HOLDEN BEACH SEWER STUDY

McGill ASSOCIATES

CONSULTING ENGINEERS
SHALLOTTE, NORTH CAROLINA

HOLDEN BEACH SEWER STUDY

TOWN OF HOLDEN BEACH

BRUNSWICK COUNTY, NORTH CAROLINA

DOUGLAS CHAPMAN, PE

McGill ASSOCIATES

5041 Main Street, Suite 3
Shallotte, North Carolina 28470
919-378-9111

Firm License No.: C-0459

NORTH CAROLINA PROFESSIONAL SEAL 20622 ENGINEER DOUGLAS G. CHAPMAN

4-12-17

APRIL, 2017

PROJECT NO. 17.07001

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

McGill Associates is pleased to provide this report from our Sanitary Sewer System Study for the Town of Holden Beach. As part of this study, team members assessed the current conditions and vulnerability of the existing system, observed similar utility components in the adjacent towns of Sunset Beach and Oak Island, and reviewed available operational and historical weather event data. The compilation of this information allowed for the reasonable evaluation of potential risks and failure modes.

Methods to reduce sewer system vulnerability and recover from system failures more readily are summarized in the report. The associated ranking and cost of assets needed for improvements are provided to aid in effectively planning and managing any alterations to the system. Recommendations include those directly related to sewer system components and structures, as well as operational tools for employee resource management. The study was not limited to equipment function, but also included consideration of employee, environmental and public safety impacts.

Report recommendations and conclusions are based on the objective evaluation of the sanitary sewer system as a whole, along with specific focus on the critical operational components. The findings are intended to offer the Town information for helping evaluate risks and alternatives as it seeks to improve the management of the sewer utility on the island.

As a result of this study, several recommendations have been made in Section 9.0 of this document. They range from modifications to existing structures to improve reliability to less involved things such as GIS mapping of inventory and an expanded inventory of spare parts. The costs of improvements and benefits are discussed in more detail in Sections 7.0 and 9.0 along with Appendix C. One of the items having the greatest impact to the system would be modifications to the existing pump stations to mitigate the effects of floodwaters and water intrusion. Proposed pump station revision alternatives are discussed in detail in Section 7.0.

2.0 EXISTING SYSTEM DESCRIPTION

The Town of Holden Beach operates a sewer collection system on the island. The system serves over 3,000 customers, primarily single family residences, and a few businesses. Sewers collected are transported to the Brunswick County Sewer System for transport and disposal at the County's wastewater treatment plant.

2.1 COLLECTION SYSTEM

The entire Holden Beach sewer collection system operates on the vacuum sewer principle and is segregated into four (4) service areas by pump station, corresponding to Pump Stations 1 through 4. Pump Stations 2, 3, and 4 have their service areas segregated into an A zone and B zone. One typically going east and one west along the island. Pump Station 1 service area contains 4 zones, divided by east and west, and oceanfront, versus farther into the island. Each zone enters the collection tank through a separate inlet pipe and isolation valve. Refer to Figure 2.1 for a service area map of the Sewer Collection System, a larger version is included in the appendix.

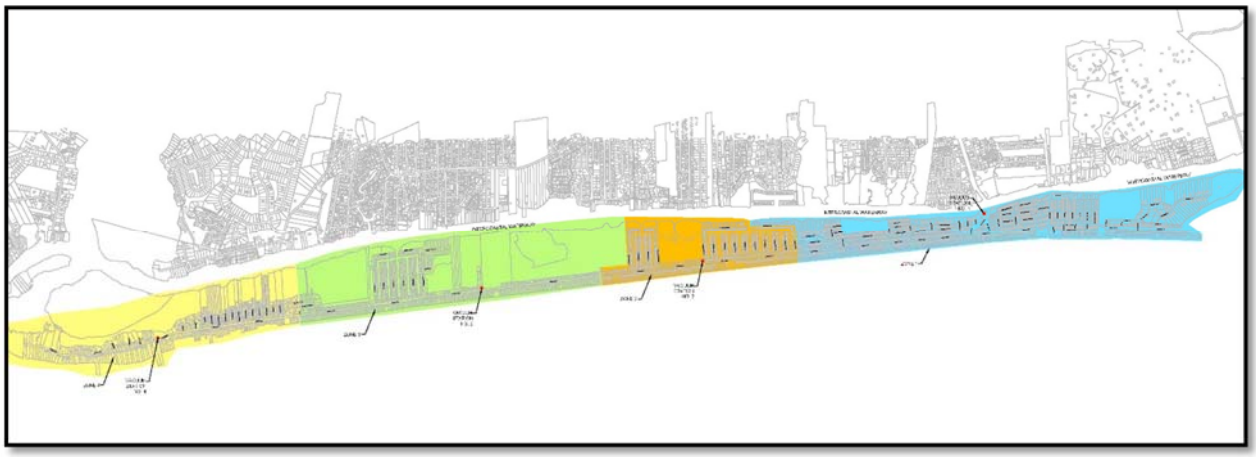


Figure 2.1 Sewer Collection System Service Area Map

The vacuum sewer system works on a principle similar to a gravity system but is modified by induced vacuum to transform gravity sewer lines into more of a saw-tooth pattern allowing a longer extension of sewer run without the added depth. Refer to Figure 2.2 for a diagram of how the vacuum sewers operate.

Figure 2.2 Vacuum Sewer Diagram

With this system, a valve pit is installed to serve two residences that collect sewer flow in a bottom compartment. Once the water level in the compartment reaches a certain level the valve is triggered to open and allow the vacuum within the system to remove the liquid from the pit until empty before closing. Each pit also connects to a nearby vent pipe to allow for air entry. Please refer to Figure 2.3 for a schematic of the valve pit. The Holden Beach system has the valve pits located generally near the road rights-of way in an existing easement between two homes with the vent pipe located adjacent to the valve pit, extending approximately 3-feet above ground elevation.

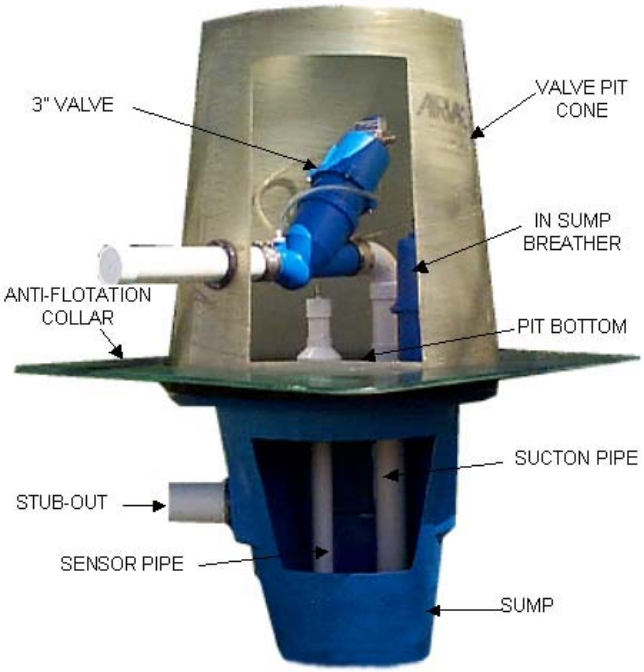


Figure 2.3 Vacuum Valve Pit Diagram

The wastewater collected from Pump Station 2 on the island is transported to Pump Station 1 where it is combined with vacuum sewers collected in service area 1 and then pumped by submersible sewage pumps across the intracoastal waterway to the main land and the Brunswick County sewer system. Likewise, sewers collected by the Pump Station 3 vacuum system are pumped to Pump Station 4 where they are combined with vacuum sewers in service area 4 and pumped by submersible sewage pumps across the intracoastal waterway to the main land and the Brunswick County sewer system. Please refer to Figure 2.4 for a schematic of the system.

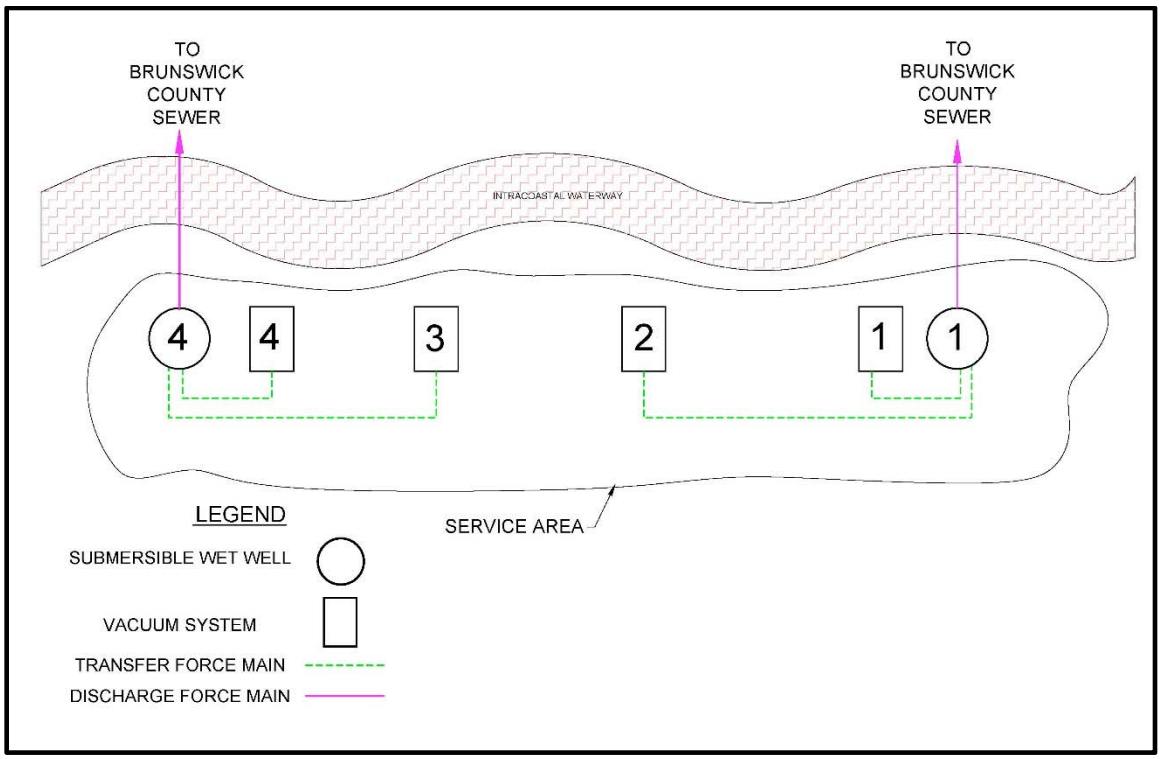


Figure 2.4 Holden Beach Sewer System Schematic

Different from other sewer collection types, a vacuum system experiences issues and/or failures when the system has inadequate vacuum in a section of sewer. When such a condition happens, and the vacuum level drops below a preset minimum, an alarm notifies Town staff to investigate the situation. Town staff then begins a process of isolating segments of the sewer with divisional valves that are located in the sewer mains to determine where the loss of vacuum is, whether it is a main sewer line problem or whether it is a valve pit with the valve inadvertently in the open position. None of the existing valve pits have any type of communication or telemetry monitoring

that would indicate to Town staff that a valve is open or closed. Therefore, it is a manual process to go from valve to valve, generally first checking the vent pipe itself to see if a valve is open to identify the problem within that zone of the collection system. While this process is laborious, there is little to no alternative other than some type of indication on each valve pit, a technology that is still emerging.

2.2 PUMP STATIONS

The vacuum portion of all four of the Holden Beach pump stations are built with a similar layout. The vacuum collection and sewage transfer pumps and equipment are located within a subsurface concrete structure. This structure includes, in the lowest level, the vacuum collection tank and the associated 2 sewage pumps which transfer waste from the collection tank to the next point within the collection system. In the upper level of the subsurface structure is located all of the electrical equipment and controls which operate the system as well as the vacuum pumps. Please refer to Figure 2.5 for a section view of the existing pump station layouts. In addition to the collection tank sewage pumps and vacuum pumps, each of the pump stations is equipped with a number of ancillary and support related features. Those include a ventilation system which provides both positive fresh air into the pump station as well as exhausting air from the pump well. Also, the pump station is equipped with two hatches – one hatch is in place to allow for removal of the pumps that are within the pump station and the second hatch is for employee access to the pump station. The pump stations have been retrofitted to include a small building enclosure over access hatches to allow the access hatches to remain open unless there is a suspected flood condition. Each of the facilities are also equipped with odor control systems to reduce obnoxious odors from the vacuum system as well as any associated wet wells. The Town is currently in the process (generators have been acquired and are awaiting installation) of adding back-up power generators to each of the pump stations.

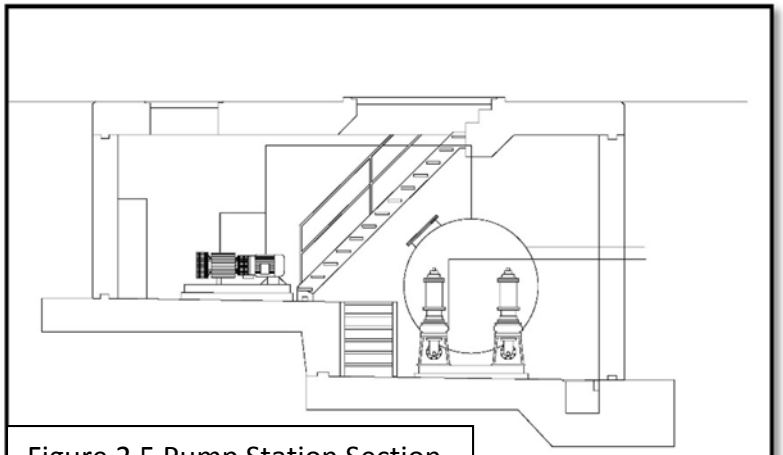


Figure 2.5 Pump Station Section

These units are trailer mounted and can be removed from the island in the event of an emergency condition/evacuation.

Further, two of the pumping stations, stations 1 and 4, collect sewage from the other respective pump stations and combine that with sewage from their own service area in a subsurface wet well adjacent to the vacuum pump station structure. At these two stations, the wet wells are equipped with submersible sewage pumps that transfer waste water under the intracoastal waterway and off the island to the Brunswick County sewer system. While the electrical for the submersible pumps are located above grade adjacent to the wet well, all remaining electrical equipment and appurtenances is primarily located within the underground pump station structure.

2.2.1 VACUUM

The vacuum system has a number of intricate equipment and controls to make the system operate other than simply running the vacuum pumps. Sewer enters the pump station through pipes from the individual zones served by that system. As those pipes enter the pump station structure, each line has its own vacuum gauge and isolation valve before connecting to the top of the collection tank. The sewage collection tank is a large carbon steel tank - sizes vary depending upon capacity and service area - which is the buffer between the collection system and the vacuum pumps to maintain adequate vacuum at varying liquid levels. The liquid level within the collection tank varies as waste water comes in and as the sewage pumps adjacent to the tanks are operated to transport waste water out of the collection tank. The collection tank is equipped with a series of liquid level monitors as well as vacuum monitors to determine that the system is operating as it should. The collection tank works as a sealed system but does have limited access points for maintenance and repairs. For operation of the

vacuum system the collection tank must be in service at all times. Further, for general design and operation of the system the tank must be oriented such that the collection lines gravity flow into the top of the tank and sewage is pumped out of the bottom of the tank.

To provide vacuum for the system a series of vacuum pumps are installed within the pump station structure. All vacuum pumps within each pump station have a similar capacity and motor sizing. The pumps are simply operated as necessary (generally the first pump starts followed by the second pump approximately 30 seconds later) to provide the preset vacuum range in the control system, which is typically between 15 and 20 psi. The vacuum pumps work on a rotary vane principle that include monitors for high vacuum, low vacuum, and are belt driven with open drip proof motors as the primary driver. All vacuum pumps within the system are started by solid-state reduced voltage starters, operating at a constant speed. Each vacuum system does have a telephone based alarm system that notifies Town staff when a given system has unacceptably low vacuum.

2.2.2 SEWAGE

The sewage transport components at the Holden Beach pump stations are segregated into two types of systems. The first type – included at all four (4) pump stations – are sewage transfer pumps, which are connected to the collection tank. The other types are submersible pumps located in a wet well adjacent to the subsurface structure at Pump Stations 1 and 4. These pumps transport sewage from the pump station under the intracoastal waterway to the mainland for disposal.

As outlined earlier the collection tanks at each pump station collect waste water from the vacuum system of each service area. Once the waste water level within the collection tank rises to a preset level, wastewater is pumped out of the tanks by

one (1) of two (2) sewage transfer pumps. The suction piping for these pumps are located at the bottom of the collection tanks. These non-clog centrifugal pumps are equipped with submersible motors that will allow them to be submerged in water and still operate. However, each pump has a solenoid control valve for air inlet on the suction side of the pump which is located less than 2 feet above the lower level floor. Submersion of this valve by flood waters would stop the pump from operating. Each pump is also equipped with a small equalizer line on the discharge side of the pump that can be problematic due to clogging of solids within the piping. Though these pumps have submersible motors and electrical cords connected to them, the electrical cords connect to a junction box that is located only approximately 3-4 feet above the lower level floor, which is not waterproof and is a point of water entry into the electrical system. Each pump station is equipped with two of these sewage transfer pumps one to be a duty pump and one as an installed backup. Beyond that, Town staff maintains one spare pump in their inventory either at the pump station or at their maintenance facility.

The second portion of sewage handling at the pump stations is included at Pump Stations 1 and 4. Each of these pump stations is equipped with a separate wet well that collects sewage from its own vacuum system area as well as sewage transferred from another pump station area. In these cases, Pump Station 1 collects sewage from Pump Station 2 and Pump Station 4 collects sewage from Pump Station 3. (Refer to Figure 2.4 earlier in this report for a schematic of these layouts.) Flow is pumped into the wet wells, which are large precast concrete structures that are equipped with two submersible wastewater pumps. These pumps operate on wet well level and as the wet well reaches a preset point, one of the pumps comes on, should the level continue to rise, a second pump would come on. The electrical supply and controls for these submersible pumps are located above grade with a hood to

protect the units from rain water but they are located slightly above finish grade and well below the base flood elevation.

2.2.3 ELECTRICAL

When evaluating electrical and control components within any of the pump stations there is a multitude of items that are subject to failure either due to flooding or simple ceasing to function. While there are numerous vulnerable components within the system, many are simple items that would not render the system inoperable such as, lights, switches, receptacles etc. Consequently, the more critical items within the pump station include; control solenoids, level sensors and the sewage and vacuum pump controls and power systems. These control panels are made up of a myriad of individual components that provide the overall system operation, from solenoids to relays to PLC's. A further complexity in this area relates to the fact that these control panels are all custom built and would therefore require either a very expensive complete replacement item or quite a few individual component replacement items.

As mentioned earlier, nearly all the electrical components within the pump station would exhibit some form of partial or complete failure should they be subject to saltwater inundation. To prepare for such a catastrophic event, we would propose at a minimum identifying the path forward through temporary operations of pumping equipment by manual means and simple electric starters until complete replacements could be fabricated and installed. However, to truly mitigate the failure, the components could be removed and installed at elevations above the base flood elevation to adequately protect from such damage. A description of such a project will be outlined in a later section.

The vulnerability to failure from simple component issues throughout the system is likely to occur primarily within the operational controls of the facility, and lies with individual components. Later in Section 4 we will identify a number of

equipment components, their availability for replacement, and recommended items to stock on hand.

2.3 VALVE PITS

The point of service for the vacuum sewer system is a structure, located at a set of two residences or a single unit at a business, which is called a valve pit. The valve pits are small tanks that are constructed underground where the building sewer drains into a small lower compartment. This tank is also vented to allow air into the compartment during a vacuum cycle. Each pit is equipped with a valve that is triggered to open to allow the vacuum within the sewer system to evacuate the compartment and transport the sewer from the compartment into the sewer collection line. That valve is triggered by a sensor, based on liquid level within the compartment. All of the operation controls and settings on the individual valves are hydraulic and mechanical and do not have any electrical components in them. Further, these units are capable of operating in a submerged condition. While there is some long term wear due to being submerged or operating in the presence of saltwater, there is no immediate cause of failure. Consequently flooding of the valve pit is only a concern during maintenance or troubleshooting.

The biggest risks associated with the individual valve pits are problems associated with a valve being hung in the open position or the occurrence of a large flood event such that the water level will rise to the point that it can enter the vent pipes. Either of these conditions can cause the vacuum system to be disabled. The continued open position of a valve is the most common, yet least catastrophic failure of the vacuum system. When a valve continues in an open position longer than the standard 10-15 seconds that it takes to evacuate the valve pit, the overall system cannot maintain its vacuum and therefore its ability to adequately evacuate other valve pits within that portion of the system. The Town staff is notified when this condition happens due to a low vacuum level within the system and they then begin to isolate portions of the system to find the open valve. Once the faulty valve is located it's generally a simple procedure to trigger the valve to close.

The valves on Holden Beach currently do not have any type of telemetry or communications that can report their status back to a central facility for troubleshooting. Technologies to accomplish this are emerging, and may be comparable to the system that the Town uses for water meter reading and monitoring.

Finally, the largest opportunity for catastrophic problems with the valve pit portion of the system would be a large flooding event where water levels in sections of the island get high enough to allow the vent pipes to start taking on flood waters. Typically, the vent pipes on the Holden Beach valve pits extend approximately 3 feet above a finished grade. While this level protects them from the normal storm events, it is well below the base flood elevation established on the island and therefore gives opportunity for the system to this type of failure. While the water level has rarely been high enough on the island to impact vents, select areas were under water during Hurricane Matthew. Those flooded areas include sections of Scotch Bonnet Drive, Shell Drive, and areas just west of Swordfish Drive. When this happens, flooding of the vent pipes could cause water logging of the system (if valves open and/or fail) and eventually cause the vacuum system to discontinue service. Refer to Figure 2.4 for a general diagram of a typical valve pit installation.

2.4 ESSENTIAL FACILITIES

The Town of Holden Beach has a number of facilities on the island that are important to daily operations including Town Hall, which contains the Police Department. Beyond these facilities, the remainder of the non-residential facilities on the island are a limited number of commercial establishments, either restaurants, retail stores or professional offices that are not critical in day to day operations and could be evacuated during an emergency condition. Further, the Town Public Works maintenance facilities are located on the mainland, on Sabbath Home Road away from the island and generally the immediate threat of flooding and storm surges. Consequently, there are no facilities identified on the island that must stay in operation during emergency conditions (when mandatory evacuations are enacted) that would require sewer service.

Once an emergency has subsided, service to Town Hall (and the Police Department) is critical to coordinating recovery efforts, and assisting residents. Town Hall is served by Pump Station 1, the main station on the island, and the one that is best protected from flooding conditions. Generally, service can be restored to this area with modest effort.

3.0 COMPARISON COMMUNITIES

While vacuum sewers are not common throughout North Carolina there are several vacuum sewer systems very similar to the Holden Beach system located within the Brunswick County barrier island communities. Consequently, McGill Associates was tasked with visiting these communities and comparing Holden Beach facilities and operations to those of the neighboring communities. To accomplish this task McGill and Town staff met with two neighboring communities – Oak Island and Sunset Beach to visit their pump stations and also interview operation staff to garner any information from those systems that would be beneficial in evaluating the Holden Beach system.

3.1 SUNSET BEACH

The sewer collection system on Sunset Beach, the most recently completed of the vacuum sewers investigated, is a smaller system than either of the other systems discussed. While this system was initiated by Sunset Beach, it is operated and maintained by Brunswick County, and only serves properties on the island at Sunset Beach. The Sunset Beach system again is constructed with similar principles to both Holden Beach and Oak Island (vacuum portions), but only contains one pumping station. This one pumping station contains two zones of vacuum sewer collection lines.

The pump station at Sunset Beach again includes a vacuum collection tank and sewage transfer pumps that are located within the lower level of the structure below grade. In

contrast to either of the other pump station layouts the Sunset Beach station has essentially three levels, the lower level including the vacuum collection tank, the center level being used generally for storage and access at grade, and the upper level which contains vacuum pumps, electrical equipment and controls. This upper level at Sunset Beach is constructed above the base flood elevation to provide adequate protection. The remainder of the pump station, the at grade level and the lower level, while located to protect from minor flooding, is designed such that the lower level can be inundated in a major flood event by providing flood vents in the center level. This pump station is located however adjacent to a marsh leading up to the intracoastal waterway and would therefore take considerable water level increases (from the ocean side) before flood waters would enter the doorway and vents. Staff reports that since its initial construction in 2012, there has been no flooding from storm or surface waters at the Sunset Beach pump station. Sewage collected in the vacuum collection tank is transferred by the sewage pumps across the intracoastal waterway to the Brunswick County sewer system.

In addition to similar vacuum pump station equipment, the valve pits within the Sunset Beach system are comparable to those in both Holden Beach and Oak Island with one exception. The difference in this system is that all of the vent pipes on Sunset Beach are located adjacent to the residences and extend above the base flood elevation for protection.

3.2 OAK ISLAND

While Oak Island by general geography has some similarities to Holden Beach it also has some noticeable differences. Those differences also carry over to the overall system layout and sewage disposal methods. The Town of Oak Island is located partially on a barrier island and partially on the mainland and as a result the Town sewer collection system extends to both of these areas. A further difference with Holden Beach is the

fact that Oak Island has some sewers that are not vacuum sewers. These sewers include conventional gravity sewer lines in select, denser commercial areas.

The general functionality and design of the vacuum system in Oak Island is identical to Holden Beach with zones of vacuum collection sewers served by several central pump stations and valve pits servicing up to 2-4 single family residences. The main difference in the systems particularly on the island is the layout of the pumping stations. The pumping stations on Oak Island (notably the ones located on the island itself) have the vacuum sewer collection tank and sewage transfer pumps located in the lower part of the structure below grade similar to that of Holden Beach, beyond that the pump stations are drastically different. These pump stations are flood proof without any structure openings up to the base flood elevation. Therefore, access to the inside of the pump station is gained through an ascending flight of stairs to an upper level that is located above the base flood elevation. This upper level contains both the vacuum pumps and the main electrical and control equipment for the facility. To then access the collection tank, you must descend essentially two flights of stairs to the lower level. While this layout can make operation and maintenance challenging with all of the stairs to navigate, it does provide nearly complete flood protection of the entire facility, up to the base flood elevation. One exception to this protection is the fact that the emergency generator for the facility is located outside of the pump station structure, slightly above grade. This generator is mounted on a trailer and could be considered portable and removed from the site should emergency conditions be expected.

While the Oak Island pump stations on the island are protected from base level floods, the pump stations on the mainland, most noticeably the main pump station on Oak Island, are located at grade with equipment at grade. While this pump station has vacuum pumps and electrical at grade, the elevation at grade at this point is still higher than the base flood elevation, so adequate flood protection is provided.

The other item to consider, for a system to system comparison, is the vent pipes for the valve pits. Most valve pit vents on Oak Island are located nominally 3 foot above finished grade and are located within a decorative, molded plastic structure. All new vents are being installed adjacent to the structure and are being extended above the base flood elevation to eliminate the possibility of water logging the system during major flooding events.

Generally speaking, operations and maintenance of the Oak Island system is consistent with that of the Holden Beach system. One further insignificant difference, in Oak Island is the fact that Oak Island does operate its own wastewater treatment plant to treat a portion of their wastewater flow while the remainder is pumped to Brunswick County treatment facilities, as is Holden Beach.

4.0 FLOODING EVALUATION

A main issue for concern in any beach, or barrier island community, is flooding, whether by storm surge or stormwater. Consequently, flooding is a major risk for the Holden Beach sewer system. To analyze this risk, historical and potential information has been evaluated.

4.1 HISTORICAL DATA

When considering the potential failure points of any system, stormwater is always a consideration. FEMA performs periodic analysis of flood hazards throughout the United States and publishes that data in a "Flood Insurance Study" or FIS. The purpose of these studies is to develop flood risk data that is used to determine actuarial flood insurance rates. The data is also used by local jurisdictions to assist in floodplain management. The FIS is comprised of two (2) parts; the FIS report and Flood Insurance Rate Maps (FIRM). The FIS provides a summary of the study process and a summary of the data results. The FIRM maps show land mapping with the flood elevations delineated based on flooding depths/elevations. The FIS presents flood elevations for the 10% (10-year), 4% (25-Year), 2% (50-year), 1% (100-year), and 0.2% (500-year) storms; however, not all data is presented for all delineated areas. There are two current FIS studies and map series for Holden Beach. The effective FIS is dated 2008. The newest FIS and FIRM maps (dated 2015) are still considered preliminary until they have been fully vetted and adopted.

The Pump Stations all lie within mapped areas of the FIRM. Pump Stations 2, 3, and 4 are within flood hazard zones in both the effective and preliminary data sets. Pump Station 1 lies within a flood hazard based on the effective FIRM but is outside of the 0.2% flood boundary as shown on the preliminary FIRM. A list of the stations, their top slab elevation, and the published FIRM elevations are shown in Table 4.1 below.

Table 4.1 Pump Station Flood Elevation Data

Pump Station	Top of Slab Elevation	Effective FIS Elevations (Feet, NAVD 88)						
		10-YR	25-YR	50-YR	100-YR	500-YR	Base Flood Zone*	Wave Height Analysis
1	16.5	6.1	-	9.8	11.4	15	AE 15	14-16
2	8.5	6	-	9.8	11.4	15.1	VE 18	16-22
3	8.5	6	-	9.8	11.5	15.1	VE 18	16-22
4	7.5	6.1	-	9.8	11.5	15.1	AE 16	14-16

Pump Station	Top of Slab Elevation	*Preliminary* FIS Elevations (Feet, NAVD 88)						
		10-YR	25-YR	50-YR	100-YR	500-YR	Base Flood Zone*	Wave Height Analysis
1	16.5	-	-	9	-	16	0.2% 16	AE 4/VE 11
2	8.5	-	6.3	8.6	12	18	AE 12	AE 1-6/VE 11
3	8.5	-	6.2	8.8	12	18	AE 12	AE 5/VE 11
4	7.5	-	6.2	9	11	18	AE 11	AE 6/VE 12

Note: The Preliminary FIS Elevation data listed above is expected to be released in March 2018

4.2 PUMP STATION AREA FLOODING

The following screenshots show the four (4) stations and the preliminary flood designations as published on the online FRIS site.

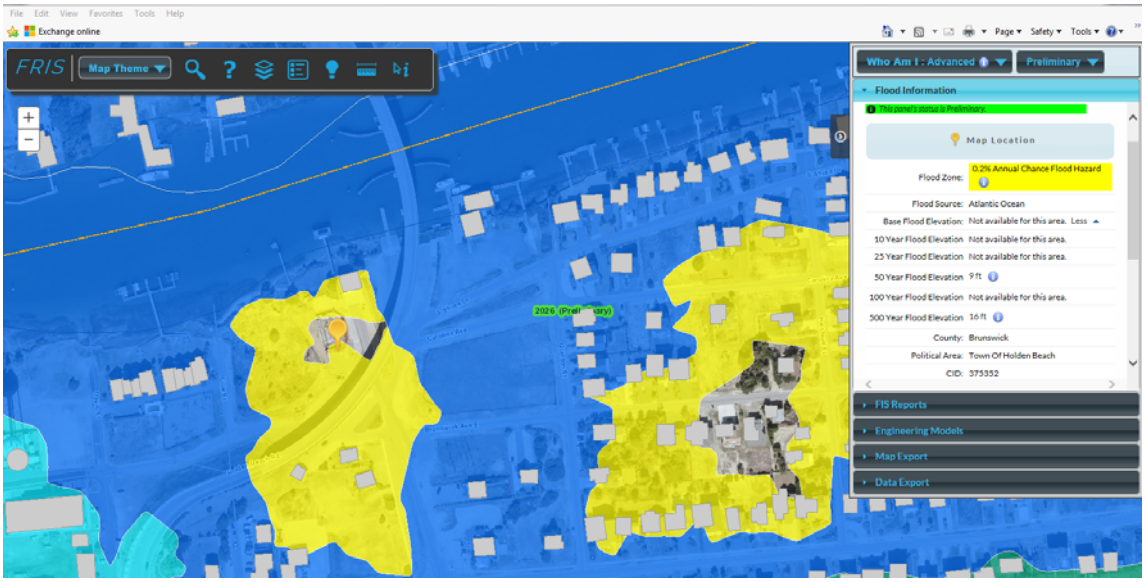


Figure 4.1 - Pump Station 1 Flood Map

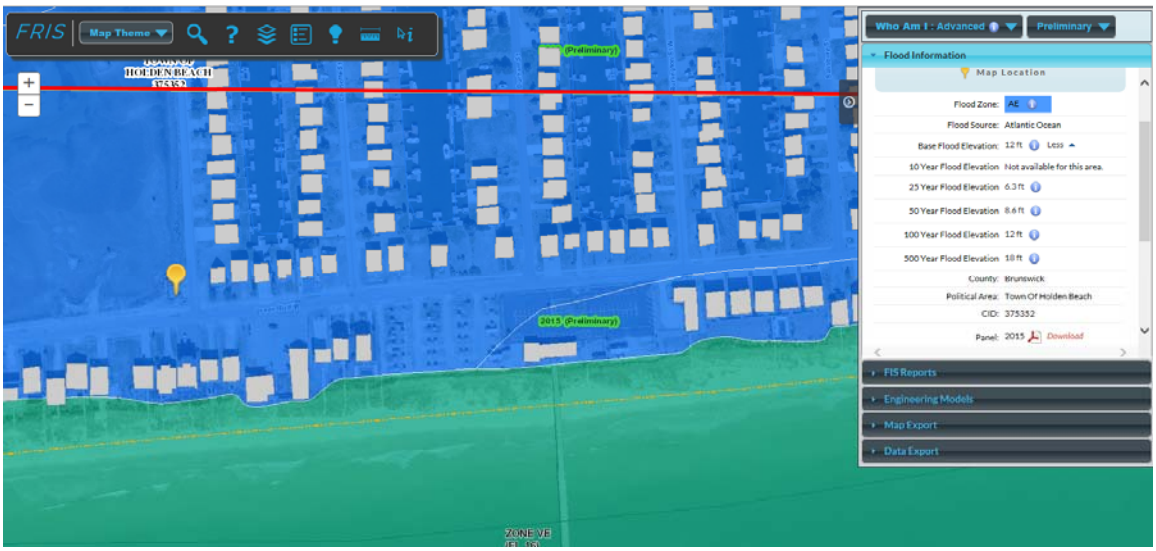


Figure 4.2 - Pump Station 2 Flood Map

Figure 4.3 - Pump Station 3 Flood Map

Figure 4.4 - Pump Station 3 Flood Map

4.3 STORM SURGE POTENTIAL

Based on the information in the FIS and FIRM maps, all of the pump stations except for 1 would be at risk for flooding in anything greater than an a 25-year storm event. Pump Station 1 would be safe from flooding in all of the studied flood frequencies. While some comfort is found in the elevation of Pump Station 1, none are immune to damage from rainfall. These are predicted storms and hurricane events have the potential to exceed the published flood elevations. Storm surge elevations from Hurricane Floyd were as high as 13.3' in Holden Beach. With the stations being below grade and having

horizontal access hatches, they are still vulnerable to water intrusion from any rainfall event.

Another point of potential system failure due to flooding is the valve pit vents located at service connections. With the understanding that these are generally 36-inches above adjacent grade, vents on high ground such as along Ocean Boulevard would generally be above floodwaters through the 25-year storm. However, those in low lying areas such as Sand Dollar Drive and Highpoint Street are vulnerable even in the 10 – year storm.

5.0 FAILURE POTENTIALS AND RISK

As we look at any "system" that is essential to a process, production, or service, we must consider a variety of factors when analyzing its potential for failure. A complex system, such as the Holden Beach vacuum sewer system is no exception. While the most obvious and ominous failure is due to flooding/storm surge, that is not the most likely. Consequently, as part of this sewer system study, we want to look at several areas of risk and potential failure.

5.1 PUMP STATION FLOODING

The previous section outlined a compilation of historical flood data, as well as potentials for storm surge flooding and data relative to accepted base flood elevations. Likewise, we have considered the simple terrain surrounding each of the pump stations, and the down gradient flood relief potential at each station.

Of the four (4) stations on the island, Pump Station 1 is located above the base flood elevation, and therefore is less susceptible to flooding, yet it still has issues with water intrusion from ground water and regular stormwater. However, safety concerns related to electrical equipment and vacuum pumps located below grade are still prevalent. Circumstances in the past have resulted in minor levels of flooding in at least one of the Town's pump stations as evidenced in the photos herein.

The remaining stations all are located such that the top of the structure is well below the base flood elevation, and only slightly higher than the surrounding grade. Refer to Table 4.1 in the previous section for a summary of the top elevation and related base flood elevation for the Holden Beach pump stations. Though these stations are equipped with "flood proof" hatches, the simple ground and stormwater entering them currently would leave one with the expectation that the system would definitely be inundated during a major flood event. With the protocol to turn off the vacuum system, which removes any structure sump pumping, the structure and related systems

are likely to become fully submerged during a catastrophic storm event. Should the structure flood with salt water, most of the electrical equipment and the vacuum equipment could be damaged beyond repair.

5.2 VALVE PIT FLOODING

While the area in the top portion of the valve pit, where the actual valve is located, is likely to stay flooded much of the time, that flooding only causes minimal damage over the long term. This ground/surface flooding can be a nuisance for maintenance of the pits. The greatest risk for system impact at the valve pits in Holden Beach is the potential for major flooding to impact pit vents. Most of these vents, as outlined earlier, extend only approximately 3-feet above finish grade. Consequently, in a major flooding event, they could subject the vacuum system to water logging. Should the Town desire to alleviate this risk, vent pipes would need to be raised and/or relocated.

5.3 VACUUM/PUMP EQUIPMENT FAILURES

Earlier in this section we discussed failures in the system related to flooding, now we will address failures of both the vacuum system and the sewage pumps with respect to equipment related issues. General practices concerning the design, planning and permitting of pumping systems (including vacuum pumps) are considered critical in nature and are therefore, required to have an installed back-up with capacity equivalent to the largest unit. The Holden Beach system is not exception to this rule, with two (2) sewage pumps where one is required in all instances and one (1) additional vacuum pump more than what would be required for normal system operations – it should be noted that during busy summer months, many times all vacuum pumps are operated at select pump stations. What these requirements tell us is that these items of equipment are specialized, difficult to replace, (time and availability) and vital to system operation. Given this fact and the fact that while a back-up is installed for all sewage pumps, once one pump is out of service the system is highly vulnerable to failure. Hence the reasoning why the Town maintains spares of these pumps already. Further, Holden Beach also keeps a total of two (2) spare vacuum pumps (located at the maintenance facility) in case of failure.

The remainder of the vacuum sewer system within the pump stations themselves does have a number of key components that must be in place for the system to operate including the collection tank and numerous sensors, controls and valves. While many of

these items are critical to system operation in automatic modes the system could be operated manually with many of these items out of service. However, one of the purposes of this study is to develop a recommended list of spare components that could be maintained by the Town to alleviate risk and vulnerability. That list will be included in a later section of this report.

5.4 COLLECTION TANK

Each of the Town's vacuum sewer stations is equipped with a vacuum sewer collection tank, which acts as a temporary storage vessel in the collection system process. The volume of Tank No. 1 is 4,500 gallons while each of the other three tanks has a volume of 3,000 gallons. Each of these collection tanks is critical to its service area because they act as a pressure vessel and are contiguous with the vacuum pressure gradient that induces sewer flow within the vacuum system.

Based upon historical accounts of Town Staff, the collection system tanks were originally designed and specified to be constructed out of stainless steel material. Due to the overall expense of the project and the high cost of stainless steel material, the specified material of the collection tanks was changed to carbon steel (which is consistent with both Sunset Beach and Oak Island) with a coating system (paint) designed to protect the structural integrity of the steel vessel. While the exact, current thickness of these tanks is unknown, it is believed that the wall thickness (approximately 5/16-inch) of the vessel is sufficient to sustain acceptable operation for an extended, period of time.

While these assumptions about the current condition and thickness of these tanks may be relatively safe, they are not known as fact. Further, given the critical nature of each of these tanks to the collection system's reliable operation, more certainty should be developed regarding these tanks' condition. Periodically, the Town will remove a tank from service for a very short period of time to clean the tank and remove any remaining debris that was captured by the collection system and deposited into the tank. These periods of cleaning, require shutdown of that collection tank and consequently that entire vacuum system service area and therefore, must be limited to short durations. This limited shut down capability also limits any further inspection and maintenance of the collection system tanks.

Each station's method of construction and arrangement of the equipment within the below-grade structure also makes removal and replacement of these tanks nearly impossible. Therefore, when considering all of the factors described above, the Town has engaged a testing firm to complete a non-destructive examination (NDE) of each of

the collection system tanks. NDE methods essentially utilize radiography (x-rays) to gauge the thickness of the tanks without the need for destructing any part of the vessel or even removing the vessel from service. Such testing will establish a baseline thickness in an attempt to quantify the degree of erosion of the inner tank wall and thereby provide the Town with a more complete evaluation of the condition of these critical elements. At the writing of this report, the testing and results have yet to be completed.

5.5 ELECTRICAL FAILURES

An automated system such as the Holden Beach sewer system with its vacuum collection and sewage transfer has a complex network of electrical components and control items. Historically these types of systems have a high resiliency to equipment failures after the initial commissioning period of a system. Therefore, it is not anticipated that numerous components would fail and cause system vulnerability. However, there is a possibility of these items failing. To address these issues there are two main avenues for attack – one being availability of replacement parts, and the other being the availability of staff and/or contractors to make needed repairs. Again, later in this report we have a list of recommended spare parts to mitigate portions of these issues, and we further recommend that the Town have in place the appropriately experienced and qualified staff or contractors who can address electrical and control type issues.

5.6 VALVE FAILURES

The vacuum valves within the sewer system are quite resilient elements that work on hydraulic and mechanical principles. Most issues related to valves are those that inadvertently remain open beyond the normal vacuum operating cycle. As outlined previously, this condition develops ineffectiveness in the vacuum collection system. History would tell us there is no pattern or necessary reason that these issues persist, and fortunately they only happen on a limited basis.

6.0 REPLACEMENT COMPONENT AVAILABILITY

An important item of this sewer evaluation is the listing of key components within the pump stations. From this inventory (which includes vendors and relevant contact information), availability can be predicted, translating then into recommendations for stocking of these components.

6.1 COMPONENT INVENTORY

To develop an inventory of key components at the Town's four (4) sewer pumping stations, McGill utilized both system construction drawings and field verification. Those efforts resulted in Table 6.1 below. This table, while not exhaustive, includes our estimation of those items that are important, and many critical, to the system operation.

Table 6.1 Pump Station Component Inventory

ID #	Component Name	Equipment	Qty
1-M-001	Vertical, Dry-pit Submersible Sewage Pump	Sewage Pump Skid	2
1-E-003	Sewage Pump Motor	Sewage Pump Skid	2
1-E-005	Solenoid Valve	Sewage Pump Skid	2
2-M-001	Vertical, Dry-pit Submersible Sewage Pump	Sewage Pump Skid	2
2-E-003	Sewage Pump Motor	Sewage Pump Skid	2
2-E-005	Solenoid Valve	Sewage Pump Skid	2
3-M-001	Vertical, Dry-pit Submersible Sewage Pump	Sewage Pump Skid	2
3-E-003	Sewage Pump Motor	Sewage Pump Skid	2
3-E-005	Solenoid Valve	Sewage Pump Skid	2
4-M-001	Vertical, Dry-pit Submersible Sewage Pump	Sewage Pump Skid	2
4-E-003	Sewage Pump Motor	Sewage Pump Skid	2
4-E-005	Solenoid Valve	Sewage Pump Skid	2
1-2-3-4-P-001	8" Pneumatic Actuated Butterfly Valve	Collection Tank Skid	4
1-2-3-4-P-002	Solenoid Valve	Collection Tank Skid	4
1-2-3-4-P-003	Air Compressor	Collection Tank Skid	4
1-2-3-4-I-001	Level Sensing Probes	Collection Tank Skid	36
1-2-3-4-C-001	Vacuum Gauge	Collection Tank Skid	14
1-2-3-4-M-001	Vacuum Pump, 450 CFM, Model RC-0630	Vacuum Pump Skid	10
1-2-3-4-E-007	Crankcase Heater	Vacuum Pump Skid	10
1-E-008	Vacuum Control Panel	Control Panel	1
2-E-009	Vacuum Control Panel	Control Panel	1

ID #	Component Name	Equipment	Qty
3-E-010	Vacuum Control Panel	Control Panel	1
4-E-011	Vacuum Control Panel	Control Panel	1
1-2-3-4-C-002	2" Vacuum Valve	Pump Station Sump	4
1-2-3-4-C-005	Belimo Actuator and control rod		8
1-2-3-4-M-007	Unit heaters		8
1-2-3-4-E-006	HD Safety switch Nema 4 Stainless		8
1-2-3-4-E-008	Junction Box		28
1-2-3-4-M-009	Exhaust Fan		4
1-2-3-4-E-010	Transformer		4
1-C-009	Lift Station Control Panel	Control Panel	1
4-C-009	Lift Station Control Panel	Control Panel	1
1-2-3-4-E-013	200 Amp Generator Quick Connect		4
1-E-014	Manual Transfer Switch, NEMA 4X SST		1
1-4-E-015	600 Amp main Enclose Circuit Breaker		2
1-2-3-4-E-016	Switch for HVAC-Disc		4
1-3-4-M-009	Telephone Interface Box		3
1-E-021	100 Amp 480 VAC Safety Switch, NEMA4 SST		2
2-3-E-022	Manual Transfer Switch, NEMA 4X SST		2
1-2-3-4-E-023	100 Amp, Panelboard, NEMA 4X SST		4
2-3-4-E-024	EF-1 Fan Combination Starter/Disconnect		3
2-3-4-E-025	400 Amp Panelboard, NEMA 4X SST		3
2-3-E-026	400 Amp main Enclosed Circuit Breaker		2
4-E-028	200 Amp 480 VAC Safety Switch, NEMA4 SST		2
2-3-E-022	400 A Manual Transfer Switch		1

Due to the extents of the inventory compiled, and data collected, a more complete, detailed listing is included in the appendices. To provide "smart" numbering of equipment components, a number system was developed that includes the pump station number and an identifier that references the item as mechanical (M), electrical (E), or control (C).

6.2 VENDOR AVAILABILITY

Following identification of key components within the sewer system, detailed data (operational and capacities) were logged for each item. Then, to the extent practical, sources for replacements for these components were sought. Lead/delivery times were

solicited from these component sources, along with pertinent contact information. Table 6.2 below is an itemized listing of those components.

Table 6.2 Component Availability

ID #	Component Name	Failure Mode	Availability	Supplier
1-M-001	Vertical, Dry-pit Sewage Pump	Repair	12-weeks	AIRVAC
1-E-003	Sewage Pump Motor	Repair	12-weeks	AIRVAC
1-E-005	Solenoid Valve	Replace	1-2 weeks	AIRVAC
2-M-001	Vertical, Dry-pit Sewage Pump	Repair	12-weeks	AIRVAC
2-E-003	Sewage Pump Motor	Repair	12-weeks	AIRVAC
2-E-005	Solenoid Valve	Replace	1-2 weeks	AIRVAC
3-M-001	Vertical, Dry-pit Sewage Pump	Repair	12-weeks	AIRVAC
3-E-003	Sewage Pump Motor	Repair	12-weeks	AIRVAC
3-E-005	Solenoid Valve	Replace	1-2 weeks	AIRVAC
4-M-001	Vertical, Dry-pit Sewage Pump	Repair	12-weeks	AIRVAC
4-E-003	Sewage Pump Motor	Repair	12-weeks	AIRVAC
4-E-005	Solenoid Valve	Replace	1-2 weeks	AIRVAC
1-2-3-4-P-001	8" Pneumatic Actuated Valve	Repair	1-2 weeks	AIRVAC
1-2-3-4-P-002	Solenoid Valve	Replace	1-2 weeks	AIRVAC
1-2-3-4-P-003	Air Compressor	Replace	1-2 weeks	AIRVAC
1-2-3-4-I-001	Level Sensing Probes	Repair	1-2 weeks	AIRVAC
1-2-3-4-C-001	Vacuum Gauge	Replace	1-2 weeks	AIRVAC
1-2-3-4-M-001	Vacuum Pump	Repair	3-4 weeks	AIRVAC
1-2-3-4-E-007	Crankcase Heater	Replace	6-weeks	AIRVAC
1-E-008	Vacuum Control Panel	Replace	6-8 weeks	AIRVAC
2-E-009	Vacuum Control Panel	Replace	6-8 weeks	AIRVAC
3-E-010	Vacuum Control Panel	Replace	6-8 weeks	AIRVAC
4-E-011	Vacuum Control Panel	Replace	6-8 weeks	AIRVAC
1-2-3-4-C-002	2" Vacuum Valve	Repair	Stock	AIRVAC
1-2-3-4-C-005	Belimo Actuator w/ control rod	Replace	1-Week	Supply House
1-2-3-4-M-007	Unit heaters	Replace	2-Weeks	Chromolox
1-2-3-4-E-006	60 Amp, 277 Vac Safety switch	Replace	2-Weeks	Grainger
1-2-3-4-E-008	Junction Box	Replace	1-Week	Grainger
1-2-3-4-M-009	Exhaust Fan	Replace	2-Weeks	Granger
1-2-3-4-E-010	Transformer	Replace	5-Weeks	EATON
1-C-009	Lift Station Control Panel	Replace	4-Weeks	RSI
4-C-009	Lift Station Control Panel	Replace	4-Weeks	RSI
1-2-3-4-E-013	Generator Quick Connect	Replace	2-Weeks	APPLETON
1-E-014	600 A Manual Transfer Switch	Replace	2-Weeks	EATON
1-4-E-015	600 A Enclosed Circuit Breaker	Replace	2-Weeks	EATON

ID #	Component Name	Failure Mode	Availability	Supplier
1-2-3-4-E-016	Switch for HVAC-Disc	Replace	2-Weeks	EATON
1-3-4-M-009	Telephone Interface Box	Replace	1-Week	Grainger
1-E-021	100 Amp 480 V Safety Switch	Replace	2-Weeks	EATON
2-3-E-022	400 A Manual Transfer Switch	Replace	2-Weeks	EATON
1-2-3-4-E-023	100 Amp Panelboard	Replace	6-Weeks	EATON
2-3-4-E-024	Fan Starter/Disconnect	Replace	2-Weeks	EATON
2-3-4-E-025	400 Amp Panelboard	Replace	6-Weeks	EATON
2-3-E-026	400 A Enclosed Circuit Breaker	Replace	2-Weeks	EATON
4-E-028	200 Amp 480 V Safety Switch	Replace	2-Weeks	EATON
1-E-029	600 Amp Panelboard	Replace	6-Weeks	EATON

A complete pump station component inventory table, combining both the elements in Table 6.1 and Table 6.2, is included in the appendices.

Beyond the above listing, we have compiled a list of vendor contact information for the Town's use and benefit.

- Aqseptance Group (Umbrella company for AIRVAC brand)
  Contact: Ron White
  Address: 4217 North Old US Highway 31, Rochester, IN 46975
  Email: Ron.white@aqseptance.com
  Phone: 574-208-5861

- Supply House
  Contact: Online or Phone Ordering
  Address: 130 Spagnoli Road, Melville, NY 11747
  Web Address: www.supplyhouse.com
  Phone: 888-757-4474

- Grainger
  Contact: Online or Phone Ordering
  Address: 505 Covil Avenue, Wilmington, NC 28403
  Web Address: www.grainger.com
  Phone: 910-762-3088 or 800-472-4643

- RS Integrators, Inc.
  Contact: Ron Sigmon
  Address: 11172 Downs Road, Pineville, NC 28134
  Email: ron.sigmon@rsintegrators.com
  Phone: 704-588-8288

- Eaton
  Contact: Lance Shaw
  Address: 175 Vista Boulevard, Arden, NC 28704
  Email: lanceshaw@eaton.com
  Phone: 828-651-0572

- Rexel Inc.
  Contact: Nick Fowler
  Address: 1075 1st Avenue SW, Hickory, NC 28602
  Email: nickey.fowler@rexelusa.com
  Phone: 828-328-2646

6.3 STOCK RECOMMENDATIONS

Considering the critical nature of a component to system operations, and its difficulty in acquisition, certain items should be kept in the Town's stock of spare parts. While a ranking of critical assets is included in a later section of this report, that scoring was also factored into the following recommendations for stocking of components. Table 6.3 is a listing of components recommended for stocking by the Town, and number recommended.

Table 6.3 Recommended Spare Components

ID #	Component Name	# for Stock
1-M-001	Vertical, Dry-pit Sewage Pump	1
1-E-005	Solenoid Valve	1
2-M-001	Vertical, Dry-pit Sewage Pump	1
2-E-005	Solenoid Valve	1
3-M-001	Vertical, Dry-pit Sewage Pump	1
3-E-005	Solenoid Valve	1
4-M-001	Vertical, Dry-pit Sewage Pump	1
4-E-005	Solenoid Valve	1
1-2-3-4-P-002	Solenoid Valve	1
1-2-3-4-I-001	Level Sensing Probes	4
1-2-3-4-M-001	Vacuum Pump	4

7.0 MITIGATION MEASURES TO REDUCE VULNERABILITY

As risks for failure have been identified through this report, measures to mitigate those risks must also be investigated. The following is a list of the potential mitigation measures for a variety of items.

7.1 FLOODING / STORM

Of the Holden Beach pump stations, only Pump Station 4 has seen flooding within the system's first 10+ years of existence. Given the lack of being constructed above the base flood elevation, or even noticeably above the surrounding grades, this is no surprise. Consequently, the pump stations are quite vulnerable to this type of failure. At the time of construction, the pump station structures, which include all electrical and mechanical components below grade, were installed with compliance for flood protection by installing what would presume to be flood proof hatches. While in theory these flood proof hatches may be intended to keep out all water during a major flood, it is very unlikely. Further, should the flooding rise more than about 3 feet above finished grade, the air intake vent and exhaust vents for the wet wells would then become inundated with flood waters.

Should the pump station structure become inundated with flood waters on Holden Beach, the results of such an event would be catastrophic to the operations of this system. Flooding of the pump station structures by salt water would cause failure in short order of most, if not all, of the electrical equipment submerged, and the majority of the mechanical equipment with exception of the sewage pumps. This list of vulnerable equipment includes; electrical control panels, disconnects, vacuum pumps and motors, pneumatic valve actuators, collection tank level sensors, ventilation equipment along with an assortment of individual electrical and control components.

To mitigate these risks of components failures upon flooding inundation, the equipment at risk must be removed from the existing structure and installed above the base flood elevation, or the existing structure must be substantially protected from flooding to the base flood elevation. Alternatives to address these issues will be outlined later in this section.

7.2 VACUUM PUMPS

The layout of the Holden Beach system includes the vacuum pumps (a key component of the vacuum sewer system) located within the pump station structure, below grade. As outlined in the previous section this installation leaves these units quite vulnerable to catastrophic failure due to flooding. Though other risks exist with vacuum pump failures, the only solution to mitigate risk of failure due to flooding would be to relocate the vacuum pumps above the base flood elevation as installations in Sunset Beach and Oak Island were constructed.

Beyond the apparent risk due to flood damage, the vacuum pumps are precision mechanical components that are subject to normal failure due to wear and tear, material defects and system dynamics. Consequently, in understanding the critical nature of their operation to the functionality of the system, each pump station has one (1) vacuum pump that is an installed back up should there be a failure of another pump within the system. However, as reported by staff, often during peaks of the summer season, all vacuum pumps are necessary at Pump Station 1. Beyond failure of these units, they do require regularly scheduled maintenance and periodic rebuilds. To ensure their long life we recommend that all maintenance suggested by the manufacturer and planned rebuilds be accomplished as directed by the manufacturer. Further, to reduce the risks associated with multiple vacuum pump failures at a single location, given the redundant sizing of these units, we recommend that the town maintain at least one (1) complete vacuum pump and motor assembly in stock at their maintenance facility on the mainland for each of the four (4) pump stations, for a total of four (4).

To further reduce risks of vacuum system failure and provide back-up, a portable vacuum system could be acquired and brought in to connect to the collection tank at a given pump station to bring the system back online should there be a large-scale failure within either of the pump stations. These portable systems would require portable connections to be installed at each pump station and also a significant initial capital cost to purchase. However, these systems would provide invaluable resources should they be needed.

7.3 ELECTRICAL

When evaluating electrical and control components within any of the pump stations there is a multitude of items that are subject to failure either due to flooding or simple

ceasing to function. Of these components, many are simple items that would not render the system inoperable such as, lights, switches, receptacles etc. Consequently, the more critical items within the pump station include; control solenoids, level sensors and the power and control systems for both the sewage and vacuum pumps. These control panels are made up of a myriad of individual components that provide the overall system operation, from solenoids to relays to PLC's. A further complexity in this area relates to the fact that these control panels are all custom built and would therefore require either a very expensive complete replacement item or quite a few component replacement items.

As mentioned earlier, nearly all the electrical components within a pump station would exhibit some form of partial or complete failure should they be subjected to saltwater flooding. Should such a catastrophic event happen, we would propose at a minimum identifying the path forward through temporary operations of pumping equipment by manual means and simple electric starters until complete replacements could be fabricated and installed. However, to truly mitigate the risk of these components for such a failure the components could be removed and install at elevations above the base flood elevation to adequately protect from such damage. A description of such potential projects will be outlined in a following section.

The vulnerability to failure from simple component issues throughout the system is primarily likely to occur within the operational controls of the facility, and lies with individual components. As outlined in Section 6 previously we have identified a number of equipment components, their availability to replacement and any recommended items to stock on hand.

7.4 SCADA COMMUNICATIONS

Currently, operating data communications at the Holden Beach pump stations is limited to telephone based auto dialers that simply provide a limited number of alarm points (collection tank level, low vacuum, and high heat) at each facility. Mitigation of this limited communication would be identical to that previously outlined for electrical in simply moving those elements above base flood elevation.

However, this area of the system can be greatly enhanced by installing a truer supervisor, control and data acquisition (SCADA) system (required for critical facilities by the National Electrical Code) that provides monitoring of the system and its components in addition to simply having alarms. Such a system could also provide a trending and

history of functions and activity including alarms at each pump station. Costs for a proposed SCADA system will be included in individual proposed alternatives later in this section.

7.5 VALVE PITS

The orientation, layout and construction of valve pits were described previously in this report. While the valve portion at the top of the pit is highly suspect to storm water flooding, the valves essentially are submersible and waterproof. Consequently, from a failure and vulnerability stand point primarily the only risk to the system related to the valve pits lies within the vent piping. While most of the vent pipes within the system are at least 3-feet above the adjacent grade they are all well below the base flood elevation and only nominally above historic flood data. Should these vents be submerged they would result in the vacuum system becoming water logged and the result would be a ceasing of normal operations. However, normal practices and procedures, should the water level be expected to rise to such a point, is to disable the vacuum system and it remain out of service until waters receded. Mitigation for vent piping issues would be possibly relocating the vent pipes adjacent to structures and/or extending them to an elevation above the base flood elevation, similar to the installations on Sunset Beach. The relocation of vents to the structure from their current location may be necessary to provide adequate protection from heavy winds should they be extended up to an elevation 12 to 14 feet above grade.

7.6 GIS MAPPING

Some GIS based mapping of the existing sewer lines and sewer system had begun, yet that effort was not fully completed and implemented. Consequently, Town staff does not have adequate mapping of their sewer system absent of reviewing construction drawings for the areas. While this component would not change the risks of the system for failure due to flooding and equipment issues, it would provide a very useful tool to the Town staff in maintaining and troubleshooting the vacuum sewer collection system. Current staff does a good job at maintaining the existing system due to their extensive knowledge of the locations of valves and connections. However, this data is not recorded in the definitive fashion for others to utilize.

Again, this is not a specific recommendation relative to vulnerability and failure of the sewer system, but it is an item that McGill recommends the Town endeavor to complete the acquisition of data and adequate mapping to equip staff for the future.

7.7 ALTERNATIVES

Of the various items throughout the Holden Beach sewer system that this report references or comments on, there is a limited number of proposed improvements that have alternatives to be considered. Those efforts are primarily limited to any proposed improvements at the Town's sewer pumping stations. Consequently, the improvements proposed are primarily relative to risks and system vulnerability to storm surge and flooding. Therefore, from our investigation, McGill has reduced the number of potential alternatives to three (3), primarily related to the relocation or protection of electrical equipment components and mechanical equipment and components.

The first alternative includes phases of minor changes to electrical components to address existing ground water infiltration into the pump station. These phases include improved conduit runs that do not extend under the existing structure, sealing off conduits more effectively to reduce water migration, and installation of wiring and electrical components where possible that are more water resistant/ waterproof. While this alternative would have the lowest cost of any of the alternatives, it also has the least measures of protection.

Alternative 2 includes relocation of the vacuum pumps and all mechanical and electrical components to an upper level of the pump station, constructed higher than the base flood elevation. This construction would be similar to that seen in Sunset Beach, and would protect those components from any damages relative to storm surge and flooding. However, it would not remove all vulnerability to issues with the vacuum system, in that the vacuum collection tank and sewage transfer pumps would remain within the lower level of the structure. This lower level would then only be protected from flood damage by installing flood vents on the structure that would allow it to become inundated without damage in the event of sufficiently high water. This alternative provides a significantly higher level of protection than Alternative 1 but slightly less than Alternative 3, and carries a similar cost impact. Figure 7.1 below exhibits how the proposed structure would be constructed.

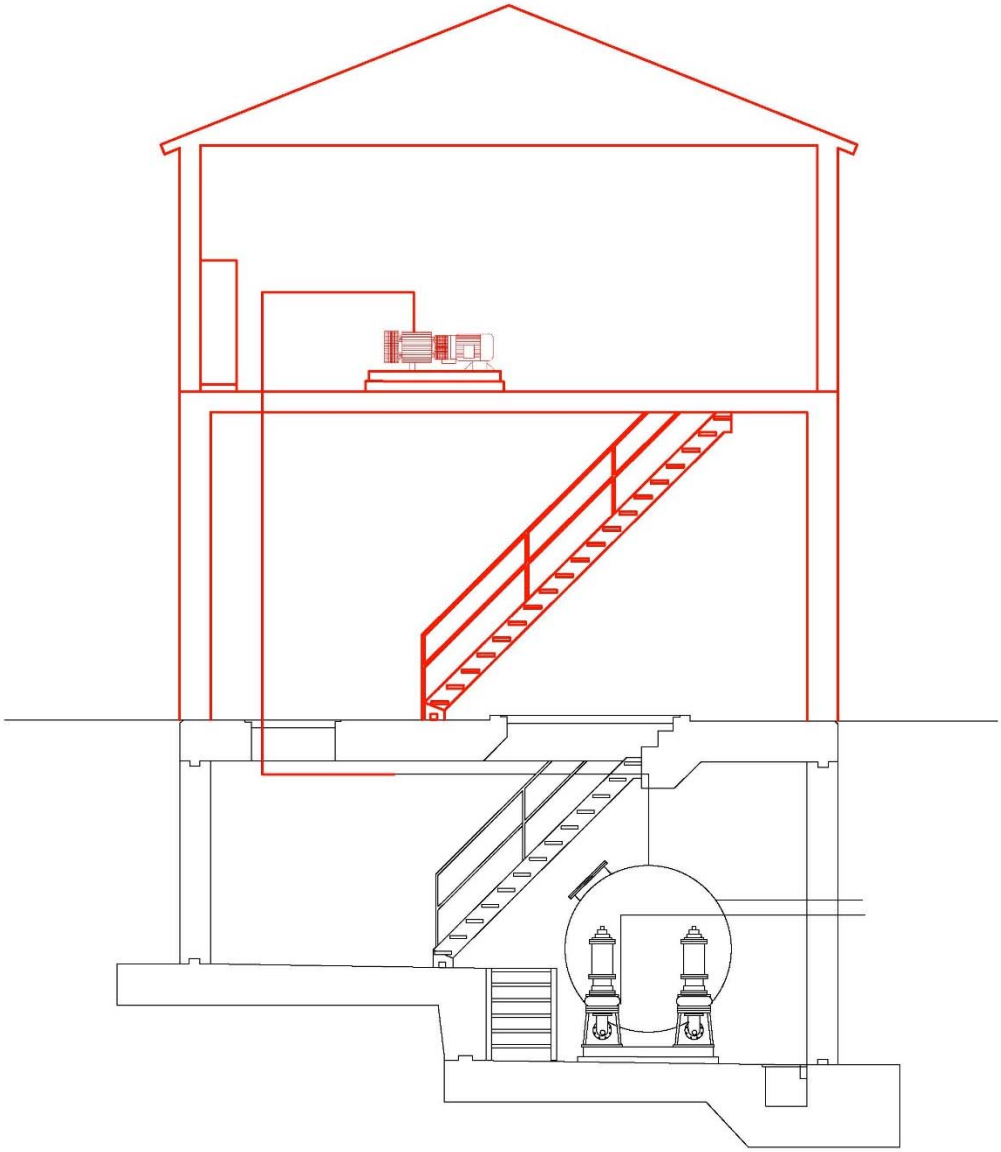


Figure 7.1 Alternative 2 Proposed Pump Station Section

The third alternative considered includes the items identified in Alternative 2, but also extends the existing structure walls of the pump station from existing grade up above the base flood elevation, so that the entire pump station can be adequately protected from storm surge and flooding. While this alternative provides the greatest measure of protection it also provides the highest proposed cost and has more difficult accessibility. Figure 7.2 below includes a general layout for the proposed improvements.

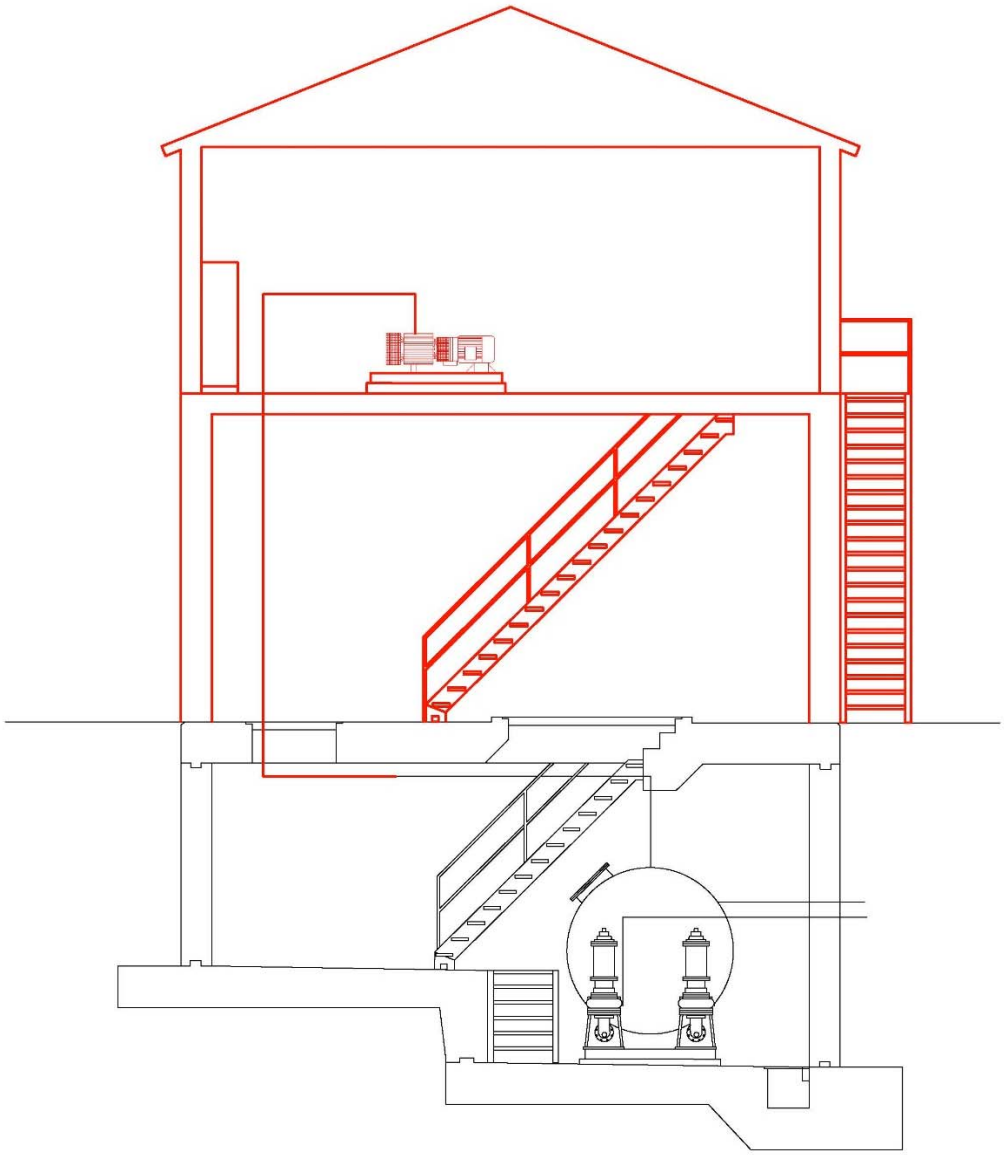


Figure 7.2 Alternative 3 Proposed Pump Station Section

7.8 PROPOSED IMPROVEMENTS

7.8.1 ALTERNATIVE 1

Alternative 1 includes replacement of several items, to eliminate existing conduits that extend under the structure slabs and eliminate (or replace as necessary) the electrical handhole. That phase of the work is targeting reducing water intrusion primarily from ground water. Further the project would include raising select items within the lower level of the structure to provide more flood

resistance. The final phase of this work will be to install components that are more water resistant that those currently in place for electrical items as possible. This alternative is targeted at improving day to day employee safety, and does not reduce flooding risks.

7.8.2 ALTERNATIVE 2

Alternative 2 includes significant modifications and additions to the existing pump station structure. The most significant addition is construction of an intermediate and upper level to the pump station structure. The intermediate level is primarily used for ingress/egress and storage. To meet all applicable codes, this level will be required to have flood venting that allows the lower level to flood during storm events.

The upper level will then be used to house the vacuum pumps, all electrical and control components, and heating/ventilation equipment. This level will be constructed at least 2-feet above the base flood elevation, and therefore provides "complete" protection of these items from flooding. The exterior of the structure would be upgraded to improve the visual appearance, for blending with the surrounding areas.

It should be noted that the current elevation of Pump Station 1 above the base flood elevation would allow the structure to be constructed without two (2) higher levels, but one (1).

Improvements to the structure will include cutting a large access hatch (and associated structural modifications) to the existing pump station top to allow removal and replacement of the vacuum collection tank in the future. Also, a larger sump pump would be installed.

Finally, SCADA monitoring will be added at each pump station to allow remote monitoring of the facilities, increase response effectiveness, and provide data trending.

7.8.3 ALTERNATIVE 3

Alternative 3 is very similar to Alternative 2, and includes significant modifications and additions to the existing pump station structure. The most significant addition is construction of an intermediate and upper level to the pump station structure. The prime difference between these two (2) alternatives is access to the structure and the intermediate level, which is only used for accessing the lower level from the upper level. This intermediate level

would be an extension of the structure with solid concrete walls constructed "water-tight" extending up 2-feet above the base flood elevation. Similar to Oak Island, this construction would, to the maximum extent practical, make the pump station flood proof.

The upper level will then be used to house the vacuum pumps, all electrical and control components, and heating/ventilation equipment. This level will be constructed at least 2-feet above the base flood elevation, and therefore provides "complete" protection of these items from flooding. The exterior of the structure would be upgraded to improve the visual appearance, for blending with the surrounding areas. Access stairs would be constructed on the outside to allow ingress/egress to the upper level, and internal stairs will be installed for ingress/egress to the lower level.

Improvements to the structure will include cutting a large access hatch (and associated structural modifications) to the existing pump station top to allow removal and replacement of the vacuum collection tank in the future.

Again, SCADA monitoring will be added at each pump station to allow remote monitoring of the facilities, increase response effectiveness, and provide data trending.

7.8.4 VALVE PITS

Relocation and/or raising of the valve pit vents located along the island comes with significant costs, due to the numerous installations. The costs are estimated based on either piping the vent from the current location, to one of the structures served and connecting it to the residence for support, or extending the vent pipe at the current location, with a wind resistant support. The estimated cost per installation is approximately $1,000, which when applied to over 1,500 locations, comes to a total of at least $1,500,000.

7.8.5 GIS MAPPING

Completion of the sewer system GIS mapping is a worthy endeavor for the Town, and carries significant long-term benefits. We estimate that to complete this effort could be accomplished for approximately $60,000.

7.9 OPINIONS OF PROBABLE COST

Based on the alternatives outlined above, preliminary opinions of probable costs have been developed at a planning level for comparison purposes. For these items a

summary of the order of magnitude costs are listed below in Table 7.1. Refer to the appendices for individual detailed cost estimates.

Table 7.1 Preliminary Opinion of Probable Costs – Alternatives 1, 2 and 3

Pump Station	Alternative 1	Alternative 2	Alternative 3
1	$100,000	$1,611,500	$1,679,400
2	$75,000	$1,378,900	$1,475,600
3	$75,000	$1,378,900	$1,475,600
4	$80,000	$1,413,000	$1,509,400
Total	$330,000	$5,782,300	$6,140,000

8.0 CRITICAL ASSET RANKING

In this type of facility evaluation it is important to consider the criticality of the assets and components that comprise the sewer system. Consequently, McGill has reviewed the facilities, and listed key components, as outlined earlier in this report. From that listing, the criticality of each asset is developed based on a scoring matrix, utilizing key criteria.

8.1 SCORING MATRIX

To analyze the componence and assets within the Holden Beach sewer system McGill Associates developed a list of five criteria to rank the importance of assets and potential for system vulnerability. Those items include; employee safety, system operation, environmental impact, component availability and ease of repair.

Always a top priority is considerations of safety to employees and staff working on the system. For this factor, we will consider the risk to employees for working on items that may be dangerous and/or items that provide a risk to injuring employees including electric shock.

System operations are of utmost importance in maintaining the functionality of the sewer system. Consequently, many components, as outlined earlier, are vital to operation of the system. Some components have installed backups, others are needed for automatic system operation, while others are vital for the system to function.

As with any sewer system, protection of the environment and any risk for sanitary sewer overflows or backups are a concern. While this item is closely related to system operation (from overflow stand point) the risk is also related to spills of chemicals and lubricants.

Many components within the system do not have installed backups and are not readily available from a manufacturer. Items that are difficult to obtain, have long lead items, and/or are specialty items, carry a higher weight within this category of the scoring matrix.

The final element analyzed within our scoring matrix for the Holden Beach sewer system is ease of repair. This item is a combination of functions; including whether the Town staff can make a repair or replacement, or whether a contractor must be called in to address the issue. Further consideration is given to items of a complex nature that are very time consuming in their troubleshooting and replacement.

8.2 ASSET RANKING

Based on the scoring criteria above, scores of 1 – 10 have been assigned to each asset identified, for the five (5) categories. Table 8.2 below includes a list of those items that scored 30 or higher in this evaluation. Refer to the appendices for a complete asset scoring list.

Table 8.2 Critical Asset Rankings

ID#	PS#	Asset	Priority Score
1-M-001	1	Vertical, Dry-pit Submersible Sewage Pump (2)	31
1-E-003	1	Sewage Pump Motor (2)	37
1-2-3-4-E-023	1	100 Amp,Panelboard, NEMA 4X SST	37
1-E-021	1	100 Amp 480 VAC Safety Switch, NEMA4 SST	33
1-E-014	1	Manual Transfer Switch, NEMA 4X SST	36
1-2-3-4-E-010	1	Transformer	37
1-C-009	1	Lift Station Control Panel	42
1-E-008	1	Vacuum Control Panel	46
1-2-3-4-M-001	1	Vacuum Pump, 450 CFM, Model RC-0630	34
2-E-009	2	Vacuum Control Panel	46
1-2-3-4-M-001	2	Vacuum Pump, 450 CFM, Model RC-0630	32
2-M-001	2	Vertical, Dry-pit Submersible Sewage Pump (2)	31
1-2-3-4-E-010	2	Transformer	37
1-2-3-4-E-023	2	100 Amp, Panelboard, NEMA 4X SST	36
2-3-E-022	2	Manual Transfer Switch, NEMA 4X SST	36
1-2-3-4-E-025	2	400 Amp Panelboard, NEMA 4X SST	37
2-3-E-026	2	400 Amp main Enclosed Circuit Breaker	30
3-E-010	3	Vacuum Control Panel	46
2-3-E-026	3	400 Amp main Enclosed Circuit Breaker	32
1-2-3-4-E-025	3	400 Amp Panelboard, NEMA 4X SST	30
1-2-3-4-E-023	3	100 Amp, Panelboard, NEMA 4X SST	36
2-3-E-022	3	Manual Transfer Switch, NEMA 4X SST	30
1-2-3-4-E-010	3	Transformer	37
1-2-3-4-M-001	3	Vacuum Pump, 450 CFM, Model RC-0630	36
4-E-011	4	Vacuum Control Panel	46

ID#	PS#	Asset	Priority Score
4-E-028	4	200 Amp 480 VAC Safety Switch, NEMA4 SST	34
1-2-3-4-E-025	4	400 Amp Panelboard, NEMA 4X SST	36
1-2-3-4-E-023	4	100 Amp, Panelboard, NEMA 4X SST	36
1-2-3-4-E-010	4	Transformer	37
4-C-009	4	Lift Station Control Panel	42
1-2-3-4-M-001	4	Vacuum Pump, 450 CFM, Model RC-0630	38
4-M-001	4	Vertical, Dry-pit Submersible Sewage Pump (2)	31
4-E-003	4	Sewage Pump Motor	37

9.0 RECOMMENDATIONS AND CONCLUSIONS

Through the course of this evaluation McGill Associates has studied a number of factors related to operations and maintenance of the Holden Beach sewer system. During our evaluation, we focused on risks stemming from items that would affect the systems functionality and areas where the system is vulnerable to failure. Given the location of Holden Beach as a barrier island on the coast and therefore suspect to major storms and hurricane events, flooding has been a primary concern, however a number of other factors can affect the systems functionality and can impact employee safety.

While we have identified a number of items that can be accomplished, modified or constructed that would improve the reliability and operations of the Holden Beach sewer system, several of those are reasonably insignificant with respect to their benefit during catastrophic failure. One such item would be GIS mapping of the sewer system. While most municipal utility systems have developed varying levels of utility mapping within their geographical information system, the Holden Beach system mapping remains incomplete. While completion of the mapping does not reduce the risk to catastrophic failure it would be an invaluable tool to current and future maintenance staff in their efforts to troubleshoot problems within the vacuum sewer system, and complete utility locates for those excavating in the areas of the sewers.

Most items identified in this report to reduce risk for system damage, failure and vulnerability in this report are capital intensive. Providing flood protection measures to the Town's four (4) pumping stations is the primary item. While this report outlines three (3) alternatives for improving the pump station's reliability, Alternative 1 only provides minimal protection during less intense storm events, not major flooding. Further, should Alternative 1 be chosen, it would not resolve the requirement to ultimately perform the upgrades outlined in the other alternatives in the future. This fact stems from NEC code requirements that must be adhered to as part of any major replacement.

The other alternatives truly address the Town's concerns regarding system risk and vulnerability. Alternatives 2 and 3 would also transform the Holden Beach pump stations to construction similar to neighboring Sunset Beach or Oak Island, respectively. Each of these two (2) alternatives carry a relatively similar cost, with less than 7% difference in overall expense. They do each carry different advantages and disadvantages. While slightly less flood resistant than Alternative 3, Alternative 2 has several advantages that come in to consideration on a daily basis. These include ease of access for staff to perform maintenance and opportunity for removal and replacement of the vacuum collection tank in the future. The ease of access for staff results in a much more direct entry (for upper or lower levels) on foot, with tools, and with

equipment. Given these factors, McGill Associates recommends that the Town thoroughly investigate moving forward with Alternative 2 as a measure to protect the Town's investment in infrastructure, and secure the residents and visitors utility service for the future. Implementation of these improvements can be phased, one pump station at a time, beginning with the most vulnerable, to soften the impact on the enterprise fund. Should no alternative be chosen, we recommend that the Town pursue a central SCADA system to provide remote monitoring of the sewer pump stations. While capacity evaluations are not a part of this study, staff reports of vacuum pumps needed at Pump Station 1 during peak flow periods, prompt McGill to recommend that the addition of another vacuum pump be considered upon alternative implementation.

At this juncture, improvements to individual valve pits is effectively limited to changing the vent pipe locations/elevations on numerous systems. It is hard to justify the extreme cost for a wholesale change of the vent pipes, with limited benefit. We recommend that the Town move forward with an approach to eventually raise all vents that begins with 1) all new construction includes vents above the base flood elevation, and 2) all remodeling/upgrades to structures include raising vents above the base flood elevation. While the system remains vulnerable for this threat until all vents are raised, when waters are predicted to reach these heights, mandatory evacuations will be in place and the vacuum system will be disengaged, reducing risks. We do recommend that the Town continue to investigate potentials for a communication system that would notify staff of open valves, and provide trending and system monitoring data to better equip staff for system maintenance.

Finally, McGill recommends that the Town consider some purchase arrangement for a portable vacuum system that could be put in place should one of the systems become disabled for any reason; failure or maintenance.

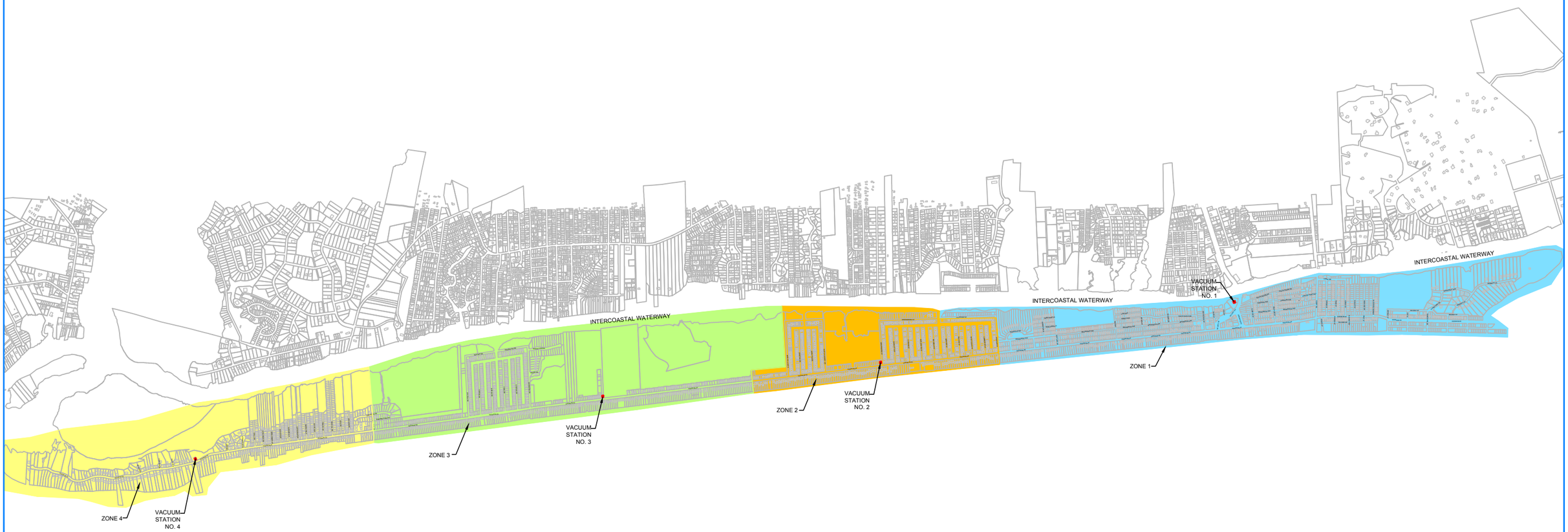
APPENDIX A

Sewer Collection System Service Area Map

SEWER COLLECTION SYSTEM
ZONE MAP

TOWN OF HOLDEN BEACH

BRUNSWICK COUNTY, NORTH CAROLINA



McGill ASSOCIATES
ENGINEERING · PLANNING · FINANCE
1240 19th STREET, LANE NW HICKORY, NC 28601 PH. (828) 328-2024 FIRM LICENSE # C-0459

APPENDIX B

Pump Station Component Inventory

ID #	Component Name	Details	Equipment	Qty	Failure Mode	Availability	Supplier	Contact	Stock
1-M-001	Vertical, Dry-pit Submersible Sewage Pump	744 GPM, 50.8' TDH, 20 HP, 1200 RPM, 480V motor; pump needs to be rotated every 4-6 months; Yeomans	Sewage Pump Skid	2	Repair	10-12 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-E-003	Sewage Pump Motor	20 HP, 1200 RPM, 480V motor; needs to be rotated every 4-6 months	Sewage Pump Skid	2	Repair	10-12 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-E-005	Solenoid Valve	at sewage pump, 5 year shelf-life	Sewage Pump Skid	2	Replace	1-2 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
2-M-001	Vertical, Dry-pit Submersible Sewage Pump	251 GPM, 599' TDH, 30 HP, 1200 RPM, 480V motor; pump needs to be rotated every 4-6 months; Yeomans	Sewage Pump Skid	2	Repair	10-12 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
2-E-003	Sewage Pump Motor	30 HP, 1200 RPM, 480V motor; needs to be rotated every 4-6 months	Sewage Pump Skid	2	Repair	10-12 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
2-E-005	Solenoid Valve	at sewage pump, 5 year shelf-life	Sewage Pump Skid	2	Replace	1-2 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
3-M-001	Vertical, Dry-pit Submersible Sewage Pump	340 GPM, 64.3' TDH, 20 HP, 1800 RPM, 480V motor; pump needs to be rotated every 4-6 months; Yeomans	Sewage Pump Skid	2	Repair	10-12 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
3-E-003	Sewage Pump Motor	20 HP, 1800 RPM, 480V motor; needs to be rotated every 4-6 months	Sewage Pump Skid	2	Repair	10-12 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
3-E-005	Solenoid Valve	at sewage pump, 5 year shelf-life	Sewage Pump Skid	2	Replace	1-2 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
4-M-001	Vertical, Dry-pit Submersible Sewage Pump	321 GPM, 32.3' TDH, 10 HP, 1200 RPM, 480V motor; pump needs to be rotated every 4-6 months; Yeomans	Sewage Pump Skid	2	Repair	10-12 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
4-E-003	Sewage Pump Motor	10 HP, 1200 RPM, 480V motor; needs to be rotated every 4-6 months	Sewage Pump Skid	2	Repair	10-12 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
4-E-005	Solenoid Valve	at sewage pump, 5 year shelf-life	Sewage Pump Skid	2	Replace	1-2 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-2-3-4-P-001	8" Pneumatic Actuated Butterfly Valve	factory installed actuator, 5 year shelf-life	Collection Tank Skid	4	Repair	1-2 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-2-3-4-P-002	Solenoid Valve	at actuator/valve, 5 year shelf-life	Collection Tank Skid	4	Replace	1-2 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-2-3-4-P-003	Air Compressor	for actuator/valve, 1 year; not unique and can be replaced with any market compressor	Collection Tank Skid	4	Replace	1-2 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-2-3-4-I-001	Level Sensing Probes	SST probes with probe holders, 30 years shelf-life; conductance probes, could be dried off and reused	Collection Tank Skid	36	Repair	1-2 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-2-3-4-C-001	Vacuum Gauge	4.5" Dia, 0-30" HG, from AIRVAC, 30 years shelf-life	Collection Tank Skid	14	Replace	1-2 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-2-3-4-M-001	Vacuum Pump, 450 CFM, Model RC-0630	Busch, Model RC-0630, 450 scfm, 25 HP motor; pump needs to be rotated every 4-6 months	Vacuum Pump Skid	10	Repair	3-4 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-2-3-4-E-007	Crankcase Heater	keep vac. pump oil hot; 10 year shelf-life	Vacuum Pump Skid	10	Replace	6 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-E-008	Vacuum Control Panel	NEMA 12 enclosure, 480V/True 3Ph/60 Hz; 250 amp main disconnect, relay Logic, (4) 25HP soft starters for vacuum pumps, (2) 20HP cross the line sewage pumps, 16 channel telephone alarm dialer, chart recorder; 1 year shelf life	Control Panel	1	Replace	6-8 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
2-E-009	Vacuum Control Panel	NEMA 12 enclosure, 480V/True 3Ph/60 Hz; 175 amp main disconnect, relay Logic, (2) 25HP cross the line starters for vacuum pumps, (2) 30HP soft starters sewage pumps, 16 channel telephone alarm dialer, chart recorder; 1 year shelf life	Control Panel	1	Replace	6-8 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
3-E-010	Vacuum Control Panel	NEMA 12 enclosure, 480V/True 3Ph/60 Hz; 150 amp main disconnect, relay Logic, (2) 25HP cross the line starters for vacuum pumps, (2) 20HP cross the line starters sewage pumps, 16 channel telephone alarm dialer, chart recorder; 1 year shelf life	Control Panel	1	Replace	6-8 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
4-E-011	Vacuum Control Panel	NEMA 12 enclosure, 480V/True 3Ph/60 Hz; 125 amp main disconnect, relay Logic, (2) 25HP cross the line starters for vacuum pumps, (2) 10HP cross the line starters sewage pumps, 16 channel telephone alarm dialer, chart recorder; 1 year shelf life	Control Panel	1	Replace	6-8 weeks	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	No
1-2-3-4-C-002	2" Vacuum Valve	for sump evacuation; 10 year shelf-life; controller will need to be rebuilt	Vac. Station Sump	4	Repair	Stock	AIRVAC	Ron White, Aqseptance Group, Inc, ron.white@aqseptence.com, 574-208-5861	Stock
1-2-3-4-C-005	Belimo Actuator and control rod	Belimo		8	Replace	1 week	Supply House	Online Ordering: www.supplyhouse.com	Stock
1-2-3-4-M-007	Unit heaters			8	Replace	2-Weeks	Chromolox	Online Ordering: www.grainger.com	No
1-2-3-4-E-006	60 Amp, 277 Vac 1 Pole NF HD Safety switch Nema 4 Stainless	Siemens Brand or Square D Brand		8	Replace	2-Weeks	Grainger	Online Ordering: www.grainger.com	No
1-2-3-4-E-008	Junction Box			28	Replace	1-WEEK	Grainger	Online Ordering: www.grainger.com	Stock
1-2-3-4-M-009	Exhaust Fan			4	Replace	2-Weeks	Grainger	Online Ordering: www.grainger.com	No
1-2-3-4-E-010	Transformer	25kva 480V-120/240V, 1PH		4	Replace	5-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
1-C-009	Lift Station Control Panel	Duplex 47HP Pumps	Control Panel	1	Replace	4-Weeks	RSI	Ron Sigmon, RS Integrators, Inc, ron.sigmon@rsintegrators.com, 704-588-8288	No, Custom
4-C-009	Lift Station Control Panel	Duplex 12HP Pumps	Control Panel	1	Replace	4-Weeks	RSI	Ron Sigmon, RS Integrators, Inc, ron.sigmon@rsintegrators.com, 704-588-8288	No, Custom
1-2-3-4-E-013	200 Amp Generator Quick Connect			4	Replace	2-Weeks	APPLETON	Lance Shaw, Eaton, lanceshaw@eaton.com, 828-651-0572	No
1-E-014	600 Amp 277/480 VAC Manual Transfer Switch, NEMA 4X SST		Panelboard	1	Replace	2-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
1-4-E-015	600 Amp main Enclose Circuit Breaker		Panelboard	2	Replace	2-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
1-2-3-4-E-016	Switch for HVAC-Disc			4	Replace	2-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
1-3-4-M-009	Telephone Interface Box			3	Replace	1 week	Grainger	Online Ordering: www.grainger.com	No
1-E-021	100 Amp 480 VAC 3 Pole NF Safety Switch, NEMA4 SST		Panelboard	2	Replace	2-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
2-3-E-022	400 Amp 277/480 VAC Manual Transfer Switch, NEMA 4X SST		Panelboard	2	Replace	2-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
1-2-3-4-E-023	100 Amp, with 100A/2 MCB 120/230 VAC 3W,**Panelboard**, NEMA 4X SST		Panelboard	4	Replace	6-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
2-3-4-E-024	EF-1 Fan NEMA Size 1 Combination Starter/Disconnect NEMA 4 SST		Panelboard	3	Replace	2-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
2-3-4-E-025	400 Amp 277/480 VAC MLO **Panelboard**, NEMA 4X SST		Panelboard	3	Replace	6-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
2-3-E-026	400 Amp main Enclosed Circuit Breaker		Panelboard	2	Replace	2-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
4-E-028	200 Amp 480 VAC 3 Pole NF Safety Switch, NEMA4 SST		Panelboard	2	Replace	2-Weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No
1-E-029	600 Amp, 480Y/277V 3Ph **Panelboard**		Panelboard	1	Replace	6-weeks	EATON	Nick Fowler, Rexel Inc, nickey.fowler@RexelUSA.com, 828-328-2646	No

APPENDIX C

Preliminary Cost Estimates

PRELIMINARY OPINION OF PROBABLE COST
ALTERNATIVE 2 - PUMP STATION IMPROVEMENTS - PUMP STATION 1
HOLDEN BEACH, NORTH CAROLINA
April 2017

ITEM	DESCRIPTION	QUAN.	UNIT	UNIT PRICE	TOTAL
1	Mobilization (3.0%)	1	LS	3%	$ 35,000
2	Ground Level Structure Addition - Floor	40	CY	$ 1,000	$ 40,000
3	Ground Level Structure Addition - Walls	2,000	SF	$ 100	$ 200,000
4	Ground Level Structure Addition - Roof	2,000	SF	$ 50	$ 100,000
5	Structural Modification to Existing	1	LS	$ 80,000	$ 80,000
6	New Vacuum Pump Skid	1	LS	$ 220,000	$ 220,000
7	Piping Improvements	1	LS	$ 50,000	$ 50,000
8	System Controls	1	LS	$ 50,000	$ 50,000
9	Demolition	1	LS	$ 50,000	$ 50,000
10	Electrical Replacement	1	LS	$ 140,000	$ 140,000
11	SCADA	1	LS	$ 50,000	$ 50,000
12	Façade	1	LS	$ 100,000	$ 100,000
13	Site Improvements	1	LS	$ 60,000	$ 60,000
14	Miscellaneous	1	LS	$ 25,000	$ 25,000
	CONSTRUCTION SUBTOTAL				**$ 1,200,000**
	CONTINGENCY (15%)				$ 180,000
	ENGINEERING DESIGN AND PERMITTING				$ 108,000
	BID AND AWARD				$ 7,500
	CONSTRUCTION OBSERVATION & ADMINISTRATION				$ 96,000
	LEGAL/ADMINISTRATIVE/EASEMENTS				$ 20,000
	TOTAL PROJECT				**$ 1,611,500**

Notes:

1. All costs shown are in current dollars.

2. The Engineer maintains no control of labor costs, materials, equipment or services furnished by others, the Contractor(s)' methods for determining prices, or competitive or market conditions. The opinions herein for project and construction costs represent the Engineer's best judgment, and are based on experience and qualifications as a Professional Engineer who possesses familiarity with the construction industry. The Engineer does not guarantee the accuracy of the cost opinions which may vary from bids or actual project and construction costs.

PRELIMINARY OPINION OF PROBABLE COST
ALTERNATIVE 2 - PUMP STATION IMPROVEMENTS - PUMP STATION 2 or 3
HOLDEN BEACH, NORTH CAROLINA
April 2017

ITEM	DESCRIPTION	QUAN.	UNIT	UNIT PRICE	TOTAL
1	Mobilization (3.0%)	1	LS	3%	$ 29,800
2	Ground Level Structure Addition - Walls	68	CY	$ 1,500	$ 102,000
3	Upper Level Structure Addition - Floor	39	CY	$ 2,500	$ 97,500
4	Upper Level Structure Addition - Walls	930	SF	$ 100	$ 93,000
5	Upper Level Structure Addition - Roof	930	SF	$ 50	$ 46,500
6	Structural Modification to Existing	1	LS	$ 70,000	$ 70,000
7	New Vacuum Pump Skid	1	LS	$ 120,000	$ 120,000
8	Piping Improvements	1	LS	$ 40,000	$ 40,000
9	System Controls	1	LS	$ 40,000	$ 40,000
10	Demolition	1	LS	$ 50,000	$ 50,000
11	Electrical Replacement	1	LS	$ 110,000	$ 110,000
12	SCADA	1	LS	$ 50,000	$ 50,000
13	Façade	1	LS	$ 100,000	$ 100,000
14	Site Improvements	1	LS	$ 50,000	$ 50,000
15	Miscellaneous	1	LS	$ 25,000	$ 25,000
	CONSTRUCTION SUBTOTAL				**$ 1,023,800**
	CONTINGENCY (15%)				$ 153,600
	ENGINEERING DESIGN AND PERMITTING				$ 92,100
	BID AND AWARD				$ 7,500
	CONSTRUCTION OBSERVATION & ADMINISTRATION				$ 81,900
	LEGAL/ADMINISTRATIVE/EASEMENTS				$ 20,000
	TOTAL PROJECT				**$ 1,378,900**

Notes:

1. All costs shown are in current dollars.

2. The Engineer maintains no control of labor costs, materials, equipment or services furnished by others, the Contractor(s)' methods for determining prices, or competitive or market conditions. The opinions herein for project and construction costs represent the Engineer's best judgment, and are based on experience and qualifications as a Professional Engineer who possesses familiarity with the construction industry. The Engineer does not guarantee the accuracy of the cost opinions which may vary from bids or actual project and construction costs.

PRELIMINARY OPINION OF PROBABLE COST
ALTERNATIVE 2 - PUMP STATION IMPROVEMENTS - PUMP STATION 4
HOLDEN BEACH, NORTH CAROLINA
April 2017

ITEM	DESCRIPTION	QUAN.	UNIT	UNIT PRICE	TOTAL
1	Mobilization (3.0%)	1	LS	3%	$ 30,600
2	Ground Level Structure Addition - Walls	68	CY	$ 1,500	$ 102,000
3	Upper Level Structure Addition - Floor	39	CY	$ 2,500	$ 97,500
4	Upper Level Structure Addition - Walls	930	SF	$ 100	$ 93,000
5	Upper Level Structure Addition - Roof	930	SF	$ 50	$ 46,500
6	Structural Modification to Existing	1	LS	$ 70,000	$ 70,000
7	New Vacuum Pump Skid	1	LS	$ 120,000	$ 120,000
8	Piping Improvements	1	LS	$ 45,000	$ 45,000
9	System Controls	1	LS	$ 50,000	$ 50,000
10	Demolition	1	LS	$ 50,000	$ 50,000
11	Electrical Replacement	1	LS	$ 120,000	$ 120,000
12	SCADA	1	LS	$ 50,000	$ 50,000
13	Façade	1	LS	$ 100,000	$ 100,000
14	Site Improvements	1	LS	$ 50,000	$ 50,000
15	Miscellaneous	1	LS	$ 25,000	$ 25,000
	CONSTRUCTION SUBTOTAL				**$ 1,049,600**
	CONTINGENCY (15%)				$ 157,400
	ENGINEERING DESIGN AND PERMITTING				$ 94,500
	BID AND AWARD				$ 7,500
	CONSTRUCTION OBSERVATION & ADMINISTRATION				$ 84,000
	LEGAL/ADMINISTRATIVE/EASEMENTS				$ 20,000
	TOTAL PROJECT				**$ 1,413,000**

Notes:

1. All costs shown are in current dollars.

2. The Engineer maintains no control of labor costs, materials, equipment or services furnished by others, the Contractor(s)' methods for determining prices, or competitive or market conditions. The opinions herein for project and construction costs represent the Engineer's best judgment, and are based on experience and qualifications as a Professional Engineer who possesses familiarity with the construction industry. The Engineer does not guarantee the accuracy of the cost opinions which may vary from bids or actual project and construction costs.

PRELIMINARY OPINION OF PROBABLE COST
ALTERNATIVE 3 - PUMP STATION IMPROVEMENTS - PUMP STATION 1
HOLDEN BEACH, NORTH CAROLINA
April 2017

ITEM	DESCRIPTION	QUAN.	UNIT	UNIT PRICE	TOTAL
1	Mobilization (3.0%)	1	LS	3%	$ 36,500
2	Ground Level Structure Addition - Floor	40	CY	$ 1,000	$ 40,000
3	Ground Level Structure Addition - Walls	2,000	SF	$ 100	$ 200,000
4	Ground Level Structure Addition - Roof	2,000	SF	$ 50	$ 100,000
5	Structural Modification to Existing	1	LS	$ 80,000	$ 80,000
6	New Vacuum Pump Skid	1	LS	$ 220,000	$ 220,000
7	Piping Improvements	1	LS	$ 50,000	$ 50,000
8	System Controls	1	LS	$ 50,000	$ 50,000
10	Demolition	1	LS	$ 50,000	$ 50,000
10	Electrical Replacement	1	LS	$ 140,000	$ 140,000
11	SCADA	1	LS	$ 50,000	$ 50,000
12	Façade	1	LS	$ 100,000	$ 100,000
13	Site Improvements	1	LS	$ 60,000	$ 60,000
14	Miscellaneous	1	LS	$ 75,000	$ 75,000
	CONSTRUCTION SUBTOTAL				**$ 1,251,500**
	CONTINGENCY (15%)				$ 187,700
	ENGINEERING DESIGN AND PERMITTING				$ 112,600
	BID AND AWARD				$ 7,500
	CONSTRUCTION OBSERVATION & ADMINISTRATION				$ 100,100
	LEGAL/ADMINISTRATIVE/EASEMENTS				$ 20,000
	TOTAL PROJECT				**$ 1,679,400**

Notes:

1. All costs shown are in current dollars.

2. The Engineer maintains no control of labor costs, materials, equipment or services furnished by others, the Contractor(s)' methods for determining prices, or competitive or market conditions. The opinions herein for project and construction costs represent the Engineer's best judgment, and are based on experience and qualifications as a Professional Engineer who possesses familiarity with the construction industry. The Engineer does not guarantee the accuracy of the cost opinions which may vary from bids or actual project and construction costs.

PRELIMINARY OPINION OF PROBABLE COST
ALTERNATIVE 3 - PUMP STATION IMPROVEMENTS - PUMP STATION 2 or 3
HOLDEN BEACH, NORTH CAROLINA
April 2017

ITEM	DESCRIPTION	QUAN.	UNIT	UNIT PRICE	TOTAL
1	Mobilization (3.0%)	1	LS	3%	$ 32,000
2	Ground Level Structure Addition - Walls	82	CY	$ 1,500	$ 123,000
3	Upper Level Structure Addition - Floor	39	CY	$ 2,500	$ 97,500
4	Upper Level Structure Addition - Walls	930	SF	$ 100	$ 93,000
5	Upper Level Structure Addition - Roof	930	SF	$ 50	$ 46,500
6	Structural Modification to Existing	1	LS	$ 70,000	$ 70,000
7	New Vacuum Pump Skid	1	LS	$ 120,000	$ 120,000
8	Piping Improvements	1	LS	$ 40,000	$ 40,000
9	System Controls	1	LS	$ 40,000	$ 40,000
10	Demolition	1	LS	$ 50,000	$ 50,000
11	Electrical Replacement	1	LS	$ 110,000	$ 110,000
12	SCADA	1	LS	$ 50,000	$ 50,000
13	Façade	1	LS	$ 100,000	$ 100,000
14	Site Improvements	1	LS	$ 50,000	$ 50,000
15	Miscellaneous	1	LS	$ 75,000	$ 75,000
	CONSTRUCTION SUBTOTAL				**$ 1,097,000**
	CONTINGENCY (15%)				$ 164,600
	ENGINEERING DESIGN AND PERMITTING				$ 98,700
	BID AND AWARD				$ 7,500
	CONSTRUCTION OBSERVATION & ADMINISTRATION				$ 87,800
	LEGAL/ADMINISTRATIVE/EASEMENTS				$ 20,000
	TOTAL PROJECT				**$ 1,475,600**

Notes:

1. All costs shown are in current dollars.

2. The Engineer maintains no control of labor costs, materials, equipment or services furnished by others, the Contractor(s)' methods for determining prices, or competitive or market conditions. The opinions herein for project and construction costs represent the Engineer's best judgment, and are based on experience and qualifications as a Professional Engineer who possesses familiarity with the construction industry. The Engineer does not guarantee the accuracy of the cost opinions which may vary from bids or actual project and construction costs.

PRELIMINARY OPINION OF PROBABLE COST
ALTERNATIVE 3 - PUMP STATION IMPROVEMENTS - PUMP STATION 4
HOLDEN BEACH, NORTH CAROLINA
April 2017

ITEM	DESCRIPTION	QUAN.	UNIT	UNIT PRICE	TOTAL
1	Mobilization (3.0%)	1	LS	3%	$ 32,700
2	Ground Level Structure Addition - Walls	82	CY	$ 1,500	$ 123,000
3	Upper Level Structure Addition - Floor	39	CY	$ 2,500	$ 97,500
4	Upper Level Structure Addition - Walls	930	SF	$ 100	$ 93,000
5	Upper Level Structure Addition - Roof	930	SF	$ 50	$ 46,500
6	Structural Modification to Existing	1	LS	$ 70,000	$ 70,000
7	New Vacuum Pump Skid	1	LS	$ 120,000	$ 120,000
8	Piping Improvements	1	LS	$ 45,000	$ 45,000
9	System Controls	1	LS	$ 50,000	$ 50,000
10	Demolition	1	LS	$ 50,000	$ 50,000
11	Electrical Replacement	1	LS	$ 120,000	$ 120,000
12	SCADA	1	LS	$ 50,000	$ 50,000
13	Façade	1	LS	$ 100,000	$ 100,000
14	Site Improvements	1	LS	$ 50,000	$ 50,000
15	Miscellaneous	1	LS	$ 75,000	$ 75,000
	CONSTRUCTION SUBTOTAL				**$ 1,122,700**
	CONTINGENCY (15%)				$ 168,400
	ENGINEERING DESIGN AND PERMITTING				$ 101,000
	BID AND AWARD				$ 7,500
	CONSTRUCTION OBSERVATION & ADMINISTRATION				$ 89,800
	LEGAL/ADMINISTRATIVE/EASEMENTS				$ 20,000
	TOTAL PROJECT				**$ 1,509,400**

Notes:

1. All costs shown are in current dollars.

2. The Engineer maintains no control of labor costs, materials, equipment or services furnished by others, the Contractor(s)' methods for determining prices, or competitive or market conditions. The opinions herein for project and construction costs represent the Engineer's best judgment, and are based on experience and qualifications as a Professional Engineer who possesses familiarity with the construction industry. The Engineer does not guarantee the accuracy of the cost opinions which may vary from bids or actual project and construction costs.

APPENDIX D

Critical Asset Ranking

Asset List for Physical

	Prioritization					
Asset	Employee Safety	System Operation	Environment	Availability	Ease of Repair/ Replacement	Priority Level Total
Physical						
-Wastewater						
--Collection						
Vacuum/Pump Station No. 1						
----Vertical, Dry-pit Submersible Sewage Pump (2)	1	7	7	10	6	31
-----Sewage Pump Motor (2)	1	10	10	10	6	37
-----Solenoid Valve (2)	1	10	10	2	1	24
----Mechanical						
-----Exhaust Fan (1)	8	4	1	2	2	17
-----Unit Heaters (2)	1	4	1	2	2	10
----Electrical						
-----Exhaust Fan NEMA Size 1 Combination Starter/Disconnect NEMA 4 SST (1)	7	4	4	2	2	19
-----100 Amp, with 100A/2 MCB 120/230 VAC 3W,Panelboard, NEMA 4X SST (1)	7	10	10	5	5	37
-----100 Amp 480 VAC 3 Pole NF Safety Switch, NEMA4 SST (1)	7	10	10	2	4	33
-----Disc. Switch for Unit Heaters (2)	7	4	4	2	4	21
-----600 Amp Main Enclosed Circuit Breaker, NEMA 4XSS (1)	7	7	7	2	5	28
-----600 Amp 277/480 VAC Manual Transfer Switch, NEMA 4X SST (10	7	10	10	2	7	36
-----200 Amp Generator Quick Connect (1)	7	8	8	2	4	29
-----Dry Type Transformer (1)	7	10	10	5	5	37
----Submersible Pump Station Control Panel (1)	9	10	10	4	9	42
----2" Vacuum Valve	1	3	3	2	4	13
----Vacuum Control Panel	9	10	10	8	9	46
-----Vacuum Pump (4)	1	10	10	4	9	34
-----Crankcase Heater	1	5	3	2	2	13
----8" Pneumatic Actuated Butterfly Valve (4)	1	10	10	2	3	26
-----Air Compressor	1	3	3	1	1	9
-----Solenoid Valve	1	10	10	2	1	24
----Level Sensing Probes	1	10	10	1	1	23
----Vacuum Gauge	1	3	3	1	1	9
Vacuum Station No. 2						
----Vacuum Control Panel	9	10	10	8	9	46
-----Vacuum Pump (2)	1	10	10	2	9	32
-----Crankcase Heater	1	5	3	2	2	13
----Vertical, Dry-pit Submersible Sewage Pump (2)	1	7	7	10	6	31
-----Solenoid Valve (2)	1	10	10	2	1	24
-----Sewage Pump Motor (2)	1	10	10		6	27
----Mechanical						
-----Exhaust Fan	8	4	1	2	2	17
-----Unit Heaters (2)	1	4	1	2	2	10
----Electrical						
-----Dry Type Transformer	7	10	10	5	5	37
-----Exhaust Fan NEMA Size 1 Combination Starter/Disconnect NEMA 4 SST	7	4	4	2	2	19
-----100 Amp, with 100A/2 MCB 120/230 VAC 3W,Panelboard, NEMA 4X SST	7	10	10	4	5	36
-----400 Amp 277/480 VAC Manual Transfer Switch, NEMA 4X SST	7	10	10	2	7	36

Asset	Employee Safety	System Operation	Environment	Availability	Ease of Repair/ Replacement	Priority Level Total
-----400 Amp 277/480 VAC MLO Panelboard, NEMA 4X SST	7	10	10	5	5	37
-----400 Amp main Enclosed Circuit Breaker	7	8	8	2	5	30
-----200 Amp Generator Quick Connect (1)	7	8	8	2	4	29
----2" Vacuum Valve	1	3	10	2	4	20
----8" Pneumatic Actuated Butterfly Valve (1)	1	10	8	2	4	25
-----Solenoid Valve (1)	1	10	10	1	1	23
-----Air Compressor (1)	1	3	3	1	4	12
----Level Sensing Probes (9)	1	10	10	1	1	23
----Vacuum Gauge	1	3	10	1	1	16
Vacuum Station No. 3						
----Vacuum Control Panel	9	10	10	8	9	46
----8" Pneumatic Actuated Butterfly Valve (1)	1	10	10	2	3	26
-----Air Compressor (1)	1	3	3	1	1	9
-----Solenoid Valve (1)	1	10	7	2	1	21
----Vertical, Dry-pit Submersible Sewage Pump (2)	1	5	7	10	6	29
-----Solenoid Valve	1	10	10	2	1	24
-----Sewage Pump Motor (2)	1	10	10			21
----Mechanical						
-----Exhaust Fan	8	4	1	2	2	17
-----Unit Heaters (2)	1	4	1	2	2	10
----Electrical						
-----400 Amp main Enclosed Circuit Breaker	7	8	10	2	5	32
-----400 Amp 277/480 VAC MLO Panelboard, NEMA 4X SST	7	10	4	4	5	30
-----Exhaust Fan NEMA Size 1 Combination Starter/Disconnect NEMA 4 SST	7	4	10	2	2	25
-----100 Amp, with 100A/2 MCB 120/230 VAC 3W,Panelboard, NEMA 4X SST	7	10	10	4	5	36
-----400 Amp 277/480 VAC Manual Transfer Switch, NEMA 4X SST	7	10	4	2	7	30
-----Disc. Switch for Unit Heaters (2)	7	4	7	2	2	22
-----200Amp Generator Quick Connect (1)	7	8	4	2	4	25
-----Dry-Type Transformer (1)	7	10	10	5	5	37
----2" Vacuum Valve (1)	1	4	10	2	4	21
----Vacuum Pump (2)	1	10	8	8	9	36
-----Crankcase Heater	1	4	4	4	8	21
----Vacuum Gauge	1	4	4	1	1	11
----Level Sensing Probes (9)	1	10	10	1	1	23
Vacuum/Pump Station No. 4						
----Vacuum Control Panel	9	10	10	8	9	46
----Mechanical						
-----Exhaust Fan	8	4	1	2	2	17
-----Unit Heaters (2)	1	4	1	2	2	10
----Electrical						
-----200 Amp 480 VAC 3 Pole NF Safety Switch, NEMA4 SST	7	10	10	2	5	34
-----Exhaust Fan NEMA Size 1 Combination Starter/Disconnect NEMA 4 SST	7	4	4	2	2	19
-----400 Amp 277/480 VAC MLO Panelboard, NEMA 4X SST	7	10	10	4	5	36
-----100 Amp, with 100A/2 MCB 120/230 VAC 3W,Panelboard, NEMA 4X SST	7	10	10	4	5	36
-----Disc Switch for Unit Heaters	7	4	7	2	2	22
-----600 Amp main Enclose Circuit Breaker	7	7	7	2	5	28
-----200 Amp Generator Quick Connect	7	10	4	2	4	27

Asset	Employee Safety	System Operation	Environment	Availability	Ease of Repair/ Replacement	Priority Level Total
-----Dry-Type Transformer (1)	7	10	10	5	5	37
----Submersible Pump Station Control Panel (1)	9	10	10	4	9	42
----2" Vacuum Valve (1)	1	4	8	1	3	17
----Vacuum Pump (2)	1	10	10	10	7	38
-----Crankcase Heater	1	5	3	2	2	13
----Vacuum Gauge	1	4	4	1	1	11
----Level Sensing Probes (9)	1	10	10	1	1	23
----8" Pneumatic Actuated Butterfly Valve (1)	1	10	10	2	3	26
-----Air Compressor (1)	1	3	3	1	1	9
-----Solenoid Valve (1)	1	7	7	1	1	17
----Vertical, Dry-pit Submersible Sewage Pump (2)	1	7	7	10	6	31
-----Solenoid Valve (2)	1	10	10	2	1	24
-----Sewage Pump Motor (2)	1	10	10	10	6	37