to the upgrading of waste water treatment plants are provided to address the identified failure modes. Where useful, cost estimates are provided for select solutions to facilitate inclusion in the budgeting process. In addition, proactive management systems are discussed to enhance the reliability of these significant capital investments.

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1.0 INTRODUCTION

On August 31, 2016, western Tampa Bay began to experience the effects of Hurricane Hermine. As the rains fell and the tide surged, wastewater treatment facilities were stress tested by Inflow and Infiltration, power outages and mechanical failures. Several community wastewater systems in the region contributed to more than 203 million gallons in sanitary sewer overflows (SSOs) and unpermitted effluent discharges attributable to both the acute effects of the storm and the chronic erosion of system reliability and capacity.

On October 7, 2016, Northeast Florida was raked by the onslaught of Hurricane Matthew's winds and its tidal surge. JEA, the region's largest wastewater utility, experienced widespread power outages, associated with downed transmission lines, which became the primary cause of 9 million gallons of SSOs for the utility. The effects of the storm's tidal surge on the evacuated City of St. Augustine were outside the experience of most residents. The seven foot elevation surge flooded the evacuated city with salt water from the Matanzas Bay to the San Sebastian River, inundating lift station control panels with as much as four feet of water. In the face of these challenges, the city's WWTP remained operational and the conveyance system experienced smaller and fewer SSOs than the other utilities evaluated.

In response to these storm events and the incidents that ensued, Governor Rick Scott instructed the FDEP to evaluate the overflows, determine the underlying causes, work with wastewater utilities to identify solutions that will help minimize overflows during hurricanes and extreme storm events in the future, and enhance clean drinking water and healthy water ways for the Sunshine State.

1.1 SCOPE OF THE EVALUATIONS

On November 7, 2016, RS&H received written authorization of its proposal for Sanitary Sewer Overflow Evaluations and Solutions in Response to Hurricanes Hermine and Matthew. The scope of work focused on 26 SSOs and unpermitted effluent release incidents that occurred in the state between August 31 and October 15, 2016. During this period the State Watch office registered approximately 250 million gallons of SSO spills. The incidents evaluated for this document account for 212 million gallons (85%) of the SSOs recorded in the state over the period evaluated.

The authors and the FDEP would like to acknowledge and thank the wastewater utilities that participated in this evaluation to help Florida continually improve the reliability of its wastewater treatment infrastructure. Utilities that supported this effort include:

- City of St. Petersburg
- City of Gulfport
- City of Largo
- Pinellas County Utilities
- City of Clearwater
- JEA
- City of St. Augustine

1.2 METHODOLOGY

The scope of work commenced with review of the data collected by the State Watch office and other sources. Based upon this information and knowledge of wastewater utilities a questionnaire was developed to guide face to face interviews with each of the utilities.

Since the managers and operators of the wastewater utilities have superior working knowledge of the characteristics and responses of their utilities to extreme weather events, face to face interviews were conducted to obtain additional information on each of the 26 incidents evaluated. The utility data was supplemented by an analyses of stormwater and water levels (i.e. tidal flooding) to assess conditions at the time of the event. The analysis provides rainfall accumulations, tidal surge height and duration as well as the maximum sustained winds and maximum gusts experienced.

The engineering study also evaluated the Emergency Response Plans used by the utilities to prepare and respond to hurricane and extreme weather events and compared these actions to the Ten State Standards. The evaluation reviewed EPA guidelines for wastewater utility Best Management Practices for extreme weather events. These BMPs were supplemented with a benchmarking review of approaches taken by the City of New York in response to Hurricane Sandy, by New Orleans in response to Hurricane Katrina, and by Houston, TX and Pensacola, FL in response to extraordinary precipitation events.

To identify solutions that will minimize overflows during extreme weather, the engineering team considered the recommendations obtained from the utilities in concert with the EPA BMPs and the BMPs obtained through benchmarking.

1.3 DOCUMENT OVERVIEW

This document summarizes the storm conditions that catalyzed the SSOs and unpermitted discharges (Section 2). It provides an overview of each utility, the incident(s) experienced, the results of the interviews and data gathering, as well as recommended solutions by utility where available (Section 3). It summarizes and benchmarks BMPs developed by communities for extreme weather events. Section 5 summaries each of the failure modes and solutions to address them.

2.0 STORMWATER AND WATER LEVEL ANALYSIS

Precipitation data for Hurricanes Hermine and Matthew was collected to evaluate the correlation of rainfall with inflow and infiltration (I&I) before and during the storm events. The precipitation data was obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) weather stations located throughout the study area. Precipitation data was also obtained from local municipality rain gauges within the study area. Refer to Figures 2-1 and 2-2 for the weather stations and rain gauge locations. The following sections summarize the collected precipitation, tidal surge and wind data for each hurricane.

2.1 PRECIPITATION DATA

2.1.1 Hurricane Hermine

There are 14 NCEI weather stations located throughout the Southwest District study area that provide daily precipitation records (see Figure 2-1). The NCEI weather stations record information based on the Universal Time Coordinated (UTC) time zone which is offset from Eastern Standard Time by minus 5 hours and offset from Eastern Daylight Saving Time by minus 4 hours. Hourly precipitation data records at these weather stations for late summer 2016 were not available at the time of this study. Table 2-1 summarizes the average precipitation encountered in each municipality evaluated in the Southwest District for the month of August 2016, and the 3 days during Hurricane Hermine that sustained significant rainfall.

TABLE 2-1 NCEI WEATHER STATIONS PRECIPITATIONS DATA SUMMARY

Location	NOAA Rain Station IDs	August 2016 Rainfall Total (in)	8/31/2016 Precipitation (in)	9/01/2016 Precipitation (in)	9/02/2016 Precipitation (in)	3 Day Storm Total (in)
City of St Petersburg	US1FLPN0009 US1FLPN0013 US1FLPN0058 US1FLPN0033	13.4	2.6	4.6	1.7	**8.9**
City of Gulfport	US1FLPN0006 US1FLPN0017	17.2	3.6	6.8	3.0	**13.4**
City of Largo	US1FLPN0047 US1FLPN0001	10.9	1.9	6.4	3.4	**11.7**
City of Clearwater	US1FLPN0036 US1FLPN0051 US1FLPN0016	13.1	2.9	4.8	3.4	**11.1**
Pinellas County	US1FLPN0060 US1FLPN0049 US1FLPN0034	13.9	2.8	4.3	1.8	**8.9**
Average Over Study Area		13.7	2.8	5.4	2.7	**10.9**

FIGURE 2-1 SOUTHWEST DISTRICT RAIN AND TIDAL STATION LOCATIONS

Daily precipitation data from 20 rain gauges located throughout the Southwest District study area were provided by local municipalities. Hourly precipitation data records at these rain gauges were not available at the time of this study. Table 2-2 summarizes the average precipitation encountered in each municipality evaluated in the Southwest District for the month of August 2016, and the 3 days during Hurricane Hermine that sustained significant rainfall.

TABLE 2-2 LOCAL MUNICIPALITIES RAIN GAUGES PRECIPITATION DATA SUMMARY

Location	Rain Gauge IDs	August 2016 Rainfall Total (in)	8/31/2016 Precipitation (in)	9/01/2016 Precipitation (in)	9/02/2016 Precipitation (in)	3 Day Storm Total (in)
City of St Petersburg	AWWRF, NEWRF, NWWRF, SWWRF	18.7	7.9	1.3	0.7	**9.9**
City of Gulfport	Lift Stations 1 & 2, 5330 23rd Ave S., 1617 49th Street S.	21.9	9.4	1.5	1.1	**12.0**
City of Largo	Lift Stations 6, 17, 19, 27, 28, 35, 25, 48, 49	Not Available	7.5	1.6	1.2	**10.3**
City of Clearwater	East WRF & Marshall St. WRF	15.9	5.5	2.3	2.0	**9.8**
Pinellas County	OTH-2	16.0	5.4	0.7	1.9	**8.0**
Average Over Study Area		18.1	7.1	1.5	1.4	**10.0**

According to the information provided in Tables 2-1 and 2-2, the overall precipitation associated with Hurricane Hermine over the 3 day period between August 31st and September 2nd 2016 is similar between the NCEI weather stations and the local municipalities' rain gauges. However, the distribution of the rainfall over the three day period differs between the NCEI and local municipalities' collected information. The local municipalities' rain gauge information show that the majority of precipitation (approximately 71%) occurred on 8/31/2016. This difference in data is most likely the result of the data being recorded based on two different time zones. Hourly precipitation data would provide a better understanding of the precipitation distribution; however, hourly information was not available at the time of this study.

According to precipitation data recorded by the Southwest Florida Water Management District (SWFWMD) over a period of time between 1915 and 2016, the mean precipitation for August in the Southwest District study area is 8.78 inches. The average precipitation recorded for August 2016 shown in Tables 2-1 and 2-2 is 13.7 inches and 18.1 inches respectively. Subtracting out the precipitation on August 31, 2016 (the first day of significant rainfall from Hurricane Hermine) shows the average precipitation for August 1st through the 30th in Tables 2-1 and 2-2 to be 10.9 inches and 11.0 inches respectively. Based on this information the Southwest District study area experienced approximately 2.2 more inches of precipitation in August 2016 between August 1st through the 30th then the average monthly rainfall for August. Therefore, the area had been experiencing above average rainfall prior to Hurricane Hermine which produced on average 7.1 inches of precipitation in a 24 hour period according to Table 2-2 and an average of 10.5 inches of precipitation over a three day period according to Tables 2-1 and 2-2.

The highest average recorded 24 hour precipitation of 9.4 inches (City of Gulfport) and the highest average recorded 3 day precipitation of 13.4 inches (City of Gulfport) associated with Hurricane Hermine in the Southwest District study area closely represent a **25 year storm recurrence interval** according to the *NOAA Atlas 14, Volume 9, Version 2, Point Precipitation Frequency Estimates for St. Petersburg* (refer to Figure 2-3).

2.1.2 Hurricane Matthew

There are 10 NCEI weather stations located throughout the Northeast District study area that provide daily precipitation records (refer to Figure 2-4). Hourly precipitation data records at these weather stations for early Fall 2016 were not available at the time of this study. Table 2-3 summarizes the average precipitation encountered in each municipality evaluated in the Northeast District for the months of August and September 2016; and the 2 days during Hurricane Matthew that sustained significant rainfall.

TABLE 2-3 NCEI WEATHER STATIONS PRECIPITATION DATA SUMMARY

Location	NOAA Rain Station IDs	August 2016 Rainfall Total (in)	September 2016 Rainfall Total (in)	10/07/2016 Precipitation (in)	10/08/2016 Precipitation (in)	2 Day Storm Total (in)
City of Jacksonville	USW00093837 US1FLDV0059 US1FLDV0033 US1FLDV0069 US1FLDV0003 USW00053860 US1FLDV0063 US1FLDV0042 US1FLDV0028	3.4	5.8	1.2	6.2	**7.4**
City of St. Augustine	US1FLSJ0004	3.6	6.8	1	6.5	**7.5**
Average Over Study Area		3.5	6.3	1.1	6.4	**7.5**

Daily precipitation data from rain gauges located throughout the Northeast District study area were not provided by local municipalities at the time of this study. According to the information provided in Table 2-3, the overall precipitation associated with Hurricane Matthew over the 2 day period between October 7th and October 8th 2016 totaled approximately 7.5 inches. Hourly precipitation data would provide a better understanding of the precipitation distribution; however, hourly information was not available at the time of this study.

According to precipitation data recorded by the St Johns River Water Management District (SJRWMD), the average precipitation for August and September is 6.73 inches and 7.49 inches respectively (average of Duval and St. Johns Counties). The average precipitation recorded for August and September 2016 shown in Table 2-3 is 3.5 inches and 6.3 inches respectively. This data indicates the Northeast District study area experienced below average precipitation accumulations in August and September 2016.

The 24 hour precipitation of 6.4 inches and the 2 day precipitation of 7.5 inches associated with Hurricane Matthew in the Northeast District study area closely represent a **10 year storm recurrence interval** according to the *NOAA Atlas* 14, *Volume 9, Version 2, Point Precipitation Frequency Estimates for Jacksonville* (refer to Figure 2-4). The Jacksonville Precipitation Frequency Estimate generally represents the precipitation frequency throughout the Northeast District study area.

FIGURE 2-2 NORTHEAST DISTRICT RAIN AND TIDAL STATION LOCATIONS

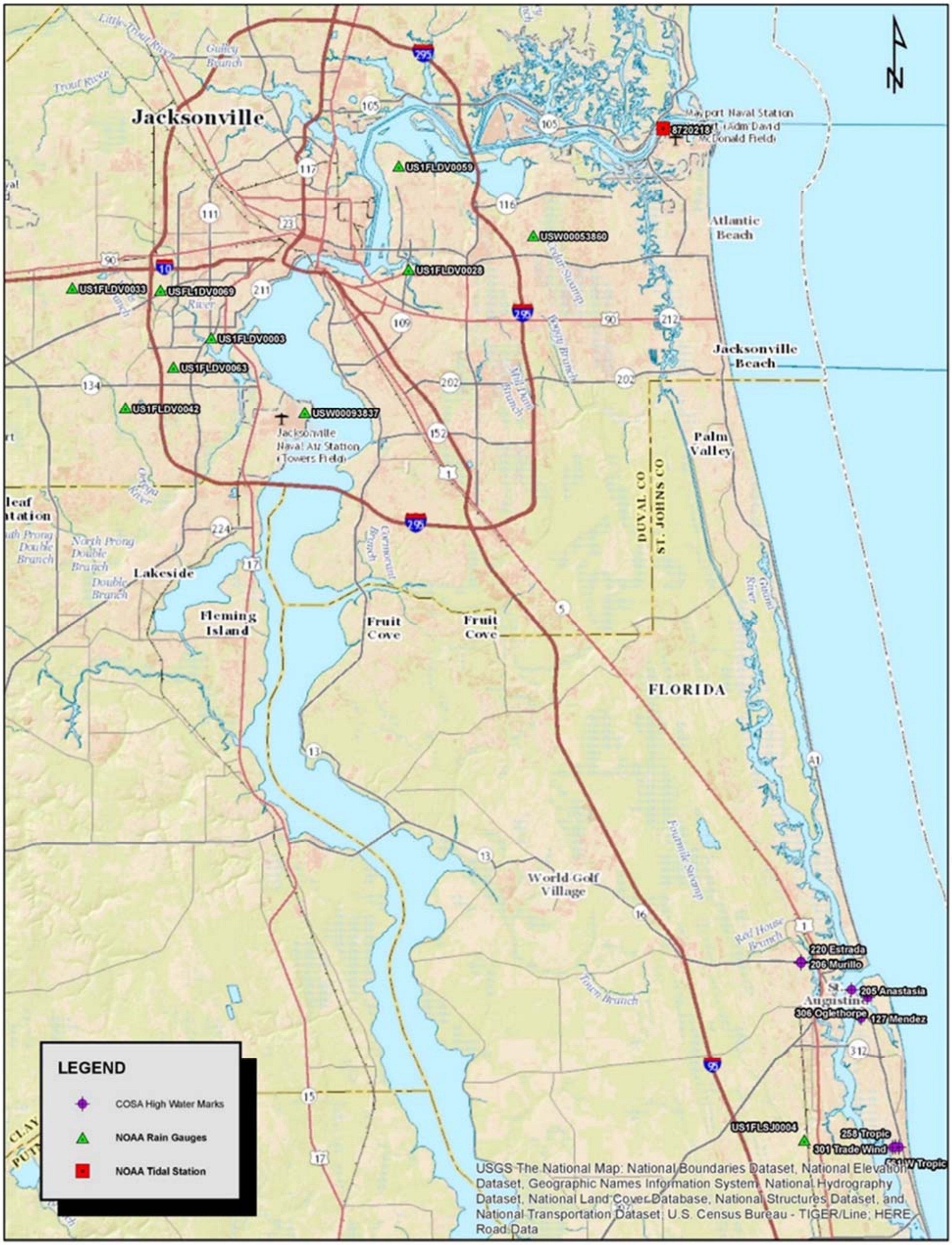


FIGURE 2-3 ST. PETERSBURG PRECIPITATION FREQUENCY

NOAA Atlas 14, Volume 9, Version 2
Location name: St Petersburg, Florida, USA*
Latitude: 27.7716°, Longitude: -82.6633°
Elevation: 49.12 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.570 (0.479–0.691)	0.641 (0.539–0.778)	0.753 (0.630–0.917)	0.840 (0.698–1.03)	0.953 (0.757–1.20)	1.03 (0.802–1.32)	1.11 (0.827–1.46)	1.18 (0.838–1.61)	1.27 (0.860–1.79)	1.33 (0.876–1.92)
10-min	0.835 (0.702–1.01)	0.939 (0.789–1.14)	1.10 (0.922–1.34)	1.23 (1.02–1.51)	1.40 (1.11–1.75)	1.51 (1.17–1.94)	1.63 (1.21–2.14)	1.73 (1.23–2.36)	1.86 (1.26–2.62)	1.94 (1.28–2.81)
15-min	1.02 (0.856–1.23)	1.15 (0.962–1.39)	1.34 (1.13–1.64)	1.50 (1.25–1.84)	1.70 (1.35–2.14)	1.85 (1.43–2.36)	1.98 (1.48–2.61)	2.11 (1.50–2.88)	2.26 (1.54–3.19)	2.37 (1.57–3.43)
30-min	1.56 (1.31–1.89)	1.70 (1.43–2.06)	1.94 (1.62–2.36)	2.15 (1.79–2.63)	2.46 (1.98–3.13)	2.71 (2.12–3.52)	2.98 (2.24–3.98)	3.26 (2.33–4.50)	3.66 (2.50–5.21)	3.97 (2.62–5.75)
60-min	2.03 (1.71–2.46)	2.21 (1.86–2.68)	2.53 (2.12–3.08)	2.83 (2.35–3.46)	3.27 (2.63–4.19)	3.64 (2.85–4.74)	4.04 (3.03–5.41)	4.47 (3.20–6.19)	5.08 (3.47–7.26)	5.57 (3.68–8.08)
2-hr	2.50 (2.11–3.01)	2.72 (2.30–3.28)	3.13 (2.63–3.78)	3.50 (2.93–4.26)	4.08 (3.31–5.20)	4.57 (3.60–5.92)	5.10 (3.86–6.80)	5.68 (4.09–7.82)	6.50 (4.48–9.25)	7.18 (4.77–10.3)
3-hr	2.73 (2.31–3.27)	3.01 (2.55–3.61)	3.51 (2.96–4.23)	3.98 (3.34–4.82)	4.70 (3.82–5.98)	5.30 (4.19–6.85)	5.96 (4.52–7.92)	6.67 (4.82–9.16)	7.69 (5.31–10.9)	8.51 (5.68–12.2)
6-hr	3.15 (2.69–3.76)	3.55 (3.02–4.23)	4.28 (3.63–5.12)	4.97 (4.18–5.98)	6.04 (4.95–7.69)	6.96 (5.54–8.98)	7.97 (6.09–10.6)	9.08 (6.61–12.4)	10.7 (7.43–15.1)	12.0 (8.05–17.1)
12-hr	3.67 (3.14–4.35)	4.19 (3.58–4.97)	5.20 (4.43–6.19)	6.19 (5.24–7.40)	7.79 (6.46–9.94)	9.20 (7.38–11.9)	10.8 (8.29–14.3)	12.5 (9.19–17.1)	15.1 (10.6–21.2)	17.2 (11.6–24.3)
24-hr	4.29 (3.69–5.05)	4.93 (4.23–5.80)	6.22 (5.32–7.35)	7.53 (6.40–8.94)	9.69 (8.11–12.4)	11.6 (9.41–15.0)	13.8 (10.7–18.3)	16.3 (12.1–22.2)	19.9 (14.1–28.0)	23.0 (15.7–32.3)
2-day	5.02 (4.34–5.87)	5.76 (4.97–6.74)	7.30 (6.27–8.56)	8.87 (7.58–10.5)	11.5 (9.69–14.6)	13.9 (11.3–17.8)	16.5 (12.9–21.8)	19.6 (14.6–26.6)	24.1 (17.2–33.6)	27.9 (19.1–38.9)
3-day	5.54 (4.80–6.45)	6.35 (5.49–7.39)	8.00 (6.90–9.35)	9.69 (8.31–11.4)	12.5 (10.6–15.8)	15.0 (12.2–19.2)	17.9 (14.0–23.4)	21.1 (15.8–28.4)	25.8 (18.5–35.9)	29.8 (20.5–41.5)
4-day	5.98 (5.19–6.94)	6.81 (5.91–7.91)	8.52 (7.36–9.93)	10.3 (8.81–12.0)	13.1 (11.1–16.5)	15.7 (12.8–20.0)	18.6 (14.6–24.3)	21.9 (16.4–29.5)	26.8 (19.2–37.1)	30.9 (21.3–42.8)

FIGURE 2-4 JACKSONVILLE PRECIPITATION FREQUENCY

NOAA Atlas 14, Volume 9, Version 2
Location name: Jacksonville, Florida, USA*
Latitude: 30.323°, Longitude: -81.6632°
Elevation: 0.33 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.529 (0.445–0.635)	0.606 (0.509–0.729)	0.731 (0.612–0.881)	0.833 (0.693–1.01)	0.972 (0.775–1.21)	1.08 (0.837–1.36)	1.18 (0.881–1.54)	1.29 (0.913–1.72)	1.42 (0.965–1.96)	1.52 (1.00–2.14)
10-min	0.774 (0.651–0.930)	0.887 (0.746–1.07)	1.07 (0.896–1.29)	1.22 (1.01–1.48)	1.42 (1.13–1.77)	1.58 (1.23–2.00)	1.73 (1.29–2.25)	1.88 (1.34–2.52)	2.08 (1.41–2.87)	2.23 (1.47–3.13)
15-min	0.944 (0.794–1.13)	1.08 (0.909–1.30)	1.31 (1.09–1.57)	1.49 (1.24–1.80)	1.74 (1.38–2.16)	1.92 (1.49–2.44)	2.11 (1.57–2.74)	2.29 (1.63–3.07)	2.54 (1.72–3.50)	2.71 (1.79–3.82)
30-min	1.42 (1.19–1.71)	1.64 (1.37–1.97)	1.98 (1.66–2.39)	2.27 (1.89–2.75)	2.65 (2.11–3.31)	2.94 (2.29–3.73)	3.23 (2.41–4.20)	3.52 (2.50–4.71)	3.89 (2.65–5.37)	4.17 (2.76–5.87)
60-min	1.86 (1.57–2.24)	2.13 (1.79–2.57)	2.59 (2.17–3.13)	2.99 (2.48–3.62)	3.55 (2.84–4.46)	3.99 (3.11–5.09)	4.46 (3.34–5.83)	4.94 (3.52–6.65)	5.60 (3.82–7.76)	6.11 (4.04–8.60)
2-hr	2.31 (1.95–2.75)	2.63 (2.23–3.15)	3.20 (2.69–3.84)	3.70 (3.10–4.46)	4.44 (3.59–5.57)	5.04 (3.96–6.41)	5.68 (4.28–7.41)	6.36 (4.57–8.53)	7.30 (5.02–10.1)	8.05 (5.36–11.3)
3-hr	2.55 (2.16–3.03)	2.89 (2.45–3.44)	3.52 (2.97–4.20)	4.10 (3.44–4.91)	4.98 (4.06–6.26)	5.72 (4.52–7.28)	6.52 (4.95–8.51)	7.39 (5.34–9.92)	8.64 (5.97–11.9)	9.65 (6.44–13.4)
6-hr	2.98 (2.54–3.52)	3.38 (2.88–3.99)	4.13 (3.51–4.90)	4.86 (4.10–5.78)	6.00 (4.94–7.55)	6.99 (5.58–8.89)	8.09 (6.19–10.5)	9.30 (6.78–12.5)	11.1 (7.71–15.2)	12.5 (8.41–17.3)
12-hr	3.46 (2.97–4.06)	3.95 (3.39–4.64)	4.88 (4.17–5.75)	5.78 (4.90–6.83)	7.20 (5.97–9.03)	8.45 (6.78–10.7)	9.82 (7.57–12.7)	11.4 (8.33–15.1)	13.6 (9.53–18.6)	15.4 (10.4–21.2)
24-hr	4.00 (3.46–4.67)	4.62 (3.98–5.39)	5.77 (4.96–6.75)	6.87 (5.87–8.08)	8.60 (7.17–10.7)	10.1 (8.15–12.7)	11.7 (9.10–15.1)	13.6 (10.0–17.9)	16.2 (11.4–22.0)	18.4 (12.5–25.1)
2-day	4.62 (4.01–5.35)	5.39 (4.67–6.24)	6.80 (5.87–7.90)	8.11 (6.97–9.47)	10.1 (8.48–12.5)	11.9 (9.63–14.8)	13.8 (10.7–17.6)	15.8 (11.8–20.8)	18.8 (13.3–25.3)	21.2 (14.6–28.8)
3-day	5.06 (4.41–5.84)	5.90 (5.14–6.81)	7.42 (6.44–8.59)	8.83 (7.61–10.3)	11.0 (9.22–13.5)	12.8 (10.4–15.9)	14.8 (11.6–18.8)	17.0 (12.6–22.2)	20.1 (14.3–26.9)	22.6 (15.5–30.5)
4-day	5.44 (4.75–6.26)	6.31 (5.51–7.27)	7.89 (6.86–9.11)	9.35 (8.07–10.8)	11.6 (9.72–14.1)	13.4 (11.0–16.6)	15.5 (12.1–19.6)	17.7 (13.2–23.0)	20.8 (14.9–27.9)	23.4 (16.2–31.5)

2.2 TIDAL SURGE

Tidal data for Hurricanes Hermine and Matthew were collected to evaluate the coastal tidal surge effect I&I. The tidal data was obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service (NOS) Center for Operational Oceanographic Products & Services (CO-OPS) tidal stations located throughout the study area. Tidal surge high water elevations were also obtained from St Johns County's Emergency Management Office for the St Augustine area in the Northeast District. Refer to Figures 2-1 and 2-2 for the tidal stations and high water elevation locations. The following sections summarize the collected tidal data for each hurricane.

The tidal surge caused by Hurricane Hermine in the Southwest District and Hurricane Matthew in the Jacksonville area of the Northeast District were compared to the Mean Higher High Water (MHHW) elevation, which is the average of the higher high water height each tidal day observed over the National Tidal Datum Epoch (period of time from 1983 through 2001). Tables 2-4 and 2-5 summarize the height of the peak tidal surge above the MHHW elevation for Hurricanes Hermine and Matthew respectively. The tables also summarize the duration of the tidal surge above the MHHW.

2.2.1 Hurricane Hermine

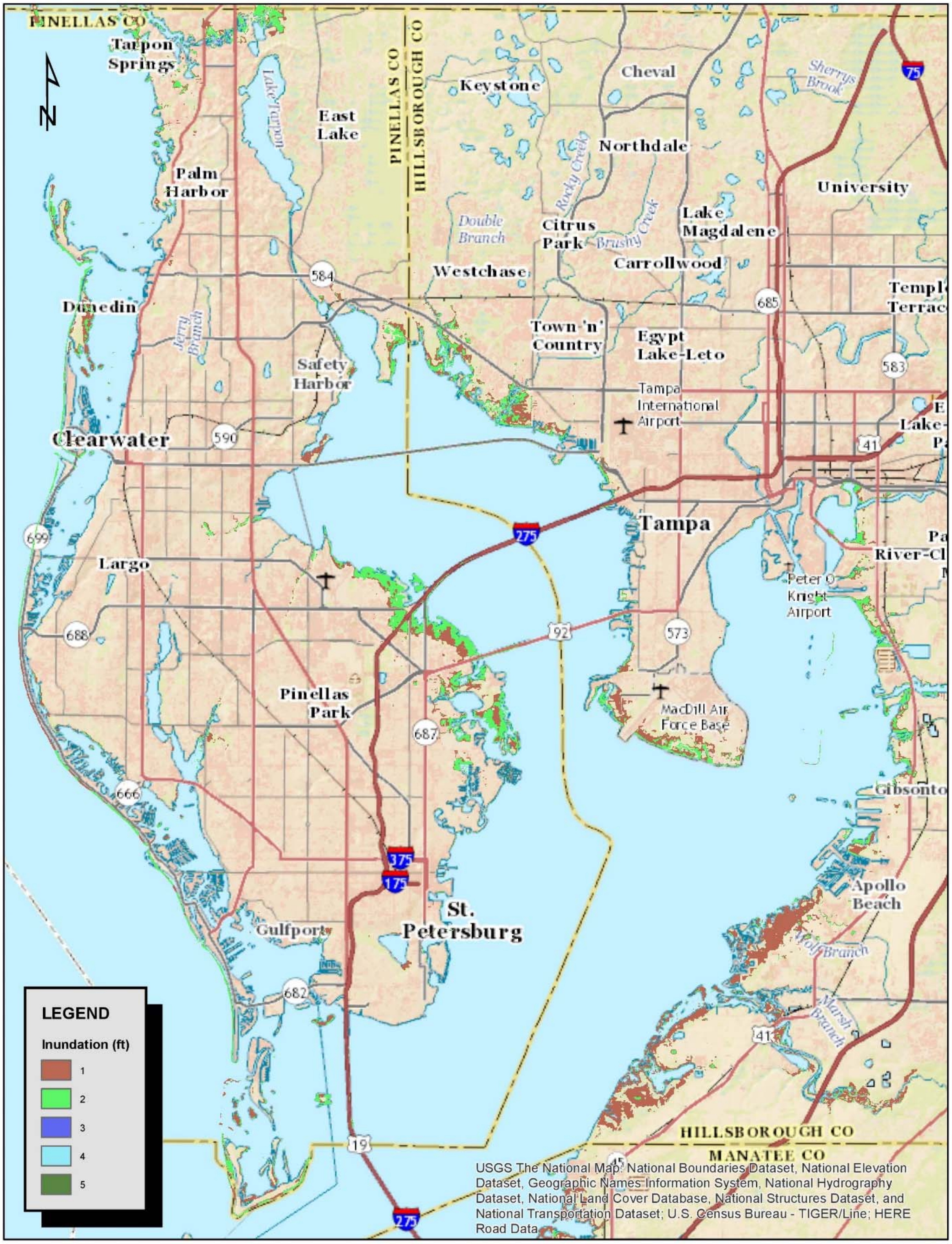
There are 4 NOAA/NOS/CO-OPS tidal stations located throughout the Southwest District study area that provide tidal records. The NOAA/NOS/CO-OPS stations record information based on the Universal Time Coordinated (UTC) time zone, which is the successor to the Greenwich Mean Time (GMT) time zone. The NCEI weather stations record information based on the Universal Time Coordinated (UTC) time zone, which is offset from Eastern Standard Time by minus 5 hours and offset from Eastern Daylight Saving Time by minus 4 hours. Table 2-4 summarizes the tidal surge encountered in the Southwest District during Hurricane Hermine. In addition to tidal surge, Hurricane Hermine produced sustained winds up to 47 mph and wind gusts up to 62 mph in the Southwest District study area according to the NOAA/NOS/CO-OPS tidal station meteorological data.

TABLE 2-4 NOAA/NOS/CO-OPS TIDAL DATA SUMMARY

Location	Tidal Station ID	MHHW Elev., feet (NAVD 88)	Date of Tidal Surge Peak	Time of Tidal Surge Peak, UTC (EDST)	Tidal Surge above MHHW Duration, Hours	Tidal Surge Peak Elev., feet (NAVD 88)	Peak above MHHW, feet
St. Petersburg	8726520	0.90	9/02/2016	07:00 (03:00)	34.8	3.23	**2.33**
McKay Bay	8726667	1.14	9/02/2016	06:00 (02:00)	33.2	4.13	**2.99**
Clearwater Beach	8726724	1.07	9/01/2016	03:00 (23:00)	32.9	3.94	**2.87**
Old Port Tampa	8726607	0.95	9/02/2016	07:00 (03:00)	33.8	3.87	**2.92**
Average Over Study Area		**1.02**	-	-	**33.7**	**3.80**	**2.78**

According to the information provided in Table 2-4, the Southwest District study area experienced an average peak tidal surge increase of 2.78 feet above the MHHW elevation during Hurricane Hermine. In addition, the tidal surge was above the MHHW elevation for approximately 33 hours. Elevated tailwater conditions are commonly associated with tidal surges. Elevated tailwater along with major rainfall from hurricanes typically overwhelm storm water drainage systems increasing the likelihood of inundation of low lying areas. According to the NOAA National Hurricane Center (NHC) GIS Archive information for Potential Storm Surge Flooding (Inundation), inundation of low lying areas within the Southwest District study area was predicted as the hurricane approached the area. As predicted inundation was experienced in low lying areas up to an approximate elevation of 4.0 feet (NAVD 88). Refer to Figure 2-5 for the NHC Potential Storm Surge Flooding Map showing the inundation in the Southwest District study area. The map is based on the National Weather Service (NWS) Sea Lake, and Overland Surges from Hurricanes (SLOSH) model.

FIGURE 2-5 SOUTHWEST DISTRICT STORM SURGE FLOODING MAP



2.2.2 Hurricane Matthew

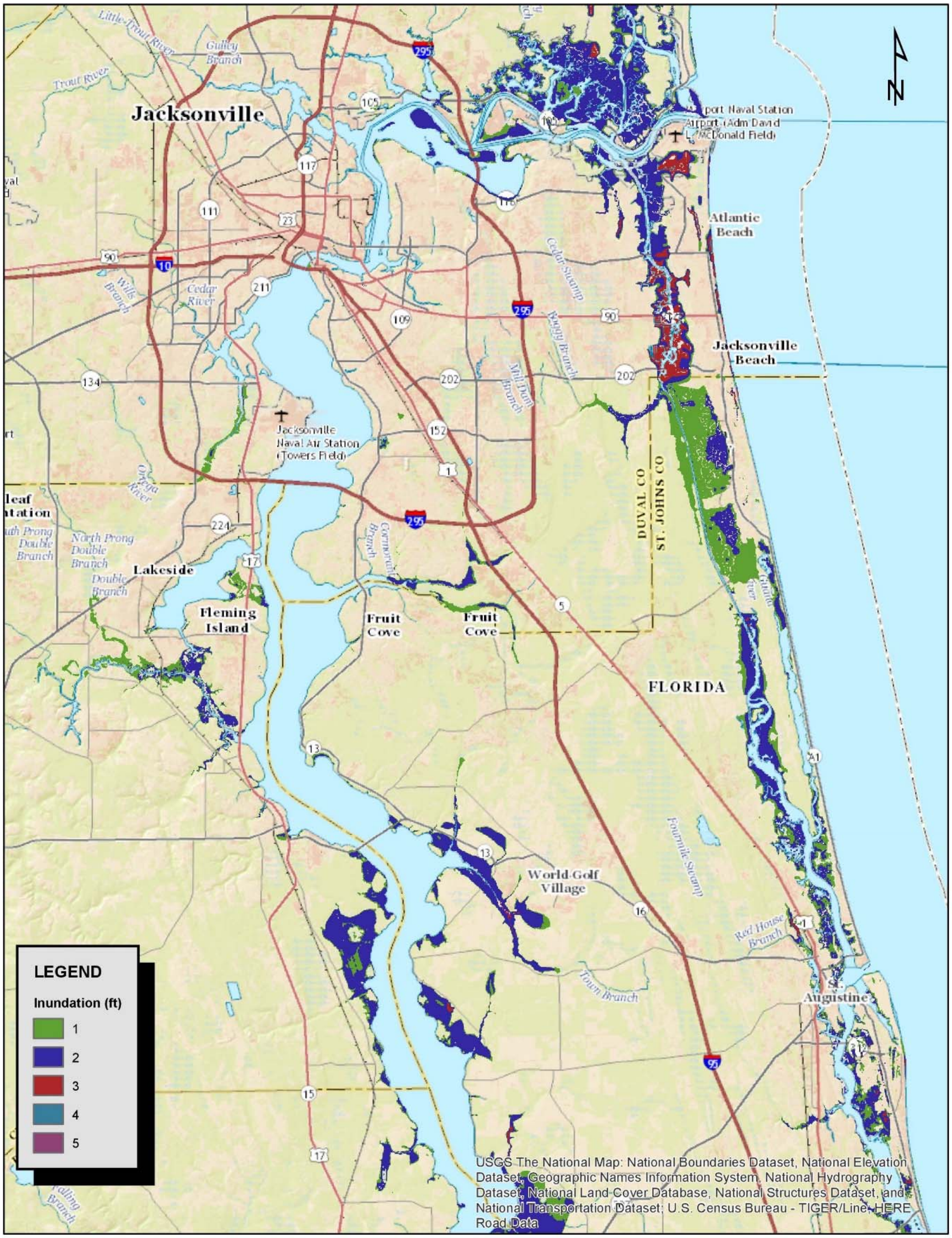
There is one (1) NOAA/NOS/CO-OPS tidal station located in the Jacksonville area of the Northeast District study area that provides tidal records. Table 2-5 summarizes the tidal surge encountered in the Jacksonville area during Hurricane Matthew. In addition to tidal surge, Hurricane Matthew produced sustained winds up to 51 mph and wind gusts up to 67 mph in the Northeast District study area according *Weather Underground* meteorological data. Wind gusts up to 87 mph were also documented by *weather.com* in a Hurricane Matthew Recap report.

TABLE 2-5 NOAA/NOS/CO-OPS TIDAL DATA SUMMARY

Location	Tidal Station ID	MHHW Elev., feet (NAVD 88)	Date of Tidal Surge Peak	Time of Tidal Surge Peak, UTC (EDST)	Tidal Surge above MHHW Duration, Hours	Tidal Surge Peak Elev., feet (NAVD 88)	Peak above MHHW, feet
Mayport	8720218	1.94	10/07/2016	19:00 (15:00)	10.5	5.12	**3.18**
Average Over Study Area		**1.94**	-	-	**10.5**	**5.12**	**3.18**

According to the information provided in Table 2-5, the Jacksonville area of the Northeast District study area experienced an average peak tidal surge increase of 3.18 feet above the MHHW elevation during Hurricane Matthew. In addition, the tidal surge was above the MHHW elevation for approximately 10.5 hours. According to the NOAA NHC GIS Archive information for Potential Storm Surge Flooding (Inundation), inundation of low lying areas within the Northeast District study area was predicted as the hurricane approached the area. As predicted inundation was experienced in low lying areas up to an approximate elevation of 5.0 feet (NAVD 88). Refer to Figure 2-6 for the NHC Potential Storm Surge Flooding Map showing the inundation in the Northeast District study area.

FIGURE 2-6 NORTHEAST DISTRICT STORM SURGE FLOODING MAP



2.2.2.1 St. Augustine Tidal Surge Conditions

The tidal surge peak elevation recorded in Jacksonville was more than 25% lower than the tidal surge experienced in St. Augustine located approximately 30 miles south of Jacksonville. The differences in the tidal surge are likely associated with the proximity of the tidal gauge, the timing of the tidal phases, the storm conditions and unique hydraulic dynamics of each location. However, St Johns County collected tidal surge high water mark elevations throughout the St. Augustine area. Table 2-6 summarizes the tidal surge high water mark elevations encountered in the St. Augustine area during Hurricane Matthew.

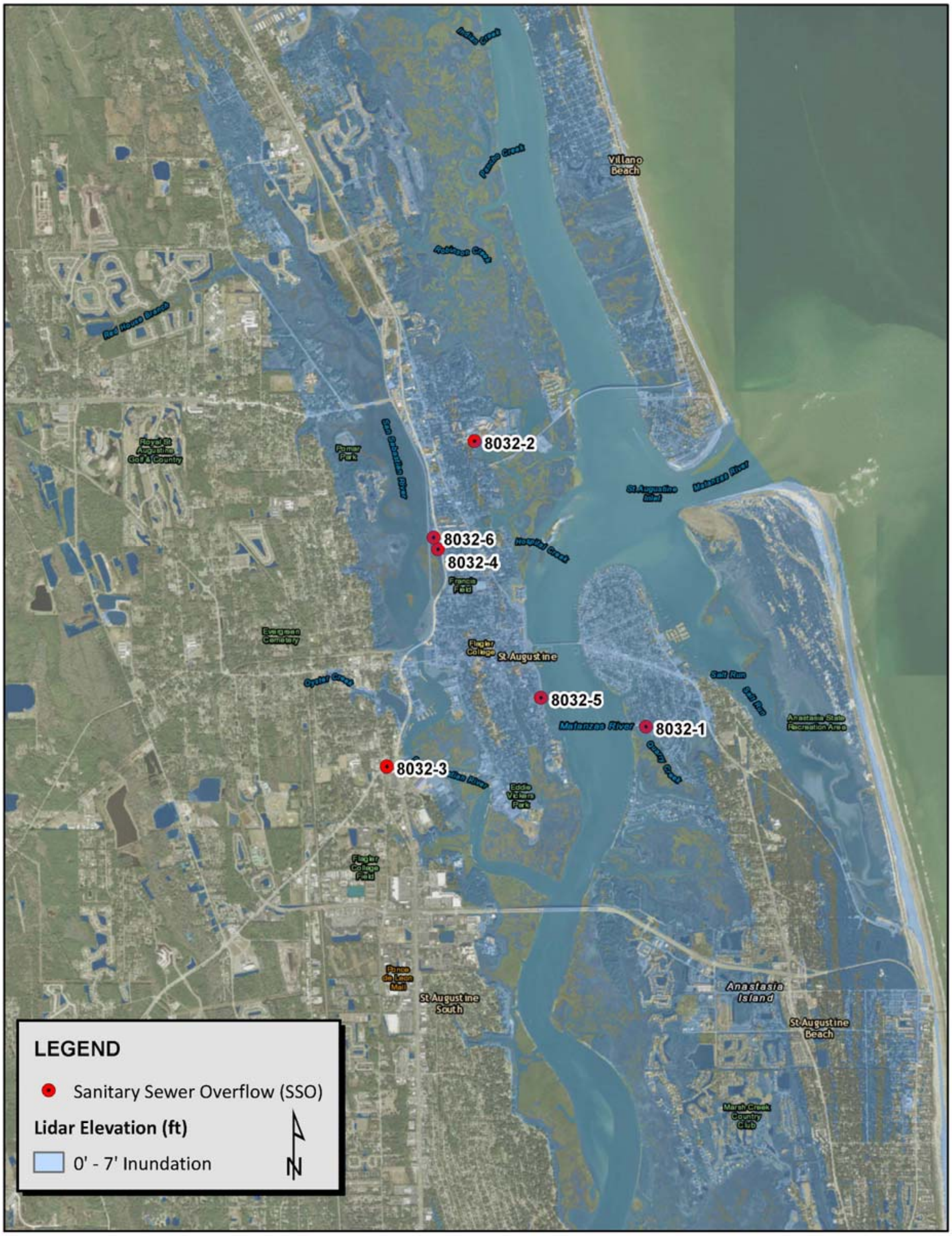
Table 2-6 St. Augustine High Water Mark Elevation Summary

Recorded High Water Mark Elevation Location	High Water Mark Elevation, feet (NAVD 88)
220 Estrada Ave.	6.91
206 Murillo Ave.	6.48
306 Oglethorpe Blvd.	7.08
205 Anastasia Blvd.	7.07
127 Menendez	7.19
301 Trade Wind Ln	6.81
258 Tropic Way	7.19
561 W Tropic Way	7.47
Average Over Study Area	**7.03**

According to the information provided in Table 2-6, the St. Augustine area of the Northeast District study area experienced an average peak tidal surge of approximately elevation 7.0 feet (NAVD 88) during Hurricane Matthew. To conceptualize the extent of the tidal surge in the St. Augustine area, Light Detection and Ranging (LIDAR) information was obtained to develop a base layer of topographic elevations at the SSO locations and surrounding areas. A mean tidal surge elevation of 7 feet (NAVD 88) was superimposed upon the topographic data to illustrate the tidal flooding experienced by St. Augustine at the Peak of Hurricane Matthew (see Figure 2-7).

Review of Figure 2-7 reveals the extent of the tidal surge in St. Augustine wastewater service area and its surroundings. In areas of St. Augustine the surge over-topped lift stations and flooded control panels.

FIGURE 2-7 APPROXIMATION OF TIDAL INUNDATION FROM HURRICANE MATTHEW IN THE ST. AUGUSTINE AREA



2.3 FEDERAL INSURANCE RATE MAPS

Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM) were obtained for each incident location evaluated in this study. Table 2-7 summarizes the FIRM information for each of the 26 incidents evaluated.

TABLE 2-7 SUMMARY OF FIRM INFORMATION

Incident ID#	Location	Flood Map#	Flood Zone at Location	Determined Base Flood Elevation Near Location, feet (NAVD 88)
Southwest District				
City of St. Petersburg				
3560	7500 26th Ave North, St. Petersburg	12103C0211G	X	15
3593	601 8th Ave SE, St. Petersburg	12103C0219G	AE	8
City of Gulfport				
3572	49th Street S and 31st Avenue South, Gulfport	12103C0277G	AE	12
City of Largo				
3704	5100 150th Ave North, Largo	12103C0137G	AE	9
Pinellas County Utilities				
4263	1400 Indian Rocks Road, Largo	12103C0114G	AE	10
4300	6597 Wayne St, St. Petersburg	12103C0208H	AE	15
3507	7401 54th Ave N, St Petersburg	12103C0203H	X (OFA)	10
City of Clearwater				
3568	1605 Harbour Dr., Clearwater	12103C0114G	AE	12
3566	1208 Fairburn Ave., Clearwater	12103C0106H	AE	10
3752	N. Betty Ln. and Engman St., Clearwater	12103C0106H	AE	10
3563	307 S Corona, Clearwater	12103C0109H	X	69
3636	1250 Holt Ave., Clearwater	12103C0106H	AE	10
Northeast District				
Jacksonville Electric Authority (JEA)				
3960	7834 Holiday Rd South, Jacksonville	12031C0387H	D	5
4002	7039 Alachua Ave. Jacksonville	12031C0342H	D	11
4004	12750 Meadowsweet Lane, Jacksonville	12031C0403H	D	20
4008	1060 Ellis Road North, Jacksonville	12031C0353H	AE	17
4011	5233 west 5th Street, Jacksonville	12031C0351H	D	15
4313	3254 Townsend Blvd., Jacksonville	12031C0377H	D	20
4316	5104 118th Street	12031C0527H	AE	4
4325	10797 Fort Caroline Road, Jacksonville	12031C0382H	AE	5

TABLE 2-7 SUMMARY OF FIRM INFORMATION (cont'd)

Incident ID#	Location	Flood Map#	Flood Zone at Location	Determined Base Flood Elevation Near Location, feet (NAVD 88)
City of St. Augustine				
8032-1	Solano Ave., St Augustine	12109C0318H	AE	9
8032-2	Macaris Street, St Augustine	12109C0312H	AE	9
8032-3	State Road 207 & Ferry Place, St. Augustine	12109C0314H	X	9
8032-4	US1 near Zaxby's, St. Augustine	12109C0314H	AE	9
8032-5	Bayfront by St. Francis Street, St. Augustine	12109C0318H	AE	10
8032-6	1111 N. Ponce de Leon Blvd., St. Augustine	12109C0314H	AE	9

The following describes the flood zones shown in Table 2-7:

- Zone AE – Base flood elevations determined.
- Zone X – Areas determined to be outside the 500-year floodplain.
- Zone X, Other Flood Areas (OFA) – Areas of 500-year flood; areas of 100-year flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 100-year flood.
- Zone D – Areas in which flood hazards are undetermined, but possible

Based on the information summarized in Table 2-7, a majority of the reported locations are located in special flood hazard areas that are subjected to inundation during a 100-year flood, areas within the 500-year flood plain; and areas in which flood hazards are undetermined, but possible. It is important to note that while the point of an SSO may be outside of a floodplain, drainage basin upstream and the overflow may be in a flood zone. Table 2-7 includes the Base Flood Elevation (the water surface elevation of the 100-year flood) at or adjacent to the SSO locations. Any sanitary sewer collection system component (manholes, lift stations, etc.) at or below the Base Flood Elevation would be inundated during a 100-year or larger storm. LIDAR Figures 2-8 and 2-9 illustrate approximate surface elevations (NAVD 88) at each SSO location.

FIGURE 2-8 LIDAR ELEVATION MAP FOR SOUTHWEST STUDY AREA

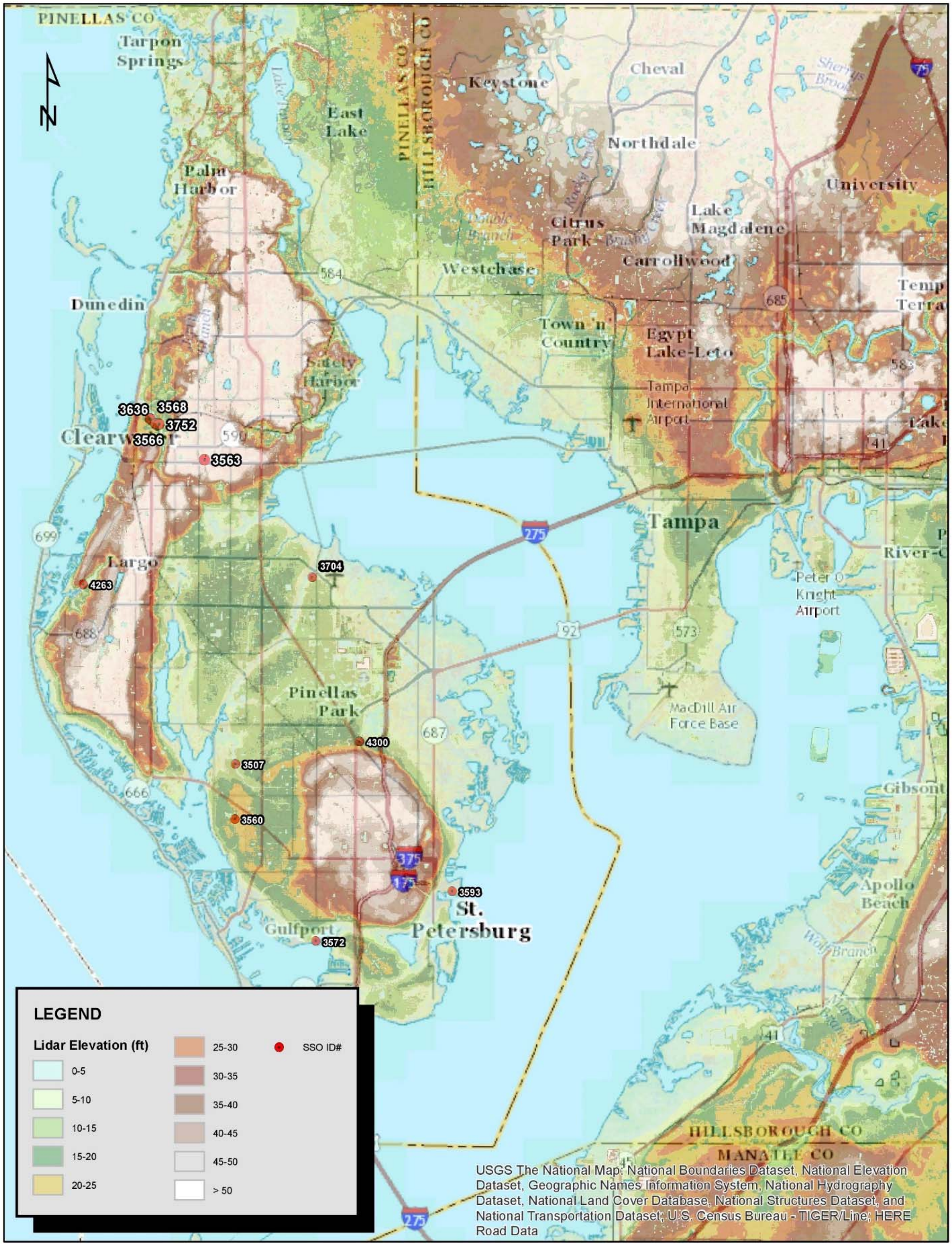
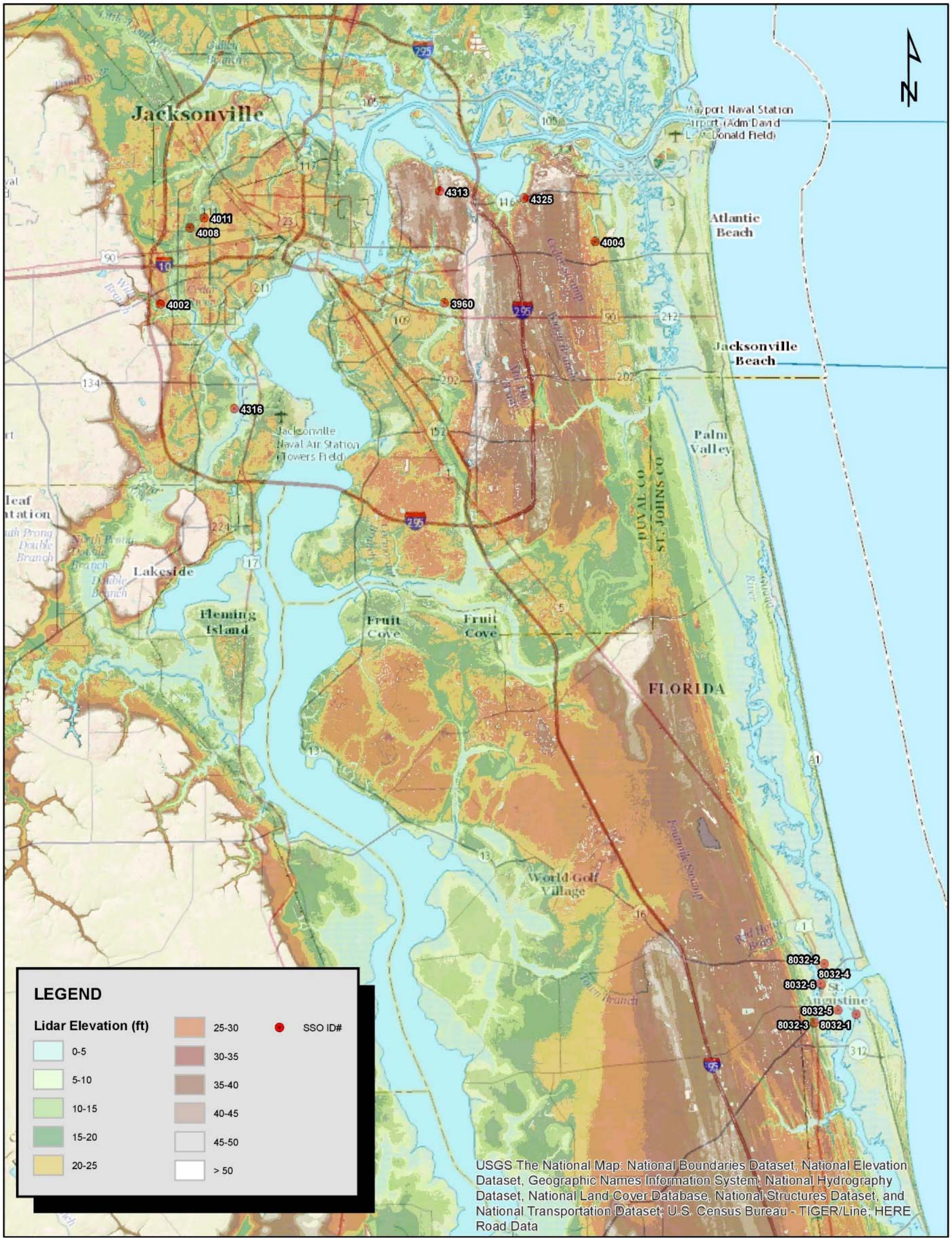


FIGURE 2-9 LIDAR ELEVATION MAP FOR NORTHEAST STUDY AREA



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3.0 UTILITY, HURRICANE IMPACTS AND SSO DISCUSSIONS

This section describes each of the incidents evaluated, including the utilities where they occurred, the hurricane conditions and associated weather events they experienced, the failure modes that led to the SSO or unpermitted discharge and their characteristics. In addition, detailed information obtained through face to face interviews, telephone conversations and the supplemental data provided by each of the utilities is also described. The section is organized by utilities.

3.1 CITY OF ST. PETERSBURG

3.1.1 Utility Description

The City of St. Petersburg wastewater collection and transmission system includes four service areas. The collection and transmission system consists of approximately 900 miles of gravity mains, 19,378 manholes, 97,932 laterals, 83 lift stations, and approximately 50 miles of force mains. The St Petersburg wastewater system dates back to 1894. Approximately 25 percent of the wastewater system was installed by 1933 and a majority of the remaining system was constructed between 1950 and 1962. The City of St Petersburg also accepts wastewater from other local municipalities for treatment including: City of Gulfport, City of St. Pete Beach, Tierra Verde, City of South Pasadena, City of Treasure Island, and Fort Desoto.

The city owns four water reclamation facilities (WRF) which are permitted by the FDEP. One of the WRFs (Albert Whitted) was closed in April 2015. The effluent from the WRFs is discharged through the City's reclaimed distribution system and into deep injection wells (permitted by FDEP). Reclaimed water meeting required quality standards is the only water permitted for discharge into the deep injection wells. The following table summarizes information regarding each WRF.

TABLE 3-1 SUMMARY OF WASTEWATER RECLAMATION FACILITIES IN CITY OF ST. PETERSBURG

WRF	WRF Address	WRF Location	FDEP Permit Number	Capacity (MGD)	(1)Average Dry Weather Flow (MGD)	(1)Average Groundwater Infiltration (MGD)
Northeast WRF	1160 62nd Ave., Northeast, St. Petersburg	Lat. 27^0 49' 40" N; Long. 82^0 37' 05" W	FLA 128856	16	2.5	5.0
Northwest WRF	7500 26th Ave., North, St Petersburg	Lat. 27^0 47' 43" N; Long. 82^0 44' 29" W	FLA 128821	20	4.0	6.0
Southwest WRF	3800 54th Ave., South, St Petersburg	Lat. 27^0 43' 04" N; Long. 82^0 41' 03" W	FLA 128848	20	5.5	10
Albert Whitted WRF	601 8th Ave., Southeast, St Petersburg	Lat. 27^0 45' 46" N; Long. 82^0 37' 36" W	FLA 128830	(12)	NA – Flows diverted to SWWRF	NA – Flows diverted to SWWRF

(1) Information obtained from Wet Overflow Mitigation Program – Phase I study performed by CH2M Hill in April 2016

The AWWRF was closed down in April 2015 because it was not capable of providing storage capacity for one day of effluent in the event the effluent does not meet disinfection criteria as required by rule, and operational cost savings. With the closing of the AWWRF, the injection wells located at the plant were repurposed to accept only excess reclaimed water from the city's reclaimed distribution system.

According to city personnel, capacity related SSO's have occurred within certain areas of the city's collection system during rainfall events with precipitation close to or greater than a 10-year storm recurrence. Historically, the city has designed its collection system to handle up to a 10-year design storm. The city's collection system and WRF's, which experienced increased flow rates, handled rainfall invents in 2012 (Tropical Storm Debbie) and 2013 without major incident. The storm event in July/August 2015, which exceeded a 10-year storm recurrence, produced SSO's within the city.

Based on previous gravity system flow metering efforts, routine city analysis and a current flow metering project in progress, normalized estimates for rainfall dependent I/I (RDII), and groundwater infiltration (GWI) are being analyzed and tracked at a WRF service area wide level and within more detailed individual basins where historical flow data was/is collected. Results of the current 2016 city wide flow metering project are still in evaluation and will be used to update the current design conditions and hydraulic model. Current estimates of dry-weather flow predict that base GWI may be as high as 38% - 45% of dry weather flow at a system wide level.

The City of St Petersburg utilizes Oracle Work and Asset Management (WAM) as their computerized maintenance management system (CMMS). The city also has preventative maintenance contracts with Ringpower Corp. for emergency generators and a contract with Electrical Engineering Enterprises for maintenance of the City's electrical switch gear Equipment. Work orders (even for service) are generated to document work and show cost for all work performed on the city's system.

3.1.2 Conditions Associated with Hurricane Hermine

Prior to August 31, 2016 the City and surrounding Pinellas County experienced above average rainfall for the month of August. The area also experienced an average accumulation of approximately 10.5 inches over a three-day period (August 31 to September 2, 2016) with a peak average accumulation of 7.1-inches over a 24-hour period. The highest average recorded 24-hour precipitation of 9.4 inches (City of Gulfport) and the highest average recorded 3-day precipitation of 13.4-inches (City of Gulfport) closely represent a 25-year storm recurrence interval.

Hurricane Hermine also produced a tidal surge with a peak elevation of approximately 3.8 feet (NAVD 88) which is approximately 2.78-feet above the mean higher high water elevation (MHHW). The tidal surge was above the MHHW elevation for approximately 33 hours. Section 2.0 provides additional information on the stormwater and water level analysis for Hurricane Hermine.

3.1.3 Unpermitted Discharge Overview and Review of FDEP Reported Data

The City of St Petersburg reported 10 unpermitted discharges to FDEP resulting from Hurricane Hermine. The reported unpermitted discharges ranged in volume from 450 gallons to 93,000,000 gallons, totaling nearly 152 million gallons. This represents almost 72% of the discharge volumes reported to FDEP for Hurricanes Hermine and Matthew. Two of ten unpermitted discharges for the City of St. Petersburg were chosen to be evaluated in detail for this study. The discharges were prioritized to focus on common failure modes and they represent over 99% of the unpermitted discharge reported by the City. The following table provides a summary of the information reported to the state including; the cause of failure as well as the volume of the unpermitted discharge released to surface waters.

TABLE 3-2 EVENT SUMMARIES IN CITY OF ST. PETERSBURG

Incident ID #	Location	Water Reclamation Facility (WRF)	Cause	Volume (gallons)
3560	7500 26th Avenue, N	Northwest	Hydraulic overload caused by excessive rainfall	58,000,000
3593	601 8th Avenue, SE	Albert Whitted	Hydraulic overload caused by excessive rainfall	93,000,000
			TOTAL	151,000,000

3.1.4 Interviews with the City of St. Petersburg Water Resources Department

On November 17, 2016 an interview was conducted with representatives of the City of St. Petersburg Water Resources Department. Representatives included: John E. Palenchar, P.E., Interim Water Resources Director; Charles R. Wise, Jr., Water Reclamation Manager; Janet G. DeBiasio, Plant Operations Specialist; Lane Longley, Wastewater Collection Division Manager; and Matthew C. Wilson, Engineer II. In addition to the interview, email correspondence with the Water Resource Department personnel followed between November 21 and December 7, 2016. The email correspondence provided information requested during the interview and additional information.

The discussion which follows addresses the two selected unauthorized discharges. These discharges were prioritized to ensure that the majority of the discharge volume was addressed as well as all causes of failure reported to the state watch office. Failure causes addressed include overflows at two water reclamation facilities.

3.1.4.1 Incident No. 3560 - Northwest Water Reclamation Facility (NWWRF)

The unpermitted discharge occurred at the NWWRF. The volume of the discharge was 58 million gallons. The discharge originated from vents on the two holding tanks at the WRF. The holding tanks are used to retain treated reclaimed water prior to disposal in the injection wells or transmission to the community's reclaimed water distribution system. The overflow water eventually was conveyed by surface overflow and stormwater conveyance systems to the Walter Fuller Park stormwater pond north of the NWWRF. The overflow at the NWWRF was the product of I&I, and inundation in the sanitary sewer collection system which hydraulically overloaded the WRF beyond its capacity (in particular the effluent sand filters). The high volume of I&I was associated with saturated soils, elevated groundwater levels and above average rainfall.

FIGURE 3-1 NWWRF HOLDING TANK OVERFLOWING TO GRADE

In addition, inundation was caused by the sustained 33-hour tidal surge in conjunction with the high precipitation event. The aging collection system in the NWWRF service area, which also collects significant sanitary flow from St. Pete Beach, reportedly contains broken pipes, separated pipe joints, damaged manholes, leaky manhole covers, etc. These anomalies allowed excess water intrusion into the system from groundwater mounding, tidal inundation, and stormwater flooding.

In addition to I&I flows, high volumes of reclaimed and reject water contributed to the WRF being hydraulically overloaded. The high volume of reclaimed water influent is most likely a result of customers not using the reclaimed water during the rainy period. Between September 1 and September 4, 2016 more influent was coming into the WRF than could be disposed of in the deep injection wells and stored in the holding tanks resulting in the 58 million gallons of overflow from the holding tanks. The volume was estimated based on flow meters at the WRF deep injection wells, influent meters, and volume in the holding tanks. Average daily flow to the NWWRF for FY 2016 was approximately 11 MGD. The average daily flow over the four day period between September 1 and September 4, 2016 was 37.5 MGD (more than 3 times the normal average daily flow).

The primary failure mode at this location was hydraulic overloading caused by I&I and inundation in the service area sanitary sewer collection system. The effluent sand filters at the WRF were overflowing into the effluent trough; therefore, some of the flow was by-passed resulting in partially treated water (not meeting reclaimed water requirements) being discharged into the deep injection wells. In addition, during peak flows between September 1 and September 4, 2016 more influent was coming into the WRF than could be disposed of in the wells. The City's recommendation to prevent or alleviate this unpermitted discharge during a similar event is to increase the disposal capacity by adding another injection well and increase the hydraulic capacity of the effluent filters by constructing an additional filter.

3.1.4.2 Incident No. 3593 - Albert Whitted Water Reclamation Facility (AWWRF)

This discharge occurred at the AWWRF (decommissioned in April 2015). The volume of the discharge was 93 million gallons. The unpermitted discharge at the AWWRF was a result of flow being diverted from the Southwest Water Reclamation Facility (SWWRF) because the influent to the SWWRF was exceeding capacity. The AWWRF unpermitted discharged was released to Tampa Bay through an historic outfall pipe. The discharge took place between August 30 and September 3, 2016. The AWWRF was reopened to manage the excessive flow of influent diverted through lift station 85 from the SWWRF, initially for storage only, but ultimately flow was discharged into Tampa Bay. The wastewater received basic chlorination prior to discharge.

According to city staff, when influent flow at the SWWRF is over 40 MGD, the influent overflows the headworks. This happened during Hermine, causing the grit and rag compactor motors on the headworks to be submerged and electrically nonfunctional. In addition, the SWWRF filtration system was overwhelmed and flows were bypassing the filtration resulting in effluent not meeting reclaimed water quality; therefore, SWWRF was taken off reclaimed water distribution and effluent was disposed down the injection wells to the maximum extent possible. The excessive inflows to the SWWRF was the product of I&I, and inundation in the sanitary sewer collection system which hydraulically overloaded the WRF beyond its capacity (in particular the headworks and filtration system). The high volume of I&I was associated with saturated soils, elevated groundwater levels and above average rainfall. In addition, inundation was caused by the 33-hour tidal surge in conjunction with the high precipitation event.

The aging collection system in the Albert Whitted and Southwest service areas, which also collects sanitary flow from the City of Gulfport, contains broken pipes, separated pipe joints, damaged manholes, leaky manhole covers, etc. These anomalies allowed excess water intrusion into the system from groundwater mounding, tidal inundation, and stormwater flooding. In addition to I&I flows, high volumes of unused reclaimed water from the city's distribution system and Eckerd College contributed to the SWWRF being hydraulically overloaded. The high volume of reclaimed water influent is most likely a result of customers not using the reclaimed water during the rainy period. Between August 30 and September 4, 2016 more influent was coming into the SWWRF than could be disposed of in the deep injection wells and/or stored in the holding tanks. Therefore flows were diverted from lift station 85 to the AWWRF resulting in the 93 million gallons of treated wastewater being discharged to Tampa Bay.

FIGURE 3-2 AWWRF OUTFALL PIPE DISCHARGE TO TAMPA BAY

The SWWRF flows were calculated / estimated based on flows to the deep injection wells and change in level of the storage tanks because the headworks were being bypassed. Other factors related to the SWWRF estimate was flow of reclaim water coming from Eckerd College and flow meter at Lift Station 85. Lift Station 85 (LS85) is the master lift station that was constructed to convey wastewater from the Albert Whitted service area to the SWWRF. The AWWRF flows were estimated based on the SWWRF flows and LS85 meter. Some meters were maxed out and not working (injection wells); and some were bypassed (SWWRF headworks). The valve at LS85 split the flows downstream of the flow meter to both the AWWRF and the SWWRF. Flow to the AWWRF was dependent on how open the valve was. The valve was adjusted to maximize the flows to the SWWRF without causing overflows in the system. At times the valve was nearly closed and other times nearly fully open. Knowing how many pumps were running also helped City staff estimate the release. Average daily flow to the SWWRF for FY 2016 was approximately 20 MGD. The average daily flow over the 5 day period between August 30 and September 3, 2016 was 43.7 MGD (more than double the average daily flow). A peak flow of approximately 54 MGD was experienced on September 2, 2016.

The primary failure mode at this location was hydraulic overloading of the SWWRF caused by I&I and inundation in the Albert Whitted and Southwest service areas' sanitary sewer collection systems. According to the *Wet Overflow Mitigation Program – Phase I* study performed by CH2M Hill in April 2016, the most cost effective recommendations to prevent or alleviate this incident during a similar event includes the following upgrades at the SWWRF: expansion of the facility headworks, provide additional screening and grit removal capacity, provide another secondary clarifier, provide additional filtration capacity, provide additional disinfection capacity, and provide yard piping improvements. Also recommended is the installation of additional injection wells at the SWWRF site.

3.2 CITY OF GULFPORT

3.2.1 Utility Description

The City of Gulfport's wastewater collection and transmission system consists of 220,000 LF of gravity sanitary sewer mains and force mains, 878 manholes, and 2 lift stations. The collection system was permitted by the FDEP, however, operation permits are not required by rule. According to the *Sanitary Sewer Evaluation Survey (SSES) Final Report* prepared by Cardno in July 2016, wastewater collected from the mid and western section of the city flows by gravity in a generally southern direction to Lift Station No. 2 (LS-2) located on the southeast corner of 58th Street South and Shore Boulevard South (Lat. 27^{0} 44'15.26" N; Long.

82^{0} 42’42.30” W). LS-2 then conveys the wastewater to Lift Station No. 1 (LS-1) located at the southwest corner of 29th Avenue South and Miriam Street South (Lat. 27^{0} 44’27.24” N; Long. 82^{0} 41’41.84” W). LS-1 is also the collection point for wastewater for the mid and eastern half of the City. LS-1 pumps wastewater to the City of St. Petersburg collection system where it is ultimately conveyed to the City of St. Petersburg Southwest Water Reclamation Facility for treatment. The portion of the collection system south of Gulfport Blvd. and west of 59th Street South is owned and operated by Pinellas County Utilities and pumped to the City of St. Petersburg’s Northwest Water Reclamation Facility for treatment. As the city was incorporated in 1910 and a majority of the collection system was constructed circa 1960, similar to surrounding communities, a majority of the collection system is nearing the end of its design life.

FIGURE 3-3 LIFT STATION NO. 1

FIGURE 3-4 LIFT STATION NO. 2

According to the SSES report, the city’s average daily flow for the period between January 1, 2013 and August 31, 2014 is 1.02 MGD with a maximum daily flow of 3.04 MGD on September 26, 2013. Based on metering performed during the SSES study, the estimated dry weather infiltration rate during the period of flow monitoring is approximately 150,000 GPD. The City’s sanitary sewer system experiences substantial increases in wastewater flows during rain events caused by I&I. The wastewater system is being systematically addressed based on the SSES report.

According to the SSES report, the city reported 4 SSO incidents to FDEP between 2013 and 2015. On July 8, 2013, an SSO of 750,000 gallons was reported because of an equipment failure, and on September 27, 2013 an overflow of 90,000 gallons was reported because of rainfall. Both of the 2013 SSOs were located upstream of LS-1 in the area of 49th Street South and Tradewinds Drive South. In 2014, an estimated SSO volume of 110,000 gallons was discharged between September 28 and September 30. In 2015, an estimated SSO volume of 186,000 gallons was discharged. Both the 2014 and 2015 SSOs were located upstream of LS-1 at the intersection of 50th Street South and 31st Avenue South, and were a result of excessive rain. According to city staff, SSOs generally occur when precipitation approaches a 25-year storm occurrence. city staff stated the collection system’s peak capacity is 3.5 MGD. However, based on the September 27, 2013 SSO incident which had an overflow of 90,000 gallons, the peak capacity of the system is most likely below 3 MGD as the peak flow the day prior was 3.04 MGD based on the SSES report

The city actively tracks customer's complaints, and has rehabilitated gravity sewer pipes with point repairs, cured-in-place-pipe (CIPP) liners, and polyethylene slip liners. Over 47,000 LF of the system's 220,000 LF of pipe was lined prior to the start of the SSES project.

The city maintains a SSO Standard Operating Procedure (SOP) to document protocols for notification and cleanup response in the event that an overflow occurs within the city's wastewater collection system. The city's lift stations are equipped with generators to provide backup power. The city has a semi-annual contract to maintain the generators. In addition, city staff performs weekly preventive maintenance on the generators.

3.2.2 Conditions Associated with Hurricane Hermine

Prior to August 31, 2016 the city and surrounding Pinellas County experienced above average rainfall for the month of August. The area also experienced an average accumulation of approximately 10.5 inches over a three-day period (August 31 to September 2, 2016) with a peak average accumulation of 7.1-inches over a 24-hour period. The highest average recorded 24-hour precipitation of 9.4 inches (City of Gulfport) and the highest average recorded 3-day precipitation of 13.4-inches (City of Gulfport) closely represent a 25-year storm recurrence interval.

Hurricane Hermine also produced a tidal surge with a peak elevation of approximately 3.8 feet (NAVD 88) which is approximately 2.78-feet above the mean higher high water elevation (MHHW). The tidal surge was above the MHHW elevation for approximately 33 hours. Section 2.0 provides additional information on the stormwater and water level analysis for Hurricane Hermine.

3.2.3 SSO Overview and Review of FDEP Reported Data

The City of Gulfport reported one SSO to FDEP resulting from Hurricane Hermine. The reported overflow (SSO ID #3572) was 892,500 gallons. This represents 0.40% of the SSO volumes reported to FDEP for Hurricanes Hermine and Matthew. The reported SSO location is at the intersection of 49th Street South and 31st Avenue South. The cause of the release was hydraulic overload of the collection system due to excessive rainfall.

TABLE 3-3 EVENT SUMMARIES IN CITY OF GULFPORT

Incident ID #	Location	Cause	Volume (gallons)
3572	49th Street S & 31st Avenue S	Hydraulic overload caused by excessive rainfall and tidal surge	892,500

3.2.4 Interviews with the City of Gulfport Public Works Department

On November 17, 2016 an interview was conducted with representatives of the City of Gulfport Public Works Department. Representatives included: Mr. Don Sopak, Public Works Director and Clay Lott, Utilities Supervisor. In addition to the interview, email correspondence with the Public Works Department personnel followed on November 21st. The email correspondence provided information requested during the interview and additional information.

3.2.4.1 Incident No. 3572 - 49th Street S & 31st Avenue S

The SSO occurred at five manholes in the vicinity of 49th Street South and 31st Avenue South. The volume of the SSO was estimated at 892,500 gallons. The overflow ultimately discharged untreated wastewater to Boca Ciega Bay via overland flow. The overflow was a product of I&I, and inundation in the sanitary sewer collection system, which hydraulically overloaded beyond the system's capacity (in particular LS-1). The high volume of I&I was associated with saturated soils, elevated groundwater levels and above average rainfall. In addition, inundation was caused by the 33-hour tidal surge in conjunction with the high precipitation event. The City's aging collection system contains broken pipes, separated pipe joints, damaged manholes, leaky manhole covers, etc. These anomalies allowed excess water intrusion into the system from groundwater mounding, tidal inundation, and stormwater flooding. The SSO release volume was estimated based on a rate of flow at each manhole for the duration of the overflow. The average daily flow for the City's collection system over the 6 day period between September 1 and September 6, 2016 was approximately 3.3 MGD (more than 3 times the normal average daily flow).

The primary failure mode at this location was hydraulic overloading of the collection system caused by excessive rainfall and tidal surge at the lower elevations. A root cause analysis of this SSO suggested that addressing a proximate cause by rehabilitating the collection system gravity mains and manholes would have potentially prevented the inundation of the system. The City's Public Works staff concur with this assessment per the SSES report that system wide rehabilitation of pipes and manholes would have alleviated the SSO. It's concluded that the failure modes at this location were symptoms of an aging wastewater collection system.

3.3 CITY OF LARGO

3.3.1 Utility Description

The City of Largo's wastewater collection and transmission system service area is more than 16 miles and serves more than 100,000 people. The boundaries of the Largo Sewer District are vastly greater than the corporate bounds of the City of Largo. The collection and transmission system consists of over 320 miles of collection and transmission lines and over 5,400 manholes. The City of Largo has fifty-two (52) lift stations located throughout the service area.

The city operates an FDEP permitted Wastewater Reclamation Facility at 5100 150th Ave North, Largo Florida. The FDEP permit number is FL0026603. The Largo WWRF is designed for an 18 MGD Average Annual Dry Flow. The facility can handle peak flows of 27-30 MGD. At the conclusion of the Disinfection and Effluent Pumping Improvement Project and the Influent Pumping and Headworks Improvement Project, the plant will be capable of peak hourly flows of 42.5 MGD and an estimated 34 MGD through the facility.

The City of Largo has an Emergency Operations Plan in place that is meant to provide an immediate, coordinated response by the Environmental Services Department in the event of a hurricane. The city also has an Emergency Response Plan. A portion of the document establishes the personnel and procedures that are required to mitigate the effects of a hurricane.

3.3.2 Conditions Associated with Hurricane Hermine

Hurricane Hermine created heavy rainfalls throughout the city between August 31st, 2016 and September 2nd 2016. The most significant rainfall occurred in the southwest quadrant of the city. According to the National Oceanic and Atmospheric Administration (NOAA) the City of Largo received between 11 and 15 inches of rainfall. The City's Lift Station 19 rain gauge, located at 12760 Indian Rocks Road on the west end of Largo, measured rainfall in excess of 11.5 inches within a 24 hour period. This accumulation is within 0.1 inches of the 50-year storm recurrence interval for St. Petersburg, FL. Further data on the rainfall experienced by the City of Largo during the storm is shown in section 2.0.

3.3.3 Incident Overview and Review of FDEP Reported Data

TABLE 3-4 SSO EVENT SUMMARIES IN CITY OF LARGO

Incident ID#	Location	Cause	Volume (gallons)
3704	5100 150th Ave N	I&I and Power Outage	11,880,000

3.3.4 Interviews with the City of Largo Public Works Group

On November 16th, 2016 an interview was conducted with representatives of the City of Largo Public Works Department. Representatives included Irvin Kety, P.G. Environmental Services Director and Bill Brown, Wastewater Collections System Manager. The discussions addressed the release that occurred during the storm as well as solutions and on-going projects that are intended to resolve future SSOs and effluent releases. One of the main concerns for the community is Infiltration and Inundation creating a flow peaking factor of between 2.5 and 3.0.

3.3.4.1 Incident No. 3704-- 5100 150th Ave North

The focal incident in Largo revolves around an 11.88 Million Gallon effluent release from Largo's Wastewater Reclamation Facility (WWRF) that was discharged into the Cross Bayou Bypass. The spill amount was estimated by the city based on a pump curve. The spill was a result of bottlenecks created during the Disinfection and Effluent Pumping Improvement Project. The effluent that was released was fully treated and underwent the biological process for Carbonaceous biochemical oxygen demand (CBOD), Total suspended solids (TSS) and Total Phosphorous reduction, denitrification filters for Total Nitrogen and TSS reduction, followed by disinfection with sodium hypochlorite. The only process not taking place for this pumped effluent was dechlorination. Infiltration and Inflow is responsible for the higher than average quantities of water that were reaching the facility.

The failure mode is a combination of hydraulic overloading from infiltration and inflow that is creating a burden on the system in conjunction with the loss of capacity due to ongoing upgrades at the facility. A significant operational problem occurred early on the morning of September 1, 2016. Two of the six clarifier sludge blankets hydraulically washed out over the weirs into the clarifier effluent. This caused the denitrification filters to overflow intermittently because of suspended solids blinding the filter. Operational staff were able to minimize this issue and get the sludge blankets under control by diverting flow to the equalization tanks thus balancing flow between the three process trains and manually backwashing the seven in-service denitrification filters.

The City of Largo is in the final phases of a project called "The Set Weather" project. This ambitious project is a 14-mile sewer improvement project that is designed to alleviate and prevent SSOs during heavy rainfall events. The project, which is scheduled for completion in the spring, sets out to resolve areas of concern through constructing and installing a new sanitary force main, gravity line and interceptor force main. The project also includes the reconstruction of 7 lift stations throughout the city.

As mentioned previously, the city is also in the midst of a dual project known as the Wastewater Reclamation Facility Disinfection and Effluent Pumping System Improvement Project.

3.4 PINELLAS COUNTY

3.4.1 Utility Description

Pinellas County Utilities maintains and operates 289 pump stations, and there are 22,297 manholes in the collection system. As of 2005, Pinellas County Utilities provides wastewater collection and treatment services to 230,847 unincorporated residents. Pinellas County Utilities (PCU) operates over 1,458 miles of sewer line in Pinellas County. The wastewater initially flows through gravity sewers to larger collectors and interceptors. Pump stations move the wastewater through force mains to the wastewater treatment plants.

The county operates the FDEP permitted South Cross Bayou Water Reclamation Facility located at 7401 54th Ave N in St. Petersburg. The facility has an FDEP Permit number of FL0040436. The system has a 66 MGD peak flow capacity. The South Cross Bayou Water Reclamation Facility is an Advanced Wastewater Treatment Facility utilizing a tertiary treatment process. By the end of a four step cleaning process, the water is 99.9 % pure. The treated water goes out as reclaimed water to be used for irrigation purposes. If necessary, the remaining water is released into nearby Joe's Creek following additional treatment. The chlorine is removed (neutralized) through the addition of sulfur dioxide. The released water is also re-aerated to enrich it with additional oxygen through the use of a cascade system.

The effluent events that took place as a result of Hurricane Hermine in Pinellas County can be summarized as two SSOs and one unpermitted discharge of partially-treated effluent. The SSOs were documented at 1400 Indian Rocks Road in Largo and 6597 Wayne St. in St. Petersburg. The unpermitted discharge took place at the South Cross Bayou Water Reclamation Facility at 7401 54^{th} Ave N in St. Petersburg.

Pinellas County has an Emergency Response Plan that establishes designations for personnel for each phase of storms. The county also has a list of specific actions to follow for impending storms by response level depending on time of year and proximity of storms. This document includes the inspections and repairs of equipment required for proper service.

3.4.2 Conditions Associated with Hurricane Hermine

Prior to August 31, 2016 Pinellas County experienced above average rainfall for the month of August. The area also experienced an average accumulation of approximately 10.5 inches over a three-day period (August 31 to September 2, 2016) with a peak average accumulation of 7.1-inches over a 24-hour period.

The highest average recorded 24-hour precipitation of 9.4 inches (City of Gulfport) and the highest average recorded 3-day precipitation of 13.4-inches (City of Gulfport) closely represent a 25-year storm recurrence interval.

Hurricane Hermine also produced a tidal surge with a peak elevation of approximately 3.8 feet (NAVD 88) which is approximately 2.78-feet above the mean higher high water elevation (MHHW). The tidal surge was above the MHHW elevation for approximately 33 hours. Section 2.0 provides additional information on the stormwater and water level analysis for Hurricane Hermine.

3.4.3 Incident Overview and Review of FDEP Reported Data

TABLE 3-5 INCIDENT EVENT SUMMARIES IN PINELLAS COUNTY

Incident ID#	Location	Cause	Volume (gallons)
3507	7401 54^{th} Ave N, St. Petersburg	Infiltration and Inundation	7,130,000
4263	1400 Indian Rocks Road, Largo	I&I and Power Outage	288,000
4300	6597 Wayne St., St. Petersburg	Infiltration and Inundation	144,000
		TOTAL	**7,562,000**

3.4.4 Interviews with Pinellas County Utilities

RS&H attempted face to face interviews with Pinellas County Utility staff for this effort. Unfortunately, the workload of the staff precluded face to face interviews. However, multiple phone calls, e-mails and transmission of electronic data were facilitated by Matt Wotowiec, Water Quality Monitoring Manager and the information required for this evaluation was obtained.

3.4.4.1 Incident No. 3507 7401 54th Ave N St. Petersburg

The event at the South Cross Bayou WRF was an unpermitted discharge of 7.13 million gallons of partially treated effluent that did not meet the 1ppm residual requirement for chlorine. The volume of the spill was determined by flow metering and timelines specific to the event. The collection system as a whole experienced higher than normal hydraulic loads during the storm with Inflow and Infiltration being the primary cause. Subsequently, the facility experienced extremely high flows through the Chlorination Contact Basin and was unable to keep pace with the change in hydraulic load. The effluent was released to Joe's Creek which is a tidal flow from lower Boca Ciega Bay. There were no residential or commercial properties that were directly impacted by the effluent release.

The failure mode in the county system is hydraulic overloading caused by Inflow and Infiltration. Per the county, I&I occurs during typical seasonal rainfall and puts a burden on the system of up to 85 million gallons per day during major rainfall events, which far exceeds the per day peak flow of 66 million gallons per day. Studies of collection system to identify problems as well as repairs and upgrades will be required to reduce the amount of stormwater entering the system.

3.4.4.2 Incident No. 4263 -1400 Indian Rocks Road, Largo

There were multiple events that led to the SSO of 288 thousand gallons at 1400 Indian Rocks Road. Inflow and infiltration were large contributors to the issue, however, the system also dealt with a lift station failure caused by a power outage in the area. The power outage occurred on September 1st and had a duration of 3.3 hours (i.e. 200 minutes). Four feeders in the area were affected during that time. The wastewater collection points for the reporting address are Manhole 21CN-SM1764 and Pump Station 21CN – SP 1054. The effluent from the overflows was released to McKay Creek. There were no residential or commercial properties that were directly impacted by the overflow event.

The failure modes identified for this event are hydraulic overloading caused by infiltration and inflow as well as a lift station failure that was caused by a limited power outage (i.e. 200 minutes) that occurred on September 1st. Infiltration and Inflow reduction will benefit the system as a whole and the addition of a backup generator in the event of a power outage could also provide benefit, however, there are cost and space concerns associated with backup generator installation.

3.4.4.3 Incident No. 4300 - 6597 Wayne St., St. Petersburg

A 144 thousand gallon SSO occurred at 6597 Wayne Street as a result of Inflow and Infiltration during Hurricane Hermine into the gravity system of Pinellas County. The wastewater collection points for the reporting address are Manhole 16LN-SM1020 and Pump Station 17LS-SP3118. The effluent from the overflows was released to Sawgrass Lake. There were no residential or commercial properties that were directly impacted by the overflow event.

The failure mode was hydraulic overloading caused by Inflow and Infiltration on the system. The city is recommending that I&I be reduced to meet the current design criteria of the wastewater treatment facility through a system-wide study of the collection system that identifies and takes corrective action on areas that are creating significant impacts.

3.5 CITY OF CLEARWATER

3.5.1 Utility Description

The City of Clearwater wastewater collection system is comprised of over 364 miles of gravity wastewater lines, 38 miles of wastewater force mains, over 8,400 manholes and clean outs, and 78 wastewater pump stations. This system collects wastewater from residential areas and businesses, transporting it to the city's three wastewater treatment plants. The city employs 40 people to maintain the wastewater collection system and provides wastewater collection and treatment services to over 100,000 residents.

The city operates three FDEP permitted Wastewater Reclamation Facilities: Marshall Street Plant Water Reclamation Facility, East Plant Water Reclamation Facility, and the Northeast Water Pollution Control Facility. Two of the three collection systems experienced incidents during the storm, these included: the Marshall Street Plant, FDEP Permit No. FL0021857, and the East Pollution Reclamation Facility, FDEP Permit No. FL0021865. The Marshall Street Water Reclamation Facility is designed for a 10 MGD average daily flow and a 25 MGD peak hourly flow. East Water Reclamation Facility is designed for a 5 MGD average daily flow and 12. 5 design peak hourly flow.

The City of Clearwater has an Emergency Response Plan (ERP), however the plan reportedly contains security sensitive information as a result the city did not provide a copy for this evaluation.

3.5.2 Conditions Associated with Hurricane Hermine

Prior to August 31, 2016 the city and surrounding Pinellas County experienced above average rainfall for the month of August. The area also experienced an average accumulation of approximately 10.5 inches over a three-day period (August 31 to September 2, 2016) with a peak average accumulation of 7.1-inches over a 24-hour period. The highest average recorded 24-hour precipitation of 9.4 inches (City of Gulfport) and the highest average recorded 3-day precipitation of 13.4-inches (City of Gulfport) closely represent a 25-year storm recurrence interval.

Hurricane Hermine also produced a tidal surge with a peak elevation of approximately 3.8 feet (NAVD 88) which is approximately 2.78-feet above the mean higher high water elevation (MHHW). The tidal surge was above the MHHW elevation for approximately 33 hours. Section 2.0 provides additional information on the stormwater and water level analysis for Hurricane Hermine.

3.5.3 Incident Overview and Review of FDEP Reported Data

TABLE 3-6 INCIDENT EVENT SUMMARIES IN CITY OF CLEARWATER

Incident ID#	Location	Cause	Volume (gallons)
3563	307 S Corona Ave.	Bottleneck in Interceptor	2,900,000
3566	1208 Fairburn Ave.	Pump Failure at Marshall St. WRF	8,000,000
3568	1605 Harbour Dr.	Pump Failure at Marshall St. WRF	10,000,000
3636	1250 Holt Ave.	Pump Failure at Marshall St. WRF	6,562,080
3752	N. Betty Ln/Engman St.	Pump Failure at Marshall St. WRF	4,218,480
		TOTAL	**31,680,560**

3.5.4 Interviews with the City of Clearwater Public Works

On November 16th, an interview was conducted with David Porter, PE, and Public Utilities Director of the City of Largo Public Works Department. The discussions addressed the incidents that occurred during the storm as well as solutions and on-going projects that are intended to resolve future SSOs.

3.5.4.1 Incident No. 3563-- 307 S. Corona Ave.

A significant event that occurred in the City of Clearwater was a 2.9 million gallon spill in the East Pollution Plant collection system that was caused by an interceptor being over capacity. According to the city, there is a bottleneck in the piping of the Corona interceptor in that part of the system. As a result of the spill, the effluent flowed into the storm system and ultimately out to Tampa Bay. One home was impacted by the spill. An engineering evaluation of the problem has been completed and a solution is in the process of being designed.

The failure mode of the spill at the Corona Interceptor was a combination of hydraulic overloading caused by inflow and infiltration; and there is a previously documented bottleneck in that section of the system, of which the City of Clearwater has completed an engineering evaluation and is working towards remedying the bottleneck.

In 2015, the city contracted McKim and Creed, Inc. to conduct a "multi-phase Inflow and Infiltration Flow Reduction Analysis" in an attempt to fully understand the areas that are prone to inflow and rain dependent infiltration. The study concluded that during rainfall events, the WRFs recorded flows of up to 3.5 times greater than average dry weather during a 24-hour period. The study also determined that a majority of the high flow volumes can be attributed to direct stormwater inflow, but that groundwater infiltration was also significant during inclement weather. The city then contracted McKim and Creed to conduct smoke testing to determine where the areas of infiltration are the most severe.

The study identified the greatest contributors to inflow and addressed potential solutions. Utilizing the information in these studies, the city began a seven phase project that will analyze and address I&I contributors through permanent flow monitoring and infiltration remediation. They are currently simultaneously engaged in the first four phases of the project which include I & I Analysis, Source Identification, Abatement, and Permanent Flow Monitoring. The remaining phases will be required to go through a procurement process through approval from their town council.

3.5.4.2 Incident Nos. 3566, 3568, 3636 and 3752 -- Marshall St. Water Reclamation Facility

The larger of the two events in the city of Clearwater revolved around the catastrophic failure of a volute in a main sewage pump at the Marshall Street Water Reclamation Facility that caused flooding within the drywell of the Headworks system and led to an electrical failure. When the pump volute broke on the first floor of the dry well, water started flooding into the dry well. The water level rose in the dry well, eventually reaching the second level where the motors and electrical switchgear are located. Once the water reached the electrical equipment, it created an electrical failure by shorting out the system and all of the pumps stopped running. The failure of the pumps forced the facility out of service, causing a series of manholes in the vicinity of the plant to overflow. Leading to the following SSO events:

- 1208 Fairburn Ave. – Incident# 3566
- 1605 Harbour Dr. – Incident # 3568
- 1250 Holt Ave. – Incident # 3636
- N. Betty Ln/Engman St.- Incident # 3752

This event culminated in a total spill of 28.78 million gallons that flowed into Stevenson Creek. A business in the area of the Marshall Street WRF was impacted by the event. As a lessons learned scenario, the City of Clearwater has decided to avoid placing electrical equipment below ground in the future.

While hydraulic overloading caused by infiltration and inundation is a concern for the area, the failure mode of this event was a catastrophic failure of a volute at the Marshall Street WRF. The city recommends a decrease of I&I by repairing and replacing sewers. While the city is still investigating the cause of the failure of the volute it has acknowledged a lessons-learned scenario in the area and has determined that electrical equipment should be placed at higher elevations in future drywells.

3.6 JEA

3.6.1 Utility Description

JEA wastewater collection and transmission system consists of approximately 3,868 miles of gravity sewers and force mains that service approximately 240,000 sewer customers. According to JEA, approximately 69% of the gravity systems and force mains are made of PVC. The remaining lines are made of various materials including: concrete, vitrified clay, ductile iron, cast iron, and polyethylene. JEA's sewer system has approximately 1,375 pumping stations, approximately 800 low pressure sewer units, and 11 wastewater treatment plants with a rated average daily treatment capacity of approximately 0.2 to 52.5 million gallons per day (MGD).

Of the 11 wastewater treatment plants in JEA's wastewater collection system, four were associated with the SSO's investigated in this report during Hurricane Matthew. Each wastewater treatment plant is permitted by the FDEP. Each plant description and other pertinent information is provided below.

Southwest District WRF is associated with incident numbers 4316 and 4002. The permit number is FL0026468. It has an effective date of May 22, 2014 and an expiration date of May 21, 2019. The facility is located at 5420 118th Street (Lat. 30^{0} 13′ 57.92″ N; Long. 81^{0} 43′ 20.99″ W). The permitted average annual daily flow is 14.0 MGD. Treated wastewater from this facility is discharged to the Lower St. Johns River (Class III marine waters – WBID 2213E).

Arlington East WWTF is associated with incident numbers 3960, 4325, and 4004. The permit number is FL0026441. It has an effective date of May 26, 2014 and an expiration date of May 5, 2019. The facility is located at 1555 Millcoe Road (Lat. 30^{0} 20′ 47.94″ N; Long. 81^{0} 32′ 35.37″ W). The permitted average annual daily flow is 25.0 MGD. Treated wastewater from this facility is discharged to the St. Johns River (Class III marine waters – WBID#2213B) and to a public access reuse system.

Buckman WWTF is associated with incident numbers 4011 and 4008. The permit number is FL0026000. It has an effective date of April 21, 2014 and an expiration date of April 20, 2019. The facility is located at 2221 Buckman Street (Lat. 30^{0} 21′ 8″ N; Long. 81^{0} 37′ 44″ W). The permitted average annual daily flow is 52.0 MGD. Treated wastewater from this facility is discharged to the St. Johns River (Class III marine waters – WBID 2213D).

Monterey Water Reclamation Facility is associated with incident number 4313. The permit number is FL0023604. It has an effective date of April 24, 2014 and an expiration date of April 23, 2019. The facility is located at 5802 Harris Ave (Lat. 30^{0} 19′ 50.17″ N; Long. 81^{0} 36′ 4.19″ W). The permitted average annual daily flow is 3.60 MGD. Treated wastewater from this facility is discharged to the St. Johns River (Class III marine waters = WBID 2213D).

The storm related SSOs described in this report were the direct result of power failures and were not system capacity or I&I related failures. JEA has invested over $1 billion in wastewater collection and treatment system improvements in the past 20 years, including over $350 million of I&I prevention via pipe bursting work in the early 2000's. The results of this I&I preventative investment is that during recent storm events. The JEA system performed well related to I&I issues and did not experience collection system or treatment system capacity issues during Hurricane Matthew. As an example, the four wastewater plants referenced in this study only experienced flow increases from 114% to 204% of annual average daily flow during the hurricane.

TABLE 3-7 FLOW COMPARISONS FOR JEA WASTEWATER FACILITIES

	Annual	**Flows During Hurricane Matthew, mgd**			**Flow Percentages above Average**		
	Avg Flow, mgd	Fri, 10/7	Sat, 10/8	Sun, 10/9	Fri, 10/7	Sat, 10/8	Sun, 10/9
Arlington East	19.6	22.2	24.8	25.8	114%	126%	132%
Buckman	28.9	59.0	53.0	41.1	204%	183%	142%
Monterey	1.5	2.6	2.0	2.2	173%	130%	145%
Southwest	10.5	12.5	18.1	15.2	NA*	172%	145%
* NA - SSO at 5104 118th							

JEA has a contract in place for preventive maintenance for dedicated generators and automatic transfer switches at pump stations. A general contractor performs maintenance checks on an annual, three quarterly, and eight monthly check basis totaling 12 per year. Each of the three check types entails various degrees of complexity. The general contractor submits the preventive maintenance data into an excel spreadsheet that's entered into the Computerized Maintenance System (CMMS) database. The remaining mechanical and electrical equipment at pump stations is maintained by JEA personnel. Stations generally receive one preventive maintenance check per month, and may get additional visits if alarm conditions are noted in Supervisory Control and Data Acquisition (SCADA). Results of the preventive maintenance and corrective maintenance are recorded in Maximo.

JEA utilizes an Emergency Response Plan for hazardous weather conditions. They also have: Restoration – Wastewater Plants and Lift Stations Functional Response Procedure; Restoration – Water Plants and Pump Stations Functional Response Procedure; and Restoration – Water / Wastewater / Reuse Water Distributions and Collections Functional Response Procedure. These procedures provide guidance to respond to and restore operations and provide information after emergencies.

JEA conducts a week long joint emergency preparedness exercise prior to the start of each hurricane season. The preparation includes review of Functional Response Procedures (FRP) such as: Restoration – Water Plants and Pump Stations FRP; and Restoration-Water/Wastewater/Reuse Water Distributions and Collections FRP. ―These procedures provide guidance to prepare, respond to and restore operations and provide information after emergencies.

Immediately prior to onset of an extreme weather event, JEA's wastewater staff prepares facilities by securing equipment, ensuring the 240 fixed generators are fueled, and positioning the 80 portable generators/diesel pumps across the service area for post storm deployment. During the storm, JEA also leveraged available resources from FLA Warn to augment its portable fleet and operations staff.

JEA developed a Framework to Resiliency plan for their Sanitary Sewer System to identify actions to be implemented to harden the facilities for extreme events such as Hurricane Matthew. Included is a system resiliency assessment to be conducted in three phases: immediate opportunities which are feasible to be implemented prior to the next hurricane season, evaluate mid-range defensive actions such as raising elevation of electrical equipment or installing storm barriers at critical equipment locations, and assess design standard changes beyond current industry standards which would build to new resiliency standards for both new and scheduled replacement of infrastructure assets.

3.6.2 Conditions Associated with Hurricane Matthew

The week prior to October 7, 2016, the City of Jacksonville received approximately 1.23-inches of rainfall. On Friday, October 7, 2016, Hurricane Matthew was approximately 30 miles east of the City of Jacksonville with maximum sustained winds of 105 miles per hour. During the storm, the City of Jacksonville received approximately 7.4-inches of rain. A maximum wind speed of 48 mph and a maximum wind gust of 68 mph were recorded on shore during the storm.

Of the 67 SSO's which occurred during Hurricane Matthew, two pump stations were flooded by the storm and 55 SSOs were caused by various losses of power. The 12 remaining SSO's included force main and gravity sewer incidents as well as a septic tank effluent pump repair. All sites with power outages that were not equipped with fixed generators, were provided with a roving generator once the storm passed and it was safe for field personnel to mobilize to the sites. However, there was a 12-hour period during the storm where it was unsafe for field crews to mobilize to the sites to respond to pump stations.

3.6.3 SSO Overview and Review of FDEP Reported Data

Given the size of JEA's service territory, SSOs associated with the storm were reported in groups to the State Warning site. Specific SSO's in those groups were assigned a unique ID number. Of the 67 SSOs, this investigation evaluated the eight with the highest volume. The table provided below shows the incident number reported to the state for these SSOs, the cause of failure as well as the volume of the SSO lost to surface water.

TABLE 3-8 SSO EVENT SUMMARIES FOR JEA

SSO ID # 2016-	Location	Pump Station	Cause SSO Volume (gallons)	SSO Volume (gallons)	
				Surface Water	Total
3960	7834 Holiday Rd.	NA	Power failure caused the fixed generator breaker switch to trip.	1,100,000	1,100,000
4002	7039 Alachua St.	JEA Alachua Pump STAT	Power failure caused a VFD controller to trip.	848,000	848,000
4004	12750 Meadowsweet Ln.	NA	Power failure caused the gravity system to surcharge.	194,000	194,000
4008	1060 Ellis Road North	NA	Power failure. Lift station is not equipped with a fixed generator.	387,000	387,000
4011	5233 West 5th St.	NA	Power failure. Lift station is not equipped with a fixed generator.	514,000	514,000
4313	3254 Townsend Blvd.	NA	Power failure caused the fixed generator breaker switch to trip.	327,000	327,000
4316	5104 118th St.	JEA East MSTR Pump	Power failure resulted in a VFD pump and mechanical seal relay trip.	5,000,000	5,000,000
4325	10797 Fort Caroline Road	NA	Power failure caused a VFD pump to trip.	327,000	327,000
			Total	8,707,000	8,707,000

The discussion which follows addresses the eight spills identified for this investigation.

3.6.4 Interviews with the JEA Representatives

On November 17, 2016, RS&H conducted an interview with the following JEA representatives: Paul K. Steinbrecher, P.E., Director, Permitting & Regulatory Conformance; Brian J. Roche, P.E., CPA, Vice

President/General Manager – Water/Wastewater Systems; and Deryle Calhoun, Jr., P.E., Director, Water, Wastewater and Reuse Treatment – Water/Wastewater Systems. Follow-up phone calls were made to JEA during the week of November 28, 2016 to gather additional information regarding the SSO's.

The eight SSOs discussed below summarize 8,707,000 gallons reported during the storm. Failure causes addressed include; power failure, equipment failure, no emergency generator, and gravity system surcharge.

3.6.4.1 Incident No. 3960 – 7834 Holiday Road.

The SSO occurred at a lift station, which caused the discharge of 1,100,000 gallons of untreated wastewater to discharge into Pottsburg Creek. During the storm, electrical faults occurred and transmission line power failed due to tree damage. The station's fixed generator was called upon to power the station. However, the generator's breaker tripped upon starting, making the generator unavailable. During the height of the storm (approximately 12-hours), there was a period where it was not safe for JEA personnel to mobilize to the lift station to reset the breaker switch. Once it was safe, JEA personnel mobilized to the lift station, reset the breaker switch, and placed the station on its fixed generator power.

The SSO release quantity was estimated using the annual average daily flow of the pump station multiplied by the duration of the event. The duration of the event was estimated using the wet well water level information provided by SCADA.

The primary failure mode at this location was power outage. A root cause analysis of this SSO revealed re-evaluating the breaker switch for the fixed emergency generator to repair and/or replace faulty components, or re-design the electrical system to prevent the breaker switch from tripping during future power surges and electrical faults would limit the cascading of electrical problems following an outage or surge.

3.6.4.2 Incident No. 4002 – 7039 Alachua St.

The SSO occurred at the JEA Alachua Pump Station. It resulted in the discharge of 848,000 gallons of untreated wastewater into Wills Branch. During the storm, electrical faults occurred and transmission line power failed reportedly due to downed trees which resulted in the VFDs for the pumps to trip and go offline. During the height of the storm (approximately 12-hours), there was a period where it was not safe for JEA personnel to mobilize to the lift station to reset the VFD control system. In addition, the fixed pony pump failed to start due to a failure of pressure level transducers. Once it was safe, JEA personnel mobilized to the lift station, reset the control system, which placed the station on its fixed generator power and reactivated the VFDs.

The SSO release quantity was estimated using the annual average daily flow of the pump station multiplied by the duration of the event. The duration of the event was estimated using the wet well water level information provided by SCADA.

The primary failure mode at this location was power outage. A root cause analysis of this SSO revealed that re-evaluating the VFD control systems to repair and/or replace faulty components, or re-design the electrical system to prevent the VFDs from tripping during future power surges and electrical faults would limit the cascading of electrical problems following an outage or surge.

3.6.4.3 Incident No. 4004 – 12570 Meadowsweet Lane

The SSO occurred at a lift station, which caused the discharge of 194,000 gallons of untreated wastewater to discharge into Mt. Pleasant Creek. Nothing was recovered. During the storm a power outage at the downstream pump station (12785 Meadowsweet Lane) caused the gravity system to surcharge at a manhole located at 12750 Meadowsweet Lane.

The SSO release quantity was estimated using the annual average daily flow of the pump station multiplied by the duration of the event. The duration of the event was estimated using the wet well water level information provided by SCADA.

The primary failure mode at this location was power outage. A root cause analysis of this SSO suggested that equipping the lift station with an emergency generator may have averted the SSO.

3.6.4.4 Incident No. 4008 – 1060 Ellis Road Northwest 5th Street

The SSO occurred at a lift station, which caused the discharge of 387,000 gallons of untreated wastewater into Little 6 Mile Creek. During the storm, transmission line power failed reportedly due to tree damage. The station is not served by a fixed generator, therefore, no emergency backup power was available when the power failed. During the height of the storm (approximately 12-hours), there was a period where it was not safe for JEA personnel to mobilize to the lift station to add a portable generator. Once it was safe, JEA personnel mobilized to the lift station and utilized a portable generator to pump down the system.

The SSO release quantity was estimated using the annual average daily flow of the pump station multiplied by the duration of the event. The duration of the event was estimated using the wet well water level information provided by SCADA.

The primary failure mode at this location was transmission line power outage. A root cause analysis of this SSO suggested that equipping it with an emergency generator during the storm would have averted the SSO.

3.6.4.5 Incident No. 4011 – 5233 West 5th Street

The SSO occurred at a lift station, which caused the discharge of 514,000 gallons of untreated wastewater into Little 6 Mile Creek. During the storm transmission line power failed reportedly due to tree damage. The station is not served by a fixed generator, therefore, no emergency backup power was available when the power failed. During the height of the storm (approximately 12-hours), there was a period when it was not safe for JEA personnel to mobilize to the lift station to add a portable generator. Once it was safe, JEA personnel mobilized to the lift station and utilized a portable generator to pump down the system.

The SSO release quantity was estimated using the annual average daily flow of the pump station multiplied by the duration of the event. The duration of the event was estimated using the wet well water level information provided by SCADA.

The primary failure mode at this location was power outage. A root cause analysis of this SSO suggested that equipping it with an emergency generator during the storm would have averted the SSO.

3.6.4.6 Incident No. 4313 – 3254 Townsend Blvd.

This SSO incident occurred at a lift station, which caused the discharge of 337,000 gallons of untreated wastewater into Newcastle Creek. During the storm, electrical faults occurred and transmission line power failed reportedly due to tree damage that resulted in pump VFDs to trip and go offline. During the height of the storm (approximately 12-hours), there was a period where it was not safe for JEA personnel to mobilize to the lift station to reset the VFD control system. Once it was safe, JEA personnel mobilized to the lift station, reset the control system, and placed the station on its fixed generator power.

The release quantity was estimated using the annual average daily flow of the pump station multiplied by the duration of the event. The duration of the event was estimated using the wet well water level information provided by SCADA.

The primary failure mode at this location was power outage. A root cause analysis of this incident suggested re-evaluating the VFD control systems to repair and/or replace faulty components, or re-design the electrical system to prevent the VFDs from tripping during future power surges and electrical faults.

3.6.4.7 Incident No. 4316 – 5104 118th Street

The SSO incident occurred at the JEA East Master Pump Station and caused the discharge of 5,000,000 gallons of untreated wastewater into an unnamed dredged canal. The canal discharges to the Ortega River. During the storm, electrical faults occurred and transmission line power failed, reportedly due to tree damage, that resulted in VFD pumps and a mechanical seal relay to trip and go offline. During the height of the storm (approximately 12-hours), there was a period where it was not safe for JEA personnel to mobilize to the lift station to reset the VFD control system. Once it was safe, JEA personnel mobilized to the lift station, reset the control system, and placed the station on its fixed generator power.

The pump station is one of the largest pump stations in the wastewater treatment plant (WWTP) basin. At the time the pump station lost power, the decrease in flow registered on the WWTP meter. The change in flow at the WWTP was multiplied by the duration of the event to calculate the quantity released. The duration of the event was estimated using the wet well water level information provided by SCADA (13.5 MGD x 9hrs / 24hrs / day = approximately 5 million gallons).

The primary failure mode at this location was power outage. A root cause analysis of this SSO suggested re-evaluating the VFD control systems to repair and/or replace faulty components, or re-design the electrical system to prevent the VFDs from tripping during future power surges and electrical faults.

3.6.4.8 Incident No. 4325 – 10797 Fort Caroline Road

The SSO occurred at a lift station, which caused the discharge of 327,000 gallons of untreated wastewater into the St. Johns River. During the storm, electrical faults occurred and transmission line power failed reportedly due to tree damage that resulted in pump VFDs to trip and go offline. During the height of the storm (approximately 12-hours), there was a period when it was not safe for JEA personnel to mobilize to the lift station to reset the VFD control system. Once it was safe, JEA personnel mobilized to the lift tation, reset the control system, and placed the station on its fixed generator power.

The release quantity was estimated using the annual average daily flow of the pump station multiplied by the duration of the event. The duration of the event was estimated using the wet well water level information provided by SCADA.

The primary failure mode at this location was power outage. A root cause analysis of this SSO suggested re-evaluating the VFD control systems to repair and/or replace faulty components, or re-design the electrical system to prevent the VFDs from tripping during future power surges and electrical faults.

3.7 CITY OF ST. AUGUSTINE

3.7.1 Utility Description

The City of St. Augustine's wastewater collection and transmission system services 28,817 acres and serves more than 19,500 people. The collection and transmission system consists of 140 miles of collection and transmission lines of which 79.3 miles are gravity sewers and 60.7 miles are force main. For the gravity sewer portion 57% of the system is more than 30 years old and 18% of the force main portion is older than 30 years. Of the City's 75 lift stations 79% are greater than 10 years old.

The city owned wastewater treatment plant's FDEP permit number is FL0021938. It has an effective date of November 19, 2014 and an expiration date of November 19, 2019. The plant is located at 501 Riberia Street (Lat. 29^0 52'36.72" N; Long. 81^0 18' 35.5" W). The permitted average annual daily flow is 4.95 million gallons per day (mgd). The average dry weather flow is 3 mgd. The maximum daily flow associated with the storm was more than 11 million gallons. The plant operated throughout the storm without interruption of power. The average infiltration and inflow into the system is estimated to be approximately 700,000 gpd. During heavy or lengthy rainfall events areas of the collection system consisting primarily of clay pipe suffer from I&I. These areas are being systematically addressed through the city's Capital Improvement Plan.

The city maintains an organizational chart and associated job descriptions which document the nature of the work to be performed, minimum requirements for the position, necessary special qualifications or certifications, examples of the type of work to be performed and the licenses required for the position. Training is provided to staff on safety, confined space entry, traffic control, trench/shoring, and discharge detection and elimination. The city uses a computer based maintenance management system, GIS, SCADA, spreadsheets and databases for its management information system. The entire collection system is represented in a geodatabase using ESRI software. Since 2000, as-built records have been maintained as hardcopies and pdfs. Each pump station is inspected weekly. These inspections include electric meter readings, visual inspections, generator inspections, check valve inspections and pump run times.

The city maintains a Sewer Overflow Response Plan for SSO notifications of spills. The collection system has an average annual budget of $1,100,000 and Capital Improvement Program of $700,000. The city allocates $500,000 in its annual budget for I/I elimination by slip-lining the sewer lines and manhole rehabilitations. Approximately 60% of repair funds are spent on emergency repairs. The City of St. Augustine endorses St. Johns County's Comprehensive Emergency Management Plan (CEMP). The CEMP guidance defines the Emergency Management Cycle: Mitigation, Preparedness, Response, Recovery and return to Mitigation.

Power losses to the pump stations are addressed through onsite generators, portable generators, portable pumps and vacuum trucks. Of the city's 75 pump stations 13 have emergency generators on-site.

Budgetary management dictates the prioritization of locations where emergency generators are dedicated to pump stations. Pump stations are provided with bypasses that were used to expedite return to service following the storm.

3.7.2 Conditions Associated with Hurricane Matthew

Prior to October 7 the city experienced four-days of rainfall with an accumulation of 6.03 inches. In preparation for the storm, city staff installed flood prevention measures at the WWTP (i.e. sandbags, etc.), pumped down sewage from the collection system, mobilized emergency generators for lift stations, filled emergency generator fuel supply tanks, prepositioned critical assets and arranged for support from other Florida wastewater utilities. In September 2016, St. Augustine Utility staff including the field superintendent supported the City of Tallahassee's response to Hurricane Hermine through FlaWARN.

FlaWARN is the formalized system of "utilities helping utilities" address mutual aid during emergency situations. FlaWARN provides immediate relief for member utilities during emergencies by matching personnel, tools and equipment to assist the utility. The city credits FlaWARN and the help provided by participating county utilities with expediting the recovery process by factors of 2 to 3 times faster or more than what could have been achieved with city resources alone.

In response to the anticipated hurricane conditions, mandatory evacuation orders were issued on Wednesday October 5 for barrier islands, and the City of St. Augustine. As winds associated with the hurricane began to increase city operations were curtailed and city personnel evacuated the area.

FIGURE 3-5 TIDAL SURGE FLOODING AT COSA PUMP STATION 22

On Friday, October 7 Hurricane Matthew was 30 miles east of the city with maximum sustained winds of 105 miles per hour. Rainfall accumulations during October 7 and 8 amounted to 4.2 inches in addition to the 6.03 inches that occurred before the onslaught of the storm. A maximum wind speed of 51 mph and a maximum wind gust of 67 MPH were recorded on-shore during the storm. Around high tide, which occurred at 1:24 PM the tidal surge from the storm was experienced with high water level marks measured at 7.18 feet above the NGVD 1988 datum, flooding the FPL substation in St. Augustine as well as businesses and residences.

In the face of these challenges, which included tidal surges that overtopped lift stations with as much as four feet of salt water (see Figure 3-5) and the resultant inundation of large swaths of the city, the city's public works staff with the support of utility teams accessed through FlaWARN diligently responded to the SSOs associated with the storm. The city's public works staff commenced system restoration activities at 6:30 AM on October 8 after the storm had passed and approval was given for access to the city's wastewater conveyance and transmission system. All spills were controlled via tank & haul operations and by bypass pumping by Sunday October 9, 2016 at 6 PM. The city's wastewater treatment plant remained operational throughout the storm with the assistance of its emergency generator. Staff took pre-storm precautions to sandbag vulnerable portions of the facility to ensure its reliability during the storm.

3.7.3 SSO Overview and Review of FDEP Reported Data

Given the extent of the tidal surge and the serious impacts to the city's operations, eleven SSOs associated with the storm were reported as a group to the State Warning site and one post storm incident was reported on the day it happened bringing the total SSOs reported to 12. Of the twelve SSOs reported to the state this investigation evaluated the six with the highest values. The following table provides the information reported to the state for the six SOs evaluated. The volume designations in the table reflect the amount of the SSO that was released to surface water and the amount recovered as well as the total volume of the SSO. To facilitate discussion, a unique identification number was developed for each of the spills. For example, the first spill on the table at Solano Ave. is referred to as Incident No. 8032-1 in the discussions that follow.

TABLE 3-9 SSO EVENT SUMMARIES IN CITY OF ST. AUGUSTINE

Incident ID #	Location	Pump Station	Cause	SSO Volume (gallons)		
				Surface Water	Recovered	Total
8032-1	Solano Ave.	50, 51, 52	Power failure at all three stations; PS 50: moisture in control panel, PS 52: control panel flooded	108,000	0	108,000
8032-2	Macaris Street	20	Power failure	10,000	19,000	29,000
8032-3	State Road 207 & Ferry Place	65	Power failure	49,500	0	49,500
8032-4	US1 near Zaxby's	5	Power failure, entire station flooded	24,000	0	24,000
8032-5	Bayfront by Francis Street	24	Power failure, control panel flooded	45,000	0	45,000
8032-6	1111 N. Ponce de Leon Blvd	NA	Force main break (10/9/16, 4 pm - 6 pm)	0	25,150	25,150
			TOTAL	236,500	44,150	280,650

3.7.4 Interviews with the City of St. Augustine Public Works Department

On November 18 an interview was conducted with representatives of the City of St. Augustine Public Works Department. Representatives included: Martha Graham, P.E., Public Works Director; Todd Grant, P.G., Deputy Director of Public Works; William Menendez, P.E., Engineering Division Manager; Reuben Franklin, P.E., Project Engineer; Wade Giddens, Utility Field Operations Manager and Danny Hodges, Utility Field Operations Supervisor. A follow up meeting was held on December 8, 2016 to refine the identification of the extreme weather conditions and the SSOs that occurred as a result of Hurricane Matthew. City of St. Augustine Public Works representatives at this meeting included Todd Grant, P.G., Deputy Director of Public Works; William Menendez, P.E., Engineering Division Manager and Wade Giddens, Utility Field Operations Manager.

3.7.4.1 Incident No. 8032-1 Solano Avenue

The SSO occurred at pump stations 50, 51 and 52. The volume of the SSO was 108,000 gallons. The SSO discharged to surface water, none was recovered. Power failure to the pump stations was primarily associated with loss of power from FPL's transmission system either from downed trees or substation flooding. Calls to FPL to obtain the cause of the outage were not fruitful. Public works staff found the system inoperable upon arrival on October 8, as well as, moisture in the control panel for pump station 50 and partial flooding of the control panel for pump station 52 (see Figure 3-6) which prevented their operation.

FIGURE 3-6 PUMP STATION NO. 52 FLOODING

The SSO release volume was estimated based on flow rates into these pump stations and the duration of time from when the SSO was first observed. Typically approximately 4 to 500 thousand gallons per day flows through these pump stations. The volume of the SSO, 108,000 gallons is significantly less than the daily flow particularly when the tidal surge volumes are considered. The City has equipped approximately 80% of the manholes in this basin with inflow dishes to limit the amount of inflow during storm events.

The failure mode at this location was either the flooding of the control panel and pump station or the transmission line power outage. Since the relative timing of these events cannot be identified, the visual evidence of the flooded control panel provides justification for establishing inundation of the control panel as the primary failure mode.

3.7.4.2 Incident No. 8032-2 Macaris Street

The SSO occurred at pump station 20. The volume of the SSO was 29,000 gallons. The SSO release volume was estimated based on flow rates into the pump station and the duration of time from when the SSO was first observed until it was abated. The majority of the discharge 65% (i.e. 19,000 gallons) was recovered, the balance discharged to surface water. Depressions in the area of the pump station allowed the retention and ultimate collection of the SSO discharge. Power failure to the pump stations was reportedly associated with an FPL transmission line being affected by significant tree canopy debris. The pump station was not flooded.

The pump station was not equipped with an emergency generator but was equipped with a by-pass pump out, which allowed the rapid restoration of system flow at this location. Typical flow through this pump station is approximately 4 to 500 thousand gallons per day.

The primary failure mode at this location was power outage. While there was no emergency generator at this location there is a generator connection and an emergency by-pass pump out. A root cause analysis of this SSO suggested that equipping it with an emergency generator during the storm would have averted the SSO. However, economic conditions dictate the prioritization of locations where emergency generators are dedicated to the pump stations. Another solution, though more financially challenging, is to bury the electric utility service to the pump station to limit impacts from falling tree debris. The presence of depressions in the vicinity of pump station 20 and the blockage of stormwater grates with tree debris helped to decrease the amount of the SSO ultimately released to the environment.

3.7.4.3 Incident No. 8032-3 State Road 207 and Ferry Place

The SSO occurred at pump station 65. The volume of the SSO was 49,500 gallons. The SSO release volume was estimated based on flow rates into the pump station and the duration of time from when the SSO was first observed until it was abated. The SSO discharged to surface water, none was recovered. Power failure to the pump stations was associated with an FPL power outage. The pump station is not equipped with an emergency generator because the area is reportedly too small to warrant an emergency generator.

The primary failure mode at this location was power outage. While there was no emergency generator at this location. A root cause analysis of this SSO suggested that equipping it with an emergency generator during the storm would have averted the SSO. However, economic conditions dictate the prioritization of locations where emergency generators are dedicated to the pump stations. Another solution, though more financially challenging, is to bury the electric utility service to the pump station to limit impacts from falling tree debris.

3.7.4.4 Incident No. 8032- 4 US1 near Zaxby's

The SSO occurred at pump station No. 5, which is located adjacent to the tidal San Sebastian River. The volume of the SSO was 24,000 gallons. The SSO release volume was estimated based on flow rates into the pump station and the duration of time from when the SSO was first observed until it was abated. The SSO discharged to surface water, none was recovered. Approximately 100 to 125,000 gallons typically flow through this station each day.

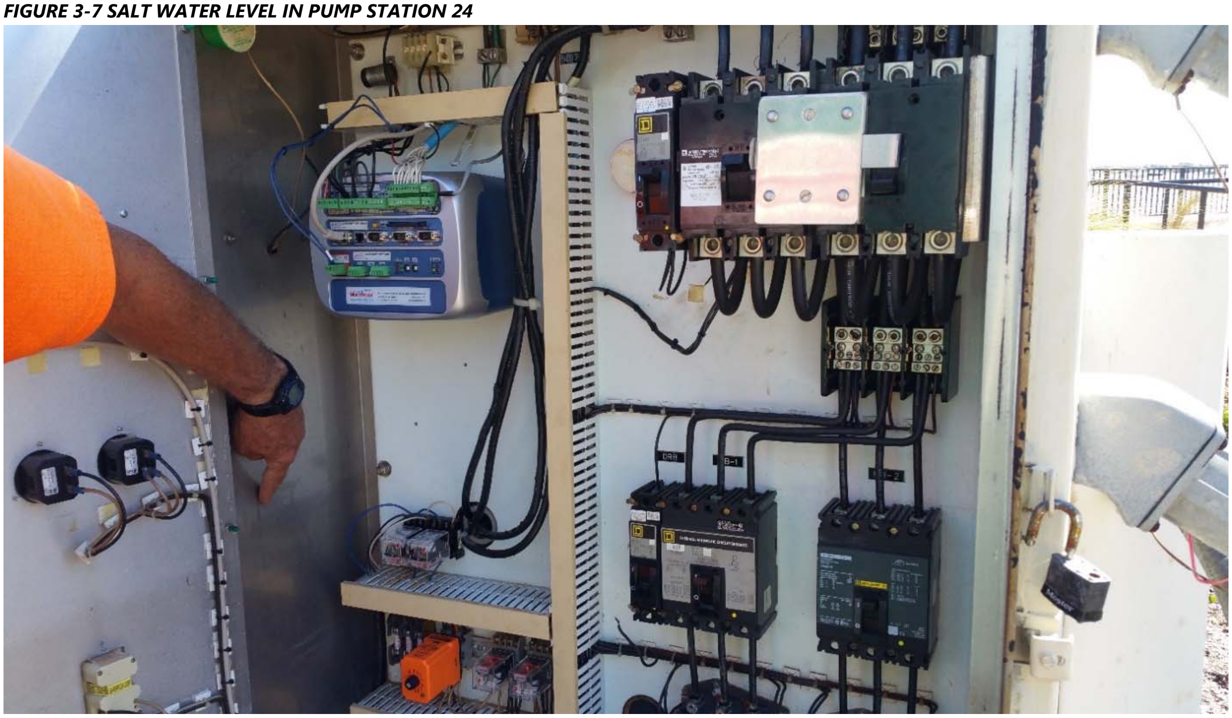
The primary failure mode at this location was tidal inundation. Raising the generator or the control panel would not have prevented the SSO. Conversations with the City of St. Augustine Public Works staff indicate that the pump station is a canned system and the pumps in it failed because they were flooded by the tidal surge flooding. The City plans to upgrade this system with submersible pumps that will be able to operate under flood conditions.

3.7.4.5 Incident No. 8032—5 Bayfront by St. Francis

The SSO occurred at pump station 24. The volume of the SSO was 45,000 gallons. The SSO release volume was estimated based on flow rates into the pump station and the duration of time from when the SSO was first observed until it was abated. The SSO discharged to surface water, none was recovered.

The primary failure mode at this location was inundation from tidal surge. Once the control panel flooded, power to the pumps failed. Figure 3-7 provides a perspective on the height of panel flooding experienced, the finger in the photo indicates the height of the salt water inside of the panel during the storm event. The pump station was not equipped with an emergency generator. If it had been, it would have reportedly been flooded. Approximately 250,000 gallons typically flow through this station each day.

FIGURE 3-7 SALT WATER LEVEL IN PUMP STATION 24



3.7.4.6 Incident No. 8032-6 1111 N. Ponce de Leon Blvd.

The SSO was a force main break. The volume of the SSO was 25,150 gallons. The SSO release volume was approximated based on estimated flow rates through the force main and the duration of time from when the SSO was first observed until it was abated. All of the SSO was recovered, none reached surface water. The failure of the force main was associated with the extreme flow in conjunction with the fact that the crown of the cast iron force main was subjected to hydrogen sulfide corrosion when operating under typical flow conditions. The extreme flows and pressures in combination with the weakening due to corrosion caused the force main to break. The unique location of the force main failure adjacent to a retention pond allowed the containment and ultimate recovery of the SSO discharge.

The primary failure mode at this location was the extreme flows and pressures that the force main was subject to in conjunction with the corrosive weakening of the force main. The location of the force main failure adjacent to a retention pond suggests the value of locating pump stations adjacent to retention ponds that can contain SSOs and reduce the volumes discharged to the environment.

3.7.4.7 City of St. Augustine Summary

Of the six SSOs evaluated three were associated with the tidal surge experienced by the City. Information from the St. Johns County EMO indicates that high water levels associated with the surge were as much as 7.48 ft. in elevation (NGVD, 1988). For one of three incidents Public Works staff indicated they would be upgrading the inundated station with submersible pumps that can operate under flooded conditions.

Of the remaining three SSOs two were associated with power outages and one was a force main break. The two power outages may have been averted if an emergency generator was present but the financial realities of effectively managing public works resources precludes the deployment of emergency generators to all stations. The force main break failure reportedly resulted from the extreme flows experienced by the cast iron pipe and weakening from the corrosive effects of hydrogen sulfide. The damaged force main was repaired and the city is working to abandon the force main in the future.

It is worthwhile to note that SSO No. 8032-6 and two of the other SSOs, which weren't evaluated, had all or portions of their volumes contained by retention ponds or blocked stormwater drainage features. These spills are examples of conditions that initially contained the release and ultimately prevented all or portions of the release from entering surface water and the environment.

3.8 SUMMARY OF FAILURE MODES

In summary, the most frequently occurring failure mode was power loss, whether caused by storm surge flooding, wind, or utility outages. In some instances backup power systems were in place, but failed to operate as designed. Power loss was the failure mode for all JEA SSOs and the majority of those which occurred in St. Augustine.

The second most frequently occurring failure mode was I&I. Failures due to I&I led to the greatest volume of SSOs by far. These failures were associated with excessive precipitation during hurricane Hermine that overwhelmed stormwater systems and infiltrated wastewater systems. All SSOs and unpermitted effluent releases occurring at the St. Petersburg, Pinellas County, and Gulfport utilities were caused by I&I related failures. The largest incidents by volume occurred at the St. Petersburg utility and were caused by I&I related to excessive precipitation during hurricane Hermine.

WWTP Anomalies led to large volume effluent releases at Clearwater and Largo. This failure mode led to a total of 14,780,000 gallons spilled in the two utilities.

Pump Failure led to three incidents at the Clearwater utility that totaled 18,780,560 gallons.

Flooding/Inundation led to a total of 60,256 gallons spilled in St. Augustine. These SSOs were related to storm surge associated with Hurricane Matthew and inundation of pump stations that were not designed to operate in wet conditions.

Finally, a force main failure occurred in St. Augustine, causing a 25,150 gallon SSO, when a force main failed due to the high storm related flows and chronic corrosion of the pipe crown from hydrogen sulfide.

Table 3-10 details the SSOs by volume, the failure mode that led to the SSO, and the cause of the SSO reported to RS&H as reported to FDEP and/or through utility employee interviews.

TABLE 3-10 INCIDENTS BY VOLUME AND FAILURE MODE

FDEP ID # 2016-	Volume (Gallons)	Failure Mode	Utility	Cause of Incident (based on staff interviews)
3593	93,000,000	I & I	St. Petersburg	I & I
3560	58,000,000	I & I	St. Petersburg	I & I
3704	11,880,000	WWTP Anomaly	Largo	Spill #2 was a result of bottlenecks created during the Disinfection & Effluent Pumping Improvement Project
3568	10,000,000	Pump Failure	Clearwater	Marshall St- main sewage pump headwork failure
3566	8,000,000	Pump Failure	Clearwater	Marshall St- main sewage pump headwork failure
3507	7,130,000	I & I	Pinellas County	None
3636	6,562,080	Pump Failure	Clearwater	Marshall St- main sewage pump headwork failure
4316	5,000,000	Power Loss	JEA	Power Outage
3752	4,218,480	Pump Failure	Clearwater	Marshall St- main sewage pump headwork failure
3563	2,900,000	WWTP Anomaly	Clearwater	East- Capacity of a portion of the Corona Interceptor system with a reduced line size.
3960	1,100,000	Power Loss	JEA	Power Outage
3572	892,500	I & I	Gulfport	Excessive rainfall
4002	848,000	Power Loss	JEA	Power Outage
4011	514,000	Power Loss	JEA	Power Outage
4008	387,000	Power Loss	JEA	Power Outage
4313	337,000	Power Loss	JEA	Power Outage
4325	327,000	Power Loss	JEA	Power Outage
4263	288,000	I & I	Pinellas County	I & I; Power Outage
4004	194,000	Power Loss	JEA	Fallen Tree
4300	144,000	I & I	Pinellas County	I & I

TABLE 3-10 INCIDENTS BY VOLUME AND FAILURE MODE

FDEP ID # 2016-	Volume (Gallons)	Failure Mode	Utility	Cause of Incident (based on staff interviews)
8032-1	108,000	Tidal Surge System Flooding	St. Augustine	Power failure at all three stations; PS 50: moisture in control panel, PS 52: control panel flooded
8032-3	49,500	Power Loss	St. Augustine	Power failure
8032-5	45,000	Flooding / Inundation	St. Augustine	Power failure, control panel flooded
8032-2	29,000	Power Loss	St. Augustine	Power failure
8032-6	25,150	Force Main Failure	St. Augustine	Force main break (10/9/16, 4 pm - 6 pm)
8032-4	24,000	Power Loss	St. Augustine	Power failure, entire station flooded

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4.0 EMERGENCY RESPONSE PLANS AND INDUSTRY

This section evaluates the utility Emergency Response Plans relative to the Ten States Standard and EPA Guidelines within the context of the failure modes identified in Section 3 (i.e. Power loss, I&I, inundation, WWTP anomalies, force main breaks and pump failure). In addition BMPs for these failure modes were identified by researching New York City's response to Hurricane Sandy, New Orleans' response to Hurricane Katrina, and Houston, TX's and Pensacola FL's response to recent extreme precipitation events.

4.1 TEN STATE STANDARDS

The Ten State Standards (TSS), created by the Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers and adopted by the states represented, are a guide in the design and preparation of plans and specifications for wastewater facilities. In Chapter 40, Wastewater Pumping Stations, of the TSS, Section 47 Emergency Operation states "The objective of emergency operation is to prevent the discharge of raw or partially treated wastewater to any waters and to protect the public health by preventing back-up of wastewater and subsequent discharge to basements, streets, and other public and private property." The following are wastewater pumping station design requirements as directed by the Ten State Standards.

The TSS requires wastewater pumping station structures and electrical and mechanical equipment to be protected from physical damage by the 100 year flood and remain fully operational during the 25 year flood. Redundant design is a requirement of TSS and each pumping unit shall have capacity such that, with any unit out of service, the remaining units will have capacity to handle the design peak hourly flow.

Buoyancy is another design requirement of the TSS and shall be considered where high groundwater conditions are anticipated and adequate provisions shall be made for protection. Electrical equipment in raw wastewater wet wells are required to comply with the National Electrical Code requirements for Class I, Division 1, Group D locations.

Pumping stations designed in accordance with TSS are required to have alarm systems with backup power and shall activate in case of power failure, dry well sump and wet well high water levels, pump failure, unauthorized entry, or any other cause of pump station malfunction. The alarm system is required to transmit and identify alarm conditions to a municipal facility or the responsible person(s) in charge of the lift station during off-duty hours.

Emergency pumping capability is a requirement of the TSS unless adequate storage capacity is provided with on-system overflow prevention. As stated in the TSS, emergency pumping capability shall be accomplished by one of the following:

- Connection of the station to at least two independent utility substations able to supply power without interruption;
- Portable or in-place internal combustion engine equipment to generate electrical or mechanical energy; and
- Portable pumping equipment

The TSS recommends Emergency High Level Overflows to be installed for use when possible periods of extensive power outages, mandatory power reductions, or uncontrollable emergency conditions are foreseen. A high level overflow is to supplement alarm systems and emergency pumping capability in order to achieve the TSS emergency operations objective.

4.2 EPA GUIDELINES

On February 12, 2013, the White House Office of the Press Secretary released *Presidential Policy Directive – Critical Infrastructure Security and Resilience Presidential Policy Directive/PPD-21*, which states: "It is the policy of the United States to strengthen the security and resilience of its critical infrastructure against both physical and cyber threats." To these ends, the Environmental Protection Agency (EPA) published *Flood Resilience – A Basic Guide for Water and Wastewater Utilities*. Which is a guide for local utilities on strategy to increase the utility's resilience to flooding. Utilities can build flood resilience by executing mitigation measures. Emergency planning activity, equipment modification/upgrade, or new capital investment/contraction project are all measures that can be taken to mitigate flooding. An emergency response plan, barriers around key assets, elevated electrical equipment, emergency generators, and bolted down chemical tanks are a few examples of mitigation measures.

The EPA guide includes worksheets with four basic steps to utilize as an approach to flood resilience:

Step 1 is to understand the threat of flooding. This step is to recognize the various factors involved in flooding, including rainfall, topography, river-flow, drainage, and tidal-surge. As indicated in the Flood Resilience guide worksheet, this is achieved by: 1) Reviewing utility records of past flooding events; 2) Identifying potential sources of flooding that could impact the utility; 3) Obtaining Federal Emergency Management Agency (FEMA) 100-year and 500-year Flood Maps; 4) Identifying within which floodplain the utility systems is located; and 5) Defining what flooding threat to prepare for.

Step 2 is to identify vulnerable assets and determine consequences. This step includes conducting on-site inspections and measuring/documenting elevations of utility assets to determine vulnerability to flooding. Consequences are then determined based on replacement costs and impacts to facility operations. Finally, determine priority need for mitigation to improve flood resilience. Priority shall be based on both the vulnerability of the asset/operation to flooding and the consequences for the utility.

Step 3 is to identify and evaluate mitigation measures. First, the utility's requirements to maintain a minimum level of service during a flood needs to be established. Then identifying what flood mitigation measures can prevent damage to key assets and disruptions to those identified in Step 2. Finally, those identified mitigation measures should be pursued based on cost, effectiveness, and practicality. In this final step, each mitigation effort shall be classified as low, medium, or high and thoughts provided in evaluating the mitigation option.

Step 4 is to develop a plan to implement mitigation measures. The plan shall have specific timeframes on when and how to implement recommended mitigation options identified in Step 3. Funding sources are sought for mitigation measures during this step through internal utility capital improvement funding, Local/State funding/bonds, and/or Federal funding. Finally, follow the implementation plan to build resilience to flooding.

The EPA's *Flood Resilience – A Basic Guide for Water and Wastewater Utilities* is a guide for local utilities on strategy to increase the utility's resilience to flooding by identifying vulnerabilities, recommending measures to mitigate flooding, establishing a plan, and following the plan. More information as well as the EPA worksheets can be found here:

https://www.epa.gov/sites/production/files/2015-08/documents/flood_resilience_guide.pdf

4.3 EMERGENCY RESPONSE PLANS RELATIVE TO FAILURE MODES

Each municipality has their own set of standards that they follow in the event of a hurricane. These standards may come in the form of Standard Operating Procedures (SOP), Emergency Response Plans (ERP) or Emergency Operations Plans (EOP).

Each municipality's emergency response plan is unique in representing attention to detail as a function of funding (larger utilities tend to have more in depth plans). Most are generalized local public health, safety, and welfare for a wide range of disasters. Some exhibit specifics related to SSO notification and restoration after a severe weather event.

Emergency response/operation plans at the highest levels indicate interface and reporting responsibilities assigned to titled administrative and supervisory positions, multi-tiered levels of up-line reporting as well as standby responsibilities, and ultimately instructions to workers who will accomplish preventative measures and restoration after a weather related event. In general most plans are based upon after-the-fact notification and cleanup response as required by FDEP regulation 62-604.550 Abnormal Events.

4.3.1 City of St. Petersburg

The City of St. Petersburg has both a Water Reclamation Facility Emergency Response Plan (WRFERP) and a Water Resources Emergency Operations Plan (WREOP) in place as means to prepare and respond to emergency situations.

Per the Water Resources Emergency Operations Plan, the purpose is to:

- Identify emergency situation(s) that could potentially jeopardize public health and safety.
- Provide a framework for an organized, coordinated response to the emergency.
- Outline Departmental roles and responsibilities during the emergency, including:
  - Isolating, containing, quarantining, and monitoring the emergency that has developed.
  - Determining the magnitude of impact to the City of St. Petersburg (City) utility service area.
  - Prioritizing and scheduling corrective action(s).
- Establish uniform policies and procedures consistent with the City's Disaster Operations Plan (DOP).
- Provide for organized post-emergency relief operations, with short and long-term recovery assistance from other City Departments and Municipal, County, State, and Federal jurisdictions.
- It does not provide quantitative means for estimation of overflow.
- Counter measures for severe weather SSO events are not indicated.

The purpose of the WRFERP is to establish the procedure and instruct the personnel required in the days leading up to a major weather event as well as instructions for cleanup and damage assessment.

The WRFERP also assesses some of the threats of flooding as they relate to operations of facilities as well as how to mitigate some of these threats.

4.3.2 City of Gulfport

The City of Gulfport also has Standard Operating Procedures plan in place to document protocols for notification and cleanup response if an overflow occurs at wastewater collection facilities within the City of Gulfport wastewater collection system. The SOP lists a municipal organization chart with notification responsibilities. SSO amounts are based on "representative" photographs for estimating overflows at manholes. It is unknown at this time how the city prepares for major storm events before they occur. Countermeasures for preventing SSO due to severe weather events are not indicated.

4.3.3 City of Largo

The City of Largo has an Emergency Operations Plan in place that is meant to provide an immediate, coordinated response by the Environmental Services Department in the event of a hurricane. The city also has an Emergency Response Plan that establishes the personnel and procedures that are required to mitigate the effects of a hurricane. Neither the Emergency Response Plan nor the Emergency Operations Plan provide a quantitative means for estimation of overflow. Countermeasures for preventing SSO due to severe weather events are not indicated. The plan is divided into seven "Response levels" based on the condition of the storm:

- Condition 5 – Hurricane Season (June 1 – Nov 30)
- Condition 4 – Alert – Hurricane Advisory indicating potential threat within 72 hours.
- Condition 3 – Hurricane Watch or approximately 36-48 hours to forecasted landfall
- Condition 2 – Hurricane Warning or approximately 12-24 hours to forecasted landfall
- Condition 1 – 12 hours or less to forecasted landfall
- Landfall – Threat removed or damage assessment and recovery
- Re-Entry – Recovery is underway

4.3.4 Pinellas County

Pinellas County Utilities has an Emergency Response Plan in place as a means to respond to emergency situations and cleanup response. The ERP sets response levels for impending storms and how to respond to them accordingly. South Cross Bayou WRF has specific countermeasures established for each Response level. The Levels are as follows:

- Response Level 7: Hurricane Preparedness & Planning (March 1 – June 1)
- Response Level 6: Hurricane Season (June 1 through November 30)
- Response Level 5: Hurricane Alert (120 hours to 48 hours) (5 days to 2 days) to landfall
- Response Level 4: Hurricane Watch (48 hours to 36 hours) (2 days to 1-1/2 days)
- Response Level 3: Hurricane Warning (24 - 36 Hours)
- Response Level 2: Hurricane Evacuation (12 - 24 Hours)
- Response Level 1: Hurricane Landfall (0 -12 Hours or 40 mph or higher winds)
- Response Level 0: Recovery, All Clear / Re-Entry (40 mph winds or less)

Each of these response levels come with a set of tasks that allow the municipality the ability to prepare for a storm. As part of their ERP, Pinellas County also keeps a record of pump stations and generators in the event that power is lost.

4.3.5 City of Clearwater

The City of Clearwater has an Emergency Response Plan in place, however, it is for the entire utility system. The Utility ERP contains information that relates to the security of the system, therefore the City of Clearwater elected to refrain providing a copy of the utility ERP.

4.3.6 JEA

JEA has procedures in place for restoring functionality to each of their systems known as Functional Response Procedures (FRP). JEA has an FRP in place for Wastewater Plants and Lift Stations, Water Plants and Pump Stations and Water/Wastewater/Reuse Water Distribution and Collection. The FRP is written as an SSO notification and cleanup response and is based on the Florida Rural Water Association Template. In each of these procedures, the FRPs have the following objectives:

- Determine the nature/extent of damage to JEA resources for proper system restoration prioritization and resource allocation.
- Provide information after an emergency or disaster and detail the situation, location, and extent and nature of damage.
- Provide information to determine priorities and requirements for deployment of resources and personnel in affected areas.
- Determine need and types of materials and external resources, including mutual aid, contract crews and federal/state assistance.
- Document and support requests for assistance.

As a countermeasure, immediately prior to the onset of an extreme weather event, JEA's wastewater staff prepares facilities by securing equipment, ensuring the 240 fixed generators are fueled, and positioning the 80 portable generators/diesel pumps across the service area for post storm deployment. However, there are no written emergency operation procedures for lift stations. During the storm, JEA also leveraged available resources from FLA Warn to augment its portable fleet and operations staff.

JEA also has a Sanitary Sewer Overflow Response Plan which documents each event with the intention to "ensure proper SSO reporting and minimize the adverse effects that may be caused by Sanitary Sewer Overflow".

4.3.7 City of St. Augustine

The City of St. Augustine currently utilizes the "Hurricane Operations Plan 2015" as the public works department hurricane response plan. During hurricane events, the plan creates a chain of command made up of supervisors and managers of their respective utility reporting to the director and deputy director. The plan acts as a guide to the personnel associated with the City of St. Augustine as to their specific responsibilities in the event of a storm. The plan "outlines the procedures for the mitigation of a hurricane-related emergency" by establishing five distinct time frames; the Pre-Emergency period, the Hurricane

Watch Period, Hurricane Warning Period, Landfall, and the Recovery period. Countermeasures for preventing SSO due to severe weather events are indicated, however, there are no written emergency operation procedures for lift stations.

4.3.8 Observations and Recommendations

The evaluated ERPs are generally written as a reactionary guide, rather than an SSO prevention guide in advance of severe weather events. After review of documents provided by the municipalities, it is recommended that emergency operations plans be developed and included within the ERPs to mitigate potential SSOs. The following items represent examples of general enhancements that could be considered for inclusion within ERP procedures to prevent or minimize SSOs and unpermitted discharges:

- The ERP should identify locations with increased SSO potential.
- The ERP should have provisions requiring coordination with the Public Works Department for inspection of the stormwater collection system to ensure that there are no blockages and that the conveyance system is functioning properly.
- The ERP should have provisions to ensure that all backup generators are fully fueled and functioning correctly.
- The ERP should address procedures for providing maximum storage capacity at WRFs in order to mitigate increased flow rates resulting from I&I.
- The ERP should include provisions to leverage available resources from the FLA Warn system.
- The ERP should provide instructions for preparing facilities by securing equipment.
- THE ERP should identify locations across the service for positioning of portable generators/diesel pumps.
- The ERP should consider running on emergency generators from immediately prior to a severe weather event until after the severe weather event.

These are examples of procedures that could be performed; this is not an all-inclusive list. Each municipality should evaluate SSOs and unpermitted discharges after each severe weather event to identify and establish procedural updates to mitigate future incidents. Further, in depth, evaluations of each municipality's wastewater collection system should be considered for the development of guidelines in preparation for severe weather events.

4.4 BENCHMARKING

Benchmarking is a strategic management process, in which selected aspects of an organization's operations are compared to peers within the same industry with the goal of identifying best management practices (BMPs) that have been successfully applied by others. Benchmarking studies can take different forms and may be focused on operational, organizational, or financial aspects of an organization. For the purposes of this report, the benchmarking effort centered on revealing recently developed, applicable and proven BMPs to improve wastewater utility resilience in coastal communities impacted by hurricanes and other extreme weather events. The BMPs identified are practical, cost-effective operational measures that could potentially be implemented by utilities in Florida. Implementing the identified BMPs will improve utilities' storm preparedness, and help ensure clean drinking water and healthy waterways by reducing the risk of future SSOs.

4.4.1 Benchmarking Process

RS&H conducted benchmarking research on four cities to identify BMPs others have recommended and implemented following extreme precipitation and hurricane events which caused power loss, inflow and infiltration, flooding/inundation, WWTP anomalies, force main failures, and/or pump failures. The four cities researched included New York City, which experienced Hurricane Sandy in 2012; New Orleans, which experienced Hurricane Katrina in 2005, Houston, Texas, which experienced a series of extreme precipitation events in 2015 and 2016; and Pensacola, Florida, which experienced up to 20 inches of precipitation in one day in 2014.

4.4.1.1 New York City, NY

New York City's (NYC) Bureau of Wastewater Treatment operates 14 water pollution control plants treating an average of 1.5 billion US gallons of wastewater a day. These include 89 wastewater pump stations, 8 dewatering facilities and 490 sewer regulators. Hurricane Sandy struck the United States about 8 p.m. eastern time on Oct. 29, 2012, making landfall near Atlantic City, N.J. with 80 mph winds. Sandy's storm surge was increased by a full moon that made high tides 20 percent higher than normal. The record storm surge that accompanied Hurricane Sandy submerged many NYC treatment plants and associated lift stations in seawater, degrading their ability to pump and treat wastewater. Ten of the City's 14 wastewater treatment plants and more than 40 sanitary sewer pumping stations were damaged in the hurricane. Nine of the damaged wastewater treatment plants had spills that each exceeded 10 million gallons. New York City reported six sewage spills larger than 100 million gallons, and 28 larger than one million gallons. In all, an estimated 1.6 billion gallons of raw and partially treated sewage spilled in NYC during hurricane Sandy.

Following the storm, NYC's Department of Environmental Protection identified six protective strategies to be incorporated into the City's wastewater facility design standards, discussed in section 4.4.2 below. RS&H's review of NYC's post-Sandy response to restoring the City's sanitary sewer infrastructure revealed more than a dozen best management practices (BMPs) applicable to other communities.

4.4.1.2 New Orleans, LA

Early in the morning of August 29, 2005, Hurricane Katrina struck the Gulf Coast of the United States. The 400-mile wide storm made landfall with a Category 3 rating, bringing sustained winds of 100–140 miles per hour. It is estimated that 1,236 public water systems were damaged or destroyed by Katrina. 200 sewage-treatment plants were affected in Louisiana, Mississippi and Alabama. In New Orleans, loss of power to lift stations created sewage overflows into homes, businesses and streets, and resulted in contamination of hundreds of miles of water-distribution pipes. Approximately 80% of New Orleans was flooded during Katrina, with some areas inundated up to 20 feet deep. Due to the severity of the flooding that occurred in the city, the total volume of SSOs that occurred is not known.

The Sewerage & Water Board of New Orleans serves an area of approximately 86 square miles and a population of approximately 350,000. It consists of more than 1,300 miles of gravity collection and trunk sewers ranging in size from 8-inches to 84-inches in diameter and more than 120 miles of force mains ranging in size from 6-inches to 72-inches in diameter. There are 86 sewer lift pump stations which convey wastewater to the City's two wastewater treatment plants, one on the East Bank and one on the West Bank (Algiers) of the Mississippi River with a combined capacity of 132 million gallons per day (mgd). Hurricane

Katrina destroyed the East Bank treatment plant and flooded almost every lift station on the East Bank. In 2011, the Sewerage & Water Board estimated $136.3 million in FEMA funds had been spent to repair Katrina's damages to the sewer system. RS&H reviewed annual reports and other documents detailing BMPs and upgrades to the system following Katrina. These range from large scale flood protection projects to policy recommendations.

4.4.1.3 Houston, TX

The City of Houston, Texas has experienced multiple extreme precipitation events in the last few years, overwhelming the sanitary sewer systems and causing SSOs totaling hundreds of thousands of gallons. Houston received more than 10 inches of rainfall in May, June, and October of 2015, equivalent amounts in April and May of 2016, and more than 7.5 inches in the first two days of June 2016. On May 26, 2016, more than 15 inches of rain fell just northeast of Houston within a 12 hour period, just a few days after more than 20 inches fell northwest of the city. The rainfall was the region's second 100-year rainstorm in less than a week. This event flooded the Southwest Wastewater Treatment Plant, damaging electrical and mechanical systems and caused the release of more than 100,000 gallons of untreated wastewater. RS&H reviewed the Water and Wastewater Utility's website and Capital Improvement Plan Process Manual to identify BMPs the City is implementing following the flood-related spills.

4.4.1.4 Pensacola/Escambia County, FL

On April 29, 2014, Pensacola and surrounding regions in Escambia County received more than 20 inches of precipitation overnight. The area had already experienced a relatively large storm event the previous day, resulting in saturated ground which was unable to absorb the heavy rainfall. Practically all of the rainfall was converted to runoff, which produced historic flooding. The precipitation was later described as approaching a 500-yr storm event. The flood conditions in Escambia County displaced residents, washed out roadways and caused more than $25M in damage to public facilities. Several sanitary sewer overflows (SSOs) occurred as a result of the surcharge of stormwater (from storm drains, retention ponds, curb inlets and overloaded surface drainage) that entered the sewer collection system. In all, approximately 30 SSOs occurred, totaling approximately 737,000 gallons. More than a dozen BMPs were identified from Escambia County's Stormwater Advisory Team (SWAT) and from the Emerald Coast Utility Authority's (ECUA) 2014 and 2015 annual reports.

4.4.2 Benchmarking Results

The benchmarking study identified 30 BMPs from the four utilities that are applicable to utilities in Florida. The selected BMPs have the potential to address the six failure modes identified that contributed to SSO's experienced by Florida utilities during hurricanes Hermine and Matthew. These failure modes include: power loss, I&I, flooding/inundation, WWTP anomalies, force main failures, and pump failures. Some BMPs address failure modes through infrastructure improvements/upgrades, others through organizational changes, improved technology, or regulatory approaches to be developed in cooperation with government agencies.

RS&H identified five broad goals that emerged from BMPs implemented by the reported wastewater utilities. These include:

1. **Effectively managing existing assets** to ensure maintenance is adequate to prevent failures and that systems operate as designed;

2. **Maximizing or improving system performance** to prevent WWTP anomalies, force main failures, and pump failures;
3. **Reducing stormwater infiltration** to reduce failures caused by excessive precipitation and/or storm surge flooding entering the wastewater system;
4. **Improving resilience** by reducing vulnerability to extreme weather events by flood-proofing infrastructure and installing backup power systems; and,
5. **Improving insurance** coverage to ensure private portions of wastewater systems are properly maintained to increase resilience/reduce I&I prior to a storm, speed recovery afterwards, and reduce costs for affected customers,.

Utilities in New York, New Orleans, Houston and Pensacola used a number of strategies to meet the goals above and proactively address many of the same failure modes that contributed to SSOs in Florida during hurricanes Hermine and Matthew. Some utilities formalized resilience strategies in planning documents; for instance NYC's Department of Environmental Protection identified six protective strategies. These include: elevating equipment above critical flood elevations; making pumps submersible/encasing electrical equipment in watertight casings; constructing static barriers around vulnerable locations; sealing structures with watertight windows and doors; temporary sandbagging facilities; and providing backup power generation to pumping stations. Other utilities did not provide a formal list of strategies, but they could be inferred through commonalities among the BMPs they put in place. The following ten strategies used by the utilities studied:

1. **Improving asset management** by implementing an asset management program to guide capital investments, and utilizing a needs-based prioritization approach to plan infrastructure upgrades;
2. **Improving flow monitoring** of the system by installing rain gauges, flow monitors and electronic monitoring systems for pump/lift stations;
3. **Increasing system capacity** by increasing catch basin cleaning/maintenance and upgrading force mains;
4. **Improving grease control** through education/promotion of grease recycling, and by updating grease trap regulations;
5. **Leveraging GIS technology** to model/improve system performance and identify drainage problems;
6. **Identifying maintenance needs** by using Closed Circuit Television (CCTV), smoke testing, cathodic protection surveys, ultrasonic testing and more frequent inspections;
7. **Reducing infiltration** by improving drainage of low lying areas, revising land development codes, incentivizing green infrastructure, low-impact development and daylighting deculverting streams;
8. **Improving backup power systems** by expanding the use of backup generators and/or large scale backup power systems;
9. **Implementing flood protection measures** that include elevating equipment and electronic controls, installing physical flood barriers, and using sandbags as a temporary measure; and
10. **Offering customers an insurance option** for repair of private service lines to cover their costs after a storm and quickly get systems operational again.

4.4.3 Recommendations and Conclusions

The results of the benchmarking exercise were then focused on the six failure modes discussed in Section 3.0. These failure modes include: power loss, inflow and infiltration, flooding/inundation, WWTP anomalies, force main failures, and pump failures. Table 4-1 below shows the goal categories, the specific objectives to achieve the goals, the identified BMPs, their description and purpose, the utilities studied that recommended or implemented the BMP, and the identified failure modes the BMP could prevent or address. Note that some BMPs have the potential to address multiple failure modes (for example, improved Asset Management can address all failure modes identified).

TABLE 4-1 BEST MANAGEMENT PRACTICES DRAWN FROM BENCHMARKING RESEARCH

#	Goal	Strategy	BMP	BMP Description/ Purpose	Utility(s)	Failure Mode(s) Addressed
1	EFFECTIVELY MANAGE ASSETS	Asset Management	Implement an Asset Management Program	Make the right capital investments at the right time using an Asset Management Plan	NY	Power Loss I&I Flooding/Inundation WWTP Anomalies Force Main Failures Pump Failures
2	EFFECTIVELY MANAGE ASSETS	Asset Management	Utilize needs prioritization approach for upgrading lift stations and other infrastructure	Utilize a formal needs-based prioritization approach to plan upgrades to vulnerable infrastructure	H; P	Power Loss I&I Flooding/Inundation WWTP Anomalies Force Main Failures Pump Failures
3	MAXIMIZE SYSTEM PERFORMANCE	Monitor Flow	Install flow sensors / rain gauges	Remotely monitor high flow conditions, determine system capacity under various weather scenarios	NY; P	I&I Flooding/Inundation
4	MAXIMIZE SYSTEM PERFORMANCE	Improve Capacity	Increase catch basin cleaning and maintenance	Prevent flooding and protect water quality	NY	I&I Flooding/Inundation
5	MAXIMIZE SYSTEM PERFORMANCE	Leverage GIS Technology	Model system performance using GIS	Model system performance under different conditions and predict problem spots	NY	Power Loss I&I Flooding/Inundation WWTP Anomalies Force Main Failures Pump Failures
6	MAXIMIZE SYSTEM PERFORMANCE	Grease Control	Update grease trap regulations	Reduce grease clogs by updating grease trap regulations, increase inspections, and educate the business and development communities about compliance	NY; P	WWTP Anomalies Force Main Failures Pump Failures
7	MAXIMIZE SYSTEM PERFORMANCE	Grease Control	Promote grease recycling	Reduce amount of grease in system by promoting and incentivizing yellow grease recycling for use as biodiesel fuel	NY; P	WWTP Anomalies Force Main Failures Pump Failures
8	MAXIMIZE SYSTEM PERFORMANCE	Monitor Flow	Electronic monitoring of pump/lift stations	Continuously monitor performance and maximize system storage capacity through remote electronic monitoring	NY	WWTP Anomalies Force Main Failures Pump Failures

TABLE 4-1 BEST MANAGEMENT PRACTICES DRAWN FROM BENCHMARKING RESEARCH (cont'd)

#	Goal	Strategy	BMP	BMP Description/ Purpose	Utility(s)	Failure Mode(s) Addressed
9	MAXIMIZE SYSTEM PERFORMANCE	Identify Maintenance Needs	Utilize CCTV and smoke testing to identify maintenance needs	Identify leaks or needed maintenance through regular CCTV and smoke testing studies	NO	WWTP Anomalies Force Main Failures Pump Failures
10	MAXIMIZE SYSTEM PERFORMANCE	Identify Maintenance Needs	Conduct annual cathodic protection survey of sewage collection systems	Identify leaks or needed maintenance through annual cathodic protection survey	NO	Force Main Failures
11	MAXIMIZE SYSTEM PERFORMANCE	Increase Capacity	Increase capacity of mains to handle high flow events	Replace force mains or use cured-in-place pipe lining approach (CIPPL)	H;P	Force Main Failures
12	MAXIMIZE SYSTEM PERFORMANCE	Leverage GIS Technology	Utilize GIS to ID drainage problem areas and prioritize improvements	Prioritize stormwater drainage improvements using GIS analysis	H	I&I Flooding/Inundation
13	MAXIMIZE SYSTEM PERFORMANCE	Leverage GIS Technology	Utilize GIS in asset management approach	Improve Asset Management planning using GIS	P	Power Loss I&I Flooding/Inundation WWTP Anomalies Force Main Failures Pump Failures
14	MAXIMIZE SYSTEM PERFORMANCE	Identify Maintenance Needs	Implement monthly testing of generators and automatic transfer switches (ATFs)	Ensure generators and ATFs work as designed during a storm event or power outage	P	Power Loss
15	REDUCE STORMWATER INFILTRATION	Reduce Infiltration	Promote Green Infrastructure (GI) approaches	Promote GI and incorporate into project designs to manage stormwater runoff and reduce I&I	NY; NO	I&I Flooding/Inundation
16	REDUCE STORMWATER INFILTRATION	Reduce Infiltration	Improve drainage of low-lying areas	Reduce I&I by improving stormwater drainage in problem areas	NO	I&I Flooding/Inundation
17	REDUCE STORMWATER INFILTRATION	Reduce Infiltration	Revise land development codes to reduce I&I	Revise land development codes to reduce stormwater runoff and reduce I&I	P	I&I Flooding/Inundation

TABLE 4-1 BEST MANAGEMENT PRACTICES DRAWN FROM BENCHMARKING RESEARCH (cont'd)

#	Goal	Strategy	BMP	BMP Description/ Purpose	Utility(s)	Failure Mode(s) Addressed
18	REDUCE STORMWATER INFILTRATION	Reduce Infiltration	Develop LID manual and provide incentives for implementation	Reduce stormwater runoff / I&I by incentivizing Low Impact Development	P	I&I Flooding/Inundation
19	REDUCE STORMWATER INFILTRATION	Reduce Infiltration	Require new developments to submit 100-year flood elevations for entire systems	Improve resiliency of new developments by requiring all structures to be located outside the 100-year floodplain	P	I&I Flooding/Inundation
20	REDUCE STORMWATER INFILTRATION	Reduce Infiltration	Consider daylighting streams that have been covered over to restore natural flow and riparian environments	Improve natural flow and reduce stormwater runoff/ I&I by daylighting streams	P	I&I Flooding/Inundation
21	UNDERSTAND AND REDUCE VULNERABILITY	Improve Risk Assessment	Consider all flood risks when designing projects	Upgrade flood risk analysis to consider all current and future conditions	NY	Power Loss I&I Flooding/Inundation WWTP Anomalies Force Main Failures Pump Failures
22	UNDERSTAND AND REDUCE VULNERABILITY	Backup Power	Install large backup power station for WWTP operations	Prevent WWTP power failure through large scale backup power station	NO	Power Loss
23	UNDERSTAND AND REDUCE VULNERABILITY	Identify Maintenance Needs	Use ultrasonic testing to study sewer force main reliability and service life	Monitor service life of sewer force mains to prioritize maintenance or replacement	NO	Force Main Failures
24	UNDERSTAND AND REDUCE VULNERABILITY	Backup Power	Expand use of backup generators	Provide backup power for lift stations during power outages	NO; P	Power Loss
25	UNDERSTAND AND REDUCE VULNERABILITY	Flood Protection	Construct flood control structures to protect WWTPs	Flood proof WWTPs or other vulnerable infrastructure by constructing earthen berms or other flood control structures	NO	Flooding/Inundation WWTP Anomalies

TABLE 4-1: BEST MANAGEMENT PRACTICES DRAWN FROM BENCHMARKING RESEARCH (cont'd)

#	Goal	Strategy	BMP	BMP Description/ Purpose	Utility(s)	Failure Mode(s) Addressed
26	UNDERSTAND AND REDUCE VULNERABILITY	Flood Protection	Upgrade/Rehab/ Flood proof pump stations	Renovate pump/lift stations to elevate electronics and reduce chance of floodwater intrusion	NO	Power Loss I&I Flooding/Inundation WWTP Anomalies Force Main Failures Pump Failures
27	UNDERSTAND AND REDUCE VULNERABILITY	Flood Protection	Stormproof vulnerable infrastructure through physical flood barriers and elevating electronic controls	Flood proof lift stations and other vulnerable infrastructure by elevating electronics and installing physical flood control barriers	NO; P	Flooding/Inundation WWTP Anomalies Pump Failures
28	UNDERSTAND AND REDUCE VULNERABILITY	Improve Risk Assessment	Update precipitation frequency estimates using NWS data	Improve risk assessment planning by updating precipitation frequency estimates	P	I&I Flooding/Inundation WWTP Anomalies Force Main Failures Pump Failures
29	IMPROVE INSURANCE	Private Insurance Option	Develop a water/sewer insurance protection plan for customers	Participating customers pay a small monthly premium in exchange for guaranteed repair of a service line break. This measure would both improve wastewater system resilience prior to a storm and speed repairs after one occurs.	NY	I&I Flooding/Inundation WWTP Anomalies Force Main Failures Pump Failures
30	UNDERSTAND AND REDUCE VULNERABILITY	Flood Protection	Temporary sandbagging	Protect vulnerable infrastructure with sandbags during flood events	NY	Flooding/Inundation

Key:
NY-New York City Bureau of Wastewater Treatment
NO-Sewerage and Water Board of New Orleans
H-City of Houston Public Utilities Division
P- Pensacola/Emerald Coast Utility Authority

5.0 FAILURE MODES AND RECOMMENDED SOLUTIONS

Hurricanes Hermine and Matthew caused an estimated $1.59 billion in damage with Hurricane Hermine contributing approximately $210 million and Hurricane Matthew accounting for approximately $1.38 billion. Hurricane Hermine's 10+ inches of rain over a 3-day period, combined with a 33-hour tidal surge, stressed wastewater infrastructure with the hydraulic overloading of the collection systems, resulting in various Waste Water Treatment Plant (WWTP) challenges including flooded headworks and a volute failure on a key WWTP pump.

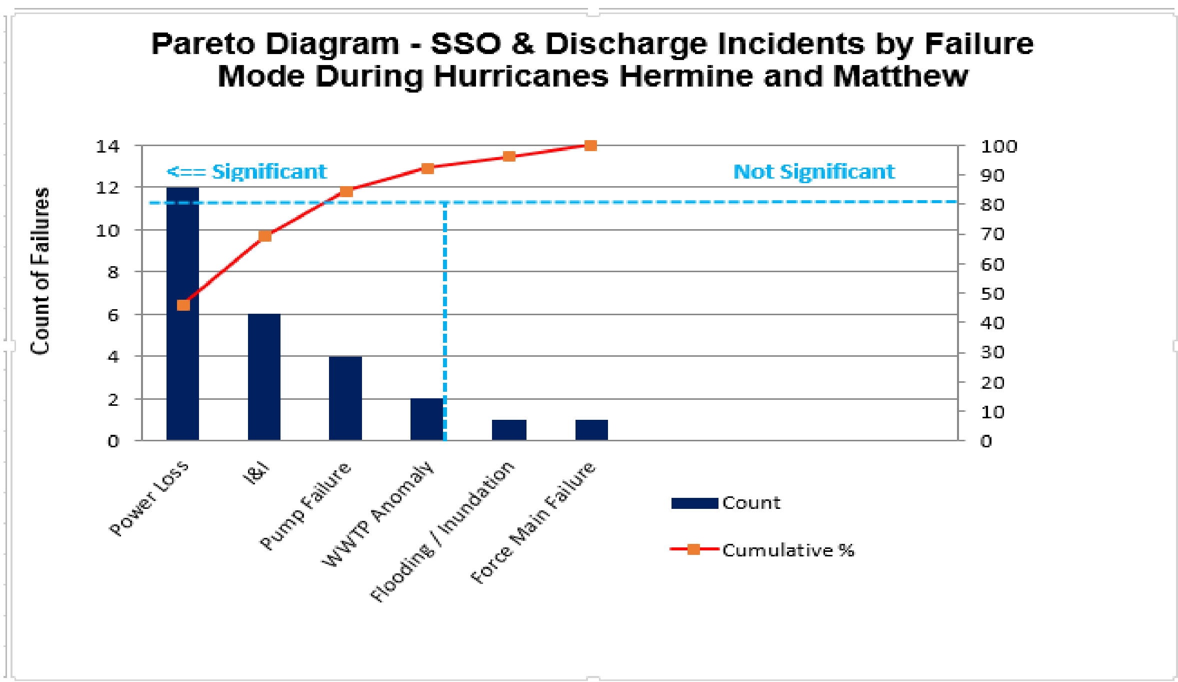
Hurricane Matthew produced less rain and had a shorter duration tidal surge than Hurricane Hermine, but manifested its damage through 60+ mph winds that downed trees and power lines. The tidal surge flooding from Matthew was significantly higher than Hermine, reaching elevations of more than 7 feet in St. Augustine where it inundated lift stations and flooded an electric substation.

The following section identifies the failure mode frequencies for the 26 SSOs evaluated and provides solutions for these failures.

5.1 PARETO ANALYSIS OF FAILURE MODES

Review of the 26 SSO and wasterwater discharges presented in Figure 5-1 reveals six failure modes. The frequency of these failures during Hurricanes Hermine and Matthew were plotted on a Pareto Chart on an occurrence basis. The plotted data highlights the most common failure modes experienced during the hurricanes and guides the selection of solutions to address them. It should be noted that this approach can exclude potentially important problems that may be small initially, but can grow over time.

FIGURE 5-1 PARETO CHART OF SSO & DISCHARGE INCIDENTS BY FAILURE MODES DURING HURRICANE HERMINE AND MATTHEW



The occurrence-based Pareto analysis indicates that power loss was the leading cause of failure, followed by I&I, flooding/inundation, WWTP anomalies, force main failure, and pump failure. An SSO volume-based Pareto analysis reveals a heavy bias for I&I which accounts for more than 85% of the volume-based failure modes followed by pump failures, WWTP anomaly, power loss, flooding/inundation and force main failure. The last two failure modes barely register on the volume-based Pareto chart.

To provide scalable and actionable solutions relative to the SSOs experienced during the 2016 Hurricanes, all of the failure modes in the occurrence-based Pareto chart are addressed in the following section.

5.2 POWER LOSS

Power loss was the most frequently reported failure across all utilities evaluated. Without power, wastewater treatment plants do not operate properly, pump stations do not pump when needed, and sewage flow continues until the system overflows (e.g., manhole backup, lift station overflow, storage tank overflow, plant bypass, etc.).

Of the ten power loss occurrences evaluated, eight occurred at JEA facilities and two occurred at City of St. Augustine facilities. The power losses were caused either by Hurricane Matthew's winds, or by the associated tidal surge which inundated the FPL substation in St. Augustine. All of the power losses affected lift stations. This failure mode was associated with 8,322,900 gallons of SSO or about 4% of the total volume evaluated.

The following table summarizes the root cause of each power loss-related SSO, whether or not emergency generators were present, and the proximate cause that prevented the emergency generators and associated systems from functioning as intended.

TABLE 5-1 SUMMARY OF POWER LOSS FAILURES

Incident #	Volume (gal)	Root Cause	Emergency Generator Present?		Secondary Cause
			YES	NO	
3960	1,100,000	Transmission line power outage (downed trees)	X		Emergency generator breaker trips de-energizing station.
4002	848,000	Transmission line power outage (downed trees)	X		VFD tripped de-energizing motors
4004	194,000	Transmission line power outage (downed trees)		X	Downstream pump station w/o emergency generator fails and causes gravity sewer overflow.
4008	387,000	Transmission line power outage (downed trees)		X	Portable generator not present during loss of power.
4011	514,000	Transmission line power outage (downed trees)		X	Portable generator not present during loss of power.
4313	337,000	Transmission line power outage (downed trees)	X		VFD tripped de-energizing motors

Incident #	Volume (gal)	Root Cause	Emergency Generator Present?		Secondary Cause
4316	5,000,000	Transmission line power outage (downed trees)	X		VFD tripped de-energizing motors
4325	327,000	Transmission line power outage (downed trees)	X		VFD tripped de-energizing motors
8032-2	29,000	Transmission line power outage (downed trees)		X	Portable generator not present during loss of power.
8032-3	49,500	Transmission line power outage (undetermined)		X	Portable generator not present during loss of power.
TOTAL VOLUME	8,322,900				

The root cause for all of the lift station failures was loss of power from the electric utility. In 9 of 10 cases, the loss of power was due to downed trees which impacted transmission lines. Failed power sources accounted for approximately 87% of the SSO volume spilled for this failure mode. Four of the five lift station power failures were associated with Variable Frequency Drives (VFD) tripping, which prevented motor operation. The remaining failure was due to a circuit breaker that tripped at the generator. SSOs from facilities without emergency generators accounted for 13% of this failure mode's SSO volume.

In order to provide strategies to increase water utilities' resilience to power loss, the EPA developed and made available their *Power Resilience Guide for Water and Wastewater Utilities*. It provides strategies to increase wastewater utility reliability during extreme weather events. The guide also summarizes seven critical areas for improving power reliability, each of which is briefly previewed below.

Communications

This area is intended to increase awareness of critical assets and their locations, promote a "storm-ready" wastewater utility, establish the wastewater utility as a priority return-to-service customer, train and exercise staff to improve emergency response plans and actions, and how to effectively communicate with the public before, during, and after the storm.

Power Assessment

Power assessments performed by qualified electricians are designed to determine the emergency generator power requirements for critical equipment. These assessments can be performed by in-house staff, contractors, or by calling the US Army Corps of Engineers (USACE) Prime Power group at 800-243-3472 or 703-805-2561. The USAC provide free electric power assessments for utilities. The power assessment results can be entered into the Emergency Power Facility Assessment Tool (EPFAT) database to obtain a state or federally provided generator in a regional emergency. USACE provides this support to FEMA under the 2007 Robert T. Satafford Dissaster Relief and Emergency Assisance Act.

Generators

Six critical decision points on generators are explained in the guide including: sizing, renting vs owning, selection of fuel types (i.e. diesel, natural gas, propane or gasoline), electrical connections, placement, storage, and maintenance.

Fuel

The EPA's guide gives multiple tips ranging from generator fuel storage and transportation, to ways of reducing the amount of fuel used.

Energy Efficiency

Reducing the energy requirements of equipment reduces the demand requirement for emergency generators. The guide references the EPA's energy management guidebook for wastewater utilities.

On-site Power

Distributed energy resources (DER) incorporating power generation, power storage and electric load technologies are discussed for a variety of DER options, including photovoltaic systems (i.e. site panels, microturbines for wind, fuelk cells. Internal combustion engine and combined heat and power.

Funding

The EPA's tool "Federal Funding for Utilities - Water/Wastewater in National Disasters (FedFunds)" provides comprehensive information on funding programs from various federal agencies. Examples of emergency power resilience projects that have been funded successfully through external sources include: 1.) Purchase, rental and upgrade of equipment; 2.) Electric connections and transfer switches; 3.) Elevation of control panels and generators out of the floodplain;, 4.) Flood protection for electric substations and transformers; and 5.) Energy efficiency measures.

5.2.1 Potential Solutions for the Power Loss Failure Modes

5.2.1.1 Improving Utility Power Reliability

For nine of the SSOs evaluated, the power loss was attributable to power lines impacted by Hurricane Matthew's wind event, primarily by downed trees.

Wind and storm driven transmission line power loss is a function of tree pruning. FPL and other investor-owned electric utilities use Florida Public Service Commission approved standard overhead lines as the most cost-effective type of construction.

Florida's power suppliers, in general (FPL typical), maintain a routine clearing of main (feeder) power lines every three years and neighborhood (lateral) lines every six years. There is then a 5 in 6 chance in any year that a neighborhood or community lift station has not had its surrounding trees trimmed, which is compounded by a 2 in 3 chance that the main feeder lines to those lift stations have also not been trimmed.

JEA has an aggressive tree trimming schedule of 2.5 years for feeders and laterals. Notably, the resulting tree damage relating to outages from Hurricane Matthew on the JEA system was primarily attributed to soil/root system failures rather than tree trimming frequency. Extremes in soil moisture due to drought or flooding make trees much more susceptible to root failure. Northeast Florida experienced a Nor'easter in the days just prior to Hurricane Matthew. As a result, soils in the Northeast Florida area were saturated to the point where high winds caused many trees to uproot. Therefore the vast majority of the tree related outages in the aftermath of Hurricane Matthew were from trees falling/uprooting outside of the traditional utility trim zone.

The JEA Electrical Transmission & Distribution Preventative Maintenance Department is also focusing on maintaining and improving wastewater lift station reliability through vegetation management. Several years ago JEA began a program of inspecting lift station SCADA antennas for vegetation interference as a part of the routine 2.5 year trimming cycle. Additionally, JEA has recently included assessing the lift station electrical feeds for vegetation related work (and/or minor engineering modifications) to improve the reliability of the lift stations.

Community-wide conversion costs from overhead to underground service are significant. The work includes building a new system, while operating the existing service, then dismantling the existing service once the new system is up and running. Conversions in and through older and established neighborhoods – regardless of the type of excavation used (boring or trenching) – require a significant amount of utility coordination associated with avoiding impacts to buried phone, cable, sewer, gas lines, water lines, etc.

FPL, for example, has approximately 67,000 miles of distribution lines serving 4.7 million customers in 35 Florida counties. There are also approximately 6,500 miles of transmission lines. More than one-third of FPL's system, greater than 24,000 miles, is underground and often the result of municipalities setting underground requirements, the costs for which are borne by builders and developers and ultimately by customers in the price they pay for real estate. However, power lines must eventually come above ground, so no system is completely underground and infallible. The cost of converting overhead service to underground service may become financially more restrictive.

5.2.1.2 Improving Electric Power Reliability and Recovery Times

In lieu of improving the utility power source, another option is to provide a redundant power source to the lift stations. Out of the nine SSOs evaluated, five had connection points for temporary generators to provide a redundant electrical source, none of which had generators in place at the time of the event.

For smaller volume lift stations, a permanent standby generator may not be cost effective. However, if there's knowledge or forewarning that a large storm event is imminent, it may be advantageous to connect a portable generator to the lift station and allow it to use the generator as the primary power source during the event. Typically during larger events, a localized power source would have fewer power fluctuations, and would be more reliable than the utility provider.

Five of the SSOs evaluated had permanently installed generators with automatic transfer switches (ATS) that had power loss due to a tripped protective relay in a VFD, or an opened main circuit breaker in the generator. For the lift station that had loss of power when the generator circuit breaker tripped, the historical data in the generator controller will need to be reviewed to see if there was a fault on the generator that caused the circuit breaker to trip. If there was no fault at the generator, then the likely cause for the circuit breaker trip would be from the load side of the circuit breaker (i.e., lift station side), as in some type of coordination issue with the lift station motors or VFD causing an overcurrent condition on the circuit breaker. The lift stations with the VFD tripping can be a bit more complicated in that the VFD could have tripped before, during, or after power was transferred to the generators. Reviewing the historical data and event summary on the VFD, the generator controller, and the ATS controller should provide a better understanding of when the event occurred and what caused the trip. There are simply too many settings on a typical VFD to be able to hypothesize what the root cause of the VFD tripping may have been, and the utility has not developed a hypothesis.

For lift stations with permanent generator connections, it may be advantageous to transfer the lift stations to operate off of the permanent generator when there's knowledge of a large imminent event that could reduce the reliability of the utility source. Trying to transfer power from one power source to another during the time that the lift station needs reliable power the most increases the chance that an electrical event will happen during, or immediately after, the transfer of power. There are several events that need to happen sequentially in order to successfully transfer power sources such as: sensing the loss of the utility feed, starting of the generator, transferring of the connection points, and restarting of the lift station motors. If all these events can be avoided during the time when the lift station needs power the most, it could greatly reduce the number of potential failure points in the system.

5.2.1.3 Emergency Generator Costs

Standby generators can range from 20 to 250kW, with power output requirements depending primarily on the size of the pump at each lift station.

These output requirements generally range from 10 to 100 hp, with 50 hp being in the mid-range of pump station demands. The generators can be temporary and mobile, or permanent fixtures in the area of each lift station. The added reliability from the addition of generators can help in the prevention of SSOs during major storm events.

A 125kW diesel-driven generator will handle the power requirements for the 50 hp pump station demands. The cost for a generator package including installation, equipment, day tank, transfer switch, muffler, charger, battery, and feeders is approximately $46,500.00.

5.3 INFLOW AND INFILTRATION (I&I)

Inflow and Infiltration (I&I) related events had the highest volume of all the incidents evaluated with approximately 174 million gallons, or about 82% of the SSO volume reported. All of these occurred in the Tampa Bay area and were related to the rainfall and tidal surge conditions caused by Hurricane Hermine. The two leading proximate causes for these SSOs and effluent releases are aging collection systems and treatment facilities that lacked the capacity to properly manage the wastewater flows during the storm. Aging collection systems were described by the utilities as having broken pipes, separated pipe joints, damaged manholes, leaky manhole covers, etc. The capacity issues at the treatment plants include:

1) Inadequate disposal well and effluent filter capacity (Incident # 3560).
2) Limited capacity of facility headworks, screening and grit removal, secondary clarifier and filtration (Incident # 3593).
3) Limited capacity of Chlorination Contact basin (Incident # 3507).

The second most frequent proximate causes for the incidents include two types:

1) High volume of unused reclaim water returned to the Water Reclamation Facility (Incident #'s 3560 and 3593) - this proximate cause contributed to approximately 151,108,000 gallons of combined SSOs

2) Capacity bottlenecks in the conveyance system which reportedly accounted for 14,780,000 gallons total (Incident #s 3704 and 3563).

The final proximate cause (Incident # 4263) is associated with significant I&I compounded by a 3.3 hour lift station power loss that contributed 288,000 gallons to the SSO total. Table 5-2 summarizes the root causes of these failures and the associated proximate causes.

TABLE 5-2 SUMMARY OF I&I FAILURES

Incident ID #	Volume (gal)	Root Cause	Proximate Causes
3560	58,000,000	I&I from rainfall and tidal surge	Aging collection system
			NWWRF limited disposal capacity for storm I&I
			High volume of unused reclaim water during storm returned to NWWRF
3593	93,108,000	I&I from rainfall and tidal surge	Aging collection system
			SWWRF limited capacity for storm I&I
			High volume of unused reclaim water during storm returned to SWWRF
3572	892,500	I&I from rainfall and tidal surge	Aging collection system
3704	11,880,000	I&I from rainfall and tidal surge	Capacity bottleneck created during system improvement project
3507	7,130,000	I&I from rainfall and tidal surge	Hydraulic overloading of the South Cross Bayou WRF Chlorination Contact basin
4263	288,000	I&I from rainfall and tidal surge	Limited power outage (3.3 hrs.) to lift stations affects four feeder lines.
4300	144,000	I&I from rainfall and tidal surge	
3563	2,900,000	I&I from rainfall and tidal surge	Bottleneck in the piping of the Corona Interceptor
TOTAL VOLUME	**174,234,500**		

5.3.1 Aging Collection Systems

As part of a comprehensive plan, the City of St. Petersburg is planning to reduce I&I throughout targeted portions of the City's owned collection system by rehabilitation (pipe lining) or replacement of cracked sewers, manholes, and laterals and plugging or raising of low-lying openings in the sewer system, such as holes in manhole lids. According, to the *Wet Weather Overflow Mitigation Program – Phase I* Study, repair of all the defective public sewer components will achieve approximately a 30 percent reduction in

I&I. Rehabilitation of the collection system will help reduce the I&I that contributed to SSO #3560 and #3593. The City's Wastewater Improvement Plan announced on November 3, 2016, includes $10.5 million in rehabilitation of the collection system in the short-term (October 2017) and $74 million in the long-term (2021).

The City of Gulfport completed a recent *Sanitary Sewer Evaluation Survey (SSES)*, dated 2016, performed by Cardno in which additional evaluation (CCTV inspection) and recommendations for rehabilitation of the collection system were documented. The rehabilitation of the collection system includes rehabilitation or replacement of cracked sewers, manholes, and laterals. Rehabilitation of the collection system will help reduce the I&I that contributed to the SSOs that occurred as part of incident #3572. The SSES recommended evaluations and rehabilitation are expected to be accomplished over the next 25 years at a cost of approximately $20 million.

5.3.2 WWTP Capacity Concerns

As part of the City of St. Petersburg comprehensive plan to alleviate SSOs and unpermitted effluent releases, the following upgrades are planned at the SWWRF to increase capacity of the plant: expansion of the facility headworks, provide additional screening and grit removal capacity, provide another secondary clarifier, provide additional filtration capacity, provide additional disinfection capacity, provide yard piping improvements and provide plant reliability improvements. Also planned is the installation of additional injection wells. The improvements at the SWWRF are planned to be completed between 2017 and 2021 and will cost approximately $31 million. Similar upgrades are recommended at the NWWRF to increase the capacity of the plant. The recommended improvements at the NWWRF include: providing additional effluent filters, providing another injection well, and providing plant reliability improvements. The improvements at the NWWRF are planned to be completed between 2017 and 2021 and will cost approximately $58 million. The implementation of the recommended upgrades at the SWWRF and NWWRF will increase the capabilities of these plants to handle the high amounts of I&I experienced during Hurricane Hermine which led to SSOs 3593 and 3560 respectively. According, to the *Wet Weather Overflow Mitigation Program – Phase I* Study, the improvements to the WRFs, particularly to the SWWRF, are more cost effective than extensive I&I removal in mitigating potential future overflows.

In order to alleviate the overflow at the South Cross Bayou WRF (Incident # 3507), Pinellas County plans to study the collection system that contributes flow to the plant to identify sources of I&I and to rehabilitate portions of the system that are found to be defective.

5.3.3 Conveyance System Capacity Bottlenecks

A bottleneck is a portion of a system that is either obstructed or too narrow to allow full flow. Blockages, such as fats, oils and grease (FOG) or large debris, can cause bottlenecks in the system which can cause backups and SSOs. Undersized lines can also cause backups which means the volume leaving the interceptor is lower than volume entering. The Corona Interceptor in the City of Clearwater experienced an SSO that was the combination of a bottleneck and significantly increased Inflow and Infiltration into the system. The City of Clearwater has evaluated the situation and is working towards an engineered solution to this issue.

5.3.4 I&I Estimation and Gravity Main Evaluation with Costs

I&I evaluations are designed to identify the base sanitary flow, which can be calculated based on customer connections and water usage rates. The rate of groundwater infiltration can be estimated from system influent flows during dry weather periods when water levels are high. This would typically occur in the mid to late Fall in Florida. Estimating the rate and volume of inflow (i.e. rain event contributions) can then be calculated by subtracting the base sanitary flow and infiltration flow data from the wet weather flow data. This data in conjunction with flow records can then be used to calculate peak inflows, maximum monthly I&I rates , average annual I&I rates and annual I&I volumes. This information can also be approximated for basins within the wastewater conveyance network to prioritize manhole and gravity sewer line repairs.

Once I&I estimates are developed the utility can begin the evaluation of the sanitary sewer system elements to target I&I points of entry and to develop an effective program to eliminate these unwanted contributions to the system. Typical elements included in these evaluations are manholes and gravity mains through the use of physical inspections as well as closed circuit TV (CCTV), and acoustic and smoke testing surveys. The cost estimate developed below for the City of St. Petersburg in 2015 provides budgetary costs on a linear foot basis that utilities may consider for evaluation of their systems once I&I evaluations and calculations are complete.

Table 5-3 COST ESTIMATE FOR SANITARY SEWER EVALUATION SURVEY OF GRAVITY MAINS

Table E.5. Cost Breakdown for Sanitary Sewer Evaluation Survey of Gravity Mains

Item	Value	Cost/LF	Comment
Gravity Mains		$ 2.6	Includes acoustic, smoke testing, and CCTV
Manholes		$ 0.4	
Subtotal		**$ 3.0**	
Overhead	10%	$ 0.3	
Profit	5%	$ 0.2	
Mob/Bond/Ins	5%	$ 0.2	
Field Inspection	0%	$ -	
Misc. (Permitting, etc.)	2%	$ 0.1	
Subtotal		**$ 3.7**	
Contingency	30%	$ 1.1	
Subtotal		**$ 4.8**	
Engineering Costs	17%	$ 0.8	
Subtotal		**$ 5.6**	
Johnson Co. 2016 RS Means City Factor		93.20	
Escalation		0.7%	
St. Pete's 2016 RS Means City Factor		95.30	
Factor		1.03	(RS Means Factor St. Pete's/ RS Means Factor Johnson Co.) + Escalation
Subtotal Adjusted for Time and City		**$ 5.8**	
Total Unit Cost		**$ 10.3**	Final adjustment based on difference in Cost of Rehab comparison from Johnson Co. and St. Pete's Bid Costs. See discussion below in Table E.6.

Source: City of St. Petersburg Public Works Department

5.3.5 Conveyance system Piping Repairs to Reduce I&I with Costs

The most effective method of preventing I&I in the piping of a conveyance system is to repair damaged and defective piping and to limit the amount of "fugitive clear water" that enters the sewer system through direct connections. The first step in reducing I & I is identifying the areas of greatest concern. Smoke testing is an effective technique in locating and identifying the presence of defects in sewer and storm water systems. Smoke testing is where smoke is mixed with large volumes of air and is forced into a system using blowers. The smoke then travels through the system, leaking out wherever there are defects in the system. A properly working sanitary sewer line will allow the smoke to leave through manholes and vents in the system. Video inspection is also an effective tool in locating blockages and defects in piping. Sewer video inspection is essentially the process of running a high-resolution, well-lit video line through waste pipes to locate blockage points. Once the vulnerabilities in the system are found, work crews can repair or replace the damaged or defective pipe to ensure a proper seal in the system.

The costs to replace and repair conveyance system piping varies significantly depending on diameter and material of piping in the system. Using RSMeans and previous studies from the Cities of Gulfport and Clearwater, cost data has been provided below as a tool to help in estimation.

TABLE 5-4 CONVEYANCE SYSTEM COSTS

Task	Cost (Per LF unless specified)	Source
CCTV Inspection and Analysis	$5.11	Gulfport Sanitary Sewer Evaluation Survey
Smoke Testing	$0.35	Clearwater Flow Monitoring Technical Memorandum
Excavation and Fill (4' deep w/ 1/2 C.Y. excavator)	$7.55/B.C.Y.	RS Means 31 23 16.13 0060
Replace: Piping (10" HDPE)	$11.40	RS Means 33 31 13.20 3060
Replace: Piping (10" PVC)	$18.60	RS Means 33 31 13.25 2120
Replace: Piping (10" Concrete)	$23.50	RS Means 33 41 13.60 1030
Repair: 8" Clamp (10" dia, PVC)	$410/Ea	RS Means 33 01 10.20 1835
Rehab: 300' runs, HDPE (6"-15")	$114.00	RS Means 33 01 30.71 0100

5.4 FLOODING AND INUNDATION FAILURES

The control panel and lift station flooding failure mode only occurred in the City of St. Augustine. It is associated with the 7+ ft. elevation tidal surge experienced from Hurricane Matthew. The total volume of the SSO associated with this type of spill was 177,000 gallons which is less than 0.10 % of the total volume of SSOs evaluated. However, when reviewing disaster response literature for communities impacted by large storm surges this failure mode rapidly advances to a leading cause of failure. As indicated in table 5-3 the root cause of this failure was tidal surge and the proximate causes included elevation of the control panel and appurtenant structures and the presence of non-submersible lift station pumps. The benchmarking effort provided several potential solutions for this failure mode including the consideration of flood risks when designing the system and upgrading and rehabilitating pump stations to flood proof them. Table 5-5 summarizes the SSOs associated with flooding and inundation.

TABLE 5-5 SUMMARY OF FLOODING AND INUNDATION FAILURES

SSO ID#	Volume	Root Cause	Proximate Causes
8032-1	108,000	Tidal Surge & System Flooding	Elevation of Control Panel & Appurtenant Equipment
8032-4	24,000	Tidal Surge & System Flooding	Elevation of Control Panel & Appurtenant Equipment
8032-5	45,000	Tidal Surge & System Flooding	Elevation of Control Panel & Appurtenant Equipment
			Flooding of non-submersible pumps

5.4.1 Tidal Surge and System Flooding

The control panel and lift station flooding that occurred in St. Augustine is a recent example of the hurricane-driven flood risks faced by Florida's coastal utilities. To help utilities manage this risk the EPA developed a flood resilience guide for water and wastewater utilities to examine the threat of flooding, determine impacts to utility assets and identify cost-effective mitigation options.

To understand the threat of flooding, users are guided through a process that extracts the historical flooding experience for the utilities, information on the FEMA flood maps as well as the flooding elevation to be used as part of the risk management process. This data is then compared to the elevation of utility assets to determine operational and economic impacts. To minimize service disruption, mitigation measures are prioritized using the criteria of effectiveness, practicality and cost. An implementation plan is then developed which details the mitigation measure, the actions and associated timeline to implement the mitigation measure, the responsible individual and the funding source.

The guide provides numerous mitigation measures for lift stations, headworks and wastewater treatment plants. Suggested mitigation measures recommended in the guide for increasing the reliability of a wastewater system in the event of flooding are provided below:

TABLE 5-6 MITIGATION OPTIONS FOR LIFT STATION FLOODING

1. Prevent lift stations from flooding.	
a. Procure temporary flood barriers (e.g. sandbags) for use in minor flooding.	$
b. Extend vent lines above anticipated flood stage to prevent floodwater from entering the lift station.	$-$$
c. Install gates and backflow prevention device on influent and emergency overflow lines to prevent inundation of the lift station by the collection system and the overflow.	$
d. Install permanent physical barriers (e.g. flood walls, levees, sealed doors)	$$
e. Install green infrastructure to attenuate or divert flood water and storm surges away from the lift station.	$$
2. Protect critical components if lift stations do flood.	
a. Install unions in the conduit system to reduce the time required to repair damaged sections.	$
b. During upgrades or design of new equipment, develop capability to temporarily remove and safely store vulnerable components before a flood when there is enough advanced notice to do so.	$-$$$
c. Waterproof electrical components, controls and circuitry.	$$
d. Relocate or elevate electrical components (e.g. motors, switchgears, motor control centers, cathodic protection systems, exhaust fans, etc.) above the flood stage.	$$
e. Replace vulnerable components with a submersible option (e.g. pumps, flow meters, gate/valve operators, etc.)	$$$
f. Replace a below-grade lift station with an above-grade station elevated higher than the flood stage.	$$$
3. Have a means of bypassing normal lift station operations when necessary.	
a. Maintain a call list of multiple vendors that can provide "pump around" services in an emergency or enter into an agreement with one.	$
b. Procure potable pumps to restore operation of a damaged lift station following an event.	$$
c. Implement a regionalization project to enable diversion of wastewater flows to an alternate system for emergency wastewater collection and conveyance.	$$$

Cost Key (Provides relative costs of mitigation measures – actual costs may differ for your utility)

$ - Little to no cost. Some internal level of effort required, but no contractor support needed.

$$ - Moderate cost/complexity. Likely involves contractual costs.

$$$- High cost/complexity. Will require one or more contractors to implement this option

In addition to the suggested mitigation measure identified above it should also be noted that the FlaWARN program of mutual aid between utilities is a valuable asset for restoring the entire wastewater system to operation following a storm. City of St. Augustine staff credit their partners from FlaWARN for expediting service restoration by as much as 3 to 4 times faster.

5.4.2 Elevation of Control Panels and Appurtenant Equipment

Control of submersible lift station pumps is through an adjacent, above grade, energized, control panel with control wiring entering the station wet well through water tight plugged conduits. Elevating the control panel above a flood prone elevation will enable the station to operate under sustained power.

There is little more required to elevate a control panel other than increasing the elevation of its attachment to its support structure. There is a practical limit to the height at which a control panel should be elevated, with consideration given to the Service Individual working without a ladder.

It is recommended to construct all improvements above grade in accordance with code to at least the height of, but not less than the 100-year flood plain elevation. Construct electrical improvements, emergency generators, switch gear, SCADA, control panels, alarms, telecommunications gear, power supplies, etc., in accordance with code to at least the height of, but not less than 3'-6" above adjacent grade or provide waterproof enclosure for very large gear that is impractical to elevate.

5.4.3 Submersible Lift Station Pumps

Submersible pumps are waterproof and constructed to remain and be operated under water. Submersible pumps are selected on the basis of maximum flow for a specific set of performance criteria. Exceeding the specific set of performance criteria will result, in time, in an overflow.

The design of a submersible lift station includes a determination made with regard to the population served, or a fixture count if design is for a facility or community of facilities. Flow characteristics in gallons per day (GPD) have been predetermined by municipalities for fixture units and population served. A calculation is made from facility/population flow characteristics to determine the station's Average Daily Flow (ADF) in GPD.

A "peaking factor" is calculated (UFC 3-240-02 for reference) and multiplied by the ADF. Any additional flow, such as HVAC condensate, is added above the peaked ADF. Peaked ADF is converted from GPD to gallons per minute (GPM). The resultant flow is the station peak ADF, or single pump maximum capacity in GPM. Consideration is given for force main and fitting losses, which increase the demand on the pump pressure. No consideration is typically given for the incursion of inflow and infiltration into a system.

Each pump of at least two (redundancy required by TSS), must be capable of producing the station's peak ADF. Multiple equivalent pumps working together in a lift station are capable of more flow than the single pump peak ADF. Centrifugal pumps in parallel are used to overcome larger volume flows than one pump can handle alone. Pressure is constant and flow is additive.

Submersible lift station wet wells are designed for specific volumes, which include the accumulation of calculated ADF over time prior to initiation of the lead pump. In the case of higher than peak ADF, a second (or more) pump is activated. Influent flow that exceeds the total capacity of all of a lift station's pumps (greater than its design), will lead to system backup and eventual overflow, either overtopping of the lift station (rare) or backup through manhole lids (typical).

The estimate of new construction for a "typical" community/neighborhood submersible lift station, duplex 7.5 HP pumps, float controls, control panel, force main and no emergency generation of standby power follows:

TABLE 5-7 SUBMERSIBLE PUMP STATION COSTS

Task	Quantity	Unit Cost	Cost
Trenching	1 Mile	$ 4/LF	$ 21,120
Dewatering	36 Days	$ 225/Day	8,100
Pipe Bedding	1 Mile	$ 6/LF	31,680
4" HDPE Force Main	1 Mile	$ 8.50/LF	44,800
Detectable Tape	1 Mile	$0.085/LF	448
Lift Station, Package	1 Each	$ 75,000	75,000
Testing	1 Each	$ 2500	2,500
Subtotal			183,729
Taxes and Insurance			25,000
Sub. Overhead	12%		25,000
Sub. Profit	8%		18,700
Prime Profit	8%		20,000
Bond	1%		2,700
TOTAL			$275,000

Community costs are variable. No engineering or inspection has been included. Contingency is not included.

5.4.4 Flood Prevention Techniques for Wastewater Infrastrucuture and Costs

It is important to look at the realities of flooding and tidal surge produced within the natural environment, particularly Florida's. The history of storm surge in Florida extends only 160 years, yet hurricane activity in Florida has existed for thousands of years. Based only on the 160-year historical records, northwestern Florida gets hit by a hurricane packing a five-meter (16-foot) storm surge every 400 years. However, based on paleohurricane storm surge reconstructions, northwestern Florida is predicted to experience a storm surge of 6.3 meters (20.7 feet) every 100 years, 8.3 meters (27.2 feet) every 500 years, and 11.3 meters (37.1 feet) in a worst case scenario event. [1]

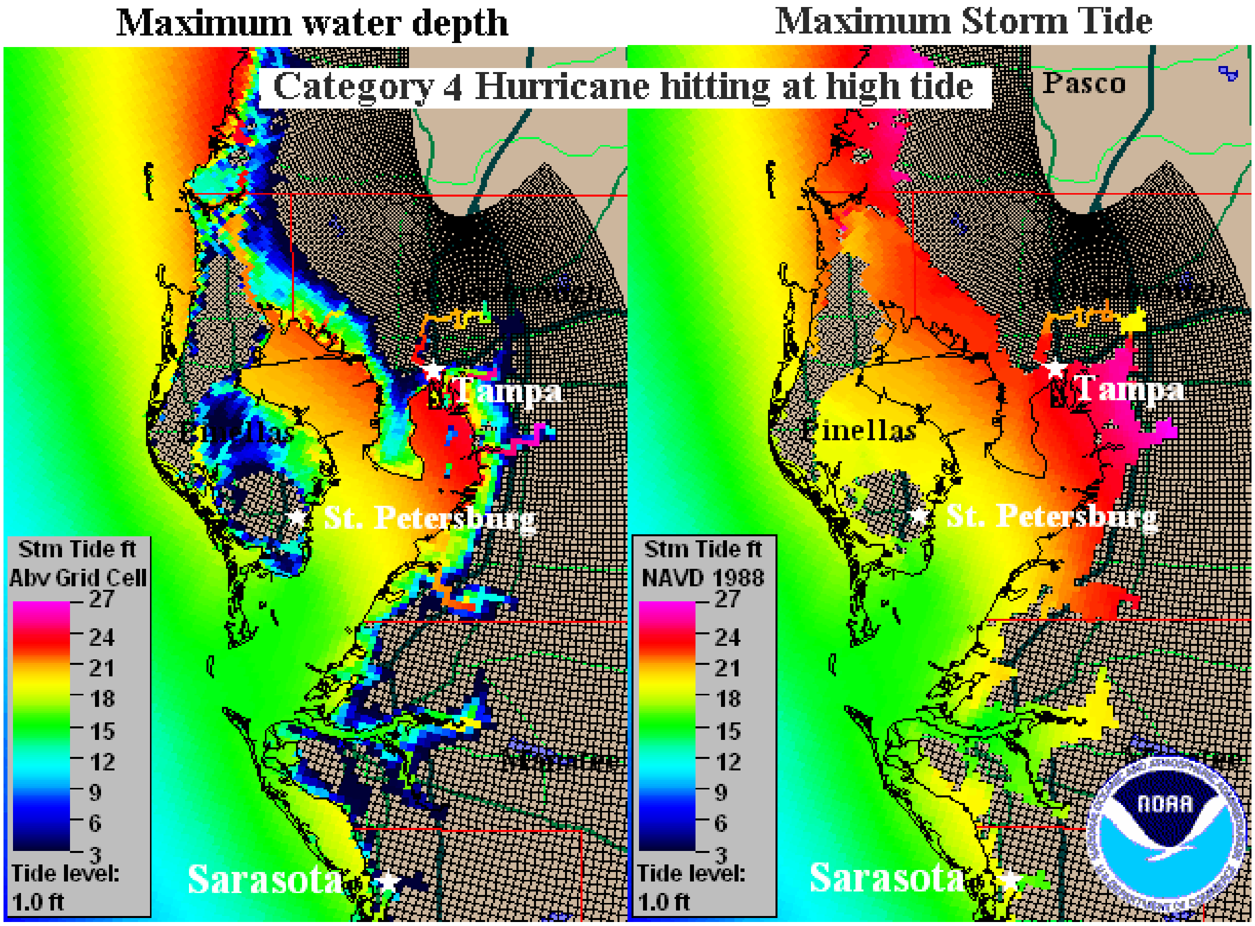
[1] http://earthsky.org/earth/history-of-storm-surge-in-florida-strongly-underestimated ; EarthSky in Earth, Human World, Science Wire, September 23, 2014

FIGURE 5-2 HURRICANE DENNIS (2005) PRODUCED SURGE FLOODING OF 7-9 FEET NEAR ST. MARKS, FL.

Hurricane Opal (1995) caused extensive surge damage from Pensacola to Mexico Beach with a maximum tide of 24-feet, recorded near Ft. Walton Beach. Unnamed Great Miami Hurricane (1926) inundated Coconut Groves by as much as 15-feet.

Surge vulnerability facts from NOAA indicate Gulf coastal county population density increased by 32% from 1990 to 2008; much of the densely populated Atlantic and Gulf coastlines lies less that 10-feet above mean sea level; over one-half of the Nation's economic productivity is located within coastal zones; 72% of ports, 27% of major roads, and 9% of rail lines in the Gulf Coast region are equal to or below 4-feet elevation; a storm surge of 23-feet has the ability to inundate 67% of Interstate highways, 57% of arterial roadways, almost one-half of all rail miles, 29 airports, and virtually all ports in the Gulf Coast area. Not all of these statistics are focused strictly in Florida, but their impact is certain.

FIGURE 5-3 NOAA SLOSH MODEL



Faced with the reality of massive flooding in the event of a Cat-4, sustained wind speed of 143 mph, high tide, it is unlikely that preventative waterproofing measures, as currently employed, will have an impact on the continuance of wastewater activities during or "shortly" thereafter such an event.

For hurricanes of significantly lesser severity, the prediction of height through NOAA SLOSH Modeling is a maximum 6-hour notice in advance of the event and the demarcation of high water afterwards, there are multiple waterproofing considerations that can be instituted: sandbagging; elevation of energized equipment; waterproofing of equipment; conversion of equipment (pumps) to submersibles; raising vents; influent backflow prevention; emergency overflow; permanent physical barriers; pipeline construction that benefits swift reconstruction; waterproof electrical control panels; components, and circuitry; manhole diaphragms.

Costs for representative waterproofing elements follow:

TABLE 5-8 WATERPROOFING COSTS

Task	Cost (Ea unless specified)	Source
Sandbags (polypropylene)	$0.40	ULINE
Temporary Submersible Pump (Gould's 4" 30HP 1150 GPM)	$9,336.00	Pump Products Inc.
Manhole Diaphragms	$1,200.00	ASAP Distribution
Waterproof Moisture Barrier (30" x 200' Roll)	$200.00	Rhizome Barrier Supply
5200 Marine Adhesive Sealant (10 oz. cartridge)	$16.99	ASAP Distribution

5.5 WWTP ANOMALY

The Wastewater facilities are imperative to a proper functioning water collection system. Anomalies in the system can lead to SSOs and damage to the facilities and systems that are intended to serve the public.

Three major events were influenced by anomalies in the wastewater facilities that occurred simultaneously with the storm event. The following table summarizes the root and proximate causes and volumes that were released.

TABLE 5-9 SUMMARY OF WWTP ANOMALIES

SSO ID#	Volume	Root Cause	Proximate Causes
3560	58,000,000	I&I from rainfall and tidal surge	Aging collection system
			NWWRF limited disposal capacity for storm I&I
			High volume of unused reclaim water during storm returned to NWWRF
3593	93,000,000	I&I from rainfall and tidal surge	Aging collection system
			SWWRF limited capacity for storm I&I
			High volume of unused reclaim water during storm returned to SWWRF
3704	11,880,000	I&I from rainfall and tidal surge	

In summary, nearly 163 million gallons of water were released (about 76% of the total studied) from the events in St. Petersburg and Largo; and while the root causes of the SSO events were Inflow and Infiltration, the system also experienced proximate causes in the form of anomalies in their respective systems. In St. Petersburg, the Northwest and Southwest Water Reclamation Facilities experiencing high volumes of unused reclaim water during the storm. Customers were not using reclaimed water during the rainy season. This proximate cause contributed to the hydraulic overloading. The additional amount of unused reuse water, coupled with the closing of the Albert Whitted WRF, generated a greater than capacity condition for the Northwest and Southwest Facilities, which led to the spill.

In the City of Largo, a bottleneck and loss of capacity was created by ongoing upgrades at the facility. During the Disinfection and Effluent Pumping Improvement Project, the WWRF disinfection tank was under construction and required the use of traveling bridge sand filters as a temporary disinfection tank. This resulted in a hydraulic bottleneck that would not allow the sand filters to flow by gravity to the dechlorination tank.

5.5.1 Potential Solutions for the WWTP Anomalies

In the city of St. Petersburg, the decommissioning of AWWRF added a substantial burden on the system. One of the options to reduce these anomalies includes the recommissioning of the AWWRF. The additional capacity by the temporary reopening of the AWWRF would ease burdens within other city facilities as improvements are made. Improvements are already underway within other city collection, transmission, and treatment facilities that will result, in time, lead to greater capacity, a reduction in SSO's, and allow the reclosure of the aged AWWRF.

In the case of the city of Largo, redundant systems could mitigate the effects of ongoing construction projects, however these efforts may be cost-prohibitive.

5.6 FORCE MAIN FAILURE

Sewer force mains are necessary to move wastewater great distances in significantly shallower conditions than afforded through construction of gravity mains. There is a practical limit, in Florida, of about 16-feet in depth, below which the open-cut cost per linear foot of installed pipe becomes prohibitively high. In instances of long runs from source to treatment works, it is practical and financially sound to install a lift station as an interceptor to the gravity system. Pumps provide flow and pressure to the force main, which is buried from 3 to 5 feet below grade rather than 16-feet (or deeper) below grade for the gravity main. If a force main is not functioning, as is the case with the failure in St. Augustine, wasterwater fails to flow through the pipe and inevitably ends up where it has the least resistance. The failure to flow causes SSOs and discharge in unwanted locations. Of the events that occurred during the storm, one location experienced a force main failure.

The following table summarizes the root and proximate causes of the event as well as the volume that was released.

TABLE 5-10 SUMMARY OF FORCE MAIN FAILURE

SSO ID#	Volume	Root Cause	Proximate Causes
8032-6	25,150	Force Main Failure	Extreme Flows Hydrogen Sulfide Corrosion

Force main failure was the root cause of the 25-thousand gallon spill that occurred on Ponce de Leon Blvd in St. Augustine. Extreme flows and pressures in the force main in conjunction with the corrosive weakening of the components in the pipe lead to the failure.

5.6.1 Potential Solutions for the Force Main Failure Modes

The first and foremost solution to the force main break is to repair the infrastructure in the area. Further solutions include the prevention of force main breaks by performing routine maintenance, minimizing extreme flow events through the reduction of I&I, and reducing corrosion through the mitigation of hydrogen sulfide in the system.

5.6.1.1 Mitigating Hydrogen Sulfide Corrosion

Dissolved in water, hydrogen sulfide is known as hydrosulfuric acid or sulfhydric acid, a weak acid. The presence of hydrogen sulfide can lead to accelerated and extensive damage to all components of wastewater collection systems including the treatment facilities. Hydrogen sulfide corrosion can significantly shorten the design life of sewers and associated mechanical and electrical systems. The best methods for mitigating the hydrogen sulfide corrosion is to first identify areas of corrosion through inspections, measuring of current corrosion and estimating corrosion rates. Several methods can help control the rate of corrosion. These methods include:

Reducing dissolved sulfide content.

There are currently three methods of reducing the dissolved sulfide content. The first is oxidation where oxygen, air, hydrogen peroxide or potassium permanganate are added to the system chemically, or biochemically oxidize the sulfide. This not only converts the sulfide to elemental sulfur or sulfate ion, but it also prevents the creation of biological sulfide. The second method is precipitation, where iron salt is added to the sewer to chemically bind sulfide to form an insoluble precipitate. Finally, pH elevation through the addition of sodium hydroxide inactivates the sulfate reducing bacteria.

Using corrosion resistant materials and coatings.

With the recent evolution in material sciences, corrosion resistant materials like plastics, concrete, coatings and paints provide a barrier that is resistant to acid that attacks the pipes.

Providing ventilation of the enclosed area of the sewer.

Mechanical ventilation of the enclosed areas, or the purging of the areas with nitrogen or clean air, can reduce atmospheric hydrogen sulfide levels and moisture in the system.

Conducting routine preventative maintenance.

Cleaning the sewers through processes like flushing or pigging can minimize the accumulation of debris in the system. The accumulations generally lead to reduced velocities, which increases the time that organic material can deposit and sulfides can be generated.

The EPA provides a useful resource in the publication titled "Hydrogen Sulfide Corrosion: Its Consequences, Detection, and Control"

5.7 PUMP FAILURE

Pumps are necessary at wastewater facilities to move fluids from one location to another. The Marshall Street Headworks consists of a splitter box where the all of the facility flow enters and screening takes place to remove large debris from the water. The wastewater then flows from the wet well into the main sewage pumps through suction lines into the pumps. From there, the wastewater is pumped to the rest of the plant. If a pump fails for any reason, the water doesn't get where it is intended to go, and accumulates in unfavorable locations.

The following table summarizes the root and proximate causes of the spill that occurred at Marshall Street WRF as well as the volume of effluent that was released.

TABLE 5-11 SUMMARY OF PUMP FAILURE

SSO ID#	Volume	Root Cause	Proximate Causes
3566	8,000,000	Pump Failure at WWRF	Inflow and Infiltration
3568	10,000,000	Pump Failure at WWRF	Inflow and Infiltration
3636	6,562,080	Pump Failure at WWRF	Inflow and Infiltration
3752	4,218,480	Pump Failure at WWRF	Inflow and Infiltration

In summary, a pump failure at the Marshall Street Wastewater Reclamation Facility in Clearwater was the primary case of the SSO events in the area of the facility. The pump split in 360 degrees at the volute and flooded the drywell, leading to an electrical failure of the entire system. This lead to wastewater inundation at the facility and in the immediate area. In total, the failure of the pump caused a series of SSOs that culminated in a total spill of 28.78 million gallons at four locations.

5.7.1 Potential Solutions for the Pump Failure Modes

The fundamental solution for the pump failure is to repair the volute of the pump that caused the failure and inspect and maintain pumps for proper operation. The next step in solving the issue of pump failures is to mitigate the pump failures altogether.

5.6.1.1 Mitigating Pump Failures

The first step in Pump Failure mitigation is to know and understand the root causes of pump failure. A research paper by Heinz Bloch titled "Root Cause Analysis of Five Costly Centrifugal Pump Failures" concluded that all failures belong to one of more of only seven categories:

- Faulty Design
- Material Defects
- Fabrication or processing errors
- Assembly or installation defects
- Off design or unintended service conditions
- Maintenance deficiencies and
- Improper operation

The ability to identify these failures can mitigate the risks that are associated with centrifugal pump operations. This is true in the case of the failure of the pump at the Marshall WRF. The City of Clearwater is currently investigating the cause of the failure of the volute on the pump at the WRF.

5.8 GENERAL CONSIDERATIONS FOR ENHANCING SYSTEM RELIABILITY

Utilities can effectively address several of the solutions identified in this section using internal resources in conjunction with a systematic approach such as the Plan, Do, Check, Act model used in Environmental Management Systems (i.e. ISO-14001) or through the use of EPA's Guide for Evaluating Capacity Management, Operation and Maintenance (CMOM) Programs at Sanitary Sewer Collection Systems. The goals of this guide are to limit SSOs and to preserve the significant capital assets that the community waste water systems represent. Through use of the guide communities increase the likelihood that they are properly reinvesting in wastewater infrastructure to ensure design capacity, to limit SSOs and to extend the design life of systems.

Another no cost/low cost solution that Florida communities should consider is participation in the FlaWARN Program. FlaWARN is the formalized system of "utilities helping utilities" address mutual aid during emergency situations. FlaWARN provides immediate relief for member utilities during emergencies by matching personnel, tools and equipment to assist the utility. Use of FlaWARN is attributable to faster return to service times for utilities impacted by extreme weather.

While no cost/low cost solutions may be easier for implementation, the challenge of maintaining a capital intensive waste water system will ultimately require investment to ensure the reliability of the infrastructure.

In addition to the utility level solutions discussed above, the FDEP's regulatory role informed by the root causes and solutions discussed above can be used to support a state-wide initiative for reduction of SSOs and unpermitted discharges. Monitoring and measurement are fundamental to continual improvement. By quantifying utility performance relative to the root cause failures the FDEP will be in a position to proactively identify exemplary utilities and those needing additional support. FDEP support can be provided in the form of templates that expedite the development of wastewater management tools, such as Emergency Response Plans, awareness training for elected officials responsible for funding this infrastructure and motivation programs to drive the performance of the utilities.

Execution of an SSO reduction campaign will require standardization of the root cause analysis process, a simplified reporting mechanism and development and continual maintenance of BMP resources (e.g. starting emergency generators before anticipated power outages to minimize startup failures) among other milestones. The initiative's data collection process should evaluate the funding required by the utilities to systematically upgrade their facilities in comparison to their authorized funding levels. Funding shortfalls should be identified and the web-based outreach program on available funding enhanced as either federal and/or state resources are aligned to enhance chronically underfunded wastewater infrastructure.

The SSOs and unpermitted discharges evaluated in this document have left citizens and elected officials with a desire to improve the waste water infrastructure. In light of the report findings and the scale of the state's continual improvement initiative it is recommended that the current regulations be thoroughly reviewed to align with the objective of reducing SSOs and unpermitted discharges. At a minimum the review should focus on enhancements that will proactively mitigate SSOs before they happen, reduce their economic and environmental impact and hasten the service restoration process.