UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Detailed Design Report:
STORMWATER RETENTION SYSTEM

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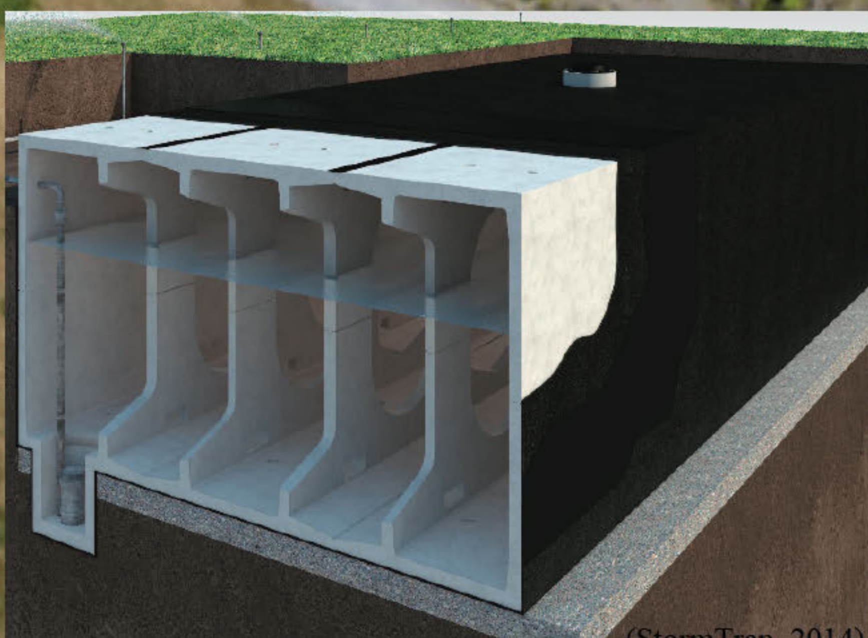
(StormTrap, 2014)

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a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

Executive Summary

CivGen Engineering has been contracted by the UBC Botanical Garden to provide a detailed design of a sub-surface stormwater storage system for the UBC Botanical Garden. The garden's irrigation system is currently sourced entirely from potable water. Two of the University of British Columbia's four catchment areas currently drain directly through or adjacent to the Garden. The stormwater retention tank design discussed in this report will reroute UBC's stormwater to meet the irrigation needs of the Garden.

Three primary Civil Engineering disciplines are the focus of the detailed retention tank design:

1. Water Resources Engineering

   This is the lead discipline of the design and governs all other aspects of the project. Tank capacity has been determined after analysis of historical stormwater supply to the catchment area and water usage trends within the Garden.

2. Structural Engineering

   The stormwater retention tank will require a slab on grade foundation to protect the modular design against differential settlements in the soil. A detailed slab design has been completed, including construction drawings and detailed design calculations.

3. Project Management Engineering

   Installing the retention tank will require significant civil works in the UBC Botanical Garden. The detailed construction work plan covers construction methods, site access, existing utilities, sequencing, scheduling, and safety.

Other civil engineering disciplines including Environmental and Geotechnical Engineering have also impacted the design and are discussed briefly in this report.

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1.0 PROJECT OVERVIEW

1.1 General

The following report outlines the detailed design of the proposed UBC Botanical Gardens stormwater management upgrade. This will be achieved with a stormwater retention tank. The scope of this report relates specifically to the detailed design of the water resources, structural and project management engineering components of the retention tank.

1.2 Design Description

As discussed in CivGen's project proposal, the addition of a stormwater retention tank would not only give the UBC Botanical Gardens the opportunity to eliminate their non-sustainable use of potable water, but also the chance to use the tank to manage peak stormwater flows and manage the outflow cliff erosion. The location, size and style of tank are some main factors that need to be considered to ensure the optimal design.

The first step in designing a stormwater retention tank was identifying a feasible location for the tank. The location must be immediately adjacent to existing stormwater infrastructure, in an area that minimizes impact on the garden and somewhere on relatively high ground to minimize pumping costs. CivGen identified the service yard on the north end of the garden as the ideal location for the tank since this location met all of the above criteria, see

Figure 2. After selecting a preliminary tank location, CivGen carried out a water resources analysis to determine the water supply from the adjacent catchment area and compare that against the Garden's water demand in order to properly size the tank. Once the tank was sized, CivGen selected a concrete modular tank system due to the system's durability, low maintenance requirements, and the structural strength that will allow vehicles to drive above it. A structural solution was now

necessary in order to design a slab that would prevent differential settlement between the concrete modular units, which could lead to damages and leaks. Once the structural slab was designed, CivGen was able to create a detailed construction schedule and carry out detailed economic analyses for the project.

1.3 Design Advantages

CivGen's stormwater retention system has many advantages to the owner (UBCBG) and UBC itself including:

- Elimination of potable water use within the garden
    - The tank has been designed to meet water demand even in the extreme event of four consecutive 1/5 year dry months in the summer.
    - Escalating water prices in Metro Vancouver make the water savings more economically significant with each passing year.
- Ability to reduce peak flows and cliff erosion at Trail #7 Outfall
    - The tank has the capacity to significantly delay and attenuate peak flows through the garden's creeks and over the outfall. This will reduce erosion in the area.
- Convenient location in current service yard
    - The installation of the tank will not negatively impact garden visitors.
    - Routine maintenance on the tank will be easily facilitated from this location.
    - Concrete modular tanks can bear the load of vehicles driving above.
- Enhance UBC's stormwater management goals
    - UBC has an integrated stormwater management plan which has the goal to integrate innovative and sustainable approaches to stormwater management on campus. The retention tank will meet the goals of providing irrigation for landscaped areas, and reducing the erosion of the Point Grey Cliffs.

2.0 DETAILED DESIGN

The detailed design has been divided into three civil engineering disciplines which are detailed in the following sections: water resources engineering, structural engineering, project management engineering.

2.1 Water Resources Engineering

The most critical task for the water resources engineering discipline was to conduct a detailed and accurate supply and demand analysis of water in the Botanical Garden in order to choose an optimal retention tank size. The first goal of the analysis was to determine the available inflow to the garden from existing UBC storm water infrastructure. After calculating inflow to the garden, the inflow (supply) was compared against the garden's water usage (demand). To meet the Client's goal of alleviating potable water usage in the garden, a stormwater retention tank would need to be sized to meet the demand of the garden. A retention tank was chosen over a retention pond in order to minimize water loss to infiltration and evaporation. Class A pan evaporation data from UBC states an average annual evaporation of 964mm (Piteau Associates). The majority of evaporation occurs in the summer months when the Botanical Garden's water demand is high and precipitation is low. The optimal size for a stormwater retention tank was found to be 5000m^3.

2.1.1 Calculating Inflow

The UBC Botanical Garden is conveniently located downslope from the majority of campus and is situated above Trail #7 outfall. This topography provides the Botanical Garden with the unique opportunity to easily collect stormwater that is already flowing through the garden from the west catchment area, see Figure 1.

Figure 1: UBC Catchment Areas (UBC)

CivGen identified the current garden works yard as an ideal location to place a retention tank due to its proximity to existing stormwater pipes, see Figure 2. Specific flow data was not available from the GeoAdvice report so CivGen had to determine potential inflows from the identified catchment area through other methods.

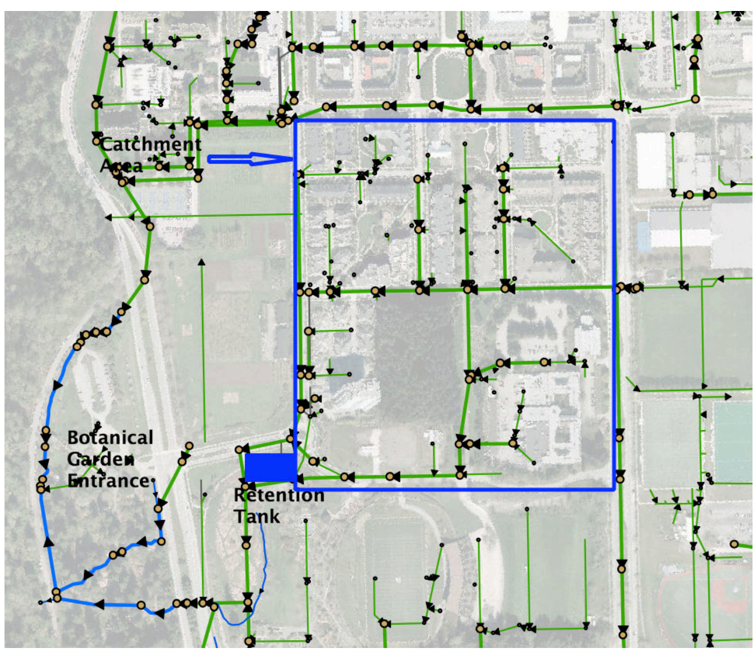

Figure 2: Proposed Retention Tank Location (GeoAdvice Engineering)

CivGen reviewed a UBC Seeds project report, which had set up a gauging station on the creek immediately downstream of the culvert outlet near the Moon Gate. This outlet is from the stormwater drainage pipe, which is being proposed to use to fill a retention tank located in the service yard. Therefore the measurements made at the culvert outlet are fairly representative of expected flows into the proposed tank. The SEEDS report suggested that the creek has base flows ranging from 4L/s in the winter months to only 0.2L/s in September. The creek was gauged using a pressure transducer and datalogger, placed in a pond created behind a weir. A relationship was created between the height of water, and discharge over the weir. Unfortunately the data in the report was based only on one year of data, and had minimal manual measurements to verify the data. CivGen used the reported numbers as a way to verify our calculations using the rational method.

The rational method was used to calculate expected inflows through the stormwater pipe in the garden. The rational method is best suited for small catchment areas like the one being analyzed. The rational method is used commonly in North America to provide estimates on runoff produced by a certain amount of precipitation. Typically the precipitation input is provided by a rainfall intensity, which is selected from an IDF curve. For determining inflow into the garden CivGen did not need to calculate a peak flow based on peak rainfall intensity, but instead needed to calculate expected total inflows. For this reason the "i" term in the rational method was chosen as daily precipitation and the value calculated as a volume not a flow rate. This assumes that the entire catchment area contributes to flow in the stormwater pipe at the storage yard location. The entire catchment area will only fully contribute when the storm duration equals or exceeds the time of concentration of the catchment area. The time of concentration for this catchment area is only 13 minutes so it is safe to assume almost all storm durations will exceed this value. The catchment area time of concentration was calculated using the following equation:

$$Tc=0.0195*L^{0.77}*S^{-0.385}$$

Where:

Tc= Time of Concentration

L= Maximum length of flow=780m

S= Grade of drainage area (m/m)= elevation difference/watershed length=(95m-78m)/550m

The flow into the stormwater pipe was calculated with the following equation. The precipitation data input was provided by the 10 year Environment Canada record for the weather station at Vancouver International Airport. Records from a previous UBC weather station were not found but previous reports state that average precipitation at UBC is 10% greater than at YVR (Piteau Associates). This excess 10% provides some contingency in the calculated inflows.

$$Q=CiA$$

C=.65 (for rolling urban areas with 50% impervious area)

A=14.5 ha

i= Precipitation in mm (from Environment Canada Record)

The average flow values calculated using the rational method were similar to those recorded at the gauging station in the UBC SEEDS report. This provides confidence in the accuracy of the calculated inflows.

2.1.2 Tank Sizing: Supply vs. Demand Analysis

The goal of installing a retention tank at the UBCBG is to eliminate potable water usage. Therefore the tank must be large enough to provide complete water supply for the garden. The most critical months to consider in the design are June-September. These months are typically much drier than the rest of the year and also have the highest demand for water, see Figure 3 below. Additionally, Metro Vancouver charges 25% more for water in these months.

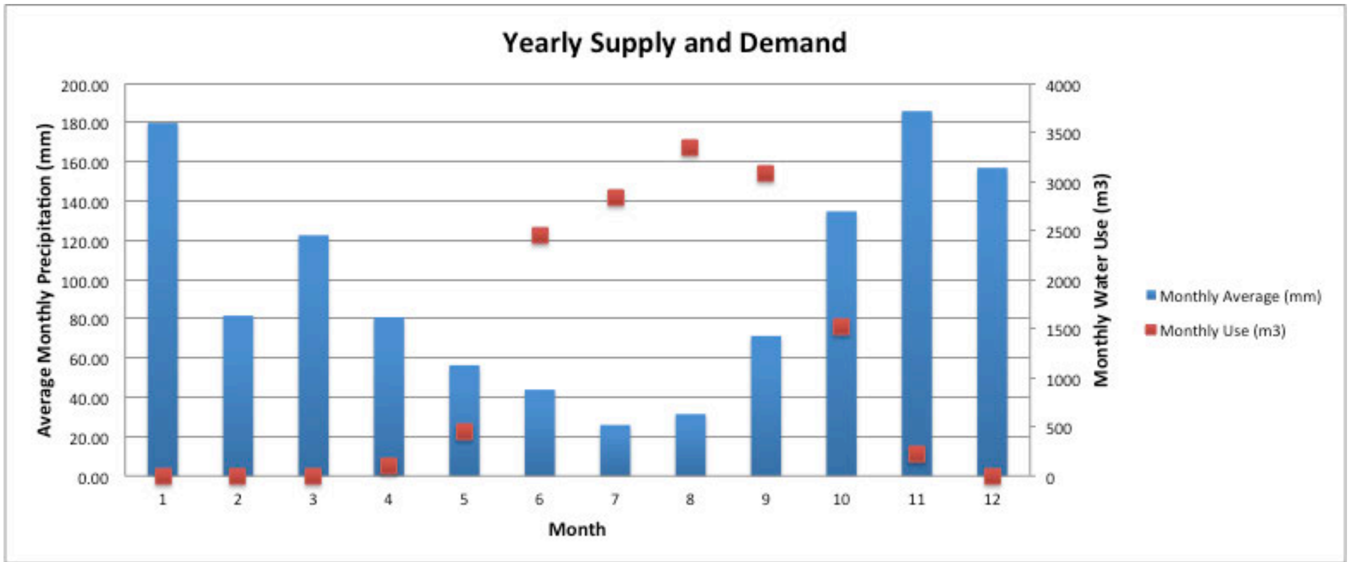

Figure 3: Comparison of Supply and Demand in UBCBG

CivGen's goal is to provide a reliable analysis and a tank that will meet the client's expectations. This means that the tank must be able to supply the garden even in drier years. Multiple scenarios were created and different tank sizes compared for their effectiveness in providing all of the water needs of the garden.

- **Real Scenarios:** CivGen analyzed how varying tank sizes would have performed based on precipitation record for years 2003-2012.
- **Synthetic Scenarios:** CivGen analyzed the Environment Canada Precipitation record for YVR and by ranking monthly precipitation values were able to determine the expected return period and frequency of low precipitation months. Three synthetic scenarios were created.
    - Scenario 1: A year with normal precipitation in the Spring, Fall and Winter but with a 1 in 5.5 year drought in the all of the Summer months.

- o Scenario 2: A year with normal precipitation in the Spring, Fall and Winter but with a 1 in 11 year drought in all of the Summer months.
- o Scenario 3: A year with average precipitation in Winter, Spring, Summer and Fall.

The real and synthetic scenarios were analyzed for 40 different tank sizes ranging from 250 m^3-10,000 m^3, see Figure 4. The optimal tank size for the retention tank was determined to be 5000 m^3. This size is optimal as it provides water to the garden for all of the scenarios except the 1/11 year summer long drought. In the event that demand exceeds the tank's supply the cost to the garden to buy supplemental water will be minimized. Additionally, if the tank is not full by May, the garden can purchase water to fill the tank before Metro Vancouver starts charging a 25% premium in June-September. The selected tank size fits CivGen's ideology of designing to the probable, not the maximum. There will be certain years where the tank may not provide enough water, but the incremental cost for the client to build a tank of twice the size would not be justified.

Monthly Supply Deficit (m3)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	1/11yr drought	1/5.5yr drought	Average
1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	-1247	-304	0	0	0	0	-1435	0	0	0	-1435	0	0
7	-971	-1272	0	-462	0	-1348	-952	-2780	0	-217	-2780	-1348	-387
8	-2954	0	-644	-2888	-2548	0	-833	0	-1493	-3067	-3067	-2954	-367
9	0	0	0	0	0	-206	0	0	0	-2619	-2619	-206	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0
Tank Size Required	**5,171**	**1,577**	**644**	**3,350**	**2,548**	**1,554**	**3,220**	**2,780**	**1,493**	**5,902**	**9,901**	**4,507**	**754**

Cost of Water to be Purchased	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	1/11yr drought	1/5.5yr drought	Average	Tank Size (m3):
	$ 5,038	$ 1,358	$ 404	$ 3,173	$ 2,353	$ 1,335	$ 3,041	$ 2,591	$ 1,272	$ 5,787	$ 9,880	$ 4,358	$ 516	250
	$ 4,782	$ 1,102	$ 148	$ 2,917	$ 2,097	$ 1,079	$ 2,785	$ 2,335	$ 1,016	$ 5,531	$ 9,624	$ 4,103	$ 260	500
	$ 4,526	$ 846	$ -	$ 2,661	$ 1,841	$ 823	$ 2,529	$ 2,079	$ 760	$ 5,275	$ 9,368	$ 3,847	$ 4	750
	$ 4,270	$ 590	$ -	$ 2,405	$ 1,585	$ 567	$ 2,273	$ 1,823	$ 504	$ 5,019	$ 9,112	$ 3,591	$ -	1000
	$ 4,014	$ 334	$ -	$ 2,149	$ 1,329	$ 311	$ 2,017	$ 1,567	$ 248	$ 4,763	$ 8,856	$ 3,335	$ -	1250
	$ 3,758	$ 78	$ -	$ 1,893	$ 1,073	$ 55	$ 1,761	$ 1,311	$ -	$ 4,507	$ 8,600	$ 3,079	$ -	1500
	$ 3,502	$ -	$ -	$ 1,637	$ 817	$ -	$ 1,505	$ 1,055	$ -	$ 4,251	$ 8,345	$ 2,823	$ -	1750
	$ 3,246	$ -	$ -	$ 1,382	$ 561	$ -	$ 1,249	$ 799	$ -	$ 3,995	$ 8,089	$ 2,567	$ -	2000
	$ 2,990	$ -	$ -	$ 1,126	$ 305	$ -	$ 993	$ 543	$ -	$ 3,739	$ 7,833	$ 2,311	$ -	2250
	$ 2,734	$ -	$ -	$ 870	$ 49	$ -	$ 737	$ 287	$ -	$ 3,483	$ 7,577	$ 2,055	$ -	2500
	$ 2,479	$ -	$ -	$ 614	$ -	$ -	$ 481	$ 31	$ -	$ 3,227	$ 7,321	$ 1,799	$ -	2750
	$ 2,223	$ -	$ -	$ 358	$ -	$ -	$ 225	$ -	$ -	$ 2,971	$ 7,065	$ 1,543	$ -	3000
	$ 1,967	$ -	$ -	$ 102	$ -	$ -	$ -	$ -	$ -	$ 2,715	$ 6,809	$ 1,287	$ -	3250
	$ 1,711	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,459	$ 6,553	$ 1,031	$ -	3500
	$ 1,455	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,203	$ 6,297	$ 775	$ -	3750
	$ 1,199	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,947	$ 6,041	$ 519	$ -	4000
	$ 943	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,692	$ 5,785	$ 263	$ -	4250
	$ 687	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,436	$ 5,529	$ 8	$ -	4500
	$ 431	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,180	$ 5,273	$ -	$ -	4750
	$ 175	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 924	$ 5,017	$ -	$ -	5000
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 668	$ 4,761	$ -	$ -	5250
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 412	$ 4,505	$ -	$ -	5500
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 156	$ 4,250	$ -	$ -	5750
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,994	$ -	$ -	6000
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,738	$ -	$ -	6250
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,482	$ -	$ -	6500
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,226	$ -	$ -	6750
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,970	$ -	$ -	7000
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,714	$ -	$ -	7250
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,458	$ -	$ -	7500
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,202	$ -	$ -	7750
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,946	$ -	$ -	8000
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,690	$ -	$ -	8250
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,434	$ -	$ -	8500
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,178	$ -	$ -	8750
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 922	$ -	$ -	9000
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 666	$ -	$ -	9250
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 410	$ -	$ -	9500
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 155	$ -	$ -	9750
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	10000

Figure 4: Tank Sizing Analysis

2.1.3 Peak Flow Reduction Benefits

The large capacity of $5000m^3$ will allow for the tank to delay and attenuate peak flow at the Trail #7 outfall. Cliff erosion is a major concern at UBC. Currently the Trail #7 outfall is undercutting the outfall pipe, and a drop of almost 1.5m from the outfall pipe to the ground surface continues to erode the cliffs back towards Old Southwest Marine Drive and the UBC Botanical Gardens. Proper management of the $5000m^3$ stormwater retention tank will help to minimize the peak flow over this outfall, and therefore lead to less erosion.

To analyze this benefit, CivGen created a two hour unit hydrograph using the SCS Method for the catchment basin that flows into the retention tank, see Figure 5.

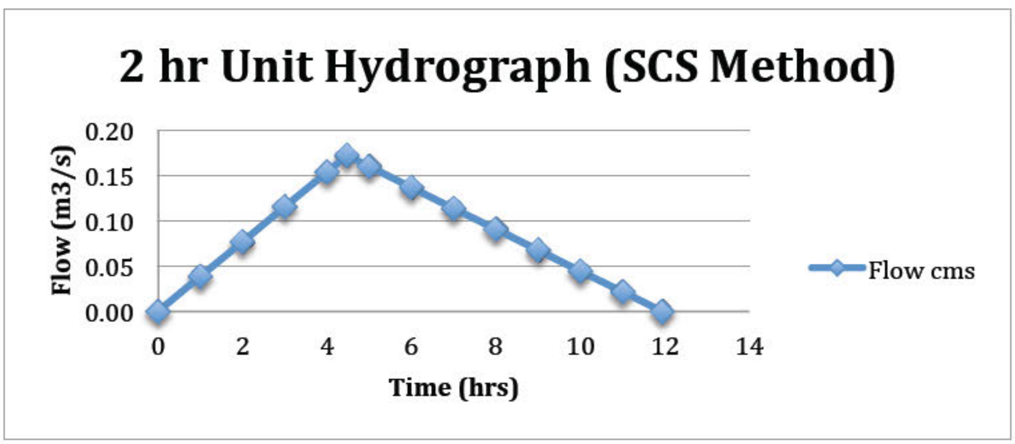

Figure 5: 2hr Synthetic Unit Hydrograph

A 6 hour, 10 year design storm was applied to the unit hydrograph to calculate flow at the retention tank using the properties of unit hydrograph and hydrograph convolution, see Table 1 and Figure 6. This design storm, provided by the District of North Vancouver Design Manual, produced a peak flow of $0.22m^3/s$ and a cumulative volume of $6300m^3$ (District of North Vancouver). Figure 6 displays that the tank volume is exceeded four hours past peak flow, meaning that the cliffs would not see the effect of peak flow erosion. If this scenario occurred in the winter, when the garden has high supply and low demand for water, the tank could be completely emptied at a slow rate. The empty tank could then be ready for use in the next storm event.

Table 1: Hydrograph Convolution - Applying Design Storm to Synthetic Hydrograph

Time	P1*UH	P2*UH	P3*UH	Q(cms)	Volume	Cum. Vol (m3)
0	0.00			0.00	0	0
1	0.01			0.01	37	37
2	0.02	0.00		0.02	73	110
3	0.03	0.03		0.06	230	339
4	0.04	0.07	0.00	0.11	386	725
5	0.05	0.10	0.01	0.16	571	1296
6	0.04	0.13	0.03	0.20	727	2023
7	0.04	0.15	0.04	0.22	809	2831
8	0.03	0.14	0.05	0.22	796	3628
9	0.02	0.12	0.06	0.20	725	4353
10	0.02	0.10	0.06	0.17	616	4969
11	0.01	0.08	0.05	0.14	494	5463
12	0.01	0.06	0.04	0.10	372	5835
13	0.00	0.04	0.03	0.07	251	6086
14		0.02	0.02	0.04	151	6237
15		0.00	0.02	0.02	55	6292
16			0.01	0.01	27	6318
17			0.00	0.00	0	6318

Design Criteria Manual: District of North Vancouver (Dec, 2006)			
	6hr Duration Design Storm (10 Year)		
	Time	Infiltration	Net Rain
P1	0"2	0.2	0.264567
P2	2"4	0.15	0.866142
P3	4"6	0.15	0.345276

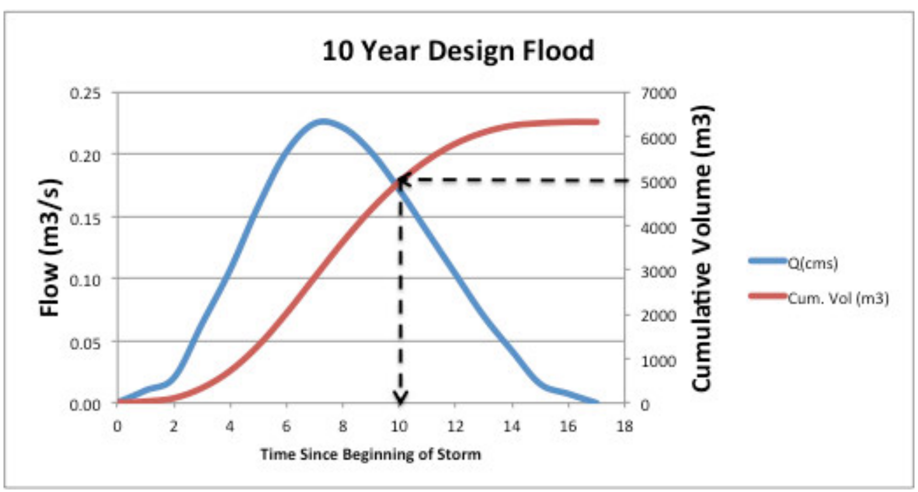

Figure 6: Attenuation of 10 Year Design Flood by 5000m3 Tank

2.1.4 Selection of Tank System

Upon determining an optimal tank size CivGen moved to select the best style of tank for the location selected. Criteria for evaluating various tank options included:

- Price
- Design-life
- Durability
- Maintenance costs
- Ease of installation
- Ability to support vehicles in service yard above tank

Upon evaluating various tank systems CivGen selected a concrete modular tank system provided by a company called StormTrap. These modular units met all of the criteria above when evaluated against other options like cast in place construction and plastic tanks. The vendor, StormTrap, was extremely cooperative and provided CivGen with a quote for a tank with 5000m^3 storage capacity. This tank will consist of 210 StormTrap's DOUBLETRAP units. Seven different styles of unit will be required to construct the tank including corner units, edge units and middle units.

This system has a design life of 50 years and requires minimal maintenance. In the event that a leak or broken component was found the damaged module could simply be replaced, as opposed to other systems which would require a full scale repair. The vendor is able to supply the units from a local manufacturer. Drawings provided by StormTrap are included in the Appendix A.

2.1.5 Integration With Existing Stormwater Main

Information regarding location, performance and size of the existing stormwater mains around the UBCBG works yard were obtained from a previous report (GeoAdvice Engineering). The stormwater mains adjacent to the garden are highlighted in Figure 7 below. All the mains shown in Figure 7 are from the same catchment area and their inverts and diameter are provided. The design will use the flow from pipe L3D-NW175CX and SM-1. Information regarding SM-1 is missing;

therefore the specifications are assumed to be similar to that of L3D-NW175BX, which runs parallel to SM-1. The design specs are outlined in Table 2.

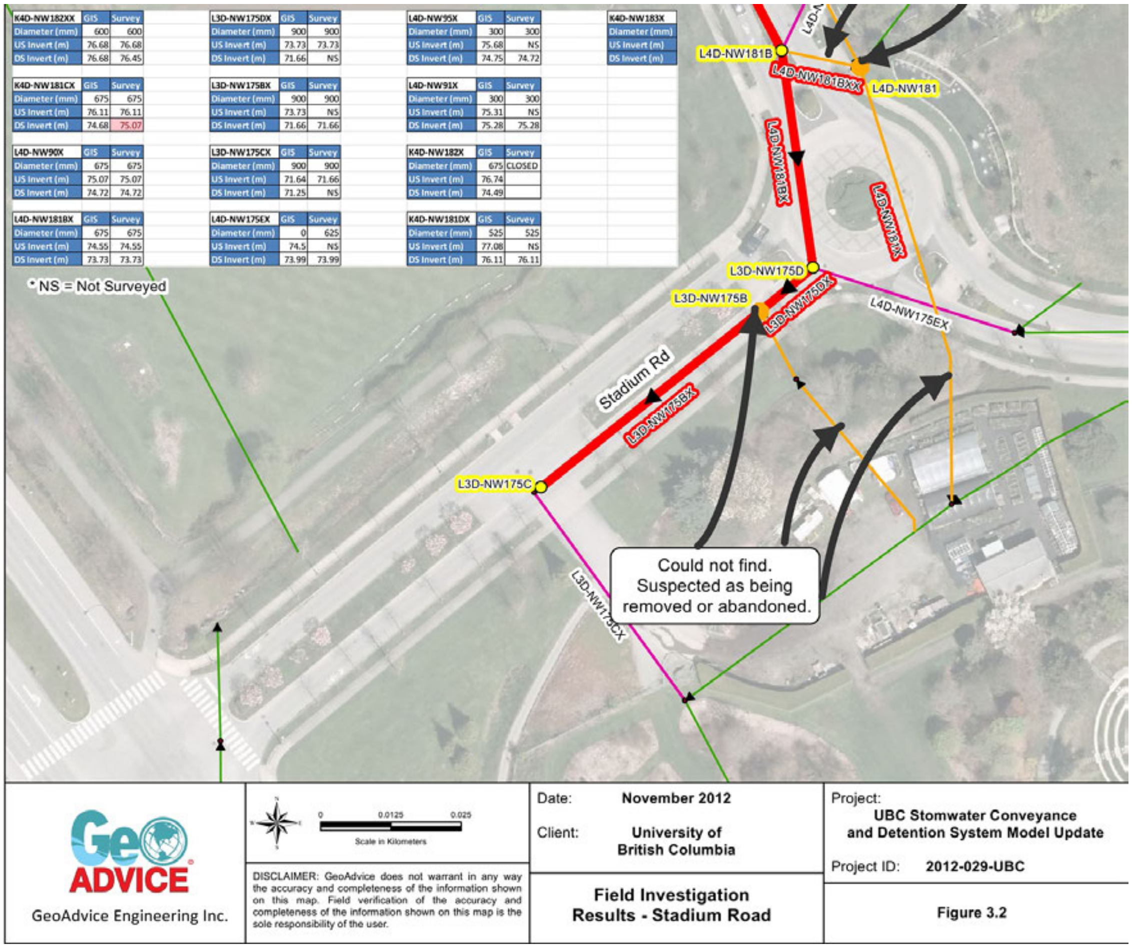

Figure 7: GeoAdvice Modeling Data

Table 2: Specifications of Existing Stormwater Main

Name	Diameter (mm)	US Invert (m)	DS invert (m)
L3D-NW175CX	900	73.71	71.66
L3D-NW175BX	900	71.66	71.25
SM-1	900	73.30	71.25

2.1.6 Flow Design

The detention tank will be gravity fed by L3D-NW175CX and SM-1. In order to maintain the original design of the stormwater main, the tank site will be leveled at 3m below DS invert of L3D-NW175CX at 68.25m. The ground elevation at the UBCBG works yard is approximately 74m-75m which is provided by the City of Vancouver. An overview of the design and elevations are provided in Figure 8 below.

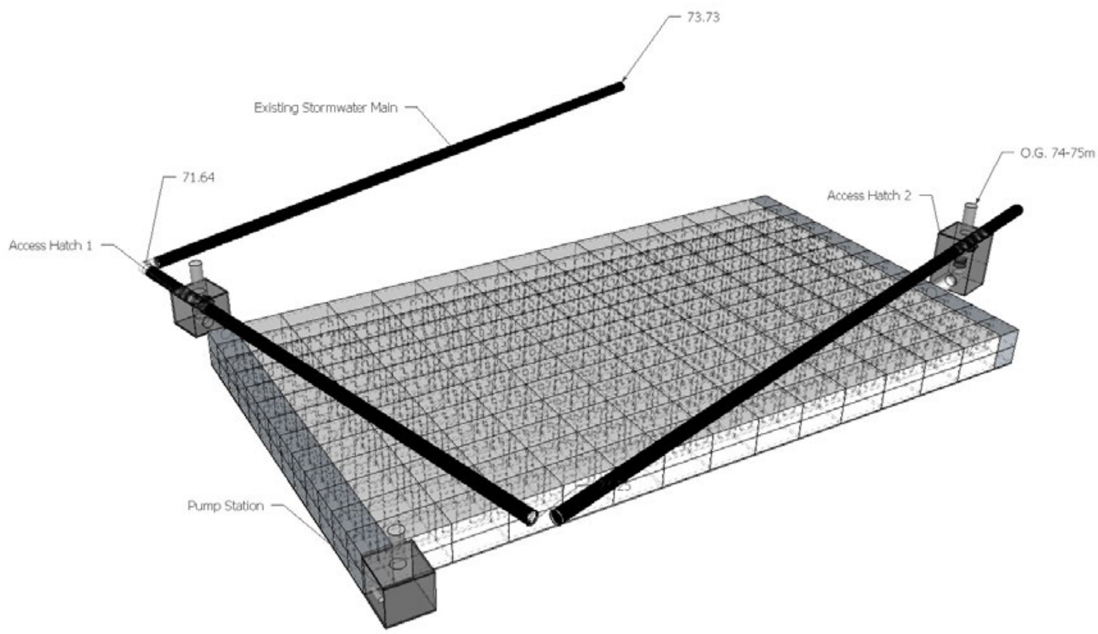

Figure 8: Schematic Layout of StormTrap Modules With Existing Stormwater Mains

The existing stormwater mains will be cut during construction and temporally diverted around the site until the retention tank is installed. Once the retention tank is in place the stormwater main will be reconnected with the new valves and access hatches. The valves will allow the stormwater flow to drop into the retention tank. Once the tank is full the water level will rise up to the valve and bypass the tank and naturally flow down the main as originally designed. During service and maintenance both valves can be shutoff and the stormwater will be able to bypass the retention tank without causing any disruption of the stormwater mains. The stored water can then be pumped into the irrigation system for use. The exact specifications of the valves and pump are not part of the design, however a concept of the valve is provided below in Figure 9.

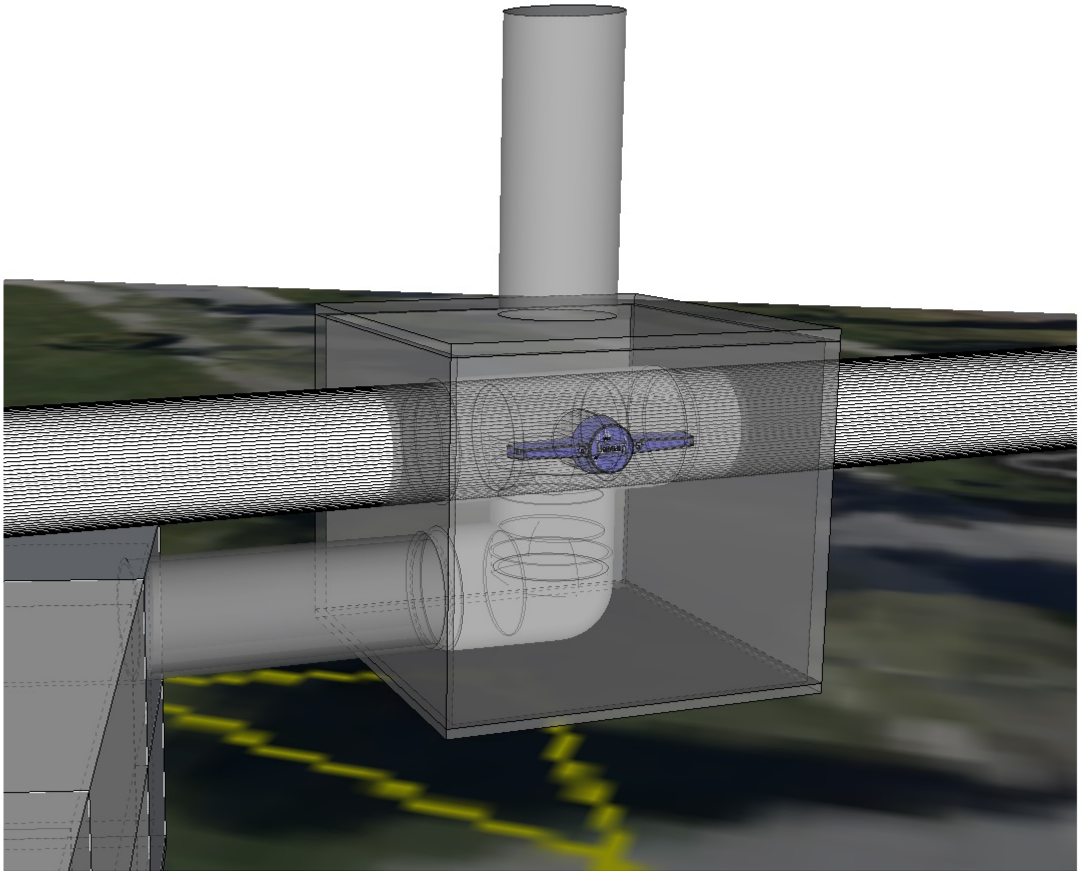

Figure 9: Concept of Valve and Access Hatch

2.2 Structural Engineering

2.2.1 Soil Conditions

The geotechnical report prepared by GeoPacific in 2013 for the Orchard Commons development was used as reference for the structural design calculations due its proximity to the UBCBG. The report indicates that the Orchard Commons site is underlain by substratified glaciofluvial sand, gravel and silt. Under the top layer of asphalt and fill material are a layer of 1m to 10m thick glacial till-like soil. Seepage was noticed at around 2m below grade, however static groundwater table was not noticed (GeoPacific, 2013). The suggested serviceability state (SLS) and ultimate serviceability state (ULS) bearing pressure is 300kPa and 450kPa, respectively (GeoPacific, 2013). The SLS bearing pressure of 300kPa was used in the design of the slab on grade.

2.2.2 Applied Loads

The applied loads considered in the design of the reinforced concrete slab on grade, in addition to the weight of the slab, must be kept under the 300kPa serviceability limit state set in geotechnical report for Orchard Commons (GeoPacific, 2013). The applied loads that were considered are as follows:

- Vehicle point loads
- Surface soil above tank
- Retention tank full of water
- Slab on grade

With the original design of the tank being right below grade, the point loads of large vehicles above where the main concern for the design of the concrete slab on grade. However, after establishing the depths of the water mains, the tank needed to be dropped another three metres creating additional depth for the vehicle point loads to be distributed as shown in Figure 10 below. Because the slab on grade was being designed while the loads of the same slab had to be considered in the applied loads on the soil, an iterative design process was established. An initial 100mm slab thickness was assumed and design was completed for the assumed thickness. The loads on the soil for the 100mm thick slab where then calculated and found to be under capacity, and thus only one iteration was necessary. For complete calculations of the applied loads, see Appendix B.

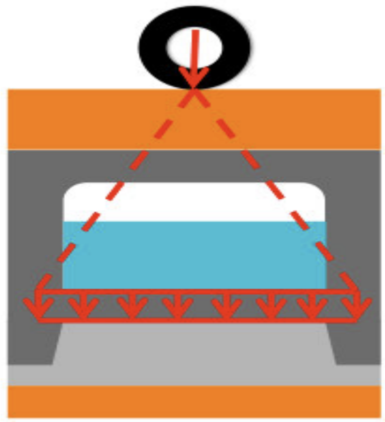

Figure 10 - Point Load Distribution

2.2.1 Structural Design

A concrete slab on grade will be installed below the retention tank modules to protect against differential settlement. Although the loads on the slab are not large, the modules of the retention tank are not connected to one another to resist vertical movement and potential differential settlement would damage the integrity of the tank. The slab eliminates the chance of the tank modules separating and causing a leak in the reservoir. Additionally the slab is relatively inexpensive when compared to the costs of the tank and intrusive repairs to the tank could exceed the cost of the slab itself.

To establish the design parameters of the reinforced concrete slab, the CSA A23.3 concrete design handbook was checked for design guidelines for a slab on grade. After finding no guidelines for a slab on grade, “Reinforced Concrete Design: A Practical Approach” by Brzv & Pao was found to have some guidance on slab on grade design but referred to PCA 2001 which we did not have access to. It was then assumed that if the design of the slab could be adequate for a simply suspended one-way slab, it would definitely be adequate for a slab on grade.

The point loads from vehicles above the slab will be distributed through the depth of both the soil and the tank. The factored loads were calculated to be about 10% of the demand and so it was assumed that the spacing requirements for flexural reinforcement could be omitted and the spacing requirements for shrinkage reinforcement would govern.

The final design was calculated to be a 100mm thick reinforced concrete slab on grade with 10M rebar spaced at 500mm on centre, each way, placed at mid depth of the slab. For complete design calculations and drawings, see Appendix B.

2.3 Project Management Engineering

The installation of the retention tank at UBCBG will require coordinated construction phasing to ensure the operation proceeds efficiently. This plan is intended to provide a guide to constructors to increase efficient project implementation and reduce potential impacts to the local community.

2.3.1 Phase One

The first phase of construction will involve preparing the site for placement of the slab. The excavation must proceed to an average depth of 6m. This depth is required so that the inlet pipe to the tank, which is at the top of the tank, will be at the same elevation as the incoming stormwater line. The site suffers from a lack of space so excavated material must be removed from the site immediately. Excavated material will be placed in a temporary stockpile at the nearby Totem Field. Access to Totem Field will need to be built to allow easy access for dump trucks. The access point depicted in Figure 11 below should be relatively easy to build and the nearby excavator should be able to complete this work on day one. Figure 11 below also shows the dump truck route where the red line represents a loaded haul and the blue line an empty return haul.

Figure 11: Site layout image showing dump truck route and Totem Field access point

Occupational Health and Safety (OHS) regulation section 20.81, Sloping and Shoring Requirements, mandate that the edge of the bottom of the excavation slope up to original grade at a 4:3 slope. This will result in an on average 4.5m wide back cut along the edge of the excavation. The excavation should begin at the southeast corner of the rectangular footprint and work backwards towards the road. Because of the depth of the excavation it should occur in three 2m lifts. This will improve efficiency by allowing the dump trucks adequate room to safely maneuver within the excavation. A ramp can be maintained at the site access point to further facilitate efficient travel.

The existing stormwater lines on the west side of the site should be temporarily disconnected and rerouted to run along the edge of the western side slope. Cutting a bench for the pipe to rest will provide some structural support and can be used to help keep the pipe in place.

One to two typical dump trucks cycling between site and the stockpile should be sufficient to handle the volume of excavated material. The trucks will be using low traffic roads that are otherwise used by local residents or clients of the adjacent hospice facility and so it is imperative that skilled flaggers be present while trucks are using the local roads. Only half of the excavated material needs to be stockpiled, the other half can be sold or dumped depending upon demand.

2.3.2 Phase Two

The second phase of construction will involve the construction of the slab formwork, reinforcement and finally the placement of concrete. The slab design is detailed in the slab design section and construction will follow these plans. Because of the poor overall site access it is recommended to pour the slab using a concrete pump truck with a long delivery boom. This will allow the pump truck to setup at the entrance to the service yard where it can receive concrete and pump out to workers for placement.

2.3.3 Phase Three

The third phase of construction will begin after approximately three days of setting time has passed for the concrete slab. At this point the slab will be sufficiently strong to bare the empty StormTrap modules. Now a large continuous piece of PPL-24 HDPE pond liner should be placed over the slab to begin forming the impermeable basin the tank modules will sit within (Aird, 2011). The pond liner should be wrapped on either side by geotextile, which will add additional strength and provide some puncture resistance to the liner. Special care should be taken to avoid placing the liner over any debris or stones that could end up between the modules and the slab. If the liner becomes punctured the system will lose some of its retention capabilities before it has even been installed.

Perimeter markings should be employed to ensure modules are placed into the excavation in an efficient manner with care taken to maintain the alignment. See Figure 12 below for an example of an efficient module placement order. Modules should be trucked in and picked directly off delivery trucks by the crane that will place them. This method of module transfer will allow for very rapid and efficient placement. Modules can be picked and placed in approximately 5-10 minutes using this method (Humes, 2011).

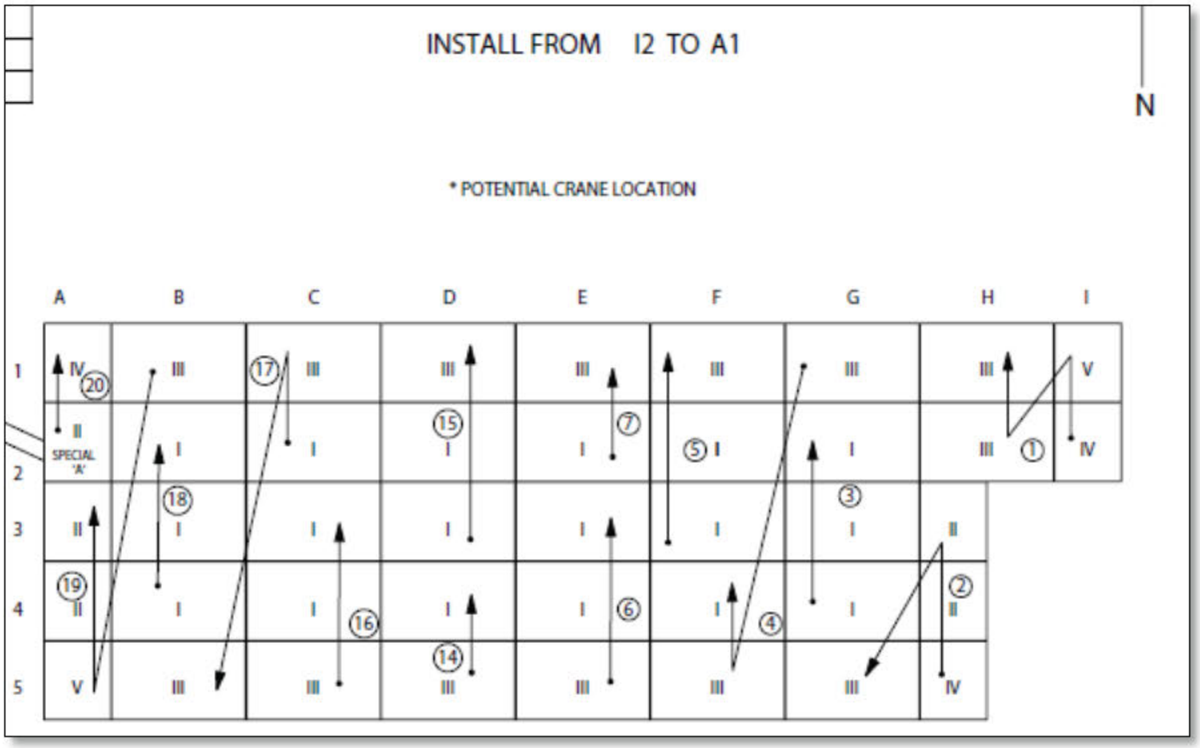

Figure 12: Example of recommended module placement order (Humes Installation guide pg.5)

2.3.4 Phase Four

Once modules have been fitted in place the exterior joints of the modules shall be sealed with a mastic joint tape to prevent soil/silt infiltration. Now the inflow and outflow pipes can be attached to the tank. During fitting a pipe collar should be attached to prevent leakage at this point.

The fourth phase commences after all modules have been fitted into place, connections attached, and modules sealed. The soil should be placed and compacted to StormTrap Recommendations. StormTrap dictates filling the soil surrounding the tank in lifts compacted to 100% standard proctor density. This will provide a strong surrounding compressive force that help to keep the tank modules tight to one another.

2.3.5 Project Schedule

The project master schedule is outlined below in Figure 13. This schedule takes into account the estimated production rates for each specific task. A construction cost estimate was created along with the project schedule. The total construction time will be 5.5 weeks.

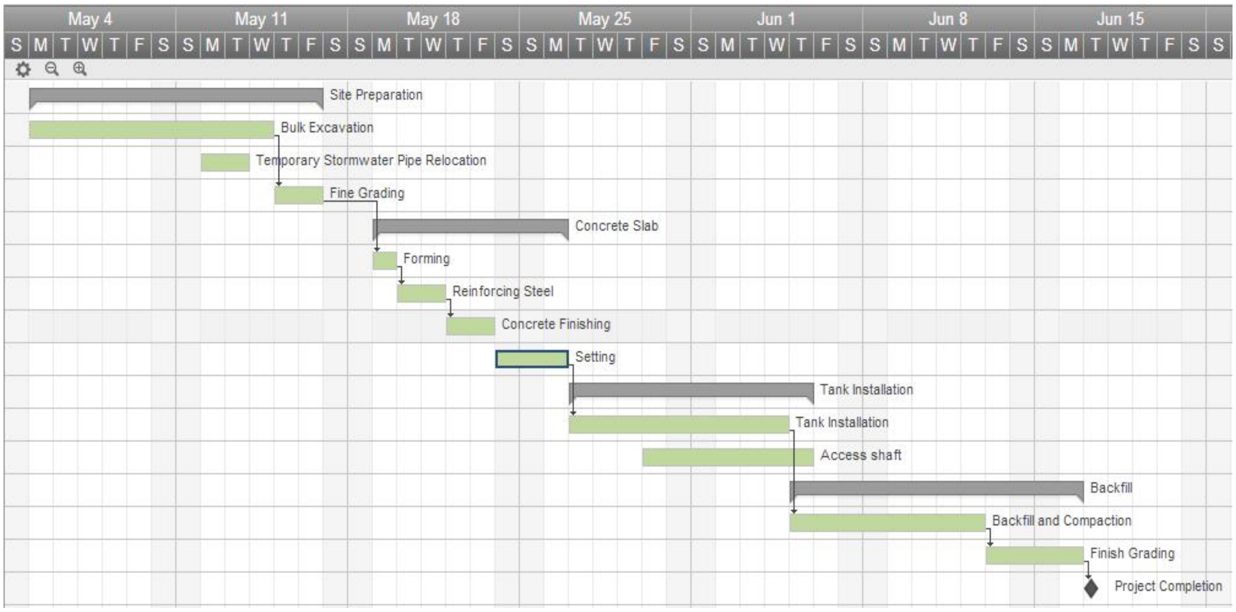

Figure 13: Retention Tank Construction Schedule

2.3.6 Safety Considerations

Safety is of the utmost important to Civgen Consulting during the construction process. The following section will provide some mitigative measures to ensure the stormwater retention project is completed safely. Figure 14 below illustrates the most common causes of injury across British Columbia in 2013.

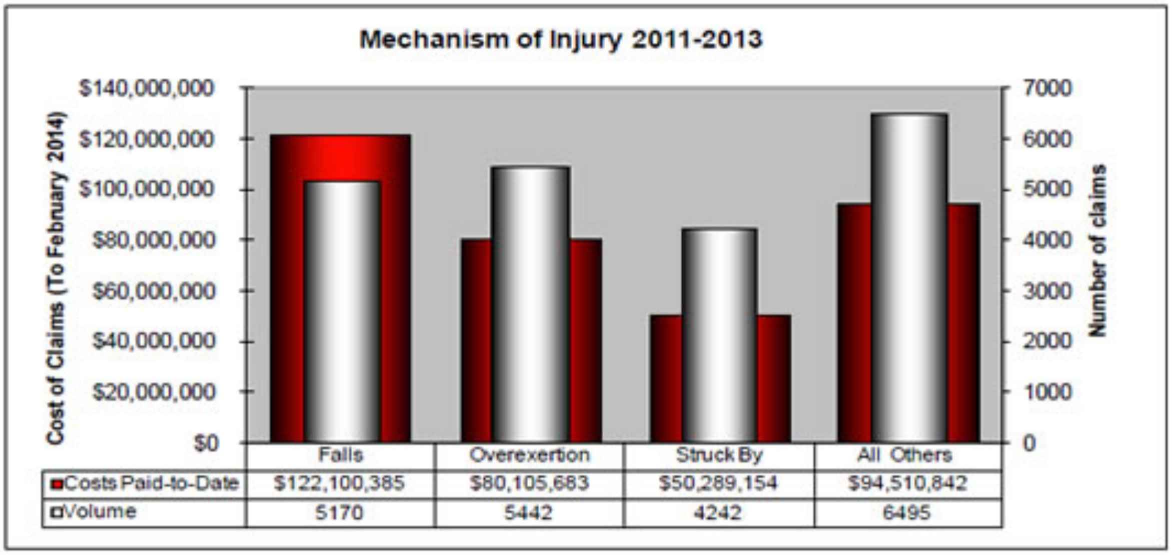

Figure 14: Most common mechanisms of injury from 2011 to 2013 (Work Safe BC, 2013)

This overall trend holds true for the main aspects of work detailed in this report, which required to install the StormTrap system. The main construction aspects involved in this project are as follows:

- Land clearing and site preparation
- Concrete pumping, placing, and formwork
- Crane work

2.3.6.1 Land Clearing and Site Preparation

Creating an excavation is always dangerous. Buried utilities, heavy equipment, and uneven terrain are just some of the hazards inherent in site clearing and excavation work. This work site is smaller than the ideal size and will therefore be fairly congested with heavy equipment working to remove the soil as quickly as possible. The site is also close to a variety of other developments and may have yet unknown buried utilities that must be found and marked. The main hazards of concern and recommended mitigations follow.

Buried Utilities

BC One Call centres must be notified a minimum of three full days before a ground disturbance is going to be undertaken. For the purposes of this work more time should be given to allow adequate time to deal with unforeseen discoveries. Always follow WorkSafeBC, OHS, and BC One Call instructions to minimize the risk of devastating utility strikes.

Sloping Requirements

OHS legislation provides a few different options for making excavations safe to the workers who must enter them to work. The option selected for this report will be a straight back slope cut at a 4:3 ratio. Figure 15 illustrates how the slides slopes in the excavation must be cut. Workers must not enter excavations or trenches that do not meet the safe sloping requirements.

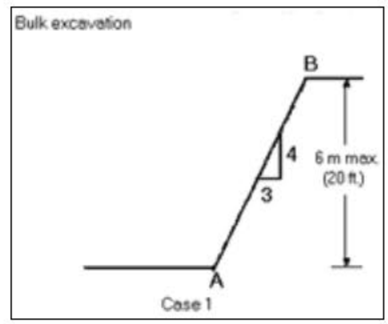

Figure 15: Excavation side sloping requirements

Moving Equipment

Moving equipment is dangerous equipment and the risks of being struck and killed by heavy equipment is of high concern for this site. For this reason flaggers should be used when construction vehicles cross the paths of civilians. Furthermore, workers should be briefed during daily cooperative safety meetings with the goal of keeping the threat of heavy vehicles fresh in everyone's minds.

2.3.6.2 Concrete Pumping, Placing, and Formwork Construction

Concrete pumping, placing, and formwork construction provides some unique risks to worker safety. The formwork and reinforcing bar construction provide many tripping hazards and also the risk of impalement. The boom of the concrete pumping truck creates the hazards associated with equipment strikes on workers.

Repetitive Stress Injuries

Building formwork and reinforcement as well as placing and finishing concrete requires repetitive and labour intensive work. It is important for workers to be mindful of their fatigue levels so they can avoid the effects of repetitive strain injuries. Task rotation is important to prevent workers from overexertion and fatigue that can lead to injury.

Concrete Boom and Hose Injuries

Concrete pump trucks have very long delivery booms that are very heavy and controlled by powerful hydraulics. Workers can receive severe injuries if struck by pump truck booms or hoses due to their mass and power. Additional the pressure required to pump concrete and sheer mass of concrete will make handling the delivery hose dangerous work. Care must be taken during the placing phase to avoid injuries caused by operator carelessness.

Tripping Hazards

Reinforcing and formwork structures provide a dangerous worksite from a tripping hazard standpoint. In addition to the risks from tripping alone; expose reinforcing bar tips can pose severe impalement threats. Workers should be thoroughly briefed during daily safety meetings on the importance of housekeeping during this stage of construction and how to best reduce the risks from tripping and impaling on reinforcing bar.

2.3.6.3 **Crane Work**

Cranes bring about concern from the inherent risks of lifting heavy loads. Concerns caused by cranes can be minimized through regular inspection of equipment and lifting apparatus. Following some fundamental safety rules regarding cranes can further reduce risk.

Crushing

The greatest risk to workers when a crane is operating onsite is a crushing injury. In order to avoid this injury a few steps should be taken:

- Cranes must not lift objects over the heads of workers
- Crane apparatus and lifting slings must be thoroughly inspected before use
- Only trained operators and riggers should be used
- Ensure capacity of crane and slings is not at risk of being exceeded

Overhead Utilities

Overhead utilities are a major concern for cranes. There are no overhead power lines immediately adjacent to the site but nevertheless the crane operator should make thorough checks before raising any booms.

3.0 ECONOMIC ANALYSIS

3.1 Initial Costs

CivGen has contracted out the supply, delivery and installation of the stormwater retention tank to StormTrap on a fixed cost contract. Civgen will be responsible for site preparation and remediation.

3.1.1 Stormwater Retention Tank

StormTrap has been awarded the contract to supply the modular retention tank. The contract includes the supply, delivery and installation of the tank at a cost of $2,135,842. StormTrap has provided a detailed price quote, which is available upon request.

3.1.2 Site preparation and remediation costs

CivGen will be responsible for preparing the site for the retention tank. The scope of the work includes excavations, hauls for temporary soil stockpiling, concrete slab installation and backfilling. The total initial project costs are outlined below in

Table 3. Excluding the retention tank, all values were obtained using RSMeans cost estimator adjusted to Vancouver, British Columbia in 2014. See Appendix C for a more detailed breakdown of each item.

Table 3: Initial Project Cost Breakdown

Item	Description	Quantity	Unit	Total O&P
1	Excavation	12700	Bm3	$ 33,274.00
2	Excavator Mobilization	1	Ea.	$ 281.32
3	Haul	14000	Lm3	$ 57,820.00
4	Fine Grading	1700	m2	$ 3,910.00
5	Backfill	7000	Lm3	$ 19,250.00
6	Concrete Forming	168	m	$ 1,582.56
7	Reinforcing Steel	3.81	Met. Ton	$ 10,137.31
8	Concrete	170	m3	$ 37,369.40
9	Concrete Placing	170	m3	$ 5,842.90
10	Retention Tank	1	Ea.	$ 2,135,842.00
		Total		**$ 2,305,309.49**

3.2 Yearly Savings, Maintenance and Inflation Considerations

Once the total costs of the project were established as shown in Table 3 above, the yearly savings made by eliminating the purchase of potable water from the city and the yearly maintenance costs were calculated to be $13,645 and $2500 respectively. The yearly maintenance costs were simply estimated by StormTrap, while the potable water savings were calculated with the current price of potable water in Vancouver and the average yearly water demand from the garden. Also, there was found to be an upward trend in the price of potable water at a rate of about 7% increase per year (Metro Vancouver). This annual increase was taken into account, creating a larger yearly savings each year. Meanwhile the yearly maintenance costs remain the same on an annual basis. With some simple economic formulas, the present worth of the annual costs and savings were determined and the total present worth of the project was established to be $2,043,284 as shown in below.

Table 4: Project Cost Breakdown

Project Cost Breakdown	
Capital Costs	
Earthworks Costs	$81,715
Concrete Slab Costs	$58,842
Retention Tank Costs	$2,135,842
Total:	$2,305,310
Annual Savings & Costs	
Water Savings	$13,645
Maintenance Costs	$2,500
Project PW	**$2,043,284**

3.3 Project Value

The implementation of the stormwater retention system is highly beneficial to the UBCBG and the University as a whole. By reducing the consumption of potable water, the garden is able to save $13,645 per year, and help to establish the university's goal in becoming the greenest university in North America. This project also offers many non-monetary benefits that may be overlooked. For example, the new system can alleviate cliff erosion problems at the stormwater outfalls by the means of reducing the peak flow during intense storm periods. The management of the stormwater retention tank can be used as a teaching and learning tool for UBC students and surrounding communities. Students could continue to work on the retention tank on later capstone design projects. Some sample projects could include: designing efficient intake valves, or writing optimization programs to control the amount of water stored in the tank.

4.0 OUTSOURCED DESIGN

With a contract to provide a detailed design for a stormwater retention tank at UBC Botanical Garden CivGen moved forward with detailed design of the tank in the three engineering disciplines discussed in Section 2 of this report.

CivGen recognizes that the detailed water resources, structural and project engineering components of the project do not cover all the design components required to construct a functional stormwater retention system. Further engineering work is needed to conduct a detailed design of the following components:

- Tank inlet/bypass valve
- Geotechnical characterization
- Design of pump and distribution system

With experience in all three of the above areas CivGen will conduct these additional detailed designs if more time is provided. Due to our involvement with the project thus far CivGen has the detailed information and understanding required to move forward with detailed design of the above components upon the owner’s request.

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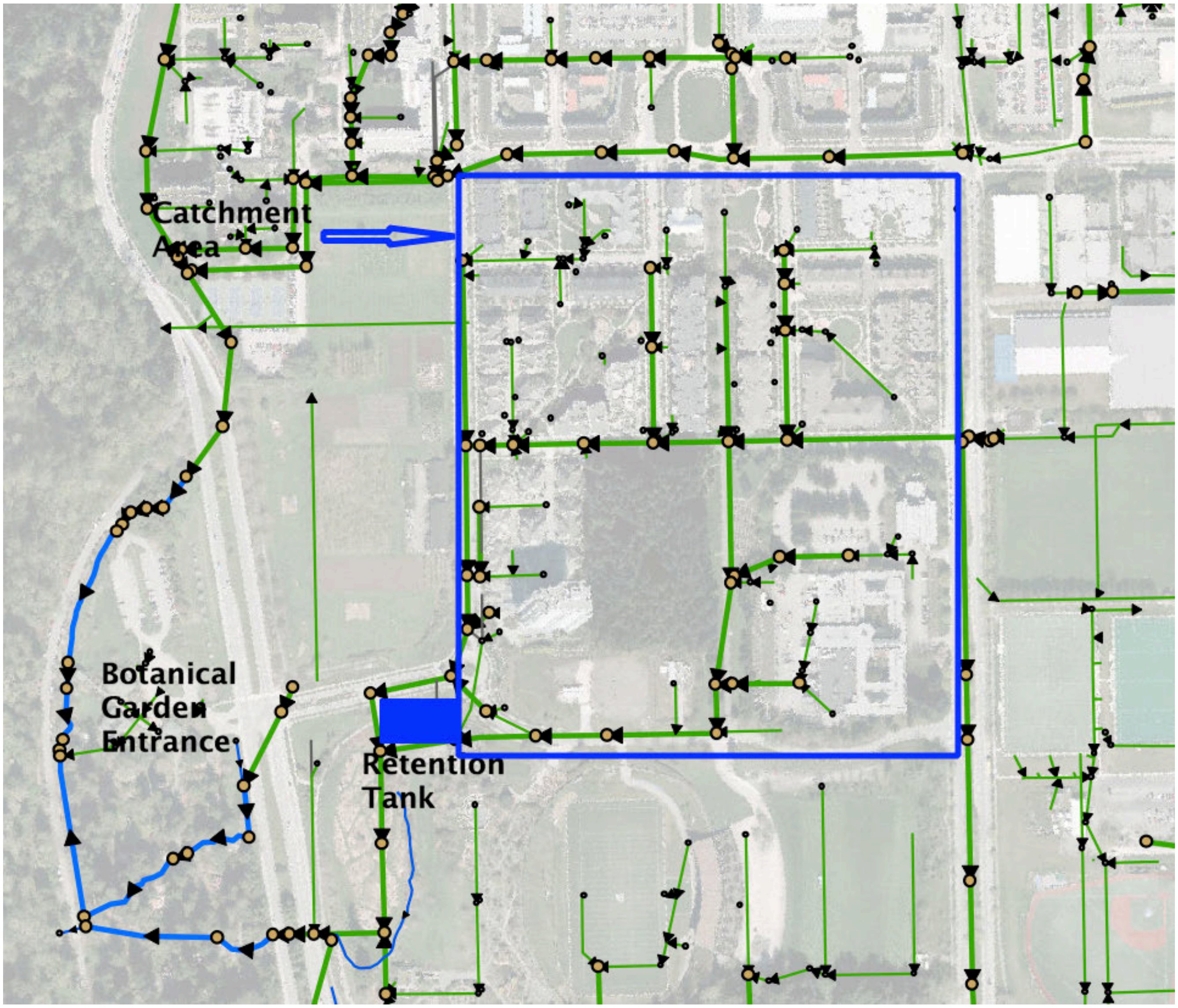
APPENDIX A - Water Resources Design Tools/Calculations

Stormwater drainage layout at UBC with catchment area feeding into UBC Botanical Garden highlighted (GeoAdvice Engineering). Used for rational method calculations. Additional resources including GIS features on Google Earth and VanMaps were used.



Calculations to create unit hydrograph using SCS Method. Calculations were carried out in Excel.

SCS Triangular Unit Hydrograph							
A=	0.055985	mi2	Qp=	484*A/Tr=	6.1	cfs	0.17 m3/s
D=	2	hrs	Tr=	D/2+tp=	4.5	hrs	
				(L^.8(S+1)^ .7)/(1900Y^			
L=	2549.213	ft	tp=	.5)=	3.5	hrs	
CN=	83	Residential 1/4ac lots	B=	1.67*Tr=	7.5	hrs	
S=	2.048193						
y=	3%						

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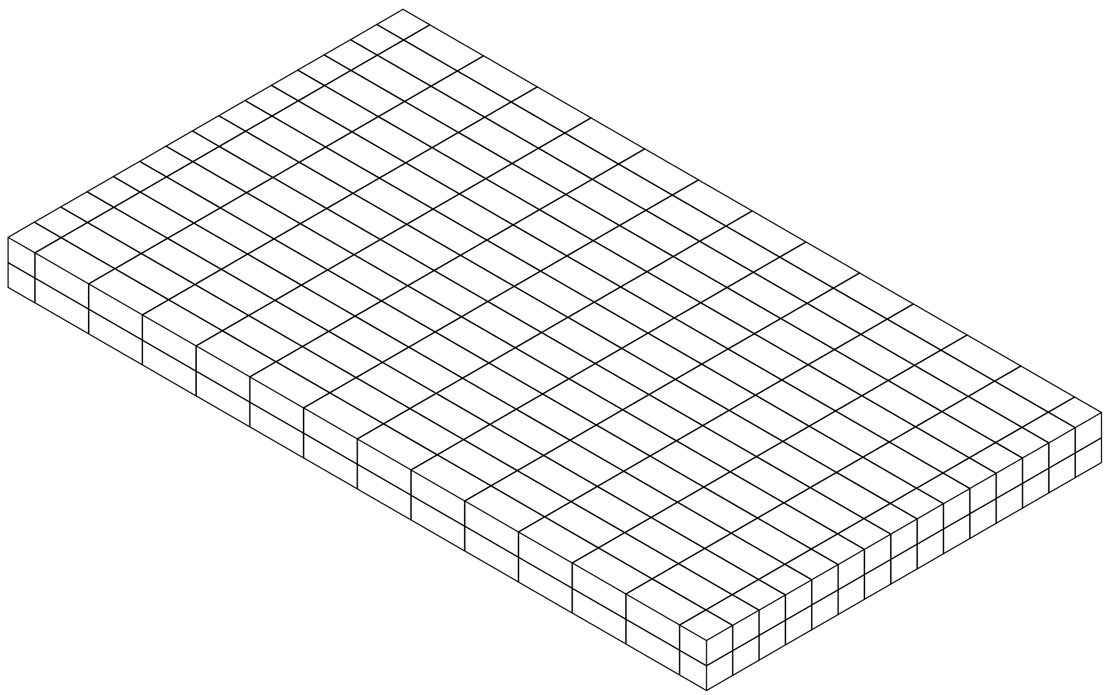
PRECAST CONCRETE MODULAR STORM WATER MANAGEMENT SYSTEMS



UBC BOTANICAL GARDENS STORMWATER CAPTURE

VANCOUVER, BC

SHEET INDEX

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1	COVER SHEET	1
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2.3	STORM LINER INSTALLATION SPECIFICATIONS	1
3	LAYOUT DETAIL	1
4	STANDARD - 3048 MM DOUBLETRAP TYPE I	1
5	STANDARD - 3048 MM DOUBLETRAP TYPE II	1
6	STANDARD - 3048 MM DOUBLETRAP TYPE III	1
7	STANDARD - 3048 MM DOUBLETRAP TYPE IV	1
8	STANDARD - 3048 MM DOUBLETRAP TYPE V	1
9	STANDARD - 3048 MM DOUBLETRAP TYPE VI	1
10	STANDARD - 3048 MM DOUBLETRAP TYPE VII	1

JOB SITE INFORMATION

DESCRIPTION	
JOB NAME:	UBC BOTANICAL GARDENS STORMWATER CAPTURE
JOB ADDRESS:	VANCOUVER, BC
ENGINEERING CO:	UNIV OF BRITISH COLUMBIA
CONTACT NAME:	RANDY CHASE
CONTACT PHONE:	604-353-7651
CONTACT FAX:	
STORM TRAP SUPPLIER:	STORMTRAP
CONTACT NAME:	MATT KAMENICK
CONTACT PHONE:	815-258-1261
CONTACT FAX:	815-416-1100
WATER STORAGE REQ'D:	4,900.00 CUBIC METER
WATER STORAGE PROV:	4,944.00 CUBIC METER
UNIT HEADROOM:	3048 MM DOUBLETRAP
UNIT QUANTITY:	210 UNITS - 420 TOTAL PIECES

STORMTRAP®

2495 WEST BUNGALOW RD
MORRIS IL 60450
P: 815-941-4663
F: 815-416-1100

ENGINEER INFORMATION:

UNIV OF BRITISH COLUMBIA

2329 W MALL
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Phone: 604-353-7651
Fax:

PROJECT INFORMATION:

UBC BOTANICAL GARDENS STORMWATER CAPTURE

VANCOUVER, BC

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CURRENT ISSUE DATE: 18-MAR-2014

APPROVED BY:

ISSUED FOR: PRELIMINARY

REV.:	DATE:	DESC.	BY:
1	18-MAR-2014	ISSUED FOR PRELIMINARY	AC

SCALE: NTS

SHEET TITLE: COVER SHEET

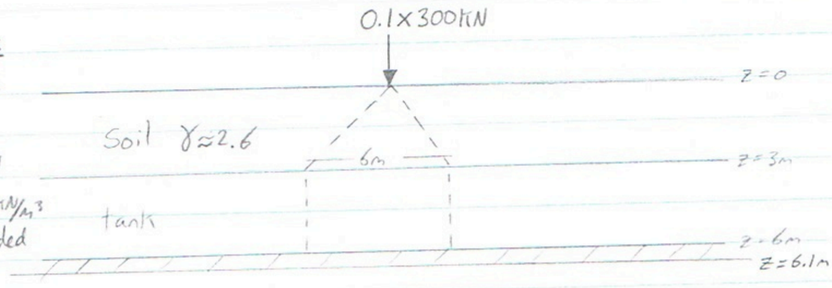
SHEET NUMBER: 01

APPENDIX B – Structural Engineering Drawings/Calculations

Colby Redekop
March 21, 2014

Reinforced concrete slab Calculations

Assumptions
$f'_c = 25$ Mpa
$\gamma_{soil} = 2.6$
Truck load = 300 kN
RC density = 24 kN/m³
* Tank specs provided by Stormtrap.



Loads

Point Load $= (0.1 \times 300kN) \div 6m = \underline{5\,kPa}$

Soil $= 2.6 \times 1000\,kg/m^3 = 2600\,N/m^3 \times 3m = \underline{7.8\,kPa}$

Tank = average module weight = 6000 kg, average size = 2m × 2m

$= 6000kg \div 2^2 m^2 \times 9.81 \times \frac{1}{1000} = \underline{15\,kPa}$

Water $= 1000\,N/m^3 \times 3m = \underline{3\,kPa}$

Slab $= 24\,kN/m^3 \times 0.1m = \underline{2.4\,kPa}$

Load on soil assuming full tank and 100mm slab:

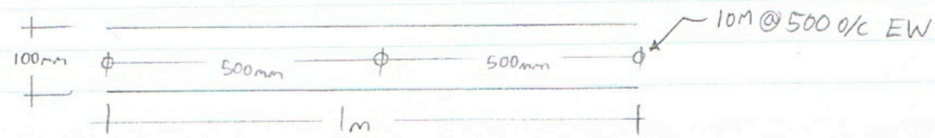
$\Rightarrow 5\,kPa + 7.8\,kPa + 15\,kPa + 3\,kPa + 2.4\,kPa = 33.2\,kPa$

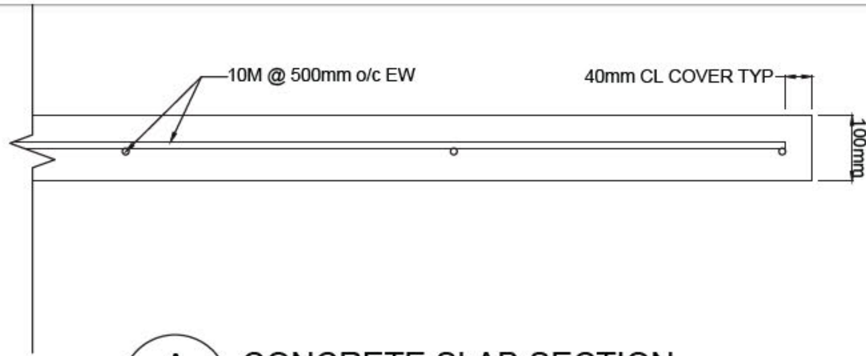
Factor of safety $= 1.5 \times 33.2\,kPa \approx \underline{50\,kPa}$

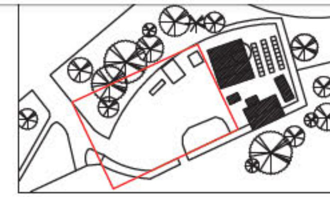
Reinforcement

- Because notes (civl 430) are for 1 way simply supported slab and we have slab on grade, assume tension reinforcing spacing limit of 3h to be neglected and use shrinkage reinforcement limits of 5h or 500mm.

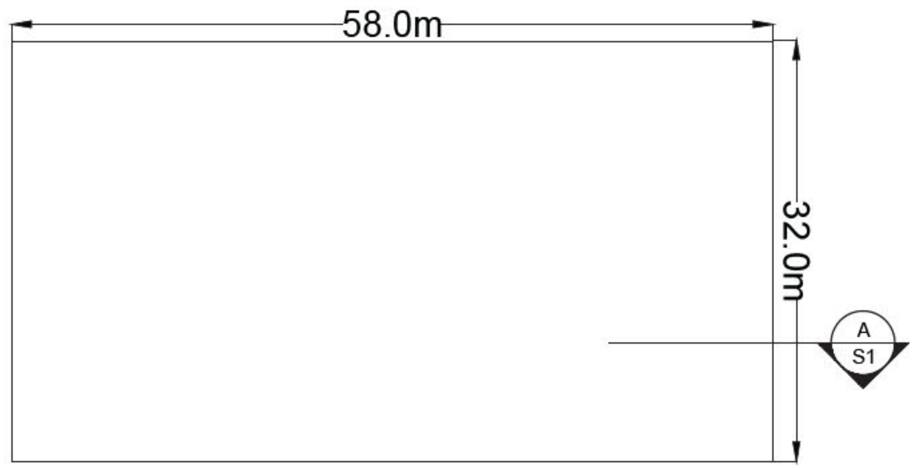
- Since $h = 100mm \Rightarrow$ max spacing = 500mm each way
- $A_s > A_{smin} = 2h\,mm^2/m$ width $= A_{smin} = 200\,mm^2/m \Rightarrow$ use 2 – 10M







A
S1
CONCRETE SLAB SECTION
ELEVATION VIEW - SCALE 1:10



-
S1
CONCRETE SLAB
ELEVATION VIEW - SCALE 1:100

REVISIONS	
SCALE	AS SHOWN
DESIGNED BY	CR
CHECKED BY	WX
DATE	APR 2, 2014
DRAWN BY	WX
PROJECT	UBCBG CONCRETE SLAB DESIGN
	S1

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APPENDIX C - Project Engineering Tools/Calculations

Quantity	LineNumber	Description	Crew	Daily Output	Duration	Labour Hours	Unit	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P	Ext. Total O&P
12700	312316420300	Excavating, bulk bank measure, 2.3 m3 capacity = 199 m3/hr, backhoe, hydraulic, crawler mounted, excluding truck loading	B12D	1590	7.987421	0.01	Bm3	$ -	$ 9,144.00	$ 24,130.00	$ 33,274.00
1	015436500020	Mobilization or demobilization, dozer, loader, backhoe or excavator, 52 kW to 112 kW, up to 80 km	B34N	4	0.25	2	Ea.	$ -	$ 104.54	$ 176.78	$ 281.32
14000	312323200014	Cycle hauling(wait, load, travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic meters, 10 min wait/load/unload, 6.12 m3 truck, 24 kph, cycle 0.8 km, excludes loading equipment	B34A	245	57.14286	0.03	Lm3	$ -	$ 28,280.00	$ 29,540.00	$ 57,820.00
1700	312216101100	Fine grading, fine grade for slab on grade, machine	B11L	870	1.954023	0.02	m2	$ -	$ 2,210.00	$ 1,700.00	$ 3,910.00
7000	312323131300	Backfill, bulk, up to 90 m haul, dozer backfilling, excludes compaction	B10B	918	7.625272	0.01	Lm3	$ -	$ 6,720.00	$ 12,530.00	$ 19,250.00
168	031113651400	C.I.P. concrete forms, bulkhead for slab on grade w/ keyway, 114 mm high, exp metal, includes erecting, bracing, stripping and cleaning	C1	366	0.459016	0.09	m	$ 660.24	$ 922.32	$ -	$ 1,582.56
3.81	032111600600	Reinforcing steel, in place, slab on grade, #10 to #22, A615M, grade 400, incl labor for accessories, excl material for accessories	4 Rodm	2.09	1.822967	15.34	Met. Ton	$ 6,324.14	$ 3,813.16	$ -	$ 10,137.31
170	033113350150	Structural concrete, ready mix, heavyweight, 21 mPa, includes local aggregate, sand, Portland cement (Type I) and water, delivered, excludes all addi ives and treatments		0	#DIV/0!	0	m3	$37,369.40	$ -	$ -	$ 37,369.40
170	033113704300	Structural concrete, placing, slab on grade, direct chute, up to 150 mm thick, includes leveling (strike off) & consolidation, excludes material	C6	84.11	2.021163	0.57	m3	$ -	$ 5,678.00	$ 164.90	$ 5,842.90
Total								**$44,353.78**	**$ 56,872.02**	**$ 68,241.68**	**$ 169,467.49**