FINAL

Drainage Investigation and Flooding Analysis

Wellington Avenue and Bridge Street (Project No. 15-037)

Prepared for

City of Newport
Department of Utilities
Water Pollution Control Division

March 2017; Revised May 2017

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Revisions (May 2017)

Modified the dimensions of the box culvert at Wellington Avenue to be 3 by 8 feet, consistent throughout.

Changed the size of the circular outfall pipe at Wellington from 60-inches to 66-inches, throughout.

Contents

Appendixes

Tables

Figures

Acronyms and Abbreviations

1D/2D	one-dimensional/two-dimensional
City	City of Newport
DEM	digital elevation model
USEPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
ft^2	square feet
GI	green infrastructure
GIS	geographic information system
h/h	hydrologic/hydraulic
King Tide	an especially high tide, such as a perigean spring tide
LiDAR	light detection and ranging
mgd	million gallons per day
MLLW	mean lower low water
NAVD 88	North American Vertical Datum of 1988
NHC	National Hurricane Center
NOAA	National Oceanic and Atmospheric Association
O&M	operations and maintenance
RSLC	relative sea level change
SLOSH	Sea, Lake, and Overland Surge from Hurricanes (NOAA model)
SWMM	Stormwater Management Model
USACE	United States Army Corps of Engineers
WPCP	Water Pollution Control Plant

Executive Summary

Two low-lying coastal areas in Newport, Wellington Avenue and Bridge Street, are experiencing an increase in surface flooding frequency. These areas are subject to “sunshine flooding,” or flooding solely caused by tidal fluctuations. Flooding occurs when harbor water backs up in the storm drain system and overtops the catch basins. The Bridge Street study area has existing tide gates within the storm drain system for the two lowest lying catch basins, but these tide gates malfunction frequently and other slightly higher unprotected catch basins flood in this area. The flooding in both areas is exacerbated when precipitation events coincide with these high tides. With sea level rise and more intense and frequent storms already being experienced, these flooding issues will only worsen unless measures are taken.

CH2M gathered all relevant information on the storm drainage system and conducted multiple field surveys to characterize the causes of flooding and conceptualize controls to alleviate/mitigate the flooding. One significant finding of the multiple field surveys was the identification of a cross-connection between the Bridge Street drainage system and the Marsh St. drainage systems. The details of this cross-connection and the revisions made to the GIS are detailed in **Section 2**.

Two-dimensional (2D) hydrologic/hydraulic (h/h) models were built for both study areas for engineering evaluations. These models were calibrated with one dry weather flooding event and one wet weather flooding event that had been photo documented. One observed dry weather flooding event during the field surveys was used to validate the models. The causes of wet weather flooding are primarily due to rainfall occurring at high tide when the storm drains are already full of harbor water. Both of these study areas have an approximate 5-year drainage return capacity at low tide, the exception being sediment built up in the Wellington Avenue storm sewers can cause wet weather flooding even at low tide.

Preliminary screening of conveyance and control technologies was conducted for both areas using the July 1, 2015 storm event at varying tide elevations. This storm was selected because it was a high intensity 2-year storm and it was current enough to be relatable to the stakeholders. The conveyance and control technologies considered include catch basin rehabilitation and sumps to keep the pipes clean, tide gates, larger pipes, pipe rerouting, green infrastructure and pump stations. The only technology found to not be beneficial was replacing existing storm sewers with larger diameter storm sewers.

Short-term and long-term recommendations were developed for each study area considering benefits, costs, and impacts on residents. To test the effectiveness, the control plans were measured against the existing conditions for a typical year to examine all the possible scenarios of rainfall and tide correspondence. Ten years of rainfall and tide data were simulated in the models which led to selecting 2013 as a typical year for engineering evaluations. This year had 74 precipitation events including a 3.7-inch rain storm and represents recent trends in tidal elevations with sea level rise. Under the typical year, the Wellington Avenue study area experiences 70 flooding events, 38 dry weather and 32 wet weather, and the Bridge Street study area experiences 31 flooding events, 24 dry weather and 7 wet weather. For these typical year events, up to approximately 70 to 80 properties may experience surface ponding on or directly adjacent to their property in the Wellington Avenue study area by a precipitation event coinciding with high tide. In the Bridge Street study area, up to approximately 40 properties may experience surface ponding on or directly adjacent to their property by a precipitation event coinciding with high tide.

The short-term controls recommended for the Wellington Avenue study area include installing tide gates on a 66-inch diameter and 3 × 8-foot box culvert storm sewer outfall, outfall dredging to access and clean the 66-inch outfall, sediment removal from storm sewers, catch basin rehabilitation, and rerouting Houston Street storm sewer to the 66-inch outfall. These recommended changes are engineered to eliminate dry weather flooding and are calculated to reduce wet weather flooding by 81 percent down to six events in the typical year. The six remaining flooding events would occur with high intensity rainfall coinciding with high tide. These controls are estimated to have a $3.9 million capital cost and $94,600 annual operations and maintenance (O&M) cost, at present value. These costs are conceptual level planning estimates only. Better refined cost estimates should be developed as part of the design of the recommended short-term controls and would provide better input to the City's capital planning processes.

The recommended long-term controls include installing an additional tide gate on an 18-inch storm outfall, green infrastructure and constructing a 55 mgd stormwater pump station. These controls are engineered to eliminate the remaining flooding events during the selected typical year and have an estimated additional $30.7 million capital cost and a $208,600 annual O&M cost, at present value.

A summary of calculated flooding frequencies for the existing condition and future conditions with implementation of the recommended actions in the Wellington Avenue study area are shown in **Figure ES-1**.

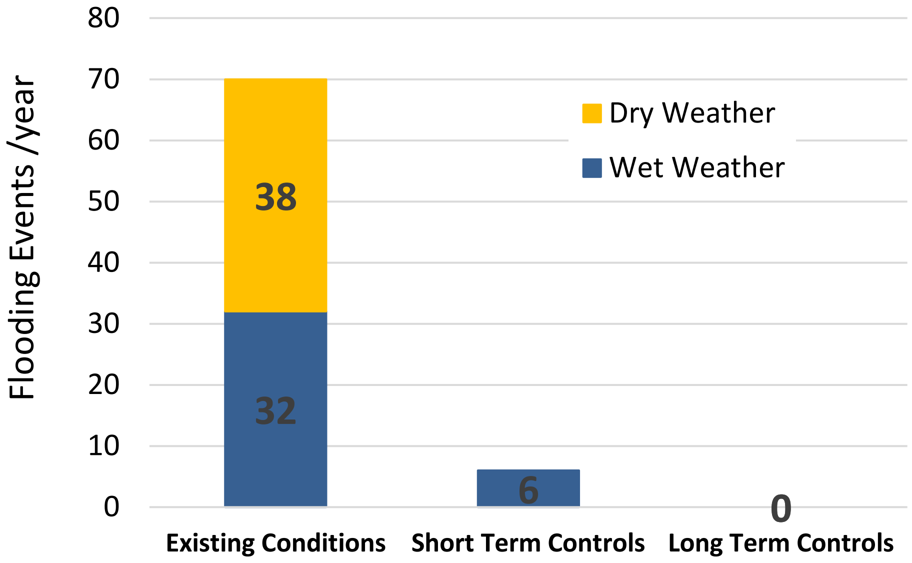


Figure ES-1. Wellington Avenue Study Area Short-term and Long-term Controls Performance
Flooding events during a typical year (2013) compared with existing conditions

The short-term controls recommended for the Bridge Street study area include installing tide gates on a 48-inch outfall, sediment removal from storm sewers, and catch basin rehabilitation. These controls are engineered to eliminate dry weather flooding and are calculated to reduce wet weather flooding by 43 percent down to four events in the selected typical year. The remaining four flooding events would occur with high intensity rainfall coinciding with high tide. These recommended changes are estimated to have a $2.1 million capital cost and a $60,400 annual O&M cost, at present value. These costs are conceptual level planning estimates only. Better refined cost estimates should be developed as part of the design of the recommended short-term controls and would provide better input to the City's capital planning processes.

The recommended long-term controls include green infrastructure and constructing a 35 mgd stormwater pump station. These controls are engineered to eliminate the remaining flooding events during the selected typical year and have an estimated additional $17.2 million capital cost and $125,900 annual O&M cost, at present value. A summary of calculated flooding frequencies for the existing condition and future conditions with implementation of the recommended actions in the Bridge Street study area are shown in **Figure ES-2**.

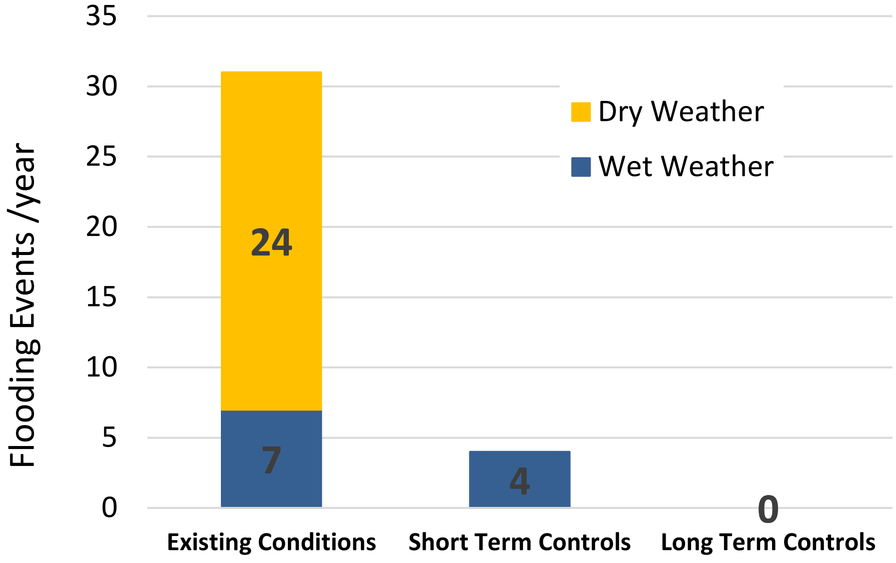


Figure ES-2. Bridge Street Study Area Short-term and Long-term Controls Performance
Flooding events during a typical year (2013) compared with existing conditions

The recommended short- and long-term actions are engineered to eliminate flooding during the selected typical year, but extreme storm surge and high intensity storms will exceed infrastructure capacities and flood these areas. It is not possible nor cost effective to develop and implement controls that would contain all events such as major hurricanes, Nor'easters (macroscale storms that occur along the upper east coast of the US and Atlantic Canada), or extreme precipitation and both study areas would likely have flooding during events of this type even with the recommended short- and long-term actions. Plans and preparations for these major events will require coordination of private property owners as well as other City entities such as the Historic District Commission, City Planner and Zoning Officer.

Climate change and sea level rise will most likely increase the frequency and magnitude of flooding and additional adaptation will be required to protect these study areas. Sea level has already risen approximately 1 foot at Newport over the past 100 years and is predicted to rise as much as 2 feet by the year 2065. With this forecasting, tide elevations will exceed bulkhead heights and topographic barriers and flood the study areas. The Wellington Avenue study area may experience 157 flooding events from the harbor by 2065. These events will begin at the west end of the sea wall opposite Columbus Avenue. Flooding may be prevented by modifying the existing weep holes and extending the sea wall around the beach to Chastellux Avenue. The Bridge Street study area may experience 27 flooding events from the harbor by 2065. These events will begin at the boatyard south of the Goat Island Connector. Additional flood resiliency adaptations beyond those recommended in this report for the storm drainage systems will most likely be required to protect the two study areas in the future.

SECTION 1

Introduction

Within the City of Newport (City), there are two low-lying coastal areas that are subject to increasing frequency of surface flooding. These areas experience what is known as “sunshine flooding,” in which flooding occurs solely from higher high tides. The primary source of this flooding is harbor water backing up in the storm drain system and spilling out of the catch basins onto streets. The flooding is exacerbated when precipitation coincides with these periods of astronomical high tides. The two areas subject to flooding are associated with existing storm drain outfalls and their respective drainage areas are delineated and described in this report as the Wellington Avenue and Bridge Street study areas. The study areas are shown in **Figure 1-1**.

The Wellington Avenue study area is located on the south side edge of the Newport Harbor. Parts of this area used to be a tidal estuary, but has since been backfilled and replaced with King Park. This drainage system contains a 66-inch and 3 × 8-foot box culvert outfall opposite Marchant Street and one 18-inch outfall opposite Chastellux Avenue. Only the 3 × 8-foot box culvert outfall is above low tide, and none of these outfalls are equipped with tide gates. The tidal flooding begins at the two lowest lying areas at the intersection of Marchant Street and Wellington Avenue and a catch basin in the west side of King Park.

The Bridge Street study area is located in The Point and is mostly backfill that has likely settled significantly since its construction. The majority of the property in this area is historic homes with limitations on any modifications the owners can make to relieve flooding impact. The drainage system contains one 48-inch outfall opposite Storer Park and falls below low tide. There exists two tide gates on the south branches along 2nd and 3rd Streets to protect the lowest lying catch basins along Marsh Street, but catch basins along Bridge Street that are unprotected by the tide gates are still low enough to experience flooding during higher tides without rainfall. Just south of this drainage system lies another 3 × 5-foot storm drain system along Marsh Street.

CH2M worked with the City and local residents to develop recommendations for alleviating/mitigating flooding in the two study areas. Public involvement was critical during the project to establish what the largest concerns are with the flooding and identify non-cost screening criteria to evaluate the advantages and disadvantages of potential conveyance and control engineering alternatives. Local residents impacted by the flooding were encouraged to work closely with the Historic District Commission, City Planner and Zoning Officer if they desired to implement resiliency related modifications to their personal properties.

Relevant information for the study areas was collected and several field investigations were conducted to understand the conditions and causes of the flooding and to develop a 2D h/h model of the storm sewer systems to perform engineering evaluations. A wide range of conveyance and control strategies were identified and evaluated with the models to examine their effectiveness. A screening analysis was performed on the alternatives using cost and non-cost benefit criteria including those identified by local residents. After the screening process, recommended short- and long-term conveyance and control alternatives were developed for each study area.

The intended life cycle of the recommendations would most likely be 50 years. Therefore, noting that these areas will most likely be susceptible to the effects of continuing sea level rise and climate change, the engineering evaluations and planning were performed with consideration of forecasted sea levels and rainfalls 50 years into the future.

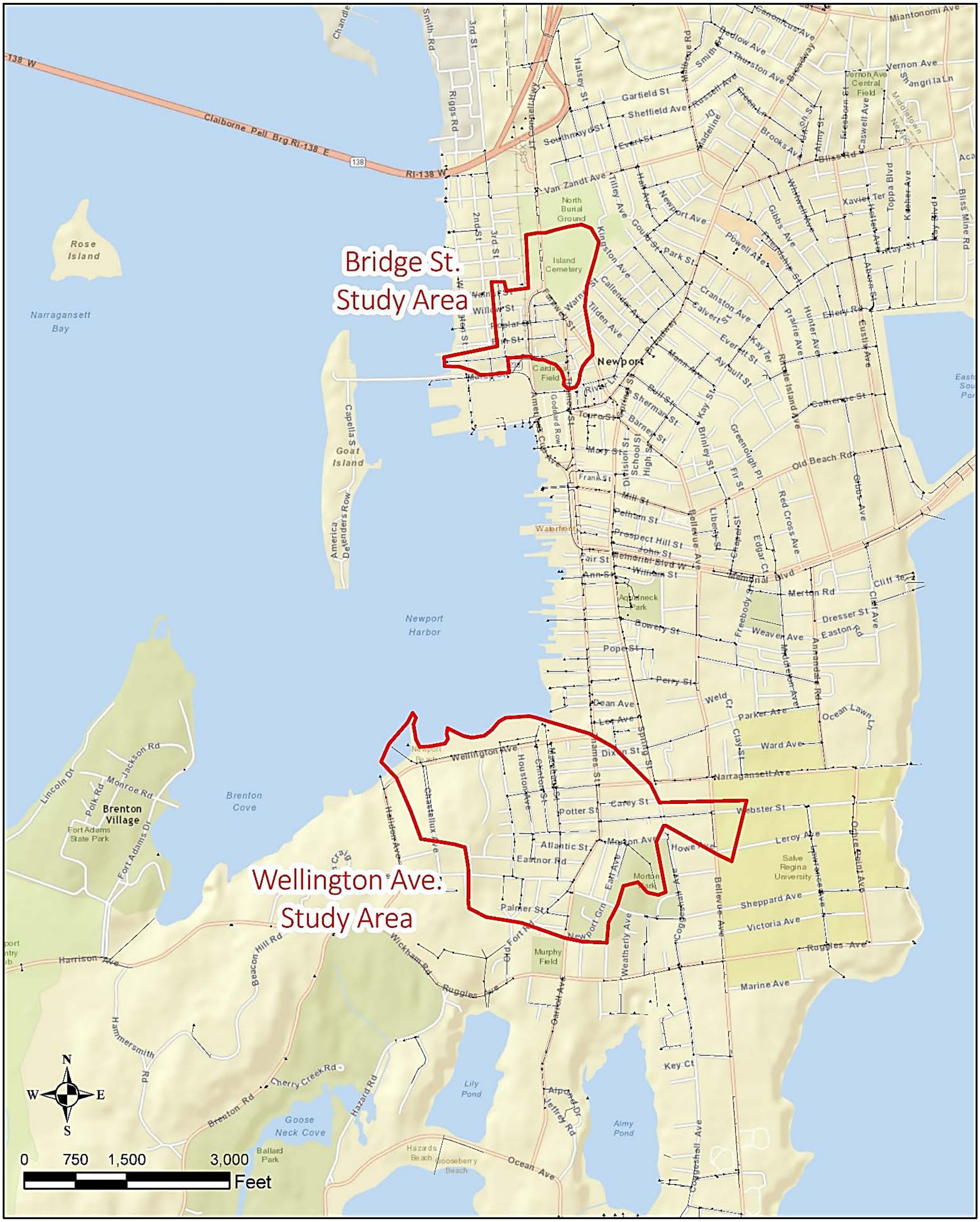


Figure 1-1. Drainage Investigation and Flooding Analysis Study Areas

The two study areas of Bridge Street and Wellington Avenue

SECTION 2

Data Collection

2.1 Overview and Objectives

The overall objective under this task was to acquire all relevant data in the study areas to construct h/h models, understand the causes of flooding and ultimately develop alternatives to alleviate/ eliminate the flooding. CH2M compiled geographic information system (GIS) data, light detection and ranging (LiDAR) data, maps, record drawings, rainfall records, FEMA Flood Insurance Rate Maps (FIRMs), tidal records and dry weather and wet weather flooding photos and documentation for the two study areas from the City of Newport, local residents, and previous engineering work. The main effort of this task was to update these data sources, identify data gaps, and fill those gaps via additional data collection and field investigations for the City in general and especially in the two study areas.

2.2 Existing Data

Data that was reviewed, updated, and used to create the h/h models and develop alternatives included the following:

- Existing GIS data and record drawings were used to establish the best information available on the storm drain systems serving the two study areas. The GIS data was checked for connectivity and continuity. A field reconnaissance survey was then performed to take measurements and verify the locations and connectivity of catch basins, manholes, tide gates and outfalls in the storm drain systems and the existing drainage conditions within the study areas. The storm drain components included:
    - Manholes
    - Catch basins
    - Laterals
    - Gravity storm sewers
    - Tide gates
    - Outfalls
- CH2M has performed extensive rainfall data analyses in previous work for the City's Combined Sewer Overflow Long-term Control Plan Implementation Program and has extensive records of rainfall for the Newport gages as well as those in the region. This information was updated with the latest data for the following gages:
    - Newport Water Pollution Control Plant (WPCP)
    - Newport State Airport
    - Regional National Oceanic and Atmospheric Association (NOAA) weather stations
- The flooding and drainage issues in these areas are impacted not only by precipitation and drainage, but also by tides. Tide data has been recorded in Newport Harbor at various locations but continuously since 1930 at NOAA Station ID: 8452660, which is located at the Naval War College on Coasters Harbor Island. This data was the source of tidal information for this project. Two vertical datums were used in the project, NAVD 88 for engineering evaluations

and planning and mean lower low water (MLLW) for information presented to the stakeholders in the public participation process. MLLW was used because it is commonly used on tide and fishing reports familiar to local residents in the two study areas.

- 1-meter LiDAR data collected from the University of Rhode Island was used to determine manhole rim elevations as well as street surface elevations used in the h/h models.
- Flood insurance maps (FIRMS) published by the Federal Emergency Management Agency (FEMA).
- Sea level rise and climate change information published by NOAA, United States Army Corps of Engineers (USACE), and the University of Rhode Island Sea Grant project was used to identify potential future high tide elevations and rainfalls.
- Previous flood documentation recorded by the City as well as CH2M during previous projects in the study areas.

Once the data was received and reviewed, missing or additional information needed was identified to be collected through field investigations.

2.3 Field Data Collection

Over 10 days were spent in the field to assess the flooding areas, collect data on the storm drain systems, talk with the residents about the flooding and observe dry weather flooding events in both study areas.

2.3.1 Storm Drain Systems

The majority of the field work included opening manholes to retrieve storm sewer sizes, invert elevations and sediment buildup, as well as finding connectivity with neighboring drainage systems and observe outfall conditions. The manhole rim elevations were obtained from the LiDAR data and storm sewer invert elevations were calculated by taking stick measurements of rim-to-invert vertical distances. Over 100 manholes were opened during the investigation. A large amount of sediment was observed in the storm sewers especially in the Wellington Avenue study area where over a foot and half of sediment was observed in the 3 × 8-foot box culvert. The sediment observed in the storm sewers is shown in **Appendix A**.

There are a total of four outfalls in both study areas with one in Bridge Street and three in Wellington Avenue. The Bridge Street outfall and the 18-inch outfall in the Wellington Avenue study area were not observed because they are completely submerged at low tide. The box culvert outfall in Wellington Avenue was observed to be in good structural condition but containing over 1.5 feet of sediment. The 66-inch outfall in Wellington Avenue lies below low tide but it was evident during observations that there is large amount of sediment surrounding the outlet of outfall that most probably extends into the outfall and restricts the discharge.

2.3.2 System Connectivity

Field investigations indicated that there appeared to be a tidal influence on water elevations in the Marsh Street storm sewer even though it has a tide gate. Dye testing was performed in several locations to determine if a cross connection did exist. Dye was placed in the Marsh Street storm sewer after high tide when water began to recede back into the harbor on the falling tide. The dye was first observed flowing upstream east on Marsh Street then north on America's Cup Avenue until a cross connection was found at the intersection of Elm Street and America's Cup Avenue. The investigation also revealed that the America's Cup Avenue storm sewer does not connect with the Bridge Street storm sewer as originally shown in the GIS, but rather flows underneath the Bridge Street storm sewer and connects with the Gladys Carr Bolhouse Road storm sewer. **Figure 2-1** shows the corrections made to the GIS data. The dye test flow diagram is shown in **Appendix A**. All other connectivity in the original GIS data was found to be accurate.

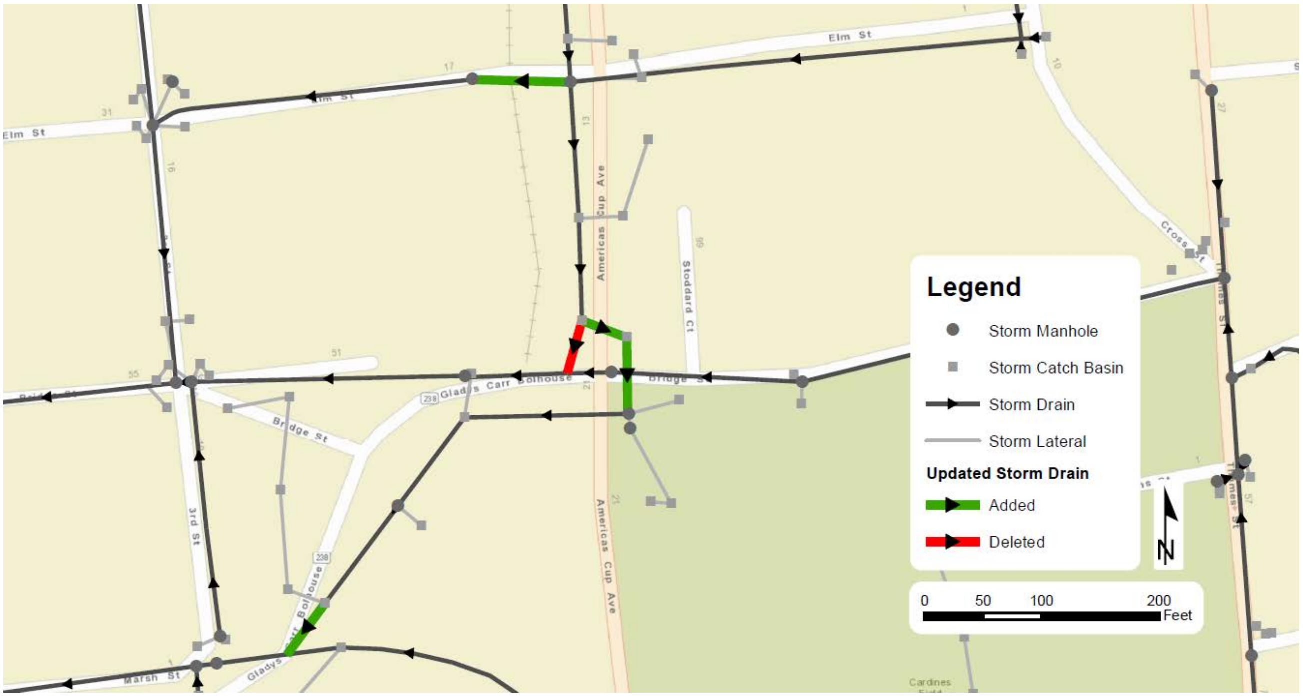


Figure 2-1. Storm Sewer GIS Corrections for the Bridge Street Study Area
Storm sewer corrections found during the Marsh Street/Bridge Street Dye Test

2.3.3 Dry Weather Flooding Observation

CH2M observed street flooding conditions in the two study areas on September 1, 2015 for a potential flooding high tide and to gather feedback from stakeholders. Some street flooding was observed and confirmed where the flooding begins in each area. Flooding first started at the intersection of Bridge Street and 3rd Street in the Bridge Street study area and at the intersection of Marchant Street and Wellington Avenue and at a catch basin on the west side of King Park in the Wellington Avenue area. Although little street flooding was observed on that day, it still provided an opportunity to confirm that the updated GIS data, NOAA tide data, and LiDAR data being used for the application of the h/h model (see Section 3) were accurate. The conversations with the stakeholders led to a better understanding of the frequency and magnitude of the flooding as well as the severity of basement flooding that occurs in both study areas. Local residents reported that the level of flooding in basements rose and fell with the lunar sequence of tides; meaning, basement flooding occurred most often when higher high tides occurred on new and full moons.

2.4 Stakeholder Involvement

Another key element of data collection for this project was understanding the concerns of the residents and stakeholders in each of the study areas. In order to ensure that the selected controls addressed the stakeholders concerns, a stakeholder involvement program was implemented and included the following:

- A survey to identify key concerns and issues
- Three public informational meetings
- A project website
- Collection of photos and information to support modeling efforts

2.4.1 Survey Results

The results of the stakeholder survey are presented in **Figures 2-2** through **2-6**. The purpose of the survey was to identify which study areas the respondents were commenting on, the greatest concerns associated with flooding in each of the study areas and the greatest concerns about the specific flooding events in each of the study areas.

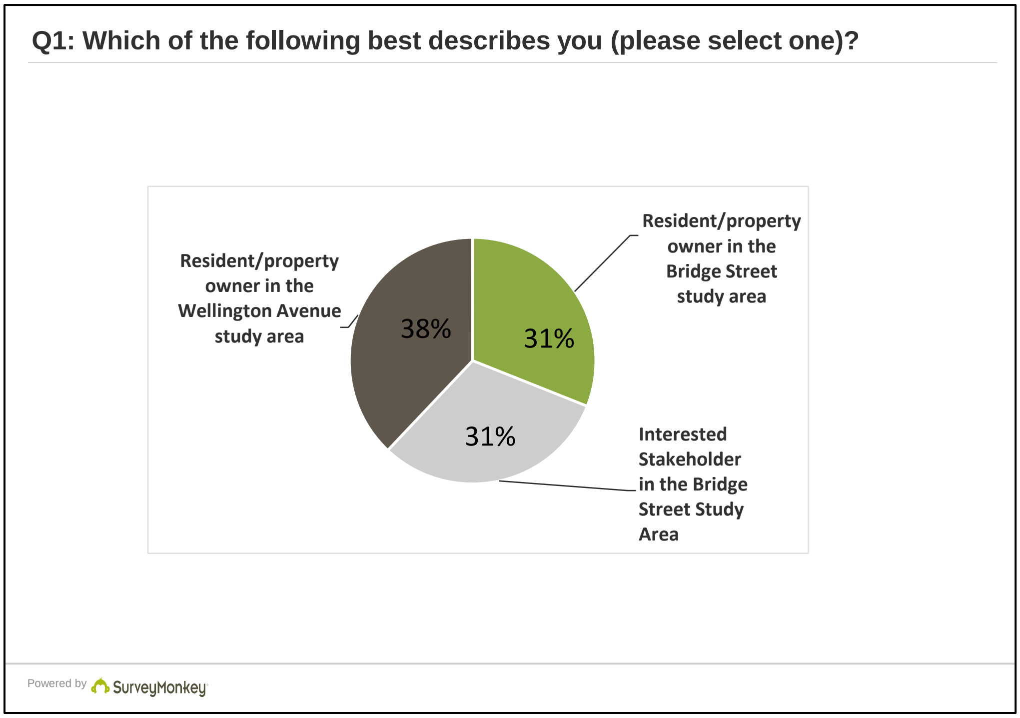


Figure 2-2. Identification of Respondents Study Area

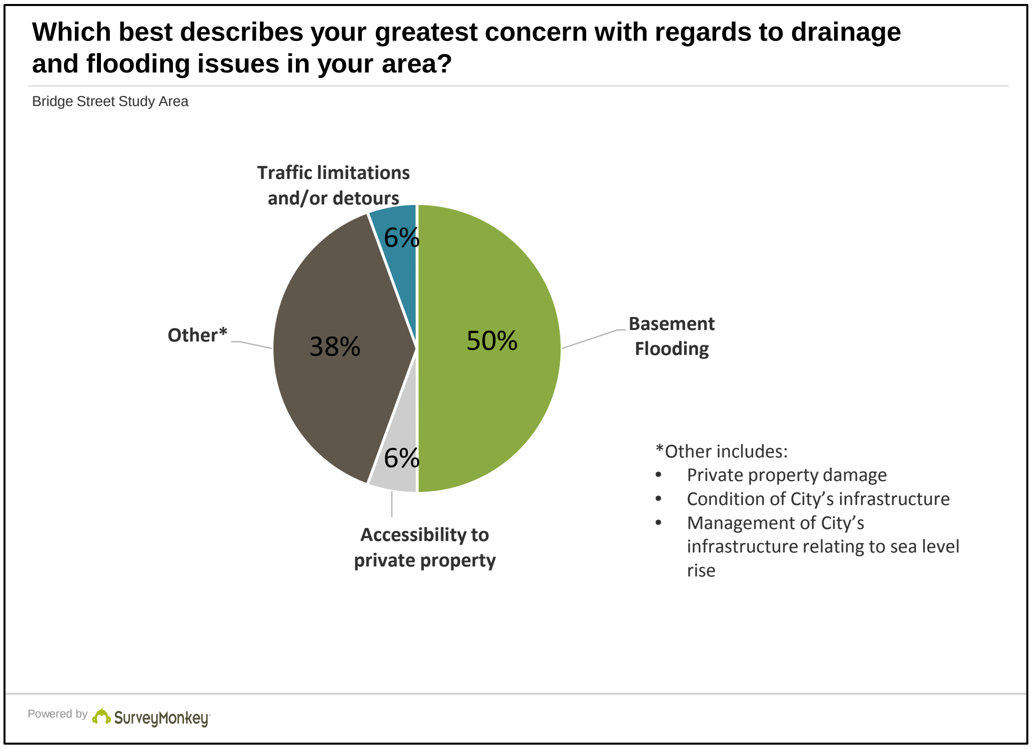


Figure 2-3. Greatest Concerns with Regard to Drainage and Flooding Issues in the Bridge Street Study Area

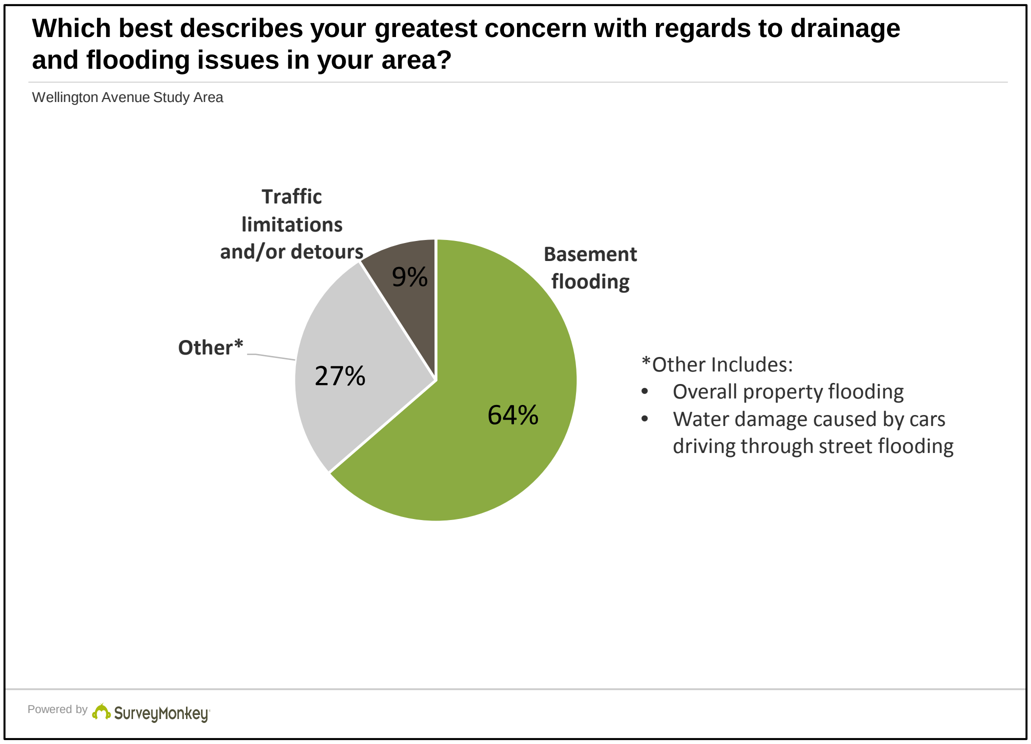
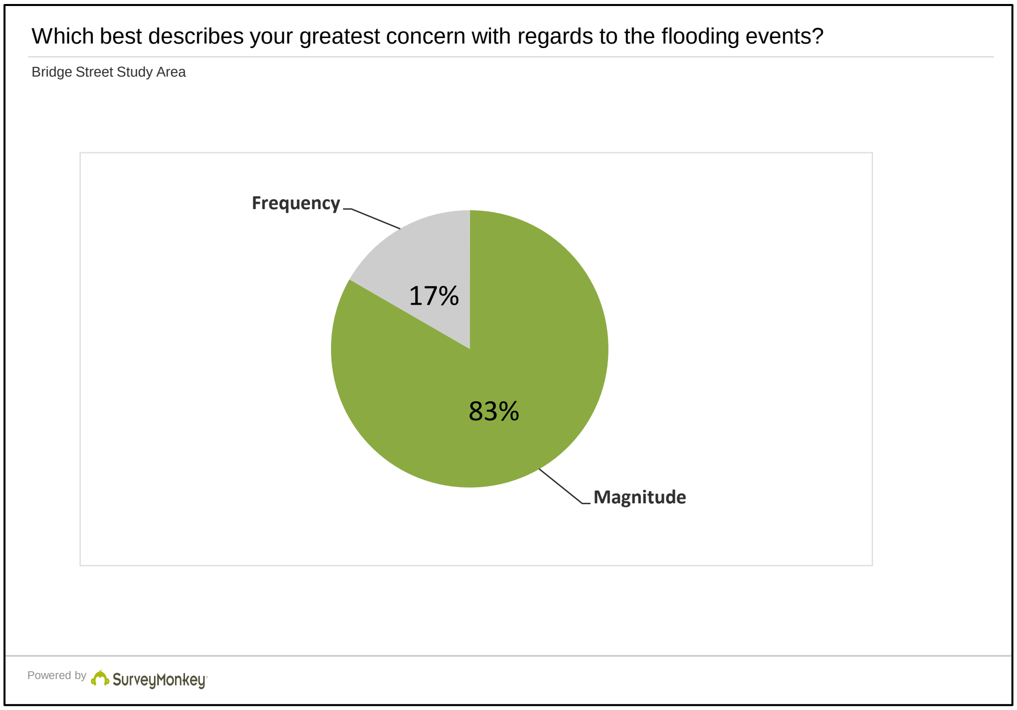


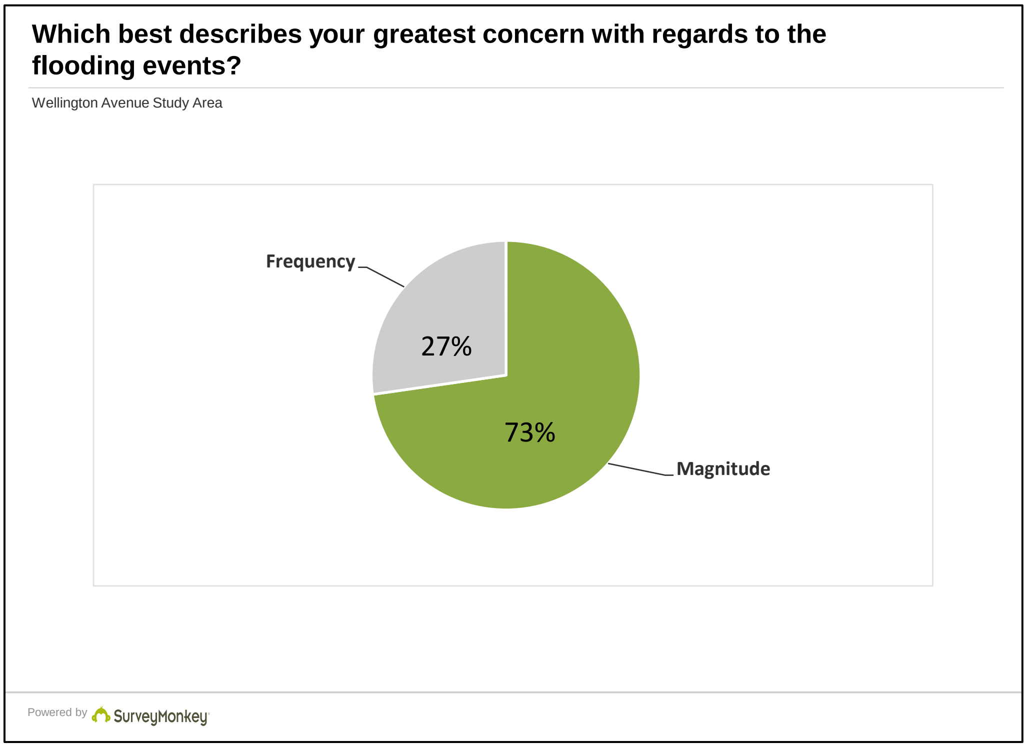
Figure 2-4. Greatest Concerns with Regard to Drainage and Flooding Issues in the Wellington Avenue Study Area



Which best describes your greatest concern with regards to the flooding events?

Bridge Street Study Area

Figure 2-5. Greatest Concern with Regard to the Flooding Events in the Bridge Street Study Area



Which best describes your greatest concern with regards to the flooding events?

Wellington Avenue Study Area

Figure 2-6. Greatest Concern with Regard to the Flooding Events in the Wellington Avenue Study Area

2.4.2 Public Informational Meetings

Three public informational meetings were held at the Pell Elementary School on Dexter Street to support the sharing and collection of information with stakeholders in regards to the project. The dates of the three meetings and the primary purpose of each meeting are listed below:

1. July 15, 2015: Introduction to the Project
2. September 17, 2015: Mid-Project Update
3. December 15, 2015: Alternatives Evaluation Results

The full presentations from each of these meetings are included in **Appendices D**, **E**, and **F**.

2.4.3 Project Website

A project website was developed in order to post the public informational meeting presentations for those stakeholders that were unable to attend the meetings. It was also used to post additional information about the project background, and that could not be covered in the public informational meetings. The project website address is: www.newportdrainageinvestigation.com

SECTION 3

Model Selection, Development and Calibration

3.1 Model Development

This section describes the development of the 2D h/h models of the two study areas. The networks in each study area model comprise hydraulic and hydrological components with associated modeling parameters. PCSWMM Professional 2D was the modeling software used for this project. All of the storm drainage system components are georeferenced correctly in the model using its GIS capability, with one- and two-dimensional terrain model coupling. The software uses the same computational engine to perform h/h calculations as the current USEPA Stormwater Management Model, SWMM5.

3.1.1 Hydraulics

The hydraulic component in the model represents all the infrastructure including manholes, catch basins, sewers, tide gates and boundary conditions. After the GIS data was updated from the field investigations it was imported into the model with respective invert elevations, rim elevations, sewer dimensions, and sediment depths observed in the field. This import into the model included the GIS revisions to accurately reflect the cross-connection between the Bridge Street and Marsh Street drainage networks as described in **Section 2**. The downstream boundary condition for both models was input as the dynamic tide elevation retrieved from NOAA in 6-minute data for the Newport tide gage.

3.1.2 Hydrology

The hydrology component in the model calculates all the rainfall that is converted into runoff and enters the storm sewer system, as well as any surface flow caused by flooding.

3.1.2.1 Subcatchment Delineation

Based on the LiDAR digital elevation model (DEM) and the GIS, CH2M used PCSWMM automated watershed delineation processes using both topographic features and the storm drainage system for accurate determination of subcatchment boundaries (see **Figure 3-1)**. The target subcatchment areas were set to 0.75 acres. These subcatchments were routed to their corresponding catch basins in the model. Roofs were also modeled as individual subcatchments. This allows the user to model a rooftop connection or disconnection with ease when developing different scenarios such as future conditions when all roofs should be disconnected from the combined sewer system.

Figure 3-1. Wellington Avenue Study Area Subcatchment Delineation and Flow Paths

The subcatchments developed from the DEM and ArcHydro in the Wellington Avenue Study Area

3.1.2.2 2D Terrain Model

A 2D terrain model was integrated into the 1D model. This component acts as a second layer to represent how the flood waters behave once they have surcharged out of the storm drain system via manholes and catch basins. This enables an evaluation of the extent of the flooding as well as maximum flooding depths. This tool helped pinpoint problem areas and was used to calibrate the model.

3.2 Model Calibration

The models of the study areas were calibrated against documented flooding photographs. For each area, one wet weather flooding event and one dry weather flooding event were selected for calibration. The field reconnaissance flooding event on September 1, 2015 was used as a validation event. The calibration process involved adjusting parameter values with the highest amount of uncertainty within a justifiable and reasonable range. In this study, the parameters adjusted were the soil infiltration parameters, pervious to impervious routing, overland surface flow length and pipe Manning's roughness coefficient, n. Model calculations and photographs are shown below in **Figures 3-2** through **3-6**. The yellow arrows on the maps point to the photograph vantage point.

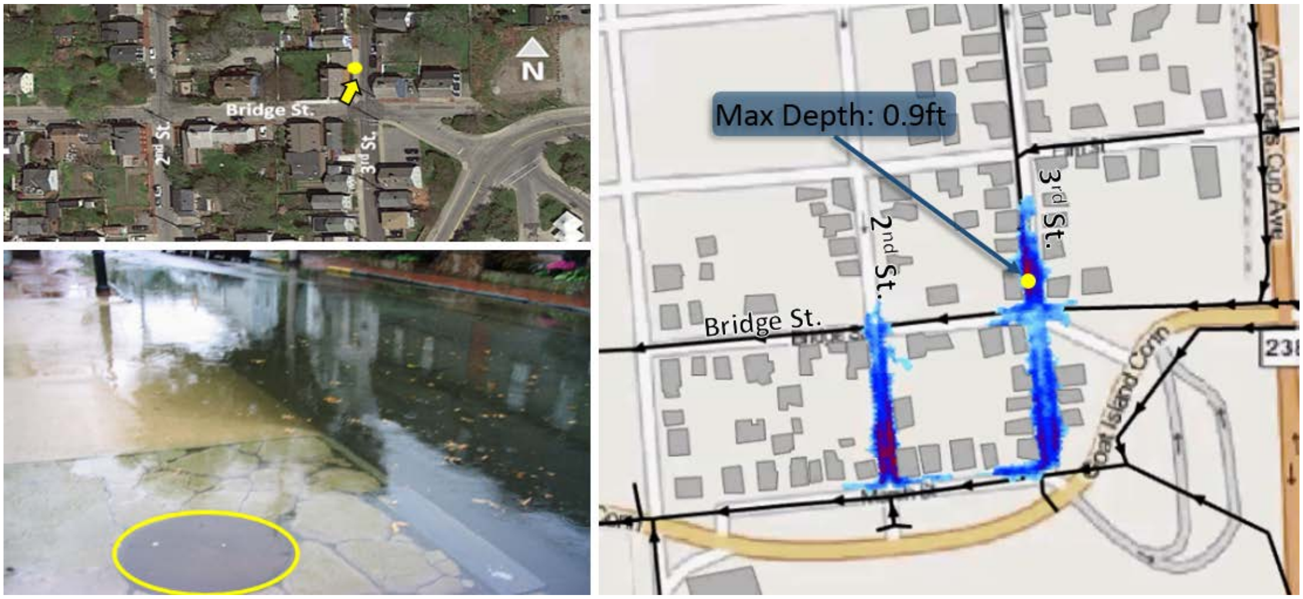


Figure 3-2. Bridge Street Dry Weather Flooding Calibration Event

This event was a king tide on Oct. 27, 2011 of 5.9 feet (MLLW), no rain

Figure 3-3. Bridge Street Wet Weather Flooding Calibration Event

This was a 1.2 inch rainfall event occurring at a high tide of 4.3 feet (MLLW) on July 1, 2015

Figure 3-4. Wellington Avenue Dry Weather Flooding Calibration Event

This event was a king tide on Oct. 7, 2010 of 5.8 feet (MLLW), no rain

Figure 3-5. Wellington Avenue Wet Weather Flooding Calibration Event

This was a 3.6 inch rainfall event partially occurring at a high tide of 5.8 feet (MLLW) on Apr. 15, 2007

Figure 3-6. Wellington Avenue Dry Weather Flooding Validation Event

This event was a high tide on Sept. 1, 2015 of 5.0 feet (MLLW) seen in the field, no rain

SECTION 4

Selection and Analysis of Potential Control Options

4.1 Overview and Objectives

The objective of this task was to identify potential conveyance and control engineering alternatives that could help mitigate the flooding magnitude, duration and frequency and test their effectiveness in each study area with the calibrated models.

4.2 Potential Conveyance and Control Alternatives

The potential conveyance and control alternatives considered for this study are listed below:

- Tide Gates. Tide gates to prevent harbor water from backing up into the storm drain systems. This control has the potential to prolong flooding because a head differential is required to open the tide gate for discharges.
- Sediment Management. Sediment removal from catch basins and storm sewers not only restores the full storage space in the storm drain system, but also maximizes the drainage capacity of the system to keep streets clear of standing water. Catch basin sumps serve as a settling chamber to collect grit, sand, and debris before stormwater enters storm sewers. Cleaning the sumps on a regular basis provides maximum storage in the catch basins and may be less costly and disruptive to the community than flushing the storm sewers themselves. Storm sewers may still have to be flushed but on a less-frequent basis if sumps are maintained.
- Catch Basin Rehabilitation. Catch basins have either vertical openings or horizontal grates on streets. Catch basin structures can be damaged or destroyed by structural defects, accidents, road repaving. Inlets may be restricted or paved over thus diminishing the inlet capacity and therefore increasing flooding and flood duration.
- Enlarging Storm Sewers. Replacing existing storm sewers with larger diameter sewers increases the capacity of the sewers and creates more storage within the system. This is effective if tide gates are used to prevent harbor water from backing up and filling the storm drain system. This, however, is an expensive solution and may not be physically feasible in some areas due to other existing utility lines in narrow streets of historic neighborhoods, especially in the Bridge Street study area.
- Rerouting Stormwater Flows. Rerouting catch basin laterals or storm sewers within the same systems or to adjacent systems alleviates hydraulic conditions if capacity exists in the downstream system.
- Green Infrastructure. Green infrastructure (GI) uses vegetation, soils, and other elements, and practices to restore some of the natural processes required to manage stormwater via constructed natural areas that mimic nature by storing and draining runoff. This control is typical used to reduce runoff and improve stormwater quality. GI can be constructed on streets and in parks. However, runoff reductions are relatively small on an individual project basis along streets is it typically used in combination with other controls because it will not provide a

complete solution to flooding issues. The runoff captured by GI is usually stored underground and feeds groundwater. This can be problematic in areas where basement flooding already exists due to high water tables and should only be used in higher elevation areas upstream in storm drainage systems where drainage to the water table is not problematic. Implementing GI over time can be a long-term strategy to mitigate the impacts of climate change that is forecasted to increase the intensity and volume of storms in the future. The number and sizes of GI projects could be implemented in a phased approach to counteract observed rainfall trends.

- Stormwater Pump Stations. Pump stations provide the highest amount of relief, but come at a high cost. High tide levels prevent stormwater from leaving low-lying storm sewer systems such as those in the two study areas. A pump station can be designed will drain a storm sewer system at all tidal elevations in Newport Harbor. The conveyance capacities of the storm sewer systems would then be the only restrictions on drainage.

4.3 Engineering Screening Analysis

To cut down on model computation time, the alternatives were screened by modeling each using a single storm event at differing tide conditions. The July 1, 2015 storm was used as the event. This was a 1.2-inch storm with a 2-year, 1-hour return frequency that was relatable to the stakeholders because it occurred recently while the project was underway. These alternatives were compared with the existing conditions to display their calculated contributions to flood mitigation. The results of the screening analysis are shown in **Figure 4-1** and all the comparisons are visually presented in **Appendix B**.

Tide gates were calculated to provide the largest flood reduction and eliminate dry weather flooding events. The increased storage it provides by keeping harbor waters out of the system can also potentially mitigate flooding during wet weather events as well.

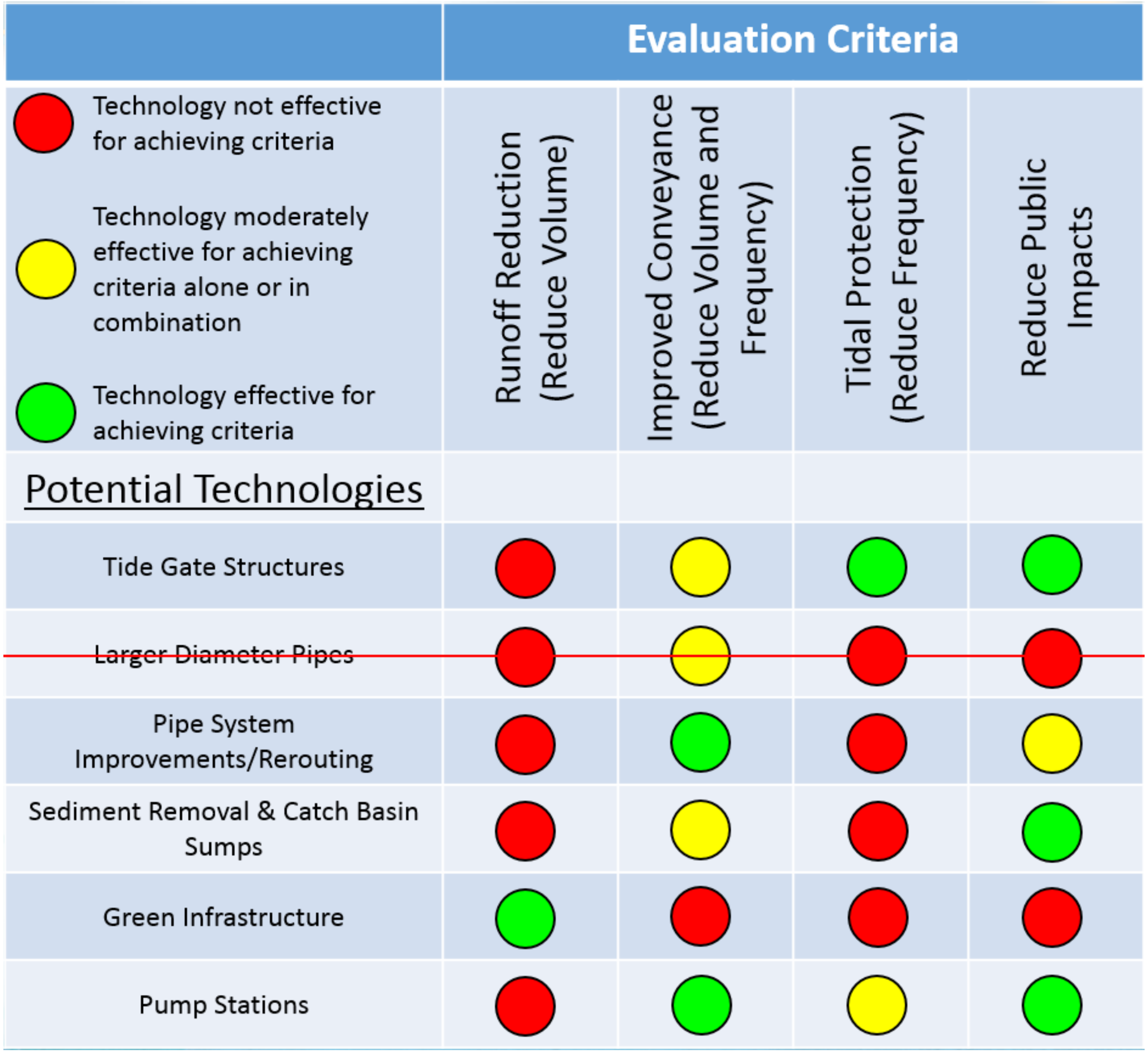
The screening analysis indicated that the existing system has the necessary conveyance capacity to handle a high-intensity/short-duration storm at low tide. Replacing existing storm sewers with larger storm sewers does not appear necessary based on the calculations. The same condition was calculated for the storm at high tide. Therefore, replacing existing storm sewers with larger storm sewers was not considered for a recommended alternative.

One rerouting alternative was calculated to be effective in the Wellington Avenue study area. This involves rerouting the Houston Street catch basins to the 66-inch storm sewer outfall system from their existing connections to the 18-inch storm sewer. The 66-inch storm sewer outfall system has a greater hydraulic capacity and if the Houston Street catch basins were rerouted to this storm sewer it could alleviate flooding in the Houston Street area.

Removing the observed sediment from the storm sewers was also calculated to be effective, especially in the Wellington Avenue study area. The alternative is calculated, to restore both systems to a 5-year conveyance capacity at low tide.

Constructing GI was calculated to improve drainage, but would not be able to eliminate flooding alone.

It was calculated that constructing stormwater pump stations would eliminate any of the remaining flooding the other controls could not eliminate. Minimum sizes of pump stations were identified during the screening analysis to be further explored in combination with the other technologies in the detailed engineering evaluations described in the next section.



🔴 Technology not effective for achieving criteria

🟡 Technology moderately effective for achieving criteria alone or in combination

🟢 Technology effective for achieving criteria

	Evaluation Criteria			
Potential Technologies	Runoff Reduction (Reduce Volume)	Improved Conveyance (Reduce Volume and Frequency)	Tidal Protection (Reduce Frequency)	Reduce Public Impacts
Tide Gate Structures	🔴	🟡	🟢	🟢
~~Larger Diameter Pipes~~	~~🔴~~	~~🟡~~	~~🔴~~	~~🔴~~
Pipe System Improvements/Rerouting	🔴	🟢	🔴	🟡
Sediment Removal & Catch Basin Sumps	🔴	🟡	🔴	🟢
Green Infrastructure	🟢	🔴	🔴	🔴
Pump Stations	🔴	🟢	🟡	🟢

Figure 4-1. Potential Control Technologies Screening Results

Results from the screening of potential control technologies for both study areas under the evaluation criteria. Larger diameter pipes has been taken out of consideration as limited benefits were found during the screening process.

SECTION 5

Typical Year Selection

5.1 Overview and Objectives

The potential benefits of improvements to the Bridge Street and Wellington Avenue study areas were evaluated using the calibrated h/h models of the City's storm drainage systems. The application of these models provided insight on the causes of historic flooding events. They also provided a platform to quantify how future system improvements may reduce the frequency and magnitude of future flooding events.

In order to quantify the design alternatives that best meet the community's objectives it is important that potential improvements be evaluated for a wide variety of realistic conditions. Correspondingly, this study used what is known as a "typical year" as a design condition for these evaluations. The benefit of simulating the system's performance for an entire year is that alternatives are tested against a wide range of conditions, such as a small storm at high tide and a large storm at low tide. Initially, the models were used to establish a benchmark for how the existing systems perform for the "typical year." Then the models were used to evaluate the benefits of potential improvements to the storm drainage system.

To identify a "typical year" for this study and to establish a baseline for the system's performance, the models were used to simulate storm sewer performance in the Bridge Street and Wellington Avenue study areas for the last 10 years of recorded of precipitation and tide data. Rainfall data collected at the Newport State Airport and tide data collected from NOAA tide Station 8452660 were used. Calculations from the model simulation of the Bridge Street system are shown in **Table 5-1** and **Figure 5-1** and of the Wellington Avenue system are shown in **Table 5-2** and **Figure 5-2**. Key observations from the 10-year simulation include:

- 80 percent of the simulated flooding events in the Bridge Street study area were caused by high tidal elevations with no rain (dry weather events).
- 58 percent of the simulated flooding events in the Wellington Avenue area were caused by high tidal elevations with no rain (dry weather events)
- Flooding events caused or influenced by rainfall (wet weather events) occur between three and nine times per year in the Bridge Street study area. These events generally occur when short-duration and high-intensity storms coincide with a high tide.
- Flooding events caused or influenced by rainfall (wet weather events) occur between 17 and 37 times per year in the Wellington Avenue study area. These events can happen at either high or low tide, and for both short-duration, intense storms and longer-duration, less intense storms.

The changes in dry weather flooding frequency from 2006 through 2015 somewhat track tidal elevations observed at the NOAA station in Newport during that period. Average sea levels during those years showed an increasing trend from 2006 to 2010/2011 and then a decreasing trend to 2015. The differences in the averages that were observed by NOAA were in very small increments but reflect the overall variability of tides and the frequency of flooding events that were calculated using the h/h models for those years.

Table 5-1. 10 -Year Flooding Calculations for the Bridge Street Study Area

Number of flooding events for the Bridge Street study area by cause and year, 2006 - 2015

Year	Total Rainfall (in)	Total Flooding Events	Wet Weather Events	Dry Weather Events
2006	44.8	**15**	6	9
2007	33.6	**16**	6	10
2008	38.3	**14**	3	11
2009	37.9	**26**	7	19
2010	27	**43**	7	36
2011	36.4	**50**	7	43
2012	26.2	**46**	9	37
2013	27	**31**	7	24
2014	37.2	**25**	6	19
2015*	25.1	**11**	3	8

* through Oct 3

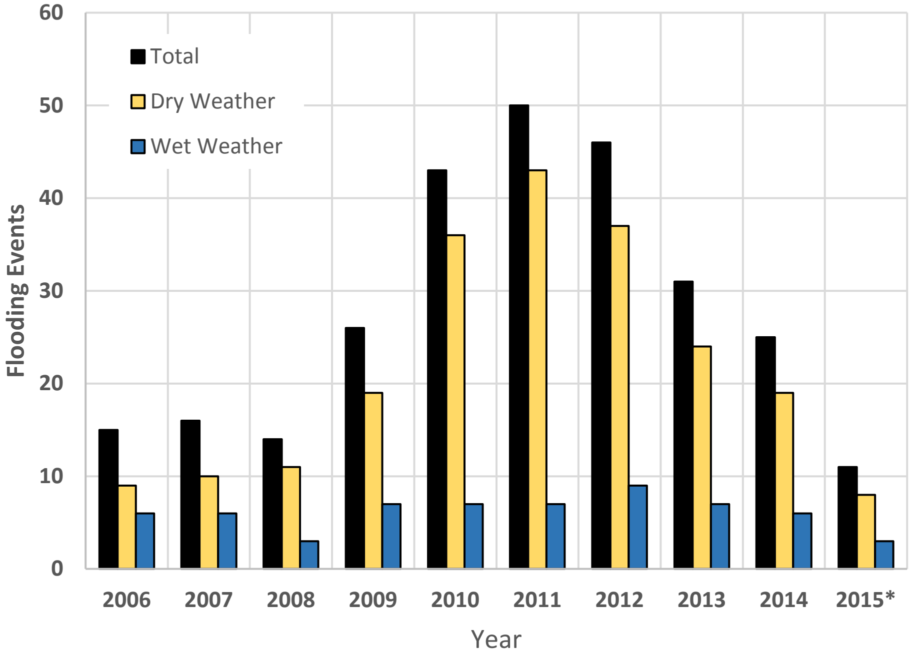


Figure 5-1. 10-Year Flooding Calculation for the Bridge Street Study Area

Number of flooding events for the Bridge Street study area by cause and year, 2006-2015

Table 5-2. 10-Year Flooding Calculations for the Wellington Avenue Study Area

Number of flooding events for the Wellington Avenue study area by cause and year, 2006 - 2015

Year	Total Rainfall (in)	Total Flooding Events	Wet Weather Events	Dry Weather Events
2006	44.8	**63**	37	26
2007	33.6	**49**	27	22
2008	38.3	**49**	26	23
2009	37.9	**57**	27	30
2010	27	**82**	21	61
2011	36.4	**83**	36	47
2012	26.2	**77**	25	52
2013	27	**70**	32	38
2014	37.2	**71**	22	49
2015*	25.1	**37**	17	20

* through Oct 3

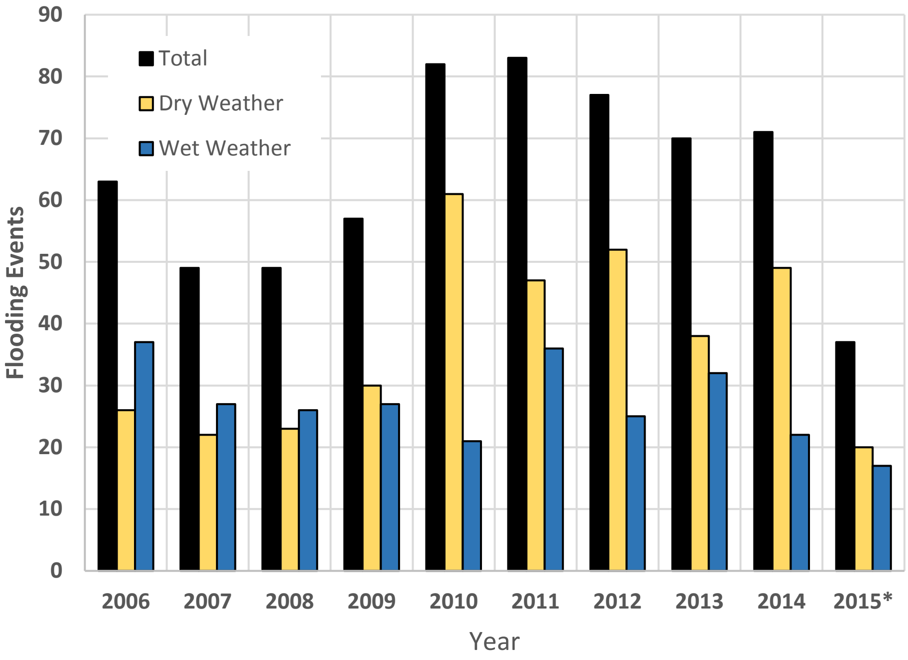


Figure 5-2. 10 Year Flooding Calculations for the Wellington Avenue Study Area

Number of flooding events for the Wellington Avenue study area by cause and year, 2006-2015

Comparing the frequency and causes of flooding over the last 10 years demonstrates the unique characteristics for each study area. The more frequent tidal flooding shown for the Wellington Avenue study area can be attributed to two locations with lower elevations than are found in the

Bridge Street study area. The more frequent rain caused flooding in the Wellington Avenue study area can be attributed to conveyance capacities within its drainage system.

Although simulation of the system's performance for a 10-year period provides a foundation for understanding historic trends, to accommodate the evaluation of a wide variety of improvement scenarios for each study area, a "typical year" was selected as a design condition to evaluate alternatives and combinations of alternatives. Although the data presented in **Tables 5-1** and **5-2** show wide variations in annual precipitation volumes and tidal conditions, 2013 was identified to most closely meet the project's planning needs. It includes 74 precipitation events ranging from trace amounts up to 3.7 inches, and a peak intensity of 2.4 inches per hour. The observed tidal conditions for 2013 were also on the current observed sea level rise trend at the NOAA tide station in Newport.

SECTION 6

Recommended Short-term and Long-term Controls

6.1 Overview and Objectives

A phased approach of cost-effective engineered alternatives was developed for recommended short-term and long-term implementation. The alternatives were developed using the existing conditions under the 2013 “typical year” described in **Section 5**.

Short-term controls were developed to address today’s climate conditions and to reduce observed/historic flooding issues. These controls will target the controls with largest benefit in reduction in number of flooding events and magnitude of flooding events with minimal technical or legal barriers and capital costs ranging from $1.5 million to $6 million. These controls will be complimentary to long-term controls and could take up to 5 years to implement once funding has been procured and approved.

Long-term controls were developed to address current flooding issues that may not be mitigated by the short-term controls, such as large events at high tide. Because the current systems are designed for a 5-year storm, these alternatives were conceptualized for a 5-year storm. These controls will likely have technical and legal barriers, capital costs ranging from $13 million to $46 million, and will likely take 20 to 25 years to implement.

This section describes the recommended short- and long-term controls for the Wellington Avenue and Bridge Street study areas based on evaluations of the alternatives on an individual basis and as combinations of alternatives.

6.1.1 Wellington Avenue Short-term Controls

The recommended Wellington Avenue short-term controls are illustrated in **Figure 6-1** and include the following:

- Tide gates on the 3 × 8-foot box culvert (flap gate) and the 66-inch storm sewer (duck bill)
- Outfall dredging to access and clear the 66–inch storm sewer outfall
- Sediment removal from 6,300 linear feet of storm sewers
- Rehabilitation of 23 catch basins
- Rerouting the 18-inch storm sewer segment at Houston Street to the 66inch storm sewer outfall system.

Figure 6-1. Conceptual Layout of the Short-term controls in the Wellington Avenue Study Area

These recommended controls are engineered to eliminate dry weather flooding and are calculated to reduce wet weather flooding events by 81 percent during the selected typical year (2013). This equates to a reduction in flooding events from 70 times per year to 6, reduces a calculated volume of flooding from 5.8 million gallons of flooding per year to 0.2 million gallons, and reduces a calculated 62 hours of flooding per year down to 5 hours during a typical year. The remaining wet weather events are due to rain events coinciding with high tide. The calculations of flooding frequencies for the existing condition and with the recommended short-term controls are graphically shown below in **Figure 6-2**. **Table 6-1** presents the maximum flood depth and number of properties experiencing surface ponding on or directly adjacent to their property for the largest storm in a typical year for existing conditions and with the short-term controls.

The total capital cost is estimated at $3.9 million with $94,600 per year for O&M, at present value. The complete cost estimate breakdown is provided in **Appendix C**. These costs are conceptual level planning estimates only and are a combination of Class 5/Class 4 estimates as defined by Association for the Advancement of Cost Engineering International (AACEI). Better refined cost estimates should be developed as part of the design of the recommended short-term controls and would provide better input to the City’s capital planning processes.

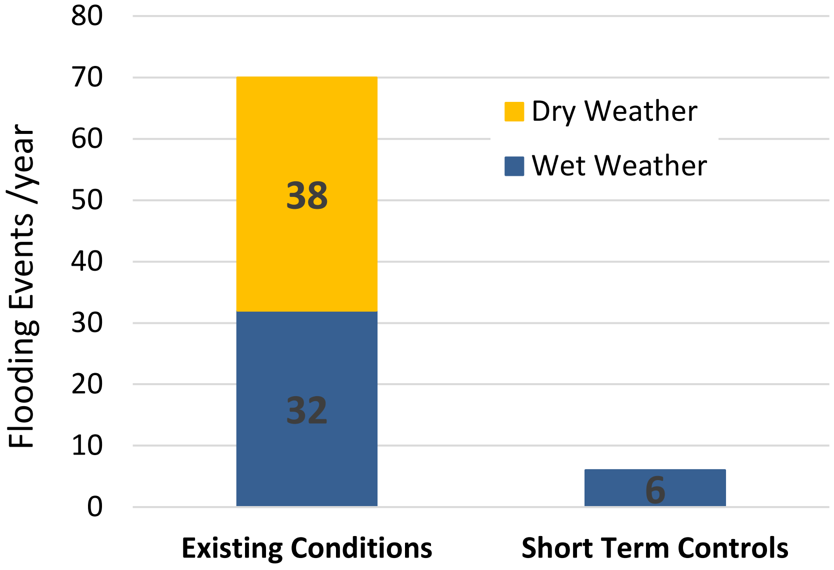


Figure 6-2. Wellington Avenue

Table 6-1. Wellington Avenue Short-term Controls: Maximum Flood Depth and Number of Properties Experiencing Surface Ponding During Largest Storm in a Typical Year

	Existing Conditions	Short-term Controls
Approximate Maximum Flood Depth	2.6 ft.	0.87 ft.
Approximate Number of Properties Experiencing Surface Ponding	80	32

Note: These numbers are estimates from model results for the typical year analysis. Under the short-term controls there will be larger storms or major events such as hurricanes that will occur less frequently and result in greater flood depths and number of properties experiencing surface ponding.

The capital and operations and maintenance (O&M) cost estimates for the Wellington Avenue short-term controls are shown in **Table 6-2**. The assumptions used to develop these cost estimates are presented in **Appendix C**.

Table 6-2. Wellington Avenue Short-term Controls Cost Estimates

Wellington Avenue Short-term Control Option Components	Quantities	Capital Cost* (-25% to +50%)	Additional Annual O&M Cost
3'X8' Box Culvert Tide Gate Structure	1 structure including trash rack and 2 4'X4' flap tide gates	$850,000 $638,000 - $1.3M	$9,000/yr
66" Duckbill Tide Gate Structure	1 structure including trash rack and 1 66" duckbill tide gate	$800,000 $600,000 - $1.2M	$9,000/yr
Storm Drain Cleaning	6,288 ft. (1.2 miles)	$1.1M $575,000 - $1.7M	$75,000/yr
Catch Basin Rehabilitation & Addition of Sumps	23 Catch Basins	$561,000 $421,000 - $842,000	$1,600/yr
Harbor Dredging* * Assumes material not hazardous	4,500 cy sediment removed	$536,000 $402,000 - $804,000	
Reroute Houston St. Catch Basins	75 ft. new pipe Block 18" pipe	$81,000 $61,000 - $122,000	
Total		**$3.9M** **$2.7M - $6.0M**	**$94,600/yr**

Wellington Avenue Short-term Control Option Components	Quantities	Capital Cost* (-25% to +50%)	Additional Annual O&M Cost
3'X8' Box Culvert Tide Gate Structure	1 structure including trash rack and 2 4'X4' flap tide gates	$850,000 $638,000 - $1.3M	$9,000/yr
60" Duckbill Tide Gate Structure	1 structure including trash rack and 1 60" duckbill tide gate	$800,000 $600,000 - $1.2M	$9,000/yr
Storm Drain Cleaning	6,288 ft. (1.2 miles)	$1.1M $575,000 - $1.7M	$75,000/yr
Catch Basin Rehabilitation & Addition of Sumps	23 Catch Basins	$561,000 $421,000 - $842,000	$1,600/yr
Harbor Dredging* * Assumes material not hazardous	4,500 cy sediment removed	$536,000 $402,000 - $804,000	
Reroute Houston St. Catch Basins	75 ft. new pipe Block 18" pipe	$81,000 $61,000 - $122,000	
Total		**$3.9M** **$2.7M - $6.0M**	**$94,600/yr**

*Total capital cost includes design, construction, services during construction. Potential additional costs: Permitting, Easement acquisition, and , Hazardous materials testing and disposal. It is also likely that the Harbor dredging would need to be repeated following the initial capital expenditure presented above, but it is unknown at this time how frequently this activity would need to occur following the initial proposed dredging.

6.1.2 Wellington Avenue Long-term Controls

The recommended Wellington Avenue long-term controls are illustrated in **Figure 6-3** and include the following:

- All short-term controls
- An additional tide gate on the 18–inch storm sewer outfall (duck bill)
- Green infrastructure:
  - Approximately 54,000 square feet (ft^2) of bio-retention type units
  - Approximately 73,000 ft^2 of permeable pavement type units

- Stormwater pump station:
  - 55 mgd capacity
  - 18 feet of hydraulic head
  - 160 feet of 66-inch outfall connection

Figure 6-3. Conceptual Layout of the Long-term controls in the Wellington Avenue Study Area

These recommended controls are engineered to eliminate the remaining flooding during a typical year not addressed by the short-term controls.

The total capital cost is estimated at $30.7 million with an additional $209,000 per year for O&M, at present value. The complete cost estimate breakdown is shown in **Appendix C**. These costs are conceptual level planning estimates only and are a combination of Class 5/Class 4 estimates as defined by Association for the Advancement of Cost Engineering International (AACEI).

Although these controls are calculated to eliminate flooding during a typical year, higher intensity storms and storm surges may produce flooding. Rainfalls with greater than a 5-year return frequency will exceed storm drainage system capacities. Most of this study area is in the 100- and 500-year FEMA coastal flooding zones. Extreme storm surges, such as seen with Hurricane Sandy in 2012, will overtop bulkheads and flood the study area starting at the end of the sea wall opposite Columbus Avenue at a tide elevation of 6.4 feet (MLLW). It is not possible nor cost effective to develop and implement controls that would contain all events such as major hurricanes, Nor’easters (macroscale storms that occur along the upper east coast of the US and Atlantic Canada), or extreme precipitation and both study areas would likely have flooding during events of this type even with the recommended short- and long-term actions.

The capital and O&M cost estimates for the Wellington Avenue long-term controls are shown in **Table 6-3**. The assumptions used to develop these cost estimates are presented in **Appendix C**.

Table 6-3. Wellington Avenue Long-term Controls Cost Estimates

Wellington Avenue Long-term Control Option Components	Quantities	Capital Cost* (-25% to +50%)	Additional Annual O&M Cost
3'X8' Box Culvert Tide Gate Structure	1 structure including trash rack and 2 - 4'X4' flap tide gates	$850,000 $638,000 - $1.3M	$9,000/yr
66" Duckbill Tide Gate Structure	1 structure including trash rack and 1 - 66" duckbill tide gate	$800,000 $600,000 - $1.2M	$9,000/yr
Storm Drain Cleaning	6,288 ft. (1.2 miles)	$1.1M $575,000 - $1.7M	$75,000/yr
Catch Basin Rehabilitation & Addition of Sumps	23 Catch Basins	$561,000 $421,000 - $842,000	$1,600/yr
Harbor Dredging* * Assumes material not hazardous	4,500 cy sediment removed	$536,000 $402,000 - $804,000	
Reroute Houston St. Catch Basins	75 ft. new pipe Block 18" pipe	$81,000 $61,000 - $122,000	
Green Infrastructure	54,000 sf bioretention 73,000 sf permeable pavement	$6.5M $4.9M - $9.8M	$65,000/yr $48,000 - $81,000/yr
18" Duckbill Tide Gate Structure	1 structure including trash rack and 1 - 18" duckbill tide gate	$614,000 $461,000 – $921,000	$9,000/yr
Pump Station	1 - 55 MGD Pump Station	$19.7M $14.8M - $29.6M	$40,000/yr
Total		**$30.7M** **$22.9M - $46.3M**	**$208,600/yr**

Wellington Avenue Long-term Control Option Components	Quantities	Capital Cost* (-25% to +50%)	Additional Annual O&M Cost
3'X8' Box Culvert Tide Gate Structure	1 structure including trash rack and 2 - 4'X4' flap tide gates	$850,000 $638,000 - $1.3M	$9,000/yr
60" Duckbill Tide Gate Structure	1 structure including trash rack and 1 - 60" duckbill tide gate	$800,000 $600,000 - $1.2M	$9,000/yr
Storm Drain Cleaning	6,288 ft. (1.2 miles)	$1.1M $575,000 - $1.7M	$75,000/yr
Catch Basin Rehabilitation & Addition of Sumps	23 Catch Basins	$561,000 $421,000 - $842,000	$1,600/yr
Harbor Dredging* * Assumes material not hazardous	4,500 cy sediment removed	$536,000 $402,000 - $804,000	
Reroute Houston St. Catch Basins	75 ft. new pipe Block 18" pipe	$81,000 $61,000 - $122,000	
Green Infrastructure	54,000 sf bioretention 73,000 sf permeable pavement	$6.5M $4.9M - $9.8M	$65,000/yr $48,000 - $81,000/yr
18" Duckbill Tide Gate Structure	1 structure including trash rack and 1 - 18" duckbill tide gate	$614,000 $461,000 – $921,000	$9,000/yr
Pump Station	1 - 55 MGD Pump Station	$19.7M $14.8M - $29.6M	$40,000/yr
Total		**$30.7M** **$22.9M - $46.3M**	**$208,600/yr**

*Total capital cost includes design, construction, services during construction. Potential additional costs: Permitting, Easement acquisition, and hazardous materials testing and disposal. It is also likely that the Harbor dredging would need to be repeated following the initial capital expenditure presented above, but it is unknown at this time how frequently this activity would need to occur following the initial proposed dredging.

6.1.3 Bridge Street Short-term Controls

The recommended Bridge Street short-term controls are illustrated in **Figure 6-4** and include the following:

- A tide gate on the Bridge Street storm sewer outfall (duck bill)
- Removing old tide gates on 2nd Street and 3rd Streets. Once the new tide gates are in place, these will provide no flood protection and will increase the head loss through the system.
- Sediment removal in 4,200 linear feet of storm sewers
- Rehabilitation of 20 catch basins

Figure 6-4. Conceptual Layout of the Short-term controls in the Bridge Street Study Area

These recommended controls are engineered to eliminate dry weather flooding and are calculated to reduce wet weather flooding events by 43 percent during the selected typical year. This equates to a calculated reduction in flooding events from 31 times per year to 4, a calculated reduction in the volume of flooding from 1.0 million gallons of flooding per year to 0.1 million gallons, and a calculated reduction of 32 hours of flooding per year to 2.1 hours during the selected typical year. The remaining wet weather events are due to rain events coinciding with high tide. The calculated frequencies of flooding events without and with the short-term recommendations are graphically shown below in **Figure 6-5**. **Table 6-4** presents the maximum flood depth and number of properties experiencing surface ponding on or directly adjacent to their property for the largest storm in a typical year for existing conditions and with the short-term controls.

The total capital cost is estimated at $2.1 million with $60,400 per year for O&M. The complete cost estimate breakdown is shown in **Appendix C**. These costs are conceptual level planning estimates only and are a combination of Class 5/Class 4 estimates as defined by Association for the Advancement of Cost Engineering International (AACEI). Better refined cost estimates should be developed as part of the design of the recommended short-term controls and would provide better input to the City's capital planning processes.

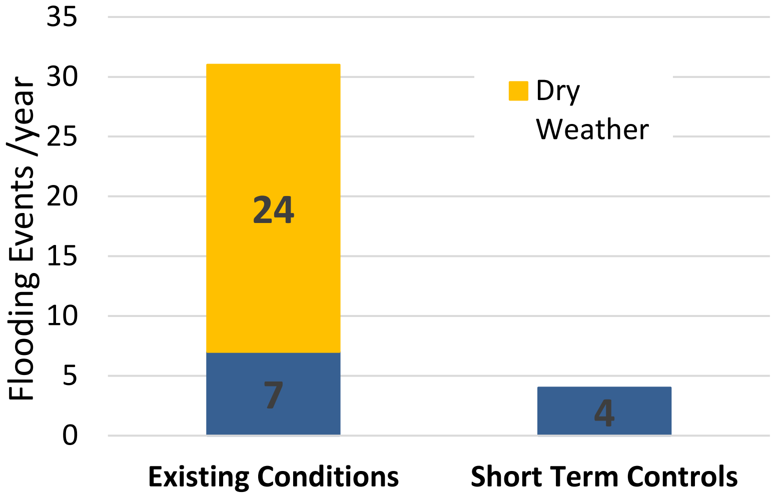


Figure 6-5. Bridge Street Study Area Short-term Controls Performance

Flooding events during a typical year (2013) compared with existing conditions

Table 6-4. Bridge Street Short-term Controls: Maximum Flood Depth and Number of Properties Experiencing Surface Ponding During Largest Storm in a Typical Year

	Existing Conditions	Short-term Controls
Approximate Maximum Flood Depth	0.93 ft.	0.67 ft.
Approximate Number of Properties Experiencing Surface Ponding	40	26

Note: These numbers are estimates from model results for the typical year analysis. Under the short-term controls there will be larger storms or major events such as hurricanes that will occur less frequently and result in greater flood depths and number of properties experiencing surface ponding.

The capital and O&M cost estimates for the Bridge Street short-term controls are included in **Table 6-5**. The assumptions used to develop these cost estimates are presented in **Appendix C**.

Table 6-5. Bridge Street Short-term Controls Cost Estimates

Bridge Street Short-term Control Option Components	Quantities	Capital Cost* (-25% to +50%)	Additional Annual O&M Cost
48" Duckbill Tide Gate Structure	1 structure including trash rack and 1 48" duckbill tide gate	$850,000 $638,000 - $1.3M	$9,000/yr
Storm Drain Cleaning	4,167 ft (0.8 miles)	$723,000 $542,000 - $1.1M	$50,000/yr
Catch Basin Rehabilitation & Addition of Sumps	20 Catch Basins	$479,000 $359,000 - $719,000	$1,400/yr
Total		**$2.1M** **$1.5M - $3.1M**	**$60,400/yr**

*Total capital cost includes design, construction, services during construction. Potential additional costs: Permitting, Easement acquisition.

6.1.4 Bridge Street Long-term Controls

The recommended Bridge Street long-term controls are illustrated in **Figure 6-6** and include the following:

- All short-term controls
- Green infrastructure:
  - Approximately 30,000 ft^2 of bio-retention type units
  - Approximately 21,000 ft^2 of permeable pavement type units
- Stormwater pump station:
  - 35 mgd capacity
  - 15 feet of hydraulic head

Figure 6-6. Conceptual Layout of the Long-term controls in the Bridge Street Study Area

These recommended controls are engineered to eliminate the remaining flooding during a typical year not addressed by the short-term recommendations. The total capital cost is estimated at

$17.2 million with an additional $129,900 per year for O&M, at present value. The complete cost estimate breakdown is shown in **Appendix C**.

As in the Wellington Avenue study area, these controls are engineered to eliminate flooding during the selected typical year, higher intensity storms and storm surges may produce flooding. Rainfalls with greater than a 5-year return frequency will exceed storm drainage system capacities. Most of this study area is in the 100- and 500-year FEMA coastal flooding zones. Extreme storm surges, such as seen with Hurricane Sandy in 2012, will overtop bulkheads and flood the study area starting at the boat yard south of the Goat Island Connector at a tide elevation of 7.1 feet (MLLW). It is not possible nor cost effective to develop and implement controls that would contain all events such as major hurricanes, Nor'easters (macroscale storms that occur along the upper east coast of the US and Atlantic Canada), or extreme precipitation and both study areas would likely have flooding during events of this type even with the recommended short- and long-term actions.

The capital and O&M cost estimates for the Bridge Street long-term controls are included in **Table 6-6**. The assumptions used to develop these cost estimates are presented in **Appendix C**. These costs are conceptual level planning estimates only and are a combination of Class 5/Class 4 estimates as defined by AACEI.

Table 6-6. Bridge Street Long-term Controls Cost Estimates

Bridge Street Short-term Control Option Components	Quantities	Capital Cost* (-25% to +50%)	Additional Annual O&M Cost
48" Duckbill Tide Gate Structure	1 structure including trash rack and 1 - 48" duckbill tide gate	$850,000 $638,000 - $1.3M	$9,000/yr
Storm Drain Cleaning	4,167 ft (0.8 miles)	$723,000 $542,000 - $1.1M	$50,000/yr
Catch Basin Rehabilitation & Addition of Sumps	20 Catch Basins	$479,000 $359,000 - $719,000	$1,400/yr
Green Infrastructure	30,000 sf bioretention 21,000 sf permeable pavement	$2.9M $2.2M - $4.4M	$29,500/yr $22,000 - $37,000/yr
Pump Station	1 - 35 MGD Pump Station	$12.2M $9.2M - $18.3M	$36,000/yr
Total		**$17.2M** **$12.9M - $25.8M**	**$125,900/yr**

*Total capital cost includes design, construction, services during construction. Potential additional costs: Permitting, Easement acquisition.

6.2 Future Climate Conditions

The recommended controls will not be able to prevent flooding during extreme events. Most of both study areas are in the 100- and 500-year FEMA coastal flooding zones shown on their FIRMs. The impacts calculated by NOAA using its Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model indicate that a Category 1 hurricane would currently flood all of both study areas. The National Hurricane Center (NHC) recorded three Category 2 and three Category 3 hurricanes for Newport County from 1900 to 2009.

With sea level rise and climate change, these extreme events will likely become more frequent and will impact more areas. As shown in **Figure 6-7**, sea levels have risen approximately 1 foot in the past 100 years and will continue to rise at the same rate, at a minimum. Local sea level rise forecasts indicate that sea levels will likely rise by as much as 2 feet by the year 2065. **Figure 6-8** shows estimated relative sea level change (RSLC) from various models run by NOAA and USACE as of September 2015.

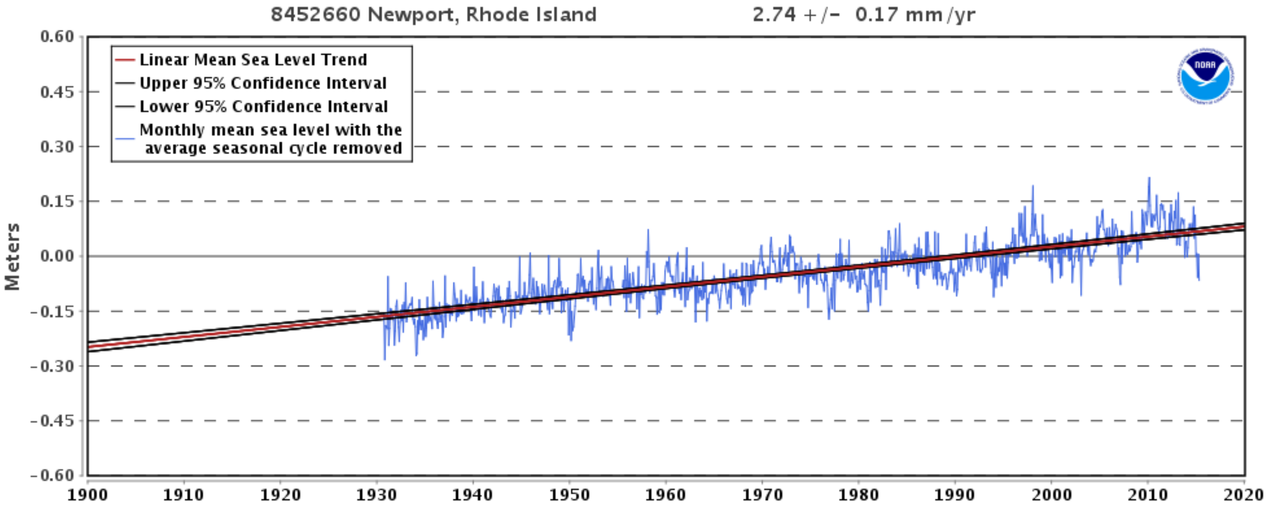


Figure 6-7 Newport Sea Level Rise

Seal level rise measured in Newport by NOAA since 1930

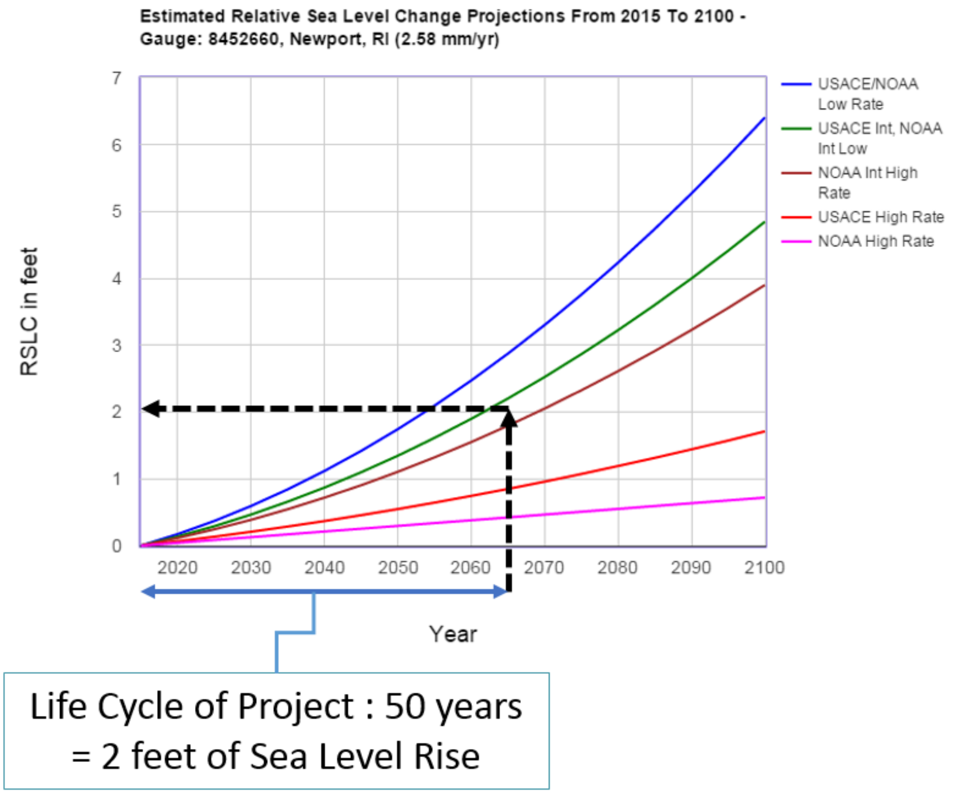


Figure 6-8 Estimated Relative Sea Level Change Projections

Sea level projections by NOAA and USACE from 2015 to 2100 (http://www.corpsclimate.us/ccaceslcurves.cfm)

Both study areas are expected to experience a significant increase in the frequency of flooding due to water overtopping existing bulkheads and surface barriers with 2 feet of sea level rise. The Wellington Avenue study area will flood 157 times per year and Bridge Street study area will flood

27 times per year just from tides. Extending the existing sea wall along Wellington Avenue to Chastellux Avenue (see **Figure 6-9**) and modifying the weep holes to only drain could protect the Wellington Avenue study area from this type of flooding during a typical year in 2065.

Figure 6-9 Wellington Avenue Sea Wall Extension

Required sea wall extension to prevent tidal flooding during a typical year in 2065

SECTION 7

Conclusion

7.1 Summary of Findings

The topography and storm drain systems in the Wellington Avenue and Bridge Street study areas both lie below an increasing elevation of higher high tides each year. This will be very problematic with preventing tidal flooding while also trying to convey stormwater out of the systems when tides are high. Tide gates in these areas have become a necessity and are probably the most critical control alternative to implement as the areas are already experiencing more than 30 dry weather flooding events per year. There are a number of controls available to mitigate flooding during rainfall events at high tide, but to completely eliminate flooding during these events, stormwater pump stations must be constructed. However, at low tide, both study areas have a 5-year conveyance capacity when storm sewers are clear of sediment. CH2M developed complimenting short- and long term controls for both study areas to mitigate flooding based on cost effectiveness and implementability considering potential legal and technical barriers.

The recommended short-term controls for the Wellington Avenue study area include two tide gates, outfall dredging, sewer sediment removal, catch basin rehabilitation, and rerouting an 18-inch storm sewer segment. These controls are engineered to eliminate dry weather flooding and reduce wet weather flooding by a calculated 81 percent during a typical year selected for the study. They also reduce the number of properties experiencing surface ponding on or directly adjacent to their property during the typical year from approximately 80 to 32 for a precipitation event coinciding with high tide.

Long-term controls recommended to eliminate the remaining wet weather flooding include an additional tide gate, green infrastructure, and a 55 mgd stormwater pump station. The estimated costs for the short- and long-term controls are $3.9 million capital and $94,600 annual O&M, and an additional $30.7 million and $209,000 annual O&M, respectively, at present value. These costs are conceptual level planning estimates only and are a combination of Class 5/Class 4 estimates as defined by AACEI. Better refined cost estimates should be developed as part of the design of the recommended short-term controls and would provide better input to the City’s capital planning processes.

The recommended short-term controls for the Bridge Street study area include one new tide gate, sewer sediment removal and catch basin rehabilitation. These controls are engineered to eliminate dry weather flooding and reduce wet weather flooding by a calculated 43 percent during the selected typical year. They also reduce the number of properties experiencing surface ponding on or directly adjacent to their property during the typical year from approximately 40 to 26 for a precipitation event coinciding with high tide.

Long-term controls recommended to eliminate the remaining wet weather flooding include green infrastructure and a 35 mgd stormwater pump station. The estimated costs for the short- and long-term controls are $2.1 million capital and $60,400 annual O&M, and an additional $17.2 million and $129,900 annual O&M, respectively, at present value. These costs are conceptual level planning estimates only and are a combination of Class 5/Class 4 estimates as defined by AACEI. Better refined cost estimates should be developed as part of the design of the recommended short-term controls and would provide better input to the City’s capital planning processes.

These controls are engineered to eliminate flooding during a typical year under today’s climate, but there still exist storm surges and extreme rainfall events that will produce flooding. Rainfalls greater than a 5-year return frequency at high tide will cause street flooding even with stormwater pump stations due to the conveyance capacity of the systems. Both study areas are in 100- and 500-year coastal storm surge zones and would likely be flooded by a Category 1 hurricane. Once a storm surge exceeds an elevation of 6.4 feet (MLLW) at Wellington Avenue and 7.1 feet (MLLW) at Bridge Street, harbor water will flood these study areas. It is not possible nor cost effective to develop and implement controls that would contain all events such as major hurricanes, Nor’easters (macroscale storms that occur along the upper east coast of the US and Atlantic Canada), or extreme precipitation and both study areas would likely have flooding during events of this type even with the recommended short- and long-term actions.

Plans and preparations for these major events will require coordination of private property owners as well as other City entities such as the Historic District Commission, City Planner and Zoning Officer. Private property owners interested in adapting their properties in preparation for these types of events as well as sea level rise are encouraged to work directly with these City entities to determine the best avenues for implementing resiliency projects.

Sea level rise and climate change will most likely cause coastal flooding of these study areas on a weekly basis. Additional flood resiliency adaptations beyond those recommended in this report for the storm drainage systems will most likely be required to protect the two study areas in the future.

Appendix A
Field Reconnaissance

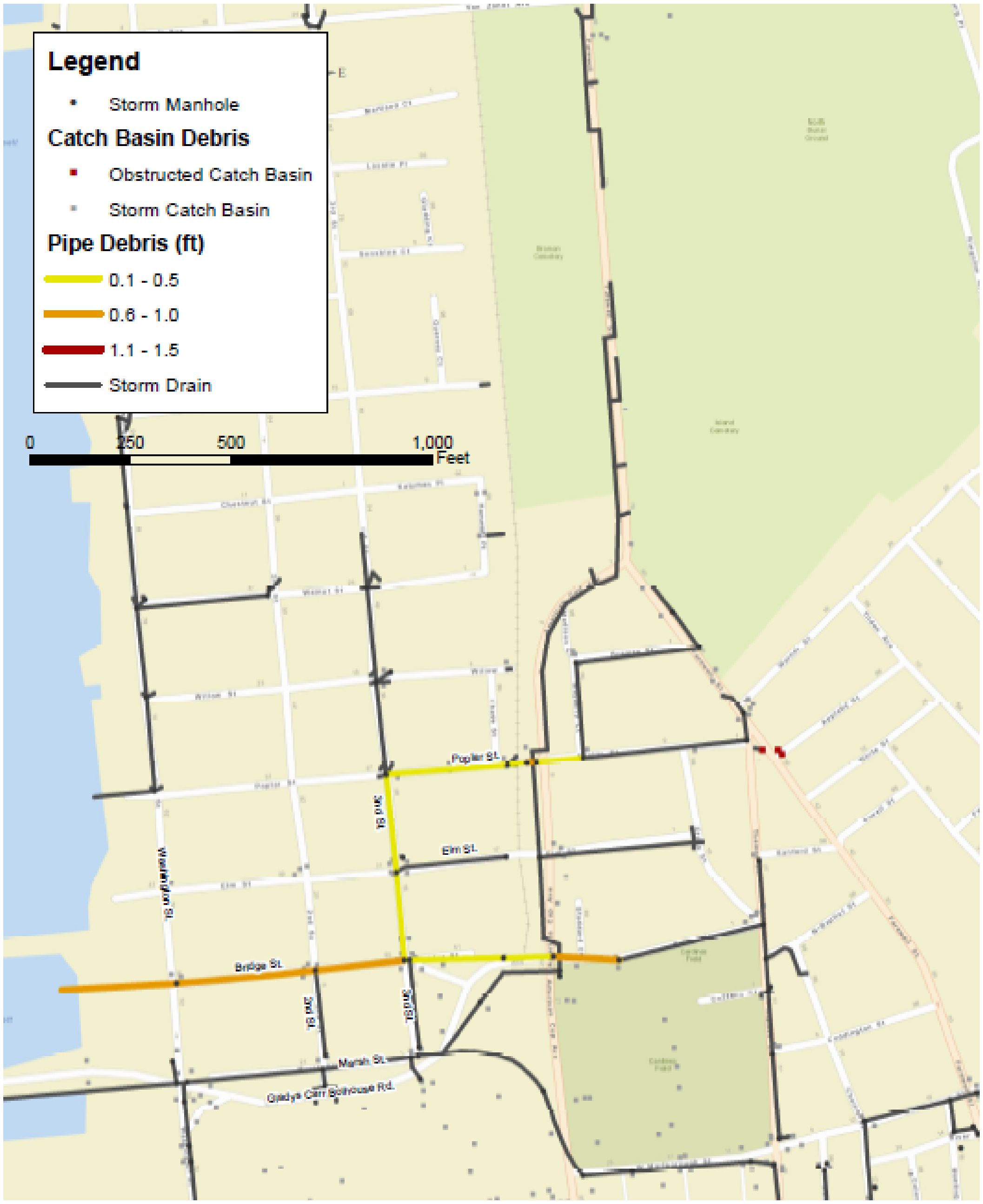
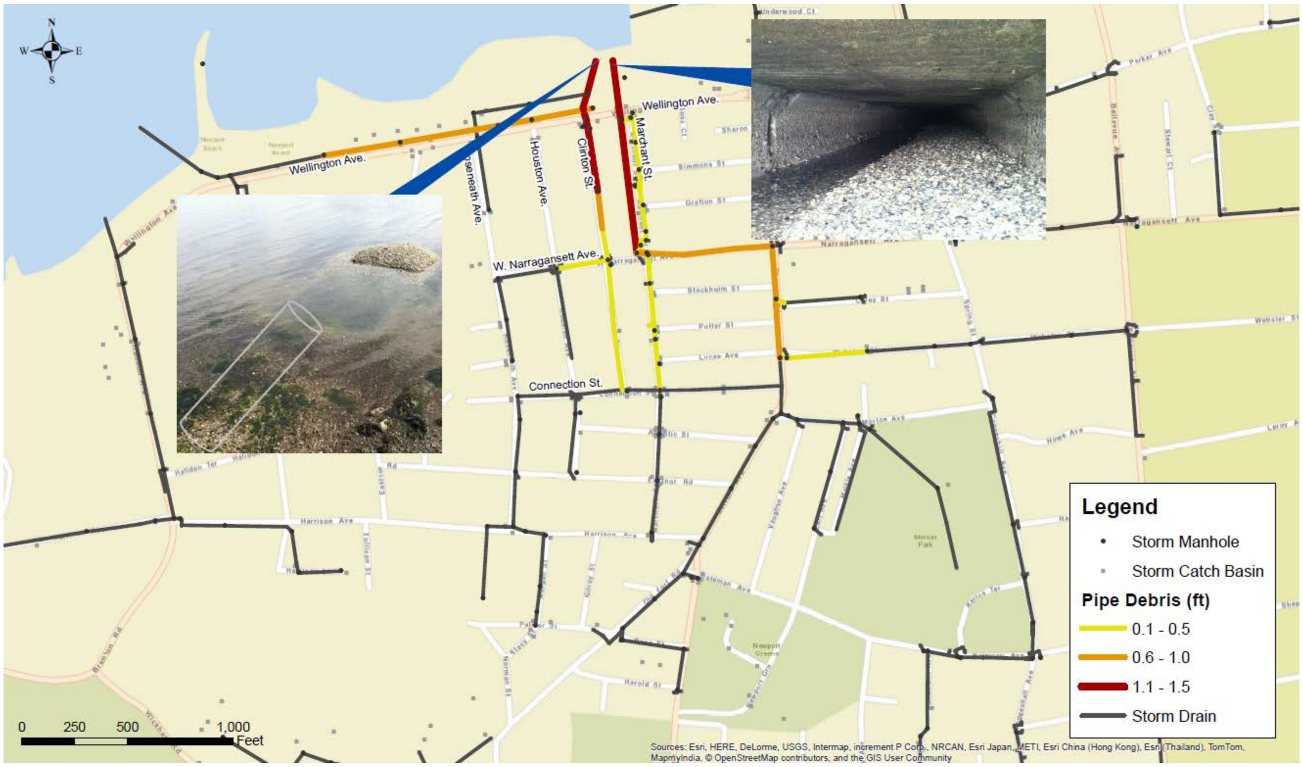


Figure A-1. Bridge Street Debris

Debris quantity discovered during the field investigation in the Bridge Street



Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure A-2. Wellington Avenue Debris

Debris quantity discovered during the field investigation in the Wellington Avenue

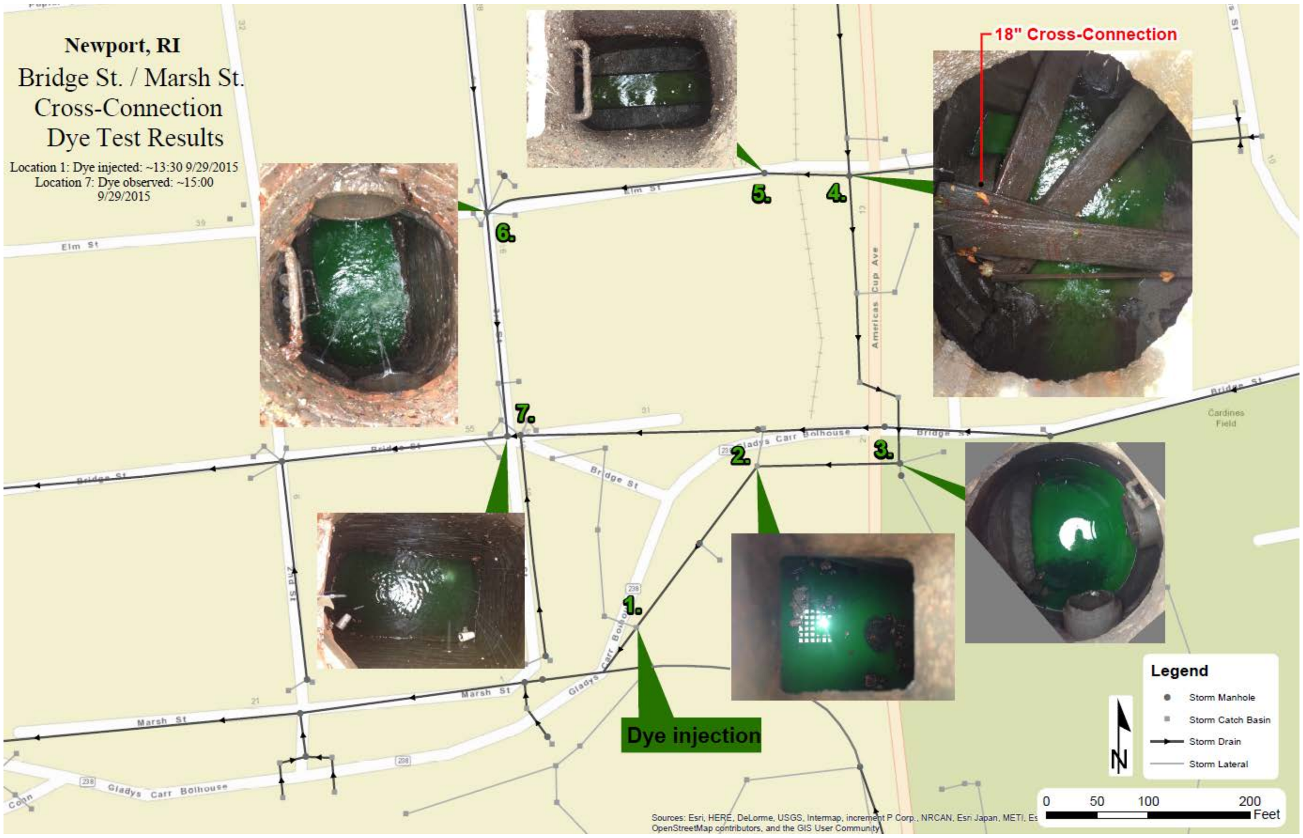


Figure A-2. Wellington Avenue Debris

Debris quantity discovered during the field investigation in the Wellington Avenue

Appendix B

Potential Controls Performance Screening

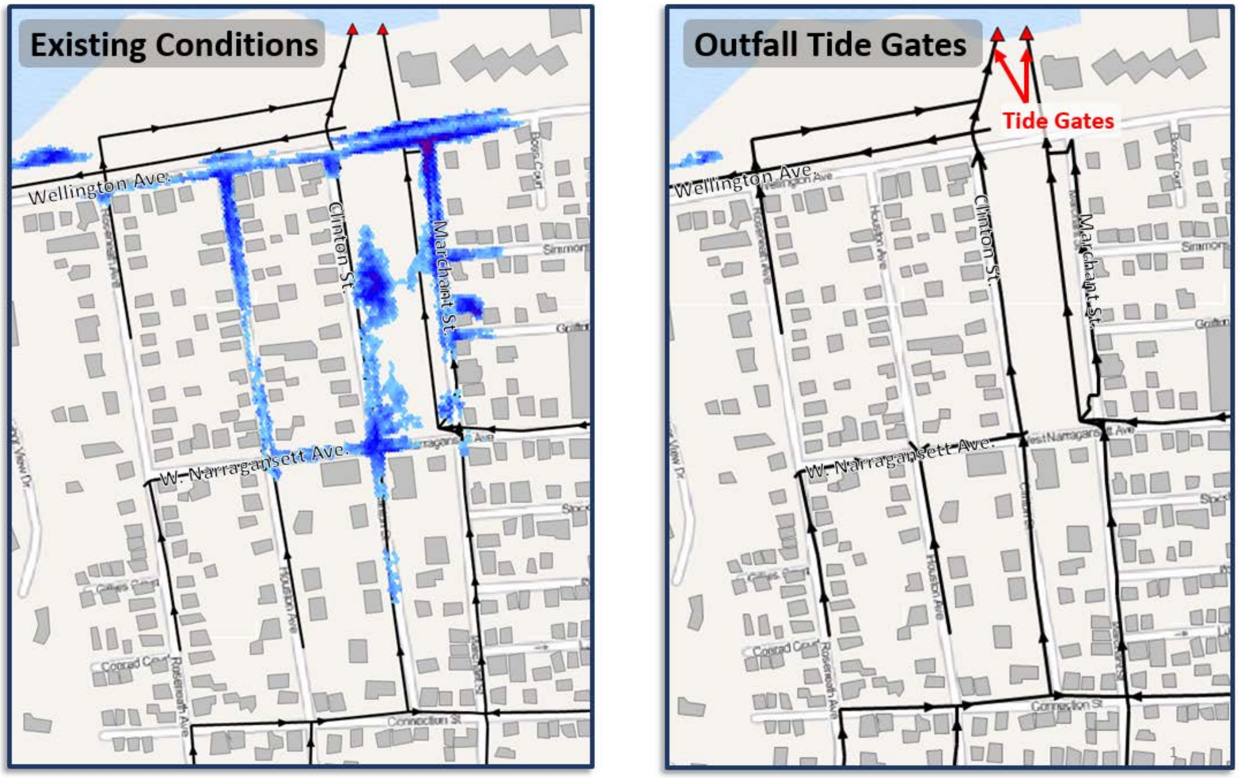


Figure B-1. Wellington Avenue Outfall Tide Gates – King Tide

Comparison between existing conditions and outfall tide gates for the 10/7/2010 King Tide of 5.8 ft (MLLW), no rain

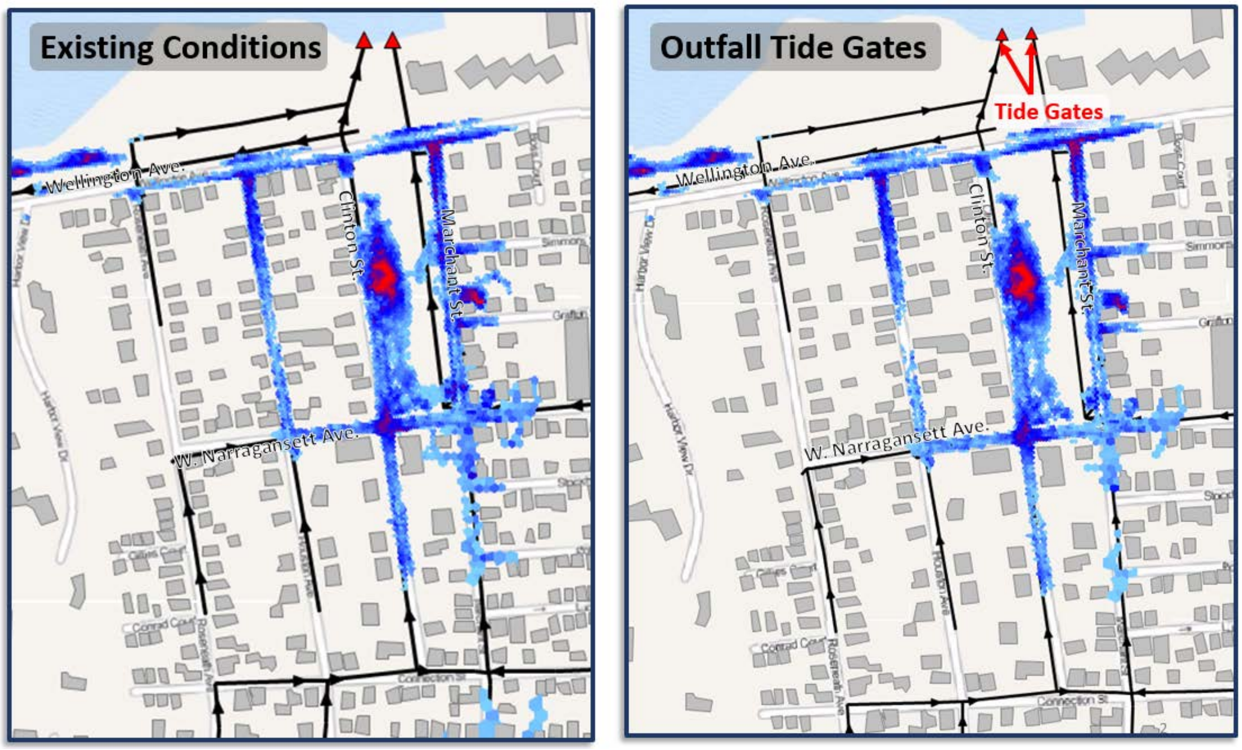


Figure B-2. Wellington Avenue Outfall Tide Gates – Rain at High Tide

Comparison between existing conditions and outfall tide gates for the 7/1/2015 rain event of 1.2 in at high tide of 4.3 ft (MLLW)

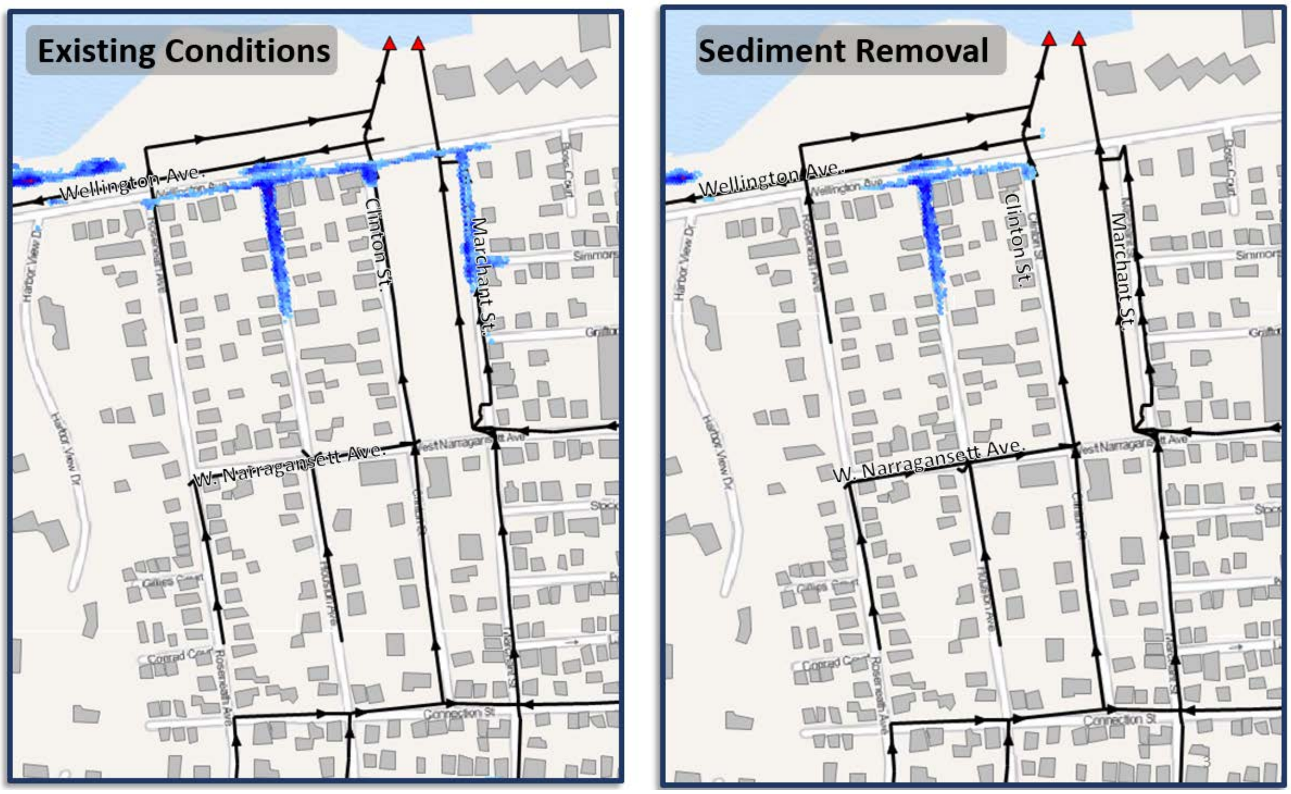


Figure B-3. Wellington Avenue Pipe Sediment Removal – Rain at Low Tide

Comparison between existing conditions and pipe sediment removal for the 7/1/2015 rain event of 1.2 in at a theoretical low tide

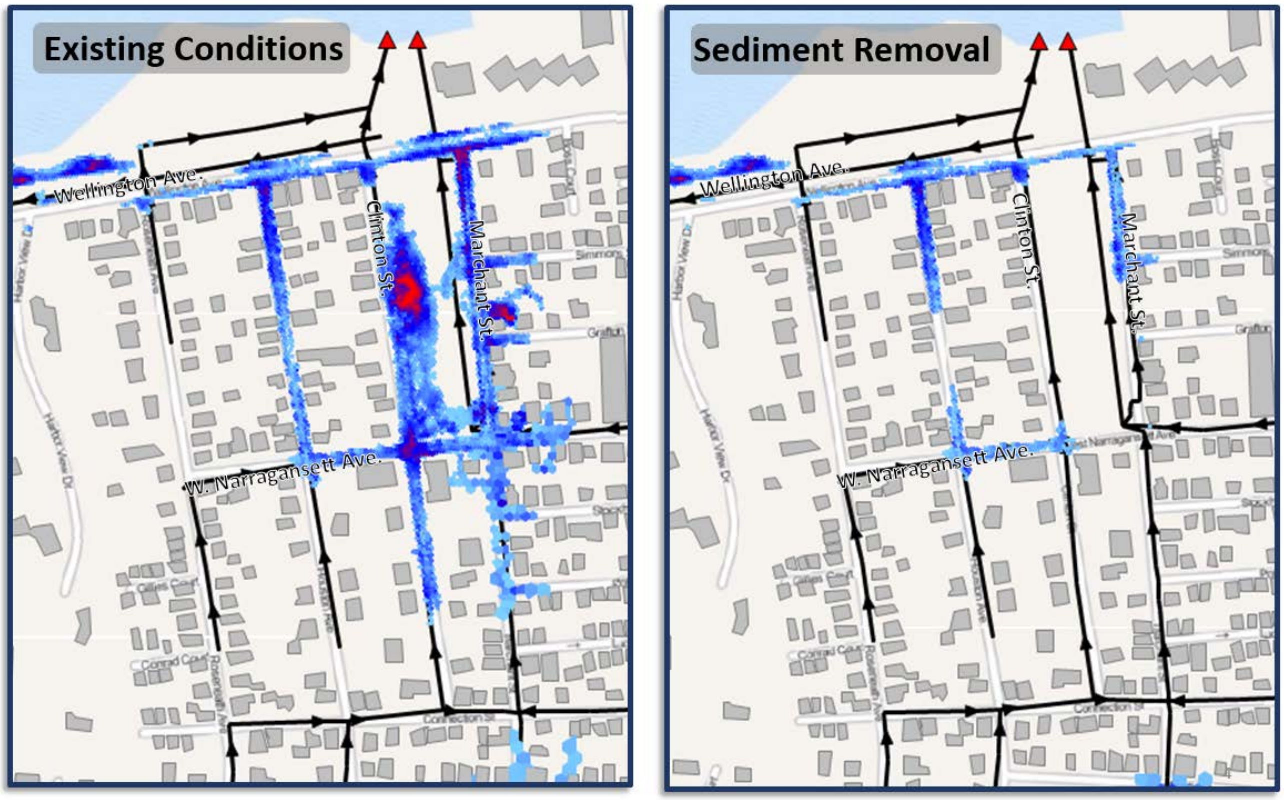


Figure B-4. Wellington Avenue Pipe Sediment Removal – Rain at High Tide

Comparison between existing conditions and pipe sediment removal for the 7/1/2015 rain event of 1.2 in at high tide of 4.3 ft (MLLW)

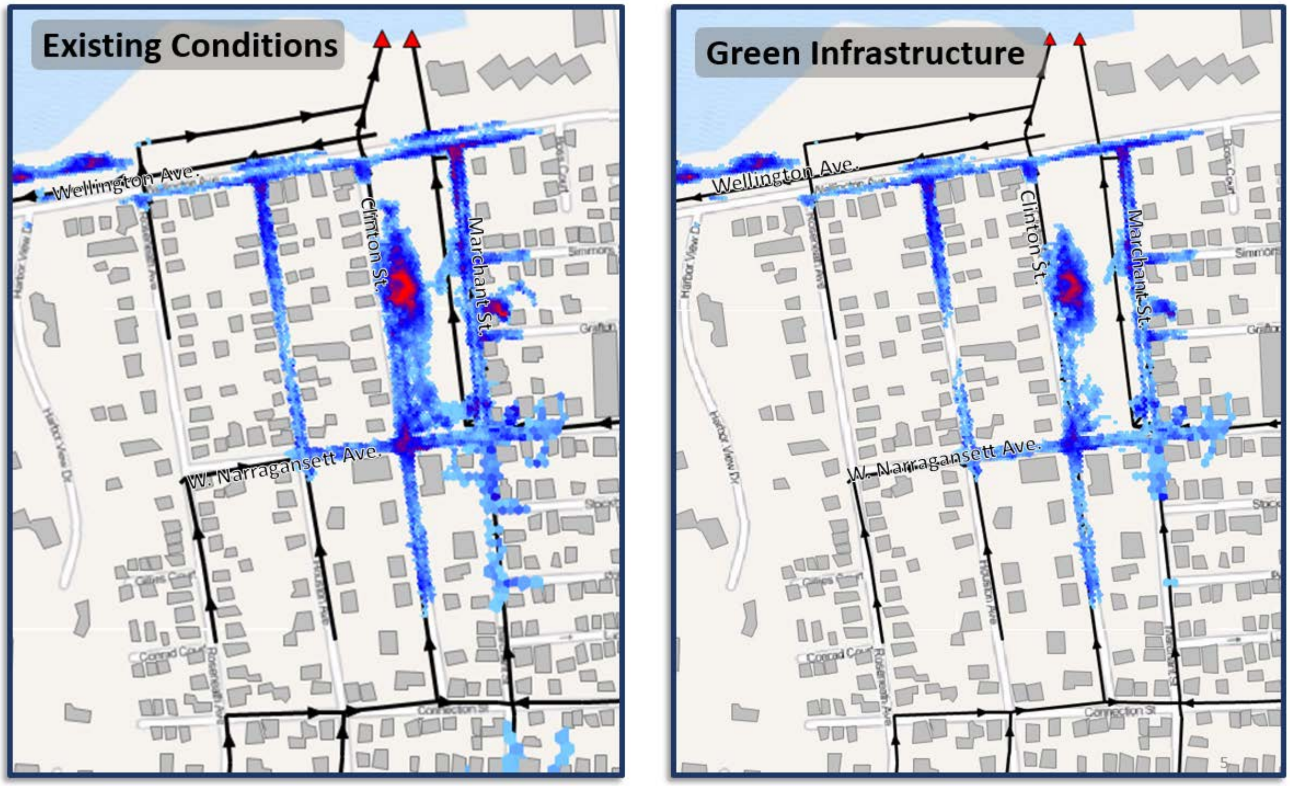


Figure B-5. Wellington Avenue Green Infrastructure – Rain at High Tide

Comparison between existing conditions and green infrastructure for the 7/1/2015 rain event of 1.2 in at high tide of 4.3 ft (MLLW)

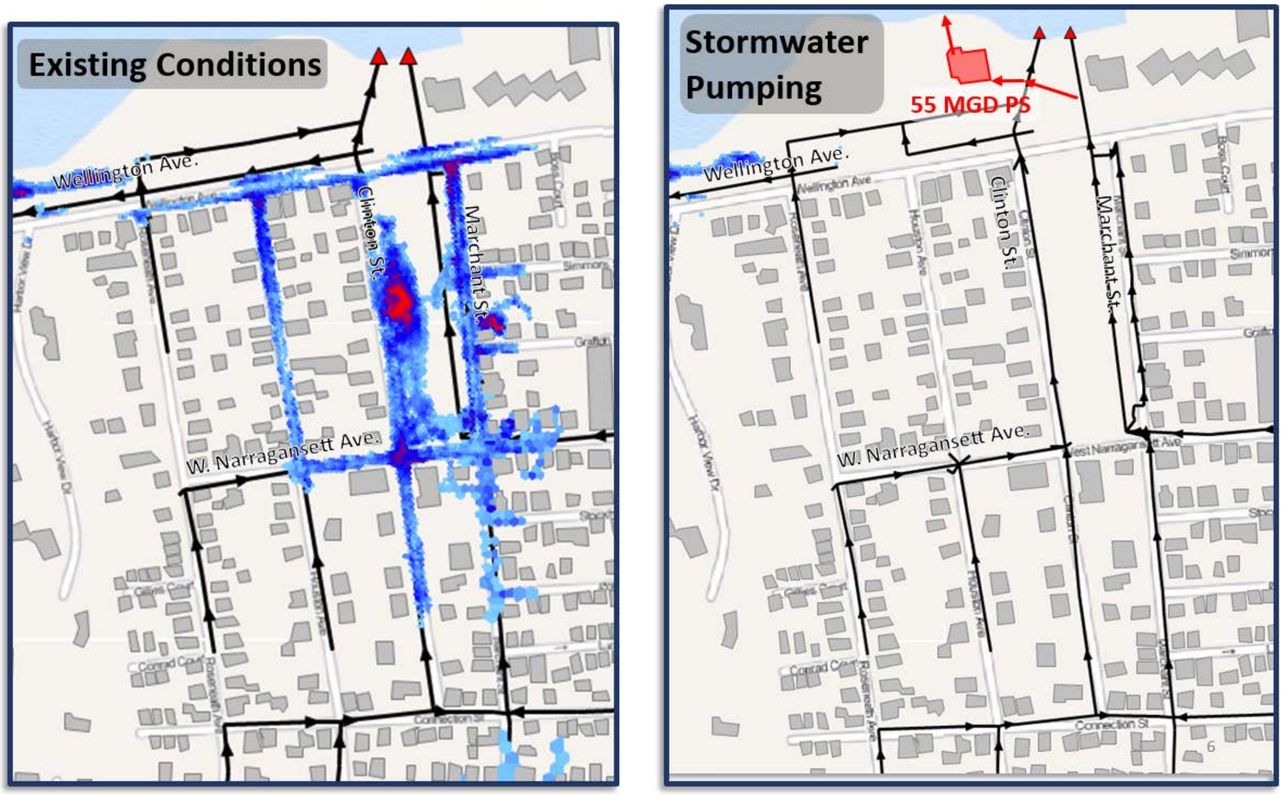


Figure B-6. Wellington Avenue Stormwater Pump Station – Rain at High Tide

Comparison between existing conditions and stormwater pump station for the 7/1/2015 rain event of 1.2 in at high tide of 4.3 ft (MLLW)

Figure B-7. Bridge Street Outfall Tide Gates – King Tide

Comparison between existing conditions and outfall tide gates for the 10/27/2011 King Tide of 5.9 ft (MLLW), no rain

Figure B-8. Bridge Street Outfall Tide Gates – Rain at High Tide

Comparison between existing conditions and outfall tide gates for the 7/1/2015 rain event of 1.2 in at high tide of 4.3 ft (MLLW)

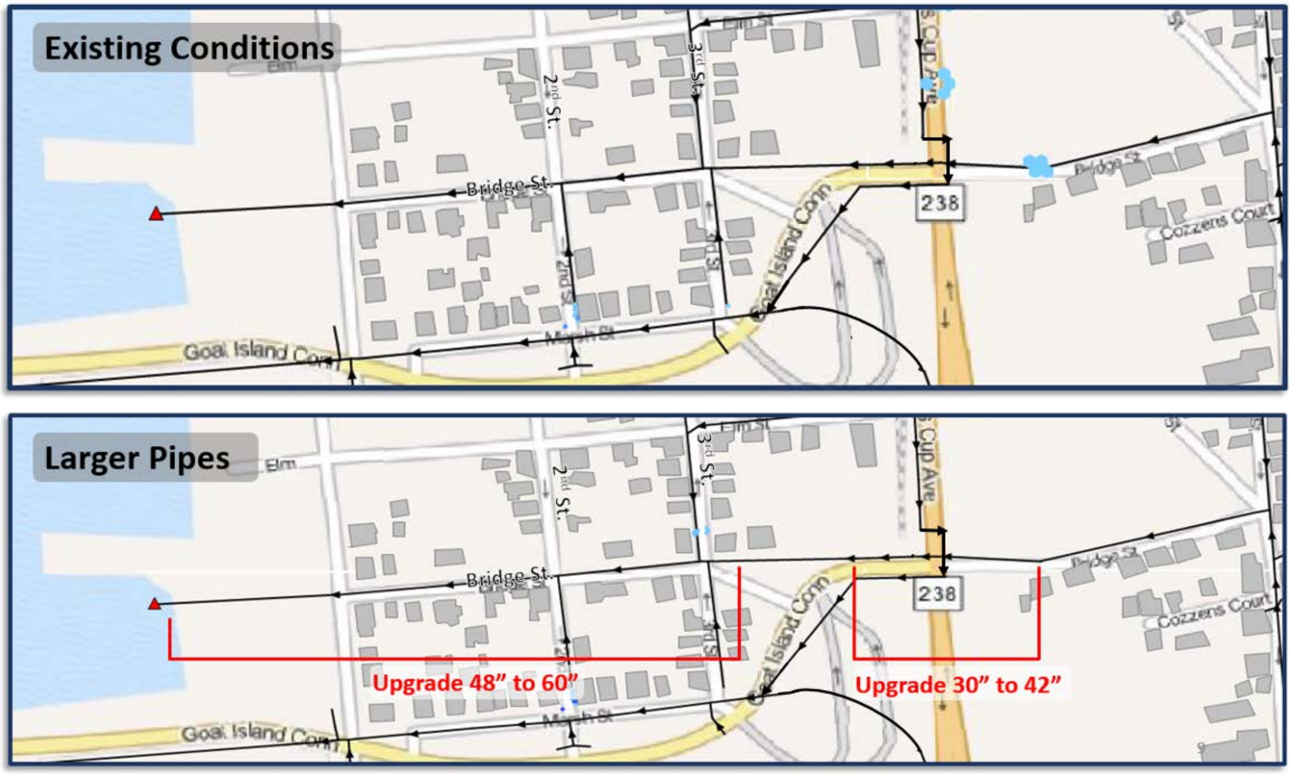


Figure B-9. Bridge Street Larger Pipes – Rain at Low Tide

Comparison between existing conditions and larger pipes for the 7/1/2015 rain event of 1.2 in at a theoretical low tide

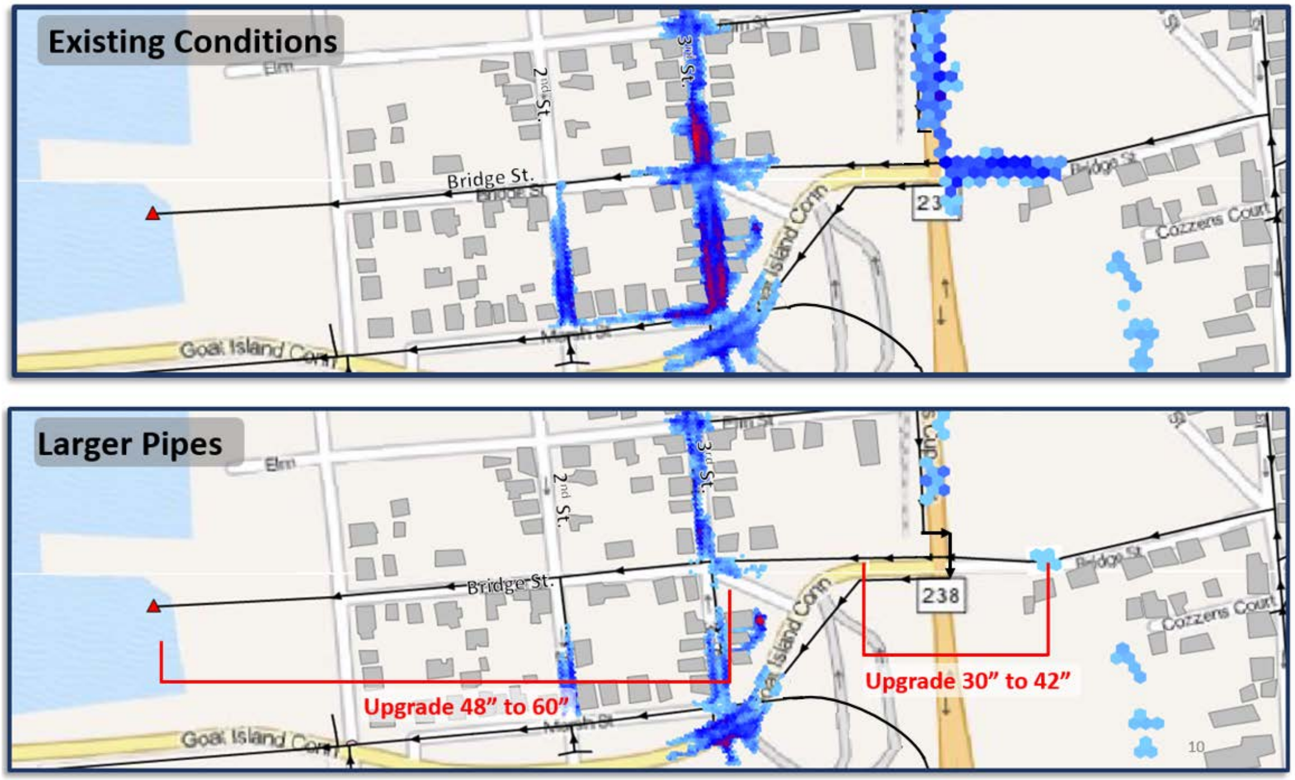


Figure B-10. Bridge Street Larger Pipes – Rain at High Tide

Comparison between existing conditions and larger pipes for the 7/1/2015 rain event of 1.2 in at high tide of 4.3 ft (MLLW)

Figure B-11. Bridge Street Green Infrastructure – Rain at High Tide

Comparison between existing conditions and green infrastructure for the 7/1/2015 rain event of 1.2 in at high tide of 4.3 ft (MLLW)

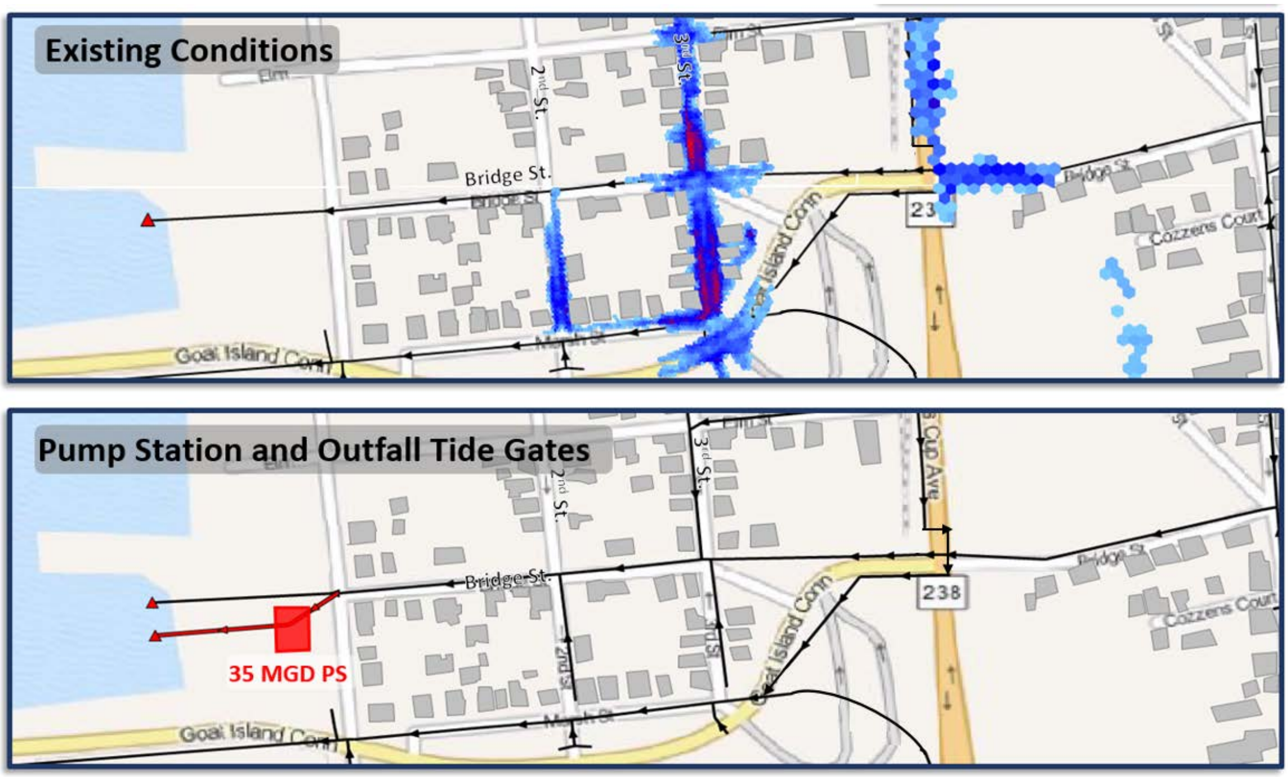


Figure B-12. Bridge Street Stormwater Pump Station – Rain at High Tide

Comparison between existing conditions and stormwater pump station for the 7/1/2015 rain event of 1.2 in at high tide of 4.3 ft (MLLW)

Appendix C
Price Estimation

Basis of Estimate

Drainage Investigation and Flood Analysis

Wellington Avenue and Bridge Street

March 2016; Revised May 2017

Revisions

Modified the dimensions of the box culvert at Wellington Avenue to be 3 by 8 feet, consistent throughout.

Changed the size of the circular outfall pipe at Wellington from 60-inches to 66-inches, throughout.

Appendices:

1. Purpose of Estimate

The purpose of this Estimate is to establish an Engineer's opinion of probable capital and operational and maintenance (O&M) costs at a preliminary level of design.

2. General Project Description

The Drainage Investigation and Flood Analysis for Wellington Avenue and Bridge Street includes short-term and long-term control options for historic flooding issues in the Wellington Avenue and Bridge Street drainage areas including: Construction of Tide Gate Structures, pipe and box culvert cleaning, catch basin rehabilitations, Harbor dredging, Green Infrastructure, and construction of new Pump Stations.

3. Overall Capital Costs

The following is a summary breakdown of the costs. All of the costs presented are in 2015 dollars and include a 5.25% escalation factor to account for 18 months of permitting, design, and award of construction for short-term control options. Any components that would be constructed beyond 2017 should be escalated to the mid-point of construction once that implementation schedule is determined. See attached breakdown for additional detailed information.

TABLE 3.1
Capital Cost Estimates

Capital Costs	Low Range (-25%)	Estimated Costs [a]	High Range (+50%)
Bridge St. Short Term Controls	$1,486,000	**$1,981,000**	$2,972,000
Bridge St. Long Term Controls	$12,667,000	**$16,889,000**	$25,334,000
Wellington Ave. Short Term Control	$2,957,000	**$3,942,000**	$5,913,000
Wellington Ave. Long Term Control	$22,392,000	**$29,855,000**	$44,783,000

[a] See Appendix for cost estimate details

This cost estimate has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on actual labor and material costs, competitive market conditions, final project costs, implementation schedule and other variable factors. As a result, the final project costs will vary from the estimate presented herein. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help ensure proper project evaluation and adequate funding.

4. Markups

These markups are based upon general assumptions about how the projects will be contracted. Actual markup percentages may vary from those shown here, and are the responsibility of the bidding contractor.

TABLE 4.1
Markups

Subcontractor Markups	20.00%
General Conditions	7.00%

Material Sales Tax	7.00%
Mobilization	4.00%
General Contractor Overhead	12.00%
General Contractor Profit	6.00%
Bonds/Insurance	2.16%
Contingency	30.00%
Escalation	5.25%
Design Services	10.00%
Services During Construction	5.00%

5. Scope of Work

The project includes Long Term and Short Term Control options including:

Bridge St. Improvements included in the short-term control plan

- A new tide gate on the Bridge St. line
  - 48 inch pipe
- Clean the Bridge St. line
  - 855 ft. of 48 inch pipe (Sediment: 8 in)
  - 245 ft. of 42 inch pipe (Sediment: 4 in)
  - 286 ft. of 30 inch pipe (Sediment: 4 in – 10 in)
- Clean the Marsh St. line
  - 1,811 ft. of 3’ X 5’ box culvert (Sediment: 6 in – 12 in, includes piles of bricks)
  - 970 ft. of 42 inch pipe (Sediment: 6 in – 10 in)
- Catch basin rehabilitation
  - 20 Catch basins to repair and add sumps

Bridge St. Improvements included in the long-term control plan

- All short-term controls
- Green infrastructure
  - 9 Bio-retention type units (30,000 ft2 total area)
  - 9 Permeable pavement type units (21,000 ft2 total area)
- Pump station
  - 35 MGD capacity
  - 15 ft. of head

Wellington Ave. Improvements included in the short-term control plan

- Tide gate at the end of the 3’ X 8’ box culvert
- Tide gate at the end of the 66 inch line
- Clean the 3’ X 8’ box culvert

    - 917 ft. of 3' X 8' box culvert (Sediment: 18 in – 12 in)
    - 90 ft. of 12 inch pipe (Sediment: 3 in)
    - 605 ft. of 18 inch pipe (Sediment: 3 in – 8 in)
    - 74 ft. of 48 inch pipe (Sediment: 8 in)
    - 681 ft. of 54 inch pipe (Sediment: 3 in – 12 in)
- Clean the 66 inch line
    - 1007 ft. of 24 inch pipe (Sediment: 3 in – 6 in)
    - 960 ft. of 66 inch pipe (Sediment: 6 in – 24 in)
- Clean the 18 inch line
    - 1954 ft. of 18 inch pipe (Sediment: 6 in – 8 in)
- Catch basin rehabilitation
    - 23 Catch basins to repair and add sumps
- Harbor dredging and sediment removal at the 66" outfall
- Rerouting the Houston St. catch basins to the 66" outfall
    - Block off 18 inch pipe
    - Install 75 ft. of 18 inch pipe

Wellington Ave. Improvements included in the long-term control plan

- All short-term controls
- Green infrastructure
    - 4 Bio-retention type units (54,000 ft2 total area)
    - 27 Permeable pavement type units (73,000 ft2 total area)
- Pump station
    - 55 MGD capacity
    - 18 ft. of head
    - 160 ft. of 66" pipe connection

6. Escalation Rate

An Escalation Rate of 5.25% is included to set the construction period in 2017 to allow time for permitting, design and construction award.

7. Estimate Classification

This cost estimate prepared is considered a Class 5/Class4 estimate as defined by the Association for the Advancement of Cost Engineering International (AACEI). Some elements of the estimates included enough design detail to be considered a Class 4 estimate as defined by AACEI, therefore the accuracy range for this estimate is from -25% to +50% to account for the blended Class estimates.

8. Estimate Methodology

This cost estimate is considered a bottom rolled up type estimate with cost items and breakdown of Labor, Materials and Equipment. Some quotations were obtained for various items. The estimate may include allowance cost and dollars per SF cost for certain components of the estimate.

- Green Infrastructure Cost used in the estimate alternatives are from contractor bid tab information for similar type of construction based on a per square foot unit rate. Contingency, Escalation, Design Services, and Services During Construction were added to the square foot unit costs.
- Pump Station Costs used in the estimate alternatives are from contractor bid tab information for similar pump station construction. The Bid Tab Pump Station Costs have been adjusted for project location and site conditions, escalated from the bid opening date to current dollars, and the pump stations flow rate (MGD) to determine a unit cost per flow rate. This flow rate unit cost was used to produce the pump station costs per flow rate for these alternatives. Contingency, Escalation, Design Services, and Services During Construction were added to the flow rate unit costs.

9. Cost Resources

The following is a list of the various cost resources used in the development of the cost estimate:

- R.S. Means
- CH2M HILL Historical Data
- Vendor Quotes on Equipment and Materials where appropriate
- Estimator Judgment

10. Labor Costs

Labor unit prices reflect a burdened rate, including: workers compensation, unemployment taxes, Fringe Benefits, and medical insurance.

11. Major Assumptions

The estimate is based on the assumption the work will be done on a competitive bid basis and the contractor will have a reasonable amount of time to complete the work. It also assumes all contractors are equal, with a reasonable project schedule, no overtime, constructed as under a single contract, no liquidated damages.

This estimate should be evaluated for market changes after 90 days of the issue date. It is assumed that much of the fabricated equipment will be shipped from the mainland USA.

- The estimate is based on the work to be performed by a local contractors on a competitive bid basis

12. Allowances

The estimate includes the following allowances at this time:

- Green Infrastructure
- Pump Stations
- Catch Basin Rehabilitations

- Design Services
- Services During Construction

13. Excluded Costs

The cost estimate excludes the following costs:

- Material Adjustment allowances above and beyond what is included at the time of the cost estimate
- Owner’s costs such as legal and administration
- Hazardous waste remediation and or mitigation costs
- Permitting

14. O&M Costs

Of the scope of work items presented in Section 5, the following controls will also include additional O&M costs to the City:

- Tide gates
- Storm drain cleaning
- Catch basin rehabilitation and addition of sumps
- Green infrastructure
- Pump stations

Table 14.1 presents the estimated annual O&M costs to the City for each of these controls in 2015 dollars. It is assumed that these costs would escalate each year in relation to the Consumer Price Index (CPI).

Table 14.1
O&M Cost Estimates

Control Feature	Estimated O&M Cost/Year Bridge Street	Estimated O&M Cost/Year Wellington Avenue
Tide Gates	$9,030	$27,090
Additional Storm Drain Cleaning	$47,835	$71,940
Additional Catch Basin Sump Cleaning	$1,400	$1,610
Green Infrastructure	$21,750 - $36,900	$47,950 - $80,500
Pump Station	$36,000	$39,600

Tide Gate Annual O&M Estimate Basis

Based upon feedback from CH2M’s operations services group, tide gate maintenance would typically be included as part of the collection system operator’s normal O&M rounds and therefore the only additional costs would be the time for the operators to inspect and perform maintenance on the tide gates. The following assumptions were used to calculate the annual labor required to inspect and maintain the proposed tide gates:

- All tide gates inspected preceding and following significant precipitation events to ensure that they are in proper operating condition (not stuck open by trash or other debris).
- All tide gates inspected monthly regardless of precipitation.

- There are 74 precipitation events in the “typical year” based upon the typical year analysis. Of these events, it is assumed that about half of them will be significant enough in volume to require that the tide gates be inspected pre- and post-precipitation event.
- Each inspection will require 3 personnel because of confined space entry needs and will require 1 hour total time
- Labor rate for personnel inspecting the tide gates equals $35/hour
- There will be limited need for parts replacement on an annual basis

Therefore, for the 4 new tide gates the annual O&M cost would be calculated as follows:

$$Annual\ O\&M\ Bridge\ Street = \left(1\,\frac{tide\ gate}{precipitation\ event} * \left(3\,personnel * \frac{\frac{\$35}{hr}}{personnel}\right)\right) * (\left(2 * 37\,precipitation\,\frac{events}{yr}\right) + 12\,monthly\,\frac{events}{yr}) = \$9{,}030/yr$$

$$Annual\ O\&M\ Wellington\ Avenue = \left(3\,\frac{tide\ gates}{precipitation\ event} * \left(3\,personnel * \frac{\frac{\$35}{hr}}{personnel}\right)\right) * (\left(2 * 37\,precipitation\,\frac{events}{yr}\right) + 12\,monthly\,\frac{events}{yr}) = \$27{,}090/yr$$

Annual Storm Drain Cleaning

The storm drains in these areas require more frequent cleaning than can be achieved by the City’s routine cleaning cycle. It is assumed that following the initial capital effort of cleaning the lines that subsequent efforts will need to be repeated annually. Based upon actual cleaning and debris disposal rates that CH2M has for systems that it operates, the following unit rates were assumed for cleaning and debris disposal:

Cleaning - $5/linear foot (lf)

Debris disposal - $90/ton

Based upon findings of the field investigations during the project the following lengths of pipe were assumed to need annual cleaning:

Bridge St. system – 4,167 lf

Wellington Ave. system – 6,288 lf

Based upon the debris amounts removed from the Marsh St. line cleaning, the following amounts of debris were estimated for removal from each system each year:

Bridge St. system – 300 tons

Wellington Ave. system – 450 tons

$Annual\ O\&M\ Bridge\ St. =$ (4,167 lf*$5/lf)+(300 tons*$90/ton) = $47,835

$Annual\ O\&M\ Wellington\ Ave. =$ (6,288 lf*$5/lf)+(450 tons*$90/ton) = $71,940

Annual Catch Basin Cleaning

The addition of catch basins with sumps will require additional maintenance for the cleaning of the sumps. It is assumed that the sumps will be cleaned twice annually in the spring and fall. The following assumptions were used in calculating the annual O&M cost for the additional sump cleaning:

- Each catch basin/sump clean out will require 2 personnel and will require 1/2 hour total time
- Labor rate for personnel cleaning the catch basins/sumps equals $35/hour
- Each catch basin and sumps will be cleaned twice per year
- No equipment cost was included as it is assumed that the City’s operator will have a vactor truck for routine maintenance

$$Annual\ O\&M\ Bridge\ Street = 20\ sumps * 2\frac{cleanings}{yr} * 2\ personnel * \frac{\$35}{hr} * 0.5\frac{hr}{sump} = \$1{,}400/yr$$

$$Annual\ O\&M\ Wellington\ Avenue = 23\ sumps * 2\frac{cleanings}{yr} * 2\ personnel * \frac{\$35}{hr} * 0.5\frac{hr}{sump} = \$1{,}610/yr$$

Green Infrastructure Annual O&M Estimate Basis

Based upon CH2M’s database of green infrastructure (GI) O&M costs it is appropriate to present these costs as a range. The GI control options include the following along with ranges of annual O&M costs:

- Bioretention ($0.55/sf/yr - $0.95/sf/yr)
- Permeable pavement ($0.25/sf/yr - $0.40/sf/yr)

Based upon the control options there are the following square feet of GI for each study area:

GI Component	**Wellington Avenue**	**Bridge Street**
Bioretention	54,000 sf	30,000 sf
Permeable pavement	73,000 sf	21,000 sf

Therefore the additional O&M for each drainage area would be calculated as follows:

$$Annual\ O\&M\ Bridge\ Street\ (low\ range)$$
$$= \left(30{,}000\ sf\ bioretention * \frac{\frac{\$0.55}{sf\ bioretention}}{yr}\right) + (21{,}000\ sf\ permeable\ pavement$$
$$* \frac{\frac{\$0.25}{sf\ permeable\ pavement}}{yr}) = \frac{\$16{,}500}{yr} bioretention + \frac{\$5{,}250}{yr} permeable\ pavement$$
$$= \$21{,}750/yr$$

$$\begin{aligned}
&Annual\ O\&M\ Bridge\ Street\ (high\ range)\\
&= \left(30{,}000\ sf\ bioretention * \frac{\frac{\$0.95}{sf\ bioretention}}{yr}\right) + (21{,}000\ sf\ permeable\ pavement\\
&* \frac{\frac{\$0.40}{sf\ permeable\ pavement}}{yr}) = \frac{\$28{,}500}{yr} bioretention + \frac{\$8{,}400}{yr} permeable\ pavement\\
&= \$36{,}900/yr
\end{aligned}$$

$$\begin{aligned}
&Annual\ O\&M\ Wellington\ Avenue\ (low\ range)\\
&= \left(54{,}000\ sf\ bioretention * \frac{\frac{\$0.55}{sf\ bioretention}}{yr}\right) + (73{,}000\ sf\ permeable\ pavement\\
&* \frac{\frac{\$0.25}{sf\ permeable\ pavement}}{yr}) = \frac{\$29{,}700}{yr} bioretention + \frac{\$18{,}250}{yr} permeable\ pavement\\
&= \$47{,}950/yr
\end{aligned}$$

$$\begin{aligned}
&nnual\ O\&M\ Wellington\ Avenue\ (high\ range)\\
&= \left(54{,}000\ sf\ bioretention * \frac{\frac{\$0.95}{sf\ bioretention}}{yr}\right) + (73{,}000\ sf\ permeable\ pavement\\
&* \frac{\frac{\$0.40}{sf\ permeable\ pavement}}{yr}) = \frac{\$51{,}300}{yr} bioretention + \frac{\$29{,}200}{yr} permeable\ pavement\\
&= \$80{,}500/yr
\end{aligned}$$

Pump Station Annual O&M Estimate Basis

As with the capital cost estimate, the estimate for the annual O&M of the pump stations was estimated from the actual O&M costs of a similar pump station that CH2M operates in New Jersey. The key components included in the estimate include:

- Electrical use
- Natural gas (for generator)
- Telephone (SCADA)
- Repairs
- Labor

Table 14.2 details these costs for the similar pump station. The electrical use was adjusted based upon assumed number of events from the model rather than pump station size. Repairs we adjusted based upon pump station sizing. Natural gas, telephone (SCADA) and labor we assumed to be static as they are less likely to be influenced by pump station sizing.

Table 14.2

Pump Station O&M Estimates

PS O&M Component	Example Pump Station (50 MGD) Cost/Year	Bridge St. Pump Station (35 MGD) Cost/Year	Wellington Ave. Pump Station (55 MGD) Cost/Year
Electrical Use	$22,000 (assumes 35 events/yr)	$18,000 (assumes 28 events/yr)	$19,000 (assumes 30 events/yr)
Natural Gas	$400	$400	$400
Telephone (SCADA)	$500	$500	$500
Repairs	$6,500	$4,600	$7,200
Labor	0.25 FTE @ $70,000/yr = $17,500	0.25 FTE @ $70,000/yr = $17,500	0.25 FTE @ $70,000/yr = $17,500
Total	**$46,900**	**$41,000**	**$44,600**

Appendix D
Public Meeting 1 Presentation

Drainage Investigation and Flood Analysis

Wellington Avenue and Bridge Street

Project No. 15-037

Public Informational Meeting #1

Presented by:

ch2m:

July 2015

Introductions

- City of Newport
  - » Julia Forgue, PE – Director of Utilities
  - » Rob Schultz, PE – Deputy Director of Engineering
  - » JR Frey, PE – Water Pollution Control
- CH2M
  - » Peter von Zweck, PE – Project Manager
  - » Becky Weig – Public Involvement
  - » Suibing Liu, PE – Lead Engineer
  - » Chelsea Durante - Engineer

Agenda

- Project Introduction
- Project Background
  - Historic Issues
  - Sea Level Rise Trends and Projections
- Wellington Avenue Study Area
  - Study Area Boundaries
  - Recent Flooding Events
  - Results of Survey
  - Stakeholder Discussion
- Bridge Street Study Area
  - Study Area Boundaries
  - Recent Flooding Events
  - Results of Survey
  - Stakeholder Discussion
- Next Steps
  - Opportunities for public involvement
- Summary & Wrap-up

Project Introduction

Project Introduction

- Problem – Historical drainage and flooding issues in Bridge Street and Wellington Avenue neighborhoods during extreme high tides and high intensity precipitation events
- Objective – Identify sources of flooding, evaluate alternatives, develop recommendations including cost estimates
- Outcome – Short-term and long-term recommendations, including cost estimates

Following a systematic and collaborative approach will ensure the City’s goals for the project are addressed

- Detailed understanding of the contributing factors to flooding
- Detailed delineation of limits of contributing existing storm drain infrastructure
- Modeling of each study area
- Development of potential mitigation alternatives
    - » Short-term (1-3 years)
    - » Long-term
    - » Conceptual designs
    - » Levels of control
    - » Implementation schedules
- Public involvement in the development and selection of mitigation alternatives

Project Background

Project Background

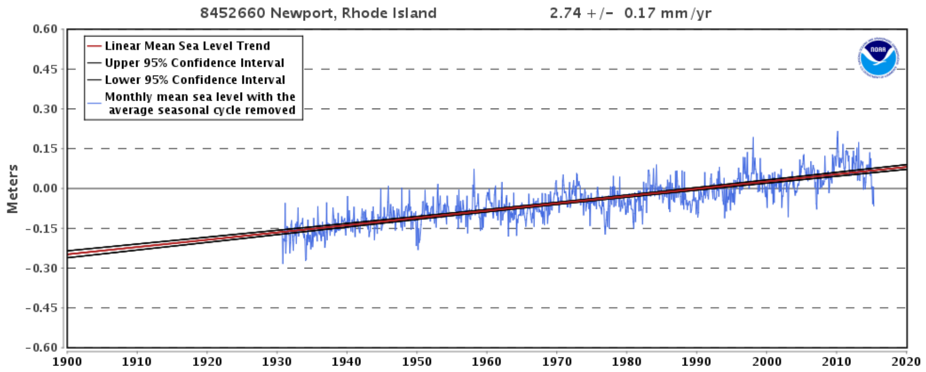
- Historical tidal or “sunshine” flooding
- Precipitation events coinciding with high tide create a compound problem
- Previous measures not 100% effective – example, tide gates at 2nd & 3rd Streets installed in November 2011
- Sea level rise and more intense and frequent storms are already being experienced….there is more projected to come

Tidal flooding at Wellington Avenue in 2011

Tidal flooding compounded by precipitation along 2nd Street in 2011

Water Levels Are Rising in Newport

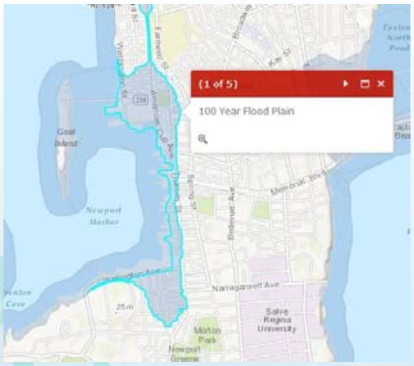
Historic sea level rise is 0.1 inch/year



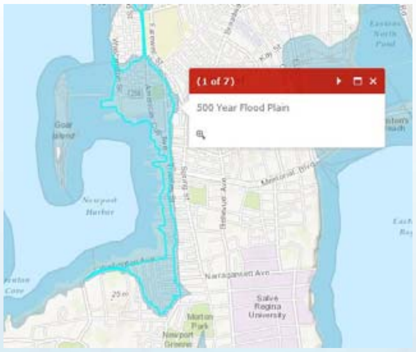
Flood Zones in Newport

100 and 500 year flood plains from the Federal Emergency Management Agency (FEMA), September 2013

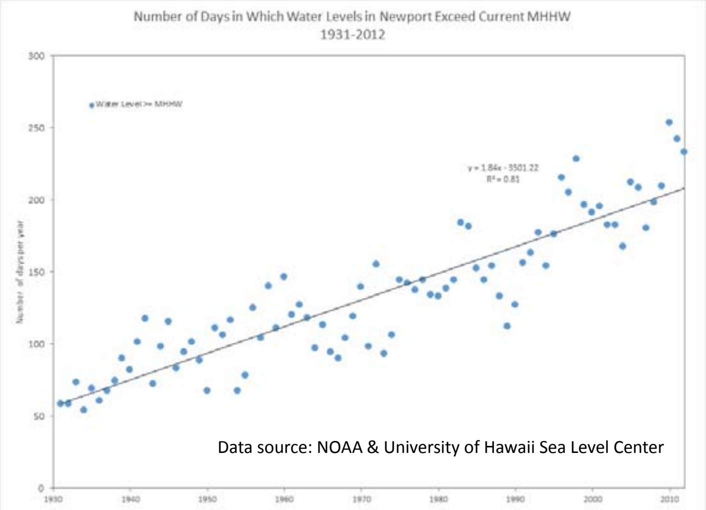
100-year Flood Zone



500-year Flood Zone



Historic Tidal Patterns for Newport – the Water Levels are Getting Higher

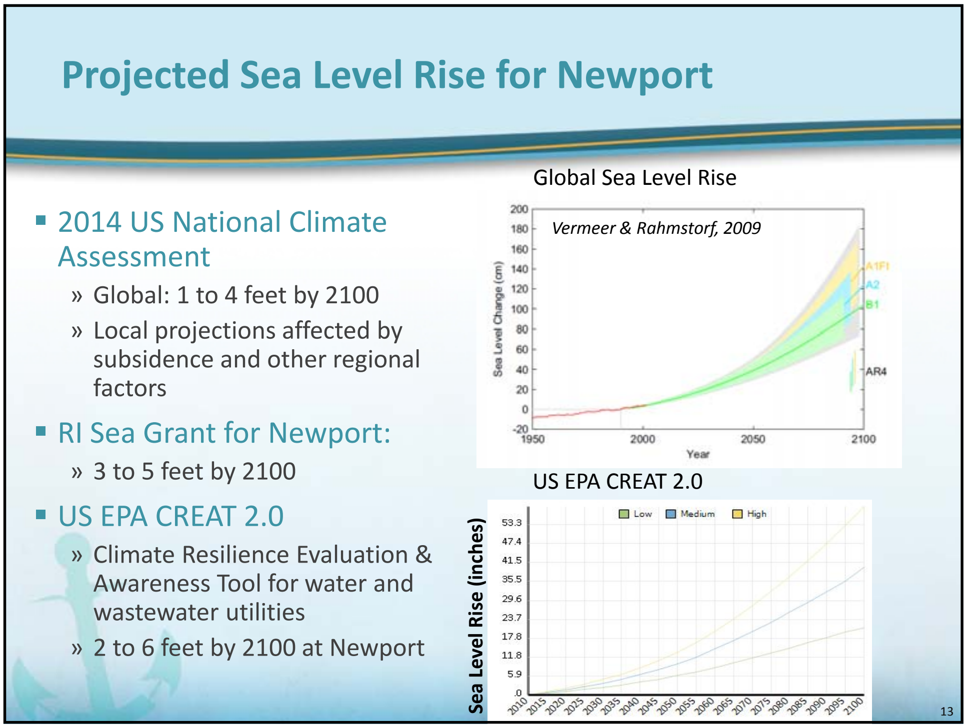


Data source: NOAA & University of Hawaii Sea Level Center

MHHW - Mean Higher High Water - High and low tides occur twice a day each. MHHW is the average of the higher high water height of each tidal day at that station. This is different from Mean High Water (MHW), which is the average of the water heights of all high tides.

Bill McMillin – Sea Level Rise Principal Technologist

- **Climate Risk and Resilience Related Experience**
  - CH2M's East Regional Technology Leader for Integrated Water Resource Management and a core member of CH2M's Climate Risk and Resilience Service Team
  - Appointed to the New Jersey Department of Environmental Protection (DEP) Science Advisory Board (SAB) on the Climate and Atmospheric Sciences Standing Committee in 2010
  - American Society of Civil Engineers, EWRI Climate Change Task Committee member
  - Member of ASCE-Structural Engineering Institute post-disaster investigation to determine structural flooding impacts in New York City after Hurricane Sandy and recommended updates to ASCE 24-05, Flood Resistant Design and Construction
  - Delivered multiple projects to EPA on climate resiliency and flood recovery
  - Task leader for NYC project to develop an adaptation and optimization strategy for addressing increased demand and minimizing risks of global climate change to New York City drainage and wastewater management systems

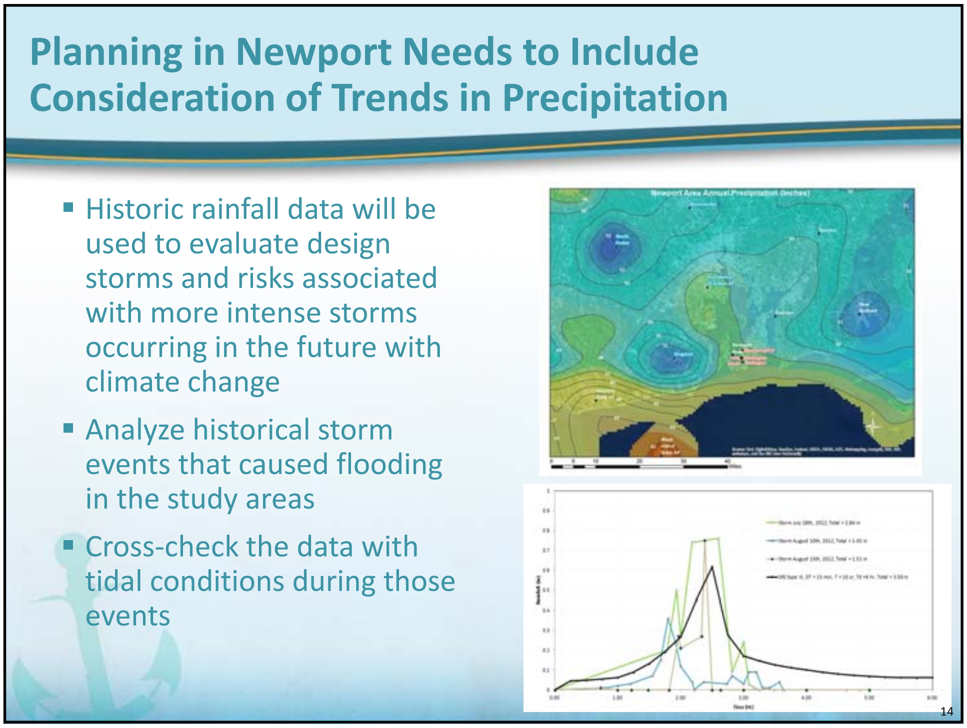


Projected Sea Level Rise for Newport

- 2014 US National Climate Assessment
  - Global: 1 to 4 feet by 2100
  - Local projections affected by subsidence and other regional factors
- RI Sea Grant for Newport:
  - 3 to 5 feet by 2100
- US EPA CREAT 2.0
  - Climate Resilience Evaluation & Awareness Tool for water and wastewater utilities
  - 2 to 6 feet by 2100 at Newport

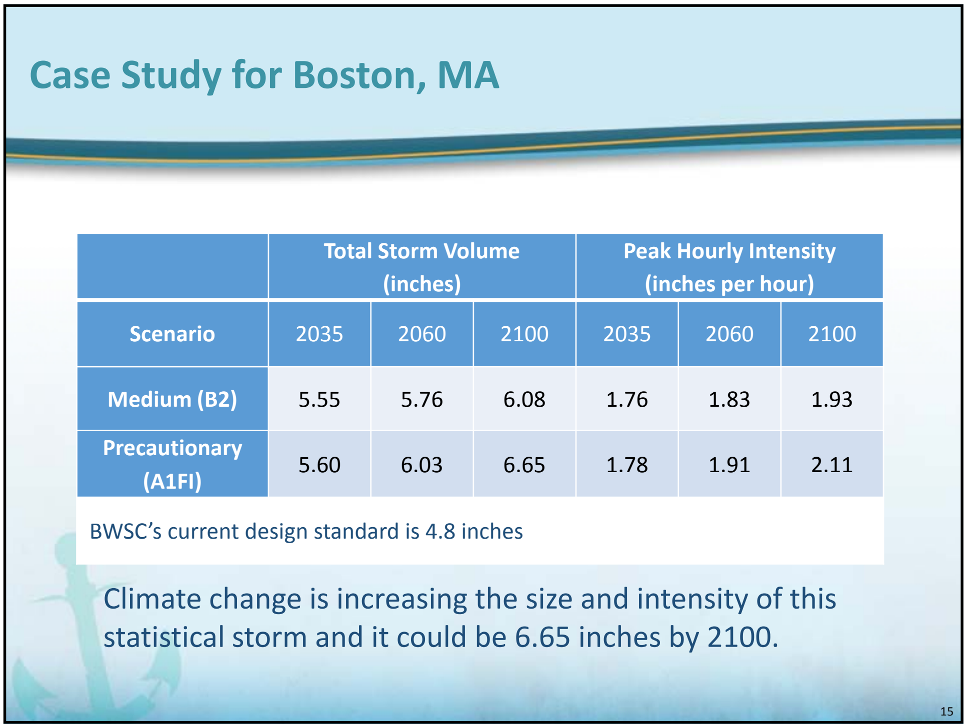
Global Sea Level Rise

US EPA CREAT 2.0



Planning in Newport Needs to Include Consideration of Trends in Precipitation

- Historic rainfall data will be used to evaluate design storms and risks associated with more intense storms occurring in the future with climate change
- Analyze historical storm events that caused flooding in the study areas
- Cross-check the data with tidal conditions during those events

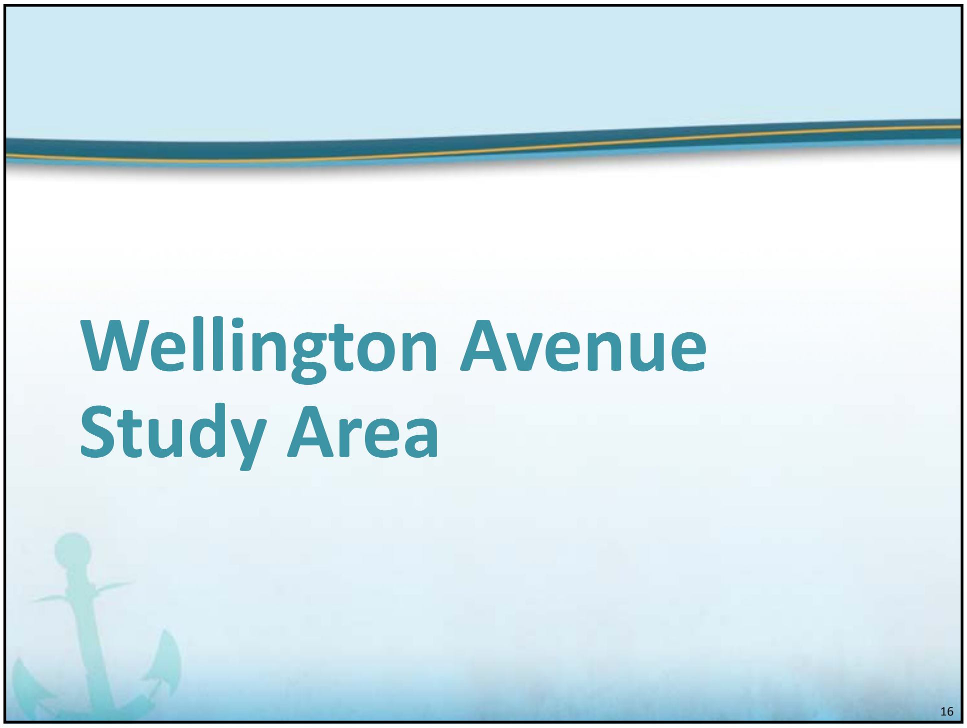


Case Study for Boston, MA

	Total Storm Volume (inches)			Peak Hourly Intensity (inches per hour)		
Scenario	2035	2060	2100	2035	2060	2100
Medium (B2)	5.55	5.76	6.08	1.76	1.83	1.93
Precautionary (A1FI)	5.60	6.03	6.65	1.78	1.91	2.11

BWSC's current design standard is 4.8 inches

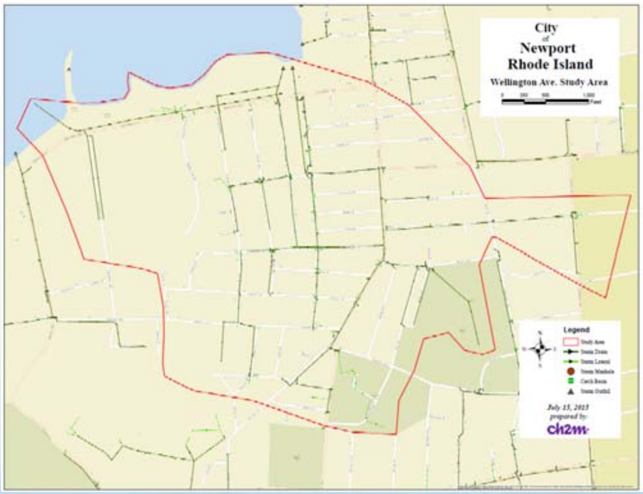
Climate change is increasing the size and intensity of this statistical storm and it could be 6.65 inches by 2100.



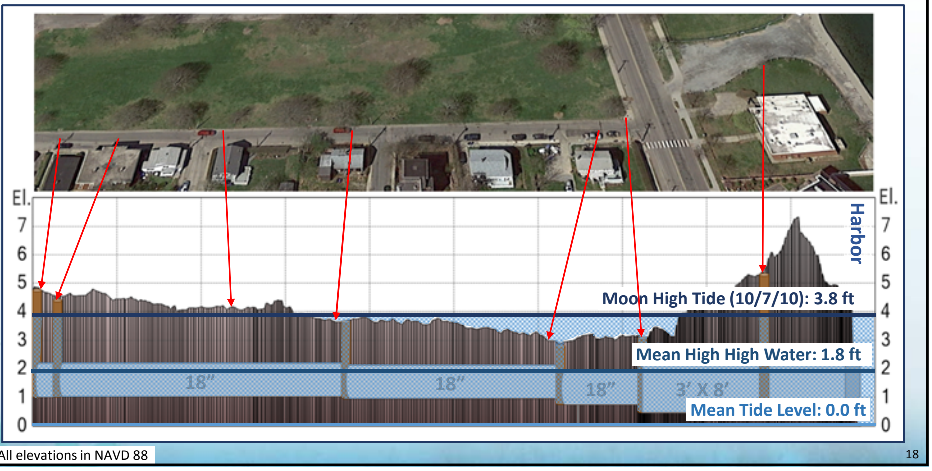
Wellington Avenue Study Area

Wellington Avenue Study Area

- Root Causes of Flooding
  - Extreme high tides
  - Storm surge
  - Sea level rise
  - Precipitation events
  - Combinations of above
- Infrastructure
  - Existing storm drain outfalls to harbor
  - No tide gates
- Impacts
  - Frequent traffic rerouting
  - Access restrictions to public facilities
  - Basement flooding



Marchant St. Flood Profile



All elevations in NAVD 88

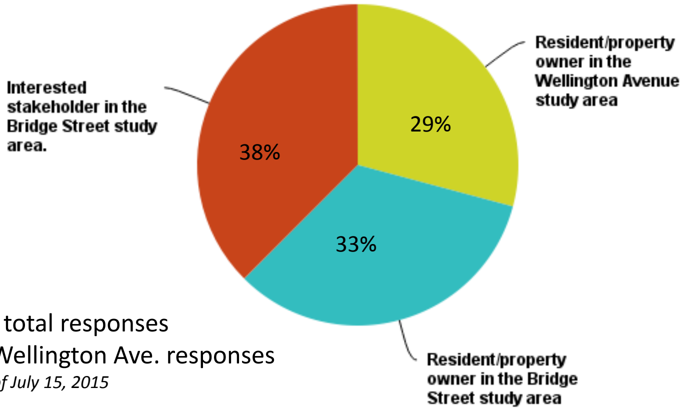
Wellington Avenue Tidal Flooding

Intersection of Wellington Avenue and Marchant Street during a High Tide on 10/07/2011

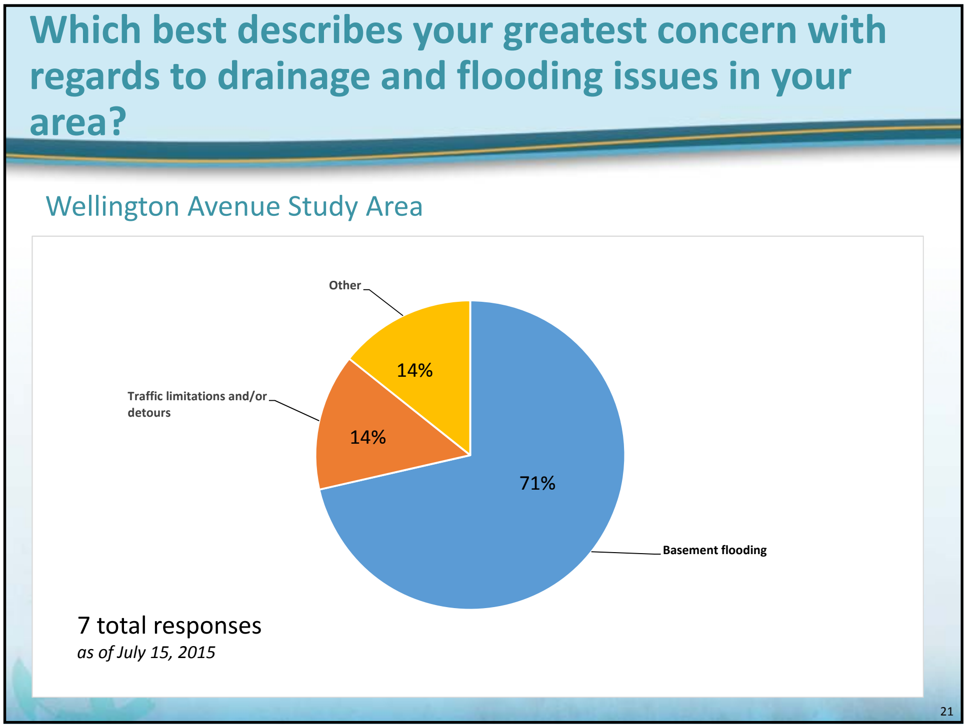
Houston Avenue facing Wellington Avenue during Superstorm Sandy

Survey Results for Wellington Avenue

Q1: Which of the following best describes you?



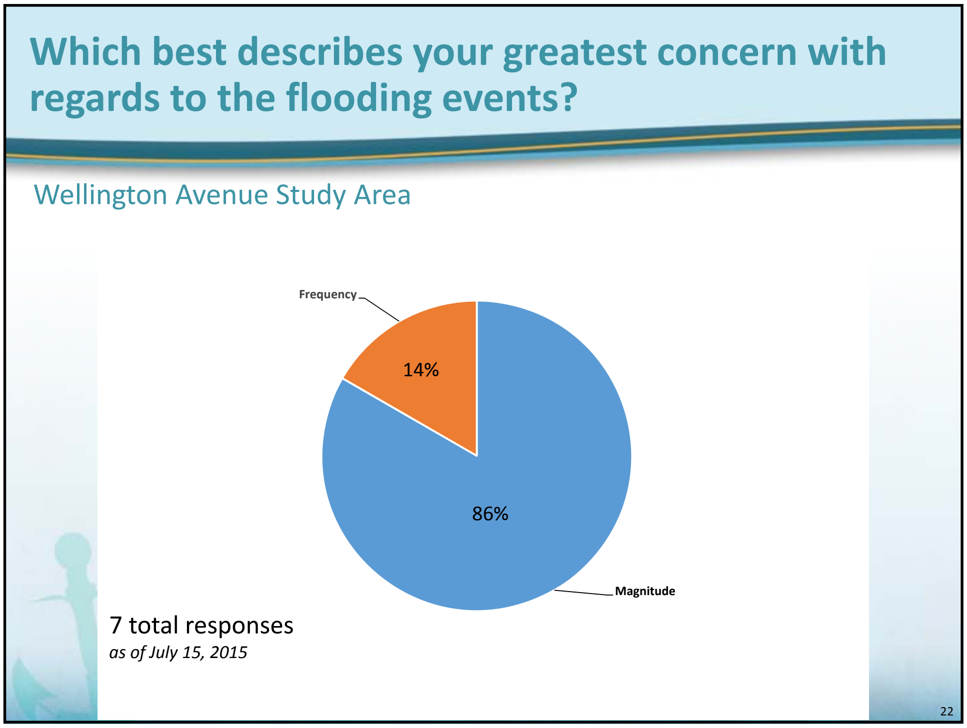
24 total responses
7 Wellington Ave. responses
as of July 15, 2015



Which best describes your greatest concern with regards to drainage and flooding issues in your area?

Wellington Avenue Study Area

7 total responses
as of July 15, 2015



Which best describes your greatest concern with regards to the flooding events?

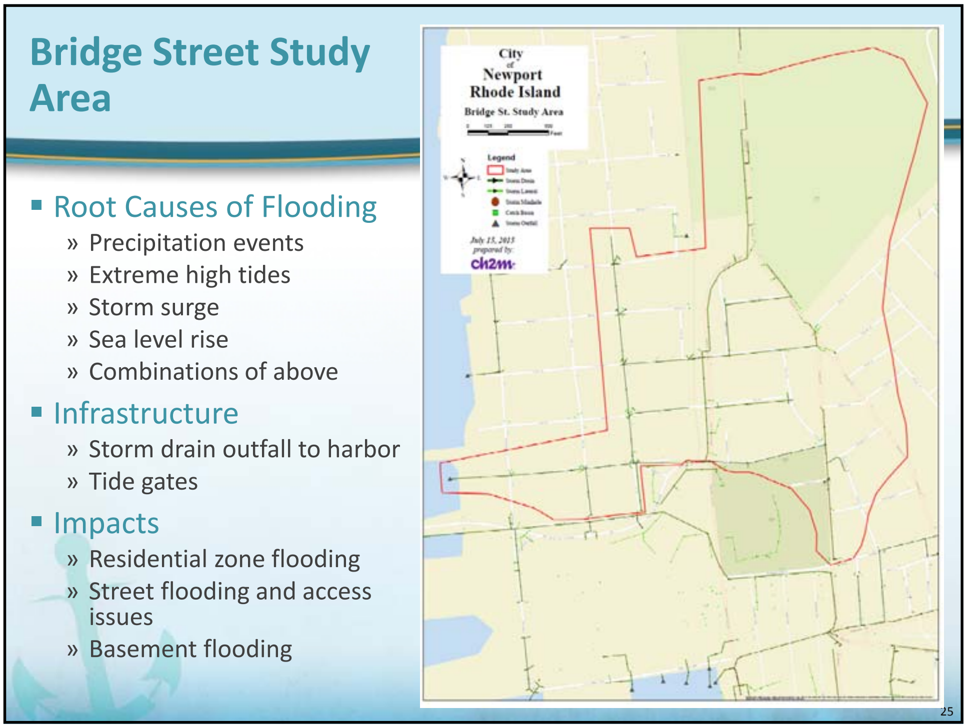
Wellington Avenue Study Area

7 total responses
as of July 15, 2015

Wellington Avenue Stakeholder Discussion

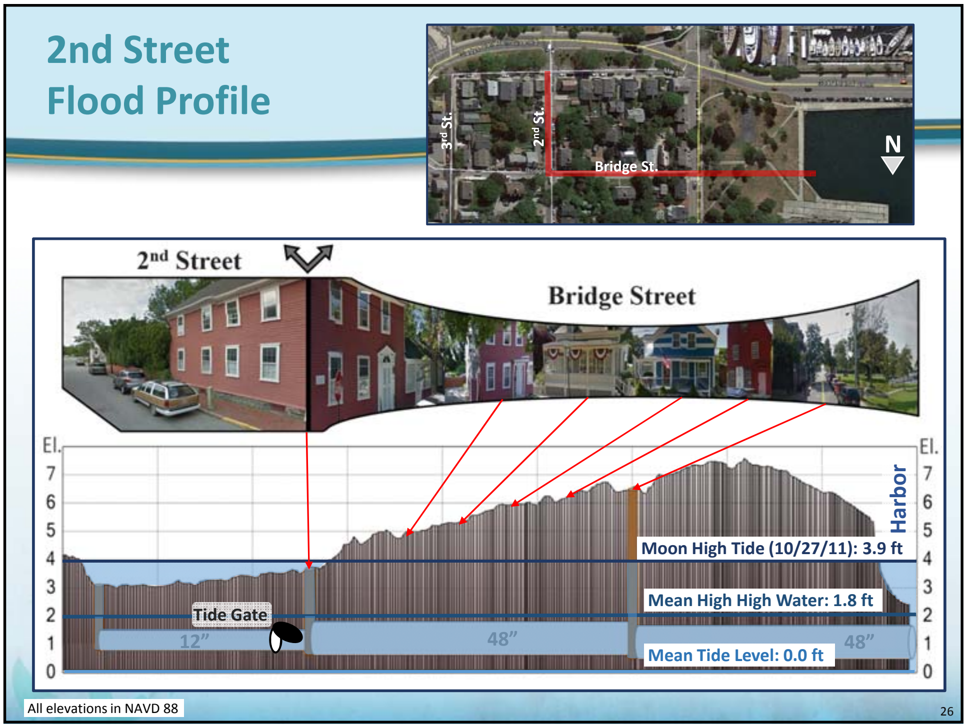
- Any key concerns not captured by the survey?
- Any additional dates of significant flooding to be used in study?
- Additional comments?

Bridge Street Study Area



Bridge Street Study Area

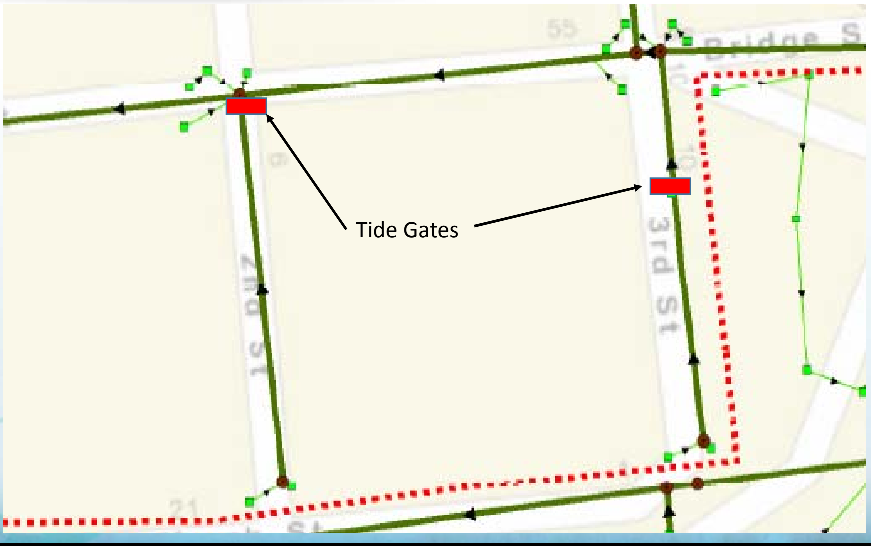
- Root Causes of Flooding
  - Precipitation events
  - Extreme high tides
  - Storm surge
  - Sea level rise
  - Combinations of above
- Infrastructure
  - Storm drain outfall to harbor
  - Tide gates
- Impacts
  - Residential zone flooding
  - Street flooding and access issues
  - Basement flooding



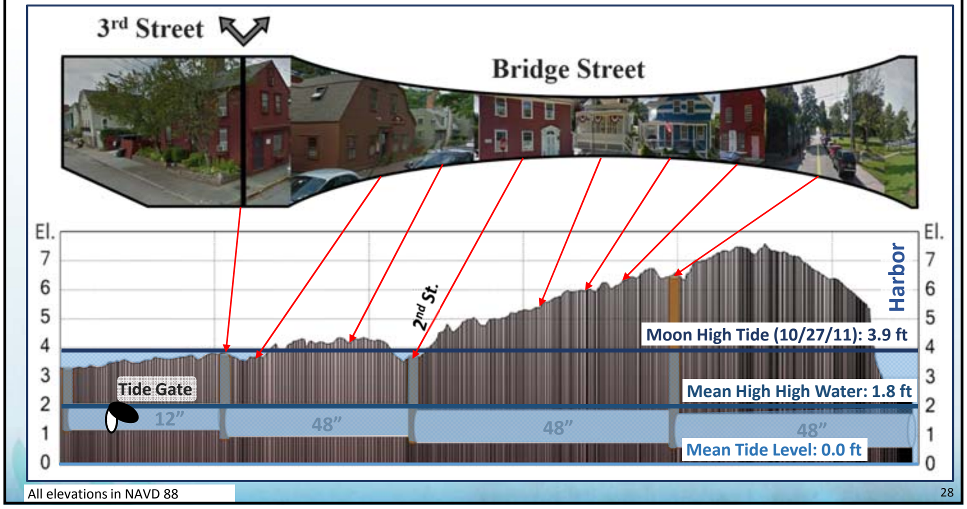
2nd Street Flood Profile

All elevations in NAVD 88

Close-up of 2nd St. Drainage System



3rd Street Flood Profile



All elevations in NAVD 88

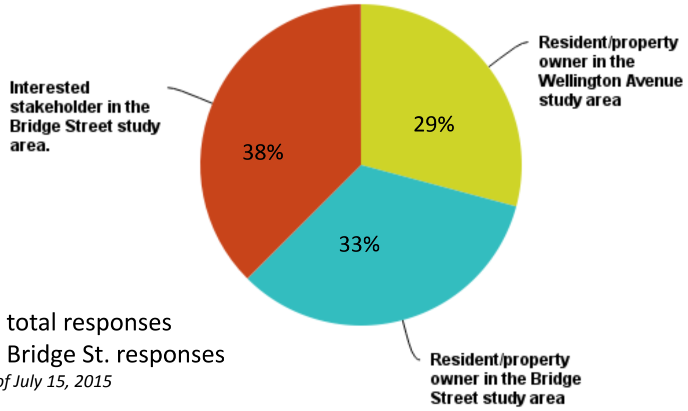
Recent Bridge Street Area Flooding

Intersection of Third Street and Marsh Street during Superstorm Sandy

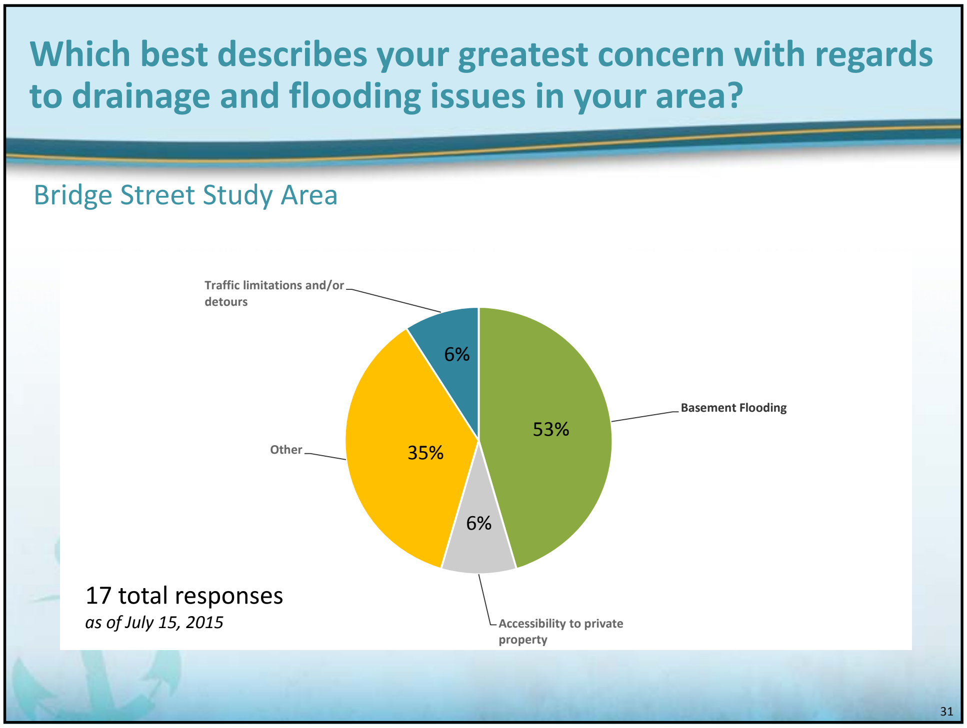
July 1, 2015 – Bridge Street between America’s Cup and Thames Street ~ 1 ¼” rainfall in 1 Hour coinciding with High Tide

Survey Results for Bridge Street

Q1: Which of the following best describes you?



24 total responses
17 Bridge St. responses
as of July 15, 2015

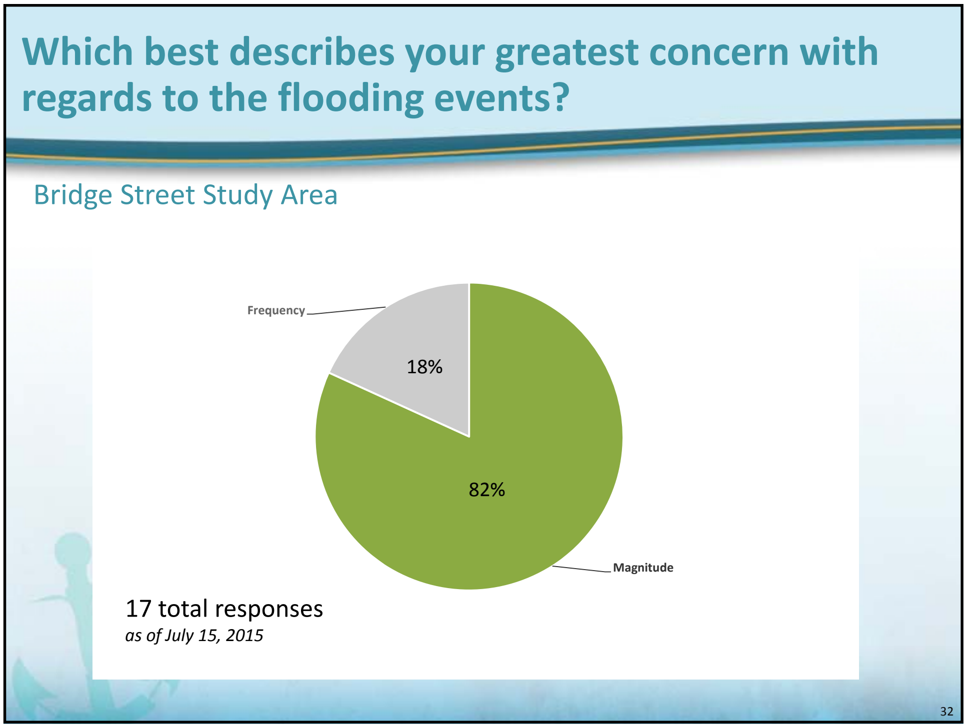


Which best describes your greatest concern with regards to drainage and flooding issues in your area?

Bridge Street Study Area

17 total responses

as of July 15, 2015



Which best describes your greatest concern with regards to the flooding events?

Bridge Street Study Area

17 total responses

as of July 15, 2015

Bridge Street Stakeholder Discussion

- Any key concerns not captured by the survey?
- Any additional dates of significant flooding to be used in study?
- Additional comments?

Next Steps

Next Steps for Both Study Areas

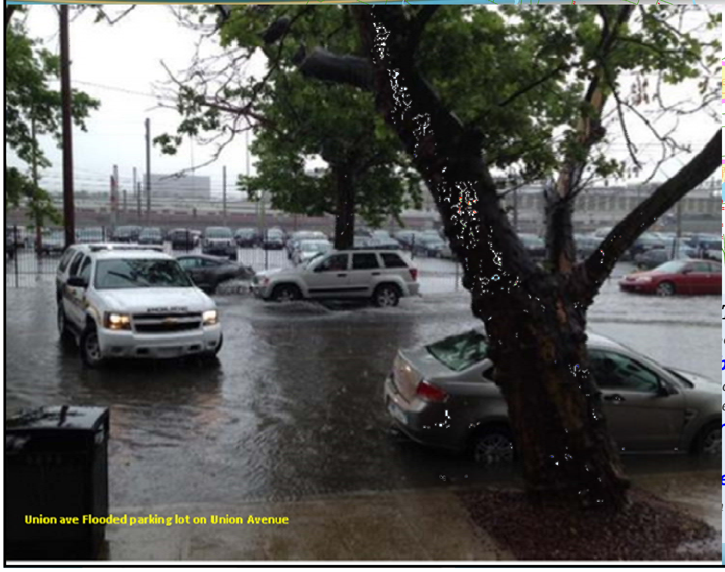
- Complete data collection
- Develop, calibrate and verify model
- Develop potential mitigation options
- Evaluate potential mitigation options using model
- Develop conceptual cost estimates
- Additional opportunities for stakeholder input and information
- Hold second public informational meeting in Fall 2015 to review modeling results and draft recommendations

Good data from the field makes for good models

- **Comprehensive Study** by developing hydrologic/hydraulic model of entire drainage basin
- **Efficient Model Development** by utilizing automation tool and LiDAR DEM
- **Accurate Simulation** by coupling pipe flow with 2D surface model

Case Study for New Haven, CT

Manhole Overflow / Street Ponding During June 13, 2014 Storm



Union ave Flooded parking lot on Union Avenue

TER

ortation said the ***Route 34***
bound Interstate 95 *was*
could be seen turning
e ramp.
reported on the
exits 46 and 45.
et South and Union
up to a foot of water in

Case Study for New Haven, CT

June 15, 2014. Union Ave. Flooding outside the New Haven Police Department on Union Ave.

Development of Mitigation Alternatives

Scenarios

- Flooding caused by normal tidal cycles
- Flooding caused by rainfall events
- Flooding caused by combinations of Sea Level Rise, storm surge, and rain events

Phased Implementation

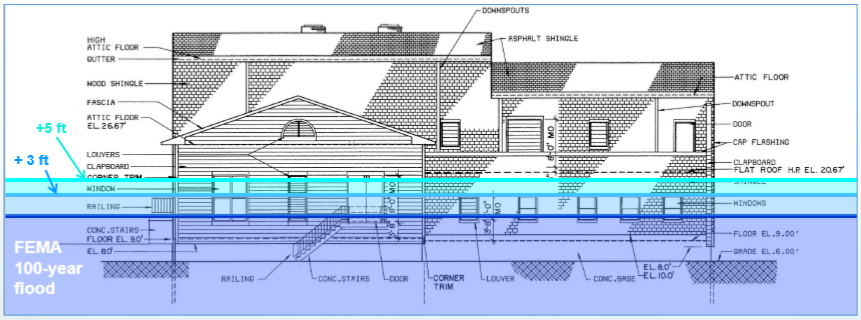
- Immediate actions
- Short-term - low cost
- Long-term mitigation and adaptation measures

Additional Opportunities for Stakeholder Involvement

- If you haven't already, please complete survey at: https://www.surveymonkey.com/s/NewportStudy
- Additional photos and information to Becky Weig at becky.weig@ch2m.com
- Updates posted to Engage Newport with link to Department of Utilities page on the City's website
  - This presentation
  - Updated survey results
  - More information as it becomes available
- Second public informational meeting in Fall 2015
- Thank you for the information provided so far!

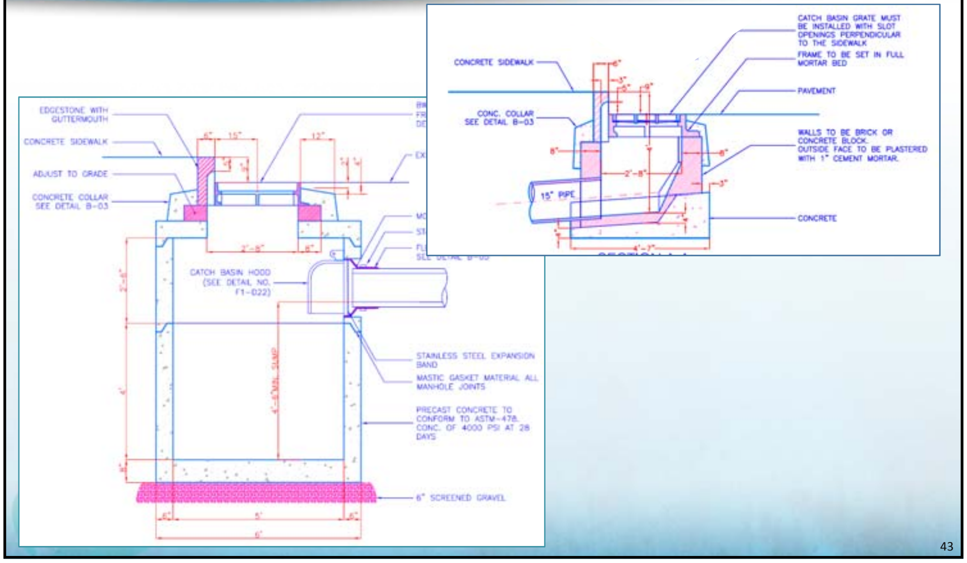
Wrap-Up & Summary

The City is Preparing Its Facilities for Changing Conditions

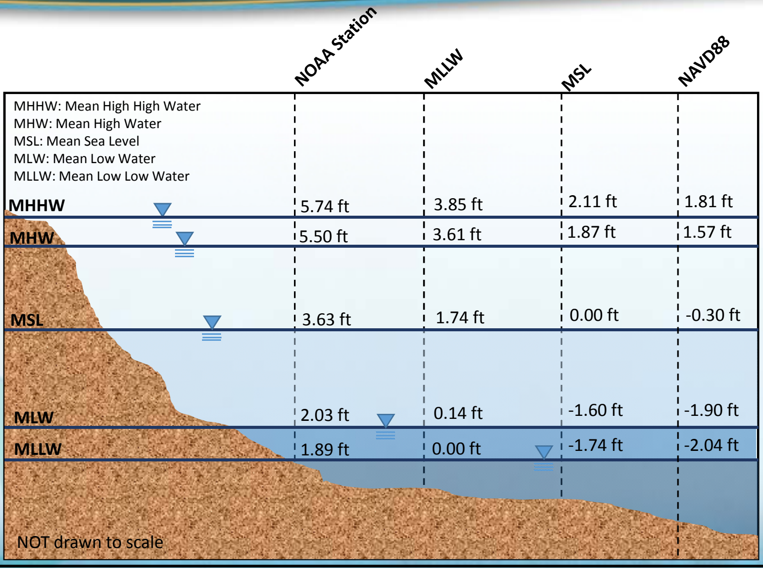


Design Flood Elevation = FEMA Zone AE, Base Flood Elev of 12 ft NAVD 88 + 1ft Freeboard + 1ft SLR = **14Ft NAVD 88**

Catch Basins with and without Sumps



Typical Datum Referenced for Newport Harbor

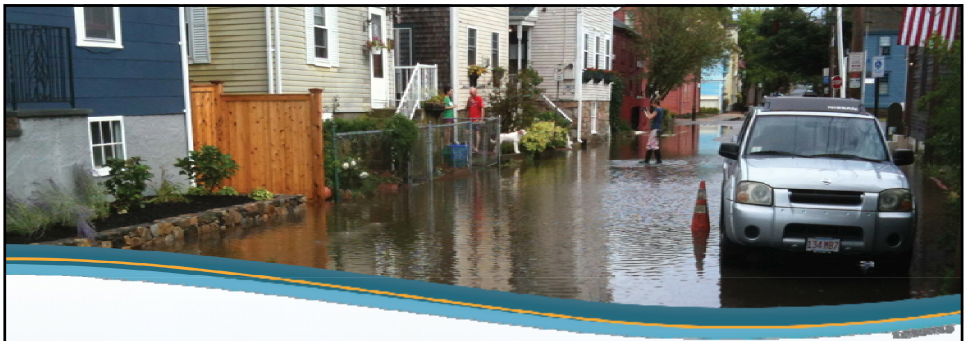


MHHW: Mean High High Water
MHW: Mean High Water
MSL: Mean Sea Level
MLW: Mean Low Water
MLLW: Mean Low Low Water

	NOAA Station	MLLW	MSL	NAVD88
MHHW	5.74 ft	3.85 ft	2.11 ft	1.81 ft
MHW	5.50 ft	3.61 ft	1.87 ft	1.57 ft
MSL	3.63 ft	1.74 ft	0.00 ft	-0.30 ft
MLW	2.03 ft	0.14 ft	-1.60 ft	-1.90 ft
MLLW	1.89 ft	0.00 ft	-1.74 ft	-2.04 ft

NOT drawn to scale

Appendix E
Public Meeting 2 Presentation



Drainage Investigation and Flood Analysis

Wellington Avenue and Bridge Street

Project No. 15-037

Please visit our project website at:
http://www.newportdrainageinvestigation.com/index.php

Public Informational Meeting #2

Mid-project Update

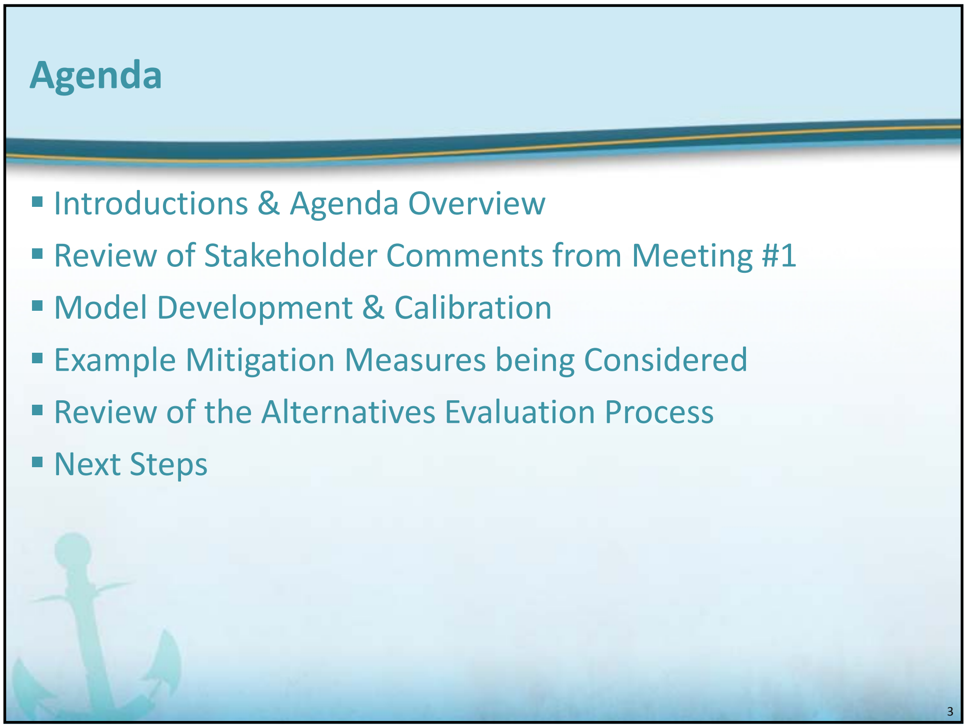
Presented by:

ch2m

September 17, 2015

Introductions

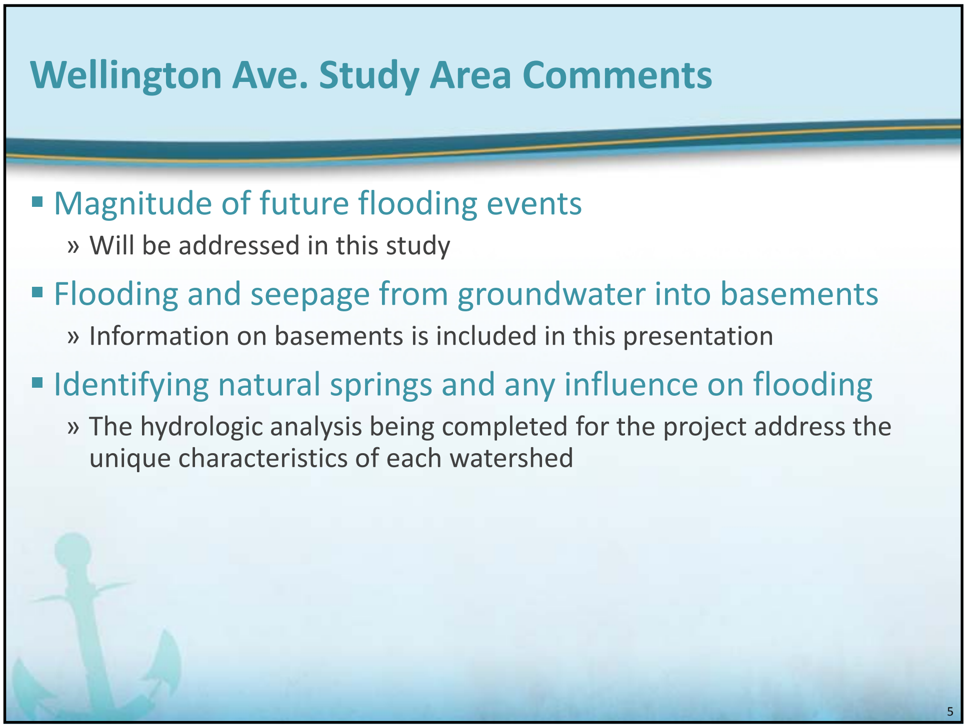
- City of Newport
    - » Julia Forgue, PE – Director of Utilities
    - » Rob Schultz, PE – Deputy Director of Engineering
    - » JR Frey, PE – Water Pollution Control
- CH2M
    - » Peter von Zweck, PE – Project Manager
    - » Becky Weig – Public Involvement
    - » Bill McMillin, PE – Senior Technologist, Climate Change & Sea Level Rise
    - » Greg Brenner – Hydraulic Modeling Engineer



Agenda

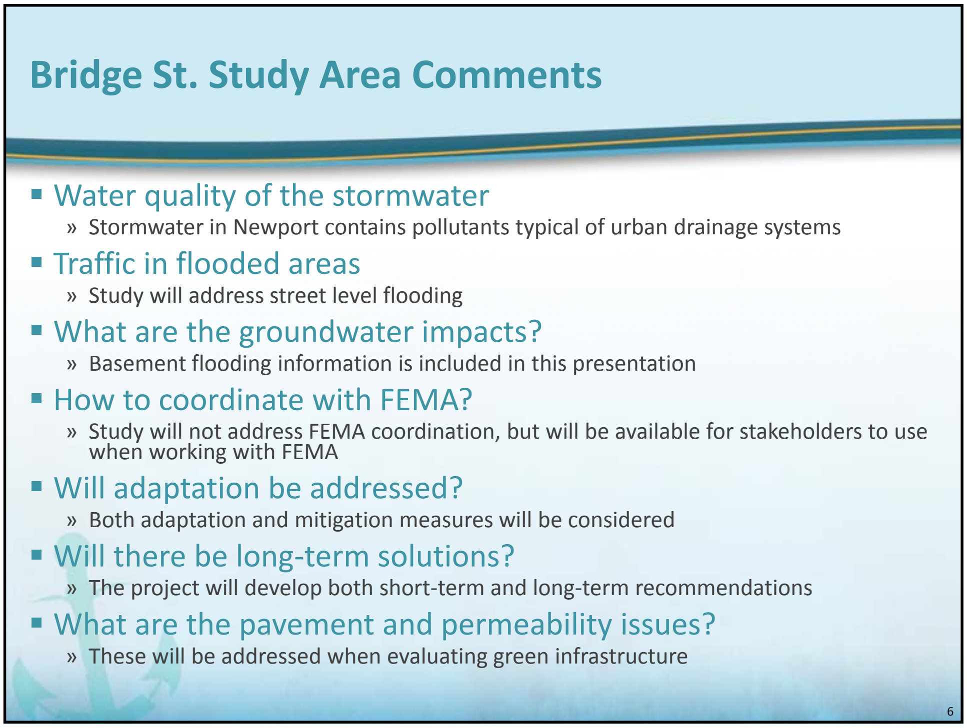
- Introductions & Agenda Overview
- Review of Stakeholder Comments from Meeting #1
- Model Development & Calibration
- Example Mitigation Measures being Considered
- Review of the Alternatives Evaluation Process
- Next Steps

Review of Stakeholder Comments from Meeting #1



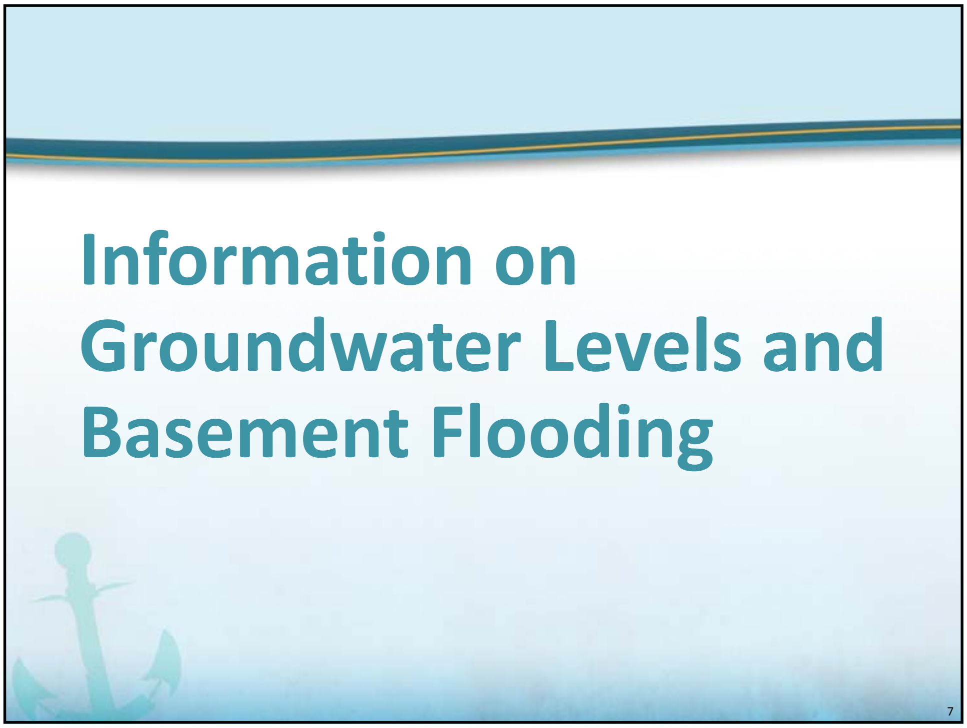
Wellington Ave. Study Area Comments

- Magnitude of future flooding events
  - » Will be addressed in this study
- Flooding and seepage from groundwater into basements
  - » Information on basements is included in this presentation
- Identifying natural springs and any influence on flooding
  - » The hydrologic analysis being completed for the project address the unique characteristics of each watershed

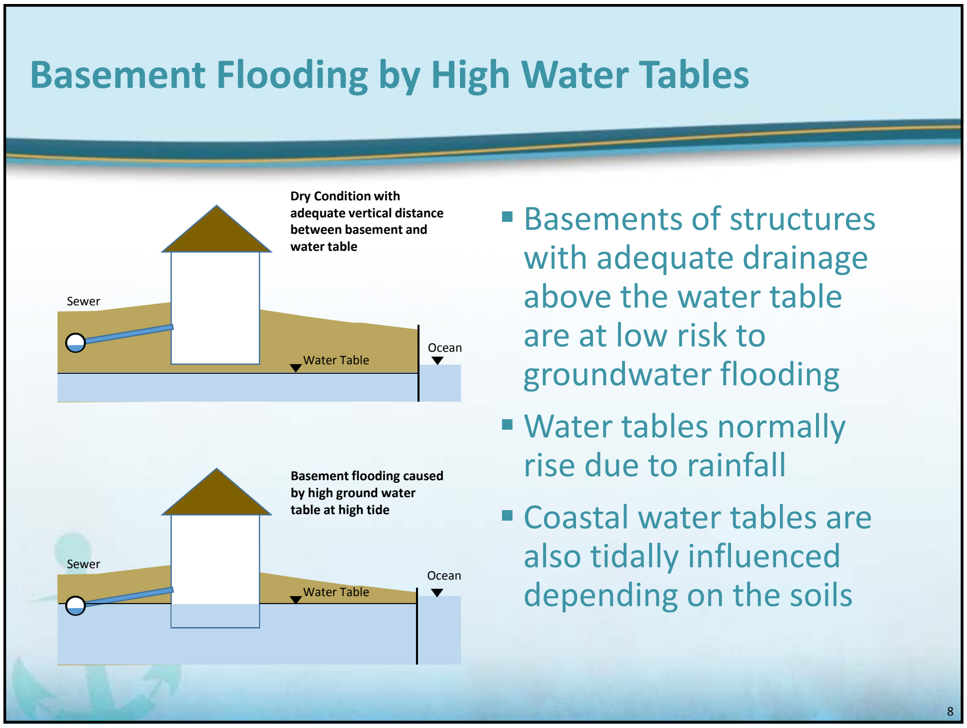


Bridge St. Study Area Comments

- Water quality of the stormwater
  - » Stormwater in Newport contains pollutants typical of urban drainage systems
- Traffic in flooded areas
  - » Study will address street level flooding
- What are the groundwater impacts?
  - » Basement flooding information is included in this presentation
- How to coordinate with FEMA?
  - » Study will not address FEMA coordination, but will be available for stakeholders to use when working with FEMA
- Will adaptation be addressed?
  - » Both adaptation and mitigation measures will be considered
- Will there be long-term solutions?
  - » The project will develop both short-term and long-term recommendations
- What are the pavement and permeability issues?
  - » These will be addressed when evaluating green infrastructure



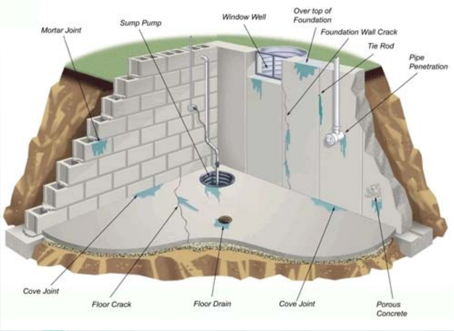
Information on Groundwater Levels and Basement Flooding



Basement Flooding by High Water Tables

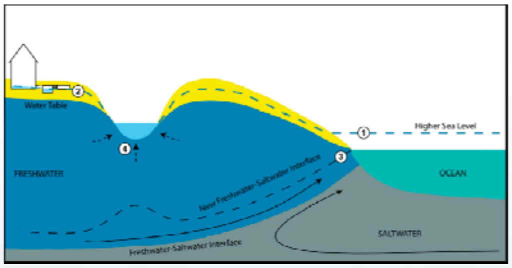
- Basements of structures with adequate drainage above the water table are at low risk to groundwater flooding
- Water tables normally rise due to rainfall
- Coastal water tables are also tidally influenced depending on the soils

Basements may Flood via Multiple Pathways



- Basement windows
- Cracks in walls and floors
- Porous concrete
- At pipe and utility penetrations
- Concrete seams
- Wall/floor
- Basement drains
- Failing drainage systems

Sea Level Rise will Worsen the Situation



- *A rise in sea-level will affect ground-water flow in coastal aquifers.*
- *An increase in the elevation of the water table (dashed–blue line) may result in basement flooding and compromise septic systems*
- *A rise in sea level may also result in an upward and landward shift in the position of the freshwater-saltwater interface*
- *Where streams are present, an increase in the water-table elevation also may increase ground-water discharge to streams and result in local changes in the underlying freshwater-saltwater interface.*

U.S. Geological Survey
http://wh.er.usgs.gov/slr/coastalgroundwater.html

Typical Measures for Preventing Basement Flooding

- Gutters and downspouts
  - drain storm water at least three feet away
  - consider running extensions or troughs
  - discharge to a splash pad
  - clean/clear gutters and downspouts regularly of leaves and debris
- Seal foundation cracks and gaps around pipes in basement walls and floors
- Sump Pumps
  - check to make sure its well is free of debris
  - position it in the lowest part of the basement
  - Pump to exterior ground surface NOT sanitary sewer system
- Basement window wells & covers
  - drain water away from at- or below-grade windows
  - fasten covers securely
- Landscape downslope away from house

Property owners are responsible for the implementation of structural and non-structural measures to prevent basement flooding.

Structural Systems to Prevent Basement Flooding

- Basement interior perimeter trough or edge drain to sump pump that pumps to exterior ground surface
- Drain tile system to sump pump
  - Around the house's exterior foundation
  - Below or interior of the foundation footings
  - Pump to exterior ground surface
- French drains outside the foundation
- Permanent concrete barriers constructed around basement entrances and windows

Model Development & Calibration

Field Investigation:

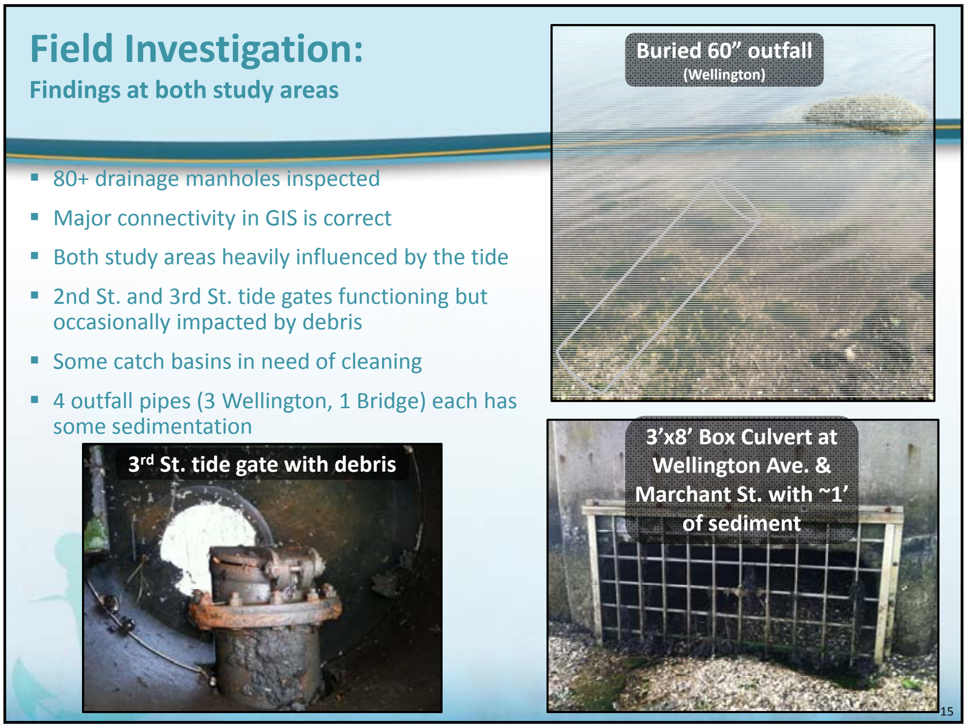
Objectives at both Study Areas

- Inspect Drainage Manholes
    - » Collect invert elevations
    - » Record pipe sizes
    - » Check pipe conditions/ sediment levels
    - » Check connectivity to neighboring systems
    - » Update GIS
- Observe High Tide Event
    - » Check tidal influence/tide gate effectiveness
    - » Record water stage for model calibration


Catch Basin in King Park at High Tide


Manhole at intersection of Thames and Webster St.


2nd St. Tide gate



Field Investigation:

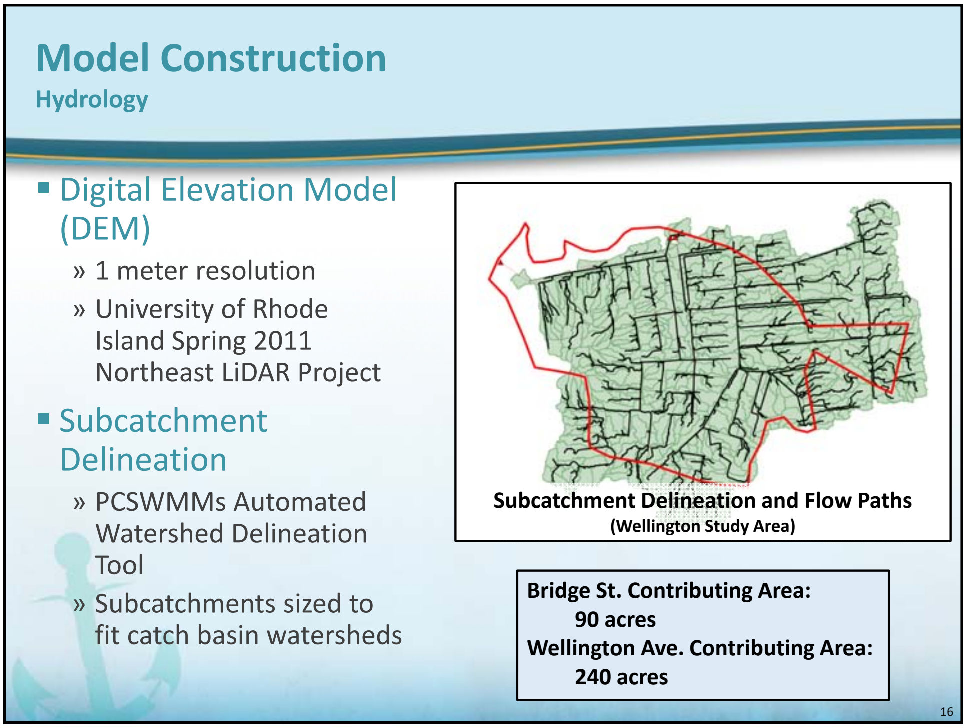
Findings at both study areas

- 80+ drainage manholes inspected
- Major connectivity in GIS is correct
- Both study areas heavily influenced by the tide
- 2nd St. and 3rd St. tide gates functioning but occasionally impacted by debris
- Some catch basins in need of cleaning
- 4 outfall pipes (3 Wellington, 1 Bridge) each has some sedimentation

Buried 60" outfall (Wellington)

3rd St. tide gate with debris

3'x8' Box Culvert at Wellington Ave. & Marchant St. with ~1' of sediment



Model Construction

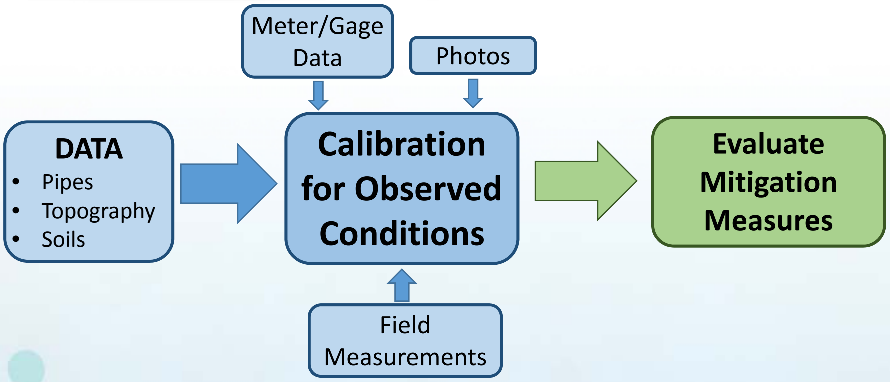
Hydrology

- Digital Elevation Model (DEM)
  - » 1 meter resolution
  - » University of Rhode Island Spring 2011 Northeast LiDAR Project
- Subcatchment Delineation
  - » PCSWMMs Automated Watershed Delineation Tool
  - » Subcatchments sized to fit catch basin watersheds

Subcatchment Delineation and Flow Paths (Wellington Study Area)

Bridge St. Contributing Area:
90 acres
Wellington Ave. Contributing Area:
240 acres

Model Calibration



DATA
- Pipes
- Topography
- Soils

Meter/Gage Data

Photos

Calibration for Observed Conditions

Field Measurements

Evaluate Mitigation Measures

Calibration is the fine-tuning of parameters to increase the models **accuracy** in reflecting observed events.

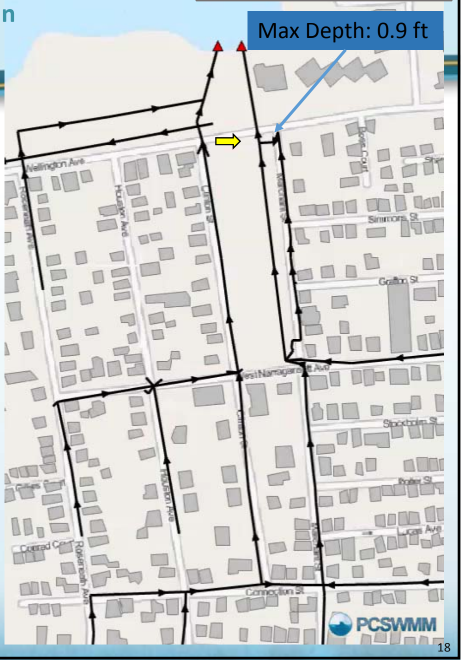
CALIBRATION: Wellington Ave.

10/7/2010 Lunar High Tide of 5.8 ft - No rain

Vertical Datum:
Mean Low Low Water (MLLW)

High Tide ±1 hour

High Tide

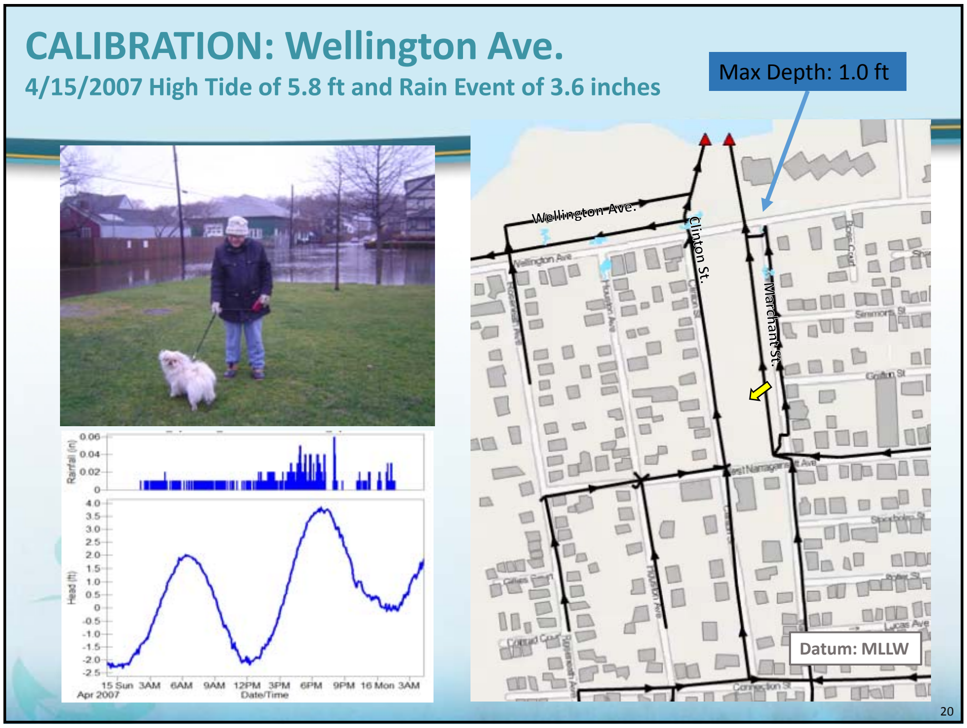


Max Depth: 0.9 ft

CALIBRATION: Wellington Ave.

9/1/2015 High Tide of 5.0 ft - No rain

Datum: MLLW



CALIBRATION: Wellington Ave.

4/15/2007 High Tide of 5.8 ft and Rain Event of 3.6 inches

Max Depth: 1.0 ft

Datum: MLLW

CALIBRATION: Bridge St.

10/27/2011 Lunar High Tide of 5.9 ft - No rain
Prior to installation of tide gates on 2nd and 3rd Streets

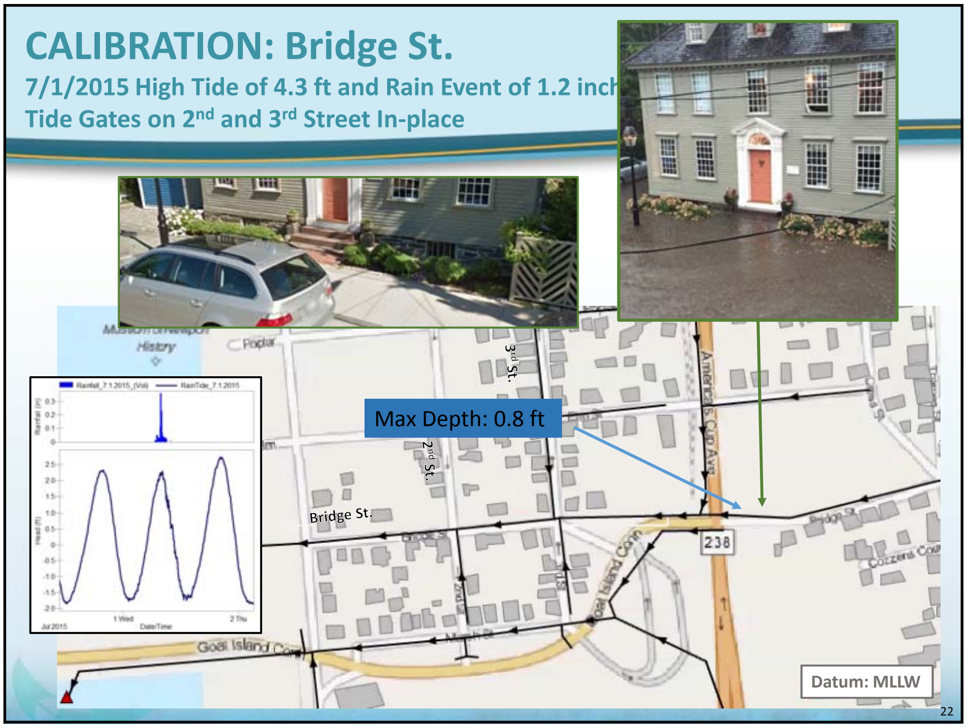
High Tide

High Tide ±1 hour

Max Depth: 0.9ft

Datum: MLLW

21



CALIBRATION: Bridge St.

7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 inch
Tide Gates on 2nd and 3rd Street In-place

Max Depth: 0.8 ft

Datum: MLLW

22

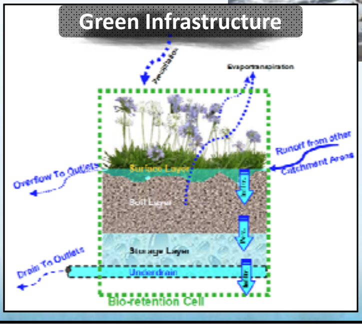
Examples of Mitigation Measures being Considered

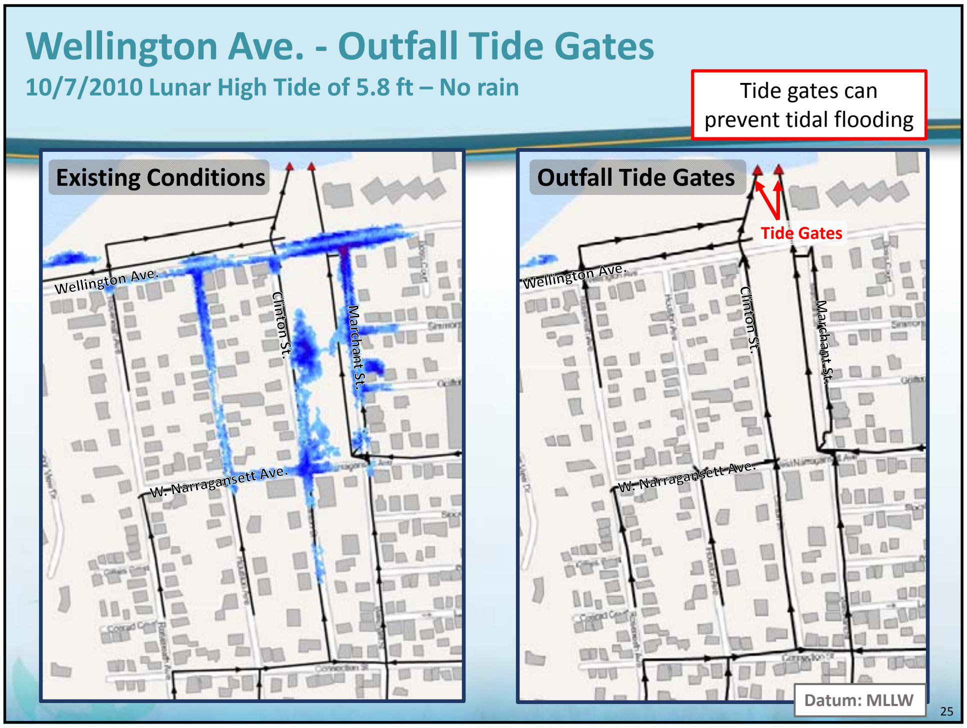
Example Mitigation Measures

- Tide Gates
  - Prevent sunshine flooding
  - May prolong rain event flooding
  - Many types
- Larger Pipes
  - Increased conveyance
  - Space constraints with other utilities (gas, water, etc.)
- Catch Basin Sumps
  - Collect debris in manhole to avoid clogging pipes
- Green Infrastructure
  - Provides storage
  - Can increase basement flooding
- Pump Station
  - Complete solution
  - Expensive, large facility


Wellington Ave. PS


Tide gates

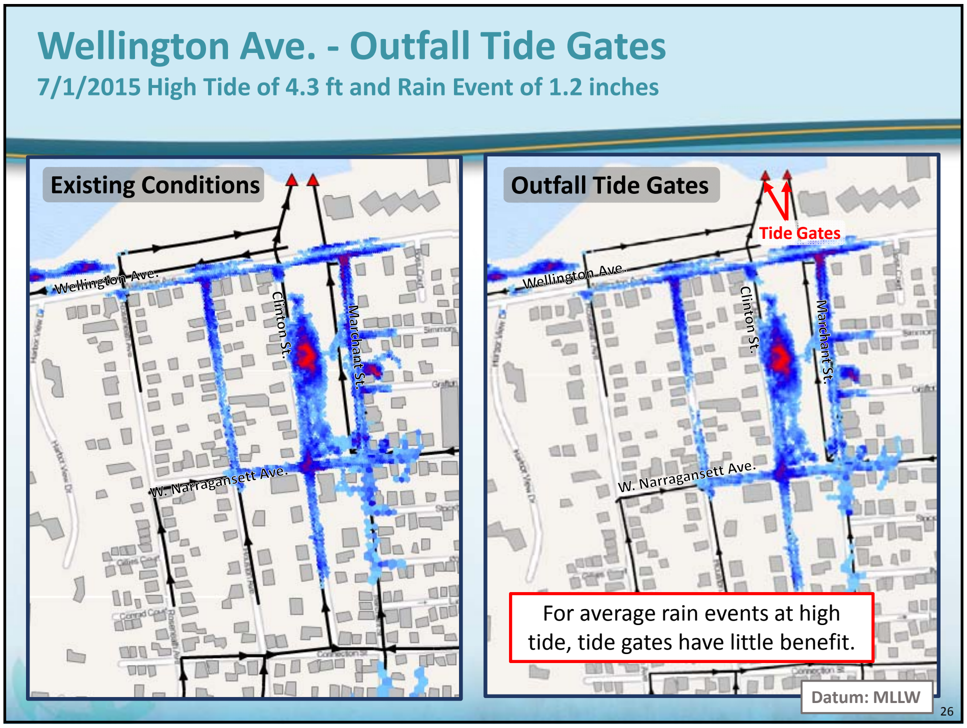

Green Infrastructure



Wellington Ave. - Outfall Tide Gates

10/7/2010 Lunar High Tide of 5.8 ft – No rain

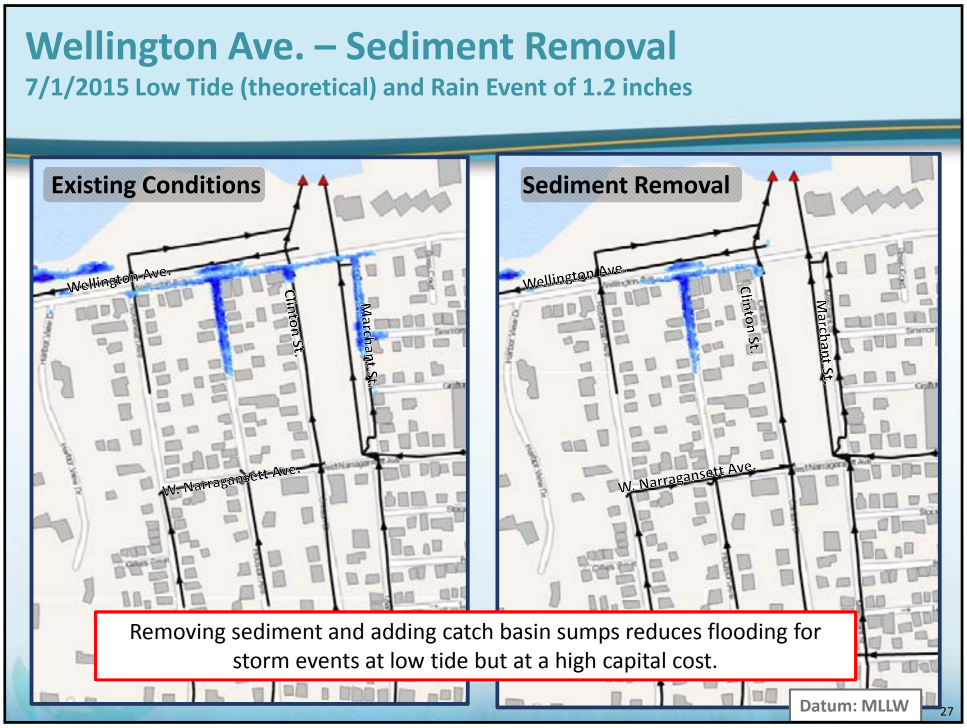
Tide gates can prevent tidal flooding



Wellington Ave. - Outfall Tide Gates

7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 inches

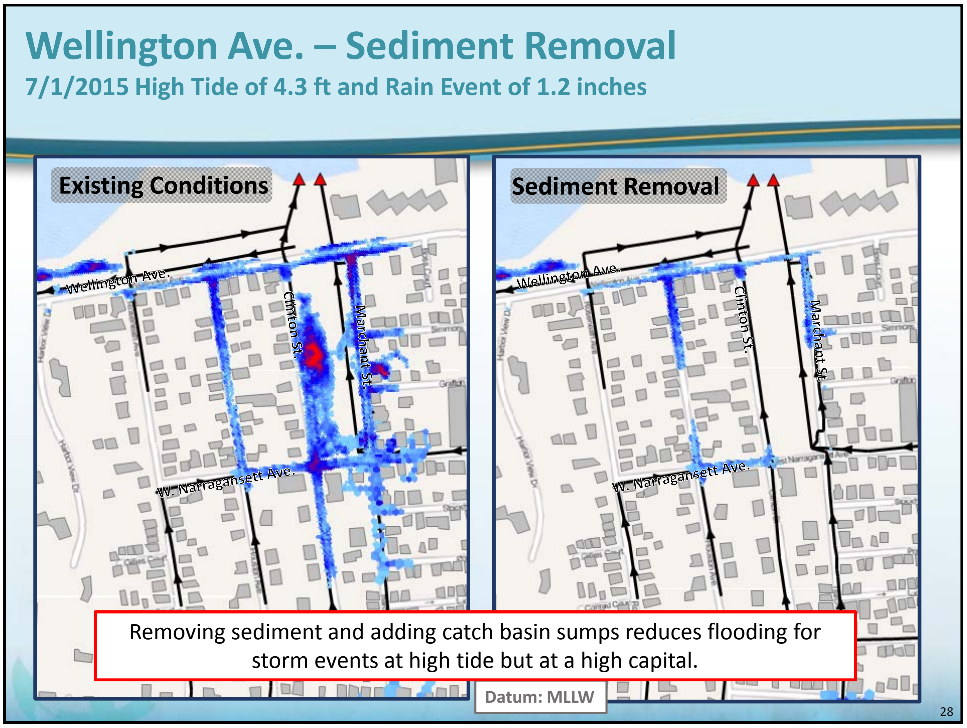
For average rain events at high tide, tide gates have little benefit.



Wellington Ave. – Sediment Removal

7/1/2015 Low Tide (theoretical) and Rain Event of 1.2 inches

Removing sediment and adding catch basin sumps reduces flooding for storm events at low tide but at a high capital cost.



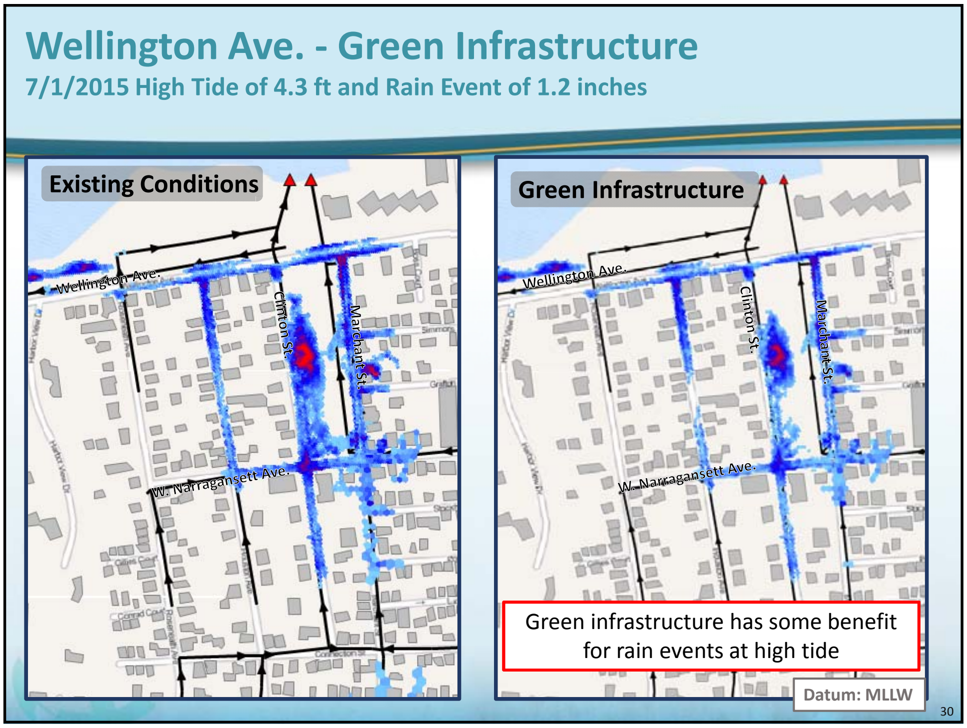
Wellington Ave. – Sediment Removal

7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 inches

Removing sediment and adding catch basin sumps reduces flooding for storm events at high tide but at a high capital.

Wellington Ave. – Green Infrastructure

- Modeled Assumptions
  - » Capture 15% of runoff primarily through infiltration
  - » Only applied in areas at low risk for basement flooding
- Available Options
  - » Permeable Pavement
  - » Bio-Retention Cells
  - » Rain Garden
  - » Green Roof
  - » Rain Barrels



Wellington Ave. - Green Infrastructure

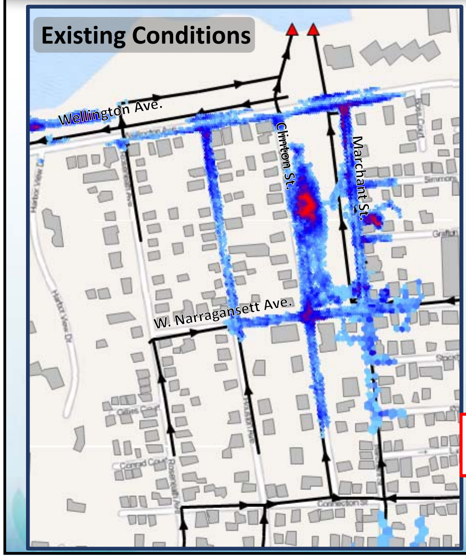
7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 inches

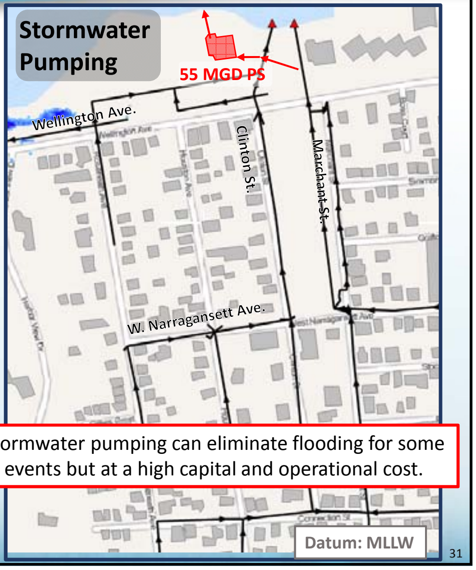
Green infrastructure has some benefit for rain events at high tide

Datum: MLLW

Wellington Ave. – Stormwater Pumping

7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 in





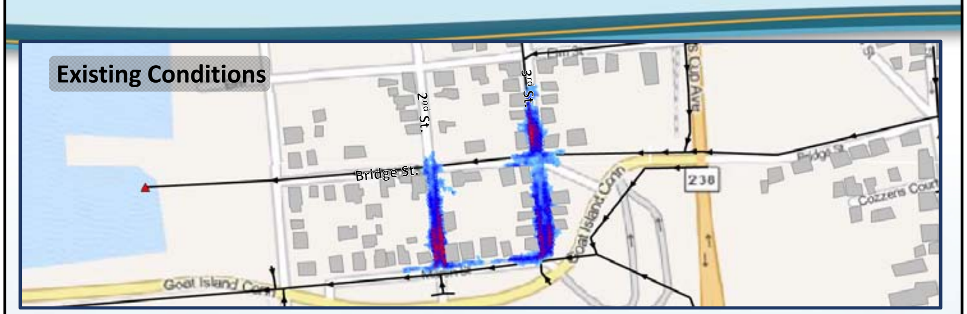
Stormwater pumping can eliminate flooding for some events but at a high capital and operational cost.

Wellington Ave. Mitigation Measures Discussion

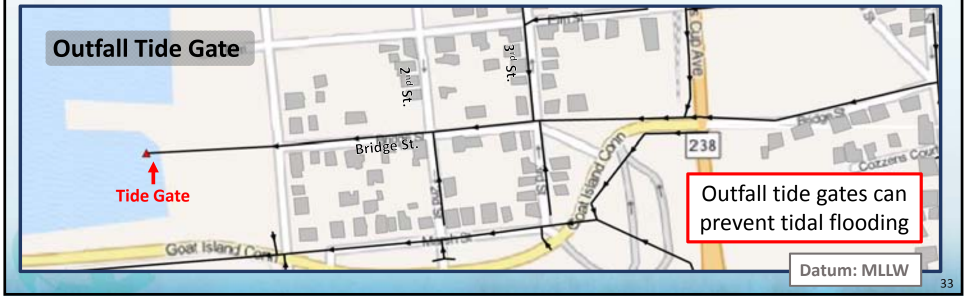
Bridge St. - Outfall Tide Gate

10/27/2011 Lunar High Tide 5.9 ft – No tide gates at 2nd St. & 3rd Streets

Existing Conditions



Outfall Tide Gate



Outfall tide gates can prevent tidal flooding

Datum: MLLW

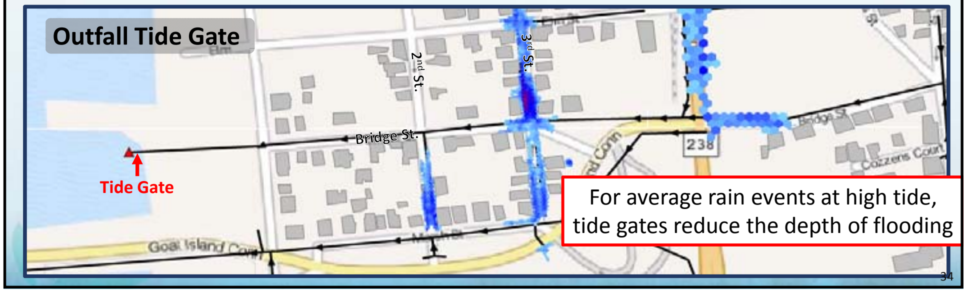
Bridge St. Outfall Tide Gate

7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 inches

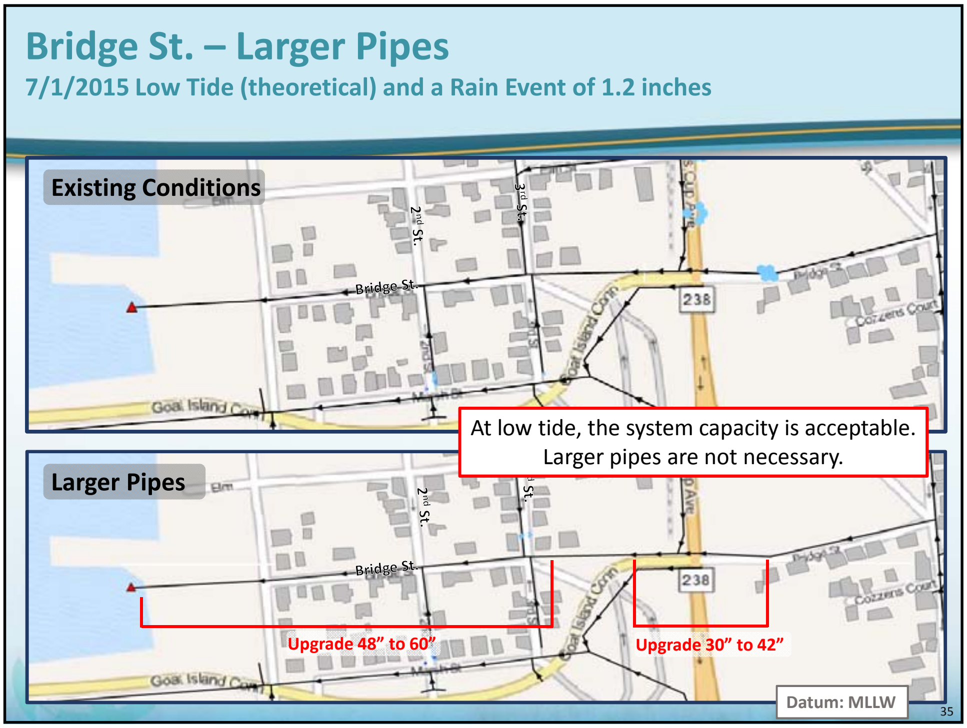
Existing Conditions

Datum: MLLW

Outfall Tide Gate



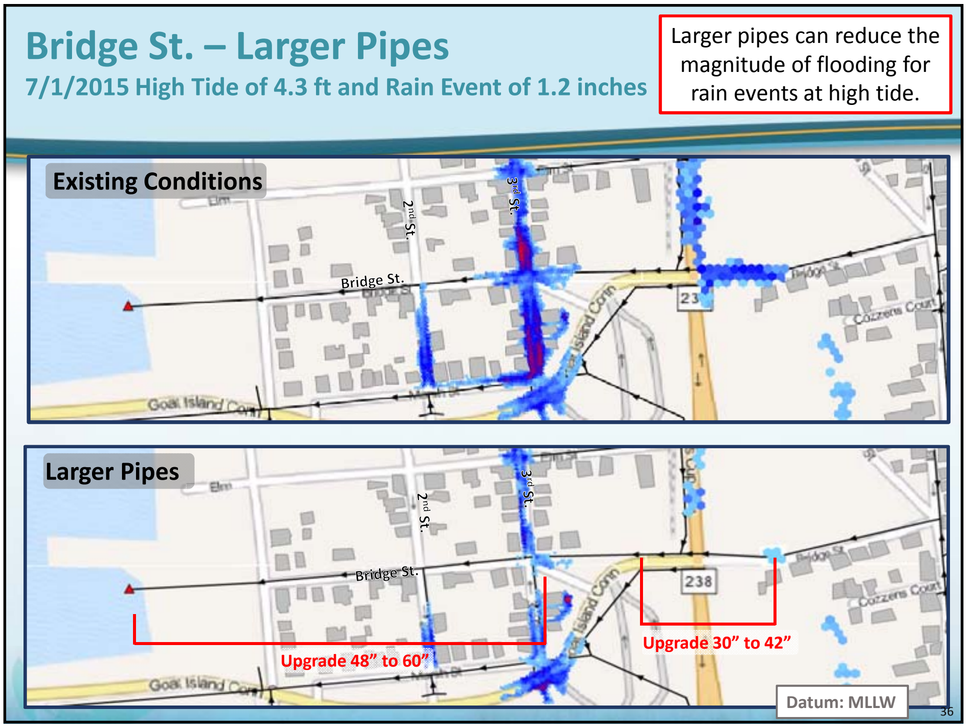
For average rain events at high tide, tide gates reduce the depth of flooding



Bridge St. – Larger Pipes

7/1/2015 Low Tide (theoretical) and a Rain Event of 1.2 inches

At low tide, the system capacity is acceptable. Larger pipes are not necessary.



Bridge St. – Larger Pipes

7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 inches

Larger pipes can reduce the magnitude of flooding for rain events at high tide.

Bridge St. – Green Infrastructure

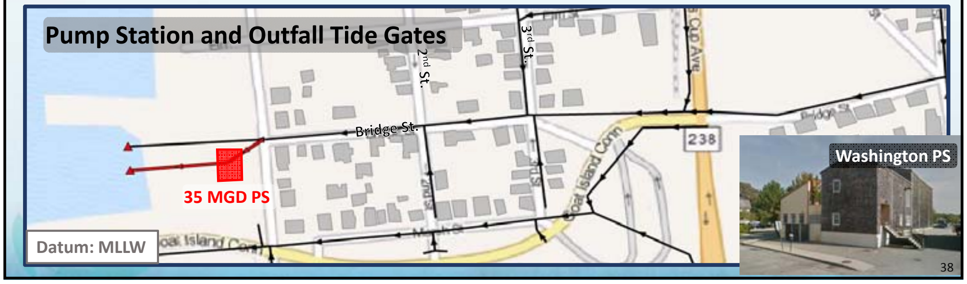
7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 inches

For rain events at high tide green infrastructure provides a small benefit.

Bridge St. – Stormwater Pumping

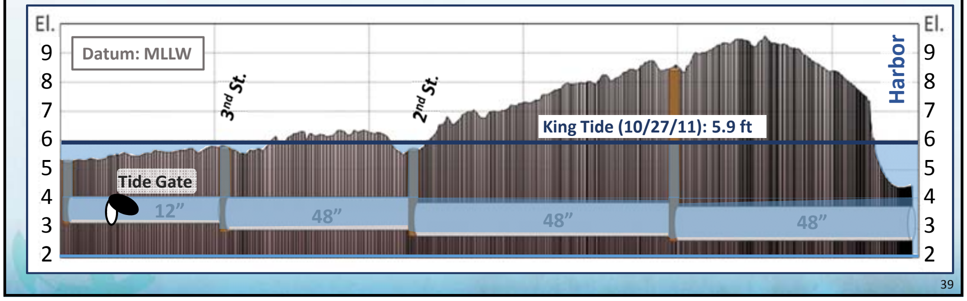
7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 inches

Stormwater pumping can eliminate flooding for some events but at a high capital and operational cost.

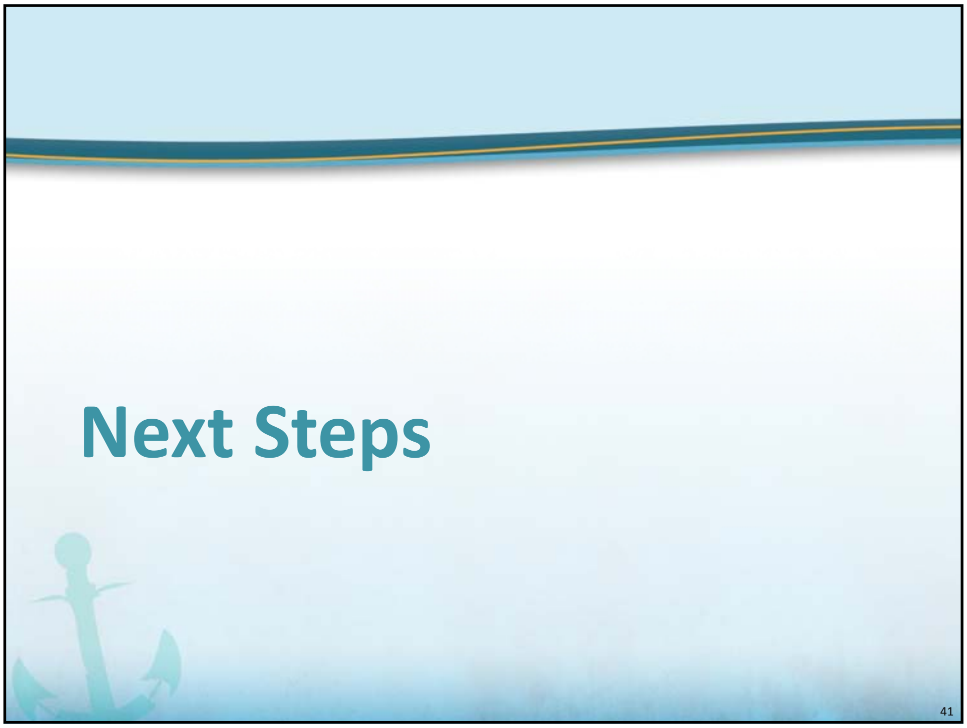


Bridge Street – Flood Protection Levees

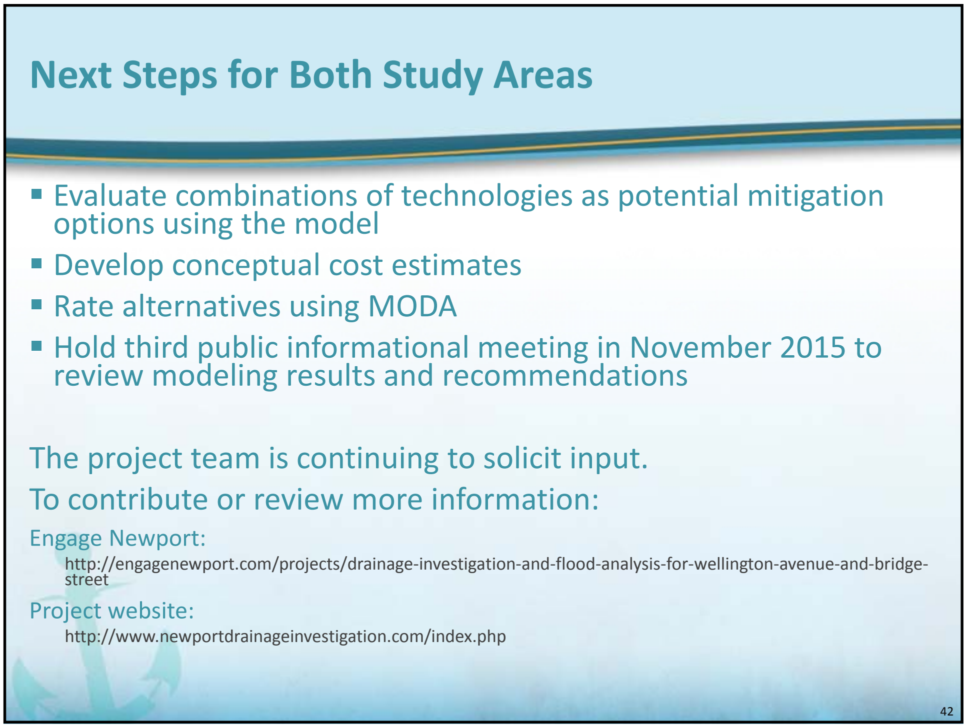
- Levees are tall embankments designed to block overland flow from a water body
- At Bridge Street a natural Levee already exists
- Most flooding issues are caused by backwater from tides



Bridge St. Mitigation Measures Discussion



Next Steps



Next Steps for Both Study Areas

- Evaluate combinations of technologies as potential mitigation options using the model
- Develop conceptual cost estimates
- Rate alternatives using MODA
- Hold third public informational meeting in November 2015 to review modeling results and recommendations

The project team is continuing to solicit input.

To contribute or review more information:

Engage Newport:

http://engagenewport.com/projects/drainage-investigation-and-flood-analysis-for-wellington-avenue-and-bridge-street

Project website:

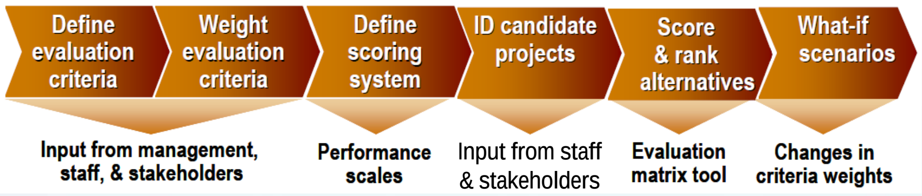
http://www.newportdrainageinvestigation.com/index.php

Determining the Best Recommendation Requires Consideration of Many Factors

- Combinations of mitigation measures
- Performance
  - Depth of flooding
  - Extent of flooding
  - Duration of flooding
- Cost considerations
- Operability of system
- Impacts to community & residents

- Utilizing multi-objective decision analysis (MODA) allows for evaluation of all factors

Multi Objective Decision Analysis



Define evaluation criteria

Weight evaluation criteria

Define scoring system

ID candidate projects

Score & rank alternatives

What-if scenarios

Input from management, staff, & stakeholders

Performance scales

Input from staff & stakeholders

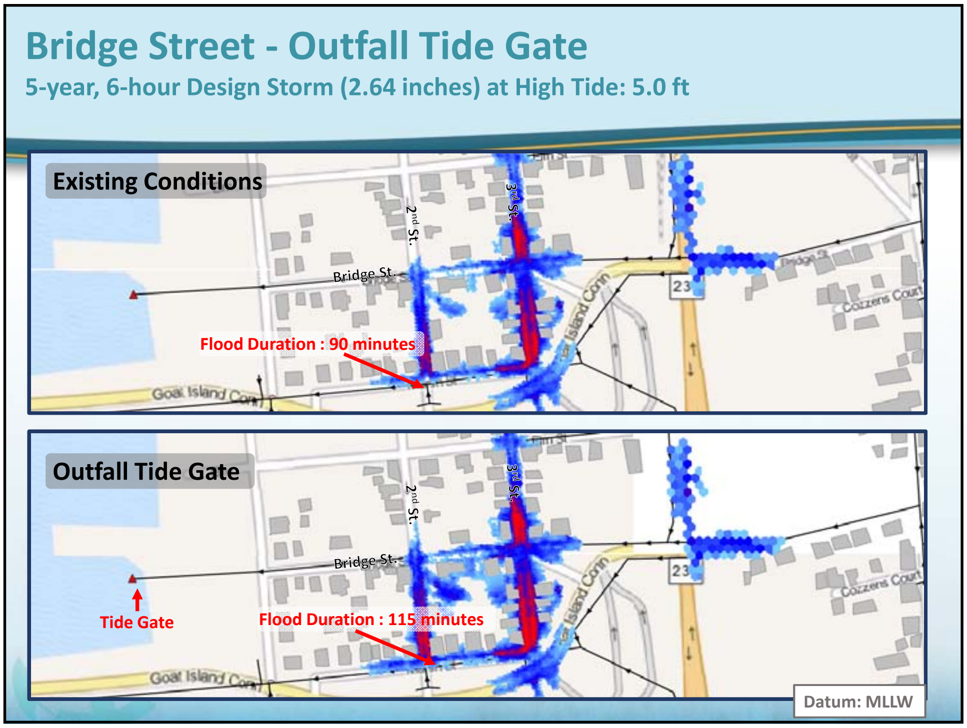
Evaluation matrix tool

Changes in criteria weights

Thank You

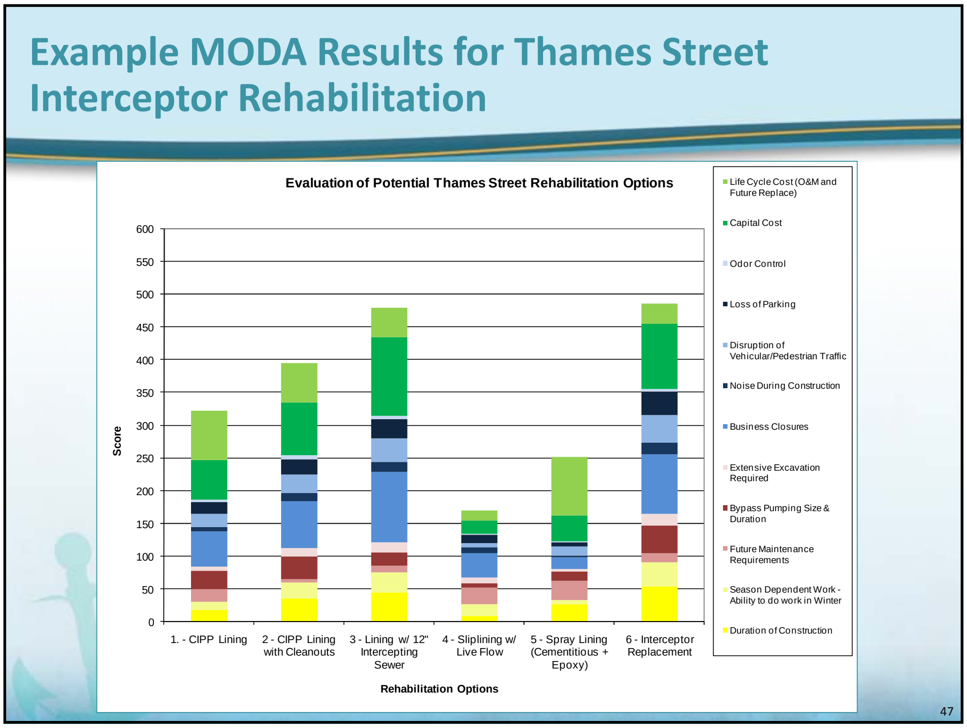
Please visit our project website at:

http://www.newportdrainageinvestigation.com/index.php

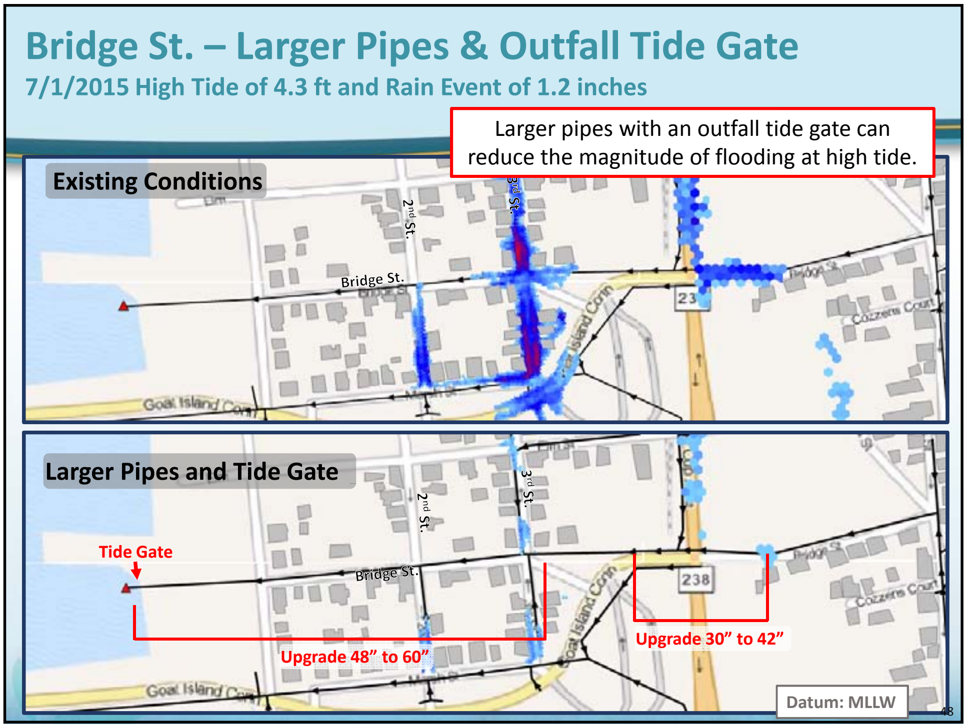


Bridge Street - Outfall Tide Gate

5-year, 6-hour Design Storm (2.64 inches) at High Tide: 5.0 ft



Example MODA Results for Thames Street Interceptor Rehabilitation



Bridge St. – Larger Pipes & Outfall Tide Gate

7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 inches

Larger pipes with an outfall tide gate can reduce the magnitude of flooding at high tide.

Existing Conditions

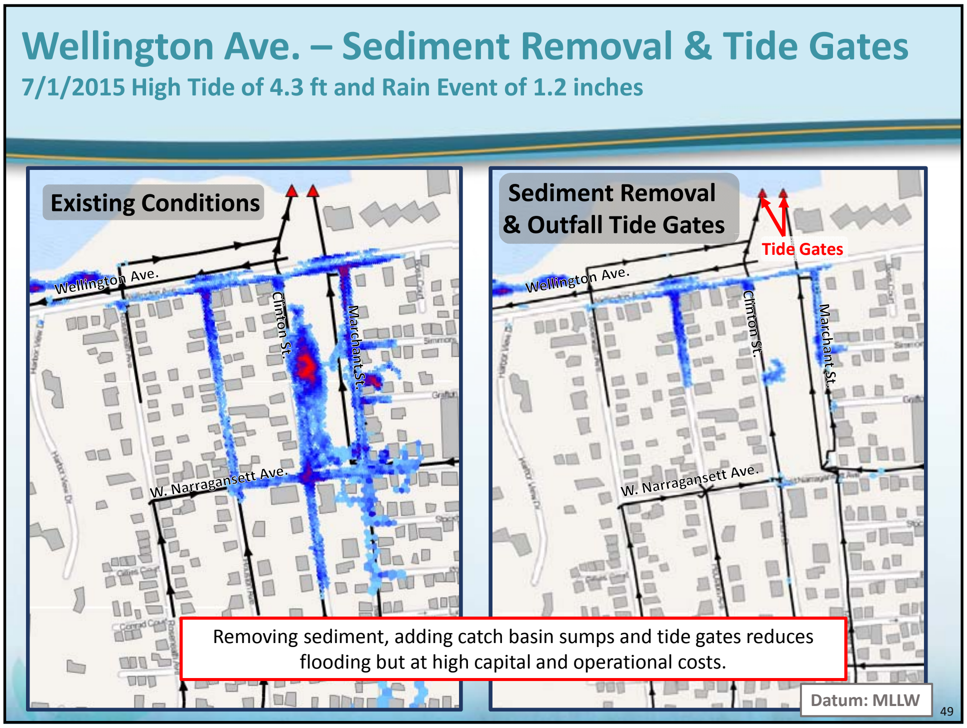
Larger Pipes and Tide Gate

Tide Gate

Upgrade 48" to 60"

Upgrade 30" to 42"

Datum: MLLW



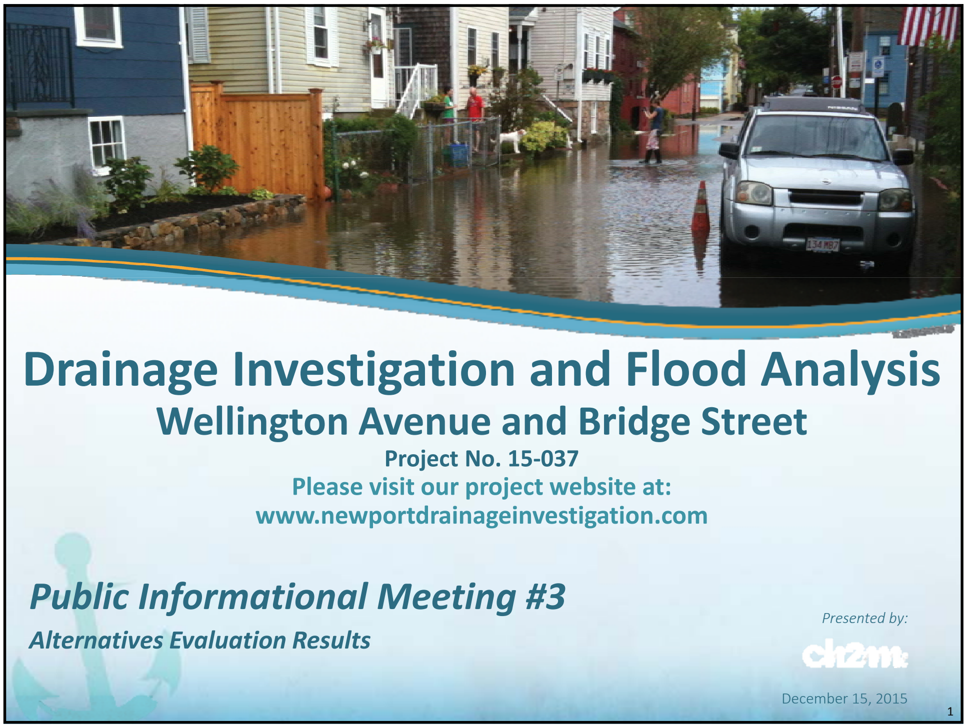
Wellington Ave. – Sediment Removal & Tide Gates

7/1/2015 High Tide of 4.3 ft and Rain Event of 1.2 inches

Removing sediment, adding catch basin sumps and tide gates reduces flooding but at high capital and operational costs.

Datum: MLLW

Appendix F
Public Meeting 3 Presentation



Drainage Investigation and Flood Analysis

Wellington Avenue and Bridge Street

Project No. 15-037

Please visit our project website at:
www.newportdrainageinvestigation.com

Public Informational Meeting #3

Alternatives Evaluation Results

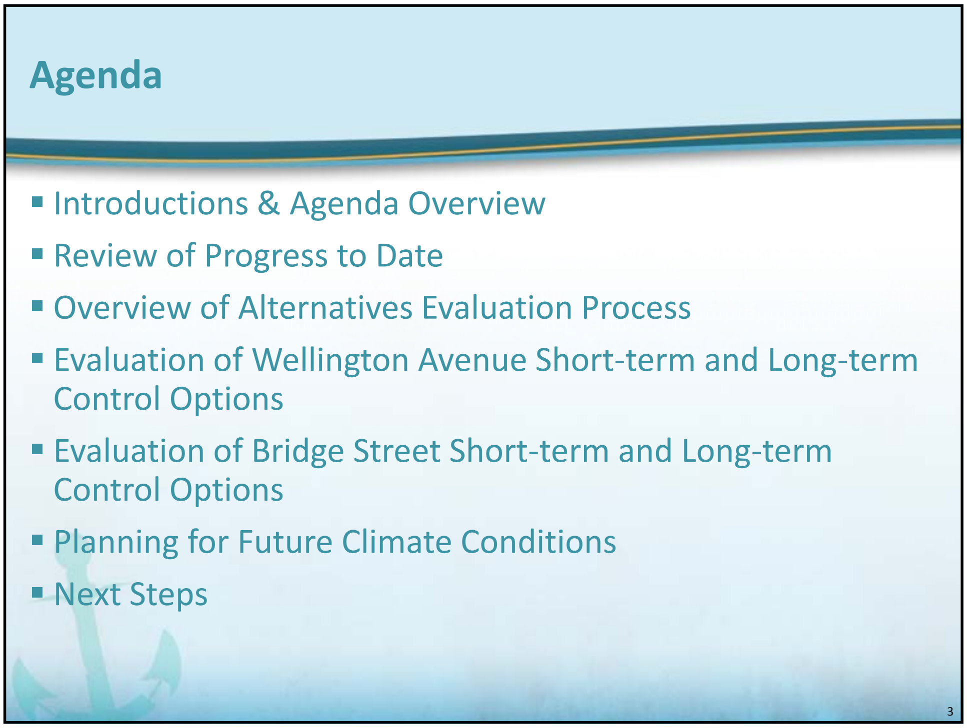
Presented by:

ch2m:

December 15, 2015

Introductions

- City of Newport
  - » Julia Forgue, PE – Director of Utilities
  - » Rob Schultz, PE – Deputy Director of Engineering
  - » JR Frey, PE – Water Pollution Control
- CH2M
  - » Peter von Zweck, PE – Project Manager
  - » Becky Weig – Public Involvement
  - » Bill McMillin, PE – Senior Technologist, Climate Change & Sea Level Rise
  - » Greg Brenner – Hydraulic Modeling Engineer



Agenda

- Introductions & Agenda Overview
- Review of Progress to Date
- Overview of Alternatives Evaluation Process
- Evaluation of Wellington Avenue Short-term and Long-term Control Options
- Evaluation of Bridge Street Short-term and Long-term Control Options
- Planning for Future Climate Conditions
- Next Steps

Review of Progress to Date

Project Background

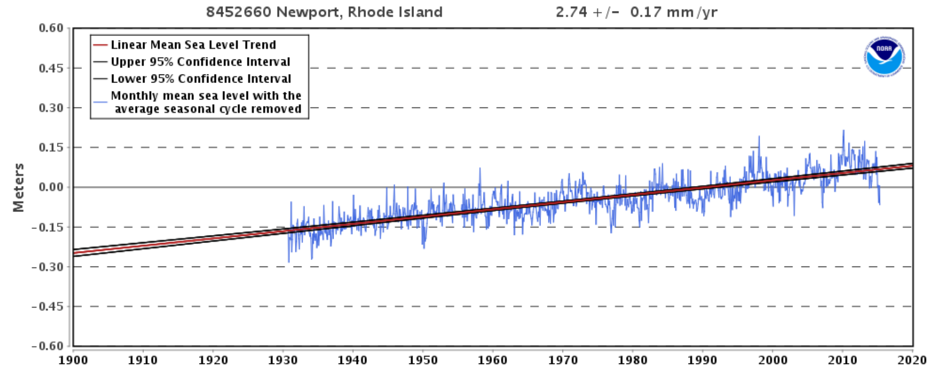
- Historical tidal or “sunshine” flooding
- Precipitation events coinciding with high tide create a compound problem
- Previous measures not 100% effective – example, tide gates at 2nd & 3rd Streets installed in November 2011
- Sea level rise and more intense and frequent storms are already being experienced….there is more projected to come

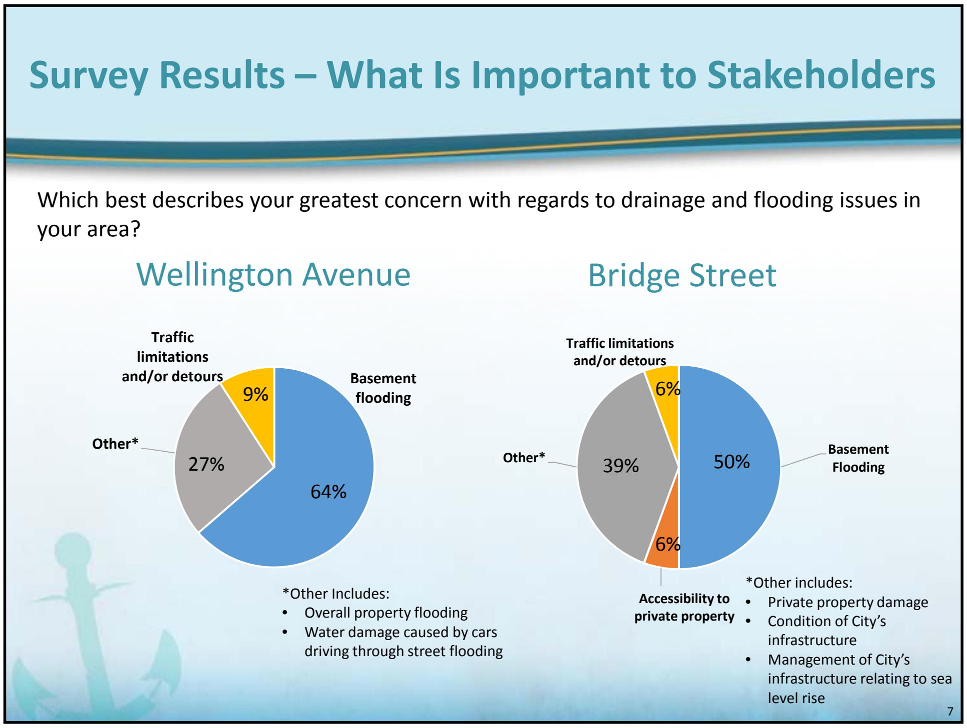
Tidal flooding at Wellington Avenue in 2011

Tidal flooding compounded by precipitation along 2nd Street in 2011

Water Levels Are Rising in Newport

Historic sea level rise is 0.1 inch/year





Survey Results – What Is Important to Stakeholders

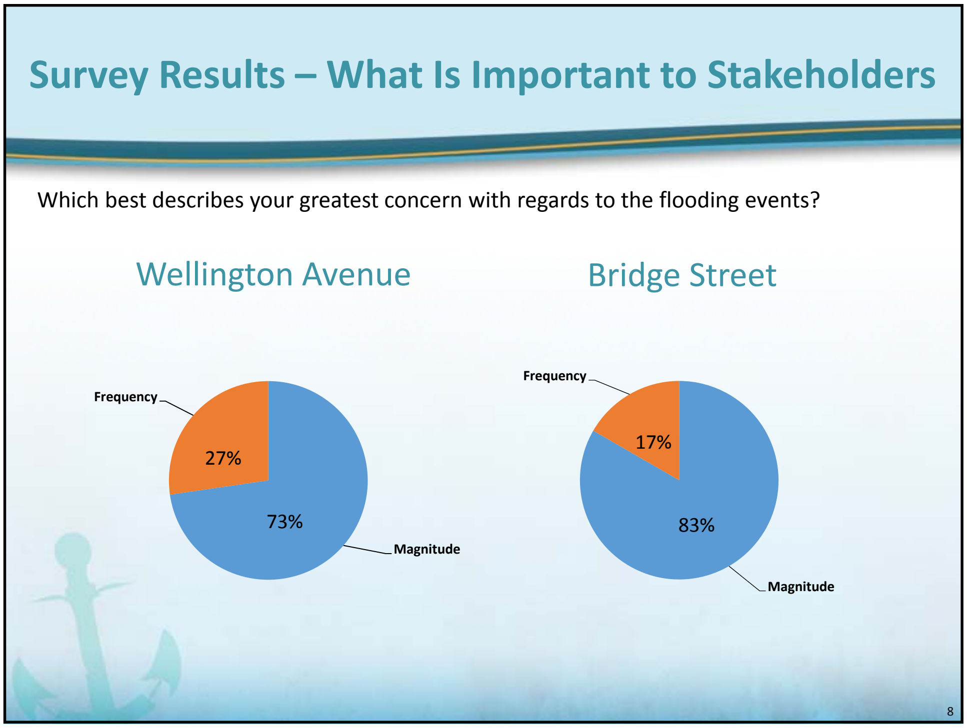
Which best describes your greatest concern with regards to drainage and flooding issues in your area?

Wellington Avenue

*Other Includes:
- Overall property flooding
- Water damage caused by cars driving through street flooding

Bridge Street

*Other includes:
- Private property damage
- Condition of City's infrastructure
- Management of City's infrastructure relating to sea level rise



Survey Results – What Is Important to Stakeholders

Which best describes your greatest concern with regards to the flooding events?

Wellington Avenue

Bridge Street

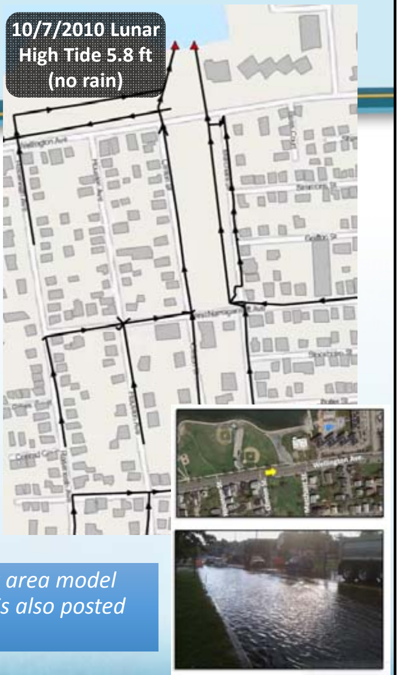
Field Investigations Were Completed in Both Study Areas

- Inspected Drainage Manholes
  - » Collect invert elevations
  - » Record pipe sizes
  - » Check pipe conditions/ sediment levels
  - » Check connectivity to neighboring systems
  - » Update GIS
- Observed High Tide Events
  - » Check tidal influence/tide gate effectiveness
  - » Record water stage for model calibration

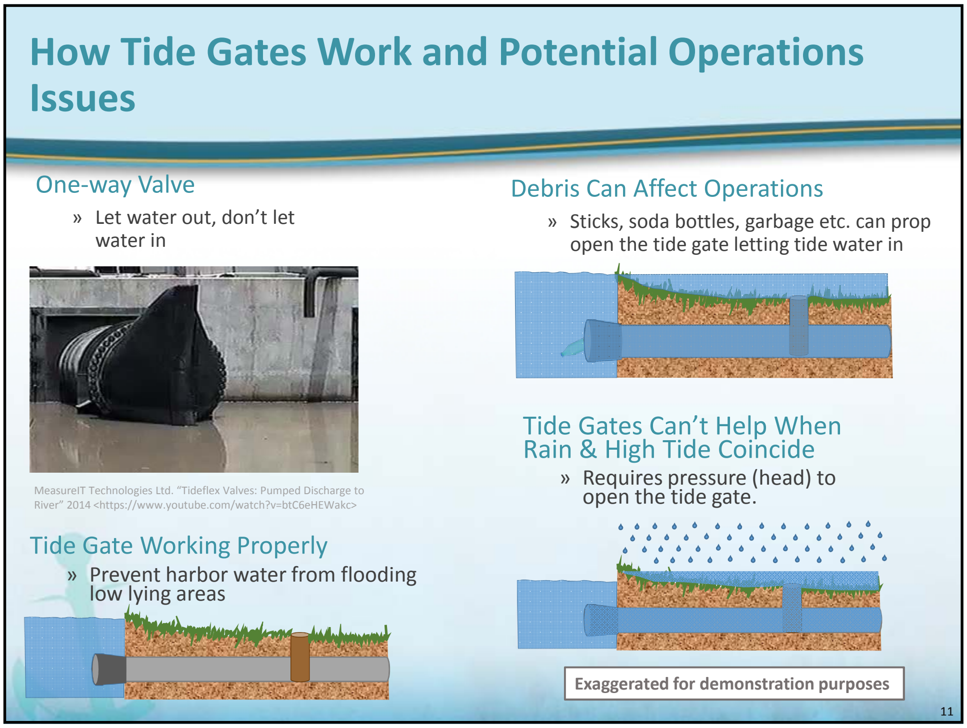
An indirect cross connection was identified between the Bridge Street and Marsh Street lines.

Models Were Developed and Calibrated

- Developed EPA SWMM Models
  - » Bridge St. Study Area
  - » Wellington Ave. study area
- Models calibrated to observed flood depths
  - » Sunshine flooding
  - » Range of rainfall events
  - » Used photos of observed events from 2010 to 2015



Wellington Avenue study area model calibration run example is also posted on the project website.



How Tide Gates Work and Potential Operations Issues

One-way Valve

» Let water out, don't let water in

MeasureIT Technologies Ltd. "Tideflex Valves: Pumped Discharge to River" 2014 <https://www.youtube.com/watch?v=btC6eHEWakc>

Tide Gate Working Properly

» Prevent harbor water from flooding low lying areas

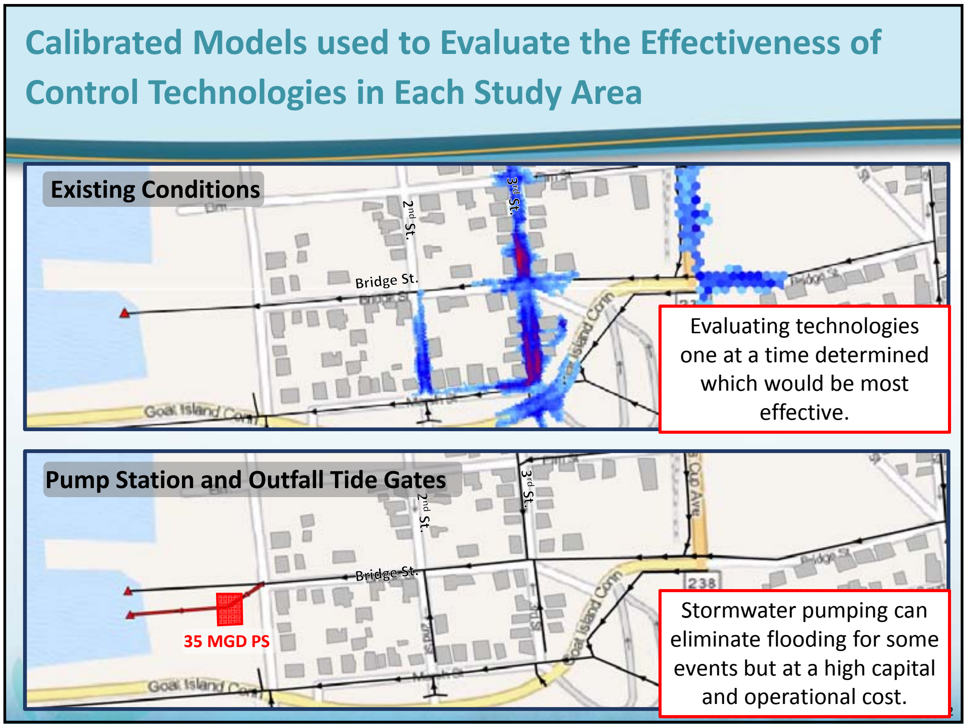
Debris Can Affect Operations

» Sticks, soda bottles, garbage etc. can prop open the tide gate letting tide water in

Tide Gates Can't Help When Rain & High Tide Coincide

» Requires pressure (head) to open the tide gate.

Exaggerated for demonstration purposes



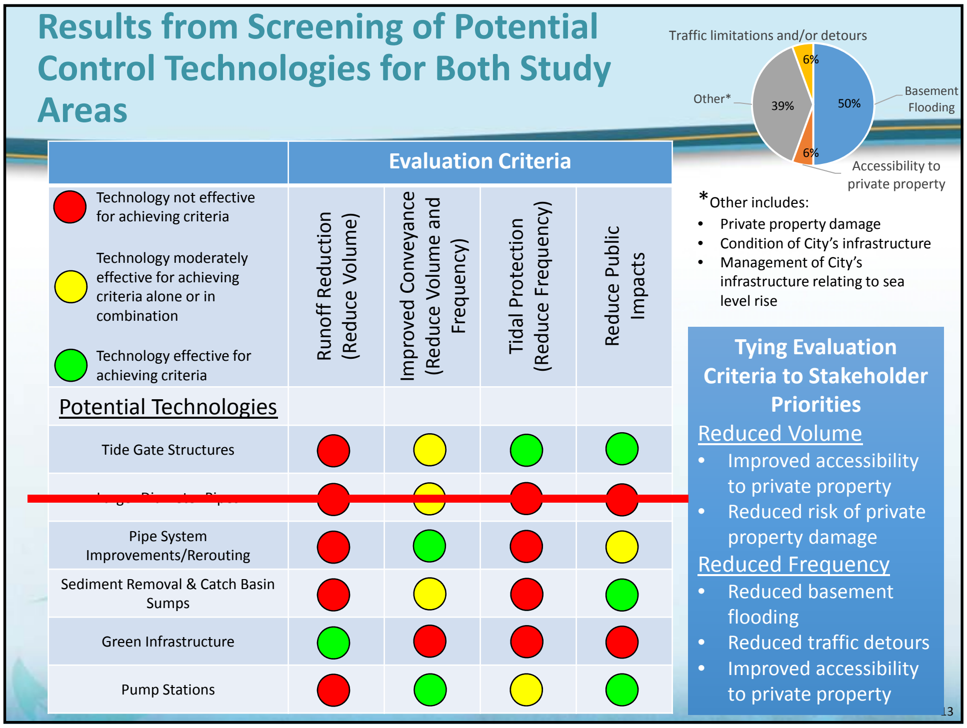
Calibrated Models used to Evaluate the Effectiveness of Control Technologies in Each Study Area

Existing Conditions

Evaluating technologies one at a time determined which would be most effective.

Pump Station and Outfall Tide Gates

Stormwater pumping can eliminate flooding for some events but at a high capital and operational cost.



Results from Screening of Potential Control Technologies for Both Study Areas

- 🔴 Technology not effective for achieving criteria
- 🟡 Technology moderately effective for achieving criteria alone or in combination
- 🟢 Technology effective for achieving criteria

	Evaluation Criteria			
	Runoff Reduction (Reduce Volume)	Improved Conveyance (Reduce Volume and Frequency)	Tidal Protection (Reduce Frequency)	Reduce Public Impacts
Potential Technologies				
Tide Gate Structures	🔴	🟡	🟢	🟢
~~Large Diameter Pipes~~	~~🔴~~	~~🟡~~	~~🔴~~	~~🔴~~
Pipe System Improvements/Rerouting	🔴	🟢	🔴	🟡
Sediment Removal & Catch Basin Sumps	🔴	🟡	🔴	🟢
Green Infrastructure	🟢	🔴	🔴	🔴
Pump Stations	🔴	🟢	🟡	🟢

*Other includes:

- Private property damage
- Condition of City's infrastructure
- Management of City's infrastructure relating to sea level rise

Tying Evaluation Criteria to Stakeholder Priorities

Reduced Volume

- Improved accessibility to private property
- Reduced risk of private property damage

Reduced Frequency

- Reduced basement flooding
- Reduced traffic detours
- Improved accessibility to private property

Overview of Alternatives Evaluation Process

Objectives for Implementing Short-term Controls

- Key Objectives
  - » Address today’s climate conditions
    - – Precipitation and tide events for a typical year
  - » Reduce observed/historic flooding issues
- Effectiveness
  - » Technologies with largest benefit
    - – Reduction in number of flooding events
    - – Reduction in magnitude of flooding events
- Implementation Considerations
  - » Shorter Implementation Schedule
    - – Minimal technical or legal barriers
    - – Capital costs ranging from $1.5M - $6M
  - » Complimentary to long-term plans
  - » Increased Operations & Maintenance costs and effort

Implementation Schedule Considerations

- Inclusion in CIP
- Funding approval
- Procurement (4-6 months)
- Design (9-12 months)
- Permitting (3-6 months)
- Bidding & Award (3-4 months)
- Construction (12-24 months)

Once funding has been procured and approved it could take up to 5 years to implement short-term controls.

Objectives for Implementing Long-term Controls

- Key Objectives
  - » Address current flooding issues that may not be mitigated by short-term controls
    - – Large rain events at high tide
  - » Address future conditions related to climate change
    - – Sea level rise
    - – Increased volumes and intensity of precipitation
- Effectiveness
  - » Technologies with largest benefit
    - – Reduction in number of flooding events
    - – Reduction in magnitude of flooding events
  - » Sized to handle a 5-year storm
- Implementation Considerations
  - » Controls that take longer to implement
    - – Technical and legal barriers
    - – Capital costs ranging from $13M - $46M
    - – Time period for financial planning
  - » Significant additional Operations & Maintenance cost and effort

Implementation Schedule Considerations

- Inclusion in CIP
- Funding planning and procurement
  - » Grants
  - » FEMA
- Land acquisition and/or easements
- Procurement (4-6 months)
- Design (9-12 months)
- Permitting (3-6 months)
- Bidding & Award (3-4 months)
- Construction (12-24 months)

It could take 20 to 25 years to implement long-term controls

Used the Calibrated Model to Evaluate the Performance of Future System Improvements

In order to identify alternatives that best meet the community's objectives it is important that potential improvements be evaluated for a wide range of realistic conditions.

Use of historic data for a typical year provides:

- Wide range of rain events from small to large
- Storms with small and large peak intensities
- Data on observed tides and sea level
- Realistic input on the frequency of rain events that occur at high tide

Study Areas were Evaluated for a 10-Year Period of Record

Wellington Avenue

Year	Total Rainfall (in)	Total Flooding Events	Wet Weather Events	Dry Weather Events
2006	44.8	63	37	26
2007	33.6	49	27	22
2008	38.3	49	26	23
2009	37.9	57	27	30
2010	27.0	82	21	61
2011	36.4	83	36	47
2012	26.2	77	25	52
2013	27.0	70	32	38
2014	37.2	71	22	49
2015*	25.1	37	17	20
* through Oct 3				

Bridge Street

Year	Total Rainfall (in)	Total Flooding Events	Wet Weather Events	Dry Weather Events
2006	44.8	15	6	9
2007	33.6	16	6	10
2008	38.3	14	3	11
2009	37.9	26	7	19
2010	27.0	43	7	36
2011	36.4	50	7	43
2012	26.2	46	9	37
2013	27.0	31	7	24
2014	37.2	25	6	19
2015*	25.1	11	3	8
* through Oct 3				

2013 includes 74 precipitation events ranging from trace amounts to 3.7 inches in depth, includes a 2 year storm, and a storm with peak intensity of 2.4 inches per hour.

* More information about the selection of the typical year is located on the project website.

Evaluation of Wellington Avenue Short-term and Long-term Control Options

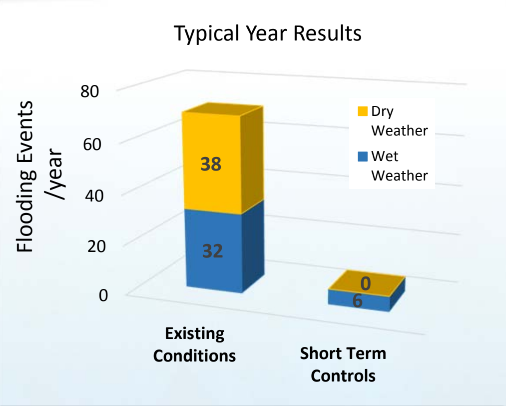
Wellington Ave. Study Area
Short-term Controls

- Tide gates
- Outfall dredging
- Sediment removal
- Catch basin sumps and rehabilitation
- Pipe system improvements

Wellington Ave. Study Area
Short-term Controls Map
Conceptual Layout

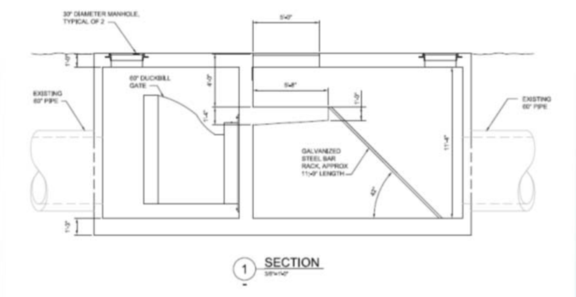
Wellington Ave. Study Area
With all Short-term Controls in Place
Performance for a Typical Year 2013

- Existing Conditions
  - » 70 flooding events/yr
  - » 5.8 million gallons/yr
  - » 62 hours flooded/yr
- Short-Term Controls
  - » 6 flooding events/yr
  - » 0.2 million gallons/yr
  - » 5 hours flooded/yr

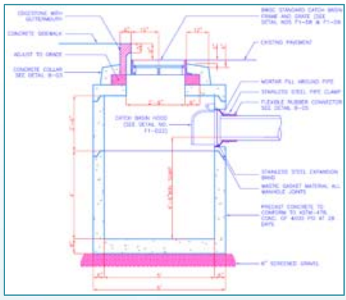


Short-term alternatives eliminate dry weather flooding and reduce wet weather flooding by 81%. Remaining wet weather events are due to rain events coinciding with high tide.

Wellington Short Term Controls

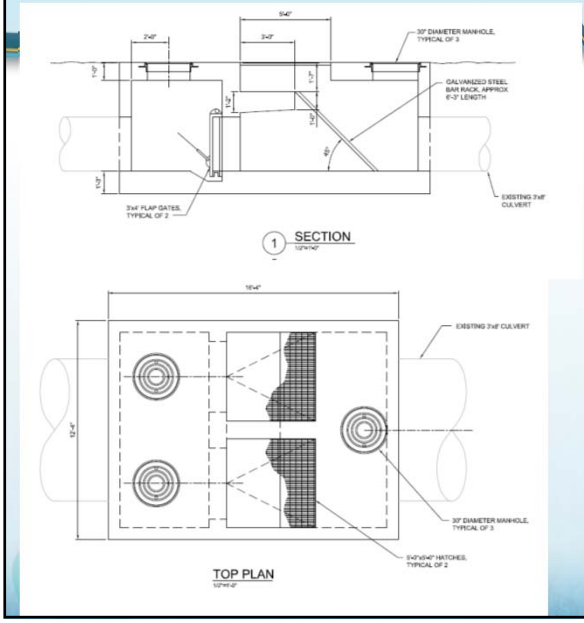


Conceptual sketch of duckbill tide gate structure for 66" circular line



Conceptual sketch for a catch basin with sump

Wellington Short Term Controls



Conceptual sketches of a flap tide gate structure for 3'X8' box culvert

Wellington Avenue Study Area
Short-term Costs

Wellington Avenue Short-term Control Option Components	Quantities	Capital Cost* (-25% to +50%)	Additional Annual O&M Cost
3'X8' Box Culvert Tide Gate Structure	1 structure including trash rack and 2 4'X4' flap tide gates	$850,000 $638,000 - $1.3M	$9,000/yr
66" Duckbill Tide Gate Structure	1 structure including trash rack and 1 66" duckbill tide gate	$800,000 $600,000 - $1.2M	$9,000/yr
Storm Drain Cleaning	6,288 ft. (1.2 miles)	$1.1M $575,000 - $1.7M	$75,000/yr
Catch Basin Rehabilitation & Addition of Sumps	23 Catch Basins	$561,000 $421,000 - $842,000	$1,600/yr
Harbor Dredging* * Assumes material not hazardous	4,500 cy sediment removed	$536,000 $402,000 - $804,000	
Reroute Houston St. Catch Basins	75 ft. new pipe Block 18" pipe	$81,000 $61,000 - $122,000	
Total		**$3.9M** **$2.7M - $6.0M**	**$94,600/yr**

* Total capital cost includes design, construction, services during construction.

Potential additional costs: Permitting, Easement acquisition, Future harbor dredging, Hazardous materials testing and disposal

Wellington Ave. Study Area
Long-term Controls

- All short-term controls
- Additional tide gate
- Green infrastructure
- Stormwater pump station
  - 55 MGD
  - Sized for a 5-year storm

Pumps for pump station will be located below ground.

Wellington Ave. Study Area

Long-term Controls Map

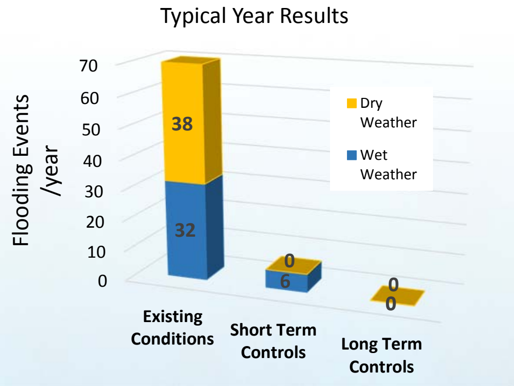
Conceptual Layout

Wellington Ave. Study Area

With all Long-term Controls

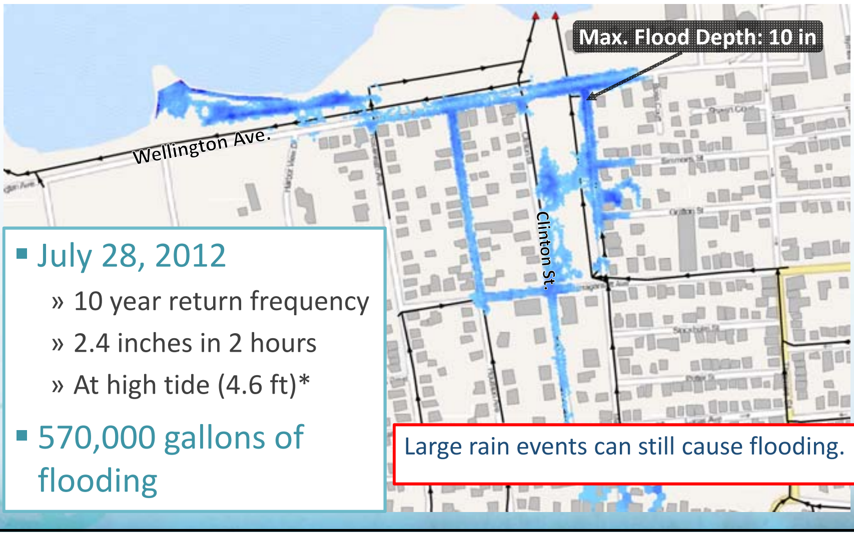
Performance for a Typical Year 2013

- Existing Conditions
  - » 70 flooding events/yr
  - » 5.8 million gallons/yr
  - » 62 hours flooded/yr
- Long-Term Controls
  - » 0 flooding events/yr
  - » 0 million gallons/yr
  - » 0 hours flooded/yr



Long-term alternatives eliminate all flooding during a typical year because there were no storm events with greater than a 5-year return in 2013.

Wellington Ave. Study Area
Large Storms vs. Design Storm
With all Long-term Controls

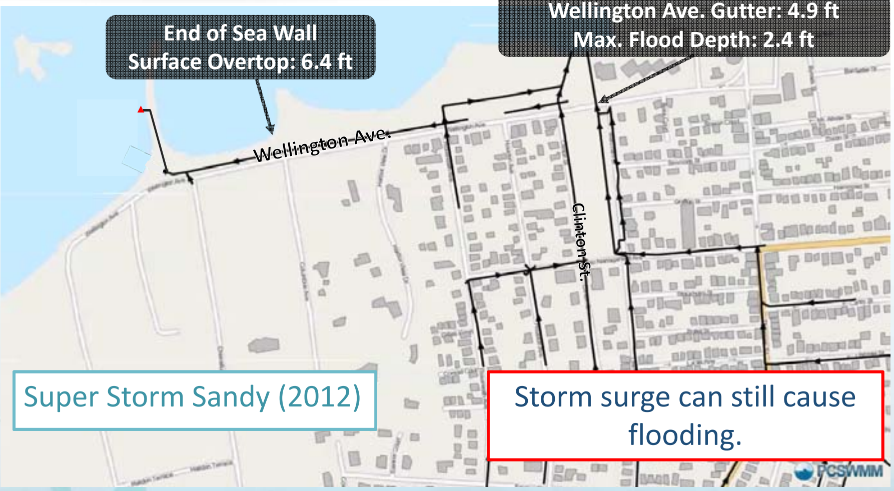


Max. Flood Depth: 10 in

- July 28, 2012
  - » 10 year return frequency
  - » 2.4 inches in 2 hours
  - » At high tide (4.6 ft)*
- 570,000 gallons of flooding

Large rain events can still cause flooding.

Wellington Ave. Study Area
Super Storm Sandy
With all Long-term Controls and Repaired Seawall



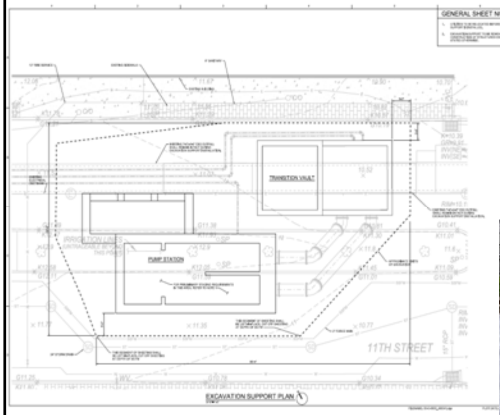
End of Sea Wall
Surface Overtop: 6.4 ft

Wellington Ave. Gutter: 4.9 ft
Max. Flood Depth: 2.4 ft

Super Storm Sandy (2012)

Storm surge can still cause flooding.

Wellington Avenue Study Area
Long-term Controls



Profile sketch of an underground pump station

Permeable Pavement

Green Infrastructure: Bio-Retention Cell

Wellington Avenue Study Area
Long-term Costs

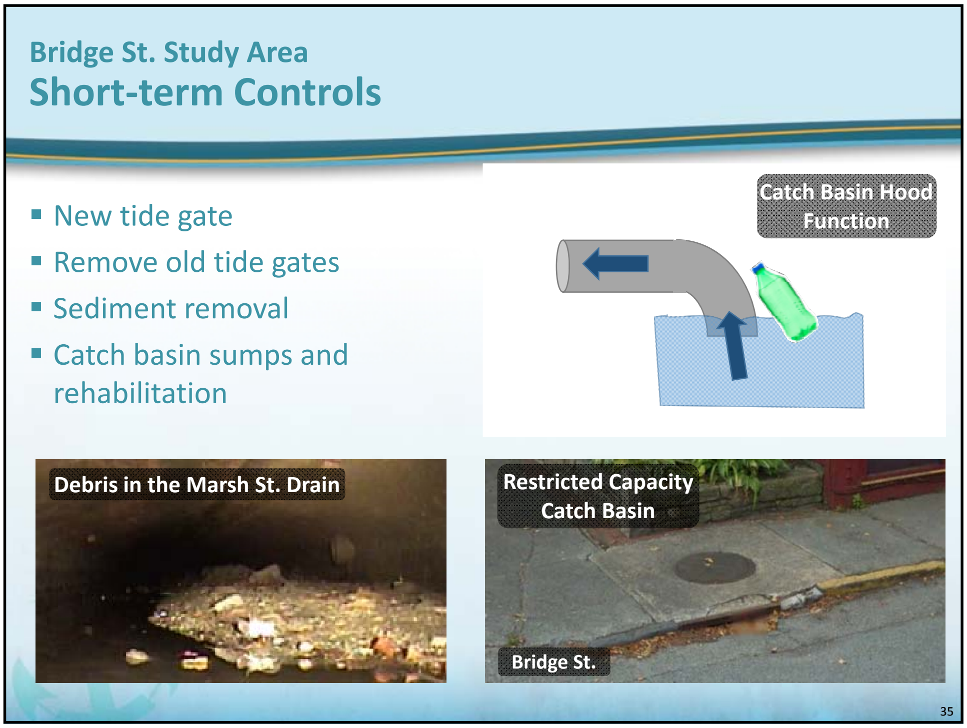
Potential additional costs: Permitting, Easement acquisition, Future harbor dredging, Hazardous materials testing and disposal

Wellington Avenue Long-term Control Option Components	Quantities	Capital Cost* (-25% to +50%)	Additional Annual O&M Cost
3’X8’ Box Culvert Tide Gate Structure	1 structure including trash rack and 2 - 4’X4’ flap tide gates	$850,000 $638,000 - $1.3M	$9,000/yr
66” Duckbill Tide Gate Structure	1 structure including trash rack and 1 - 66” duckbill tide gate	$800,000 $600,000 - $1.2M	$9,000/yr
Storm Drain Cleaning	6,288 ft. (1.2 miles)	$1.1M $575,000 - $1.7M	$75,000/yr
Catch Basin Rehabilitation & Addition of Sumps	23 Catch Basins	$561,000 $421,000 - $842,000	$1,600/yr
Harbor Dredging* * Assumes material not hazardous	4,500 cy sediment removed	$536,000 $402,000 - $804,000	
Reroute Houston St. Catch Basins	75 ft. new pipe Block 18” pipe	$81,000 $61,000 - $122,000	
Green Infrastructure	54,000 sf bioretention 73,000 sf permeable pavement	$6.5M $4.9M - $9.8M	$65,000/yr $48,000 - $81,000/yr
18” Duckbill Tide Gate Structure	1 structure including trash rack and 1 - 18” duckbill tide gate	$614,000 $461,000 – $921,000	$9,000/yr
Pump Station	1 - 55 MGD Pump Station	$19.7M $14.8M - $29.6M	$40,000/yr
Total		**$30.7M** **$22.9M - $46.3M**	**$208,600/yr**

* Total capital cost includes design, construction, services during construction.

Discussion

Evaluation of Bridge Street Short-term and Long-term Control Options



Bridge St. Study Area

Short-term Controls

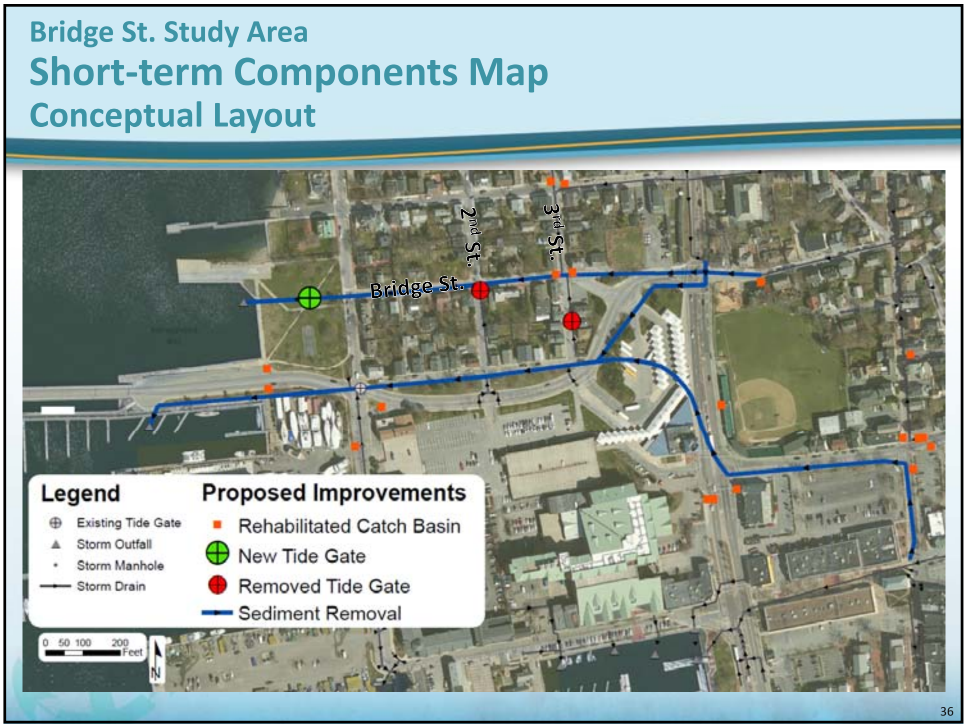
- New tide gate
- Remove old tide gates
- Sediment removal
- Catch basin sumps and rehabilitation

Catch Basin Hood Function

Debris in the Marsh St. Drain

Restricted Capacity Catch Basin

Bridge St.



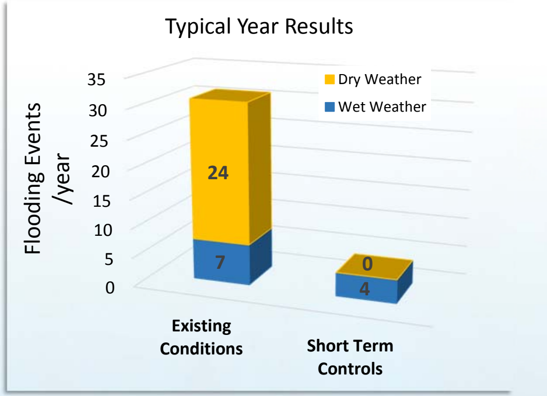
Bridge St. Study Area

Short-term Components Map

Conceptual Layout

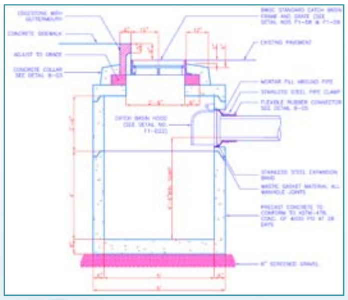
Bridge St. Study Area
With all Short-term Controls
Performance for a Typical Year 2013

- Existing Conditions
  - » 31 flooding events/yr
  - » 1.0 million gallons/yr
  - » 32 hours flooded/yr
- Short-Term Controls
  - » 4 flooding events/yr
  - » 0.1 million gallons/yr
  - » 2.1 hours flooded/yr

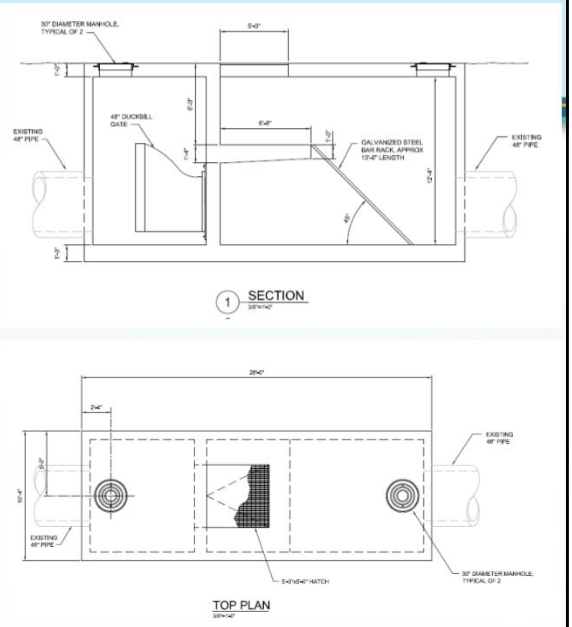


Short-term alternatives eliminate dry weather flooding and reduce wet weather flooding by 43%. Remaining wet weather events are due to rain events coinciding with high tide.

Bridge Street Study Area
Short-term Controls



Conceptual sketch for a catch basin with sump



Conceptual sketch for a 48” duckbill tide gate structure

Bridge Street Study Area
Short-term Costs

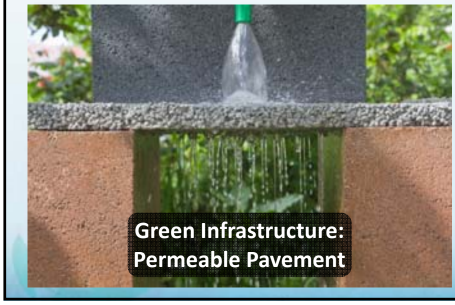
Bridge Street Short-term Control Option Components	Quantities	Capital Cost* (-25% to +50%)	Additional Annual O&M Cost
48" Duckbill Tide Gate Structure	1 structure including trash rack and 1 48" duckbill tide gate	$850,000 $638,000 - $1.3M	$9,000/yr
Storm Drain Cleaning	4,167 ft (0.8 miles)	$723,000 $542,000 - $1.1M	$50,000/yr
Catch Basin Rehabilitation & Addition of Sumps	20 Catch Basins	$479,000 $359,000 - $719,000	$1,400/yr
Total		**$2.1M** **$1.5M - $3.1M**	**$60,400/yr**

* Total capital cost includes design, construction, services during construction.

Potential additional costs: Permitting, Easement acquisition

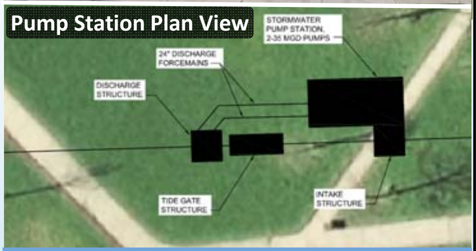
Bridge St. Study Area
Long-term Controls

- All short-term controls
- Green infrastructure
- Stormwater pump station
  - » 35 MGD
  - » Sized for a 5-year Storm



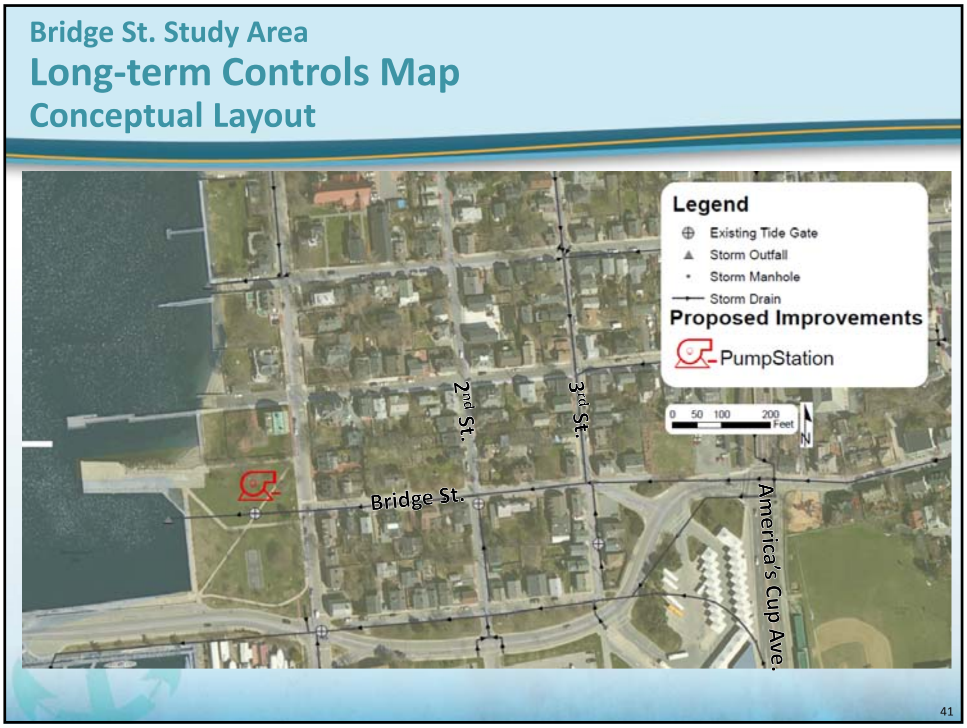
Green Infrastructure: Permeable Pavement

Pump Station Footprint

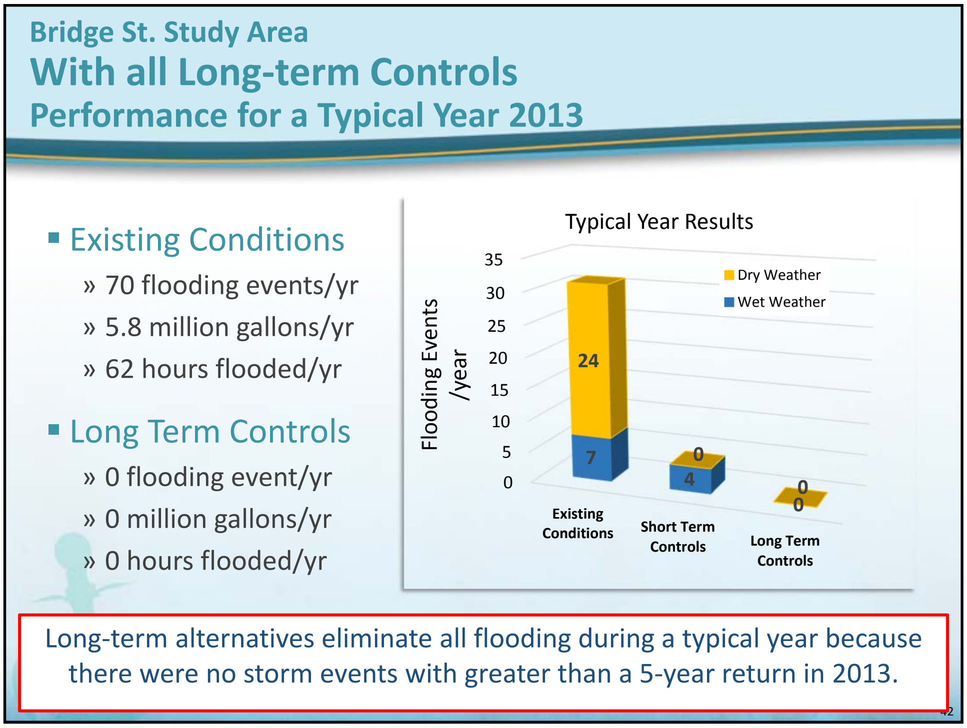


Pump Station Plan View

Pumps for pump station will be located below ground.



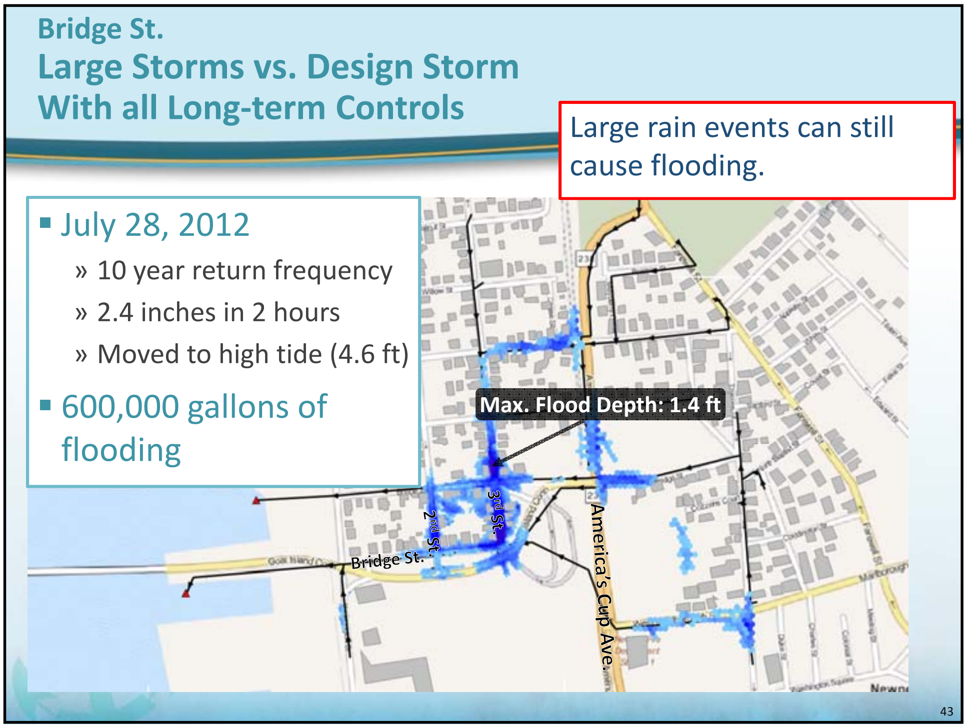
Bridge St. Study Area
Long-term Controls Map
Conceptual Layout



Bridge St. Study Area
With all Long-term Controls
Performance for a Typical Year 2013

- Existing Conditions
  - » 70 flooding events/yr
  - » 5.8 million gallons/yr
  - » 62 hours flooded/yr
- Long Term Controls
  - » 0 flooding event/yr
  - » 0 million gallons/yr
  - » 0 hours flooded/yr

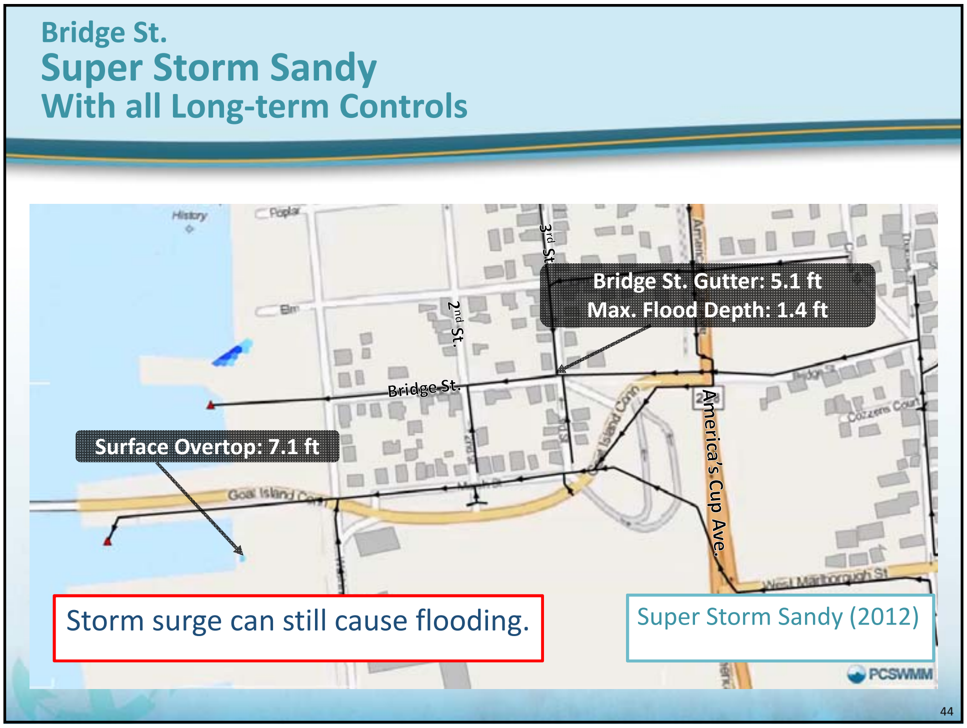
Long-term alternatives eliminate all flooding during a typical year because there were no storm events with greater than a 5-year return in 2013.



Bridge St.
Large Storms vs. Design Storm With all Long-term Controls

Large rain events can still cause flooding.

- July 28, 2012
  - » 10 year return frequency
  - » 2.4 inches in 2 hours
  - » Moved to high tide (4.6 ft)
- 600,000 gallons of flooding

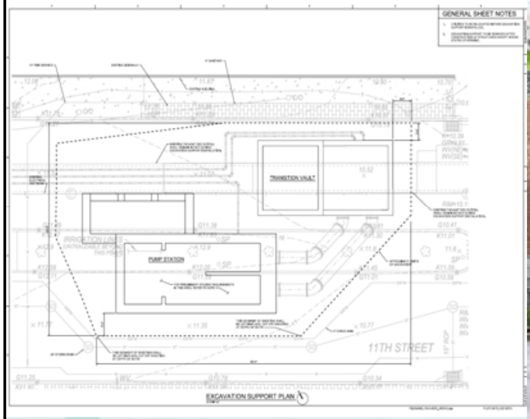


Bridge St.
Super Storm Sandy With all Long-term Controls

Storm surge can still cause flooding.

Super Storm Sandy (2012)

Bridge Street Study Area
Long-term Controls



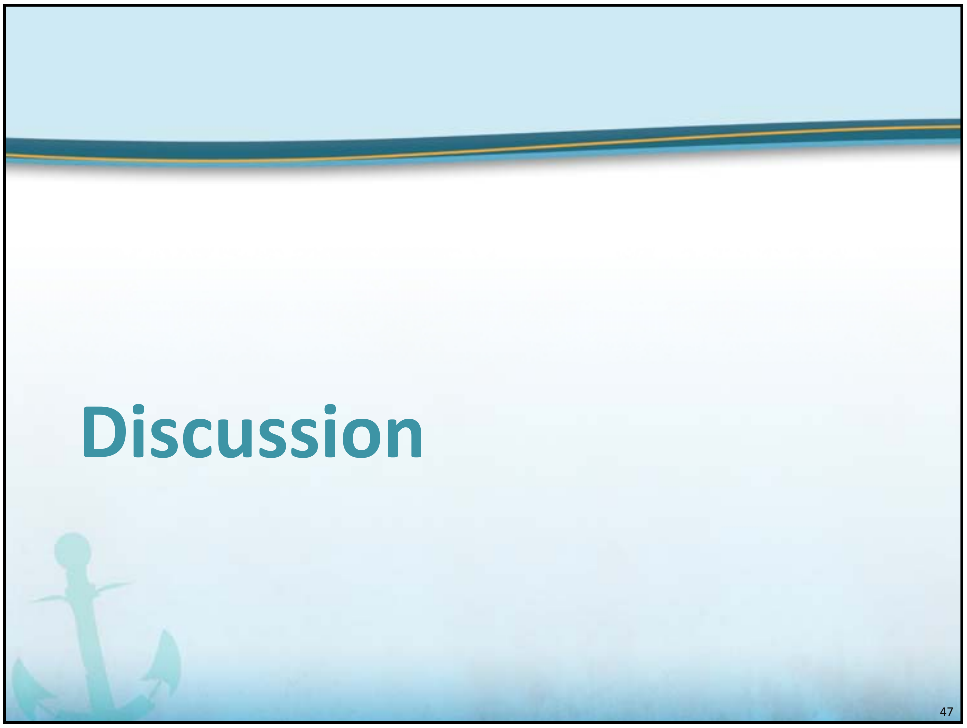
Profile sketch of similar pump station currently under construction

Bridge Street Study Area
Long-term Costs

Bridge Street Short-term Control Option Components	Quantities	Capital Cost* (-25% to +50%)	Additional Annual O&M Cost
48" Duckbill Tide Gate Structure	1 structure including trash rack and 1 - 48" duckbill tide gate	$850,000 $638,000 - $1.3M	$9,000/yr
Storm Drain Cleaning	4,167 ft (0.8 miles)	$723,000 $542,000 - $1.1M	$50,000/yr
Catch Basin Rehabilitation & Addition of Sumps	20 Catch Basins	$479,000 $359,000 - $719,000	$1,400/yr
Green Infrastructure	30,000 sf bioretention 21,000 sf permeable pavement	$2.9M $2.2M - $4.4M	$29,500/yr $22,000 - $37,000/yr
Pump Station	1 - 35 MGD Pump Station	$12.2M $9.2M - $18.3M	$36,000/yr
Total		**$17.2M** **$12.9M - $25.8M**	**$125,900/yr**

* Total capital cost includes design, construction, services during construction.

Potential additional costs: Permitting, Easement acquisition



Discussion

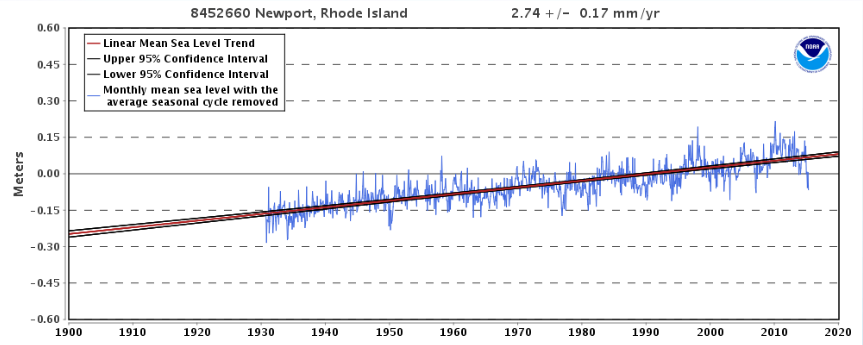
Planning for Future Climate Conditions

Improving Resiliency for Future Climate Change

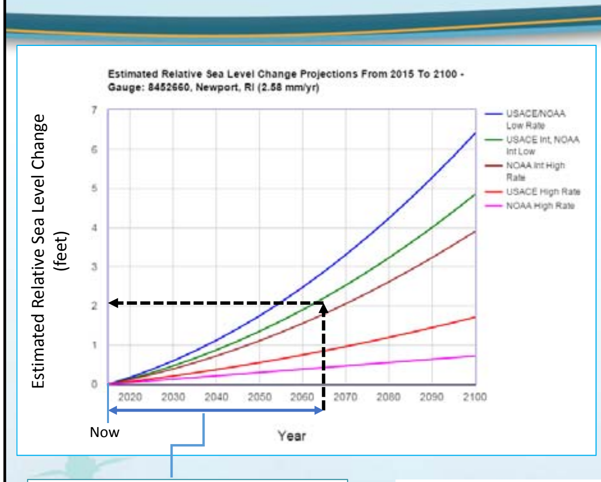
- Long-term Drainage Resiliency Planning Takes Us 50 years into the Future – to 2065
- Future Sea Level Rise and Storm Surge
  - Sea level rise may increase the elevation of the storm surge and the areas that will flood.
  - Sewer systems may be inundated in flooded areas.
  - Pump stations may be flooded and disabled.
  - More streets may be flooded if the water has nowhere to go.
- Cities and their Utilities are:
  - Identifying climate threats
  - Evaluating risks to assets and operations
  - Developing short- and long-term strategies to improve their resiliency

Water Levels Are Rising in Newport

Sea Levels Have Risen ~1 foot in the Past 100 years and will Likely Continue to Rise at the Same Rate at a Minimum



Future Newport High Tides with Climate Change



Life Cycle of Project – 50 years
= 2 feet of Sea Level Rise

Legend

Newport Sea Level Rise (SLR)

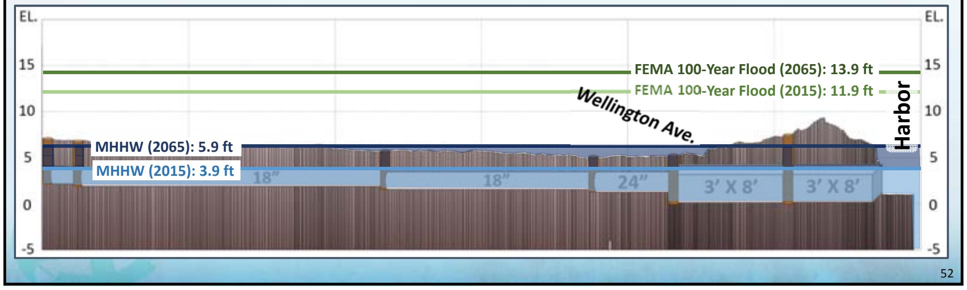
- 🟦 Mean Higher High Water (MHHW)
- 🟩 MHHW plus 1' Sea Level Rise
- 🟦 MHHW plus 3' SLR
- 🟨 MHHW plus 5' SLR
- ⬜ Waterbodies

Sea Level Rise Scenarios provided by the URI EDC

Wellington Ave Study Area

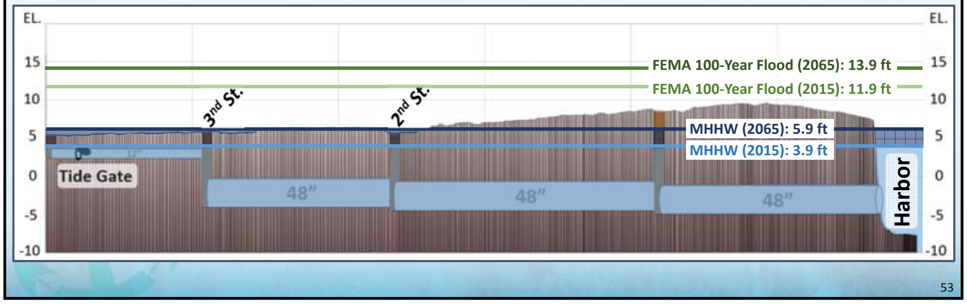
Future Profile Marchant Street – Year 2065

- In 2065, higher high tides will be above some ground surfaces
- The current 100-year storm surge inundates streets over bulkheads. In 2065, the surge will be 2 feet higher



Bridge St.
Future Profile – Year 2065

- In 2065, higher high tides will be above some ground surfaces
- The current 100-year storm surge inundates streets over bulkheads. In 2065, the surge will be 2 feet higher



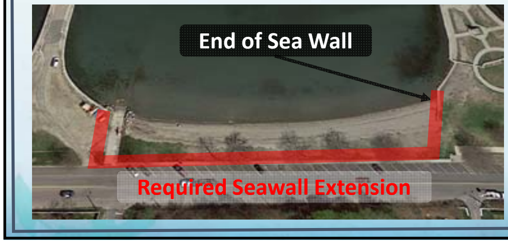
Projected Flood Events for a Typical Year Tides – 50 Years from Today Without Rainfall

Wellington Avenue Study Area

- Based on LIDAR data, overtopping elevation, tide data and the projected sea level rise to the area will flood 157 times per year
- Long-term controls to the drainage system will not prevent these flooding events
- Extending the sea wall 500 ft can eliminate all dry weather flooding events in a typical year in 2065

Bridge Street Study Area

- Based on LIDAR data, overtopping elevation, tide data and the projected sea level rise the area will flood 27 times per year
- Long-term controls to the drainage system will not prevent these flooding events



Future Flood Protection for Climate Change Achieved by Performing the Following Steps:

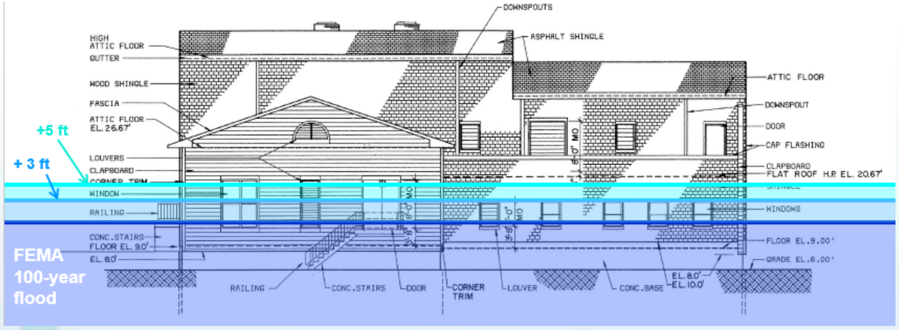
- Identify regional efforts and guidelines related to climate change.
- Define the process and considerations for planning.
- Define climate change scenarios for rainfall, sea level, storm surge and rivers.
- Evaluate sewer and storm drain system performance with climate change.
- Evaluate flooding vulnerabilities to sea level rise, storm surge and rivers.
- Develop strategies and design standards.
- Monitor changes over time and be prepared to adjust.

Newport Department of Utilities Climate Resiliency Evaluations, Strategies and Implementation

- Planning Criteria
  - Current FEMA Flood Zones
  - Flood Zone Design Criteria
  - Sea Level Rise
- Evaluated Current and Future Asset Vulnerabilities
  - Water Pollution Control Plant (WPCP)
  - Long Wharf Pump Station
  - Wellington Avenue CSO Treatment Facility
  - Washington Street CSO Treatment Facility
- Developed Design Recommendations
- Integrating Floodproofing into Facility Improvement Projects When Implemented
  - Will update design criteria based on experiences and data trends

Utility Planning in Newport Includes Consideration of Future Design Flood Elevations

Washington Street CSO Treatment Facility



Design Flood Elevation = FEMA 100-year flood zone plus 1 foot of freeboard and 1 foot of sea level rise

This evaluation identified attainable levels of protection for the Bridge Street and Wellington Avenue study areas

- High high-tides, Sea Level Rise, Storm surge

Permanent and Temporary Flood Protection

Ann Street Pier

Discussion

Next Steps

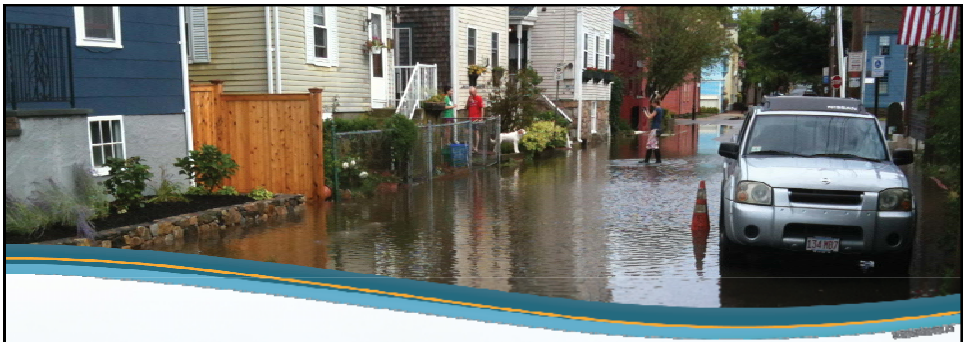
Next Steps for the Drainage System Investigation and Flooding Analysis Project

Deliver Final Feasibility Report

- Post presentation to website
- Review comments from residents and city staff
  - Instructions for sending comments by December 31 will be on website
- Prepare a report to document key findings
  - Existing Conditions
  - Model Development and Calibration
  - Screening and Evaluation of Mitigation Alternatives
  - Planning Level Cost Estimates
- Submit final report in January 2016

Implementation

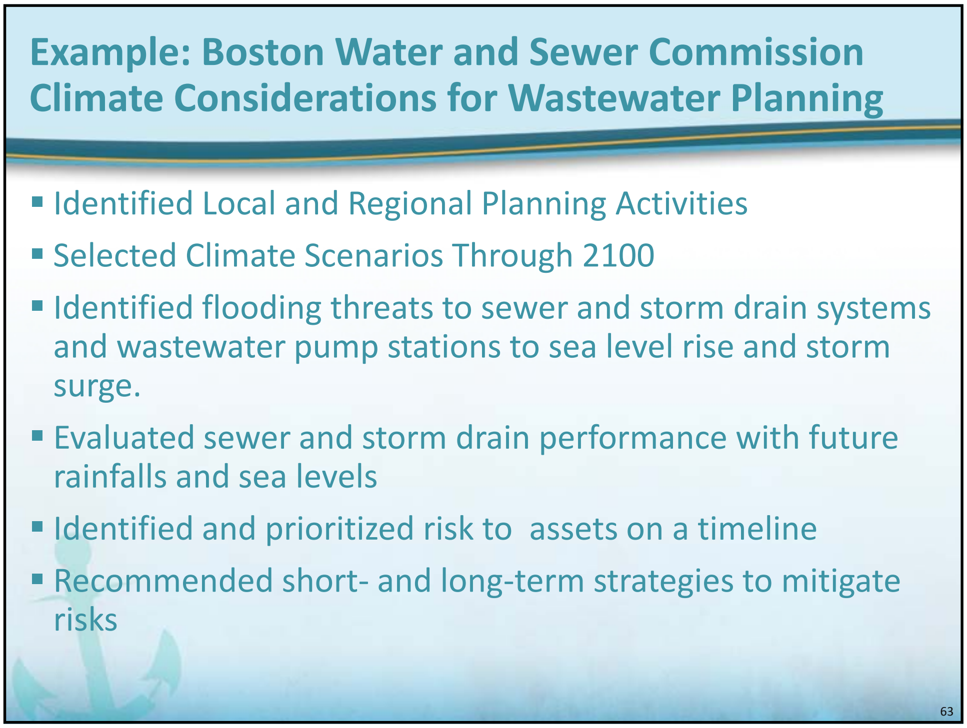
- Incorporate projects into capital planning
- Funding source
- Solicit design
- Design period
- Permitting
- Solicit construction
- Construction period



Thank You

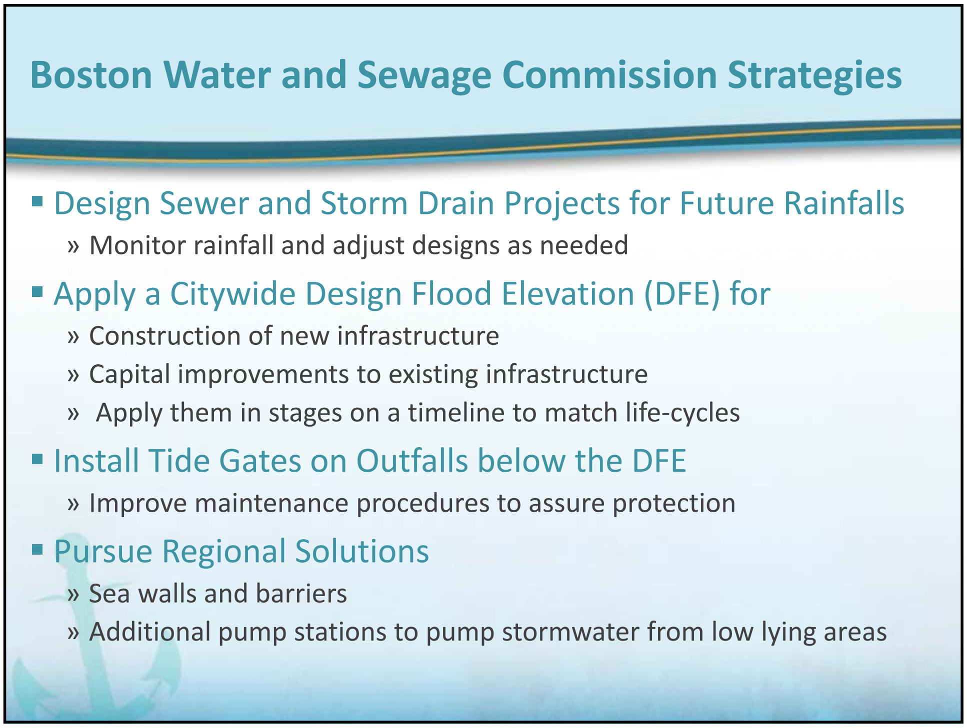
Please visit our project website at:

www.newportdrainageinvestigation.com



Example: Boston Water and Sewer Commission Climate Considerations for Wastewater Planning

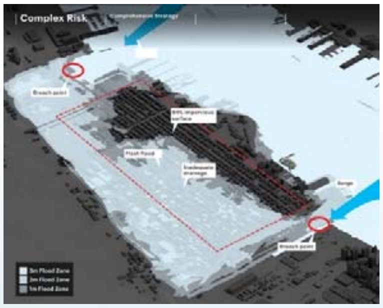
- Identified Local and Regional Planning Activities
- Selected Climate Scenarios Through 2100
- Identified flooding threats to sewer and storm drain systems and wastewater pump stations to sea level rise and storm surge.
- Evaluated sewer and storm drain performance with future rainfalls and sea levels
- Identified and prioritized risk to assets on a timeline
- Recommended short- and long-term strategies to mitigate risks



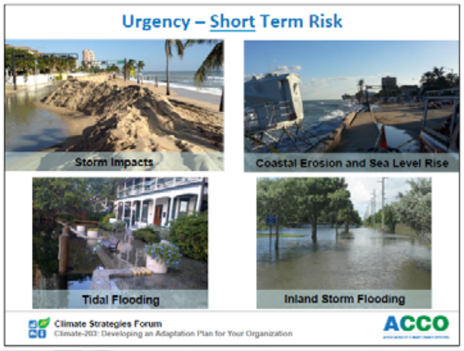
Boston Water and Sewage Commission Strategies

- Design Sewer and Storm Drain Projects for Future Rainfalls
  - » Monitor rainfall and adjust designs as needed
- Apply a Citywide Design Flood Elevation (DFE) for
  - » Construction of new infrastructure
  - » Capital improvements to existing infrastructure
  - » Apply them in stages on a timeline to match life-cycles
- Install Tide Gates on Outfalls below the DFE
  - » Improve maintenance procedures to assure protection
- Pursue Regional Solutions
  - » Sea walls and barriers
  - » Additional pump stations to pump stormwater from low lying areas

Community Sea Level Rise and Flooding Mitigation Example: Hoboken, NJ



Community Sea Level Rise and Flooding Mitigation Example: Fort Lauderdale, FL



Urgency – Short Term Risk

Storm Impacts

Coastal Erosion and Sea Level Rise

Tidal Flooding

Inland Storm Flooding

Climate Strategies Forum
Climate-203: Developing an Adaptation Plan for Your Organization

ACCO

Prioritizing of Strategies

Comprehensive Multi-Year Stormwater
Master Plan Improvement Features

BIOSWALES

RECHARGE DRAINAGE WELL

EXFILTRATION TRENCH

TIDAL CONTROL VALVES

PERVIOUS PAVERS & PAVEDRAIN

SEAWALL REPAIRS & UPGRADES

STORMWATER PRESERVES

PUMPING STATIONS

Climate Strategies Forum
Climate-203: Developing an Adaptation Plan for Your Organization

ACCO