South Campus Stormwater Detention Facility

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University of British Columbia

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CIVL 446 PROJECT II:
UBC SOUTH CAMPUS STORMWATER DETENTION FACILITY

Client: University of British Columbia - UBC SEEDS (Social Ecological Economic Development Studies) Sustainability Program

Source: Pennsylvania Environmental Council <www.stormwaterpa.org>

Presented to you by:

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Executive Summary

The South Campus of UBC faces considerable risks in the case of extreme stormwater events from 10-year and 100-year floods. The project objectives are to minimize the flood water damage and erosion to the cliffs by designing a stormwater detention system to store the floods that may occur in the South Campus of UBC. The major concerns include significant damage to important buildings in the area and erosion of the cliffs on the opposite side of SW Marine Dr. The most viable solution is to build stormwater detention facilities to store the floodwater and release it at a rate that will reduce erosion to acceptable levels. Increasing the size of certain pipes and culverts may be necessary to handle the extra water flow.

This report details chosen designs that are the most effective regarding functionality, construction and maintenance costs, and environmental impacts. Using data and rainfall models obtained through reports by GeoAdvice and Urban Systems, areas with the largest flood volumes are focused on for the most efficient location of the detention facilities.

A single location will host a multi use dry pond facility with two other locations hosting cylindrical fiberglass tanks. The intersection of Wesbrook Mall and SW Marine Dr will accommodate a large dry pond facility with a 3000 m^3 capacity, and cylindrical fiberglass tanks will be installed at Wesbrook and 16th Ave and TRIUMF Centre with 1135 m^3 and 210 m^3 capacities respectively. These designs accomplish the technical requirements of the project effectively, and these are cost effective, environmentally sustainable and in line with UBC sustainability goals. The multipurpose dry pond facility

engages the community and invites community ownership with its design, which encourages the facilities use outside of storm events.

After detailed analysis of the different components of the project, the total cost is $3’619,054. The duration of this project is estimated to be 161 days, starting notifications at the beginning of March, and finishing construction by the start of September 2016.

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1. Introduction

Stormwater detention systems for UBC South Campus will reduce if not eliminate the risks caused by an extreme rainwater event. These risks include damage to important buildings on campus, wildlife in streams, and cause cliff erosion putting UBC assets and interests in danger. Unlike UBC South Campus, other areas of UBC have had more recent construction and have incorporated stormwater detention facilities into their structures and designs. Therefore, stormwater detention systems are needed in UBC South Campus to mitigate the hazards of 10-year and 100-year flood events.

This report examines regulatory, technical, structural, environmental and social constraints, as well as an overview of the design criteria on which the project is based on. A thorough evaluation of the key components and technical considerations of the three detention facilities is outlined in this report. An estimate of the project plan and its cost, with a detailed breakdown of activities and dates is provided. Finally, risk assessment focusing on environmental impacts as well as various recommendations to improve the overall performance of this project is provided by Excellence Inc. Additional information and detailed value tables can be found in the Appendix section of this report.

Table 1 - Summary Table of Team Member Contributions to Final Design Report

Name	Contributions to Final Design
Kieran Bertsch	Underground Fiberglass Storage Tank - West 16th ave & Wesbrook Mall • Available space and feasible location analysis. • Decided on number of tanks to hold required flood volume • Excavation volume calculations, key components and technical considerations Project Plan • Construction requirements • Pipe upgrade recommendations Overall review of report • Check for spelling and grammar
Mauricio Cattani	Underground Fiberglass Storage Tank - TRIUMF • Available space and feasible location analysis. • Decided on number of tanks and dimensions to hold required flood volume. • Excavation volume calculations, key components and technical considerations. Overall review of report • Spelling and grammar check. • Edit and format of final report.
Payam Mazloum	Underground Fiberglass Storage Tank - TRIUMF • 3D modelling, drafting schematics with detailed dimensions Underground Fiberglass Storage Tank - Wesbrook & 16th • 3D modelling, drafting schematics with detailed dimensions Overall review of report • Spelling and grammar check. Overall Scheduling of all three projects in Microsoft Project
Juan Sebastian Perez	Dry Detention Pond Multipurpose Facility • Available Space and feasible location analysis • Design schematics and 3D Design in Sketchup • Development of conceptual solutions (Drainage and Multipurpose Facility) • Construction and Technical Requirements Project Design Overview
Peyman Safaei	Project Overview • Identified the objective of the design • Description of the project site • List of the constraints and issues with the project Site visit to W. 16th Ave + Wesbrook Mall, photos and measurements Risk Assessment of surface stormwater pollution Editing and review of the report
Renpeng (Bill) Xing	Project Life Cycle Cost Estimate • Pre-construction cost estimate: permitting, legal, EA, Public Notification, Geotechnical Consulting; • Construction cost estimate for all three facilities; • Facility maintenance and operating cost estimate. Geotechnical Recommendations Fiberglass Tank Research: • Researching about the most suitable underground tanks for our project and then found Containment Solution Flowtite underground fiberglass tanks; • Researching for other useful information about the tank such as installation manual, schematic drawing;

2. Project Overview

UBC South Campus area is prone to a moderate 10-year rainfall event to a more severe 100-year flooding event leading to significant stormwater runoff causing damage to important campus facilities and buildings; eroding steep cliffs; and negatively affecting the ecosystem and its aquatic and land inhabitants. Excellence Inc. team, having used data and analysis of past geological surveys and studies, have outlined our objectives as listed in the following section.

2.1 Project Objectives

The objectives of this stormwater management project are as follows:

- Detain and control the release rate of a 10-year and 100-year stormwater flood event affecting UBC South Campus and neighbouring lands
- Ensure the safety of students, staff and community residents
- Protect UBC infrastructure assets, academic, commercial/residential buildings, and facilities from stormwater runoff
- Prevent further erosion of the Pacific Spirit Park steep cliffs along Southwest Marine Drive sloping towards mouth of Fraser River
- Minimize disruption to the natural ecosystem used by the land and aquatic organisms
- Ensure that stormwater is treated as a resource for reuse to augment non-potable water demands
- Work within UBC boundaries to effectively manage stormwater

- Provide a multi-purpose public amenity facility to be used and enjoyed by the community for sport activities and community events

2.2 Project Site

The three locations in UBC South Campus that will be affected by construction are shown in Figure 1:

Figure 1 - UBC South Campus, Stormwater Detention Facility Locations
Source: © Mauricio Cattani, Google Maps 2016

<u>Multi-Purpose Dry Pond Detention Facility</u>

The Multi-Purpose Stormwater Dry Pond Detention Facility project will be located on an existing field adjacent to the parking lot of CCM (Centre for Comparative Medicine) facility at the intersection of Southwest Marine Drive and Wesbrook Mall. The stormwater collected is conveyed through the pipes and into the ditches along SW

Marine Drive to Booming Ground Creek where it is ultimately discharged into the Fraser River. The following figure shows the proposed location for this detention facility:

Figure 2 - Multipurpose Stormwater Dry Pond Detention Facility Location
Source: © Mauricio Cattani, Google Maps 2016

Cylindrical Fiberglass Tanks - Wesbrook Mall and West 16th Ave

Six 50,000 Gallon Cylindrical Fiberglass Tanks will be installed underground 50 meters to the North-East of the roundabout in Wesbrook Mall and West 16th Ave. intersection. The stormwater collected flows along 16th Avenue to the Botanical Garden Creek that discharge into Museum Creek. The following figure shows the location of the Wesbrook Mall and West 16th Ave. tanks.

Figure 3 - Fiberglass Storage Tank at Wesbrook Mall & W. 16th Ave Location
Source: © Mauricio Cattani, Google Maps 2016

Cylindrical Fiberglass Tanks - TRIUMF

Two 30,000 Gallon Cylindrical Fiberglass Tanks will be installed underground below the TRIUMF vehicle parking lot located at 4004 Wesbrook Mall. The following figure shows the proposed location for these tanks:

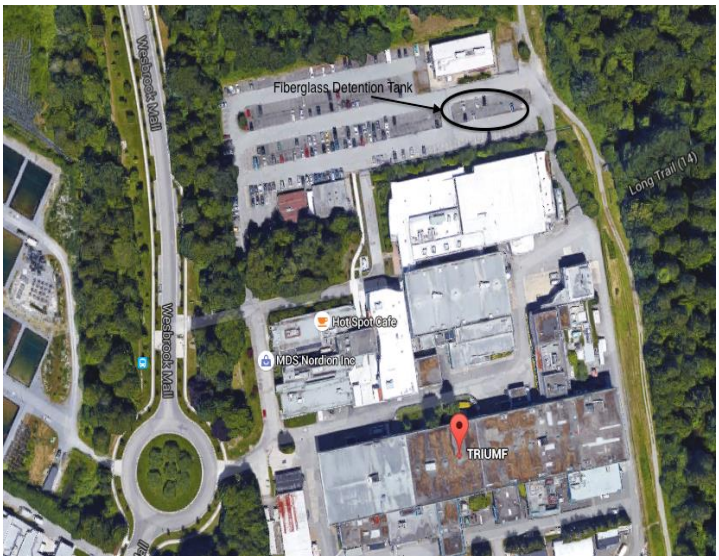

Figure 4 - Fiberglass Storage Tank at TRIUMF Parking Lot Location
Source: © Mauricio Cattani, Google Maps 2016

2.3 Constraints and Issues

It is of great importance to identify all possible constraints and issues for the construction of the UBC South Campus stormwater detention system, as they will affect the features of our design. The key issues and constraints that have been taken into account are divided into four major categories: regulatory, noise and traffic interruption, technical, and environmental. A detailed analysis of each constraint is provided in the following sections.

2.3.1 Regulatory

The regulatory constraints identified for this project relate to different laws and regulations of different governing bodies for stormwater management as well as property boundaries. In terms of stormwater management, it has been identified that the governing bodies are the Federal and Provincial Government. Under the Federal Government, different acts such as the Fisheries Act and the Canadian Environmental Management Act will regulate how stormwater is managed and disposed. Under the Provincial Government, the Water Act and Environmental Management Act are the regulations that govern how stormwater is dealt with. For instance, detention tanks handling runoff from the streets should attempt to incorporate a primary treatment system to filtrate contaminants before discharging to larger bodies of water.

Another regulatory constraint refers to property boundaries. In this case, Metro Vancouver and the Ministry of Transportation and Infrastructure (MoTI) are the governing bodies. Measures to mitigate flooding that require work done in Metro Vancouver or MoTI land demand the attainment of legal leases and access

agreements. Obtaining these may require time and could potentially delay the project. This presents a challenge since discharge from campus must pass through the land of other jurisdictions before being disposed to larger bodies of water.

2.3.2 Noise and Traffic Interruption

Excessive noise and traffic disruption were some of the issues voiced and discussed during the public consultation meeting held in March. Many residents in the area and motorists travelling to UBC via south campus routes were concerned about the impact of construction on road use and access. Although, we will be taking all the necessary steps to minimize traffic interruptions, the reduced speed limit during construction will increase trip travel time to the benefit of improved safety for the road users and our work crew.

Steps taken to remediate excessive traffic congestion and interruption are as follows:

- One lane of traffic in each direction will always be open to traffic
- Use of a certified traffic control flag person to safely direct vehicle traffic and pedestrians
- Use of prefabricated fiberglass tanks for quick delivery and short installation time
- Limit of only two heavy commercial vehicles such as concrete trucks and semi-trailers parked at the waiting lane
- Simultaneous and overlapping schedule will greatly reduce construction time

However, it must be stressed that construction will be occurring at three various location and traffic interruptions may vary from day to day and location to location depending on construction activity of the day.

Construction noise should only be evident during working hours of Monday to Friday from 7am to 5pm and occasionally on Saturdays. There will not be any construction activity on Sundays and holidays and in the evening.

All noise and traffic interruption notices will be posted on various online websites and updated regularly as work commences towards completion. There will be large information billboards posted at and near the project locations and smaller placards will be installed along the corridors affected to inform road users and direct them to detours if necessary.

2.3.3 Technical

The technical constraints that are of importance to this project put the focus on future UBC development plans as well as the geotechnical, hydrological and structural performance of different component of the design. Under the UBC Vancouver Campus Plan, it has been identified that significant development is planned to occur in UBC South Campus. UBC's future development plans are highly concentrated in South Campus, it is expected that 60% of all campus-wide development plans will take place in this area. The consequence of such development plans is the increase in total impervious areas of South Campus ranging from 75% to 95% of the total area. This translates to an increase in peak flow rates due to the increase in excess runoff surfaces.

Geotechnical, hydrological and structural constraints are also of great concern. The geology and hydrology of the area where detention facilities are to be constructed should be fully examined and analyzed. The construction of large detention pond above surface or tanks underground can lead to large soil settlements leading to soil failure if the subsurface profile is not examined. Tanks should be chosen such that allowable serviceability states are achieved, and structurally adequate to sustain their own weight and potential external loads.

Technical aspects such as the existing pipes and culverts present various issues for UBC South Campus. Existing undersized pipes along Wesbrook Mall, which discharge to SW Marine Drive, as well as the undersized pipes along West 16th Ave. are the main cause for over-flooding. In addition to this, undersized culverts along SW Marine Drive contribute significantly to flooding in this area. Pipes and culverts are operated and owned by MoTI; hence rebuilding these elements is not a feasible option. However, retention tanks were designed to release accumulated water at a rate that the culverts and pipes can hold. Research by UBC's Integrated Stormwater Management Plan suggests that the release rate should be around 1.2 cubic meters per second for the pipes and culverts to operate at their maximum capacity without overflowing.

2.3.4 Environmental

Environmental constraints and issues focus on the existing policies regarding sustainable practices as well as the effects of water infiltration into subsoil. The UBC 20 Year Sustainability Strategy focuses on the improvement of the quality of life and enhancement of ecological integrity by incorporating campus water and wastewater systems. Similarly, under Policy #39, the Vancouver Campus Plan and the Board of

Governors require a natural system approach for stormwater management if possible. Given these policies and strategic goals, any mitigation approach considered should be a sustainable solution.

Lush vegetation and old growth trees surround UBC South Campus and many have be logged in the past to accommodate important academic buildings and facilities and overwhelming demand for residential multi-unit dwellings. Excellence Inc. has implemented a plan with the goal to save as many trees as possible and to replace the fallen trees with young regrowth. Some trees may have to be cut for the safety of the public using the multi-purpose dry pond facility for community and sport events. Special care will be taken to navigate the construction equipment and vehicles as far away from sensitive flora, streams and habitats important to the land and aquatic ecosystem of the area.

A final consideration is the fact that the climate is changing. This presents an environmental issue since models show an increase in annual rainfall, therefore 10-year storms will become more frequent. It is important to keep this in mind since any mitigation approach should not only accommodate current conditions but also be able to accommodate future climate changing conditions.

3. Design Criteria

The explicit goals that a project must achieve in order to be successful are designated as the design criteria. For the stormwater detention system the main design considerations are the design life and loads.

3.1 Design Life

The dry pond facility is expected to have a life expectancy of 60 years with minor maintenance every year and major maintenance every 20 years. The minor maintenance includes ensuring the perimeter drain is clear of debris and organic materials including inlet and outlet pipes. Major maintenance includes possible resurfacing of interior area of dry pond facility to ensure proper filtration and adequate facility quality. Maintenance and cost specifics are discussed further in section 7.3.

The cylindrical fibreglass tanks have a prescribed life expectancy of 30 years depending on level of use and liquid stored according to the specifications provided by Containment Solutions. However due to the very infrequent use and the facility storage of water only we expect the lifespan of the tanks to reach the same life expectancy of the dry pond facility of about 60 years. These tanks will require minimal maintenance duration depending on the frequency of storm events.

3.2 Design Loads

The dry pond at full capacity will be designed to hold about 3000 cubic meters of water at a maximum depth of about 1.5 meters. This equates to 15 KPa of pressure on

the surface of the facility. It is expected that the soil present on site with adequate compaction will be fully capable of handling such a load with an adequate factor of safety.

The cylindrical fiberglass tanks are installed as per Containment Solutions installation guidelines which schematic sketches and drawings are shown in Section 5 of this report.

4. Multipurpose Dry Pond Detention Facility

The most critical area to treat stormwater runoff on UBC South Campus is found to be at the intersection of Southwest Marine Drive and Wesbrook Mall. This design consists of a multipurpose dry detention pond, which can hold up to 3000 m^3 of stormwater. The following figure shows a model of the dry pond design.

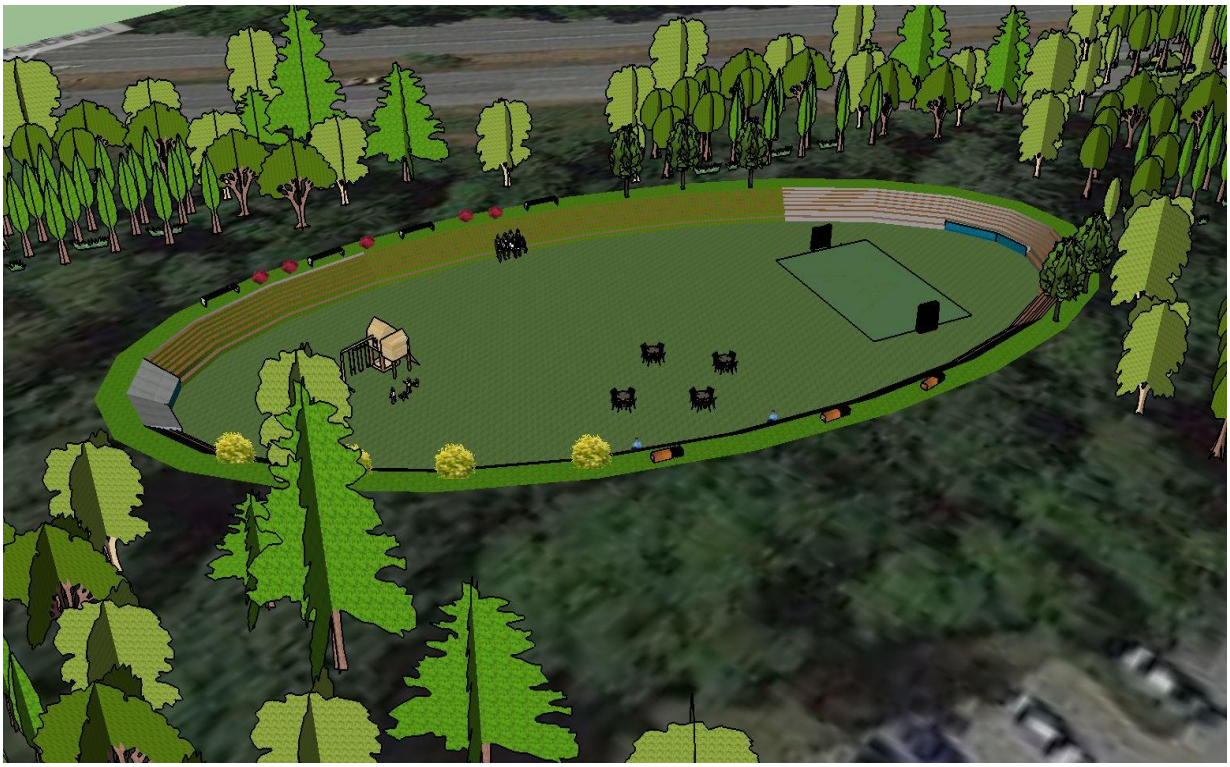

Figure 5 - Multi-purpose Dry Detention Pond Overview
Source: © Juan Sebastian Perez, Sketchup 2015

4.1 Overview

Dry detention ponds/basins temporarily detain and store collected stormwater runoff for a short period of time, hence releasing the stormwater slowly to reduce peak stormwater discharge, control the flood and prevent downstream creek and cliff erosion. Furthermore the detention pond also provides an interactive space for UBC's

community by enhancing its use with a multipurpose approach. An example of a possible use of the dry pond is shown below in Figure 6.

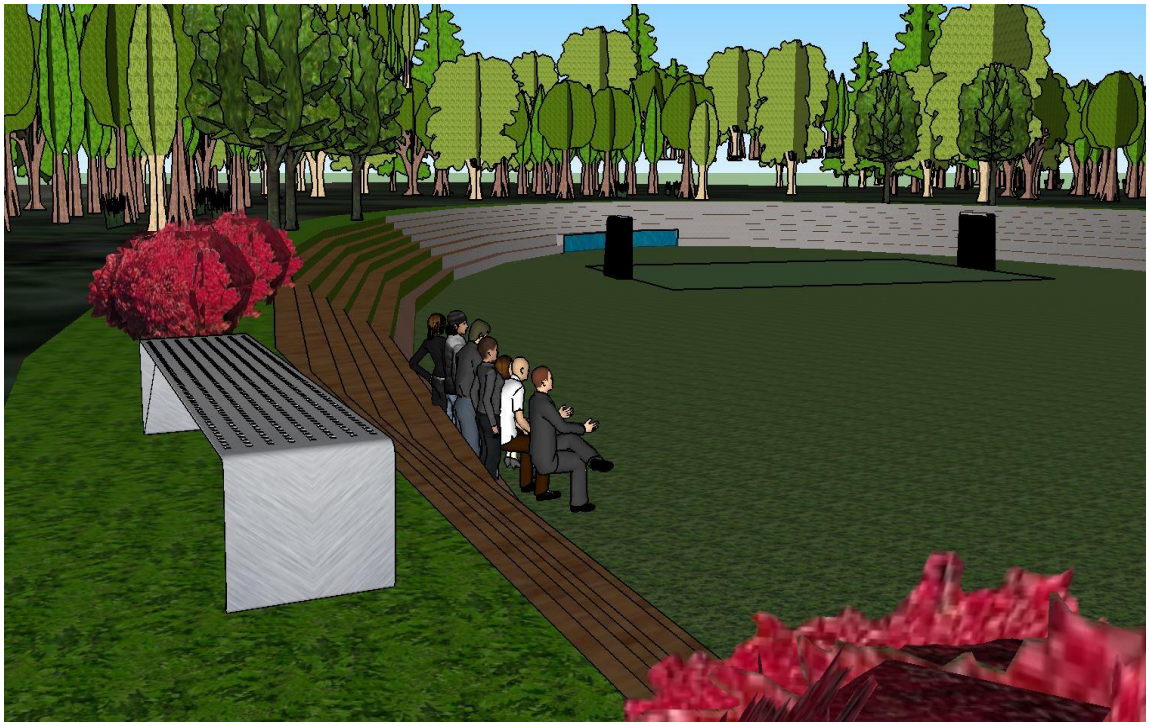

Figure 6 - Dry Detention Pond Interactive Spaces
Source: © Juan Sebastian Perez, Sketchup 2015

4.2 Key Components of Design

In order to contain the required 3000 m^3 of stormwater, the pond will have a longitudinal length of 50m, a width of 40m and a depth of 1.5m. The pond filtration system will encompass a tile drainage trench which will be connected directly to water distribution pipes which will fill the trench during floods while also draining the water at a suitable rate, if the trench fills up then the pond will start to fill up. The following figure illustrates the drainage system of the dry detention pond:

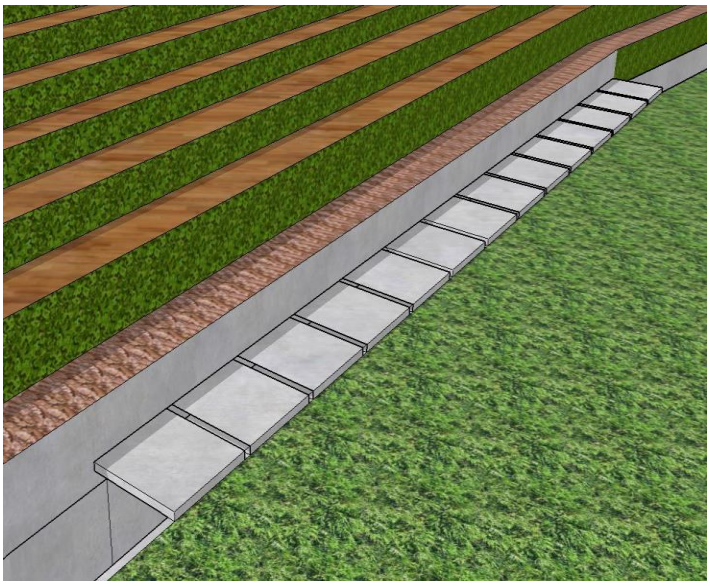

Figure 7 - Trench Drainage
Source: © Payam Mazloum, Sketchup 2015

The design specifies a multilayer filtering system. This system has the advantage of draining water to the drainage trench while also filtering the water and providing a growing medium for gardening or lawn. The multilayer filtering system will be located at the floor of the pond. A similar example of a filtering system is shown in Figure 8.

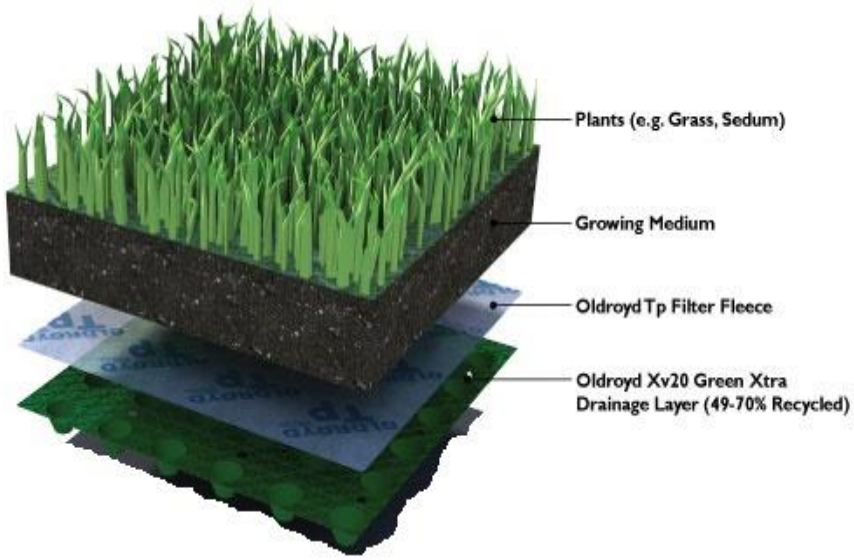

Figure 8 - Multilayer Growing and Filtering System
Source: Intercongreen

Moreover the pond will have a variety of spaces for people to do different activities such as sports, events or gardening. The following figure illustrates a possible recreation activity that can be implemented to this multipurpose detention facility.

Figure 9 - Multipurpose Dry Detention Pond Recreation Activities
Source: © Payam Mazloum, Sketchup 2015

4.3 Technical Considerations

Construction for the dry pond does not require highly trained workers or difficult technical considerations. Nevertheless, it is important to note the following construction considerations:

- Excavation needs to be enough for pond space
- The soil below needs to have enough compaction

- Slopes on the sides of the pond have to be gentle (4:1, Horizontal: Vertical)
- Multilayer filtering system needs some technical expertise in the installation
- The pond will have approximately 15 kPa of maximum load which needs to be supported by soil and sediments.

The pond also requires a specified maintenance and monitoring schedule in order to maintain its 50 years life expectancy at maximum efficiency. Maintenance must address filtering and drainage systems issues constantly.

5. Underground Fiberglass Storage Tanks

The remainder of the stormwater from a 100-year flood will be stored in underground fiberglass storage tanks located in key locations on the South Campus of UBC. The following section outlines the key components and technical considerations for each design.

5.1 Overview

The fiberglass storage tanks are provided by Containment Solutions. There will be two locations for the fiberglass storage tanks. Since the requirements at each location vary, the sizes of the tanks will be different. The tanks located near the intersection of West 16th Ave. and Wesbrook Mall will have a diameter of 12', and the tanks located at the TRIUMF parking lot will have 10' diameter.

5.2 West 16th Ave & Wesbrook Mall

The second largest volume of stormwater detention tanks will be located on the North side of the intersection along W. 16th Ave. According to GeoAdvice's technical report, the flood volume predicted in this area is 1000 m^3. The area is currently a grassy hill so no trees will have to be removed for the excavation for the tanks.

5.2.1 Key Components

In order to contain the required 1000 m^3 of stormwater, six cylindrical fiberglass tanks with a diameter of 12' and volume of 50,000 Gallons each (189 m^3) are installed.

This equates to a total capacity of 1135 m^3. They will be arranged in three rows of two tanks as shown in Figure 10. The excavation area will be 87m x 25m.

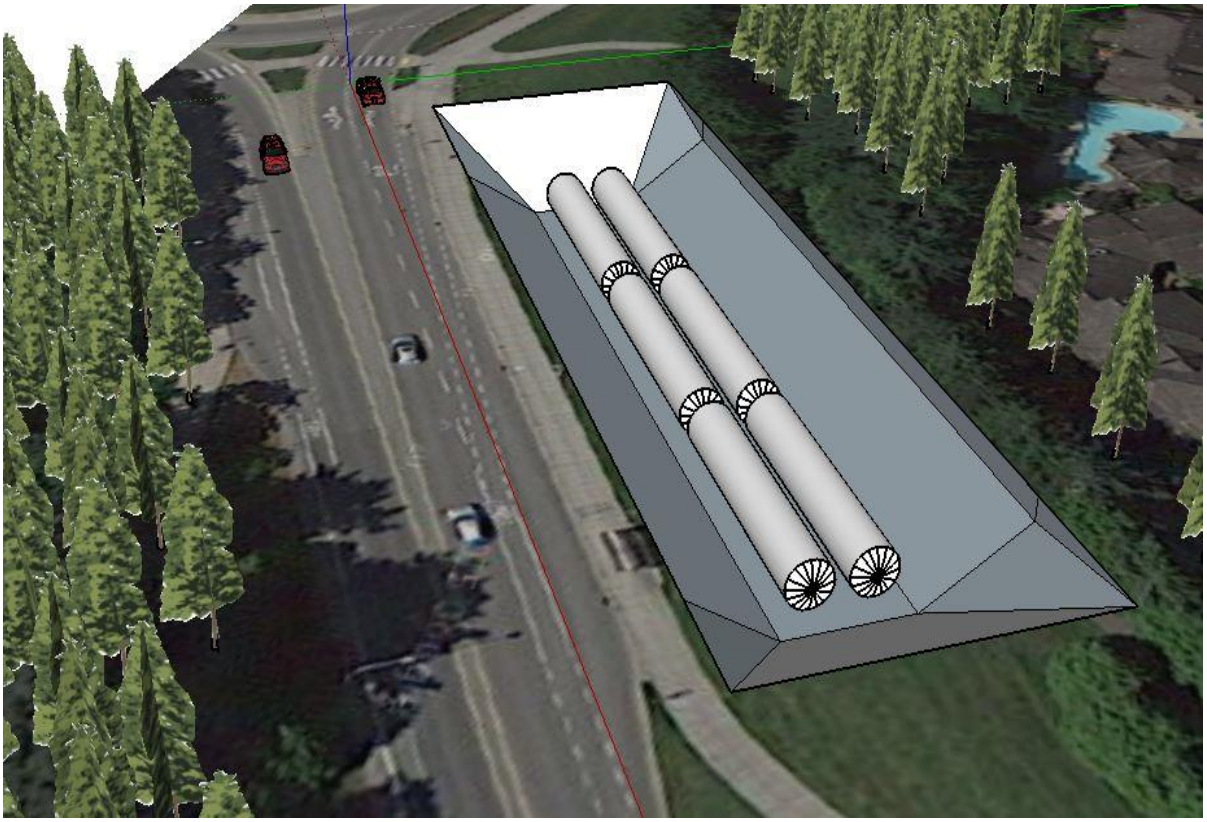

Figure 10 - Overview of Cylindrical Fiberglass Tanks
Source: © Payam Mazloum, Sketchup 2016, Google Maps 2016

5.2.2 Technical Considerations

By following the installations guidelines provided by the manufacturers, Containment Solutions, the tanks will have 0.75m of backfill below and 1.2m above. The tanks will have a 0.75m distance between them. Since the tanks are 3.66m in diameter, this yields an overall excavation depth of 5.61m. A safe slope of 1:2 will be used on all sides of the excavation pit. The excavation area required for this depth would include part of the road, so traffic would need to be detoured for the construction. In order to

avoid rerouting and disrupting traffic on W 16th Ave, shoring of 1.75m will be used as shown in Figure 11 below.

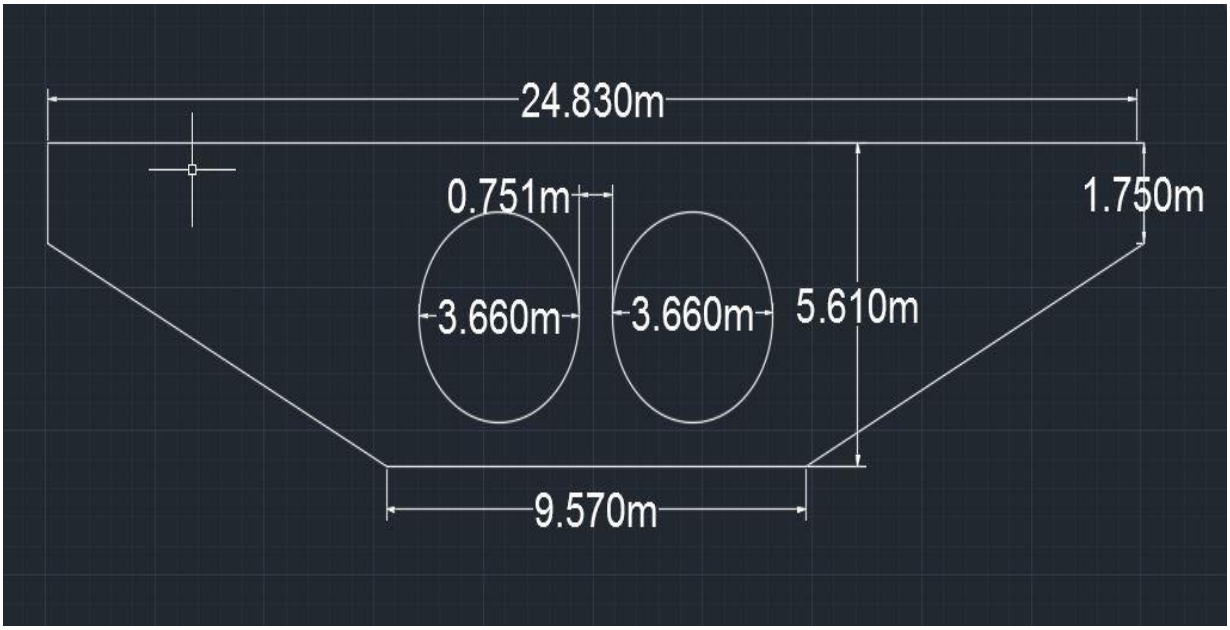

Figure 11 - Side View of Excavation Area with Shoring and Dimensions
Source: © Payam Mazloum, AutoCad 2016

By installing the shoring, the excavation volume necessary has decreased by approximately 500 m^3 compared to without the shoring. Using the measurements in Figure 11 above and including the reduction in volume, the excavation volume is estimated at 8700 m^3.

5.3 TRIUMF Parking Lot

Another critical location identified on UBC South Campus was around TRIUMF Centre. According to GeoAdvice, the predicted 100-year flood in this location is 210 m^3. In order to contain such flood volume, 2 tanks 10’ diameter with a 30,000 Gallon capacity each will be used, which yields a total capacity of 60,000 Gallons (227 m^3).

The proposed location for the installation of these tanks is in TRIUMF's parking lot, which is shown in Figure 12 below:

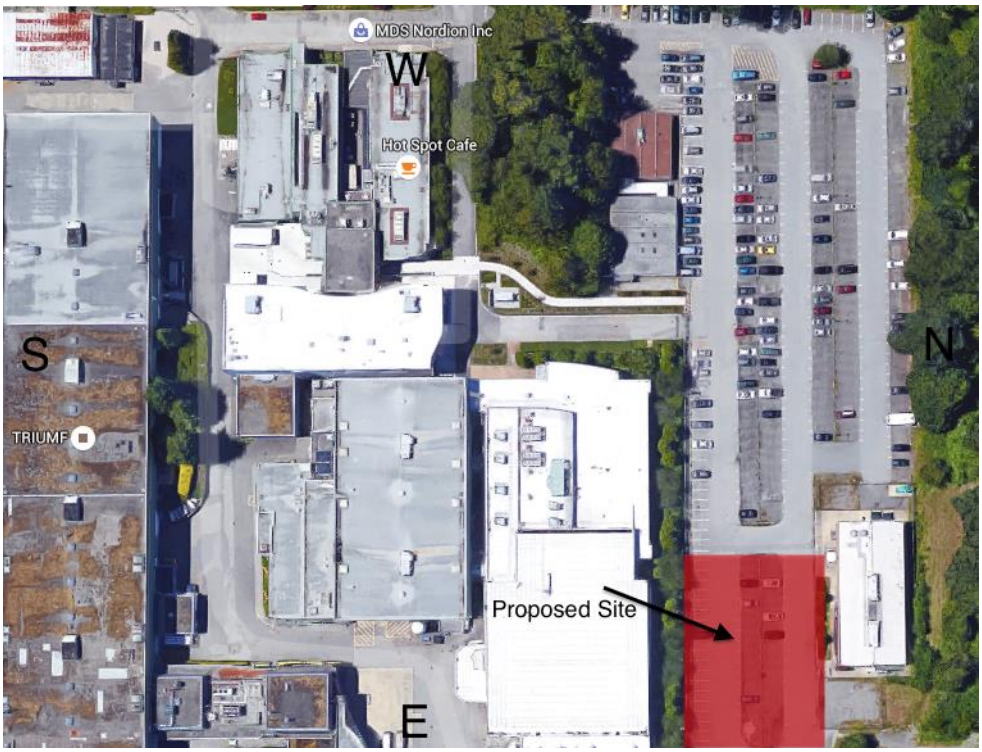

Figure 12 - Proposed Site for TRIUMF tanks
Source: © Mauricio Cattani, Google Maps 2016

5.3.1 Key Components

Two methods of installation have been proposed for this tank. The first method is using shoring, since the excavation depth will require additional support to avoid failure. By using this method, the excavation volume will total 749 m^3, extending over an area of 20m by 10m. The second method considers a slope of 1:2 to maintain excavation safety standards and avoid the use of shoring. This method requires larger excavation volume, which yields a total of 1,680 m^3 extending over an area of 36m by 26m. Both of these

methods are feasible in terms of available space in the proposed site. A plan view of the two methods of installation are shown in the following figures:

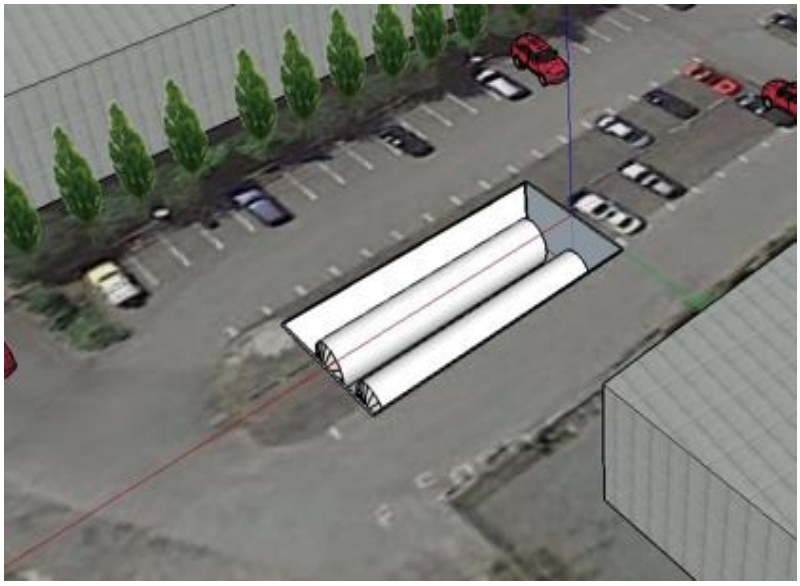

Figure 13 - Underground Fiberglass Storage Tanks (Shoring Method)
Source: © Payam Mazloum, Sketchup 2016, Google Maps 2016

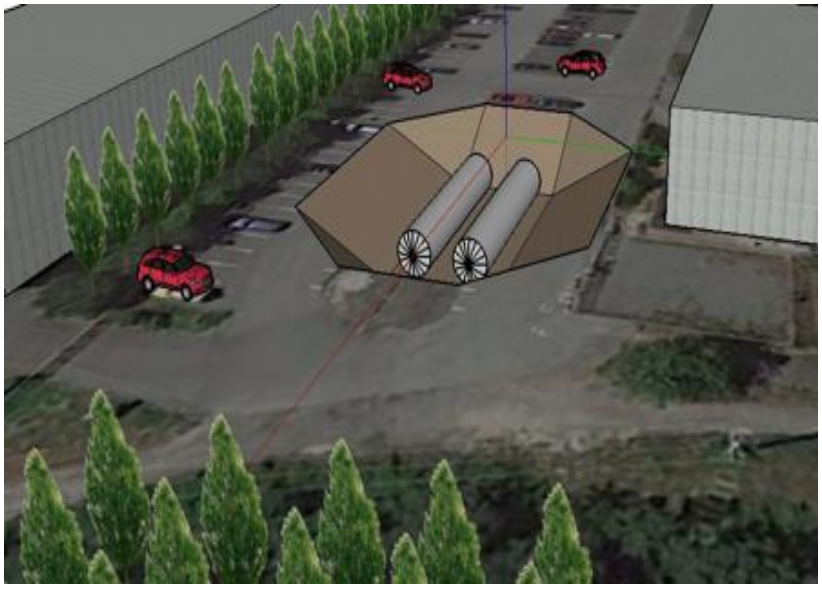

Figure 14 - Underground Fiberglass Storage Tanks (No-Shoring Method)
Source: © Payam Mazloum, Sketchup 2016, Google Maps 2016

5.3.2 Technical Considerations

The manufacturer of these tanks, Containment Solutions, provides installation guidelines that specify the dimensions and distances required to safely maintain the tanks. The required backfill below and above the tanks has to be 0.5m and 0.46m respectively. The distance between tanks has to be 0.48m and the distance required from the tanks to the nearest wall has to be 1.5m. Taking this requirements into account as well as the tank diameter, the excavation depth has to be 4m deep. A summary of the dimension and tank layout is provided in the following figures:

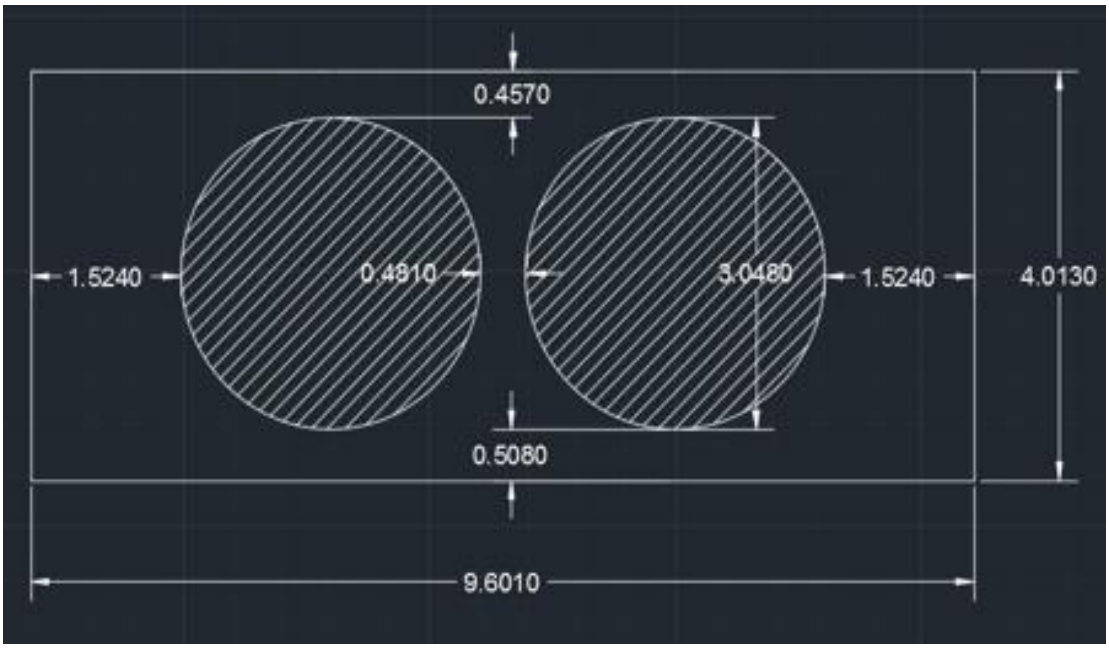

Figure 15 - Side View Storage Tanks
Source: © Payam Mazloum, AutoCad 2016

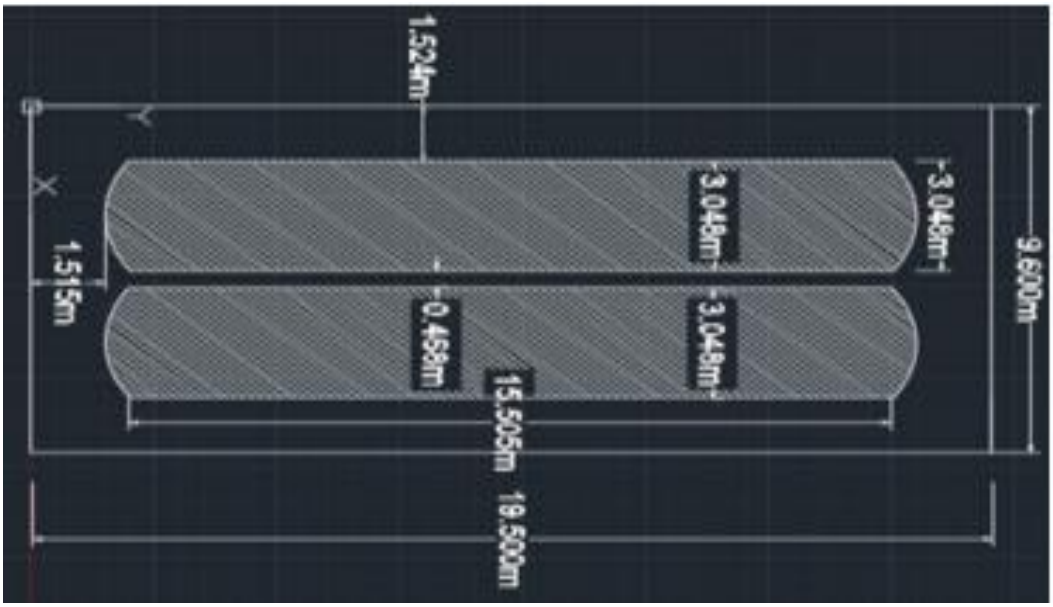

Figure 16 - Plan View Storage Tanks
Source: © Payam Mazloum, AutoCad 2016

It is worth noting that some assumptions were made in order to decide on the dimensions and distances for the above layout to maintain a conservative design. It was assumed that TRIUMF parking lot has considerable traffic, therefore the tanks will be subject to traffic loads. It was also assumed a wet hole excavation, given the rainy conditions in Vancouver area and a possible water table 2m below the surface. It was also assumed unstable excavation, since geotechnical reports indicate gravels, silts and sands are present in the subsurface.

6. Draft Plan

The draft plan for construction of the dry pond and stormwater detention tanks includes the construction schedule, construction requirements and the anticipated issues. The following section outlines the different components of the project schedule.

6.1 Construction Schedule

The dry pond and stormwater detention tanks begin construction after preliminary notices which include public information sessions, permitting and licensing. After approval the construction schedules will commence. One specialized crew will work on the TRIUMF tanks at the same time as the site team for the construction of the Dry Pond. Once the TRIUMF tanks are complete construction will proceed to the W. 16th Ave. & Wesbrook Mall tank. A summary table of construction dates, tasks and durations are shown below in Table 2.

Table 2 - Summary Table of Construction Dates

Task Name	Duration	Start	Finish
Preliminary Notices	33 days	Mon 28-03-16	Wed 11-05-16
Dry pond Construction	61 days	Thu 12-05-16	Thu 04-08-16
TRIUMF Detention Tanks	32 days	Thu 12-05-16	Fri 24-06-16
Wesbrook & 16th Detention Tanks	52 days	Mon 27-06-16	Tue 06-09-16

For a detailed schedule, please see Appendix C, which shows a more in-depth schedule made using Microsoft Project.

6.2 Construction Requirements

In order for the construction of the dry pond and detention tanks to go smoothly, the schedule must be followed in the order presented. As it will hold the majority of the stormwater, the dry pond is the largest and most important part of the design, so it will be constructed first. Excavating for the TRIUMF detention tanks involves blocking off part of the parking lot, so this part of the schedule needs to be completed on-time in order to create the least inconvenience for the people working in the TRIUMF centre.

6.3 Anticipated Issues

Since the soil properties have not been fully tested at the dry pond location, some unexpected conditions may arise that delay the schedule. For the TRIUMF tanks, the underground pipes and cables will need to be mapped out more thoroughly to ensure that the excavation does not interfere with any of the pipes already in place. For the tanks located at W 16 Ave. the main concern is regarding the shoring. The goal is to be able to install the shoring and excavate for the tanks without disrupting traffic, but if installing the shoring needs extra room, some traffic detours may need to be put in place for a short period of time.

7. Cost Estimate

UBC South Campus stormwater management project will include three detention facilities: a multipurpose dry pond and two fully underground fiberglass tank systems. The total project cost estimate consists of two parts: community notification and consultation cost and total construction cost. The construction expenditures play a more important role on affecting the total project cost estimate. In this section, both parts of cost estimate and annual operation and maintenance costs would be discussed in detail.

7.1 Community Notification & Consultation Cost Estimate

This section summarizes the preconstruction phase of the project. Before any construction activities start, the following activities listed in Table 3 must be completed to acquire legal and public/community approval on the project. The design team will carry out all of the aesthetic and structural designs for the dry detention pond facility. However, some foundation consultations from geotechnical experts regarding soil capacity, soil permeability and soil layer types throughout the depth are still needed. Table 3 illustrates the estimated cost for each activity. A spreadsheet with a detailed cost estimate for this section can be found in Appendix D.

Table 3 - Community Notification & Consultation Cost Breakdown

Cost Category	Cost (CAD)
Public Notification	288,000
Geotechnical Consulting	72,000
Environmental Assessment	250,000
Permitting	46,861
Legal	100,000
TOTAL COST	**$756,861**

7.2 Construction Cost Estimate

The total estimated construction cost for all the three facilities is $3,619,054 Canadian dollars (CAD). Table 4 illustrates the breakdown of the cost for each storm water detention facility. The multipurpose dry pond facility contributes the most towards to the total construction cost due to its longer construction period and larger size. It is also the facility that has the most engineering and architectural design involvement, because it is a public accessible facility that has the largest stormwater storage capacity on UBC South Campus. The Wesbrook Mall & W. 16th Ave underground tank facility has similar cost compared to the dry pond facility. The main reason for this is because

this tank facility also needs to store a huge amount of water during flood events and the available space for construction is very limited. In order to store the anticipated flood volume and also minimize the local traffic disturbance, oversized fiberglass tanks are required (50,000 gallon in capacity).

Containment Solution Inc. does not normally carry tanks, which are that large in size, so they have to make a special order from their contracted factory. This increase the procurement costs for tanks dramatically for both tank facilities. Comparing to the Wesbrook Mall & W. 16th Ave tank facility, the TRIUMF tank facility is much cheaper in cost due to its much smaller excavation volume and smaller fiberglass tanks in regular size (30,000 gallons in capacity).

Table 4 - Total Construction Cost Breakdown

Facility	Cost (CAD)
Multipurpose Dry Pond	1,813,826
Wesbrook Mall+16th Ave Fiberglass Tanks	1,331,165
TRIUMF Fiberglass Tanks	474,063
TOTAL COST	**$3,619,054**

The estimated total construction cost for the multipurpose dry pond facility is $1,813,826 CAD. The construction activity breakdown is illustrated in Table 5. The pond is designed to retain 3000 cubic meter of water during 100-year flood event so it is the largest detention facility. This explains why excavation cost and foundation treatment

cost are two of the major costs for the dry pond facility. Underground pipe placement is another major cost to the entire project. According to the pond design, 4000 m of pipes need to be upsized, 5000 m of pipes need to be newly installed and 1000 m of pipes need to diverged. This is the most time consuming part in the entire dry pond construction phase, as well as the most expensive part.

Table 5 - Multipurpose Dry Pond Facility Construction Cost Breakdown

Construction Activity	Cost (CAD)
Tree Removal	72,000
Excavation	210,065
Foundation Work	57,799
Pond Bottom Treatment	270,529
Underground Piping Placement	733,000
Concrete Place	307,290
Site Restoration	24,335
Landscaping	102,430
Others	36,378
TOTAL COST	**$1,813,826**

Table 6 contains the detailed construction activities and their costs for the Wesbrook Mall & W.16th Ave tank facility. The most expensive part of the entire facility construction is procurement. As mentioned earlier, the fiberglass tanks that are utilized in this facility are exceptionally large tanks with 50,000 gallon capacity each. They have to be specially ordered by our tank supply company named Containment Solution Inc. The total cost for this facility is $1,331,165 CAD.

Table 6 - Wesbrook Mall & West 16th Ave. Construction Cost Breakdown

Construction Activity	Cost (CAD)
Procurement	869,080
Excavation	182,064
Foundation Compaction	14,030
Piping	2,600
Backfill	166,243
Site Restoration	76,290
Others	20,858
TOTAL COST	**$1,331,165**

The detailed construction activities for the TRIUMF tanks are illustrated in Table 7. Same kinds of fiberglass tanks are used for this facility. However, the size of each

tank is much smaller, which is only 30,000 gallons in capacity. The main reason for this is that the anticipated 100-year flood volume much less than the location at Wesbrook Mall and 16th Ave. The construction site and working space are located right at TRIUMF parking lot. In order to minimize the parking lot disturbance, temporary shoring is utilized to minimize the construction space occupation and reduce the excavation volume. The total cost for the TRIUMF tank facility comes up to $474,063 CAD.

Table 7 - TRIUMF Tank Facility Construction Cost Breakdown

Construction Activity	Cost (CAD)
Procurement	156,645
Excavation	15,680
Temporary Shoring	2,880
Foundation Compaction	4,370
Shoring Removal	1,440
Piping	1,400
Backfill	8,500
Site Restoration	262,290
Others	20,858
TOTAL COST	**$474,063**

7.3 Annual Operation & Maintenance Cost Estimate

For the dry detention pond, the annual cost of routine maintenance and operation is estimated at 5% of the construction cost, which is $90,100 CAD. However, semi-annual and annual inspections are still needed to minimize maintenance cost or keep maintenance cost from rising as its service time increases. Semi-annual inspections will note the erosion of pond banks and bottom. Annual inspection will cover the inspection on embankment damage, sediment accumulation in the facility and debris accumulation near the water inlets and outlets. Aside of annual standard maintenance, 5 to 7 year maintenance and 25 to 60 year maintenance are also required to ensure the proper functionality of the facility. The design life for minor maintenance of the dry pond facility is 60 years. So after passing the 60-year mark, the annual maintenance cost will increase.

Unlike the multipurpose dry pond facility, neither of the tank facilities are publicly accessible. So both of the tank facilities are considered as lightly used during years with normal precipitations. This will result in a much cheaper annual maintenance costs for both fiberglass tank facilities compare to the maintenance costs for dry pond, which is estimated as $5,000 CAD annually. However, major maintenance is still required every 20 years to ensure the tank integrity.

8. Risk Assessment

The stormwater detention system for UBC South Campus will provide a safe conveyance of large volumes of stormwater aimed to protect the people and property of UBC campus and to maintain the ecological integrity and health of the landscape. Risk Management programs must be implemented to identify, analyze and respond to risks on projects.

8.1 Stormwater Pollution

Stormwater surface runoff, which will eventually flow into the stormwater conveyance pipe systems, may carry variety of materials with potential negative impacts on the water quality. The bulk of UBC's stormwater runoff is from the streets and sidewalks and provides the majority of the contaminants. These include sediments from the wear of the road as well as from the construction sites. Other materials include, excess nutrients, metals, organic contaminants, oxygen demanding materials, oil and grease, and even harmful bacteria and viruses. These materials will pose a negative impact on the survival of the fish and degradation of the aquatic ecosystem.

In order to protect the environment from such pollutants, risk assessment programs such as a water pollution prevention policies and guidelines must be drafted. Proper stormwater quality control procedures regarding operations and activities at UBC must be followed to reduce or remove the pollutant threat. Harmful chemicals should be identified and depositing of any substance, which will negatively affect the aquatic habitat, must be prohibited. The benefits of detention facilities such as the stormwater dry pond and underground storage tanks allow the sediments to sink and settle at the

bottom before the runoff will reach the streams reducing turbidity and improving the water quality. The detention option also allows for a simple installation of a primary treatment for the stormwater runoff in order to minimize the amount of sediments that leave the campus stormwater system.

9. Recommendations

The following section outlines Excellence Inc. recommendations with regards to geological studies, pipe upgrades and community gardening.

9.1 Geological Studies

All of the available borehole information for UBC South Campus is provided by EXP Service Inc. and EBA. A total of 19 boreholes were drilled on the North side of the Ortona Rd along Wesbrook Mall; and a geotechnical report was provided for each borehole. However, none of these boreholes are located near our stormwater detention facilities. This adds some uncertainties to the soil properties on site and makes our foundation design less adequate for the facilities located on the South side of Ortona Rd. Moreover, all of the boreholes were hand pitted and their depths are very shallow, normally between 0.66m and 3.0m. Maximum excavation depth for our detention facilities exceeds 5.0 m. The risk of getting unexpected soil properties is very high once excavation exceeds 3.0m-depth mark and excavation costs may increase if construction team encounters hard layers. No soil strength test data could be found in the geotechnical reports. Accurate soil strength is unknown for UBC South Campus region.

Our recommendation is that boreholes and geotechnical studies must be carried out along the specified sites for the three different detention facilities. Standard penetration tests and cone penetrometer tests should be carried out multiple times to acquire accurate soil strength properties. The risk of increasing cost and delaying project schedule will be mitigated if these geotechnical studies are done properly.

9.2 Pipe Upgrades

The pipes leading into the proposed stormwater detention facilities should be upgraded to be able to handle the extra flow. At the moment, some of the pipes cannot even handle the 10-year flow. The SWMM model needs to be updated to be able to accurately design for a network of larger pipes to accommodate the 100-year stormwater flows to the different detention facilities.

9.3 Community Gardening

The inclusion of a multilayer filtering system and growing medium provides the opportunity for the community to elaborate a garden in which many people can contribute and interact together. It is recommended to have a community garden on the pond as it will contribute in gathering people and having a good environment with the space.

10. Conclusion

Stormwater detention facilities are of great importance to mitigate risks associated with 10-year and 100-year rainfall events. It reduces the risk of property damage, cliff erosion and takes into account general public consideration by reducing flooding and culvert output flows. The selected multi-purpose dry detention pond and installed fiberglass tanks exhibit high levels of sustainability, low effective costs, low maintenance costs, relative flexibility of use and redesign capability.

The intersection of Wesbrook Mall and SW Marine Dr will accommodate the large dry pond facility with a 3000 m^3 capacity, and cylindrical fiberglass tanks installed at Wesbrook Mall and West 16th Ave. and TRIUMF Centre with 1135 m^3 and 210 m^3 capacity respectively. The total cost accumulates to $3,619,054 CAD for all aspects of the construction process, not including maintenance. The duration of this project is estimated to be 161 days, starting notifications at the beginning of March, and finishing construction by the start of September 2016.

These designs accomplish the technical requirements of the project effectively. The multipurpose dry pond facility engages the community and invites community ownership with its design, which encourages the facilities use outside of storm events.

Some recommendations would include an analysis of the current system piping flow and then conducting piping upgrades as necessary. Additionally further community feedback would be beneficial to see what facilities need to be adjusted as well as further consideration of other stormwater systems such as hard surface runoff mitigation through green surfaces.

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Appendix A - Annotated Photos and Drawings

The following photos and annotated drawings are provided as an addition to the report figures. Detailed dimensions and cross-sections will aid with the visualization and understanding of the detention system designs.

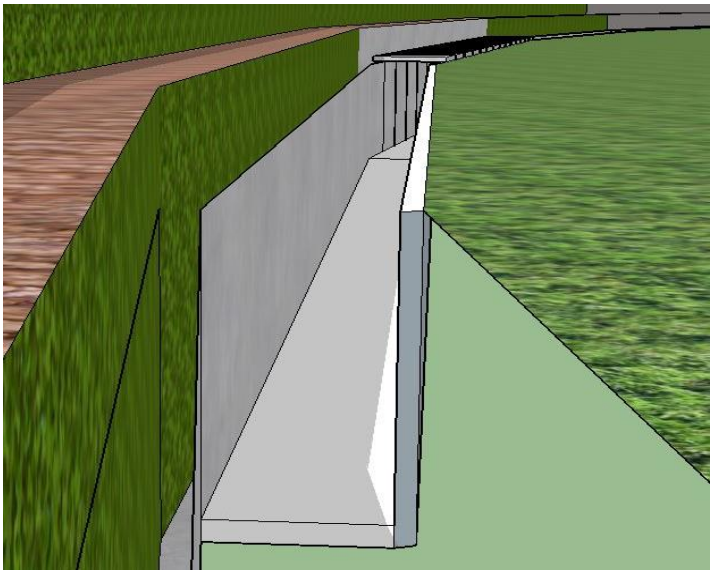


Figure 17 - Drain Trench Side View
Source: © Payam Mazloum, Sketchup 2015

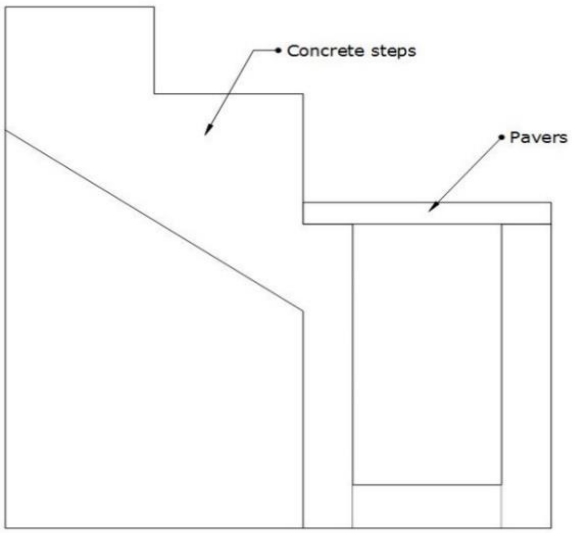


Figure 18 - Drainage Side Schematic View
Source: © Payam Mazloum, Layout 2015

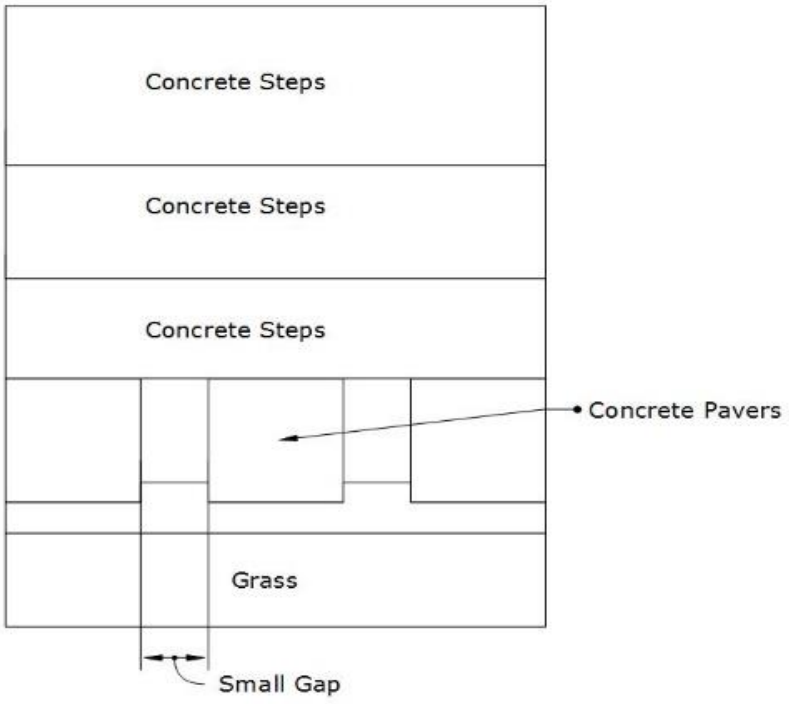


Figure 19 - Drainage Top Schematic View
Source: © Payam Mazloum, Layout 2015

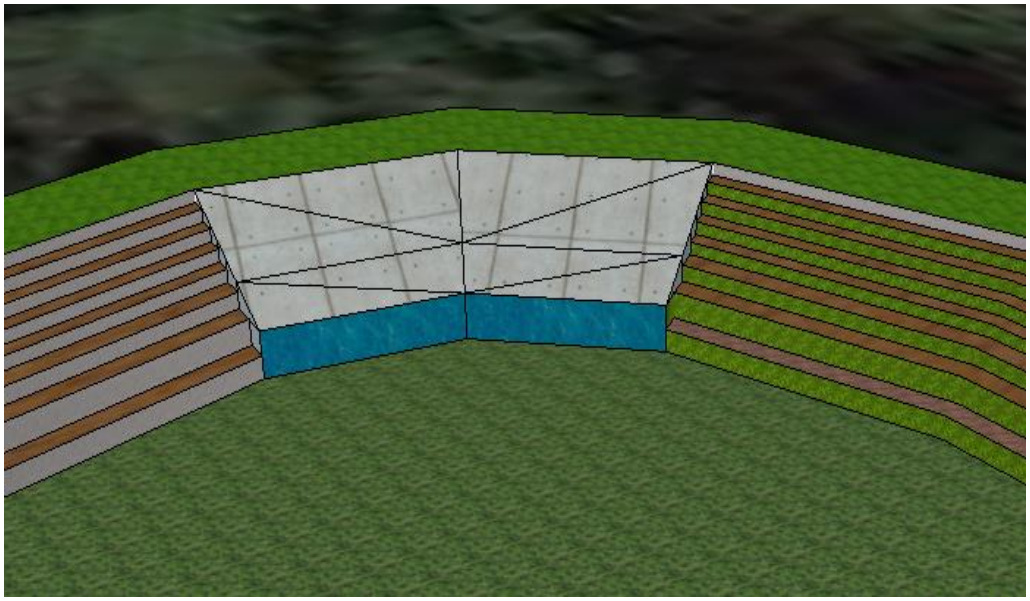


Figure 20 - Inlet Design Front View (Dry Pond Facility)
Source: © Juan Perez, Sketchup 2015

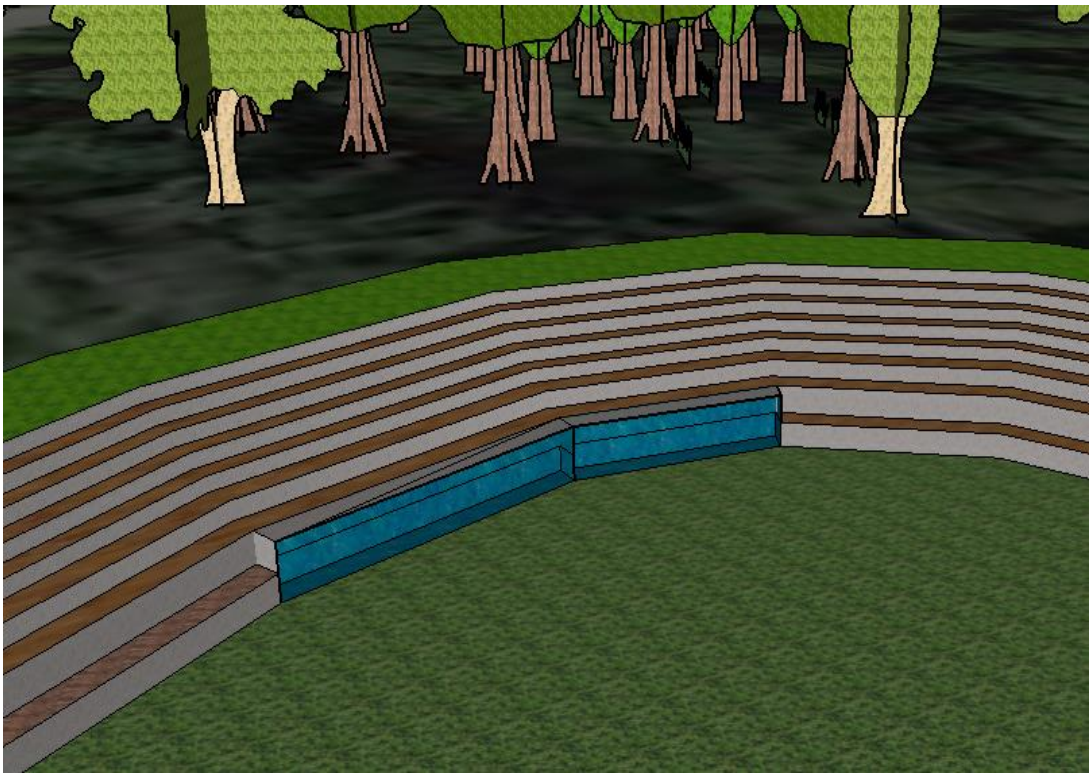


Figure 21 - Outlet Design Lateral View (Dry Pond Facility)
Source: © Juan Perez, Sketchup 2015

The following photos demonstrate the current state of the culvert at Wesbrook Mall and SW Marine Dr. This justifies our recommendation on pipe and culvert upgrades.

Figure 22 - Outflow Culvert at SW Marine DR and Wesbrook Mall

Figure 23 - Culvert Inlet at Wesbrook Mall, 200m North of SW Marine Dr. Interection

Appendix B - Sample Calculations

Cost Estimate Sample Calculations

Multi-purpose Dry Pond

Subgrade Excavation Volume:

- Area of the bottom of the pond:

  A = a*b*pi = (20m)(40m)(pi) = 2513 m^2

- Excavation volume without side slopes:

  V1 = A*h = (2513 m^2)(3.5m) = 8796 m^3

- Side slopes excavation volume (rise : run = 1 : 4):

  Side slope rise: rise = h = 3.5m

  Side slope run: run = 4*h = 14m

  Side slopes excavation: V2 = (run^2*pi*rise)/2 = 1078 m^3

- Total excavation volume:

  V Total = V1 + V2 = 8796 m^3 + 1078 m^3 = 9874 m^3

Trench Excavation Volume:

- Pond bottom perimeter:

  p = pi*{3*(a+b) – [(3*a+b)(a+3*b)]^(0.5)} = 194 m

- Total trench excavation volume:

  V trench = p*w*d = (194m)(.66m)(1m)=130 m^3

  Where “w” is the trench width and “d” is the trench depth.

Concrete Volume for Trenches:

- V conTrench = p*(w+2*d)*t = (194m)[(0.66m)+2*(1m)](0.2m) = 103 m^3

  Where “t” is the concrete thickness.

Number of Concrete Pavers Needed:

- #pavers = p/dp = (194m)/(0.61m) = 320 pavers

Where “dp” is the side length of each paver and pavers that are used for the dry pond are in square shape.

Wesbrook Mall + 16th Ave Tanks (Triumf facility has similar calculations):

Number of tanks needed:

- Single tank storage capacity:

  V 12’ = (50000 gallons)(0.00379 m^3/gallon) = 189.3 m^3

- # 12’ tanks:

  V flood / V 12’ = 959 m^3 / 189.3 m^3 = 5.07 tanks = 6 tanks

  Where “V flood” is the total anticipated storm flood volume at that area.

Foundation Compaction Area:

A bottom = w1*L = (9.57m)(63.74m) = 610 m^2

Where “w1” is the foundation width.

Compacting backfill volume:

V backfill = V exc – [(# 12’) * (V 12’) + V ass] = 9779 $yard^3$

Where the “V exc” is the total excavation volume; “V ass” is the accessories total volume including piping, sumps and so on.

Site restoration area:

A grass = (w2+20m)(L+20m)(10.76 ft^2 / m^2) = (24.83m+20m)(63.74m)(10.76 ft^2/m^2) = 54000 ft^2

TRIUMF Tanks Excavation Volume Calculations

Specification according to Containment Solutions Installation Guidelines:

Tank Diameter, d = 3.048m
Tank Length, L = 16.5m
Backfill above tank, B_1 = 0.457m
Backfill below tank, B_2 = 0.508m
Distance between tanks, D_1 = 0.457m
Distance between tank and excavation wall, D_2 = 1.524m

$$Depth\ of\ excavation, H = d + B_1 + B_2 = 3.048 + 0.457 + 0.508 = 4.013m$$

Excavation volume for shoring method:

$$Length\ of\ excavation, L_1 = L + 2 * D_2 = 16.5 + 2(1.524) = 19.5m$$

$$Width\ of\ excavation, W = 2 * D_2 + 2 * d + D_1 = 2(1.524) + 2(3.048) + 0.457 = 9.6m$$

$$Volume\ of\ excavation, V_1 = L_1 * W * H = 19.5 * 9.6 * 4.013 = 749\ m^3$$

Excavation volume for no-shoring method:

For no-shoring, required slope is 1:2. Since the depth of excavation is 4m, the horizontal projection, L_p should be 8m in length.

$$Area\ of\ slope\ , A_s = \frac{1}{2} * H * L_p = \frac{1}{2} * 4 * 8 = 16\ m^2$$

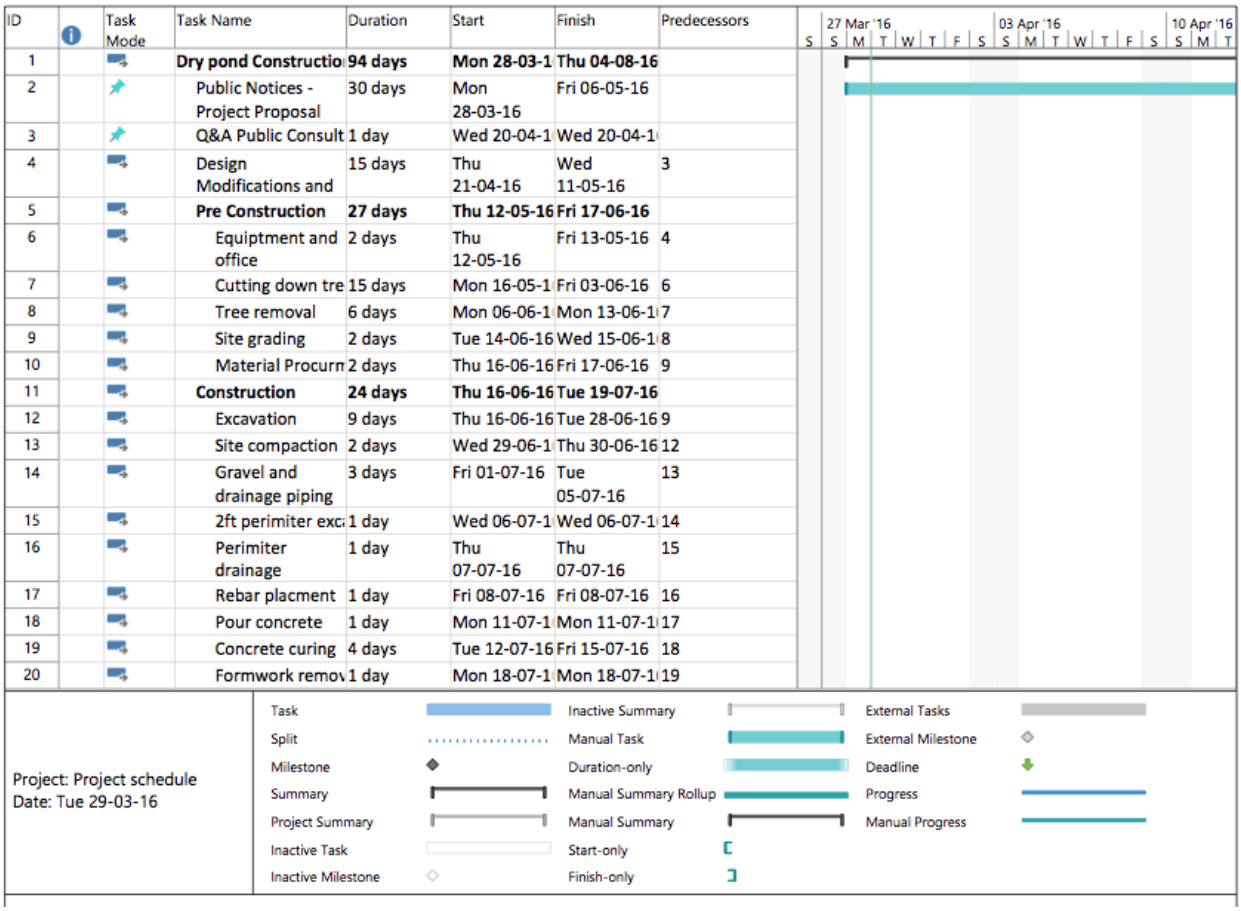
$$Volume\ slope\ A, V_A = A_s * L_1 = 16 * 19.5 = 312\ m^3$$

$$Volume\ slope\ B, V_B = A_s * W = 16 * 9.6 = 153.6\ m^3$$

$$Total\ Volume\ of\ Excavation, V_2 = V_1 + 2 * V_A + 2 * V_B = 749 + 2(312) + 2(153.6) = 1{,}680\ m^3$$

Appendix C - Construction Schedule

The following figures present a detailed review of the construction schedule. It is presented in two formats: as a tabular form with detailed start and end of activities, and in calendar form for an easier understanding of the events.



ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		**Dry pond Constructio**	**94 days**	**Mon 28-03-1**	**Thu 04-08-16**	
2		Public Notices - Project Proposal	30 days	Mon 28-03-16	Fri 06-05-16	
3		Q&A Public Consult	1 day	Wed 20-04-1	Wed 20-04-1	
4		Design Modifications and	15 days	Thu 21-04-16	Wed 11-05-16	3
5		**Pre Construction**	**27 days**	**Thu 12-05-16**	**Fri 17-06-16**	
6		Equiptment and office	2 days	Thu 12-05-16	Fri 13-05-16	4
7		Cutting down tre	15 days	Mon 16-05-1	Fri 03-06-16	6
8		Tree removal	6 days	Mon 06-06-1	Mon 13-06-1	7
9		Site grading	2 days	Tue 14-06-16	Wed 15-06-1	8
10		Material Procurn	2 days	Thu 16-06-16	Fri 17-06-16	9
11		**Construction**	**24 days**	**Thu 16-06-16**	**Tue 19-07-16**	
12		Excavation	9 days	Thu 16-06-16	Tue 28-06-16	9
13		Site compaction	2 days	Wed 29-06-1	Thu 30-06-16	12
14		Gravel and drainage piping	3 days	Fri 01-07-16	Tue 05-07-16	13
15		2ft perimiter exc	1 day	Wed 06-07-1	Wed 06-07-1	14
16		Perimiter drainage	1 day	Thu 07-07-16	Thu 07-07-16	15
17		Rebar placment	1 day	Fri 08-07-16	Fri 08-07-16	16
18		Pour concrete	1 day	Mon 11-07-1	Mon 11-07-1	17
19		Concrete curing	4 days	Tue 12-07-16	Fri 15-07-16	18
20		Formwork remov	1 day	Mon 18-07-1	Mon 18-07-1	19

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
21		Soil backfill	1 day	Tue 19-07-16	Tue 19-07-16	20
22		**Finishes**	**12 days**	**Wed 20-07-1**	**Thu 04-08-16**	
23		Landscaping	5 days	Wed 20-07-1	Tue 26-07-16	21
24		Installation of multipurpose	7 days	Wed 27-07-16	Thu 04-08-16	23
25		**TRIUMF Detention Tanks**	**32 days**	**Thu 12-05-16**	**Fri 24-06-16**	
26		Site mobilization	2 days	Thu 12-05-16	Fri 13-05-16	4
27		Excavation	5 days	Mon 16-05-1	Fri 20-05-16	26
28		Shoring installation	1 day	Mon 23-05-1	Mon 23-05-1	27
29		Formwork placmen	2 days	Tue 24-05-16	Wed 25-05-1	28
30		Rebar placment	2 days	Thu 26-05-16	Fri 27-05-16	29
31		Concrete pour	1 day	Mon 30-05-1	Mon 30-05-1	30
32		Concrete curing	3 days	Tue 31-05-16	Thu 02-06-16	31
33		Formwork removal	1 day	Fri 03-06-16	Fri 03-06-16	32
34		Tank placment	1 day	Mon 06-06-1	Mon 06-06-1	33
35		Piping attachments	1 day	Tue 07-06-16	Tue 07-06-16	34
36		Shoring removal	1 day	Wed 08-06-1	Wed 08-06-1	35
37		Backfill	2 days	Thu 09-06-16	Fri 10-06-16	36
38		Soil compaction	3 days	Mon 13-06-1	Wed 15-06-1	37
39		Rebar placment	2 days	Thu 16-06-16	Fri 17-06-16	38
40		Concrete pour	1 day	Mon 20-06-1	Mon 20-06-1	39
41		Concrete curing	3 days	Tue 21-06-16	Thu 23-06-16	40
42		Site removal and cleanup	1 day	Fri 24-06-16	Fri 24-06-16	41
43		**Wesbrook & 16th Detention Tanks**	**52 days**	**Mon 27-06-16**	**Tue 06-09-16**	
44		Site mobilization	2 days	Mon 27-06-1	Tue 28-06-16	42
45		Excavation	10 days	Wed 29-06-1	Tue 12-07-16	44
46		Shoring installation	2 days	Wed 13-07-1	Thu 14-07-16	45
47		Formwork placmen	3 days	Fri 15-07-16	Tue 19-07-16	46
48		Rebar placment	4 days	Wed 20-07-1	Mon 25-07-1	47
49		Concrete pour	2 days	Tue 26-07-16	Wed 27-07-1	48
50		Concrete curing	4 days	Thu 28-07-16	Tue 02-08-16	49
51		Formwork removal	2 days	Wed 03-08-1	Thu 04-08-16	50
52		Tank placment	2 days	Fri 05-08-16	Mon 08-08-1	51
53		Piping attachments	3 days	Tue 09-08-16	Thu 11-08-16	52
54		Shoring removal	2 days	Fri 12-08-16	Mon 15-08-1	53
55		Backfill	5 days	Tue 16-08-16	Mon 22-08-1	54
56		Soil compaction	8 days	Tue 23-08-16	Thu 01-09-16	55
57		Landscaping	2 days	Fri 02-09-16	Mon 05-09-1	56
58		Site removal and cleanup	1 day	Tue 06-09-16	Tue 06-09-16	57

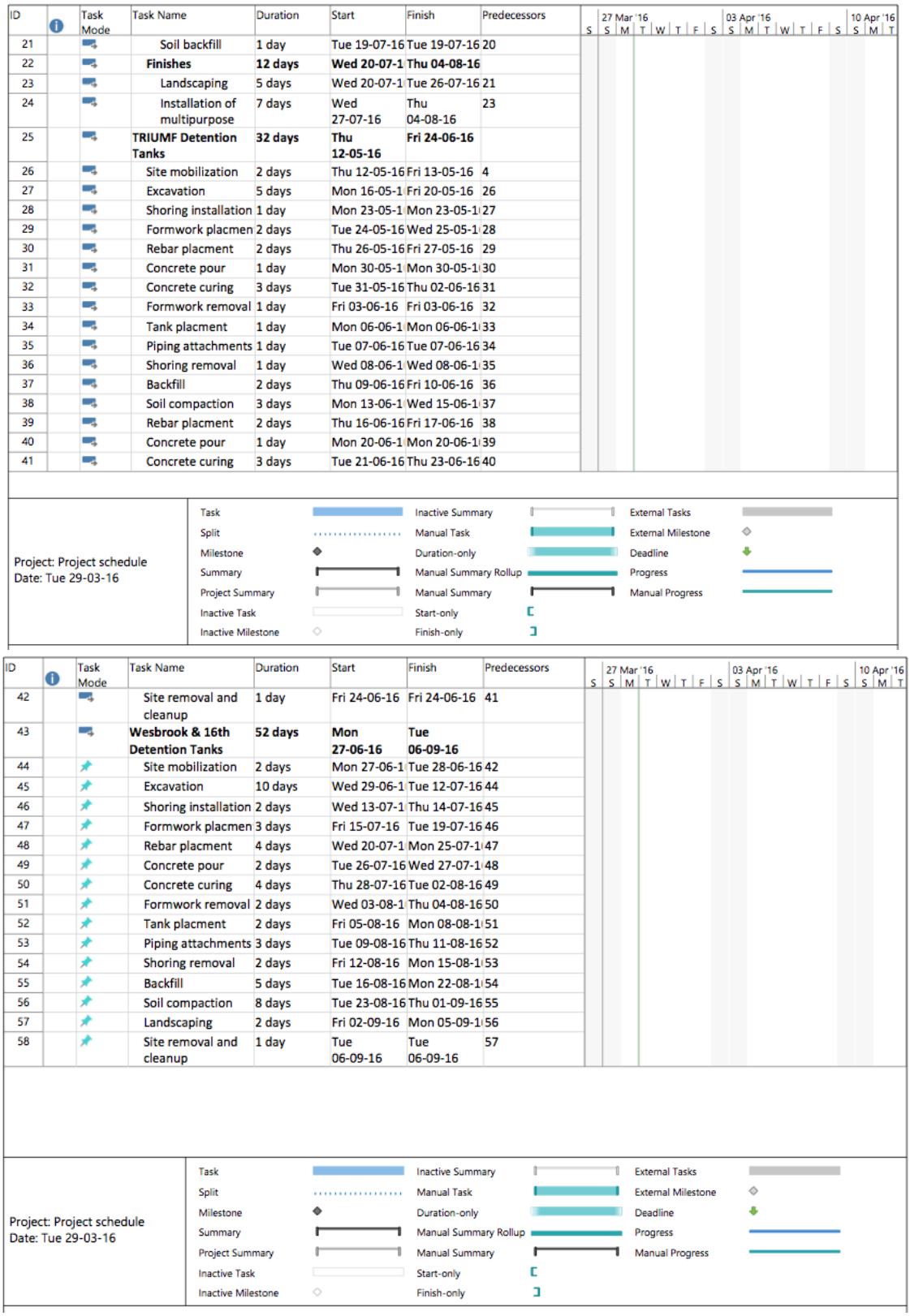
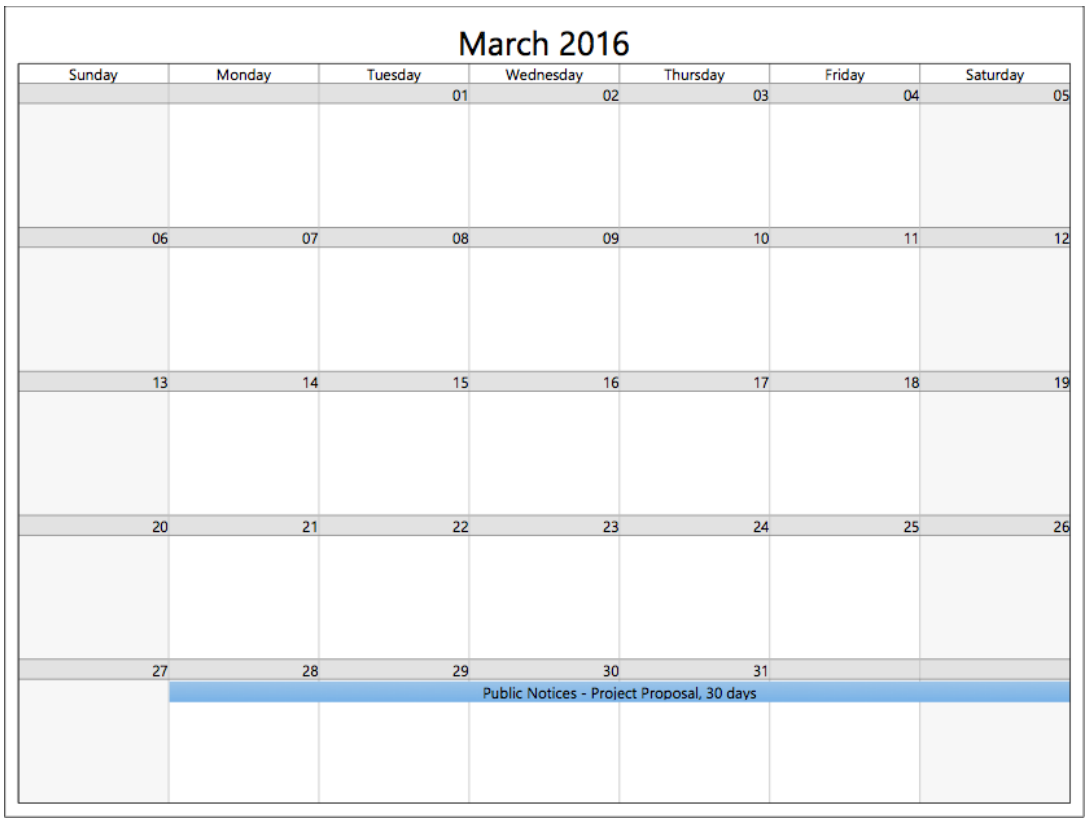


Figure 24 - Detailed Project Schedule (Tabular Form)
Source: © Payam Mazloum, Microsoft Projects 2015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Public Notices - Project Proposal, 30 days


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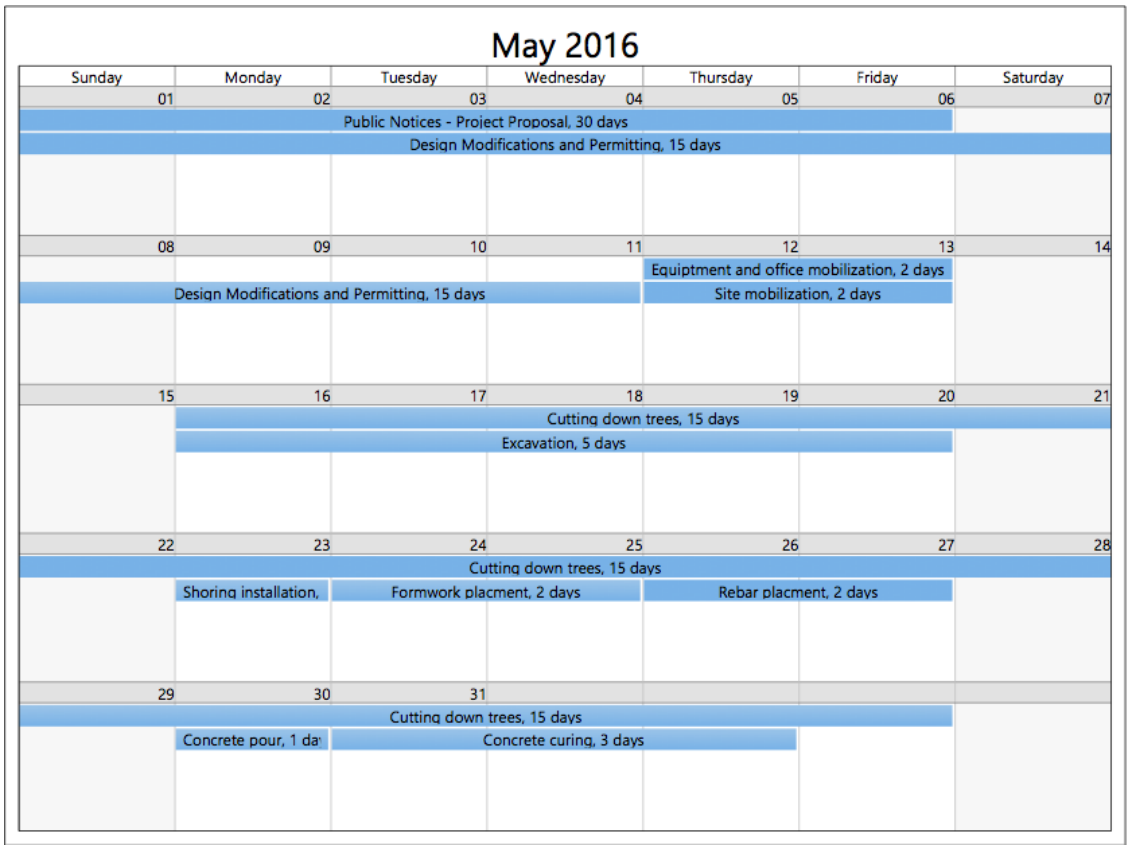
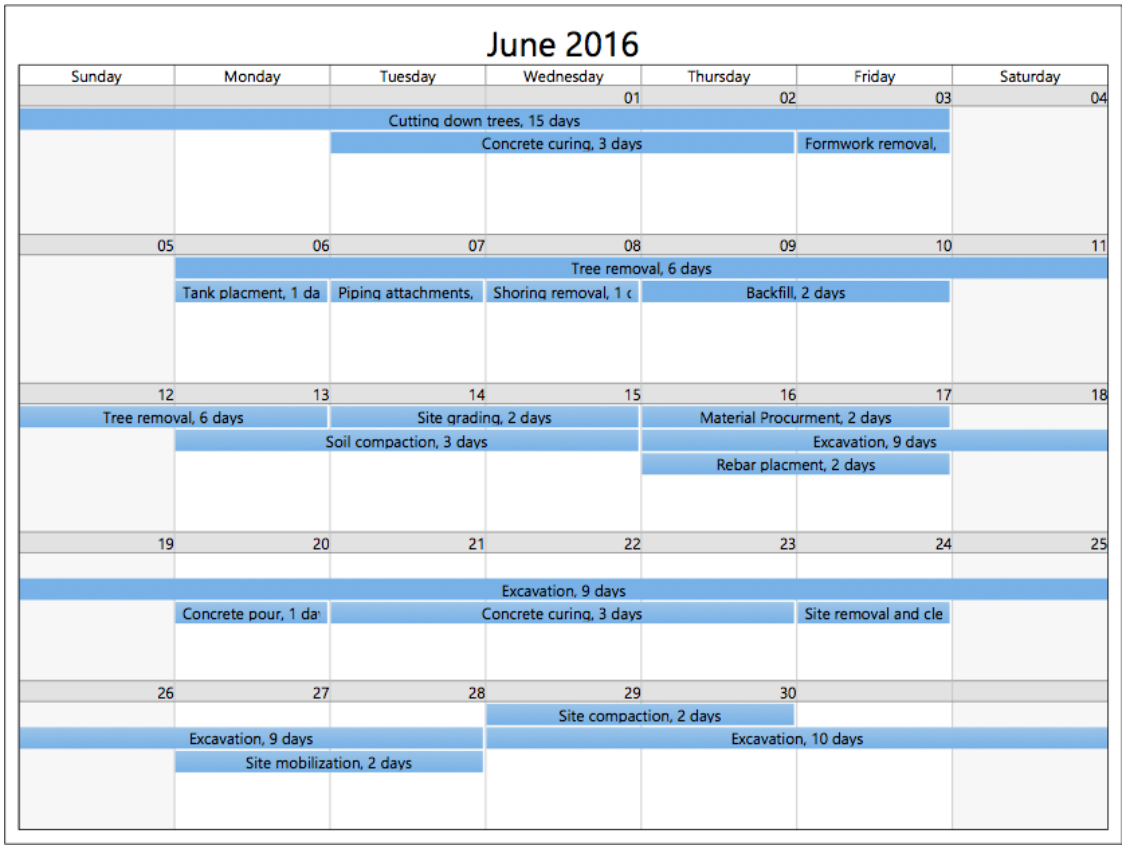
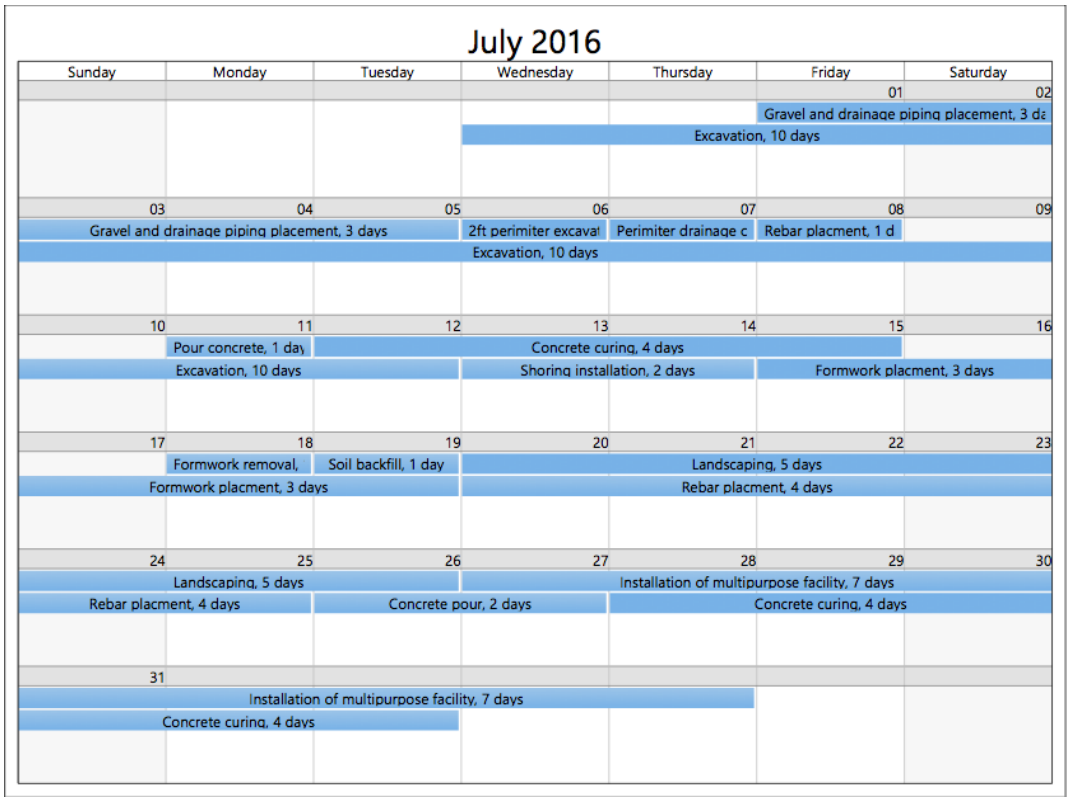
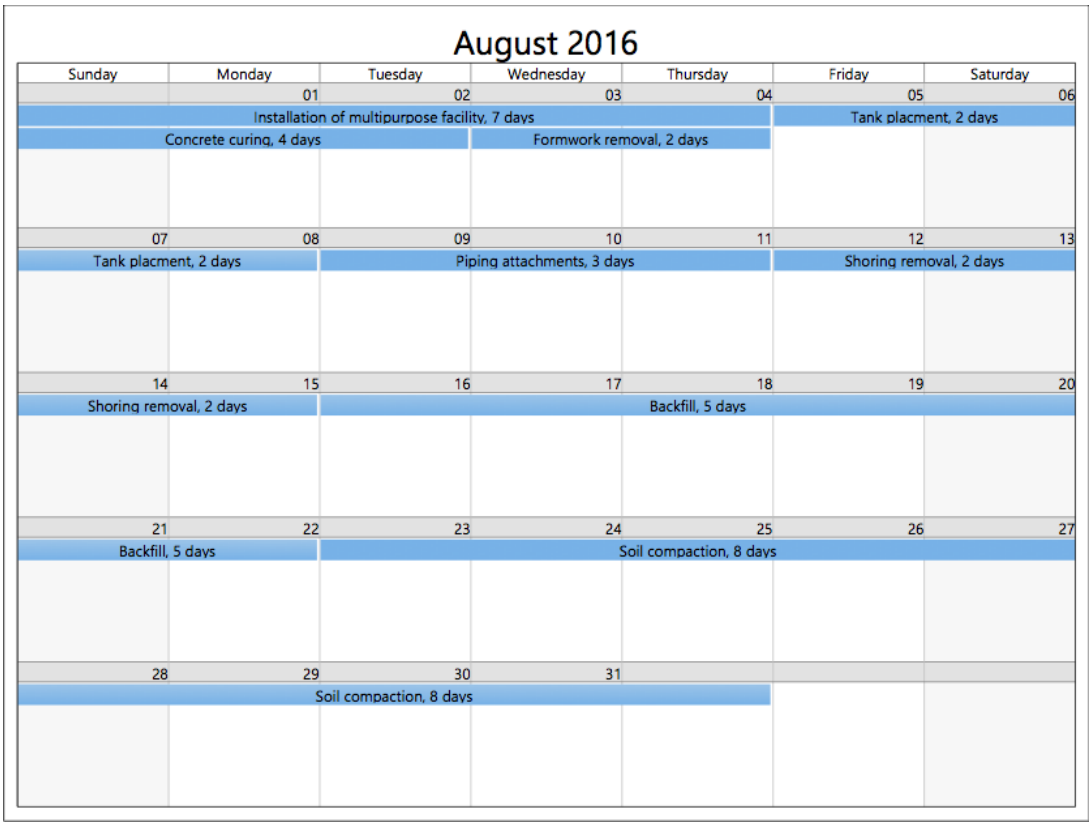
Public Notices - Project Proposal, 30 days
Design Modifications and Permitting, 15 days


May 2016
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
01
02
03
04
05
06
07
Public Notices - Project Proposal, 30 days
Design Modifications and Permitting, 15 days
08
09
10
11
12
13
14
Equiptment and office mobilization, 2 days
Design Modifications and Permitting, 15 days
Site mobilization, 2 days
15
16
17
18
19
20
21
Cutting down trees, 15 days
Excavation, 5 days
22
23
24
25
26
27
28
Cutting down trees, 15 days
Shoring installation,
Formwork placment, 2 days
Rebar placment, 2 days
29
30
31
Cutting down trees, 15 days
Concrete pour, 1 da
Concrete curing, 3 days


June 2016
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
01
02
03
04
Cutting down trees, 15 days
Concrete curing, 3 days
Formwork removal,
05
06
07
08
09
10
11
Tree removal, 6 days
Tank placment, 1 da
Piping attachments,
Shoring removal, 1 c
Backfill, 2 days
12
13
14
15
16
17
18
Tree removal, 6 days
Site grading, 2 days
Material Procurment, 2 days
Soil compaction, 3 days
Excavation, 9 days
Rebar placment, 2 days
19
20
21
22
23
24
25
Excavation, 9 days
Concrete pour, 1 da
Concrete curing, 3 days
Site removal and cle
26
27
28
29
30
Site compaction, 2 days
Excavation, 9 days
Excavation, 10 days
Site mobilization, 2 days


July 2016
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
01
02
Gravel and drainage piping placement, 3 da
Excavation, 10 days
03
04
05
06
07
08
09
Gravel and drainage piping placement, 3 days
2ft perimiter excavat
Perimiter drainage c
Rebar placment, 1 d
Excavation, 10 days
10
11
12
13
14
15
16
Pour concrete, 1 day
Concrete curing, 4 days
Excavation, 10 days
Shoring installation, 2 days
Formwork placment, 3 days
17
18
19
20
21
22
23
Formwork removal,
Soil backfill, 1 day
Landscaping, 5 days
Formwork placment, 3 days
Rebar placment, 4 days
24
25
26
27
28
29
30
Landscaping, 5 days
Installation of multipurpose facility, 7 days
Rebar placment, 4 days
Concrete pour, 2 days
Concrete curing, 4 days
31
Installation of multipurpose facility, 7 days
Concrete curing, 4 days


August 2016
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
01
02
03
04
05
06
Installation of multipurpose facility, 7 days
Tank placment, 2 days
Concrete curing, 4 days
Formwork removal, 2 days
07
08
09
10
11
12
13
Tank placment, 2 days
Piping attachments, 3 days
Shoring removal, 2 days
14
15
16
17
18
19
20
Shoring removal, 2 days
Backfill, 5 days
21
22
23
24
25
26
27
Backfill, 5 days
Soil compaction, 8 days
28
29
30
31
Soil compaction, 8 days

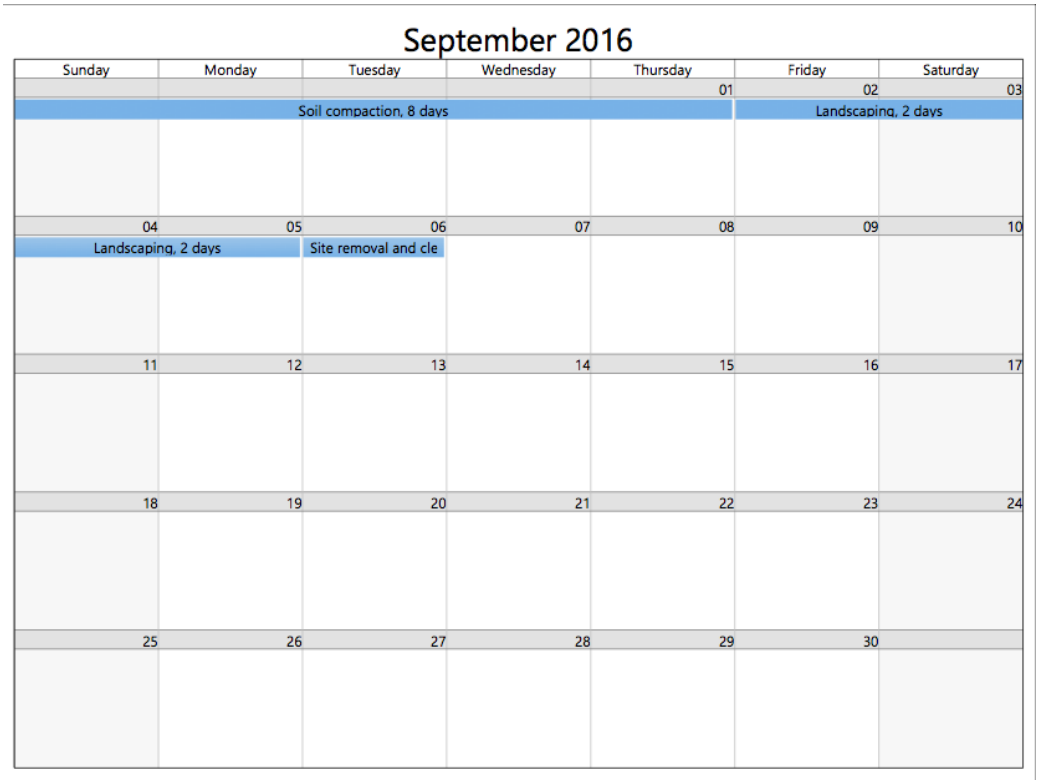


Figure 25 - Detailed Project Schedule (Calendar Form)
Source: © Payam Mazloum, Microsoft Projects 2015

Appendix D - Cost Estimate Table & Calculations

The following tables are a detailed analysis of the construction costs, with a detailed breakdown of different activities and their respective costs.

Table 8 - Communitiy Notification and Consultation Detailed Cost Breakdown

Item	Cost Category	Quantity	Cost
1000	Public Notification	180 days	288000
2000	Geotechinacal Consulting	2 weeks	72000
3000	Environmental Assesment	EA	250000
4000	Permitting		46861
4010	Development-building Permit	2550 square meters (total structaure area)	3234
4020	Tree Removal Permit	100 trees	18479
4030	Water and Sewer Connection Permit	n/a	5000
4040	Noise Bylaw Exemption Permit	5 days or earlier before proposed activities	148
4050	Soil Testing and Foundation Consulation	n/a	20000
5000	Legal	EA	100000
		Total Cost:	756861

Table 9 - Dry Pond Facility Detailed Cost Breakdown

Construction Activity	Break Down	Quantity	Unit	Unit Cost	Total Cost
Tree Removal	10m (tree height)	20	trees	300	6000
	10 - 20m (tree height)	30	trees	600	18000
	20 - 30m (tree height)	30	trees	800	24000
	>30m (tree height)	20	trees	1200	24000
Excavation	Subgrade Excavation	9873.1	m^3	21	207335.1
	Trench Digging	130	m^3	21	2730
Foundation Work	Foundation Compaction	2513	m^3	23	57799
Pond Bottom Treatment	Multi-layer Filtering Green Bottom	27053	ft^2	10	270529
Underground Piping Placement	Pipe Upsize	4000	m	75	300000
	Pipe Addition	5000	m	40	200000
	Pipe Diversion	1000	m	25	25000
	Pipe Installation	2080	m	100	208000
Concrete Placing	C2 Class 32 Mpa Concrete (trench)	105	m^3	186	19530
	C2 Class 32 Mpa Concrete (stairs)	300	m^3	186	55800
	Rebars	1000	m	7	7000
	Labouring	3600	hrs	60	216000
	Concrete Pavers	320	pavers	28	8960
Site Restoration	Finish-up Serveying	2	days	2600	5200
	Clean-up & Restor Site	4	days	3250	13000
	Restore Non-pay Road and Yard	3	days	2045	6135
Landscaping	Grass and Garden Installation	24203	ft^2	3	72609
	Playground Installation	n/a	n/a	n/a	29821
Others	40 Yards Recycle Bin Rental	2	bins	1358.4/bin/month	10867.2
	Fences	200	fences	15/fence/month	12000
	1/4*4*8 Plywood	100	plywood	29.99	2999
	Lumber 2*4	200	lumber	2.99	598
	Lumber 6*4	200	lumber	13.57	2714
	On-site Toilets	6	toilets	300/toilet/month	7200
				Total	1813826

Table 10 - Wesbrook Mall & West 16th Ave Facility Detailed Cost Breakdown

Construction Activity	Break Down	Quantity	Unit	Unit Cost	Total Cost
Precurments	12' - 50000 gallon tanks	6	tanks	105000	630000
	Vertical Turbine Pump	2	pumps	6650	13300
	Steel Motor Mounting Plate	2	plates	130	260
	Fiberglass Vertical Pump Vault (L=17'6'')	2	vaults	6845	13690
	Flanged Nozzles	20	nozzles	25	500
	Flexible Connectors (12'')	14	connectors	645	9030
	Dual NST Fill Point	6	n/a	150	900
	Vent/Level Indicator	2	indicators	200	400
	Watertight Fiberglass Tank Sump (48'')	6	tank sumps	5220	31320
	Fiberglass Collar (48''-6'')	6	collars	2000	12000
	Deadman Anchors	6	anchors	13320	79920
	Fiberglass Anchor Straps	72	straps	770	55440
	Turnbuckles	72	turnbuckles	310	22320
Excavation	Subsoil Excavation	11379	yard^3	16	182064
Foundation Compaction	Soil Compaction	610	m^2	23	14030
Piping	Internall Piping	50	m	40	2000
	Externall Piping	12	m	50	600
Backfill	Compacting Backfill	9779	yard^3	17	166243
Site Restoration	Finish-up Serveying	2	days	2600	5200
	Clean-up & Restor Site	4	days	3250	13000
	Restore Non-pay Road and Yard	2	days	2045	4090
	Grass Installation	54000	ft^2	1	54000
Others	40 Yards Recycle Bin Rental	2	bins	1358.4/bin/month	10867.2
	Fences	80	fences	15/fence/month	4800
	1/4*4*8 Plywood	40	plywood	29.99	1199.6
	Lumber 2*4	40	lumber	2.99	119.6
	Lumber 6*4	20	lumber	13.57	271.4
	On-site Toilets	3	toilets	300/toilet/month	3600
				Total:	1331164.8

Table 11 - TRIUMF Facility Cost Breakdown

Construction Activity	Break Down	Quantity	Unit	Unit Cost	Total Cost
Precurments	10' - 30000 gallon tanks	2	tanks	35000	70000
	Vertical Turbine Pump	1	pumps	6650	6650
	Steel Motor Mounting Plate	1	plates	130	130
	Fiberglass Vertical Pump Vault (L=17'6'')	1	vaults	6845	6845
	Flanged Nozzles	6	nozzles	25	150
	Flexible Connectors (12'')	10	connectors	645	6450
	Dual NST Fill Point	2	n/a	150	300
	Vent/Level Indicator	2	indicators	200	400
	Watertight Fiberglass Tank Sump (48'')	2	tank sumps	5220	10440
	Fiberglass Collar (48''-6'')	2	collars	2000	4000
	Deadman Anchors	2	anchors	13320	26640
	Fiberglass Anchor Straps	16	straps	770	12320
	Turnbuckles	16	turnbuckles	770	12320
Excavation	Subsoil Excavation	980	yard^3	16	15680
Temparary Shoring	Plywood Shoring	240	m^2	12	2880
Foundation Compaction	Soil Compaction	190	m^2	23	4370
Shoring Removal	Plywood Shoring	240	m^2	6	1440
Piping	Internall Piping	30	m	40	1200
	Externall Piping	5	m	40	200
Backfill	Compacting Backfill	500	yard^3	17	8500
Site Restoration	Finish-up Serveying	2	days	2600	5200
	Clean-up & Restor Site	4	days	3250	13000
	Restore Non-pay Road and Yard	2	days	2045	4090
	Paving	1000	m^2	240	240000
Others	40 Yards Recycle Bin Rental	2	bins	1358.4/bin/month	10867.2
	Fences	80	fences	15/fence/month	4800
	1/4*4*8 Plywood	40	plywood	29.99	1199.6
	Lumber 2*4	40	lumber	2.99	119.6
	Lumber 6*4	20	lumber	13.57	271.4
	On-site Toilets	3	toilets	300/toilet/month	3600
				Total:	474062.8