Ogunquit Sewage Treatment Plant FINAL ENGINEERING REPORT

Adaptation Options to Protect the Ogunquit Sewage Treatment Plant against Floods, Storm Surges, and Sea Level Rise

Funding for the development of this Report provided by:

Gulf of Maine Council on the Marine Environment

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

225587

Southern Maine Regional Planning Commission

August 2012

WOODARD & CURRAN

TABLE OF CONTENTS

SECTION PAGE NO.

LIST OF TABLES

LIST OF FIGURES

APPENDICES

GLOSSARY OF ACRONYMS

ACRE	- Applied Coastal Research and Engineering, Inc.
CBRA	- Coastal Barrier Resource Act
CBRS	- Coastal Barrier Resource System
CHRT	- Coastal Hazard Resiliency Tools
CMOM	- Capacity, Management, Operations, and Maintenance
HAT	- Highest Annual Tide
I/I	- Infiltration and Inflow
IPCC	- Intergovernmental Panel on Climate Change
LiDAR	- Light Detection and Ranging
MaineDEP	- Maine Department of Environmental Protection
MGD	- Million Gallons per Day
MGS	- Maine Geological Survey
NPDES	- National Pollutant Discharge Elimination System
NRPA	- Natural Resource Protection Act
PS	- Pump Station
SLR	- Sea Level Rise
SMRPC	- Southern Maine Regional Planning Commission
UV	- Ultraviolet
WWTP	- Wastewater Treatment Plant

EXECUTIVE SUMMARY

The Ogunquit Wastewater Treatment Plant (WWTP) is located in a Coastal Sand Dune System between the Ogunquit River estuary and the Gulf of Maine. In addition to being located in a Coastal Sand Dune System, which is regulated by the Maine Department of Environmental Protection (MaineDEP), the facility is also located within a Coastal Barrier Resource System (CBRS), which is a habitat for endangered species. The WWTP and its associated coastal pump stations have experienced flooding from major storm events, such as the Patriot's Day Storm of 2007, and are facing increasing risks from such events because of Sea Level Rise (SLR) and increasing storm frequency. Adaptation options to protect the WWTP and associated pump stations against floods, storm surges, and SLR had to be identified. This report was developed to outline mitigation strategies based on an assessment of the aforementioned risks, in conjunction with other high-level risks such as: anticipated changes in regulatory requirements, aging infrastructure, changes in population demographics, and competition for funding.

SLR at the Ogunquit WWTP is estimated to be about one foot by the year 2050 and 3.2-feet by the year 2100. These estimates represent a conservative upper bound to SLR predictions, which accounts for the contribution of ice sheets. SLR could be exacerbated by ice cap melting, causing it to accelerate over time in a non-linear fashion. The following figure shows a graph of the various SLR estimates for Ogunquit from 2012 to 2100.

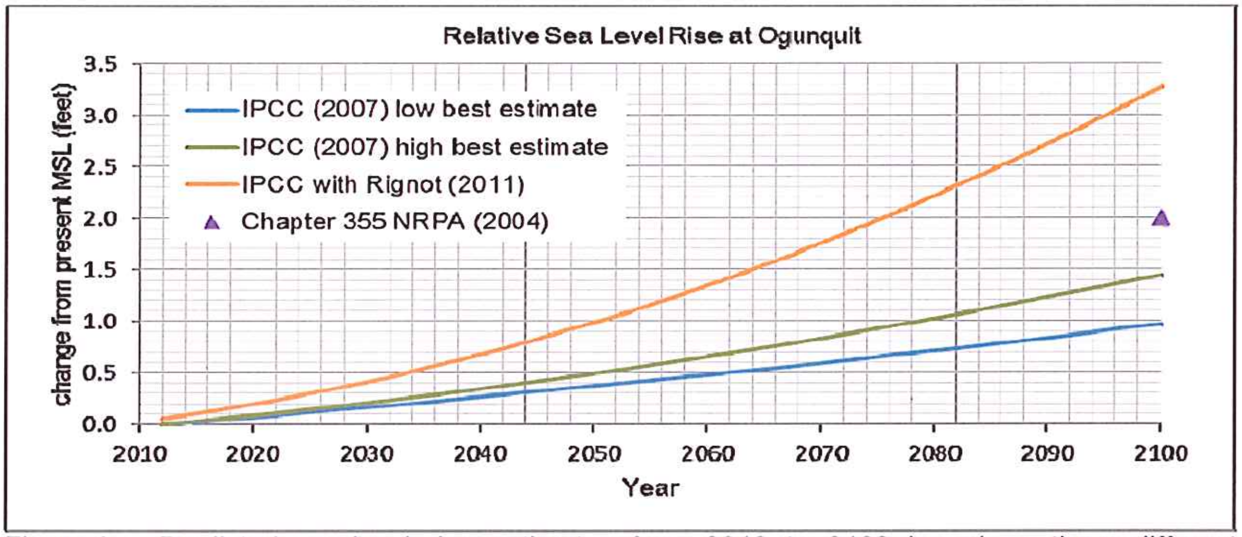


Figure 4. Predicted sea-level rise estimates from 2012 to 2100 based on three different methods: the IPCC high and low best estimates from 2007, and the IPCC high estimate with the updated contributions from ice sheets from Rignot *et al.* (2011). The anticipated rise in sea-level of 2 feet by 2100 described in Chapter 355 of NRPA also is shown.

The access road to the Ogunquit WWTP, and a portion of the site, are susceptible to flooding during major storm events. By 2050, it is anticipated that a 100-year storm event would cover the access road, and perhaps some of the low lying portions of the site. By 2100, a 100-year storm surge may inundate the majority of the site and be very close to inundating the outside process tanks. **If the facility becomes inundated, or needs to shut down for lack of power, the beach will be closed.** In addition to SLR, dune erosion represents a certain risk to the WWTP. The dune, and sea wall contained within it, is essential for protecting the facility. The eroding dune will become more susceptible to failing during storm events over time and it is estimated that the dune will deteriorate completely in the next 30 to 50 years. These projections indicate that the WWTP is at high risk from a combination of SLR and shoreline change within the next 20 to 30 years, potentially sooner if SLR and flooding increase more rapidly.

The challenges with the Ogunquit WWTP are exacerbated because the site is located in a Coastal Sand Dune System, which is regulated by the MaineDEP and has restrictions such as lot coverage; construction within these systems requires a Maine Natural Resource Protection Act (NRPA) Permit. Frontal dune systems have stricter regulations than back dune systems, such that no new seawalls or expansions of the existing seawall would be permitted. It is important to note that, due to coastal erosion and dune recession, the frontal dune system will eventually progress to engulf larger areas of the project site, so that it will become increasingly difficult to permit any activities that may be needed to maintain or upgrade the facility. Additionally, the State recently accepted the federal designation of a CBRS, prohibiting state funding or financial assistance for any development activities within the CBRS, unless the project involves the maintenance, replacement, reconstruction, repair, or in limited circumstances, expansion of state-owned or state-operated structures, facilities or roads. The project site is also adjacent to marshlands, which are also regulated by MaineDEP and may require NRPA permitting. This area, indicated by the 100-year flood elevation, will also begin to engulf more of the site over time, so that permitting certain activities will become more difficult.

With the last major upgrade to the Ogunquit WWTP facility occurring in 1993, rehabilitation and/or replacement of components of the facility will be required in the upcoming years. In the next five years alone, it is anticipated that the pump room will require work, and an ultraviolet (UV) disinfection system will be installed. The WWTP currently provides secondary treatment; it is likely that nutrient removal will be required, as this is anticipated to be applied to all plants as a standard requirement. Such upgrades will likely require a significant investment. Another planning consideration will be understanding what needs will emerge for implementing improvements to the Ogunquit collection system (pipes, pump stations, manholes, etc.), as there is a significant amount of infiltration and inflow (I/I) that flow to the WWTP. Such I/I will need to be reduced significantly to make a new WWTP more affordable. Additionally, CMOM (Capacity, Management, Operations, and Maintenance) regulations requiring higher levels of collections system performance are now a requirement of the National Pollutant Discharge Elimination System (NPDES) permit renewal process.

Regionalization with another neighboring facility is an option for mitigating these risks. The Wells wastewater system extends up to the Wells/Ogunquit town line, which provides opportunities to connect to the Wells system, and has therefore been evaluated. The Wells WWTP has not experienced issues with flooding, as most components are at a higher mean elevation than Ogunquit, assets are maintained inside of an elevated building structure, and the plant site lies further inland off the barrier structure. Major upgrades are not expected in the next 5-10 years. The Wells WWTP does not currently have adequate capacity to accept the sewage flows from Ogunquit; however, the Wells WWTP staff anticipates expanding to add new pump stations for growth north of Route 95, and there are extra tanks and adequate land for considerable expansion. Additionally, the Wells WWTP is not located within a Coastal Sand Dune System or a CBRS. It is therefore anticipated that the Wells WWTP will not face the same construction or funding challenges that Ogunquit will have. It should be noted that other regional alternatives may also exist.

Even under the best scenarios, there appears to be no practical long-term solution that would feasibly allow the Town to continue utilizing the existing WWTP site beyond 2032-2052 given current projections. Woodard & Current believes that the best strategy for the WWTP is to move off the existing site, once the existing site reached the end of its useful life in 20-50 years. The Ogunquit Sewer District should begin preparing a 20-50 year Strategic Plan that will explore the options available to determine the most cost effective plan and timeline. In this way, the District will be able to explore options and set sustainable rates in the coming years to fund investments that will be necessary for the transition. Options to explore may include the formation of an enterprise fund or other capital reserve funding measure. The following is an outline of a potential strategy to be considered moving forward:

0-15 years

- Conduct engineering evaluation of existing structures & identify temporary safeguards for future coastal flood events
- Reduce I/I
- Conduct river flooding study
- Apply for grants & evaluate funding options
- Prepare financial plan

15-25 years

- Decide whether to regionalize or construct new facility
- Evaluate potential sites
- Evaluate ordinance & conduct town negotiations
- Begin permitting process

1. INTRODUCTION

1.1 BACKGROUND

The Ogunquit Wastewater Treatment Plant (WWTP) is located in a Coastal Sand Dune System between the Ogunquit River estuary and the Gulf of Maine. In addition to being located in a Coastal Sand Dune System, which is regulated by the Maine Department of Environmental Protection (MaineDEP), the facility is also located within a Coastal Barrier Resource System (CBRS), which is also a habitat for endangered species. The facility and its associated coastal pump stations have experienced flooding from major storm events, such as the Patriot's Day Storm in April of 2007, and are facing ever increasing risks from such events because of rising sea levels and increasing storm frequency.

The Ogunquit WWTP, which provides secondary treatment for approximately 1.28 million gallons per day of sanitary wastewater, operates 12 pumping stations and approximately 20 miles of sewer lines, is a critical piece of infrastructure for the community, protecting both public health and the health of the coastal environment, which supports an abundance of wildlife and a large portion of the economy in the Town of Ogunquit. The Ogunquit WWTP is a mature facility with the last major upgrade occurring in 1993. While the facility is currently in compliance with MaineDEP requirements, scheduled upgrades are on the horizon to update major equipment and to deal with the potential of changing regulations.

1.2 PROJECT NEED

In 2011, the Maine Geological Survey (MGS) and the Southern Maine Regional Planning Commission (SMRPC) collaborated with the Town of Ogunquit on the Coastal Hazard Resiliency Tools (CHRT) project, which identified the Ogunquit WWTP as vulnerable to Sea Level Rise (SLR). The MGS generated simulations for the CHRT demonstrating the facility's vulnerability to both SLR and storm surges.

Faced with these risks, adaptation options to protect the WWTP and associated wastewater pump stations against floods, storm surges, and SLR had to be identified. To meet this goal, this preliminary engineering report was developed to outline mitigation strategies based on an assessment of the aforementioned risks, in conjunction with other high-level risks such as: anticipated changes in regulatory requirements, aging infrastructure, changes in population demographics, and competition for funding.

2. PREDICTIONS OF SEA LEVEL RISE, FLOODS, AND STORM SURGE

Applied Coastal Research and Engineering, Inc. (ACRE) developed a report outlining their analysis of Sea Level Rise (SLR) and coastal processes for the Ogunquit WWTP. Their report, dated July, 2012, has been provided in Appendix A of this report for your reference. The following is a summary of their findings.

2.1 SEA LEVEL RISE

Sea Level Rise (SLR) is estimated to range from an additional one foot increase by the year 2050 and a 3.2-foot increase by the year 2100. These estimates represent a conservative upper bound to SLR predictions, which accounts for the contribution of ice sheets to SLR. Ultimately, SLR could be exacerbated by ice cap melting, causing it to accelerate over time in a non-linear fashion. Figure 4 of Appendix A shows a graph of the various SLR estimates for Ogunquit from 2012 to 2100.

2.2 FLOODING FROM STORM SURGE

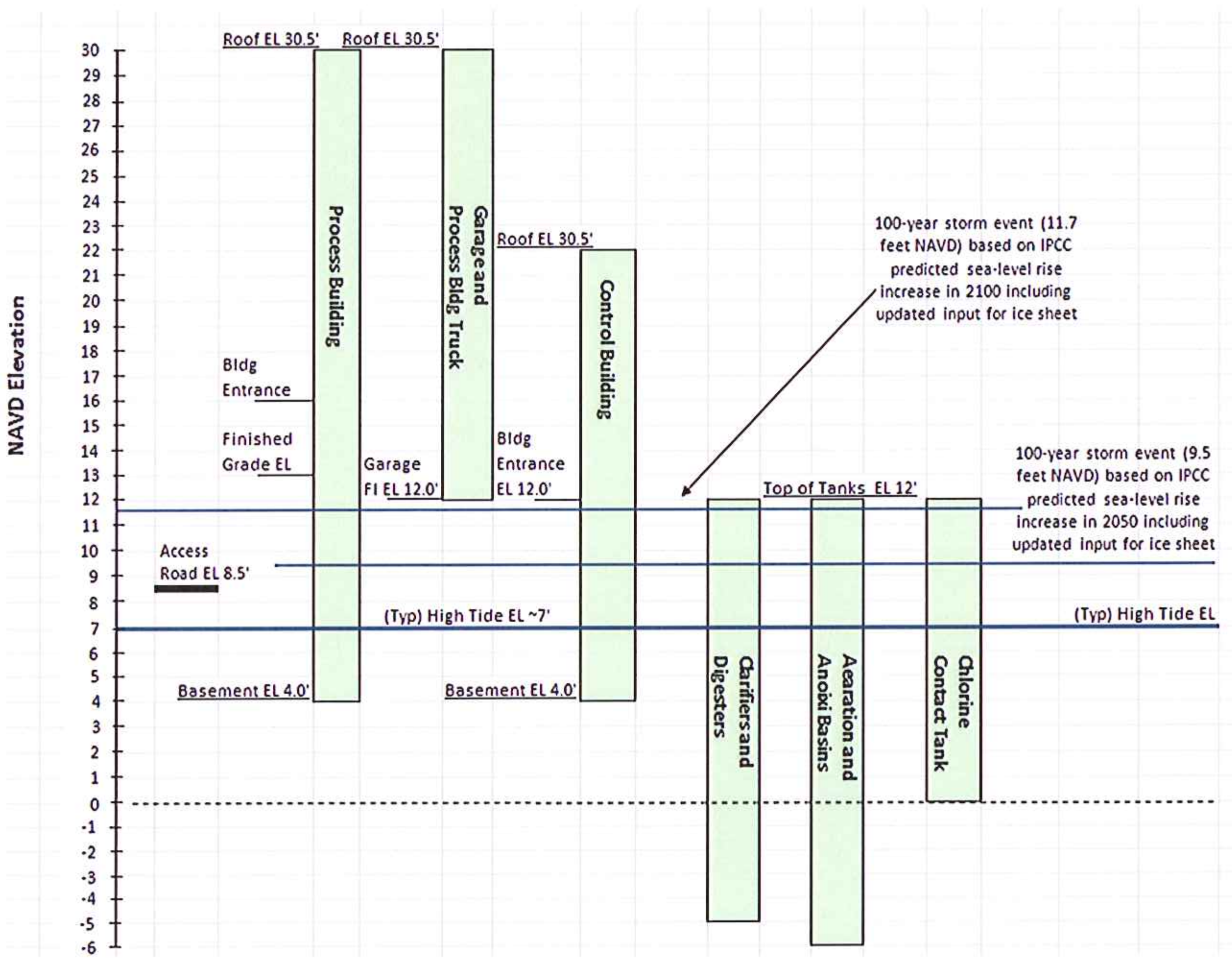
The access road to the Ogunquit WWTP, and a portion of the site itself, are currently susceptible to flooding during major storm events. An additional 5-inches of flooding is anticipated during 100-year storm events by 2050. This would cover the access road to the plant[1]. If the potential for ice sheet melting is included (Rignot, et al. 2011) the storm surge in 2050 could be as high as 9.5-feet, which is one foot above the current 100-year storm surge. This would exacerbate flooding of the access road, and perhaps some of the low lying portions of the site. The estimate for the 2100 100-year storm surge, when considering contributions from the ice sheets, may be as high as 11.75-feet, which is 3.25-feet above the current 100-year storm surge; this would inundate the majority of the site and be very close to inundating the outside process tanks. Refer to Figures 8 through 11, contained in Appendix A, for aerial photographs of the site showing anticipated flood areas from the 100-year storm based on alternate predictions of SLR in 2050 and 2100. Figure 7 of Appendix A shows present day inundation during the 100-year storm.

Ultimately, SLR and storm surge are directly correlated and the increase in SLR will exacerbate storm surge, causing the frequent minor storm events experienced in the present day to appear more severe and just as frequent in the future, much like ice cap melting accelerates SLR. Figure 5 of Appendix A shows a graph of the predicted 100-year flood elevations, which account for the various SLR estimates, for Ogunquit from 2012 to 2100.

The analysis for SLR indicates that the structures within the Ogunquit WWTP will not be at severe risk from a 100-year storm until 2100. At that time, if ice sheet contribution has accelerated SLR to the extent predicted by Rignot, et al. (2011), the plant would be inundated in such a storm. Based on these predictions, it is likely that access to the plant during 100-yr storm will be in jeopardy by 2050. This is illustrated in Figure 2-1.

[1] It is important to note that the Ogunquit WWTP currently has backup power and fuel storage sufficient for one week's supply; fuel trucks will need adequate access to the site in order to keep the facility running. Without power, the facility cannot operate. The beach will need to close when the plant is not running due to inadequate treatment. Each day that the beach is closed will ultimately cost the Town significant amounts of money.

Figure 2-1 - Ogunquit WWTP Structures Elevations



2.3 SHORELINE CHANGE

Shoreline erosion will continue to result in a decreased width of the existing dune system, which currently helps to protect the facility from storm surge. The eroding dune will become more susceptible to failing during storm events over time. Regardless of SLR, dune erosion represents the most certain risk to the Ogunquit WWTP. Dune or shoreline movement is historically demonstrated and will continue. SLR will only exacerbate the issue of dune erosion. It is estimated that the dune will deteriorate completely in the next 30 to 50 years.

2.4 CONCLUSION

We consider the Ogunquit WWTP to be at high risk from a combination of SLR and shoreline change within the next 20 to 30 years, potentially sooner as SLR and flooding increase over time. Depending on the risk tolerance of the Ogunquit Sewer District, the risks associated with site flooding will likely become unacceptably high to remain on the exiting site without considerable mitigation measures 20-30 years into the future. Based on this analysis, it is the assessment of Woodard & Curran that the Ogunquit Sewer District should begin a Strategic Planning effort to identify alternatives to the current WWTP location. The basic options will be to build a new treatment facility in Ogunquit, or to regionalize with Wells and/or perhaps with York. Because risk will increase slowly over time, there will be ample opportunity to coordinate planning with growth, infrastructure renewal and other issues of concern.

3. REGIONALIZATION: ASSESSMENT OF WELLS FACILITY AS AN ALTERNATIVE TREATMENT SITE

ACRE developed a memorandum outlining their analysis of increases in the 100-year storm flooding elevations for the Wells WWTP, utilizing the same assumptions and methods outlined in the report they developed for the Ogunquit WWTP. Their memorandum, dated August 6, 2012, has been provided in Appendix B of this report for your reference. The following is an assessment of the Wells WWTP as a potential alternative treatment site for the Town of Ogunquit, which was conducted due to the proximity of the two facilities; other sites for regionalization may be possible, and can be evaluated at a future date.

3.1 WELLS WWTP BACKGROUND

The Wells WWTP is located on a 10-acre site. The collection system consists of 10 pump stations and approximately 50 miles of newer (approximately 35 years old), large, deep PVC and concrete pipes. This system currently ranges right up to the Wells/Ogunquit town line, which provides opportunities to connect to the Wells Collection system or redirect the flows from the Ogunquit WWTP.

The Wells WWTP has not experienced issues with flooding, as most components are at a higher mean elevation than Ogunquit, assets are maintained inside of an elevated building structure, and the plant site lies further inland off the barrier structure. The pump stations, which have been equipped with flood gates as necessary, have not experienced flooding issues.

3.1.1 Aging Infrastructure

The Wells WWTP was built in 1970. It has been approximately 12 years since the last major upgrade at the Wells WWTP. HVAC upgrades are currently underway. Major upgrades are not expected in the next 5-10 years.

3.1.2 Changing Regulations

The Wells WWTP currently provides secondary treatment for the Town's wastewater and discharges to the ocean, similarly to the Ogunquit WWTP. It is anticipated that any changes in regulations that will impact the Ogunquit WWTP, as discussed in Section 4.1.3 of this Report, will also impact the Wells WWTP. It is anticipated that providing nutrient removal will be a future requirement for all WWTPs. In the event that this happens, the Wells facility has ample space on-site for necessary additions, as discussed in the following sections of this Report.

3.1.3 Growth & Increased Demands

The Wells WWTP has a 2 million gallon per day (MGD) license, and currently receives approximately 1.2 MGD. The Wells WWTP does not currently have adequate capacity to accept the sewage flows from Ogunquit; however, the Wells WWTP staff anticipates expanding to add new pump stations for growth north of Route 95. There are extra tanks and adequate land for considerable expansion. Because the facility does not have charter restrictions, accepting sewage flows from other Towns, such as Ogunquit, would be permissible. The size and layout of the Wells Sewer Collection System would likely accommodate the additions that would be necessary to accept flows from Ogunquit during dry weather periods.

3.1.4 Competition for Funding

The Wells WWTP is a District-owned facility, similarly to the Ogunquit WWTP; however, it is not located within a Coastal Barrier Resource System. It is therefore anticipated that the Wells WWTP will not face the same funding challenges that Ogunquit will have, as discussed in Section 4.1.5 of this Report.

3.2 CONCLUSION

ACRE's analysis shows some on-site flooding during a 100-year event in the year 2100, but the level of flooding does not appear to have a considerable impact on the process. Furthermore, the size of the existing site, and need for additional capacity if the Wells WWTP were to take flows from Ogunquit, would permit construction of new facilities that could be located to mitigate the future flood risks.

We have looked at the collection system of the Wells plant in regards to Ogunquit, and there appear to be opportunities to connect to the Wells Collection system and redirect the flows from the Ogunquit WWTP to the Wells WWTP. Wells has indicated that the amount of infiltration and inflow in the Ogunquit collection system will need to be addressed. Given the risks associated with the Ogunquit WWTP site, discussed in Sections 2 and 4 of this Report, we do not recommend converting the existing plant into a pump station, so as to redirect flows to the Wells WWTP. A specific tie-in point to the Wells Collection System, and a reassessment of the Ogunquit Collection System, should be evaluated in regards to costs and risks at a future date.

4. OTHER SIGNIFICANT RISKS TO THE OGUNQUIT WWTP

4.1 FACILITY CONCERNS

As stated previously, there are significant long-term risks to the Ogunquit WWTP related to dune erosion and SLR. The timeframe for planning and addressing these threats is estimated to be 20 to 50 years. There are also other risks to consider during planning efforts, some of which will need to be mitigated more immediately. It is suggested that they be considered in parallel with the decision about how long to keep investing in the operability of the current plant at the current site.

Yet another planning consideration will be understanding what needs will emerge for implementing improvements to the collection system (pipes, pump stations, manholes, etc.), as there is a significant amount of infiltration and inflow (I/I) to the Ogunquit WWTP. If investing in a new WWTP or sending flow to a neighboring plant, such I/I will likely need to be reduced significantly. This will be driven by economics and in the form of regulations. CMOM (Capacity, Management, Operations, and Maintenance) regulations requiring higher levels of collections system performance are now a requirement of the National Pollutant Discharge Elimination System (NPDES) permit renewal process. When discussing the potential for regionalization with the Wells Sewer District, it was evident that the Wells plant would have great difficulty in dealing with the I/I currently associated with the Ogunquit collection system.

4.1.1 Pump Stations

At a kickoff meeting held on April 9, 2012, at the Ogunquit WWTP, between Woodard & Curran, the OSD, SMRPC, and MGS, concern was expressed for the facility's pump stations; specifically, Pump Stations (PS) #1, #4, and #12. PS#1 and PS#12 are both located in the proximity of the plant site, as shown in Figure 4-1. PS#1 has already experienced issues with flooding during such storm events as the Patriot's Day Storm on April 16, 2007, as shown in the photograph presented as Figure 4-3. Figure 4-4: Existing 100-Year Storm Surge at PS#1 & PS#12 shows how the rim elevations of PS#1 and PS#12 compare to the present day 100-year storm flood elevation, confirming existing flooding issues. As discussed in Section 2 of this Report, this flooding will only get worse over time and exacerbate an existing issue.

PS#4 is located in Perkins Cove, as shown in Figure 4-2, and also has issues with flooding; however, due to the scope of this analysis, this pump station, and others further inland and away from the WWTP, is outside the range of the analysis conducted by ACRE. Data on specific flooding and storm surge impacts is unavailable. However, based on the available storm surge elevations, it is anticipated that the storm surge elevations in Perkins Cove are similar to other nearby coastal areas. While no protective dune exists in this area and the landform along the eastern side of the cove is relatively low-lying, this region is relatively protected from open ocean waves and it should not be subjected to direct impacts from waves, even at the higher water levels predicted by the relative sea-level rise analysis; this would need to be confirmed by modeling.

4.1.2 Aging Infrastructure

With the last major upgrade to the Ogunquit WWTP facility occurring in 1993, certain rehabilitation and/or replacement of some components of the facility will be required in the upcoming years. The costs to maintain and renovate the existing facility long-term may ultimately outweigh the benefits. In the next five years alone, it is anticipated that the pump room will require some work, and an ultraviolet (UV) disinfection system will be installed to maintain the quality of the treatment plant.

4.1.3 Changing Regulations

The Ogunquit WWTP currently provides secondary treatment for the Town's wastewater, and discharges through an ocean outfall several hundred feet off-shore, at a depth of about 30-feet. Although the impact of nutrients (nitrogen and phosphorus) in the Ogunquit WWTP effluent to the receiving waters is not fully understood, it is likely that nutrient removal will be required as a future limitation, as this is anticipated to be applied to all treatment plants as a standard treatment requirement. In the event that this happens, the site has adequate space to add tankage and equipment within the plant boundary limits, in addition to existing tankage that may be repurposed for nutrient removal (see Figure 4-6). However, it should be noted that such upgrades will likely require a significant investment by the Sewer District, and state regulations, as discussed in Section 4.2 of this Report, may restrict the construction of additional structures.

4.1.4 Growth & Increased Demands

Changes in population demographics, including seasonal residents and visitors, can increase sewer usage patterns and put a higher demand on the Ogunquit facility. Summer is a peak season for the Town of Ogunquit, and flows spike considerably. Population growth and sewer system expansion are not anticipated to greatly increase wastewater flows to the WWTP in the short term, but must be considered in any facilities planning for the next 20 years.

4.1.5 Competition for Funding

The Coastal Barrier Resource System (CBRS) the facility is located within has regulations that could affect funding for any proposed work. In accordance with the Coastal Barrier Resources Act (CBRA) of 1982, certain activities to develop or rebuild within CBRSs cannot be funded using federal subsidies. Consultation with the U.S. Fish and Wildlife Service may grant the use of federal monies for certain exempted activities within a CBRS, such as emergency assistance. Additionally, if the facility attained federal flood insurance before 1982, the policy may not be renewed upon substantial improvements or damages to the facility.

The State of Maine has recently accepted the federal designation of a CBRS, and created the Maine Revised Statute Title 38, Chapter 21: Coastal Barrier Resource System. The governing statute prohibits state funding or financial assistance for any development activities within the Coastal Barrier Resource System (CBRS), unless the project involves the maintenance, replacement, reconstruction, repair, or in limited circumstances, expansion of state-owned or state-operated structures, facilities or roads identified in §1903(1)(A) of the Act. The Ogunquit WWTP may therefore have trouble attaining funds for certain types of projects on the current site.

4.2 STATE REGULATIONS

On June 6, 2012, staff from Woodard & Curran, OSD, SMRPC, ACRE, and MGS met with Marybeth Richardson of the Maine Department of Environmental Protection (MaineDEP), to discuss initial thoughts on sea level rise, storm surge, and flooding impacts, and what work to mitigate these threats the MaineDEP thought could be permitted within the Coastal Sand Dune System that the Ogunquit WWTP is located wholly within. Coastal Sand Dunes are regulated by Chapter 355 of the MaineDEP Rules, which outlines specific standards for projects within these systems, such as lot coverage restrictions, and construction within these systems typically requires a Maine Natural Resource Protection Act (NRPA) Permit.

It should be noted that Section 5.C. of Chapter 355 stipulates that "A project may not be permitted if, within 100 years, the property may reasonably be expected to be eroded as a result of changes in the shoreline such that the project is likely to be severely damaged after allowing for a two foot rise in sea level over 100 years. Beach nourishment and dune restoration projects are excluded from this requirement." As demonstrated in Section 2 of this Report, this scenario is entirely likely.

It was determined that no new seawalls or expansions of the existing seawall would be permitted within the frontal dune system; however, beach nourishment and dune creation, similar to the existing man-made dune which fronts the facility, would be allowed. Refer to Figure 4-5 of this report for an aerial photograph showing the limits of the dune system; note that the D1 area represents the frontal dune, and the D2 area is representative of the back dune system.

The back dune system could also potentially be an area where more work could be permitted. The MaineDEP also indicated that tide gates were not a favorable option due to maintenance requirements.

Frontal dune systems have stricter regulations than back dune systems. It was noted that due to coastal erosion and dune recession (which is mapped every 10 years) the frontal dune system will eventually progress to engulf larger areas of the project site, so that it will become increasingly difficult to permit any activities that may be needed to maintain or upgrade the facility.

It was noted that the project site is also adjacent to marshlands, indicated by the Highest Annual Tide (HAT) line or 100-year flood elevation, which are regulated by Chapter 310 of the MaineDEP Rules. Activity in an around this resource may require NRPA permitting. As previously discussed, this area will ultimately begin to engulf more of the site over time, so that permitting certain activities will become more difficult. Refer to Figure 4-6 for a layout of the site with respect to the current HAT.

4.3 MUNICIPAL CONSIDERATIONS

Parcel coverage issues could also restrict the level of permitted site work, as the OSD owns the parcel that the facility is located on, but the land abutting that parcel is owned by the Town of Ogunquit. The rights to construct any work outside of the boundaries of the OSDs parcel would need to be granted by the Town. If the Town of Ogunquit were to utilize the Wells site, or any other neighboring facility, varying municipal requirements may be another factor to consider in that the Town's Ordinance may need to be evaluated and revised to accommodate another Town's potentially more stringent requirements.

4.4 STRUCTURAL CONCERNS

The Wright-Pierce record drawings for the 1990 facility upgrade indicate that the Control Building has a finished floor elevation of 12.5 feet and most tank structures have grade elevations in the range of 10 to 12 feet. The outfall plan and profile record drawings indicate that the Extreme High Water Line at the time of the design was approximately 7.9 feet, and by the year 2050 this is expected to increase to as much as 9.5 feet during a 100-year storm event. Due to water damage to the structural record drawings, it is unclear what specific assumptions for design ground/sea water elevations were used for the structural design of tanks and building foundations at the facility.

Increased Sea Level Rise (SLR) and storm surge could result in a higher risk of leakage into inhabited basement spaces, as well as floatation of structures. Leakage into the basement of the Control Building, for example, could result in severe damage to critical electrical and process equipment (refer to Figure 4-6 for the location of the Control Building). Due to these expected increases in groundwater elevations (likely above those used as a basis for the original design), it is recommended that floatation checks be performed by a structural engineer for all structures to ensure that structures are not at risk for flotation, in the case that the Town of Ogunquit elects to continue utilizing the existing treatment site. It is further recommended that a structural condition assessment be performed to evaluate the current condition of structures and the presence of leakage, moisture damage, cracking, deterioration, etc. The results of this further evaluation will provide a more thorough understanding of how much and what type of impact the increased SLR will have on the structures at this facility.

Figure 4-1: Map of PS#1 & PS#12

Figure 4-2: Map of PS#4

Figure 4-3: Photograph of PS#1 during Present Day Flooding

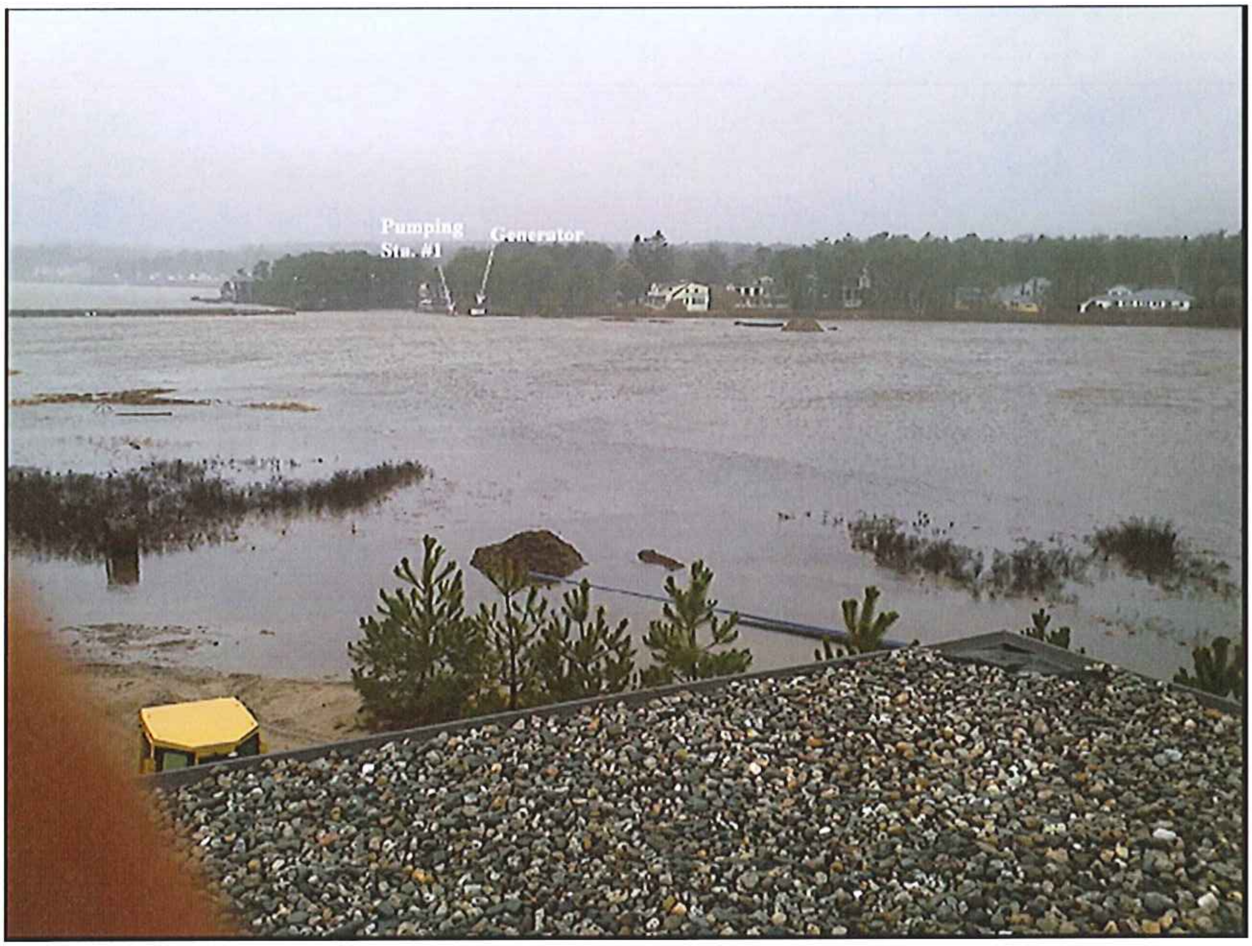


Figure 4-4: Existing 100-Year Storm Surge at PS#1 & PS#12

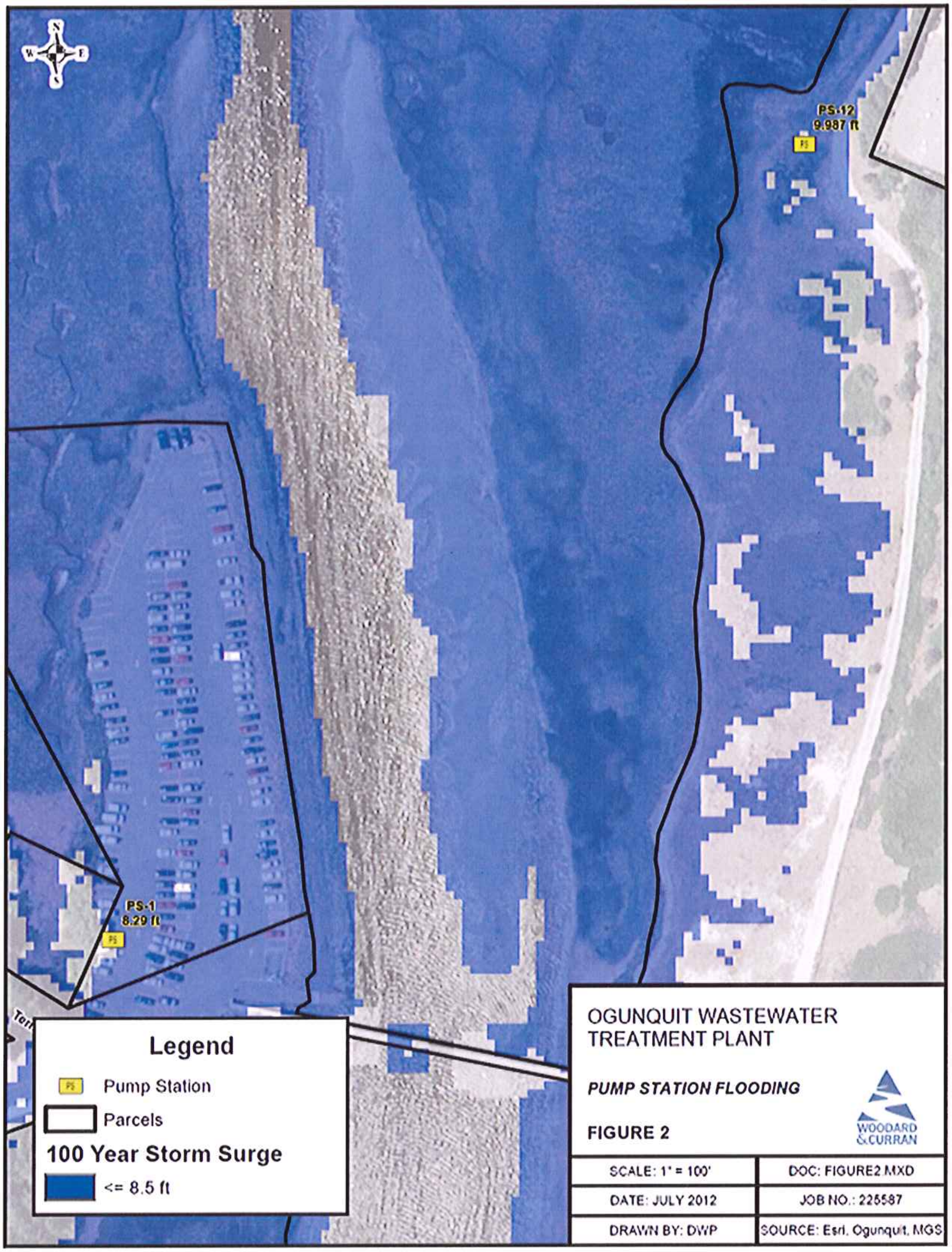


Figure 4-5: Maine Geological Survey Coastal Sand Dune Geology

Maine Geological Survey

Address: 22 State House Station
Augusta, Maine 04333

Telephone: 207-287-2801
E-mail: mgs@maine.gov

Home page: http://www.maine.gov/doc/nrimc/nrimc.htm

See back for description of map units.

Coastal Sand Dune Geology

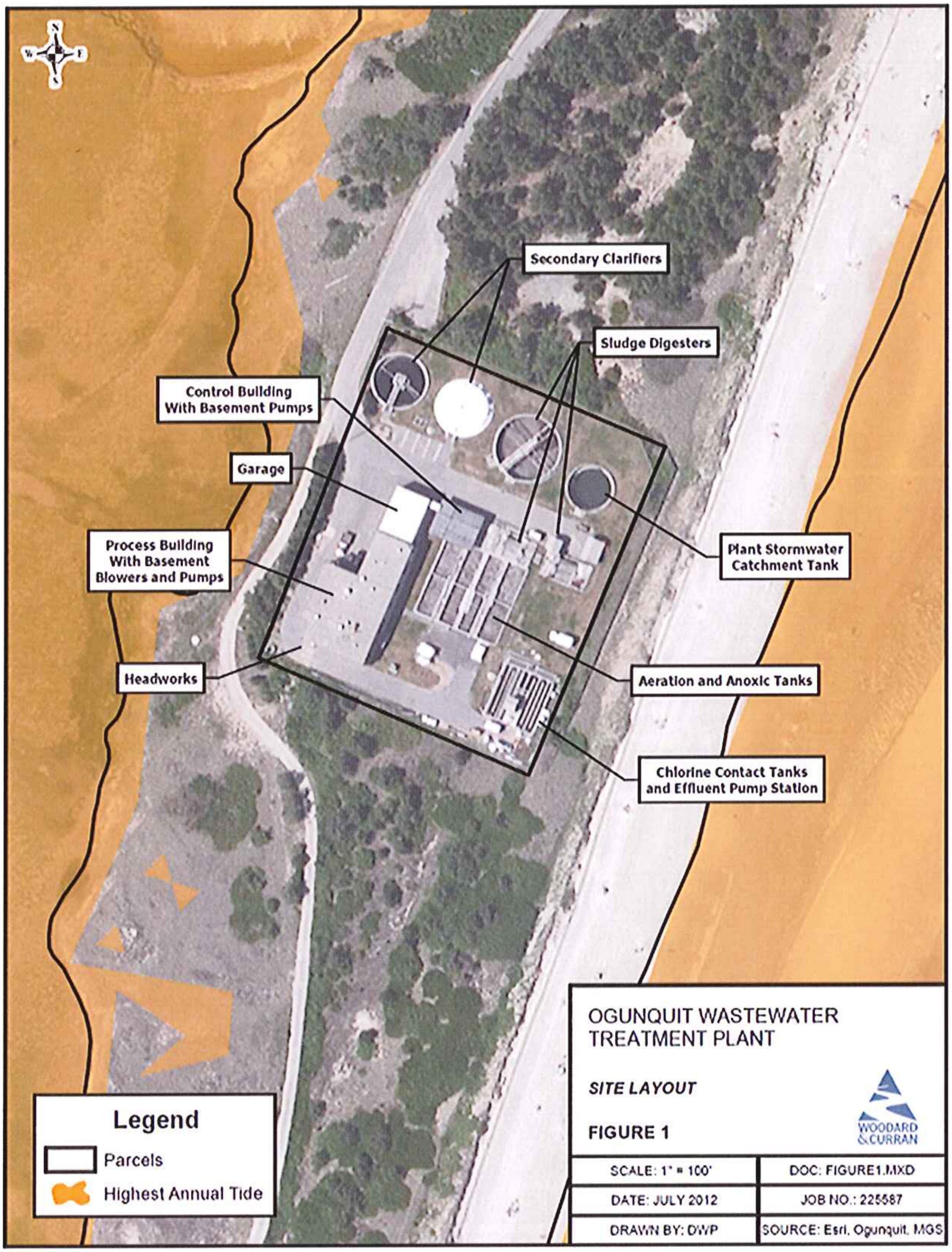
Ogunquit Beach, North, Ogunquit, Maine

by Peter A. Slovinsky and Stephen M. Dickson

Open-File No. 11-78

2011

Figure 4-6: Ogunquit WWTP Site Layout



5. ADAPTATION RECOMMENDATIONS

Several mitigation strategies were considered in this assessment, such as elevating equipment, installing dune retention systems, relocating equipment, relocating the WWTP, and redirecting sewage flows from Ogunquit to Wells.

Ultimately, even under the best case scenarios, there appears to be no practical long-term solution that would feasibly allow the Town to continue utilizing the existing treatment site without mitigation measures that would involve major permitting, funding, and construction efforts, such as elevating the site's assets and/or dune nourishment (rehabilitating a man-made dune retention system) in the frontal dune, and salt marsh enhancement in the back dune. If the facility becomes inundated, or needs to shut down for lack of power, the beach will be closed.

Woodard & Current believes that the best long-term strategy for the Ogunquit WWTP is to move off the existing site. This Report is a preliminary evaluation of potential strategies; however, the Ogunquit Sewer District should begin preparing a 20-50 year Strategic Plan that will explore the options available to the District. This planning effort must consider the assets of the entire collection, conveyance and treatment system to determine the most cost effective transition plan and timeline. This will enable the District to develop the financial plan or model to determine the impact to sewer rates. In this way, the District will be able to explore options and set sustainable rates in the coming years to fund the short term plant investments, as well as longer term investments that will be necessary for the transition to a regional solution or a new treatment plant. Options to explore may include the formation of an enterprise fund or other capital reserve funding measure.

Summaries of the risks we have outlined in this Report, an analysis of the costs associated with the two options (constructing a new Ogunquit WWTP, or regionalizing with a neighboring town) and potential strategies to consider are contained in the following sections.

5.1 SUMMARY OF RISKS

Table 5-1 is included below as a visual illustration of the various risk factors as they apply to specific facility assets or processes. This table provides a rough comparative or relative risk assessment based on the criticality of the asset or process against the various vulnerabilities to be considered. In this risk assessment model, the risk number is simply determined by multiplying the relative criticality ranking with the highest relative vulnerability ranking.

Table 5-1: Vulnerabilities & Associated Risks on the Short, Mid, & Long-term Horizons

Ogunquit WWTP Assets/Process	Asset Criticality	Vulnerability												Comparitive Risk		
		Growth & Expansion Risk			Sea Level Rise/Beach Erosion/Storm Risk			Regulatory Risk			Age Related Degradation Risk					
		S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Headworks	2	1	1	3	1	2	4	1	2	2	1	3	3	2	6	8
Aeration Tanks	3	1	1	2	1	2	4	1	2	2	1	2	3	3	6	12
Clarifiers	3	1	2	2	1	2	4	1	1	2	1	2	3	3	6	12
Disinfection and Eff Pumping	3	1	1	2	1	2	4	1	2	2	1	3	3	3	9	12
Ocean Outfall	3	1	1	2	1	1	4	1	2	2	1	1	2	3	6	12
Sludge Digesters	2	1	1	1	1	2	4	1	1	1	1	2	3	2	4	8
Back up Power	3	1	1	1	1	3	4	1	2	2	1	3	3	3	9	12
Sludge Dewatering	2	1	1	2	1	2	4	1	1	2	1	2	3	2	4	8
Garages	1	1	1	1	1	2	4	1	1	1	1	1	1	1	2	4
Control Building	3	1	1	1	1	3	4	1	1	1	1	1	2	3	9	12
Process Building	3	1	1	1	1	3	4	1	1	1	1	1	2	3	9	12
Site Piping	3	1	1	1	1	2	4	1	1	1	1	2	3	3	6	12
Pumping Stations	3	1	1	2	1	2	3	1	1	1	1	2	3	3	6	9
Collection System	3	1	1	2	1	2	2	1	2	3	2	3	4	6	9	12

Asset Criticality is rated 1-3 (3 highest) and color coded (1=green, 2=orange, 3=red)
S= Short Term (1-10 yrs), M = Mid-Term (10 – 25 yrs), L = Long Term (25 – 50 yrs)
Vulnerability is rated 1-4 (4 greatest) and color coded (1=green, 2=orange, 3=purple, 4=red)
Comparitive Risk is rated 1-12 (12 highest) and color coded (1-3=green, 4-6=orange, 7-9=purple, 10-12=red)

5.2 COST ANALYSIS

The capital cost for a new facility the size of the Ogunquit WWTP is roughly $20 million. Without additional information and further study at the Wells facility, it is not certain what the costs will be to upgrade the Wells facility to be a regionalized (Wells and Ogunquit) facility. It is possible that the application of technologies such as integrated fixed film or ballasted flocculation systems will be able to maximize the use of existing tankage. A rough estimate for construction costs at the Wells facility would be in the range of $4-12 million.

One issue that will impact the overall construction cost for either a new plant or an upgraded Wells facility will be addressing infiltration and inflow (I/I) and other upgrades to the collection system. There will be expenses for upgrading the collection facilities, which are necessary to maintain the system. These investments may reduce the capital expenditure of a new plant or a combined facility at Wells. Without the benefit of a clearer understanding of the magnitude of the I/I issues at the Ogunquit facility, it is not possible to accurately assess the cost impact of I/I issues.

If a new WWTP is built, the operating costs of the new Ogunquit facility are expected to be similar to the operating costs of the existing facility. The current operation is well managed, the staffing level and annual expenditure level is good, and it is not expected to change significantly if a new facility is built. The 2011 audited operating expense for the District was $1,281,847. If a combined facility is established at Wells, the staffing level will need to increase to accommodate the Ogunquit collection system. Currently, the Wells Sewer District has a similar staffing level to Ogunquit, and a combined facility is anticipated to require only two or three more employees at Wells. Therefore, a combined facility is anticipated to have three to four fewer employees than two separate facilities. Fewer employees and operating expenses for one combined facility will realize savings in comparison to operating two separate facilities.

At this time, the impacts to the sewer rates for Ogunquit have not been studied for either scenario. It is certain that, within 20 to 30 years, either a new plant will be built in Ogunquit or a combined facility at

Wells will be established, and there will be significant expenses associated with either alternative. Ultimately, it appears that building a new plant for Ogunquit will likely be the highest cost alternative in both capital and overall operational costs.

5.3 POTENTIAL STRATEGY

Included below is an outline of a potential strategy to be considered moving forward. This list includes various issues and additional studies that this Report has discussed, and which will need to be resolved or completed.

0-15 years

- Conduct engineering evaluation of existing structures & identify temporary safeguards for future coastal flood events
- Reduce I/I
- Conduct river flooding study
- Apply for grants & evaluate funding options
- Prepare financial plan

15-25 years

- Decide whether to regionalize or construct new facility
- Evaluate potential sites
- Evaluate ordinance & conduct town negotiations
- Begin permitting process

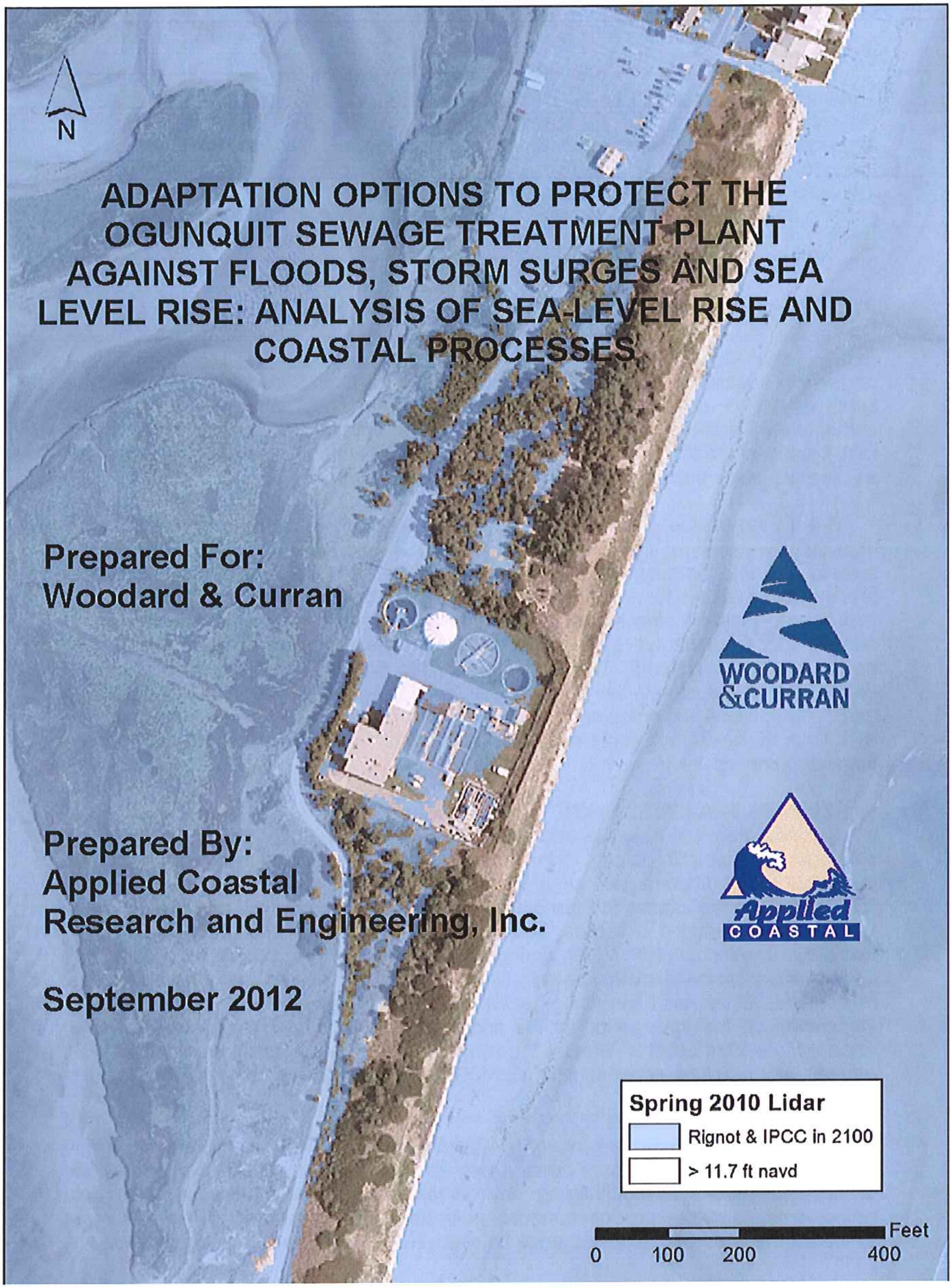
APPENDIX A: APPLIED COASTAL RESEARCH AND ENGINEERING, INC. ANALYSIS OF SEA-LEVEL RISE AND COASTAL PROCESSES FOR THE OGUNQUIT WWTP

ADAPTATION OPTIONS TO PROTECT THE OGUNQUIT SEWAGE TREATMENT PLANT AGAINST FLOODS, STORM SURGES AND SEA LEVEL RISE: ANALYSIS OF SEA-LEVEL RISE AND COASTAL PROCESSES

Prepared For:
Woodard & Curran

Prepared By:
Applied Coastal Research and Engineering, Inc.

September 2012



A. INTRODUCTION

The primary goal of this evaluation of adaptation options for the Ogunquit Sewage Treatment Plant is to guide future planning strategies through the identification of technical information necessary to evaluate the influence of sea-level rise on the plant and implement sound coastal hazard mitigation strategies. Development of the overall assessment of local sea-level rise and historical shoreline change, as well as the influence on future flooding and storm events, required compilation and review of existing data, creation of a range of potential sea-level rise scenarios that are specifically applicable to Ogunquit Beach, analysis of shoreline change and dune migration, and preparation of GIS data layers and maps to present the information in a usable format.

Characterization of coastal hazards is not a new concept. Recently, the U.S. Geological Survey (USGS) has developed relative coastal vulnerability assessments (e.g. Hammer-Klose *et al.*, 2004 and Thieler and Hammer-Klose, 1999). Although these large-scale assessments are useful, the unique geological and geographic setting of the southern Maine coast benefits from a more site-specific analysis. In addition, contemporary analyses techniques (e.g. GIS, rectified aerial photography, and digital topographic information) allow for more accurate delineation of coastal features, as well as other variables that help characterize local coastal hazards.

Due to the unique geologic and geographic setting, the southern Maine shoreline consists of a variety of shoreline types, ranging from bedrock outcrops to barrier beach systems. Due to the geographic orientation of the southern Maine shoreline the coast is primarily susceptible to major damage from extra-tropical storms (northeasters). As indicated in Figure 1, the Maine shoreline is characterized by glacial deposits, many forming bluffs punctuated by areas of lower-lying barrier beaches fronting estuaries and/or salt marsh systems. This stretch of the New England coast is unique, as glacial drumlin deposits dominate the regional sediment supply to beaches. Since the geologic and geographic setting of the southern Maine coast governs how the shoreline responds over time, these characteristics need careful consideration in the assessment of coastal hazards planning.

B. RELATIVE SEA-LEVEL RISE

Separate from the daily rise and fall of the tide, the average elevation of the ocean changes over time with respect to the land. This average position is called relative sea level (RSL), and different geologic and atmospheric processes contribute to changes in RSL. Some of the causes include glacial ice melt, thermal expansion of the ocean as the global temperature increases, and the rising or sinking of the earth's crust itself. While the specific causes of RSL change are the topic of much scientific and political debate, historical evidence indicates that over the past ~100 years, the relative sea-level in Portland, Maine has been rising generally in a linear fashion (see Figures 2 and 3). Depending on the time period of the analysis and/or the tidal datum selected (e.g. Annual Mean Sea Level or Annual High Water), the long-term range varies from 1.84 mm per year or 0.61 feet per century (Slovinsky, 2011) to 2.5 mm per year (0.82 feet per century).

While long-term tide records (e.g. Portland, ME) provide valuable insight into historical changes over the past century, they do not necessarily dictate future response of sea-level rise due to changing environmental conditions. In addition to data refinements, numerous predictive models have been developed over the past 15 years to predict the effects of climate change on relative sea-level rise in the coming decades.

As more data becomes available and models are refined to reflect our current state-of-knowledge, predictions should become more accurate, with a better defined range of potential sea-level rise scenarios. The Intergovernmental Panel on Climate Change (IPCC) has developed a series of sea-level rise predictions starting in 1999, and improvements in available data, analysis techniques, and modeling capabilities have further refined the range of predicted values.

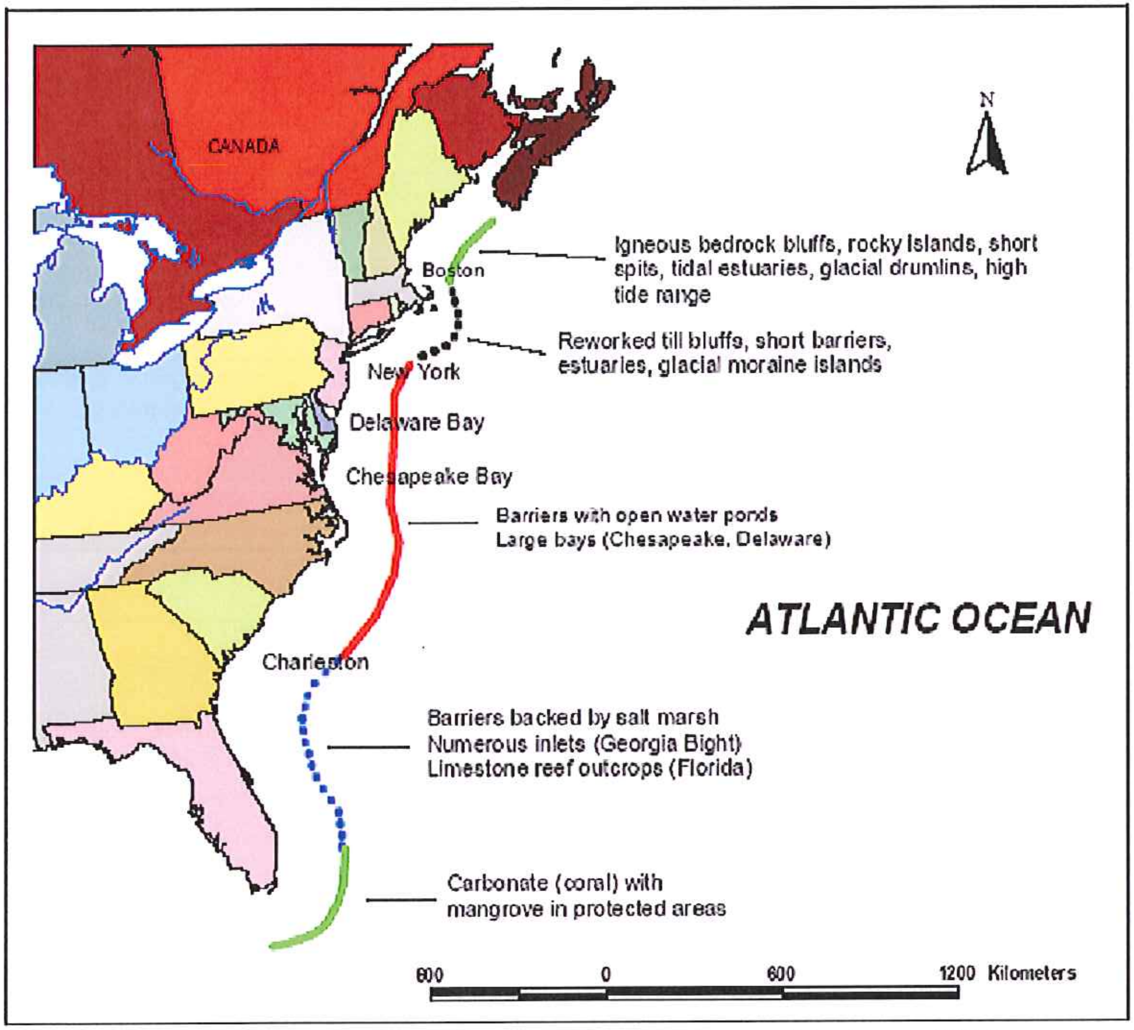


Figure 1. Atlantic coast characteristics (from the U.S. Army Corps of Engineers, 2002).

Based on the most recent available IPCC report (AR4 from 2007) regarding predictions in global sea-level rise, curves were developed for site-specific regional subsidence of the Ogunquit area (Figure 4). These curves represent the low and high best estimates of predicted relative sea-level rise for the Ogunquit area, where the subsidence rate was determined from available GPS data (Sella *et al.*, 2007). Based on the actively monitored GPS data, the subsidence rate for southern Mane was found to be 0.6 mm per year. These predictions indicate that relative sea-level rise at Ogunquit will be between 0.97 and 1.44 feet by 2100, which are both below the Chapter 355 of the state Natural Resources Protection Act that indicated 2 feet of sea-level rise by 2100 was the best estimate to utilize in support of the Coastal Sand Dune Rules.

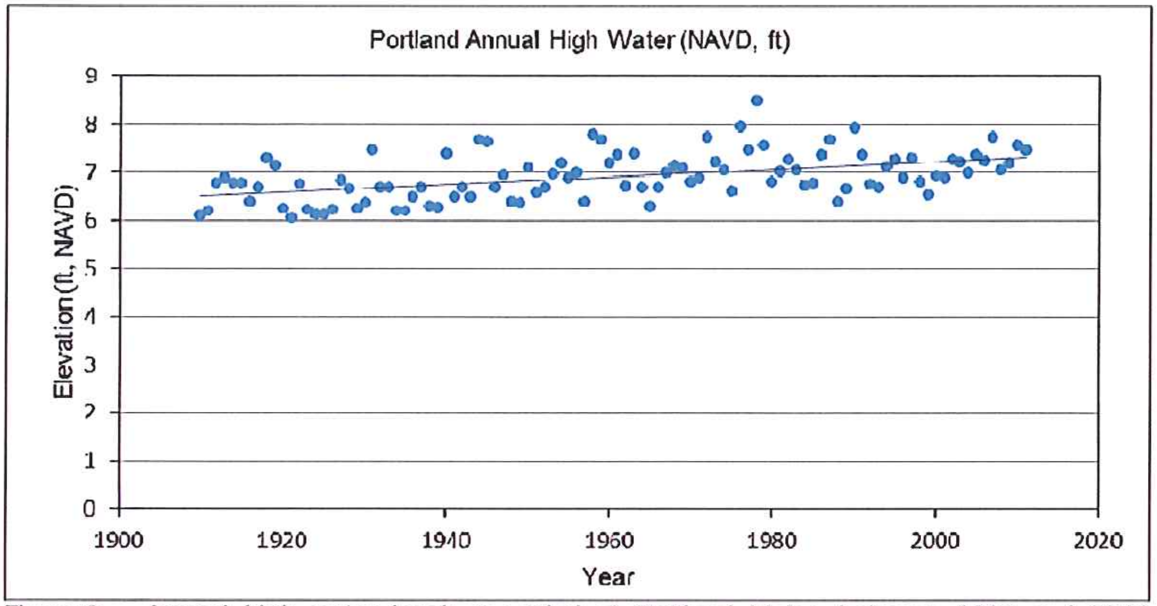


Figure 2. Annual high water levels recorded at Portland Maine between 1910 and 2011 indicate a linear trend in sea-level rise over the past century of approximately 2.5 mm per year.

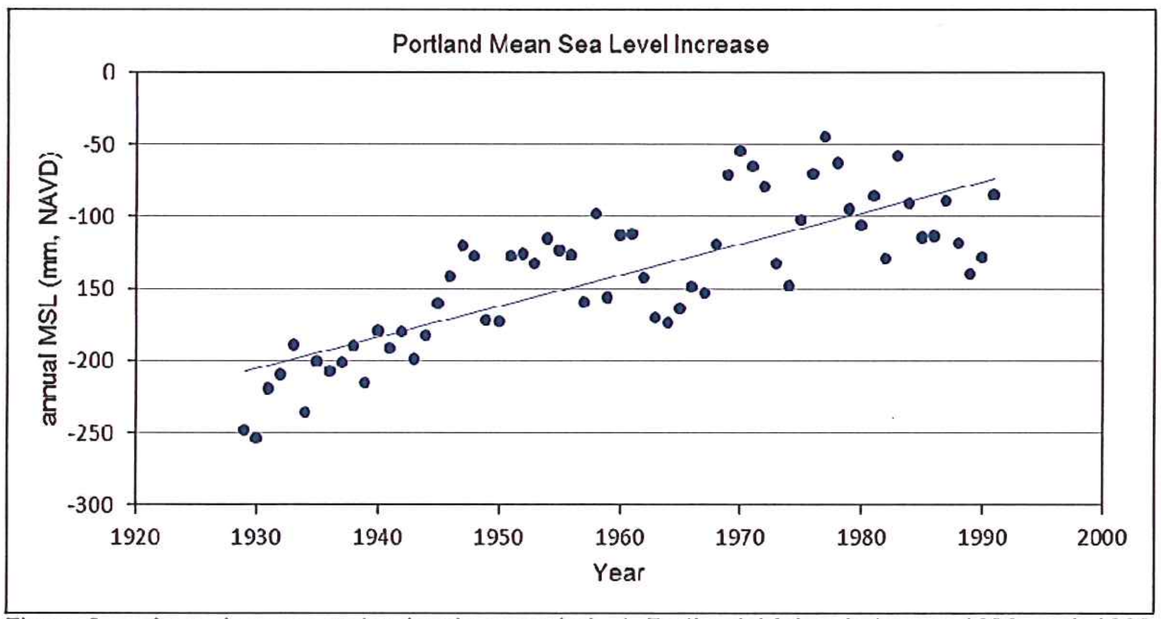


Figure 3. Annual mean water levels recorded at Portland Maine between 1929 and 1992 indicate a linear trend in sea-level rise over this time period of approximately 2.2 mm per year.

It should be noted that the IPCC (2007) report indicated that one significant area where more research was needed was the evaluation of Greenland and Antarctic ice sheets and their future contribution to sea-level rise. The range of potential contribution from these additional sources can substantially increase future sea-level rise predictions. Rignot, *et al.* (2011) developed estimates of the contributions from both Greenland and Antarctic ice sheets based upon data collected between 1992 and 2009. Over this time period, a curve fit to the ice sheet loss data indicates that ice loss is accelerating. To predict future contributions of ice sheet loss, Rignot *et al.* (2011) extrapolate this acceleration rate into the future and provide estimates of the contribution these ice sheets will have to sea-level rise by 2050 (~15 cm) and 2100 (~56 cm) relative to 2009/2010. These future predictions are based upon the assumption that the year-to-year acceleration trend observed between 1992 and 2009 will remain constant until 2100. Regardless, this empirical approach can be utilized to provide a contemporary effective "upper bound" to sea-level rise predictions. It should be noted that the authors of this technical letter indicated that caution should be exercised when using their predictions, as the analysis is based upon a short-term data set (1992 to 2009) with relatively high inter-annual variability. The modeled predictions also require that ice cap melting continues to accelerate year-to-year through 2100 and it remains unclear whether this is possible. The predictions developed by Rignot *et al.* (2011) are shown as the upper curve in Figure 4. Overall, this figure provides a summary of applicable high and low future site-specific sea-level rise scenarios that can be incorporated into future planning efforts for both the Ogunquit and Well wastewater treatment plants.

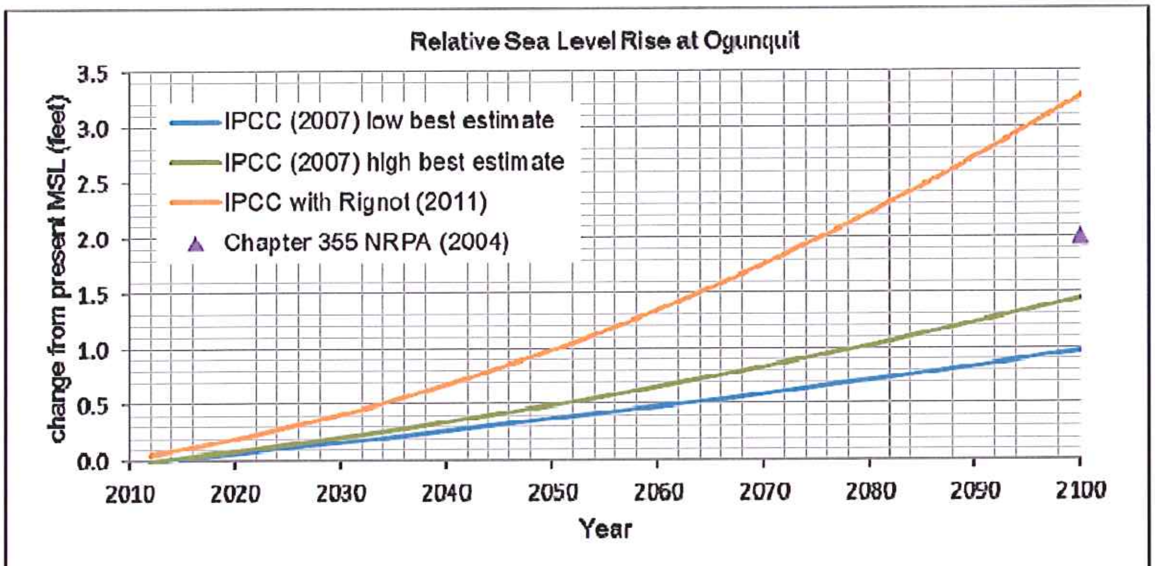


Figure 4. Predicted sea-level rise estimates from 2012 to 2100 based on three different methods: the IPCC high and low best estimates from 2007, and the IPCC high estimate with the updated contributions from ice sheets from Rignot *et al.* (2011). The anticipated rise in sea-level of 2 feet by 2100 described in Chapter 355 of NRPA also is shown.

C. INFLUENCE OF SEA-LEVEL RISE ON STORM FREQUENCY

The coast of southern Maine is primarily susceptible to the impacts of extra-tropical storms or northeasters. Typically, these storms last for several tidal cycles and can generate large long-period storm waves and relatively modest storm surge. For example, Mean Higher High Water (MHHW) is approximately 4.6 feet NAVD, where the 10-year storm surge reaches about 7.6 feet NAVD and the 100-year storm surge reaches about 8.5 feet NAVD, a storm surge of 3.0 feet and 3.9 feet above MHHW, respectively. In general, the significant storms that impact the coast of southern Maine cause relatively frequent moderate flooding, with the difference in storm surge elevations between the 1-year and 100-year return period storms only slightly greater than 2 feet. This minor difference allows nearly every significant northeaster to cause some localized flooding problems, depending on the specific tidal and wind conditions at a site. In addition, due to the low-lying areas along the landward edge of the barrier beach system adjacent to the salt marsh, small changes can induce significant upland flooding of the roadway in the vicinity of the Ogunquit Wastewater Treatment Plant.

In addition to the concerns of general sea-level rise on making infrastructure more susceptible to the influence of storm surge, a number of climate scientists have indicated that the frequency of severe weather events will increase as the planet continues to warm. However, there does not appear to be any scientific consensus regarding an increase in storm activity in the northeastern U.S. that will potentially cause an increase in extra-tropical storm frequency. For this reason, the evaluation of sea-level rise on storm frequency described in this report only includes the influence of projected increases in sea-level on storm surges and does not address any issues related to potential increased (or decreased) future storm intensity. Based on this methodology, Figure 5 illustrates the future predicted increases in the 100-year storm conditions for the various sea-level rise scenarios described in the previous section.

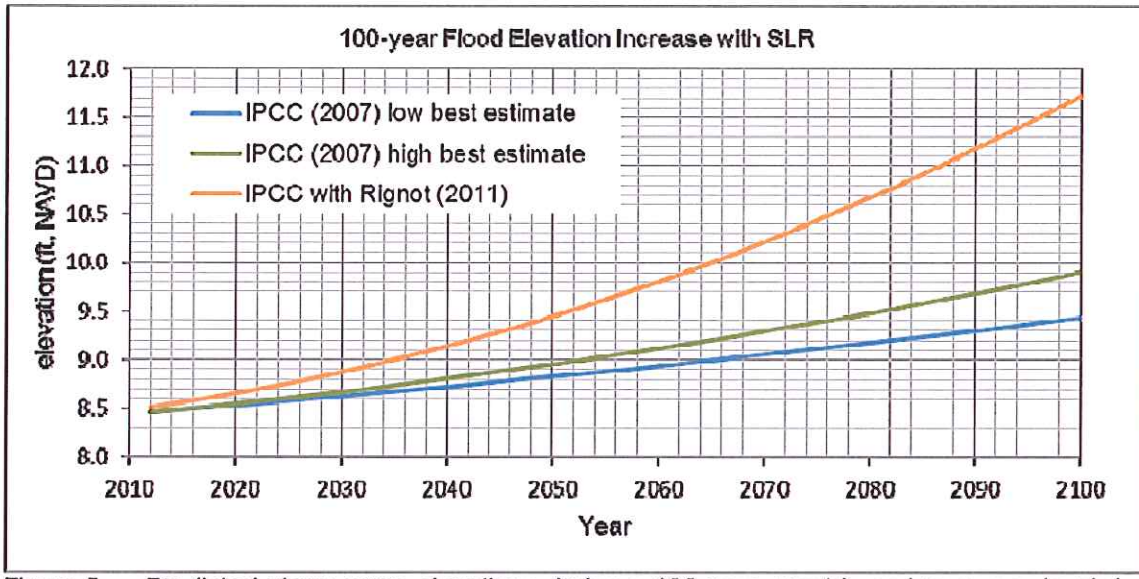


Figure 5. Predicted storm surge elevations during a 100-year event based upon sea-level rise estimates from 2012 to 2100 from three different methods: the IPCC high and low best estimates from 2007, and the IPCC high estimate with the updated contributions from ice sheets from Rignot *et al.* (2011).

The historical tide gage record in Portland, Maine extends back over 100 years to 1910, where Table 1 shows the highest water elevations observed over this time period. The two highest recorded water levels are from 1978. More recently, the April 2007 northeaster ranks as the 6th highest water level observed over the past 102 years. This long-term tide gage record was utilized to develop a return frequency curve for still water storm surge elevations (Figure 6). It is possible that river flow due to heavy rains can also locally influence the storm surge level in salt marsh systems; however, peak riverine flows typically do not coincide with the time of storm surge (major flows from rivers are often delayed by days relative to the storm surge peak), and the cross-sectional area of the flow channel through a salt marsh greatly increases as a result of storm surge, allowing better riverine flow conveyance.

Using the various storm surge scenarios from the previous section, storm return frequency curves can be generated for any range of predicted sea-level rise. In addition to the existing conditions storm return frequency curve, Figure 6 includes storm return frequency curves for each of the predicted sea-level rise scenarios for the year 2100. As shown, the curves shown on this figure clearly illustrate the increased frequency of storm surge inundation for all future scenarios. As an example, Figure 6 shows that the flood elevation for a 100-year storm under existing conditions (8.1 feet NAVD) will be exceeded once every 10 years in 2100, even under the most conservative assumptions regarding future sea-level rise. The 8.5 feet NAVD storm surge level will be exceeded approximately once every five years under the IPCC High Best Estimate conditions expected in 2100. If the predictions presented in Rignot, *et al.* (2011) occur, ever storm in 2100 will create a storm surge that is greater than the present 100-year storm surge level.

Table 1. The highest historical water levels observed since 1910 in Portland, Maine.

Rank	Date	Elevation feet (NAVD)	Return Period (years)
1	1978 Feb 07	8.49	98.1
2	1978 Jan 09	8.37	75.5
3	1976 Mar 16	7.96	30.8
4	1990 Dec 04	7.93	28.9
5	1958 Apr 07	7.79	21.2
6	2007 Apr 16	7.74	19.1
7	1972 Feb 19	7.73	18.6
8	1944 Nov 30	7.69	17.1
9	1959 Dec 29	7.69	17.1
10	1987 Jan 02	7.68	16.7

Figures 7 through 11 illustrate the influence of flooding related to the various levels of storm surge indicated by the sea-level rise analysis. First, Figure 7 shows the storm surge for the existing conditions during a 100-year storm, where the area flooded is shown in blue. The topographic information used for the basis of this depiction is the LiDAR data from 2010. Figures 8 and 9 utilize the average of the IPCC (2007) High and Low Best Estimates for 2050 and 2100, respectively. Using this analysis technique the predicted 100-year storm surge in 2050 is 8.9 feet NAVD and in 2100 is 9.7 feet NAVD. During present conditions, LiDAR data indicates that the roadway providing access to the site experiences some flooding during the 100-year event and this condition will be exacerbated in 2050, as an additional 5 inches of surge can be anticipated according to the IPCC (2007) sea-level rise conditions.

Figures 10 and 11 utilize the High Best Estimate from the IPCC (2007) with an updated estimate of future contributions from both the Greenland and Antarctic ice sheets developed by Rignot, *et al.* (2011). High and Low Best Estimates for 2050 and 2100, respectively. Using this analysis technique the predicted 100-year storm surge in 2050 is 9.5 feet NAVD and in 2100 is 11.7 feet NAVD. Using these higher predictions of future sea-level rise indicate that the site of the Ogunquit Wastewater Treatment Plant will be inaccessible during a 100-year storm by 2050 and that most of the site will be completely inundated during a 100-year storm event in 2100. Since the storm surge elevation difference between a 10-year and 100-year storm event is only about 1 ft, a significant future increase in sea-level, as predicted by Rignot, *et al.* (2011), will cause even relatively frequent storms to flood the treatment plant site in 2100. Even with the more conservative IPCC (2007) estimates, a storm that occurs once every 10 years will substantially flood the roadway access to the plant.

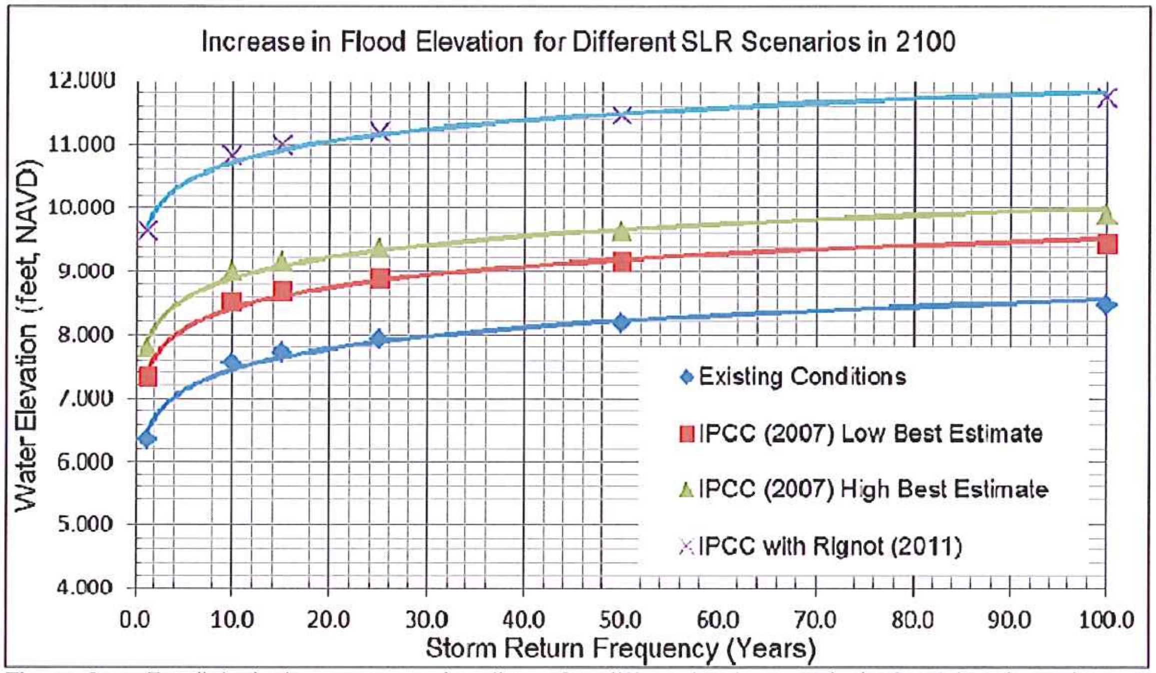


Figure 6. Predicted storm surge elevations for different return periods for 2100 based upon sea-level rise estimates from 2012 to 2100 using the three different methods: the IPCC high and low best estimates from 2007, and the IPCC high estimate with the updated contributions from ice sheets from Rignot *et al.* (2011). The existing conditions storm surge frequency curve is shown for comparison.

Figure 7. Aerial photograph from 2010 showing the areas that are inundated by flood waters for a 100-year storm event (8.5 feet NAVD) based on existing conditions. The areas shaded in blue would be under water during the storm event. Topographic and bathymetric data utilized for this representation were derived from the 2010 LiDAR survey.

Figure 8. Aerial photograph from 2010 showing the areas that are inundated by flood waters for a 100-year storm event (8.9 feet NAVD) based on IPCC predicted average sea-level rise increase in 2050. The areas shaded in blue would be under water during the storm event. Topographic and bathymetric data utilized for this representation were derived from the 2010 LiDAR survey.

Figure 9. Aerial photograph from 2010 showing the areas that are inundated by flood waters for a 100-year storm event (9.7 feet NAVD) based on IPCC predicted average sea-level rise increase in 2100. The areas shaded in blue would be under water during the storm event. Topographic and bathymetric data utilized for this representation were derived from the 2010 LIDAR survey.

Figure 10. Aerial photograph from 2010 showing the areas that are inundated by flood waters for a 100-year storm event (9.5 feet NAVD) based on IPCC predicted sea-level rise increase in 2050 including updated input for ice sheet contributions (Rignot, *et al.*, 2011). The areas shaded in blue would be under water during the storm event. Topographic and bathymetric data utilized for this representation were derived from the 2010 LiDAR survey.

Figure 11. Aerial photograph from 2010 showing the areas that are inundated by flood waters for a 100-year storm event (11.7 feet NAVD) based on IPCC predicted sea-level rise increase in 2100 including updated input for ice sheet contributions (Rignot, *et al.*, 2011). The areas shaded in blue would be under water during the storm event. Topographic and bathymetric data utilized for this representation were derived from the 2010 LiDAR survey.

D. HISTORICAL SHORELINE CHANGE

Ogunquit Beach system provides protection for the Ogunquit Waste Water Treatment Plant from the high water levels and intense wave action experienced during coastal storms. Severe erosion of the beach and dune fronting this plant could potentially result in a breach in the dune and a catastrophic failure of the plant. In order to quantify this risk, the morphological patterns of Ogunquit Beach should be evaluated relative to other coastal hazards.

The use of historical shoreline and bathymetric/topographic change information allows the quantification of coastal processes by providing a measure of nearshore accretion or erosion. For the Ogunquit Beach shoreline, high quality shoreline data sets are available dating back to 1869. This 140+ year time period provides accurate long term information about the evolution of the shoreline fronting the treatment plant. No significant natural or anthropogenic alterations to the shoreline that would result in the severe alteration of morphologic patterns of the beach have occurred over this time period. Therefore, this historical data captures current shoreline trends and may be used to estimate the future morphology of Ogunquit Beach.

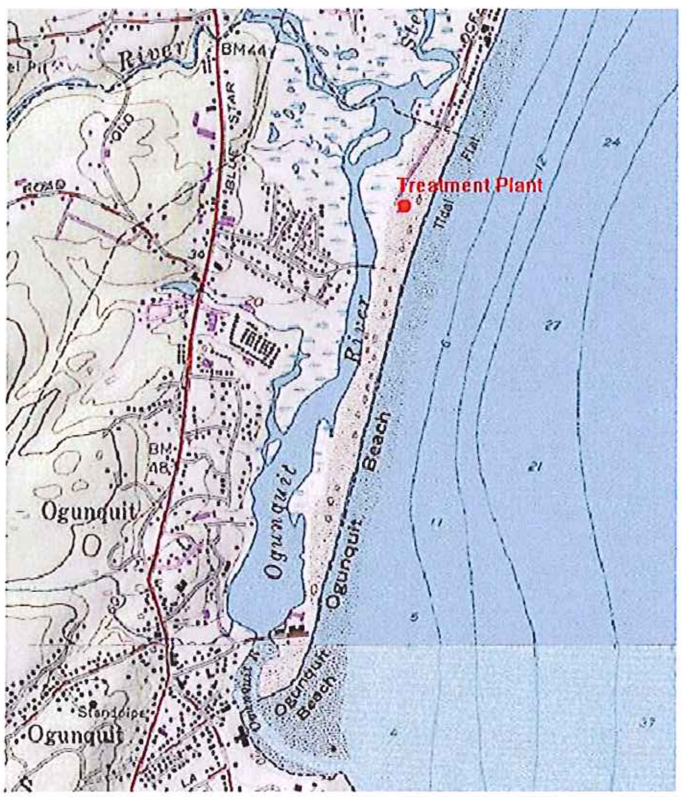


Figure 12. Topographic map showing Ogunquit Beach and the location of the Ogunquit Waste Water Treatment Plant.

Rates of change in high-water shoreline position for the two time periods 1869 to 1953 and 1953 to 2010 were evaluated along Ogunquit Beach up to 2000 ft to the north and south of the water treatment plant. The 1869 shoreline position was mapped using traditional survey procedures and complied on U.S. Coast and Geodetic Survey Topographic Sheet T-1121. The 1953 position was compiled from an aerial survey and supplemental land surveys on Topographic Sheet T-11164. Scans of the original Tsheets were georeferenced in ArcGIS and the shorelines were extracted by on-screen digitizing using the line drawing tool. The 2010 shoreline position was visually interpreted from color orthophotographs flown at low tide and available to download from the MEGIS Data Catalog website. Elevation profiles extracted from the concurrent LiDAR dataset were also used to determine the 2010 high-water position.

The high-water shoreline position change rates were calculated in the Automated Shoreline Analysis Program that is run as an extension in ArcGIS (ArcASAP). This program requires a user-defined spatial interval (50 ft was used for this study) and the general shoreline orientation to determine the amount of shoreline advance or retreat for the time interval. ArcASAP performs the shoreline change calculations by casting normal transects from the earlier shoreline to the later shoreline at each analysis point specified along the input shoreline. The data output is a table of shoreline change magnitudes and rates for each transect where shoreline change denoted with a minus sign represents erosion.

All shoreline position data contain inherent errors associated with field and laboratory compilation procedures. The potential measurement and analysis uncertainty between the data sets is additive when shoreline positions are compared. Because the individual uncertainties are considered to represent standard deviations, a root-mean-square (RMS) method was used to estimate the combined potential uncertainties in the data sets. The positional uncertainty estimates for each shoreline were calculated using the information in Table 2. These calculations estimated the total RMS uncertainty to be ±41.7 ft or ±0.5 ft/year for 1869 to 1953 and ±20.0 ft or ±0.5 ft/year for 1953 to 2010.

Table 3 shows maximum, minimum, and average change rates for each of time intervals. During the 141 year time period, shoreline change rates ranged from 0.2 to -1.6 ft/year. The highest erosion rates occurred during the more recent time period, 1953 to 2010. The only rates of accretion occurred almost 2000 ft north of the water treatment plant and between 400 and 1000 ft south of the plant from 1869 to 1953. The lower average change rate, -0.4 ft/year, also occurred from 1869 to 1953. Overall, the average change rates for both time periods were negative and the erosion rates increased during the later time period.

Considering the 1869 shoreline as the "initial condition" of this study, the high water line of the section of beach that now fronts the treatment plant has moved landward (eroded) over the 141 years of data. The seasonal change in high water line was neglected for this analysis because seasonal effects on the migration of the high water line are small when compared to both the accuracy of measurement and the overall movement of the high water line throughout the analysis. Figure 13 shows the movement of the high water line from July of 1869 to April of 1953, where a section of the beach experiences landward shoreline movement of approximately one foot per year. This suggests a slightly erosional to stable beach, as much of the high water line on the beach showed little movement. From April of 1953 to August of 2010 shoreline change is more prevalent. Figure 14 shows this as most of the beach experiences over one foot of shoreline loss per year. This shoreline loss indicates general erosion of the beach. Overall, both of these analyses show a trend of landward high water line movement and the change in shoreline movement rate shown in the two figures indicates a more recent acceleration in beach erosion. Regardless, the rate of shoreline recession is relatively moderate and there is no indication that the sediment supply to the beach system has changed throughout the historical record. The long-term record does indicate some variability in the location of the greatest erosion; however, this influence likely is in response to localized beach/dune volume, rather than an indication of a diminished sediment supply.

Based on the historical shoreline analysis, the more recent time period (1953 to 2010) indicates an increase in shoreline erosion rate. This acceleration in erosion rate also would cause a related response to dune erosion and long-term dune stability. As the shoreline retreats, the dune volume fronting the bulkhead also will decrease and this will eventually allow the dune in the vicinity of the Waste Water Treatment Plant to be susceptible to a storm-induced breach. Depending on storm severity, it is possible that the already decreased volume of the dune could allow a breach during a severe event. Regardless, continued loss of the fronting dune will make this threat rapidly increase in the next 10-20 years and this threat can be considered relatively imminent for planning purposes.

Table 2. Estimates of Potential Error Associated with Shoreline Position Surveys.

Traditional Engineering Field Surveys (1869)	
Position of rodded points	±3 ft
Location of plane table	±7 to 10 ft
Interpretation of high-water shoreline position at rodded points	±10 to 13 ft
Error due to sketching between rodded points	up to ±16 ft
Cartographic Errors (1869, 1953)	Map Scale 1:10,000
Inaccurate location of control points on map relative to true field location	Up to ±10 ft
Placement of shoreline on map	±16 ft
Line width representing shoreline	±10 ft
Digitizer error	±3 ft
Operator error	±3 ft
Historical Aerial Surveys (1953)	Map Scale 1:10,000
Delineating high-water shoreline position	±16 ft
Orthophotography (2010)	
Delineating high-water shoreline position	±10 ft
Position of measured points	±10 ft

Table 3. Shoreline Change Rates

	Minimum ft/year	Maximum ft/year	Average ft/year
July 1869 to April 1953	-1.2	0.2	-0.4
April 1953 to August 2010	-1.6	-0.6	-1.2

Figure 13. Long-term shoreline change between 1869 and 1953 for the section of Ogunquit Beach fronting the Ogunquit Waste Water Treatment Plant. Shoreline change is color-coded, where the highest erosion rate is represented as orange and areas of minimal shoreline change are represented as grey.

Figure 14. Long-term shoreline change between 1953 and 2010 for the section of Ogunquit Beach fronting the Ogunquit Waste Water Treatment Plant. Shoreline change is color-coded, where the highest erosion rate is represented as red and areas of minimal shoreline change are represented as grey.

E. RECENT BATHYMETRIC AND TOPOGRAPHIC CHANGE

A survey of the beach and dune elevation, using LiDAR, was conducted in transects across the beach. The location of these transects may be seen in Figure 15. Surveys were conducted in September of 2000, May to July of 2004, and May of 2010. Transects B and C represent sections of the beach and dune directly seaward of the plant. Transect D is located approximately 600 feet south of the plant and Transect A is located approximately 45 feet north of the plant.

Figure 16 shows the change in beach and dune elevations at each transect. The dune immediately fronting the treatment plant may be observed between 250 and 375 feet from the start of Transects B and C. The profile of the dune at all transects remains constant during all surveys, indicating that the dune has neither eroded nor accreted over the 2000 to 2010 time period. Furthermore, there is no evidence of the dune fronting the plant is moving towards the bulkhead of the plant during this time.

A comparison of the 2004 and 2010 transects to the 2000 transects, shows that the overall beach elevation, seaward the dune, is higher at all transects during September of 2000. Furthermore the beach has a steeper slope in 2004 and 2010. Due to the timing of the surveys, this appears to be a seasonal effect, where the natural beach cycle of high wave action and erosion during the winter (which causes sand to migrate offshore), and lower wave action leading to upper beach accretion during the summer. The Ogunquit Beach profile cyclically changes in this manner, with only minor net erosion occurring on a year-to-year basis. In general, other than the seasonal variations, the beach transects show a stable beach system between 2000 and 2010.

Using the data from the 2004 and 2010 surveys, the average slope of the beach fronting the dune was calculated in the vicinity of the treatment plant for Transects A through C. As a control, the slope of the beach fronting the dune in Transect D also was calculated. The 2000 surveys were neglected from these calculations to exclude seasonality effects on the data, potentially biasing the results with a more gradual summer beach berm. Transect D shows the beach profile away from the influence of the treatment plant, while the combination of Transects A, B, and C show the beach slope immediately seaward of the plant. At Transect D, the computed slope of the beach is 1:35, while the slope of the beach seaward of the plant (Transects A through C) is approximately 1:21, where the beach slope was similar for Transects A, B, and C.

Transects B and C, located through the bulkhead fronting the waste water treatment plant, show a dune approximately 100 feet wide. In contrast, Transects A and D show the dune width of approximately 200 feet. This reduced dune width and volume illustrates an adverse effect that the plant location is having on the dune. The existence of the plant 'footprint' and the bulkhead fronting the plant prevents the dune from migrating naturally landward. This unnatural reduced dune width at Transects B and C, make this area more susceptible to a dune breach during a severe storm event. However, at least in the 10-year time period covered by the LiDAR surveys, there has been no appreciable change to the dune volume, position, or width at any of the Transect locations.

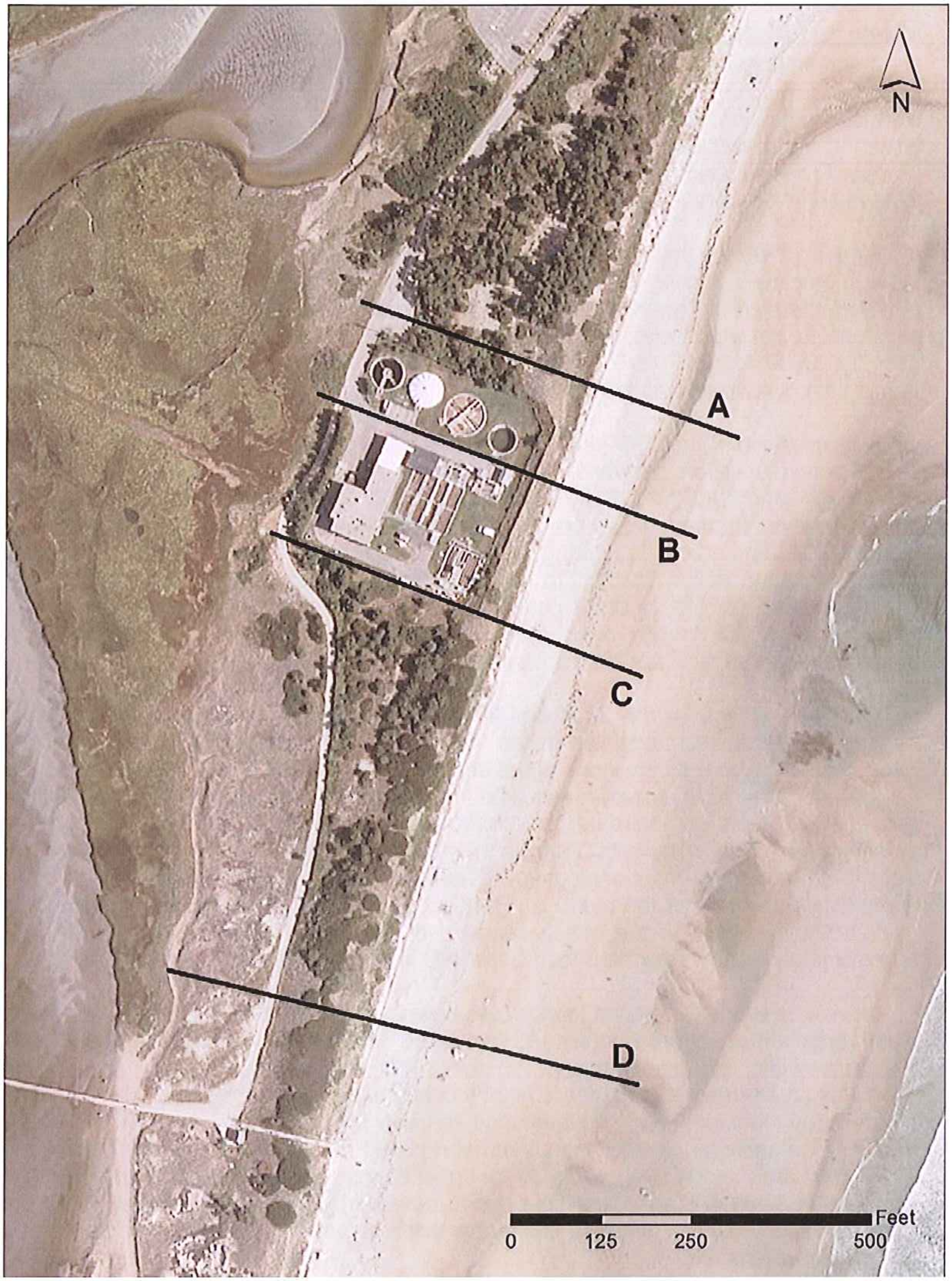


Figure 15. Aerial Photograph showing the location of each transect of Ogunquit Beach. Transect letter matches with the corresponding letter of each beach profile shown in Figure 16.

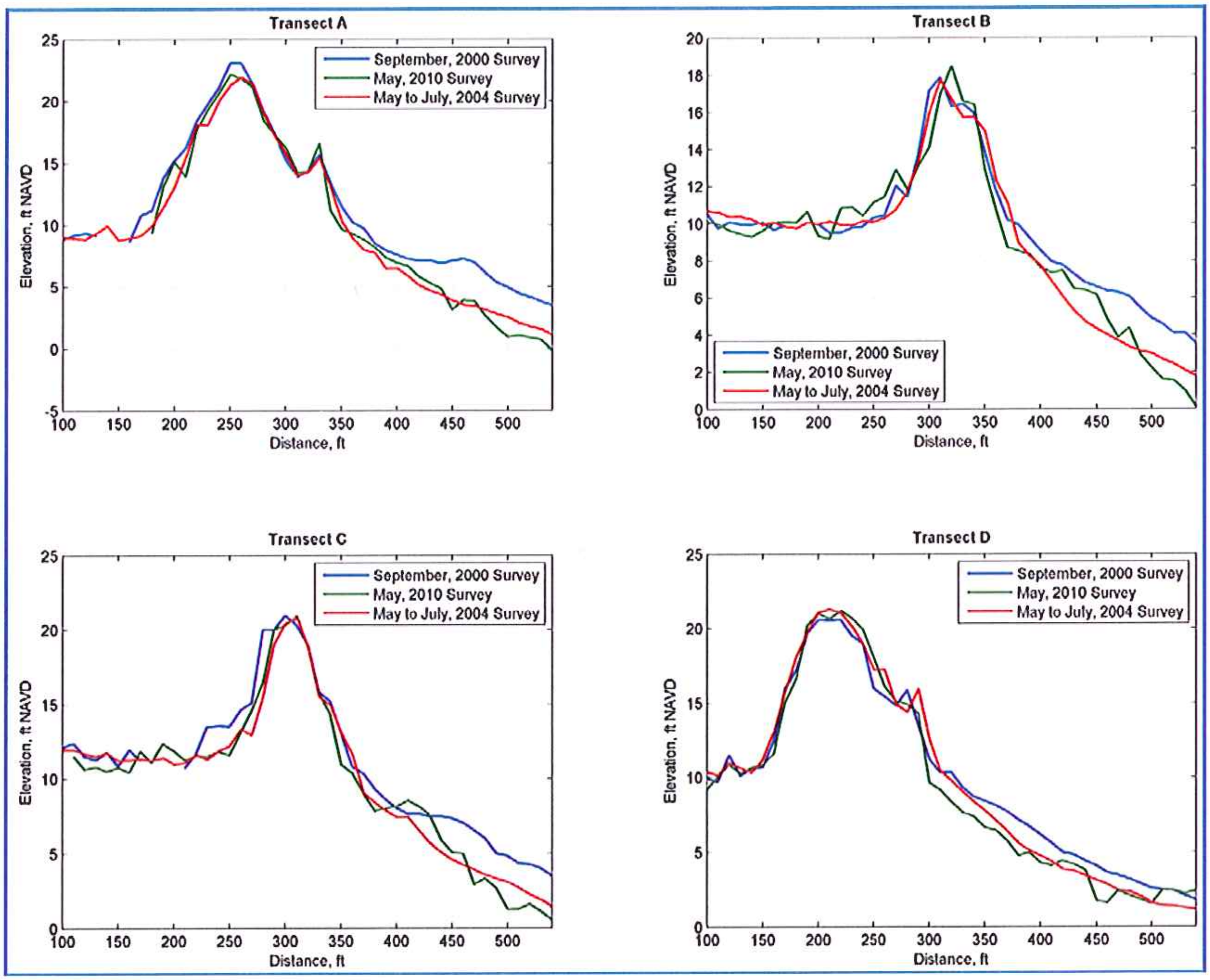


Figure 16. Ogunquit Beach Profiles from September, 2000 to May, 2010. The profiles were created using LIDAR. The location of each transect is shown in the aerial photograph seen in Figure 15.

F. CONCLUSIONS

The assessment of potential sea-level rise scenarios, increased effects of sea-level rise on flood risk, a historical shoreline change, and recent topographic/bathymetric changes in the overall beach system, indicates that the Ogunquit Waste Water Treatment Plant is at risk from both sea-level rise and ongoing coastal erosion. The following general conclusions were developed from the quantitative assessment:

- The available literature and modeling analyses continue to show a relatively wide range in future predictions of sea-level rise. The Intergovernmental Panel on Climate Change (IPCC) provided high and low estimates in 2007 that were below the estimate utilized by the State of Maine for regulatory purposes (i.e. 2 feet of sea-level rise by 2100). More recent literature suggests that the contributions from the ice sheets on Greenland and Antarctica may have been underestimated by the IPCC. For this study, estimates of sea-level rise by 2100 range from approximately 1.0 feet to 3.2 feet.

- While there is no scientific consensus regarding the increase in severe weather events created by climate change in the northeastern U.S., the continued increase in relative sea-level will cause relatively minor coastal storms to have storm surges similar to severe storms in the future. However, the severity of this impact is directly related to the future rate of sea-level rise.
- The present beach erosion rate in the vicinity of the Ogunquit Waste Water Treatment Plant is between 1.0 and 1.5 feet per year. The rate over the past ~60 years is approximately double the rate that occurred between 1869 and 1953. The rates of coastal erosion are relatively low and there is not a direct threat to the plant from long-term erosion over the next few decades.
- Because of the plant siting within a barrier beach and dune system, ongoing coastal erosion has led to a decrease in the overall dune width and associated volume fronting the treatment plant. The existence of the infrastructure prevents the dune form from naturally migrating landward. This loss in dune volume potentially makes the area fronting the plant susceptible to breaching during a storm, since the likelihood of a dune breach during a storm is directly related to the cross-sectional area of the dune. As the surrounding dune continues to migrate landward as the shoreline migrates landward, the volume of dune fronting the plant also will decrease, further exacerbating a potential storm breach of the dune at this location. At the present rate of beach erosion, the dune fronting the plant will be completely lost within the next 30-to-50 years. Depending on storm severity, it is possible that the already decreased volume of the dune could allow a breach during a severe event. Regardless, continued loss of the fronting dune will make this threat rapidly increase in the next 10-20 years and this threat can be considered relatively imminent for planning purposes. Due to the placement of the sheet pile wall along the seaward edge of the Waste Water Treatment Plant property, a future breach is most likely to occur at ether the north or south ends of the shore protection structure.
- The storm susceptibility analysis related to sea-level rise and the ongoing beach erosion indicate that the Ogunquit Wastewater Treatment Plant will be at high risk within the next 20-to-30 years. At present, a 100-year storm will not directly jeopardize the plant; however, accelerated sea-level rise and/or severe erosion of the fronting dune system during a single major storm could put the plant at significant risk well before the 20-to-30 year time period.

APPENDIX B: APPLIED COASTAL RESEARCH AND ENGINEERING, INC. MEMORANDUM ON THE INCREASE IN 100-YEAR STORM FLOODING AT THE WELLS WWTP

Applied Coastal Research and Engineering, Inc.
766 Falmouth Road
Suite A-1
Mashpee, MA 02649

MEMORANDUM

Date: **August 6, 2012**

To: **Seth Garrison, Woodard and Curran**

From: **John Ramsey**

Subject: **Increase in 100-Year Storm Flooding at the Wells Wastewater Treatment Plant**

The flooding scenarios at the Wells Wastewater Treatment Plant are identical to the scenarios developed for the Oqunquit Wastewater Treatment Plant, where Figures 1 through 5 illustrate the influence of flooding related to the various levels of storm surge indicated by the sea-level rise analysis. First, Figure 1 shows the storm surge for the existing conditions during a 100-year storm, where the area flooded is shown in blue. The topographic information used for the basis of this depiction is the LiDAR data from 2010. Figures 2 and 3 utilize the average of the IPCC (2007) High and Low Best Estimates for 2050 and 2100, respectively. Using this analysis technique the predicted 100-year storm surge in 2050 is 8.9 feet NAVD and in 2100 is 9.7 feet NAVD. During present conditions, LiDAR data indicates that the site experiences no flooding during the 100-year event and this condition is similar in 2050, as an additional 5 inches of surge can be anticipated according to the IPCC (2007) sea-level rise conditions. Figure 3 (100-year storm conditions in 2100 as predicted by the IPCC, 2007) indicates that the area to the eastern side of the wastewater treatment plant would be flooded.

Figures 4 and 5 utilize the High Best Estimate from the IPCC (2007) with an updated estimate of future contributions from both the Greenland and Antarctic ice sheets developed by Rignot, *et al.* (2011). High and Low Best Estimates for 2050 and 2100, respectively. Using this analysis technique the predicted 100-year storm surge in 2050 is 9.5 feet NAVD and in 2100 is 11.7 feet NAVD. Using these higher predictions of future sea-level rise indicate that the eastern portion of the site of the Wells Wastewater Treatment Plant will be flooded during a 100-year storm by 2050 and that this flooding will be exacrerbated during a 100-year storm event in 2100. Since the storm surge elevation difference between a 10-year and 100-year storm event is only about 1 ft, a significant future increase in sea-level, as predicted by Rignot, *et al.* (2011), will cause even relatively frequent storms to flood the treatment plant site in 2100. Unlike the Ogunquit plant, the roadway servicing the Wells Wastewater Treatment Plant will not be flooded during a 100-year storm event, even utilizing the 'worst-case' future sea-level rise scenarios.

Figure 1. Aerial photograph from 2010 showing the areas that are inundated by flood waters for a 100-year storm event (8.5 feet NAVD) based on existing conditions. The areas shaded in blue would be under water during the storm event. Topographic and bathymetric data utilized for this representation were derived from the 2010 LiDAR survey.

Figure 2. Aerial photograph from 2010 showing the areas that are inundated by flood waters for a 100-year storm event (8.9 feet NAVD) based on IPCC predicted average sea-level rise increase in 2050. The areas shaded in blue would be under water during the storm event. Topographic and bathymetric data utilized for this representation were derived from the 2010 LiDAR survey.

Figure 3. Aerial photograph from 2010 showing the areas that are inundated by flood waters for a 100-year storm event (9.7 feet NAVD) based on IPCC predicted average sea-level rise increase in 2100. The areas shaded in blue would be under water during the storm event. Topographic and bathymetric data utilized for this representation were derived from the 2010 LiDAR survey.

Figure 4. Aerial photograph from 2010 showing the areas that are inundated by flood waters for a 100-year storm event (9.5 feet NAVD) based on IPCC predicted sea-level rise increase in 2050 including updated input for ice sheet contributions (Rignot, *et al.*, 2011). The areas shaded in blue would be under water during the storm event. Topographic and bathymetric data utilized for this representation were derived from the 2010 LiDAR survey.

Figure 5. Aerial photograph from 2010 showing the areas that are inundated by flood waters for a 100-year storm event (11.7 feet NAVD) based on IPCC predicted sea-level rise increase in 2100 including updated input for ice sheet contributions (Rignot, *et al.*, 2011). The areas shaded in blue would be under water during the storm event. Topographic and bathymetric data utilized for this representation were derived from the 2010 LiDAR survey.

WOODARD
&CURRAN

woodardcurran.com
COMMITMENT & INTEGRITY DRIVE RESULTS