South Campus Stormwater Detention Facility

Brody Granger, Doyoul Bae, Emma Gerard, Grace Ke Lim Kim, Sadaf Neyshaboori

University of British Columbia

CIVL 446

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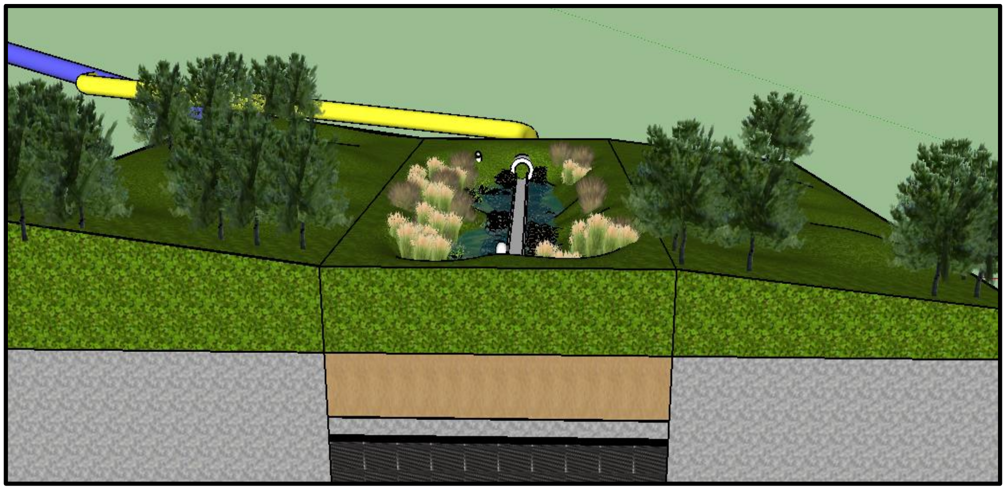
CIVL 446 Detailed Design Final Report

UBC South Campus Stormwater Detention Facility



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Prepared By: Team 9

Emma Gerard

Brody Granger

Do Youl Bae

Kelim Kim

Sadaf Neyshaboori

EXECUTIVE SUMMARY

Point Grey Consultants Ltd. was retained by Doug Doyle, Associate Director of Municipal Engineering for UBC Campus and Community Planning to design a stormwater management system for the UBC South Campus. The system is designed to provide stormwater detention for up to a 100 year storm, with a storage capacity of 4150 m^3. This is achieved using an underground detention tank overlaid by a bio-retention pond which allows ponding of water. Pollution removal occurs as the bio-retention pond infiltrates stormwater flows up to a 2 year storm.

The underground detention tank is 0.61 m high by 70 m long by 30 m wide and is to be located on the north corner of the intersection of Wesbrook Mall and SW Marine Drive.

The overlaid bio-retention pond of the same area as the tank is to be constructed with 1 m of engineered soils with an infiltration rate of 43 mm/hr and planted with vegetation. A dyke surrounding the bio-retention pond will allow ponding of water up to 1.4m. Water that currently flows through the 1.05 m diameter storm main will be re-routed into a 1.05m culvert which discharges into the bio-retention pond. This water enters a central trough that runs the length of the bio-retention pond and spills onto adjacent rock that slows and distributes the water. Overflow pipes located 0.5 m above the surface of the bio-retention pond discharge water into the underground tank when ponding exceeds this level.

A new by-pass pipe at 105 m upstream of the tank along the road will connect the existing stormwater main to the detention tank. An orifice outlet releases water at maximum rate of 261 L/s and discharges into the existing 1.2 m storm main.

Throughout the design process, Point Grey Consulting has used the United States Environmental Protection Agency's Storm Water Management Modelling (US EPA SWMM) software. Numerical modelling of 100 year storms before and after the addition of this detention facility show that local flooding has been eliminated.

The final design report contains the detailed design description of the detention tank and the bio-retention pond. This includes tank, bio-retention pond, and bypass pipe locations and dimensions

shown in AutoCAD and Sketchup drawings. A finalized cost estimate, work schedule, detailed construction activities along with specific site constraints is presented. Finally, recommendations are given for further improvement of the design.

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1.0 INTRODUCTION

This report will illustrate the design particulars of a stormwater filtration and detention facility intended to improve the capacity of the UBC South Campus storm water system, and the quality of stormwater discharged into receiving waters.

Stormwater management in urbanized settings has two main goals: 1) to safely convey stormwater and thereby prevent loss of life and damage to property, and 2) to mitigate damage from erosion and pollution caused by stormwater runoff. The first of these goals was the impetus for undertaking design work. The existing storm water infrastructure in the South Campus of UBC is not able to safely convey large storm water flows. Numerical modelling of the existing drainage network indicates that flooding will occur during a 10 year rainfall event[1], and substantial flooding with potential for damage to assets and erosion will occur during a 100 year storm event. During the Preliminary Design Phase (CIVL 445), a detention tank located northeast of the intersection of SW Marine Dr. and Wesbrook Mall was determined to be the most effective solution for managing flooding.

The second goal, mitigation of environmental damage due to pollution and erosion, has substantially influenced the details of the design presented in this report. Prior to the development of UBC South Campus, rainfall was absorbed by forest canopies and vegetation, and retained in the soil. Groundwater from precipitation made up the base flow of streams such as Booming Ground Creek, which is one of the main receiving bodies for stormwater from South Campus. Surface flow during major stormwater events would account for peak flow in such streams. After development, the removal of vegetation and increase in impervious surfaces such as building roofs and paved areas causes a more rapid movement of greater volumes of stormwater into receiving water bodies. The goal of reducing peak flows and removing pollution such as sediments, hydrocarbons, and metals can be achieved by imitating features of the natural hydrological regime in which soil and vegetation control the flow of water.

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[1] A 10 year storm has a recurrence interval of 10 years, which means that the probability of a storm occurring in any given year is 1 in 10, or 10%. Likewise, a 100 year event has a 1% chance of occurrence in any given year. Storms with a smaller probability of occurrence deliver larger volumes of water.

Bio-retention ponds are an example of a technique applied in low impact urban drainage designs elsewhere to contain and filter stormwater through a natural systems approach. To meet both of the design goals described above, it was determined that the UBC South Campus stormwater system could be improved by including a new system that combines a bio-retention pond with a wide and shallow subsurface detention tank. A combined facility would provide water holding capacity in both the detention tank and the bio-retention pond, and allow for the natural filtration of water as it passes through the filter bed of the retention pond into the tank below.

The details of this design are described in following sections of the report. Section 2 gives a description of the system and outlines the design inputs that informed the sizing of the facility. Section 3 offers a detailed description of each component of the facility. Section 4 gives the construction work plan for the project. Section 5 gives a cost estimate. Finally, Sections 6 and 7 offer recommendations for further improvement of the design and a conclusion to the report.

2.0 SYSTEM DESCRIPTION

This section presents the functioning of the detention system and key design factors including its location, storage capacity and allowable rate of discharge. The modelling and hydrologic analysis that went into the determination of these parameters is also discussed.

2.1 Location of the Facility

The detention tank system was chosen to be located along Wesbrook Mall, at the intersection with SW Marine Drive, in a currently treed area. This location was chosen because it is near the far downstream end of the stormwater system, at a location where numerical modelling predicted flooding would occur during large rainfall events. Additionally, the area is sloped such that a gravity-driven detention facility could be installed. A map of the location of the system components is shown in Figure 6.

2.2 Hydraulic Design Input

The determination of the treatment and detention capacity of the design relied on simulations done using stormwater modelling software. This part of the design process is discussed here.

2.2.1 SWMM Model

The United States Environmental Protection Agency's Storm Water Management Model (US EPA SWMM) is a free software package for numerical modelling of stormwater systems. Simulations are based on user input of drainage area, network characteristics, and rainfall patterns. The base model that was used to analyze our design was provided by the client at the outset of the project in the fall of 2015. This model represented the whole of the stormwater system at UBC, and was reduced to a model of only the south campus to speed up computations. Figure 1 shows the South Campus SWMM model.

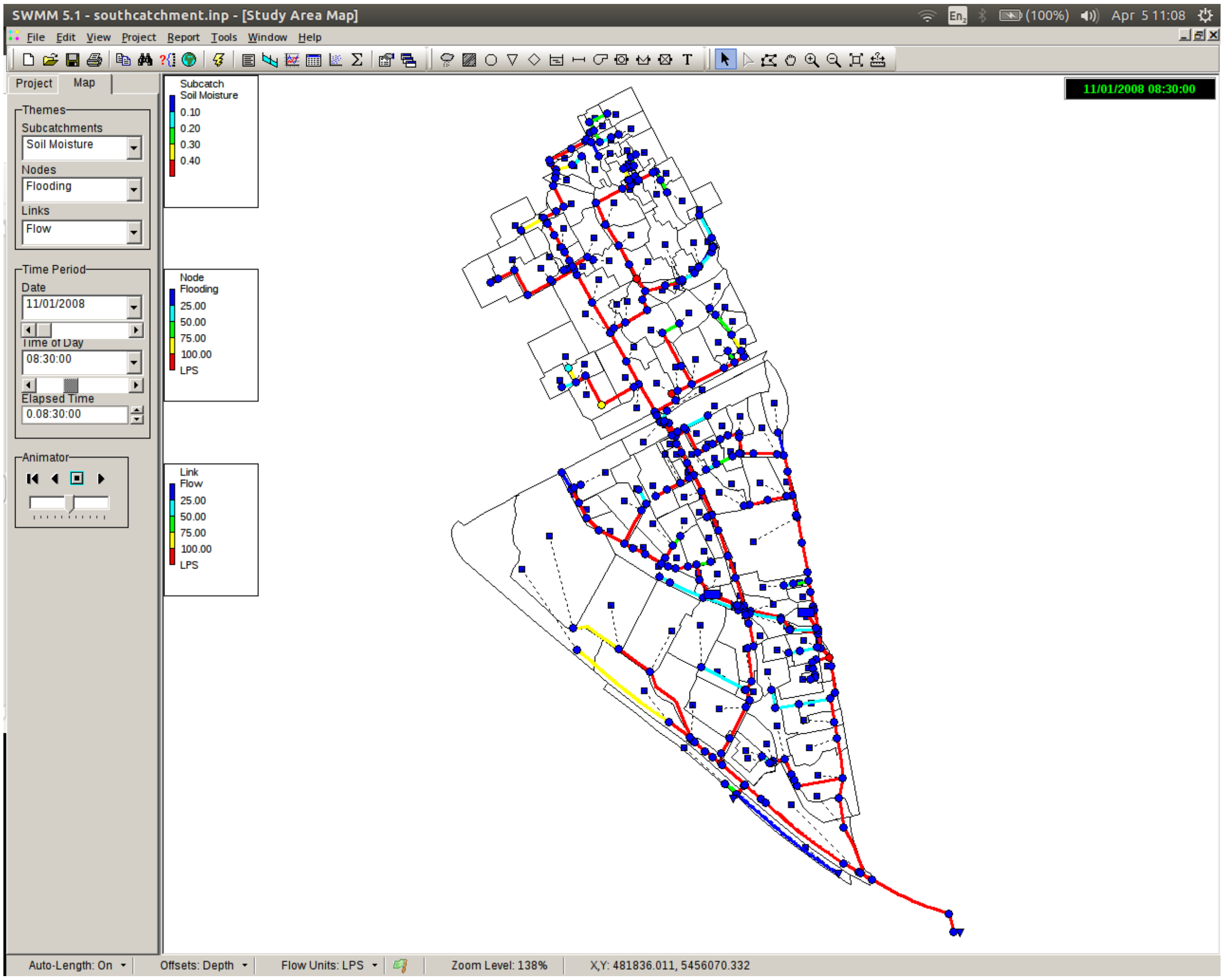

Figure 1. SWMM Model of UBC South Campus

2.2.2 System Treatment Capacity

The sizing and specification of the bio-retention pond was based on modelling of a 2 year storm. A rainfall pattern was created by scaling a 10 year design storm which was included in the base SWMM model. The IDF curve for UBC (see Appendix B) shows the average rainfall intensity for a 24 hour, 2-year storm event to be approximately 2.5 mm/hr. The 10-year design storm has an average intensity of 3.4 mm/hr, so each hourly rainfall intensity was scaled by a factor of 0.74 to simulate a 2-year storm. The rainfall pattern of the 2-year storm is shown in Figure 2.

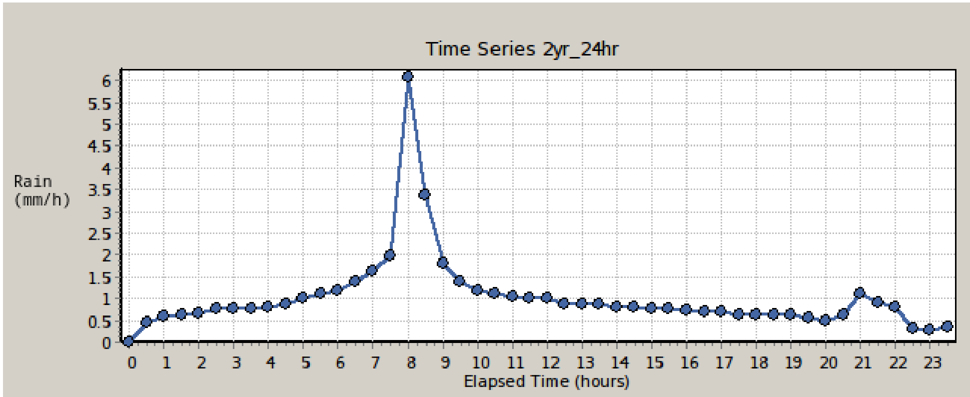

Figure 2. 2 Year Design Storm Rainfall Pattern

Simulation of this two year storm indicated that the bio-retention pond would need to infiltrate a volume of 3200 m^3. Calculations based on the size of the bio-retention pond determined the required rate of infiltration through the soil was 43 mm/h. The calculations done to determine this infiltration rate are given in Appendix B.

2.2.3 System Detention Capacity

To determine the required detention capacity of the design, a 100 year storm event was simulated. The IDF curve shows the average rainfall intensity for a 24 hour, 100-year storm event to be approximately 4.5 mm/hr. The hourly rainfall intensities of the 10-year design storm were scaled by a factor of 1.3 to simulate a 100-year storm. The rainfall pattern of the 100-year storm is shown in Figure 3.

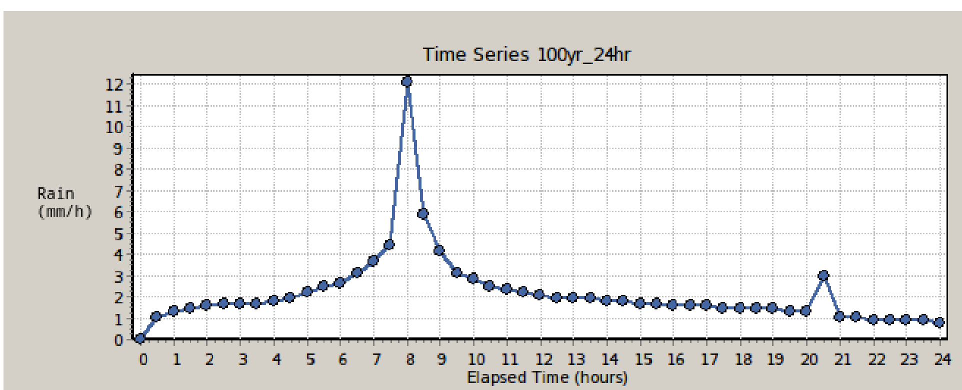

Figure 3. 100 Year Design Storm Rainfall Pattern

During these simulations, the tank was modelled as a simple pond with an area of 2100 m^2 and a 30 cm orifice outlet. In the 100-year, 24 hour storm simulation, the tank reaches a maximum depth of around 1.8 m, with a maximum flow exiting the orifice of 261 L/s. At this maximum depth, the total volume of stored water is 3800 m^3, and an additional 350 m^3 of storage is available before water would overtop the dyke. This additional storage serves as a safety factor to account for uncertainties in the required capacity that are discussed in Section 6.

2.2.4 Maximum Allowable Discharge

In Prof. James Atwater's CIVL 409 course, a maximum allowable flow of 3 L/s/ha was given as a reference value for outfall design. This value is multiplied by the drained area to give a maximum rate of discharge. The total drained area of the South Catchment is 184 ha, but not all of this area would drain into the bio-retention pond. Based on the delineation of subcatchments in the SWMM model, the drained area flowing into the bio-retention pond is around 90 ha. This equates to a maximum allowable discharge of 270 L/s.

2.3 System Operation

The function of the system depends on the amount of stormwater flowing through it. System operation under two conditions is presented in this section.

2.3.1 Treatment: Less than 2 year storms

During rainfall events smaller than a 2 year storm, the system's function is to treat stormwater by infiltration through the bio-retention pond. Flows from the bypass pipe are discharged into the central trough, where fine particles settle out and water is distributed along the length of the bio-retention pond. Water spills from the trough onto rock, slowing it down before it moves into the vegetation. Water not taken up by the vegetation flows down through the soil into the underground detention tank. In this way, stormwater is released to the Booming Ground Creek outfall at a lower rate than in the existing infrastructure. An illustration of the design operating in its treatment capacity is shown in the Figure 4 below:

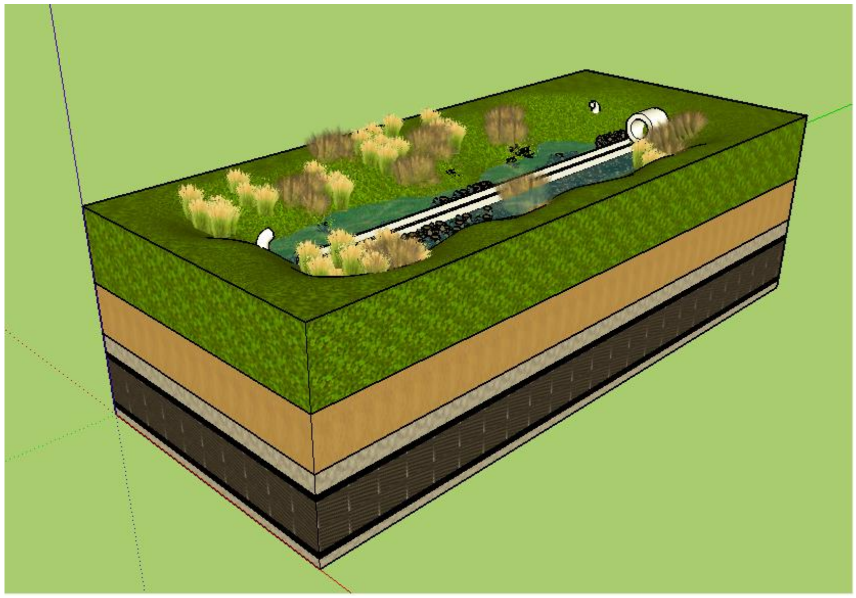

Figure 4. 2 year Figure 4. 2 Year Storm Operation

2.3.2 Detention: Greater than 2 year storms

During large rainfall events, the system's function is to detain stormwater and release it at a rate of less than 270 LPS. This maximum value is discussed in Section 2.3 of the report. During heavy rainfall, water cannot infiltrate into the bio-retention pond at the same rate that it flows in from the bypass pipe, and ponding of water begins to occur. If ponding reaches a level of 0.5 m above the bio-retention pond, it begins spilling into two 30 cm diameter overflow pipes which discharge directly into the underground tank. Ponding of water can continue up to the crest of the dyke at a level of 1.4 m above the bio-retention pond. This level of ponding is designed to be sufficient to detain runoff from up to a 100 year storm. An illustration of the design operating in its detention capacity is shown in the Figure 5 below:

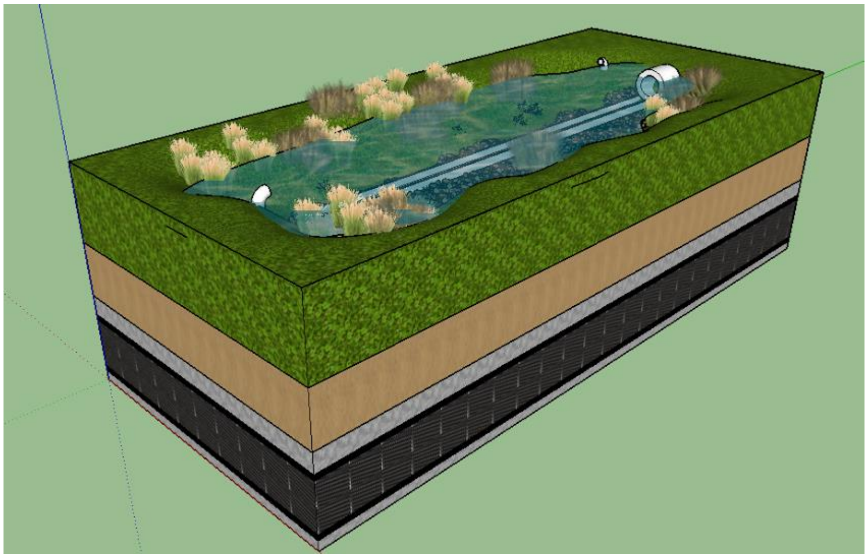

Figure 5. 100 Year Storm Operation

3.0 DESIGN COMPONENTS

The facility design is composed of two main parts, the detention tank bio-retention pond, along with the by-pass pipes joining the facility with the existing drainage network. Together the tank and bio-retention pond represent a combined holding capacity of approximately 4150 m^3. Figure 6 presents a plan view of the system as integrated with the surrounding area.

Figure 6. Plan view of AutoCAD rendering of the facility, overlain onto Google Earth image

The details of the tank and bio-retention pond are presented in this section.

3.1 Detention Tank

The detention tank is located underground, beneath the bio-retention pond. The dimensions and materials are discussed below, along with the tank outlet location.

3.1.1 Dimensions and Materials

The detention is designed with dimensions of 70 m x 30 m x 0.61 m (L x W x H). The width of the tank lines up parallel to Wesbrook road, while the length of the tank extends across the treed lot. The distance between the middle of the road to the edge of the tank is roughly 43m.

Brentwood Stormtank Pack™ units were chosen to construct the tank. These are polymer based, modular tank units designed specifically for integration with bio-retention ponds and rainwater harvesting applications , and locally distributed by Layfield Group out of Richmond BC. Products of this brand have been used elsewhere in the Lower Mainland for stormwater management projects. The modular tank units possess a 95% void space and are simple to install. Due to the greater constructability, there was a strong preference for this kind of modular tank option over a cast-in-place concrete design. The Pack units are available in the standard size of 0.61 m in height, which was able to meet the needs of the project.

The tank will contain 1217 m^3 of water when full. This is roughly 0.41% of the total holding capacity of the facility. The rest of the capacity is provided by the bio-retention pond.

3.1.2 Tank Discharge Outlet

As discussed in Section 2, the maximum allowable tank discharge rate from the detention facility during a 100-year storm is 270 L/s. Two types of detention tank outlets were evaluated: a control valve and an orifice. Both options performed well in SWMM simulations, and the orifice was chosen because of cost benefits due to its greater simplicity. In an orifice, the release of flow is controlled by the hydraulic head in the tank. With a 30 cm orifice, the model predicted a maximum discharge of 261 L/s during a 100 year storm.

3.2 Bio-retention Pond

The bio-retention pond holds stormwater delivered to it by the storm drain network, and improves water quality as it percolates through the filter medium, at a calculated rate, into the tank below.

3.2.1 Size and Dimensions

The bio-retention pond was designed to cover the same area as the detention tank, or 30m x 70m. The perimeter of the pond is raised 1.4 m at a slope of 1:2, and forms a dyke that allows water to be retained within the pond. The bio-retention pond is limited to retain water up to the height of 0.5 m by way of two overflow pipes, each with the diameter of 30 cm. In the case of a 100 year storm, when flow entering the retention pond greatly exceeds the rate of infiltration into the tank, the pond will fill up and overflow pipes will carry the water directly into the tank. This will prevent flooding of the pond and overflow onto SW Marine Drive. Once the tank and overflow pipes are full, the pond will continue to fill. The total holding capacity of the pond is approximately 2940 m^3.

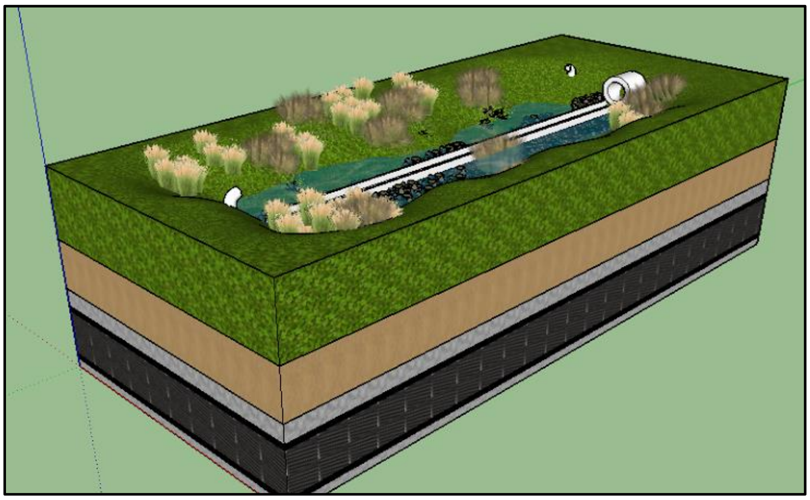

Figure 7. Illustration of bio-retention pond underlain by detention tank

3.2.2 Soil layer compositions

The bio-retention pond is composed of a 1 m thick filter media layer to allow for the growth of plants and filtration of stormwater through physical, chemical, and biological processes. The filter media is composed of a 0.7 m thick layer of engineered soil that will provide the desired infiltration rate of roughly 1-2 inches per hour. The engineered soil is a mixture of primarily sand, along with mulch and compost and a small fraction of clay.

Mulch and clay is required in order to adsorb heavy metals, nutrients, and organics. Mandy different mixtures for soil filtration media and planting media are possible. Based on a number of design guides available, the chosen soil composition for the filter media is the following[2]:

- Media contains 70% sand (with fineness modulus between 2.75 and 3.1, or ASTM C33), 20% shredded mulch, and 10% organic compost.
- Media contains less than 5% fines (including clays and silts).
- Media is covered with a 3” thick triple shredded bark mulch layer.

The gradation requirements for the filter sand are outlined in ASTM C33, as shown in Table 1.

Table 1. Grading Requirements for C33 Fine Aggregate (Sand)

Sieve	Percent Passing
9.5-mm ($^3/_8$-in.)	100
4.75-mm (No. 4)	95 to 100
2.36-mm (No. 8)	80 to 100
1.18-mm (No. 16)	50 to 85
600-µm (No. 30)	25 to 60
300-µm (No. 50)	5 to 30
150-µm (No. 100)	0 to 10

A 0.3 m thick gravel layer is placed below the engineered soil to provide an area for water to permeate and enter the tank. It also reduces the chance of fine sediments reaching the geotextile fabric, which lines the top of the detention tank.

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[2] Chosen soil mixture is based on sources including Delaware Department of Natural Resources and Environmental Control Bio-retention BMP technical manual (2014 draft), and EPA-designed Bio-retention design guide available on the Low-Impact Development website (2003). A balance was found between the many different soil mixtures possible. Some sources suggested greater sand content, others greater composted organics content or mulch content. A relatively larger sand and mulch content was selected in order to maximize infiltration rates.

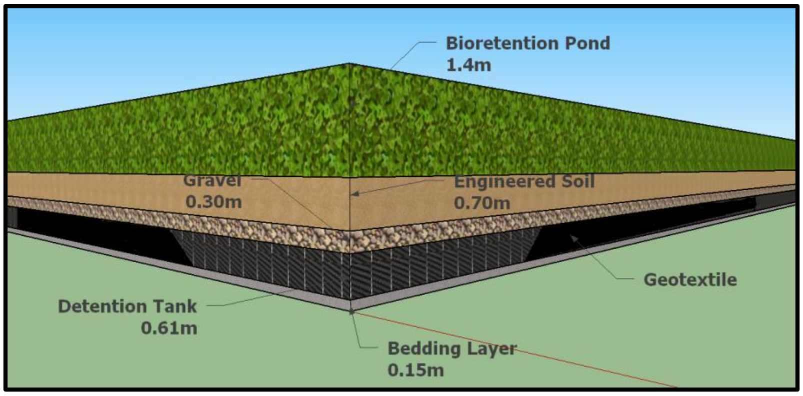


Figure 8 : Schematic Drawing of bio-retention pond layers

Non-woven geotextiles intended for filtration applications are available in sieve sizes (or apparent opening sizes) of 50, 70, 80 and 100 (as per ASTMD4751). A sieve size 70 corresponds to a grain size of 0.212 mm, which represents a fine sand. Due to the relatively low fines content of the C33 fine aggregate to be used in the filter bed, the clogging of size a 70 geotextile layer should be minimal.

3.2.3 Bio-retention Pond Distribution Channel

The possibility of erosion of the bio-retention pond due to the momentum of flow emerging from the by-pass pipe was considered. To minimize this risk, a trough was designed to distribute the water evenly throughout the length of the retention pond from the point where the bypass pipe outlet is day-lighted.

The channel is 50 m long and 0.6 m wide. The trough edges are 0.15 m high. The end of the channel is blocked with a stopper. Perforated openings are spaced evenly along the sides of the channel to allow water to escape.

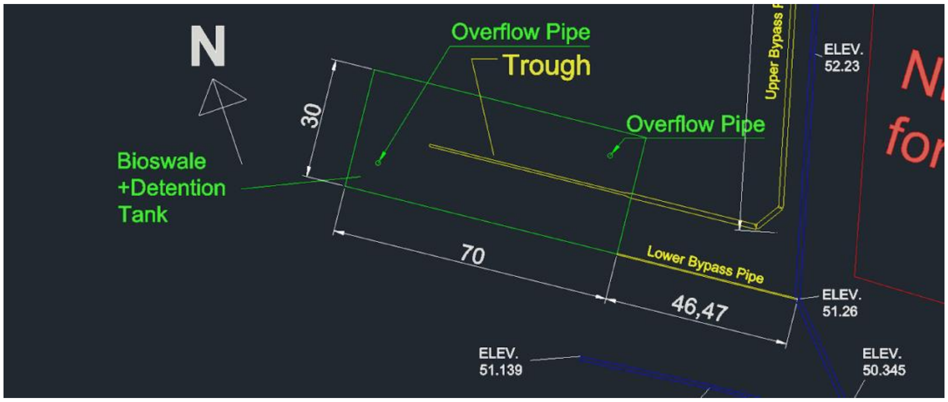


Figure 9. AUTOCAD rendering of bio-retention pond (green) along with bypass pipes and channel/trough (yellow)

When the flow through the system is relatively low, water is evenly discharged through the holes of the trough. When flow is high, water will fill up the channel and flow over the sides of the trough, while still being evenly distributed down the length of the pond. A rock bed beneath the distribution channel will act to dissipate the flow momentum and thereby mitigate erosion.

3.2.3 Vegetation

A number of shrubs and emergent plants are recommended for planting in the bio-retention pond. Some of these species are currently planted within the landscaped parts of the UBC campus, as they are suited to the mild and wet climate of the Pacific North-West. Table 2 lists a number of possible plant species that were recommended in a technical guide for low-impact stormwater design in the Puget Sound region. This region contains the Seattle metropolitan area and has a climate very similar to that of the Vancouver region.

Table 2. List of plants recommended for a 'Zone 1' bio-retention pond in the Pacific North-West (Hinman, C. 2012).

Shrubs	Comments
Red-twig Dogwood	Prefers moist/wet soils; tolerates flooding
Dwarf Dogwood	Prefers moist/wet soils; provides good ground cover
Yellow Dogwood	Prefers moist/wet soils; easily grown
Isanti Dogwood	Prefers moist/wet soils
Black Twinberry	Prefers moist loamy soils; tolerates shallow flooding
Pacific Wax Myrtle	Prefers moist soils; drought tolerant
Pacific Ninebark	Moist or dry soils; drought tolerant
Clustered Wild rose	Prefers moist soils; tolerates both flooding and dry conditions
Dwarf Arctic Willow	Grows well in poor soils; moderately drought tolerant

Douglas Spirea Steeplebush	Prefers seasonally inundated soils
Emergents	**Comments**
Slough Sedge	Seasonally saturated soils; excellent soil binder; drought tolerant
Sawbreak Sedge	Prefers wet soils; excellent soil binder
Common Rush	Prefers wet soils; drought tolerant
Daggerleaf Rush	Prefers shallow pooling; excellent soil binder
Slender Rush	Prefers moist soils
Hardstem Bulrush	Prefers prolonged inundation
Small-fruited Bulrush	Tolerates prolonged inundation

Each of these recommended plants will withstand periodic standing or flowing water. Many, but not all plants on the list, withstand dry periods occurring in the summer. The budget and resources available for watering plants during the dry summer months should be considered before selecting the plant species. All of the plants generally need some watering during dry months during the first two to three years after planting until the plant is fully established (Hinman, C. 2012). Many of the emergent species are good soil binders, meaning that their roots form dense networks or mats and prevent soil erosion. This will aid in the natural maintenance of the bio-retention pond.

3.2.4 Maintenance Hand-over with UBC Plant Operations

The bio-retention pond will require periodic maintenance of plants and soil for it to provide adequate infiltration and pollutant removal. In periods of drought, some plants may need watering. In the event of a 10 or 100 year storm causing high flows through the culvert and prolonged inundation, some plants may need replacement, and the top soil of the retention pond may need to be fixed. The mulch layer needs to be replaced every 3-5 years to account for heavy metal accumulation, even though heavy metals loads in the UBC drainage system are not expected to be very high. Clogging occurs typically at the top of the soil column, so turning over the top 3-6 inches each year may be required to maintain infiltration rates of at least 1-2 inches per hour. It is also expected that some foreign debris or garbage may end up in the retention pond from time to time, requiring periodic cleanup.

There will need to be a way to monitor the infiltration rates of the bio-retention pond at least once per year. It is suggested that flow monitors and cameras be installed in both the downstream bypass connection and the upstream storm drain in order to compare flows in and out of the retention pond system and calculate infiltration rates.

It is proposed that the maintenance of the bio-retention pond be made part of the regular landscaping and maintenance duties conducted by UBC Building Operations on campus. The maintenance work required is similar to the regular work performed by UBC's landscaping and gardening crews. Hand-over will require some coordination with the Building Operations manager and transfer of bio-retention pond design plans so that it may be placed into their care indefinitely.

3.3 Bypass Pipe connections

Bypass pipes will be required upstream and downstream of the detention facility to join the facility with the existing storm drain under Wesbrook road. The bypass pipes were required to have a minimum 0.5% slope, in order to allow the system to drain by gravity and prevent system back-up further upstream. Figure 10 offers a basic schematic of the position of upper and lower bypass pipes with respect to the existing storm drain. For a more detailed view of the bypass connections, a wide view of the system and surrounding area is given in Appendix A.

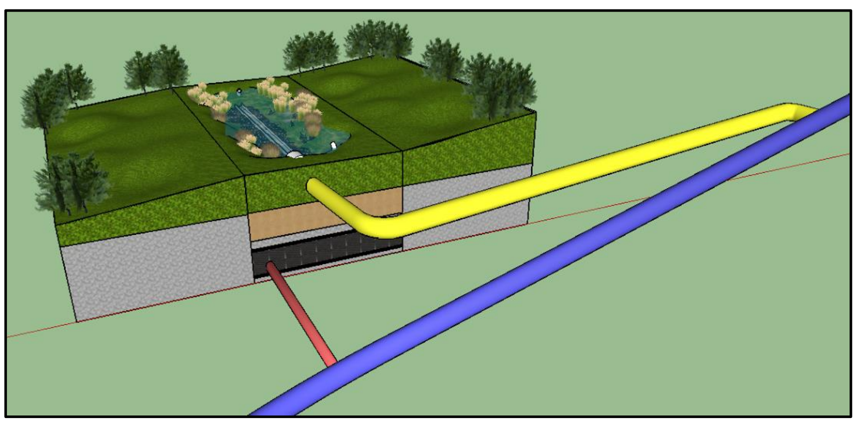


Figure 10: Existing storm drain in blue, upper bypass in yellow, lower bypass in red.

3.3.1 Upper bypass pipe

The upper bypass pipe has a 1.05 meter diameter, which is the same size as the existing storm drain at the junction. Its total length is 167.7 meters and it has a slope of 0.5 percent throughout its whole length. The minimum allowable slope was chosen so that the storm drain connection would be located as close as possible to the bio-retention pond, and thus reduce the length of the bypass pipe section required. The manhole junction at which the upper bypass pipe will connect to the existing storm drain is located roughly 105 m up-road from the upper edge of the detention tank and retention pond. A detail of the bypass pipe at the junction location is shown in Figure 11.

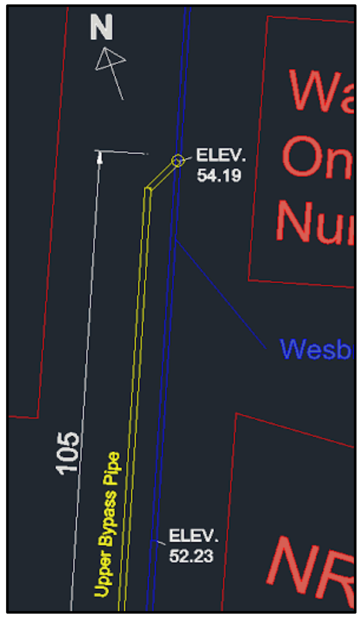


Figure 11. AUTOCAD rendering of upper bypass junction (yellow) with existing storm drain (blue)

The bypass pipe connects to the existing storm drain at a newly constructed manhole, and diverges from the junction at two 45 degree turns until set back 3 m from the drain. The bypass pipe extends 105 m parallel to the existing drain, roughly underneath the sidewalk. It then turns 79 degrees to the west and travels 38 meters, where it merges with the trough into the bio-retention pond.

3.3.2 Lower bypass pipe

The lower bypass pipe has a 0.3 m diameter and a total length of 46.47 m at a 0.5% slope. The lower bypass pipe connects to the existing Junction T6D-S24, located on the east corner of the Southwest Marine Drive and Wesbrook Mall intersection. The bypass pipe, which is fitted with a steel orifice plate to control the rate of discharge, extends in a straight line from the edge of the detention tank to the junction.

4.0 Construction Work Plan

The installation of the detention tank and the bio-retention pond on top of it in the UBC South Campus area requires coordinated construction phasing to make sure that the operation proceeds efficiently. This plan is intended to give the constructors a guide for the project implementation. The sum of the project is to last 135 days. A condensed form of the schedule in shown in Figure 12.

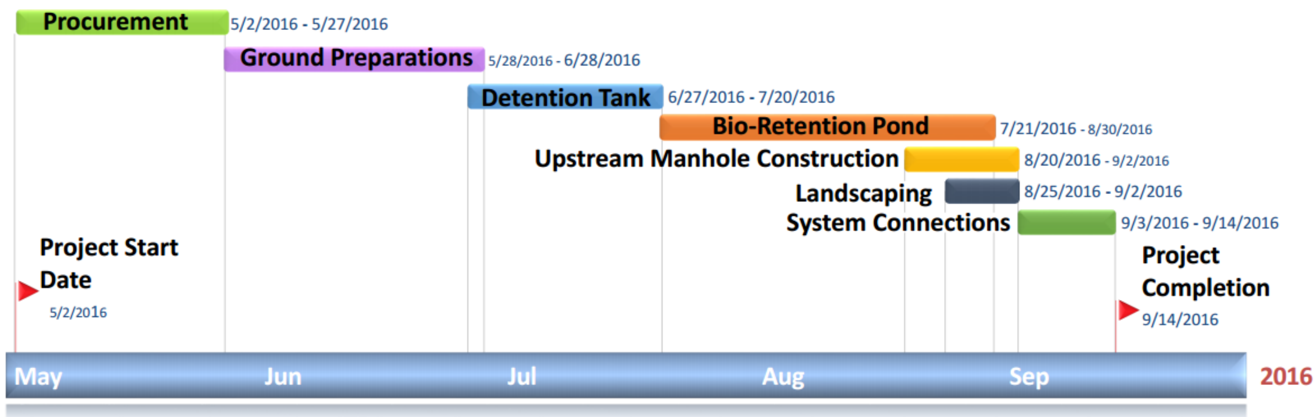


Figure 12 Condensed work schedule showing task categories and project dates

Detailed Construction Schedule can be found in Appendix C. Below is list of steps that are involved in the construction work. The construction steps relating to the detention tank were given by the Brentwood Installation Guide. For required depths and dimensions, refer to Section 3.

Site Preparation:

- Clear the forested lot
- Survey and stake out excavation points
- Excavate the tank pit and the sidewalk of Wesbrook Mall up to the planned junction
- Extend the excavation 1 m beyond the detention tank dimensions to allow for adequate placement of side backfill material.
- Compact the sub-grade to 95% Standard Proctor Density and ensure it is level.
- Install first geomembrane liner

- Place 6” leveling bed composed of ¾ inch gravel
- Install second geomembrane liner with excess material around the edges.

Detention tank Assembly:

- Assemble and install Brentwood StormTank Packs units
- Install and seal PVC outlet pipe with detention tank
- Wrap the StormTank packs on all sides with the excess geomembrane liner
- Install overflow pipes
- Backfill sides evenly with crushed stone around the tank perimeter

Bio-retention Pond Construction:

- Secure permeable geotextile fabric on top of the detention tank
- Place gravel layer to required depth
- Place engineered soil on top of gravel layer, to required depth
- Use excavated soil to construct the perimeter of bio-retention tank to grade
- Install the distribution channel gravel/rip rap bed
- Set in place the bottom section of the upstream bypass pipe
- Install the distribution channel and connect with the bypass pipe using a reducer section
- Fill and compact around the bypass pipe section
- Plant vegetation and trees

Upstream manhole Construction:

- Install a temporary PVC storm drain bypass to circumvent the planned location of the new manhole
- Construct manhole at the new junction
- Remove temporary PVC bypass when connecting the detention facility to the storm drain (described in next step).

System connection (during dry weather):

- Set in place the remaining sections of the upstream bypass pipe.
- Connect (corrugated PVC pipe) to storm drain junction
- Connect downstream bypass pipe to second storm drain junction (T6D-S24)

5.0 Cost Estimate

The cost estimate was developed by considering contractor costs and owner costs for the project. Contractor costs include labour and equipment to construct and manage the project over 137 days. Owner costs include the materials required for the project, along with project management costs during the bid tendering process and project construction process. The cost estimate does not include consulting fees, as it was assumed the detailed design was completed by UBC's group of engineers and planners. Project costs were calculated in 2016 dollars. It was assumed that all capital spending will occur in 2016.

Project maintenance costs were calculated based on a discount rate of 8% and a 50-year design life. Costs associated with facility maintenance were limited to the bio-retention pond. It was assumed that the top soil and some of the vegetation in the pond would be replaced every 5 years. Annual maintenance, as described in Section 3.2.4, would be absorbed into the current budget of UBC Building Operations for landscaping work. The Discounted Present Worth of the maintenance cost over the 50 year design life was included into the total Capital Cost. The complete project cost estimate is presented in Table 3. Appendix D presents the cost calculation sheets that were used, as well as cost assumptions.

Table 3. Project Capital Costs and Discounted Maintenance Costs

Project Cost Breakdown	
Owner Costs	
Materials	$703,000.00
Project Management Costs	$117,000.00
Contractor Costs	
Equipment	$266,000.00
Labour	$539,000.00
Contractor Overhead (10% of costs)	$81,000.00
PW of Maintenance Cost (over 50 years)	$47,000.00
Sub Total	**$1,753,000.00**
Escalation (0%)	-
Contingency (20%)	$351,000.00
Project Total	**$2,104,000.00**

6.0 Recommendations for Improvement

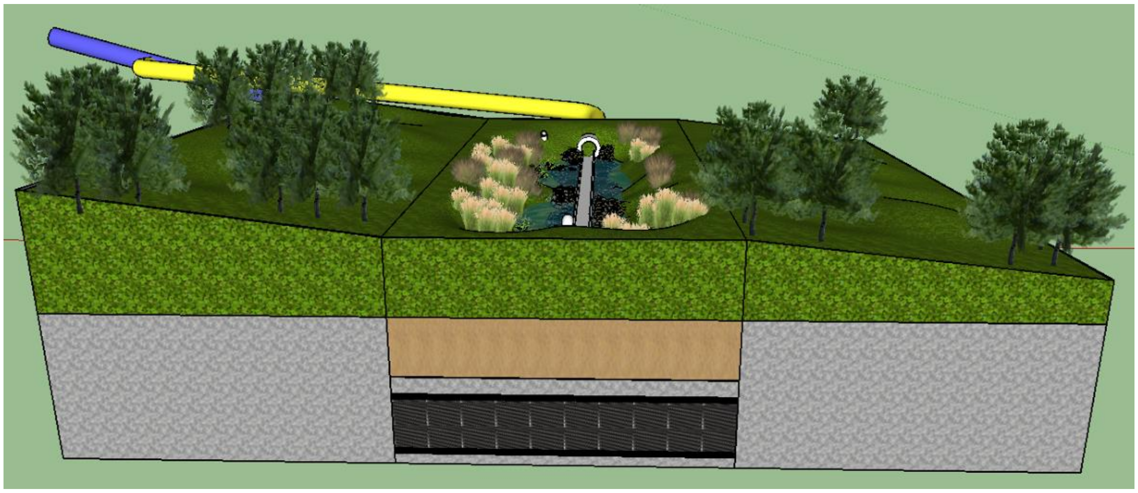
A major source of uncertainty in the sizing of the bio-retention pond was the complexity of water movement through the pond, overflow pipes, underground tank, and orifice outlet. As discussed in Section 2.2.3, the tank was modelled as a simple pond to determine the combined capacity requirement of the tank and pond. This method provides an estimate, but more detailed analysis of the flow through this hydraulic structure should be done to confirm that the capacity is sufficient. A combination of numerical modelling using computational fluid dynamics and physical modelling using a scale model of the tank and pond would provide a good degree of confidence in the performance of the design.

7.0 Conclusion

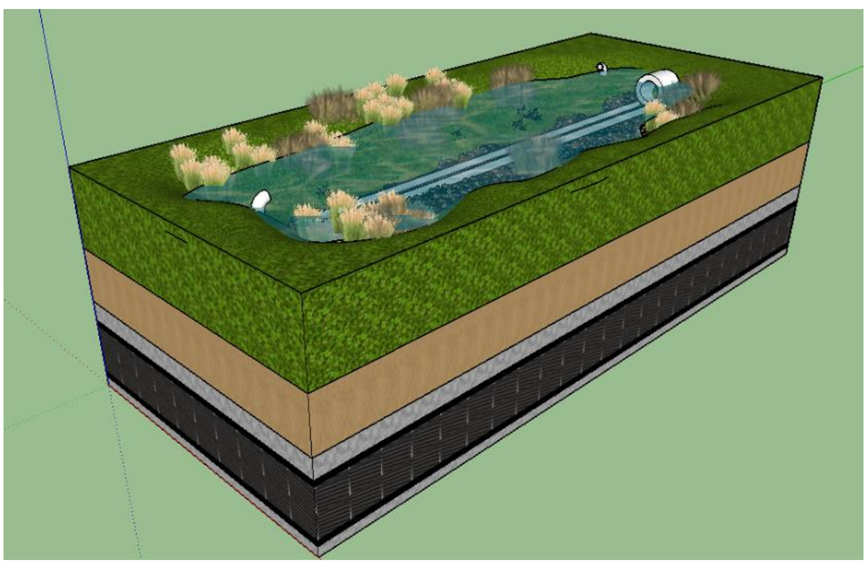
Making necessary upgrades to civil infrastructure often provides an opportunity to include innovative solutions to unaddressed problems. In the case of the design presented in this report, the necessity to prevent flooding during large rainfall events provided an opportunity to address pollution generated by ordinary rainfall events. Although the costs of the long term effects of surface runoff pollution are not as certain as the costs associated with flooding, a project that can effectively handle both challenges makes sense both economically and environmentally.

APPENDIX A: DETAILED DESIGN DRAWINGS

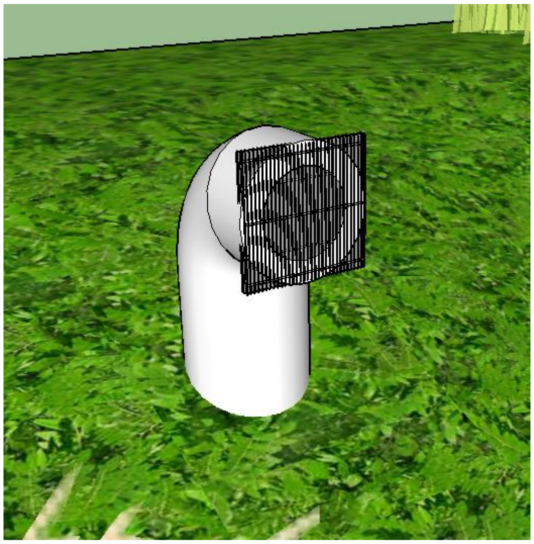
A1) Facility View 1



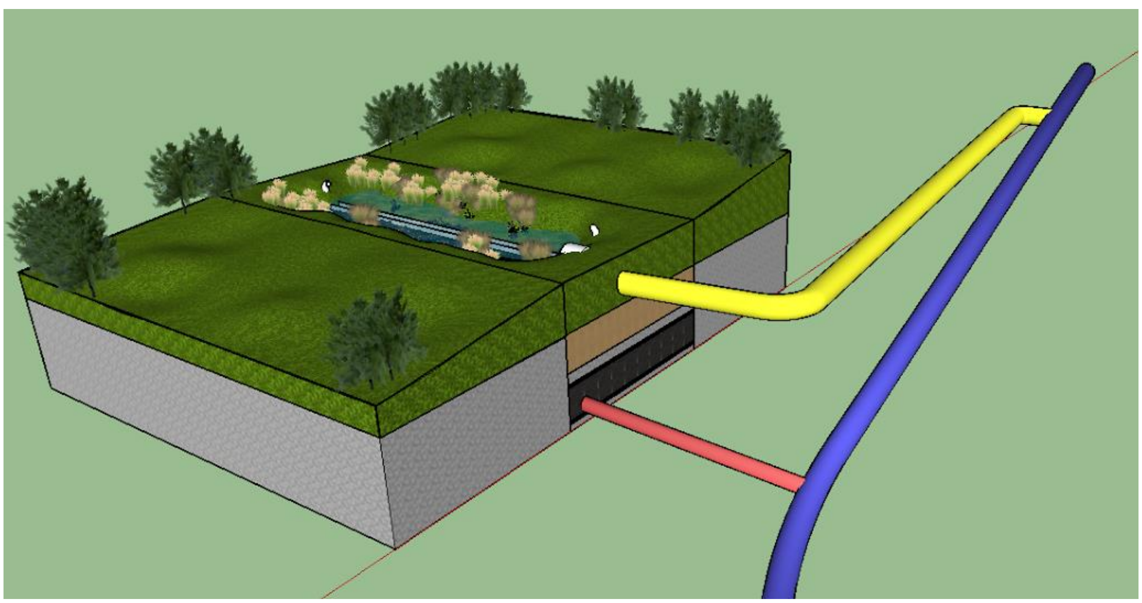
A2) Facility View 2



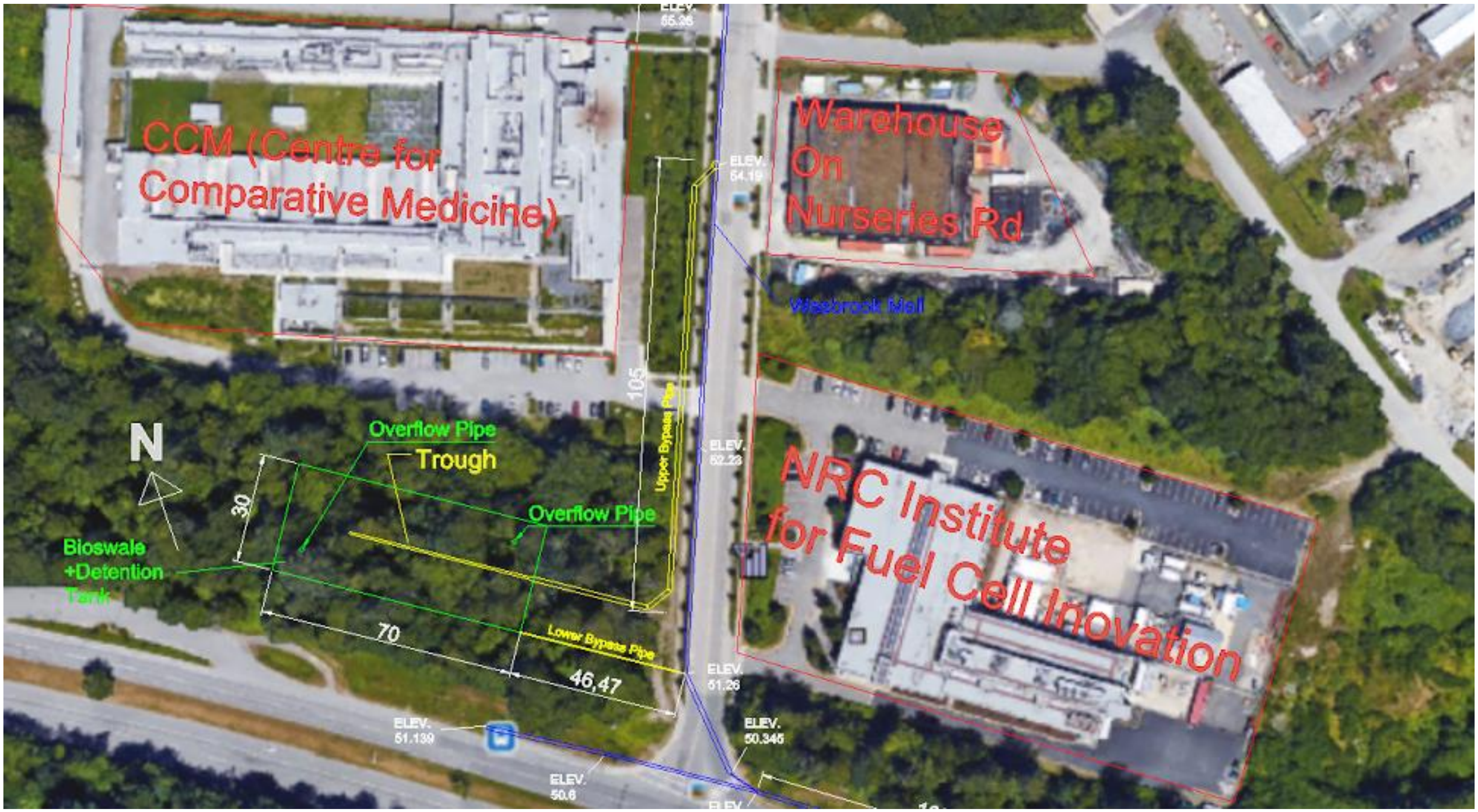
A3) View of bio-retention pond overflow pipe



A4) Facility View 4

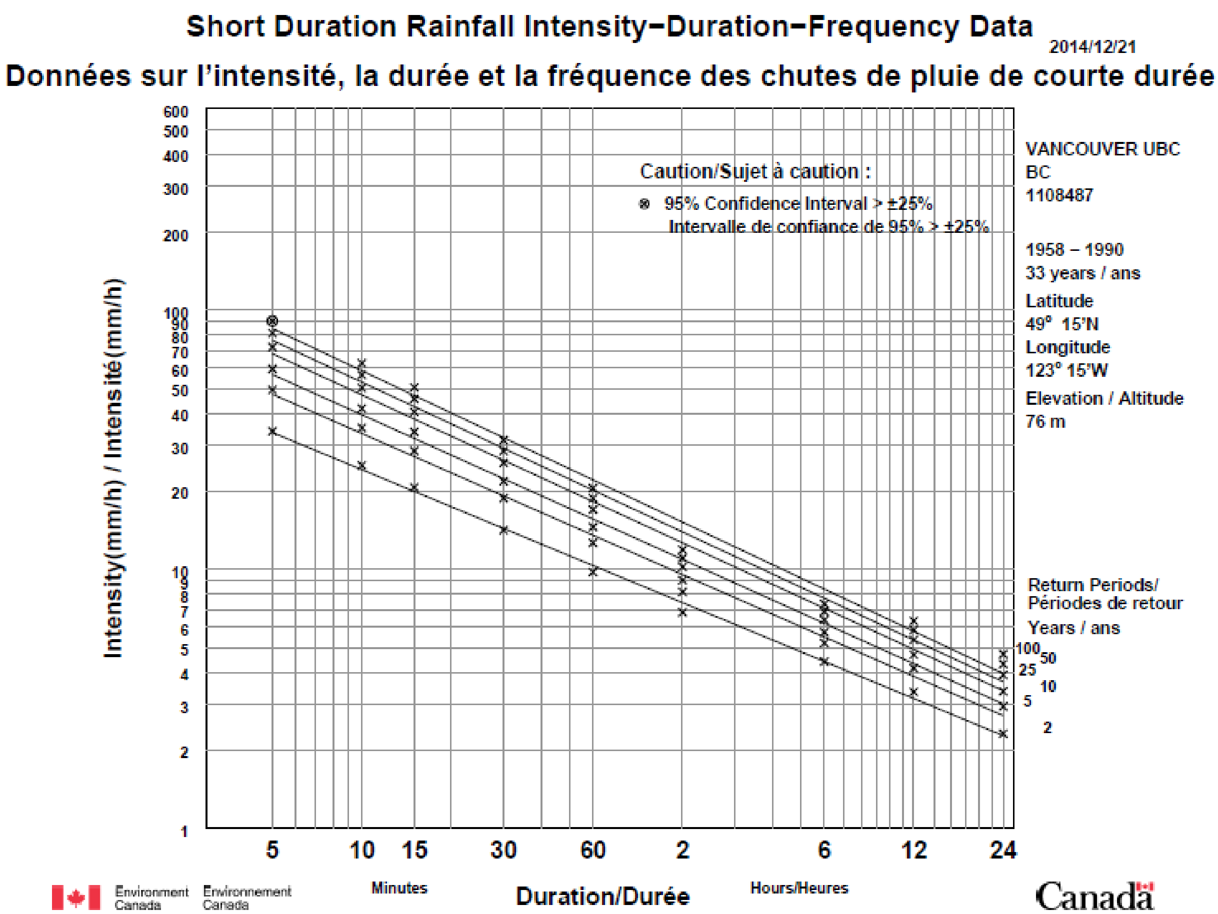


A5) AutoCAD Output Expanded



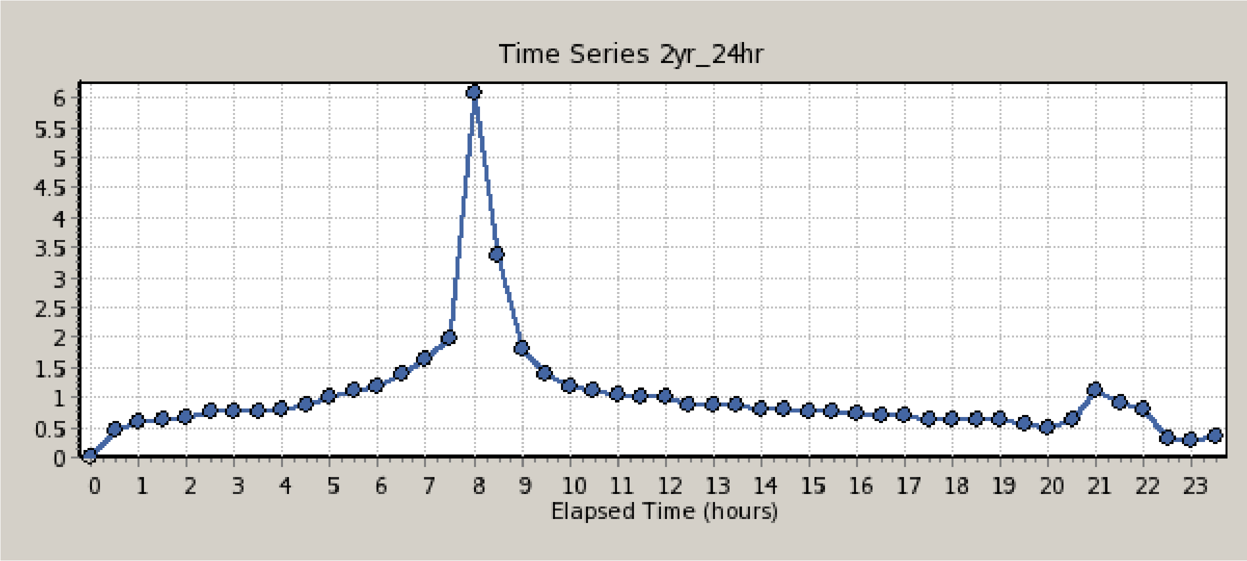
APPENDIX B FLOW VOLUME CALCULATIONS

B1) IDF Curve for UBC used in SWMM simulations:

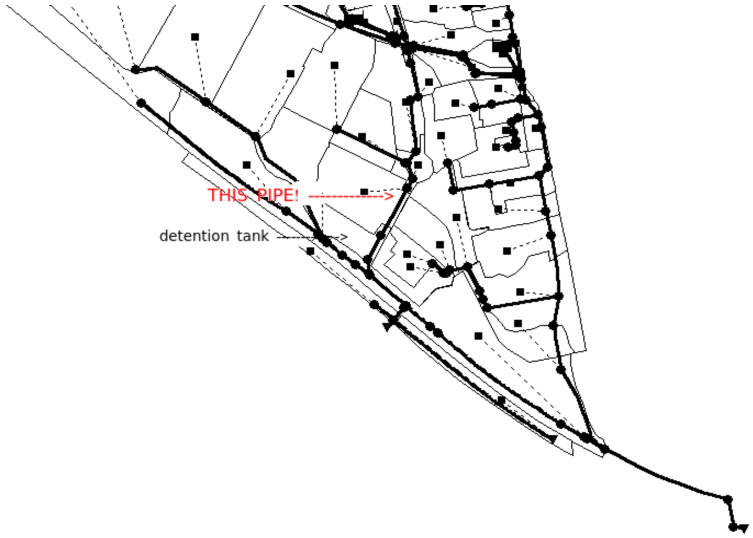


B2) Design flow/volume for 2-yr storm event:

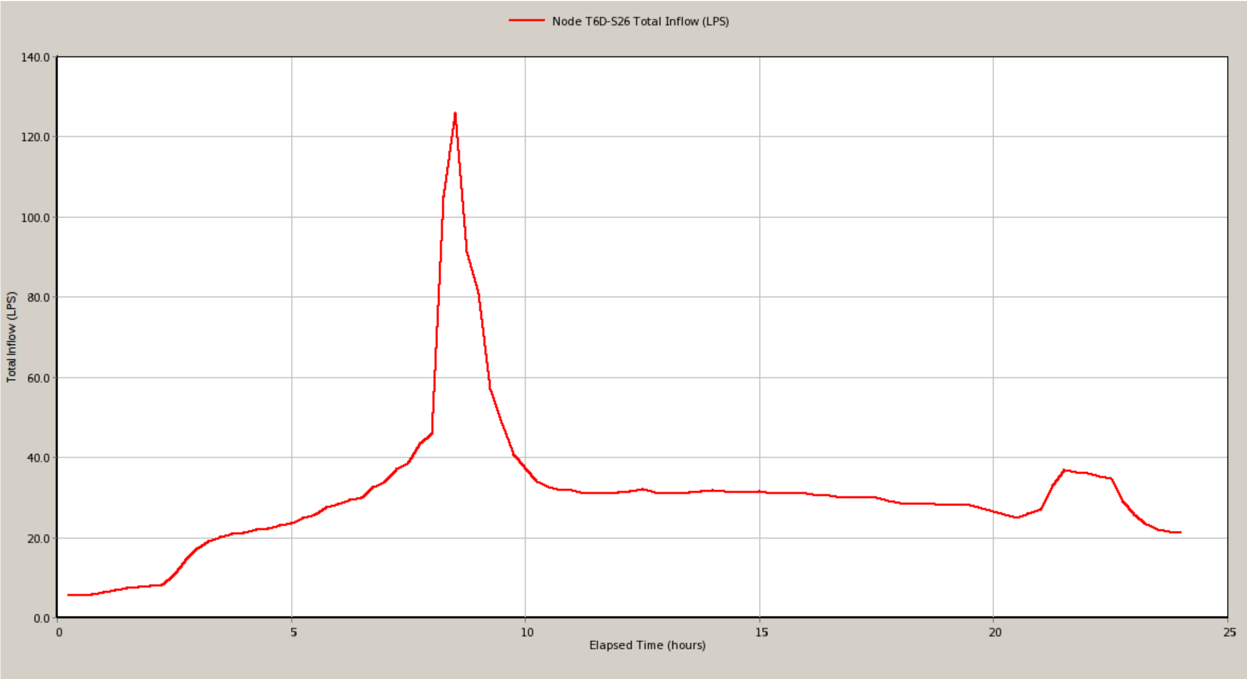
Using this 2 year storm time series:



The flow/volume results are reported for the section of pipe that would be diverted through our rad bio-swale into our rad detention tank:



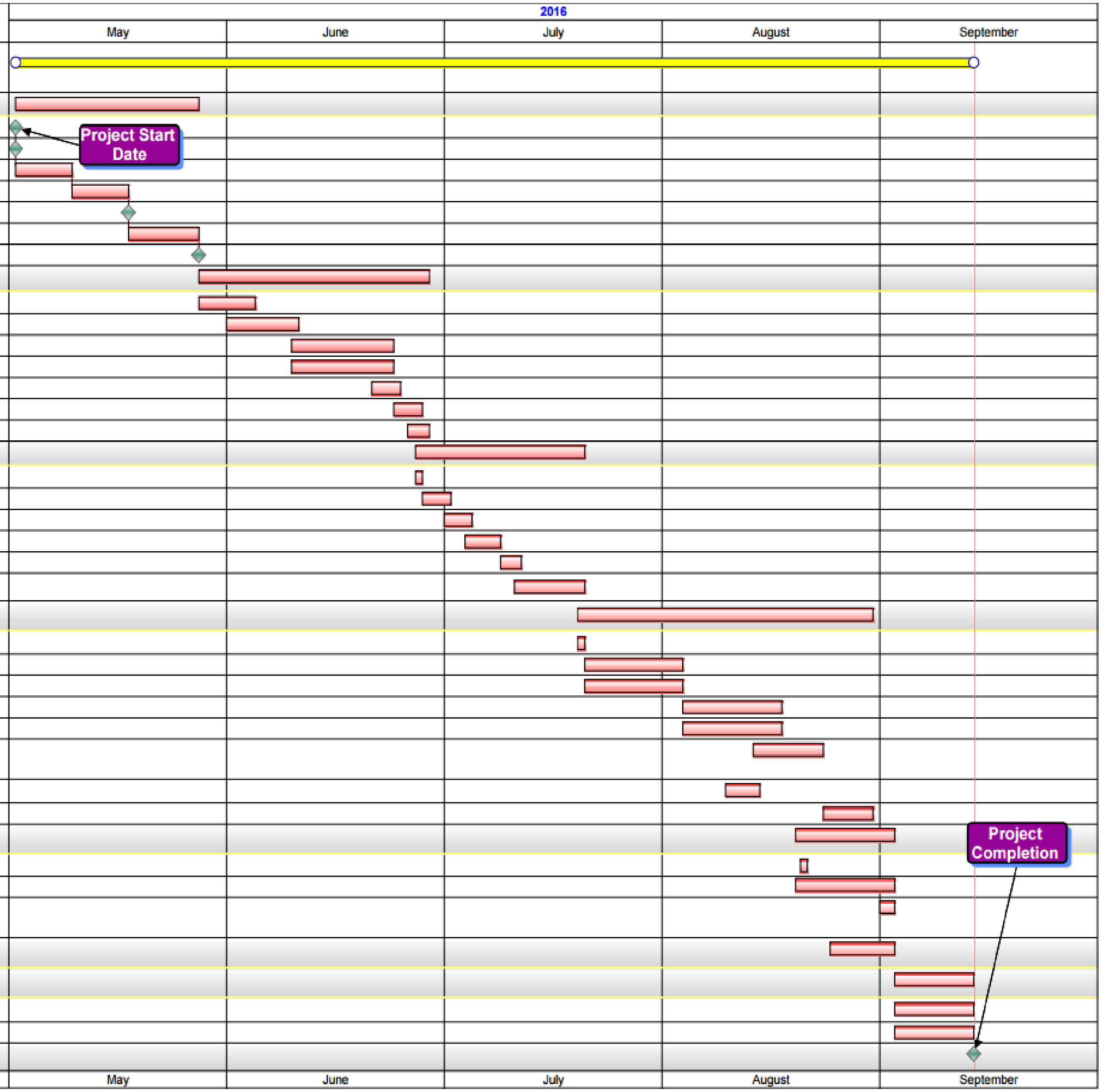
This is the graph of the flow:



From the above graph, average flow is found to be 37 LPS. Over a 24 hour period, this is equivalent to ~3200 m^3 total volume. Over a 30 x 70 (2100 m^2) area, this equates to 43 mm/h.

APPENDIX C: WORK SCHEDULE

Activity Name	Duration (Days)	Start Date	Finish Date
UBC South Campus Stormwater Management Project	135.00	2/5/16	13/9/16
Procurement	**26.00**	**2/5/16**	**27/5/16**
Design Approval	0.00	2/5/16	2/5/16
Release for Tender	0.00	2/5/16	2/5/16
Tender Process	8.00	2/5/16	9/5/16
Contract Decision Making Process	8.00	10/5/16	17/5/16
Award Contract	0.00	18/5/16	18/5/16
Permits	10.00	18/5/16	27/5/16
Project Start-up	0.00	28/5/16	28/5/16
Ground Preparations	**32.00**	**28/5/16**	**28/6/16**
Clearing	8.00	28/5/16	4/6/16
Surveying	10.00	1/6/16	10/6/16
Tank Pit Excavation	14.00	10/6/16	23/6/16
Excavation along Westbrook Mall	14.00	10/6/16	23/6/16
Tank Pit Sub-grade	4.00	21/6/16	24/6/16
Install First Geomembrane Liner	4.00	24/6/16	27/6/16
Place a 6" Leveling Bed	3.00	26/6/16	28/6/16
Detention Tank Installation	**24.00**	**27/6/16**	**20/7/16**
Install Second Geomembrane Liner	1.00	27/6/16	27/6/16
Assemble and Install Detention Tank	4.00	28/6/16	1/7/16
Install PVC Outlet	4.00	1/7/16	4/7/16
Wrap Sides of Packs in Liner	5.00	4/7/16	8/7/16
Seal Outlet Connection	3.00	9/7/16	11/7/16
Backfill Around Sides of Tanks	10.00	11/7/16	20/7/16
Bio-Retention Pond	**42.00**	**20/7/16**	**30/8/16**
Lay Permeable Geotextile Fabric	1.00	20/7/16	20/7/16
Lay Gravel Backfill	14.00	21/7/16	3/8/16
Lay Engineered Soil	14.00	21/7/16	3/8/16
Install Culvert	14.00	4/8/16	17/8/16
Install Distribution Channel	14.00	4/8/16	17/8/16
Construct Perimeter of Bio-Retention Pond to Grade	10.00	14/8/16	23/8/16
Lay Riprap	5.00	10/8/16	14/8/16
Plant Vegetation	7.00	24/8/16	30/8/16
Upstream Manhole Construction	**14.00**	**20/8/16**	**2/9/16**
Bypass Storm Drain Using PVC Pipe	1.00	20/8/16	21/8/16
Construct Manhole	14.00	20/8/16	2/9/16
Remove PVC When Connecting Bypass to the Storm Main	2.00	1/9/16	2/9/16
Landscaping	**9.00**	**25/8/16**	**2/9/16**
Sysyem Connections	**11.00**	**3/9/16**	**13/9/16**
Connect Downstream Bypass to the Storm Main	11.00	3/9/16	13/9/16
Connect Upstream Bypass to the Storm	11.00	3/9/16	13/9/16
Project Completion	**0.00**	**14/9/16**	**14/9/16**



APPENDIX D: COST ESTIMATE SHEETS

D1) Equipment Cost Calculations

Equipment Piece	Number of Pieces	Days Rented	Cost Per Day	Total
6200 lb Mini Excavator	3	35	342	35910.00
66" Skid Steer Loader	2	35	325	22750.00
Cat 730 Rock Truck	1	21	450	9450.00
Contractor Pick-Up Truck	1	137	30	4110.00
Backhoe	1	8	363	2904.00
20kW Generator	1	137	158	21646.00
Fencing	175	137	0.62	14917.78
Storage C-Cans	2	137	64	17475.72
Miscelaneous Power Tools and Equipment	5	137	200	137000.00
Plate Rev Vibrating Compactor 28"	3	14	135	5670.00
			Total	266163.50

Assumptions:

- days required for rental of equipment matches approximately with construction schedule
- backhoe used for clearing lot
-excavator to dig area of 2304 m2, volume of 6912 m3 for tank
-excavator to dig area of 546 m3 for the bypass pipes + junctions
- loader to move detention tank modules to the location, then set in place manually.
- excavator with slings to move bypass pipes into position
- loader to perform backfill
- rock truck used to haul aggregate for tank levelling bed and bio-pond filter bed
- generateor for electric equipment

Prices Obtained from: www.ContractorsRentalSupply.ca

D2) Material Cost Calculations

Materials	Quantity	Unit	Price	Unit
Riprap for bio-retention channel	60	m3	53.00	/m3
3/4" Stone	1145	m3	34.67	/m3
Medium Sand Fill	1470	m3	64.00	/m3
Top Soil/Mulch	840	m2	57.90	/m3
Geomembrane	4380	m2	3.84	/m2
Geofabric	2200	m2	3.84	/m2
Brentwood Storm Pack	1281	m3	300.00	/m3
Trough Channel	50	m	80.00	/m
Plants	700		7.50	each
1.05 m Dia. Corrugated Steel Culvert	168	m	555.00	/m
300 mm Diameter PVC Culvert	47	m	100.00	/m
PVC Orifice Plate Fitting	1		300.00	each
Manhole Construction (including connection)	1		4000.00	each

Unit Prices found from:
www.transportation.alberta.ca/Content/docType257/Production/UnitPriceList.pdf

Dry Sand - 1.6 tonne/cubic meter
300 mm of gravel above tank
150 mm of gravel for the subgrade levelling bed
2 layers of geomemebrane (below and above levelling bed)
1 layer of geotextile fabric (directly above tank) extending outwards 0.5 m from tank perimeter
Brentwood Storm Pack - $300 / m3 was an estimate from a Brentwood Sales employee

Maintenance Cost Assumption: Replace 300 plants and 0.1 m thick layer of top soil every 5 years

Maintenance Cost every 5 years:	123840	
PW of Annual Costs over 50 year life:	46950	sumpf (F x (P/F, I, N))

D3) Labour Cost Calculations

Contractor Costs

Personnel	Duties	Unit Rate	Hours	Cost
Project Manager	Has authority over supervisory engineers or a large group containing both professionals and non-professionals. (E5 designation)	214.00	198.00	42372
Site Foreman	Manages construction personnel on site and reports all progress to the Project Manager (E4 designation)	191.00	396.00	75636
Quality Assurance Coordinator	Ensures quality of onsite work meets all design specifications (Equivalent to T6)	187.00	198.00	37026
Health and Safety Officer	(Equivalent to a T5)	170.00	396.00	67320
Builders	Labourers, welders, pipe fitters (average cost). Estimate 4 man crew operating at all times.	400.00	792.00	316800
	Total			$ 539,154.00

Owner Cost

Personnel	Duties	Unit Rate	Hours	Cost
Project Manager	Oversees entire project and reports directly to UBC Properties Trust and the UBC Board of Governors (E6 designation)	266.00	158.40	42134.40
Quality Control/Inspection	Ensures all work being performed is in line with all design specifications (Equivalent to T6)	187.00	113.14	21157.71
Bid Submission Team	Creating the initial bid to be sent out to tender as well as to evaluate all bid proposals received (Equivalent to E3)	153.00	176.00	26928.00
Preliminary Estimation Team	Initial cost estimations, preliminary project schedules, scopes of work (Equivalent to T3)	153.00	176.00	26928.00
	Total			$ 117,148.11

Contractor Assumptions:

Hours calculated based on 8 hours per day, 22 days per month work schedules, and 4.5 months for the project
Assume that PM, Superintendent, QA Coordinator will spend 1/4 of working hours on project.
Site Foreman, and HS Officer spend 1/2 full time on project.
Builders have a charge out rate of $100 per hour; 4 builders on site daily

Owner Assumptions:

UBC Inspector will be on site to inspect work roughly once per week.
Project manager for UBC will spend 1/5 of their work time on the project (i.e. work hours over the 4.5 months of construction divided up between other projects/duties etc.)

Hourly Rates

Staff Classification / Standard Hourly Rate

PROFESSIONAL SERVICES		TECHNICAL SERVICES	
E1	$119	T1	$99
E2	$138	T2	$109
E3	$153	T3	$129
E4	$191	T4	$141
E5	$214	T5	$170
E6	$266	T6	$187
E7	$293	T7	$192

Source:http://www.acec-bc.ca/media/12763/acecbcFeeGuide14.pdf

SOURCES:

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Delaware Department of Natural Resources and Environmental Control. (2014). Bio-retention BMP and Standards. Retrieved from: http://www.dnrec.delaware.gov/swc/Drainage/Documents/Sediment%20and%20Stormwater%20Program/Technical%20Document/Tech%20Doc%20Updates%202014/Article%203/3.06.2.2.%20Bioretention_Rev%202014-05.pdf