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Stormwater

A Practical Approach to DESIGNING Small Stormwater Pumping Stations

Compromise and careful planning solve persistent flooding problems on Virginia's Broad Bay Island.

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Flooding caused by ponding of stormwater runoff in a depressed roadway section can range from being a nuisance problem–impeding cars, trucks, or school buses–to being a major safety and liability issue for the municipality by impeding or preventing emergency vehicle passage and by hindering automotive brake performance. The solution for flat areas such as in Virginia Beach, VA, appears to be clear but expensive: use pumps to move water to the nearest outfall. Sometimes this is easier said than done.

Engineers face numerous problems in designing a stormwater pumping system. It is like trying to complete a complex jigsaw puzzle with missing pieces. The missing pieces, or design challenges, can include the following:

Inadequate Survey Information.

It is usually not practical to survey the entire watershed. Large-scale topographic maps must be used for watershed delineation and hydrologic calculations. Not all inverts of existing structures can be obtained or found in record drawings. Depth of underground utilities surveyed, such as water, gas, electric, cable, and sanitary sewer laterals, remain unknown unless further subsurface investigation is performed.

After a storm, standing water was often several feet deep, restricting access to the mainland

Limited Right of Way. This poses a major problem in selecting the optimal site for the pumping station and control panel. It is usually cost-prohibitive, time-consuming, and unpopular for the municipalities to acquire property.

Lack of Suitable Power Source. A three-phase power supply is required for most economical pumping motors. If a power source is not available, the owner must negotiate with the utility company to locate the three-phase power line close to the pumping station or use an expensive, and sometimes unreliable, power inverter.

Adequacy and Acceptability of the Outfall. Often the closest outfall is selected, but it could pose environmental or sedimentation concerns or require a new permit.

Design Storm for Pumps. A common concern is underutilization of the stormwater pumps. Engineers must use prudent judgement or use the standard design-year storm.

Lack of Geotechnical Analysis. This is the most important consideration for wet-well foundation stability but is often omitted.

Community Concerns. If not acknowledged and properly addressed early in the design process, the concerns of citizens, civic leagues, and neighborhood associations can create bottlenecks during construction. Meanwhile, by policy and practice, the municipality is obligated to try to satisfy all of them.

Experience tells us these missing pieces of information must be found before the stormwater pumping station design can be completed successfully. Once the design is completed and construction begins, unforeseen issues might surface. This article details a particularly relevant case in the Virginia Beach area that illustrates a practical approach in the design of neighborhood drainage improvements and how construction issues can be successfully addressed.

Project Background

Broad Bay Island is located at the western end of Broad Bay, in the Great Neck area of Virginia Beach near the Lynnhaven Inlet at the mouth of the Chesapeake Bay. It is bordered to the north by Long Creek. Approximately 2 mi. long and 0.25 mi. wide, the island originally formed as a natural sandbar and was connected to the Great Neck peninsula by a marsh to the south.

As the island was developed for residential and commercial use in the 1940s and '50s, the marsh was

dredged to give yacht owners a better navigable channel, and the island was built up with fill material to accommodate increased development. Eventually canals were cut through the island, giving most homes direct backyard waterway access. In 1991, *Real Estate Weekly* called Broad Bay Island "Virginia Beach's answer to Venice. Broad Bay Island is canals: serene, secluded canals that invite you to glide into the neighborhood straight up to your own back door."

While Broad Bay Island's lush aquatic setting provides residents a quiet and charming lifestyle, the island's tidal roots present numerous challenges to engineers seeking a peaceful coexistence between residents and the natural environmental forces inherent to the area.

The project site, the 2500 block of Broad Bay Road, has provided a vivid illustration of this struggle almost since modern neighborhoods began to proliferate on the island. The area was subject to frequent stormwater flooding at a sag location in the roadway. The flooding problem was further compounded and stormwater dissipation was significantly impeded by infill development in natural drainageways, low elevations (only 4 ft. above sea level at the project location), and a high groundwater table that is tidally influenced. The area acted as the sump for a 7-ac. drainage area.

Until just a few years ago, stormwater runoff naturally, albeit slowly, drained down across the lot just to the south of the area. But subsequent construction on the lot cut off the natural path of drainage. The City of Virginia Beach eventually installed three dry wells in an attempt to relieve the drainage problem, but they quickly clogged with silt before achieving any noticeable improvement. Engineers performing preliminary visits to the site observed that the area could remain flooded for as long as two days after a storm. And the standing water was often several feet deep at the low point, effectively rendering travel through the area impossible.

Even during periods of light to moderate rainfall, the area was prone to begin flooding almost immediately following the onset of a storm. As Broad Bay Road is the primary road crossing the island and linking the island's residents with the mainland to the north and south, the flooding effectively brought life on the island to a standstill and severed the island's connection to the rest of the Virginia Beach area. Of greater concern, however, was the effect of roadway flooding on the ability of emergency vehicles to reach all areas of the island. As the population of Broad Bay Island continued to grow, the problem was quickly evolving from a public nuisance to a major safety and liability issue for the city.

In Search of a Solution

The City of Virginia Beach first asked Woolpert LLP to consider the Broad Bay Road situation in 1998. During their initial field visit, engineers carefully weighed the feasibility of a variety of remedies. Immediately the topographic flatness and high groundwater conditions of Broad Bay Island began to eliminate options.

Under different circumstances, dry wells might have resulted in significant improvements. But the three dry wells installed a few years earlier never adequately relieved the flooding problem. Because of the island's high water table and other factors, water collected in the dry wells simply had nowhere to go. By 1998, they had clogged and had ceased working altogether.

Another possibility was developing a gravity drainage solution using nearby Long Creek as a stormwater outfall receiving system. Engineers quickly determined that the work needed to compensate for the island's low elevation and lack of natural slope would have resulted in a gravity drainage system with inadequate slopes and surcharged or flooding conditions because of high tide.

A pumping-based strategy quickly revealed itself as the only realistic solution to the Broad Bay Road flooding situation. Despite concerns about long-term maintenance costs and other challenges inherent to this approach, it was determined to be the most economical and effective way to resolve the area's flooding problem.

Challenges

Riprap placed at the gravity outfall pipe helped control erosion from the increased discharge.

As with any engineering and design project, the Broad Bay Road stormwater drainage improvement project came with its share of hurdles. Municipal engineering projects are not always what they seem on the surface. And although the Broad Bay Road project might be considered a relatively small project, small projects can often be among the most challenging, as there is a diminished budget contingency. From the municipality's perspective, performing an additional round of surveys on a $50,000 project stings much worse than it would on a $5 million project.

It is also worth noting that some of the most significant challenges associated with the project had little to do with geography, topography, hydrodynamics, or any other engineering consideration. Area residents took a very personal interest in many phases of this project and

remained actively involved in the process throughout its duration.

One of the key factors of success for this project, however, was maintaining open and honest communication between the engineering firm, the municipality, and the residents. Ongoing dialog helped minimize the impact of unforeseen challenges on the project. Every step of the way, the consultants and the City of Virginia Beach worked together to address challenges and formulate successful solutions.

The original design proposal called for installation of a submersible pump inside a manhole to discharge water into Broad Bay located to the south of the project site. The force main would have been laid between two residential properties along the property-line drainage easement to the Broad Bay outfall. This design was easily the most cost-effective, as it represented the shortest route from the pump station to the outfall. Unfortunately, even as city officials considered this option, one of the property owners began construction of a new fence along the property line and raised objections about locating the force main on his property. Compounding this challenge, residents of the area began voicing concerns about sedimentation problems at the proposed discharge site.

Another challenge faced by designers, engineers, and construction crews was the extraordinarily narrow right of way (ROW) along Broad Bay Road. At the project location, the ROW was only 40 ft. wide with a 26-ft.-wide road cross-section. Confining construction to such a narrow space between the road and the ROW limits presented numerous challenges as designers considered ways to accommodate a 9-ft.-diameter manhole base (in a hole 10-11 ft. in diameter) and pump control panel, in addition to the multiple existing underground utilities located in the ROW. Here again, local residents worked actively with engineers to determine acceptable locations for the various project elements. So, simply stated, when resident concerns begin to conflict with solid engineering logic, a 40-ft. space can become very cramped very quickly.

Float controls activate the pumps based on the water level inside the manhole. Two pumps operate simultaneously during heavy flooding.

Maintaining traffic flow on Broad Bay Road was another area of concern. Because of the island's long, narrow layout and geographically limited road network, there was no acceptable way to detour traffic. At least one lane of the road had to remain passable during the construction workday, two lanes during off-work hours.

Engineers carefully weighed the feasibility of a variety of remedies.

An ancillary challenge associated with the Broad Bay Road project had to do with the power supply. The pumping solution designed by the engineers relied on a three-phase power supply to ensure use of the most economical pumping motor for maximum performance and cost-efficiency. Three-phase power was available in the area, but there was no transformer at the project site. While this challenge ultimately proved easy to remedy, there are never guarantees when a commercial utility provider is called into a project. For example, Dominion Virginia Power was repeatedly forced to postpone work on the project because of storm damage to power lines in other areas–work that clearly took precedence over the Broad Bay Road project.

The new gravity storm-drain system discharging to the pump station consists of double drop inlets and piping along Broad Bay Road.

Tailoring a Solution

With client objectives and aforementioned challenges in mind, the consultants worked with the city engineer to develop a solution that would uniquely address the flooding problem on Broad Bay Road and produce a successful outcome for all parties. Before specific design work could even begin, engineers had to perform a preliminary assessment of the area to ensure that all

potential variables and pitfalls had been addressed prior to development and execution of the pump station solution. Surveyors from the consulting firm performed a topographic survey and utility location of the project area. Later, a subconsultant dug test holes to more accurately locate some of the underground utilities. Ground elevations were measured at 20-ft. intervals throughout the project area. Existing stormwater management structures were also identified and located. The city's topographic maps were studied to provide a delineation of the 7-ac. watershed. A comprehensive hydrologic analysis of the area was performed to determine the peak inflow rate and formulate an inflow hydrograph.

During the drainage improvement project, the City of Virginia Beach worked with residents to provide road and landscape improvements in the area.

After completing work to develop a firmer knowledge of the area's drainage characteristics, engineers began establishing preliminary design criteria: rainfall event return period or frequency, high-water level inside the sump or manhole, redundancy or spare-pump requirement, backup power requirement, and others. Then engineers reviewed the feasibility of using grate inlet structures and interconnecting pipes to provide additional storage, which could possibly reduce the size of the pump.

With a preliminary design strategy in place, engineers performed research to locate suitable suppliers of the equipment and services that would be needed to execute the final design. To be considered were the pump station (pumps and manhole), force main, check valves, power source and supply, and control panel. At this stage, one of the primary concerns, based on feedback from the city engineer, was locating pumping equipment that would offer outstanding durability and long-term reliability. Another consideration was choosing a pump size compatible with the needs of the project site: too large a pump wastes the client's money and ultimately leads to a shorter life span because of overcycling, and too small a pump fails to adequately address the duration and frequency of flooding.

Having completed these early phases of the work, the consulting firm then prepared a preliminary design layout and cost estimate for the city's review. The initial plan submitted to the City of Virginia Beach almost immediately encountered resistance from area residents. The most significant resulting design change was the selection of a new outfall location and subsequent relocation of the force main. The alternate solution called for a longer force-main alignment to the east and parallel to Broad Bay Road. Under the new plan, water would be discharged into Long Creek, located to the northeast of the project site.

Faced with the new force-main alignment and the increased distance between the project site and the discharge area, engineers had to redesign the pump. New surveys were needed, as was an updated assessment of the new design's impact on trees and existing utilities. The new outfall location was also studied to determine the need for erosion control measures.

Once an updated plan was prepared, the consultant and the City of Virginia Beach worked together to proactively present the plan to affected residents and to collect their feedback. This consensus approval approach proved successful. Residents quickly grew more supportive, and the project began in earnest with only minor changes soon thereafter.

The resulting plan called for the construction of a manhole 7 ft. in diameter and 11.4 ft. deep. To satisfy resident concerns, the location of the pump station control panel was moved to the west of the pump station site. Making this move, however, added complications, as electrical codes required the control panel to be located at an elevation above the 100-year floodplain.

The pump station was then built inside the manhole using a phased, two-pump design. To achieve maximum efficiency during light rainfall without sacrificing maximum performance during flood conditions, float controls were used to activate one or more pumps based on the level of water collecting inside the manhole–with both pumps operating simultaneously at maximum capacity during periods of heavy flooding.

The pumps chosen had a combined pumping rate capable of pumping the runoff from a one-year frequency storm event, meaning they were capable of displacing the amount of runoff associated with a storm with a 90% chance of occurring within the course of a year. Each of the submersible pumps was equipped with a 10-hp electric motor capable of pumping 1,000 gal./min. at 26 ft. of total dynamic head. To minimize the possible effects of saltwater corrosion on the system, the pumps were constructed of stainless steel, and the piping for the force main was made from high-density polyethylene.

Engineers and the city coordinated with Dominion Virginia Power to supply three-phase power to the pump station. The new gravity storm drain system that discharged to the pump station consisted of double drop inlets and piping located on either side of Broad Bay Road.

Finally, water was discharged through an 8-in. force main into an existing drop inlet, which ultimately discharged into a canal just a few feet from the main body of Long Creek. To address the impact of increased floodwater discharge at the outfall area, an existing drainage structure was used as an energy dissipater with riprap placed at the gravity outfall pipe to help reduce the velocity of the discharging water.

Final Analysis

Since construction was completed earlier this year, runoff at the Broad Bay Road project site has consistently dissipated within only a few minutes at most, a process that previously took up to two days. Even during severe storm conditions (which have not been encountered since project completion), initial pump tests indicated that flooding should remain at a minimal level and disappear altogether only a few minutes following the conclusion of a storm.

Perhaps more importantly, initial anecdotal feedback from residents to the City of Virginia Beach since project completion has been overwhelmingly positive. Immediately residents realized that a routine rainfall no longer paralyzes the Broad Bay Island community.

In fact, maintaining positive relationships with area residents and ensuring their ultimate satisfaction as taxpayers remained a paramount concern for the duration of the process. During execution of the drainage improvement project, the City of Virginia Beach also worked with residents to simultaneously provide road and landscape improvements in the area. In addition to improving the aesthetics of the area, this measure eliminated future inconvenience to residents, maximized construction efficiencies whenever possible, and ensured that the drainage system was installed with as little impact to the residents as possible. Ultimately that was the measure of success for the Broad Bay Road project. The basic engineering objective was to move water from "point A" to "point B" as effectively and efficiently as possible. But with any municipal engineering project, there is no denying that beyond the studies, the calculations, and the design specifications, there is always a human element, and to ensure a successful outcome, it must be addressed thoughtfully and thoroughly.

In the final analysis, the improvements at the Broad Bay Road project site were successful not only because they effectively addressed the flooding problem, but also because they made life on Broad Bay Island safer and more pleasant for its residents, with minimal interruption to their daily lives.

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