SAVING 450 YEARS OF HISTORY FROM TIDAL FLOODING IN ST AUGUSTINE, FLORIDA **March 2019**

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Abstract:
St Augustine, south of Jacksonville in St. Johns County, has an urban population of approximately 13,000. It was founded in 1565 by the Spanish admiral Pedro Menéndez de Avilés, Florida's first governor. Spain ceded Florida to USA in 1819 and St Augustine remained the territorial capital until 1824. Given St. Augustine's distinct historical character the city is a major tourist attraction with many people coming to experience the architecture and history in the city. Access to the Atlantic Ocean is via the St. Augustine Inlet of the Matanzas River. The city has been largely unscathed during its long history, however in recent years flooding has become a problem, putting the buildings at risk of damage and decay. With an elevation just above sea level the city is at risk with rising sea levels and increased storm occurrences.

One such event occurred on October 7, 2016 when Hurricane Matthew caused widespread flooding in downtown St. Augustine.[(1)] During the hurricane the city's streets flooded, largely due to the overtaxed and aged storm sewer system.[(2)]

The effects of Hurricane Matthew were profound. With the downtown inundated residents were left with the clean-up task of pulling down walls, replacing water damaged furniture and restoring the Spanish colonial style buildings to their original glory.

This old city is doing what it can to handle new threats. They have begun installing valves to keep seawater from flowing back into storm water drains, which helps prevent sunny day flooding. They have also been conducting a study with a plan to dredge Maria Sanchez Lake and install a pump station to help during flood events.

St. Augustine is one of many chronically flooded communities along Florida's coast, and officials in these diverse places share a concern: They are afraid their buildings and communities will be further inundated by rising seas in just a couple of decades. The effects are a daily reality in much of Florida. Drinking water wells are being fouled by seawater. Higher tides and storm surges make for more frequent road flooding from Jacksonville to Key West, and they are overburdening aging flood-control systems[(3)]. By working together, the communities along the coast of Florida can learn from each other about best practices and successful techniques.

St Augustine did just that when looking at outfall protection. Fort Lauderdale has recently undertaken a major project of upgrading their outfalls to protect against sunny day flooding and flooding caused by backflow from the sea into the stormwater systems.

In the presentation we will discuss the issues surrounding flooding in St Augustine, what was learnt during the research phase and what technical solutions St Augustine are implementing to solve a problem that affects many low-lying communities in the US, and around the world. We will also talk about the results of the project and discuss the best practices implemented in the project.

[(1)] Martin, Jake (October 8, 2016). "Hurricane Matthew: Surveying damage in St. Augustine the morning after". The St. Augustine Record. Retrieved 8 October 2016.

[(2)] (MICHAEL BRAUN, MBRAUN@NEWS-PRESS.COM Published 7:14 p.m. ET Oct. 7, 2016 | Updated 7:01 p.m. ET Oct. 8, 2016 http://www.news-press.com/story/news/2016/10/07/hurricane-matthew-floods-st-augustine-beach-area/91748012/)

[(3)] http://jacksonville.com/news/metro/2015-05-11/story/st-augustines-flooding-problems-getting-worse

KEY WORDS:
Flooding, Sunny day flooding, Rising sea level, Climate Change, Best Practice, Stormwater, Case Study: St Augustine

PRESENTER PROFILE:
The Author, Kerry Olsson, has worked in the stormwater segment for 10 years worldwide. She has been involved in projects in USA, England, New Zealand and Australia primarily working with councils to ensure their infrastructure is future-proof in terms of flood prevention caused by backflow in stormwater systems.

The Author, Jessica L. Beach, has been a professional Engineer since 2005. Formally with St. Johns River Water Management District, and now with the City of St Augustine, she has witnessed the impact that flooding can have on communities, and what steps can be taken to help and mitigate the effects.

The Presenter, James Logan, has been in the New Zealand water and wastewater industry for 20 years. Now with a focus on stormwater and wastewater drainage systems, he has seen the extraordinary results that the WaStop has delivered in communities around New Zealand and the South Pacific.

1. INTRODUCTION

St Augustine, on the Southeast of USA, was founded by Spanish explorers in 1565 and is the oldest continuously occupied European-established settlement within the borders of the continental USA. According to the 2010 census the population was 12,975 and the population estimate today is around 14,000.

Founded on September 8, 1565 by the Spanish admiral Pedro Menéndez de Avilés, St Augustine took its name from the feast day of St Augustine which was the day Avilés ship first sighted land in Florida. The city was the capital of Spanish Florida for over 200 years and was designated as the capital of British East Florida for a 20-year period until being ceded to Spain in 1783. In 1819 Spain ceded St Augustine to the United States and was designated the capital of the Florida Territory in 1821. It remained the capital until the territorial government moved and made Tallahassee the capital in 1824.

Henry Flagler, a co-founder with John D. Rockefeller of the Standard Oil Company, spent the winter of 1883 in St. Augustine and found the city charming, but considered its hotels and transportation systems inadequate.[4] He had the idea to make St. Augustine a winter resort for wealthy Americans from the north, and to bring them south he bought several short line railroads and combined these in 1885 to form the Florida East Coast Railway. He built a railroad bridge over the St. Johns River in 1888, opening up the Atlantic coast of Florida to development.[5][6]

Flagler began construction in 1887 on two large ornate hotels in the city, the 540-room Ponce de Leon Hotel and the 250-room Hotel Alcazar. The next year, he purchased the Casa Monica Hotel across the street from both the Alcazar and the Ponce de Leon. His chosen architectural firm, Carrère and Hastings, radically altered the appearance of St. Augustine with these hotels, giving it a skyline and beginning an architectural

[4] *Sidney Walter Martin (1 February 2010). Florida's Flagler. University of Georgia Press. p. 130. ISBN 978-0-8203-3488-2.*

[5] Jim Cox (24 February 2016). *Rails Across Dixie: A History of Passenger Trains in the American South*. McFarland. p. 85. ISBN 978-0-7864-6175-2.

[6] Walter W. Manley; E. Canter Brown; Eric W. Rise; Florida Supreme Court Historical Society (1997). *The Supreme Court of Florida and Its Predecessor Courts, 1821-1917*. University Press of Florida. p. 263. ISBN 978-0-8130-1540-8.

trend in the state characterized by the use of the Moorish Revival style. With the opening of the Ponce de Leon in 1888, St. Augustine became the winter resort of American high society for a few years.[7]

In 1965, St. Augustine celebrated the 400th anniversary of its founding,[8] and jointly with the State of Florida, inaugurated a program to restore part of the colonial city. The Historic St. Augustine Preservation Board was formed to reconstruct more than thirty-six buildings to their historical appearance, which was completed within a few years. When the State of Florida abolished the Board in 1997, the City of St. Augustine assumed control of the reconstructed buildings, as well as other historic properties including the Government House. In 2010, the city transferred control of the historic buildings to the University of Florida.

In 2015, St. Augustine celebrated the 450th anniversary of its founding with a four-day long festival and a visit from Felipe VI of Spain and Queen Letizia of Spain.[9]

Preservation of St Augustine's history and architecture is important for the City itself, and the country as a whole. Protection from storms and flooding is part of the work being undertaken to ensure the cultural heritage is preserved for generations to come.

Flooding has greatly affected the city over its long history, specifically the low-lying areas such as Davis Shores. Whether from catastrophic hurricanes, sea level rise or "sunny day flooding", this ever-present concern has been a priority for the longevity of the city, its residents, visitors and infrastructure.

2. BACKGROUND

2.1 SUNNY DAY FLOODING

Sunny day flooding is occurring because the local tides are getting higher. Tides are affected by the alignment of the Sun, Earth and Moon. Due to rising sea levels, high tides are much higher than usual, and are flooding roads, homes and businesses, eroding beaches and causing sewage overflows. This type of flooding happens on days when not a single drop of rain has fallen. Sunny day flooding is especially problematic during high spring tides, or "King Tides", which occur as part of the natural tidal cycle. King Tides are also getting higher due to rising sea levels. Sunny day flooding happens 10 to 20 times per year in Miami. It can even occur twice in one day, depending on the timing of the high tides. Tidal flooding is also occurring in Sarasota, St. Augustine and Manatee County. Some Florida residents have witnessed portions of the barrier islands near their communities going underwater. Scientists speculate that the cause of increased tidal flooding and rising sea levels is human-made climate change.[10]

It is common knowledge that most of the water on Earth— 97 percent, in fact — is contained in the oceans. The remaining 3 percent is freshwater, and is found in rivers, lakes, groundwater sources, ice and glaciers. Much of that freshwater— a whopping 99 percent— is frozen in glaciers and ice sheets. Climate change is causing land-based glaciers and ice sheets to melt. It is also causing the thermal expansion of the ocean's water. Greenland is covered by 660,000 square miles of ice sheets, and Antarctica has 5.4 million square miles of ice. In an article in Popular Mechanics, Avery Thompson describes how a part of the Pine Island Glacier the size of Manhattan broke off from Antarctica and floated out to sea in January 2017. The threat of the ice sheets melting plays a partial role in rising sea levels. Another component is the fact that there is no longer enough white surface at the poles to reflect sunlight back into space, leading to even more increases in temperature. Due to the increase in the Earth's global temperature, these frozen sources of water will begin to melt and flow into the oceans through rivers and groundwater sources. This will raise the levels of the oceans around the

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[7] Sidney Walter Martin (1 February 2010). *Florida's Flagler*. University of Georgia Press. pp. 117–118. ISBN 978-0-8203-3488-2.

[8] *History News*. 20-21. American Association for State and Local History. 1965. p. 208.

[9] Gardner, Sheldon (July 16, 2015). "King and queen of Spain to visit St. Augustine in September". The St. Augustine Record. Retrieved 8 October 2016.

[10] https://voicesforbiodiversity.org/articles/sunny-day-flooding

world. Rising sea levels and the associated tidal flooding pose a direct threat to the state of Florida. The National Oceanic and Atmospheric Administration (NOAA) has speculated that Florida will face increasing occurrences of tidal flooding by 2050.

According to NOAA's gauge stations around Florida's coastline, the water is rising by a third of an inch every year. If this trend continues for the next thirty years, the effect on Florida will be devastating. The threats of rising sea levels and sunny day flooding affect not only the coastline, but also the rivers, bays, inlets and canals that run throughout the state. Florida's water supply and water treatment facilities are also at risk. There are estimates that the seas could rise between 8 inches to 5.5 feet by 2070 (20cm – 168cm). Even a 3-foot (92cm) rise in sea level would displace millions of Floridians from their coastal homes and devastate thousands of communities.

Another example of the devastating global impacts that climate change and sea-level rise could have was detailed in an article published in The Guardian that described a recent joint study by the US Geological Survey, the Deltares Institution in the Netherlands, and Hawaii University. In their review of potential sea-level rise, which also included a study of the effects of wave-driven flooding, they concluded that residents living in low-lying areas, especially the small islands and atolls in the Pacific and Indian Oceans, could be displaced from their homes by the rising sea level and contamination of their freshwater supplies with salt water. Because of this, hundreds of thousands of people in these regions are at risk of losing their homes and having to evacuate for higher ground.

The study is not the first of its kind, nor is it the first warning of the negative impacts that many people will be facing due to climate change. Other evidence was described in a CBC radio interview with Anote Tong, the former president of a small island nation in the Pacific Ocean called Kiribati, where the effects of sea-level rise are already happening. Citizens of the island nation have been forced to evacuate their homes because the water is encroaching onto the island. They are the first "climate change refugees." Tong has become their voice and is trying to raise awareness of the effects that climate change is having on these small islands that, like Florida, are facing the risk of being completely submerged. Tong is also consulting with various countries, such as the United Arab Emirates and Japan, in developing land-reclamation technologies that could help small island nations in their battle against the rising tides.

2.2 ST AUGUSTINE AND SUNNY DAY FLOODING

During sunny day temporary tidal flooding events, sea water enters the city's stormwater drainage system, backing up and into the streets, creating street flooding. In the Davis Shores community in St Augustine there are approximately 21 outfalls that collect the stormwater from the streets and discharge through the existing pipe system into either the Matanzas River or Salt Run.

Sunny Day Flooding in St Augustine October 2017

Sunny Day Flooding in St Augustine October 2017

Tidal outfalls are often lower than the high tide level leading to flooding during high tides and King Tide events. When tidal levels rise the outfalls become filled with sea water which in turn pushes back up the pipe and out of the street drains, flooding streets and homes.

2.3 PILOT STUDY – FLORIDA DEPARTMENT OF ECONOMIC OPPORTUNITY

St. Augustine has put more than one quarter-million dollars of funding forward to kick off a project that focuses on the flooding around Lake Maria Sanchez. It is an endeavour that has also attracted major support from the Federal Emergency Management Agency because of Hurricane Matthew.

This pilot study area for the Florida Department of Economic Opportunity was titled the "Community Resiliency: Planning for Sea Rise" project and is actually divided in half, according to Reuben Franklin Jr., professional engineer and mobility manager employed by the city of St. Augustine.

"The project was split into two phases," said Franklin. "Phase one began in April 2016 and was completed in June 2016. This phase consisted of a sea level rise vulnerability analysis for the city. Phase two began in June 2016 and was completed in May 2017. This phase consisted of an adaption plan based on the vulnerability analysis."

Because many Florida communities like St. Augustine have been experiencing the undesirable impacts of elevated sea levels, harsher storms and more intense downpours, the DEO community resiliency initiative aids

them in assessing vulnerabilities to projected increases in coastal flooding and in creating strategies to make their areas better able to recover quickly.

The objective — and probably the most intensive hazard mitigation project — is to make the area able to defend itself from a Category 1 hurricane, which is something St. Augustine's seawall is capable of holding back.

"The project has been approved for the HMGP (Hazard Mitigation Grant Program) grant funding at 75 percent of the entire $11.5 million cost," said Franklin. "The design will be funded first, and once approved, the construction monies will be allocated. So, currently the design is approved and funded."

2.4 STUDY OUTCOMES

The city's share of the total project will be around $2,875,000, including the design phase. Included in the project are the installation of stormwater backflow prevention valves; the creation of a larger stormwater collection system on Cordova, Bridge and Granada streets; excavating the lake; the placement of a stormwater pumping station at lake control gates; and the design of a system to protect properties along the marsh south of South Street from flooding.

The city is working to protect historical/cultural resources and low-lying critical infrastructure through the installation of tide check valves on stormwater outfalls to prevent tidal waters from backing up through the stormwater system and cause flooding.

The stormwater backflow valves should help residents see fewer flooding incidents over the course of the year. Sunny day flooding happens about 12 to 16 times a year in St. Augustine.

2.5 PROJECTS TO SAVE THE CITY

The city is in the beginning stages of designing a pump station and flood protection barrier for the Lake Maria Sanchez Basin. Jessica Beach, professional engineer, is the city's stormwater engineer heading up the projects around the City.

While the city is taking proactive measures to address sea level rise, Beach noted that this was not the only project to address the matter.

"It's multiple projects that are in various stages: some are completed; some are nearing completion; some are in the design and permitting stages; and others are future/ planned projects," said Beach.

There are three local governments involved — the city of St. Augustine, city of Clearwater and Escambia County. The single biggest challenge was coming to terms with the complexity of the idea of sea level rise and how much it impacts the city.

The city also plans to secure disaster relief funds from the U.S. Department of Housing and Urban Development, which had been awarded to St. Johns County of which St. Augustine is the county seat.

Flood Type	Description	Frequency	Water Elevation	Source
Mean Higher High Water (MHHW)	The higher daily high tide elevation, defining the limit of what land is essentially "inundated" or has very limited use.	Daily	~2 ft NAVD88	NOAA VDatum software
Nuisance Flooding	Areas frequently flooded by tides and/or small coastal storms. Results in shallow flooding, which may disrupt or limit use.	12-17 times a year	3.75 ft NAVD88	Tidal gauge analysis and coordination with community
1% annual chance flood event	Areas subject to flooding by significant coastal storms. Defines the Special Flood Hazard Area as delineated on Federal Emergency Management Agency Flood Insurance Rate Maps. Also known as the "Base Flood".	~26% chance in 30 years	Range from 6-10 ft	Preliminary FEMA FIS update for St. Johns County, FL.

This chart shows definitions of flood types from the "Coastal Vulnerability Assessment." (Graphic provided)

2.6 FINAL REPORT

According to the "Final Report of St. Augustine — Analysis & Appendix," three types of coastal flooding were identified for analysis in the pilot program:

- Mean Higher High Water, or MHHW — defined as the highest daily high tide, representing the limit of where land is "wetted" on a daily basis and has very limited use.
- Nuisance flooding — defined as a minor flood event that occurs monthly, often resulting in the flooding of roads. This type of flooding has the largest potential for increase with SLR.
- The 1 percent annual chance flood, also known as the 100-year recurrence interval flood — defined as the Special Flood Hazard area depicted on FEMA Flood Insurance Rate Maps. Such an event has a 1 percent chance of occurring in any given year, and a 26 percent chance of occurring over a 30-year timeframe.

Of the three types evaluated, nuisance flooding has the largest potential to impact St. Augustine in the near term.

Because the study assessed the vulnerability of the city to these existing flood conditions with an incremental approach, this involved gradually increasing sea level by half-foot increments to identify "tipping points" in vulnerability. The vulnerability assessment — or how vulnerability to flooding will change with SLR — objective items included:

- Infrastructure — percent of network affected by scenario and days inundated for road segments
- Historic resources — bridges, water/wastewater
- Archaeological resources — percent of archaeological zone or cemetery affected by scenario
- Groundwater impacts — local and regional response to SLR

Ultimately, the project aims to achieve five goals in vulnerable coastal communities:

- Make infrastructure and the built environment robust to expected changes.
- Make systems — physical or organizational — that are vulnerable to SLR more flexible by altering and/or moving their components.
- Enhance the ability of natural systems to reduce vulnerabilities.
- Identify mal-adaptions and begin undoing them.
- Inform the public about the short- and long-term risks that SLR will create.

Various policy tools are available to localities seeking to adapt to SLR. Some of these tools include transferable development rights; incentives; setbacks and buffers; rebuilding restrictions; stormwater utility; special assessments; building codes and design; floodplain regulations; zoning and overlay zones; hard- and soft-armoring permits; conditional development; impact fees; conservation easements; real estate disclosures; coastal land acquisition programs; and land trusts.

Two intensive reports that have been made on this project were released during 2018 — the "Coastal Vulnerability Assessment" and the "Strategic Adaption Plan." [11]

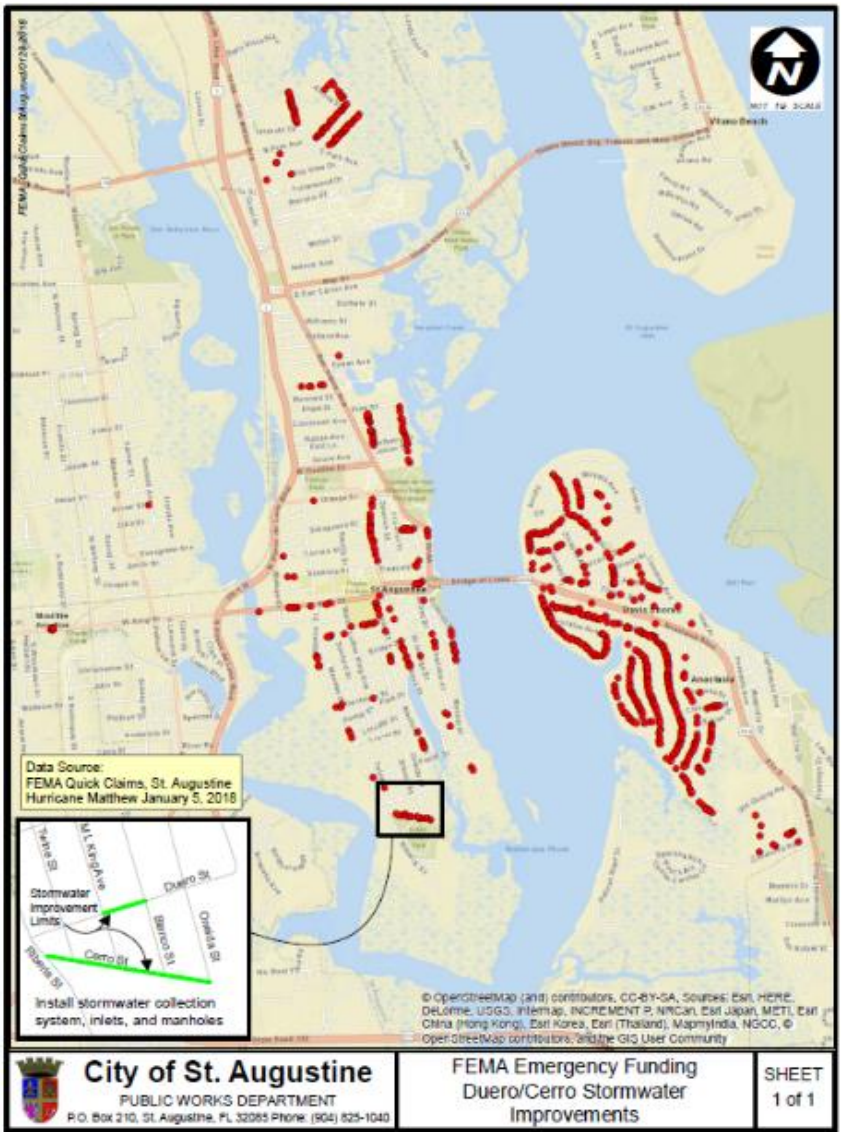
2.7 DAVIS SHORES PROJECT

One of the projects to come as a result of the report was Davis Shores Tide Check Valves project for Flood Mitigation (nuisance flooding) and was scheduled to take place during FY18.

Davis Shores was a particularly hard-hit area during Hurricane Matthew. Numerous homes were inundated with sea water and high levels of damaged were recorded. The Hurricane itself caused damage but a great deal of the damaged was caused from unprotected outfalls or check valves that no longer functioned and therefore allowed water from the sea to push up the outfall pipe and flood the surrounding area.

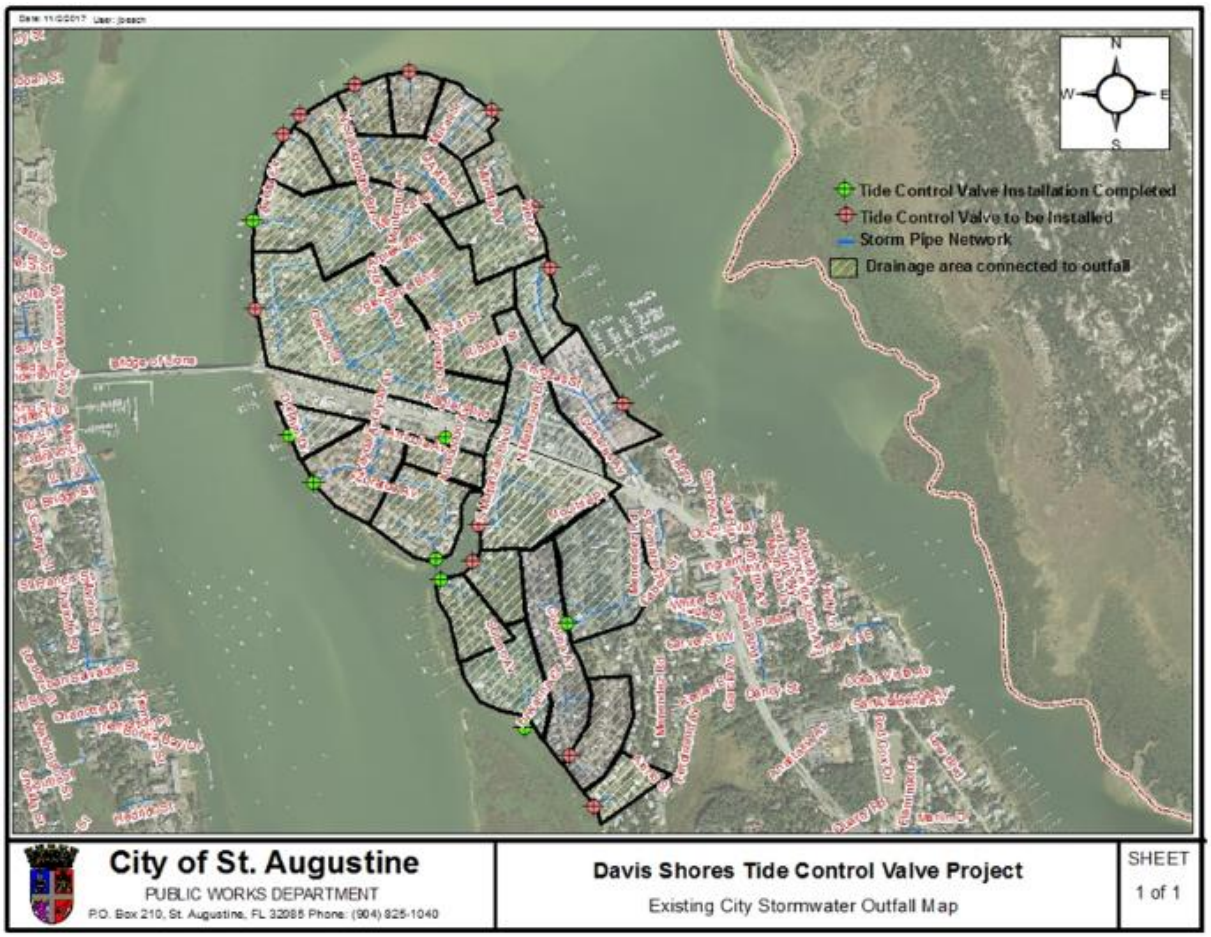
Davis Shores neighborhood post Hurricane Matthew

11 http://www.citystaug.com/government/public_works/ResiliencySustainability/CoastalVulnerability.php



Map showing FEMA Claims from Hurricane Matthew

Existing stormwater outfalls in Davis Shores were predominantly unprotected or had valves that had failed. 21 outfalls in total were identified as problem outfalls.



The City's stormwater system will gravity discharge through its underground pipe network and into the Matanzas Inlet or Salt Run when the tides are low (or below) the bottom of the outfall pipe. As the tide rises, especially during higher than normal tide events, the salt water can back up and into the pipe network, and in extreme conditions, cause street flooding.

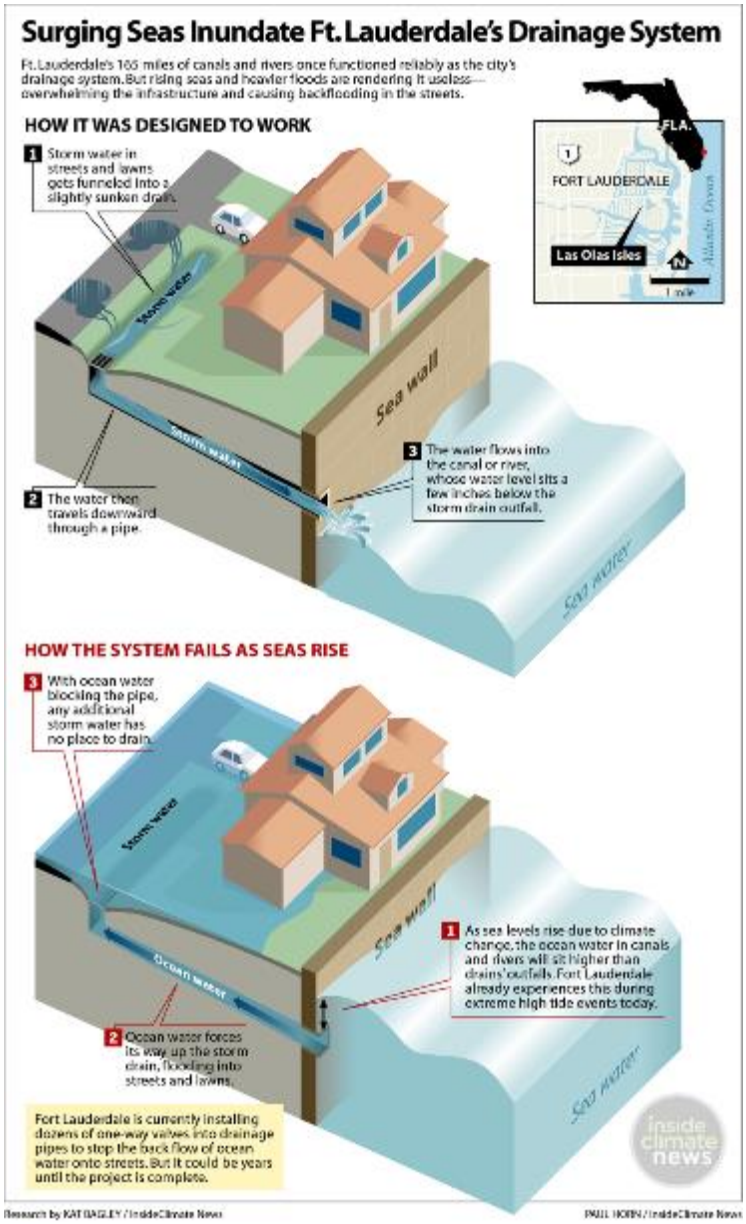


Illustration showing how Fort Lauderdale stormwater system works. St Augustine functions in the same way.

In addition to tidal flooding events, if weather conditions persist concurrently with tidal flooding (such as rainfall or Nor'easter winds), this can significantly amplify the flooding effects. It is not uncommon during these Nor'easter events, that the winds push tide water further up into the storm water collection system, resulting in more extensive road flooding.

2.7.1 NON-FUNCTIONING VALVES

The City has several locations where there are non-functioning valves. Some of these valves had reached their life expectancy and needed replacing, others had failed and were allowing water to go back up the outfall pipe during high tide events. The City documented all their outfalls to see which outfalls had non-return valves installed, if they were functioning or not, or if there was no valve installed at all.

The older non-return valves were either duckbills or flap valves. Both styles of valves are installed outside of the outfall pipe making them vulnerable to damage during storm events, and also require high levels of maintenance. Oyster growth often rendered these valves useless as the sealing point of the valve was no longer able to close and seal during tidal events.

Older style duckbill valve damaged and non-functioning due to oyster growth and general material degradation.

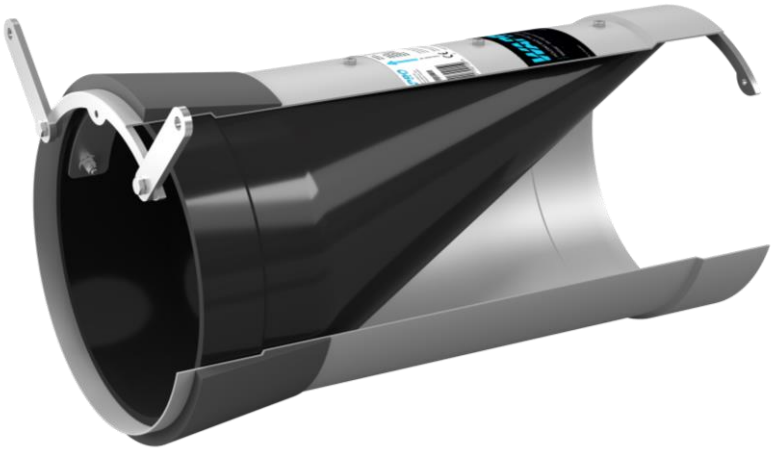
WaStop valve installed inside the existing pipe after removal of the duckbill.

2.7.2 CHOICE OF VALVE

The City of Saint Augustine explored the alternatives available on the market for replacing duckbills and flap valves. Jessica Beach, P.E., Project Manager Public Works City of Saint Augustine, contacted other Cities who had been suffering from the same issues with tidal flooding. Fort Lauderdale had recently undertaken a project to replace a number of their non-functioning valves and had been trialing the two types of inline check valves available. One of those being the CheckMate manufactured by TideFlex, and the other WaStop manufactured by Wapro. Fort Lauderdale's experience was that the WaStop was the better option given its low headloss and completely tight seal which minimizes the risk of oysters and other marine growth on the valve or upstream.

The valves differ in a few ways, the CheckMate is constructed completely from rubber whereas the WaStop is constructed using a stainless housing and an elastomer membrane. The WaStop maintains its shape due to the rigidity of the housing and the mechanical memory in the membrane. The CheckMate has an internal fixation band whilst the WaStop has external fixation points. Both valves are installed inside the pipe and are protected as such from damage from sun and debris.

CheckMate® manufactured by TideFlex®



WaStop® manufactured by Wapro AB

The City of Saint Augustine chose to install both types of valves to assess the differences between them over time, and during installation. Findings were that whilst the WaStop took longer to install it was a better fit once in place. The CheckMate was however easier to use in locations where the valve needed to be deformed to fit in between jetty pilings and such like. The WaStop valve weighs about half that of a CheckMate which allowed the City to install the majority of the valves themselves, saving up to 72% on the total cost compared to needing a contractor with heavy lifting equipment.

Cost Comparison (US$)	DN600 In House Install	DN750 In House Install	DN750 Contractor Install
Materials - (tools, straps, bolts, riprap for outfall)	$430	$430	$30,609
Valve Cost (WaStop)	$6,930	$10,068	
Labour - (can vary, depending on preparation, cleaning, CCTV and install)	$1,318 (4-man crew + resetting valve – additional equipment & labour)	$570 (4-man crew)	
Subtotal	**$8,678**	**$11,068**	**$30,609**
Cost Savings	$21,930	$19,541	
% Cost Savings	**72%**	**64%**	

Installation of a WaStop check valve DN750 (30").

3.0 RESULTS

Immediately following the installation of the valves effect could be seen. The streets that regularly flooded due to high tides or King Tide events were instantly protected. A large majority of the valves were installed prior to the first King Tide following the release of the report and funding.

Before Installation of Non-Return Valve	After Installation of Non-Return Valve
	
OF-0117 (Before): street flooding during King Tide event (October 2017) due to non-functioning valve	OF-0117 (After): no street flooding during King Tide event (December 2017) - tidal flooding eliminated

	
OF-0142 (Before): street flooding during King Tide event (October 2017) due to no valve in outfall	OF-0142 (After): no street flooding during King Tide event (December 2017) - tidal flooding eliminated
	
OF-0139 (Before): street flooding during King Tide event (October 2017) due to no valve in outfall	OF-0139 (After): no street flooding during King Tide event (December 2017) - tidal flooding eliminated

3.1 LESSONS LEARNT

3.1.1 OWNERSHIP

In some installations flooding occurred after the valves were installed. Extensive investigation was undertaken to find where the flooding was coming from. Several points were identified as weaknesses.

It was determined that one area that was heavily flooded post installation was flooded due to an outlet not being protected with a non-return valve. This particular outfall was not owned by the City, and therefore was not part of the Davis Shores project.

Blue arrow points to the outfall with no non-return valve which caused flooding in the red circled areas. The isolated blue circled area was not affected.

Flooding occurring due to an unprotected outfall not owned by the City.

3.1.2 OVERTOPPING

Another vulnerability is when the sea level rises to the point when it overtops the sea wall. When this happens water quickly spreads around the low-lying area. During January 2018 this occurred due to a high tide along with sustained high winds (32 km/h) which added 60cm to the high tide elevation.

In these circumstances valves hold back the flooding until it overtops, then the height of water over the top of the wall determines the flooding level. A project to raise sea walls is being investigated.

Flooding caused by overtopping.

3.2 PUBLIC OUTREACH

It was found that public outreach helped increase the level of understanding of those affected by flooding. Information prior to undertaking the project helped those affected understand when the risk was high for flooding, and to give them a warning prior to a King Tide event.

As the investigation moved through the phases the public was kept informed and part of the project. When the project moved to the valve installation phase the public were informed what the valves would do, how they would help, and what type of flooding they couldn't help such as overtopping. It is also important for the public to know that when there is a high tide event at the same time as a heavy rainfall, water could accumulate on the streets as the valves are in the closed position protecting against backflow, and therefore are unable to let flow out unless the upstream pressure is higher than the downstream pressure.

4. CONCLUSIONS

The project has been a success with protection of many areas earlier affected heavily by sunny day flooding. More work needs to be done to completely protect the history, heritage and residents of Saint Augustine but the immediate risk is mitigated.

Other areas have been identified for installation of non-return valves and projects have been planned for the coming two years including pump stations and sea wall raising.