Design of a Subsurface Storage Reservoir and Collection/ Distribution System

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Executive Summary

In an effort to make the UBC Botanical Gardens become more sustainable, Group 20 Inc. has been contracted to design a subsurface storage reservoir and collection/distribution system to reduce the Gardens' use of potable water for irrigation and to mitigate the erosion of the cliffs near the Gardens by reducing the peak stormwater flows. This system will tap into the UBC stormwater main running underneath the Gardens and will feature an aesthetically pleasing surface retention pond, a reed bed to filter out contaminants, and a subsurface storage tank to store the treated water. This system is designed to store 1150 m^3 of treated water, which will reduce the Gardens' potable water usage by 30% during the summer months. The capital cost of the project is estimated to be \$678,000 over an eight-week construction period. Operations and maintenance costs are estimated to be \$1,300 annually over the 50-year design life of the system.

Group 20 Inc. performed the detailed design related to the hydrotechnical, environmental, and geotechnical components for the stormwater detention pond and subsurface storage system, with detailed designs for the remaining components being completed by others.

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1 INTRODUCTION

The UBC Botanical Gardens (the Gardens) is concerned with its current use and management of water. To address these concerns, Group 20 Inc. has compiled the following report detailing the design of a subsurface storage reservoir and a collection/distribution system for the Gardens.

1.1 Project Background

Currently, the Gardens are using potable water to irrigate their plant collections. In order to become more sustainable, it would be beneficial for the Gardens to collect stormwater to use for irrigation. Group 20 Inc. has been contacted to design a subsurface storage reservoir and collection/distribution system. This system is to be used to retain stormwater from one of UBC's catchments to irrigate the Gardens and to reduce the erosion of cliffs immediately west of the Gardens by absorbing flows from storm surges. This system will predominantly be underground to minimize its impact on the aesthetics of the Gardens. Social amenities and attractive landscaping will also be installed in this area with consultation with Garden staff to make it a destination for visitors of the Garden to enjoy.

1.2 Design Overview

The use a natural passive water treatment system to filter stormwater for irrigation use in the Gardens has been determined to be the most ideal option. The design project will consider the use of a stormwater retention pond and a subsurface storage tank to reduce base flows, as well as a system to distribute the stored water. The collection system will be designed to maximize on-site water retention using best management practices for stormwater collection, and the design will also include a bypass during storm events. Water quality will be a key aspect of the project; as such, the design will include the re-development of the current cattail pond into a bio-filtration system preceding the distribution of water into the Gardens for irrigation purposes.

1.2.1 System Layout

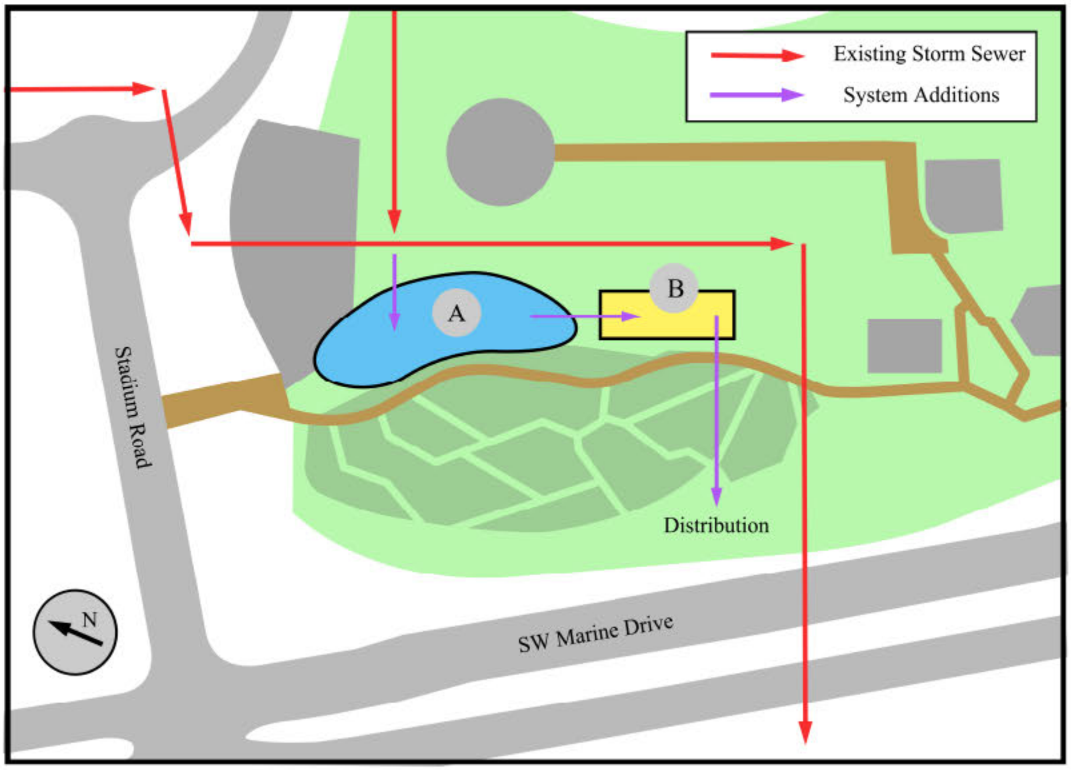


Figure 1: Simplified aerial system layout. Stormwater retention pond (A) and reed bed filtration system (B).

Stormwater is collected initially at the junction of two existing storm sewers in the north gardens, as seen in the above figure. This will provide the gardens with a significant fraction of the stormwater generated in the northwest catchment area of UBC. From here, the path of water through the collection/treatment/distribution system is summarized in Figure 2.

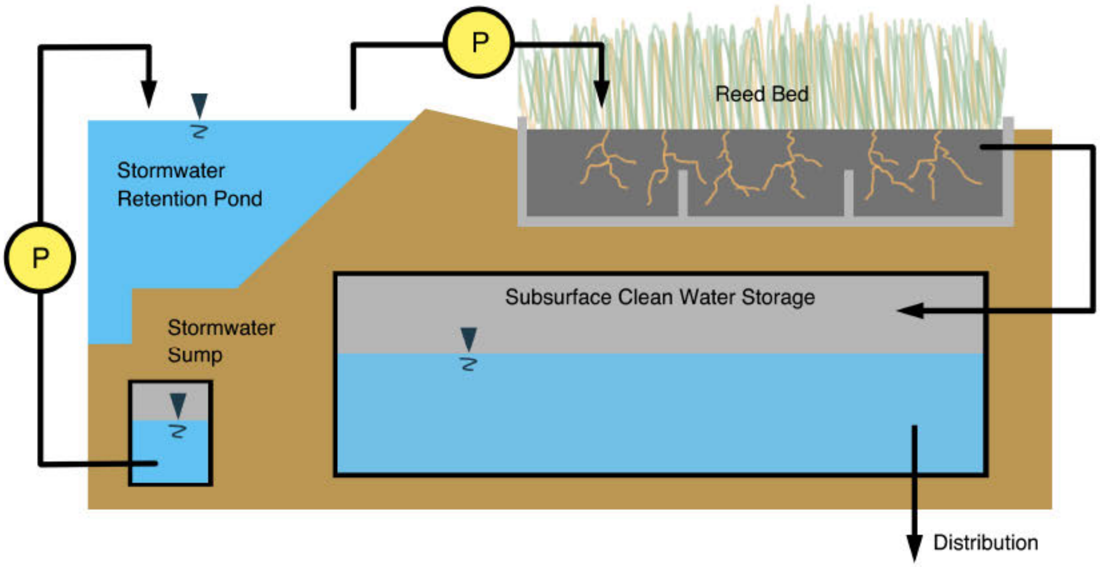


Figure 2: Section view of overall system layout.

The flow of water through the system is as follows:

1. Water from the existing storm sewer is collected in the stormwater sump and pumped into the stormwater retention pond. Storm flows that exceed the pump capacity will bypass the system through the existing pipe network.
2. Water from the retention pond is pumped continuously at 15 m^3/day into the reed bed for treatment.
3. Water drains from the reed bed at a rate of 15 m^3/day into the subsurface storage tank. This mechanism is gravity operated; no pump is needed.
4. Water is pumped from the subsurface storage tank into a distribution system for irrigation use. Potable water will be supplemented when the system does not meet demand.

1.2.2 Social Amenities

In order to integrate the design with the overall aesthetics of the Botanical Gardens, social amenities will be placed around the water retention system for visitor use and education. Park benches will be placed around the reed bed and retention pond, so visitors can sit and enjoy the beauty and tranquility of the area. A floating pier or footbridge will be constructed across the surface retention pond to enhance the beauty of this feature and to improve pedestrian circulation in the area. Informational signs will also be placed around the area to educate visitors about the stormwater reuse system and how it improves the Gardens' sustainability initiatives.

A landscaping plan around the stormwater detention system will be created in conjunction with the Gardens' staff. The area around the detention system can be used as habitats for the Gardens' plant collections, with trees such as willows being planted along the south. These would also act as a solar barrier to minimize the evaporation of water in the retention pond.

2 TECHNICAL ANALYSIS

Before designing the individual components within our system, we needed to understand fully the irrigation needs of the Gardens and the availability of stormwater throughout the year. To accomplish this, a water use model was created by combining irrigation data from UBC Building Operations with statistics on rainfall, soil infiltration, evapotranspiration and runoff from a study at UBC by Piteau Associates Engineering Ltd. (discussed more thoroughly in Section 2.2.1.1). While looking more closely at this data, it became apparent that stormwater availability during the summer is minute compared to the rest of the year. Even the small amount of rain that falls from May to October appeared to be evaporated or absorbed by soil and plants. Figure 3 shows the relationship between precipitation and runoff at the UBC campus. Figure 4 shows runoff volume in comparison to the garden's irrigation requirements.

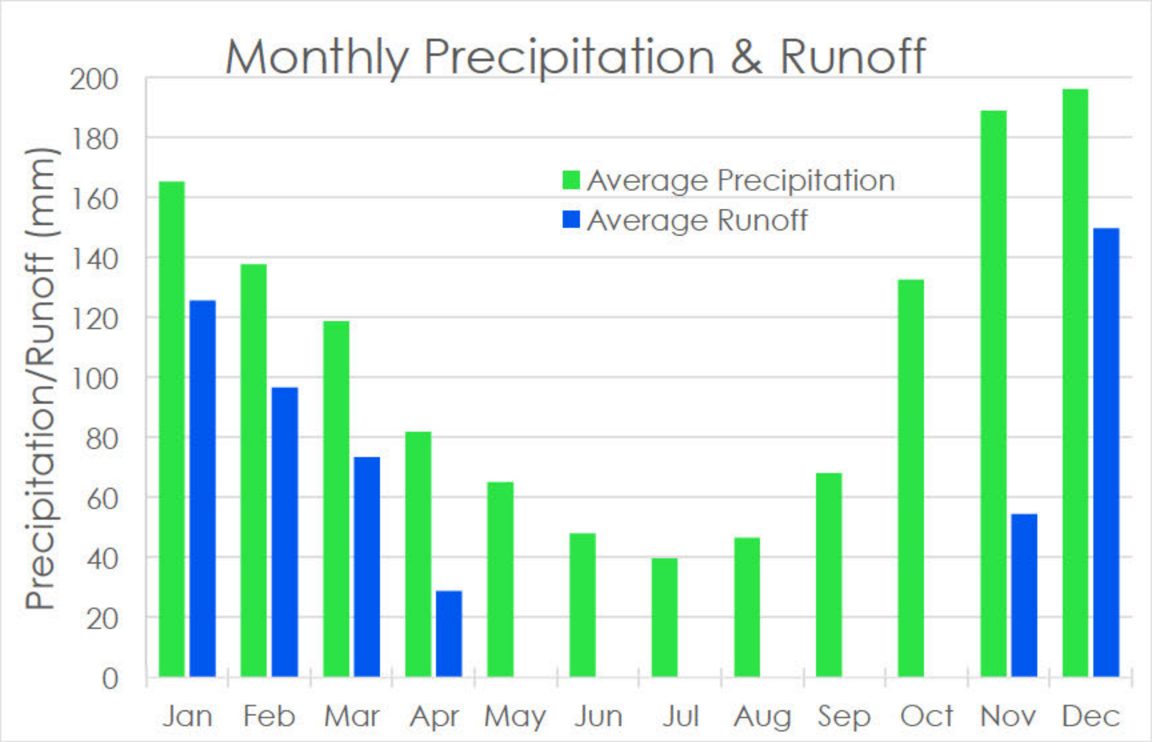


Figure 3: Average monthly precipitation and runoff at UBC.

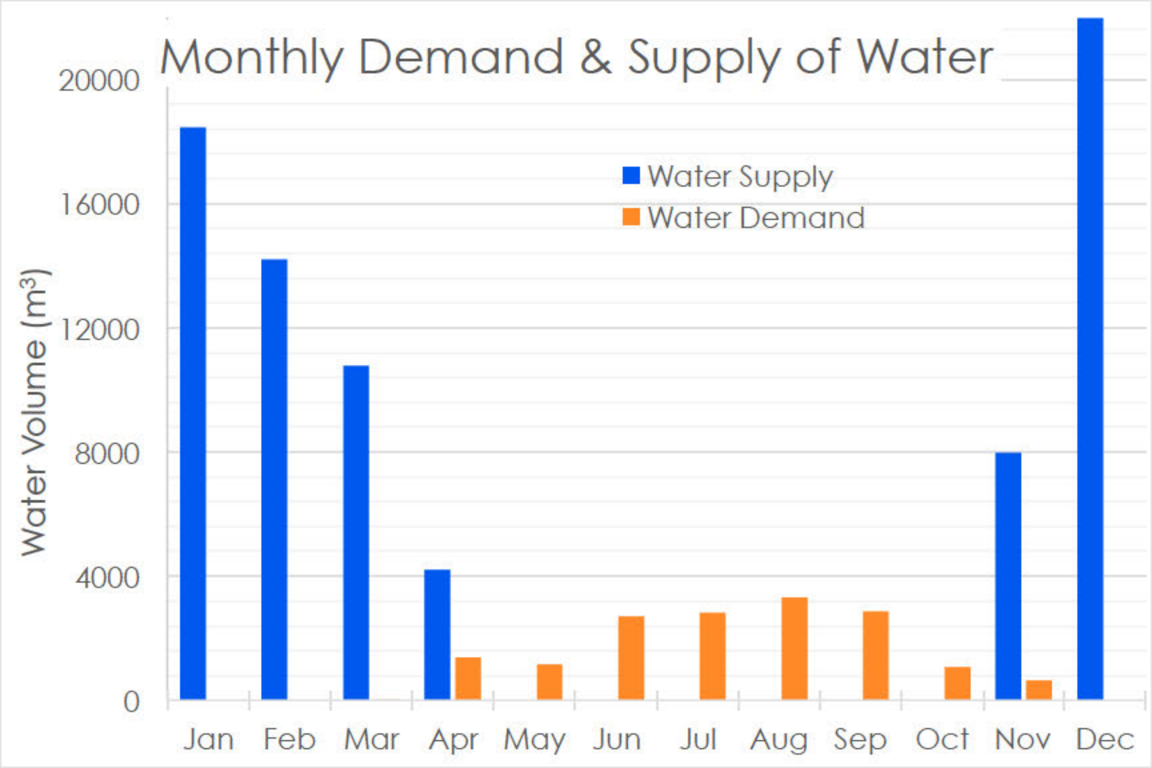


Figure 4: Average monthly irrigation requirements and available stormwater runoff.

Using our water model and the data presented above, we were able to design a system which stores an initial volume of treated and untreated water during wetter months in preparation for the dry season. Given average weather conditions, we expect to be able to provide more than 30% of the garden's irrigation demand from May to October, and almost 100% of demand for the rest of the year. Table 1 summarizes the required storage and treatment volumes of our proposed system.

Table 1: Overall system storage and treatment volumes.

	Usable Storage Volume (m^3)	Treatment Volume (m^3/day)
Stormwater Retention Pond	2884	-
Reed Bed Filtration System	-	15
Subsurface Clean Water Storage Tank	1150	-

2.1 Water Treatment System

One of the key considerations in the design of our stormwater retention and distribution system was water quality. The UBC Botanical Gardens are home to thousands of species of plants, many of which could be sensitive to contaminants commonly associated with surface runoff. Stormwater contamination varies widely depending on location and time of year. The British Columbia Ministry of Environment lists suspended solids, oxygen demanding substances, heavy metals and trace elements, organic contaminants, and pathogens as the most commonly detected pollutants in urban runoff. Group 20 Inc.'s ultimate goal was to provide irrigation with some reduction in these contaminants using a system that is almost entirely self-sufficient and compatible with UBC's sustainability goals. Prior to its use in irrigation, the stormwater should be treated at least to the level of secondary effluent to ensure the health of the collections and individuals in close proximity to the gardens.

Ultimately, a biofiltration system referred to as a reed bed was selected as an appropriate design solution. Reed beds are simple, lined channels filled with gravel and planted with the common reed (Phragmites australis). The primary treatment mechanism in biofiltration systems is a thin layer of microorganisms fixed to the gravel; this is known as an attached growth system. Reeds supply the bacteria and other microorganisms in the reed bed with oxygen and remove excess nutrients through uptake. Similarly designed systems with a 5-day residence time have produced a 95% reduction in BOD, a 95% reduction in total suspended solids, 60-80% removal of nitrogen, and 2.5 – 3 log removal of fecal coliforms (99 – 99.9% removal). Table 2 summarizes the level of treatment we expect the reed bed to provide. Note that these are average values and that some variability should be expected in all parameters, especially stormwater quality during times of significant land alteration (i.e. construction). There will also be some suspended solids removal in the stormwater retention pond as a result of settling.

Table 2: Water quality summary for stormwater, secondary effluent, and the expected reed bed effluent. Sources: Performance of Reed Beds and Single Pass Sand Filters (2001), Dr. Pierre Bérubé (CIVL 406).

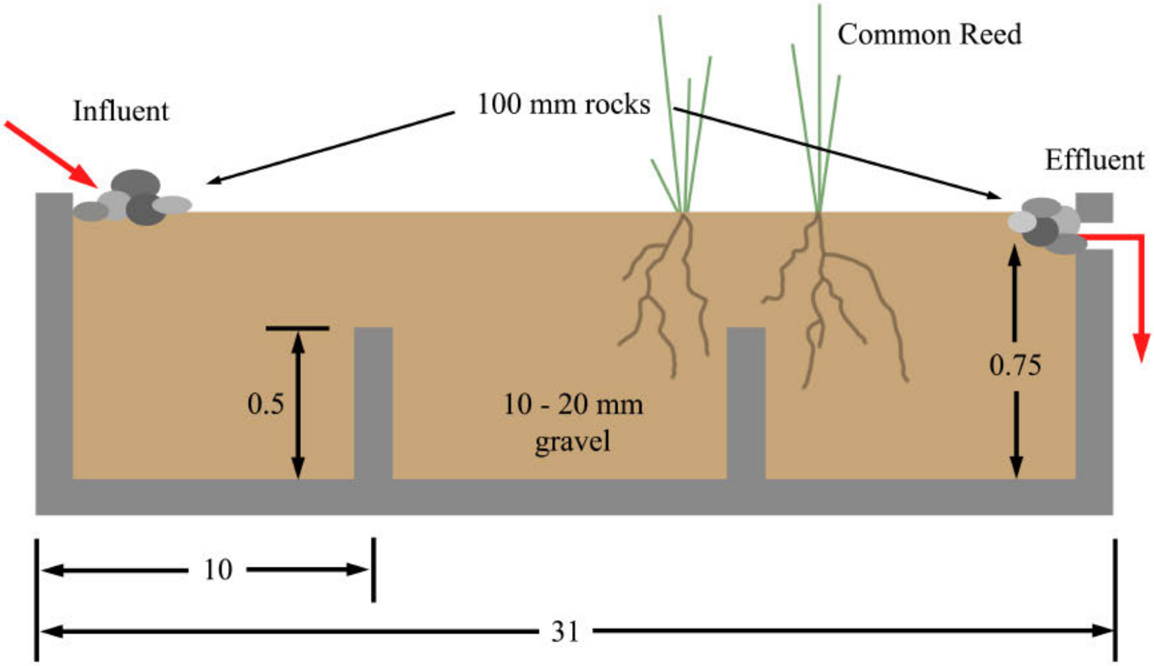
	BOD (mg/L)	Suspended Solids (mg/L)	Total Nitrogen (mg/L)	Fecal Coliforms (mg/L)
Stormwater Runoff	20	400	3-10	15000
Secondary Effluent	< 25	< 15	< 10	< 1000
Reed Bed Effluent	1	20	0.6-4	15-150

Compared to many treatment systems, reed beds are fairly straightforward to design. For the purposes of this report, only a preliminary design of the reed bed system has been conducted. Certain components, including a detailed design of the bed foundation and inflow/outflow systems, will be designed by others.

The size of the reed bed was selected based on the required treatment volume (V_T) of 15 m^3/day and a recommended hydraulic residence time (HRT) of 5 days. The reed bed is filled with 10-20 mm size gravel, with an assumed porosity (ε) of 0.4. The required reed bed volume (V) can then be found using the following relationship:

$$V = \frac{HRT \times V_T}{\varepsilon} = \frac{5 \times 15}{0.4} = 187.5\ m^3$$

Given this volume, a 0.75 m deep reed bed has a required area of 250 m^2. To ensure continuous, steady movement of water through the gravel, an L:W ratio of approximately 3:1 to 4:1 is recommended, and horizontal baffles are installed to encourage flow through the biologically active root layer. The channel itself should be lined with durable waterproof material, such us watertight concrete. Thin polymer liners will often be insufficient, as roots from the reed bed will punch through the membrane and the system will fail. The figure below illustrates the overall reed bed design. All labeled dimensions are accurate, however relative scale has been sacrificed for readability in this document.



All dimensions shown are in metres unless otherwise stated.

Figure 5: Basic reed bed design and dimensions.

The final reed bed dimensions are 9 m by 31 m at the surface, and 0.75 m deep at the outlet pipe. Large rocks (50-100 mm) are placed at the inlet and outlet pipes to prevent accumulation and loss of material, as well as to evenly distribute the influent. Reeds are planted 4-5 reeds/m^2 or greater.

Maintenance of the reed bed will be required occasionally. Starting one year after installation, and twice per year after that, the reeds should be harvested to a height of approximately 20 cm above the gravel surface. Harvesting may be done in spring and fall, and encourages new growth and absorption of nutrients from the treated water. The water level should also be gradually lowered by about 200 mm for two weeks of the year (during the dry season). This will promote root growth, and can be accomplished with a variable-depth outlet pipe or simply by stopping the flow of water and allowing evaporation.

2.2 Water Detention Systems

2.2.1 Initial Retention

The storm water collection system has been designed with the intent of reducing the potable water used by the Gardens in such a way which can be boasted as environmentally sound, and in a way which allows the Gardens to run operations by more sustainable practices. Group 20 Inc.'s approach to tackling this issue involved the analysis of multiple styles of detention systems, and water treatment methods. All of these systems were based off of the idea that using the considerable storm water flow for the southern Campus filtered for oil, metals, and contaminants harmful to the local ecosystem would be great enough to provide a significant reduction in potable water use. Designs considering one storage tank that would be filled with water filtered directly after being diverted from the storm system, and storage tanks holding diverted water that would be emptied as needed were initially considered, but proved to be altogether infeasible. The idea for an initial retention pond, which would be large, naturally shaped, and functional for dilution and settling was decided upon as the initial mechanism for retention. This pond will be the first step after a basic oils-removal process, and will feed water into the reed pond filtration system.

2.2.1.1 Flow Design

The idea of implementing a second storage tank for filtered water allowed for bridging the gap between goals and constraints. By creating a tank which could be fully filled during wet winter months where irrigation aside from rainwater was necessary, the system could begin the dry summer months with an initial capacity. A spreadsheet model was created to analyze and design the required volumes of the system (See Table 3). Calculating the volume within the pond and in the tank per each day, considering evaporation, processing requirements, and water usage became a simple balancing game once the final storage tank volume of 1150 m^3 was decided upon. This element has been designed as a wet pond, which is to have sloped sides to allow growth of indigenous plant life, and will slope towards a 1 m deep rectangular section intended to remain fully filled year-round. The reasoning behind this concept is that of aesthetics and beautification. An empty, lined pit, has no place within the UBC Botanical Gardens, and so it has been avoided thusly, and instead, at the end of summer, there will be a beautiful, marshy slope leading into a small pool.

Table 3: Water Use Model

	Day	Volume Evaporated from Ret. Pond m^3	Grey Pond Volume m^3	Volume Processed by Reed bed m^3	Tank m^3	Volume Taken from Tank m^3	Potable water used m^3
May	0	-1.27	2884	15	1150.000	-21.389	-48.611
	1	-1.27	2867.95	15	1143.611	-21.389	-48.611
	2	-1.27	2851.67	15	1137.222	-21.389	-48.611
	3	-1.27	2835.40	15	1130.833	-21.389	-48.611
	4	-1.27	2819.12	15	1124.444	-21.389	-48.611
	5	-1.27	2802.85	15	1118.056	-21.389	-48.611
	…	…	…	…	…	…	…
October	176	3.97	51.99	15	25.556	-21.389	-48.611
	177	3.97	40.95	15	19.167	-21.389	-48.611
	178	3.97	29.92	15	12.778	-21.389	-48.611
	179	3.97	18.89	15	6.389	-21.389	-48.611
	180	3.97	7.86	15	0.000	-21.389	-48.611

2.2.1.2 Geometric Design

The full water system will be located between the Great Lawn, and SW Marine Drive. Due to the location of the lawn, and the collections growing adjacent to the road, the pond had to be sized to fit within a 25meter width. The pond shall be shaped as a naturally occurring body, curved and decorated. The minimum volume of this shape will be 2885 m^3. The pond can be considered in two sections, a forebay, and still-water section. All sediments are intended to settle within the forebay to allow for cost effective maintenance. Within the forebay is the flow inlet, which will be guarded by rip-rap to reduce entry velocity with the purpose of keeping turbidity low. Five meters away from the inlet will be berm of cobble and gravel to ensure that minimal settle-able materials reach the far end of the pond. The walls of the pond have been designed with a 3H:1V cross fall, chosen for safety during both the construction and in-use phases.

2.2.1.3 Soil Recycling and Excavation Reduction

The pond itself requires a large volume. The introduction of a wide berm raised above ground level around the pond perimeter, constructed using excavated materials, is the solution applied to reduce this volume. Using this approach, the mass-haul required was reduced to null. The berm selected will be a height of 1.20 m above the original ground surface, and will have a 3 m flat top to allow for a pathway and benches to be built, and should prove scenic. The outer edge of the berm is to be sloped outwards at 10H:1V until it reaches the existing surface. See Figure 10 in the Appendix for further details. Using these geometries, the total depth of excavation was reduced by 1.30 meters, and the total volume excavated between the pond and the treated water tank was reduced by over 1000 cubic meters, or 23%.

2.2.2 Treated Water

Water which has been treated by the reed bed system is drained into the subsurface storage tank. There, it is stored until needed for use by the Botanical Gardens as shown in

Figure 2. Water is then pumped out of the storage through pipes to the garden's distribution system.

2.2.2.1 Aesthetics

As part of the design to integrate the new system into the existing Botanical Gardens, the storage tank is placed underground to reduce the project's overall footprint on the gardens. With the reed bed placed directly above the storage tank, there is still an opportunity for educating students and the general public about the garden's unique solution in tackling both its water usage and erosion problems.

2.2.2.2 Performance

As part of the optimization we conducted in our water-use model, the underground water storage requires at least 1150 m^3 of storage. This storage capacity will allow the Botanical Gardens to achieve the targeted 30% reduction in their current potable water usage during the summer months. The system also supplies all of the garden's water demand during non-summer months. The result of this efficient optimization has allowed the sizing of the subsurface storage tank to be less than one-third the volume the system can provide given no water recharge.

In addition, the treated water is designed to flow into the storage tank by gravity due to the tank's placement below the reed bed. By keeping the treated water storage from being exposed to the environment, multiple benefits are accrued. Benefits include being able to keep contaminants from reaching the treated water, and a minimized amount of treated water lost to the environment due to evaporation. The strategic placement of the tank assists in minimizing operating costs to the Botanical Garden.

2.3 Stormwater Collection

The proposed stormwater retention system is designed to collect water from an existing storm sewer located in the north gardens. Figure 6 illustrates how water is transferred from the pipe to the proposed retention pond. In the figure, the mechanism encircled in green indicates the pump and sensors system.

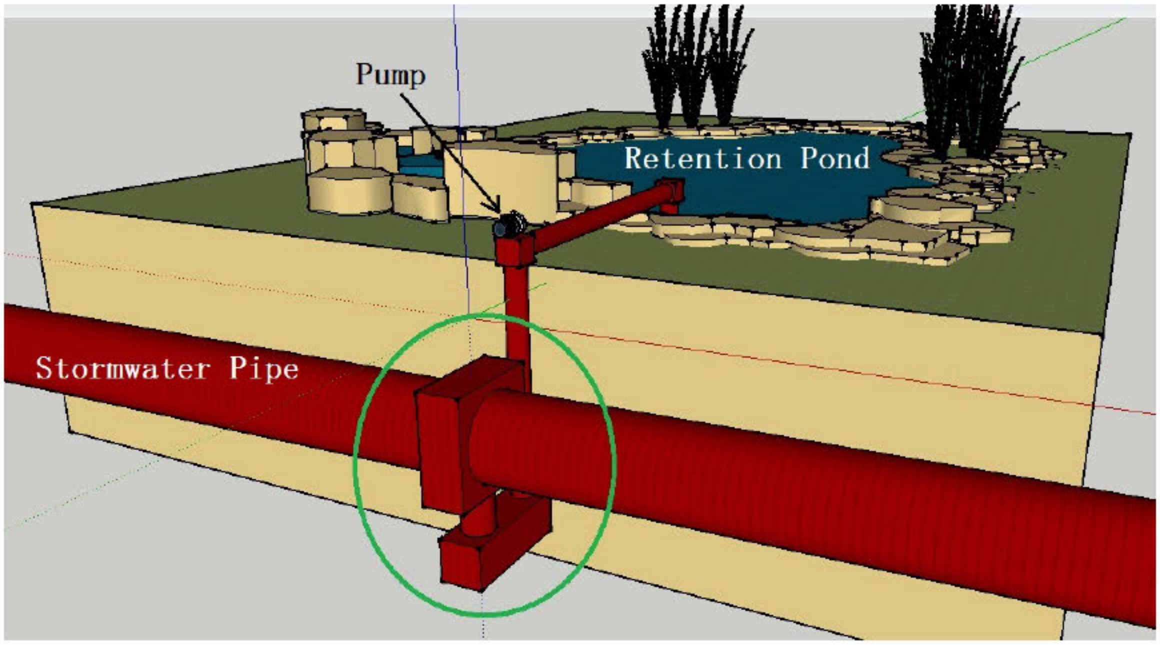


Figure 6: Stormwater Collection System

2.3.1 Pump and Sensors

Bringing water from the existing stormwater pipe to the proposed retention pond can be achieved by using a system of pumps and sensors. The use of this system is efficient, economical, and entirely autonomous. In order to make the system work, the existing storm sewer will need to be modified. As shown by Figure 7, a small water tank is built at a lower elevation that the storm sewer. Once the tank is filled with water, a pump will transfer the contents into the retention pond. The water in the pipe will flow to the tank first, and after the tank is full, excess stormwater will flow into the downstream pipe, as was previously the case. The dimensions of the tank are 1.2 m long by 0.5 m wide, and 0.8 m deep. Two sensors are installed in the tank at different heights. As shown in Figure 7, Sensor 1 is an activation sensor located 0.7 m above the base of the tank, and Sensor 2 is a pause sensor located 0.1 m above the base of the tank. When the water level in the tank reaches Sensor 1, the pump will start to work and bring water to the retention pond. When the water level drops to Sensor 2, the pump will stop working and wait for the water level to reach Sensor 1 before starting again. If there is no rainfall, Sensor 1 will not be activated, and the pumps will remain inactive.

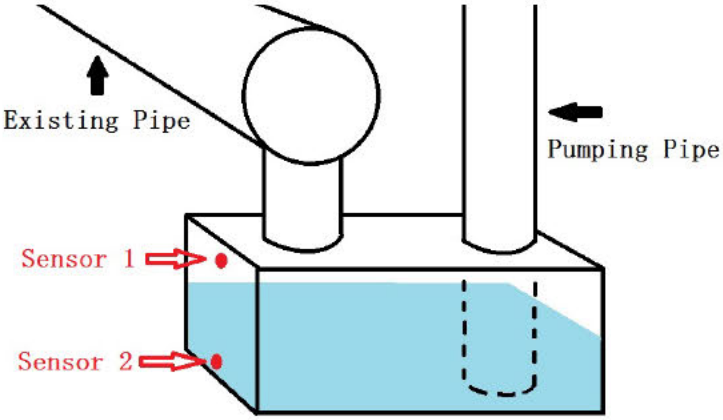


Figure 7: Pump and Sensors System

In the retention pond, there is an additional pause sensor. This sensor is located at a depth about 0.5 m below the surface of the pond. This sensor indicates the maximum water level in the pond. When the water reaches this sensor, the pump will stop pumping water into the pond.

The pump system will be fully computer controlled and autonomous. The computer will read the data from these sensors and activate and deactivate the pump as needed.

2.4 Stormwater Diversion

If, for any reason, the water level in the retention pond exceeds the design capacity, a diversion will be needed to release the excess water in a controlled manner. This could potentially be the result of a pump malfunction or a particularly severe storm. During periods of intense rainfall, the water level in the retention pond may rise significantly, eventually overflowing and flooding the garden. In order to prevent this scenario, a stormwater diversion system was designed.

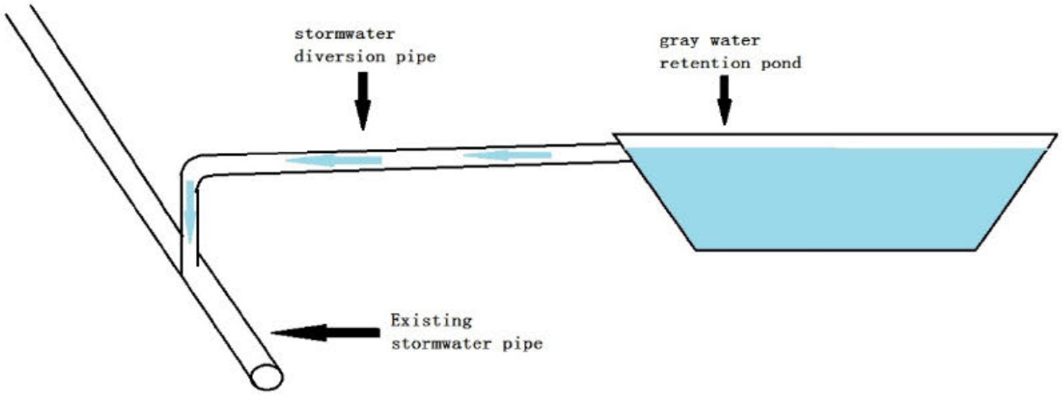


Figure 8: Stormwater Diversion System

The overall purpose of the stormwater diversion system is to redirect the excess water in the retention pond to the existing stormwater pipe by placing a pipe between them, as shown in Figure 8. A 40 cm diameter pipe is recommended and it will be installed with a slope of approximately 1:10. As a result, gravity will drain excess water from the retention pond into the storm sewer. The bottom of the pipe as it exits the pond will be about 50 cm below the surface of the pond. When the water level in the pond exceeds the limit, water will automatically flow into the diversion pipe, eliminating the risk of overflow into the gardens. The construction of the diversion system is simple and economical. A trench will be dug with an average depth of approximately 1.5 m. The length of the 40 cm pipe depends on the distance between the retention pond and the existing stormwater pipe. The overall cost of the stormwater diversion system is small relative to the cost of the retention pond, and a more detailed cost analysis will be shown in the following section.

3 CONSTRUCTION MANAGEMENT

Construction timelines and costs have be determined by obtaining quantity takeoffs from our designs and referencing RSMeans construction data to determine the required staff, duration and cost of each construction task. Each task duration and cost has been adjusted to account for changes in productivity and other factors related to weather. Using the data generated from RSMeans, Microsoft Project software was then used to generate a schedule of the construction phase in the form of a Gantt chart.

3.1 Estimating

Estimating for the project at the UBCBG was conducted using RSMeans 2014 unit-price cost data as the primary source, with additional information acquired from local vendors and other third-party sources. Table 4 shows a breakdown of the project's construction costs, separated by the project's components. A more detailed breakdown of the estimate, separated by individual construction tasks, can be found in Table 6 in the Appendix.

Table 4: Breakdown of Construction Costs by Component

Component	Cost
Preconstruction	$ 23,000
Stormwater Detention Pond	$ 81,000
Reed Bed	$ 30,000
Subsurface Storage Tank	$ 396,000
Distribution System	$ 10,000
Social Amenities	$ 10,000
Total Construction Costs	**$ 550,000**

As shown by Table 4 above, construction costs for this project are relatively low, with two components being responsible for much of the costs – namely the stormwater detention pond and subsurface storage tank.

The relatively high costs for the stormwater detention pond is a result of the amount of material which requires excavation. Even with the implementation of the soil recycling solution to reduce the amount of material that needs to be removed from site, the total excavation required for the construction of the detention pond is 2400 m^3, with an associated cost of approximately $10,000. In addition, the construction of the berm required to effectively "lift" the pond also has an associated cost $10,000. Lastly, the installation of the pond liner is estimated to be a large expense, with an anticipated cost of $30,000.

As for the construction of the subsurface storage tank, essentially all of the cost comes from the purchase of the 1160 kL precast concrete tank. It was decided that a precast concrete tank was required to address concerns that alternatives would be unable, economically, to withstand the weight of the soil and reed bed directly above. Overall, the precast concrete tank has an estimated cost of $375,000.

On top of the total construction cost of $550,000, a contingency of 10% was added, and the standard 12% tax rate was applied. The results of this can be seen in Table 5.

Table 5: Breakdown of Total Project Costs

Component	Cost
Total Construction Costs	$ 550,000
Contingency (10%)	$ 55,000
Taxes (12%)	$ 73,000
Total Project Costs	**$ 677,000**

Note: the costs do not add up due to rounding to the nearest $1,000.

With regards to the annual operating and maintenance costs, this was estimated using a few basic assumptions. Firstly, it was assumed that all three pumps would be in continuous operation for 6 months out of each year. Using standard energy rates, the annual operating cost of the three pumps is $400. Secondly, the replacement and maintenance periods for the pumps are anticipated to be 12 and 6 years respectively. Each pump has an assumed replacement cost of $550 and service cost of $200. Thirdly, the maintenance periods of the stormwater detention pond, reed bed, and various social amenities were assumed to occur semi-annually, with labour requirements of one employee working for 6 hours being used. The annual maintenance costs of these three components is $640. Finally, by taking the annual costs and averaging them over the project's design life of 50 years, an annual operating and maintenance cost of $1,300 was determined. However, this value does not account for issues such as the time value of money. This issue and more are explored in Section 4.1.

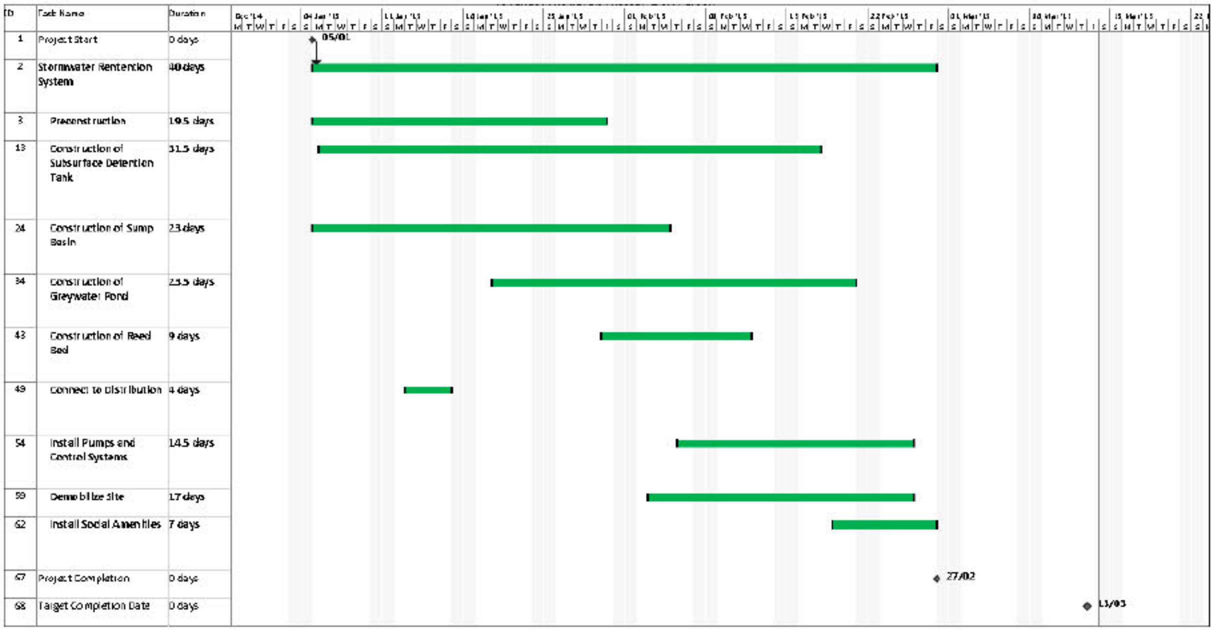
3.2 Scheduling

The goal of the project schedule is to have construction of the stormwater detention system completed during the Botanical Gardens' off-season, which runs from November

15 to March 15 every year. To complete the project within this timeframe, we recommend the project start in early January for three reasons:

1. Less precipitation from January to March than from November to January.
2. Avoidance of schedule disruptions arising, from the Christmas and New Year holiday season, by starting in early January.
3. Spring is a more favourable time for planting and landscaping.

To estimate the duration of construction, a schedule was created in Microsoft Project. Task durations were determined using a combination RSMeans data and experience. A Gantt chart showing the details of the schedule can be found in Figure 11 in the Appendix, while a summary of the schedule components are outlined in Figure 9 below:



ID	Task Name	Duration
1	Project Start	0 days
2	Stormwater Rentention System	40 days
3	Preconstruction	19.5 days
13	Construction of Subsurface Detention Tank	31.5 days
24	Construction of Sump Basin	23 days
34	Construction of Greywater Pond	23.5 days
43	Construction of Reed Bed	9 days
49	Connect to Distribution	4 days
54	Install Pumps and Control Systems	14.5 days
59	Demobilize Site	17 days
62	Install Social Amenities	7 days
67	Project Completion	0 days
68	Target Completion Date	0 days

Figure 9: Project Schedule Summary

Based on the schedule shown in Figure 9, the project can be completed in 40 days with a single excavator and crew of eight skilled labourers with experience in excavation and landscaping construction. On this schedule, two weeks of float have been allocated to absorb any construction delays or undertake tasks which have been overlooked before the end of the Gardens' offseason.

Some of the activities on the schedule, such as concrete coring, electrical work, and dewatering, will most likely be performed by specialist contractors and require minimal work contribution from the general construction forces. In general, the critical path of this project is governed by excavation and the installation of the pond liner, as shown in the Gantt chart in Figure 11 in the Appendix.

4 IMPACT ANALYSIS

Implementation of this project will have a number of impacts to the Gardens. In determining the scope for this project, Group 20 Inc. evaluated the issues and established a set of solutions aimed at addressing the key problems and resulting in positive residual impacts for the Gardens. Group 20 Inc. identified two main issues that fall within the scope of this project. First, the Gardens currently use potable water for 100% of their irrigation, and, second, during high flow storm events, there is a significant amount of streambed erosion caused by a stormwater outflow located in the Gardens. The design produced by this project aimed to address these key issues and also to meld with the mission of the UBC Botanical Gardens. By tapping into the current stormwater collection system from nearby catchment areas on the university lands to irrigate the Gardens, there is a 31% reduction in the use of potable water in the Gardens. Using stormwater also decreases peak flows resulting in reduced streambed erosion. Furthermore, the water treatment system developed in this project presents a great opportunity to create a learning environment for natural water treatment processes. Finally, the project design recommends the inclusion of certain amenities such as benches and a dock to add to the aesthetic appeal of the design. Ultimately, every project involving construction has economic, social, and environmental impacts. The design of this project has incorporated key features to reduce negative impacts and amplify positive impacts.

4.1 Economic

A major constraint for this project is the limited amount of funds available to the Gardens. As a result, the main concerns of our design were keeping capital costs to a minimum and incorporating components into our design that would attract more visitors to the Gardens. This section analyzes the direct and indirect economic impacts associated with the project.

The direct economic impacts for this project capital costs, operation and maintenance costs, and savings produced by the reduction in water usage. The most prominent economic impact of this project is the cost of construction at $678,000. This cost includes a 10% contingency as well as taxes at a rate of 12%. The design was analyzed to identify cost saving measures wherever possible. A key feature of the design includes soil recycling: by using excavated soil to create a berm to construct the stormwater retention pond rather than simply excavating all necessary materials, the design allowed for a 31% reduction in the necessary initial soil excavation plus a 100% reduction in the mass of soil hauled off-site. This soil recycling method resulted in cost reductions of $3,700 for excavation and $3,000 for material hauling. A more detailed breakdown of the construction costs is located in Section 3.1 of this report.

Another direct economic impact associated with the project is the operation and maintenance. These costs, however, are quite small and are estimated to be at approximately $1,300 per year. The operation and maintenance of the project is comprised primarily of the occasional dredging of the stormwater retention pond and basic upkeep (i.e. weeding) of the reed bed. Further details of the cost components associated with operation and maintenance can be found in Section 3.1.

This project is dominated mostly be the high initial capital costs; however, there are some tangible savings associated with the design. Reducing the Gardens' potable water usage by 31% produces a direct 31% savings on the cost of water. To calculate the savings associated with the reduced water usage, water rates were taken to be $2.385 per unit from October 1st to May 31st and $2.988 from June 1st to September 30th, where one unit of water is equivalent to 2.83168466 cubic meters (City of Vancouver, 2014). These rates are consistent with the City of Vancouver's proposed metered utility rates based on the Greenest City 2020 initiatives. Based on these rates and the Gardens' water usage throughout the year, which is illustrated in Figure 4 in Section 2, the savings generated by the reduction in water use is on average $6,100 annually.

Some indirect economic impacts may also be identified for this project. These impacts include reduced costs associated with streambed reparation and increased revenues attributed to new amenities (i.e. educational and aesthetic) resulting from the project. Furthermore, decreasing the usage of potable water at the Gardens reduces the strain on existing water infrastructure, eliminating the need for costly system upgrades that could lead to higher utility rates and also helps the city live within its water means, ensuring that all residents have access to abundant safe, clean water, no matter how much the city grows. For the purposes of this analysis, values for these indirect economic impacts were not generated; however, through appropriate research and statistical analysis, additional savings could be calculated and attributed to the project.

Given the direct costs of the project discussed above, Group 20 Inc. conducted a present worth analysis of the project. For the purposes of this analysis, a minimum acceptable rate of return (MARR) of 12% was assumed. It is recommended that further analysis be conducted in order to determine a more accurate value for the Gardens' financial situation. Given a MARR of 12% and a lifetime of 50 years for the project, the present worth of each direct cost was calculated. The construction of the project is expected to finish in much less than a year; as such, the present worth of the construction costs remains the same at $678,000. The annual operations and maintenance costs are $1,300, which, calculated over the lifetime of the project, corresponds to a present worth of $10,800. The savings generated by project are $6,100 per year, which corresponds to a present worth of $50,700. In total, the present worth of the cost of this project is $638,100.

4.2 Social

The social impacts of this project are also significant. The project's water treatment system is a natural water treatment process, which showcases nature's ability to filter out contaminants from water without chemical disinfectants. The project provides the Gardens with an opportunity to create a learning environment for natural water treatment processes. Furthermore, the surrounding areas of the stormwater pond and the reed bed will include benches and a dock to add to the aesthetic appeal of the project creating an anchor point in the Gardens. The stormwater collection and treatment system will strengthen the Garden's sustainability initiatives and will be an attraction for the Gardens.

4.3 Environmental

There are a number of positive environmental impacts generated by this project. The most prominent environmental impact is the 31% reduction in potable water usage. Potable water is produced by collecting water from natural water systems and exposing it to treatment processes, including chemical disinfection. Reducing potable water usage decreases the amount of water needed to be removed from its natural environment and reduces the amount of water treatment necessary. Moreover, the water treatment system for this project uses natural processes to remove contaminants without the use of any chemical additives.

Another environmental impact of the project is the reduction of streambed erosion. Streambed erosion can cause disruption and destruction of habitats and ecosystems. By diverting stormwater into the Garden for treatment and use, there results a reduction in the base flows from the stormwater outfall located in the Garden. Decreasing base flows decreased erosion, thus preserving habitats and ecosystems. A further additional environmental impact is associated with the construction of the project. Construction activities cause many negative environmental impacts; however, Group 20 Inc. has incorporated soil recycling into the construction of this project. By using excavated soil to create a berm to increase the volume of the stormwater pond, the magnitude of excavation needed is decreased by 31% and the amount of soil required to be hauled off site is decreased by 100%.

5 RECOMMENDATIONS

As part of Group 20 Inc.'s detailed design, we include the following recommendations for the UBC Botanical Gardens.

With the addition of large masses onto the project area including a water retention pond, reed bed and subsurface storage tank, a geotechnical study of the project area is recommended prior to project implementation. This will enable the bed foundation and inflow/outflow systems to be properly designed by others, as matters such as settlement will be accounted for. This better ensures the long-term stability of the investment being added to the Gardens.

Due to the subjective nature of how well this project is received by the viewing public, we recommend that the Gardens' staff and volunteers be an integral part of decision processes which this project requires. This is especially important with the landscaping, amenities and the scheduling of the construction as we have mentioned in this report.

We recognize the importance of integrating the new infrastructure into its surroundings, and the impact construction has on an operating facility. In order to minimize the effects on the Gardens, we recommend that construction begin in January according to our schedule, such that the project is complete two weeks prior to reopening of the Gardens in March. By ensuring continued access to surrounding areas during implementation and improved access post-construction, guests and staff alike will be much more receptive to the new stormwater retention and treatment facility.

The educational component of the completed project also benefits greatly from consulting with the Gardens' staff and volunteers. With their knowledge of where visitors currently visit, signage and other informative pieces can be placed in the most effective spots to maximize potential visitor engagement. This additional engagement adds value to this project, with increased awareness of the UBC Botanical Gardens itself, and its sustainability initiatives.

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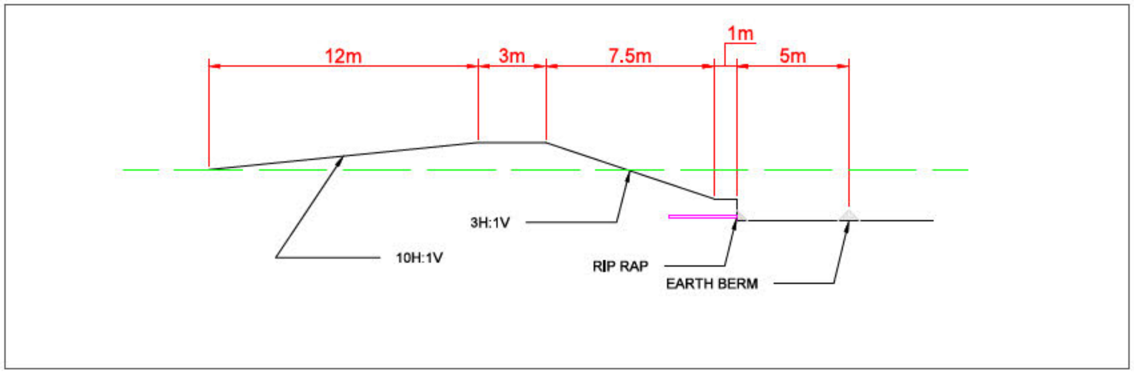
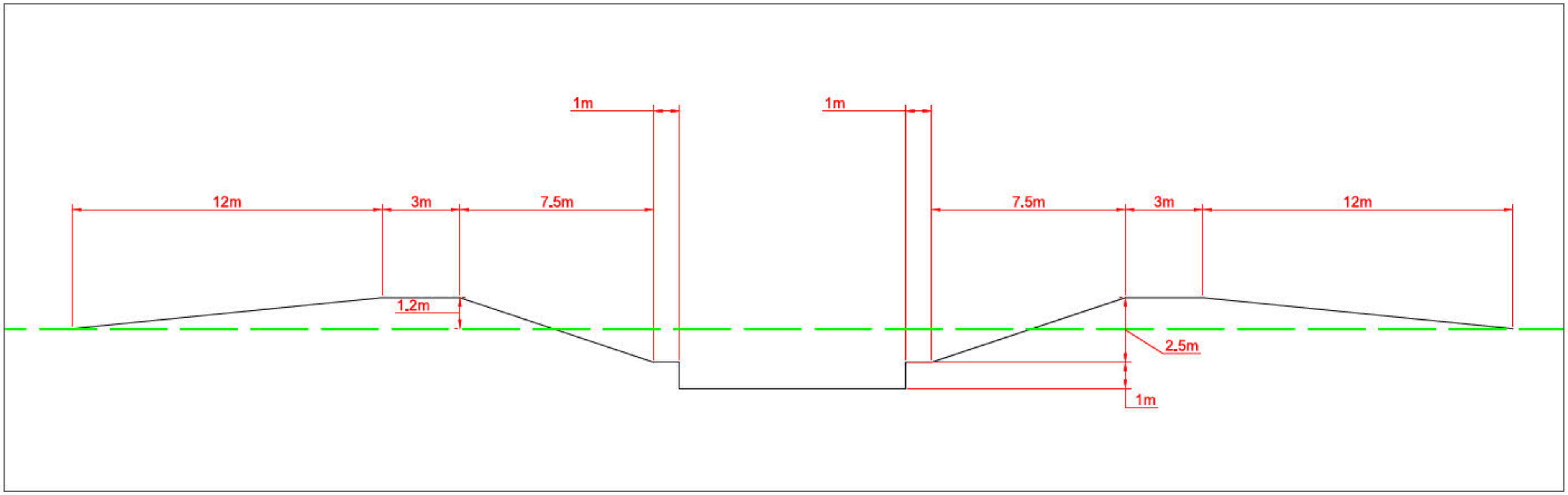
Appendix



POND INLET DETAIL

STONE	─
DESIGN El.	─
EXISTING El.	─
PIPE	─



TYPICAL CROSS-SECTION

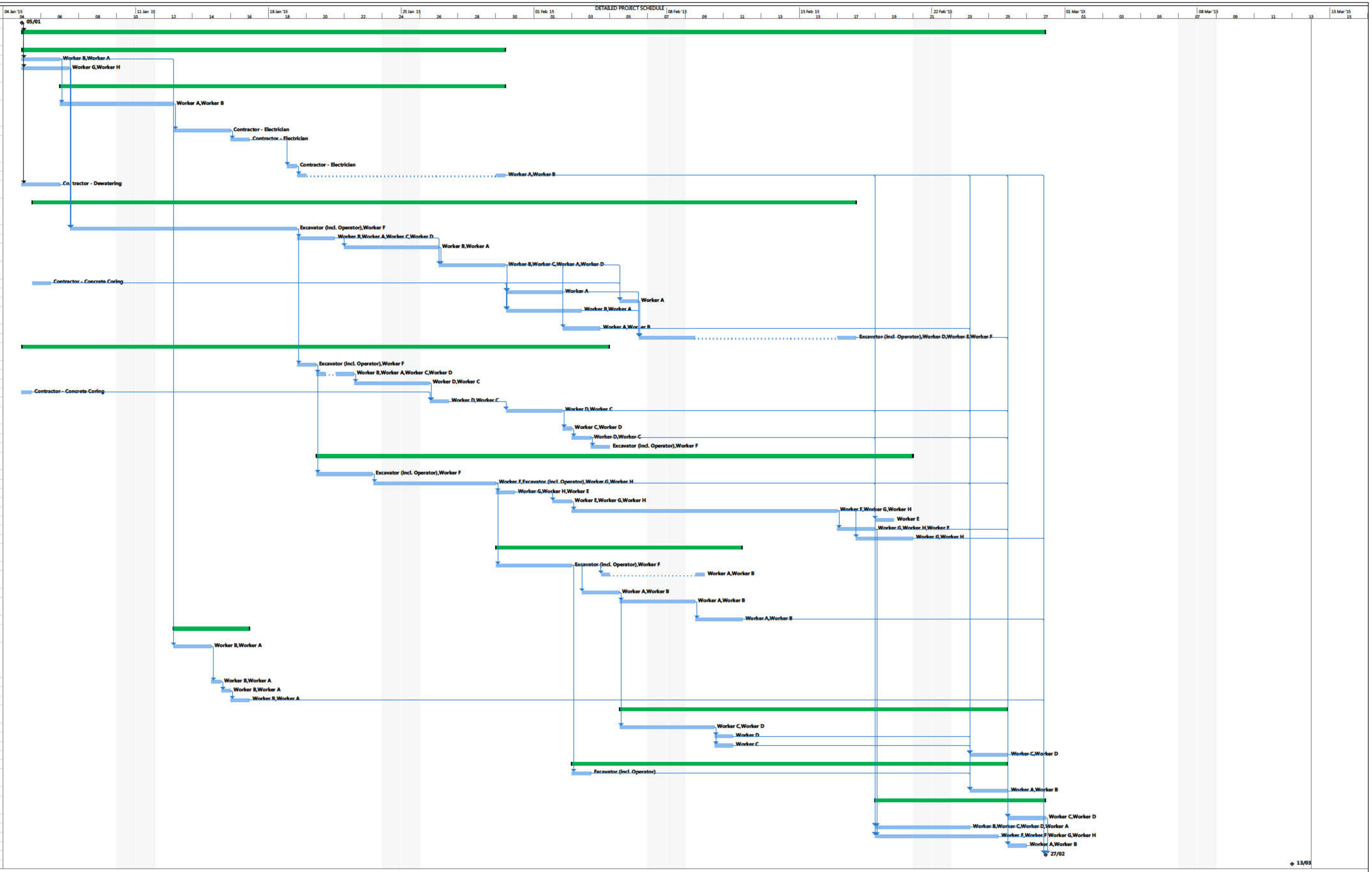
Figure 10: Stormwater Retention Pond Cross Sections

Table 6: Project Estimate

Component	Task	Line Number	Description	Unit	Crew	Total O&P	Quantity	Duration (Crew Days)	Total Costs (Incl. O&P)
Preconstruction Work	Surveying	017123131100	Crew for layout of trenching or pipe laying, 2 person crew	Day	A6	$ 1,111.02	1.00	1.000	$ 1,111.02
	Fence off Project Area	015626500020	Fencing, chain link, 1200mm high, 3mm thick	m	2 Clab	$ 19.79	300.00	2.459	$ 5,937.00
	Equipment Mobilization	015436500020	Mobilization, up to 40km haul distance, excavator, 52 to 112 kW	Ea.	B34N	$ 281.32	1.00	0.250	$ 281.32
	Equipment Demobilization	015436500020	Demobilization, up to 40km haul distance, excavator, 52 to 112 kW	Ea.	B34N	$ 281.32	1.00	0.250	$ 281.32
	Lay conduit & wire	15113500340	Temporary electrical power equipment, 400 A, Aluminum conduit, in trench	m	1 Elect	$ 144.14	100.00	7.813	$ 14,414.00
Removal of Cattail Pond	Pump out Water	312319200600	Dewatering, pumping 8 hours, attended 2 hrs per day, 50mm diaphragm pump used for 8 hours, in	Day	B10H	$ 245.26	2.00	0.500	$ 490.52
	Removal of Cattail Plants & Other Material	312316420250	Excavator, hydraulic, crawler mtd., 1.15 m3 cap. = 95.6 m3/hr	Bm3	B12B	$ 3.17	1000.00	1.307	$ 3,170.00
Construction of Stormwater Detention Pond	Excavation	312316420250	Excavator, hydraulic, crawler mtd., 1.15 m3 cap. = 95.6 m3/hr	Bm3	B12B	$ 3.17	2400.00	3.137	$ 7,608.00
	Construction of Berm	312323132350	Spreading in 203mm layers, small dozer	Lm3	B10B	$ 3.12	3600.00	4.444	$ 11,232.00
	Material Cost - Sand Layer	030513250950	Aggregate, sand, washed, for concrete, loaded at the pit, prices per m3, includes material only	m3		$ 51.17	75.00	0.000	$ 3,837.75
	Hauling of Sand Layer	312323200024	Hauling, borrow, loose cubic meters, 6.12 m3 truck, 24kmh ave., cycle 12.9km, 10 min. wait/Ld./Ul	Lm3	B34A	$ 15.01	75.00	1.115	$ 1,125.75
	Installation of Sand Layer	312323131300	Dozer backfilling, bulk, up to 90m haul, no compaction	Lm3	B10B	$ 2.75	75.00	0.082	$ 206.25
	Material Cost - Gravel Berm	030513250850	Aggregate, crushed bank gravel, loaded at pit, prices per m3, includes material only	m3		$ 62.14	6.00	0.000	$ 372.84
	Hauling of Gravel	312323200024	Hauling, borrow, loose cubic meters, 6.12 m3 truck, 24kmh ave., cycle 12.9km, 10 min. wait/Ld./Ul	Lm3	B34A	$ 15.01	6.00	0.089	$ 90.06
	Construction of Gravel Berm	312323131300	Dozer backfilling, bulk, up to 90m haul, no compaction	Lm3	B10B	$ 2.75	6.00	0.007	$ 16.50
	Concrete Cutting	038113500300	Concrete sawing, concrete slabs, plain, up to 75 mm deep, includes blade cost, layout, and set up ti	m	B89	$ 5.69	12.00	0.037	$ 68.28
	Connection to Existing Stormwater Line	312316130090	Excavating, trench, 1.2 m to 2m deep, 0.38 m3 excavator	Bm3	B11M	$ 10.62	80.00	0.523	$ 849.60
	Shoring	314116104500	Sheet piling, wood, solid sheething, 3.25 m2/hr in & 9.76 m2/hr out, 6m deep excavation	m2	B31	$ 175.70	36.00	1.845	$ 6,325.20
	Tapping into Stormwater Line	331213154850	Tap and insert gate valve, 300 mm main, 200 mm branch	Ea.	B21	$ 761.18	1.00	0.426	$ 761.18
	Tank for Stormwater Line		325 gallon underground cistern tank	Ea.		$ 500.00	1.00	0.000	$ 500.00
	Pump for Stormwater Line	332113101510	Pumps, installed in wells up to 30m deep, 100mm submersible, 0.37 kW	Ea.	Q1A	$ 994.41	1.00	0.311	$ 994.41
	Piping for Stormwater Line Connection	331113350300	Water supply, HDPE, 200 mm diameter	m	B22A	$ 88.46	80.00	0.820	$ 7,076.80
	Backfill	312323130500	Backfill and compact, by hand, 150 mm layers, air rammer/tamper, add	Em3	B9D	$ 16.30	27.00	0.186	$ 440.10
	Repaving	320129701140	Full depth patching of rigid pavement, light traffic, replace concrete with 31 MPa ready mix, 8.83-9	Ea.	A2	$ 739.49	1.00	0.125	$ 739.49
	Place Rip Rap	313713100100	Machined Riprap and rock lining, machine placed for slope protection	Lm3	B12G	$ 87.68	8.00	0.169	$ 701.44
	Pump for Reed Bed	332113101510	Pumps, installed in wells up to 30m deep, 100mm submersible, 0.37 kW	Ea.	Q1A	$ 994.41	1.00	0.311	$ 994.41
	Connection to Reed Bed	312316130090	Excavating, trench, 1.2 m to 2m deep, 0.38 m3 excavator	Bm3	B11M	$ 10.62	8.00	0.052	$ 84.96
	Piping for Reed Bed Connection	331113350300	Water supply, HDPE, 200 mm diameter	m	B22A	$ 88.46	8.00	0.082	$ 707.68
	Installation of Pond Liner	334713531200	Pond and reservoir liners, mebrane lining systems, HDPE, 9290 m2 or more, 2 mm thick, per m2	m2	3 Skwk	$ 20.61	1500.00	10.067	$ 30,915.00
	Installation of Trash Rack		Install low flow trash rack	Ea.		$ 1,700.00	1.00	0.000	$ 1,700.00
	Pond Landscaping		Planting shrubs, wetland plants, etc.	Ea.		$ 30.00	100.00	0.000	$ 3,000.00
Construction of Reed Bed	Excavation	312316130090	Excavating, trench, 1.2 m to 2m deep, 0.38 m3 excavator	Bm3	B11M	$ 10.62	200.00	1.307	$ 2,124.00
	Hauling of Excavated Material	312323200024	Hauling, borrow, loose cubic meters, 6.12 m3 truck, 24kmh ave., cycle 12.9km, 10 min. wait/Ld./Ul	Lm3	B34A	$ 15.01	200.00	2.973	$ 3,002.00
	Material Cost - Gravel Layer	030513250850	Aggregate, crushed bank gravel, loaded at pit, prices per m3, includes material only	m3		$ 62.14	200.00	0.000	$ 12,428.00
	Hauling of Gravel Layer	312323200024	Hauling, borrow, loose cubic meters, 6.12 m3 truck, 24kmh ave., cycle 12.9km, 10 min. wait/Ld./Ul	Lm3	B34A	$ 15.01	200.00	2.973	$ 3,002.00
	Installation of Gravel Layer	312323131300	Dozer backfilling, bulk, up to 90m haul, no compaction	Lm3	B10B	$ 2.75	200.00	0.218	$ 550.00
	Planting of Reeds		Wetland plants	Ea.		$ 6.00	1250.00	0.000	$ 7,500.00
Construction of (Subsurface) Filtered Water Detention Pond	Excavation	312316130090	Excavating, trench, 1.2 m to 2m deep, 0.38 m3 excavator	Bm3	B11M	$ 10.62	1200.00	7.843	$ 12,744.00
	Ground Preparation	312323130500	Backfill and compact, by hand, 150 mm layers, air rammer/tamper, add	Em3	B9D	$ 16.30	320.00	2.207	$ 5,216.00
	Water Storage Tank	331613160100	Prestressed conc. water storage tanks, 1160 kL	Ea.		$ 375,000.00	1.00	0.000	$ 375,000.00
	Concrete Coring (For Connection Locations)	038213100700	Concrete core drilling, includes bit cost, layout and set-up time, reinforced concrete slab, up to 150	Ea.	B89A	$ 80.75	2.00	0.143	$ 161.50
	Connection to Reed Bed	312316130090	Excavating, trench, 1.2 m to 2m deep, 0.38 m3 excavator	Bm3	B11M	$ 10.62	5.00	0.033	$ 53.10
	Piping for Reed Bed Connection	331113350300	Water supply, HDPE, 200 mm diameter	m	B22A	$ 88.46	5.00	0.051	$ 442.30
	Piping for Pump Connection	331113350300	Water supply, HDPE, 200 mm diameter	m	B22A	$ 88.46	5.00	0.051	$ 442.30
	Connection to Pump	312316130090	Excavating, trench, 1.2 m to 2m deep, 0.38 m3 excavator	Bm3	B11M	$ 10.62	5.00	0.033	$ 53.10
	Testing and Inspection	014523507510	Volumetric tightness test, <= 1010 m3	Ea.		$ 734.40	1.00	0.000	$ 734.40
	Backfill	312323131300	Dozer backfilling, bulk, up to 90m haul, no compaction	Lm3	B10B	$ 2.75	320.00	0.349	$ 880.00
Connection to Existing Distribution System	Excavation	312316420250	Excavator, hydraulic, crawler mtd., 1.15 m3 cap. = 95.6 m3/hr	Bm3	B12B	$ 3.17	27.00	0.035	$ 85.59
	Hauling of Excavated Material	312323200024	Hauling, borrow, loose cubic meters, 6.12 m3 truck, 24kmh ave., cycle 12.9km, 10 min. wait/Ld./Ul	Lm3	B34A	$ 15.01	27.00	0.401	$ 405.27
	Shoring	314116104500	Sheet piling, wood, solid sheething, 3.25 m2/hr in & 9.76 m2/hr out, 6m deep excavation	m2	B31	$ 175.70	36.00	1.845	$ 6,325.20
	Connection to Existing Distribution System	312316130090	Excavating, trench, 1.2 m to 2m deep, 0.38 m3 excavator	Bm3	B11M	$ 10.62	5.00	0.033	$ 53.10
	Installation of Prefabricated Pumphouse Shed		7' x 7' storage shed	Ea.		$ 1,250.00	1.00	0.000	$ 1,250.00
	Pump Installation	332113101510	Pumps, installed in wells up to 30m deep, 100mm submersible, 0.37 kW	Ea.	Q1A	$ 994.41	1.00	0.311	$ 994.41
	Dig trench from pumphouse to existing distribution network	312316130090	Excavating, trench, 1.2 m to 2m deep, 0.38 m3 excavator	Bm3	B11M	$ 10.62	15.00	0.098	$ 159.30
	Lay pipe	331113201160	Water supply, polyethylene pipe, C901, 1103 kPa, 50 mm diameter	m	Q1A	$ 18.17	15.00	0.135	$ 272.55
	Backfill	312323131300	Dozer backfilling, bulk, up to 90m haul, no compaction	Lm3	B10B	$ 2.75	15.00	0.016	$ 41.25
Social Amenities	Floating Pier	355113230200	Docks, fixed, pipe supported dock, galvanized steel pipe, treated wood dock	m2	F3	$ 682.91	10.00	0.828	$ 6,829.10
	Benches		Faux wood garden bench	Ea.		$ 150.00	5.00	0.000	$ 750.00
	Picnic Tables		Cedar picnic table, 6' x 5'	Ea.		$ 400.00	5.00	0.000	$ 2,000.00
							Total Construction Costs		$ 549,531.35
							Contingency (10%)		$ 54,953.14
							Taxes (12%)		$ 72,538.14
							Total Project Costs		**$ 677,022.62**

DETAILED PROJECT SCHEDULE

ID	Task Name	Duration
1	Project Start	0 days
2	**Stormwater Rentention System**	**40 days**
3	**Preconstruction**	**19.5 days**
4	Surveying	2 days
5	Install Perimeter Fencing	2.5 days
6	**Install Electrical Supply**	**17.5 days**
7	Dig trench from electrical source to near pump locations	4 days
8	Lay conduit/wire	3 days
9	Set up electrical connections for pumps	1 day
10	Test electrical	0.5 days
11	Backfill	1 day
12	Dewater Existing Cattail Pond	2 days
13	**Construction of Subsurface Detention Tank**	**31.5 days**
14	Excavation	8 days
15	Shoring	2 days
16	Place subgrade/compact	3 days
17	Install precast tank sections	3.5 days
18	Concrete coring	1 day
19	Connect to overflow	1 day
20	Connect to reed bed	1 day
21	Connection to pumphouse	2 days
22	Install Float Sensor	2 days
23	Backfill	2 days
24	**Construction of Sump Basin**	**23 days**
25	Excavation	1 day
26	Shoring	1.5 days
27	Compaction	2 days
28	Concrete coring	0.5 days
29	Install sump basin	1 day
30	Connect to storm overflow	1 day
31	Install pump	0.5 days
32	Connect to inflow	1 day
33	Backfill	1 day
34	**Construction of Greywater Pond**	**23.5 days**
35	Excavation	3 days
36	Berm construction	4.5 days
37	Place gravel layer	1 day
38	Place sand layer	1 day
39	Install pond liner	10 days
40	Install pump	1 day
41	Place riprap	2 days
42	Pond landscaping	3 days
43	**Construction of Reed Bed**	**9 days**
44	Excavation	2 days
45	Connect to Detention Tank	1 day
46	Place gravel layer	2 days
47	Place sandy soil layer	2 days
48	Plant reeds	2.5 days
49	**Connect to Distribution**	**4 days**
50	Dig trench from Detention Tank to Existing Distribution	2 days
51	Lay pipe	0.5 days
52	Install fittings	0.5 days
53	Backfill	1 day
54	**Install Pumps and Control Systems**	**14.5 days**
55	Install Pumphouse	3 days
56	Install Pump	1 day
57	Install Controller	1 day
58	Test system	2 days
59	**Demobilize Site**	**17 days**
60	Demobilize Equipment	1 day
61	Remove Fencing	2 days
62	**Install Social Amenities**	**7 days**
63	Install benches	2 days
64	Floating pier	3 days
65	Landscaping	4.5 days
66	Install informational s	1 day
67	Project Completion	0 days
68	Target Completion Date	0 days



Project: Stormwater Retention/															
	Task	Milestone	◆	Project Summary		Inactive Milestone	◇	Manual Task		Manual Summary Rollup		Start-only	[	External Tasks	
	Split	Summary		Inactive Task		Inactive Summary		Duration-only		Manual Summary		Finish-only	]	External Milestone	◇

Deadline | Critical | Critical Split | Progress | Manual Progress