COLLEGE OF ENGINEERING
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
BIOLOGICAL SYSTEMS ENGINEERING

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Dear Dr. Hession,

Enclosed is the requested technology review for the project titled "Newton Creek Resiliency Project." This document discusses rising sea levels due to climate change and its adverse effects on the city of Norfolk and the St. Paul redevelopment area. Potential solutions, such as shallow bioretention ponds, migrating salt marshes, and grassed detention areas are included. The appendices that follow detail team brainstorming sessions, encountered and anticipated challenges, a Gantt chart project timeline, and team member responsibilities.

Sincerely,

Ellie Buehrer | Gavriel Cambridge | Cyrus Li | Parker Sullivan

Enclosure: Technology Review

Newton Creek Resiliency Project

Technology Review

BSE 4125: Comprehensive Design Project
October 31, 2023

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Introduction

Coastal areas around the world are home to more than 40% of the world's population (United Nations, 2007). Communities in these coastal areas face the traditional challenges of stormwater management associated with urbanization, as well as rising sea levels as a result of anthropogenically induced climate change. Increasing atmospheric greenhouse gas concentrations have led to warmer global temperatures, melting polar ice caps and increasing sea level, while also increasing the intensity and frequency of heavy precipitation events (Nicholls and Cazenave, 2010) As such, coastal communities face a unique series of challenges in the coming years if they are to adapt to rapidly changing conditions.

One such community is found in Norfolk, Virginia. Newton Creek is a tidal creek in the St. Paul's neighborhood of Norfolk that was converted to industrial and residential land in the 1920’s by infilling the creek channel and installing a stormwater drainage network (Jepsen, 2019). In modern storm events, this area floods as the existing stormwater system is no longer equipped to handle the higher intensity precipitation events that occur more frequently with climate change. Simultaneously, rising sea levels have led to increased tidal inundation in the low-lying areas of the former creek bed.

A redesign of this site would allow for increased drainage of surrounding areas, provide blue-green space for community recreation, and provide habitat for coastal species. Utilization of natural solutions such as living shorelines and adaptive bioretention ponds is critical to the success and longevity of a design solution. These designs have the potential to adapt to the inevitable rise of sea level, and transition from a stormwater management solution to a longer-term coastal resilience solution as conditions change (Zaratzian et al., 2016). Current solutions for flooding focus on either stormwater or tidal flooding independently of each other, and are often relatively short-lived (Lasage et al., 2014).

Traditional stormwater management to reduce flooding involves the resizing of pipes to increase flow, detention and retention ponds to increase storage and residence time, and finally increasing capacity for downstream delivery of floodwaters. Many of these solutions are simply not possible in coastal areas, as a result of the topography in the area. Low-lying coastal areas have higher water tables, meaning that storage solutions would provide insignificant storage without uncovering the water table. Furthermore, passive drainage of coastal areas is difficult as there is very little change in elevation between flooded areas and sea level. These challenges are only exacerbated by rising water tables and sea levels.

In addition to stormwater management, conventional defenses against tidal inundation include a variety of gray infrastructure, such as sea walls, jetties, and other man-made barriers designed to dissipate wave energy and impound inland areas against flooding. These solutions have limited efficacy over a design life, as they degrade with time and are unable to adapt to rising sea levels. Natural barriers, on the other hand, can adapt to changing conditions, and improve in performance with time. Some natural coastal resilience solutions include native vegetation, shellfish and reef communities, and dynamic sediment features such as dunes and deltas.

In some cases, flooding may be inevitable, and an engineering solution to eliminate it may not exist. In such instances, moving development inland is one of the most feasible solutions to dealing with these challenges, and provides an opportunity for the creation of designs that can adapt to changing conditions. Embracing inland migration makes way for a solution that addresses the current and near-future challenges with stormwater management, and has the potential to transition into a long-term coastal resilience solution as sea levels rise. This project aims to create a stormwater management solution with the intended purpose of transitioning into a coastal resilience solution at the end of its design lifetime. This report serves as a review of existing designs addressing similar challenges in addition to applicable engineering, ecology, hydrology, and soil concepts relevant to the creation of our design, and to generate reasonable standards for design selection and performance.

A combination of all of the approaches described above can be implemented at the Newton Creek site to effectively reduce flooding in the upland area, impede sediment and other pollutants from entering the Elizabeth River, reduce coastal erosion by constructing a living reef, create community spaces, and foster new ecosystems. Lastly, to improve upon previous development efforts in this region, the Newton Creek project should keep the future population of Norfolk in mind, and create a solution that will not falter in the face of future environmental conditions (as the old designs largely have).

Technology Review

In order to aid the design process, a number of engineering standards have been selected. Four design standards in particular were chosen based on their relevance to the unique challenges posed by the project at Newton Creek. The standards outlined in the Virginia Department of Environmental Quality (VADEQ, 2011a) Stormwater BMP Clearinghouse are of particular interest to a project like this one, because they outline tried and true methods for the construction of multiple stormwater detention installations, for example bioretention cells, dry and wet swales, constructed wetlands, and extended detention ponds, among other structures. At a site like Newton Creek, close to the shore where the water table can be just a few inches below the ground at high tide, even minor digging will lead to permanent standing water in any sediment or water detention structure. Therefore, multiple design types present themselves depending on the depth of excavation. From least to most excavation required, those designs are bioretention cells, constructed wetlands, then wet ponds or extended detention ponds.

A bioretention cell functions by capturing storm runoff, filling temporarily to a depth of between 6-12 in. The water is allowed to quickly infiltrate into the ground through a filter bed, which is typically composed of sand, soil, and organic material (VADEQ, 2011a). The now filtered stormwater is collected through a pipe, often perforated, back into a larger stormwater conveyance system. This type of system is known as a *bioretention filter.* Alternatively, the cell may allow water to infiltrate directly back into the cell, recharging the groundwater aquifer untreated. This type of design is most suited for areas with low potential for stormwater contamination, and is referred to as a *bioretention basin,* according to the VA BMP Clearinghouse. At the Newton Creek project, there is ample room to include one or multiple bioretention filters or basins, especially in the more upland area. Additionally, there is a location at the site containing impervious concrete lined channels meant to hold stormwater before being discharged through modified Filterra units. That particular BMP could be modified and retrofitted to act more like a bioretention cell.

One limitation of a bioretention cell is that, according to the VADEQ, “A separation distance of 2 ft is recommended between the bottom of the excavated bioretention area and the seasonally high groundwater table.” The report goes on to specify that this distance may be modified down to 12 inches for coastal plain locations, like that of Norfolk and the Newton Creek site.

It should be noted that any large engineering project must carefully balance innovation and the use of standards. The methods described in widely used standards have a proven track record of effectiveness, and can therefore be relied upon to provide quality advice and guidelines for the construction of new BMP's. However, standards do have their limitations, especially when the design of a BMP is planned at a location substantially different from the environment in which the standard was developed. This is true even after considering the special modifications described in Section 7.2 of the VA DEQ Clearinghouse Standard No. 9 for Bioretention cells, which do give some recommendations for the construction of bioretention cells in coastal plain environments. These modifications include using a linear approach to bioretention by stringing multiple cells together (thus retaining a sufficient hydraulic head), installing a large diameter underdrain (at least 6 in) and reducing the depth to the seasonally high water table, and modifying the plant species used in such a BMP, along with other considerations (VADEQ, 2011a).

Even with these modifications in mind, other innovative practices should be considered to enhance the short term efficacy and ensure long-term continued effectiveness of any BMP's designed in this environment. For example, an impervious liner may be applied underneath the bioretention cell if 1 ft of clearance between the bottom of the cell and the seasonally high water table can not be achieved (MDEP, 2016) In this way, the bioretention cell can allow stormwater to infiltrate and be connected into a larger conveyance system, while insulating the unit from the contamination of groundwater due to a high water table. Another suggestion was made during a recent site visit by the assistant director of Wetlands Watch, a local non-profit, who suggested that the surface area of a bioretention cell may be increased to larger than normal dimension if standard excavation depths can not be achieved. In this way, the Treatment Volume (Tv) of the BMP is maintained, without interference from a seasonally high water table.

Clearly, the highwater table characteristics of the site at Newton Creek pose challenges to the use of a bioretention cell as an effective BMP. Another option, which requires slightly deeper excavation, would be the construction of wetland. The VA DEQ Clearinghouse BMP Standard No. 13 described guidelines and methods for the construction of such a practice, and describes this practice as a shallow basin with a permanent pool of water 6-18 in. deep. When a rain event occurs, fresh stormwater is conveyed into the constructed wetland, where it displaces the previous treated volume of water. Thus, the water is filtered through the processes of biological uptake, gravitational settling, and other microbial processes. (VADEQ, 2011b). In addition, whereas a primary consideration of bioretention cells is separating the captured stormwater and groundwater, a constructed wetland may actually be enhanced by connection to the underlying aquifer, which can help ensure stable wetland conditions, as outlined in Section 5 of the VA DEQ Clearinghouse No 13.

Similar to the other BMP standards described by the VA DEQ Clearinghouse, there are two levels of constructed wetlands that can be built, with level 1 being a relatively more simple design compared to level 2. Level 2 requires more intense design consideration, and is therefore more effective as a nutrient removal measure (VADEQ, 2011b). What differentiates a Level 1 constructed wetland from a Level 2 constructed wetland? In the most general sense, a Level 1 constructed wetland is smaller, and has less diverse topography. There is uniform depth of inundation across the BMP, and the surface area of the BMP is less than 3% that of the drainage area. Furthermore, a Level 1 design includes no upland area; it is merely an inundated area with emergent wetland properties. This design should include a forebay. A Level 2 constructed wetland, on the other hand, has multiple cells. The topography in this design is not homogeneous, and it includes an upland area. As such, this type of design may include trees. In the most intensive Level 2 constructed wetland design, a wet pond is also included somewhere in the design. Table 13.3 of the VA DEQ Clearinghouse Standard No. 13 summarizes these differences.

What factors are most important to constructed wetland design? The VA DEQ lists the three most important considerations: plant community, contributing hydrology, and landscape position (VADEQ, 2011b). At a site like Newton Creek, a fourth consideration is also of paramount importance: integration with existing human communities and infrastructure. In an ideal world, a project like this would occur in a vacuum. The surrounding landscape would be a perfect clean slate, and the design team could make whatever decision they wanted to. Reality is far from this situation, and as such, any constructed wetland design will need to be modified to fit these criteria. On the site of this project, multiple existing infrastructure, including power lines, sewer lines, parking lots, historic buildings, roads, overpasses, and rail track will need to be kept in consideration. Moreover, the infrastructure described above is merely the physical infrastructure which must be kept in mind. Also at the Newton Creek site are multiple overlapping communities which are drawn to the area because of its proximity to the nearby Amtrak Station, Old Dominion University, and a Baptist church.

What impacts would a constructed wetland in such close relation to this existing infrastructure and communities have? How can the negative impacts of such a project be mitigated? These questions should be considered and adequately addressed for a wetland design to be chosen. Another standard, created by ASABE entitled "Prevention of Mosquito Problems Associated with Irrigation and Drainage Systems" provides valuable advice for where to start. Mosquitoes can carry a number of pathogens which pose a risk to the public health, including but not limited to Malaria parasites, Filaria, and the Japanese B encephalitis virus. In section 3.3 it is stressed that while in some agricultural contexts chemical control measures may be used (such as Bacillus thuringiensis israelensis (H-14)), insecticide resistance is on the rise in mosquito populations. Therefore, "non-chemical control measures such as habitat management and the use of biological predators should be encouraged" (VADEQ, 2011b). By laying the groundwork for the development of an entire ecosystem- allowing for native fauna in the form of amphibians, birds, and fish to thrive alongside native flora- mosquito populations can be effectively managed. In a sense, these natural habitats can provide both aesthetic and ecological services while mitigating the negative elements of constructed wetland construction.

Figure 1. Green Treefrog (*Hyla cinerea*) from Jeff Robertson Park, Norfolk, VA (photo: Cyrus Li).

Ultimately, mitigation of mosquito activity will have to be balanced against other goals of this project. For example, creation of wildlife habitat, making room for tidal and floodwater, and aesthetics may require design elements which conflict with reducing mosquito population. No single objective, therefore, can be elevated over the rest. These conflicting interests must be resolved as smoothly as possible, although some give and take will certainly be required. One possibility at the Newton Creek site would be to simply build any constructed wetlands as far away from community centers as possible. The Asian Tiger Mosquito, Aedes albopictus, is one of the most common mosquito species in the region (Mosquito-Borne Diseases, 2023). This species does not travel more than .5 mi away from its breeding grounds, however, so moving potential breeding sites as far away as possible from where humans congregate could be a good strategy (Asian Tiger Mosquito, 2023).

Creation of habitat, and mitigating the negative effects associated with it, are only one of the goals of the Newton Creek project. Possibly the most important aim of this project is to manage flooding. Excess storm water may be captured in a bioretention cell, constructed wetland, or wet pond as described above, but where will the water go once it is collected, and how will it move from the BMP to its ultimate destination? Useful clues can be found in the ASABE Standard "Underground Outlets for Conservation Practices." This standard defines terminology associated with these practices, planning and design, construction and maintenance, and safety considerations.

One of the earliest considerations addressed in this standard is that underground conduits can serve to convey contaminated runoff directly to receiving waters, and should therefore only be installed as part of a larger conservation system that addresses nutrient and pest management, as well as residue management and filter areas (Underground Outlets, 2016). Strategies for addressing these concerns have largely been described above. Nevertheless, the design team will need to ensure that any underground conduits they construct follow this advice, and only convey water after it has had a chance to be treated by other BMPs.

Section 5 of the ASABE Standard, entitled "Design," described the core function of any underground conduit system: to "remove water at a rate and quantity to meet the requirements of the practice it is serving." It goes on to state that while typically this means sizing the conduit to convey the entire maximum flow, if temporary storage is built into the upstream design area, the size of the conduit may be reduced. In this way, some ponding may occur, but in a controlled and safe manner. This section of the report goes on to describe typical relationships between the residence time in the ponded area upstream of the underground conduit, and volume of basin storage as a proportion of volume of runoff. For example, if the ponded area holds stormwater for 48 hr, the basin storage will have to be 75% of the runoff volume based on a 10 yr 24 hr storm event (Underground Outlets, 2016).

Table 2 of Section 5 lists various materials that can be used for such a conduit, and associated American Society for Testing and Materials (ASTM) standards that can be used for each. More information will need to be gathered before the design team can make a decision on what type of material to use for any underground conduits that will need to be constructed. This section also includes other important design recommendations, such as dimensions for the riser, and depth below ground that the conduit should be buried. Importantly, the document recommends using Manning's Equation for estimating flow through these types of conduits.

While the ASABE Standard on Underground Outlets provides an abundance of useful advice relevant to this project, it does not discuss a critical aspect of the Newton Creek site: tidal dynamics. In a tidal environment, flow can move both ways, so the recommendations in the ASABE standard will need to be modified to suit the requirements of the Norfolk Site. In order to assist in making these modifications, another standard, entitled "Hydraulic Controls on Tidal Wetlands" will be employed.

Tidal regime and surface nexus are important considerations in the design of a constructed wetland system designed for wetland migration and habitat succession. In the standard "Hydraulic Controls on Tidal Wetlands", several tidal regimes and their resulting wetland classification are outlined. Depending on the frequency of tidal inundation, different plant and animal communities may develop. Upon initial review of our site, we determined that the site as it exists today likely experiences "biweekly to annual" tidal flooding as described by Kana et al. (1986), thus classifying it as a site with potential for the formation of transitional wetlands. Further analysis of land surface elevation and salinity suggests that the formation of transitional marsh communities within the site conditions is possible, as some of the site already lies within the recommended range of 1 meter or less above mean sea level (MSL), and much of the site has potential for minor excavation to reach the recommended elevation for the formation of transitional wetland communities. With such low elevation and large amounts of stormwater inputs into the site, there is potential for the creation of both tidal and freshwater wetlands.

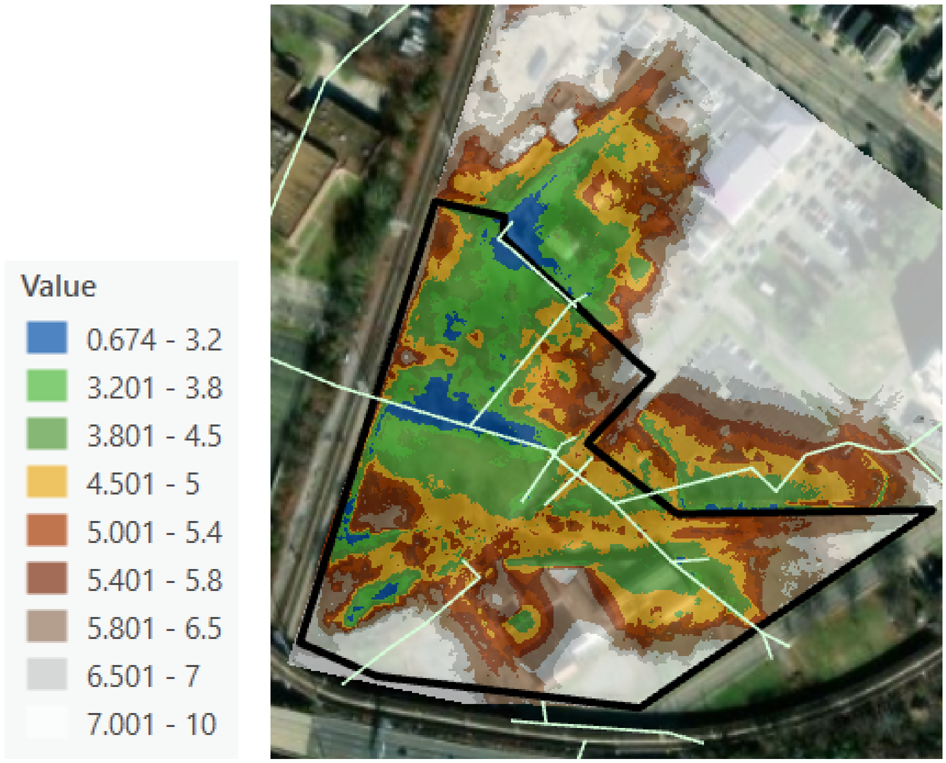

Figure 2. DEM, existing stormwater network, and site boundary for study area. Elevation in ft above mean sea level.

Although the site elevation and proximity to tidally influenced waterways are present, the surface water exchange necessary to develop tidal marsh conditions is severely limited by the presence of transportation infrastructure. Ground level train tracks to the west and elevated highway lanes to the south impede connections between the site and the remnants of Newton Creek. Katmarian et al. (1996) provides a case study on the use of ditches and culverts to restore connectivity between tidal creeks and inland marshes. Doing so allows for both increased stormwater drainage, and for the delivery of oxygenated brackish water and nutrients critical to the development of a tidal marsh. This tidal marsh would then be important in absorbing coastal flooding during high tide events and storm surges. A two-way flux through ditches and culverts depends on the difference in elevation between the restoration site and MSL, channel geometry, and channel slope. As described in the report, similar elevations (< .5 meter difference) between wetland elevation and MSL are needed to maintain frequent tidal inundation in the Southeastern United States. In the case study, over 900 meters of ditches and culverts are used to create tidal influence in a wetland isolated from the Savannah river by development. This demonstrates that it is possible to restore tidal exchange in the design site, as the site lies much closer to a tidal creek. Given that it may be possible to restore tidal influence in a section of the site, a constructed wetland or series of terraced wetlands may be built to manage flooding and water quality.

Constructed wetlands can be effective stormwater management practices by reducing flooding and improving water quality. Rizzo et al. found the constructed wetlands that were assessed to have 52.7% to 95.4% peak flow reduction (2018). Furthermore, vegetation in these wetlands can help protect shorelines and prevent erosion. (Silliman et al., 2019). However, there is often an issue with vegetation establishment in newly created wetlands. One important factor for plant establishment is the soil. Studies have shown that constructed wetlands with soils having higher organic matter, lower bulk density, neutral pH, and higher soil moisture content are associated with higher plant diversity and quality. Two options for establishing vegetation are to let the site naturally colonize or to intentionally seed and plant different wetland species. Allowing natural colonization has the potential issue of non-native and invasive species to take over the site. It was found that the naturally colonized wetlands have higher carbon sequestration and amphibian production whereas the planted wetland have higher plant diversity. When planting, it is important to take into account issues such as transplant shock. Transplant shock can be prevented by planting mature plants and using root balls (Ott, 2018).

Vegetation communities in tidal wetlands should be selected based on tolerance of salinity and inundation. According to “Creating Tidal Salt Marshes in the Chesapeake Bay”, Species such as *Distichlis spicata* are described to be tolerant of higher salinity and irregular flooding, and as such are a good fit for transitional wetlands with artificial tidal connections that may only form under higher tidal surges.

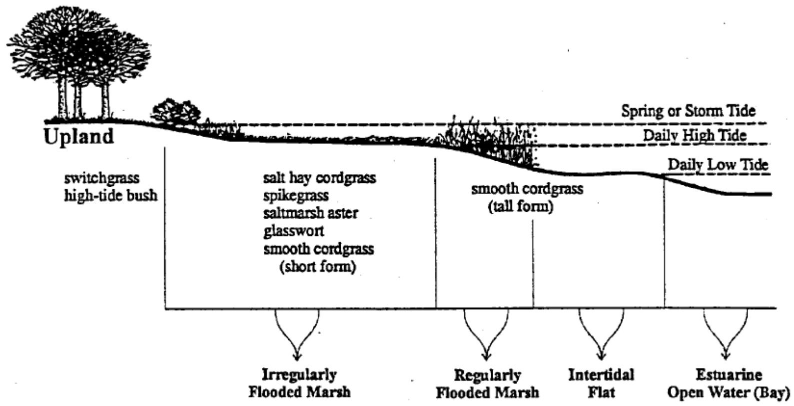

Figure 3: Tidal Regime and Plant Communities

Designing an elevation gradient will not only determine plant communities based on inundation from the higher water table, but also by the salinity associated with the groundwater in the region. Groundwater exchange coupled with surface tidal exchange through ditches and culverts is a feasible method for the formation of a saltmarsh system that can be used as a stormwater management practice. Furthermore, inland position isolated from wave activity provides a higher chance of successful marsh formation as reduced wave energy means lower losses to erosion and more rapid soil accretion.

One of the principle design considerations for this project is the transition of the site into primarily salt marsh as salinity and inundation levels increase inland due to rising sea levels. Grading the site to allow for upslope migration of plant species as salinity and water levels increase in the site is important to increase the longevity of the design. The ideal slope for inland migration can be determined using modeling software such as the Sea Level Affecting Marshes Model (SLAMM) using projected levels of sea level rise and soil accretion. Initial grading of sites with the consideration of wetland migration has proven successful in the past, as seen in the 2014 Myrtle Park restoration project, where native saline marsh grass *Spartina alterniflora* moved upslope, displacing initial plantings of the native *Spartina patens* as sea level rose upslope.

Summary and Conclusion

A variety of best management practices and wetland restoration options were considered during this study involving Newton Creek and the St. Paul redevelopment area in Norfolk, Virginia. The standards presented by both ASABE and VADEQ have been instrumental in tying together our goals for a constructed wetland with established and proven methodologies. Bioretention cells are an effective BMP for filtering stormwater; however, they become increasingly difficult to implement in coastal regions with higher water tables. While modifications are possible, connectivity between the groundwater and the surface may still be preferred, and the long-term effectiveness of the BMP is in question. A constructed wetland, meanwhile, works to reduce the severity of flooding and peak flow while likewise acting as a stormwater filter. These wetlands are usually coupled with native marsh flora to enhance its stormwater treatment while also providing natural habitats and bolstering the local ecosystem. An elevation gradient can be applied to allow for a gradual transition of the wetland to a more saline environment, allowing the migration of successive marsh species. Underground conduits can be used in association with chosen BMPs to further reduce flooding. Such devices, however, must adhere to standards outlined to minimize contamination resulting from urban runoff. One use of an underground conduit is the use of culverts to cross existing infrastructure and provide tidal connectivity to the site. The sizing of and slope of the culvert must allow for both adequate drainage of stormwater while also providing flow into the site at high tide.

There are a few things that should be further researched moving forward. One of these is the prospect of incorporating an oyster habitat into the BMP and restoration design. Clusters of Eastern Oyster (*Crassostrea virginica*) were found along the concrete channels directly below the I-264 overpass. Oysters have the ability to filter water, removing excess nutrients and sediment, while also providing structure, bank stability, and habitat for marine organisms. Adequate tidal connectivity is key to the implementation of oyster reefs in the site, however connecting the tidal creek to the design site is likely the most costly aspect of the design, as it involves modification of the existing transportation infrastructure. More research would also need to be done regarding the monetary costs of each of the options explored within the tech review. Details such as the cost of construction materials, labor and transportation, as well as maintenance are important for attaining a realistic and long-lasting solution.

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Appendix I - Potential Design Solution Brainstorming

Goal: Create a solution to reduce tidal and stormwater flooding with the following characteristics:

Tidally influenced surface nexus between restoration area and Newton Creek Mouth:

- Reduce flooding during high tide and storm surge events
- Better drainage of treated stormwater to the Elizabeth River.
- Facilitate exchange of tidal nutrients and sediment to build marsh soils and support vegetation and oyster communities
- Allow for gradual inland migration of coastal salt marsh

Stormwater treatment and storage capability:

- Central storage for two main stormwater conduits in the site
- Increase residence time, allowing for treatment in a constructed wetland with native plants.
- Provide storage without expressing water tables which are higher in coastal regions.
- Prevent backup of tidal floodwaters into stormwater drainage network.

Possible Solutions:

Terraced detention-retention system:

- Upper detention pond and an adjacent wetland were created wetland to manage stormwater. Connect to existing stormwater drains that underpass railway tracks and connect to ditch and creek.
- Lower basin that is excavated to expose the water table, and is connected to tidal flow to support coastal wetland communities of plants and oyster reefs.
- Vegetated spillway between two ponds allowing upper stormwater detention pond to drain into lower tidal basin.

- Spillway graded up berm such that tidal wetland species can migrate up the spillway and berm as sea levels rise.

Appendix II - Key Challenges

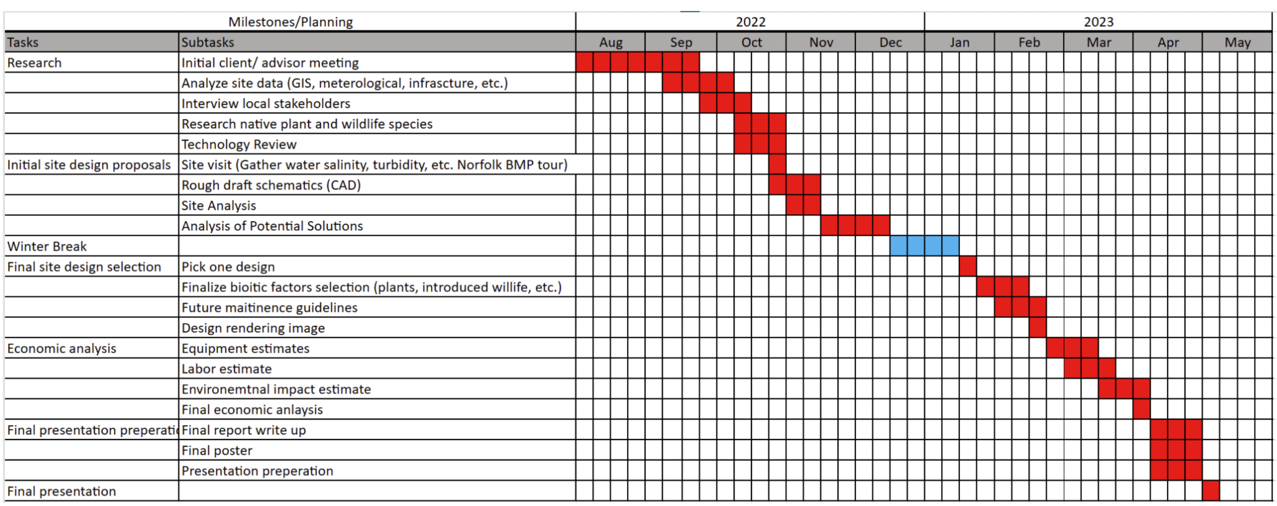
There are a number of challenges our team needs to address for an effective implementation of the Newton Creek project. The physical distance between Norfolk and Blacksburg is considerable. Our site retains a network of roads, buildings, stormwater/sewage pipes, and power lines that can impede construction. Any native flora used must take into account the limitations of maintenance crews and the existing environment. Rising sea levels can further complicate design requirements.

Certain components of the built environment in the Newton Creek/St. Paul's neighborhood must be left intact. These come either in the form of large infrastructure projects or are buildings that hold community and/or historical value. Public infrastructure constraints include the forked east-west I-264 overpass; a stretch of The Tide light rail between NSU and Harbor Park stations, which runs parallel to I-264 before weaving underneath the overpass; and a perpendicular stretch of Norfolk Southern railway (running underneath both) connected to adjacent Norfolk Station. The McDemmond Center for Applied Research and its parking lot, as well as the Gethsemane Community Fellowship church, must also be preserved due their value to Norfolk State University and the community of St. Paul, respectively. A small play area located at Reservoir Avenue Mini Park may also need to be moved or removed. Additionally, several power lines and sanitary pipes traversing the site are expected obstacles that are costly to remove and replace.

Maintenance of a salt marsh environment and its native flora will also provide a new set of challenges. As we have learned during our team's site visit with Wetlands Watch, landscape maintenance crews are oftentimes inexperienced with the upkeep of constructed marshlands or other BMPs. A level of simplicity in the selection of marsh species will be necessary to ensure the project's effectiveness throughout its lifespan. Marsh grass species in the genus *Spartina*- which have played a major role in similar coastal redevelopments- typically have full sun requirements. This comes as diurnal shade is expected due to The Tide and the I-264 overpass. A visual assessment of the site confirms the presence of introduced herbaceous plants and woody shrubs. These plants are often aggressive, and can outcompete any native flora while being painstaking to remove. The proximity to both interstate and rail networks, along with several large lots, implies various sources of entry for pollutants.

The Newton Creek site itself is approximately 300 miles away from Blacksburg, or roughly a 5-hour drive in both directions. This distance can be problematic, as conducting an in-person site visit often requires considerable logistical planning. Effective designs will rely on a number of measurements- especially water quality parameters- taken on-site. In order to address this challenge, the team can take two actions. One is to compile an ongoing list of measurements which must be taken at Newton Creek, so that during the next site visit every necessary measurement can be taken. The second action that can be taken is to make use of online databases, such as USGS, NOAA, etc., to locate data that might otherwise be too time-consuming to retrieve.

Appendix III - Major tasks and timeline



Appendix IV - Specific Team Roles

Section	Team Member
Cover Letter	Cyrus
Cover Page	Ellie
Introduction	Ellie, Gavriel, Cyrus
Review of State of Technology	Ellie, Gavriel, Cyrus, Parker
Summary & Conclusion	Gavriel, Cyrus
References	Ellie, Cyrus, Parker
Appendix I	Gavriel
Appendix II	Cyrus, Parker
Appendix III	Ellie
Appendix IV	Ellie