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March 10, 2021

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Subject: **Erosion and Water Quality Analysis of Lassing Park**

Michael Perry & Carlos Frey,

Please find enclosed the Final Design Report. As discussed on Monday January 18th, Lassing Park has many needed improvements to stormwater, water quality, and erosion issues that were present during the site inspection. Aqua Engineering will design solutions to combat these growing issues. The suggested solutions include; the removal of the old pier, placement of geotextiles and a living shoreline on the north side, improvements to existing stormwater utilities, implementation of a rain garden, and a vegetated swale. These recommendations will help solve the problems at Lassing Park, restore the park back to its original beauty and preserve the natural aquatic ecosystems without compromising the needs and lifestyles of the surrounding community. All work proposed or performed will be done in accordance with accepted engineering practice.

The undersigned hereby submits the enclosed proposal for design services for Lassing Park.

Thank You,

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Erosion and Water Quality Analysis of Lassing Park

Prepared for City of St. Petersburg, FL
April 9, 2021

AQUA ENGINEERING

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Executive Summary

The City of St. Petersburg (City) has tasked Aqua Engineering (Engineer) with performing an evaluation of Lassing Park (seen in Figure 0) to prepare a comprehensive plan to address the current stormwater design failures to improve water quality and combat erosion, while protecting the coast and its natural habitats. It is the Engineer's objective to solve the problems at Lassing Park and restore it to its original beauty and preserve its natural aquatic ecosystems without compromising the needs and lifestyles of the people who use the park for recreation and leisure. Aqua Engineering has determined the park is experiencing a number of issues affecting its community and natural habitats. These problems can be grouped into two distinct categories: water quality and erosion.

Figure 0. Lassing Park Aerial of Site Location

The park contains eight stormwater outflow pipes that release water directly onto the shore. Approximately half of the outflows are concrete, with the rest being PVC. The outflows contain various levels of backwashing, one of which has been completely buried, and most of the

PVC outflows are broken. It is expected that the outflows, which collect water directly from neighboring roadways, are playing a role in diminishing the water quality of the beach, which is home to a large seagrass bed and much aquatic life. A site visit revealed the presence of stagnant water in the park's only drainage ditch, located at the south end of the park. This water is likely the main culprit in producing a foul odor that permeates throughout the south side of the park and several residential backyards that border the ditch. The engineer has confirmed, through the evaluation of 2018 and 2019 water samples, that the water quality at the park does not meet state requirements in terms of dissolved oxygen, phosphorus, and fecal indicators. The drainage basin of each outflow has been delineated in ArcGIS and the flows that need to be accounted for by each pipe have been calculated using the rational method.

Accelerated erosion at the park has been identified by examining historical images in Google Earth. This erosion is primarily evident at the northern end of the park. Greenspace has been continually lost at this end, and the progression of erosion shows the potential to continue into the parking lot of an Army Reserve Center, which borders the park. The team explored five alternatives to fighting erosion at the north end. The solutions include:

1. The removal of an abandoned pier at the north end of the park to allow sediment transport
2. The use of geotextile sandbags and a coir turf reinforcement mat to stabilize the shoreline and dissipate wave and wind energy, along with the planting of red mangroves along the area most susceptible to scour
3. Improvements to existing stormwater structures via FOG skimmers and mitered end structures
4. The implementation of a bioretention garden to facilitate natural filtration of the largest stormwater catchment basin that feeds into the park
5. The implementation of a vegetated swale at the south end of the park to encourage natural filtration and reduce the likelihood of stagnant water causing odor and mosquito problems

After conducting the site visit, Aqua Engineering performed a literature review to determine a list of potential solutions that may be implemented. A survey was distributed to the surrounding community to determine what problems they saw at the park and what potential solutions they would support. Alternatives were modeled in AutoCAD to provide the client with visual aids as to the locations and appearance of the suggested solutions. A cost analysis was also performed using data from vendors and the Florida Department of Transportation's 2020-2021 itemized average cost spreadsheet. Each alternative was evaluated using a Pugh Matrix.

All alternatives scored much higher on the evaluation than the "do nothing" alternative, so the team believes them all to be viable solutions moving forward. Alternative 3, which is the stormwater improvements, scored the highest with a total of 161 points out of a possible 180. This is because the team believes this solution to be the most immediate and cost effective in terms of addressing water quality issues at the park. Alternative 5, the vegetated swale, also scored very well and is the only alternative that will address odor issues at the south end of the park that were identified during the site visit. Alternative 2, which is the geotextiles and living shoreline, received the high score and is the preferred solution to address the progressive erosion at the site. As the alternatives are not mutually exclusive, the team recommends that the city consider the implementation of these three alternatives (2, 3, and 5) in a phased approach. The phases will be placed in the following order:

1. Stormwater Infrastructure Improvements
2. Vegetated Swale Addition/ Re-Design
3. Geotextile and Mangrove Living Shoreline
4. Bioretention Bed (Possible Phase)

The bioretention bed will only be included in the phased approach if there is available funding from grants and if the City of St. Petersburg is willing to spend the amount of money necessary to implement this alternative.

Table of Contents

1.0 Introduction 1

1.1 Background 1

1.2 Objectives 2

1.3 Tasks 2

1.4 Site Description 3

1.5 Summary of Community Survey 7

2.0 Analysis of Alternatives 7

2.1 Alternative 0 - “Do Nothing” 8

2.2 Alternative 1 - Old Pier Removal 8

2.3 Alternative 2 - Geotextiles and Living Shoreline 9

2.4 Alternative 3 - Stormwater Improvements 11

2.5 Alternative 4 - Bioretention Bed/ Rain Garden 14

2.6 Alternative 5 - Vegetated Swale 15

3.0 Permitting 16

4.0 Recommendations 17

References 19

Appendices

Appendix A - AutoCAD Plans and Profiles

Appendix B - Data Tables and Schematics

Appendix C - Sample Calculations

Appendix D - Cost Analysis

List of Figures

Figure 1. Lassing Park Aerial of Site Location 1

Figure 2. Google Earth Capture of Total Erosion at Lassing Park (1994 - 2020) 3

Figure 3. Google Earth Capture of North End Erosion at Lassing Park (1994 - 2020) 3

Figure 4. Existing Stormwater Piping in Poor Condition 4

Figure 5. Exiting Stormwater Ditch at South End in Poor Condition 5

Figure 6. Google Earth Capture of Old Pier Rubble at North End of Lassing Park 8

Figure 7. Photo of Old Pier Rubble Taken during Lassing Park Site Visit 9

Figure 8. Biodegradable Coir Geotextile Turf Reinforcement Mat 10

Figure 9. Red Mangroves 10

Figure 10. Geotextile Sandbags 11

Figure 11. Delineated Basins in ArcGIS 12

Figure 12. Bioretention Bed Example 14

Figure 13. Vegetated Swale in a Residential Community 15

List of Tables

Table 1. 2018 and 2019 Water Quality Data Parameters for Lassing Park 5

Table 2. Enterococci Bacterial Monitoring Results from Lassing Park 6

Table 3. Summary of Community Survey Sent to Residents of Lassing Park 7

Table 4. Results for Calculated Flows for Each Basin at Different Return Periods 13

Table 5. Vegetated Swale Design Criteria 16

Table 6. Pugh Matrix Evaluation of Alternatives 17

1.0 - Introduction

1.1 - Background

The City of St. Petersburg (City) owns and operates Lassing Park, a 14.2-acre site located in St. Petersburg at 2042 Beach Dr SE, St. Petersburg, FL 33705. Residents use Lassing Park for outdoor recreation such as exercise, fishing, and relaxing. Aqua Engineering collected field notes and took photos during a pre-scoping site visit on January 18, 2021 at low tide. Aqua Engineering was accompanied by client, Michael Perry, a City of St. Petersburg Stormwater Department Engineer. Michael Perry walked the park with Aqua Engineering and specified the most substantial issues at Lassing Park. Aqua Engineering found that the park is experiencing the following issues: substantial erosion, aging stormwater utilities, and inadequate water quality. Aqua Engineering continued to communicate with the client to ensure that their goals for Lassing Park were met.

Figure 1 is an aerial view of Lassing Park and as seen from the Google Earth image, the park has a seagrass bed, grassy recreational area, and dredged sand bordering a deep channel that leads to Tampa Bay. The north end of the park borders a U.S. Federal Army Reserve Center. To the west and south of the park are the Old Southeast and Tropical Shores communities, respectively.

Figure 1. Lassing Park Aerial of Site Location

In 2011, Tampa Bay Watch, and organization dedicated to the protection and restoration of the Tampa Bay, proposed placing three oyster bars near the shoreline to control the erosion at Lassing Park's north end. This was never implemented due to resistance from the Old Southeast and Tropical Shores neighborhood associations, who were concerned about the safety of dogs who frequented the park (Gadsden, 2012). However, it is important to note that Lassing Park is not classified as a dog beach by the City of St. Petersburg. There are many signs posted at the site stating this information. Recently, Tampa Bay Watch received state and federal permits to continue with the execution of oyster reef balls, fossilized shell bags and coastal wetland plant species. If funding is secured, this project will begin implementation in Fall 2021.

In June 2015, AECOM, developed the St. Petersburg Waterfront Parks Master Plan for the City. In the Master Plan, a kayak launch, trails, and breakwaters were proposed for Lassing Park (AECOM, 2015). However, this master plan was never implemented and none of those features were installed.

1.2 - Objectives

The City of St. Petersburg has tasked Aqua Engineering with preparing a comprehensive plan to address the current stormwater design failures in order to improve water quality and combat erosion, while protecting the coast and creating habitat. In addition, the comprehensive plan should address protection of the coast and creating habitat. The goal of the comprehensive plan is to mitigate the stormwater design failures and to return the park back to its original beauty. In addition, the comprehensive plan should achieve the goal of preserving the natural aquatic ecosystems, with consideration of the needs and lifestyles of the people who use the park for recreation and leisure.

1.3 - Tasks

Aqua Engineering followed the scope of work as agreed upon during the kick-off meeting, site visit with City staff, and initial stages of the project. The following tasks were carried out in order to achieve the objective listed above.

1.3.1 - Project Management and Set Up

Aqua Engineering attended an online kick-off meeting via Microsoft Teams with City staff to review the objectives of the project. The project manager reviewed work progress and communicated regularly with the City, organizing client meetings when necessary. Internal progress meetings were conducted every Wednesday and additional meetings were scheduled as necessary. Aqua Engineering conducted a pre-scoping site visit on January 18. Accompanied by Michael Perry, a City of St. Petersburg Stormwater Department Engineer, Aqua Engineering was able to identify and evaluate elements of the park that need to be addressed. A review of literature was conducted to develop solutions for each problem identified. Aqua Engineering requested information from the City for land surveys, GIS shapefiles, and stormwater utility atlas sheets. The team conducted a community survey to garner support and involvement in the hopes that the new proposal will be met more favorably than past proposals.

1.3.1.1 Kickoff Meeting via Microsoft Teams w/ City Staff

1.3.1.2 Coordination and Communication

1.3.1.3 Site Visit on January 18, 2021

1.3.1.4 Data Request - GIS Shapefiles and Stormwater Utility Atlas Sheets

1.3.1.5 Community Survey

1.3.1.6 Weekly Internal Meetings

1.3.2 - 30% Design

A literature review was conducted in order to brainstorm alternatives for the proposed solution. Aqua Engineering consulted Dr. Cheryl Hapke, a professor at the University of South Florida (USF) St. Pete campus who specializes in coastal geology. Dr. Hapke also happens to be a resident of the Old Southeast neighborhood bordering Lassing Park. The consultation with Dr. Hapke aided Aqua Engineering in conducting Google Earth erosion modeling to determine the area of the park most prone to scour. Basins were delineated using ArcGIS and ATLAS Maps to determine stormwater flows. Detailed solutions were formulated to address each aspect of the park that demands attention. Data was collected from the City and online sources for each potential solution.

1.3.2.1 Literature Review

1.3.2.2 Erosion Modeling via Google Earth

1.3.2.3 Basin Delineation using ArcGIS and ATLAS Maps

1.3.2.4 Stormwater Analysis via Rational Method

1.3.2.4 Retrieval/ Analysis of Water Quality Records

1.3.3 - 60% Design

The team continued research through review of the literature. Detailed models of the proposed solutions were created using AutoCAD and SWMM modeling software. A detailed expense analysis was constructed for each alternative of the design solution, including equipment, material, and installation costs. The required permitting for each alternative was collected and incorporated into the cost analysis.

1.3.3.1 Continued Literature Review

1.3.3.2 Model Designs using SWMM/ AutoCAD

1.3.3.3 Analyze Cost of Each Alternative

1.3.3.4 Verify that Alternatives are up to City/ State/ National Permitting

1.3.4. - 100% Final Design

Aqua Engineering evaluated the final alternatives and developed a schedule for their implementation. The team incorporated all City comments into the final design report. The project manager and editor ensured all comments were incorporated. Aqua Engineering submitted the proposed alternative solutions, costs, and supporting documents to the City.

1.3.4.1 Incorporation of Client Comments

1.3.4.2 Verify Parameters for Stormwater Alternatives

1.3.4.3 Verify Parameters for Erosion Alternatives

1.3.4.4 Rank and Evaluate Alternatives

1.3.4.5 Develop a Schedule for Implementation

1.3.4.6 Propose Finalized Alternative Solution(s) in Final Design Report

1.4 - Site Description

Lassing Park is a tide dominated beach, meaning the surf zone extends longer than usual and the nearshore zone is steep after the bar. Since 1994, Lassing Park's shoreline has receded approximately 20,000 ft^2. In June 2012, Tropical Storm Debby hit Florida's west coast and increased the erosion of Lassing Park, especially at the north end of the park. The overall erosion of Lassing Park from 1994 to 2020 can be seen in Figure 2, and the erosion of the north end can be seen in Figure 3.

A B

Figure 2. Google Earth Capture of Total Erosion at Lassing Park 1994 (A) & 2020 (B)

A B

Figure 3. Google Earth Capture of North End Erosion at Lassing Park 1994 (A) & 2020 (B)

The stormwater structures throughout Lassing Park are in need of significant repair. Many of the PVC stormwater pipes are broken and some are almost completely buried by the sand, causing slow discharge flows. The concrete pipes present dangers because of broken pieces and exposed rebar (Figure 4).

Figure 4. Existing Stormwater Piping in Poor Condition

A 180-foot-long ditch is located at the south end of the park borders the backyards of residential properties of Tropical Shores (Figure 5). An underground pipe with an inner diameter of approximately 12 inches discharges directly into the open ditch. At the time of the site visit, this contained pipe flowing water, but there had been no significant rain in the preceding days. The last precipitation event occurred 3 days prior to the site visit and lasted 2 hours. The constant water flow observed could be produced due to groundwater infiltration or illicit wastewater connections from members of the community. Although there was constant flow from the pipe, the water in the ditch remained stagnant and produced a noticeable odor. This poor drainage could be caused by improper grading of the ditch. While the original design of the ditch may have had a proper slope, this slope has been flattened to nearly zero over time. This is most likely caused by erosion of the base of the ditch. The base of the drainage outlet appears to have signs of where the original height of the soil was, but this has since significantly dropped, as shown in Figure 5. Additionally, this stormwater outflow was found to have a layer of grease on the water. The stagnant water, low flow speeds, decomposition of organic matter, noticeable odor, and unusual color all are indicators of poor water quality.

Figure 5. Existing Stormwater Ditch at South End in Poor Condition

In 2018 and 2019, samples were collected offshore from Lassing Park to investigate the water quality. The samples were taken in the middle of the seabed area, but were most likely affected by the stormwater discharge. The resulting data is presented in Table 1. Data for *Enterococci*, a fecal indicator through 2016 and 2018 are shown in Table 2.

Table 1. 2018 and 2019 Water Quality Data Parameters for Lassing Park (WaterAtlas)

Parameter	Units	2018 Results	2019 Results	Acceptable
Salinity	ppt	20.67	27.92	0.5 - 35
Phosphorus (P), Total	ug/L	177	80	10-40
pH	none	7.79	8.07	6.5 - 8.5
Nitrogen (N), Nitrate + Nitrite	ug/L	10	20	<1000
Enterococcus Bacteria, Total	cfu/100mL	10	10	<70
Dissolved Oxygen (DO)	mg/L	4.76	6.42	7 - 8

The data presented in Table 1 shows salinity values that classify the water as brackish, a combination of saltwater and freshwater, as the values are between 0.5 to 35 ppt (NOAA, 2021). Brackish water is typically present where rivers meet oceans, estuaries, or where a mangrove swamp exists. Since this area contains minimal mangroves and there are no rivers nearby, the low salinity levels are most likely caused by stormwater runoff.

In marine environments, dissolved oxygen (DO) levels should fall between 7 and 8 mg/L. The measured concentrations fall significantly short of the safe range for DO. The 2018 concentration is close to 4 mg/L, the level at which fish will become absent from ocean waters (VIMS, 2021). Unsafe levels of DO are caused by phosphorus and nitrogen entering the Lassing Park marine ecosystem and stimulating the growth of plants and algae. Plants and algae consume phosphorus and nitrogen, which causes more of a bloom and when the plants and algae die and decompose the process of the decomposition uses the DO and results in the unsafe DO levels for the other aquatic life, such as fish (MPCA, 2009). Rainfall runoff transports these nutrients into the waterways from impervious areas of surrounding basins.

Phosphorus is being sent to the stormwater system, then discharging directly into Lassing Park. This could be the largest contributor to the poor water quality of the park. Phosphorus is the primary cause of the unsafe dissolved oxygen levels. The phosphorus levels to sustain aquatic life should be between 10 to 40ug/L to ensure oxygen is not used up (U.S. EPA, 2006). As shown in Table 1, the values for phosphorus are significantly higher than the allowable limit, causing the possible stimulation of eutrophication. These levels could be attributed to the stormwater runoff being discharged into the bay.

Nitrogen is another nutrient that affects the DO levels. Nitrogen is a contributing nutrient for algae growth in marine ecosystems. The 2018 and 2019 samples showed nitrate and nitrite levels to be 10 ug/L and 20 ug/L, respectively. With a maximum value of 1000 ug/L, the nitrate and nitrite levels are acceptable for aquatic life.

The City of St. Petersburg sampled Lassing Park and other St. Petersburg beaches from 2016 to 2018 and issued a Water Quality Report Card. This data is displayed in Table 2. Lassing Park was only tested for *Enterococci*, a bacterium that typically inhabits the intestinal tracts of humans and animals (City of St. Petersburg, 2019). Out of a total of 93 samples taken from 2016 to 2018, 14 of them showed an exceedance of 70 cfu/100 mL of *Enterococci*. This indicates that stormwater runoff and possibly human and animal feces are contaminating the water.

Table 2. Enterococci Bacterial Monitoring Results from Lassing Park (City of St. Petersburg)

	Enterococci (Exceedance > 70 (cfu/100mL))		**Fecal Coliform (Exceedance > 800 (cfu/100mL))**	
Year	Number of Samples	Number of Exceedances	Number of Samples	Number of Exceedances
2016	1	0	0	0
2017	33	6	0	0
2018	59	8	0	0
All	93	14	0	0

1.5 - Summary of Community Survey

A survey was distributed to the surrounding neighborhood of Lassing Park and it was determined that most residents preferred the park to be natural or preferred only natural improvements. Most of the neighboring residents preferred absolutely no structures or anything that could be harmful to the environment and present hazards to themselves or their pets.

Table 3. Summary of Community Survey Sent to Residents of Lassing Park

Question	Most Popular Answer
What do you typically use the park for?	Exercise, Relaxation, Water Sports
Is there anything at the park that you have noticed needs updates.	No, Piping, Water Quality, Ditch on South End
Stormwater utilities are currently running untreated into the bay, we would like to add a form of natural filtration which would improve the water quality and smell. Would you have any issues with the existing stormwater structures at Lassing Park being updated or replaced outright?	No (82%) Yes (18%)
If you chose yes on the previous question, please explain why.	Need more information or No park development
If there were to be any updates to the park or beach, what kind of updates would you be against? Please provide as much detail as possible and include a reason for your opposition.	No structures and keep the park natural

If we were to implement natural solutions to address the water quality, which of the following would you be most satisfied with? Check as many boxes that you agree with.	Rain Gardens, Living Shoreline, Vegetated Swale
To help with the erosion, one design option would be to use riprap in conjunction with mangroves, at the north end where the old pier lies. Would this be something you'd be opposed to?	No, but they didn't like the riprap addition

2.0 - Analysis of Alternatives

Aqua Engineering has developed multiple alternative solutions for the problems faced at Lassing Park. When considering the alternatives, Aqua Engineering decided not to include the oyster bar/ oyster reef ball living shoreline solution. A previous plan proposed by the Tampa Bay Watch to implement a living shoreline at the beach was unsuccessful because the community was unhappy with the concept due to safety concerns. Although a solution preferred by the City, Aqua Engineering believes that any use of oysters will be a potential problem for approval and implementation due to community concerns. Keeping the oysters contained within a netting could allay some of these concerns; however, the team still perceives that the oyster structures could pose a safety threat to those who walk in the area during low tide. Any living creature will try to spread; using netting will not stop oyster larvae from spreading and attaching to other substrate materials in the area. The natural progression will be for the oyster beds to become larger and more widespread over time. During storms, the shells will wash up on the beach and any netting used to contain them could be damaged over time by storm and wave activity, making the nets ineffective at containment. The sharp edges of oyster shells could potentially hurt someone that steps on them or is accidentally tripped due to them being partially submerged, creating a hazard to both dogs and humans.

The alternative solutions selected to be evaluated and proposed are presented below. The proposed alternatives include: (1) “do nothing”, (2) old pier removal, (3) geotextiles and living shoreline, (4) stormwater improvements, (5) rain garden, and (6) vegetated swale.

2.1 - Alternative 0 - “Do Nothing”

A survey was distributed to the residents in the surrounding neighborhoods at Lassing Park and it was found that most residents did not want any substantial changes. The general consensus was that the park should remain natural and have a minimal amount of structures. With this in mind, the Aqua Engineering team found it pertinent to include a “do nothing” alternative to compare the other alternatives to. This alternative can be chosen if the financial, environmental, and social costs of all other alternatives outweigh the benefits. If the “do nothing” alternative is chosen, the present problems at Lassing Park will persist and increase over time. Poor water quality will continue to threaten the seagrass bed and aquatic life. As erosion progresses, the park will continue to lose greenspace until there is nowhere left for the community to play with their pets, walk, and enjoy other recreational activities.

2.2 - Alternative 1 - Old Pier Removal

2.2.1 - Literature Review

The surf zone at Lassing Park extends longer than usual and the nearshore zone is steep after the bar. Google Earth images demonstrate that a substantial amount of sediment is available on the north side of the park, above an old pier (Figure 6). The presumption that this structure may be have been a pier was confirmed by Michael Perry, a City of St. Petersburg Engineer who was interviewed during the initial site visit (Figure 7). The team consulted with Dr. Cheryl Hapke, a Marine Science Professor at the University of South Florida (USF) with a PhD in Coastal Geology, who has studied the Lassing Park shoreline. Based on two discussions with Dr. Hapke, it was determined that longshore drift carries sediment from north to south at the park. The presence of rubble from the old pier shows a high likelihood of inhibiting this natural sediment transport. Removing a portion of the old pier rubble may facilitate future sediment transport by longshore drift and replenish the park at the north end where the effects of scour have become the most evident.

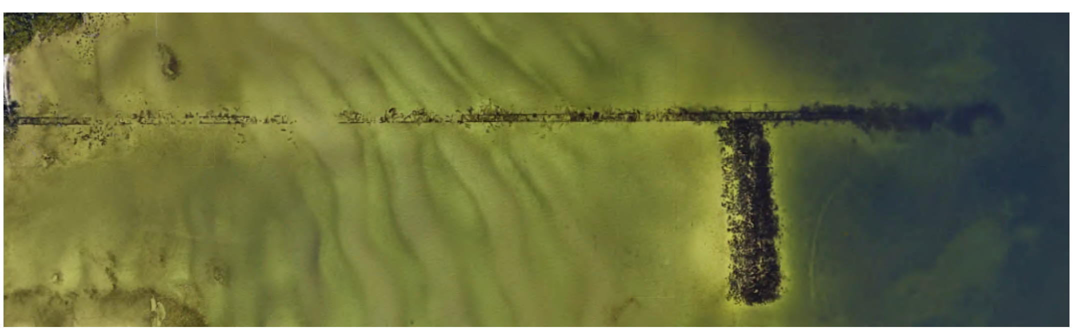


Figure 6. Google Earth Capture of Old Pier Rubble at North End of Lassing Park

Figure 7. Photo of Old Pier Rubble Taken during Lassing Park Site Visit

2.2.2 - Design Criteria

In order to facilitate the migration of sand from north to south at the beach, the removal of the pier rubble would need to be performed in a minimally invasive manner, such that none of the existing mangroves that currently lie adjacent to the pier would be disturbed. While the pier runs a distance of nearly 1000 feet away from the shoreline during high tide, the team believes that removing 250 feet closest to the shore could allow longshore drift to occur, unimpeded. Approximately 2,340 ft^2 of excavation and removal of the old pier rubble would need to occur. The depth of the foundation is unknown, making it hard to approximate the extent of the demolition that would be required to extract the remaining concrete. The removal could prove to be quite costly due to the fact that the rubble is in the water and partially covered by sand. However, the extraction could prove to be a bit easier if the work was scheduled to take place during low tide events. A cost analysis revealed that the project could be completed for about $90,000.

2.2.3 - Evaluation of Alternative

The evaluation of this alternative involved the criteria of initial costs, community safety and quality of life, erosion control, and environmental impact. The removal of the pier is considered to have a low impact on the community and aquatic life because the pier is only rubble at this point and provides no notable function or habitat. Aqua Engineering was unable to determine the exact age of this pier, as it was built before 1994 when Google Earth Image captures became available. In these photos, it can be seen that the pier is just as deteriorated as it is now, showing it must be over 25 years old. The removal of the pier may enhance the safety of the park due to the fact that many residents use this section of the park to walk out to the sandbar during low tide and the existing rubble presents a tripping hazard.

2.3 - Alternative 2 - Geotextiles & Living Shoreline

2.3.1 - Literature Review

Geotextiles can consist of natural fibers such as coir (coconut straw), or can be formed from more durable synthetic fibers, most commonly polypropylene. Woven geotextiles are more durable but are less capable than their nonwoven counterparts at facilitating drainage.
Living shorelines can take a multitude of forms (Royle, 2015), but are primarily aimed at controlling coastal erosion while preserving and enhancing natural ecosystems. The addition of mangroves along the shore has been shown to provide subsurface rigidity to help the shore maintain its structure. Mangroves also provide natural shading and nurseries for marine life and would improve the natural aesthetics of the park, while minimally reducing walkability. Aqua Engineering spoke with Dr. Hapke, and she recommended that a biodegradable coir geotextile (Figure 8) could benefit the beach by stabilizing the sand while giving time for the roots of newly planted mangroves to develop and become effective at fighting erosion (Figure 9).

Figure 8. Biodegradable Coir Geotextile Turf Reinforcement Mat (Sandbaggy)

Figure 9. Red Mangroves (Britannica, 2019)

2.3.2 - Design Criteria

For the implementation of geotextiles at Lassing Park, there are a few important factors to consider. The lining that will sit on the flat part of the beach needs to be thin and secure, so as to not present a tripping hazard for beach goers. The material should be durable enough to withstand walkers, pets, and wave energy. A longer effective life will make the alternative more cost effective and minimize the need for routine upkeep or replacement. For aesthetic purposes, the geotextile should be sand-colored so that it blends well with the existing beach and is concealed as much as possible. For geotextile sandbags, they must have the durability and drainage capacity that the flat liner possesses, but also be resistant to tractive forces to maintain stability in the event that humans or wave energies dislodge them. Mangroves added at the park must be planted at an appropriate depth for their roots to take hold and for them to be able to absorb necessary nutrients for them to thrive. Using AutoCAD, a plan and profile view was modeled for this alternative and is included in Appendix A.

2.3.3 - Evaluation of Alternative

This alternative has the potential to be the most effective and least invasive strategy to fight erosion as Lassing Park's north end. It would require little maintenance or upkeep after the initial installation and would present little risk to beach goers. Sandbags may optionally be stacked to a height such that they offer a place to sit for those walking on the north end of the beach (Figure 10). The use of local sand would reduce the cost of implementing sandbags, as only the purchase of the geotextile sacks would be necessary. Coir material would be biodegradable, accomplishing the desired functions of holding in the sand of the north end until mangroves that are planted fully take root. Planting mangroves is proven to fight coastal erosion without presenting any safety risks to beach goers. It is suggested that partially matured and salt-conditioned mangroves be implemented so they have the best chance of developing root structures that will be adequate to fight erosion. Aqua Engineering determined that the red mangrove propagules and juvenile plants are to be planted along the north stretch of the beach as a long-term solution. Once the roots have established themselves, the mangroves should effectively prevent scour for well over 50 years with little maintenance. For a coir geotextile liner, mangroves, and the installation and maintenance costs of each, the total is estimated to be approximately $70,500 for an area of 0.40 acres. This is a relatively inexpensive solution, especially given the long-term beneficial impact that the implementation of this solution may have.

Figure 10. Geotextile Sandbags (SECUTEX®, 2019)

2.4 - Alternative 3 - Stormwater Improvements

2.4.1 - Literature Review

When conducting the initial site visit, several of the stormwater outflow pipes were found to be broken and contain some level of backwashing. Backwash in the outflow pipes can cause flooding within the pipes and the system as a whole due to the fact that water is not allowed to escape at the rates which the pipes are designed. Some of the outflows were completely buried and could not be examined during the site visit. By improving the design of the outflow structures, the pipes will be better equipped to accommodate their respective design flows.

Another issue noted was the presence of visible oil in the water leading from the pipe outflows to the beach. The presence of excessive amounts of fats, oil, and grease (FOG) in the bay can be harmful to aquatic life. The implementation of FOG skimmers is a relatively inexpensive and non-intrusive way to pull these pollutants from stormwater flows before they are conveyed into receiving water bodies.

2.4.2 - Design Criteria

The first step in hydraulically assessing the stormwater infrastructure of Lassing Park was to delineate the basins. This was done using current stormwater infrastructure data provided by the City of St. Petersburg. Elevation data from Google Earth was used to adjust the basins. It was determined that a total of 8 pipes discharged into the Lassing Park beach, therefore 8 basins were delineated.

A map was constructed to delineate the basins using ArcGIS (Figure 11). The basins analyzed were segregated to account for different types of pervious and impervious areas. The purpose of this was to determine the flows for each basin using the rational method which requires a runoff coefficient dependent on permeability of each basin. A map was constructed to determine the pervious and impervious areas (Figure B, Appendix B). The runoff coefficient was determined, seen in Table A, Appendix B. The results for the runoff coefficients for each basin are shown in Table B, Appendix B. To calculate the rational method flows, it is necessary to estimate the intensity used in the equation. This intensity is calculated using the time of concentration which is assumed to be the storm duration in the Zone 6 IDF curves provided by Florida Department of Transportation (FDOT) (Figure C, Appendix B).

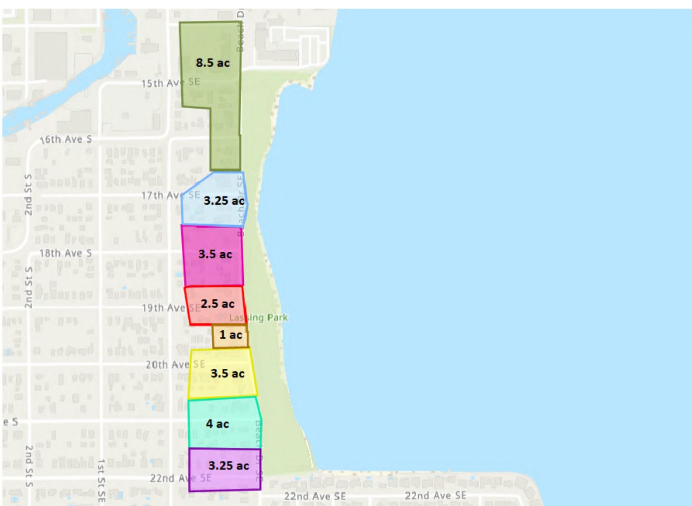


Figure 11. Delineated Basins in ArcGIS

To estimate time of concentration, three methods were used and averaged, the Kirpich method, SCS Ranser method, and the CiA method as seen in the sample calculations in Appendix C.

More complex modeling using the Stormwater Management Model (SWMM) software is necessary to fully assess the functionality of the current stormwater infrastructure. For redesigning the stormwater outflows, the final product aims to ensure proper conveyance of flows for the design storm return period. The design would need to be easily incorporated into the existing pipe system so that the pipes do not all require replacing.

To verify the results obtained with the Rational Method the team decided it would be best to apply the SCS curve number method. Upon further investigation it was discovered that the hydrologic soil group of the basins analyzed was mostly A, however a portion of the basins was catalogued as B. A Geographic Information System (GIS) map was created using QGIS (Figure D, Appendix B). After analyzing the distributions of the basins it was determined that the percentages of areas with soil classification B was between 8% and 36%, however most of the basins that had a significant portion of area classified as B were also the ones with the most percentage of impervious area, which has a curve number of 99 for all hydrologic soil groups. It was therefore assumed that the basins belonged to the hydrologic soil group A. The results for the flows are shown in Table 4. The results of the flows calculated were significantly different from those calculated with the Rational Method. It is worth noting that the rational method has many limitations, especially when calculating the time of concentration values due to the specificity of the equations used.

Table 4. Results for Calculated Flows for Each Basin at Different Return Periods

Basin	***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***
Return Period (years)	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
2	10.59	12.67	12.22	3.19	9.18	14.65	18.86	20.38
3	11.29	13.49	13.06	3.39	9.74	15.83	20.00	23.13
5	12.35	14.51	13.91	3.48	10.02	16.54	20.57	24.23
10	13.06	15.33	15.17	3.77	10.85	17.72	22.29	27.54
25	14.65	17.37	17.07	4.26	12.24	20.08	25.15	30.84
50	15.70	18.39	18.33	4.59	13.22	21.26	27.15	33.05
100	16.76	19.82	19.80	4.84	13.91	23.15	28.58	37.45

After obtaining reference values for the flows it was decided that the next step for the hydraulic assessment of the existing stormwater infrastructure was to create a pipe network representative of the field conditions. To accomplish this it was assumed that the pipes for each basin followed the same slope as the terrain slope in the basin analyzed. The results for the slopes of each basin are shown in Table C, Appendix B. With these slopes, it was possible to create the stormwater infrastructure pipe network. To do this the pipe networks were created using Civil 3D software. The diameters and direction of the pipes were extracted from the atlases provided by the City of St. Petersburg. Plan and profile views were generated for each pipe using the software and the observations made in field. A general plant view of the pipe networks was generated and can be found in Appendix A. An example of the detailed drawings generated are also shown in Appendix A. The surface used as reference was generated using global mapper software which resulted in a 3D model of the area and was useful for generating the topographic surface of the area analyzed.

Concrete endwalls protect the ends of pipes. Since most of the pipes at Lassing Park are broken on the ends, this is a needed solution. Concrete endwalls can be incorporated into the naturally occurring hill as much as possible so that it will not take away from the natural aesthetics of the shoreline or present unnecessary hazards. The plan view in Appendix A models the concrete endwalls that Aqua Engineering suggests being implemented.

FOG skimmers can be incorporated into existing stormwater catchment systems so they may provide necessary separation close to the point of capture and may be easily maintained. While they will require maintenance, skimmers will provide the capacity to hold FOG such that upkeep will not be necessary more than two times per year.

2.4.3 - Evaluation of Alternative

Concrete armoring has been historically been shown to protect outflow structures and prevent backwashing into the system. The implementation of this armoring around the current outflows would be a relatively cost-effective way to assure that these structures operate as designed. By embedding the armoring into the existing hillside, the aesthetics of the shoreline would be minimally disturbed, and park-goers would have little risk of tripping over them.

FOG skimmers are another inexpensive alternative that are effective in improving water quality. These would be implemented roadside so that FOG is captured before they make their way into the park.

2.5 - Alternative 4 - Bioretention Bed/ Rain Garden

2.5.1 - Literature Review

With the natural aesthetic of the park, results of the community survey, and existence of a previously planted garden at Lassing Park, it can be presumed that the frequent visitors prefer natural solutions. Because of this, Aqua Engineering proposes a bioretention bed, or rain garden, as a means of enhancing water quality while still bringing attention to the park's native beauty (Figure 12).

Figure 12. Bioretention Bed Example (Rutgers, 2019)

Bioretention gardens were implemented in the 1990's to attenuate stormwater that accumulated as a result of manmade structures (Un, 2010). The purpose is to facilitate natural processes of water drainage and filtration that impervious land prevents. Filtration, precipitation and the activity of microbes in the plant root zone (i.e., rhizosphere) help to capture, assimilate and transform nutrients, organic matter, solids, metals and FOG before they are released into receiving waters. By routing stormwater runoff through bioretention systems, plants are given time to absorb nutrients or pollutants such as nitrogen and phosphorus from the influent before it is released into collecting water bodies or systems. By holding water within the bioretention system for a predetermined amount of time, plants are able to facilitate evapotranspiration of the influent water, thus reducing the loading to the stormwater system. Plants will help treat the water, thereby improving the water quality of the effluent from the system.

2.5.2 - Design Criteria

A potential bioretention installation at Lassing Park would need to be spatially efficient so that it would not take up too much of the walkable park area. Because the first inch of rainfall from any storm event carries the highest nutrient and pollutant loading, the rain garden should have the capacity to attenuate at least this volume of water from its respective catchment basin. The rain garden size was calculated using 7% of the impervious area of the basin as shown in the sample calculation section of the appendices. The rain garden should incorporate plants that are non-toxic to animals, particularly dogs, while also maximizing natural filtration and evapotranspiration. AutoCAD models of the bioretention bed design are shown in Appendix A.

2.5.3 - Evaluation of Alternative

The park has a total of eight stormwater outflows with catchment basins of varying sizes. The northernmost outflow is best suited for the incorporation of a rain garden because it provides drainage for both industrial and residential properties, and it is the largest catchment basin identified. A rain garden that is 0.38 acres in size was deemed appropriate to attenuate the first inch of rainfall from any event, as stipulated in the design criteria (U.S. Department of Agriculture, 2005). The rain garden would be one foot in depth, and because of the raised nature of the park's greenspace, its implementation would not require disturbance of the groundwater table. Overall, the estimated cost for the implementation of the bioretention bed will cost around $417,000.00 with O&M cost estimated to be around $12,000 (FDOT 2019). Though the expense is high, the bioretention bed would significantly reduce pollutants and bacteria in the water caused by the stormwater runoff.

2.6 - Alternative 5 - Vegetated Swale

2.6.1 - Literature Review

Vegetated swales are considered low-impact development alternatives (Figure 14). They are shallow channels that are used to convey runoff, facilitate infiltration, and reduce nutrient loading into receiving water bodies (Acomb and Clark, 2008). They are an alternative to traditional conduits that rely primarily on pipes and gutters. During the site visit, the ditch at the south end of the park, adjacent to the backyards of several residents, was found to have stagnant water that was producing an odor. By re-grading the ditch and introducing vegetation, effluent flow will decrease because the plants will soak up any additional water, filter the remaining water, and enhance the water quality before it enters the bay.

Figure 13. Vegetated Swale in a Residential Community (DEQ, 2003)

2.6.2 - Design Criteria

The objective of implementing a vegetated swale at the south end of the park is to adequately treat stormwater within the swale. In doing so, the re-graded swale with plants will have adequate time to absorb optimal amounts of nutrients before discharging into the bay. Additionally, the amount of plants will contribute to keeping the water flow at a constant, steady rate so that stagnant water does not accumulate in the ditch. Stagnant water can provide a breeding ground for mosquitoes and undesirable bacteria and odors. To ensure that the swale will no longer have stagnant water, the slope of the swale will need to be readjusted. The slope of the proposed swale was calculated using the Manning's Equation for an open channel flow, as shown in the appendices. First, the constraints were found using a design n-value of 0.033 and a maximum permissible velocity of 4 ft/s for a grass channel lining. The velocity was chosen as a maximum to ensure that the grass lining does not get displaced before its roots are defined. The hydraulic radius was found given the existing channel width, proposed side slopes, and proposed wetted depth. The proposed criteria were then calculated, as shown in Table 5 below.

Table 5. Vegetated Swale Design Criteria

Parameter	Proposed
Slope (ft/ft)	1.28%
Velocity (ft/s)	4
Side Slope (ft/ft)	0.25
Roughness Coefficient	0.033
Hydraulic Radius (ft)	0.6923

The proposed vegetated longitudinal and side slopes are modeled in Appendix D. Certain plants will be added that can tolerate soil with low phosphorus content, high phosphorus sorption capacity, and a high carbon to nitrogen capacity (Acomb and Clark, 2008). The native Florida plants considered for the vegetated swale will be non-toxic to animals that frequent the park. The following are the plants that Aqua Engineering has considered for the proposed vegetated swale:

- Switchgrass (*Panicum virgatum*)
- Hairawn Muhly (*Muhlenbergia capillaris*)
- Canna lilies (*Canna indica*)

2.6.3 - Evaluation of Alternative

Creating a vegetated swale at the south end of Lassing park will help treat stormwater runoff, improve water quantity within it, and create a more aesthetically pleasing environment for surrounding residents. The swale will need to be regraded so that plants within the swale can have enough time to absorb the optimal amount of nutrients. The area of the swale that will need to be regraded is about 6,895 square feet. The associated cost of swale construction is $156,344 with an estimated annual $12,000 operations and maintenance cost (FDOT 2019). The type of plants need to be non-toxic to pets and are native to Florida's coastal region. The soil within the swale will contribute to the nutrient balance by consisting of a low phosphorus content, high phosphorus sorption capacity, and a high carbon to nitrogen capacity (Acomb and Clark, 2008). The number of varying plant species will contribute to improving water quantity within the swale because of osmosis. This vegetated swale will reduce stagnant water and thus minimize unpleasant odors that arise from it. This alternative will be relatively low in cost, improve public health by reducing stagnant water, and treat poor water quality from stormwater runoff. Additionally, this alternative will maintain the park's natural aesthetic, promote natural habitats, be sustainable and resilient with minimal maintenance and stay true to the definition of a passive park in which it is classified.

3.0 - Permitting

Aqua Engineering referred to Southwest Florida Water Management District (SWFWMD), City of St. Petersburg, Florida Statutes, and Florida Administrative Code for the required permitting for each of the alternative solutions. General permits were chosen based on the design of the solutions. The following are the general permits that will be used for this project:

Stormwater Improvements

- 62-330.451, F.A.C.
- Nationwide Permit #7
- SWFWMD Individual Permit (Part IV of Chapter 373, Florida Statutes)
- City of St. Petersburg Sec. 27-249. (Code 1973, § 28-44; Code 1992, § 27-178)

Living Shoreline, Swale & Rain Garden

- 62-330.631, FAC & 62-330.632, FAC
- Nationwide Permit #54
- Nationwide Permit #27
- 18-2.004 F.A.C. & 18-20.006 F.A.C.
- 62-331.238 FAC & 62-331. 240 F.A.C.

Construction & Administration

- Chapter 253 F.S.
- Chapter 258 F.S.
- 18-21.007 F.A.C. & 18-21.009 F.A.C.
- 62-331.210 F.A.C. & 62-331.214 FAC & 62-331. 225 FAC
- 62-330.485 F.A.C.
- City of St. Petersburg Dredge and Filling: Seawalls (Code 1973, 10-3; Code 1992, 7-32)

Each permit will be issued to the corresponding government agency or municipality. The permits will have application fees and impact fees that will be determined by the government agency or municipality after their review. These costs are more difficult to determine as they are per specific codes that each government agency and municipality will be assessed based on local ordinates.

4.0 - Recommendations

The criteria on which the recommendations are based were categorized into 5 different sections which take into account different aspects of the feasibility of each solution. The criteria are defined as follows. Table 6 evaluates each of these alternatives using a Pugh matrix.

- Cost
- Community Safety/ Quality of Life
- Control Erosion/ Address Stormwater and Water Quality

- Environmental Impact of Implementation
- Sustainability/ Resilience

Table 6. Pugh Matrix Evaluation of Alternatives

Criteria	Weight	Alternative					
		Do Nothing	Old Pier Removal	Geotextiles & Living Shoreline	Stormwater Improvements	Rain Garden	Vegetated Swale
Cost (Initial + O&M)	4	10	7	8	10	1	5
Community Safety & Quality of Life	4	2	7	10	10	10	10
Control Erosion/Address WQ	5	1	6	8	8	7	6
Environment Impact	2	2	4	7	10	10	10
Sustainability/Resilience	3	2	10	5	7	6	9
	Total	**63**	**124**	**141**	**161**	**117**	**141**

The ratings for the cost evaluation were derived using linear interpolation from the least to most expensive alternatives. Most alternatives received full scores in their ability to enhance community safety and quality of life, with the exception of the removal of the old pier. This is because the community survey revealed that many residents walk around the pier out to an adjacent sandbar during high tide. The removal of the pier rubble could reduce walkability by dispersing the sediment. The rating of each alternative to address erosion or water quality was determined based on two factors: the effectiveness the solution would have in addressing the problem and the proportion of the park that would benefit from the implementation of the alternatives. While no alternative received full marks in this category, alternatives 2 through 5 were found to be the most significant in their ability to address the two challenges Lassing Park faces. The environmental impact category was based on the anticipated equipment and materials that would be needed for each alternative. Because most of the alternatives use vegetation or natural solutions to address the issues at the park, they would require minimal heavy machinery. This led to most of the ratings in this category being high, with the exception of the do nothing alternative and alternatives 1 and 2. The sustainability/ resilience of each alternative was based on Aqua Engineering's opinion of how well the alternative would hold up over time, respond to severe weather events, and the amount of maintenance required to keep the alternative in a functional state.

Based on the evaluation of each alternative Aqua Engineering determined the appropriate recommendation for Lassing Park. The most appropriate solutions to meet the City's needs and the communities desires are Alternatives 3, 2, and 5; improving stormwater infrastructure through concrete endwalls and FOG skimmers, the implementation of geotextiles and a mangrove living shoreline, and the addition of a vegetated swale in the ditch at the south end of Lassing Park. The rain garden (Alternative 4) presents the most viable solution in addressing water quality through its ability to filter nitrogen and phosphorus but received a lower rating due to its anticipated cost. The team believes that this alternative would be more feasible if the City pursued grants from SWFWMD and the National Fish and Wildlife Foundation (NFWF). SWFWMD offers assistance through the Water Quality/ Natural Systems Project and operates via the leveraging of local and district funding. The intention of the project is to restore natural characteristics to the shoreline. NFWF has a National Coastal Resilience Fund, geared toward protecting coastal communities and strengthening natural infrastructure, and is funded by non-government industries. Some supporters of the fund include NOAA and the Shell Oil Company. Both the rain garden and the vegetated swale would qualify for funding from these grant opportunities.

The timeline for the implementation of these recommendations would be to have four phases to keep the beach usable while construction is underway. The first phase would be to improve the stormwater infrastructure through the concrete endwalls and the FOG skimmers solutions. Phase 2 would consist of the addition of the vegetated swale at the south end of Lassing Park. After, phase 3 will include the implementation of the geotextiles and mangrove living shoreline solution. If funding is secured, the team would recommend the implementation of the rain garden as the final phase of the project.

References

Acomb, G., M. Clark (2008) Florida Field Guide to Low Impact Development, University of Florida- Program for Resource Efficient Communities, Gainesville, FL.

AECOM (2015) St. Petersburg Downtown Waterfront Master Plan, City of St. Petersburg, FL. 84-86. <https://www.stpete.org/city_initiatives/docs/FINAL_DWMP_2015_06_04_web.pdf>

Britannica Encyclopedia (2019) "Mangrove plant", Flowering Plants, accessed 7 April 2021, <https://www.britannica.com/plant/mangrove>

City of St. Petersburg (2019) Water Quality Report Card 2019, Ambient Water Quality Monitoring Program, St. Petersburg, FL.

Department of Environmental Quality (2003) Biofilters For StormWater Discharge Pollution Removal, DEQ Northwest Region StormWater Department, Oregon

Florida Department of Transportation (2021) Drainage manual, Tallahassee, Florida. Andrew D. Short (2012) Coastal Processes and Beaches, Nature Education Knowledge 3, Sydney, Australia.

Florida Department of Transportation (2019) Historical Item Average, Tallahassee, Florida. <https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/programmanagement/estimates/historicalcostinformation/files/historicalitemaverage_12month_20190101-20191231.pdf?sfvrsn=940303c2_2>

Gadsden, Sandra (2012) Plan to Protect Lassing Park from Erosion is a Chance to Educate Dog Owners, Tampa Bay Times. <https://www.tampabay.com/opinion/columns/plan-to-protect-lassing-park-from-erosion-is-a-chance-to-educate-dog-owners/1240170/>

SECUTEX® geotextile - made in Malaysia. (2019, May 31). Retrieved April 09, 2021, from <https://naue.asia/products/geotextile-sandbags-sand-container-and-tubes-secutex-soft-rock/>

Minnesota Pollution Control Agency (2009) Low Dissolved Oxygen in Water: Causes, Impact on Aquatic Life - An Overview, Water Quality/Impaired Waters, St. Paul, MN.

Municode Library (2021) "Supplement 38 Code of Ordinances, City of St.Petersburg accessed 8 March 2021, <https://library.municode.com/fl/st._petersburg/codes/code_of_ordinances?nodeId=PTIISTPECO_CH21PARE_ARTIIICHUSDEPAPR_S21-83IDCHPAPRnces>.

Natural service conservation service (2010) Hydrology National Engineering Handbook, 15, United States department of agriculture, Washington DC.

NOAA (2021) "What is an Estuary? Estuaries Tutorial", in National Ocean Service, U.S. Department of Commerce, accessed 22 February 2021, <https://oceanservice.noaa.gov/education/tutorial_estuaries/est01_whatis.html#:~:text=In%20fresh%20water%20the%20concentration,from%200.5%20to%2035%20ppt.>

Plage, E. (2016) "Oyster Reef Balls," Tampa Bay Watch, accessed 10 February 2021, <https://tampabaywatch.org/restoration/oyster-communities/oyster-reef-balls/>

Royle, Z. (2015) “Living Shorelines,” American Littoral Society, accessed 18 February 2021, <https://www.cleanoceanaction.org/fileadmin/editor_group2/Water_Quality/Living_Shorelines_ALS.pdf>.

Rutgers EcoComplex (2019) Green Infrastructure Champion Training: Part 5 “How To Design and Build a Rain Garden”, Water Resources Program, Bordentown, NJ.

Sandbaggy “Coir Mat - Biodegradable Erosion Control Matting - Lasts 2-5 Years”, Products, accessed 7 April 2021, <https://sandbaggy.com/products/coir-mat?variant=32811871797353>

Tampa Bay News (2020) “Piece of Florida history fades into the Gulf, as state completes demolition of Redington Long Pier,” Tampa Bay Newspaper, accessed 3 March, 2021, <https://www.tbnweekly.com/beach_beacon/article_6a1eed7c-9540-11ea-941d-677d33352760.html >

Un, K. (2010) “Fact Sheet: Vegetated Swales,” Metropolitan Area Planning Council (MA), accessed 15 Februaru, 2021, <https://www.mapc.org/resource-library/fact-sheet-vegetated-swales/.>

U.S. Department of Agriculture (2005) Rain Gardens, Natural Resources Conservation Service, Washington, DC.

U.S. EPA (2006) Total Phosphorus, Stream Monitoring, U.S. Environmental Protection Agency, Washington, DC.

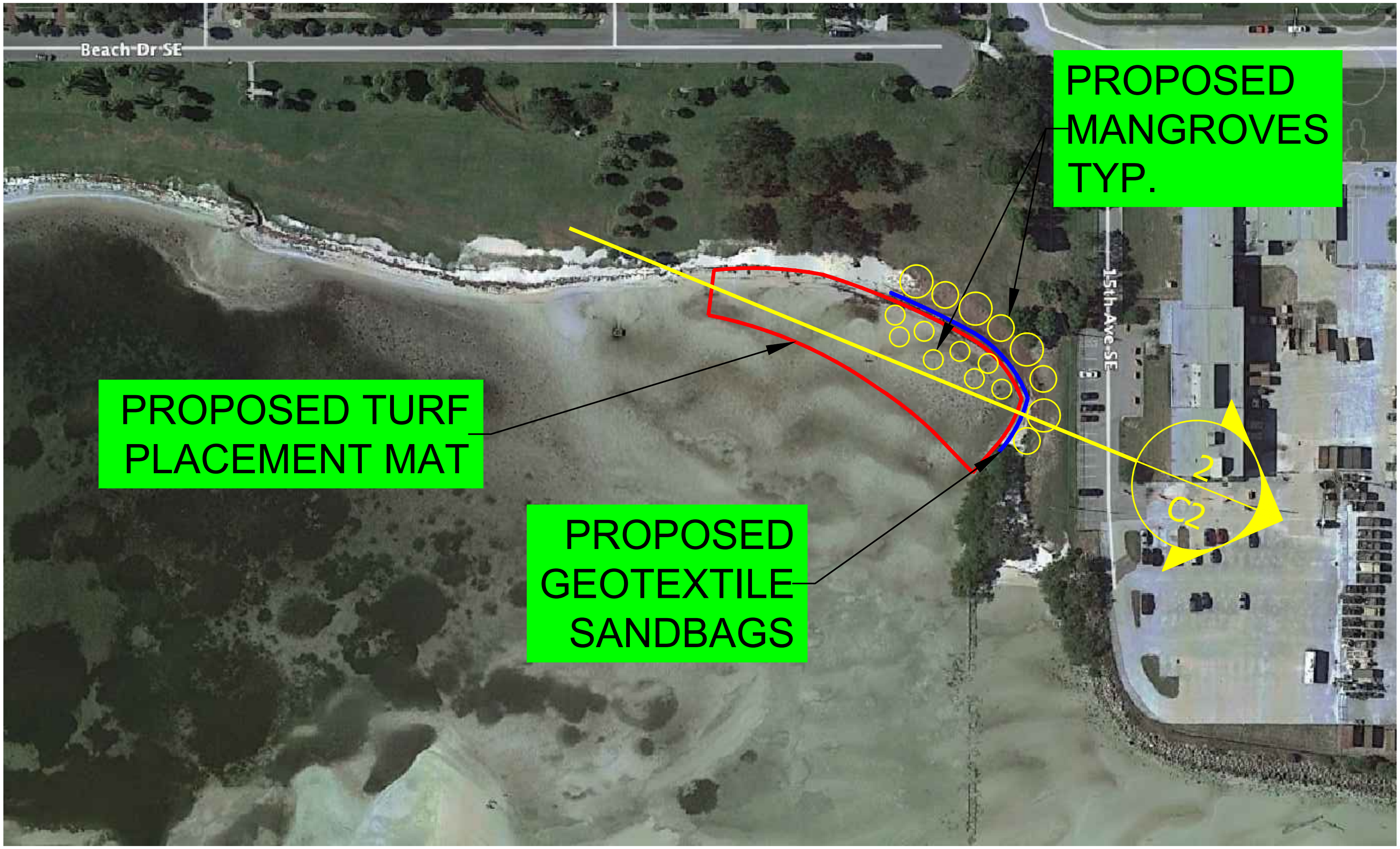
Virginia Aquarium Water Quality Parameters Explained, Marine Science Center.

Virginia Institute of Marine Science (2021) “Dead Zone Impacts”, accessed 22 February 2021, <https://www.vims.edu/research/topics/dead_zones/impacts/index.php#:~:text=The%20concentration%20of%20dissolved%20oxygen,migrating%20out%20of%20the%20area.>

Water Atlas “Pinellas County Wateratlas”, Water Atlas - University of South Florida, accessed 17 February 2021 <https://wateratlas.usf.edu/>

Appendices

Appendix A - AutoCAD Plans and Profiles



1 GEOTEXTILE AND LIVING SHORELINE LAYOUT

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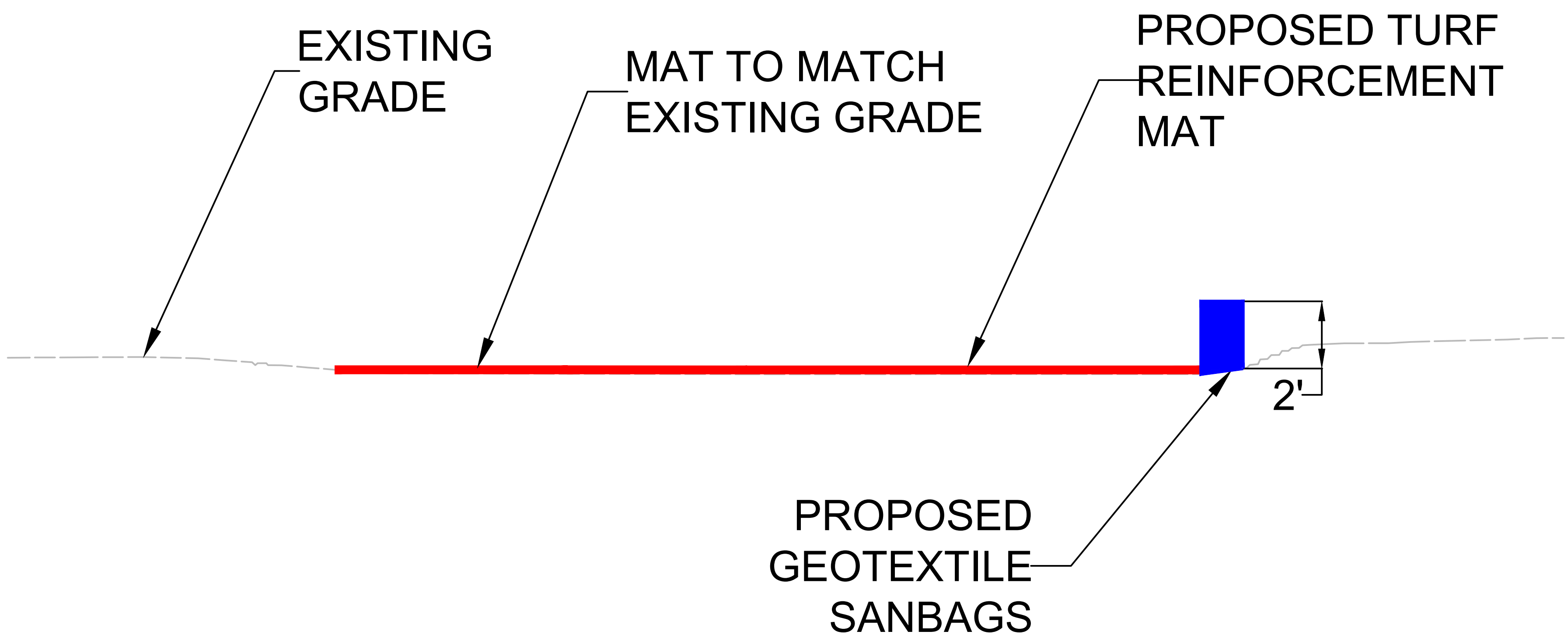

2 GEOTEXTILE PROFILE

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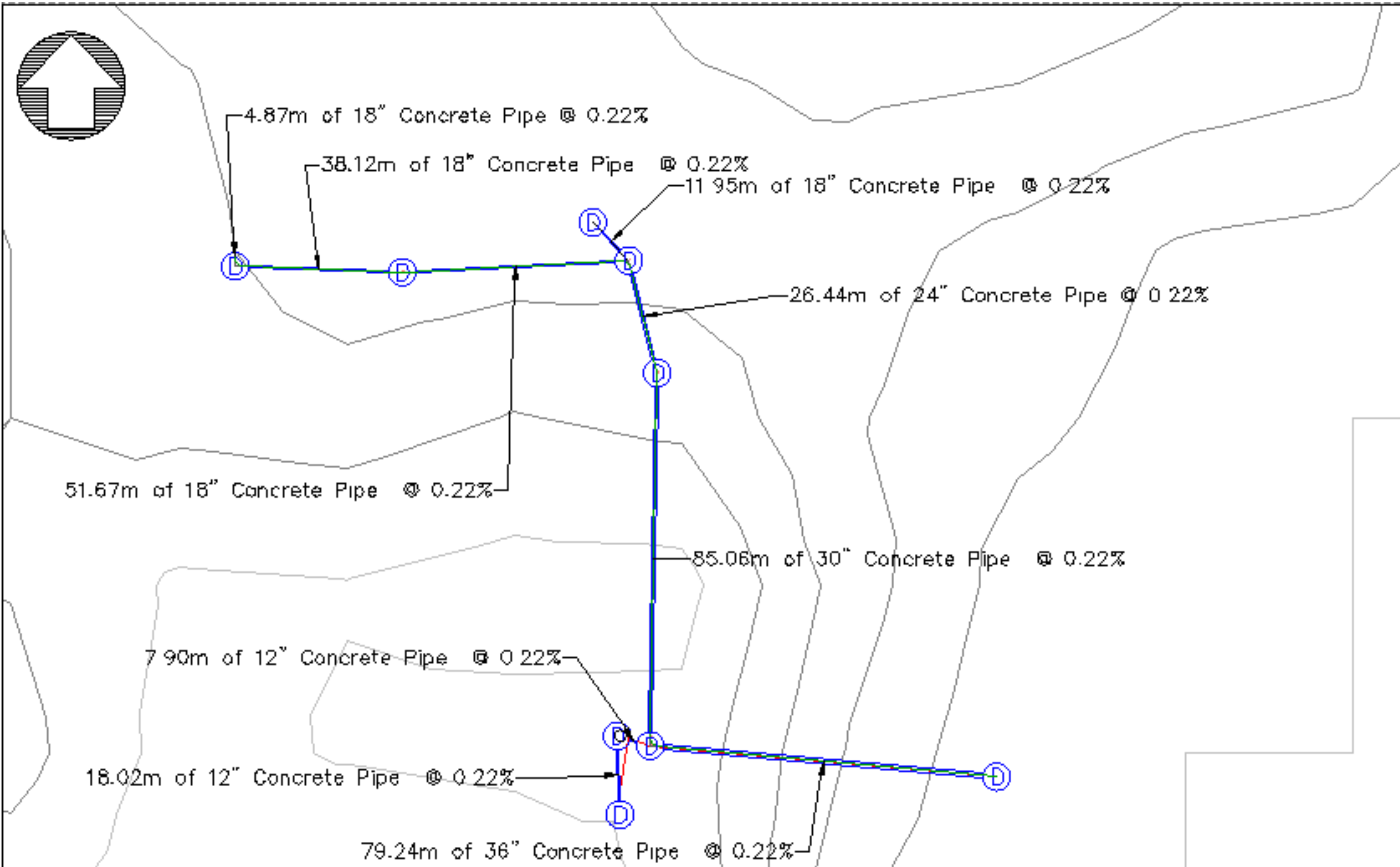

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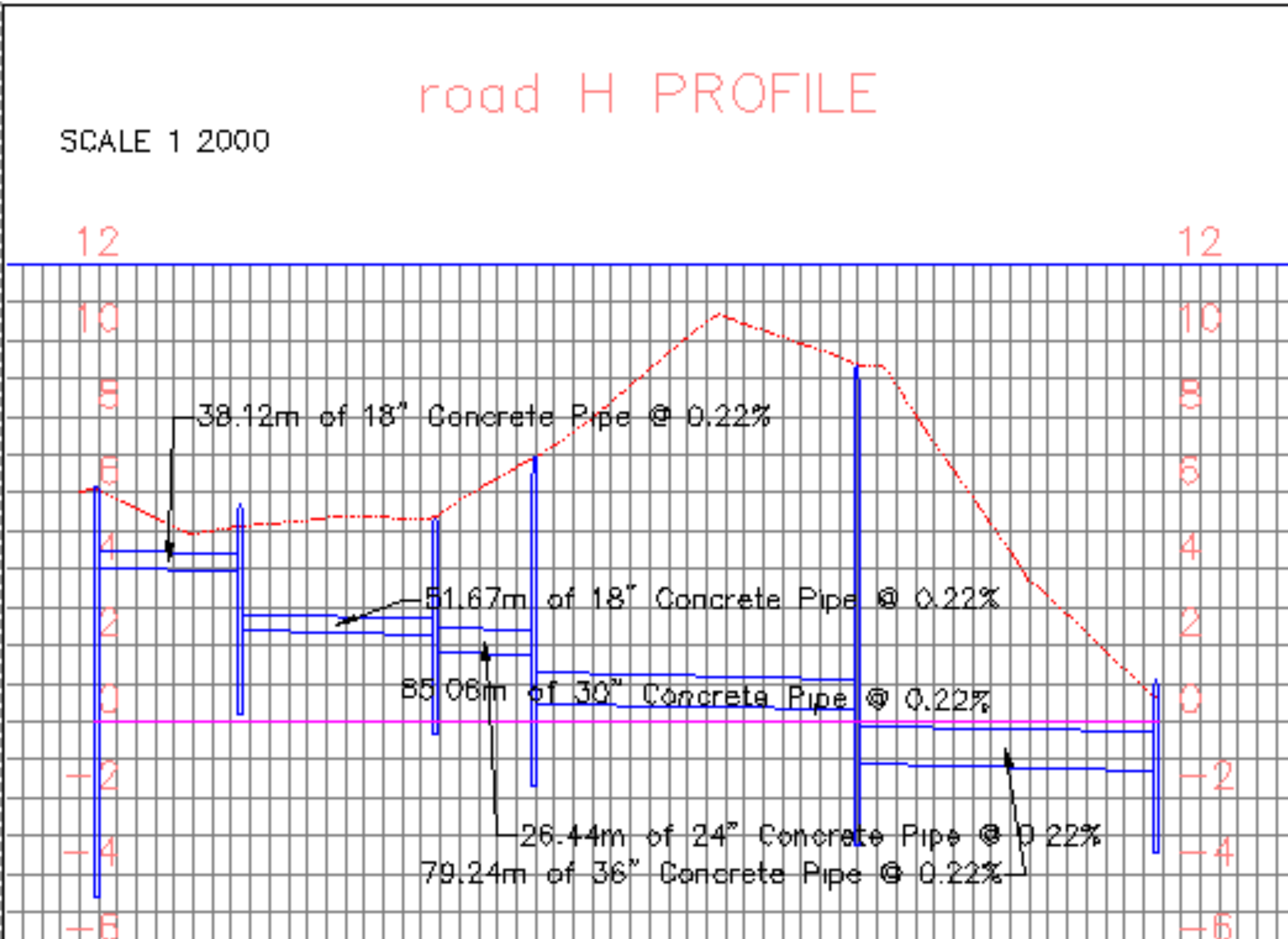

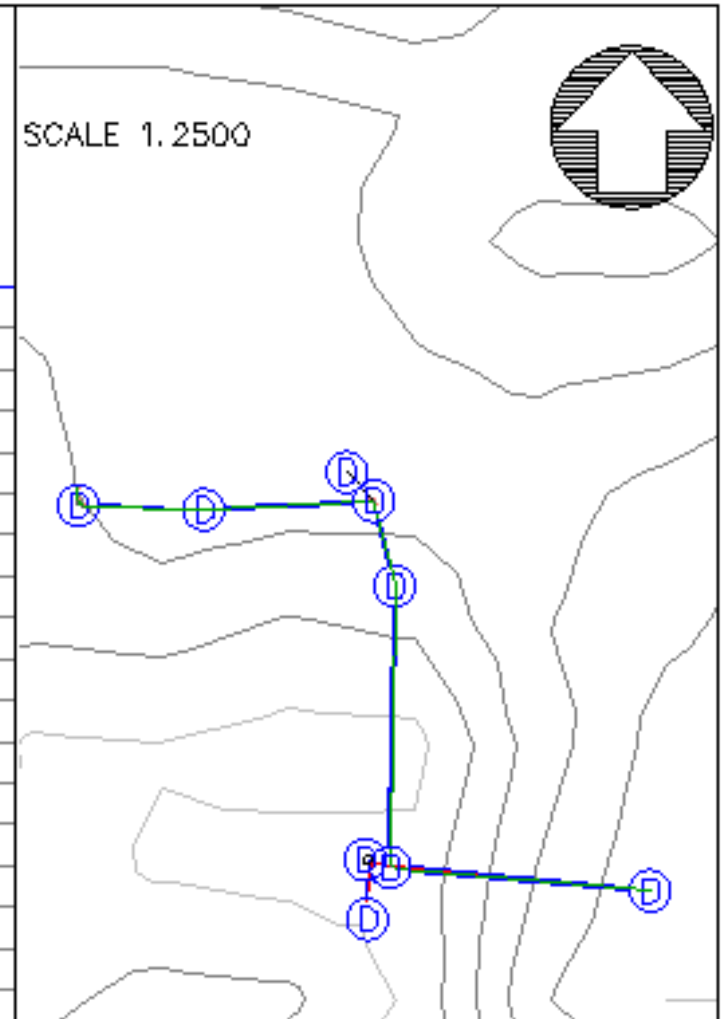

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33705

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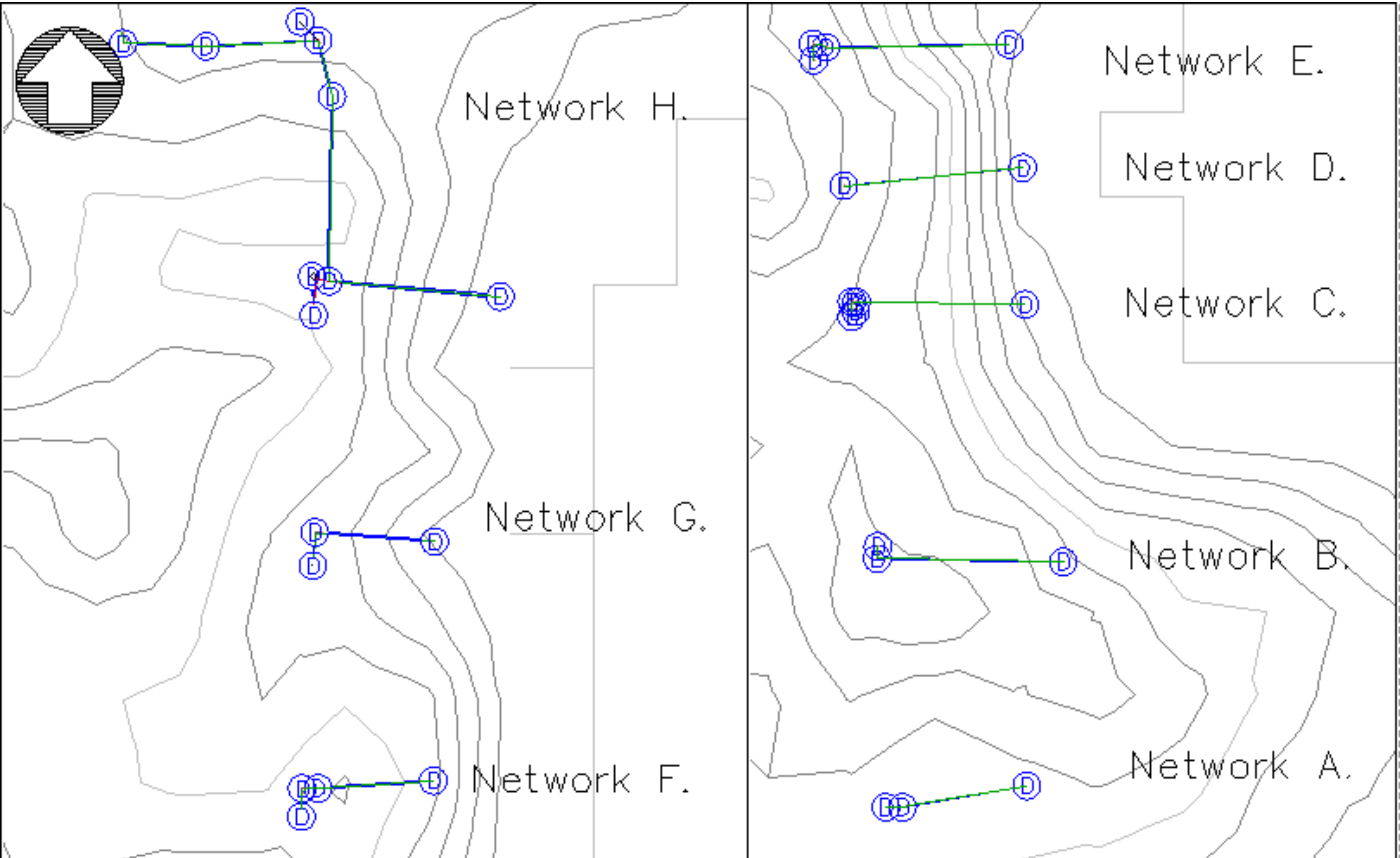

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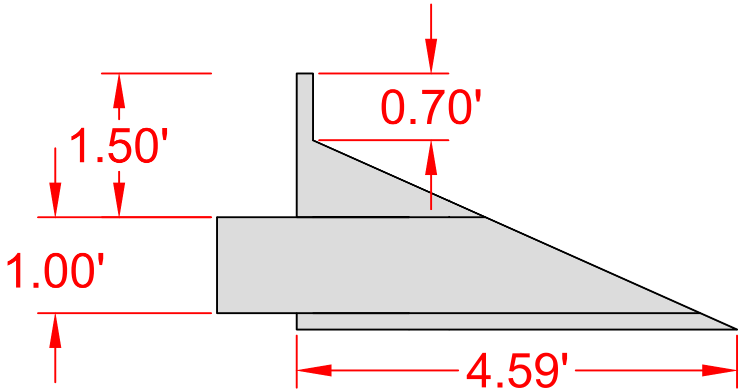

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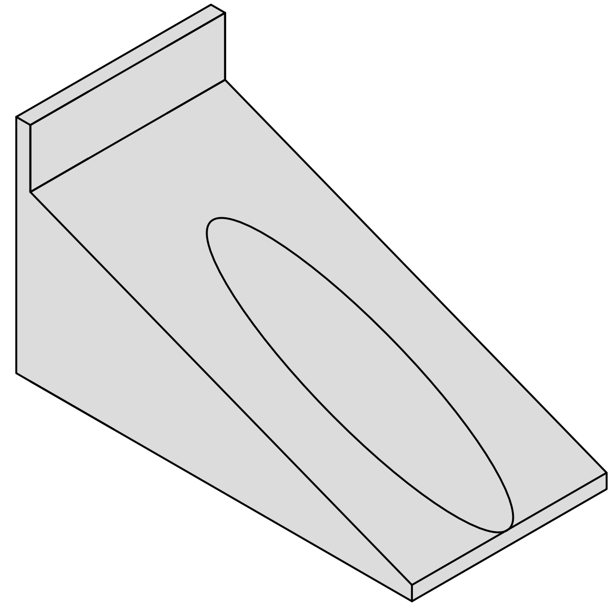
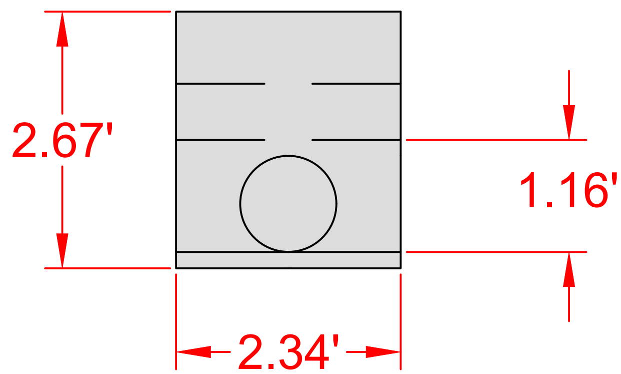


3D VIEW



FRONT VIEW

3 STORMWATER STRUCTURES

Scale: 1:150

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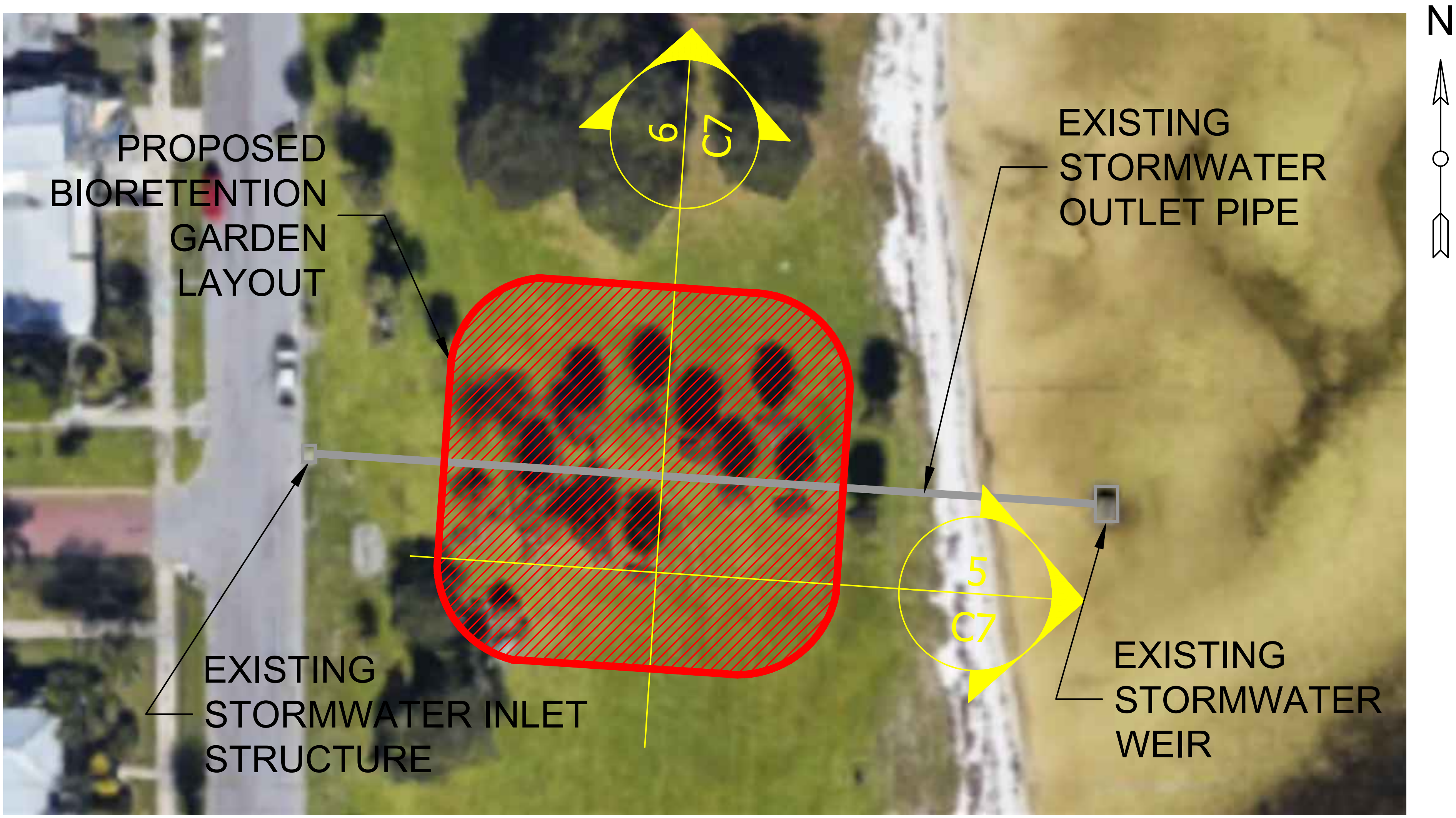

4 BIORETENTION GARDEN

Scale: 1:50

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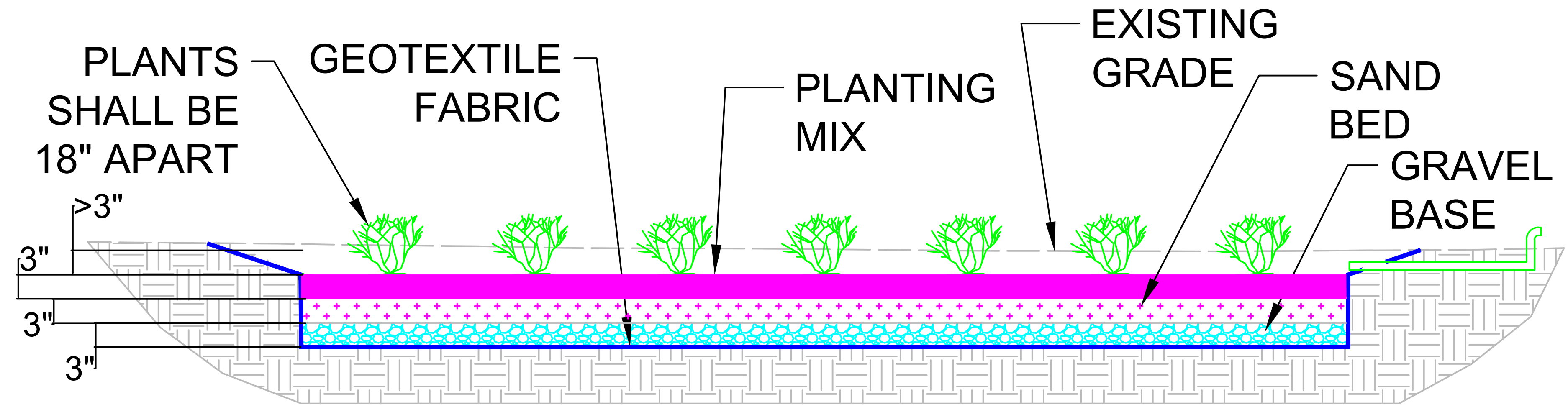

6 BIORETENTION GARDEN SECTION NS

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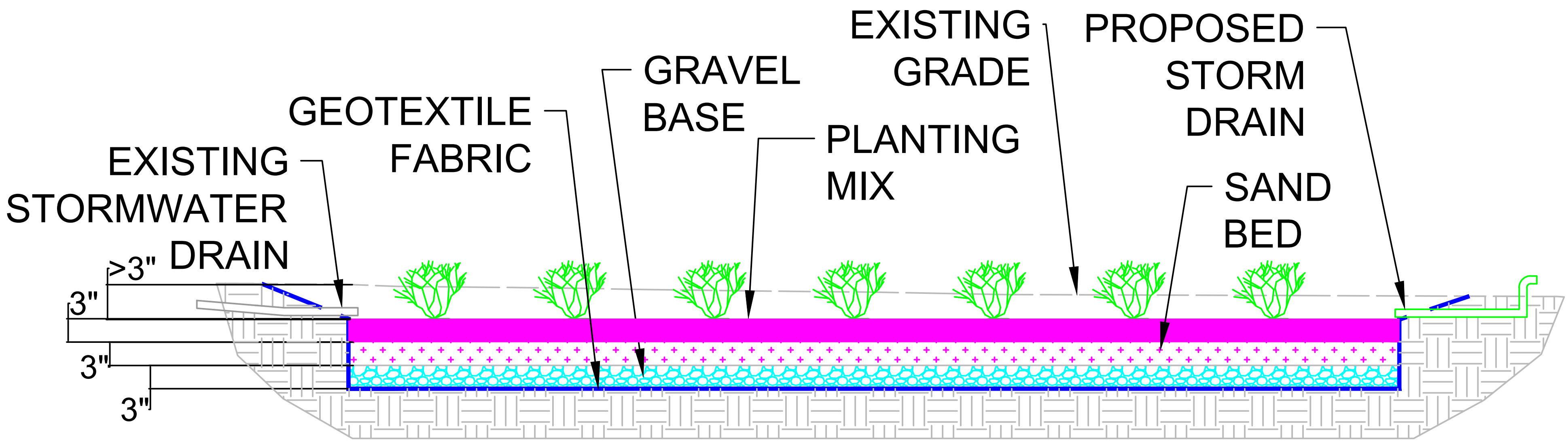

5 BIORETENTION GARDEN SECTION EW

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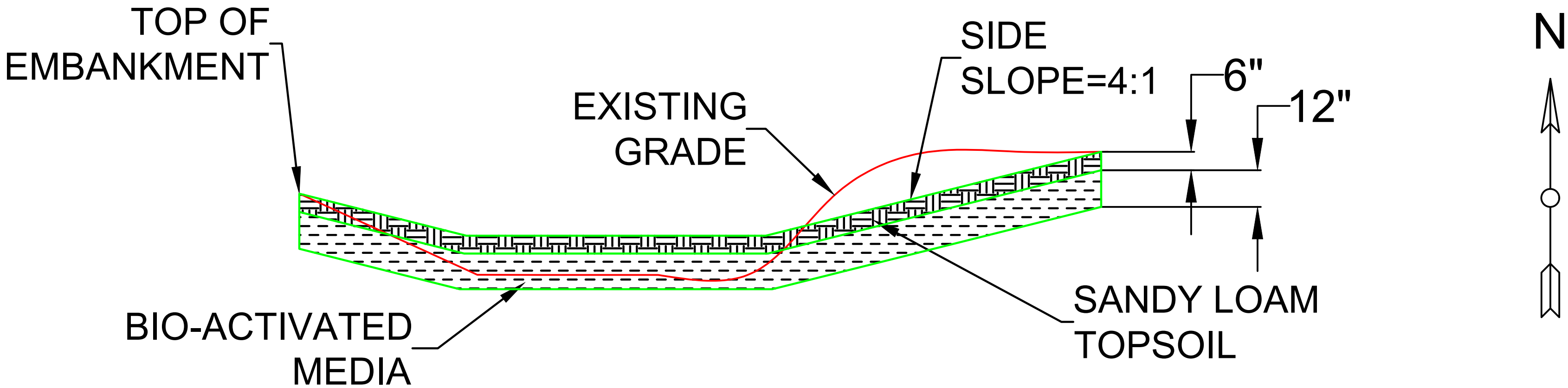
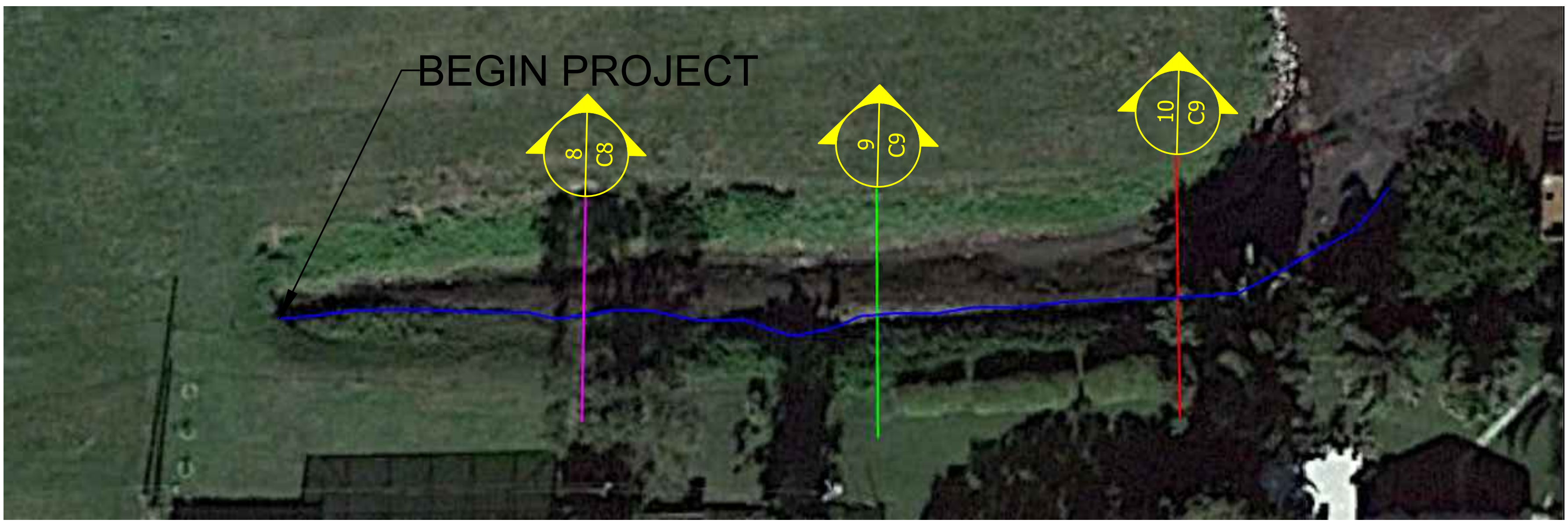
SCALE AS SHOWN	
SHEET C8	



8 VEGETATED SWALE PROFILE

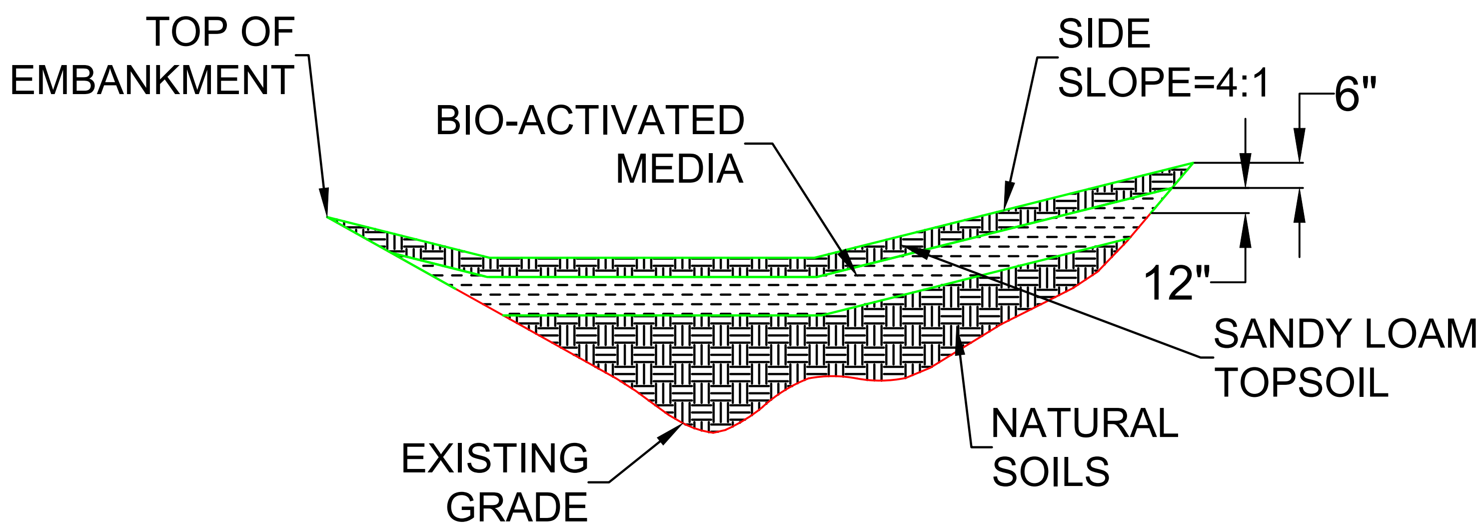
Scale: NTS



7 VEGETATED SWALE

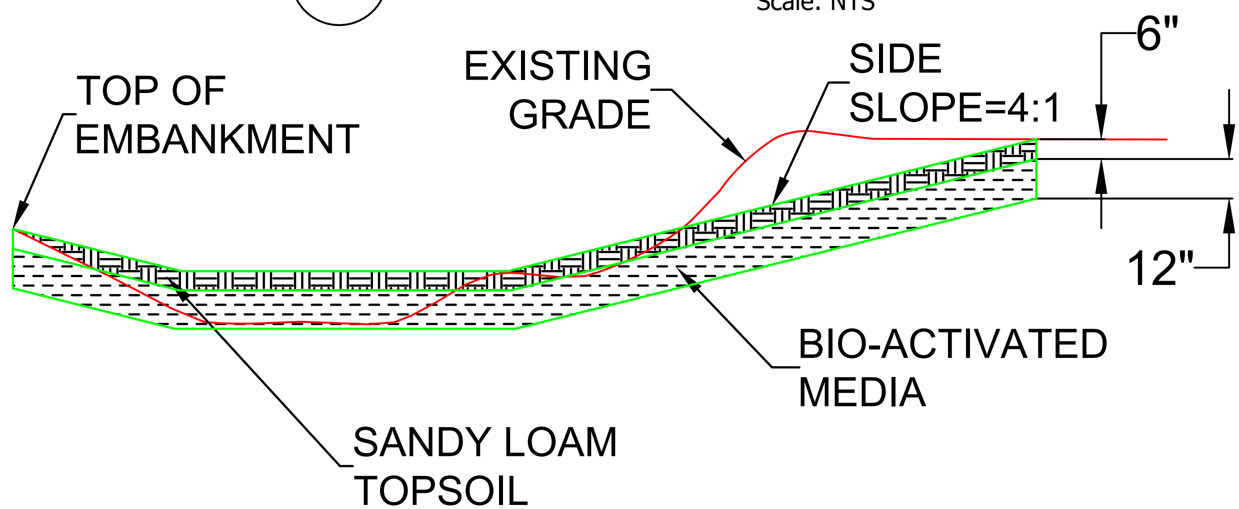
Scale: 1:20

Aqua Engineering	AQUA ENGINEERING 4202 E FOWLER AVE TAMPA, FL 33620	CITY OF ST.PETERSBURG LASSING PARK 2042 BEACH DR. SE ST.PETERSBURG, FL 33705	DATE: 04/09/2021 DRAWN BY: MP SCALE AS SHOWN SHEET C9



10 VEGETATED SWALE PROFILE

Scale: NTS



9 VEGETATED SWALE PROFILE

Scale: NTS

Aqua Engineering	AQUA ENGINEERING 4202 E FOWLER AVE TAMPA, FL 33620	CITY OF ST.PETERSBURG LASSING PARK 2042 BEACH DR. SE ST.PETERSBURG, FL 33705	DATE: 04/09/2021 DRAWN BY: MP SCALE AS SHOWN SHEET C10

Appendix B - Data Tables and Schematics

Figure A. Existing Stormwater Infrastructure of Lassing Park and the Surrounding Area

Figure B. Segregated Basins Constructed with ArcGIS

Table B. Runoff Coefficients for Different Surfaces

Slope	Land Use	Sandy Soils Min.	Sandy Soils Max.	Clay Soils Min.	Clay Soils Max.
Flat (0-2%)	Lawns	0.05	0.10	0.13	0.17
	Rooftops and pavement	0.95	0.95	0.95	0.95
	Pervious pavements[2]	0.75	0.95	0.90	0.95
	Woodlands	0.10	0.15	0.15	0.20
	Pasture, grass, and farmland[3]	0.15	0.20	0.20	0.25
	Residential				
	SFR: 1/2 acre lots and larger	0.30	0.35	0.35	0.45
	SFR: smaller lots and duplexes	0.35	0.45	0.40	0.50
	MFR: apartments, condominiums	0.45	0.60	0.50	0.70
	Commercial and Industrial	0.50	0.95	0.50	0.95

Table C. Results for C Coefficient for Each Basin

Basin	*Impervious Area (acres)*	*Pervious Area (acres)*	*C*
A	1.50	1.68	0.55
B	1.69	2.17	0.53
C	1.88	1.62	0.60
D	0.45	0.28	0.66
E	1.18	1.37	0.55
F	2.00	2.31	0.55
G	1.61	1.40	0.60
H	5.13	3.19	0.66

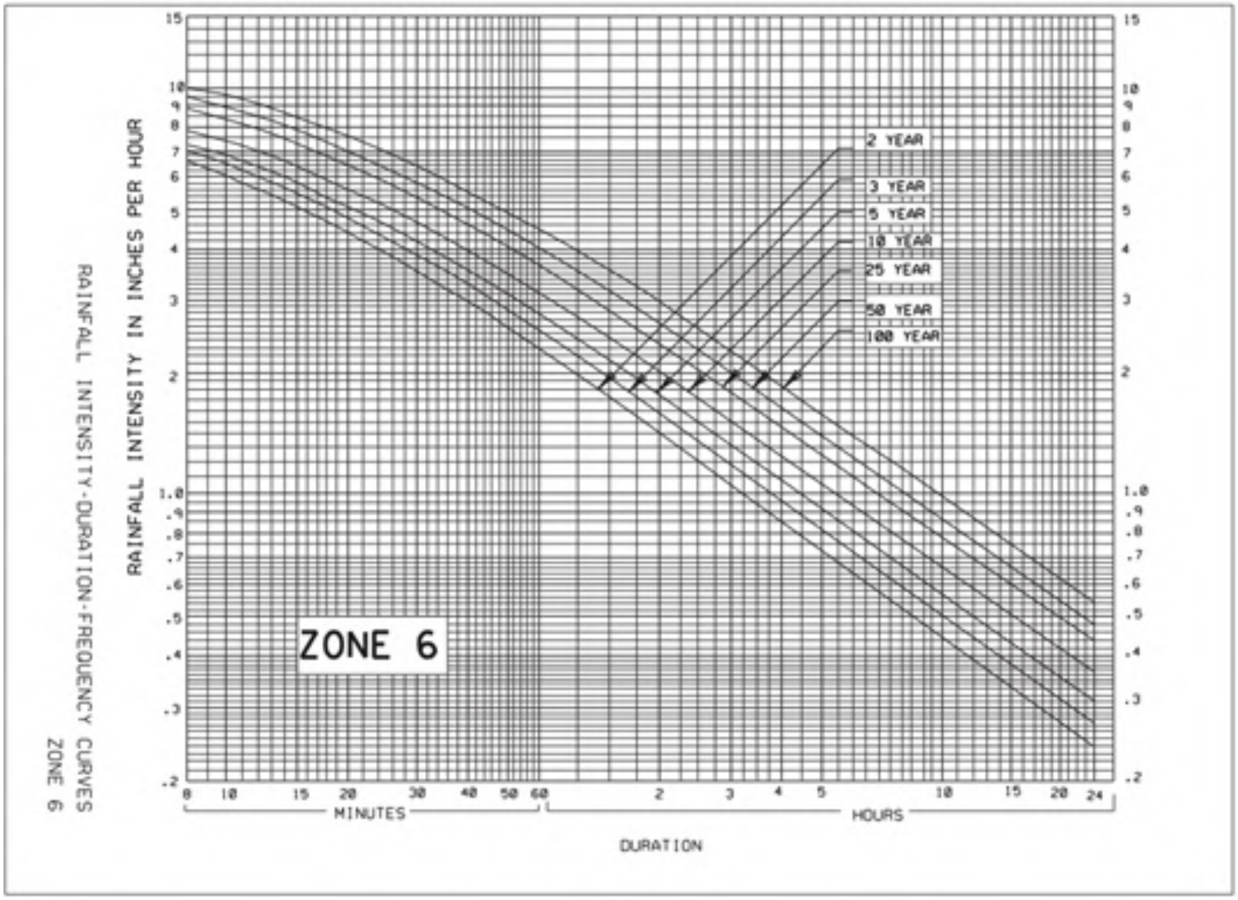


Figure C. Zone 6 IDF Curves

Table D. Terrain Slopes for Each Pipe Network

Pipe #	*Inlet Height*	*Inlet Correction (- 3 feet)*	*Exit Height*	*Length (feet)*	*Slope(%)*
H	5	2	0	928	0.22
G	5	2	0	171	1.17
F	7	4	0	177	2.26
E	8	5	0	203	2.46
D	10	7	0	294	2.38
C	10	7	0	242	2.89
B	10	7	0	279	2.51
A	8	5	2	190	1.58

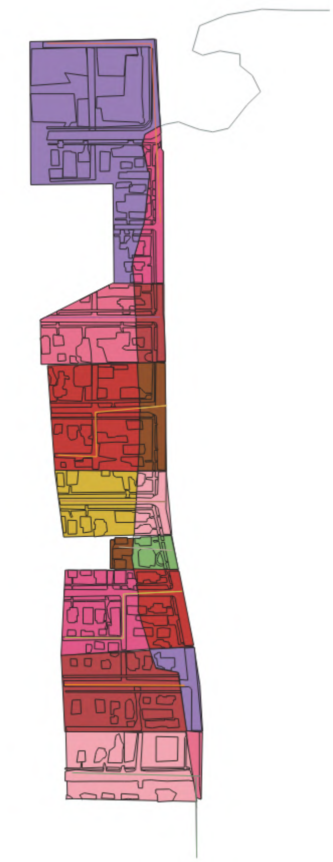


Figure D. GIS Generated for Hydrologic Soil Group Boundary

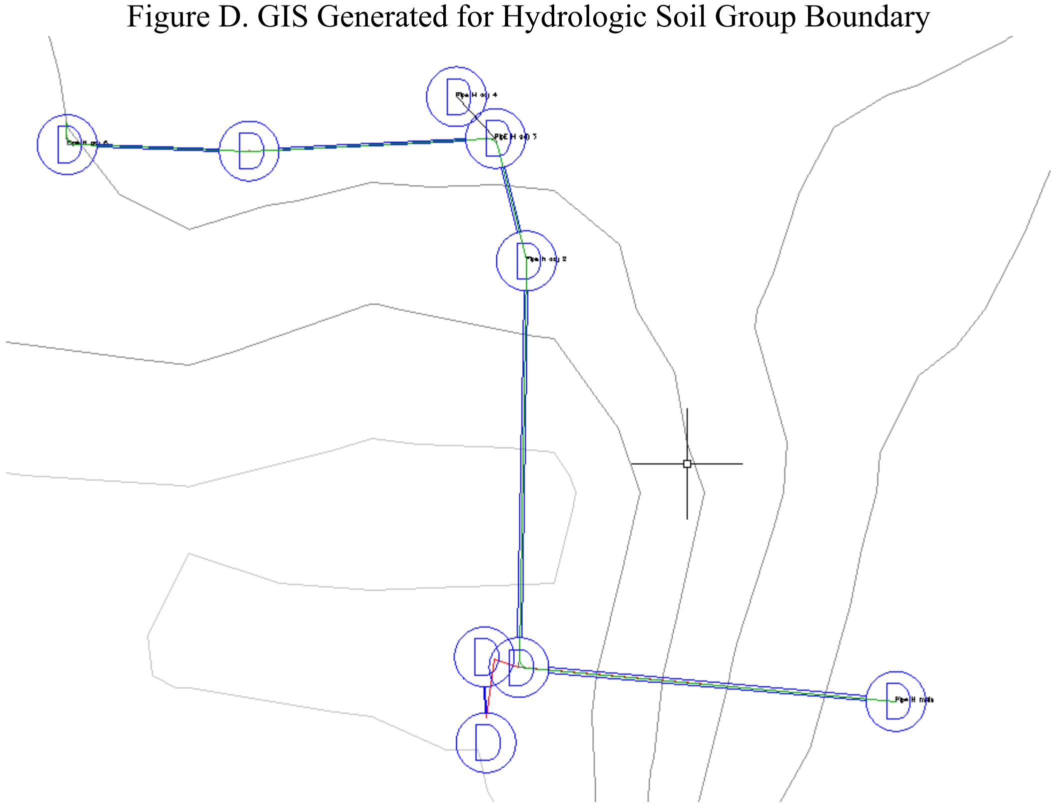


Figure E. Stormwater Pipe Network for Basin H Constructed in Civil 3D

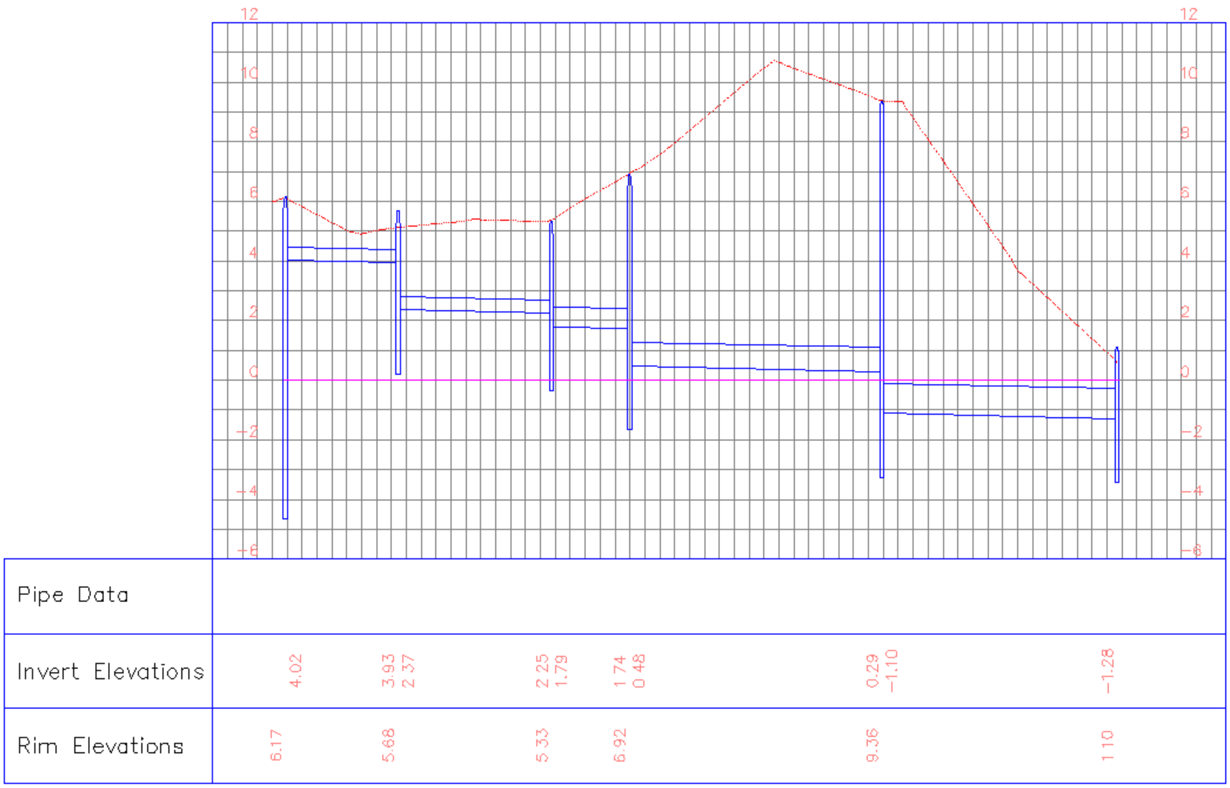


Figure F. Stormwater Pipe Network for Basin H Constructed in Civil 3D Profile

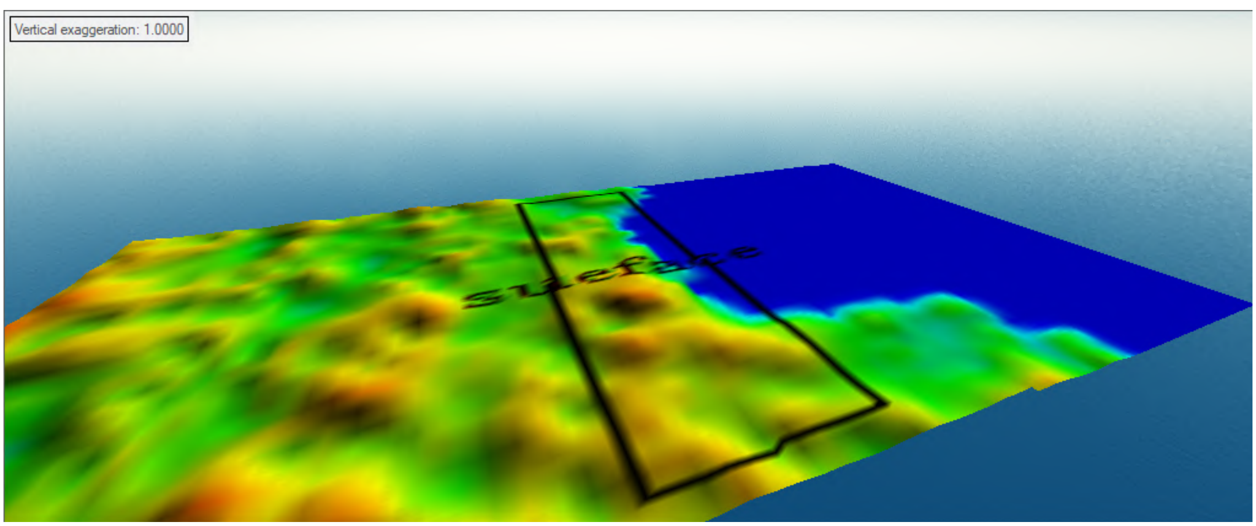


Figure G. 3D Model Constructed with Global Mapper Software

Appendix C - Sample Calculations

Rain Garden Sizing (USDA, 2005):

$$Rain\ Garden\ Size = Impervious\ Area * 0.07$$

$$Impervious\ Area = C * Basin\ Size$$

$$Impervious\ Area = 0.645 * 8.5\ acres = 5.48\ acres$$

$$Rain\ Garden\ Size = 5.48\ acres * 0.07 = 0.38\ acres$$

Open Channel Manning's Equation (FDOT,2021):

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

$$R = \frac{bd + xd^2}{b + 2dx}$$

$$R = \frac{(5ft * 1ft) + (4ft * (1ft)^2)}{5ft + (2 * 1ft * 4ft)} = 0.6923\ ft$$

$$\frac{4ft}{s} = \frac{1.49}{0.033} * \left(0.6923^{\frac{2}{3}}\right) * \left(S^{\frac{1}{2}}\right)$$

$$S = 0.0128 = 1.28\%$$

Time of Concentration:

Kirpich Method:

$$T_c = 0.06628\ \left(\frac{L}{S^{0.5}}\right)^{0.77}$$

SCS Ranser Method:

$$T_c = 0.947\ \left(\frac{L^3}{H}\right)^{0.385}$$

CiA Method:

$$T_c = 0.28\ \left(\frac{L}{S^{0.25}}\right)^{0.76}$$

Table A. Sample Calculation for Time of Concentration in Basin B

	imperia units	*SI units*	*Kirppich*	*SCS Ranser*	*CIA*	*average (hours)*	*average (mins)*
L	439.00	133.81	0.15	0.15	0.19	0.16	9.72
H	1.00	0.30					
C	0.53	0.53					
S	0.00	0.00					
A	3.87	15647.08					

Appendix D - Cost Analysis

Alternative 1 - Old Pier Removal

Item	Description	Quantity	Unit	Unit Cost	Amount
1	Removal of Existing Structure	2340	SF	$39.19	$ 91,704.60
				TOTAL	$ 91,704.60

Alternative 2 - Geotextiles and Living Shoreline

Item	Description	Quantity	Unit	Unit Cost	Amount
1	Red Mangrove Propagules	200	EA	$ 5.00	$ 1,000.00
2	Red Mangrove Juvenile Plants	20	EA	$ 15.00	$ 300.00
3	Mangrove Installation	220	EA	$ 10.00	$ 2,200.00
4	Coir Geotextile Mat/ Liner	1835	SY	$ 5.24	$ 9,615.40
5	Geotextile Sandbags	15.00	EA	$ 749.00	$ 11,235.00
6	Earth Anchors	10	EA	$ 50.00	$ 500.00
7	Earthwork/ Sand Fill	3670.00	CY	$ 11.67	$ 42,828.90
8	Geotextile Installation	700.00	FT	$ 4.00	$ 2,800.00
				TOTAL	$ 70,479.30

Alternative 3 - Stormwater Improvements (Concrete Armoring and FOG Skimmers)

Concrete Endwall:

Item	Description	Quantity	Unit	Unit Cost	Amount
1	Regular Excavation	24	CY	$9.14	$219.36
2	Mitered End Section, 15"	8	EA	$1,403	$11,221.92
3	Utility Pipe, Adjust/Modify	16	LF	$70.00	$1,120.00
4	Bedding Stone	2	TN	$147.78	$295.56
				TOTAL	$12,856.84

FOG Skimmers:

Item	Description	Quantity	Unit	Unit Cost	Amount
1	Ultra-Curb Guard Fixed Model	24	LF	$ 284.00	$ 6,816.00
2	Annual Upkeep - Buildup Removal	32	EA	$ 25.00	$ 800.00
				TOTAL	$ 7,616.00

Alternative 4 - Bioretention Bed (Rain Garden)

Item	Description	Quantity	Unit	Unit Cost	Amount
1	Selective Clearing and Grubbing - Areas with Trees to Remain	0.381	AC	$ 17,834.95	$ 6,792.12
2	Pipe Filling and Plugging - Place out of Service	614.41	CY	$ 342.17	$ 210,232.63
3	Litter Removal	0.381	AC	$ 39.37	$ 14.99
4	Landscape Complete Small Plants	1	LS	$ 123,000.00	$ 123,000.00
5	Irrigation System	1	LS	$ 57,418.00	$ 57,418.00
6	Utility Fittings for PVC Pipe, Furnish and Install, Elbow, 12"	12	EA	$ 1,164.00	$ 13,968.00
7	Utility Pipe - PVC, F&I 8"	6	LF	$ 34.15	$ 204.90
8	Utility Fittings for PVC Pipe, Furnish and Install, Reducer, 8"	12	EA	$ 498.25	$ 5,979.00
				TOTAL	$ 417,609.65
				O&M	$ 12,000.00

Alternative 5 - Vegetated Swale

Item	Description	Quantity	Unit	Unit Cost	Amount
1	Selective Clearing and Grubbing - Areas with Trees to Remain	0.1583	AC	$10,342.99	$1,637.35
2	Inlet Protection System	1	EA	$101.13	$101.13
3	Litter Removal	0.1583	AC	$25.72	$4.07
4	Clearing & Grubbing	0.1583	AC	$27,446.07	$4,344.86
5	Embankment	4086.40	CY	$6.67	$27,256.26
6	Landscape Complete Small Plants	1	LS	$123,000.00	$123,000.00
				TOTAL	$156,343.68
				O&M	$12,000.00