Group #4

Quarry Parks Project: Water Treatment Via Wetland

Group Members:

Mateo Coman

Tolulope Lawal

Chenshuo Wang

Megan Cochran

Austin Kramer

Todd Newlin

April 24, 2020

Table of Contents

Executive Summary

Columbus and Franklin County Metro Parks is seeking to make their newest addition, Quarry Trails Metro Park, energetic, unconventional, and innovative. These goals encompass each facet of the park design, and this report is intended to provide an innovative answer to a mundane, but critical, element: stormwater management. The existing infrastructure of underground storage tanks is generally sufficient, but fails to adequately treat stormwater prior to release, as well as lacking in necessary redundancy systems in the event of storm events that exceed storage capacity. This proposal recommends the construction of a surface wetland located at the unified water outlet for storage tanks C, D, and E. Calculations, located in Tables 1, 2, and 3, regarding the necessary area, flow, and detention times are based upon specifications provided in the existing park plans provided by Larry Peck, as well as a hypothetical 10-year, 24-hour storm scenario. Under these conditions, it was concluded that a wetland 97,952 square feet with a depth of 70 cm is required to successfully treat the stormwater. Additional tools of analysis include AutoCAD software, which was used to determine topographical conditions, as well as the construction of a sample wetland based upon the aforementioned calculations, portrayed in Figures 3 and 4. Additional considerations were calculated to determine an approximate total project cost, as well as discussions regarding the economic feasibility of this proposal.

Design components include two outlet weirs out of the wetland to allow flow control, a walkway to allow maintenance as well as visiting and educational opportunities to park guests, and a vegetation palette that exclusively includes wetland species native to Ohio. Using timelines provided by previously completed wetland construction projects, it was determined that construction would reach completion in approximately 7 months, with specifics regarding the construction schedule detailed in Appendix III, Table 5. Necessary maintenance regimes are detailed in Appendix IV, Tables 6 and 7. As demonstrated in Appendix I, Table 4, the combined cost of construction and design would total $410,733.87, and maintenance would cost an additional $7,331.15 per year of operation. It is determined that this final cost is feasible due to the combined environmental services provided by the wetland, as well as reducing the yearly cost of water treatment by 96%.

It was concluded that this proposed wetland could effectively treat stormwater, capture excess stormwater in a 10-year 24-hour storm event, and provide essential habitat for many threatened plant and animal species unique to Ohio, all while maintaining the aesthetic quality of other Metro Parks operated by Franklin County.

Background

The Franklin County area is filled with Metro Parks. These parks are well spread out so that the majority of its' citizens are fairly close to a park (within five miles). However, not all citizens are in this five mile distance of a park. This is something that Larry Peck (Deputy Director of the Columbus and Franklin County Metro Parks) wants to remedy. According to a lecture given by Mr. Peck, one of the goals of the Metro Parks System is to get a metro park within five miles of the citizens of Franklin County. Currently, there is only one area along the Scioto River near the Upper Arlington area which doesn't meet this goal (Figure 1.). With the recent purchase and construction of Quarry Trails Metro Park (QTMP), this "5-mile goal" will be one step closer to being realized [1].

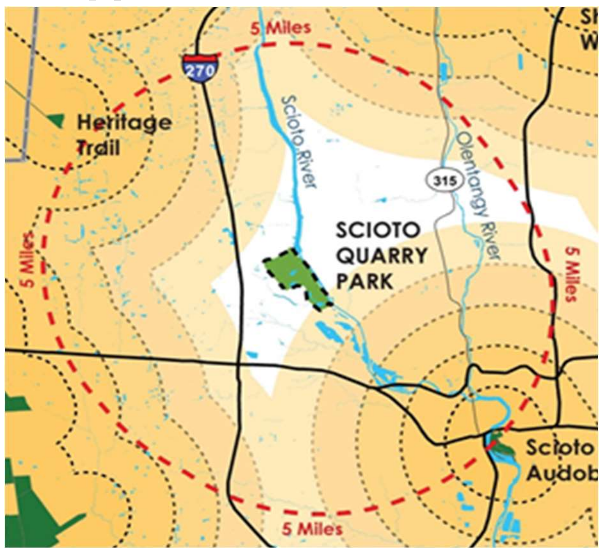

Figure 1. Area within 5 miles of Quarry Trails Metro Park

The QTMP will be the 20th metro park in Franklin County and will connect with a large urban living area and parking lot. This creates a very large (21.4 acre) impermeable area, which in turn will create a large volume of stormwater runoff, which will be held in one of three discharge containers. The QTMP would like this runoff, as it will support the ponds that are within the park, however, it will need treatment prior to discharging into the ponds. This is where our project comes into play [2].

Stormwater runoff from urban areas can contain nonpoint source pollution. Nonpoint source is when the specific source of pollution can't be identified. This pollution needs to be treated prior to its discharge into the ponds as the ponds will be supporting a thriving aquatic ecosystem. Through the wetland, several ecosystem services will be provided, including regulating (through water quality/purification, carbon sequestration, and flood control) cultural (through education and aesthetics), and supporting (through habitat and water/nutrient cycling).

Existing Conditions

The original project plans involved the stormwater detention containers A and B. These were selected to treat the runoff from the shopping and dining areas of the development area. However, upon further investigation into the project, it was found that the area where the A and B containers have their discharge pipes is much too steep to support a wetland (Figure 2). The slope at container A outflow drops from 740 ft to 725 ft over approximately 30-35 ft. Similarly, the slope at container B outflow pipe drops from 735 ft to 720 ft over approximately 30-35 ft. This grading (1:2) is far too steep for a wetland in either location [2]. The wetland couldn't be constructed at the bottom of the hill that either outflow is on because this is Milliken's Ditch which is a canal and not a viable location for a wetland.

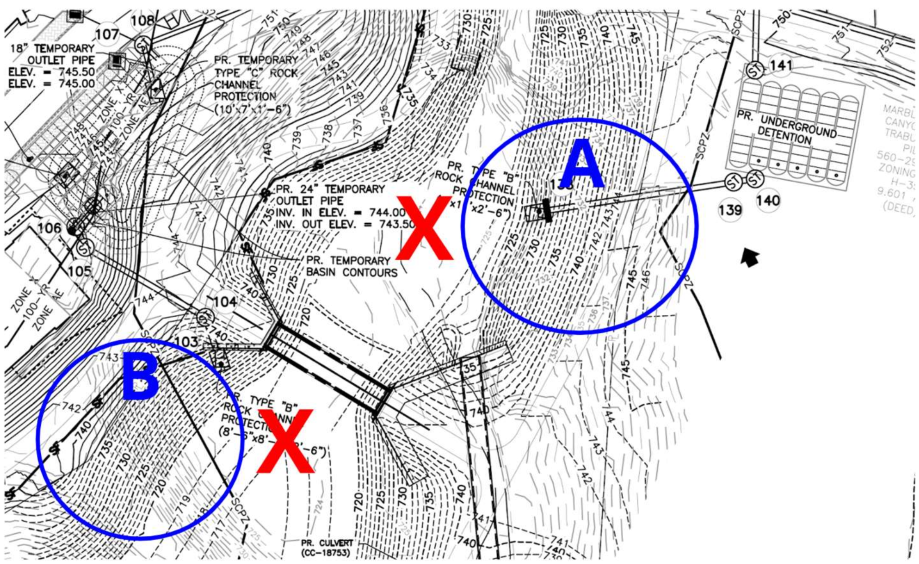

Figure 2. Topographic map for the outflow area of detention containers A and B

After detention containers A and B were rejected, detention containers C, D, and E were looked at as possible candidates for a wetland. The grading at the outflows of these containers was the first item looked at (Figure 3). The three containers are all connected and share one outflow pipe. The area around this outflow pipe was determined to be sloped ideally for a wetland, as it drops from 743 ft to 733 ft over approximately 90 ft (1:9). Comparing the locations, C/D/E was deemed an ideal candidate for a wetland due to the low grading, singular output, and maximum stormwater runoff treatment volume for a single wetland [2].

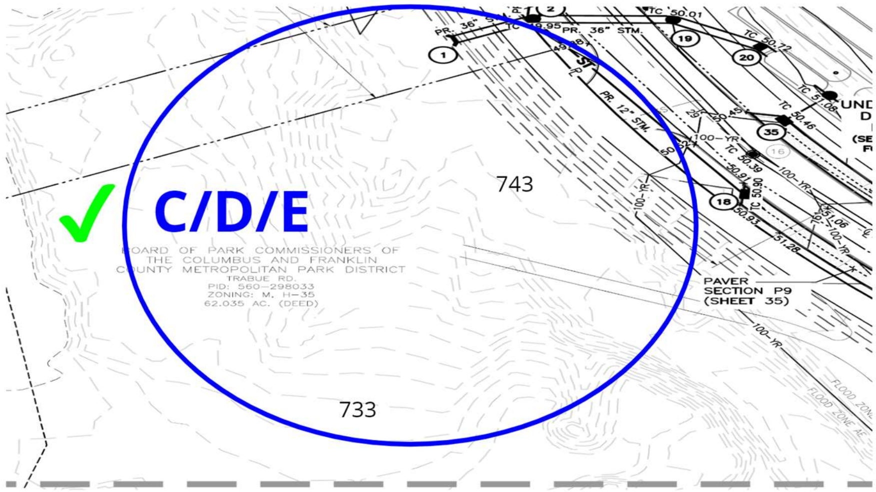

Figure 3. Topographic map for the outflow area of detention containers C, D, and E

The soil type in the area of the wetland is difficult to determine. Per the NRCS/USGA ran website, Web Soil Survey, the area is classified simply as “pT” which stands for pit/quarry. The entire area has historically been a limestone quarry and has seen large amounts of construction, excavation, and filler. Additionally, it has also been used as a landfill. This creates a new challenge as landfills can provide a large source of leaching of pollutants into the groundwater, which can have large negative effects on surface water, such as habitat and consumption. To prevent this, a four ft cap, made of an impermeable clay, was put on top of the landfill area, with additional soil brought in to cover the cap.

The area is an active construction site, due to the urban development being built as well as a still active quarry not far to the north of the proposed wetland location. There is no natural wetland in the area, but there are two ponds which can be connected during times of high rain. It is into these ponds that the wetland will discharge into. There is some vegetation in the area which will need to be removed during the wetland construction. This vegetation wasn’t intentionally planted, it was naturally brought in via wind or animals. Being an active construction area, the removal of any unwanted vegetation and the excavation of the wetland area will be more easily accomplished and without as disruptive an impact on the area than if the park and urban development were already completed.

Wetland Design

The team designed a wetland for stormwater containment tanks C, D, and E. Respectively the tanks hold 37,219, 10,656, and 14,755 cubic feet of water. The team designed the wetland to hold the volume of water exceeding the total of the tanks for a 10 year 24 hour storm event. The tanks each collected water from 11.69, 4.09, and 5.46 acres respectively. After the tanks are completely full the remaining volume comes to 224,958 cubic feet of water. From there the rest of the specifications of the wetland were solved iteratively by changing its depth. Initially a depth of 30 cm was used. However, the resulting wetland was far too large for the area near the position around the outflow [1]. A wetland with a depth range between 50-60 cm was feasible but the team decided against that because the desired longitudinal shape could not be achieved in the space. The team has decided on a wetland that is 70 cm deep (Table 1). The resulting area 97,952 square feet is ideal because of the shape it yields to prevent short circuiting. From the iterative depth and resulting area an ideal hydraulic loading rate was used to solve for Q flow [3]. Under an ideal hydraulic loading rate of 5.4 cm per day the resulting flow is 491 cubic meters per day. The team is working under the assumption that the stormwater containment tanks will be able to adjust the release of flow to match this value (Table 2). With a calculated flow of 491 cubic meters per day the resulting detention time was found to be approximately 13 days which falls within the ideal 5 to 14 days (Table 3).

Table 1: Determination of Total Depth and Area

Tank	Area (acres)	Volume Tank (Cubic ft)	Volume of rainfall (Cubic ft)	Vol. Exceeding Tanks (Cubic ft)	Depth Iteration	Units	Notes
C	11.69	37219	158281.431	121062.431	70	cm depth	10 yr 24 hr 3.73 in
D	4.09	10656	55378.191	44722.191	27.55905512	in depth	Area = Vol/Depth
E	5.46	14755	73927.854	59172.854	2.296587927	ft depth	
Total	21.24	62630	287587.476	224957.476	97952.91241	Area (square ft)	

Table 2: Determination of flow

Hydraulic Loading Rate (m/day)	Q (meters cubed / day)	A (square meters)	A (sqaure ft)	Depth (ft)	Notes
0.054	491.4071359	9100.132146	97952.91241	2.296587927	q = Q/A

Table 3: Determination of Detention Time

Detention Time (Days)	V (meters cubed)	p (surface flow)	Q (meters cubed / day)	Notes
12.96292909	6370.075856	1	491.4071359	t = V*p/Q

Once the dimensional parameters were defined for the wetland its actual shape had to be designed. To determine the actual shape of the wetland, the team overlayed the Quarry Trails Stormwater Plans with the topography map. Keeping the elevation and location of the stormwater fields in mind the following design was created in AutoCAD.

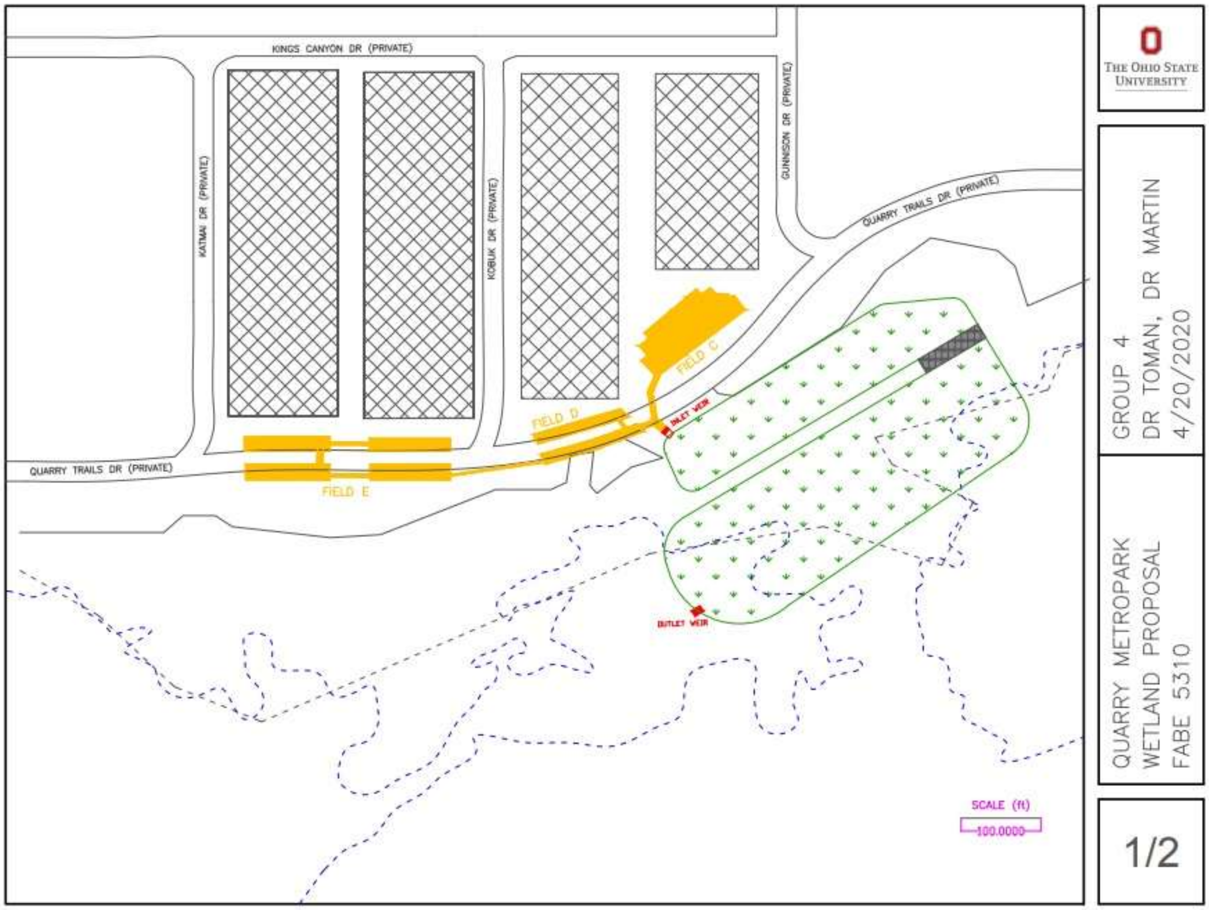

Figure 3. CAD design of proposed wetland location and design

Stormwater detention sites C, D, and E feed into the wetland at the inlet weir. The design of the wetland includes both inlet and outlet weirs in order to control the depth and water flow of the wetland. These weirs are shown in red in Figures 3 and 4. Due to the limitations of the space, the team placed a barrier in the wetland to limit short circuiting. The barrier and the slope of the wetland will force the water to flow clockwise around the wetland. The barrier is 20ft wide with sloped sides identical to the exterior walls of the wetland. The team is proposing to use this barrier as a walkway to provide educational and recreational opportunities. The walkway is followed by a bridge that allows a walking path to run completely through the wetland. Signs may be placed along the pathway to educate park goers on native plant species and the function of wetlands. This walkway also allows for ease of access for maintenance.

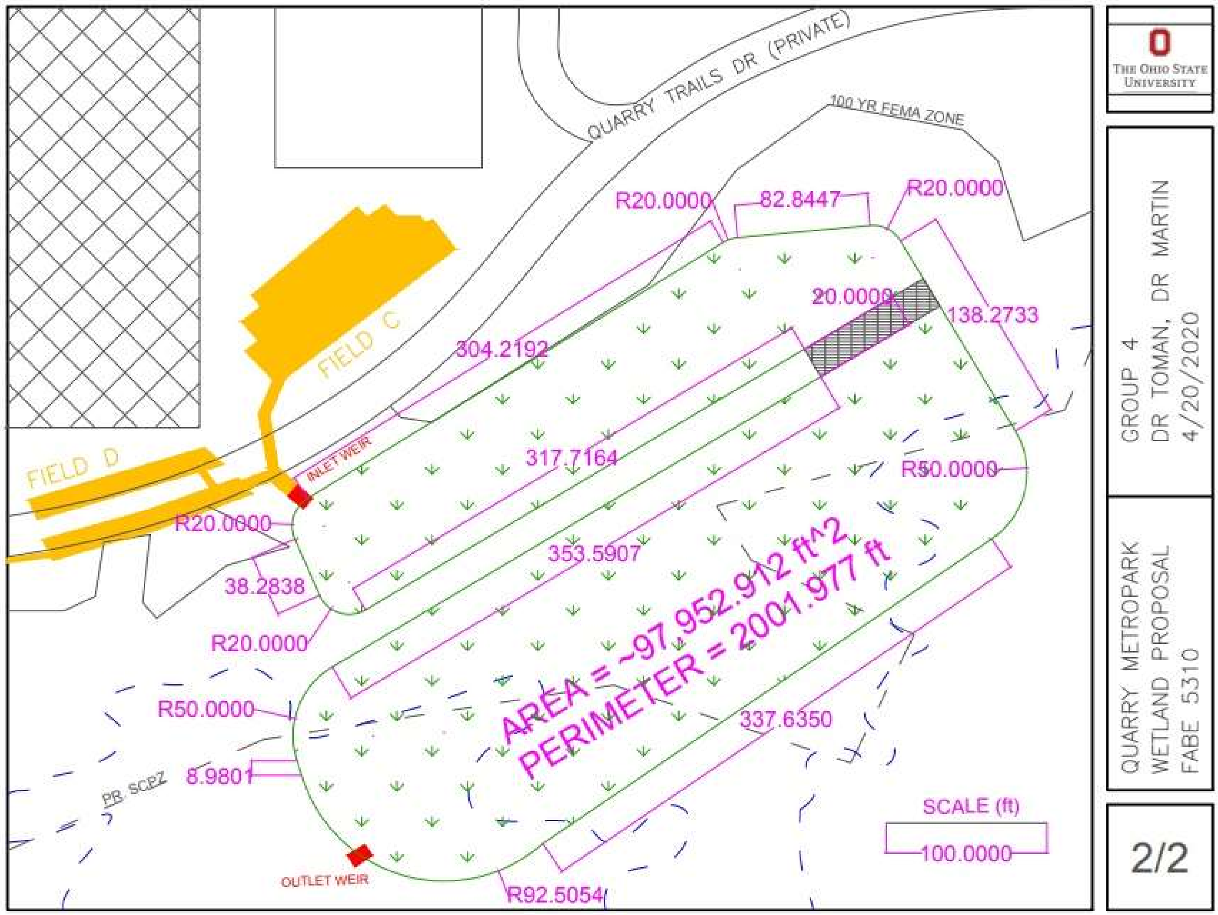

Figure 4. CAD design of wetland specifications

To maintain ideal wetland conditions the slope of the path that the water travels should be at a 1% decline. The water travels about 876 ft clockwise from the inlet weir to the outlet weir. Therefore, there will be approximately an 8.76 ft decline overall (Figure 5). This is a feasible decline due to the fact that there is only a 10 ft decline from the inlet weir to the bodies of water in the original site plan [1].

The final aspect to consider in the design is the materials of the foundation of the wetland. The materials and their respective thicknesses are shown in Figure 6.

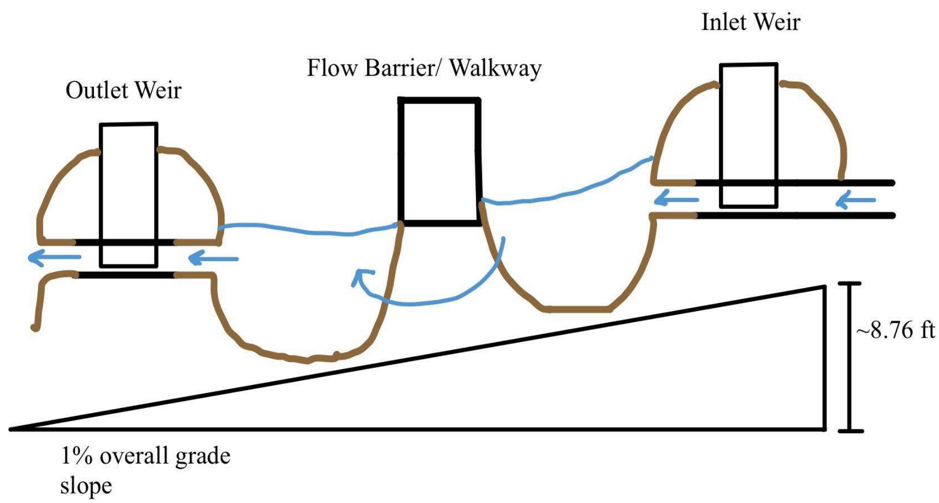

Figure 5. Side view of wetland with grading

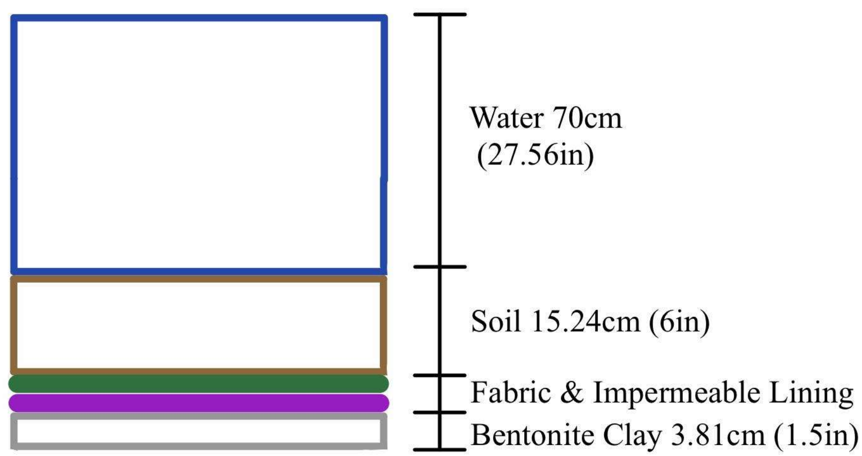

Figure 6. Side view of wetland construction materials

Economic Feasibility

By analyzing the current state of the site proposed to be the wetland site, it has been decided that the creation of a wetland would indeed be economically feasible. Currently, the pipes leading out of tanks (C,D&E) lead to a pond that surpasses an uninterrupted area of land [2]. That would be ideal for a surface flow wetland. The topography of the area also shows slight sloping that would be needed in creating such a wetland. All of these features considered are helpful in cutting cost since overall cost will not need to focus on an inlet pipe, looking for additional land, and excessive grading. It has been proposed that the available land would be ideal for a wetland.

The cost of the wetland was calculated based on factors such as design and aesthetics, construction, and maintenance and equated to a grand total of $515,866.31. With the intentions of forming a wetland that simulated natural wetlands, the main design of the wetland was proposed using a traditional surface wetland as a foundation [4]. For a traditional surface wetland, important features include: an inlet pipe, low permeability soil [5], an outlet pipe and a weir to control water levels in the wetland. In addition to an impermeable liner, Bentonite clay, soil, and a control mesh fabric for plant growth, these design features all contributed to the bulk of the wetland development. The total cost for all design aspects equated to approximately $410,733.87, about 80% of the final cost of the entire wetland. The unique feature of the walkway for maintenance and for educational purposes should acure no additional costs for the wetland.

A large feature of the wetland will be the showcasing of native Ohio plants and a portion of the design cost ($4241.50 for ~800 plants). The number of plants required was estimated based on wetland USDA wetland scenario plans for a surface wetland [6]. While many standard wetlands mostly employ the use of seedlings for vegetation, it was decided that planting pre-grown vegetation would be more cost effective in the long run. The cost of a pre-grown plant from a native Ohio Nursery is about $4.99 per plant, yet seedlings cost about $0.50-1.50. While the cost of a pre-grown plant is more expensive, this is a worthwhile expense that eliminates the need of having to wait for germination and growth of seedlings. This makes it so that the wetland can be used immediately and water treatment saving can occur immediately.

Cost would also be severed dramatically by focusing on the three connecting water tanks (C, D & E). By creating a wetland for all three tanks, cost is reduced significantly since the park would not have to treat each water source separately. The issue that arises with treating all three tanks is the large volumes of water that will be going in and out of the wetland .To create redundancy in safety for the wetland foundation given the large volumes of water, instead of focusing on one type of lining material, both bentonite clay and an impermeable liner were utilized. The use of the bentonite clay made up a large majority of the design cost but was necessary to prevent inefficiency of the wetland from a degrading liner. The second highest cost of design was the soil. Lastly, the wetland design utilized both an inlet and outlet weir which is different from a traditional surface flow wetland which only requires an outlet weir. This design aspect was necessary because of the large amounts of water that would be going in and out of the wetland. The two weirs (which equate to about $3000 each) [4] would be advantageous in promoting water control and regulating water flow rates. Cost is also decreased from not having to purchase an inlet pipe. The pipe currently leading out of the tank connections will more than likely serve as an inlet pipe.

The next highest cost factor for the wetland was in physical construction. The total construction cost equated to $77,543.53. To prepare the wetland, excavation of the site is essential as well as clearing the site. Also, for this to occur, hauling equipment will be needed. It was decided that hiring excavators would be more cost effective in eliminating the need to pay for individual excavating equipment and laborers. For a standard surface flow wetland, excavation needs to be done so that there is a slope in the wetland and hiring excavators will reduce the work needed to slope the site to ideal conditions. It was decided that hauling equipment would be necessary for moving design materials and moving cleared grubbage.

Lastly, maintenance is an important feature in making sure the wetland remains at optimal conditions and continues to provide a higher benefit to cost ratio. On average, the total cost of maintenance for a wetland is typically between 1 and 5% of the total cost of a standard wetland [4]. The overall cost of maintenance for the wetland would be approximately $7,331.15 yearly, about 1.4% of the wetland expenditure total. This includes absolutely necessary maintenance such as mowing, uprooting invasive and nuisance vegetation, and removing debris and sediment. Mowing and sediment removal will be done at least once a month and will be an essential portion of this budget once construction is complete. Nuisance vegetation uprooting will be done twice a year and would be important to do so as to avoid invasive species from overshadowing, native Ohio commercial species that will be showcased in the wetland. Please note that the construction of the wetland does not factor in labor. Since the cost of labor would fluctuate, cost will need to be assessed based on the number of individuals participating in construction, possible contracting, and paying workers to carry out maintenance.

The last proponent for overall cost is the additional $20,000. This amount of money is an initial amount to be set aside for additional costs such as repairs, replacements, and any additional maintenance fees. This would cover the cost of possibly replacing weirs and pipes, adding additional vegetation or buying fertilizer, and any maintenance that was not directly considered in the cost analysis.

The cost per acre for the wetland comes out to be about $22,000. Eliminating the cost of things such as excessive excavation, an inlet pipe, and land searching reduced the amount of money that is typically spent for executing a wetland of this size in Ohio, which is about $30,000. It is important to note, again, that the overall cost does not factor in labor.

Even though the final cost is a bit cheaper than a standard wetland, the Quarry park can reduce out of pocket costs by going through programs like the National Resources Conservation Service (NRCS Ohio) through their Agricultural Conservation Easement Program (ACEP) [8]. This program provides land easement grants to entities that are interested in utilizing environmental conservation enhancements such as wetlands.It is possible that through this program, 50% of the cost of execution for the Quarry wetland could be covered reducing the overall cost to about $260,000.

This project will be carried out at the same time as other projects, so when people buy building materials, they can buy them together with materials from other projects, which could get a discount, and avoid the waste of materials.

Societal Cost and Benefits

Overall, it is not expected for the wetland to generate any income. Any monetary income would be in the form of savings from not having to treat stormwater through a stormwater treatment plant. The wetland design will be more economical than traditional water purification design and provide ecosystem services to Metro Park.

The first type of ecosystem service will be provided by regulating services. The biggest regulating service will be provided is water purification. Instead of flow directly into the river, the wastewater will flow from the storage tanks to the wetland first. Even though the wastewater has been contained in storage tanks for several days, non-solid contamination such as BOD [7], TSS, nutrients and heavy metals still exist in the wastewater. These contamination may cause several kinds of water pollution. When the wastewater flows through the wetland, soil and wetland plants will contain and remove most of these contaminants from the wastewater to achieve the effect of water purification. The wetland also provides more retention time, which gives more time for solid contaminants to settle out of the water. The other regulating service will be provided flood regulation. The wetland can contain the excess water to decrease peak flow during the storm events, which will help to alleviate the high water flows during storm events. The wetland can also provide slight climate regulation [3]. The wetland plants can absorb greenhouse gases from the air and do photosynthesis, which can help to mitigate climate change [7]. These processes will help to increase the water quality of the purified water exiting into the river.

Another regulating service is an avoiding cost from having to potentially treat the entire volume of stormwater through the course of the year. In Ohio, the cost to treat stormwater is about $8.31 per thousand gallons of water [9]. The team calculated that if the quarry trail park was to collect every ounce of stormwater, then they would collect approximately 2.27 million gallons of water. The total cost of treating such an enormous amount of water in Ohio would be $188,000 yearly. The Most expensive portion of wetland design would be in building the wetland, but after that, the wetland would only require a yearly maintenance cost of $7331.15, saving 96 percent. Of the initial cost of 188,000.

The second type of ecosystem service will be provided by cultural services, which can provide non-material benefits. The biggest cultural service will be provided is educational service. The entire wetland design is hypaethral, so when people visit this wetland, people can see how the wetland works. People can see about the wetland to observe how the wetland purifies and stores water for flood regulation, to learn about how every contructure of wetland works, and to learn the importance of impermeable liner for the construction on the top of a landfill. The location of the wetland is near some buildings under construction. Once the buildings and wetland are done construction, people living or work in these buildings could easily access the wetland to relax, which is the spiritual service of the cultural service.

The monetary value of this wetland design is hard to evaluate. It is a support system for Metro Park. The only way to measure the benefit of this wetland design is using avoid cost or replacement costs to find out the value of water purification and flood regulation. And to see if water purification and cultural services provided by wetland can raise the “Willingness to pay” of the park.

Plan of Execution

The United States Environmental Protection Agency recommends that wetland construction operations to occur throughout the fall, and the planting to occur in the first half of spring[7]. This proposal recommends construction to occur alongside other park construction in order to reduce the costs of acquiring additional equipment, so with this consideration, a realistic timeline would see construction to begin most likely in the late summer, or late July, to accomodate for potential delays and other unforeseen scenarios. From start to finish, site construction and preparation will occur over a period of 8-9 months, however the vast majority of labor occurs within the initial 3 months.

As Appendix III, Table 5 outlines, it is first necessary to order the desired vegetation from a local nursery, which allows several months of growth under controlled conditions, minimizing the risk of failure to establish upon introduction to the wetland. There are numerous nurseries specializing in native vegetation, but Envirotech Consultants Inc. is recommended by this project due to their history in successfully cultivating plant life for constructed wetlands. Envirotech Consultants additionally offer a service to construct an ideal vegetation palette based on design plans and the intention of the site - however, using the Olentangy River Wetland Research Park as a model, likely species would include swamp milkweed, sweetgrass, sweet flag, and winterberry holly, as they have been successful in several other constructed wetlands, perform well in treating stormwater, and produce appealing colors and smells[6], important for attracting guests and encouraging participation in educational opportunities.

Construction would begin by appropriately shaping and grading the site as per the specifications contained in Tables 1, 2, and 3, as well as illustrated in Figures 4 and 5. As this process will require the use of heavy machinery, it will be necessary to coordinate with other park construction teams to ensure access to said equipment. Completion of this step will additionally include the installation of the two outlet weirs, as well as the wetland bedding matrix of the bentonite clay, fabric and impermeable lining, and the soil medium, with specific depth requirements illustrated in Figure 6. This phase is the most time-intensive, as well as the most laborious. Completion will require approximately 2 1/2 weeks' worth of workdays, however, given equipment limitations and daily conditions, these days may take place over a period of 2 months.

Following site construction, the upper layer of soil should be harrowed or ploughed with minimally-disruptive equipment, which breaks up and softens the soil to better stimulate growth conditions in the spring. Once the site is smooth, it should be flooded under a thin layer of water [7] using either water present in the storage tanks, or through nearby municipal fire hydrants. Flooding conditions should be maintained through the end of the fall, and if conditions allow, throughout the winter as well to settle the soil bed and create wetland conditions.

Lastly, between mid-April and early-May, depending on seasonal conditions, the ordered plants will be sufficiently grown and able to survive in the wetland, so they should be transferred into the wetland. Planting should occur by hand and they should be arranged in a clustered pattern[7] throughout the wetland. Alternatively, Envirotech Consultants Inc. offers a planting service which guarantees best-practice methods, however, this would also accrue additional unaccounted-for costs, with quotes offered by them upon request. Once the vegetation is successfully transplanted, the construction of the wetland is complete, and thus ready to be operated under the guidance of the maintenance schedules.

Maintenance Schedule

As described in Appendix IV, Table 6, the first year of operation requires three particular maintenance tasks [10, 11]. To ensure the site is functioning as designed, it is necessary to inspect the mechanical and natural components of the site following storm events on at least two occasions no less than three months apart. If vegetation is placed along the perimeter of the wetland to either control erosion or increase aesthetic appeal, it will be important to water them at least two times a week during their initial growing season to ensure successful establishment. Removal of failed and dead plants should also occur whenever possible, as this will maximize space and resources for the remaining population. It may also become necessary to plan replacements if clusters collapse or if otherwise deemed beneficial to the wetland.

Proceeding the initial year, the general maintenance schedule is fairly detached, as established wetlands generally operate well under a hands-off approach. Appendix IV, Table 7 contains a complete maintenance schedule compiled from the published routines of several other wetland projects [10, 11, 12]. Most items occur at a monthly frequency, and are general tasks such as mowing along the banks and cleaning trash or debris located at the inlet, outlets, or within the wetland. In order to maintain native populations, it will be necessary to remove invasive species, such as cattail, approximately twice a year, which provides an interactive and exciting educational opportunity for visitors of all ages to learn about wetland flora. Lastly, sedimentation typically takes from 10-20 years to begin impairing function, but annual inspections provide assurances that the wetland is continuing to operate as designed, and maintains the volume to capture large storm events. Routine maintenance is minimal, and can easily be incorporated into existing park routines, so the wetland will not overburden park staff or require them to receive extensive training and specialized knowledge.

Recommendations

Overall, the project was successful for the team. Being able to meet in person would have made it easier to communicate I think. The team felt really good about the presentation and the design proposed for Quarry Trails Metro Park. It is our hope that this design can be shown to Metro Parks and possibly be implemented.

The stormwater detention containers will allow some particulate to settle out prior to discharging into the ponds. However, these tanks will not remove any dissolved pollutants in the runoff. To ensure the stormwater is of the best possible quality for use in the ponds, it will need treatment. The best option for this treatment is a wetland. The wetland will provide a multitude of benefits. While the primary benefit will be water treatment and purification, it will also provide benefits such as habitat and aesthetics.

Due to the area's history as a quarry and landfill, certain precautions need to be observed. The main precaution is to prevent leaching of water from the landfill into the wetland. This can be accomplished in 2 different ways. The first, is to cap the landfill, which has already been done. The second, is to seal the wetland, only allowing water to enter and exit at designated locations. This can be accomplished using benitoite clay and an impermeable liner. This will prevent groundwater from leaching in and ensure water in the wetland remains there until it is fully treated. The use of a weir at the beginning and end of the wetland will allow for control of where water is able to enter or exit the wetland.

When paying for the wetland, it is highly recommended that the Quarry Trail Metro Park seek external funding through the Agricultural Conservation Easement Program (ACEP). This will alleviate cost and allow distribution of funds elsewhere. Also, the main purpose of using a wetland for water treatment is to take a sustainable design approach. ACEP recognizes this feat and supports entities in doing so.

Group Member Contributions

- **Mateo -** Put together the preliminary presentation and did design calculations for wetland design.
- **Megan -** Responsible for design specifications and developing Autocad Design
- **Todd Newlin** - Responsible for the Project Background and Existing Conditions sections of the report and presentation.
- **Tolulope -** Responsible for conducting research on economic feasibility and ecosystem valuation of the wetland using Ohio Standards.
- **Austin -** Wrote Executive Summary, created the plan of execution, and researched/designed maintenance schedules common in managed wetlands
- **Chenshuo** - Responsible for research on economic feasibility, ecosystem evaluation and societal cost.

References

[1] Peck, Larry. “Introduction Lecture” (2020) FABE/SENR 5310

[2] E.P. Ferris and Associates Inc. “Storm Water Plans Quarry Trials” (2020) FABE/SENR 5310

[3] Martin, Jay. “Lecture 8: Wetland Treatment Systems” (2020) FABE/SENR 5310

[4] USDA Natural Resource Conservation Service. “Constructed Wetland: Scenario Cost.” (2017)

[5] Cost-Helper. “Home and Garden.” How Much does soil cost? Retrieved From: https://home.costhelper.com/soil.html

[6] Ohio Wetland Association. “Native and Wetland Plant Information: Benefits of using Native Plants for your Wetland.”

[7] US Environmental Protection Agency. “A Handbook of Constructed Wetlands”

[8] USDA Natural Resource Conservation Service. “Agricultural Conservation Easement Program.” Retrieved From: https://www.nrcs.usda.gov/wps/portal/nrcs/oh/programs/easements/acep/stelprdb1248463/

[9] EJ Metrics. (2019). “Water and Sewer Service Affordability in Ohio.” Assessment of Opportunities for State Policy.

[10] City of Alexandria, Virginia. “Constructed Wetlands Maintenance Schedule and Guidelines” (2020)

[11] Town of Hope Mills, North Carolina. “Stormwater Wetland BMP Maintenance Plan” (2018)

[12] Minnesota Stormwater Steering Committee, Minnesota Stormwater Manual. “Operation and Maintenance of Stormwater Wetlands.” (2016

Appendix I: Wetland Cost Evaluation

Table 4 : Cost Estimate for the Quarry Parks wetland

Cost Estimate					
Division	**Item**	**Quantity**	**Unit**	**Cost**	**Total**
Design					**$410,733.87**
	Inlet/Outlet Weir	2	ea	$3,000.00	$6,000.00
	Outlet Pipe (18")	1	ea	$2,000.00	$2,000.00
	Impermeable liner	97952.91241	sf	$0.22	$21,549.64
	Bentonite Clay	169,703	lb/sf	$1.15	$195,158.45
	Vegetation	850	each	$4.99	$4,241.50
	Soil	48976.4562	cf	$2.22	$108,727.73
	Control mesh Fabric	97952.91241	sf	$0.74583	$73,056.55
Construction					**$77,543.53**
	Excavation/Grading	392013.93	cf	$0.18296	$71,722.87
	Clearing and grubbage	48976.4562	sf	$0.01313	$643.06
	Hauling equipment	20	ea	258.88	$5,177.60
Yearly Ongoing Maintanance					**$7,331.15**
	Nuisance vegetation uprooting (2x yearly)	97952.91241	sf	$0.02000	$1,959.06
	Debris/sediment removal (monthly)	97952.91241	sf	$0.03832	$3,753.52
	Mowing (monthly)	97952.91241	sf	$0.01652	$1,618.57
Additional Cost					**20,000**
	(repairs, replacement, additional maintenence)	X	X	20,000	
Total					**$515,608.55**

Appendix II: Possible Native Ohio Vegetation

- Lizard's Tail- Grows well in shade (Ohio is typically partially cloudy year-round)
- Sweet Flag
- Sweetgrass
- Swamp Milkweed
- Winterberry Holly
- Muskingum Sedge

Appendix III: Wetland Construction Schedule

Table 5: Construction Schedule for The Wetland Divided Seasonally

<table>
<tr><td>Summer/Fall</td><td>1. Order Ohio-native stock species with consultation of local nursery
a. (https://www.envirotechcon.com/nursery.html)
b. Probable species include swamp milkweed, Muskingum sedge, sweetgrass, Winterberry holly, and sweet flag
c. Plants will be several months old by time of planting
2. Shape & grade site to specifications
3. Install site design elements:
a. Impermeable lining, bentonite clay, & low-permeability soil
b. Outlet weir & control structure
4. Disk & harrow future planting area with low-impact equipment
5. Flood site with shallow water, maintaining through winter (if possible) to settle soil bed</td></tr>
<tr><td>Spring</td><td>1. Drain water at site enough for access, leaving soil moist
2. Receive stock, planting by hand in clustered arrangements, per EPA recommendations</td></tr>
</table>

Appendix IV: Wetland Maintenance Schedules

Table 6: Unique Year-One Maintenance Considerations

Unique Year-One Maintenance Considerations	
Task	**Schedule**
Site inspections to ensure functionality	No less than once every 3 months, following storm events
Water vegetation planted along buffer zones	2-3 times per week during the first growing season
Remove dead vegetation within wetland, replace if necessary	As-needed; inspect at least weekly in first growing season

Table 7: Stormwater Wetland Regime

Stormwater Wetland Maintenance Regime	
Task	**Schedule**
Remove trash and debris from perimeter	Monthly and following major storm events
Remove trash & debris from inlet/outlet	Monthly and following major storm events
Mow along bank/perimeter	Monthly
Inspect for erosion along banks, replanting if necessary	Monthly
Removal of Invasive/undesired Species	Semi-annually (mid-spring and mid-fall)
Inspect for sediment accumulation	Annually, dredge if accumulation >50% storage volume
Inspect for/repair structural and mechanical damages	Annually (early spring)
Cull over-abundant species	As-needed
Repair nonfunctional or damaged infrastructure	As-needed