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Effects of Sea Level Rise on Water Treatment & Wastewater Treatment Facilities

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Effects of Sea Level Rise on Water Treatment & Wastewater Treatment Facilities

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Abstract

Sea level rise and its associated effects threaten coastal water utilities in Massachusetts. The Massachusetts Department of Environmental Protection does not know which facilities are at greatest risk of flooding and cannot easily evaluate the impacts of a flood event on particular facilities. Our goal was to identify past research in this field, create a tool to evaluate hazard to coastal water facilities and measure the impact of flooding on these facilities. We have also provided the structure to expand upon these tools and make recommendations to the Massachusetts Department of Environmental Protection for what they can do in the future to focus their mitigation efforts.

Executive Summary

Scientific research has shown that sea levels are rising at a significant rate of around 3 millimeters per year (Intergovernmental Panel on Climate Change, 2007). Massachusetts' coastlines have become subject to high risk of flooding due to this rise and little has been done to ameliorate this threat. In 2010, the Massachusetts Department of Environmental Protection (MassDEP) conducted a study along with a group of students from WPI and identified multiple risks related to climate change which threaten Massachusetts' coastal infrastructure. One of the problems identified by this team was the risk of flooding of wastewater and drinking water treatment systems.

With the onset of rising sea levels, many water utilities have become threatened by flooding which can have multiple negative consequences. Flooded drinking water systems face a threat of contamination due to flood waters and saltwater intrusion. A drinking water system can also suffer structural damage; both occurrences could force the facility to deny clean water to thousands of citizens. Flooded wastewater facilities have the potential to release untreated waste into the ecosystem, thus causing significant damage to the environment and people alike. If the wastewater facility suffered structural damage it may have to release untreated waste for an extended period of time until the plant can be fixed. Flood damage would be costly to drinking water and wastewater municipalities both in terms of financial loss and in terms of threats to public health. Careful advance planning to prepare for the consequences of sea level rise and flooding is essential.

The primary goal of our project was to develop and apply a risk assessment tool as well as an impact assessment tool. These tools allowed us to identify the most at-risk

coastal facilities and assess the impact a flood would have on the facility itself as well as towns served by the facility. We worked with the Massachusetts Department of Environmental Protection to develop criteria by which they could measure the level of risk faced by water treatment facilities in the event of rising sea levels and storms resulting from climate change as well as the impact this event would have on the surrounding community. These criteria were further narrowed through research of risk factors, and interviews with experts in the fields of hazard assessment and water treatment. The factors included in our assessment for wastewater facilities were: history of past flooding, presence of combined sewer system, location relative to Federal Emergency Management Agency (FEMA) flood zones, location relative to Army Corps of Engineers (ACE) hurricane inundation zones, and location relative to predicted Army Corps of Engineers hurricane inundation zones. Similarly the factors used to assess drinking water facilities were: location relative to Federal Emergency Management Agency (FEMA) flood zone, location relative to Army Corps of Engineers hurricane inundation zone, and location relative to predicted Army Corps of Engineers hurricane inundation zone.

Our assessment was applied to 18 coastal wastewater facilities and 17 coastal drinking water systems. Of these 35 facilities, we were able to visit and perform five onsite analyses. While there the team also interviewed site managers to get a better understanding of problems related to potential flood damage at each of the specific sites. Figure ES.1 below shows the risk rankings of the 18 costal wastewater treatment facilities with those in red receiving a high risk rating, orange a medium rating, and green a low risk rating.

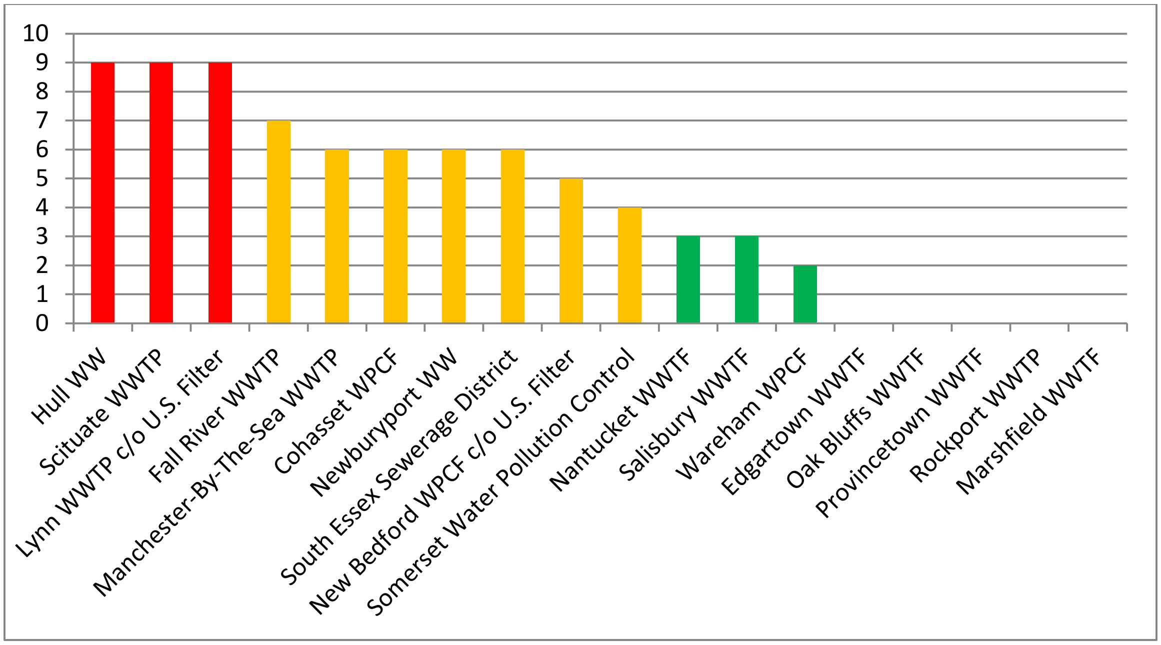

Figure ES. 1: Wastewater Facility Risk Rankings

Below in Figure ES. 2 are the compiled average risk ratings for all the drinking water systems we assessed. We assessed each component of the drinking water system individually then averaged those numbers for the system. This allowed us to look at the overall drinking water system and assign a low, medium, or high risk rating. The color system is the same as they were on the risk rating.

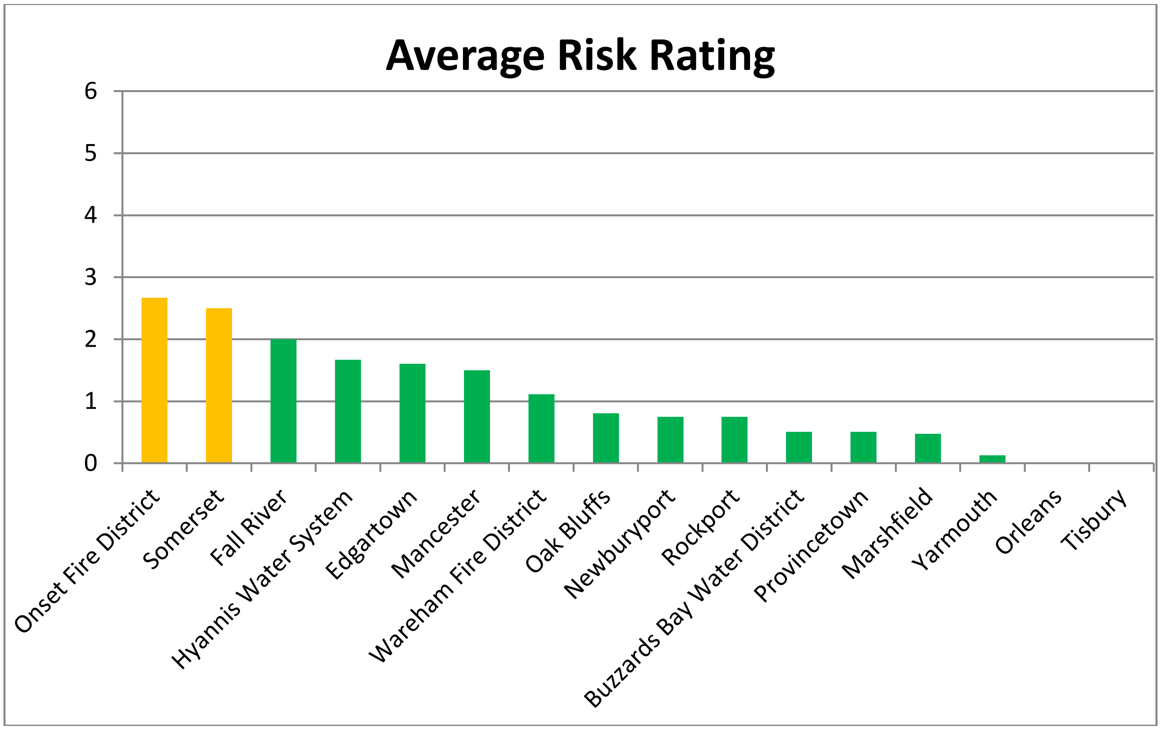

Figure ES. 2 Average Risk Rating

To consider the effects of a facility flooding on the surrounding community, we created an impact assessment tool. Suitable tools were developed for both drinking water and wastewater facilities. The factors we considered for drinking water include: number of days' worth of stored finish water, populations served, and location of the supply source. Below in Figure ES. 3 is a compiled graph of all the drinking water impact assessments which we conducted. For wastewater we considered one crucial factor, the ratio between average flow rate and design flow rate of the plant. Since we only considered one factor for wastewater we do not have a graph.

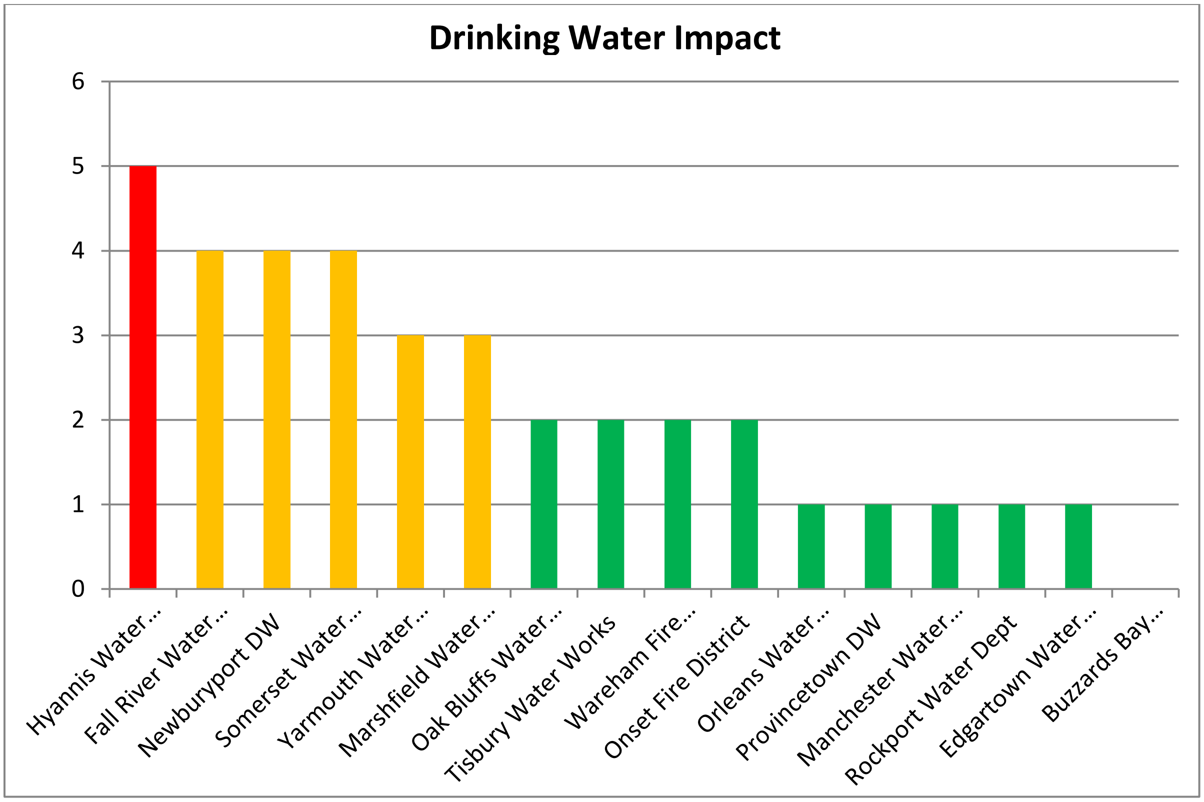

Figure ES. 3 Drinking Water Impact

Our assessment was applied to 18 coastal wastewater facilities and 17 coastal drinking water systems. Of these 35 facilities, we were able to visit and perform five onsite analyses. While there the team also interviewed site managers to get a better understanding of problems related to potential flood damage at each of the specific sites. These tools are designed for the purpose of assisting the Massachusetts Department of Environmental Protection in prioritizing which facilities to focus their mitigation efforts on. These tools will also help the Massachusetts Department of Environmental Protection assess the community impact of a flooded facility.

Authorship Table

Section	Author	Proofread
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1 Introduction

As the effects of climate change become more prevalent, countries all over the world are faced with issues of rising sea levels, increasing ambient temperature, and the effects of greenhouse gases. Of these effects, rising sea levels have become a most pressing issue. Coastal states are at higher risk of their land, used for utilities, public use, and habitation, becoming flooded and unusable. Rising sea levels also lead to an increase in the height of storm surges. These higher storm surges have the capability of overpowering current structures put in place to protect coastal areas from such events.

Numerous structures located on the Massachusetts shoreline are at risk of rising sea levels and the resultant storm surges. While residential and public spaces aren't severely dependent on location, utilities such as drinking water treatment and wastewater processing facilities require access to bodies of water to operate. These wastewater and drinking water facilities may become vulnerable to flooding and inundation that can damage the facilities themselves. The flooding and inundation can also cause dangerous malfunctions with the potential to contaminate drinking water and release untreated waste into otherwise usable bodies of water.

The initial problem faced by our sponsors at Massachusetts Department of Environmental Protection is that the severity of the potential risk associated with sea level rise is unrecognized or unheeded by officials and planners. We conveyed our findings about the risk of sea level rise to Massachusetts Department of Environmental Protection personnel. By bringing to light the hazards of sea level rise, we were able to spread awareness of this problem and present methods to reduce and possibly eliminate the risk to coastal water utilities.

Currently, specific effects of rising sea levels on wastewater and drinking water treatment facilities in Massachusetts have not been quantified by facility staff and other involved stakeholders such as town managers, selectmen, and city/town mayors. Previous effort has gone into identifying problems caused by global climate change, but has not specified the amount or possible damage that could be caused by rising sea levels and higher storm surges. High risk locations have not been identified and there is minimal knowledge of when floodwaters or rising sea levels will cause serious damage to coastal facilities. Numerous proven successful solutions, as described by Hans F. Burcharth and Steven A. Hughes in their coastal engineering manual, range from sea dikes to beach drains (USACE 2002). Unfortunately, these solutions have not been widely implemented. Also the knowledge of these solutions has not been delivered to key stakeholders with the ability to adopt said solutions.

The goal of this project was to identify the risks of rising sea levels, such as storm surges, on wastewater and drinking water treatment facilities. We located hazardous areas through study of the Massachusetts coastline and its history of sea level rise. With this information we were able to make accurate predictions about future areas of flooding. Furthermore, we studied the consequences of flooding and inundation caused by rising sea levels on wastewater and drinking water treatment facilities. This helped us to predict what would happen should these facilities not enact preventative measures. Finally we made recommendations to the Massachusetts Department of Environmental Protection Agency of where to focus their mitigation efforts.

2 Background

This chapter provides relevant background information concerning the effects of sea level rise on drinking water and wastewater treatment facilities. We provide information on rising sea levels as well as their effects, and on the basic common treatment processes used by drinking water and wastewater utilities. We also include a discussion of the various methods currently used by coastal water utilities to protect against rising sea levels and flooding.

2.1 Climate Change

Global climate change is a problem facing countries around the world. An effect of this global climate change is that average temperatures are increasing. The increase in global temperature leads to one of the most widely known effects, a rise in sea levels. Another significant effect is the expected change in precipitation patterns. The increase in global average temperatures affects climate and weather patterns in complex ways, even having opposite effects in different areas. In places such as Mexico and California, for example, the Intergovernmental Panel on Climate Change, IPCC, (2007) predicts that a decrease in precipitation is likely. However, in New England, the IPCC predicts that an increase in precipitation is very likely.

2.1.1 Rising Sea Levels

The rise of sea levels affects every nation in the world that has a coastline. According to the IPCC (2007), sea levels have been rising globally at a rate of 3mm/year since 1993. Three millimeters per year may not seem like much, however even such a minimal sea level rise over the next 50 to 100 years will be devastating to low-elevation coastal cities and islands. When compared to cities such as New Orleans and Venice, Boston has more time to prepare itself for rising sea levels, as it is currently above sea level. However this does not mean the problem of rising sea levels can wait to be addressed. In the near future, floods are predicted to occur more frequently and will likely be worse than before. While flooding of residential and commercial areas are of huge concern and probably one of the first things to come to mind when discussing sea level rise, effects on drinking water and wastewater utilities are also of great concern.

2.2 Water Utilities

Water utilities are a critical type of infrastructure within our society. "Water utilities" for our purposes refers to the public drinking water and wastewater treatment services that are often operated by the government. Davis (2009) defines public systems as, "… those systems serving at least 25 persons per day for greater than 60 days out of the year" (p. 406). Water utilities are an important part of our society's public infrastructure, and preserving their operational integrity is, and always will be, of high importance.

2.2.1 Drinking Water Treatment

About 95 percent of the population in Massachusetts receives its drinking water from a public drinking water supply system; about 82 percent of this water is treated before being distributed to the public (CCA, 2011, p. 61). This section will discuss the common goal of such facilities and a general description of processes used at drinking water treatment facilities.

The general purpose of any water treatment facility is to effectively filter, disinfect, and otherwise purify the water so that it is potable and palatable for the consumer (Davis, 2009, p. 407). Water treatment facilities take their water from both surface water sources as well as ground water sources and thus need to treat the water differently to end up with potable and palatable water for the consumer. In 1974, the Safe Drinking Water Act (SDWA) was enacted by the U.S. Congress, requiring the U.S. EPA to set uniform drinking water standards (p.410). The U.S. EPA, in response, created maximum contaminant levels (MCLs), which limit the maximum amount of each substance that can be present in treated water. Due to the differences in the quality of the source waters, the specific water treatment processes are usually determined on a case-by-case basis, taking into account the contaminants that are present and the levels of all contaminants present. For example, some water sources may have high levels of arsenic, while others may have low levels of arsenic but high levels of sulfur.

As can be seen in Figure 1, numerous purification procedures are involved in the delivery of drinking water from source to consumer. When water flows into a treatment plant from its water source, it will normally pass through a set of bar racks or a coarse screen filter (Droste, 1997, p. 230). The purpose of these systems is to filter out any large items that could be in the water, such as tree branches or shopping carts. If these large items were not removed, they could potentially block or clog subsequent processes or do damage to treatment equipment, costing both money and time to repair. After passing through the bar rack, the water will generally enter an aeration basin, or have certain chemicals such as coagulants or chlorine added to it.

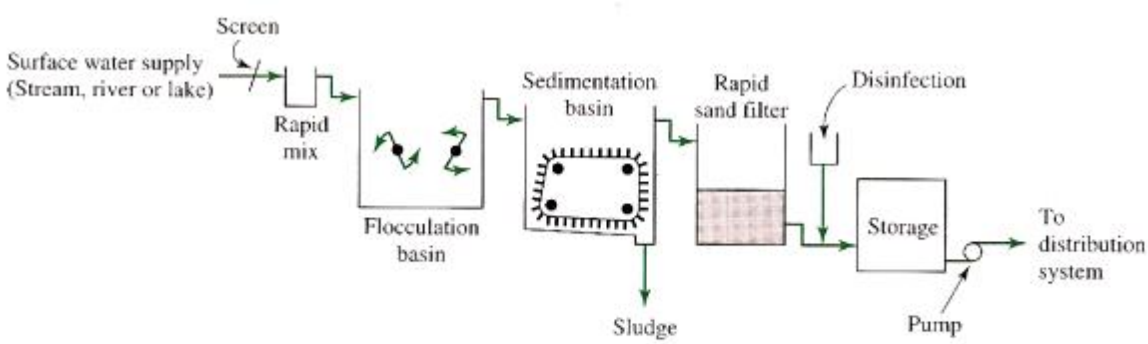

Figure 2. 1: Typical Water Treatment Process

(Image from Davis, 2009, p. 411)

Aerators are used to "remove volatile dissolved components in the water that are in excess of their saturation concentration… The addition of dissolved oxygen will enhance the oxidation of iron, manganese, and other metals to higher and more insoluble oxidation states" (Droste, 1997, p. 220). Pushing these metals to more insoluble states will allow for easier removal during sedimentation and filtration because they will not be dissolved in the water. In cases where aeration is not used, it is common for coagulants to be added to the water in a rapid mixing tank. The coagulant is a chemical reagent that is added to the rapid mixing tank in order to destabilize the microscopic suspended particles in the water. Once the water and coagulant have been rapidly mixed, the water usually flows into a flocculation basin.

In the flocculation basin, gentle mixing allows the suspended particles to form larger particles (Davis, 2009, p. 416). Larger particles are desirable because, instead of floating like the smaller particles, they sink due to gravity and can be easily removed. From the flocculation basin, the water flows into a sedimentation basin.

In the sedimentation basin, the settable solids, which include the small particles that have been combined to form larger particles and the large suspended solids are settled out by gravity as the water slowly flows through the basin (Droste, 1997, p. 222). All of the suspended solids and particles settle to the bottom, creating what is called sludge. From the sedimentation basin, water will usually flow through a filtration unit. After most of the bigger solids and settable solids have been removed from the water, it is time to remove the smaller suspended particles in the water; this is where filtration comes in.

The filtration process consists of the water moving through tanks that contain sand or plastic, which act as the filtration material as the water passes through. Fine solids that did not settle out in a sedimentation basin will be trapped in the filter. There also will be significant removal of bacteria in a filter but not enough to provide safe water. Normally larger microorganisms such as protozoa are completely removed during the process as well (Droste, 1997, p. 221). Two types of common filters are rapid filters and slow sand filters. Slow sand filters contain only sand as a filtration medium, while rapid filters commonly contain anthracite, sand, and sometimes other granular media. The next step in the process is disinfection.

According to Davis (2009), disinfection involves "the addition of chemicals (usually chlorine, chloramines, or ozone) or the application of UV radiation to reduce the number of pathogenic organisms to levels that will not cause disease. Storage [for purified water] is provided to meet peak demands and to allow the plant to operate on a uniform schedule" (p. 412). From this final stage, the water will travel to the consumers or be held in a storage tank, as stated above, until there is a need for its use.

2.2.2 Wastewater Treatment

As abundant as it may be or seem, water is still a limited resource that must be used efficiently and conservatively while maintaining quality as well. Wastewater treatment seeks to treat all domestic and industrial wastewater as well as storm water in order to maintain the quality of rivers, lakes, and other such bodies of water. Society's uses for these waters are numerous, ranging from recreation such as swimming and fishing to use as drinking water if at a safe distance away from the wastewater treatment outfall. The Merrimack River is an example of such use, essentially starting in New Hampshire then winding and flowing out into the Atlantic. Many drinking water treatment facilities intake water from rivers, with some wastewater treatment facilities discharging upstream on the same river. The city of Lowell, for example, is one downstream population center that draws its drinking water from the Merrimack.

Figure 2 shows the common processes used in an activated sludge wastewater treatment facility from the raw sewage intake to the treated water discharge into a river, the ocean or other body of water. The processes used in wastewater treatment are similar to those used in drinking water treatment and can be separated into three categories: pretreatment, primary treatment and secondary treatment (Davis, 2009, p. 474). Pre-treatment involves the use of bar racks, as in water treatment, grit chambers, and commonly an equalization basin. Grit chambers are installed to remove dense material like sand, broken glass, and pebbles. If not removed, these materials would be harmful to pumps and other mechanical devices in the treatment process. A grit chamber is much like a sedimentation basin where the water slowly flows through the basin, allowing much of the grit to settle out by gravity.

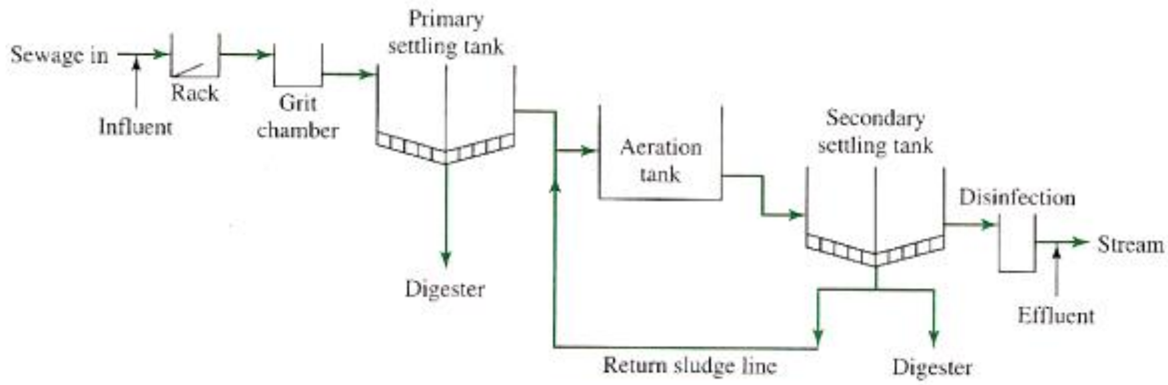

Figure 2. 2: Typical Activated Sludge Wastewater Treatment Process

(Image from Davis, 2009, p. 483)

Equalization basins commonly follow grit chambers in the treatment process. Equalization basins are used to create a uniform flow throughout the day, since there are peak flows and low flows at certain times of the day. Equalization basins essentially collect the flow that has passed through the bar racks and grit chambers, like a storage tank, and then uniformly releases the water at a constant flow rate.

Next in the process is primary treatment, which includes the use of a sedimentation tank. In the sedimentation tank, many of the suspended solids are settled out by gravity as the water flows through the tank. The sedimentation tank will normally remove about 60% of the suspended solids in raw sewage and reduce the biochemical oxygen demand (Davis, 2009, p. 473). This biochemical oxygen demand (BOD) is a measure of the oxygen used by the microorganisms in the water as they consume the organic material for food; a high BOD indicates a high amount of organic material in the water. The treatment processes are trying to remove this organic material, thus lowering BOD.

From primary treatment, the water begins to go through secondary treatment, commonly consisting of aeration, a secondary settling tank, and disinfection. In an aeration tank, the water is roughly mixed, thus supplying oxygen to the microorganisms present in the water. By doing this, the microorganisms flocculate and form what is called "activated sludge". By agitating and aerating, the microorganisms in the water become "activated" and will consume the organic matter as food. From the aeration tank, the water flows into the secondary clarifier where the activated sludge is settled out and, as depicted in Figure 2, recycled back into the aeration tank many times in order to keep a high population of the microorganisms cleaning the water. This sludge, consisting of all the microorganisms breaking down the waste, is sometimes called the biomass. From the secondary clarifier, the water flows into a tank where chemicals are added, commonly chlorine, in order to disinfect the water and kill off any harmful pathogens present.

In some cases there is need for more advanced wastewater treatment in order to remove all pollutants such as phosphorus and heavy metals (Davis, 2009, p. 500). This is done by a variety of methods commonly consisting of methods such as filtration, phosphorus removal or carbon adsorption. At this point the wastewater has been sufficiently treated and cleaned and can be pumped into the receiving waters, commonly a river or, if close enough, pumped out into the ocean.

2.2.3 Effects of Flooding on Water Utilities

Both the gradual and sudden effects of rising sea levels can cause major problems for wastewater and drinking water utilities. Flooding, as a sudden effect, caused by a combination of rising sea levels and storms can become a problem for water treatment facilities. As a gradual effect, the sea level rise may lead to saltwater intrusion, which is a concern for drinking water facilities.

A wastewater facility that is being flooded, or has been flooded, can suffer structural damage from the weight of floodwaters (Flood Damage, 2010). A prime example of this happened during the June, 2010, flood at the City of Norfolk, NE Wastewater Treatment Plant. Due to the weight of the floodwater, a critical 36 inch diameter pipe, responsible for carrying water into the wastewater plant collapsed. A collapsed pipe can cause wastewater, sometimes untreated, to be diverted into nearby fields or bodies of water. Along with structural damage, the electrical system of the plant responsible for powering the pumps would be in danger. When interviewed, Worcester Polytechnic Institute Professor John Bergendahl pointed out that without electricity all processes requiring pumps would be shut down including aeration and sludge pumping. (see Appendix C for interview transcript).

Health also becomes a problem during the flooding of water utilities. In a flooding situation, wastewater facilities may be overwhelmed by excess water. This causes sewer lines to be overwhelmed and as a result the sewage my back up into homes or low lying areas (Kane County, Illinois, 2005). This back up in the sewer lines may become a breeding ground for bacteria such as E. coli. In some cases when a wastewater facility is inundated facility operators are sometimes forced to bypass the treatment process and release untreated water into nearby rivers or streams, which may used as a source of drinking water downstream. This can cause a boil water warning to be issued. This means that citizens of the community are advised to bring any tap water to a roaring boil before it is consumed to assure the water is free of any harmful bacteria and/or pathogens. Drinking water that has not been properly treated, or that is contaminated, is hazardous to human health. Ingesting parasites, bacteria and viruses found in untreated water causes illnesses such as diarrhea (Utah Department of Health, 2011).

A drinking water facility faced with the gradual effects of rising of sea levels has to deal with the threat of saltwater intrusion. Saltwater intrusion is the migration of marine saltwater into freshwater aquifers (U.S. Geological Survey, 2000). As depicted in Figure 3 below, the seawater invades the groundwater supply. This is a particular concern for Cape Cod, MA, where all of the peninsula's drinking water is retrieved from Cape Cod's Sole Source Aquifer. Saltwater intrusion causes a rise in the water's chloride concentration, which, if ingested, can cause high blood pressure. The higher chloride concentration of the water being treated can cause the pipes of the drinking water facility to corrode. Also, as Worcester Polytechnic Institute Professor John Bergendahl noted, a flood of saltwater would "probably kill the bacteria used in biological treatment" (see Appendix C for interview transcript). These bacteria are used in both wastewater and drinking water treatment.

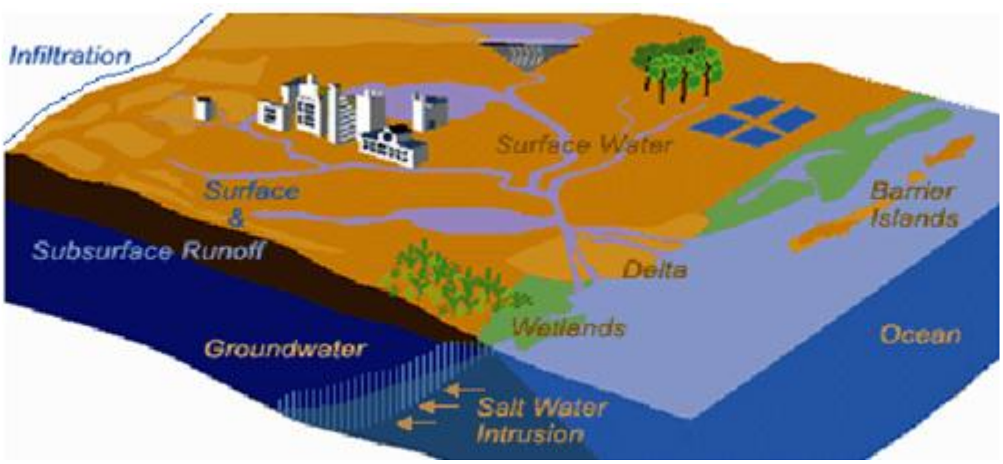

Figure 2. 3: Saltwater Intrusion

(Image from Union of Concerned Scientists, 2002)

2.3 Previous Solutions to Protect Water Utilities

Water utilities are extremely important to people living in the areas they serve, and they are often at high risk of the effects of flooding and storms. In many coastal areas these issues have already been addressed.

Responding to the threat of flooding is no easy task. Many different components of water treatment plants are at risk of performing inadequately or failing in the event of flooding. Protecting these facilities from damage is of utmost importance, either through internal fail safes or external protection. Many solutions exist to protect facilities from flooding and have uses in other fields, making them more efficient to implement and produce.

The most obvious solution to protect water treatment plants from flooding is to physically raise them. According to the Massachusetts Executive Office of Energy and Environmental Affairs (2011), the Deer Island water treatment facility was elevated in 1989 “about 1.9 feet higher to accommodate potential sea level change for at least the first fifty or sixty years of the facility’s service”. This solution is elegant, but cannot be applied to all facilities. There was a relative ease in the implementation of this solution on Deer Island that is not widely applicable or available to other such facilities in Massachusetts.

A more widely implemented solution is the construction of dams, sea walls, dykes, and other such impediments to flood waters. Depending on the type of structure, these solutions can be relatively inexpensive to build and can require little maintenance.

Dams are the most costly and high maintenance of this type of solution. In addition to their high upkeep, they cannot be placed anywhere on the coast, but instead must be located in front of running water, such as across a river. The advantage to the use of dams is that they can generate clean energy and provide some payback to the rather large initial costs. However, with government budget cutbacks and shortage of staff, smaller, more manageable structures are more often built.

Sea walls and dykes are prolific throughout the Massachusetts coast as they are inexpensive to build and will function effectively with little to no human maintenance. Often constructed of concrete, these structures simply wall off incoming floodwaters and ocean storm surges. There are a wide array of types designed and implemented that vary in effectiveness based on their location and specific requirements. T. Sawaragi (1995) describes a plethora of different structures types along with graphical information on their optimal use. The structures he describes have been implemented all over the world with varying success. With a variety of available designs, they can be applied on a case by case basis.

2.4 Concluding Thoughts

Sea level rise is an emerging problem both on a local and global scale. While there are small scale solutions in place, they use outdated technology and are designed for less drastic situations than are predicted to occur. We are only beginning to feel the effects of climate change and must respond accordingly. Based on our understanding of the processes involved in wastewater and drinking water treatment, if we wait for the next major disaster it may already be too late.

3 Methods

The goal of our project was to identify coastal wastewater and drinking water treatment facilities with a high risk of flooding due to sea level rise for the Massachusetts Department of Environmental Protection (MassDEP) in order that, they may better allocate their mitigation efforts and resources. To do this, we worked towards two primary objectives: developing a risk & impact assessment tool, and then applying this assessment tool to coastal wastewater and drinking water treatment facilities. This chapter describes the methodology we used to accomplish these objectives.

3.1 Developing a Hazard Assessment Tool

An important part of our project was developing a hazard assessment tool that could be applied to coastal wastewater and drinking water facilities, which may be at risk to flooding due to sea level rise. To identify factors for a "high risk" facility, we conducted interviews, visited facilities, researched previous studies relating to flood risk factors. Finally these collected data were formed into a risk & impact assessment. We then used this risk & impact assessment to determine the flood risk at coastal wastewater treatment facilities and drinking water systems. We used this assessment tool to identify which coastal water utilities were at high hazard.

3.1.1 Identifying Coastal Water Utilities

Our first step in this process was to locate the coastal water utilities that we would be analyzing. We defined coastal water utilities as utilities that were within one mile of the coast or tidally influenced river. Through the Massachusetts Water Pollution Control Association (MWPCA) website we were able to find a list of the wastewater treatment facilities in Massachusetts. Using satellite imagery we were able to identify the treatment facilities that were within one mile of the coast, to which we would later apply our assessments to (see Appendix H). Using coastal towns we identified while creating our list of wastewater treatment facilities along with the Environmental Protection Agency (EPA) Permit Compliance system, we were able to identify coastal drinking water systems for analysis. Through this method we identified eighteen wastewater facilities and seventeen drinking water systems for analysis.

3.1.2 On & Off-site Data Collection & Analysis

Before doing any on-site analysis we began by collecting data from Geographic Information Systems (GIS), MassDEP Document Repository Tracking System (DRTS), a recent EPA study, and through documents and information held at the MassDEP regional offices. Through GIS we located the facilities, measured their elevations and proximities to coast, determined their discharge types, and mapped the Federal Emergency Management Agency (FEMA) flood zones and the Army Corps of Engineers (ACE) hurricane inundation zones on each facility's location. From the MassDEP regional offices we acquired information on the wastewater facilities such as average effluent flow rate, storage capacity of untreated wastewater, and whether the towns sewage collection system was a combined sewer system or not. Similarly, we acquired the average flow rates, storage capacities of treated water and the populations served in both the summer and winter for each drinking water system through DRTS. Finally, from the recent EPA study we were able to find information on past flooding at each of the wastewater treatment facilities.

During our off-site data collection, we identified three wastewater facilities and two drinking water systems for on-site tours and analysis. We chose facilities located on different parts of the Massachusetts coast, including Cape Cod, in order to have as much of the coast represented in our analysis as possible. We chose Newburyport's Water Works (drinking water treatment facility) and Wastewater Treatment Facility on Massachusetts's north shore, Hull's Wastewater Treatment facility in Massachusetts Bay, and Provincetown's drinking water system and Wastewater Treatment Facility located on Cape Cod for on-site analysis. When touring the five sites we took note of characteristics we could not collect off-site such as factors that may protect against or contribute to flood hazards at the facility. We also collected other site-specific details of relevant factors to be used in our risk & impact assessment such as facility size and whether or not the facility had a flood response strategy available.

3.1.3 Interviewing Risk Analysis Experts & Plant Operators

In addition to our on- and off-site data collection, we consulted with experts in the field of risk assessment and interviewed superintendents or chief plant operators at our selected sites. First we consulted risk analysis experts to acquire a general definition as to what factors are used to determine if a facility or location has a high flood risk. We defined risk analysis experts as those who have had extensive experience in risk analysis such as professors who have done extensive research on risk assessment and those who work in the risk assessment field. These consultations revolved around what factors are taken into account when determining if a facility has a high risk of flooding as well as general risk assessment guidelines.

Next, through MassDEP, in order to gain a professional first hand perspective at the possible high-risk sites, we interviewed five wastewater and drinking water superintendents or chief operators, a design engineer, and an environmental engineer.

These interviews addressed the observed effects of rising sea levels by facility operators, what processes facility operators believe to be the most vulnerable or likely to be affected by flooding, existing adaptations and protective measures against rising sea level related or flooding used at the facility, and any future plans the facility operators had for adapting to rising sea levels. Interview protocols were formulated during preliminary off-site analysis and can be found in Appendix B while interview transcripts can be found in Appendix C.

3.1.4 Developing a Hazard Assessment Tool

First we researched previous studies that had been done elsewhere in the country and world on the effect of sea level rise on water utilities as well as adaptation strategies implemented at other utilities. The next step when creating our flood hazard assessment was compiling all the information we collected from our research, interviews and site visits. Through this research to identify relevant factors and discussion among our project group and MassDEP liaisons, we were able to create a risk assessment as outlined in Appendix D and discussed in Chapter 5. The risk factors were each given a set of possible numeric values which could then be used to give the facility an overall risk rank. A similar process was done to give each assessed facility an impact rating, discussed in Chapter 7. We then applied the assessment tool to the eighteen identified coastal wastewater facilities and seventeen drinking water systems, yielding a risk and impact rating for each facility.

4 Risk Factors

These are the factors we have identified as contributing to the risk of flooding at waste and drinking water treatment facilities and system components. These factors include whether components have been damaged by flooding in the past, which Federal Emergency Management Agency (FEMA) flood zones the components are located in, which Army Corps of Engineers (ACE) hurricane inundation areas the components are located in, and which ACE hurricane inundation areas we predict the components will be located in after 100 years of sea level rise. For wastewater treatment facilities, we also consider whether the collection system is a combined sewer/storm system.

4.1 Past Flooding

Past inundation and damage to a water utility is an important indicator of risk to treatment facilities, as a plant that has suffered from such an event in the past is at risk of flooding in the future. This factor is important because, as we found through interviews with various plant personnel, people respond more easily to past data than predictions. However, it should be noted that, with the changing climate, past data are becoming increasingly unreliable.

4.2 FEMA Flood Zones

FEMA flood zones (FEMA 2011b) show the predicted flooding that would occur due to storm surge and other storm events, taking into account elevation and geography. The FEMA flood zones used were updated in 2000 and 2005 depending on the area we were assessing. We separated the flood zones into two categories: 100 year flood zones and Zone X, which is one of FEMA's flood zone classifications. The 100 year flood zones are areas that have a 1% chance to flood annually with flood depth greater than one foot. Zone X includes the 500 year flood zones, which have a 0.2% chance to flood annually, and the areas that have a 1% chance to be flooded with less than one foot of flood depth annually. We refer to Zone X as the 500 year flood zone. A facility within the 500 year flood zone would be at less risk than one within a 100 year flood zone. A facility outside of these flood zones would be at the least risk.

4.3 Army Corps of Engineers Hurricane Inundation Areas

The Army Corps of Engineers (ACE) hurricane inundation areas predict flooding that will occur due to various category hurricanes taking into account elevation and surrounding geography. There are four categories of hurricane inundation areas, one for each category of hurricane from category 1 to category 4. Category 5 hurricanes are not included in these zones as category 5 hurricanes have no upper bound on wind velocity, which is used to calculate the inundation zone. Each zone shows areas where the ACE models predict inundation in worst-case flooding in the corresponding hurricane category. As a category 1 hurricane is the weakest category of hurricane, a facility located in a category 1 inundation area will be most at risk of flooding. A facility located within a category 4 inundation area will be at less risk than facilities located in lower category inundation areas, as the ACE predict it will require at least a category 4 hurricane to inundate the area, and lower category hurricanes will not inundate it. Facilities not in any hurricane inundation area are at less risk than facilities located within hurricane inundation areas, as the ACE predict that not even the worst-case in a category 4 hurricane will inundate the area.

4.4 Predicted Future Hurricane Inundation Areas

To estimate the risk drinking water and wastewater facilities face in the future we also estimated the levels the ACE hurricane inundation areas would reach after sea level rise, found in Table 4.1, based on median Rahmstorf sea level rise predictions for 2100 of 2.75 feet (MEOEEA 2011). We found this estimated level using average values of the current hurricane inundations zones calculated by taking a random sample of flood elevations in five areas of coastal Massachusetts (the sections are North of Boston, South of Boston, Cape Cod Bay, Cape Cod South shore, and Buzzards Bay, pictured below in Figure 4.1). These flood elevations were then compared to the elevations of the facilities, which were calculated by averaging the elevations at various points located near key facility components and structures using elevation data delivered to the State of Massachusetts by Sanborn, Inc. in 2005 (MassGIS 2005), to estimate the risk the facilities face from sea level rise and its associated impacts in the future.

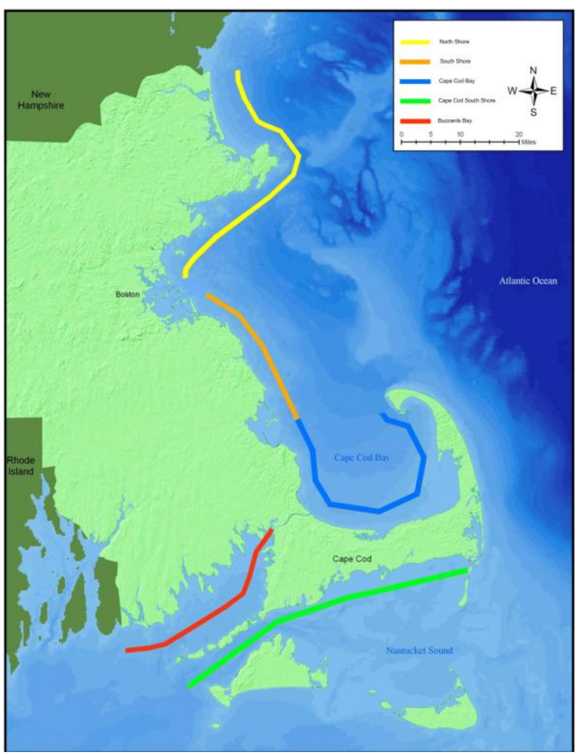

Figure 4. 1 Costal Areas of Massachusetts

Elevation (ft)	North of Boston	South of Boston	Cape Cod Bay	Cape Cod South Shore	Buzzards Bay
Category 2 + SLR	10	14	12	9	10
Category 4 + SLR	14	17	18	17	21

Table 4. 1 Predicted ACE Hurricane Area Elevations

4.5 Elevations of Individual Facility Components

The elevations of the individual components of facilities determine how high flood waters need to be in order to cause damage to the components. Many components, such as aeration basins and clarifiers, will only be disabled if flood waters go over the top of the component, mixing with the water within. However, some facilities have pumps in basements, so if flood water comes into the first floor of the structure housing them, these components would be completely submerged, disabling the facility.

4.6 Protective Structures

Defensive structures such as sea walls, dikes, and flood gates help to prevent damage to facilities due to flooding. They may increase the effective elevation of components, allowing for higher flood waters before a facility or component is disabled. To analyze these structures, effort must be taken to find both their presence in facilities around components, such as storm gates, and near facilities in the surrounding area, such as dykes and sea walls.

4.7 Combined Sewer and Storm Drain System

For wastewater facilities, combined sewer and storm drain systems will have an impact on the risk the facility faces. Combined sewer systems send runoff groundwater to a wastewater plant during a storm and significantly increase the inflow to the plant during these events. Therefore plants without a combined sewer system are at less risk than plants with combined sewer systems, as they will not have this increased inflow during a storm. It should also be considered that these systems will have overflow valves to prevent overwhelming flow to wastewater facilities and at the expense of releasing untreated sewage into the environment.

5 Risk Assessment Tool

Our hazard assessment procedure consists of two sections. The first is our risk assessment, which is a qualitative measure of the risk a particular plant faces from flooding and how this risk will change due to sea level rise. There are five factors we take into account when measuring the level of risk a wastewater facility and three factors for a drinking water facility. These factors are based on the risk factors detailed in Chapter 4. For a wastewater facility, we include FEMA flood zones, Army Corps of Engineers (ACE) hurricane inundation zones, past inundation, predicted ACE hurricane inundation zones, and combined sewer systems. For a drinking water facility, the three factors we used in our assessment are FEMA flood zones, ACE hurricane inundation zones, and predicted ACE hurricane inundation zones.

5.1 Development

To develop our risk assessment we first created assessment questions for each of the factors we had identified, which we could answer using data we had collected about each of the 18 wastewater plants and 17 drinking water systems we wanted to assess. We then assigned number values to each of the possible answers from the assessment questions in order to come up with a rating system for the overall facility. This risk assessment was used for both wastewater and drinking water and can be found in Appendix D. We did not include history of past flooding, and the combined sewer system factor when assessing drinking water systems. It is also important to note that for drinking water systems, the individual pump stations were analyzed due to the fact that many drinking water systems do not have a centralized treatment facility.

5.1.1 History of Past Flooding

For the first risk factor our question addressed if the facility had ever experienced past flooding which caused inundation or damage. This question was answered yes or no, and was assigned a numeric rating of zero for no and three for yes. The numeric rating of three for a yes was chosen because it is believed that past flooding which caused inundation or damage is an important indicator of a facility's risk of flooding, since if flood-related inundation or damage has happened before at a facility it will certainly be at more risk of flooding due to sea level rise and increased storm intensity than a facility which has not been inundated or damaged by flooding.

5.1.2 FEMA Flood Zones

For the second risk factor our assessment question is based on the facility's location within FEMA flood zones. If any part of the facility is located in a 100-year flood zone, it was assigned a rating of 2. Facilities located in a 500-year flood zone were assigned a rating of 1, and facilities located outside the flood zones were assigned a rating of zero. The 100-year flood zone was given the highest rating since if the facility is located in a 100-year flood zone it is also located in a 500-year flood zone.

5.1.3 ACE Hurricane Inundation Area

For our third risk factor our assessment question is based on which ACE hurricane inundation area the facility was located in. Facilities partially located in a category 1 or 2 area were given a rating of 2, facilities located in category 3 or 4 zones were assigned a rating of 1, and facilities located in no hurricane inundation areas were assigned a rating of zero. These number ratings were chosen because again, if a facility is located in a category 1 or 2 zone it will also be located in a 3 and 4 zone and so will be more at risk to flooding from a hurricane storm event.

5.1.4 Predicted ACE Hurricane Inundation Area

For our fourth risk factor, predicted ACE hurricane inundation area, we used the same assessment question and numerical ratings as we did for the current ACE hurricane inundation area, using the predicted levels as described in Chapter 4. We used this factor in order to get a sense of the future risks a facility may face due to sea level rise.

5.1.5 Combined Sewer System

For the final risk factor, combined sewer system, we simply asked if the sewer system that fed sewage to the facility was a combined sewer and storm drain system. If the answer was no it was given a rating of zero and if the answer was yes it was given a rating of one. This rating was chosen because we believe that while the presence of a combined sewer system increases the risk of flooding at the facility it was not as indicative of a facility's flood risk as past flooding, being located in any of the FEMA flood zones or ACE hurricane inundation areas.

5.1.6 Risk Assessment Scale

As explained above, a numeric value was assigned to each possible answer to the risk assessment questions. For mathematical simplicity we chose the lowest whole numbers. For a given facility the resulting numerical rating to each question would be added together for a total between 0-11 for wastewater facilities and 0-6 for drinking water facilities. These scales were broken up into three ranges that correspond to an overall facility risk rating of low, medium or high. For drinking water the scale was divided as: zero to two for a low rating, three to four for a medium rating, and five to six for a high risk rating. As for the division of the wastewater scale, zero to three represented a low risk rating, four to seven represented a medium rating, and finally, eight to eleven represented a high risk rating.

5.1.7 Future Risk Assessment Factors

Due to time constraints and difficulty in acquiring data, the following factors were not included in our risk assessment but should be considered in future development of the hazard assessment tool. The factors to be considered and integrated into the risk assessment for the future are protective structures and individual elevations of all the components, such as the primary clarifiers, aeration basins, flocculation basins, settling tanks, and pumps.

5.2 Applications

We applied our Risk assessment methodology to 18 wastewater and 17 drinking water facilities. The risk assessment tool is used to determine the level of risk the facility faces against rising sea levels and storm surge due to climate change. The tool is meant to be easily applied to both drinking and wastewater.

5.2.1 Wastewater

Below is an example of how the risk assessment tool is applied to a wastewater treatment facility. Hull Wastewater Treatment Plant is a good example because it received one of the highest ratings of all the assessments we completed.

Hull Wastewater Treatment Plant

Question	A	B	C	D	E	
Answer	yes	100 yr.	Cat. 2	no	Cat. 1 or 2	
Ans. # value	3	2	2	0	2	Total = 9

0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Table 5. 1: Hull Wastewater Risk Assessment

Risk Assessment

Table 5.1 shows the ranking the Hull Wastewater Treatment Plant received from our assessment. Hull Wastewater Treatment Plant has had past flooding which means that flooding is likely to occur again; however, the plant designers anticipated this and added storm gates to all openings to the building. The facility elevation is 9 feet above sea level and will remain above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. Being within the FEMA 100 year flood zone currently without the application of sea level rise means that there is at least a 1% chance that the plant will flood each year, shown below in figure 5.2. The facility is also within the Army Corps of Engineers Category 2 hurricane inundation zone; this is an indicator that the Hull Wastewater Treatment Plant is at risk of flooding due to storms, shown in figure 5.3. The facility does not have a combined sewer system which is why it received a zero in this area. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area that we found to be 14 feet, the plant was still within category 1 or 2 hurricane inundation zones.

Figure 5. 1: Hull WWTP Risk Assessment

Figure 5.1: FEMA Flood Zone map for the Hull Wastewater Treatment Plant. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)
*Note: This map and all of the following were created using GIS software.

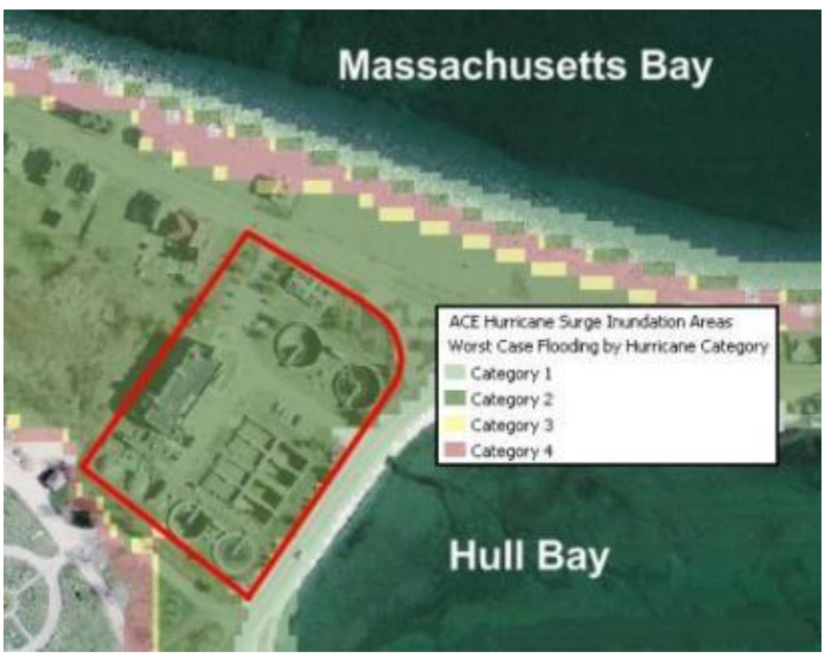

Figure 5. 2: ACE Hurricane Inundation Area map for the Hull Wastewater Treatment Plant

Provincetown Wastewater Treatment Plant

Question	A	B	C	D	E	
Answer	No	100 yr.	Cat. 2	no	Cat. 1 or 2	
Ans. # value	0	0	0	0	0	Total = 0

0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Table 5. 2: Provincetown WWTP Risk Assessment

Risk Assessment

Provincetown Wastewater Treatment Plant has no previous flooding occurrences. Therefore it was given a zero for that factor. It is also was given ratings of zero for FEMA flood zones and Army Corps of Engineers hurricane inundation zone because it was outside both these areas. The facility has an average elevation of 42 feet above sea level and will remain well above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to occur. The Provincetown Wastewater Treatment Plant also does not have any combined sewer/storm systems meaning it is not susceptible to an increase in flow due to storm water. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant not to be within any category of the predicted ACE hurricane inundation zones, again the facility was also given a zero for this situation. Provincetown's wastewater treatment facility is not at risk due to sea level rise according our assessment, receiving a zero for each factor.

Figure 5. 3 FEMA Flood Zone map for the Provincetown Wastewater Treatment Plant

The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)

Figure 5. 4: ACE Hurricane Inundation Area map for the Provincetown Wastewater Treatment Plant

Figure 5.5 below shows the risk rankings of the 18 costal wastewater treatment facilities with those in red receiving a high risk rating, orange a medium rating, and green a low risk rating.

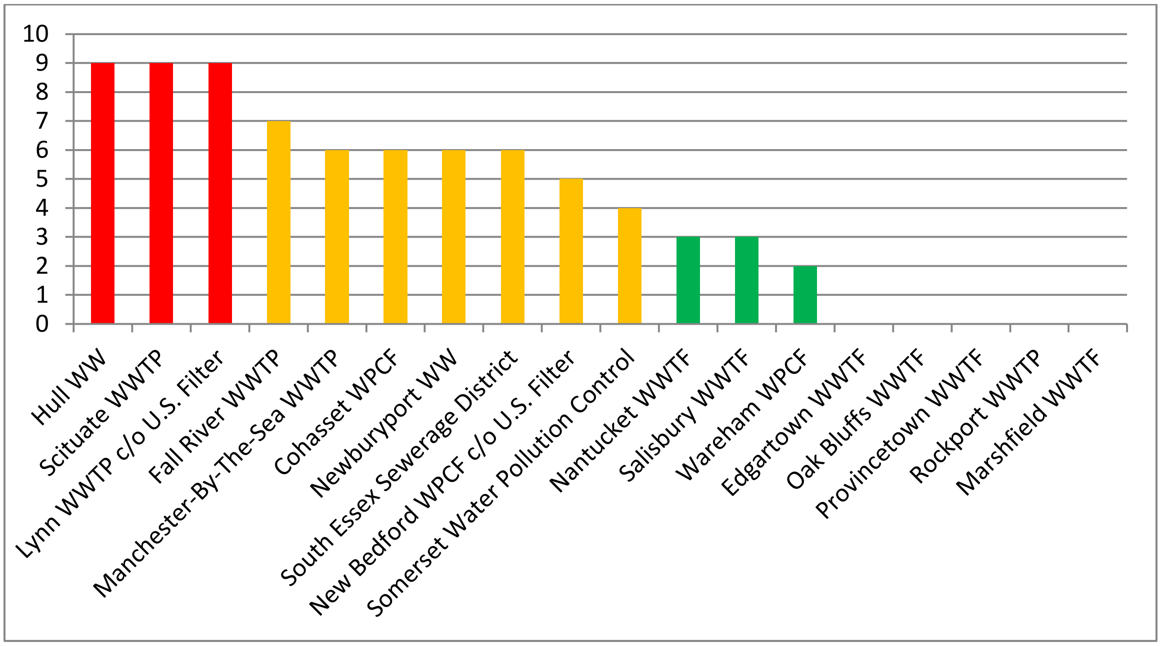

Figure 5. 5: Wastewater Risk Rankings

5.2.2 Drinking Water

Below is an example of the application of the assessment tool to a drinking water system. We used the Wareham Fire District Drinking system because, while all the pumps in the system are all in the low category, it shows how our assessment takes into consideration the location of individual pump stations and analyzes each pump station individually as well.

Wareham Fire District Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Wareham Fire District Maple Spring Wells #1-5	Answer Rating	none 0	Cat 3-4 1	Cat 3-4 1	 2
Wareham Fire District Maple Spring Wells #6-8	Answer Rating	None 0	None 0	None 0	 0
Wareham Fire District Proposed Maple Spring Well	Answer Rating	None 0	None 0	None 0	 0

0	1	2	3	4	5	6	
Low			Medium		High		Wells 1-5

0	1	2	3	4	5	6	
Low			Medium		High		Wells 6-8

0	1	2	3	4	5	6	
Low			Medium		High		Proposed Well

Table 5. 3: Wareham Fire District Drinking Water Risk Assessment

*Note, each Maple Springs well was analyzed separately, since their ratings are all identical they have been condensed into one table

Risk Assessment

None of the Wareham Fire District Maple Springs wells are within any FEMA flood zone. Locations of the wells are shown in Figure 5.6 as the green dots, while the FEMA flood zone is shown as the blue area. Only wells 1-5 are within a category three or four Army Corps of Engineers hurricane inundation zone and are predicted to remain in these categories for the next hundred years. Wells 6-8 and the proposed well are outside all Army Corps of Engineers hurricane inundation zones, shown in Figure 5.7. Thus, these wells are only at low risk of flooding.

Figure 5. 6: FEMA Flood Zone map for the Wareham Fire District Drinking Water

(500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)
*Note due to the scaling of the image some of the community groundwater wells appear to be within the 100 year flood zone, but they are not.

Figure 5. 7: ACE Hurricane Inundation Area map for the Wareham Fire District Drinking Water system.

Onset Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Onset Fire District Sand Pond Reservoir	Answer Rating	100 Year 2	Cat. 3-4 1	Cat. 3-4 1	4
Onset Fire District Well #3	Answer Rating	None 0	Cat. 3-4 1	Cat. 3-4 1	2
Onset Fire District Well #4	Answer Rating	None 0	Cat. 1-2 2	Cat 1-2 2	4
Onset Fire District Well #5	Answer Rating	None 0	Cat. 3-4 1	Cat. 3-4 1	2
Onset Fire District Well #6	Answer Rating	None 0	Cat. 3-4 1	Cat. 3-4 1	2
Onset Fire District Proposed Well #7	Answer Rating	None 0	Cat. 3-4 1	Cat. 3-4 1	2

0	1	2	3	4	5	6	
Low			Medium		High		Wells 3, 5, 6, 7
	1	2	3	4	5	6	
Low			Medium		High		Sand Pond Reservoir and Well 4

Table 5. 4 Risk Assessment Onset Fire District Drinking Water System

Risk Assessment

The Onset Fire District Sand Pond reservoir is within the FEMA hundred year flood zone but the district's wells are not in any flood zone, Figure 5.8. The wells and reservoir are all in category three or four hurricane inundation zones except for well four which is within a category one or two hurricane inundation zone, Figure 5.9. It is predicted that the wells and reservoir will all stay within their respective zones within the next hundred years.

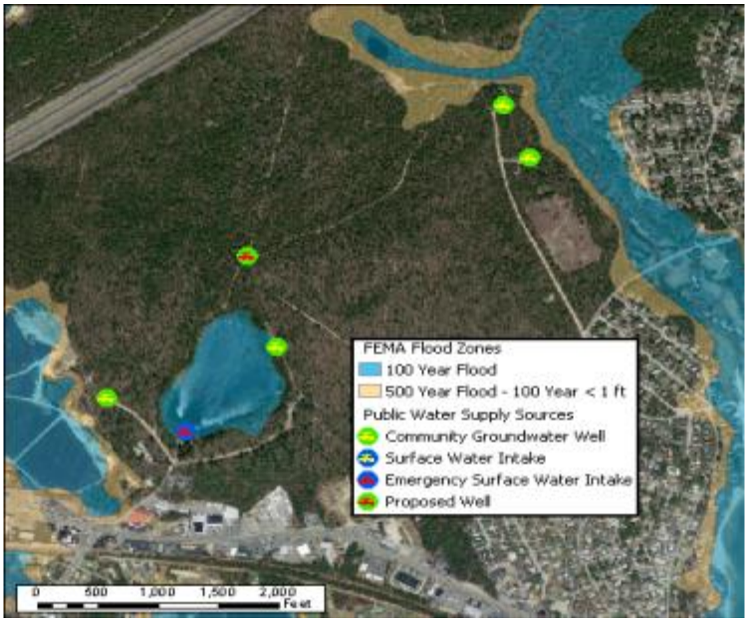

Figure 5. 8: FEMA Flood Zone map for the Onset Fire District Drinking Water System

(500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)

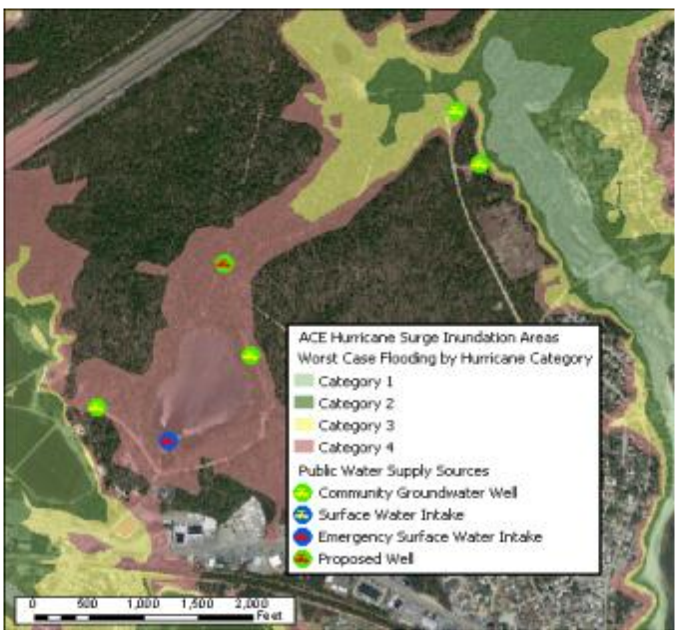

Figure 5. 9: ACE Hurricane Inundation Area map for the Onset Fire District Drinking Water System

Figure 5.10 below shows an average of the risk ratings of all system components by town. We did not use this average in our evaluations; instead we analyzed each component on its own. The orange bars represent systems with an average medium risk and the green bars represent systems with an average low risk. In some systems with low risk ratings there may be individual components which are at high risk, such as Edgartown's Lilly Pond Well that received a high risk rating of 6. However individual wells can be shut down or isolated in case of flooding allowing other components to continue to provide drinking water.

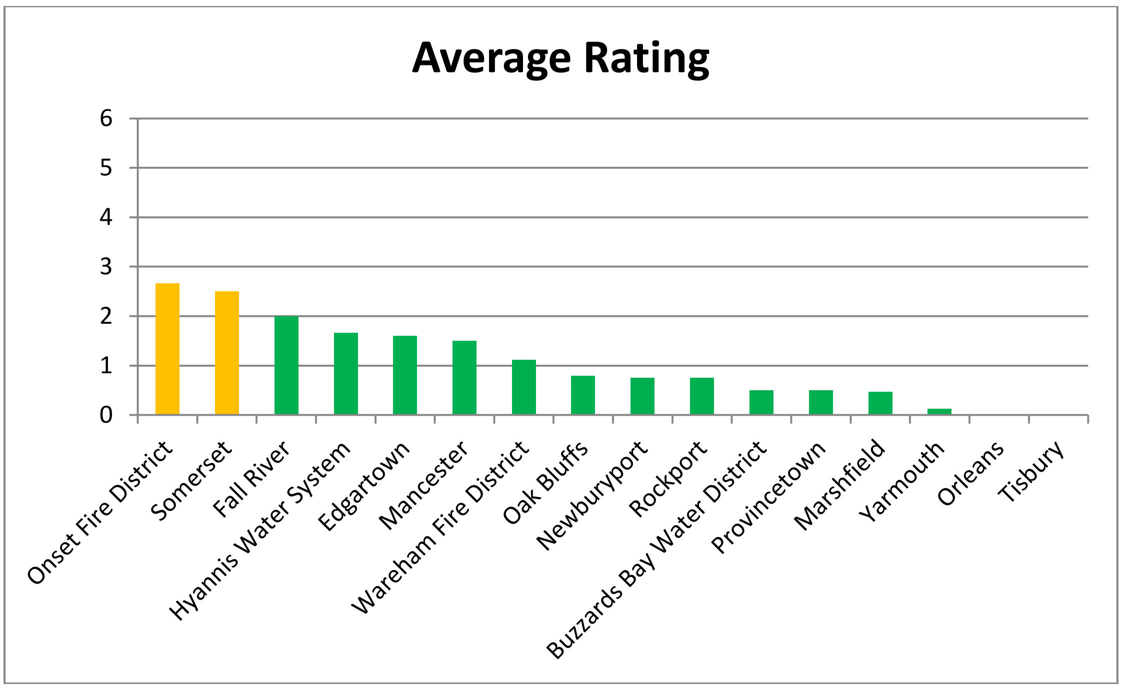

Figure 5. 10: Average Risk Ranking for Drinking Water Systems

6 Impact Factors

In order to evaluate the impact of flooding on a facility and surrounding area, we identified the following factors, which measure the effects that will occur when a facility is inundated. We found these factors through interviews with plant personnel, experts at the MassDEP, and other research of reports related to climate change and the effects of flooding. They cover a wide variety of situations and were chosen to identify which wastewater and drinking water facilities should be the focus of MassDEP's efforts after risk is taken into account.

6.1 Source Type

The distinction between the different types of water sources is of importance to note. Surface water sources such as ponds and reservoirs are open to flood waters and thus can be contaminated in the event of flooding and storm surge. Ground water sources have a natural filter that reduces the chance of them being contaminated by floodwaters. It should also be noted that because surface water sources are open to floodwaters they are regularly treated while groundwater sources are not.

6.2 Population Served

The population served by a drinking water plant is important to note. Should the plant cease to function due to flooding, the population serves as a measure of the number of people who will be without drinking water. It should be noted that many coastal populations, especially around Cape Cod, have large fluctuations between the summer and winter months due to tourism. In these cases we have measured population based on the summer months as this will account for the worst case scenario should a system be flooded.

6.3 Average Outflow Rate and Storage Capacity

The rate at which water flows from drinking water systems is also important to consider. Systems with greater average flow rates will expend their stored water much faster should flooding render them unable to treat additional water. It is important to know the amount of drinking water that can be stored as this will affect the amount of time the facility can supply clean drinking water while recovering from a flood when compared to the average outflow rate. It is important to realize the various factors that affect water usage rates such as the distinction between residential water use and industrial water use. It should also be noted that, for some coastal towns, population fluctuates significantly in the summer and winter due to tourism. In these cases it would be helpful to find the days of storage for both winter and summer months.

6.4 Average Inflow Rate and Design Flow Rate

For wastewater facilities, it is important to measure the permitted inflow relative to the facility's design flow. The risk of flooding is increased the closer a plant is to operating at capacity as a smaller increase in floodwater and subsequently flow is required to exceed the plants' capacity. The difference between these rates reveals the stress the system is under, thus plants with higher average flow rates compared to their design flow rates should be more prepared for flooding as they have less margin for failure should the plant flood.

6.5 Bypass capabilities

The bypass methods available to a wastewater treatment plant will influence the impacts a flooded plant will have on the surrounding people and environment. The ability for a plant to bypass will allow the plant to avoid excessive damage from increased flow that would otherwise render the plant inoperable. While we can assume the coastal plants we have analyzed will not bypass untreated sewage into a drinking water source, there is still the potential for the contaminants to negatively impact the environment. Boston Harbor, which received untreated sewage until 1972 (USEPA 2011), is a telling example of such impacts. There is also the damage the absence of bypass could cause to the facility. Facilities without the ability to bypass from primary to secondary treatment tanks risk losing the bacteria in their activated sludge. Recovering these bacteria is costly and time consuming, leaving the plant unable to process wastewater in the interim.

6.6 Non-residential Wastewater Producers

Surrounding wastewater producers also have a great effect on the impact of flooding. Industrial processes that contaminate large amounts of water and other large contaminators like restaurants, industrial plants, and small businesses can overload a facility that has become completely or partially inoperable from flooding. These wastewater producers may be required to cease production of wastewater should such an event occur. In this situation, greater impacts beyond those to residents will occur that can have a negative effect on the economy of the area.

6.7 Replacement Parts

Plants that store replacement parts will be better prepared to recover from flooding. As we learned from interviews at the Hull Wastewater Plant, replacement parts are made to order which takes additional time on top of delivery. Plants with multiple backup parts will be able to respond more quickly to equipment failure and reduce the impact of flooding. Figure 6.1 below shows a portable pump motor as an example of backup equipment that is key to keeping the Hull wastewater treatment plant functioning in the event of damage due to flooding.

Figure 6. 1: Portable Pump Motor

6.8 Mutual Aid Agreements

Mutual aid agreements can significantly improve impact response to flooding. As we found both at the Hull wastewater treatment plant and Provincetown wastewater treatment facility, communication and cooperation with other local organizations will give a water utility access to more workers and faster response times in an emergency. The creation of a network between plants will also allow for greater ease in the sharing of data allowing plants to develop, test, and evaluate response strategies and defense measures more quickly and effectively.

6.9 Interconnections

Interconnections are pipelines that allow the connected facilities to send finished drinking water to one another in the event of one system becoming unable to deliver finished water by itself. These interconnections help reduce the negative impact of flooding on a drinking water system as it allows the system to have a backup source should it be unable to process water.

6.10 Environmental Impacts

The various risks caused by combined sewer systems have already been discussed; however, there are associated impacts resulting from CSOs as well. While we can reasonably assume that coastal facilities and their sewer systems will discharge into or close to the ocean such that we need not worry about untreated sewage reaching drinking water systems, we need to look at the potential impact this could have on the environment. Environmental areas like marshlands downstream from wastewater facilities and their combined sewer systems can be surveyed for and studied to find the impact untreated sewage will have. The average inflow to wastewater facilities can also be used to estimate the amount of sewage that can potentially be released and thus cause greater environmental impacts.

7 Impact Assessment Tool

In order to gauge the negative impact a flood of drinking water or wastewater infrastructure would have on the community or communities the infrastructure serves, we used the factors described in Chapter 6 to create a tool to assign values to drinking water and wastewater systems, such that higher values corresponded to worse impacts.

7.1 Development

The development of the impact assessment tools required balancing multiple factors. The tools needed to be detailed enough to be used to compare facilities and gauge the severity of the impacts of flooding or storms on the community. However, these tools also needed to be simple enough to allow them to be applied easily and quickly to a large number of facilities. Additionally, they needed to only use data that were easily obtainable so that we would be able to apply the tool to the facilities we assessed. Below are descriptions of the drinking and waste water impact assessment tools and descriptions of the factors that were not used in these assessments.

7.1.1 Drinking Water

The factors related to impacts of flooding of drinking water systems that we identified and used in our assessments were the type of source raw (untreated) water is taken from, the number of people served by the drinking water system and how long the finished (treated) water storage would last in the event that the system would be unable to produce more finished water, either due to contamination of water sources or disabling of pump stations and wells. The population served by the system is an indicator of the number of people who would be impacted by risks to drinking water systems. The amount of time the system's stored finished water would last assuming that the stores were not being replenished indicates how much time the population would have to react to the impacts on their drinking water system.

The type of source the water is taken from by a drinking water system is important to consider because surface water sources are more prone to contamination due to runoff during a flood than groundwater sources are. A system that uses surface water as a water source, even if the system also had groundwater sources, was given a rating of 1, while systems that used only groundwater sources were given a rating of 0. The type of each source in a drinking water system is reported in the annual reports sent to MassDEP by drinking water system administrators.

The population served by a drinking water system is important to consider because a larger population means that more people will be impacted by a lack of drinking water should a system fail. In order to rank the systems based on population, we compared the populations served by all the systems we were assessing, and split them into three categories such that there were an approximately equal number of systems in each category. Systems which served a population of less than 15,000 were given a score of zero for this factor, while systems which served a population greater than 15,000 and less than 30,000 were given a score of one, and systems which served a population of more than 30,000 people were given a score of two. The population served by a drinking water system is reported by the system administrator in the yearly report sent to MassDEP. This scoring system is based entirely upon the population figures of the facilities we assessed, and may not be valid to use for assessing other systems.

The amount of time a system's stored finished water would last was calculated by dividing the finished water storage capacity of the system by the average daily amount of water the system distributes. This factor is important because the longer the system can distribute finished water to its population, the more likely the system will be operational before running out of stored water, and the longer the population will have to react to losing their source of drinking water. We assigned systems which have under one day of storage a score of three, systems which have at least one day of storage and less than two days of storage a score of two, systems which have at least two days and less than three days of storage a score of one, and systems which have more than three days of storage a score of zero. It is possible that this measure may be inaccurate, due to the possibility that a system may not have their storage tanks filled to capacity with finished water. The data on average flow rate and storage capacity are reported in the annual reports sent to MassDEP by the administrators of drinking water systems. Additionally, we did not take into account differences in water usage based on time of year. More accurate data on finished water storage and how water usage changes throughout the year in each water system could be used by MassDEP to create a more detailed assessment.

Factors that we identified but did not include in our assessment are: interconnections the system has with other nearby systems, disinfection methods, available emergency water sources, and water usage by different users. We did not have direct access to information pertaining to the systems' interconnections with other water systems, and we were unable to collect these data in time to include this factor in our assessments. The methods of disinfection used by drinking water treatment facilities were available to us in the data stored in MassDEP's Document Repository Tracking System (DRTS), but we did not know enough about the effects these different methods would have on the ability of a drinking water system to respond to a flood to be able to rank facilities based on this factor. The emergency water sources available to a drinking water system in the event of a flood are generally not registered with MassDEP, so acquiring these data would require asking the administrators of drinking water systems for the information. MassDEP could use figures for drinking water usage by residential, industrial, and commercial users available in DRTS to determine the human and economic impacts of a drinking water system being disabled.

7.1.2 Wastewater

The factor we used to assess the impact of a flood or other sea level rise related event is the ratio of the average flow rate at a wastewater treatment facility to the design flow capacity of that facility. This ratio measures how close to maximum capacity a wastewater treatment facility operates. A facility which operates close to maximum capacity will be less able to handle an increase in inflow which may be caused by a storm or flood than that another facility which does not operate close to maximum capacity. Since this is the only factor we used to rate the facilities, we did not assign values to these ranges. Facilities which have an average flow rate of up to 50% of their design capacities were rated as low impact, facilities with an average flow rate above 50% and up to 70% of their design capacities were rated as medium impact, and facilities with an average flow rate above 70% of their design capacities were rated as high impact.

MassDEP does not currently store information regarding the ability of wastewater treatment facilities to bypass treatment or bypass only secondary treatment in a central location, although staff in the MassDEP regional offices have this information for the facilities they are assigned to. Similarly, there are no databases with spare parts inventories, nor is there any information as to whether the administrators of the wastewater systems have any mutual agreements with neighboring systems to provide aid in the event of an emergency. These factors may be considered in future investigations, but the information must be gathered from each individual system as it is unavailable in MassDEP's current databases.

7.2 Application

Below are examples of the impact assessment being applied to drinking water systems and wastewater facilities. We applied this assessment to a total of 26 facilities and systems.

7.2.1 Drinking Water

Below are two examples of the impact assessment being applied to drinking water systems. The drinking water impact assessments for all 16 facilities can be found in Appendix M, we omitted one system which purchases its water.

Hyannis Water System

The Hyannis Water System received a high impact rating on our assessment, as shown in Table 7.1, because the department serves a large population and has less than one day's worth of storage. The Hyannis Water System serves a maximum population of 35,000 with an average rate of 2.39 million gallons per day. The department's storage capacity is 1.37 million gallons. The Hyannis Water System has the ability to store 0.57 days' worth of water at the average flow rate.

Location		Source	Pop	Days Stored	Totals
Hyannis Water System	Answer Rating	Ground 0	Above 30,000 2	Less than 1 day 3	High 5

0	1	2	3	4	5	6
Low			Medium		High	

Table 7.1: Hyannis Water System Assessment

Manchester Water Department

The Manchester Water Department received a low impact rating on our assessment, as shown in table 7.2, because the department gathers its water from a surface source but serves a population of less than 15,000 and has over three days worth of finished water storage. The Manchester Water Department serves a year round population of 5,469, with an average flow rate of 0.72 million gallons per day. The department's storage capacity is 2.22 million gallons. The Manchester Water Department has the ability to store 3.07 days' worth of water at the average flow rate.

Location		Source	Pop	Days Stored	Totals
Manchester Water Department	Answer Rating	Surface 1	Below 15,000 0	Above 3 days 0	Low 1

0	1	2	3	4	5	6
Low			Medium		High	

Table 7.2: Manchester Water Department Assessment

7.2.2 Wastewater

Examples of the impact assessment being applied to wastewater facilities are discussed below. We only have complete information for 10 of the 18 facilities we investigated, so there are fewer impact assessments for wastewater facilities than there are risk assessments. The impact assessments for these 10 facilities are located in Appendix L.

Scituate Wastewater Treatment Facility

If the Scituate Wastewater Treatment Plant becomes unable to process incoming wastewater, up to 1.24 million gallons of wastewater every day may flood the plant and the surrounding area. The plant has a design flow capacity of 1.6 million gallons. The facility received a large impact rating because the ratio of average flow to design flow yielded a value of 78%.

Hull Wastewater Treatment Facility

Hull Wastewater Treatment Facility's average flow rate is 42% of its design flow rate. We gave it a small impact rating, as the facility would need to more than double its average inflow rate to exceed capacity. If the Hull Wastewater Treatment Plant becomes unable to process incoming wastewater, up to 1.3 million gallons of wastewater every day may flood the plant and the surrounding area. Hull Wastewater Treatment plant has a design capacity of 3.07 million gallons per day; however, its average inflow is only 1.3 million gallons per day. The plant operators and town planners at the Hull Wastewater Treatment plant have realized the danger the facility is in and as such have begun planning. Below in figure 7.1 is an image given to us by the Chief Facilities Manager of Hull Wastewater Treatment Plant, Edward Petrilak. It depicts what would happen to the facility during a 100 year storm if the sea levels rose an additional 1.6 feet.

Figure 7.1: ASA, CZM Hull Wastewater Treatment Plant Flooding Map

8 Conclusion

The goals of our project were to develop a hazard assessment tool with which we could identify coastal wastewater and drinking water treatment systems with a high risk of flooding due to sea level rise and would have a large impact if flooded. This information may be used by the Massachusetts Department of Environmental Protection (MassDEP) so that they may better allocate their mitigation efforts and resources.

Based on research of climate change related reports, interviews, and onsite visits, we believe that many facilities are at risk or will be at risk of flooding due to sea level rise and in some instances head facility personnel underestimate this threat. To aid MassDEP in identifying which water utilities are most at risk of flooding due to sea level rise, we have developed a hazard assessment tool which takes into account various factors that have been, or can be, readily measured. Application of this tool produces a ranking of which facilities are most at risk relative to one another. Facility operators and personnel can themselves use this hazard assessment to determine their own vulnerabilities and begin to prepare by implementing mitigation measures such as storm gates or multiple backup systems. In conclusion we believe we have successfully created a useful assessment tool that can be used by the MassDEP and coastal water utilities to assess flood risks and potential impacts. Concurrently we have also supplied MassDEP with recommendations on how to improve this tool and on which facilities the MassDEP should focus their mitigation efforts.

8.1 Recommendations

Through our research, data collection, and interviews, we have identified additional factors that could be included in future improvements of the risk and impact assessment tool. Additionally, aside from our main recommendations on the improvements to the assessment tool, we identified possible measures and technologies being used to prepare facilities for flooding due to sea level rise. This section addresses these identified future assessment tool factors, additional measures and the recommendations that go along with them.

8.1.1 Future Additions to Assessment Tools

The following is a description of the future factors we believe should be considered when making any additional changes to the assessment tools. We include future considerations for both the risk assessment and impact assessment.

8.1.1.1 Future Risk Factors

Due to time constraints and difficulty in acquiring data, the following factors were not included in our hazard assessment but should be considered in future developments.

The first factor to be considered for the future is the elevation of individual components at a wastewater treatment facility. The elevations of the individual components of facilities determine how high flood waters need to be in order to cause damage to the components. Many components, such as aeration basins and clarifiers, will only be disabled if flood waters go over the top of the component, mixing with the water within. However, some facilities have pumps in basements, so if flood water comes into the first floor of the structure housing them, these components would be completely submerged, disabling the facility.

The second factor to be considered is the presence of defensive structures at a treatment facility or in the drinking water distribution system. There are many defense measures that are already in use in some Massachusetts water utilities that can reduce the risk as well as mitigate the effects of flooding. Defensive structures such as raised structures, sea walls, dykes, and storm gates help to prevent damage to facilities due to flooding. They may increase the effective elevation of components, allowing for higher flood waters before a facility or component is disabled. To analyze these structures, effort must be taken to find both their presence in facilities around components and near facilities in the surrounding area.

8.1.1.2 Future Impact Factors

Future impact factors to be considered for wastewater facilities include existence of a bypass system, spare part inventories, backup systems, and mutual aid agreements. MassDEP does not currently have information regarding the ability of wastewater treatment facilities to bypass treatment or bypass only secondary treatment. Similarly, there are no databases with spare parts inventories, nor is there any information as to whether the administrators of the wastewater systems have any mutual agreements with neighboring systems to provide aid in the event of an emergency. For example, through interviews in Provincetown and Hull we found that facilities that communicate with other local utilities were able to receive aid more quickly in response to emergencies. Aid might include use of another facility's equipment, or in some cases sharing of manpower between these local utilities. Creating stronger bonds between local organizations, along with a good working relationship with nearby facilities, will allow greater cooperation between Massachusetts facilities and greater communication with the MassDEP. In Hull it is common for the backup systems to be tested by using them under full load to run the plant instead of only inspecting the backup system making sure each individual component works. Replacement parts are also kept available at all times because ordering needed parts can be time-consuming to obtain and install. These factors may be considered in future investigations, but the information must be gathered from each individual system, as it is unavailable in MassDEP's current databases.

Future impact factors to be considered for drinking water systems include interconnections the system has with other nearby systems, disinfection methods, available emergency water sources, and water usage by different users. We did not have direct access to information pertaining to the systems' interconnections with other water systems, and we were unable to collect these data in time to include this factor in our assessments. The methods of disinfection used by drinking water treatment facilities were available to us, but we did not know enough about the effects these different methods would have on the ability of a drinking water system to respond to a flood to be able to rank facilities based on this factor. The emergency water sources available to a drinking water system in the event of a flood are generally not registered with MassDEP, so acquiring these data would require asking the administrators of drinking water systems for the information. MassDEP could use figures for drinking water usage by residential, industrial, and commercial users to determine the human and economic impacts of a drinking water system being disabled.

8.1.2 Recommendations to MassDEP

We suggest greater transparency, meaning more open communication, between the MassDEP, EPA, Massachusetts Water Works Association, New England Water Works Association, New England Interstate Water Pollution Control Commission, and other such state agencies across the country and a more comprehensive networking system. Much of the data we found was stored in individually isolated locations or otherwise difficult to obtain without contacting the individual in charge of each database. This takes considerable time. The database network within MassDEP is similarly fragmented in that it is composed of several databases with no central organized system. As such, it is difficult to access information without specific knowledge of its location. Making these data more accessible will not only serve to increase efficiency but will allow the various organizations within MassDEP to better understand what is already known and what isn't.

Similarly, MassDEP and water utilities lack a central database with readily accessible data regarding structural, historical, and technical information about Massachusetts's drinking water and wastewater facilities, for example the structural barriers in place at a treatment facility. Additionally, there are advantages to be gained from an increase in cooperation between MassDEP, water treatment facilities, and other local organizations, mainly in times of emergencies such as flood related events.

Glossary

- Environmental Protection Agency (EPA)
- Geographical Information Systems (GIS)
- Intergovernmental Panel on Climate Change (IPCC)
- Massachusetts Department of Environmental Protection (MassDEP)
- Maximum contaminant levels (MCLs)
- Safe Drinking Water Act (SDWA)
- Federal Emergency Management Agency (FEMA)
- Army Corps of Engineers (ACE)
- United State Geographical Service (USGS)
- Wastewater Treatment Plant (WWTP)
- Wastewater Treatment Facility (WWTF)
- Water Pollution Control Facility (WPCF)
- MassDEP Document Repository Tracking System (DRTS)

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Appendix A – Sponsor Description

Massachusetts Department of Environmental Protection

The Massachusetts Department of Environmental Protection's (2011a) stated mission is "The Department of Environmental Protection is the state agency responsible for ensuring clean air and water, the safe management of toxics and hazards, the recycling of solid and hazardous wastes, the timely cleanup of hazardous waste sites and spills, and the preservation of wetlands and coastal resources" (para. 1). It is a State department that is funded by the Massachusetts government. Its budget for the 2010 fiscal year was $53.699 million (Massachusetts Executive Office of Energy and Environmental Affairs, 2010).

The Massachusetts Department of Environmental Protection (MassDEP) (2011c) has a hierarchal structure, with the Commissioner at the top. The Deputy Commissioners of the Operations, Policy and Planning, Administrative Services, General Counsel, Legislative and Budgetary Affairs, and Public Affairs offices report directly to the Commissioner, who is appointed by the Secretary of Energy & Environmental Affairs. Under the Operations, Policy and Planning office are the Bureau of Policy and Planning (of which Douglas Fine, our primary liaison, is the Assistant Commissioner), the Bureau of Resource Protection (of which Ann Lowery, another liaison, is the Acting Assistant Commissioner), the Bureau of Waste Prevention, the Bureau of Waste Site Cleanup, and the Office of Research and Standards. We expect to be working very closely with the Bureau of Policy and Planning, as our primary liaison is its Assistant Commissioner. We also expect to work closely with the Bureau of Resource Protection, especially since their Division of Watershed Management has a Wastewater Management program that deals with storm water management and wastewater treatment plants and a Drinking Water Program that deals with water supply infrastructure.

MassDEP has many resources that they may be able to leverage to help us in our project. They are currently conducting research on climate change adaptation and the effects of climate change on the water infrastructure, the results of which should be extremely helpful to us. They also have many experienced individuals (MassDEP 2011b) who are familiar with the issues we are investigating, whose knowledge and expertise could be leveraged to great effect.

MassDEP is the only organization working on the specific problem presented by the project, but other states' Departments of Environmental Protection are working on similar problems in their own states. MassDEP does not claim to cooperate with other states' DEPs, and it does not appear that they share significant amounts of research, if they share any at all.

Appendix B – Interview Questions

<u>Questions for Professor Seth Tuler</u>

- Tell us a little about your background.
- Can you give us a synopsis of your area of interest?
- How big a role do you think government officials and local planners have in improving water utilities defense against rising sea levels compared to the role of the public and other lay men.
- What are some effective methods to help us successfully communicate the risks we find and urge response to them?

<u>Questions for Professor John Bergendahl</u>

- Can you describe for us how seawater or fresh water flooding might affect the biomass in wastewater treatment?
- Are there any processes that would be affected more negatively by floodwaters than others processes present at the treatment facility?
- What if the treatment facility is flooded?
    - Where does the excess water go?
    - How much time can it take for a facility to recover from a flood and begin operating?
- Are there procedures used by water utilities to prepare/protect them from severe storms?
- Do you know of any prevention plans to protect against flooding? If yes, common examples?

- If we were presenting information about the importance of preparing water treatment facilities to deal with sea level rising, what would be the most effective method?
- What topics/issues would you say are key for this information to cover, if any?
- What would you say your opinion is on the risk of rising sea levels effects on water utilities?

<u>Questions for Design Engineers:</u>

We are an undergraduate student from Worcester Polytechnic Institute doing a two-month, full-time project with the Massachusetts Department of Environmental Protection (MassDEP). Our project has two goals are:

> 1) Identify effects of climate-change related sea level rise and floodwaters on Massachusetts coastal wastewater and drinking water facilities
>
> 2) Communicate these risks to facility managers and other stakeholders

1. We understand that you are a ____________ at _____________, could you please describe your responsibilities here and your area of expertise?
2. Can you give us an overview of your general research and design process when it comes to water utilities?
3. Do you consider climate change and sea level rise in your design, how big of a factor are they?
    a. If so, how do you address it, i.e. do the permit requirements satisfactorily address sea level rise or must you go above and beyond to address the issue.
4. What is the greatest degree of flooding you design your plants to withstand against? (10 year, 100 year, etc.)
5. What, if any, new designs have been proposed or considered with the recent hurricane events (Irene and Katrina) and if not is there a desire to create any?

6. Do you mind if we contact you in the future for feedback concerning any material or information that we may come up with in the future?

<u>Questions for Wastewater</u>:

We are an undergraduate student from Worcester Polytechnic Institute doing a two-month, full-time project with the Massachusetts Department of Environmental Protection (MassDEP). Our project has two goals are:

1) Identify effects of climate-change related sea level rise and floodwaters on Massachusetts coastal wastewater and drinking water facilities

2) Communicate these risks to facility managers and other stakeholders

1. We understand that you are a ____________ at _____________, could you please describe your responsibilities here and your area of expertise?
2. What is the number of past flooding occurrences this plant has suffered?
    a. What were the associated impacts on your facility and its operation?
    b. Do you know the year that these floods occurred?
3. During these occurrences has flooding caused the facility to have to by-pass incoming wastewater?
    a. Where does the by-pass go?
4. What worries you the most about a facility flooding?
    a. What equipment and/or treatment processes do you believe are most at risk of flooding?
5. Do you believe that the current flood strategy at this facility is an efficient strategy? Could you please rate it on a scale of 1-10?
6. Do you have any concerns about the impacts of sea level rise to your wastewater facility?
    a. If so, what are they/ which is your biggest?

    b. If so, do you have any plans to make changes within the utility to withstand these effects?

7. What do you, as a utility, see as a major road block for readying for floods/sea level rise?
8. What information would be most helpful in explaining the risks? Should we give specific examples of how the changes will affect the system, how much change sea level rise has caused in Massachusetts and/or specific other communities that have already started planning to mitigate risk?
9. What medium would be most accessible to stakeholders? (I.e. short pamphlet, PowerPoint/slides, or some form of online resources?)
10. If we proposed possible adaptation that could be implemented at your facility what would be the principal considerations for you i.e. cost, time, higher priorities for capital investments?
11. Do you have any local maps or other documents such as plant layout drawings?
12. Do you mind if we contact you in the future for feedback concerning any material or information that we may come up with in the future?

Questions for Drinking Water:

We are an undergraduate student from Worcester Polytechnic Institute doing a two-month, full-time project with the Massachusetts Department of Environmental Protection (MassDEP). Our project has two goals are:

1) Identify effects of climate-change related sea level rise and floodwaters on Massachusetts coastal wastewater and drinking water facilities

2) Communicate these risks to facility managers and other stakeholders

1. We understand that you are a ____________ at _____________, could you please describe your responsibilities here and your area of expertise?
2. Have you experienced an emergency related to sea level rise and/or flooding during your career here?
    a. Do you believe the flooding was or wasn't related to climate change?
3. What is the number of past flooding occurrences this plant has suffered?
    a. What were the associated impacts on your facility and its operation?
    b. Do you know the year that these floods occurred?
4. Do you believe that the current flood strategy at this facility is an efficient strategy? Could you rate it on a scale of 1-10?
5. Do you have any concerns about the impacts of sea level rise to your drinking water utility?
    a. If so, what are they/ which is your biggest?
    b. If so do you have any plans to make changes within the utility to withstand these effects?

6. What do you, as a utility, see as a major road block for readying for floods/sea level rise?
7. What information would be most helpful in explaining the risks? Should we give specific examples of how the changes will affect the system, how much change sea level rise has caused in Massachusetts and/or specific other communities that have already started planning to mitigate risk?
8. What medium would be most accessible to stakeholders? (I.e. short pamphlet, PowerPoint/slides or some form of online resources?)
9. If we proposed possible adaptation that could be implemented at your facility what would be the principal considerations for you i.e. cost, time, higher priorities for capital investments?
10. Do you have any local maps or other documents such as plant layout drawings?
11. Do you mind if we contact you in the future for feedback concerning any material or information that we may come up with?

Appendix C – Interviews with Resource Persons

Tuler Interview Location: SL 334
MADEP
Thursday, April 07, 2011
Attendees: Adam Bluenau (Chair), Alicia Turner(Secretary), Professor Seth Tuler

I. Area of research
 a. Structured discussion climate change adaptation with planning officials in South Carolina

II. Advice
 a. Key people we should talk to?
  i. Town officers because they are the Planners.
  ii. Also need the town people's support
 b. Suggest small changes that are needed now and that will be helpful in the future.
  i. Small changes will get planners involved
 c. Media
  ii. Gear media to simple immediate changes not just stuff that will need to change in 30 or 50 years
  iii. Also include where residents can get assistance
  iv. Include examples/case studies
  v. Might want to create some geared at towns people

III. Helpful sites/people
 a. Review Professor Tuler's website and projects
 b. Look into the Sea Grant Program
 c. Check out ICLEI website and research
  i. Try to contact Missy Stults
 d. Other possibly helpful people
  i. Joan Carmin (MIT)
  ii. Ellen Douglas (EEOS)
  iii. Lee Tryhorn (Cornell)
   1. Did a presentation in Seattle in Jan. at a conference held by the AMS on NY Wastewater Facilities

IV. Action Items
 a. Group
  i. Review Prof. Tuler's presentation (Sunday, 4/10, 11 am)
  ii. Look at ICLEI website and into the Sea Grant Program

V. At Next Meeting
 a. Email persons listed above about possible interviews

Email Interview Transcript
Professor John Bergendahl
April 17, 2011

- Can you describe for us how seawater or fresh water flooding might affect the biomass in wastewater treatment?

The seawater would probably kill the bacteria used in biological treatment. Freshwater flooding would dilute the biomass making the treatment process ineffective.

- Are there any processes that would be affected more negatively by floodwaters than others processes present at the treatment facility?

I would guess that electrical motors (pumps and actuators) would not work if they are wet. So all processes requiring pumps would be shut down: aeration, sludge pumping, etc.

- What if the treatment facility is flooded?
    - Where does the excess water go?

Water will go to the lowest point – gravity will drive it.

-
    - How much time can it take for a facility to recover from a flood and begin operating?

First, the water has to recede. Then all electrical systems need to be restored/replaced. Most systems are instrumented, and much of that instrumentation could be impacted. Then, from a process point-of-view, the biological consortium will need to be "grown" again. That is, the microorganism in the activated sludge process will need time to increase back up to effective concentrations. That can take days to weeks, depending on conditions, including temperature.

- Are there procedures used by water utilities to prepare/protect them from severe storms?

Most facilities will try to have adequate bypass, so the facility itself won't be flooded out.

- Do you know of any prevention plans to protect against flooding? If yes, common examples?

No, they bypass when the system can't handle the flow anymore.

- If we were presenting information about the importance of preparing water treatment facilities to deal with sea level rising, in your opinion what would be the most effective method?

I think if a facility had to deal with regular flooding, I would think they would locate the facility somewhere else (higher), or try to increase the elevation of the plant on-site.

- What topics/issues would you say are key for this information to cover, if any?

Cost. It is always an issue, because someone has to pay for it.

- What would you say your opinion is on the risk of rising sea levels effects on water utilities?

I don't know. I can't imagine it is an issue short term. And many facilities will have been rebuilt and upgraded many times before it is an issue.

Newburyport September 20th, 2011

Paul Colby – Superintendent of Newburyport Waterworks

- Been working at plant for 36 years
- Knows of two major flooding events Mother's day flood and Merrimack river flood in 1936
- Concern over water runoff through farms as the extra nutrients create algae blooms that hamper water filtration
- Water temperature was a factor in filtration
- Cared about water appearance, even if water was clean, needed to be filtered so it wasn't yellow
- Enacting an $18 million improvement project to replace their clear well (which was cracked) and update their equipment
- They have a SCATA(?) system that monitors all the components in the plant and allows the operators to respond to alarms
- Built new facilities in 2005 to allow them to supply water to plum island
- No flooding problems with the Merrimack river in the time he has been there
- Largest concern was losing power
- Bartlett spring pond has dykes around it as it is most vulnerable to flooding
- Thought it would be more efficient to upgrade a facility than to build a new one
- Thought a brochure to communicate our findings would be best

Robert Bradbury – Assistant Chief Operator Barry Yaceshyn – Consultant Engineer

- Remembers four major flood events in the past 25 years
- Never had to bypass (their bypass system is sealed off)
- Equipment failure and losing power is greatest concern
- Currently under construction to renovate all their equipment
- Not concerned about sea level rise
- Need for the plant to reduce smell and noise
- Thought a brochure to communicate our findings would be best

Provincetown September 22nd, 2011

Chris Rowe – Plant Operator

- Plant uses an air vacuum system to collect waste and bring it to station
- 1-3 houses have a small vacuum system that collects wastewater and pumps it to a central pump station when it fill
- Pump station collects all the waste and send it to the plant to be processed
- The plant has an emergency response plan with a section specifically set against flooding
- Has a good relationship with the community
- Has the ability to call up surrounding stations and borrow employees
- Primary concern is happiness of the client/community, then cost
- Preferred an online resource to communicate our results

Carl Hillstrom– Drinking water

- Could think of no major flooding events, was not concerned about flooding
- Their drinking water pumps take from a lens (underground freshwater source on top of a saltwater source)
- Most concerned about population and water use (too much will reduce the lens)
- Preferred an online resource to communicate our results

Hull September 27th, 2011

Edward Petrilak – Chief Facility Manager

- The facility suffered a major flood in 1978 before the plant was run by the city. Took 2 years to fix.
- The plant has exceeded its 3.07 MGD with costal storms and, I and I (inflow-when grey water gets in the system and infiltration- water seeps in to the system through things like old clay pipes).
- Over capacity had no physical effect on the plant but washed all the bugs and bacteria into the ocean. Now to prevent the bugs being washed away a section of the population is sequestered and used to later rebuild the population so treatment could begin right away, otherwise it could take many days to rebuild the bacterial population.
- If any alarm is activated at the facility the plant must be manned. During storms there are 2-3 people on duty at all times with only 6 staff members.
- Extra running hours on the equipment during a storm.
- Spare pump motors are stocked for every major pump. Spares of everything are kept in the facility because in the case of a disaster the plant might be inaccessible.
- During a flood what is worried about the most?: Losing pump stations, equipment and staff.
- Comfortable in their well defined flood strategy. With unlimited resources replacing pipes and rebuilding pump stations just a general update all equipment. Realistically don't know where to improve more because it's always been considered since the building was built.
- No plans to make changes to the facility.
- Biggest roadblock is regulation, permits and procedures.
- What would be useful for outreach would be to find a way to overlay rising sea levels with how it would affect surges and currents. Get people to look beyond just sea level rise and to think about storm surges and currents as well.
- Always give a hard copy of outreach to be filed to ensure that the data can still be read even when the medium used to store it on can no longer be used.
- Addition to the chlorine tank walls happened in the early 2000s. Storm walls were 1978-1980.
- Other tanks were originally built to factor in flooding. And have not been added to.

Appendix D – Risk Assessment Tool

The following considerations were the basis for risk assessment categorization for waste water treatment and for drinking water.

Risk Assessment:

- Past inundation and damage (yes/no). (Source: EPA survey data)
  - Previous flooding – higher risk

Questions A) (WW only) Past flooding: No: **0** Yes: **3**

- Which FEMA flood zone is the facility in? (Source: GIS)
  - 1% annual chance of flooding (100-year flood)
  - 0.2% annual chance of flooding (500-year flood) / 100-year flood under 1 ft
  - Outside these zones

Questions B) FEMA flood zone: Outside of zones: **0** 500 yr (.02%) zones: **1** 100 yr (.1%) zones: **2**

- Which of the Army Corps of Engineers hurricane inundation zones is the facility within? (Source: GIS)
  - Category 1 – Greatest risk
  - Category 2
  - Category 3
  - Category 4
  - None – Least risk

Question C) A.C.E. hurricane inundation zones: Outside of zones: **0** Category 4&3: **1** Category 2&1: **2**

- Which of the Predicted Army Corps of Engineers hurricane inundation zones is the facility within? (Source: GIS)
    - Category 1 – Greatest risk
    - Category 2
    - Category 3
    - Category 4
    - None – Least risk

Question D) Predicted A.C.E. hurricane inundation zones:

Risk Assessment Number System

Elevation (ft)	North of Boston	South of Boston	Cape Cod Bay	Cape Cod South Shore	Buzzards Bay
Category 2 + SLR	10	14	12	9	10
Category 4 + SLR	14	17	18	17	21

Plant Elev. > Cat. 4+SLR = **0**
Cat. 2+SLR < Plant Elev. ≤ Cat. 4+SLR = **1**
Plant Elev. ≤ Cat. 2+SLR = **2**

*These data are based on the average FEMA flood zones (2007 data) flood height and the Rahmstorf sea level rise predictions from *Climate Change Adaptation Strategies for Massachusetts*

- Wastewater: Do the areas the facility serves have a combined sewer/storm drain system? (Source: MassDEP Regional offices)
    - No – Less likely to have increased flow in event of storm
    - Yes – More likely to have increased flow in event of storm

Question E) (WW only) Combined sewer system: No: **0** Yes: **2**

Wastewater scale

0	1	2	3	4	5	6	7	8	9	10	11
Low				Medium				High			

Drinking Water scale

0	1	2	3	4	5	6
Low			Medium		High	

Example of use: **Newburyport WWTP**

Question	A	B	C	D	E	
Answer	No	100yr.	Cat. 2	No	No	
Ans. # value	0	2	2	0	2	Total = 6

0	1	2	3	4	5	6	7	8	9	10	11
Low				Medium				High			

Using data we have collected we can answer question a-e above which will give a number value for each answer. Then adding up those numbers gives a total which can be looked up on the scale and gives a preliminary rating for the facility as Low, Medium, or High.

Appendix E – Impact Assessment Tool

The following considerations were the basis for impact assessment categorization for waste water treatment and for drinking water.

Impact Assessment:

- Drinking water: Type of source (Source: DRTS)
    - Surface water – More likely to be contaminated in a flood event
- Drinking water: Population served (Source: EPA Consumer Confidence Reports: http://cfpub.epa.gov/safewater/ccr/index.cfm?action=ccrsearch)
    - Higher population – A failure in the system or decrease in water quality will impact more people
- Drinking water: Days of stored finished drinking water (Source: DRTS)
    - Higher capacity – More able to provide water if treatment process shuts down
- Wastewater: Average flow rate vs. design flow rate
    - Higher ratio – The closer the facility is to reaching capacity without out a flooding event

Appendix F – Wastewater Facility Trip Reviews

On September 20th, 2011 we visited the Newburyport Wastewater Treatment Facility. The facility was currently under construction to update the equipment and reduce the noise and smell. We interviewed Robert Bradbury, the assistant chief operator, who gave us the tour and Barry Yachesyn, a consultant for the city of Newburyport who works for Weston & Sampson, the company contracted to perform the construction at the facility. While Mr. Bradbury remembers at least four past town flooding events caused by heavy rains in the last twenty five years, the wastewater plant itself was never flooded and continued to function properly. He told us that the plant had never needed to bypass its sewage and that they had actually sealed off their bypass pipe. Mr. Bradbury also told us there was no way for the plant to stop sewage inflow from the town.

On September 22nd, 2011 we visited the Provincetown Wastewater Treatment Facility. At the facility we learned of a new air vacuum system which had been implemented within the past three years to help low lying areas of Provincetown which were susceptible to flooding deal with such occurrences. We were given a tour of the facility and its components including the vacuum station. The 250 manhole AirVac systems pump directly into this vacuum station located approximately 253 feet from the coast. This station was noted by Plant Operator Chris Rowe as being vulnerable to sea level rise. He felt that the generator at the vacuum station, which could supply enough energy to power the whole system, would be safe during a flood since the generator is elevated, however the pumps themselves could be flooded. The town has a solid plan in the event of flooding of the vacuum stations, pump trucks would be hired to pump from out-of-service manholes and deliver the waste to the wastewater facility. Mr. Rowe noted for

Provincetown Wastewater Treatment Facility, flooding due to sea level rise and storm surge is a very real possibility and as such the town planners have put into action mitigation strategies.

Provincetown's wastewater facility operators had established an impressive network with surrounding facilities in the area. Mr. Rowe informed us that he could contact any of the local facilities for extra manpower or to contract pump trucks that would empty the drain pipes should the system become inoperable.

On September 27th, 2011 we visited Hull Wastewater Treatment Facility. Here we were given a tour and explanation of the mitigation strategies that the facility already had in place. These included storm gates, an example of which is shown below in Figure 4.3. These storm gates were put in after the facility suffered a devastating flood in 1978 due to a major blizzard that occurred that year, which left the area surrounding the treatment facility under six to ten feet of water (FEMA, 2008). Other adaptations include multiple backup generators, which are tested every month under load, and multiple portable pump motors ready to take over if a stationary pump were to fail. Additionally there are mechanical systems as a backup to digital systems of electronic pumps and pump controls. The facility also had numerous replacement parts for the mechanical systems to ensure quick repair in the event of equipment failure.

Figure F.1: Storm gate used at Hull Wastewater Treatment Facility

Chief Facilities Manager Edward Petrilak stated that since Hull Wastewater Treatment Facility has been in danger of flooding since it was rebuilt in 1978, it remains a constant concern to the town officials and citizens. Mr. Petrilak stressed the importance of being proactive instead of reactive since it is more costly in terms of money, environmental impact, and community impact for the town and facility to recover from a catastrophic failure than spend the time and money in advance to prevent a catastrophic failure. Public support is the greatest advantage of the facility. According Mr. Petrilak, the residents of Hull are well aware of the possibility and risks of flooding and want their utilities to be prepared for this eventuality.

Appendix G – Drinking Water Facility Trip Reviews

On September 20th, 2011 we visited the Newburyport Water Works. After being given a tour we interviewed the superintendant of the treatment facility, Paul Colby. He described to us the various construction projects that were occurring in Newburyport. A hundred year old pump station was being torn down and replaced at a higher elevation along with the replacement of a holding tank. While rising sea levels and flooding were not a primary concern of Mr. Colby, he told us that the construction of a new pump station at a higher elevation was meant to protect it from flooding of the Bartlett Spring Pond. The pond also had dykes constructed around it and a drain pipe to the Merrimack River installed due to past floods.

Fig G.1: Newburyport drinking water facility

Figure G.2: Pump Station next to the Bartlett Spring Pond

Other than construction project, the design of the water treatment plant had incorporated minimal precautions against flooding. The Newburyport Water Works facility has a computer network monitoring system which sets off an alarm system alerting workers throughout the facility that there is a problem, that along with a high elevation of 56 feet above sea level, and a distance of 896 feet from the Merrimack River, there is little reason for the plant superintendent to worry about coastal or storm surge related flooding.

On September 22nd, 2011 we visited the Provincetown Water Department. Carl Hillstrom, the Contract Water Superintendent for the town of Provincetown, doesn't feel that flooding is a concern to the drinking water facility in the near future, nor does he believe that saltwater intrusion will be a problem as long as the amount of water pumped from their source lenses (a watershed of freshwater on top of a saltwater deposit) is consistently regulated. He explained that over-pumping could result in saltwater intrusion, making further processing necessary. His primary concern was population growth and water use, stating that maintaining the water lenses was of more concern than flooding.

Plant	Distance to coast	Elevation	Average Flow Rate (MGD)	Design Flow Rate (MGD)
Cohasset WPCF	3 ft (river) / 1,083 ft (ocean)	0 ft	0.2	0.4
Edgartown WWTF	3,707 ft	33 ft		0.75
Fall River WWTP	46 ft	16 ft	18.9	30.6
Hull WW	49 ft	9 ft	1.3	3.07
Lynn WWTP c/o U.S. Filter	755 ft	14 ft	24	60
Manchester-By-The-Sea WWTP	98 ft	4 ft		1.2
Marshfield WWTF	984 ft	11 ft	1.32	2.1
Nantucket WWTF	394 ft	7 ft		2.24
New Bedford WPCF c/o U.S. Filter	230 ft	14 ft	21.5	80
Newburyport WW	42 ft (river outlet) / 14,107 ft (ocean)	10 ft	2.6	3.4
Oak Bluffs WWTF	2,953 ft	66 ft		3.4
Provincetown WWTF	3,609 ft	42 ft	0.5	
Rockport WWTP	2,067 ft	69 ft		0.8
Salisbury WWTF	2,625 ft (river) / 17,848 ft (ocean)	50 ft		1.3
Scituate WWTP	1804 ft (river) / 2,936 ft (ocean)	13 ft	1.24	1.6
Somerset Water Pollution Control	131 ft	13 ft	3.1	4.2
South Essex Sewerage District	0 ft	9 ft		29.71
Wareham WPCF	196 ft (river) / 4,921 ft (ocean)	26 ft	0.93	1.8

Appendix H – Wastewater Facility Information

Plant	Average flow rate / Design rate	Discharge	Storage Capacity (untreated waste)	FEMA flood zone
Cohasset WPCF	0.5	surface		100-year
Edgartown WWTF	0			None
Fall River WWTP	0.617647059	surface		100-year
Hull WW	0.423452769	surface		100-year
Lynn WWTP c/o U.S. Filter	0.4	surface		500-year
Manchester-By-The-Sea WWTP	0	surface		100-year
Marshfield WWTF	0.628571429	surface		100-year
Nantucket WWTF	0			500-year
New Bedford WPCF c/o U.S. Filter	0.26875	surface		100-year
Newburyport WW	0.764705882	surface		100-year
Oak Bluffs WWTF	0			None
Provincetown WWTF		ground		None
Rockport WWTP	0			None
Salisbury WWTF	0			None
Scituate WWTP	0.775			100-year
Somerset Water Pollution Control	0.738095238	surface		100-year
South Essex Sewerage District	0	surface		100-year
Wareham WPCF	0.516666667			None

Plant	ACE hurricane inundation zone	Combined sewer/storm outflow	Past Flood
Cohasset WPCF	Cat. 2	No	no
Edgartown WWTF	None	No	no
Fall River WWTP	Cat. 2	Yes	no
Hull WW	Cat. 2 (close to cat. 1)	No	yes
Lynn WWTP c/o U.S. Filter	Cat. 2	Yes	yes
Manchester-By-The-Sea WWTP	Cat. 1		no
Marshfield WWTF	Cat. 2	No	no
Nantucket WWTF	Cat. 4	No	
New Bedford WPCF c/o U.S. Filter	Cat. 3	Yes	no
Newburyport WW	Cat. 2	No	no
Oak Bluffs WWTF	None	No	no
Provincetown WWTF	None	No	no
Rockport WWTP	None		no
Salisbury WWTF	None		yes
Scituate WWTP	Cat. 1	No	yes
Somerset Water Pollution Control	Cat. 3	No	
South Essex Sewerage District	Cat. 1		
Wareham WPCF	Cat. 3	No	

Appendix I – Drinking Water System Information and Component Breakdown

Plant	Program ID	Pop. Served (Summer)	Pop. Served (Winter)	Average Residential Flow Rate (MGD)	Average Flow Rate (MGD)
Hyannis Water System	4020004	35000	18000	1.086575342000	2.394
Newburyport DW	3206000	20335	20335	1.14548011	2.043942
Somerset Water Department	4273000	19638	19638	1.181216438	2.895907
Marshfield Water Department	4171000	34000	25300	1.736131507	2.543836
Onset Fire District	4310003	13975	13975	0.375342466	0.6
Oak Bluffs Water District	4221000	23751	4227	0.67939726	0.994329
Wareham Fire District	4310000	19958	19958	1.125525436	1.364695
Tisbury Water Works	4296000	23728	3851	0.442750685	0.55206
Edgartown Water Department	4089000	14000	2500	0.64596986	0.905762
Fall River Water Department	4095000	94000	94000	6.50000000	10.25913
Yarmouth Water Department	4351000	50000	21277	2.876358904	3.663014
Manchester Water Department	3166000	5469	5469	0.57460274	0.724134
Orleans Water Department	4224000	18948	6316	0.723709696	0.98189
Buzzards Bay Water District	4036001	7700	5830	0.33904110	0.482177
Provincetown DW	4242000	27500	3434	0.316712329	0.776712
Rockport Water Dept	3252000	9890	7480	0.40699726	0.488715

Plant	Program ID	Water source	Storage Capacity (MG)	Store / Avg Res (Days)	Store / Avg Flow (Days)	FEMA flood zone	ACE hurricane inundation zone
Hyannis Water System	4020004	ground	1.37	1.26	0.57		
Newburyport DW	3206000	surface	2.75	2.40	1.35	None	None
Somerset Water Department	4273000	surface / ground	5.023	4.25	1.73	100-year	Cat 4
Marshfield Water Department	4171000	ground	5.07	2.92	1.99		
Onset Fire District	4310003	ground / surface	1.2	3.20	2		
Oak Bluffs Water District	4221000	ground	2	2.94	2.01		
Wareham Fire District	4310000	ground	2.9073	2.58	2.13		
Tisbury Water Works	4296000	ground	1.2	2.71	2.17		
Edgartown Water Department	4089000	ground	2.2	3.41	2.43		
Fall River Water Department	4095000	surface	25.5	3.92	2.49	100-year	None
Yarmouth Water Department	4351000	ground	9.25	3.22	2.53		
Manchester Water Department	3166000	surface, some ground	2.22	3.86	3.07	None	None
Orleans Water Department	4224000	ground	3.192	4.41	3.25		
Buzzards Bay Water District	4036001	ground	2	5.90	4.15		
Provincetown DW	4242000	ground	6.5	20.52	8.37	None	None
Rockport Water Dept	3252000		4.2	10.31	8.59		
Salem Water Department	3258000	purchased surface	15.8				

Town	Site Name	Source ID	Area	Total Days Pumped	Total Water Pumped (MG)	Water Source	FEMA flood zone	ACE hurricane inundation zone
Manchester	LINCOLN ST WELL	3166000-01G	North of Boston	283	65.5460	Ground	None	None
Manchester	GRAVELLY POND	3166000-01S	North of Boston	365	198.7630	Surface	100-year	None
Manchester	ROUND POND GP WELL #1	3166000-02G	North of Boston	0	0.0000	Ground		
Manchester	ROUND POND TUB WELL #2	3166000-03G	North of Boston	0	0.0000	Ground		
Newburyport	Well #1	3206000-01G	North of Boston	326	109.5920	Ground	None	None
Newburyport	Artichoke Reservoir	3206000-01S	North of Boston	365	532.1830	Surface	None	Cat 4
Newburyport	Well #2	3206000-02G	North of Boston	362	108.5520	Ground	None	None
Newburyport	Indian Hill Reservoir	3206000-02S	North of Boston	73	0.0000	Surface		
Newburyport	Bartlett Spring Pond	3206000-03S	North of Boston	150	44.1570	Surface	None	None

Town	Site Name	Source ID	Area	Total Days Pumped	Total Water Pumped (MG)	Water Source	FEMA flood zone	ACE hurricane inundation zone
Rockport	CAPE POND	3252000-01S	North of Boston		118.1330	Surface	500-year	None
Rockport	MILL BROOK REPLACEMENT WELLFIELD	3252000-02G	North of Boston	0	0.0000	Ground	None	None
Rockport	CARLSONS QUARRY (QUARRY RES.)	3252000-02S	North of Boston		105.5300	Surface	500-year	None
Rockport	SAWMILL BROOK	3252000-03S	North of Boston	0	0.0000	Emergency Surface	None	None
Rockport	LOOP POND	3252000-04S	North of Boston	0	0.0000	Emergency Surface	500-year	None
Rockport	RUM ROCK LAKE	3252000-05S	North of Boston	0	0.0000	Emergency Surface	500-year	None
Rockport	FLAT LEDGE QUARRY	3252000-06S	North of Boston	69	5.6200	Surface	500-year	None
Rockport	STEEL DERRICK QUARRY	3252000-07S	North of Boston	0	0.0000	Emergency Surface	500-year	None
Hyannis Water System	STRAIGHTWAY WELL	4020004-01G	Cape Cod South Shore	0	0.0000	Ground	None	None
Hyannis Water System	MAHER WELL # 2	4020004-02G	Cape Cod South Shore	249	145.9805	Ground	100-year	Cat 3
Hyannis Water System	HYANNISPORT	4020004-03G	Cape Cod South Shore	263	115.7314	Ground	100-year	Cat 4
Hyannis Water System	MARY DUNN WELL # 1	4020004-04G	Cape Cod South Shore	110	23.0964	Ground	None	None
Hyannis Water System	MARY DUNN WELL # 2	4020004-05G	Cape Cod South Shore	0	0.0000	Ground	None	None

Town	Site Name	Source ID	Area	Total Days Pumped	Total Water Pumped (MG)	Water Source	FEMA flood zone	ACE hurricane inundation zone
Hyannis Water System	HYANNISPORT	4020004-03G	Cape Cod South Shore	263	115.7314	Ground	100-year	Cat 4
Hyannis Water System	MARY DUNN WELL # 1	4020004-04G	Cape Cod South Shore	110	23.0964	Ground	None	None
Hyannis Water System	MARY DUNN WELL # 2	4020004-05G	Cape Cod South Shore	0	0.0000	Ground	None	None
Hyannis Water System	SIMMONS POND	4020004-06G	Cape Cod South Shore	307	134.9876	Ground	100-year	Cat 3
Hyannis Water System	MAHER WELL # 1	4020004-07G	Cape Cod South Shore	263	174.3810	Ground	500-year	Cat 4
Hyannis Water System	MARY DUNN WELL # 3	4020004-08G	Cape Cod South Shore	240	42.0259	Ground	None	None
Hyannis Water System	MARY DUNN WELL # 4	4020004-09G	Cape Cod South Shore	0	0.0000	Ground	500-year	None
Hyannis Water System	AIRPORT # 1	4020004-10G	Cape Cod South Shore	120	22.5704	Ground	None	None
Hyannis Water System	MAHER WELL # 3	4020004-11G	Cape Cod South Shore	136	73.9699	Ground	100-year	Cat 3
Hyannis Water System	STRAIGHTWAY WELL #2	4020004-12G	Cape Cod South Shore	285	138.0360	Ground	None	None
Buzzards Bay Water District	PUMP STATION # 1	4036001-01G	Buzzards Bay	257	31.4607	Ground	None	None
Buzzards Bay Water District	PUMP STATION # 2	4036001-02G	Buzzards Bay	249	36.9583	Ground	None	Cat 3
Buzzards Bay Water District	PUMP STATION # 3	4036001-03G	Buzzards Bay	254	58.8468	Ground	None	None
Buzzards Bay Water District	PUMP STATION # 4	4036001-04G	Buzzards Bay	247	48.7288	Ground	None	None

Town	Site Name	Source ID	Area	Total Days Pumped	Total Water Pumped (MG)	Water Source	FEMA flood zone	ACE hurricane inundation zone
Edgartown	MACHACKET WELL	4089000-04G	Cape Cod South Shore	7	0.5690	Ground	None	None
Edgartown	LILY POND WELL	4089000-05G	Cape Cod South Shore	246	64.9810	Ground	100-year	Cat 2
Edgartown	WINTUCKET WELL 2	4089000-06G	Cape Cod South Shore	207	54.9980	Ground	None	Cat 4
Edgartown	QUENOMICA WELL	4089000-07G	Cape Cod South Shore	248	101.1610	Ground	None	None
Edgartown	NUNNEPOG WELL	4089000-08G	Cape Cod South Shore	186	108.8870	Ground	None	None
Edgartown	PENNYWISE PATH SITE (TW 2-04	4089000-0AG	Cape Cod South Shore			Ground (Proposed)		
Fall River	NO. WATUPPA POND	4095000-01S	Buzzards Bay	365	4156.7480	Surface	100-year	None
Fall River	COPICUT RES.	4095000-03S	Buzzards Bay	29	339.4800	Surface	100-year	None
Fall River	SO. WATUPPA POND	4095000-04S	Buzzards Bay	0	0.0000	Emergency Surface		
Fall River	LAKE NOQUOCHOKE	4095000-05S	Buzzards Bay	0	0.0000	Emergency Surface		
Marshfield	MT. SKIRGO WELLS	4171000-01G	South of Boston	362	31.0343	Ground	None	None
Marshfield	PARSONAGE ST. WELL # 1	4171000-02G	South of Boston	0	0.0000	Ground	None	None
Marshfield	PARSONAGE ST. WELL # 2	4171000-03G	South of Boston	0	0.0000	Ground	None	None
Marshfield	FURNACE BROOK WELL # 2	4171000-05G	South of Boston	362	85.4634	Ground	None	None

Town	Site Name	Source ID	Area	Total Days Pumped	Total Water Pumped (MG)	Water Source	FEMA flood zone	ACE hurricane inundation zone
Marshfield	FURNACE BROOK WELL # 3	4171000-06G	South of Boston	178	28.65	Ground	None	None
Marshfield	FURNACE BROOK WELL # 4	4171000-07G	South of Boston	365	124.17	Ground	None	None
Marshfield	SO. RIVER ST. WELL	4171000-08G	South of Boston	164	17.37	Ground	None	None
Marshfield	SCHOOL ST. WELL	4171000-09G	South of Boston	361	48.72	Ground	None	None
Marshfield	PROPOSED FERRY ST. WELL #2	4171000-0AG	South of Boston			Ground (Proposed)	None	None
Marshfield	PROPOSED FAIRGROUNDS WELL	4171000-0BG	South of Boston			Ground (Proposed)	None	None
Marshfield	WEBSTER WELL # 1	4171000-10G	South of Boston	355	57.49	Ground	None	None
Marshfield	FERRY ST. WELL	4171000-11G	South of Boston	362	52.24	Ground	None	None
Marshfield	WEBSTER WELL # 2	4171000-12G	South of Boston	194	15.65	Ground	None	None
Marshfield	CHURCH ST. WELL	4171000-13G	South of Boston	203	49.24	Ground	None	None
Marshfield	UNION STATION # 1	4171000-14G	South of Boston	354	137.01	Ground	None	None
Marshfield	UNION STATION # 2	4171000-15G	South of Boston	362	51.84	Ground	None	None
Marshfield	SPRING STREET WELL	4171000-16G	South of Boston	359	38.25	Ground	None	None
Marshfield	FURNACE BROOK WELL #1A	4171000-17G	South of Boston	361	91.17	Ground	None	None
Marshfield	FERRY ST #2 WELLFIELD	4171000-18G	South of Boston	362	59.73	Ground	None	None
Marshfield	DUXBURY SUPPLY	4171000-01P		365	4.32	Purchased		
Oak Bluffs	LAGOON POND WELLFIELD	4221000-01G	Cape Cod South Shore	301	59.34	Ground	100-year	Cat 3
Oak Bluffs	FARM NECK RD. WELLFIELD	4221000-02G	Cape Cod South Shore	325	52.96	Ground	None	None
Oak Bluffs	WELL # 3 STATE FOREST	4221000-03G	Cape Cod South Shore	363	127.72	Ground	None	None
Oak Bluffs	MADISON ALWARDT SR. WELL #4	4221000-04G	Cape Cod South Shore	205	51.92	Ground	None	None
Oak Bluffs	WELL NO.5	4221000-0AG	Cape Cod South Shore	323	70.14	Ground (Proposed)	None	None
Orleans	GOULD POND GP WELL # 1	4224000-01G	Cape Cod South Shore	365	76.26	Ground	None	None
Orleans	GOULD POND GP WELL # 2	4224000-02G	Cape Cod South Shore	199	31.49	Ground	None	None
Orleans	GOULD POND GP WELL # 3	4224000-03G	Cape Cod South Shore	197	48.10	Ground	None	None
Orleans	CLIFF POND WELL # 4	4224000-04G	Cape Cod South Shore	315	49.70	Ground	None	None
Orleans	CLIFF POND WELL # 5	4224000-05G	Cape Cod South Shore	268	40.71	Ground	None	None
Orleans	CLIFF POND WELL # 6	4224000-06G	Cape Cod South Shore	365	89.98	Ground	None	None
Orleans	WELL # 7	4224000-07G	Cape Cod South Shore	37	5.23	Ground	None	None
Orleans	WELL 8	4224000-08G	Cape Cod South Shore	150	24.66	Ground	None	None

Town	Site Name	Source ID	Area	Total Days Pumped	Total Water Pumped (MG)	Water Source	FEMA flood zone	ACE hurricane inundation zone
Provincetown	KNOWLES CROSSING WELL	4242000-02G	Cape Cod Bay	325	49.83	Ground	None	None
Provincetown	PAUL D. DALEY WELLFIELD	4242000-03G	Cape Cod Bay	325	201.35	Ground	None	None
Provincetown	NO.TRURO USAF BASE WELL (04G)	4242000-04G	Cape Cod Bay	135	16.70	Ground	None	None
Provincetown	NO. TRURO USAF BASE WELL (05G)	4242000-05G	Cape Cod Bay	125	15.66	Ground	None	None
Somerset	SOMERSET RES.	4273000-01S	Buzzards Bay	365	959.14	Surface	100-year	Cat 4
Somerset	FJM #2 WELL	4273000-05G	Buzzards Bay	365	97.87	Ground	500-year	None
Tisbury	SANBORN WELL #1	4296000-01G	Cape Cod South Shore	309	78.05	Ground	None	None
Tisbury	TASHMOO WELL #2	4296000-02G	Cape Cod South Shore	305	60.04	Ground	None	None
Tisbury	MANTER WELL	4296000-04G	Cape Cod South Shore	346	94.00	Ground	None	None
Wareham Fire District	MAPLE SPRINGS WELL #1	4310000-01G	Buzzards Bay	87	42.56	Ground	None	Cat 3
Wareham Fire District	MAPLE SPRINGS WELL #2	4310000-02G	Buzzards Bay	157	113.86	Ground	None	Cat 3
Wareham Fire District	MAPLE SPRINGS WELL #3	4310000-03G	Buzzards Bay	144	94.34	Ground	None	Cat 3
Wareham Fire District	MAPLE SPRINGS WELL #4	4310000-04G	Buzzards Bay	111	71.51	Ground	None	Cat 3
Wareham Fire District	MAPLE SPRINGS WELL #5	4310000-05G	Buzzards Bay	0	0.00	Ground	None	Cat 3
Wareham Fire District	SEAWOOD SPRINGS WELL #6	4310000-06G	Buzzards Bay	232	104.36	Ground	None	None
Wareham Fire District	SEAWOOD SPRINGS WELL #7	4310000-07G	Buzzards Bay	211	170.79	Ground	None	None
Wareham Fire District	SOUTH LINE WELL #8	4310000-08G	Buzzards Bay	98	56.86	Ground	None	None
Wareham Fire District	PROPOSED MAPLE PARK WELL	4310000-0AG	Buzzards Bay			Ground (Proposed)	None	None
Onset Fire District	WELL #4	4310003-01G	Buzzards Bay	337	45.00	Ground	None	Cat 3
Onset Fire District	SAND POND RES.	4310003-01S	Buzzards Bay	0	0.00	Surface	100-year	Cat 4
Onset Fire District	WELL #3	4310003-02G	Buzzards Bay	345	59.40	Ground	None	Cat 2
Onset Fire District	WELL #5	4310003-03G	Buzzards Bay	365	39.91	Ground	None	Cat 4
Onset Fire District	WELL #6	4310003-04G	Buzzards Bay	350	74.72	Ground	None	Cat 4
Onset Fire District	PROPOSED WELL #7	4310003-0AG	Buzzards Bay			Ground (Proposed)	None	Cat 4

Town	Site Name	Source ID	Area	Total Days Pumped	Total Water Pumped (MG)	Water Source	FEMA flood zone	ACE hurricane inundation zone
Yarmouth	GP WELL # 1M	4351000-01G	Cape Cod Bay	244	124.20	Ground	None	None
Yarmouth	Higgins Crowell Well	4351000-02G	Cape Cod Bay	354	47.90	Ground	None	None
Yarmouth	GP WELL # 2	4351000-03G	Cape Cod Bay	0	0.00	Ground	None	None
Yarmouth	GP WELL # 3	4351000-04G	Cape Cod Bay	345	75.80	Ground	None	None
Yarmouth	GP WELL # 4	4351000-05G	Cape Cod South Shore	323	48.40	Ground	None	None
Yarmouth	GP WELL # 5	4351000-06G	Cape Cod South Shore	145	29.90	Ground	None	None
Yarmouth	GP WELL # 6	4351000-07G	Cape Cod South Shore	347	41.80	Ground	None	None
Yarmouth	GP WELL # 7	4351000-08G	Cape Cod South Shore	0	0.00	Ground	None	None
Yarmouth	GP WELL # 8	4351000-09G	Cape Cod South Shore	0	0.00	Ground	None	None
Yarmouth	GP WELL # 9	4351000-10G	Cape Cod South Shore	254	74.20	Ground	None	None
Yarmouth	GP WELL # 10	4351000-11G	Cape Cod South Shore	241	29.32	Ground	None	None
Yarmouth	GP WELL # 11	4351000-12G	Cape Cod South Shore	286	54.19	Ground	None	None
Yarmouth	GP WELL # 13	4351000-13G	Cape Cod South Shore	319	71.80	Ground	None	None
Yarmouth	GP WELL # 14	4351000-14G	Cape Cod South Shore	339	54.80	Ground	None	None
Yarmouth	GP WELL # 15	4351000-15G	Cape Cod Bay	313	94.50	Ground	None	None
Yarmouth	GP WELL # 16	4351000-16G	Cape Cod Bay	229	54.50	Ground	None	None
Yarmouth	GP WELL # 17	4351000-17G	Cape Cod South Shore	309	107.20	Ground	None	None
Yarmouth	GP WELL # 18	4351000-18G	Cape Cod South Shore	280	58.50	Ground	None	None
Yarmouth	GP WELL # 19	4351000-19G	Cape Cod South Shore	339	65.70	Ground	None	None
Yarmouth	GP WELL # 20	4351000-20G	Cape Cod Bay	318	47.80	Ground	None	None
Yarmouth	GP WELL # 21	4351000-21G	Cape Cod Bay	333	71.80	Ground	None	None
Yarmouth	GP WELL # 22	4351000-22G	Cape Cod Bay	331	82.20	Ground	None	None
Yarmouth	GP WELL # 23	4351000-23G	Cape Cod Bay	290	71.00	Ground	None	None
Yarmouth	GP WELL # 24	4351000-24G	Cape Cod Bay	311	58.10	Ground	None	None

Appendix J – Risk Assessments

Wastewater:

Plant Name	Report inundation or damage	FEMA Flood Zone	ACE Hurricane Zone	Combined Sewer System	Predicted ACE Hurricane Zone	Total
Hull WW	3	2	2	0	2	9
Scituate WWTP	3	2	2	0	2	9
Lynn WWTP c/o U.S. Filter	3	1	2	1	2	9
Fall River WWTP	0	2	2	1	2	7
Manchester-By-The-Sea WWTP	0	2	2	0	2	6
Cohasset WPCF	0	2	2	0	2	6
Newburyport WW	0	2	2	0	2	6
New Bedford WPCF c/o U.S. Filter	0	2	1	1	1	5
South Essex Sewerage District		2	2		2	6
Nantucket WWTF		1	1	0	1	3
Somerset Water Pollution Control		2	1	0	1	4
Salisbury WWTF	3	0	0		0	3
Wareham WPCF		0	1	0	1	2
Edgartown WWTF	0	0	0	0	0	0
Marshfield WWTF	0	2	2	0	2	6
Oak Bluffs WWTF	0	0	0	0	0	0
Provincetown WWTF	0	0	0	0	0	0
Rockport WWTP	0	0	0	0	0	0

Drinking Water:

Plant Name	Subsystem Name	FEMA Flood Zone	Army Corps Hurricane Zone	Predicted ACE Hurricane Zone	Total
Newburyport DW	Treatment Facility	0	0	0	0
Newburyport DW	Artichoke Reservoir	0	1	1	2
Newburyport DW	Bartlett Spring Pond	0	0	1	1
Newburyport DW	Well #1	0	0	0	0
Newburyport DW	Well #2	0	0	0	0
Provincetown DW	KNOWLES CROSSING WELL	0	0	1	1
Provincetown DW	PAUL D. DALEY WELLFIELD	0	0	1	1
Provincetown DW	NO. TRURO USAF BASE WELL (04G)	0	0	0	0
Provincetown DW	NO. TRURO USAF BASE WELL (05G)	0	0	0	0
Hyannis Water System	STRAIGHTWAY WELL	0	0	0	0
Hyannis Water System	MAHER WELL # 2	2	1	1	4
Hyannis Water System	HYANNISPORT	2	1	1	4
Hyannis Water System	MARY DUNN WELL # 1	0	0	0	0
Hyannis Water System	MARY DUNN WELL # 2	0	0	0	0
Hyannis Water System	SIMMONS POND	2	1	2	5
Hyannis Water System	MAHER WELL # 1	1	1	1	3
Hyannis Water System	MARY DUNN WELL # 3	0	0	0	0
Hyannis Water System	MARY DUNN WELL # 4	1	0	0	1
Hyannis Water System	AIRPORT # 1	0	0	0	0
Hyannis Water System	MAHER WELL # 3	2	0	1	3
Hyannis Water System	STRAIGHTWAY WELL #2	0	0	0	0
Edgartown	MACHACKET WELL	0	0	0	0
Edgartown	LILY POND WELL	2	2	2	6
Edgartown	WINTUCKET WELL 2	0	1	1	2
Edgartown	QUENOMICA WELL	0	0	0	0
Edgartown	NUNNEPOG WELL	0	0	0	0
Fall River Water Department	Treatment Facility	2	0	0	2
Fall River Water Department	NO. WATUPPA POND	2	0	0	2
Fall River Water Department	COPICUT RES.	2	0	0	2

Plant Name	Subsystem Name	FEMA Flood Zone	Army Corps Hurricane Zone	Predicted ACE Hurricane Zone	Total
Manchester Water Department	Treatment Facility	0	0	0	0
Manchester Water Department	LINCOLN ST WELL	0	0	1	1
Manchester Water Department	GRAVELLY POND	2	0	0	2
Buzzards Bay Water District	PUMP STATION # 1	0	0	0	0
Buzzards Bay Water District	PUMP STATION # 2	0	1	1	2
Buzzards Bay Water District	PUMP STATION # 3	0	0	0	0
Buzzards Bay Water District	PUMP STATION # 4	0	0	0	0
Oak Bluffs Water District	LAGOON POND WELLFIELD	2	1	1	4
Oak Bluffs Water District	FARM NECK RD. WELLFIELD	0	0	0	0
Oak Bluffs Water District	WELL # 3 STATE FOREST	0	0	0	0
Oak Bluffs Water District	MADISON ALWARDT SR. WELL #4	0	0	0	0
Oak Bluffs Water District	WELL NO.5	0	0	0	0
Rockport	CAPE POND	1	0	0	1
Rockport	MILL BROOK REPLACEMENT WELLFIELD	0	0	0	0
Rockport	CARLSONS QUARRY (QUARRY RES.)	1	0	0	1
Rockport	SAWMILL BROOK	0	0	0	0
Rockport	LOOP POND	1	0	0	1
Rockport	RUM ROCK LAKE	1	0	0	1
Rockport	FLAT LEDGE QUARRY	1	0	0	1
Rockport	STEEL DERRICK QUARRY	1	0	0	1
Somerset Water Department	Treatment Facility	2	1	1	4
Somerset Water Department	FJM #2 WELL	0	0	1	1
Tisbury Water Works	SANBORN WELL #1	0	0	0	0
Tisbury Water Works	TASHMOO WELL # 2	0	0	0	0
Tisbury Water Works	MANTER WELL	0	0	0	0

Plant Name	Subsystem Name	FEMA Flood Zone	Army Corps Hurricane Zone	Predicted ACE Hurricane Zone	Total
Orleans Water Department	GOULD POND GP WELL # 1	0	0	0	0
Orleans Water Department	GOULD POND GP WELL # 2	0	0	0	0
Orleans Water Department	GOULD POND GP WELL # 3	0	0	0	0
Orleans Water Department	CLIFF POND WELL # 4	0	0	0	0
Orleans Water Department	CLIFF POND WELL # 5	0	0	0	0
Orleans Water Department	CLIFF POND WELL # 6	0	0	0	0
Orleans Water Department	WELL # 7	0	0	0	0
Wareham Fire District	MAPLE SPRINGS WELL # 1	0	1	1	2
Wareham Fire District	MAPLE SPRINGS WELL # 2	0	1	1	2
Wareham Fire District	MAPLE SPRINGS WELL # 3	0	1	1	2
Wareham Fire District	MAPLE SPRINGS WELL # 4	0	1	1	2
Wareham Fire District	MAPLE SPRINGS WELL # 5	0	1	1	2
Wareham Fire District	SEAWOOD SPRINGS WELL # 6	0	0	0	0
Wareham Fire District	SEAWOOD SPRINGS WELL # 7	0	0	0	0
Wareham Fire District	SOUTH LINE WELL #8	0	0	0	0
Wareham Fire District	PROPOSED MAPLE PARK WELL	0	0	0	0
Onset Fire District	WELL #4	0	1	1	2
Onset Fire District	SAND POND RES.	2	1	1	4
Onset Fire District	WELL #3	0	2	2	4
Onset Fire District	WELL #5	0	1	1	2
Onset Fire District	WELL #6	0	1	1	2
Onset Fire District	PROPOSED WELL #7	0	1	1	2

Plant Name	Subsystem Name	FEMA Flood Zone	Army Corps Hurricane Zone	Predicted ACE Hurricane Zone	Total
Marshfield Water Department	MT. SKIRGO WELLS	0	0	0	0
Marshfield Water Department	PARSONAGE ST. WELL # 1	0	0	2	2
Marshfield Water Department	PARSONAGE ST. WELL # 2	0	0	2	2
Marshfield Water Department	FURNACE BROOK WELL # 2	0	0	0	0
Marshfield Water Department	FURNACE BROOK WELL # 3	0	0	0	0
Marshfield Water Department	FURNACE BROOK WELL # 4	0	0	0	0
Marshfield Water Department	SO. RIVER ST. WELL	0	0	0	0
Marshfield Water Department	SCHOOL ST. WELL	0	0	0	0
Marshfield Water Department	WEBSTER WELL # 1	0	0	0	0
Marshfield Water Department	FERRY ST. WELL	0	0	0	0
Marshfield Water Department	WEBSTER WELL # 2	0	0	2	2
Marshfield Water Department	CHURCH ST. WELL	0	0	0	0
Marshfield Water Department	UNION STATION # 1	0	0	0	0
Marshfield Water Department	UNION STATION # 2	0	0	0	0
Marshfield Water Department	SPRING STREET WELL	0	0	2	2
Marshfield Water Department	FURNACE BROOK WELL #1A	0	0	0	0
Marshfield Water Department	FERRY ST #2 WELLFIELD	0	0	0	0
Marshfield Water Department	PROPOSED FERRY ST. WELL #2	0	0	0	0
Marshfield Water Department	PROPOSED FAIRGROUNDS WELL	0	0	1	1

Plant Name	Subsystem Name	FEMA Flood Zone	Army Corps Hurricane Zone	Predicted ACE Hurricane Zone	Total
Yarmouth Water Department	GP WELL # 1M	0	0	1	1
Yarmouth Water Department	Higgins Crowell Well	0	0	0	0
Yarmouth Water Department	GP WELL # 2	0	0	0	0
Yarmouth Water Department	GP WELL # 3	0	0	0	0
Yarmouth Water Department	GP WELL # 4	0	0	0	0
Yarmouth Water Department	GP WELL # 5	0	0	0	0
Yarmouth Water Department	GP WELL # 6	0	0	0	0
Yarmouth Water Department	GP WELL # 7	0	0	0	0
Yarmouth Water Department	GP WELL # 8	0	0	0	0
Yarmouth Water Department	GP WELL # 9	0	0	0	0
Yarmouth Water Department	GP WELL # 10	0	0	0	0
Yarmouth Water Department	GP WELL # 11	0	0	0	0
Yarmouth Water Department	GP WELL # 13	0	0	0	0
Yarmouth Water Department	GP WELL # 14	0	0	0	0
Yarmouth Water Department	GP WELL # 15	0	0	1	1
Yarmouth Water Department	GP WELL # 16	0	0	1	1
Yarmouth Water Department	GP WELL # 17	0	0	0	0
Yarmouth Water Department	GP WELL # 18	0	0	0	0
Yarmouth Water Department	GP WELL # 19	0	0	0	0
Yarmouth Water Department	GP WELL # 20	0	0	0	0
Yarmouth Water Department	GP WELL # 21	0	0	0	0
Yarmouth Water Department	GP WELL # 22	0	0	0	0
Yarmouth Water Department	GP WELL # 23	0	0	0	0
Yarmouth Water Department	GP WELL # 24	0	0	0	0

Appendix K – Impact Assessment

Drinking Water:

Plant Name	Program ID	Source	Population Served	Days Finished Water Stored	Total
Hyannis Water System	4020004	0	2	3	5
Fall River Water Department	4095000	1	2	1	4
Newburyport DW	3206000	1	1	2	4
Somerset Water Department	4273000	1	1	2	4
Oak Bluffs Water District	4221000	0	1	1	2
Tisbury Water Works	4296000	0	1	1	2
Wareham Fire District	4310000	0	1	1	2
Onset Fire District	4310003	1	0	2	3
Yarmouth Water Department	4351000	0	2	1	3
Marshfield Water Department	4171000	0	2	1	3
Edgartown Water Department	4089000	0	0	1	1
Orleans Water Department	4224000	0	1	1	2
Manchester Water Department	3166000	1	0	1	2
Provincetown DW	4242000	0	1	0	1
Rockport Water Dept	3252000	1	0	0	1
Buzzards Bay Water District	4036001	0	0	0	0

Wastewater:
We only had enough information to consider one wastewater impact factor and as such we do not have a chart.

Appendix L – Wastewater Facility Hazard Assessments

Cohasset Water Pollution Control Facility

Question	A	B	C	D	E	
Answer	no	100 yr.	Cat. 2	no	Cat. 1 or 2	
Ans. # value	0	2	2	0	2	Total = 6

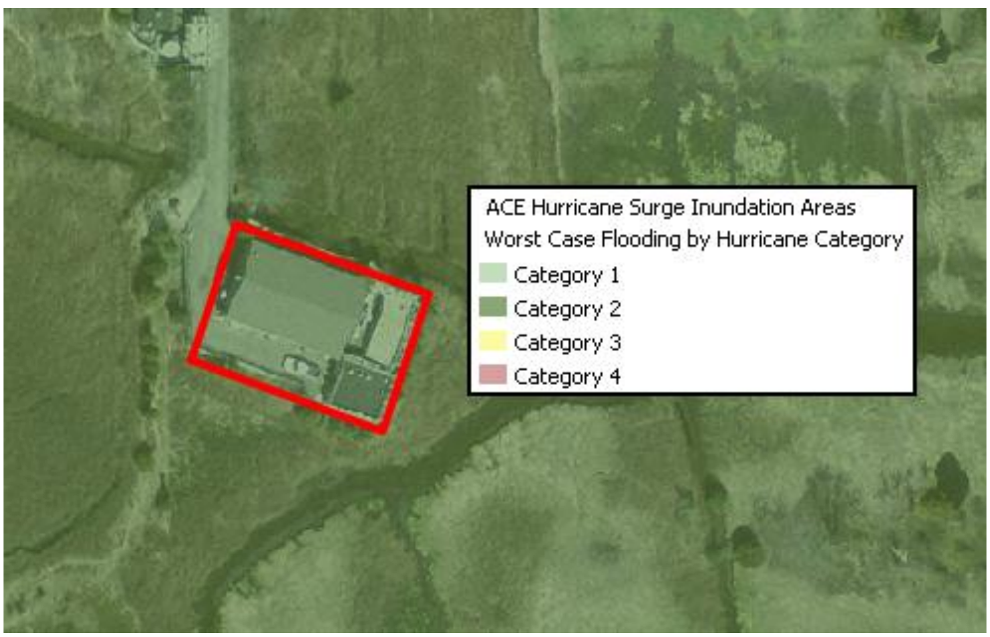
0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Cohasset WPCF Risk Assessment

Risk Assessment

Cohasset Water Pollution Control Facility has not had past flooding which means that the chance of future flooding are less likely to occur than if the facility did have past flooding. The facility is zero feet above sea level and will be below sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. Being within the FEMA 100 yr flood zone currently without the application of sea level rise means that there is at least a 1% chance that the plant will flood each year. The facility is also within the Army Corps of Engineers Category 2 hurricane inundation zone; this is an indicator that the Cohasset Water Pollution Control Facility is at risk of flooding due to storms. The facility does not have a combined sewer system so it was given a zero for this factor. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to still be within category 1 or 2 hurricane inundation zones.

FEMA Flood Zone map for the Cohasset Water Pollution Control Facility.
The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)



ACE Hurricane Surge Inundation Area map for the Cohasset Water Pollution Control Facility

Impact Assessment

If the Cohasset Water Pollution Control Facility becomes unable to process incoming wastewater, up to 0.2 million gallons of wastewater every day may flood the plant and the surrounding area. The plant has a design flow rate of 0.4 million gallons. The facility received a small impact rating because the ratio of average flow to design flow yielded a value of 50%.

Edgartown Wastewater Treatment Facility

Question	A	B	C	D	E	
Answer	No	None	None	No	None	
Ans. # value	0	0	0	0	0	Total = 0

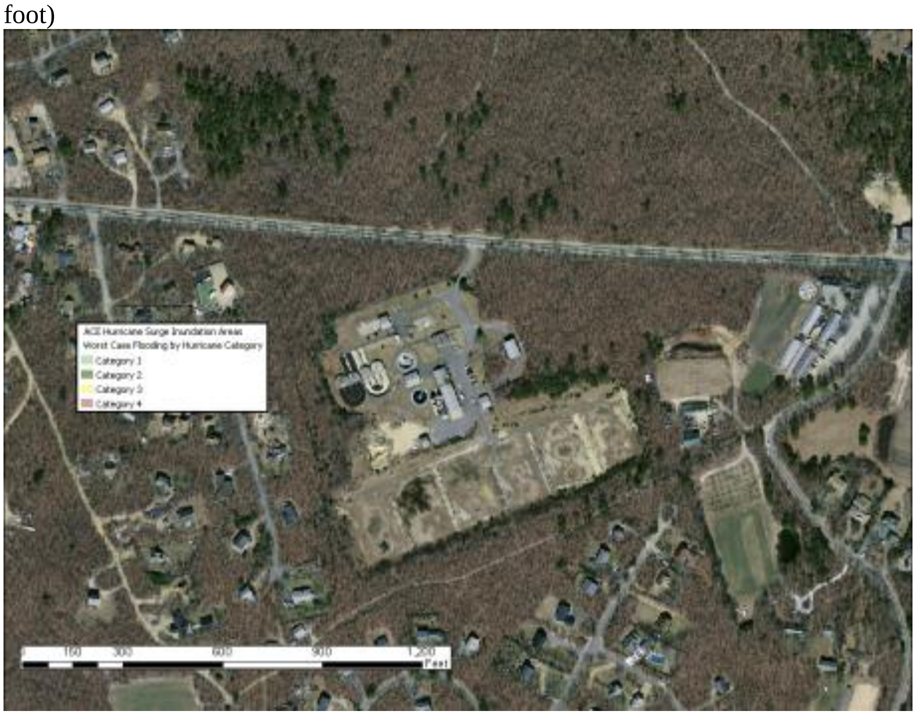
0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Edgartown WWTF Risk Assessment

Risk Assessment

Edgartown Wastewater Facility has no previous flooding occurrences; therefore it was given a zero for that factor. It was also given zero ratings for FEMA flood zones and Army Corps of Engineers hurricane inundation zones because it was outside both these areas. The facility has an average elevation of thirty-two feet above sea level and will remain well above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. The Edgartown Wastewater Facility does not have any combined sewer/storm systems meaning it is not susceptible to increase flow. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to not be within any category of our predicted ACE hurricane inundation zones, again the facility was also given a zero for this situation. Edgartown Wastewater Facility is an ideal facility according to our assessment, receiving a zero for each factor.

FEMA Flood Zone map for the Edgartown Wastewater Facility. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)



ACE Hurricane Surge Inundation Area map for the Edgartown Wastewater Facility

Fall River Wastewater Treatment Plant

Question	A	B	C	D	E	
Answer	No	100 yr.	Cat. 2	Yes	Cat. 1 or 2	
Ans. # value	0	2	2	1	2	Total = 7

0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Fall River WWTP Risk Assessment

Risk Assessment

Fall River Wastewater Treatment Plant has not had past flooding which means that the chance of future flooding are less likely to occur than if the facility did have past flooding. The facility is 16 feet above sea level and will remain above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. Being within the FEMA 100 yr flood zone currently without the application of sea level rise means that there is at least a 1% chance that the plant will flood each year. The facility is also within the Army Corps of Engineers Category 2 hurricane inundation zone; this is an indicator that the Fall River Wastewater Treatment Plant is at risk of flooding due to storms. The facility does also have a combined sewer system meaning the sewer system and storm drain systems are combined into one. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to still be within the category 1 or 2 hurricane inundation zones.

FEMA Flood Zone map for the Fall River Wastewater Treatment Plant. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)

ACE Hurricane Surge Inundation Area map for the Fall River Wastewater Treatment Plant

Impact Assessment

If the Fall River Wastewater Treatment Plant becomes unable to process incoming wastewater, up to 18.9 million gallons of wastewater every day may flood the plant and the surrounding area. The plant has a design flow rate of 30.6 million gallons. The facility received a medium impact rating because the ratio of average flow to design flow yielded a value of 62%.

Hull Wastewater Treatment Plant

Question	A	B	C	D	E	
Answer	yes	100 yr.	Cat. 2	no	Cat. 1 or 2	
Ans. # value	3	2	2	0	2	Total = 9

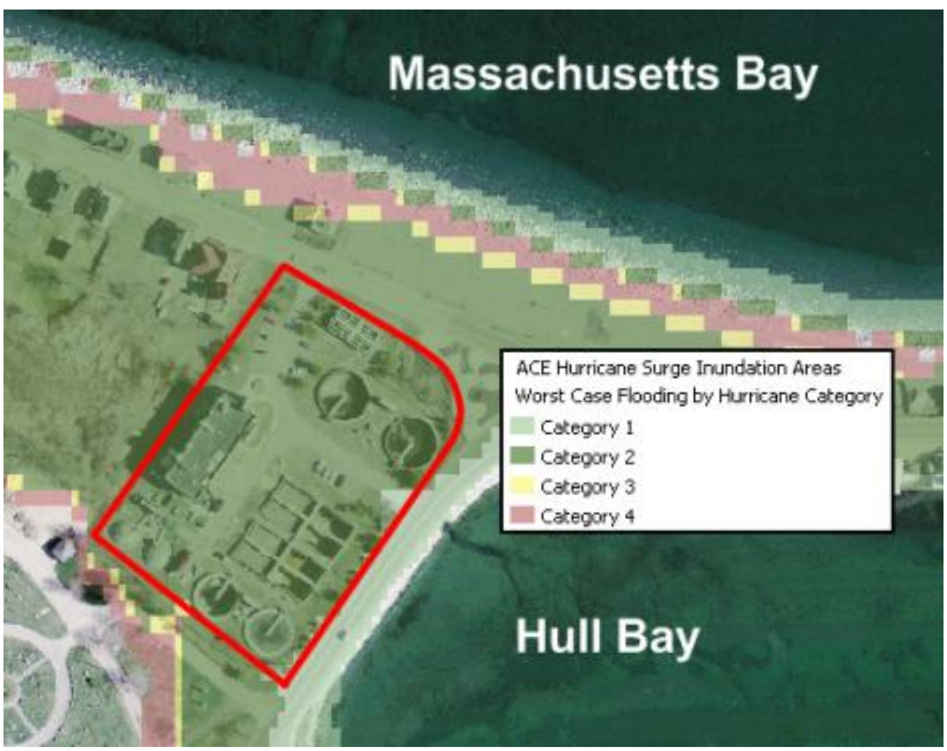
0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Hull WWTP Risk Assessment

Risk Assessment

Hull Wastewater Treatment Plant has had past flooding which means that the chance of future flooding is likely to occur again however the plant designers anticipated this and added storm gates to all openings to the building. The facility is 9 feet above sea level and will remain above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. Being within the FEMA 100 yr flood zone currently without the application of sea level rise means that there is at least a 1% chance that the plant will flood each year. The facility is also within the Army Corps of Engineers Category 2 hurricane inundation zone; this is an indicator that the Hull Wastewater Treatment Plant is at risk of flooding due to storms. The facility does not have a combined sewer system which is why it received a zero in this area. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to still be within category 1 or 2 hurricane inundation zones.

FEMA Flood Zone map for the Hull Wastewater Treatment Plant. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)



ACE Hurricane Surge Inundation Area map for the HullWastewater Treatment Plant

Impact Assessment

Hull Wastewater Treatment's average verses design flow ration of 42% which we give a small impact rating, because the facility would need to more than double its inflow rate to exceed capacity. If the Hull Wastewater Treatment Plant becomes unable to process incoming wastewater, up to 1.3 million gallons of wastewater every day may flood the plant and the surrounding area. Hull Wastewater Treatment plant has a design capacity of 3.07 million gallons per day; however, its average inflow is only 1.3 million gallons per day. The plant operators and town planners at the Hull Wastewater Treatment plant have realized the danger the facility is in and as such have begun planning. Below in figure 4.8 is an image given to us by the Chief Facilities Manager of Hull Wastewater Treatment Plant, Edward Petrilak. It depicts what would happen to the facility during a 100 year storm if the sea levels rose an additional 1.6 feet.

ASA, CZM Hull Wastewater Treatment Plant flooding map

Lynn Wastewater Treatment Plant

Question	A	B	C	D	E	
Answer	yes	500 yr.	Cat. 2	yes	Cat. 1 or 2	
Ans. # value	3	1	2	1	2	Total = 9

0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Lynn WWTP Risk Assessment

Risk Assessment

Lynn Wastewater Treatment Plant has had past flooding which means that the chance of future flooding is likely to occur again. The facility is 14 feet above sea level and will remain above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. Being within the FEMA 500 yr flood zone currently without the application of sea level rise means that there is at least a 0.2% chance that the plant will flood each year. The facility is also within the Army Corps of Engineers Category 2 hurricane inundation zone; this is an indicator that the Lynn Wastewater Treatment Plant is at risk of flooding due to storms. The facility does also have a combined sewer system meaning the sewer system and storm drain systems are combined into one. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to still be within category 1 or 2 hurricane inundation zones.

FEMA Flood Zone map for the Lynn Wastewater Treatment Plant. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)

ACE Hurricane Surge Inundation Area map for the LynnWastewater Treatment Plant

Impact Assessment

If the Lynn Wastewater Treatment Plant becomes unable to process incoming wastewater, up to 24 million gallons of wastewater every day may flood the plant and the surrounding area. The plant has a design flow rate of 60 million gallons. The facility received a small impact rating because the ratio of average flow to design flow yielded a value of 40%.

Manchester-By-The-Sea Wastewater Treatment Plant

Question	A	B	C	D	E	
Answer	no	100 yr.	Cat. 1	no	Cat. 1 or 2	
Ans. # value	0	2	2	0	2	Total = 6

0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Manchester-By-The-Sea WWTP Risk Assessment

Risk Assessment

Manchester-By-The-Sea Wastewater Treatment Plant has not had past flooding which means that the chance of future flooding are less likely to occur than if the facility did have past flooding. The facility is 4 feet above sea level and will remain above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. Being within the FEMA 100 yr flood zone currently without the application of sea level rise means that there is at least a 1% chance that the plant will flood each year. The facility is also within the Army Corps of Engineers Category 1 hurricane inundation zone; this is an indicator that the Manchester-By-The-Sea Wastewater Treatment Plant is at risk of flooding due to storms. The facility does not have a combined sewer system and was therefore given a zero for this factor. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to still be within category 1 or 2 hurricane inundation zones.

FEMA Flood Zone map for the Manchester Wastewater Treatment Plant. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)

ACE Hurricane Surge Inundation Area map for the Manchester Wastewater Treatment Plant

Marshfield Wastewater Treatment Facility

Question	A	B	C	D	E	
Answer	no	100 yr.	Cat. 2	no	Cat. 1 or 2	
Ans. # value	0	2	2	0	2	Total = 6

0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Marshfield WWTF Risk Assessment

Risk Assessment

Marshfield Wastewater Treatment Facility has not had past flooding which means that the chance of future flooding is not likely. The facility is 11 feet above sea level and will be below sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. Being within the FEMA 100 yr flood zone currently without the application of sea level rise means that there is at least a 1% chance that the plant will flood each year. The facility is also within the Army Corps of Engineers Category 2 hurricane inundation zone; this is an indicator that the Marshfield Wastewater Treatment Facility is at risk of flooding due to storms. The facility does not have a combined sewer system so it was given a zero for this factor. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to still be within category 1 or 2 hurricane inundation zones.

FEMA Flood Zone map for the Marshfield Wastewater Treatment Facility. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)

ACE Hurricane Surge Inundation Area map for the Nantucket Wastewater Treatment Facility

Impact Assessment

If the Marshfield Wastewater Treatment Facility becomes unable to process incoming wastewater, up to 1.32 million gallons of wastewater every day may flood the plant and the surrounding area. The plant has a design flow rate of 2.1 million gallons. The facility received a medium impact rating because the ratio of average flow to design flow yielded a value of 63%.

Nantucket Wastewater Treatment Facility

Question	A	B	C	D	E	
Answer	-	500 yr.	Cat. 4	no	Cat. 3 or 4	
Ans. # value	0	1	1	0	1	Total = 3

0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Nantucket WWTF Risk Assessment

Risk Assessment

Due to the unavailability of the past flooding information at the Nantucket Wastewater Treatment Facility it was assumed that the facility had not experienced past flooding. With an assumption that the facility had experienced past flooding its rating would be upgraded to a Medium Rating. The facility is nine feet above sea level and will remain above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. Being within the FEMA 500 yr flood zone currently without the application of sea level rise means that there is at least a 0.2% chance that the plant will flood each year. The facility is also within the Army Corps of Engineers Category 4 hurricane inundation zone; this is an indicator that the Nantucket Wastewater Treatment Facility is at risk of flooding due to storms however not as great of a risk as it would have if it were in category 1 or 2. The facility also does not have a combined sewer system. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to still be within category 3 or 4 hurricane inundation zones.

FEMA Flood Zone map for the Nantucket Wastewater Treatment Facility. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)

ACE Hurricane Surge Inundation Area map for the Nantucket Wastewater Treatment Facility

New Bedford Water Pollution Control Facility

Question	A	B	C	D	E	
Answer	no	100 yr.	Cat. 3	yes	Cat. 3 or 4	
Ans. # value	0	2	1	1	1	Total = 5

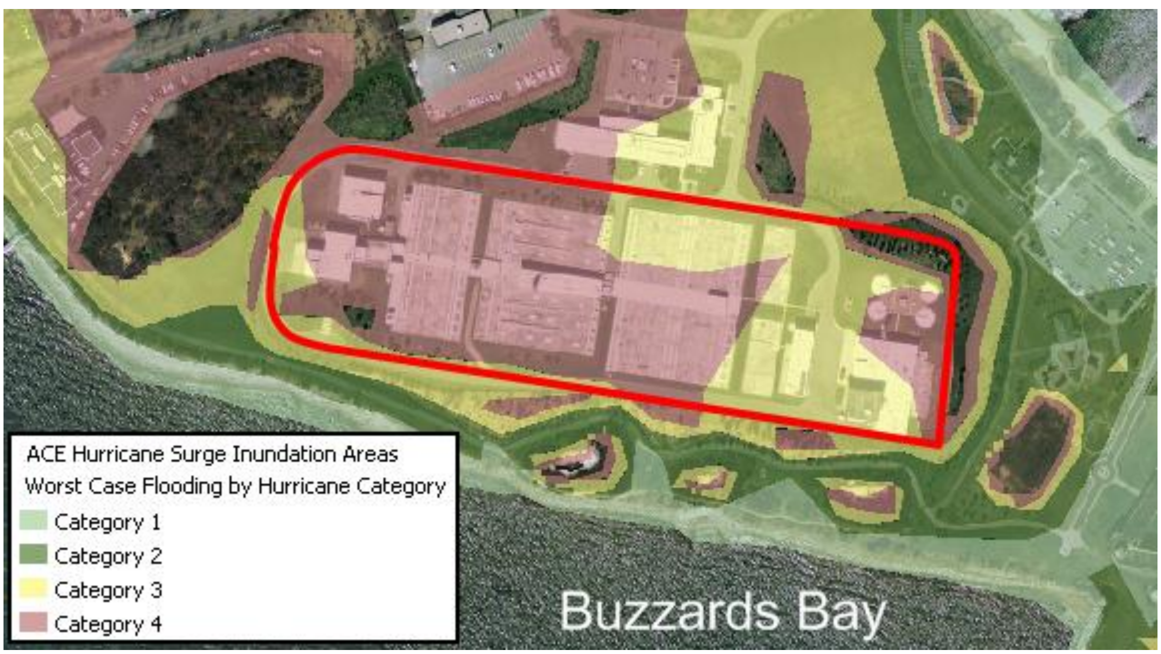
0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

New Bedford WPCF Risk Assessment

Risk Assessment

New Bedford Water Pollution Control Facility has had past flooding which means that the chance of future flooding are less likely to occur than if the facility did have past flooding. The facility is 14 feet above sea level and will remain above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. Being within the FEMA 100 yr flood zone currently without the application of sea level rise means that there is at least a 1% chance that the plant will flood each year. The facility is also within the Army Corps of Engineers Category 3 hurricane inundation zone; this is an indicator that the New Bedford Water Pollution Control Facility is at risk of flooding due to storms however not as great of a risk as it would have if it were in category 1 or 2. The facility does also have a combined sewer system meaning the sewer system and storm drain systems are combined into one. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to still be within category 3 or 4 hurricane inundation zones.

FEMA Flood Zone map for the New Bedford Water Pollution Control Facility. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)



ACE Hurricane Surge Inundation Area map for the New Bedford Water Pollution Control Facility

Impact Assessment

If the New Bedford Water Pollution Control Facility becomes unable to process incoming wastewater, up to 21.5 million gallons of wastewater every day may flood the plant and the surrounding area. The plant has a design flow rate of 80 million gallons. The facility received a small impact rating because the ratio of average flow to design flow yielded a value of 27%.

Newburyport Wastewater Treatment Plant

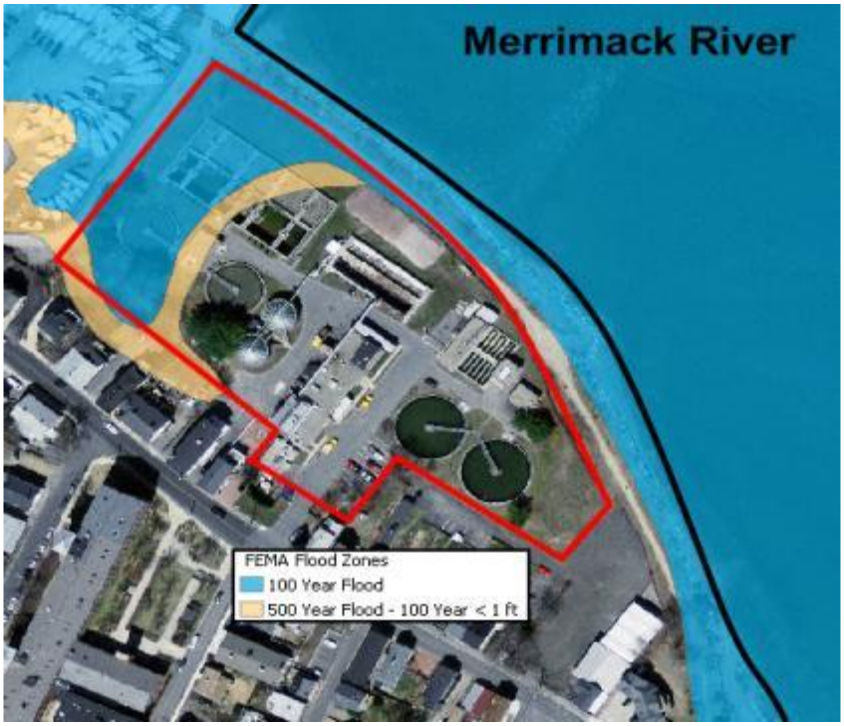
Question	A	B	C	D	E	
Answer	no	100 yr.	Cat. 2	no	Cat. 1 or 2	
Ans. # value	0	2	2	0	2	Total = 6

0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Newburyport WWTP Risk Assessment

Risk Assessment

Newburyport Wastewater Treatment Plant has had no past flooding which means that the chance of future flooding is less likely to occur than if the plant had past flooding. The facility is 10 feet above sea level and will remain above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. Being within the FEMA 100 yr flood zone currently without the application of sea level rise means that there is at least a 1% chance that the plant will flood each year. The facility is also within the Army Corps of Engineers Category 2 hurricane inundation zone; this is an indicator that the Newburyport Wastewater Treatment Plant is at risk of flooding due to storms. The facility does not have a combined sewer system which is why it received a zero in this area. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to still be within category 1 or 2 hurricane inundation zones.



FEMA Flood Zone map for the Newburyport Wastewater Treatment Plant. The red line indicates the boundary of the facility.

(500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)

ACE Hurricane Surge Inundation Area map for the Newburyport Wastewater Treatment Plant

Impact Assessment

If the Newburyport Wastewater Treatment Plant becomes unable to process incoming wastewater, up to 2.6 million gallons of wastewater every day may flood the plant and the surrounding area. The plant has a design flow of 3.4 million gallons. The facility received a large impact rating because the ratio of average flow to design flow yielded a value of 76%.

Provincetown Wastewater Treatment Plant

Question	A	B	C	D	E	
Answer	No	None	None	No	None	
Ans. # value	0	0	0	0	0	Total = 0

0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Provincetown WWTP Risk Assessment

Risk Assessment

Provincetown Wastewater Treatment Plant has no previous flooding occurrences. Therefore it was given a zero for that factor. It is also was given zero ratings for FEMA flood zones and Army Corps of Engineers hurricane inundation zone because it was outside both these areas. The facility has an average elevation of 42 feet above sea level and will remain well above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. The Provincetown Wastewater Treatment Plant also does not have any combined sewer/storm systems meaning it is not susceptible to increase flow. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to not be within any category of our predicted ACE hurricane inundation zones, again the facility was also given a zero for this situation. Provincetown is an ideal facility according our assessment, receiving a zero for each factor.

FEMA Flood Zone map for the Provincetown Wastewater Treatment Plant. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)

ACE Hurricane Surge Inundation Area map for the Provincetown Wastewater Treatment Plant

Rockport Wastewater Treatment Plant

Question	A	B	C	D	E	
Answer	No	None	None	-	None	
Ans. # value	0	0	0	-	0	Total = 0

0	1	2	3	4	5	6	7	8	9	10
Low				Medium				High		

Rockport WWTP Risk Assessment

Risk Assessment

Rockport Wastewater Treatment Plant has no previous flooding occurrences. Therefore it was given a zero for that factor. It is also was given zero ratings for FEMA flood zones and Army Corps of Engineers hurricane inundation zone because it was outside both these areas. The facility has an average elevation of 68.9 feet above sea level and will remain well above sea level if the predicted Rahmstorf 2100 sea level rise of 2.75 feet were to actually occur. The Rockport Wastewater Treatment Plant also does not have any combined sewer/storm systems meaning it is not susceptible to increase flow. By adding the Rahmstorf prediction for sea level rise to the average height of the ACE hurricane inundation zones in the area we found the plant to not be within any category of our predicted ACE hurricane inundation zones, again the facility was also given a zero for this situation. Rockport Wastewater Treatment Plant is an ideal facility according our assessment, receiving a zero for each factor.

FEMA Flood Zone map for the Rockport Wastewater Treatment Plant. The red line indicates the boundary of the facility. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot)

ACE Hurricane Surge Inundation Area map for the Rockport Wastewater Treatment Plant

Appendix M – Drinking Water System Hazard Assessments

Buzzards Bay Water District

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Pump Station #1	Answer Rating	None 0	None 0	None 0	0
Pump Station #2	Answer Rating	None 0	Cat 3 1	Cat 3-4 1	2
Pump Station #3	Answer Rating	None 0	None 0	None 0	0
Pump Station #4	Answer Rating	None 0	None 0	None 0	0

Pump Stations 1, 3, 4:

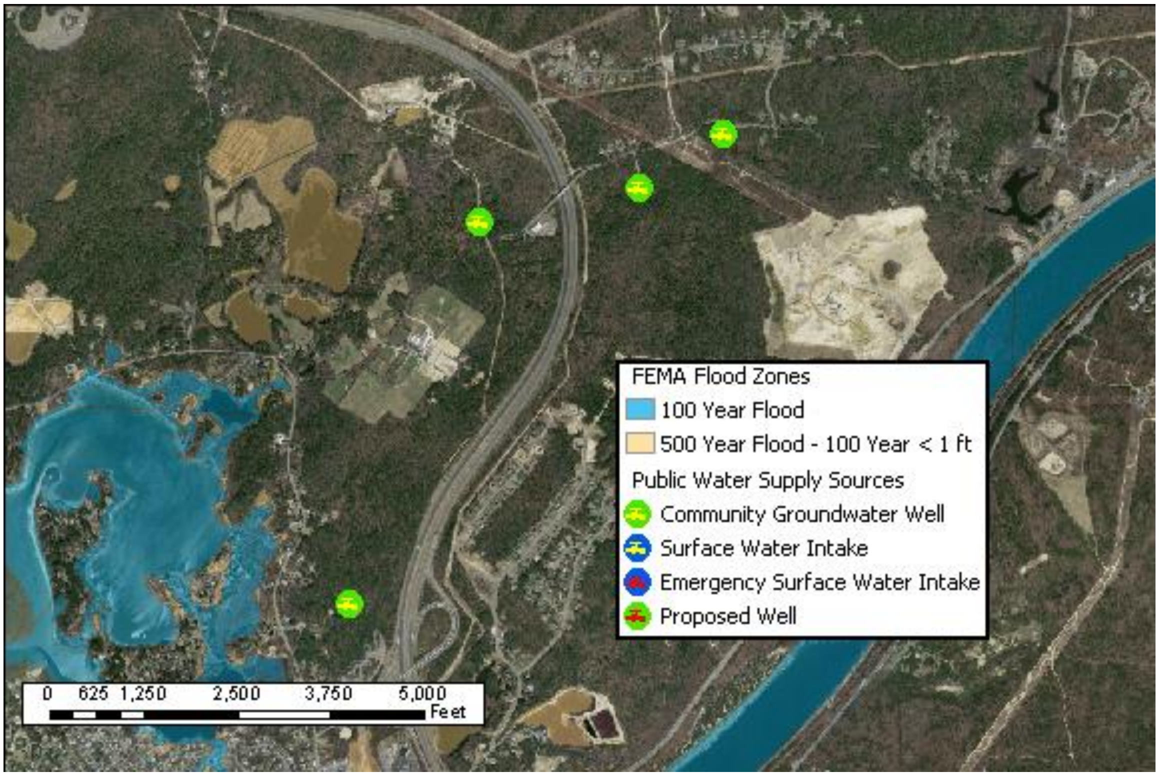
0	1	2	3	4	5	6
Low			Medium		High	

Pump Station 4:

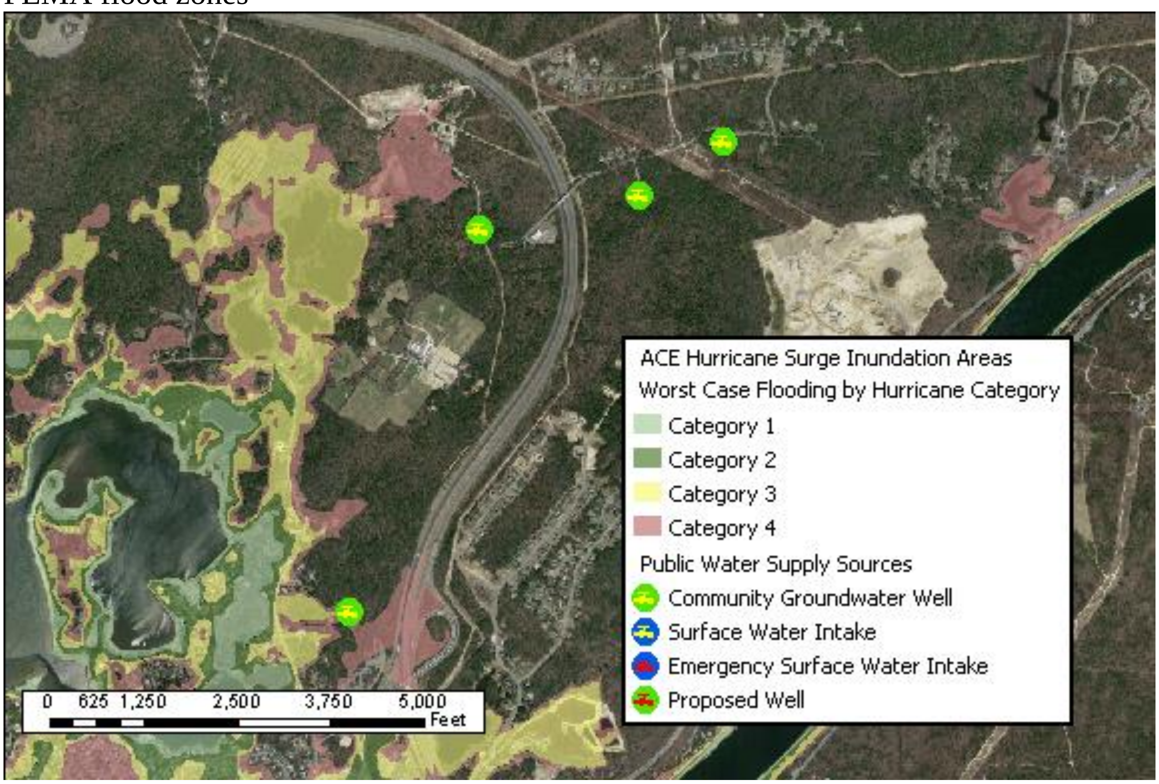
0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

None of the pump stations in Buzzards Bay Water District are in FEMA flood zones, and only one pump station is in an ACE hurricane inundation area. Pump Station #4, the pump station in the hurricane inundation area, is in the category 3 area. Based on the elevations of the pump stations, none of the stations are predicted to be moved into a worse hurricane inundation area due to sea level rise. All the pump stations have been rated as being low risk. Shown below are the four pump stations and FEMA flood zones and ACE hurricane inundation areas, respectively.



FEMA flood zones



ACE hurricane inundation areas

Buzzard Bay Water District

Location		Source	Pop	Days Stored	Totals
Buzzard Bay Water District	Answer	Ground	Below 15,000	Above 3 days	
	Rating	0	0	0	0

0	1	2	3	4	5	6
	Low		Medium		High	

Impact Assessment

The Buzzard Bay Water District received a low impact rating on our assessment because the department gathers its water from a ground source, serves a population of less than 15,000 and has over three days worth of storage. The Buzzard Bay Water District serves a population of 7,700 in the summer and 5,830 in the winter, with an average flow rate of 0.49 million gallons per day. The department's storage capacity is 2 million gallons. The Buzzard Bay Water District has the ability to store 4.1 day's worth of water at the above average flow rate.

Edgartown Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
MACHACKET WELL	Answer Rating	None 0	None 0	None 0	Low 0
LILY POND WELL	Answer Rating	100 year 2	Cat 2 2	Cat 1-2 2	High 6
WINTUCKET WELL 2	Answer Rating	None 0	Cat 4 1	Cat 3-4 1	Low 2
QUENOMICA WELL	Answer Rating	None 0	None 0	None 0	Low 0
NUNNEPOG WELL	Answer Rating	None 0	None 0	None 0	Low 0

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

The Edgartown water system has 5 water sources. The Lily Pond well is in the 100-year FEMA flood zone, as shown in the FEMA figure below, meaning that FEMA estimates it has at least a 1% chance of flooding every year. This is the only water source in a FEMA flood zone. As shown in the ACE figure below, the Lily Pond well is in the Army Corps of Engineers category 2 hurricane inundation area, and Wintucket Well 2 is in the category 4 area. Based on elevations, we predict that none of the water sources will be in a worse area than they currently are in by 2100. Overall, we estimate that the Lily Pond well is at high risk and the other 4 of Edgartown's water sources are at low risk to flooding and the effects of sea level rise.

Edgartown’s water sources and ACE hurricane inundation zones

Edgartown’s water sources and FEMA flood zones

Edgartown Water Department

Location		Source	Pop	Days Stored	Totals
Edgartown Water Department	Answer	Ground	Below 15,000	Between 2 and 3 days	
	Rating	0	0	1	1

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Edgartown Water Department received a low impact rating on our assessment because the department gathers its water from a ground source serves a population of less than 15,000 and has over two days worth of storage. The Edgartown Water Department serves a population of 14,000 during the summer and 2,500 during the winter, with an average flow rate of 0.91 million gallons per day. The department's storage capacity is 2.2 million gallons. The Edgartown Water Department has the ability to store 2.4 day's worth of water at the above average flow rate.

Fall River Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Fall River Water Department Treatment Facility	Answer Rating	100 Year 2	None 0	None 0	2
Fall River North. Watuppa Pond	Answer Rating	100 Year 2	None 0	None 0	2
Fall River Copicut Resevoir	Answer Rating	100 Year 2	None 0	None 0	2

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

The Fall River Department water treatment facility and its drinking water sources are all within the hundred year FEMA flood zone. However, neither the facility nor its sources are in any ACE hurricane inundation zones and are predicted to remain outside of these zones for the next hundred years. While the Fall River drinking water system is at a relatively high risk of flooding compared to other drinking water facilities across the Massachusetts coast, it is still designated low risk.

Fall River Water Department

Location		Source	Pop	Days Stored	Totals
Fall River Water Department	Answer Rating	Surface 1	Above 30,000 2	Between 2 and 3 days 1	4

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Fall River Water Department received a medium impact rating on our assessment because the department serves a large population, gathers its water from surface sources but has more than two days worth of storage. The Fall River Water Department serves a year round population of 94,000 with an average rate of 10.26 million gallons per day. The department's storage capacity is 25.5 million gallons. The Fall River Water Department has the ability to store 2.5 day's worth of water at the above average flow rate.

Hyannis Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
STRAIGHTWAY WELL	Answer Rating	None 0	None 0	None 0	Low 0
MAHER WELL # 2	Answer Rating	100 year 2	Cat 3 1	Cat 3-4 1	Medium 4
HYANNISPORT	Answer Rating	100 year 2	Cat 4 1	Cat 3-4 1	Medium 4
MARY DUNN WELL # 1	Answer Rating	None 0	None 0	None 0	Low 0
MARY DUNN WELL # 2	Answer Rating	None 0	None 0	None 0	Low 0
SIMMONS POND	Answer Rating	500 year 1	Cat 3 1	Cat 1-2 2	Medium 4
MAHER WELL # 1	Answer Rating	100 year 2	Cat 4 1	Cat 3-4 1	Medium 4
MARY DUNN WELL # 3	Answer Rating	None 0	None 0	None 0	Low 0
MARY DUNN WELL # 4	Answer Rating	500 year 1	None 0	None 0	Low 1
AIRPORT # 1	Answer Rating	None 0	None 0	None 0	Low 0
MAHER WELL # 3	Answer Rating	100 year 2	Cat 3 1	Cat 3-4 1	Medium 4
STRAIGHTWAY WELL #2	Answer Rating	None 0	None 0	None 0	Low 0

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

The Hyannis water system has 12 water sources. Maher Wells #1-3 and Hyannisport are in the 100-year FEMA flood zone, meaning that FEMA estimates they have at least a 1% chance of flooding every year. The only other sources in FEMA flood zones are Simmons Pond and Mary Dunn Well #4, which are in the 500-year flood zone, meaning that FEMA estimates that they have at least a 0.2% chance of flooding every year. Maher Wells #1-3, Simmons Pond, and

Hyannisport are all in category 3 or 4 hurricane inundation areas, meaning that the Army Corps of Engineers predicts that they will be inundated in the worst-case flooding caused by a category 3 or 4 hurricane, respectively. Based on elevations, we predict that only Simmons Pond's hurricane inundation zone will be upgraded, and we predict it will move to either the category 1 or 2 areas by 2100. Overall, we estimate that 7 of the water sources in Hyannis are at low risk and 5 of the water sources are at medium risk due to flooding.

Hyannis Drinking Water

Location		Source	Pop	Days Stored	Totals
Hyannis Water System	Answer	Ground	Above 30,000	Less than 1 day	High
	Rating	0	2	3	5

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Hyannis Water System received a high impact rating on our assessment because the department serves a large population and has less than one day's worth of storage. The Hyannis Water System serves a summer population of 35,000 and winter population of 18,000 with an average rate of 2.39 million gallons per day. The department's storage capacity is 1.37 million gallons. The Hyannis Water System has the ability to store 0.57 day's worth of water at the above average flow rate.

Manchester Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Manchester Water Department treatment facility	Answer Rating	None 0	None 0	None 0	0
Manchester Water Dept. Lincoln St. Well	Answer Rating	None 0	None 0	Cat 3-4 1	1
Manchester Water Dept. Gravelly Pond	Answer Rating	100 Year 2	None 0	None 0	2

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

While the Manchester Water Department and its Lincoln Street well are outside of any FEMA flood zones, the Gravelly Pond water source is within the 100 year flood zone. Additionally, neither the facility nor it water sources are in any ACE hurricane inundation zones, however, the Lincoln Street well is predicted to be within a category three or four inundation zone within one hundred years.

Manchester Water Department

Location		Source	Pop	Days Stored	Totals
Manchester Water Department	Answer Rating	Surface 1	Below 15,000 0	Above 3 days 0	1

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Manchester Water Department received a low impact rating on our assessment because the department gathers its water from a surface source but serves a population of less than 15,000 and has over three days worth of storage. The Manchester Water Department serves a year round population of 5,469, with an average flow rate of 0.72 million gallons per day. The department's storage capacity is 2.22 million gallons. The Manchester Water Department has the ability to store 3.1 day's worth of water at the above average flow rate.

Marshfield Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Parsonage St. Wells #1, 2; Webster Well #2; Spring St. Well	Answer	None	None	Cat 1-2	Low
	Rating	0	0	2	2
Proposed Fairgrounds Well	Answer	None	None	Cat 3-4	Low
	Rating	0	0	1	1
All other Wells	Answer	None	None	None	Low
	Rating	0	0	0	0

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

The Marshfield water system has 17 current water sources and 2 proposed water sources. None of the sources are located in FEMA flood zones or Army Corps of Engineers hurricane inundation zones. Based on elevations, we predict that Parsonage St. Wells #1, 2; Webster Well #2; and the Spring St. Well will be in a category 1 or 2 area and the proposed Fairgrounds Will be in a category 3 or 4 area by 2100. Overall, we estimate that all of the current and proposed water sources are at low risk.

Marshfield Water Department

Location		Source	Pop	Days Stored	Totals
Marshfield Water Department	Answer	Ground	Above 30,000*	Between 2 and 3 days	
	Rating	0	2	1	3

*Note: The summer population was used as an example of the worst case scenario

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Marshfield Water Department received a medium impact rating on our assessment because the department gathers its water from ground sources but serves a population over 30,000 and has over two days worth of storage. The Marshfield Water Department serves a population of 34,000 during the summer and 25,300 during the winter, with an average flow rate of 2.54 million gallons per day. The department’s storage capacity is 5.07 million gallons. The Marshfield Water Department has the ability to store 1.99 day’s worth of water at the above average flow rate, which we rounded to 2 days worth for our rating purposes.

Newburyport Water Works
Treatment Facility

Question	B	C	D	
Answer	None	None	None	
Ans. # value	0	0	0	Total = 0

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

Newburyport drinking water facility has no previous flooding occurrences. A pump station close to the Merrimack River was flooded in 1936, but they have since built a permanent berm and are currently in the process of moving the pump station to a higher elevation. No other flooding has occurred since and so it was given a zero rating for that factor. It was also given zero ratings for FEMA flood zones and Army Corps of Engineers' hurricane inundation zone because it was well outside both these areas. With an elevation of 56 ft, the facility would remain above sea level in the Pfeffer 2100 sea level rise scenario. Through this analysis the Newburyport Water Treatment Plant was deemed to be at low risk.

Newburyport Water Works

Location		Source	Pop	Days Stored	Totals
Newburyport Water Works	Answer	Surface	Between 15,000 and 30,000	Less than 2 days	
	Rating	1	1	2	4

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Newburyport Water Works received a medium impact rating on our assessment because the department gathers its water from surface sources and has less than two days worth of storage. The Newburyport Water Works serves a year round population of 20,335 with an average rate of 2.04 million gallons per day. The department's storage capacity is 2.75 million gallons. The Newburyport Water Works has the ability to store 1.3 day's worth of water at the above average flow rate.

Oak Bluffs

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Lagoon Pond Wellfield	Answer Rating	100-year 2	Cat 3-4 1	Cat 3-4 1	4
Farm Neck Rd. Wellfield	Answer Rating	None 0	None 0	None 0	0
Well #3 State Field	Answer Rating	None 0	None 0	None 0	0
Madison Alwardt Sr. Well #4	Answer Rating	None 0	None 0	None 0	0
Well #5	Answer Rating	None 0	None 0	None 0	0

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

The only well that appears to be in any danger is the Lagoon Pond Wellfield. It is located in a 100-year flood zone and a category 3 hurricane inundation zone. The hurricane zone the well is located in is not expected to get worse based on its elevation.

Oak Bluffs Water District

Location		Source	Pop	Days Stored	Totals
Oak Bluffs Water District	Answer Rating	Ground 0	Between 15,000 and 30,000* 1	Between 2 and 3 days 1	2

*Note: The summer population was used in this rating system for a worst case scenario.

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Oak Bluffs Water District received a low impact rating on our assessment because the department gathers its water from ground sources and at least two days worth of storage. The

Oak Bluffs Water District serves a population of 23,751 in the summer and 4,227 in the winter with an average flow rate of 0.99 million gallons per day. The department's storage capacity is 2 million gallons. The Oak Bluffs Water District has the ability to store 2.0 day's worth of water at the above average flow rate.

Onset Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Onset Fire District Sand Pond Reservoir	Answer Rating	100 Year 2	Cat. 3-4 1	Cat. 3-4 1	4
Onset Fire District Well #3	Answer Rating	None 0	Cat. 3-4 1	Cat. 3-4 1	2 2
Onset Fire District Well #4	Answer Rating	None 0	Cat. 1-2 2	Cat 1-2 2	4
Onset Fire District Well #5	Answer Rating	None 0	Cat. 3-4 1	Cat. 3-4 1	2
Onset Fire District Well #6	Answer Rating	None 0	Cat. 3-4 1	Cat. 3-4 1	2
Onset Fire District Proposed Well #7	Answer Rating	None 0	Cat. 3-4 1	Cat. 3-4 1	2

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

The Onset Fire District Sand Pond reservoir is within the FEMA hundred year flood zone but the district's wells are not in any flood zone. The wells and reservoir are all in category three or four hurricane inundation zones except for well four which is within a category one or two hurricane inundation zone. It is predicted that the wells and reservoir will all stay within their respective zones within the next hundred years.

Onset Fire District

Location		Source	Pop	Days Stored	Totals
Onset Fire District	Answer Rating	Surface 1	Below 15,000 0	Between 2 and 3 days 1	2

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Onset Fire District received a low impact rating on our assessment because the department gathers its water from surface sources but has at least two days worth of storage, and a population under 15,000. The Onset Fire District serves a population of 13,975 year round with an average flow rate of 0.6 million gallons per day. The department's storage capacity is 1.2 million gallons. The Onset Fire District has the ability to store 2 day's worth of water at the above average flow rate.

Provincetown Drinking Water System

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Provincetown Drinking Water Knowles Crossing Well	Answer Rating	None 0	None 0	Cat 3-4 1	 1
Provincetown Drinking Water Paul D. Daley Well Field	Answer Rating	None 0	None 0	Cat 3-4 1	 1
Provincetown Drinking Water North Truro USAF Base Well (04G)	Answer Rating	None 0	None 0	None 0	 0
Provincetown Drinking Water North Truro USAF Base Well (05G)	Answer Rating	None 0	None 0	None 0	 0

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

None of the Provincetown drinking water pumps are in any FEMA flood zones or ACE hurricane inundation zones. Only the Knowles Crossing Well and Paul D. Daley Well field will be in a category one or two hurricane inundation zone in one hundred years. Because of these factors the Provincetown drinking water system is at very low risk of flooding.

Location		Source	Pop	Days Stored	Totals
Provincetown Water Department	Answer	Ground	Between 15,000 and 30,000*	Above 3 days	
	Rating	0	1	0	1

*Note: The summer population was used as a worst case scenario

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Provincetown Water Department received a low impact rating on our assessment because the department serves a population of between 15,000 and 30,000 but retrieves its water from a ground source and has over three days' worth of storage. The Provincetown Water Department serves a population of 27,500 in the summer and 3,434 in the winter, with an average flow rate of 0.78 million gallons per day. The department's storage capacity is 6.5 million gallons. The Provincetown Water Department has the ability to store 8.4 days' worth of water at the above average flow rate.

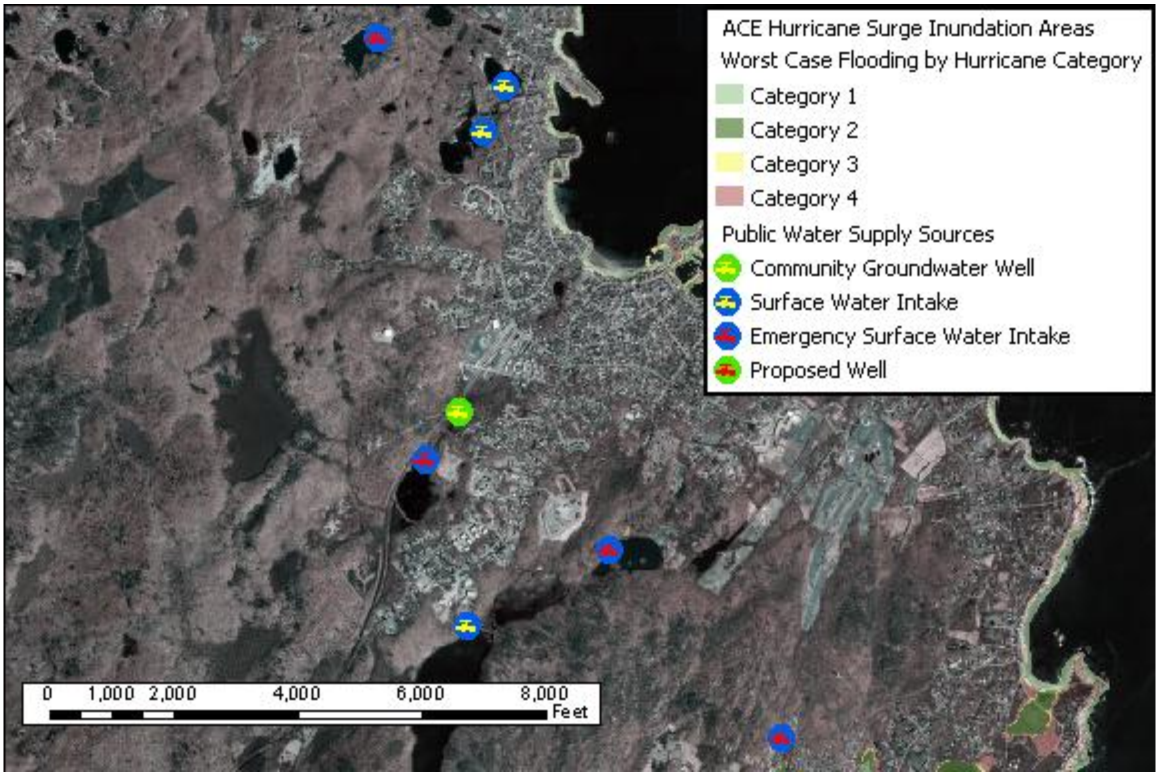
Rockport Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
CAPE POND	Answer Rating	500 year 1	None 0	None 0	1
MILL BROOK REPLACEMENT WELLFIELD	Answer Rating	None 0	None 0	None 0	0
CARLSONS QUARRY (QUARRY RES.)	Answer Rating	500 year 1	None 0	None 0	1
FLAT LEDGE QUARRY	Answer Rating	500 year 1	None 0	None 0	1

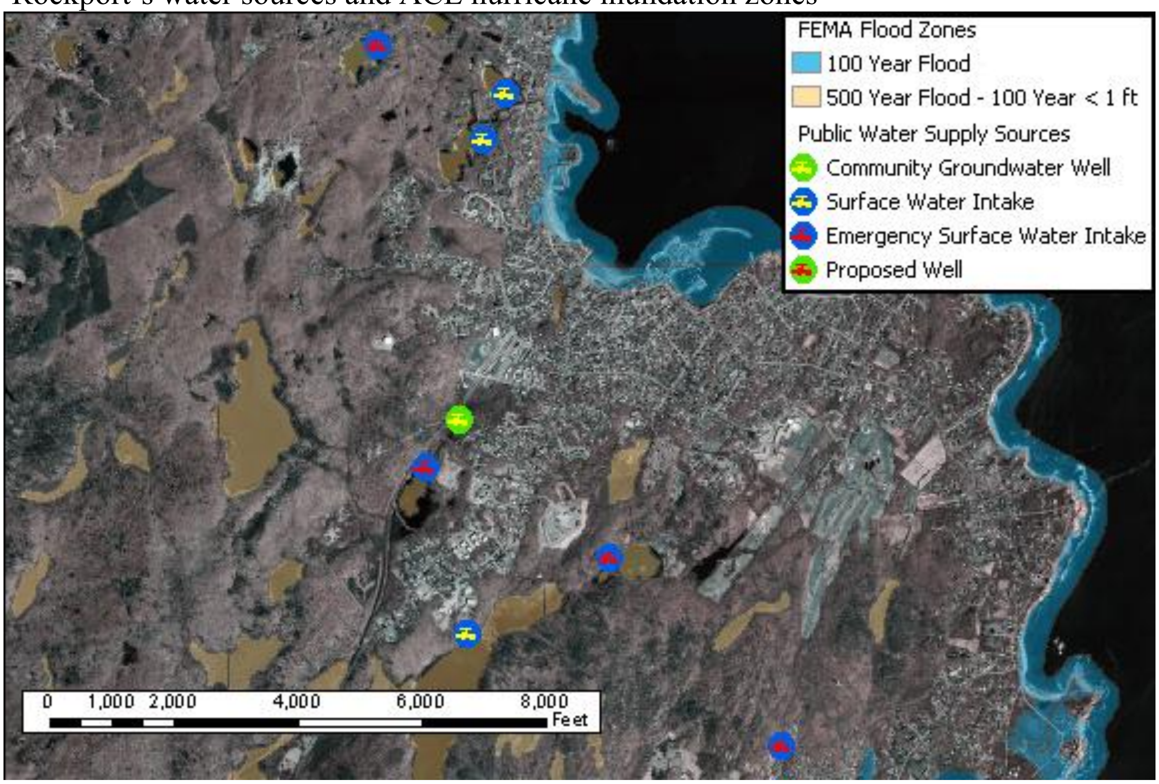
0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

The Rockport water system has 4 water sources, ignoring emergency water sources. Cape Pond, Carlsons Quarry Reservoir, and Flat Ledge Quarry are in the 100-year FEMA flood zone, meaning that FEMA estimates they have at least a 1% chance of flooding every year. None of Rockport's water sources are in any Army Corps of Engineers hurricane inundation areas. Based on elevations, we predict that none of the water sources will be in these areas by 2100. Overall, we estimate that all 4 of Rockport's water sources are at low risk to flooding and the effects of sea level rise.



Rockport’s water sources and ACE hurricane inundation zones



Rockport’s water sources and FEMA flood zones

Rockport Water Department

Location		Source	Pop	Days Stored	Totals
Rockport Water Department	Answer	Surface	Below 15,000	Above 3 days	
	Rating	1	0	0	1

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Rockport Water Department received a low impact rating on our assessment because the department gathers its water from a surface source but serves a population of less than 15,000 and has over three days' worth of storage. The Rockport Water Department serves a population of 9,890 in the summer and 7,480 in the winter, with an average flow rate of 0.49 million gallons per day. The department's storage capacity is 4.2 million gallons. The Rockport Water Department has the ability to store 8.6 days' worth of water at the above average flow rate.

Somerset Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Somerset water treatment facility (Somerset Reservoir)	Answer Rating	100 Year 2	Cat. 3-4 1	Cat 3-4 1	 4
Somerset Water Department FJM #2 well	Answer Rating	None 0	Cat. 3-4 0	Cat 3-4 1	 1

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

The Somerset Water Department treatment facility is within the FEMA hundred year flood zone and the ACE hurricane inundation zones category three or four. The facility's well is not in any FEMA flood zone or ACE hurricane inundation zone but is predicted to be within a category three or four hurricane inundation zone within the next hundred years. While the water department's well is at low risk, the facility that treats Somerset's drinking water is at medium risk.

Location		Source	Pop	Days Stored	Totals
Somerset Water Department	Answer Rating	Surface 1	Between 15,000 and 30,000 1	Less than 2 days 2	 4

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Somerset Water Department received a medium impact rating on our assessment because the department gathers its water from surface sources and has less than two days' worth of storage. The Somerset Water Department serves a year round population of 19,638 with an average flow rate of 2.9 million gallons per day. The department's storage capacity is 5.02 million gallons. The Somerset Water Department has the ability to store 1.7 days' worth of water at the above average flow rate.

Tisbury Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
All Wells	Answer Rating	None 0	None 0	None 0	0

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

The Tisbury water system has 3 wells. None of the sources are located in FEMA flood zones or Army Corps of Engineers hurricane inundation zones. Based on elevations, we predict that none of the wells will be in any hurricane inundation area by 2100. Overall, we estimate that all of the wells are at low risk.

Tisbury Water Works

Location		Source	Pop	Days Stored	Totals
Tisbury Water Works	Answer Rating	Ground 0	Between 15,000 and 30,000* 1	Between 2 and 3 days 1	2

*Note: The summer population was used in this rating system for a worst case scenario.

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Tisbury Water Works received a low impact rating on our assessment because the department gathers its water from ground sources and at least two days worth of storage. The Tisbury Water Works serves a population of 23,728 in the summer and 3,851 in the winter with an average flow rate of 0.55 million gallons per day. The department's storage capacity is 1.2 million gallons. The Tisbury Water Works has the ability to store 2.2 day's worth of water at the above average flow rate.

Wareham Fire District Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
Wareham Fire District Maple Spring Wells #1-5	Answer	none	Cat 3-4	Cat 3-4	
	Rating	0	1	1	2
Wareham Fire District Maple Spring Wells #6-8	Answer	None	None	None	
	Rating	0	0	0	0
Wareham Fire District Proposed Maple Spring Well	Answer	None	None	None	
	Rating	0	0	0	0

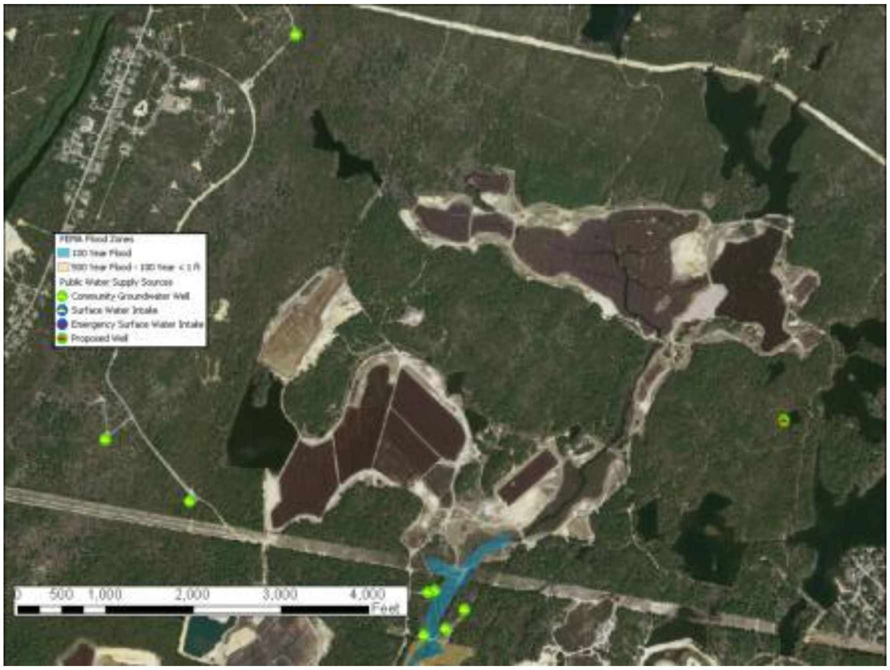
0	1	2	3	4	5	6
Low			Medium		High	

Wells 1-5

Wareham Fire District Drinking Water Risk Assessment.
*Note, each Maple Springs well was analyzed separately, since their ratings are all identical they have been condensed into one table

Risk Assessment

None of the Wareham Fire District Maple Springs wells are within any FEMA flood zone. Only wells 1-5 are within a category three or four Army Corps of Engineers hurricane inundation zone and are predicted to remain in these categories for the next hundred years. Wells 6-8 and the proposed well are outside all Army Corps of Engineers hurricane inundation zones. Thus, these wells are only at low risk of flooding.



FEMA Flood Zone map for the Wareham Fire District Drinking Water. (500 year flood – 100 year <1 ft is the combination of the 500 year flood zone and 100 year flood zone under one foot) *Note due to the scaling of the image some of the community groundwater wells appear to be within the 100 year flood zone, but they are not.

ACE Hurricane Surge Inundation Area map for theWareham Fire District Drinking Water system.

Wareham Fire District

Location		Source	Pop	Days Stored	Totals
Wareham Fire District	Answer	Ground	Between 15,000 and 30,000	Between 2 and 3 days	
	Rating	0	1	1	2

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Wareham Fire District received a low impact rating on our assessment because the department gathers its water from ground sources and at least two days' worth of storage. The Wareham Fire District serves a population of 19,958 year round with an average flow rate of 1.36 million gallons per day. The department's storage capacity is 2.9 million gallons. The Wareham Fire District has the ability to store 2.1 days' worth of water at the above average flow rate.

Yarmouth Drinking Water

Location		FEMA Flood Zone	Current ACE Area	Predicted ACE Area	Totals
GP Wells #1M, 15, 16	Answer Rating	None 0	None 0	Cat 3-4 1	1
All Other Wells	Answer Rating	None 0	None 0	None 1	0

0	1	2	3	4	5	6
Low			Medium		High	

Risk Assessment

The Tisbury water system has 24 wells. None of the sources are located in FEMA flood zones or Army Corps of Engineers hurricane inundation zones. Based on elevations, we predict that only three of the wills will be in a hurricane inundation area by 2100, and those three are predicted to be in a category 3 or 4 area. Overall, we estimate that all of the wells are at low risk.

Tisbury's water sources and ACE hurricane inundation zones

Tisbury's water sources and FEMA flood zones

Location		Source	Pop	Days Stored	Totals
Yarmouth Water Department	Answer	Ground	Above 30,000*	Between 2 and 3 days	
	Rating	0	2	1	3

*Note: The summer population was used as an example of the worst case scenario

0	1	2	3	4	5	6
Low			Medium		High	

Impact Assessment

The Yarmouth Water Department received a medium impact rating on our assessment because the department gathers its water from ground sources but serves a population over 30,000 and has over two days worth of storage. The Yarmouth Water Department serves a population of 50,000 during the summer and 21,277 during the winter, with an average flow rate of 3.66 million gallons per day. The department's storage capacity is 9.25 million gallons. The Yarmouth Water Department has the ability to store 2.5 day's worth of water at the above average flow rate.

Appendix N – Resource Table

Sources found Aug-Oct. 2011	Description	Contact Info	Application
http://www.energy.ca.gov/2008publications/DWR-1000-2008-031/DWR-1000-2008-031.PDF	California water adaptation strategy		Details management level plans for improving communication between water utility related organizations
http://www.switchtraining.eu/	SWITCH program		online program designed to inform urban planners of possible environmental solutions to storm surge and flooding
http://www.nytimes.com/gwire/2011/08/25/25greenwire-strange-bedfellows-back-bill-using-mortgages-t-32634.html	Strange Bedfellows Back Bill Using Mortgages to Spur Energy Retrofits		Congress bill to aid energy efficient: Bill provides financial bonuses to energy efficient buildings
http://www.projo.com/news/content/crmc_global_warming_10-17-07_KA7GLV6.3305a68.html	Coastal planners ready for sea-level rise		talks about organization with the sole intention of dealing with rising sea levels
http://www.geo.arizona.edu/dgesl/index.html	Arizona University Department of Geosciences Environmental Studies Laboratory		GIS maps of areas impacted by sea level rise
http://www.economist.com/node/13240162?story_id=13240162	Diversionary tactics A race against time as the region sinks		talks about problems in trying to prepare for rising sea levels
http://www.nytimes.com/cwire/2010/01/11/11climatewire-architects-plan-amphibious-landscape-for-new-45297.html	Amphibious New York Project		Example of a sea level rise focused project which involves cooperation between city planners and architects/artists
http://www.nyc.gov/html/dep/html/drinking_water/index.shtml	NYC DEP	Carter Strickland: 718-595-6600 Joe Martens	homepage is very well made and has lots of useful info on New York and it's water problems
http://www.nyc.gov/html/dep/html/drinking_water/index.shtml	2010 New York City water quality report		detailed document that informs the public of the condition of New York's water quality and everything related to it, a useful template for our final document
http://www.rms.com/publications/1953_Floods_Retrospective.pdf	50 year retrospective on North Sea flood of 1953		details how people reacted to a flood of unprecedented magnitude
http://www.deltawerken.com/en/10.html?setlanguage=en	Delta Works homepage		massive dam/dyke project, could be useful as an example
http://marketplace.publicradio.org/display/web/2011/09/01/pm-cities-begin-planning-for-a-very-different-future/	Cities begin planning for a very different future levels		has useful leads and talks about challenges of preparing for rising sea levels on a managerial level
www.niph.go.jp/soshiki/suido/pdf/h19JPUS/abstract/r02.pdf	Strategy on Wastewater Control in Japan for 21st Century		Report & PowerPoint slides on future of Japans wastewater infrastructure

www.pacinst.org/reports/sea_level_rise/report.pdf	THE IMPACTS OF SEA-LEVEL RISE ON THE CALIFORNIA COAST	Matthew Heberger: mheberger@pacinst.org Heather Cooley: hcooley@pacinst.org Eli Moore: emoore@pacinst.org Dr. Peter Glieck: pglieck@pacinst.org	Paper on the impacts of SLR on California coasts and coastal man-made structures: Gives some insight into what is being done for SLR effects and possible future planning.
http://your.kingcounty.gov/dnrp/library/archive-documents/wtd/csi/csi-docs/0807_SLR_VF_TM.pdf	Vulnerability of Major Wastewater Facilities to Flooding from Sea-Level Rise	Matt Kuharic: 206-296-8738 Matt.Kuharic@KingCounty.gov Harry Reinert: 206-296-7132 Harry.Reinert@KingCounty.gov	Report analyzing SLR in King County to see what wastewater facilities are at risk of flooding. Good for getting idea of what other states are doing, and good insight for possible analytical methods for our project.
http://www.mass.gov/czm/hazards/ss_atlas/index_map.htm	South Shore Coastal Hazards Characterization Atlas - Index of Maps		Background information on the coasts and potential coastal hazards that utilities may deal with.
http://water.epa.gov/drink/ndwac/climatechange/upload/CRWU-NDWAC-Final-Report-12-09-10-2.pdf	Final Report of the National Drinking Water Advisory Council December 9, 2010		Report containing recommendations that will assist water utilities, and stormwater systems across the nation to increase their resilience to climate change impacts. Recommendations will be useful when making recommendations of our own, and findings can be used for background information.
www.iwapublishing.com/pdf/Water21Jun2011p12top16.pdf	Japan's progress with recovery: restoring services in the disaster zone		Article about Japan repairing and restoring water & wastewater systems after Earthquake & Tsunami. Used as example of what could happen and the risks that coastal water utilities face, and also for some planning and prevention ideas.
http://www.ct.gov/dep/lib/dep/air/climatechange/adaptation/090316_infrastructure.pdf	FACING OUR FUTURE: Infrastructure Adapting to Connecticut's Changing Climate	Krista Romero: Krista.Romero@ct.gov Kevin O'Brien: Kevin.Obrien@ct.gov	Used survey as basis for creating our own survey to be sent to DW & WW facilities.
www.mass.gov/czm/stormsmart/resources/hull_inundation_report.pdf	Visualization of Inundation of Critical Coastal Facilities due to Flood Events and Sea-Level Rise		Technical report on the 3D modeling of important structures in Hull with projected sea level rise flooding. Example of possible outreach type material.
http://www.ebparks.org/files/HASPA_Seal_Level_Rise_Study_Report_v15B.pdf	PRELIMINARY STUDY OF THE EFFECT OF SEA LEVEL RISE ON THE RESOURCES OF THE HAYWARD SHORELINE		example of an area effected by sea level change and possible solutions
http://www.cleanair-coolplanet.org/climate_prepar	Preparing for the Changing		Shows which state worry the most about sea level rise

edness/NortheastAssessment2011.pdf	Climate: A Northeast-Focused Needs Assessment		
http://www.amwa.net/galleries/climate-change/AMWA_Climate_Change_Paper_12.13.07.pdf	Implications of Climate Change for Urban Water Utilities		Discusses effects climate change related change such as saltwater intrusion
http://morristowngreen.com/2011/08/29/close-call-at-morris-township-sewage-treatment-plant-during-irene-storm/	Close call at Morris Township sewage treatment plant during Irene storm		Example of what happens when a facility is flooded and forced to by-pass
http://www.newstimes.com/news/article/Irene-s-rains-could-overwhelm-treatment-plants-2144405.php	Irene's rain could overwhelm treatment plants		Example of what happens when a facility is flooded and forced to by-pass
http://www.gazette.net/article/20110828/NEWS/799999773/1029/1029/sewage-overflows-stopped-at-prince-george-8217-s-water-treatment&template=gazette	Sewage overflows stopped at Prince George's water-treatment plants		Example of what happens when a facility is flooded and forced to by-pass
http://millburn.patch.com/articles/dont-drink-the-water-2	Don't Drink the Water		Example of what might happen to a community when a facility is flooded, and the water cannot be fully treated
http://nashvillecitypaper.com/content/city-news/metro-still-calculating-cost-flood-damage-infrastructure	Metro still calculating cost of flood damage to infrastructure		Shows an example of how much a flooded facility can cost to fix, by using Nashville as an example

Appendix O – Contact List

Name	Organization	DW or WW	Date of First Interview	E-Mail
Barry Yaceshyn	Weston & Sampson	neither	9/20/2011	yaceshyb@wsein.com
Brian Meacham	WPI	neither	9/27/2011	bmeacham@WPI.EDU
Carl Hillstrom	Provincetown Drinking Water	DW	9/22/2011	chillstrom@provincetown.ma.gov
Chris Rowe	Provincetown Wastewater Treatment Plant	WW	9/22/2011	crowe@woodardcurran.com
Damon Guterman	MassDEP	DW		damon.guterman@state.ma.us
Daniel Nvule	MWRA	both	9/29/2011	Daniel.Nvule@mwra.state.ma.us
Dave Burns	MassDEP SERO	WW	9/27/2011	dave.burns@state.ma.us
David Ferris	MassDEP	WW		david.ferris@state.ma.us
Dominic Golding	WPI	neither	9/26/2011	golding@wpi.edu
Ed Petrilak	Hull Wastewater Treatment Plant	WW	9/27/2011	(781)-925-0906
Harry Reinert	King County Department of Development and Environmental Services	neither	9/15/2011	Harry.Reinert@kingcounty.gov
Jackie Leclair	EPA Region 1	WW	9/14/2011	leclair.jackie@epamail.epa.gov
Joe Dugan	Newburyport Wastewater Treatment Plant	WW		jdugan@cityofnewburyport.com
John Bergendahl	WPI	WW		jberg@wpi.edu
John Phillips	King County Department of Natural Resources and Parks	WW	9/23/2011	John.Phillips@kingcounty.gov
Marcel Belaval	EPA Region 1	neither	9/21/2011	Belaval.Marcel@epamail.epa.gov
Matthew Heberger	Co-authors "Impact of Sea Level rise on the California Coast" May 2009	neither	9/9/2011	mheberger@pacinst.org
Norman Willard	EPA Region 1	Neither	9/13/2011	willard.norman@epamail.epa.gov
Paul Colby	Newburyport Water Works	DW	9/20/2011	pcolby@cityofnewburyport.com
Paul Niman	MassDEP	DW	10/7/2011	paul.niman@state.ma.us
Robert Bradbury	Newburyport Wastewater Treatment Plant	WW	9/20/2011	rbradbury@cityofnewburyport.com
Sandra Rabb	MassDEP	neither		sandra.rabb@state.ma.us

Seth Tuler	WPI	neither		stuler@wpi.edu
Steve Estes-smargassi	MWRA	both	9/29/2011	Stephen.Estes-Smargiassi@mwra.state.ma.us
**Those with no date were contacted multiple times though the duration of our project				