UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

UBC North Catchment Storm System Revitalization

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UBC NORTH CATCHMENT STORM SYSTEM REVITALIZATION

PREPARED FOR: DOUG DOYLE, UBC SEEDS SUSTAINABILITY PROGRAM
CIVIL 446 CAPSTONE DESIGN PROJECT

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Contents

Figures

Tables

Executive Summary

T20 Consultants have designed an optimized solution to improve and protect the UBC campus drainage system. UBC SEED's sustainability goals are major influences to the design process; by integrating the new drainage system with the existing infrastructure and mitigating the impact on the surrounding ecosystem, our design has met and exceeded SEED's goals. We have achieved the main objective of preventing overflow in the spiral drain while building on the current drainage system with a Low Impact Design approach. Utilizing sub-surface detention chambers we have kept construction and maintenance costs low while creating a functioning system that minimizes impact on surface functionality. To utilize the existing infrastructure and eliminate the environmental impact of infrastructure replacement, our design continues to divert storm runoff through the existing spiral drain; preserving the drain's historical and practical benefits. A complete schedule breakdown has been provided, estimating a construction time of the entire system to be just over 11 months, including all aspects and preparation. As well we have included a detailed C level cost estimate. The total estimated cost is $3.3 million. In addition to the storm system design some future recommendations, including eventual upgrade of the spiral drain, are included.

1.0 Introduction

The stormwater system for the University of British Columbia Campus is divided into four major catchments. The North Catchment is the largest and most densely populated of the four catchments and flows out through the UBC Spiral drain located at the northern tip of campus. The UBC Spiral Drain, the last of its kind in North America, is 80 years old and has an expected remaining service life of 30-100 years. Storm sewer lines run into the 6m wide (2.5m inner diameter) Spiral Drain with water then dropping 60 vertical meters through a vortex shaft before it is cushioned at the bottom, transported and drained out into the ocean. Currently the Spiral Drain has an expected capacity of roughly a 70-year storm flood event. Given its capacity, the landscape close to the Spiral drain has been altered to retain large volumes of water in flood situations. Without these alterations, peak flows would have caused water to flow through the Pacific Spirit Park and over the cliffs surrounding campus. This would have caused significant erosion of the cliff edge and thus is extremely undesirable.

It is the goal of the University of British Columbia SEEDS (Social Ecological Economic Development Studies) Sustainability Program to research and design a replacement system for the North Catchment. The new system would be designed to perform in a 200-year (maximum) storm event and exceed stormwater quantity and quality standards. To undertake this process UBC SEEDS has contracted T20 Consulting to handle the full research and design process for this project. The Spiral Drain is in an environmentally sensitive area due to the surrounding cliffs and Pacific Spirit Park. Special care in the design process will be given to these areas to ensure the future system is non-intrusive while also adding an aesthetic element to the campus.

The following outlines individual project contributions

Name	**Contributions**
Neil Courtney	Concrete chamber design, structural analysis, cost estimate, report: proof & submit
Jack Stuart Gilbert	Hydro modelling and analysis, stormwater treatment, executive summary
Riley Jang	Construction overview, updated schedule
Donghwan Kim	Project design criteria, concrete mix design
Grant Matthews	Geotechnical analysis, introduction
Kory Wealick	CMP detention chambers, design description, initial schedule, report: compile & format

2.0 Project Design Criteria

This section provides design requirements, technical considerations of the project as well as UBC policies and Federal & Provincial regulations.

2.1 Design Requirements

The primary goal of the project is to control the quality and quantity of the stormwater to meet the demands of a 1-in-200-year storm event. The specific detailed design includes flood volume reduction, water quality improvement and erosion management.

2.2.1 Flood Volume Reduction

The main purpose of designing a storm water management system is to reduce the total runoff volume to meet the capacity during extreme rainfall. The design utilizes a combination of underground water detention chambers and storage loops to minimize the risk of overland flows.

2.1.2 Water Quality Improvement

The stormwater runoff contains sediments, metals, oils and other pollutants that are potentially harmful to the surrounding ecosystem and threats the environments. The use of stormwater filtration system has been implemented in the design to improve water quality.

2.1.3 Erosion Management

To minimize cliff erosion, the runoff flow rate must be controlled and limited. The flow rate of runoff depends on the design of pipe network system. The erosion due to a continuous flowing stormwater within detention chambers and storage loop must be minimized by controlling flows and selecting appropriate materials.

2.2 Technical Considerations

In a detailed design of storm water management system to mitigate flooding at North Catchment area in UBC, we have considered geotechnical, structural, hydrological and environmental aspects to approach our design practical, efficient and sustainable.

2.2.1 Geotechnical Consideration

Soil profile is estimated with the data provided by PITEAU ASSOCIATES, "Hydrogeological and geotechnical Assessment of Northwest Area UBC Campus." The estimated soil profile is assumed to be consistent over North Catchment area and it is used to calculate the amount of settlement, bearing stresses and horizontal and vertical pressures on the storage tank below the ground. To ensure a compact and predictable soil base, various site remediation techniques are required depends on the soil conditions. During an excavation of ground, the sheet piling technique is recommended as it is readily available and economical. Considering approximately 5m excavation is required below the ground, one or two ground anchors are suggested as it provides extra strengths and improves a slope stability.

2.2.2 Structural Consideration

The structural design of concrete storage is analyzed by following CSA standard A23.3-04 in "Design of Concrete Structures "and NBCC 2015 – National Building Codes of Canada. Based on NBCC requirements, the magnitude of the loads is determined. The designed dimensions of concrete storage are used to calculate reinforcement requirements for slabs and walls. The strip footings and walls are designed to resist both the gravity and lateral loads.

2.2.3 Hydrological Consideration

The Storm Water Management Model (SWMM) is used to simulate both single-event and long-term(continues) to meet storm water capacity for large flood events for the North Catchment area.

2.2.4 Environmental Consideration

To improve stormwater quality and to minimize pollution, Stormceptor, an oil grit separator system is used to remove pollutants such sediments or free oils. Stormceptor is preferred as it captures pollutants during all rainfall events including extreme storms. Furthermore, it can be redeveloped and constructed anywhere that stormwater quality treatment is needed.

2.3 UBC Policies and Government Laws & Regulations

The lands of UBC Vancouver campus, where the stormwater detention facility will be installed, is located in the unorganized territory of the Greater Vancouver Regional District; therefore, the project adheres to the requirements outlined in the UBC Vancouver Campus Plan and the UBC Land Use Plan. The project is designed to meet the requirements of Federal Government and Provincial Government.

2.3.1 Government Laws & Regulations

The design of stormwater management system complies with both Federal and Provincial regulations and has been designed to meet the requirements:

- Federal Government
- Canadian Environmental Protection Act: pollution prevention and the protection of the environment and human health
- Fisheries Act: serious harm to fish or any permanent alterations within all water in the fishing zones of Canada
- Provincial Government
- Water Sustainability Act: ensure a sustainable supply of fresh clean water to B.C. residents
- Environmental Management Act: a detrimental environmental impact occurs when a change in the quality of air, land and water

3.0 Design Description

3.1 Concrete Detention Chambers

This section provides an overview of the concrete detention chambers used in this project, a full structural detailing description can be found in Section 5 as well as final construction drawings in Appendix A, structural analysis calculations in Appendix E.

3.1.1 Background

To meet the large flooding demands of our project area, large concrete retention chambers needed to be designed. These chambers are essentially 1-storey reinforced concrete apartment buildings consisting of slabs (upper/lower), beams, columns, exterior walls and footings. These features will be completely sub surface, thus minimizing impact on future and existing UBC infrastructure and can be constructed in a very efficient manner with the latest industry methods used in cast in place concrete construction today.

3.1.2 Selected Locations

Concrete detention chambers were selected to be the preferred design in three of the eight locations, based off required storage volume and site constraints. Where sites had availability of square footprints these were the selected design, as opposed to the CMP chambers which utilized longer "channel" type footprints. The selected locations can be seen on the Figure 1 and Table 1 show the selected locations and outline their respective configurations.

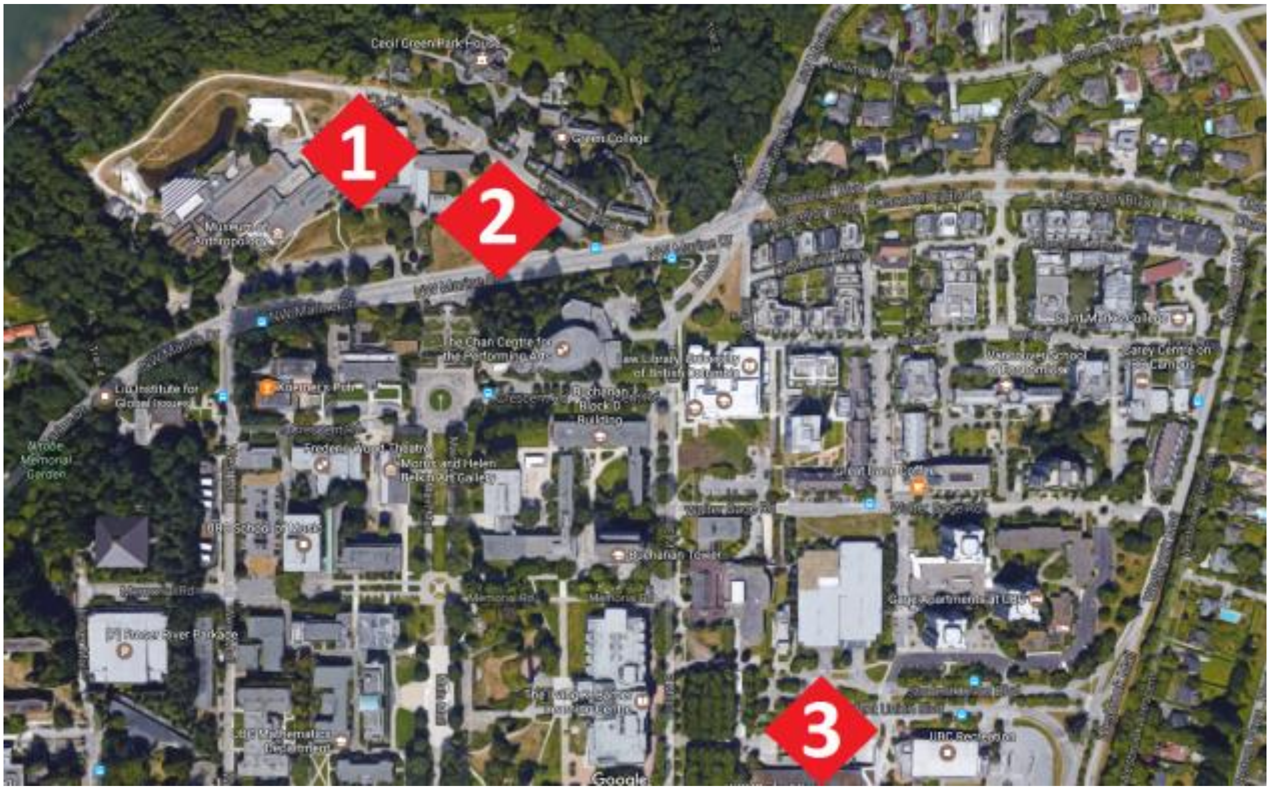


Figure 1: Concrete Detention Chamber Locations

Table 1: Concrete detention chamber details

	Tank 1	Tank 2	Tank 3
Length (m)	36	30	30
Width (m)	18	12	18
Height (m)	4.9	4.9	2.4
Volume (m^3)	2900	1500	900

3.2 Corrugated Metal Pipe (CMP) Detention Chambers

3.2.1 Background

Wherever possible in the design, corrugated metal pipe was chosen as the primary material for detention chamber construction. For this purpose, CMP offered large cost savings over alternative concrete designs. CMP is a relatively inexpensive material, and its economic advantages are further compounded by requiring a very fast and simple installation process. Additionally, CMP has a much lower carbon footprint per volume of water stored, and a longer service life.

Figure 2: Corrugated metal pipe

The design uses CMP in numerous configurations to detain a large range of water volumes, from 30 m^3 to 1670 m^3. Detention facilities were laid out with either a single containment pipe, or two to three twinned pipes. The pipes chosen ranged in diameter from 72” to 84”. Offline configurations were used in all but one CMP detention facility design.

By utilizing an offline configuration, these detention chambers will only be filled during high intensity rain events and will not be subjected to long periods of water running through them, which can lead to scouring of the corrugated internal surface. The one facility in an inline configuration has been designed with a hydraulically smooth steel liner with polymer coating, to prevent wear from scouring.

Small diameter outlets are used on each of the chambers to allow them to fill and slowly release stormwater during a high intensity rain event.

3.2.2 Selected Locations

CMP was determined to be the most suitable option in five of the eight locations requiring a detention chamber. The CMP detention facility locations were numbered from one to five for ease of reference. The governing factor allowing for choosing CMP for a facility was the availability of surface area. CMP chambers cannot be stacked, which makes them unsuitable for chambers requiring a high containment volume within a small surface area. Location numbers 1, 2, and 4 are situated under unused, grassed areas, while locations 3, and 5 are to be installed under paved roads.

Figure 3 and Table 2 show the selected locations and outline their respective configurations.

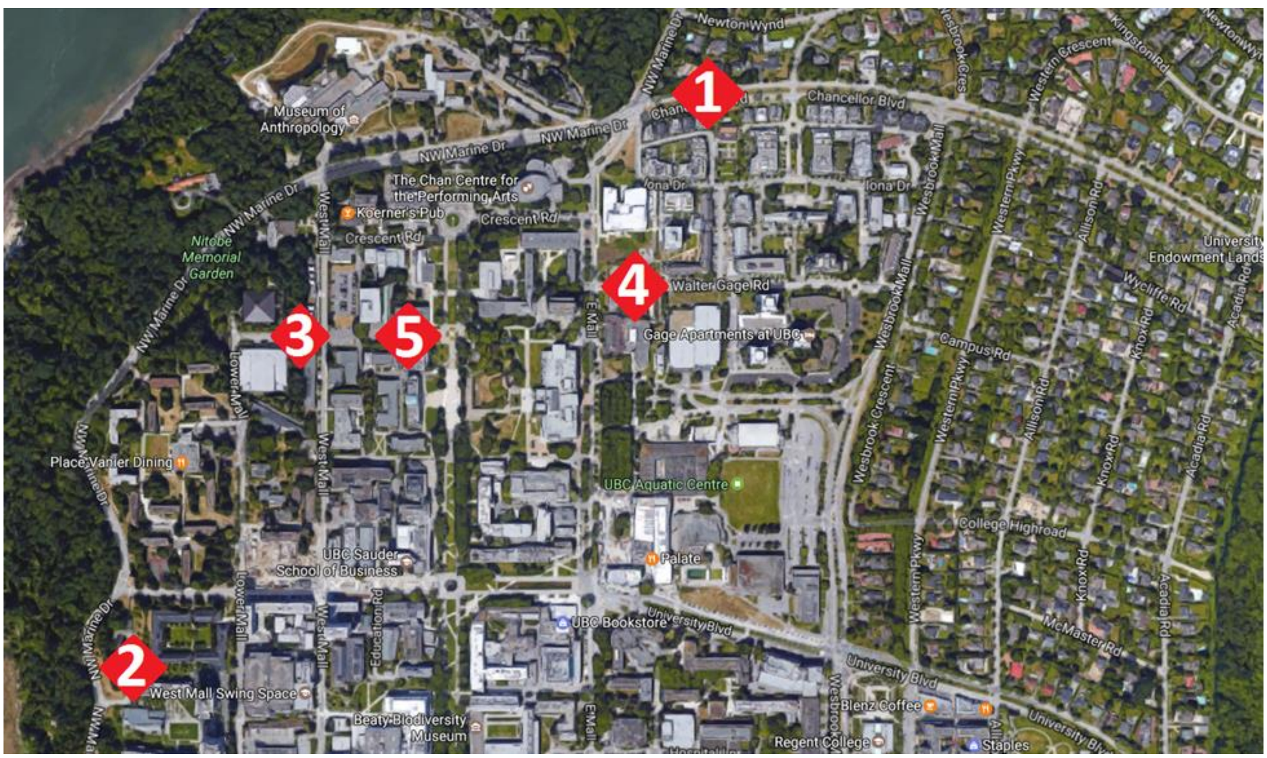


Figure 3: Corrugated metal pipe detention facility locations

Table 2: Corrugated metal pipe detention chamber details

	Location Number	Total Volume (m^3)	Length of Pipe (m)	Number of Pipes	Pipe Diameter (in)	Config.
Chancellor Blvd	1	1670	213	3	72	Inline
NW Marine Dr	2	200	37	3	72	Offline
Memorial Rd	3	120	20	2	78	Offline
Walter Gage	4	65	19	1	84	Offline
School of Music	5	30	10	1	78	Offline

4.0 Geotechnical Analysis

T20 Consultants used borehole data from Piteau Associates and estimated soil properties used by Trow Consulting Engineers to estimate the corresponding loads acting on the underground detention tanks. It is recommended that during initial excavation that the soil be analyzed to confirm assumptions.

4.1 Site Overview

For the three tanks on site two different borehole logs were used in geotechnical calculations. The two tanks located on Cecil Green Parkway (CGP) used TH01-01 while the single tank near Student Union Boulevard (SUB) used TH01-02.

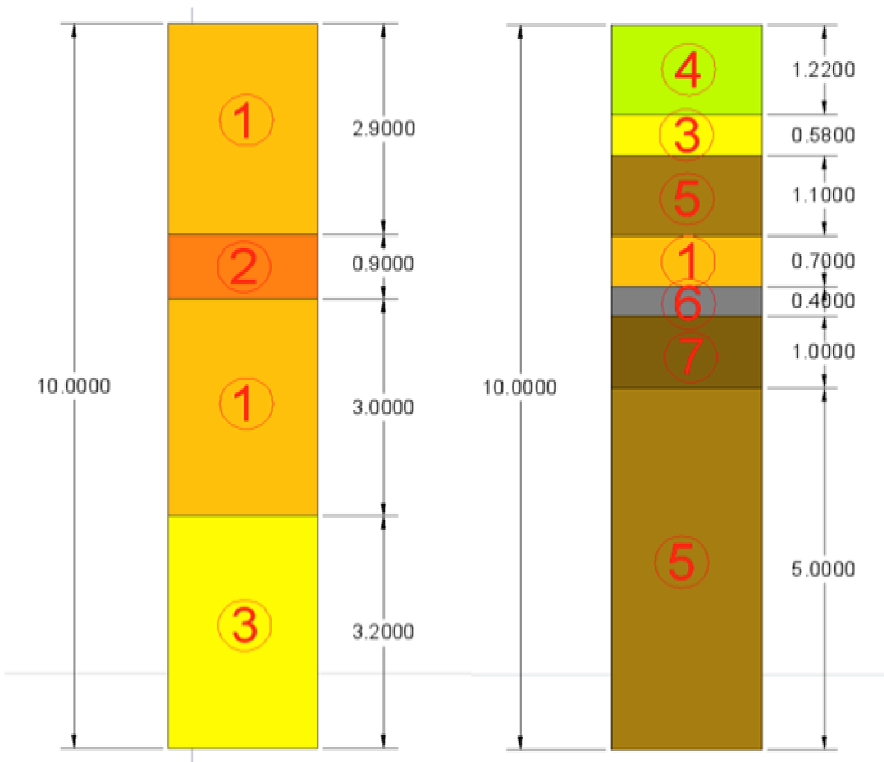


Figure 4: Left: Geological profile of TH01-01. Right: Geological profile of TH01-02

Table 3: Soil classification

Layer	Soil Classification
1	SAND - compact
2	SAND - stiff to compact
3	SAND - loose
4	FILL - till & medium sand
5	SAND-SILT
6	SILT
7	SILT - sandy

From the geological profile can see variations between both sites. For the CGP detention tanks the soil was all assumed to be Compact Sand. The SUB tank has many layers of fill, silt, & sand. It is recommended that excavated compact sand from CGP be moved to the SUB when backfilling around the tank.

Using compact sand around the tanks increases the bearing capacity and also simplifies all design. TROW Consulting estimated all sand to depth of 7m of having the same properties. Using this same estimation we are able to create a simplified homogenous geological profile surrounding both tanks.

Table 4: Estimated Soil Parameters by TROW Consulting

Soil Type	ρ (kg/m3)	Y (kN/m3)	Φ' (°)	G (Mpa)	K (kPa)	Cohesion (kPa)
SAND	2000	19.6	38	200	2000	N/A
SAND - Very Dense	2080	20.4	44	260	2600	N/A
SILT	1900	18.6	N/A	100-300	1000-3000	200-600

4.2 Lateral Earth Pressures

To prevent wall collapse the tanks are required to be designed for lateral earth pressures. When calculating the lateral loads the following assumptions were required:

- Groundwater assumed to be at 0m
- Hydrostatic stresses are present
- The detention tank is empty

It should be noted that groundwater was found to be at ~1m depths near the detention tanks, but due to the uncertainty the groundwater was said to be at ground level to maximize horizontal pressures.

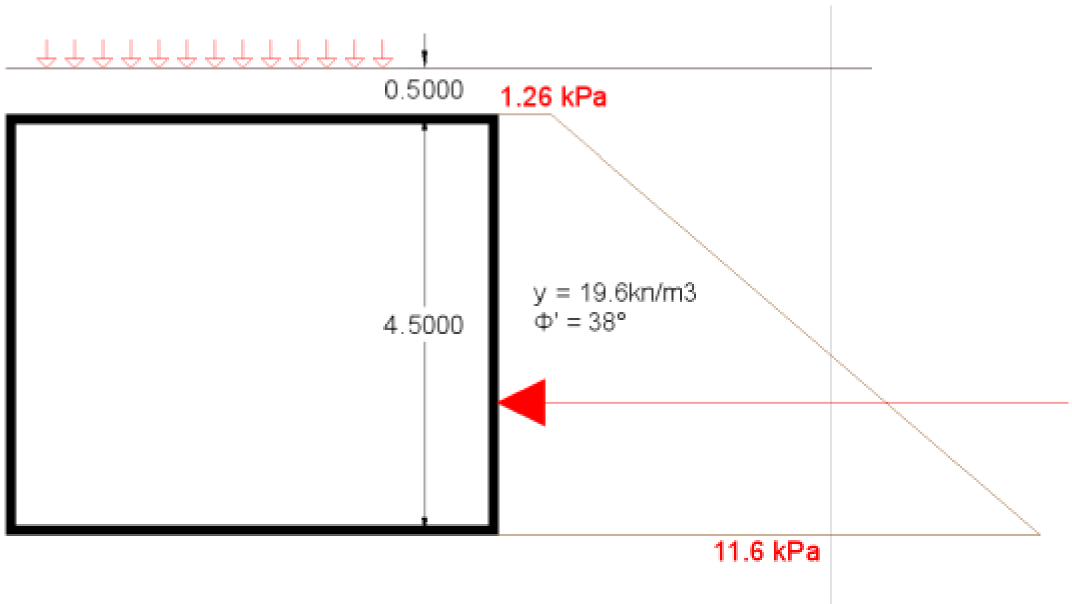


Figure 5: Soil profile acting on 4.5m tanks

Using the soil profile above a lateral earth pressure of 58kN/m was calculated for CGP tanks & 14kN/m for the SUB tank. Calculations can be found in Appendix F.

4.3 Bearing Capacity

Bearing capacity was calculated for the footings and for the global system. Due to the large tank area sand strength of soil the detention tanks are within tolerable limits meeting a factor of safety of 2.0+ for all bearing calculations. Sample calculations can be found in Appendix F.

4.4 Settlement & Liquefaction Assessment

Settlement was assessed below the column footings. Dense sand is located beneath the detention chambers and will undergo minimal settlement of less than 10mm over a 200-year life span. It is still recommended to densify the gravel below the base with a common compactor if feasible.

Liquefaction was not assessed for this project due to the location of the detention chambers. The strength of sand is sufficient for moderate seismic events however during a high seismic event the cliffs surrounding UBC may become unstable and the chambers will fail. For this reason it is not recommended to further densify the soils for liquefaction prevention.

5.0 Structural Detention Chamber Design

This section provides a detailed overview of the process associated with structural design of the concrete detention chambers. Based off of the loads determined in Section 4 as well as the concrete mix properties analyzed in Section 7 the concrete chambers were designed for the limiting case where the chambers are empty and there is no outward pressure on the walls only inward from the surrounding soil. Several references were used in the design of these structures and they included:

- CSA 23.3-4 Design of Concrete Structures
- NBCC 2015 – National Building Code of Canada
- Reinforced Concrete Design (A practical approach) - 2013 (Brze, Pao)

Full calculation sheets can be seen in Appendix F as well as detailed construction drawings in Appendix A

5.1 Concrete Structure Details

These structures were essentially designed as simple "1-storey" cast in place concrete buildings consisting of slabs (top/bottom), beams, walls, columns and footings. With the experience in the construction industry today to erect 40-storey concrete structures in this manner, a 1-storey building will be able to be built with sufficient ease and accuracy. The rest of this section will describe the sizing, reinforcement and purpose of each structural element.

5.1.2 Slabs (top)

The top slab acts as the barrier between the soil above and the concrete structure below. It takes the weight of the soil and transfers it into the beams and perimeter walls. The top slabs have clear span lengths of 6m in both directions. They have been designed with a thickness of 300mm and 20M @ 200mm spacing (both directions) on the bottom to resist positive bending moments. It also contains 20M @ 500mm spacing (both directions) at the top for slab integrity and smaller negative bending moments.

5.1.3 Slabs (bottom)

The bottom slab acts as a barrier between the water above and the soil below. It is fully supported underneath by the soil and footings and only requires concrete for minimal bending moments and shrinkage/temperature effects. It has been designed with a thickness of 150mm and 15M @ 1000mm spacing in both directions.

5.1.4 Beams

The beams transfer the loads from the slabs to the columns and the perimeter walls. They have all been designed with clear span lengths of 6m from 1 support to the next. The beam dimensions are 800mm deep with a width of 400mm. They contain 6-25M reinforcement at the bottom, 3-25M at the top and 10M stirrups @ 300mm spacing for shear reinforcement.

5.1.5 Columns

The columns transfer the loads from the beams to the pad footings below. Due to the relatively short column lengths, slenderness effects did not need to be considered. The columns are 400mm square with 4-20M reinforcement and 20M stirrups @ 300mm.

5.1.6 Walls

The perimeter walls act as the exterior barrier between the surrounding soil and the contained water. They transfer vertical loads from the beams and upper slabs to the strip footings below. They are 200mm thick with 20M @ 200mm spacing running vertically and 15M @ 500mm running horizontally.

5.1.7 Pad Footings

The pad footings take the full loads from the columns and distributed them evenly over the soil. They are 500mm thick and 2000mm square with 8-20M reinforcement in both horizontal directions.

5.1.8 Strip Footings

The strip footings run around the full perimeter length and distribute the vertical loads transferred from the walls. They are 300mm thick and 750mm wide with 3-15M running longitudinally and 15M @ 300mm running transversely across the length of the strip.

Table 5 below provides a complete summary of each elements sizing and reinforcement details. Tank 2 has been selected to show an isometric cut view of what the tanks look like and can be seen below in Figure 6.

Table 5: Element sizing and reinforcement details

Element	Sizing	Reinforcement
Slabs (Top)	Thickness = 300mm	20M @ 200mm (2-directions, bottom), 20M @ 500 (2-directions, top)
Beams	Depth = 800mm, Width = 400mm	6-25M (bottom), 3-25M (top) and 10M stirrups @ 300mm
Columns	Width = 400mm (square)	4-20M (Longitudinal) and 10M stirrups @ 300mm
Walls	Thickness = 200mm	20M @ 200mm (Vertical), 15M @ 500mm (Horizontal)
Slabs (bottom)	Thickness = 150mm	15M @ 1000mm (2-directions)
Pad Footings	Width = 2000mm (square), Thickness = 500mm	8-20M (2-diirections)
Strip Footings	Width = 750mm, Thickness = 300mm	3-15M (longitdinal) and 15M @ 300mm (Transverse)

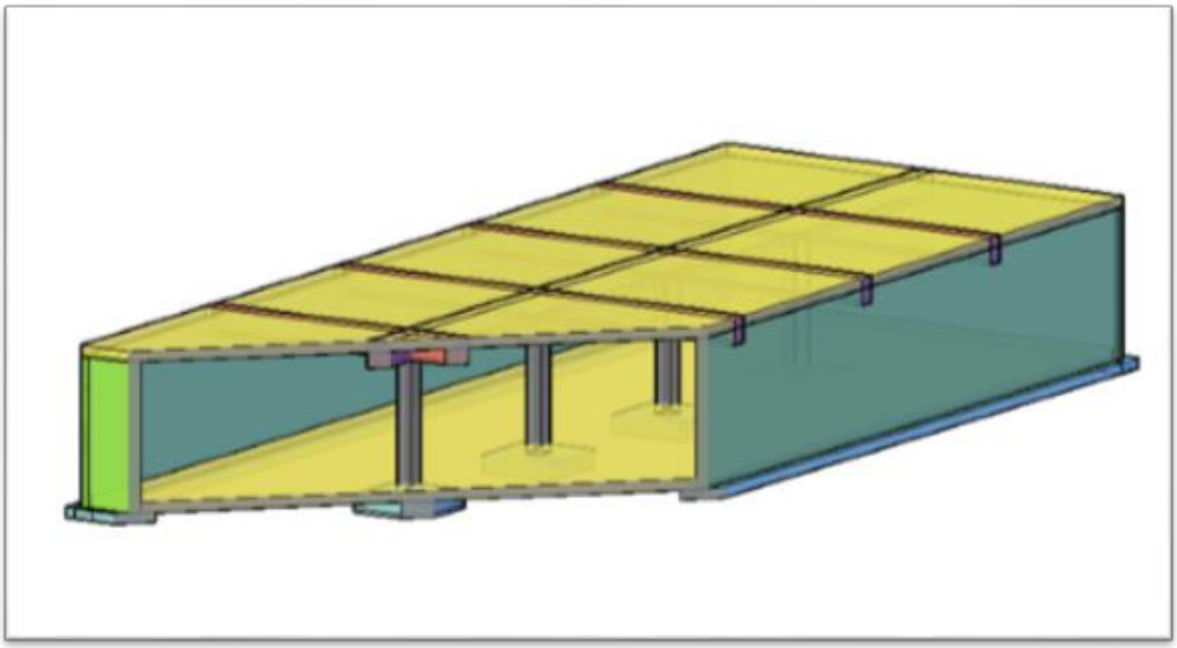


Figure 6: Concrete chamber section view

6.0 Corrugated Metal Pipe Detention Chamber Design

This section outlines the locations and general configurations for the five CMP detention chambers throughout the project. Isometric drawings are provided to demonstrate the appearance of each chamber structure. Dimensioned technical drawings for each facility are located in Appendix A.

6.1 Location 1, Chancellor Blvd Inline CMP Detention Chamber

Location 1, along Chancellor Boulevard, is the only inline configuration CMP detention facility within this project. This facility has been designed to contain a volume of 1670 m^3. An existing storm sewer trunk runs beneath the grassy median that separates the east and west lanes of Chancellor Blvd. This inline storage chamber will replace a portion of the sewer trunk and will be built in the existing sewer's location. Figure 7 outlines the area of Location 1.

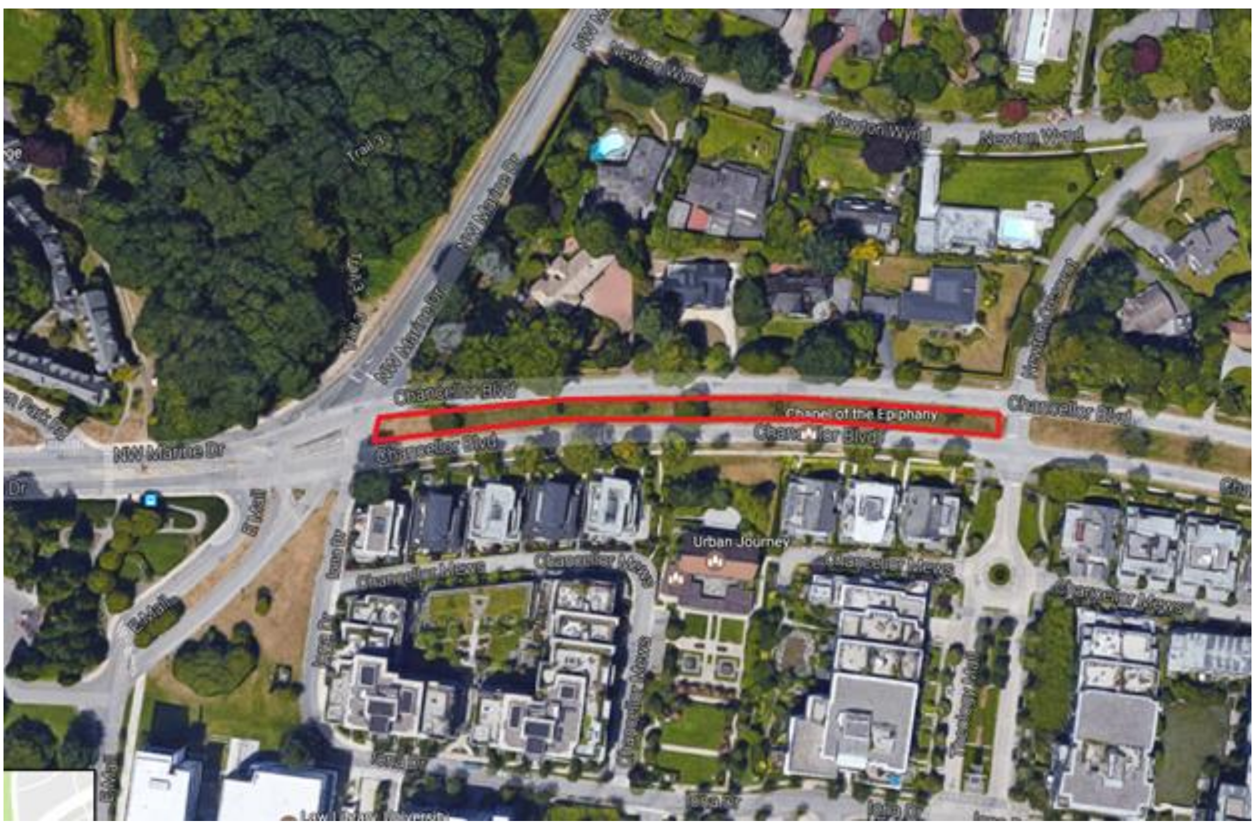


Figure 7: Location 1, Chancellor Blvd inline corrugated metal pipe detention chamber

This chamber consists of three 72" diameter pipes running a length of 213 m. As the project area contains a slight bend, the CMP chamber has been designed with a concrete 22° union which will join two sections of pipe at mid-span. Figure 8 displays an isometric view of the design and Figure 9 shows a more detailed view of the mid-span concrete union.

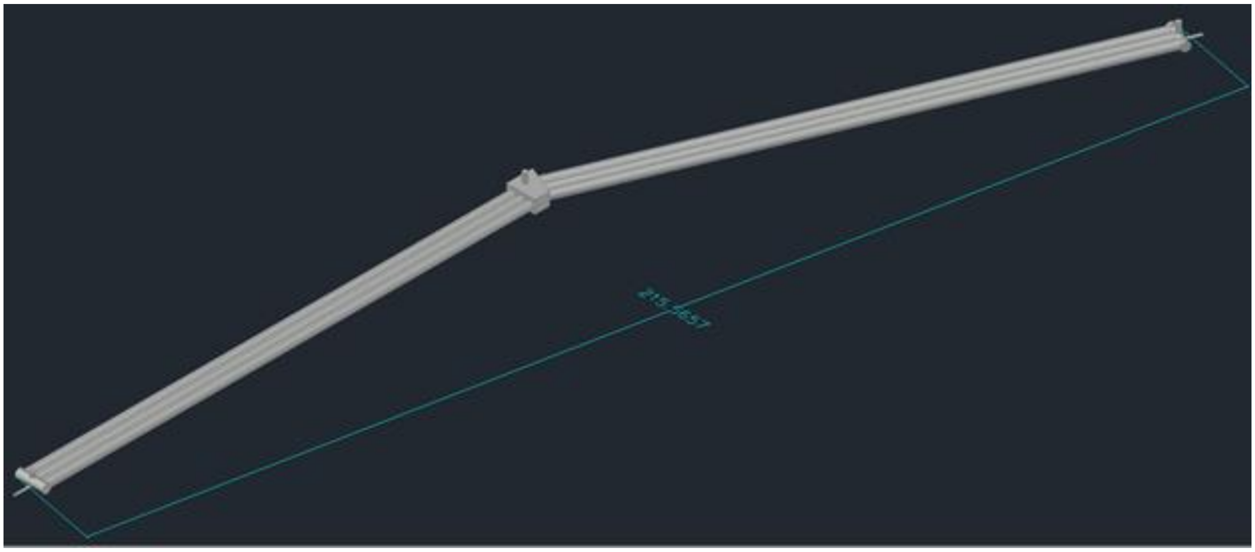


Figure 8: Isometric view of Location 1, Chancellor Blvd inline detention chamber

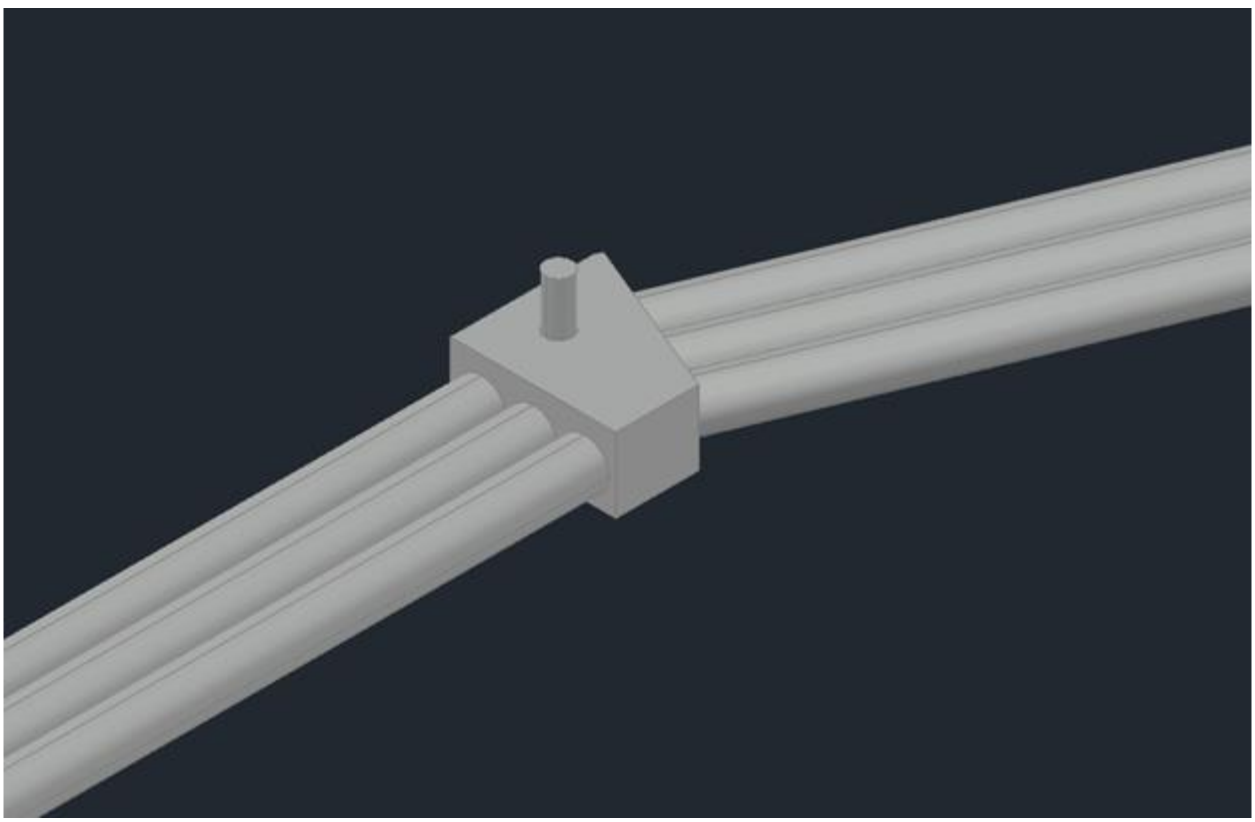


Figure 9: Isometric view of concrete 22° union located at mid-span of Chancellor Blvd detention chamber

Due to the inline configuration of this design, this detention chamber will be frequently be subjected to running water, so it was necessary to choose a CMP that can handle scouring. A CMP with a hydraulically smooth steel liner with polymer coating was chosen. Figure 10 shows a cutaway of the chosen CMP.

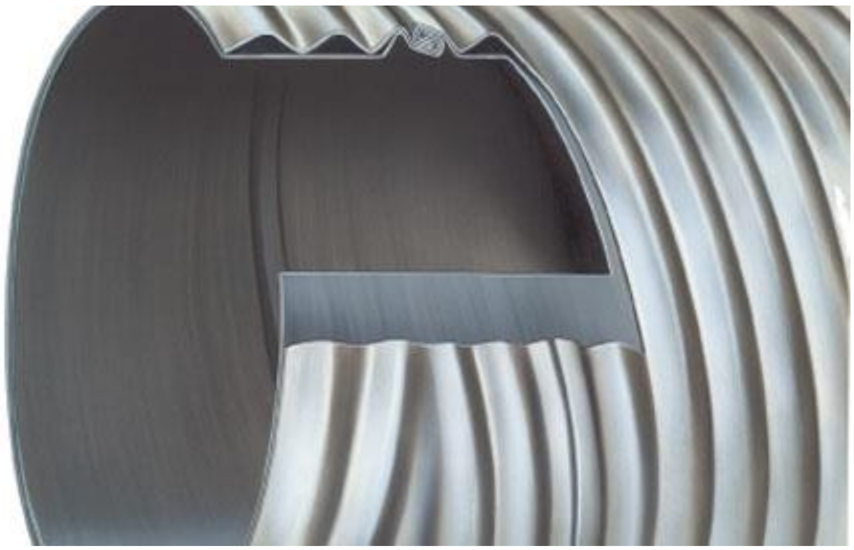


Figure 10: Corrugated metal pipe with smooth steel liner with polymer coating

6.2 Offline CMP Detention Chamber Designs

Locations 2, 3, 4, and 5 are all designed in an offline configuration. These offline tanks range in volume from 30 m^3 to 200 m^3.

6.2 1 Location 2 – NW Marine Dr

A 200 m^3 detention chamber will be constructed at this location. The chamber will consist of three 37 m long, 72” diameter pipes. Figure 11 and Figure 12 outline the project location and provide an isometric view of the detention chamber.

Figure 11: Location 2, NW Marine Dr offline corrugated metal pipe detention chamber

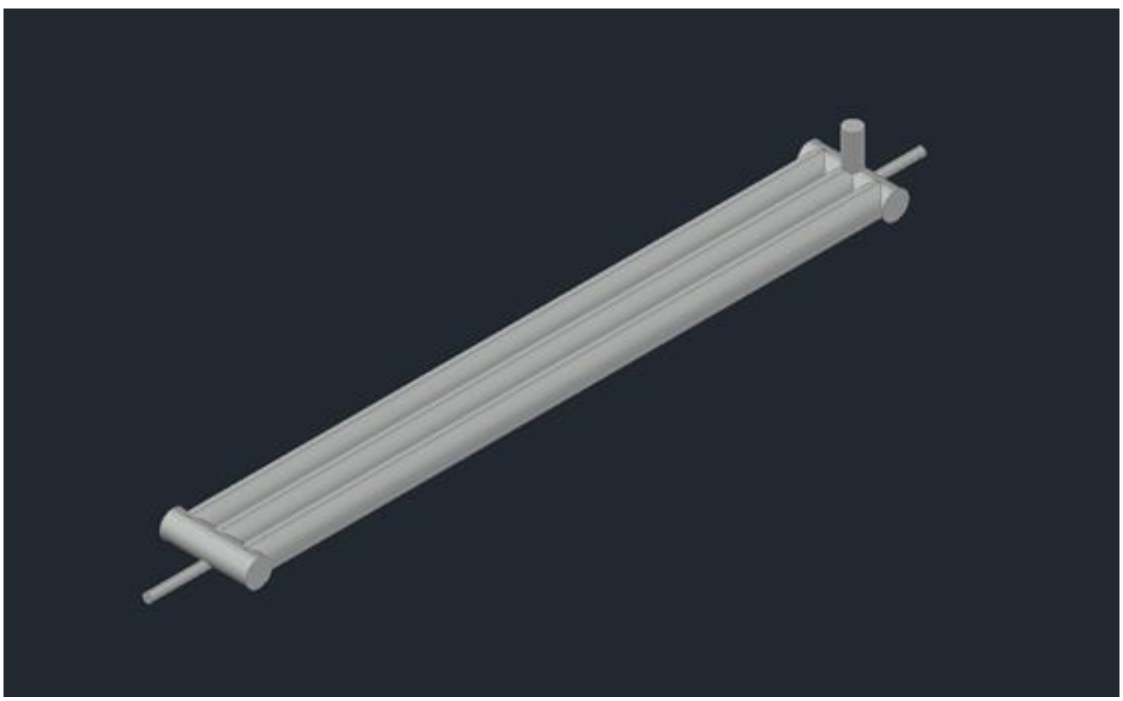


Figure 12: Isometric view of Location 2, NW Marine Dr offline detention chamber

6.2.2 Location 3 – Memorial Rd

A 120 m^3 detention chamber will be constructed at this location. The chamber will consist of two 20 m long, 78” diameter pipes. Figure 13 and 14 outline the project location and provide an isometric view of the detention chamber.

Figure 13: Location 3, Memorial Rd offline corrugated metal pipe detention chamber

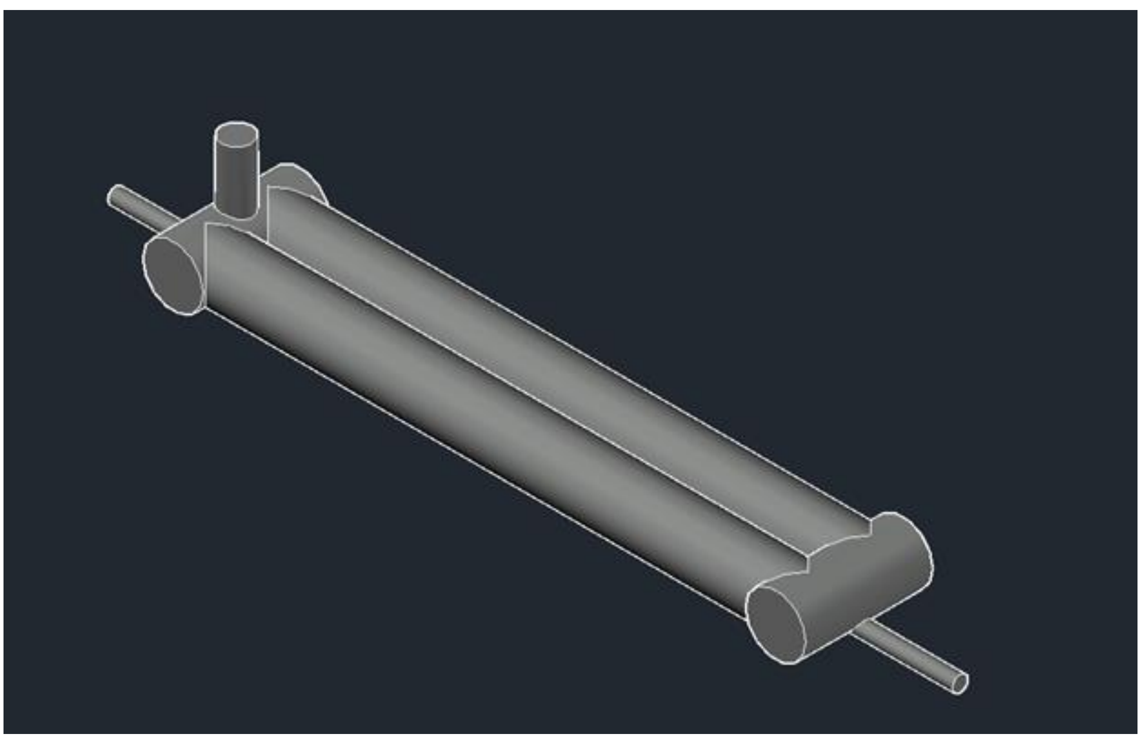


Figure 14: Isometric view of Location 2, NW Marine Dr offline detention chamber

6.2.3 Location 4 – Student Union Blvd

A 65 m^3 detention chamber will be constructed at this location. The chamber will consist of a single 19 m long, 84" diameter pipe. Figure 15 outlines the project location.

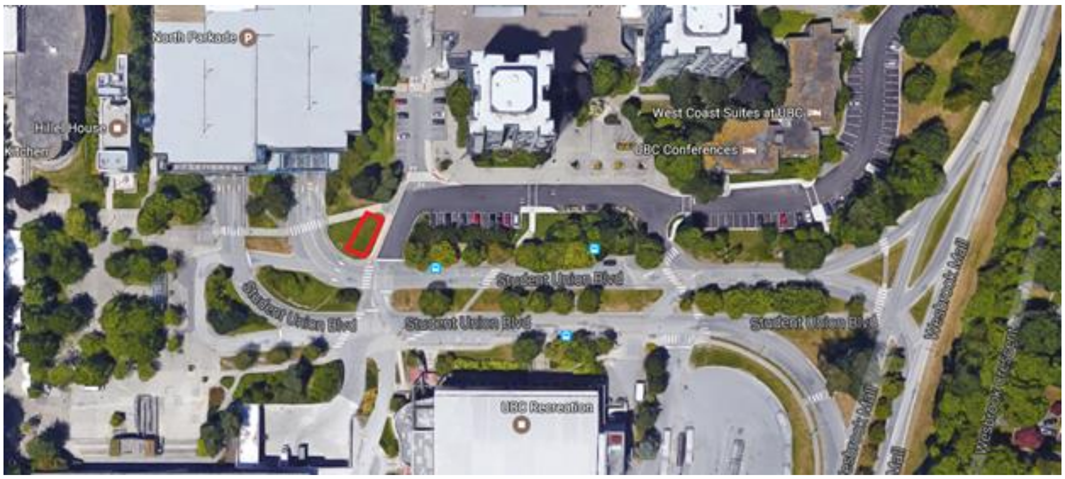


Figure 15: Location 4, Student Union Blvd offline corrugated metal pipe detention chamber

Location 5 – School of Music Parking Lot

A 30 m^3 detention chamber will be constructed at this location. The chamber will consist of a single 10 m long, 78" diameter pipe. Figure 16 outlines the project location

Figure 16: Location 5, School of Music Parking Lot corrugated metal pipe detention chamber

7.0 Concrete Mix Design

It is critical to consider corrosion-control as to increase durability of concrete; it directly affects the environment, threatens public health and eventually lead to a structural failure. The deterioration of concreate and reinforcement steel is caused from a chemical or electrochemical reaction with its surrounding environment such as soil and water. To mitigate corrosion, an appropriate concrete mix design is required followed by CSA standard. The compressive strength of concrete is 30MPa, deliberated from the structural analysis.

According to ACI211.1-91(2002), Table 6.3.1 and CSA23.1-94, Table 6, the maximum slump of the concrete is 75mm.

The air-entrained concrete is required to avoid freezing thaw cycle. In the Table 6.3.3 of ACI 211.1-91(2002), the recommended average total air content is 4.5% with an approximate mixing water of 184 kg/m3.

The reinforced structure is exposed to chloride as well as freezing and thawing condition with a strength of 30MPa; therefore, it is designed with a maximum permissible water-cement ratio of 0.45.

The maximum size of aggregate is 19mm according to section 14.2.2.1 of CSA 23.1-94. The fineness modulus of coarse aggregated is assumed to be 2.8.

From Table 6.3.6 of ACI 211.1-91(2002), the volume of coarse aggregate per unit volume of concrete is found out to be 0.62.

Table 6: Concrete aggregate details

	Fine aggregate	Coarse aggregate
Fineness Modulus	2.8	2.8
Moisture Content(%)	1.3	0
Moisture Absorption Capacity(%)	2	0.2
Specific Gravity	2.68	2.7

Note: Dry rodded density of coarse aggregate: 1530 kg/m^3

Applying an adjustment of aggregate moisture, the material proportioning in the 30MPa structural mix for 1m3 is as follows:

Table 7: Concrete mix design details

	Water	Cement	Coarse aggregate	Fine aggregate	Air
(%)	20	14.1	31.2	30.2	4.5
Kg/m^3	200	445	840	810	-

Note: water-to-cement ratio is 0.45 as it is mentioned above.

The amount of cement can be adjusted or replaced with Supplementary Cementing Materials (SCMs). Adding Silica fume supports concrete to achieve higher strength and reduces amount of calcium hydroxide formed during Pozzolanic reaction. Reducing PH of concrete mitigates a corrosion such as sulfate attack, Alkali-Aggregation or Chloride Diffusion. In this case, Silica Fume is the most recommended SCMs to use as it lowers permeability and increases resistivity of chemical attacks or abrasions. Air Entraining Agent (AEA) is also recommend to use as it prevent freeze-thaw cycle form creating internal cracks and leading corrosions.

8.0 Hydro-technical Analysis and Modelling

To ensure proper functionality of our storm system design a hydro-technical analysis has been conducted using EPA SWMM. EPA SWMM is a common modeling program that is used quite frequently in the industry for projects such as this. The client provided an initial EPA SWMM file, which included 200 year rain event data and catchment areas, therefore, all that has been altered is the infrastructure handling the storm water runoff. The below sub-sections will provide hydro-technical data supporting the effectiveness of the new components of the system.

8.1 Detention Tank 1 and Tank 2

As previously stated, detention tanks 1 and 2 are located just north of the spiral drain. These tanks are designed to fill up only during significant rain events and to slowly drain at a low flow rate which will ease demands of the spiral drain.

A network of weirs has been designed to allow excess flows within the system to flow to the detention tanks. Two weirs will lead into the smaller upstream tank, tank 2, as well as one weir allowing flow out to avoid overflow. The large, downstream tank 1 has a total of four weirs allowing flow into the tank, including an overflow weir from tank 2. Finally both tanks have a 100mm DIA drainage pipe connected to the bottom. This small pipe is designed to slowly release the detained water at a rate significantly less than the 875mm DIA storm mains. The layout of the weirs can be seen in the below EPA SWMM schematic.

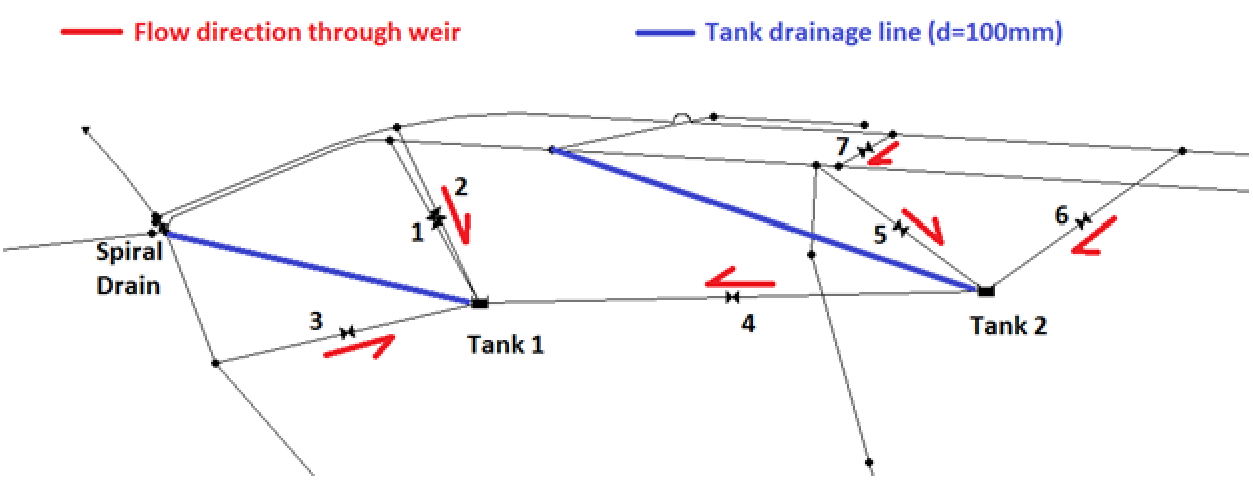


Figure 17: Tank 1 and Tank 2 Weir Schematic

The weirs labeled above have the following heights, respective from the invert of the connection point to the main storm system. Note, weir 4 acts as a precautionary overflow weir directing water from tank 2 to tank 1, when tank 2 reaches roughly 90% capacity (4.0m depth).

Table 8: Weir heights

Weir Number	Weir Height from Inlet Invert
1	2.00 m
2	2.00 m
3	2.00 m
4	4.00 m
5	1.00 m
6	0.50 m
7	2.20 m

During the 200 year rain event modeled, tank 1 fills to roughly 80% capacity while tank 2 fills to 85% capacity. However, this detention adequately prevents flooding within this area of the storm water system. A plot of the water levels within the two tanks during a 24 hour, 200 year rain event can be seen below.

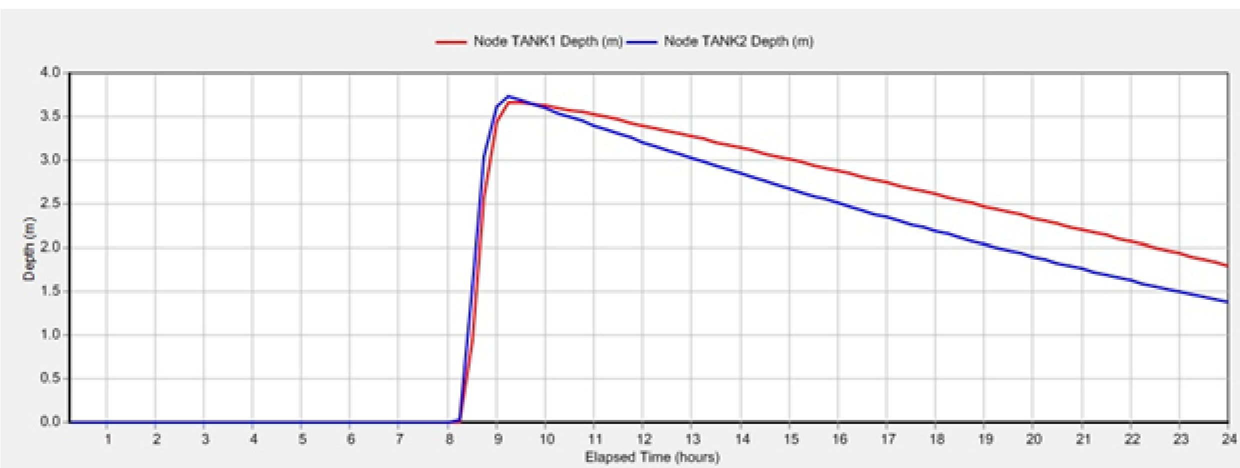


Figure 18: Water levels in tanks 1 and 2

8.2 Detention Tank 3

Detention tank 3 is similar to detention tanks 1 and 2; however it is smaller and has a much simpler arrangement of piping. As the area faces much less excessive flow than where the other two tanks are located, tank 3 has only one inlet weir and has a slightly larger 150mm DIA drainage pipe. The below EPA SWMM schematic shows the arrangement of tank 3.

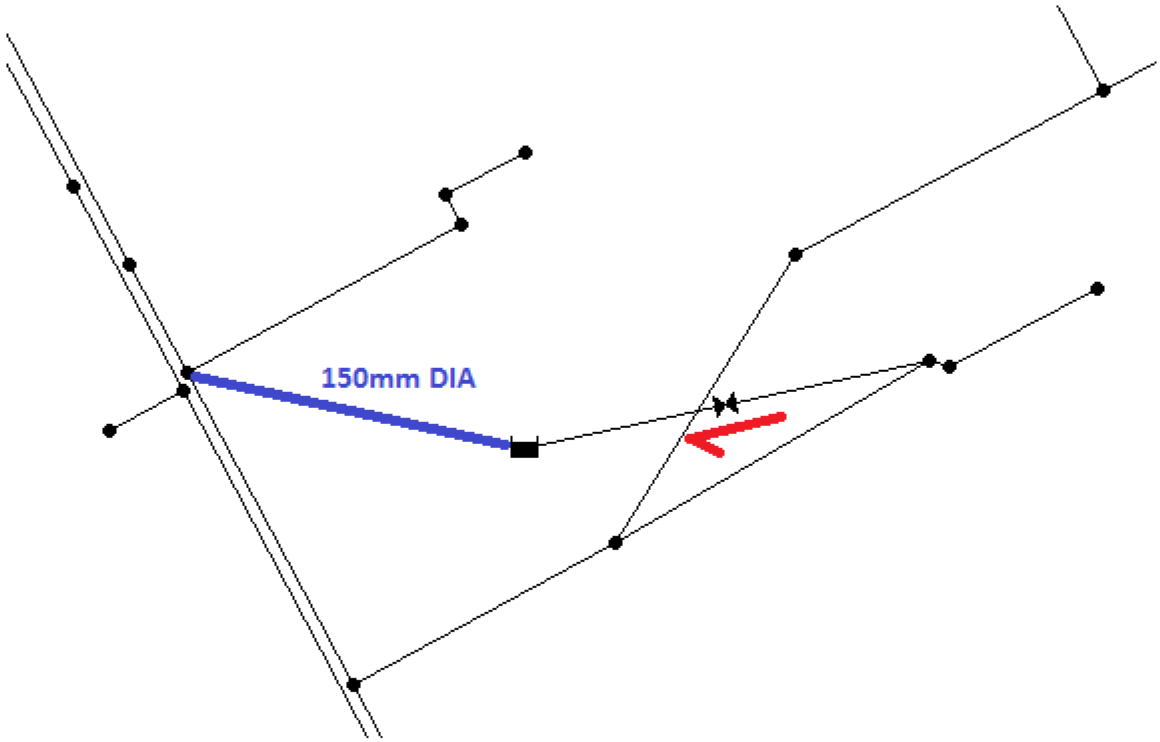


Figure 19: Schematic of Tank 3

Although this tank fills to roughly 95% capacity during a 200 year rain event, the slightly larger drainage pipe paired with the smaller size of this tank make for a much shorter drainage time. This can be seen in the image below.

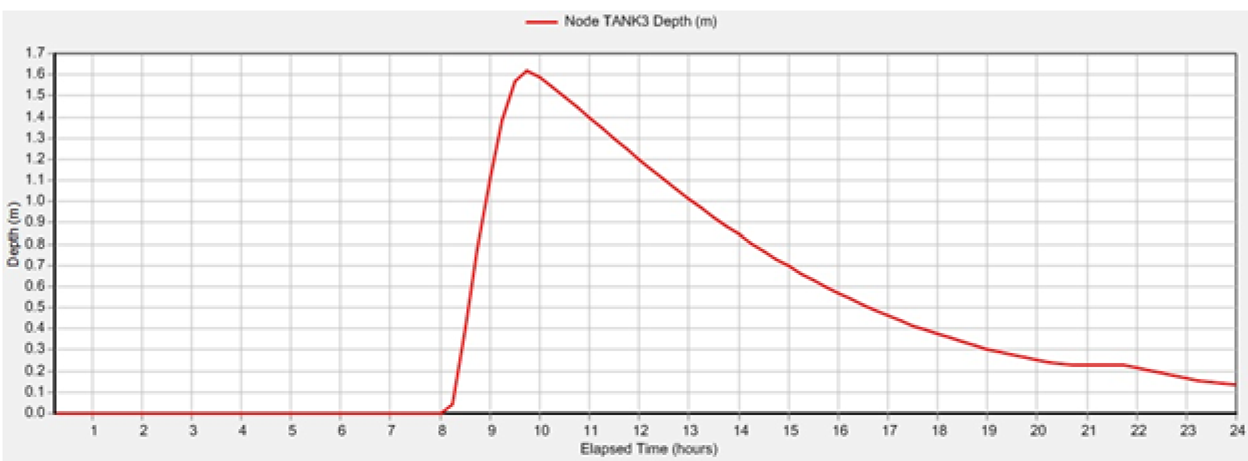


Figure 20: Tank 3 water level

8.3 Storage Loop Piping

The final component to the UBC storm system upgrades are the "storage loops" that have been designed to handle smaller scale flooding in the system. These have been described in previous sections of the report, see Section 6.0 for detailed design information. From a hydro-technical sense these storage loops can be treated as storage tanks like in the previous section. They have retention volume and an inlet weir and outlet orifice, allowing for them to slowly release excess flow to the system. However, the Chancellor Boulevard line required specific attention as it is an inline storage system.

Flow backups along Chancellor Boulevard occur as it runs west towards the spiral drain. Below is a profile of the pre-upgrades EPA SWMM model at the peak flow hour (8:30am). Circled in this profile is manhole B6D-N94 as the hydraulic grade line, shown in blue, has reached the top of the manhole, which results in flooding.

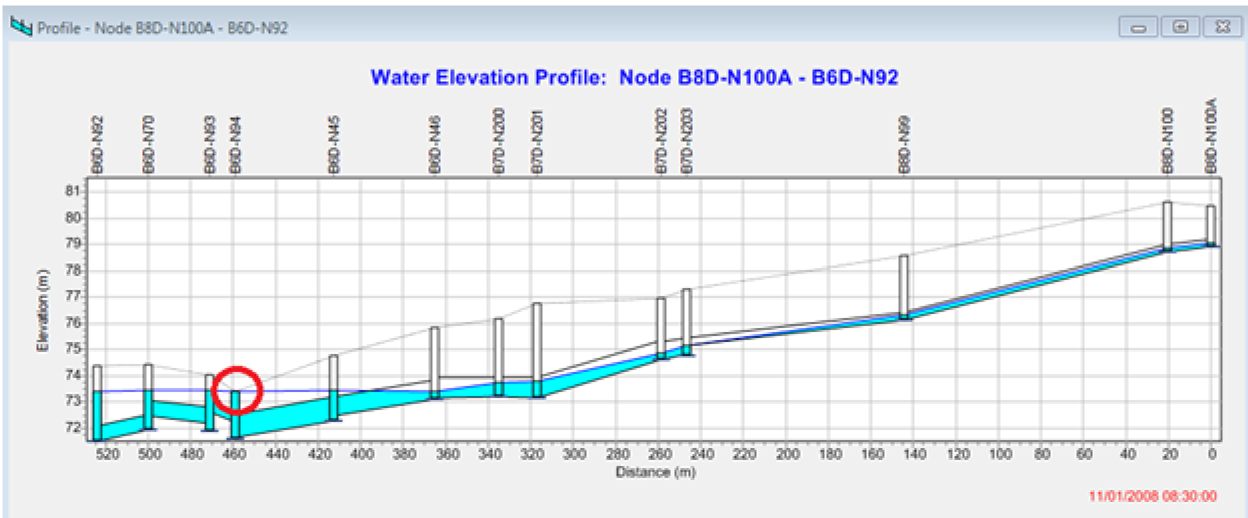


Figure 21: Flooding of Chancellor Blvd

Now with the addition of the three 72 inch retention pipes flooding has been eliminated from the system, as seen below.

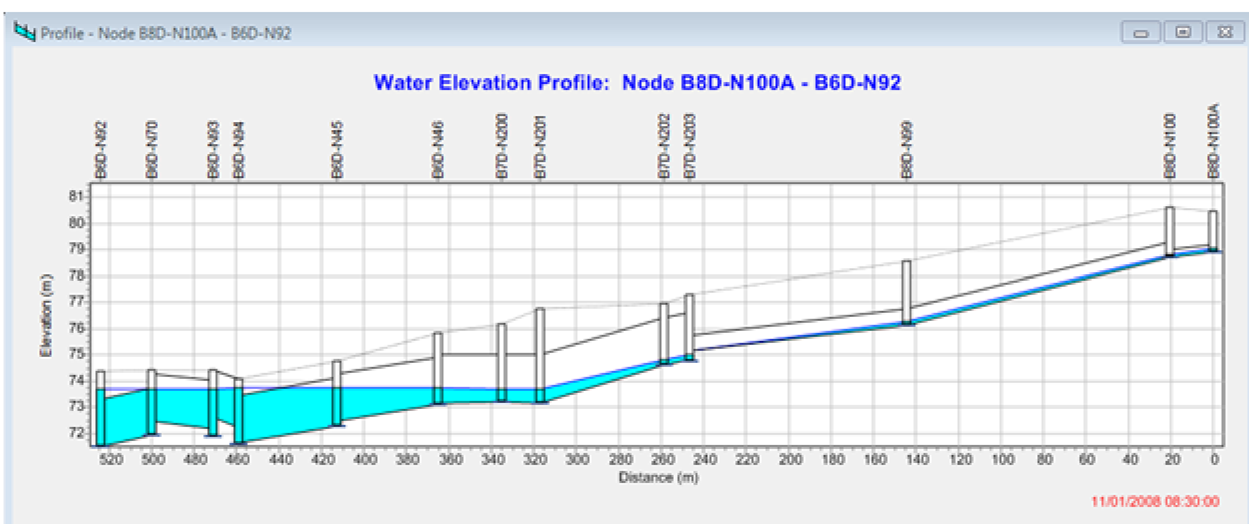


Figure 22: Upgraded Pipe Profile and HGL of Chancellor BLVD

9.0 Stormwater Treatment

Stormwater from the Northern UBC catchment is directed through the storm system and down the spiral drain, after this it is discharged directly out into the ocean. UBC SEEDS prides itself on pushing sustainability and moving towards green projects and operations. Vancouver is an environmentally sensitive area that is home to various different ecosystems, the surrounding ocean being one of the most important ones. To go along with UBC SEEDS mission statement and move towards a sustainable future, discharge water quality is of the utmost importance.

T20 Consultants has chosen to use Stormceptor Oil and Grit separators throughout the system. Stormceptor is a well-respected company that has been creating stormwater treatment systems for many years, and has become common use in the industry. The Stormceptor system can easily be installed in a standard sized manhole and are affective at removing coarse sediment, as well as oil, from surface runoff. As the UBC area consists of many parking lots and vehicle traffic, the upgrades have been designed to incorporate a Stormceptor system at each new storage feature's location, however we do recommend more be installed into the UBC stormwater system. See the below image for a rough layout of the Stormceptor system, for more information on please visit www.imbriumsystems.com/Imbrium/Stormceptor.

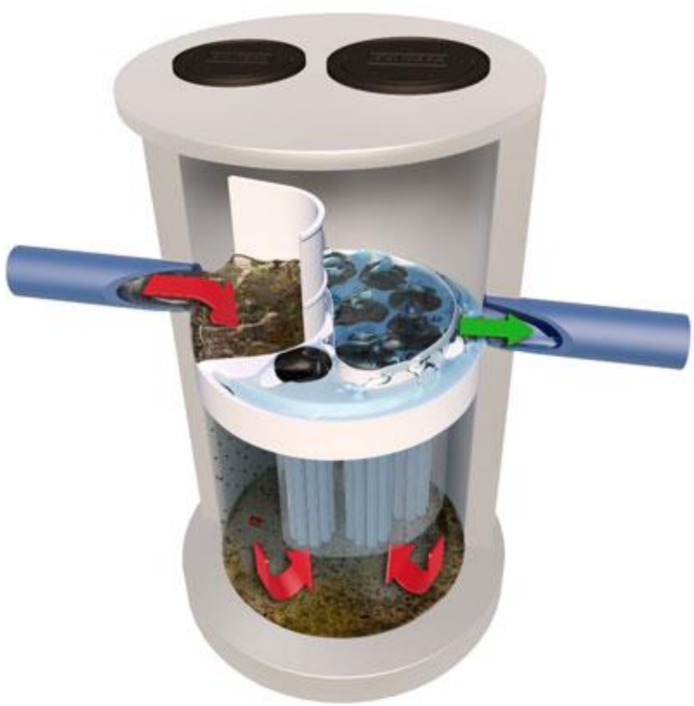


Figure 23: Stormceptor System

10.0 Construction Work Plan

Construction has been split into 7 sub-project locations. The locations of the sub-projects are:

1. Northwest Marine Drive
2. Memorial Road
3. UBC School of Music
4. Chancellor Boulevard
5. Student Union Boulevard (Walter Gage Tower)
6. Student Union Building
7. Cecil Green Park

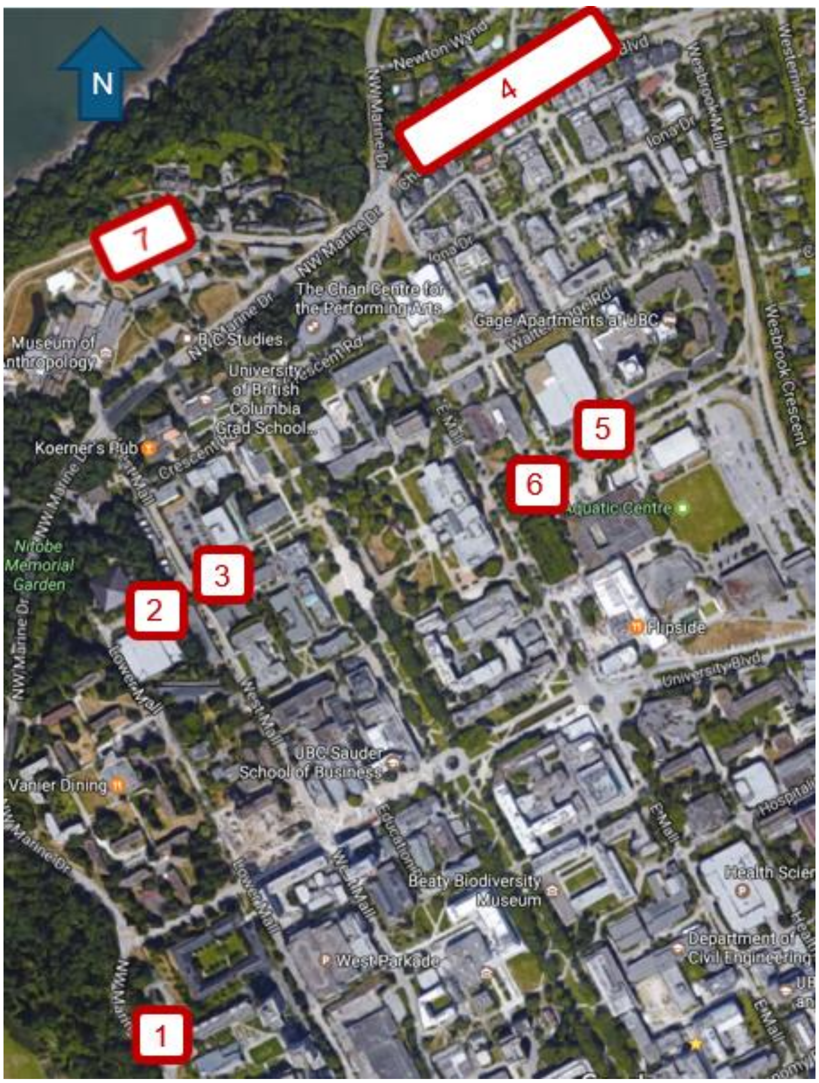


Figure 24: Construction Work Plan Overview

10.1 Construction Crews and Plan of Engagement

Construction operations will be conducted by two construction crews. The two crews will both begin work on May 1, 2017 (at separate locations) and on September 26, 2017 they are expected to commence work at Cecil Green Park together. Crew A will complete project 1 (NW Marine Dr), project 2 (Memorial Road), and project 3 (School of Music) before moving on to the final project, project 7 (Cecil Green Park). Crew B will first complete the installations for project 4 (Chancellor Boulevard), project 5 (Walter Gage), and project 6 (Student Union Boulevard) before moving on to project 7 (Cecil Green Park). Construction will wrap on April 10th, 2018. Installations of corrugated metal pipe will use the classic technique of trench and installation, and the concrete chambers will be cast-in-place.

10.1.1 Crew A

Crew A will be assigned projects 1-3, and 6. Projects 1-3 only involve the installation of corrugated metal pipe storage loops, thus Crew A will consist of 9 members: two excavators and operators, one surveyor, two dump trucks and drivers, three laborers and one foreman. The locations of these projects all have adjacent fields which can be used for pipe and equipment storage without causing interference to neighbouring activities. Project 1 (NW Marine Drive) will use the grass area next to St. John's College Parking Lot. Projects 2 and 3 (Memorial Road and UBC School of Music) are located on opposing sides of the intersection of West Mall and Memorial road, and they will use the grassy area to the northwest of the intersection for storage (just east of UBC School of Music Building).

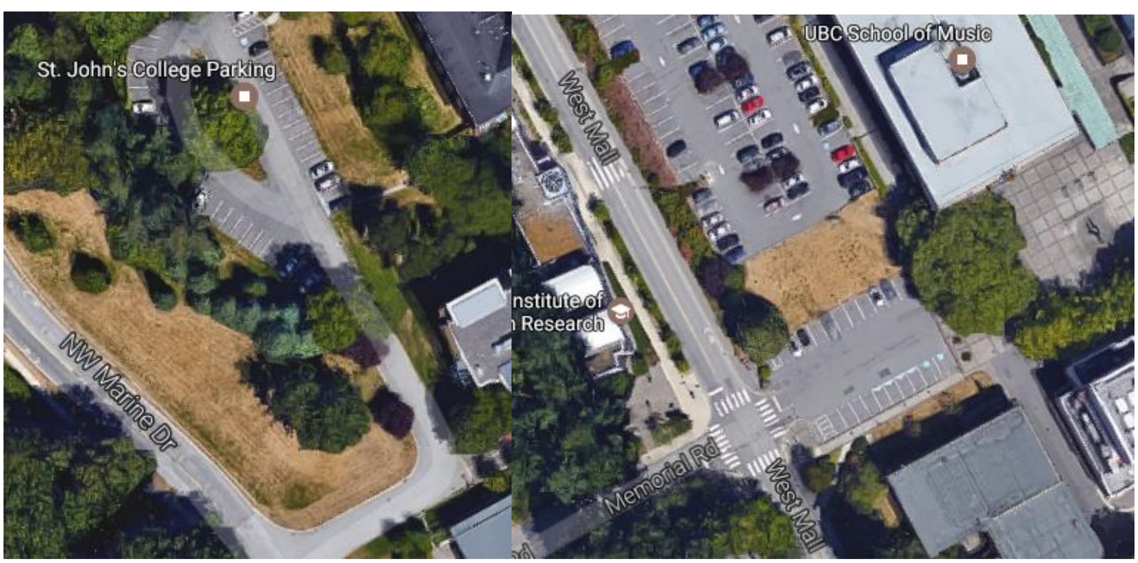


Figure 25: Storage Locations Projects 1-3 (Crew A)

During construction activities these areas will be closed to public access which will allow for excavated materials to be piled adjacent to the excavation location until they can be loaded into the dump trucks. One excavator will be digging the trenches for the storage loops while the second excavator loads the materials on to the trucks for hauling. Materials brought in for the pipe foundations and installation will share the same areas.

The installation of the pipe itself will require one or both excavators (depending on pipe segment lengths) to lift and place the pipe in the trenches as the pipe labourers aid in alignment and placement. After placement the labourers will follow standard compaction techniques to prepare the ground for repaving conditions. In areas affected that do not have pavement, crew A will restore the conditions to the pre-existing conditions they arrived to. Crew A will then move on to the next sub-project location and a paving crew will come in to finish of the restoration of roads and parking lot surfaces.

10.1.2 Crew B

Crew be will be assigned projects 4-6, two of which are corrugated metal pipe installations (projects 4 and 5) and the other being a concrete chamber (project 6 – Student Union Building). Crew B will be identical to Crew A: 9 members (two excavators and operators, one surveyor, two dump trucks and drivers, three laborers and one foreman). Project 4, Chancellor Boulevard, will use the same technique of trenching with materials being piled adjacent to the excavation; the installation is in the center median, and thus the road and road shoulder can be used for storage.

Figure 26: Storage Location Project 4 (Chancellor Boulevard)

This project is a standard pipe installation and the area will be fully restored to functioning state before Crew B will move on to projects 5 and 6.

Projects 5 and 6 are located in close proximity to one another, which is next to a large pedestrian only area. This area has plenty of room for the contractor to use for storage and set up, thus they will have some leeway deciding how they want to make use of the available area.

Figure 27: Storage Location Projects 5 & 6 (Student Union Blvd and Student Union Building)

Project 5 is another corrugated metal pipe installation, and it will use the same trenching technique as projects 1-4.

Project 6 is the first of the concrete chamber installations (3 total, 2 on project 7). Given that the crew has two excavators at its disposal, installation of project 6 will not require additional crew. The chamber here is 30m x 18m x 2.4m, meaning a hole of just over 540 square meters will be dug to a depth of about 2.7 meters. This excavation is significant but simple access from existing roads will allow dump truck drivers to efficiently move unwanted materials off site. Once excavation is complete the framework for the cast in place chamber will be built. The chamber construction will be similar to that of a single-storey apartment using slabs, beams, columns and walls. The details can be found in section 5 of this report. The concrete will need to sit for 28 days before inspection can occur, in which time the connections to the existing storm water system will be prepared and installed. Once inspected and approved the system will be completed and the site restoration will commence.

10.1.3 Cecil Green Park

Project 7 will see both Crew A and Crew B in a joint effort for installation. There will be a 1500 cubic meter concrete chamber (chamber A) and a 2900 cubic meter concrete chamber (chamber B) installed at this location. Chamber A has storage space to the south while chamber B has storage space to the east; across the parking lot to the east of chamber B is a large field which can be used for storage if the adjacent areas are insufficient.

Figure 28: Storage Location Project 7

Both chambers A and B will be cast in place operations (details can be found in section 5 of this report), with similar work procedures as project 6. The plan is to have Crew A work on chamber A, and Crew B work on chamber B. It is expected that chamber A will reach the cast in place stage before chamber B, thus during the 28 day curing period Crew A will join and aid Crew B. After the curing period is complete, and the chamber has passed inspection, the respective crew will connect it to the existing system and restore the area to the initial conditions.

10.2 Anticipated Construction Issues

Projects 1 through 5 all have similar site conditions with the regular expected construction issues. Some of the regular issues include traffic disturbances, weather delays, unknown locations for existing utilities, permitting, and site access. All of these issues are commonly encountered and the fact that the project is on UBC property actually eases the efforts to mitigate the issues; T20 Consultants has left the details of mitigation for the contractor to decipher. Project 6 has a few key interest construction issues which needed to be addressed. The issues lie within the deep excavation, the site deliveries, and the temporary loss of parking for Cecil Green residents.

10.2.1 Deep Excavation

The deep excavation is going to be performed with limited working space. Due to the space limits and total depth of the excavation it will be necessary to use sheet piles and anchors to prevent collapse of the excavated walls. T20 Consultants designed sheet piles with a single supporting anchor for this project. Sheet piles were chosen as they are economical, and are standard practice for the sites geology. The sheet piles were designed for an excavation of 6m. The piles will be 10m in length and have a single steel bar anchor at a depth of 2m. The anchor will have an unbounded length of 3.26m, a bonded length of 0.6m, and be spaced at 1.2m intervals. Sample calculations can be found in Appendix F. Post-completion the sheet piles can be removed and salvaged, however the anchors will be left in place because it is cheaper to leave them installed and they will still provided some extra stability for the area.

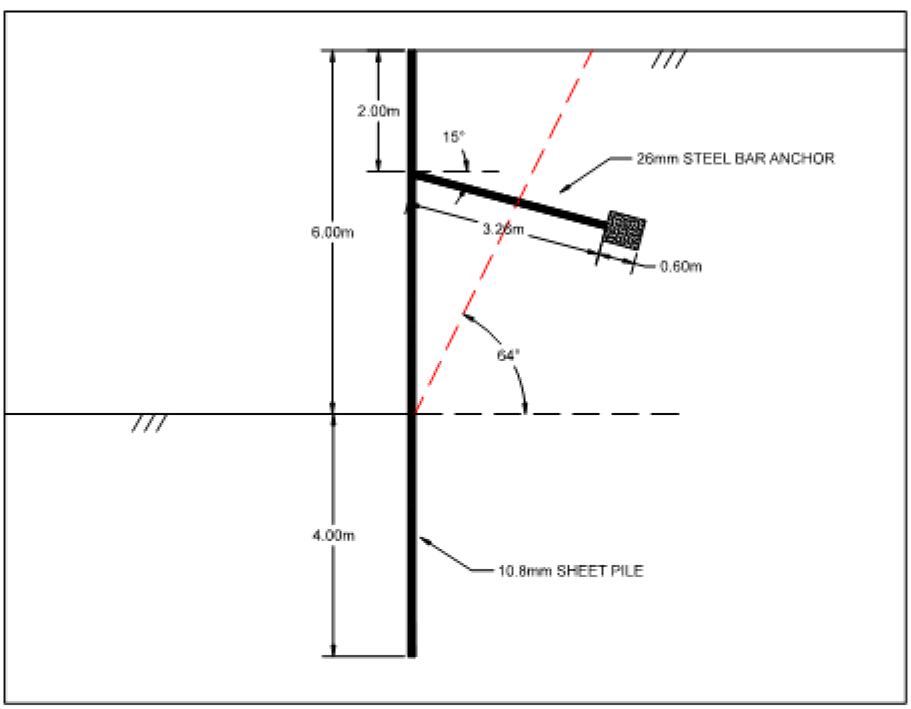


Figure 29: Sheet Pile Design

10.2.2 Museum Deliveries

The Museum of Anthropology will be affected by the construction work for chamber B; the prescribed working area will make deliveries to the museum difficult. In order to manage the issue T20 Consultants has been in contact with the Museum of Anthropology and have discussed the means of coordination between the museum delivery schedule and contractor work schedule. The museum will notify the construction crew as early as possible of when deliveries are expected and approximately how long they will take, sharing as much knowledge as they can in order to allow the crew to adequately prepare.

Figure 30: Delivery Site and Work Area

10.2.3 Temporary Parking

The final major issue to address is the temporary loss of parking. The total amount of parking spaces that will be needed once construction begins is not known, however it is recommended that the contractor builds temporary parking spaces in the green space across from the UBC Rose Gardens. This area is suitable for temporary works since it will only require re-grading and a grass finish to remedy back to pre-construction conditions.

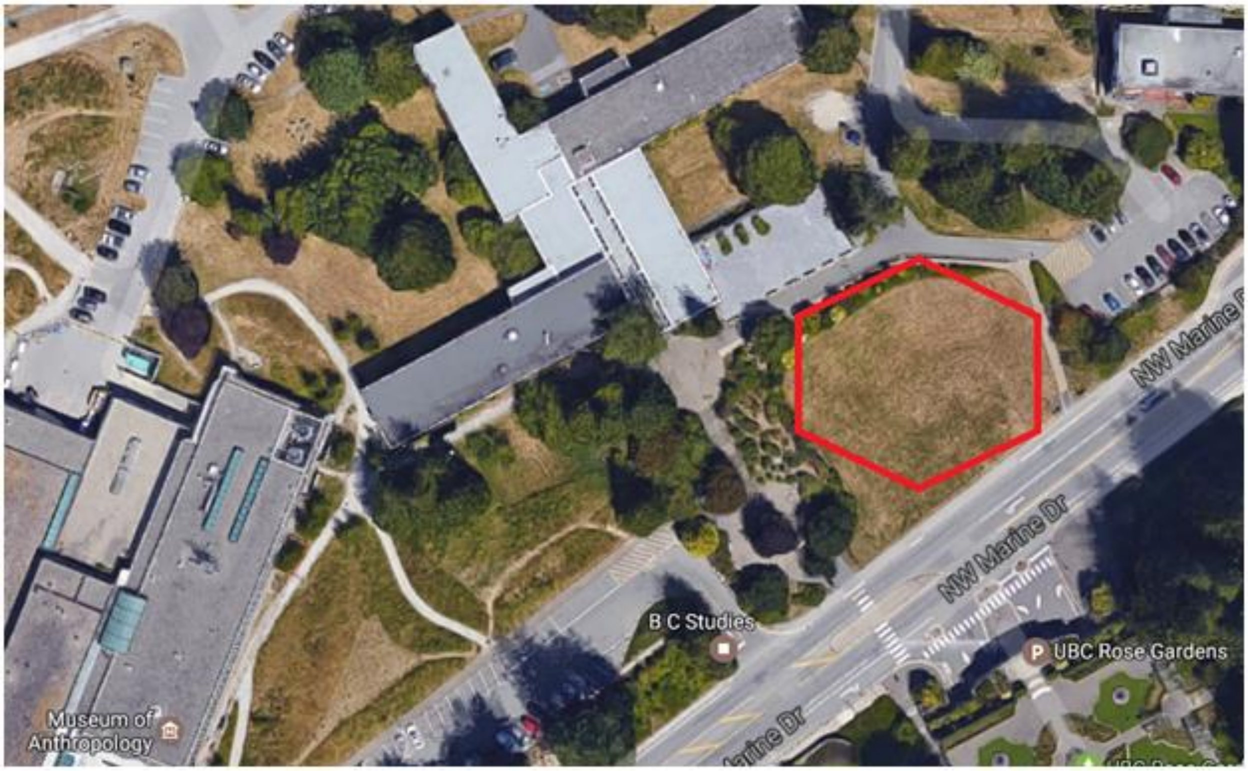


Figure 31: Temporary Parking Area

11.0 Project Schedule

The north catchment storm sewer redevelopment project is composed of storm water management installations at seven locations across the northern UBC Vancouver Campus. The different project components have been scheduled based on completion priority and convenience for efficiency. The work has been split by two crews who will work separately until reaching the final phase where they will work in tandem to wrap up the project. Additional crews could be employed to streamline the main schedule, though this scenario could limit the number of companies capable of bidding on and completing the project. With construction set to begin on May 1st, 2017, and completion scheduled for April 10th, 2018, we believe that the two crew schedule is sufficient for the size and scope of the project.

11.1 Key Constraints and Considerations

When developing the preliminary schedule, there were several key constraints that were considered. A major factor was disruption to roadways, and the significance of the affected areas. Main roads, arterial ways and isolated parking areas were considered a high priority for construction during the summer months, to minimize disruption to UBC's regular operation. The expected flow rates for sewer lines were also considered. Work that required disabling of sewer trunks for extended periods was also considered a high priority for summer months. The lowest priority projects were those which did not cause major disruptions and could be completed without severing sewer lines for more than one week.

11.2 Sub-Project Preliminary Order, Estimated Durations and Gantt Charts

This section will outline the preliminary order of sub-projects, list their expected durations, and display the outlined schedule in a summarized Gantt chart. A detailed Gantt chart for one sub-project is also provided as an example of common tasks and semi-scalable durations to be expected for each subproject. Justification of the ordering is also provided with an outline of the highest priority projects.

11.2.1 Overall Schedule and Sample Task List

This section provides figures outlining segments from the overall schedule Gantt chart. The complete task list and Gantt chart is available in Appendix D.

Task Name	Duration	Start	Finish
NW Marine Drive (CMP)	26 days	Mon 5/1/17	Mon 6/5/17
Chancellor Blvd (CMP)	62 days	Mon 5/1/17	Tue 7/25/17
Memorial Rd (CMP)	37 days	Tue 6/6/17	Wed 7/26/17
School of Music (CMP)	43 days	Thu 7/27/17	Mon 9/25/17
Student Union Blvd (CHAMBER)	44 days	Wed 7/26/17	Mon 9/25/17
Student Union Blvd (CMP)	18 days	Wed 8/16/17	Fri 9/8/17
Cecil Green Park (CHAMBERS)	141 days	Tue 9/26/17	Tue 4/10/18

Figure 32: North catchment redevelopment and sub-project order, durations, and start/finish

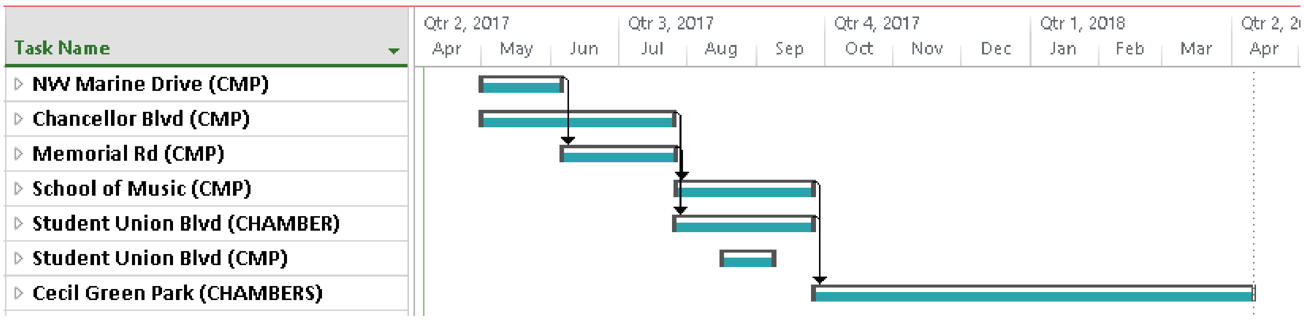


Figure 33: North catchment redevelopment sub-project summary Gantt chart

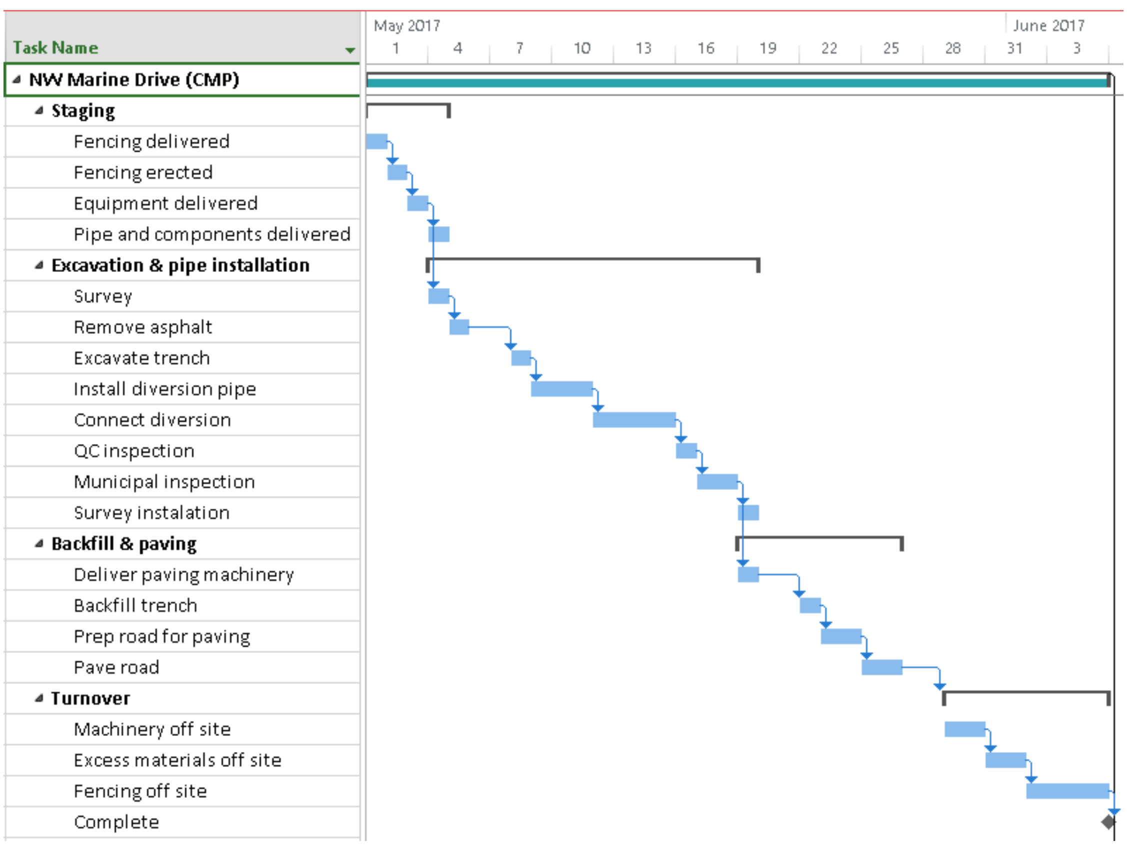


Figure 34: NW Marine Drive Gantt chart schedule

11.2.2 Individual Project Priority Justification

The following projects were deemed to be the highest priority due mainly to traffic disruptions and the need to sever sewer lines that can have high flows during rainy seasons. For these reasons, it is important that these projects be completed during the summer months when traffic and rainfall are at their lowest. Rainfall events when sewer lines have been severed will likely lead to costly work stoppages that will also delay the project’s completion. Projects not listed here can be completed during the school months without heavily disrupting the University’s typical operations.

11.2.2.1 NW Marine Drive

This project was determined to be high priority because it requires disruption to the regular use of NW Marine drive , and parking access to the St. John's College. With an estimated completion time of 26 days, this project is the second shortest duration and can be completed rapidly before moving the crew to the next project. NW Marine drive see more traffic during the school year, and thus it is ideal to complete this project in the summer months.

11.2.2.2 Chancellor Boulevard

As one of the largest, most disruptive projects, this storage loop is considered to be a very high priority. This project will decommission one lane of Chancellor boulevard for just over two months and a main storm sewer line for roughly 50 days. Due to these constraints, the completion of this project during summer months is essential for both weather and traffic. Large rain events when the main sewer trunk has been severed will have the potential to stop work and impede the schedule for many days.

12.0 Cost Estimate

A detailed Class "C" cost estimate has been performed for this project. The total construction cost for this project is estimated at $2.4 Million (CAD) and the total cost including all contingencies and profit is $3.3 Million (CAD). Quantities of material, equipment and labor have been taken from detailed design calculations and entered into estimate quantity take off sheets (see Appendix C for full estimate quantity take offs). The RS Means Building Construction Cost Data (2006) textbook has been used to get cost unit rates for all quantities involved. As data in this textbook applies to 2006 – American National Average costs two separate indexes which were taken from present RS Means data have been used to adjust to present Vancouver costs. The 2006 to 2016 transfer index was 1.366 and the National Average to Vancouver transfer index was 1.051 for a total multiplier of 1.436 compared to data in the textbook. This multiplier was applied to all values obtained to get the detailed estimate for this project. Table 9 below provides a project by project breakdown of the construction costs and a sum of all construction costs involved.

Table 9: Construction cost breakdown

Project Description	Project Total Construction Cost
Memorial Rd (120 m^3 Storage)	$66,007
Walter Gage Rd (65 m^3 Storage)	$44,000
NW Marine Drive (200 m^3 Storage)	$125,151
Cecil Green Park Rd (1500 m^3 Storage)	$269,681
Cecil Green Park Rd (2900 m^3 Storage)	$508,897
Chancellor BLVD (1670 m^3 Storage)	$918,942
School of Music (30 m^3 Storage)	$31,371
Bus Loop (900 m^3 Storage)	$451,038
Total Construction Cost	**$2,415,087**

To arrive at a final estimate cost several contingency percentages needed to be added on to the total construction cost estimate. Table 10 below highlights the list of these contingencies, their associated percentages and costs, and a final cost estimate for the project.

Table 10: Final cost estimate

Description	Percentage	Cost
Total Construction Cost		**$2,415,087**
Overhead and Profit	20.0%	**$483,017**
Permitting	1.00%	**$24,151**
Final Working Drawing Contingency	3.00%	**$72,453**
Construction Management	3.00%	**$72,453**
Engineering (Mechanical)	4.20%	**$101,434**
Engineering (Geotechnical)	2.50%	**$60,377**
Clean up (After Job Completion)	0.30%	**$7,245**
Insurance (Minimum Risk)	0.22%	**$5,313**
Annual Maintenance	2.00%	**$48,302**
Total Cost Including Overhead, Profit, and Contingencies		**$3,289,832**

13.0 Future considerations and Conclusion

This section will outline T20 Consultants future considerations for the area and our conclusion to this report.

13.1 Future Considerations

The design has been made such that it will extend the usable life of the spiral drain, and this section outlines some considerations to make as the end of the spiral drain's usable life approaches.

13.1.1 Future Land Use

The UBC campus is constantly undergoing both new development and redevelopment of the land it uses. In GeoAdvice's document "UBC Stormwater Model Analysis, Detention Analysis and System Optimization" the total impervious area of development by 2030 is estimated to be 115 hectares; approximately 30 hectares of this total is within the north catchment area of campus. Although this is a significant area, only a small portion located between Lower Mall and Marine Drive will see a significant increase in storm water flow; this area will have storm water solutions installed upon development. The future land use within the north catchment area will not significantly increase demand on the storm water system. The campus will not see flooding issues due to future developments by 2030 with this design.

13.1.2 Projected Impact on Storm System

The solution of a series of storage contraptions across campus will alleviate the flooding threat from a serious storm hitting UBC. The storage capacity that has been designed is large enough to take on average expected rainfall with ease. A 200-year storm will cause the new system to reach capacity, however there is a mere 0.5% chance of this occurring in any given year. Even as the development plans of 2030 are built, our system will serve to limit the 200-year storm to very minimal flooding, enough to prevent any serious damages to the campus lands. Currently the spiral drain has been evaluated to have a service life of at least 50 years. The addition of the detention systems will limit the instantaneous loads on the drain and extend the service life to at least 75 years. The spiral drain is a unique piece of heritage infrastructure; thus, the extension of its life is historically cherished and valuable.

13.1.3 Expected Usable Life Span

Underground concrete water tanks, with proper maintenance, have an indefinitely long service life. The kinetic load is one of the largest threats to the erosion of concrete but this load is very minimal inside the tanks. Since the addition of these tanks will help prolong the life of the spiral drain, the design does not incorporate a direct replacement; we recommend installing a vortex drain in parallel with the spiral drain within the next 75 years. This kind of remedy would be designed such that the spiral drain would be eased of most of its loads, thus significantly increasing the service life. The design for a parallel vortex drain would contain heavy considerations with respect to keeping the spiral drain in service while minimizing its load.

13.2 Conclusion

In order to meet the extreme demands of a 200-year rainfall event, UBC's north catchment drainage system needs significant upgrades in key areas. Over 9000 m^3 of potential flood loss has been accounted for in the design. The system's current drainage takes place through one outfall, a spiral drain at the northern perimeter of the campus. The drainage rate of the entire system is limited by this outfall, as well as specific flow rate capacities of pipe in high flow regions. T20 Consultants have prepared a design that contains excess stormwater on site, rather than construct any additional outflow infrastructure near the environmentally sensitive cliffs of Pacific Spirit Park. The design employs low impact principles in using storage loops of pipe to relocate flooding waters and puddles into the stormwater system's excess volumetric storage. The goal of this approach is to reduce the volumetric flow rate of stormwater delivered to the ocean through the spiral drain, and to prevent property damage in major rainfall events. This will extend the usable life of the spiral drain while also reducing the environmental impacts related to expelled sediment and other pollutants potentially carried by stormwater. Bio-retention basins were researched however in the north catchment zone the required storage upgrades are too large to be satisfied with bio-retention methods given the limited working space; subsurface storage loops with significantly larger storage capacities have been designed. This preliminary design has focused on storage loops made of regular pipes and large storage containers in the form of simple prefabricated concrete chambers.

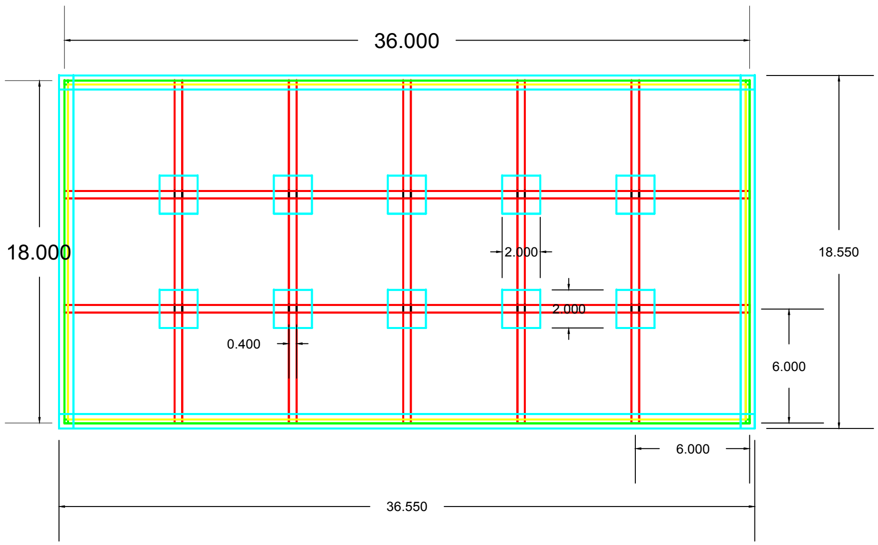
The overall project has been divided into 6 sub-projects that will be completed independently. Certain projects are considered high-priority for completion during summer months, when traffic and rainfall are minimal, while others were deemed constructible any time of year. The preliminary schedule was constructed under the assumption that two separate crews would work simultaneously on the various sub-projects during regular business hours. The addition of overtime hours, more crews, or a combination of the two, could be employed to expedite construction at additional cost. The project has a start date of May 1, 2017 and a preliminary completion date in April, 2018.

For this Detailed design the total anticipated cost was $3.3 Million. A quantity takeoff approach was utilized, using data from RS Means. Recommended percentages were included in the final estimate for items such as permitting, project management, and contingency funding.

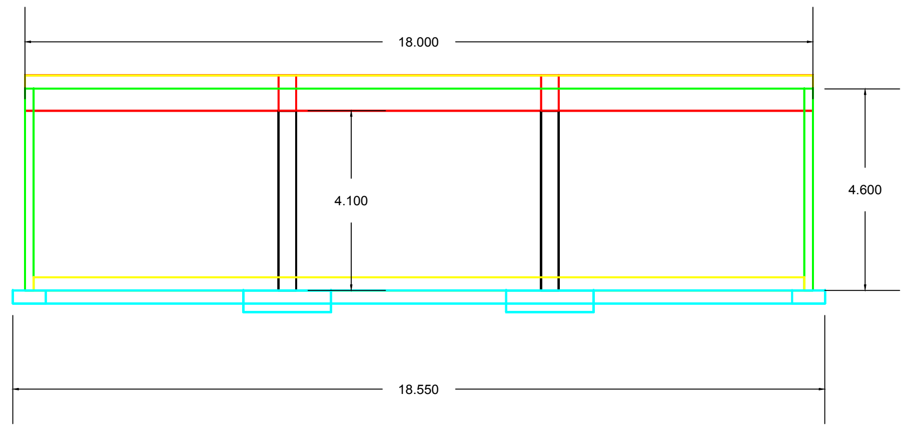
Based on future land use projections, the proposed design will sufficiently service UBC's north catchment for the duration of the spiral drain's serviceable life.

Appendix A – Design Drawings

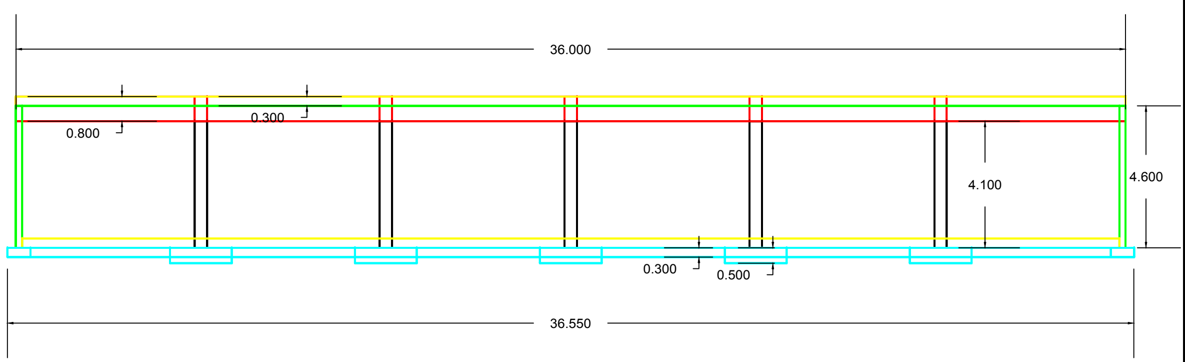
Plan View



Profile View 1



Profile View 2



LEGEND

- Beams (red)
- Columns (black)
- Footings (cyan)
- Slabs (yellow)
- Walls (green)

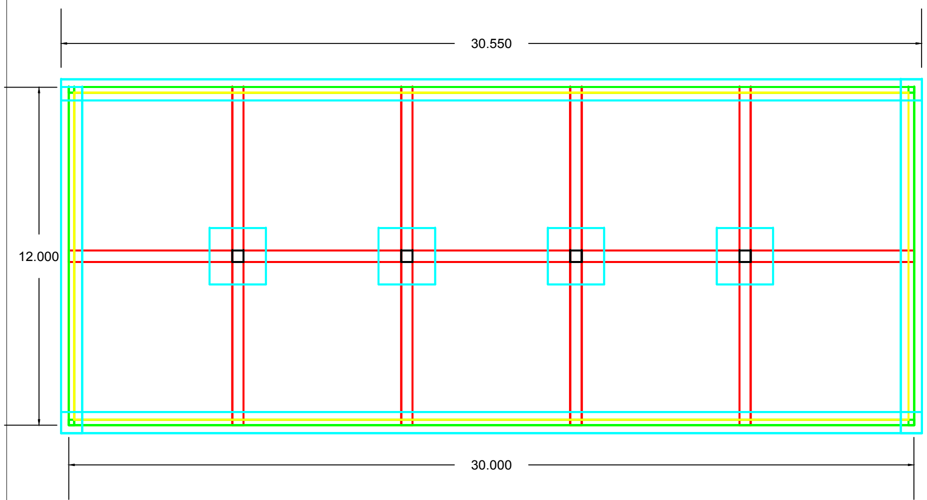
Tank 1 - Structural Drawings

Designed by: Neil Courtney
Drawn by: Neil Courtney
April 3rd, 2017

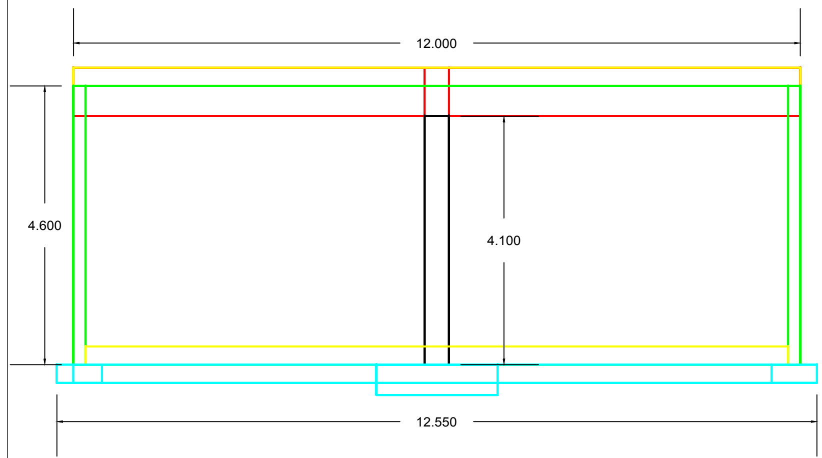
Drawing Notes

1. All drawing dimension in meters
2. See structural details page for reinforcement details
3. Drawings not to scale

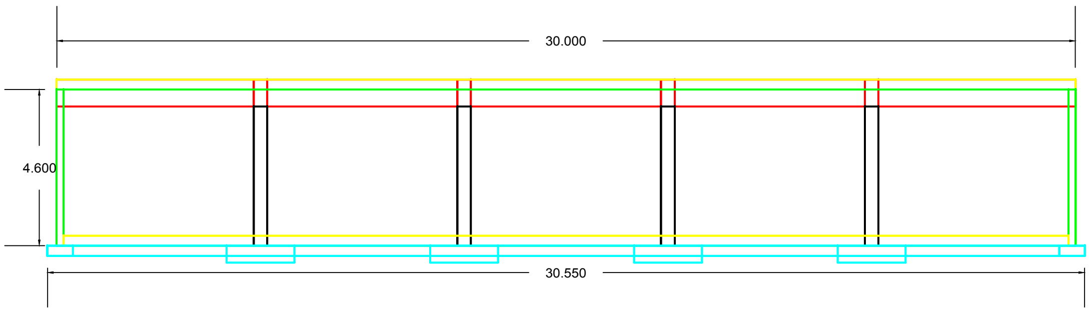
Plan View



Profile View 1



Profile View 2

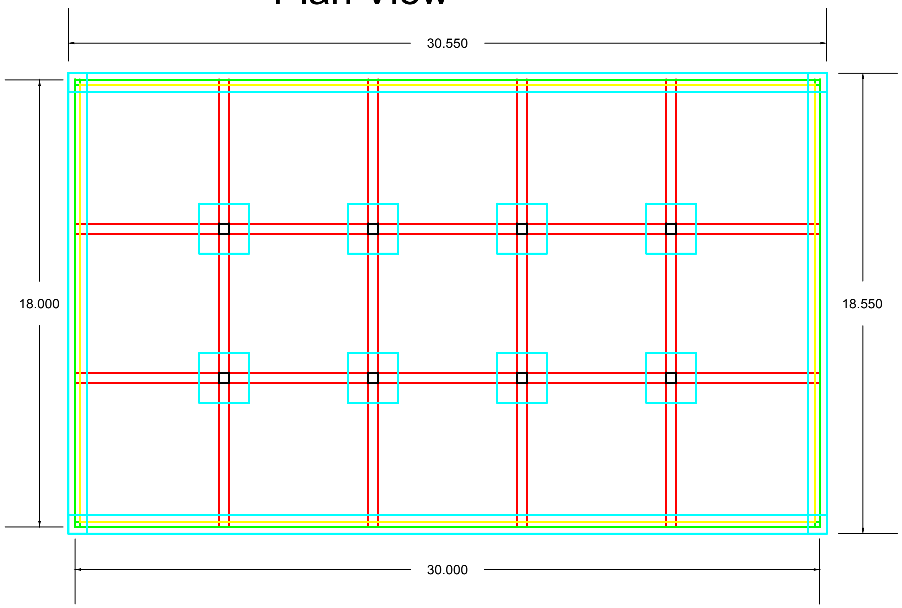


LEGEND	Tank 2 - Structural Drawings
Beams Columns Footings Slabs Walls	Designed by: Neil Courtney Drawn by: Neil Courtney April 3rd, 2017

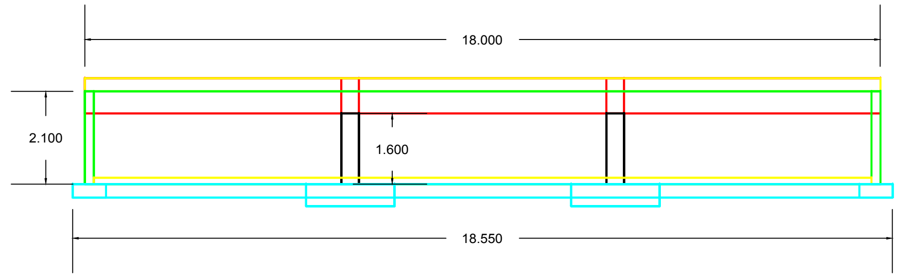
Drawing Notes

1. All drawing dimension in meters
2. See structural details page for reinforcement details
3. Drawings not to scale

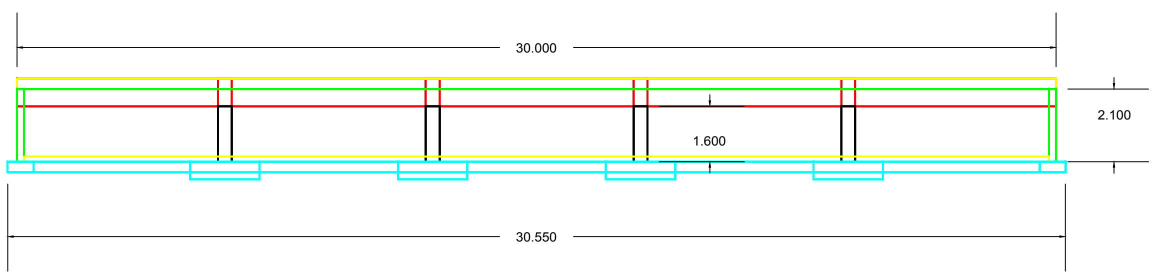
Plan View



Profile View 1



Profile View 2



LEGEND

- Beams (red)
- Columns (black)
- Footings (cyan)
- Slabs (yellow)
- Walls (green)

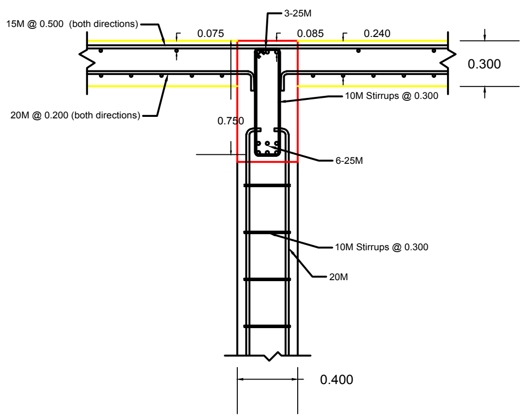
Tank 3 - Structural Drawings

Designed by: Neil Courtney
Drawn by: Neil Courtney
April 3rd, 2017

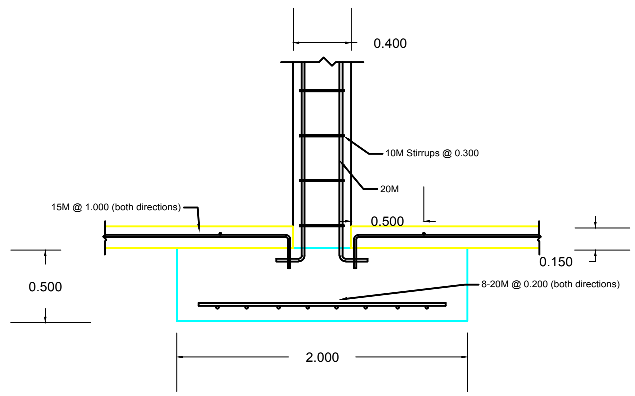
Drawing Notes

1. All drawing dimension in meters
2. See structural details page for reinforcement details
3. Drawings not to scale

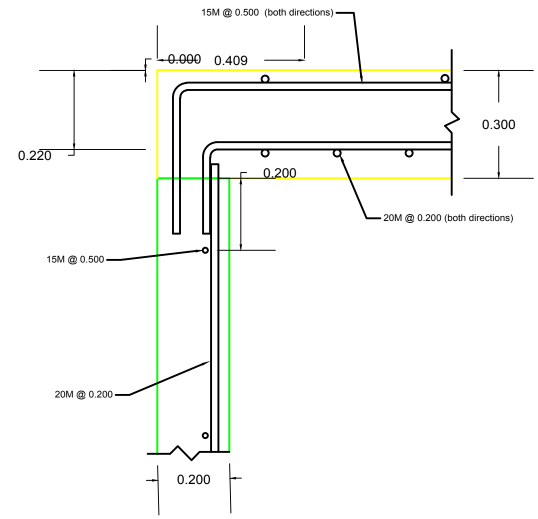
Slab - Beam - Column Conection



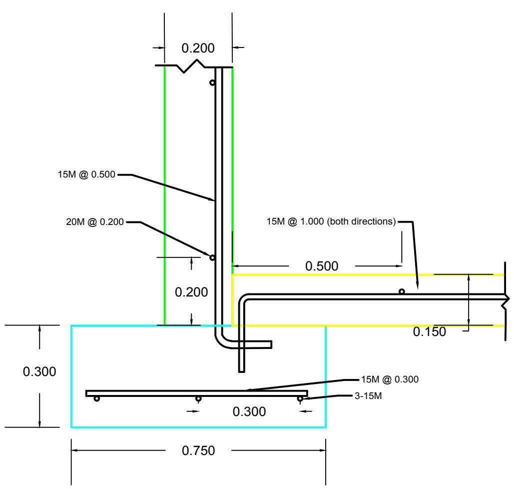
Column - Pad Footing Connection



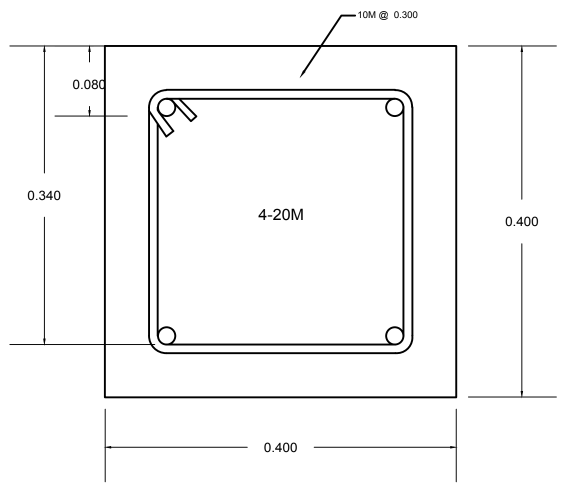
Slab - Wall Connection



Wall - Strip Footing Connection



Column Cross Section



LEGEND

- Beams
- Columns
- Footings
- Slabs
- Walls

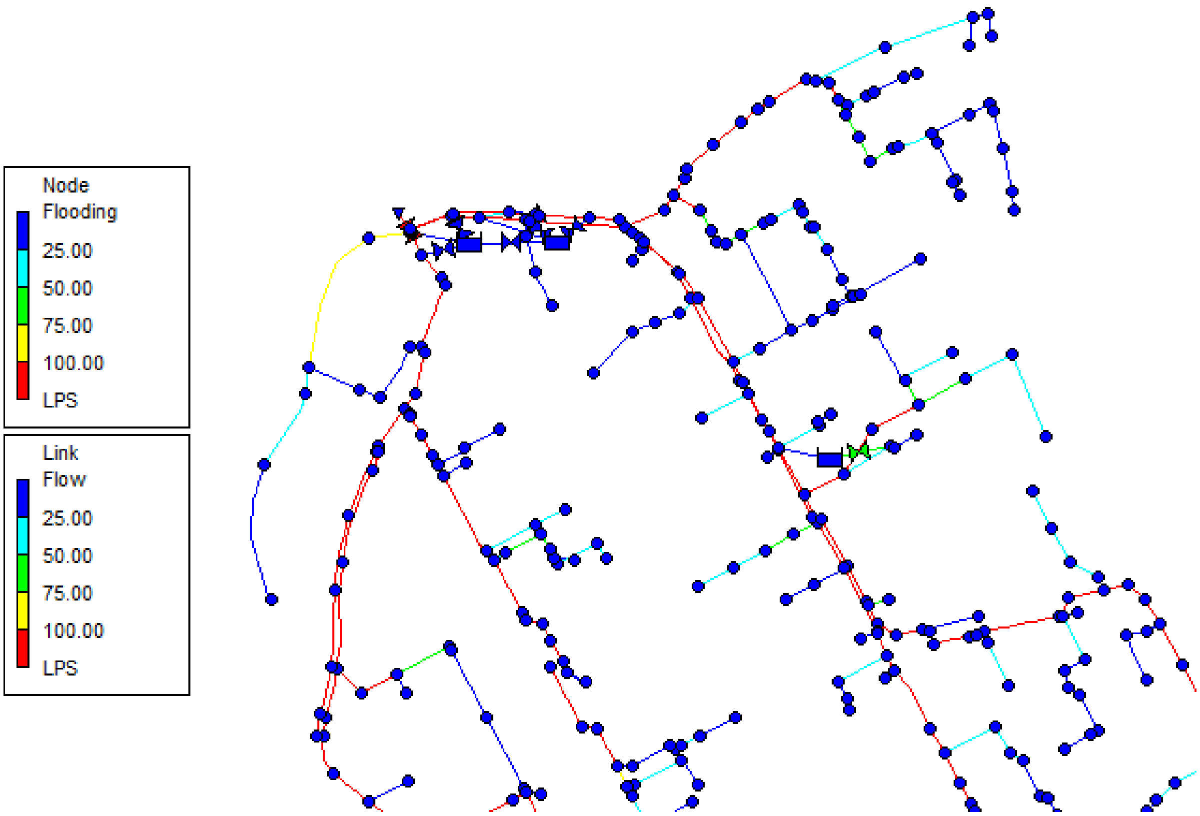
Tank Reinforcement Details

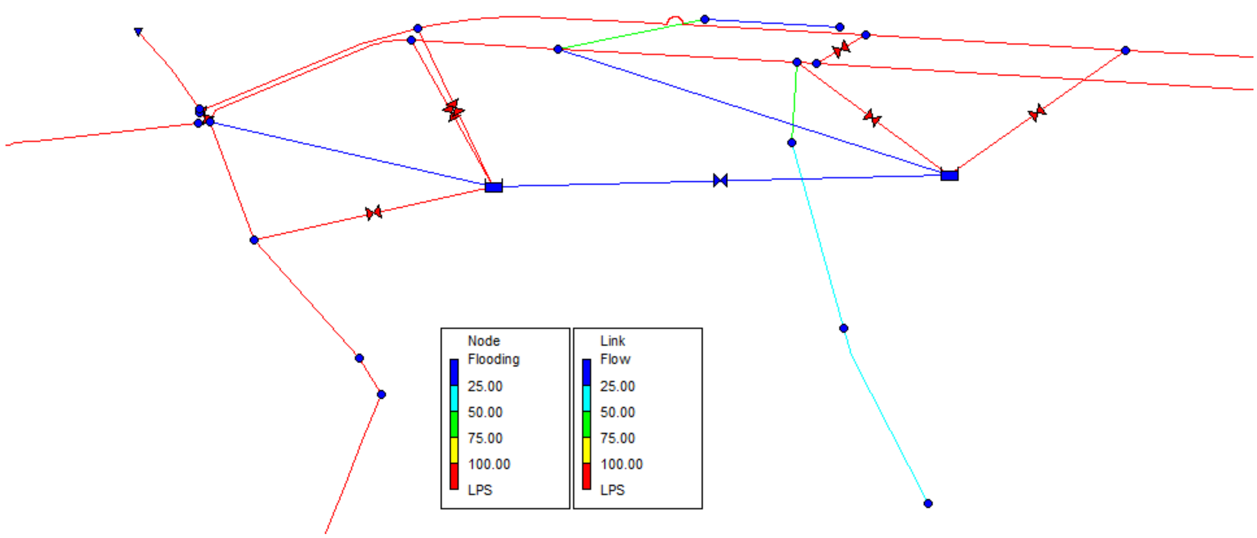
Designed by: Neil Courtney
Drawn by: Neil Courtney
April 3rd, 2017

Drawing Notes

1. All drawing dimension in meters unless otherwise noted
2. Drawings not to scale

Appendix B – Stormwater Modelling Data





EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.007)

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****

NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.

****

****

Analysis Options

****

Flow Units .... LPS
Process Models:
  Rainfall/Runoff .... YES
  RDII .... NO
  Snowmelt .... NO
  Groundwater .... NO
  Flow Routing .... YES
  Ponding Allowed .... YES
  Water Quality .... NO
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... DYNWAVE
Starting Date NOV-01-2008 00:00:00
Ending Date NOV-02-2008 00:00:00
Antecedent Dry Days 0.5
Report Time Step 00:15:00
Wet Time Step 00:15:00
Dry Time Step 00:15:00
Routing Time Step .... 15.00 sec
Variable Time Step .... YES
Maximum Trials 8
Head Tolerance .... 0.016404 m

**************************	Volume	Depth
Runoff Quantity Continuity	hectare-m	mm
**************************	---------	-------
Total Precipitation	46.025	112.650
Evaporation Loss	0.000	0.000
Infiltration Loss	11.087	27.136
Surface Runoff	32.600	79.792
Final Surface Storage	2.468	6.041
Continuity Error (%)	-0.283	

**************************	Volume	Volume
Flow Routing Continuity	hectare-m	10^6 ltr
**************************	---------	---------
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	32.326	323.263
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	1.799	17.990
External Outflow	33.544	335.441
Internal Outflow	0.804	8.043

Evaporation Loss 0.000 0.000
Exfiltration Loss 0.000 0.000
Initial Stored Volume 0.074 0.737
Final Stored Volume 0.592 5.920
Continuity Error (%) ..... -2.168
****

Highest Continuity Errors
****

Node JUNC-40 (-22.05%)
Node Q7D-S271 (-4.90%)
Node USL-78 (-1.31%)
Node D6D-N70 (-1.15%)
Node O8D-S219D (1.05%)
****

Time-Step Critical Elements
****

Link A4D-N1X (82.45%)
Link T6D-S24X (6.46%)
Link ST-2215 (4.29%)
****

Highest Flow Instability Indexes
****

Link P7D-S242AX (39)
Link ST-3096 (37)
Link CO-209 (29)
Link N8D-S265AX (26)
Link O8D-S221X (23)
****

Routing Time Step Summary
****

Minimum Time Step : 0.50 sec
Average Time Step : 2.66 sec
Maximum Time Step : 15.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 3.71
Percent Not Converging : 17.77
****

Analysis begun on: Wed Apr 05 21:10:08 2017
Analysis ended on: Wed Apr 05 21:12:01 2017
Total elapsed time: 00:01:53

Node Flooding Summary of Results

Node	Flooded	LPS	Flooding	Flooding	10^6 ltr	Meters
A4D-N1	0.01	41.07	0	9:15	0	0
A4D-N2	0.01	546.09	0	8:19	0.001	0
B5D-N82A	0.01	193.41	0	8:20	0	0
B5D-N82B	0.01	123.49	0	8:20	0	0
C5D-N88	0.01	16.17	0	8:17	0	0
D3D-N32	0.01	0.32	0	8:27	0	0
D3D-N33	0.15	31.94	0	8:30	0.009	0
D4D-N31A	0.27	8.01	0	8:30	0.006	0
D4D-N31B	0.16	5.39	0	8:30	0.002	0
D6D-N70	0.48	414.52	0	8:30	0.457	0
D7D-N108	0.01	19.24	0	8:13	0	0
E6D-N73A	0.44	63.99	0	8:30	0.062	0
E7D-N108.	1.01	43.51	0	8:30	0.071	0
E7D-N115I	0.17	6.59	0	8:29	0.002	0
F2D-N30	0.01	1.36	0	8:18	0	0
F2D-N30A	0.49	79.3	0	8:30	0.083	0
F5D-N77B	0.13	5.19	0	8:30	0.001	0
F6D-N76	0.28	110.9	0	8:31	0.064	0
F6D-N86	0.14	47.51	0	8:31	0.011	0
G3D-N56A	0.3	28.54	0	8:30	0.017	0
G3D-N58	0.32	34.09	0	8:30	0.022	0
G3D-N58B	0.01	0.28	0	8:30	0	0
G5D-N81H	0.01	0.11	0	8:31	0	0
G7D-N119	0.01	34.54	0	8:18	0	0
G7D-N120	0.01	114.61	0	8:18	0	0
H3D-N56B	0.07	2.13	0	8:30	0	0
J5D-NW29	0.05	5.57	0	8:29	0	0
J6D-N127E	1.15	35.51	0	8:30	0.06	0
J6D-NW12	0.44	11.54	0	8:30	0.01	0
J9D-S291I	0.27	12.24	0	8:29	0.007	0
J9D-S291N	0.01	0.59	0	8:18	0	0
J9D-S291C	0.2	18.51	0	8:30	0.007	0
JUNC-10	0.03	1.03	0	8:31	0	0
JUNC-19	0.75	81.86	0	8:30	0.112	0
JUNC-34	0.57	5.55	0	8:24	0.01	0
JUNC-40	0.01	2100.92	0	9:27	0.014	0
JUNC-41	0.64	483.89	0	8:20	0.389	0
K8D-S289	0.14	29.34	0	8:16	0.001	0
L8D-S282	0.01	500.45	0	8:16	0.012	0
L8D-S286	0.46	150.78	0	8:29	0.172	0
L9D-S285A	0.01	1.49	0	8:16	0	0
L9D-S285C	0.46	33.59	0	8:29	0.034	0
L9D-S285D	0.16	2.15	0	8:30	0	0
M6D-S276	0.54	52.32	0	8:30	0.056	0
MD-Culve	1.25	689.08	0	8:42	1.649	0
MH-D5	0.68	192.04	0	8:30	0.355	0
N7D-S275	1.11	103.9	0	8:30	0.23	0
N8D-S265	1.63	384.14	0	8:30	0.944	0
N8D-S265.	0.01	13.01	0	8:05	0	0
S8D-S208	0.32	239.04	0	8:31	0.18	0
T6D-S24	1.18	1434.08	0	8:41	2.868	0

Appendix C – Cost Estimate Take-Offs

Project: Memorial Rd (120m^3 Storage)
Date: April 6th, 2017
Estimator: Neil Courtney

Cost Estimate - Quantity Take-Offs

Item #	Cost Code	Description	QUANTITY TAKEOFF: No of Pieces	Length (meters)	Length (feet)	Width (meters)	Width (feet)	Depth / Height (meters)	Depth / Height (feet)	Sub-Total	Total Quantity (metric)	Units	Total Quantity (Imperial)	Units
1	02315 610 0910	Excavating, Trench (10' to 14' deep, 1 C.Y. Hydraulic backhoe)		24	78.72	4	13.12	3	9.84		288	m^3	376.69	B.C.Y.
2	02315 610 0910	Excavating, Trench (6' to 10' deep, 1 C.Y. Hydraulic backhoe)		8	26.24	1.5	4.92	2	6.56		24	m^3	31.39	B.C.Y.
3	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									85	m^3	138.97	L.C.Y.
4	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									85	m^3	138.97	L.C.Y.
5	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									85	m^3	138.97	L.C.Y.
6	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel		24	78.72	4	13.12	0.3	0.984		28.8	m^3	37.67	B.C.Y.
7	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel		8	26.24	1.5	4.92	0.3	0.984		3.6	m^3	4.71	B.C.Y.
8	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel		10	32.8	4	13.12	2	6.56		80	m^3	104.64	B.C.Y.
9	02315 640 0200	Utility Bedding For Pipe and Conduit, Sand		8	26.24	1.5	4.92	0.2	0.656		2.4	m^3	3.14	B.C.Y.
10	02740 310 0200	Asphaltic Concrete Pavement, Binder Course, 4" Thick		20	65.6	6	19.68	0.12	0.3936		120	m^2	143.52	S.Y.
11	02740 310 0460	Asphaltic Concrete Pavement, Wearing Course, 3" Thick		20	65.6	6	19.68	0.08	0.2624		120	m^2	143.52	S.Y.
12	02360 510 2660	Piping, reinforced Culvert, class 3, no gaskets, 72" Diameter	2	20	65.6		0		0		40	m	131.2	L.F.
13	02510 750 3070	Polyvinyl Chloride Pipe, 24" diameter		10	32.8						10	m	32.8	L.F.
14	01560 250 0550	Temporary Fencing Wire Mesh, 8' high		55	180.4						55	m	180.4	L.F.

Item #	METHOD: Crew Code	Crew Size	Daily Output (Units/day)	Worker-Hours (WHr/Unit)	Duration (days)	Total Worker-Hours	MATERIAL: Unit Cost	Total Cost	LABOR: Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost	EQUIPMENT: Unit Cost	Cost	TOTAL BARE COST: Total Unit Cost ($/Units)	Total Cost
1	B-12A	2	360	0.044	1.05	16.57	$ -	$ -	$30.77	$ 1.37	$ 516.06	$ 1.56	$ 587.64	$ 2.93	$ 1,103.70
2	B-12A	2	400	0.040	0.08	1.26	$ -	$ -	$30.77	$ 1.23	$ 38.61	$ 1.40	$ 43.95	$ 2.63	$ 82.56
3	B-34D	1	78	0.103	1.78	14.31	$ -	$ -	$28.90	$ 2.96	$ 411.35	$ 5.35	$ 743.49	$ 8.31	$ 1,154.84
4	B-34D	1	78	0.103	1.78	14.31	$ -	$ -	$28.90	$ 2.96	$ 411.35	$ 5.35	$ 743.49	$ 8.31	$ 1,154.84
5	B-34D	1	78	0.103	1.78	14.31	$ -	$ -	$28.90	$ 2.96	$ 411.35	$ 5.35	$ 743.49	$ 8.31	$ 1,154.84
6	B-10B	1.5	1000	0.012	0.04	0.45	$ 12.05	$ 453.91	$31.93	$ 0.38	$ 14.31	$ 0.92	$ 34.66	$ 13.35	$ 502.88
7	B-10B	1.5	1000	0.012	0.00	0.06	$ 12.05	$ 56.74	$31.93	$ 0.38	$ 1.79	$ 0.92	$ 4.33	$ 13.35	$ 62.86
8	B-10B	1.5	1000	0.012	0.10	1.26	$ 12.05	$ 1,260.86	$31.93	$ 0.38	$ 39.76	$ 0.92	$ 96.27	$ 13.35	$ 1,396.89
9	B-6	3	150	0.160	0.02	0.50	$ 4.21	$ 13.22	$28.68	$ 4.59	$ 14.41	$ 1.51	$ 4.74	$ 10.31	$ 32.36
10	B-25	11	4140	0.021	0.03	3.01	$ 7.70	$ 1,105.10	$28.49	$ 0.61	$ 87.55	$ 0.51	$ 73.20	$ 8.82	$ 1,265.85
11	B-25B	12	4900	0.020	0.03	2.87	$ 6.15	$ 882.65	$29.03	$ 0.57	$ 81.81	$ 0.47	$ 67.45	$ 7.19	$ 1,031.91
12	B-13B	7	40	1.400	3.28	183.68	$ 180.00	$ 23,616.00		$ 12.30	$ 1,613.76	$ 24.00	$ 3,148.80	$ 244.00	$ 32,012.80
13	B-20A	4	107	0.299	0.31	9.81	$ 37.50	$ 1,230.00	$31.90	$ 9.55	$ 313.24	$ -	$ -	$ 47.05	$ 1,543.24
14	2 Carp	2	600	0.027	0.30	4.87	$ 12.60	$ 2,273.04		$ 6.65	$ 1,199.66	$ -	$ -	$ 19.25	$ 3,472.70
														TOTAL BARE COST SUM	$ 45,972.26

Project: Walter Gage Rd (65m^3 Storage)
Date: April 6th, 2017
Estimator: Neil Courtney

Cost Estimate - Quantity Take-Offs

Item #	Cost Code	Description	QUANTITY TAKEOFF: No of Pieces	Length (meters)	Length (feet)	Width (meters)	Width (feet)	Depth / Height (meters)	Depth / Height (feet)	Sub-Total	Total Quantity (metric)	Units	Total Quantity (Imperial)	Units
1	02315 610 0510	Excavating, Trench (1' to 4' deep, 1/2 C.Y. Tractor loader/backhoe)		20	65.6	3.5	11.48	1.5	4.92		105	m^3	137.33	B.C.Y.
2	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									85	m^3	138.97	L.C.Y.
3	02510 750 4560	Polyvinyl Chloride Pipe, 12" diameter		20	65.6		0		0		20	m	65.6	L.F.
4	01560 250 0550	Temporary Fencing Wire Mesh, 8' high			0		0		0		180	m	590.4	L.F.
12	02360 510 2660	Piping, reinforced Culvert, class 3, no gaskets, 84" Diameter	1	20	65.6		0		0		20	m	65.6	L.F.

Item #	METHOD: Crew Code	Crew Size	Daily Output (Units/day)	Worker-Hours (WHr/Unit)	Duration (days)	Total Worker-Hours	MATERIAL: Unit Cost	Total Cost	LABOR: Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost	EQUIPMENT: Unit Cost	Cost	TOTAL BARE COST: Total Unit Cost ($/Units)	Total Cost
1	B11M	2	200	0.080	0.69	10.99	$ -	$ -	$30.40	$ 2.43	$ 333.72	$ 1.39	$ 190.90	$ 3.82	$ 524.62
2	B-34D	1	78	0.103	1.78	14.31	$ -	$ -	$28.90	$ 2.96	$ 411.35	$ 5.35	$ 743.49	$ 8.31	$ 1,154.84
3	B-20A	4	186	0.172	0.35	11.28	$ 18.80	$ 1,233.28	$31.90	$ 5.50	$ 360.80	$ -	$ -	$ 24.30	$ 1,594.08
4	2 Carp	2	600	0.027	0.98	15.94	$ 12.60	$ 7,439.04	$ 33.25	$ 6.65	$ 3,926.16	$ -	$ -	$ 19.25	$ 11,365.20
12	B-13B	7	40	1.400	1.64	91.84	$ 180.00	$ 11,808.00		$ 12.30	$ 806.88	$ 24.00	$ 1,574.40	$ 244.00	$ 16,006.40
														TOTAL BARE COST SUM	**$ 30,645.14**

Project: NW Marine Dr (200m^3 Storage)
Date: April 6th, 2017
Estimator: Neil Courtney

Cost Estimate - Quantity Take-Offs

			QUANTITY TAKEOFF												METHOD						MATERIAL		LABOR			EQUIPMENT		TOTAL BARE COST	
Item #	Cost Code	Description	No of Pieces	Length (meters)	Length (feet)	Width (meters)	Width (feet)	Depth / Height (meters)	Depth / Height (feet)	Sub-Total	Total Quantity (metric)	Units	Total Quantity (Imperial)	Units	Crew Code	Crew Size	Daily Output (Units/day)	Worker-Hours (WHr/Unit)	Duration (days)	Total Worker-Hours	Unit Cost	Total Cost	Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost	Unit Cost	Cost	Total Unit Cost ($/Units)	Total Cost
1	02315 610 0510	Excavating, Trench (6' to 10' deep, 1 C.Y. Hydraulic backhoe)		24	78.72	6	19.68	3	9.84		432	m^3	565.03	B.C.Y.	B-12A	2	400	0.040	1.41	22.60	$ -	$ -	$30.77	$ 1.23	$ 694.99	$ 1.40	$ 791.05	$ 2.63	$ 1,486.04
2	02315 610 0510	Excavating, Trench (6' to 10' deep, 1 C.Y. Hydraulic backhoe)		36	118.08	1.5	4.92	2	6.56		108	m^3	141.26	B.C.Y.	B-12A	2	400	0.040	0.35	5.65	$ -	$ -	$30.77	$ 1.23	$ 173.75	$ 1.40	$ 197.76	$ 2.63	$ 371.51
3	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									247.5	m^3	404.65	L.C.Y.	B-34D	1	78	0.103	5.19	41.68	$ -	$ -	$28.90	$ 2.96	$ 1,197.76	$ 5.35	$ 2,164.86	$ 8.31	$ 3,362.62
4	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									247.5	m^3	404.65	L.C.Y.	B-34D	1	78	0.103	5.19	41.68	$ -	$ -	$28.90	$ 2.96	$ 1,197.76	$ 5.35	$ 2,164.86	$ 8.31	$ 3,362.62
5	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel		24	78.72	6	19.68	0.3	0.984		43.2	m^3	56.50	B.C.Y.	B-10B	1.5	1000	0.012	0.06	0.68	$ 12.05	$ 680.87	$31.93	$ 0.38	$ 21.47	$ 0.92	$ 51.98	$ 13.35	$ 754.32
6	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel		8	26.24	8	26.24	0.3	0.984		19.2	m^3	25.11	B.C.Y.	B-10B	1.5	1000	0.012	0.03	0.30	$ 12.05	$ 302.61	$31.93	$ 0.38	$ 9.54	$ 0.92	$ 23.10	$ 13.35	$ 335.25
7	02315 640 0200	Utility Bedding For Pipe and Conduit, Sand		36	118.08	1	3.28	0.2	0.656		7.2	m^3	9.42	B.C.Y.	B-6		150	0.160	0.06	1.51	$ 4.21	$ 39.65	$28.68	$ 4.59	$ 43.23	$ 1.51	$ 14.22	$ 10.31	$ 97.09
8	02740 310 0200	Asphaltic Concrete Pavement, Binder Course, 4" Thick		8	26.24	10	32.8	0.12	0.3936		80	m^2	95.68	S.Y.	B-25		4140	0.021	0.02	2.01	$ 7.70	$ 736.74	$28.49	$ 0.61	$ 58.36	$ 0.51	$ 48.80	$ 8.82	$ 843.90
9	02740 310 0460	Asphaltic Concrete Pavement, Wearing Course, 3" Thick		8	26.24	10	32.8	0.08	0.2624		80	m^2	95.68	S.Y.	B-25B		4900	0.020	0.02	1.91	$ 6.15	$ 588.43	$29.03	$ 0.57	$ 54.54	$ 0.47	$ 44.97	$ 7.19	$ 687.94
10	02315 520 0020	Fill, Spread dumped material, By dozer, Onsite Pre-excavated Fill		24	78.72	6	19.68	1	3.28		144	m^3	188.34	B.C.Y.	B-10B	1.5	1000	0.012	0.19	2.26	$ -	$ -	$31.93	$ 1.38	$ 259.92	$ 1.92	$ 361.62	$ 1.30	$ 244.85
11	02510 750 3070	Polyvinyl Chloride Pipe, 24" diameter		36	118.08						36	m	118.08	L.F.	B-20A	4	107	0.299	1.10	35.31	$ 37.50	$ 4,428.00	$31.90	$ 9.55	$ 1,127.66	$ -	$ -	$ 47.05	$ 5,555.66
12	01560 250 0550	Temporary Fencing Wire Mesh, 8' high		70	229.6						70	m	229.6	L.F.	2 Carp	2	600	0.027	0.38	6.20	$ 12.60	$ 2,892.96	$33.25	$ 6.65	$ 1,526.84	$ -	$ -	$ 19.25	$ 4,419.80
12	02360 510 2660	Piping, reinforced Culvert, class 3, no gaskets, 60" Diameter	3	37	121.36		0		0		111	m	364.08	L.F.	B-13B	7	48	1.167	7.59	424.88	$ 127.00	$ 46,238.16		$ 33.50	$12,196.68	$ 19.80	$ 7,208.78	$ 180.30	$ 65,643.62
																												TOTAL BARE COST SUM	**$ 87,165.22**

Project: Cecil Green Park Rd (1500 m^3 Storage)
Date: April 6th, 2017
Estimator: Neil Courtney

Cost Estimate - Quantity Take-Offs

			QUANTITY TAKEOFF												METHOD						MATERIAL		LABOR			EQUIPMENT		TOTAL BARE COST	
Item #	Cost Code	Description	No of Pieces	Length (meters)	Length (feet)	Width (meters)	Width (feet)	Depth / Height (meters)	Depth / Height (feet)	Sub-Total	Total Quantity (metric)	Units	Total Quantity (Imperial)	Units	Crew Code	Crew Size	Daily Output (Units/day)	Worker-Hours (WHr/Unit)	Duration (days)	Total Worker-Hours	Unit Cost	Total Cost	Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost	Unit Cost	Cost	Total Unit Cost ($/Units)	Total Cost
1	02315 610 1300	Excavating, Trench (14' to 20' deep, 1 C.Y. Hydraulic backhoe)		20	65.6	20	65.6	5	16.4		2000	m^3	2615.90	B.C.Y.	B-12A	2	320	0.050	8.17	130.80	$ -	$ -	$30.77	$ 1.54	$ 4,028.49	$ 1.75	$ 4,577.83	$ 3.29	$ 8,606.31
2	02315 610 0510	Excavating, Trench (6' to 10' deep, 1 C.Y. Hydraulic backhoe)		40	131.2	1.5	4.92	2.5	8.2		150	m^3	196.19	B.C.Y.	B-12A	2	400	0.040	0.49	7.85	$ -	$ -	$30.77	$ 1.23	$ 241.32	$ 1.40	$ 274.67	$ 2.63	$ 515.99
3	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									463.44	m^3	757.69	L.C.Y.	B-34D	1	78	0.103	9.71	78.04	$ -	$ -	$28.90	$ 2.96	$ 2,242.77	$ 5.35	$ 4,053.65	$ 8.31	$ 6,296.42
4	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									463.44	m^3	757.69	L.C.Y.	B-34D	1	78	0.103	9.71	78.04	$ -	$ -	$28.90	$ 2.96	$ 2,242.77	$ 5.35	$ 4,053.65	$ 8.31	$ 6,296.42
5	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									463.44	m^3	757.69	L.C.Y.	B-34D	1	78	0.103	9.71	78.04	$ -	$ -	$28.90	$ 2.96	$ 2,242.77	$ 5.35	$ 4,053.65	$ 8.31	$ 6,296.42
6	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									463.44	m^3	757.69	L.C.Y.	B-34D	1	78	0.103	9.71	78.04	$ -	$ -	$28.90	$ 2.96	$ 2,242.77	$ 5.35	$ 4,053.65	$ 8.31	$ 6,296.42
7	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel		20	65.6	20	65.6	0.3	0.984		120	m^3	156.95	B.C.Y.	B-10B	1.5	1000	0.012	0.16	1.88	$ 12.05	$ 1,891.30	$31.93	$ 0.38	$ 59.64	$ 0.92	$ 144.40	$ 13.35	$ 2,095.34
8	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel		10	32.8	8	26.24	0.3	0.984		24	m^3	31.39	B.C.Y.	B-10B	1.5	1000	0.012	0.03	0.38	$ 12.05	$ 378.26	$31.93	$ 0.38	$ 11.93	$ 0.92	$ 28.88	$ 13.35	$ 419.07
9	02315 640 0200	Utility Bedding For Pipe and Conduit, Sand		40	131.2	1.5	4.92	0.2	0.656		12	m^3	15.70	B.C.Y.	B-6		150	0.160	0.10	2.51	$ 4.21	$ 66.08	$28.68	$ 4.59	$ 72.04	$ 1.51	$ 23.70	$ 10.31	$ 161.82
10	02740 310 0200	Asphaltic Concrete Pavement, Binder Course, 4" Thick		8	26.24	10	32.8	0.12	0.3936		80	m^2	95.68	S.Y.	B-25		4140	0.021	0.02	2.01	$ 7.70	$ 736.74	$28.49	$ 0.61	$ 58.36	$ 0.51	$ 48.80	$ 8.82	$ 843.90
11	02740 310 0460	Asphaltic Concrete Pavement, Wearing Course, 3" Thick		8	26.24	10	32.8	0.08	0.2624		80	m^2	95.68	S.Y.	B-25B		4900	0.020	0.02	1.91	$ 6.15	$ 588.43	$29.03	$ 0.57	$ 54.54	$ 0.47	$ 44.97	$ 7.19	$ 687.94
12	02315 520 0020	Fill, Spread dumped material, By dozer, Onsite Pre-excavated Fill		29	95.12	23	75.44	1	3.28		667	m^3	872.40	B.C.Y.	B-10B	1.5	1000	0.012	0.87	10.47	$ -	$ -	$31.93	$ 1.38	$ 1,203.92	$ 1.92	$ 1,675.01	$ 1.30	$ 1,134.12
13	02510 750 3070	Polyvinyl Chloride Pipe, 24" diameter		30	98.4						30	m	98.4	L.F.	B-20A	4	107	0.299	0.92	29.42	$ 37.50	$ 3,690.00	$31.90	$ 9.55	$ 939.72	$ -	$ -	$ 47.05	$ 4,629.72
14	02510 750 4560	Polyvinyl Chloride Pipe, 12" diameter		10	32.8						10	m	32.8	L.F.	B-20A	4	186	0.172	0.18	5.64	$ 18.80	$ 616.64	$31.90	$ 5.50	$ 180.40	$ -	$ -	$ 24.30	$ 797.04
15	01560 250 0550	Temporary Fencing Wire Mesh, 8' high		110	360.8						110	m	360.8	L.F.	2 Carp	2	600	0.027	0.60	9.74	$ 12.60	$ 4,546.08	$33.25	$ 6.65	$ 2,399.32	$ -	$ -	$ 19.25	$ 6,945.40
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Beams, 25' span									25	m^3	32.5	CY	C-14A		18.55	10.782	1.75	350.42	$ 298.00	$ 9,685.00		$ 360.00	$ 11,700.00	$ 39.00	$ 1,267.50	$ 697.00	$ 22,652.50
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Columns 16" x 16" Average Reinforcing									4.5	m^3	5.85	CY	C-14A		12.57	15.911	0.47	93.08	$ 410.00	$ 2,398.50		$ 535.00	$ 3,129.75	$ 57.50	$ 336.38	$ 1,002.50	$ 5,864.63
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Elevated Slabs, Two way beam & slab, 25' span									72	m^3	93.6	CY	C-14A		35.87	5.799	2.61	542.79	$ 195.00	$ 18,252.00		$ 194.00	$ 18,158.40	$ 20.00	$ 1,872.00	$ 409.00	$ 38,282.40
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Footings, spread , over 5 C.Y									8	m^3	10.4	CY	C-14A		81.04	1.382	0.13	14.37	$ 242.00	$ 2,516.80		$ 44.00	$ 457.60	$ 0.26	$ 2.70	$ 286.26	$ 2,977.10
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Footings, Strip, 36" x 12", reinforced									18.9	m^3	24.57	CY	C-14A		60	1.867	0.41	45.87	$ 115.00	$ 2,825.55		$ 59.50	$ 1,461.92	$ 0.35	$ 8.60	$ 174.85	$ 4,296.06
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Slab on Grade (foundation mat), over 20 C.Y									54	m^3	70.2	CY	C-14A		56.4	1.986	1.24	139.42	$ 154.00	$ 10,810.80		$ 63.50	$ 4,457.70	$ 0.38	$ 26.68	$ 217.88	$ 15,295.18
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Grade walls, 8"thick, 14' high									75.6	m^3	98.28	CY	C-14A		27.26	7.337	3.61	721.08	$ 203.00	$ 19,950.84		$ 243.00	$ 23,882.04	$ 26.50	$ 2,604.42	$ 472.50	$ 46,437.30
																												TOTAL BARE COST SUM	$ 187,827.47

Project: Cecil Green Park Rd (2900 m^3 Storage)
Date: April 6th, 2017
Estimator: Neil Courtney

Cost Estimate - Quantity Take-Offs

			QUANTITY TAKEOFF												METHOD						MATERIAL		LABOR			EQUIPMENT		TOTAL BARE COST		TOTAL INCL O&P COST		Notes
Item #	Cost Code	Description	No of Pieces	Length (meters)	Length (feet)	Width (meters)	Width (feet)	Depth / Height (meters)	Depth / Height (feet)	Sub-Total	Total Quantity (metric)	Units	Total Quantity (Imperial)	Units	Crew Code	Crew Size	Daily Output (Units/day)	Worker-Hours (WHr/Unit)	Duration (days)	Total Worker-Hours	Unit Cost	Total Cost	Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost	Unit Cost	Cost	Total Unit Cost ($/Units)	Total Cost	Total Unit Cost ($/Units)	Total Cost	
1	02315 610 1300	Excavating, Trench (14' to 20' deep, 1 C.Y. Hydraulic backhoe)		29	95.12	23	75.44	8	26.24		5336	m^3	6979.22	B.C.Y.	B-12A	2	320	0.050	21.81	348.96	$ -	$ -	$30.77	$ 1.54	$ 10,748.00	$ 1.75	$ 12,213.64	$ 3.29	$ 22,961.64	$ 4.26	$ 29,731.48	
2	02315 610 0510	Excavating, Trench (6' to 10' deep, 1 C.Y. Hydraulic backhoe)		30	98.4	1.5	4.92	3	9.84		135	m^3	176.57	B.C.Y.	B-12A	2	400	0.040	0.44	7.06	$ -	$ -	$30.77	$ 1.23	$ 217.19	$ 1.40	$ 247.20	$ 2.63	$ 464.39	$ 3.40	$ 600.35	
3	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									1000.8	m^3	1636.30	L.C.Y.	B-34D	1	78	0.103	20.98	168.54	$ -	$ -	$28.90	$ 2.96	$ 4,843.45	$ 5.35	$ 8,754.20	$ 8.31	$ 13,597.65	$ 10.35	$ 16,935.70	
4	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									1000.8	m^3	1636.30	L.C.Y.	B-34D	1	78	0.103	20.98	168.54	$ -	$ -	$28.90	$ 2.96	$ 4,843.45	$ 5.35	$ 8,754.20	$ 8.31	$ 13,597.65	$ 10.35	$ 16,935.70	
5	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									1000.8	m^3	1636.30	L.C.Y.	B-34D	1	78	0.103	20.98	168.54	$ -	$ -	$28.90	$ 2.96	$ 4,843.45	$ 5.35	$ 8,754.20	$ 8.31	$ 13,597.65	$ 10.35	$ 16,935.70	
6	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									1000.8	m^3	1636.30	L.C.Y.	B-34D	1	78	0.103	20.98	168.54	$ -	$ -	$28.90	$ 2.96	$ 4,843.45	$ 5.35	$ 8,754.20	$ 8.31	$ 13,597.65	$ 10.35	$ 16,935.70	
7	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									1000.8	m^3	1636.30	L.C.Y.	B-34D	1	78	0.103	20.98	168.54	$ -	$ -	$28.90	$ 2.96	$ 4,843.45	$ 5.35	$ 8,754.20	$ 8.31	$ 13,597.65	$ 10.35	$ 16,935.70	
8	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									1000.8	m^3	1636.30	L.C.Y.	B-34D	1	78	0.103	20.98	168.54	$ -	$ -	$28.90	$ 2.96	$ 4,843.45	$ 5.35	$ 8,754.20	$ 8.31	$ 13,597.65	$ 10.35	$ 16,935.70	
9	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel		29	95.12	23	75.44	0.3	0.984		200.1	m^3	261.72	B.C.Y.	B-10B	1.5	1000	0.012	0.26	3.14	$ 12.05	$ 3,153.74	$31.93	$ 0.38	$ 99.45	$ 0.92	$ 240.78	$ 13.35	$ 3,493.97	$ 13.64	$ 3,569.87	
10	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel		10	32.8	8	26.24	0.3	0.984		24	m^3	31.39	B.C.Y.	B-10B	1.5	1000	0.012	0.03	0.38	$ 12.05	$ 378.26	$31.93	$ 0.38	$ 11.93	$ 0.92	$ 28.88	$ 13.35	$ 419.07	$ 13.64	$ 428.17	
11	02315 640 0200	Utility Bedding For Pipe and Conduit, Sand		30	98.4	1.5	4.92	0.2	0.656		9	m^3	11.77	B.C.Y.	B-6	3	150	0.160	0.08	1.88	$ 4.21	$ 49.56	$28.68	$ 4.59	$ 54.03	$ 1.51	$ 17.78	$ 10.31	$ 121.36	$ 13.25	$ 155.97	
12	02740 310 0200	Asphaltic Concrete Pavement, Binder Course, 4" Thick		8	26.24	10	32.8	0.12	0.3936		80	m^2	95.68	S.Y.	B-25	11	4140	0.021	0.02	2.01	$ 7.70	$ 736.74	$28.49	$ 0.61	$ 58.36	$ 0.51	$ 48.80	$ 8.82	$ 843.90	$ 9.95	$ 952.02	
13	02740 310 0460	Asphaltic Concrete Pavement, Wearing Course, 3" Thick		8	26.24	10	32.8	0.08	0.2624		80	m^2	95.68	S.Y.	B-25B	12	4900	0.020	0.02	1.91	$ 6.15	$ 588.43	$29.03	$ 0.57	$ 54.54	$ 0.47	$ 44.97	$ 7.19	$ 687.94	$ 8.20	$ 784.58	
14	02315 520 0020	Fill, Spread dumped material, By dozer, Onsite Pre-excavated Fill		29	95.12	23	75.44	1	3.28		667	m^3	872.40	B.C.Y.	B-10B	1.5	1000	0.012	0.87	10.47	$ -	$ -	$31.93	$ 1.38	$ 1,203.92	$ 1.92	$ 1,675.01	$ 1.30	$ 1,134.12	$ 1.59	$ 1,387.12	
15	02510 750 3070	Polyvinyl Chloride Pipe, 24" diameter		30	98.4						30	m	98.4	L.F.	B-20A	4	107	0.299	0.92	29.42	$ 37.50	$ 3,690.00	$31.90	$ 9.55	$ 939.72	$ -	$ -	$ 47.05	$ 4,629.72	$ 55.50	$ 5,461.20	
16	01560 250 0550	Temporary Fencing Wire Mesh, 8' high		200	656						200	m	656	L.F.	2 Carp	2	600	0.027	1.09	17.71	$ 12.60	$ 8,265.60	$33.25	$ 6.65	$ 4,362.40	$ -	$ -	$ 19.25	$ 12,628.00	$ 24.00	$ 15,744.00	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Beams, 25' span									51.84	m^3	67.392	CY	C-14A		18.55	10.782	3.63	726.62	$ 298.00	$ 20,082.82		$ 360.00	$ 24,261.12	$ 39.00	$ 2,628.29	$ 697.00	$ 46,972.22	$ 930.00	$ 62,674.56	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Columns 16" x 16" Average Reinforcing									7.2	m^3	9.36	CY	C-14A		12.57	15.911	0.74	148.93	$ 410.00	$ 3,837.60		$ 535.00	$ 5,007.60	$ 57.50	$ 538.20	$ 1,002.50	$ 9,383.40	$ 1,350.00	$ 12,636.00	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Elevated Slabs, Two way beam & slab, 25' span									129.6	m^3	168.48	CY	C-14A		35.87	5.799	4.70	977.02	$ 195.00	$ 32,853.60		$ 194.00	$ 32,685.12	$ 20.00	$ 3,369.60	$ 409.00	$ 68,908.32	$ 535.00	$ 90,136.80	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Footings, spread , over 5 C.Y									20	m^3	26	CY	C-14A		81.04	1.382	0.32	35.93	$ 242.00	$ 6,292.00		$ 44.00	$ 1,144.00	$ 0.26	$ 6.76	$ 286.26	$ 7,442.76	$ 335.00	$ 8,710.00	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Footings, Strip, 36" x 12", reinforced									24.3	m^3	31.59	CY	C-14A		60	1.867	0.53	58.98	$ 115.00	$ 3,632.85		$ 59.50	$ 1,879.61	$ 0.35	$ 11.06	$ 174.85	$ 5,523.51	$ 218.00	$ 6,886.62	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Slab on Grade (foundation mat), over 20 C.Y									97.2	m^3	126.36	CY	C-14A		56.4	1.986	2.24	250.95	$ 154.00	$ 19,459.44		$ 63.50	$ 8,023.86	$ 0.38	$ 48.02	$ 217.88	$ 27,531.32	$ 268.00	$ 33,864.48	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Grade walls, 8"thick, 14' high									97.2	m^3	126.36	CY	C-14A		27.26	7.337	4.64	927.10	$ 203.00	$ 25,651.08		$ 243.00	$ 30,705.48	$ 26.50	$ 3,348.54	$ 472.50	$ 59,705.10	$ 625.00	$ 78,975.00	
																												TOTAL BARE COST SUM	$ 354,436.66	TOTAL O&P COST SUM	$ 454,312.45	

Project: Chancellor BLVD (1670 m^3 Storage)
Date: April 6th, 2017
Estimator: Neil Courtney

Cost Estimate - Quantity Take-Offs

			QUANTITY TAKEOFF											
Item #	Cost Code	Description	No of Pieces	Length (meters)	Length (feet)	Width (meters)	Width (feet)	Depth / Height (meters)	Depth / Height (feet)	Sub-Total	Total Quantity (metric)	Units	Total Quantity (Imperial)	Units
1	02315 610 0910	Excavating, Trench (10' to 14' deep, 1 C.Y. Hydraulic backhoe)		210	688.8	4	13.12	3.5	11.48		2940	m^3	3845.37	B.C.Y.
2	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									813.75	m^3	1330.43	L.C.Y.
3	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									813.75	m^3	1330.43	L.C.Y.
4	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									813.75	m^3	1330.43	L.C.Y.
5	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									813.75	m^3	1330.43	L.C.Y.
6	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel Drain Rock		210	688.8	4	13.12	3	9.84		2520	m^3	3296.03	B.C.Y.
7	02315 520 0020	Fill, Spread dumped material, By dozer, Onsite Pre-excavated Fill		210	688.8	4	13.12	0.5	1.64		420	m^3	549.34	B.C.Y.
12	02360 510 2660	Piping, reinforced Culvert, class 3, no gaskets, 72" Diameter	3	213	698.64		0		0		639	m	2095.92	L.F.
9	01560 250 0550	Temporary Fencing Wire Mesh, 8' high		450	1476		0		0		450	m	1476	L.F.

	METHOD						MATERIAL		LABOR			EQUIPMENT		TOTAL BARE COST	
Item #	Crew Code	Crew Size	Daily Output (Units/day)	Worker-Hours (WHr/Unit)	Duration (days)	Total Worker-Hours	Unit Cost	Total Cost	Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost	Unit Cost	Cost	Total Unit Cost ($/Units)	Total Cost
1	B-12A	2	360	0.044	10.68	169.20	$ -	$ -	$30.77	$ 1.37	$ 5,268.16	$ 1.56	$ 5,998.78	$ 2.93	$ 11,266.94
2	B-34D	1	78	0.103	17.06	137.03	$ -	$ -	$28.90	$ 2.96	$ 3,938.07	$ 5.35	$ 7,117.80	$ 8.31	$ 11,055.88
3	B-34D	1	78	0.103	17.06	137.03	$ -	$ -	$28.90	$ 2.96	$ 3,938.07	$ 5.35	$ 7,117.80	$ 8.31	$ 11,055.88
4	B-34D	1	78	0.103	17.06	137.03	$ -	$ -	$28.90	$ 2.96	$ 3,938.07	$ 5.35	$ 7,117.80	$ 8.31	$ 11,055.88
5	B-34D	1	78	0.103	17.06	137.03	$ -	$ -	$28.90	$ 2.96	$ 3,938.07	$ 5.35	$ 7,117.80	$ 8.31	$ 11,055.88
6	B-10B	1.5	1000	0.012	3.30	39.55	$ 12.05	$ 39,717.21	$31.93	$ 0.38	$ 1,252.49	$ 0.92	$ 3,032.35	$ 13.35	$ 44,002.05
7	B-10B	1.5	1000	0.012	0.55	6.59	$ -	$ -	$31.93	$ 1.38	$ 758.09	$ 1.92	$ 1,054.73	$ 1.30	$ 714.14
12	B-13B	7	40	1.400	52.40	2934.29	$ 180.00	$377,265.60		$ 12.30	$25,779.82	$ 24.00	$50,302.08	$ 244.00	$ 511,404.48
9	2 Carp	2	600	0.027	2.46	39.85	$ 12.60	$ 18,597.60	$33.25	$ 6.65	$ 9,815.40	$ -	$ -	$ 19.25	$ 28,413.00
														TOTAL BARE COST SUM	**$ 640,024.12**

Project: School of Music (30m^3 Storage)
Date: April 6th, 2017
Estimator: Neil Courtney

Cost Estimate - Quantity Take-Offs

			QUANTITY TAKEOFF											
Item #	Cost Code	Description	No of Pieces	Length (meters)	Length (feet)	Width (meters)	Width (feet)	Depth / Height (meters)	Depth / Height (feet)	Sub-Total	Total Quantity (metric)	Units	Total Quantity (Imperial)	Units
1	02315 610 0510	Excavating, Trench (1' to 4' deep, 1/2 C.Y. Tractor loader/backhoe)		10.5	34.44	3.5	11.48	1.5	4.92		55.125	m^3	72.10	B.C.Y.
2	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									45	m^3	73.57	L.C.Y.
3	02510 750 4560	Polyvinyl Chloride Pipe, 12" diameter		20	65.6		0		0		20	m	65.6	L.F.
4	01560 250 0550	Temporary Fencing Wire Mesh, 8' high			0		0		0		180	m	590.4	L.F.
12	02360 510 2660	Piping, reinforced Culvert, class 3, no gaskets, 72" Diameter	1	10	32.8		0		0		10	m	32.8	L.F.

	METHOD						MATERIAL		LABOR			EQUIPMENT		TOTAL BARE COST	
Item #	Crew Code	Crew Size	Daily Output (Units/day)	Worker-Hours (WHr/Unit)	Duration (days)	Total Worker-Hours	Unit Cost	Total Cost	Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost	Unit Cost	Cost	Total Unit Cost ($/Units)	Total Cost
1	B11M	2	200	0.080	0.36	5.77	$ -	$ -	$30.40	$ 2.43	$ 175.20	$ 1.39	$ 100.22	$ 3.82	$ 275.42
2	B-34D	1	78	0.103	0.94	7.58	$ -	$ -	$28.90	$ 2.96	$ 217.77	$ 5.35	$ 393.61	$ 8.31	$ 611.38
3	B-20A	4	186	0.172	0.35	11.28	$ 18.80	$ 1,233.28	$31.90	$ 5.50	$ 360.80	$ -	$ -	$ 24.30	$ 1,594.08
4	2 Carp	2	600	0.027	0.98	15.94	$ 12.60	$ 7,439.04	$ 33.25	$ 6.65	$ 3,926.16	$ -	$ -	$ 19.25	$ 11,365.20
12	B-13B	7	40	1.400	0.82	45.92	$ 180.00	$ 5,904.00		$ 12.30	$ 403.44	$ 24.00	$ 787.20	$ 244.00	$ 8,003.20
														TOTAL BARE COST SUM	**$ 21,849.29**

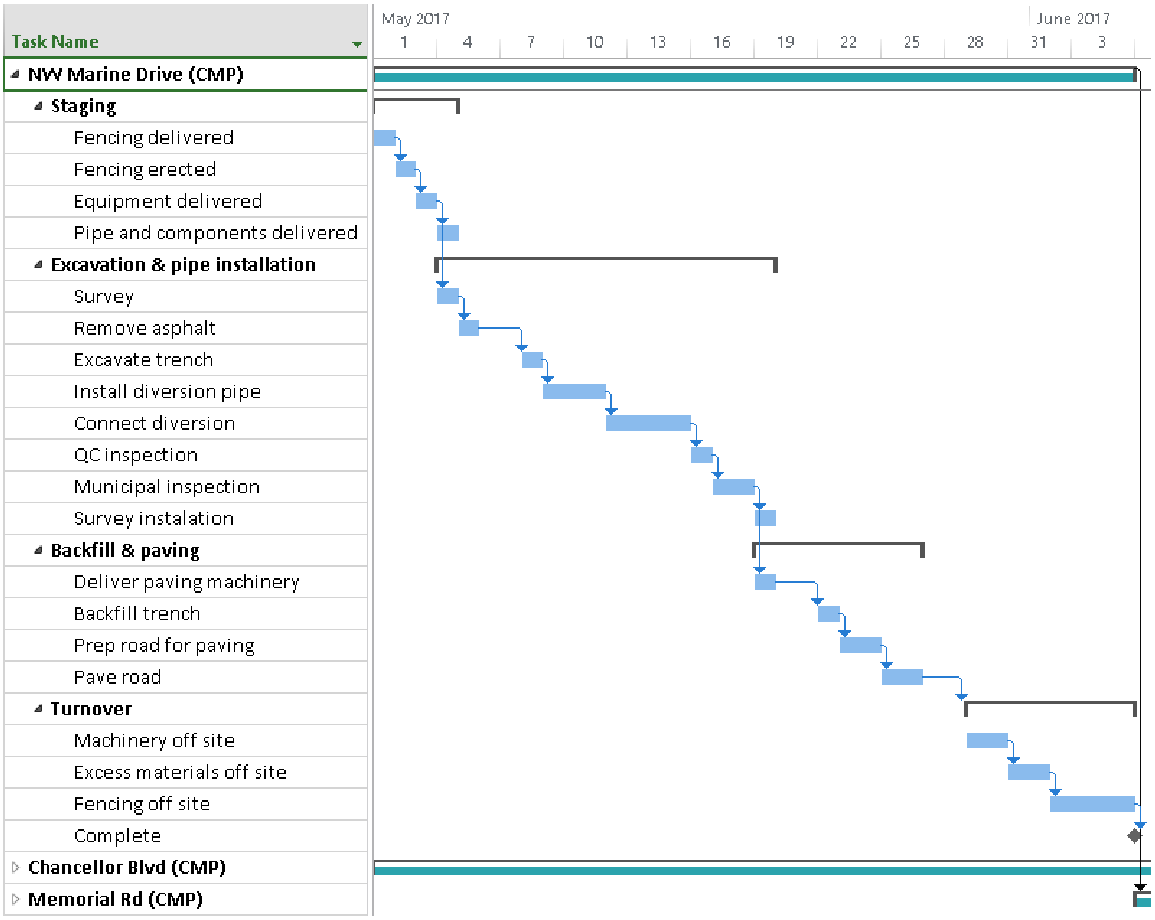
Project: Bus Loop (900m^3 Storage)
Date: April 6th, 2017
Estimator: Neil Courtney

Cost Estimate - Quantity Take-Offs

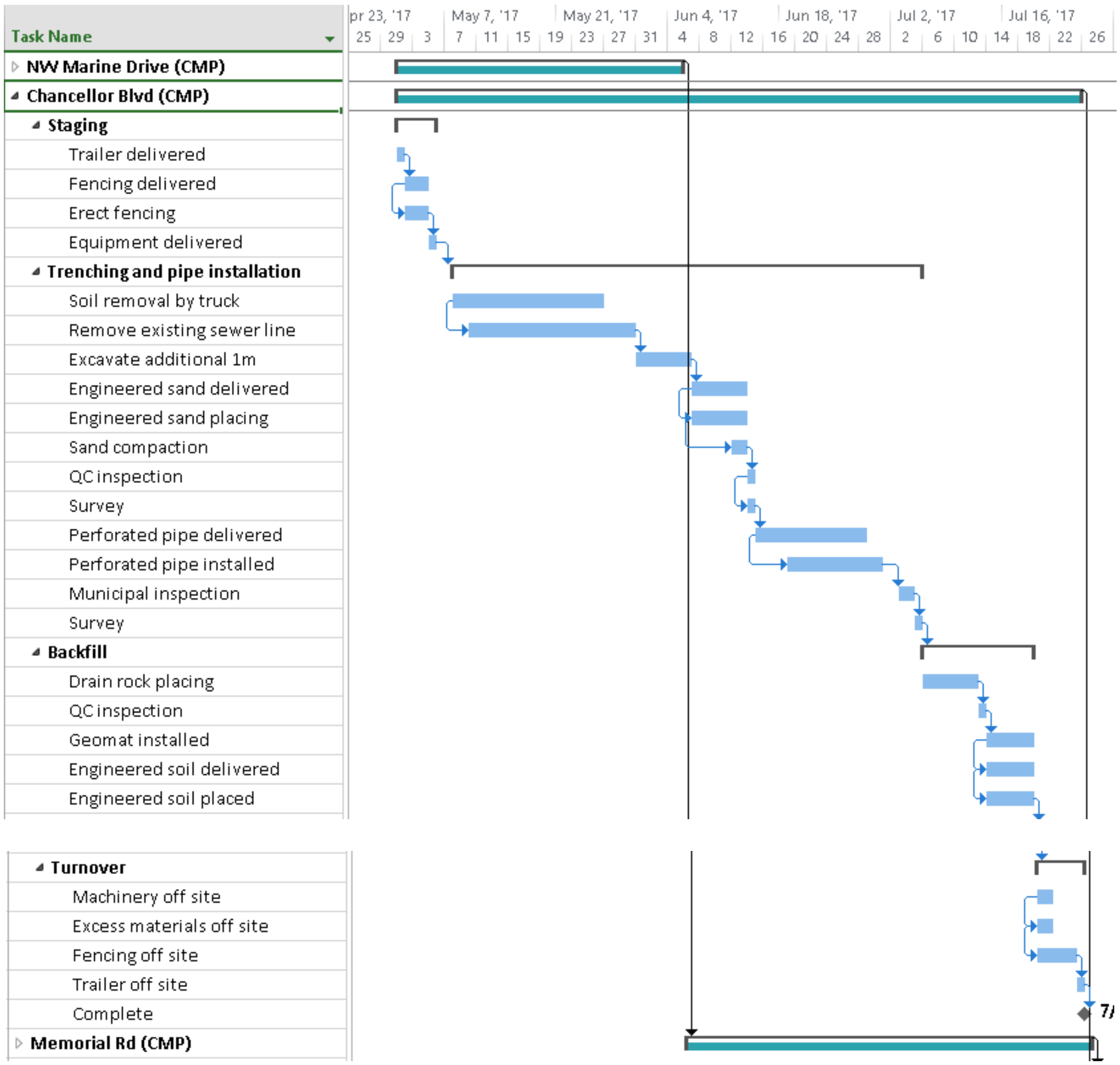
			QUANTITY TAKEOFF												METHOD						MATERIAL		LABOR			EQUIPMENT		TOTAL BARE COST		TOTAL INCL O&P COST		Notes
Item #	Cost Code	Description	No of Pieces	Length (meters)	Length (feet)	Width (meters)	Width (feet)	Depth / Height (meters)	Depth / Height (feet)	Sub-Total	Total Quantity (metric)	Units	Total Quantity (Imperial)	Units	Crew Code	Crew Size	Daily Output (Units/day)	Worker-Hours (WHr/Unit)	Duration (days)	Total Worker-Hours	Unit Cost	Total Cost	Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost	Unit Cost	Cost	Total Unit Cost ($/Units)	Total Cost	Total Unit Cost ($/Units)	Total Cost	
1	02315 610 0510	Excavating, Trench (6' to 10' deep, 1 C.Y. Hydraulic backhoe)		9.5	31.16	4.5	14.76	3	9.84		128.25	m^3	167.74	B.C.Y.	B-12A	2	400	0.040	0.42	6.71	$ -	$ -	$30.77	$ 1.23	$ 206.33	$ 1.40	$ 234.84	$ 2.63	$ 441.17	$ 3.40	$ 570.33	
2	02315 610 0510	Excavating, Trench (6' to 10' deep, 1 C.Y. Hydraulic backhoe)		8	26.24	0.5	1.64	3	9.84		12	m^3	15.70	B.C.Y.	B-12A	2	400	0.040	0.04	0.63	$ -	$ -	$30.77	$ 1.23	$ 19.31	$ 1.40	$ 21.97	$ 2.63	$ 41.28	$ 3.40	$ 53.36	
3	02315 610 0510	Excavating, Trench (6' to 10' deep, 1 C.Y. Hydraulic backhoe)		50	164	50	164	2	6.56		5000	m^3	6539.75	B.C.Y.	B-12A	2	400	0.040	16.35	261.59	$ -	$ -	$30.77	$ 1.23	$ 8,043.89	$ 1.40	$ 9,155.65	$ 2.63	$ 17,199.54	$ 3.40	$ 22,235.15	
4	02315 610 0510	Excavating, Trench (1' to 4' deep, 1/2 C.Y. Tractor loader/backhoe)		144	472.32	1	3.28	1	3.28		144	m^3	188.34	B.C.Y.	B11M	2	200	0.080	0.94	15.07	$ -	$ -	$30.40	$ 2.43	$ 457.68	$ 1.39	$ 261.80	$ 3.82	$ 719.48	$ 5.20	$ 979.39	
5	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									943.57	m^3	1542.68	L.C.Y.	B-34D	1	78	0.103	19.78	158.90	$ -	$ -	$28.90	$ 2.96	$ 4,566.33	$ 5.35	$ 8,253.34	$ 8.31	$ 12,819.67	$ 10.35	$ 15,966.74	
6	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									943.57	m^3	1542.68	L.C.Y.	B-34D	1	78	0.103	19.78	158.90	$ -	$ -	$28.90	$ 2.96	$ 4,566.33	$ 5.35	$ 8,253.34	$ 8.31	$ 12,819.67	$ 10.35	$ 15,966.74	
7	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									943.57	m^3	1542.68	L.C.Y.	B-34D	1	78	0.103	19.78	158.90	$ -	$ -	$28.90	$ 2.96	$ 4,566.33	$ 5.35	$ 8,253.34	$ 8.31	$ 12,819.67	$ 10.35	$ 15,966.74	
8	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									943.57	m^3	1542.68	L.C.Y.	B-34D	1	78	0.103	19.78	158.90	$ -	$ -	$28.90	$ 2.96	$ 4,566.33	$ 5.35	$ 8,253.34	$ 8.31	$ 12,819.67	$ 10.35	$ 15,966.74	
9	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									943.57	m^3	1542.68	L.C.Y.	B-34D	1	78	0.103	19.78	158.90	$ -	$ -	$28.90	$ 2.96	$ 4,566.33	$ 5.35	$ 8,253.34	$ 8.31	$ 12,819.67	$ 10.35	$ 15,966.74	
10	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									943.57	m^3	1542.68	L.C.Y.	B-34D	1	78	0.103	19.78	158.90	$ -	$ -	$28.90	$ 2.96	$ 4,566.33	$ 5.35	$ 8,253.34	$ 8.31	$ 12,819.67	$ 10.35	$ 15,966.74	
11	02315 490 1255	Hauling (20 mile round trip, .5 load/hr)									943.57	m^3	1542.68	L.C.Y.	B-34D	1	78	0.103	19.78	158.90	$ -	$ -	$28.90	$ 2.96	$ 4,566.33	$ 5.35	$ 8,253.34	$ 8.31	$ 12,819.67	$ 10.35	$ 15,966.74	
12	02315 520 0020	Fill, Spread dumped material, By dozer, Gravel Drain Rock		45	147.6	45	147.6	0.5	1.64		1012.5	m^3	1324.30	B.C.Y.	B-10B	1.5	1000	0.012	1.32	15.89	$ 12.05	$ 15,957.81	$31.93	$ 0.38	$ 503.23	$ 0.92	$ 1,218.36	$ 13.35	$ 17,679.40	$ 13.64	$ 18,063.44	
13	02315 640 0200	Utility Bedding For Pipe and Conduit, Sand		152	498.56	0.5	1.64	0.5	1.64		38	m^3	49.70	B.C.Y.	B-6	3	150	0.160	0.33	7.95	$ 4.21	$ 209.25	$28.68	$ 4.59	$ 228.13	$ 1.51	$ 75.05	$ 10.31	$ 512.43	$ 13.25	$ 658.55	
14	02740 310 0200	Asphaltic Concrete Pavement, Binder Course, 4" Thick		15	49.2	8	26.24	0.12	0.3936		120	m^2	143.52	S.Y.	B-25	11	4140	0.021	0.03	3.01	$ 7.70	$ 1,105.10	$28.49	$ 0.61	$ 87.55	$ 0.51	$ 73.20	$ 8.82	$ 1,265.85	$ 9.95	$ 1,428.02	
15	02740 310 0460	Asphaltic Concrete Pavement, Wearing Course, 3" Thick		15	49.2	8	26.24	0.08	0.2624		120	m^2	143.52	S.Y.	B-25B	12	4900	0.020	0.03	2.87	$ 6.15	$ 882.65	$29.03	$ 0.57	$ 81.81	$ 0.47	$ 67.45	$ 7.19	$ 1,031.91	$ 8.20	$ 1,176.86	
16	02150 750 3050	Polyvinyl Chloride Pipe, 18" diameter		140	459.2		0		0		140	m	459.2	L.F.	B-20A	4	160	0.200	2.87	91.84	$ 21.50	$ 9,872.80	$31.90	$ 6.40	$ 2,938.88	$ 27.90	$ -	$ 33.00	$ 15,153.60	$ 29.00	$ 13,316.80	
17	02510 750 4560	Polyvinyl Chloride Pipe, 12" diameter		11	36.08		0		0		11	m	36.08	L.F.	B-20A	4	186	0.172	0.19	6.21	$ 18.80	$ 678.30	$31.90	$ 5.50	$ 198.44	$ -	$ -	$ 24.30	$ 876.74	$ 29.00	$ 1,046.32	
18	01560 250 0550	Temporary Fencing Wire Mesh, 8' high		240	787.2		0		0		240	m	787.2	L.F.	2 Carp	2	600	0.027	1.31	21.25	$ 12.60	$ 9,918.72	$33.25	$ 6.65	$ 5,234.88	$ -	$ -	$ 19.25	$ 15,153.60	$ 24.00	$ 18,892.80	
19	01560 250 0550	Temporary Fencing Wire Mesh, 8' high		50	164		0		0		50	m	164	L.F.	2 Carp	2	600	0.027	0.27	4.43	$ 12.60	$ 2,066.40	$33.25	$ 6.65	$ 1,090.60	$ -	$ -	$ 19.25	$ 3,157.00	$ 24.00	$ 3,936.00	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Beams, 25' span									42.4	m^3	55.12	CY	C-14A		18.55	10.782	2.97	594.30	$ 298.00	$ 16,425.76		$ 360.00	$ 19,843.20	$ 39.00	$ 2,149.68	$ 697.00	$ 38,418.64	$ 930.00	$ 51,261.60	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Columns 16" x 16" Average Reinforcing									4	m^3	5.2	CY	C-14A		12.57	15.911	0.41	82.74	$ 410.00	$ 2,132.00		$ 535.00	$ 2,782.00	$ 57.50	$ 299.00	$1,002.50	$ 5,213.00	$ 1,350.00	$ 7,020.00	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Elevated Slabs, Two way beam & slab, 25' span									108	m^3	140.4	CY	C-14A		35.87	5.799	3.91	814.18	$ 195.00	$ 27,378.00		$ 194.00	$ 27,237.60	$ 20.00	$ 2,808.00	$ 409.00	$ 57,423.60	$ 535.00	$ 75,114.00	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Footings, spread , over 5 C.Y									16	m^3	20.8	CY	C-14A		81.04	1.382	0.26	28.75	$ 242.00	$ 5,033.60		$ 44.00	$ 915.20	$ 0.26	$ 5.41	$ 286.26	$ 5,954.21	$ 335.00	$ 6,968.00	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Footings, Strip, 36" x 12", reinforced									21.6	m^3	28.08	CY	C-14A		60	1.867	0.47	52.43	$ 115.00	$ 3,229.20		$ 59.50	$ 1,670.76	$ 0.35	$ 9.83	$ 174.85	$ 4,909.79	$ 218.00	$ 6,121.44	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Slab on Grade (foundation mat), over 20 C.Y									81	m^3	105.3	CY	C-14A		56.4	1.986	1.87	209.13	$ 154.00	$ 16,216.20		$ 63.50	$ 6,686.55	$ 0.38	$ 40.01	$ 217.88	$ 22,942.76	$ 268.00	$ 28,220.40	
		Concrete in place, Including Forms (4 uses), concrete, placement, reinforcing steel and finishing, Grade walls, 8"thick, 8' high									38.4	m^3	49.92	CY	C-14A		45.83	4.364	1.09	217.85	$ 157.00	$ 7,837.44		$ 145.00	$ 7,238.40	$ 15.75	$ 786.24	$ 317.75	$ 15,862.08	$ 410.00	$ 20,467.20	
12	02360 510 2660	Piping, reinforced Culvert, class 3, no gaskets, 84" Diameter	1	19	62.32		0		0		19	m	62.32	L.F.	B-13B	7	32	1.750	1.95	109.06	$ 305.00	$ 19,007.60		$ 50.00	$ 3,116.00	$ 29.50	$ 384.50	$ 244.00	$ 445.00	$ 285.00	$ 17,761.20	
																												TOTAL BARE COST SUM	$ 314,138.79	TOTAL O&P COST SUM	$ 407,058.07	

Appendix D – Project Schedule

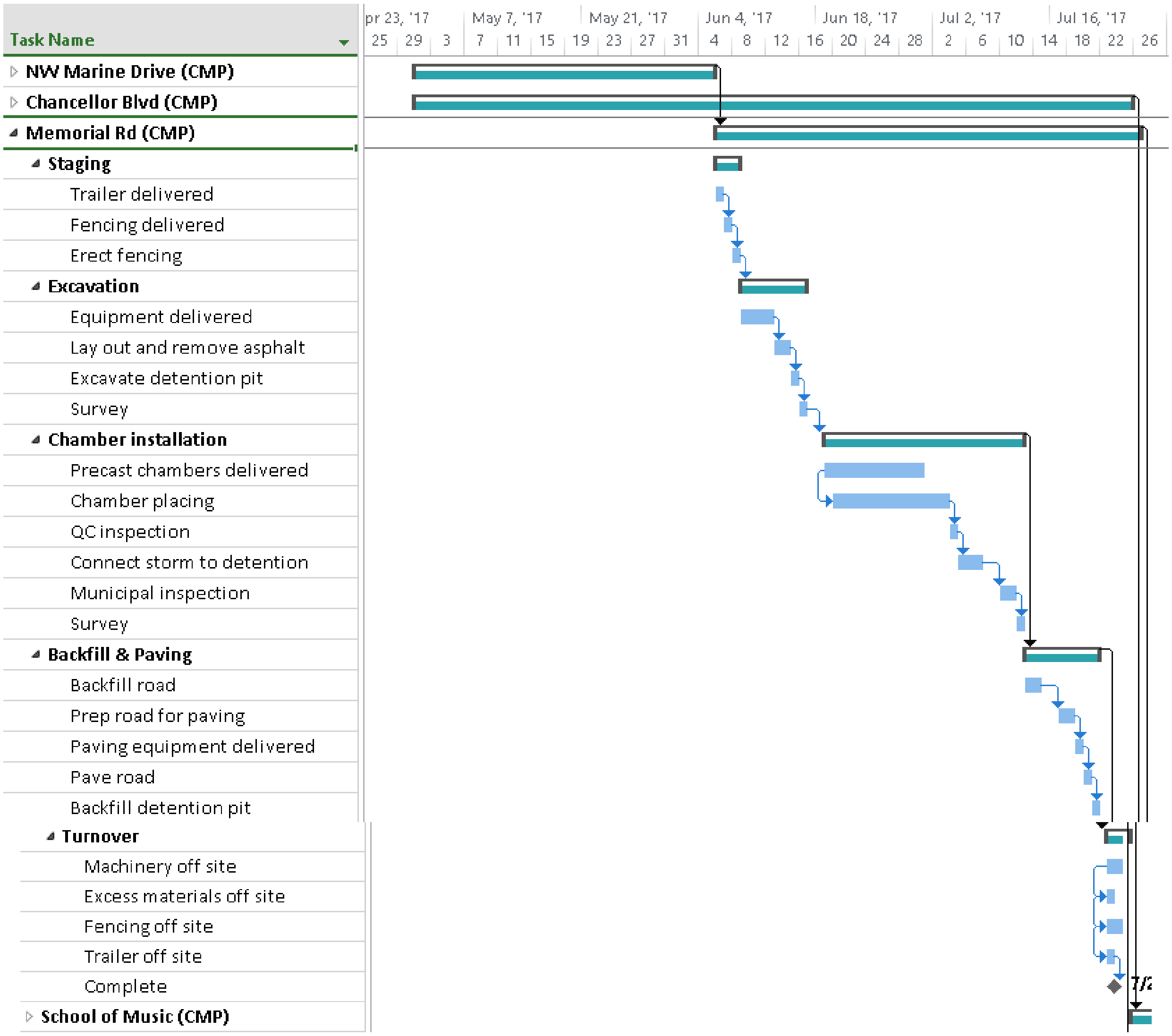
(NW Marine Drive Gantt Chart)



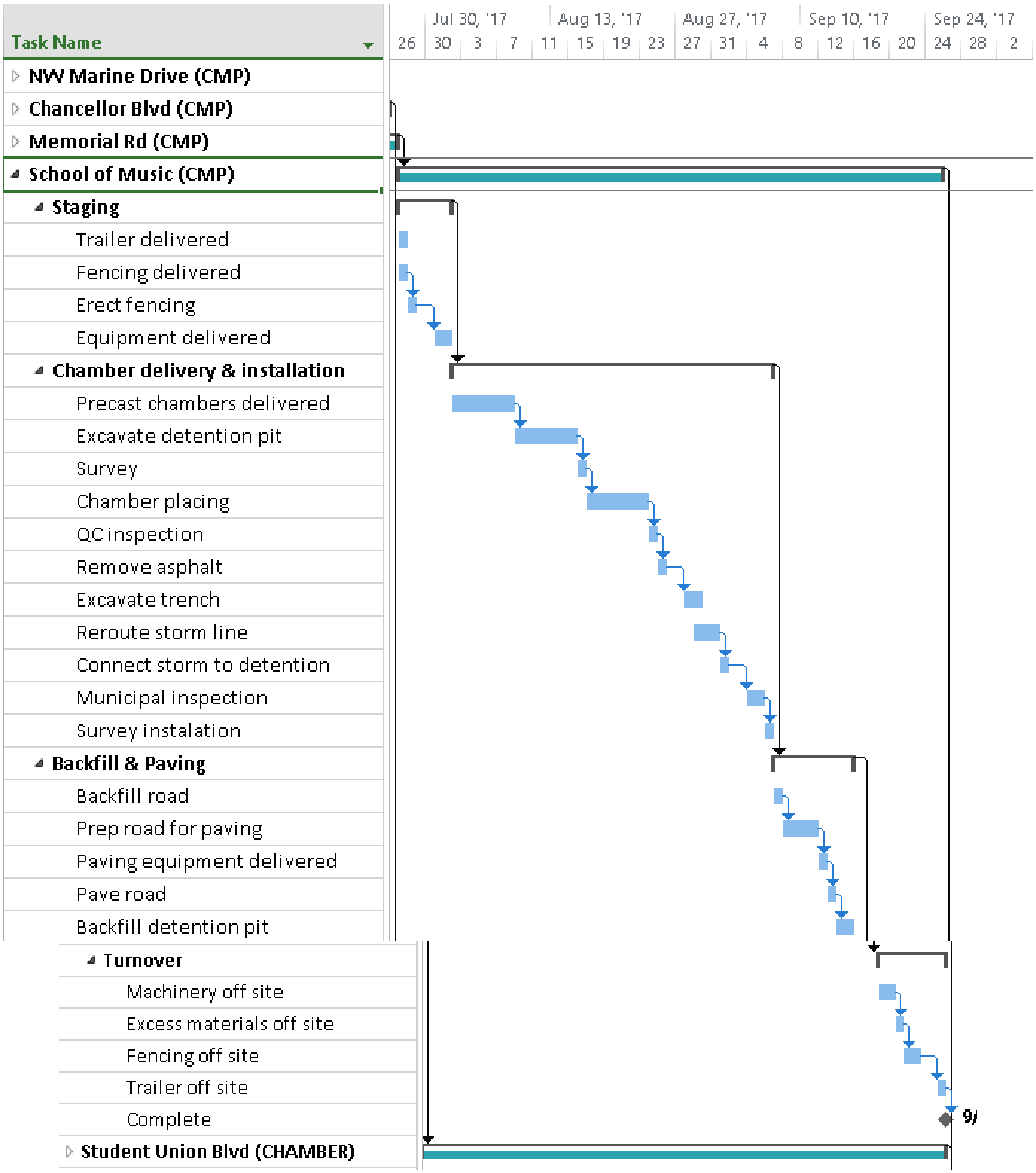
(Chancellor Blvd Gantt Chart)



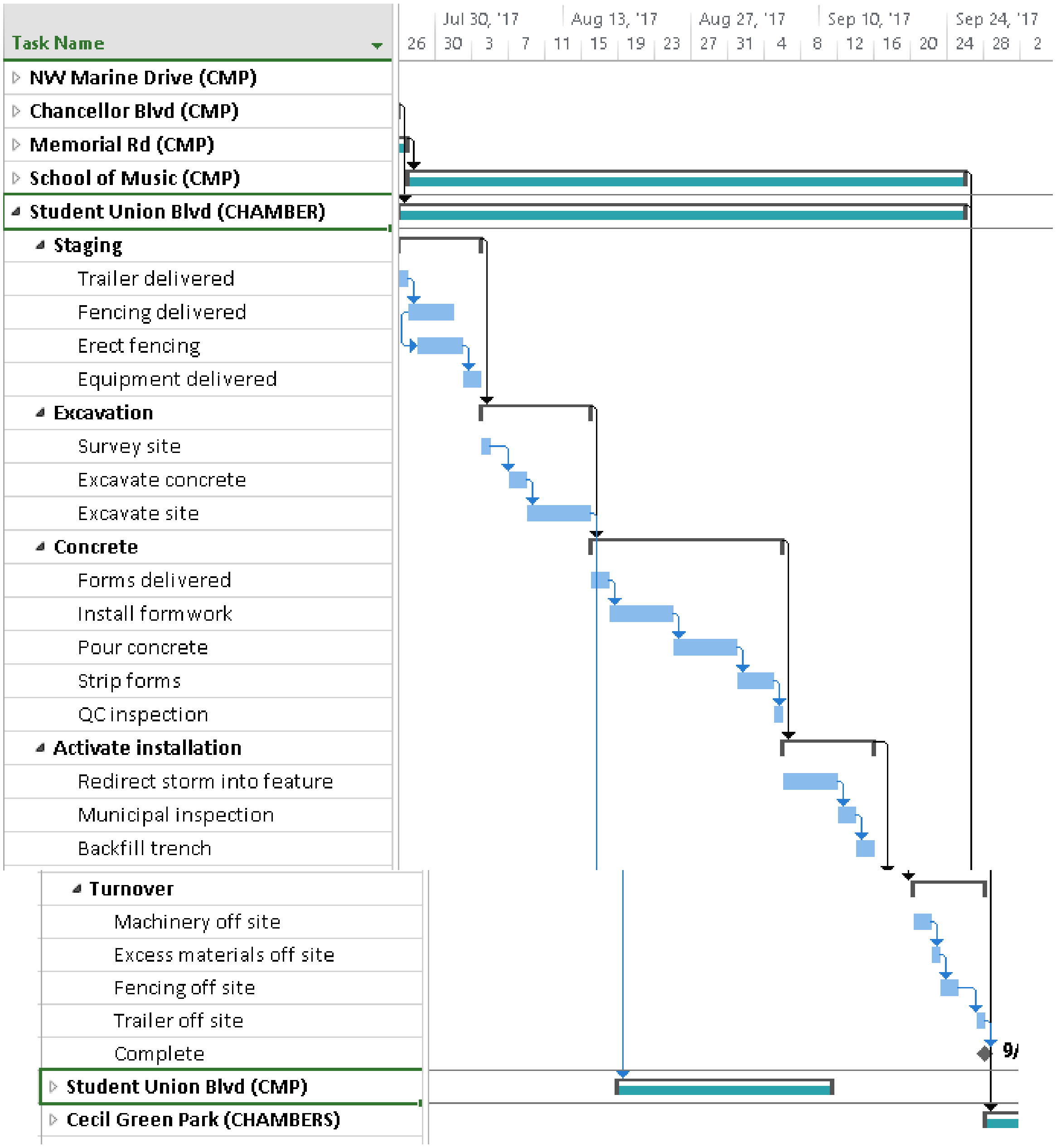
(Memorial Road Gantt Chart)



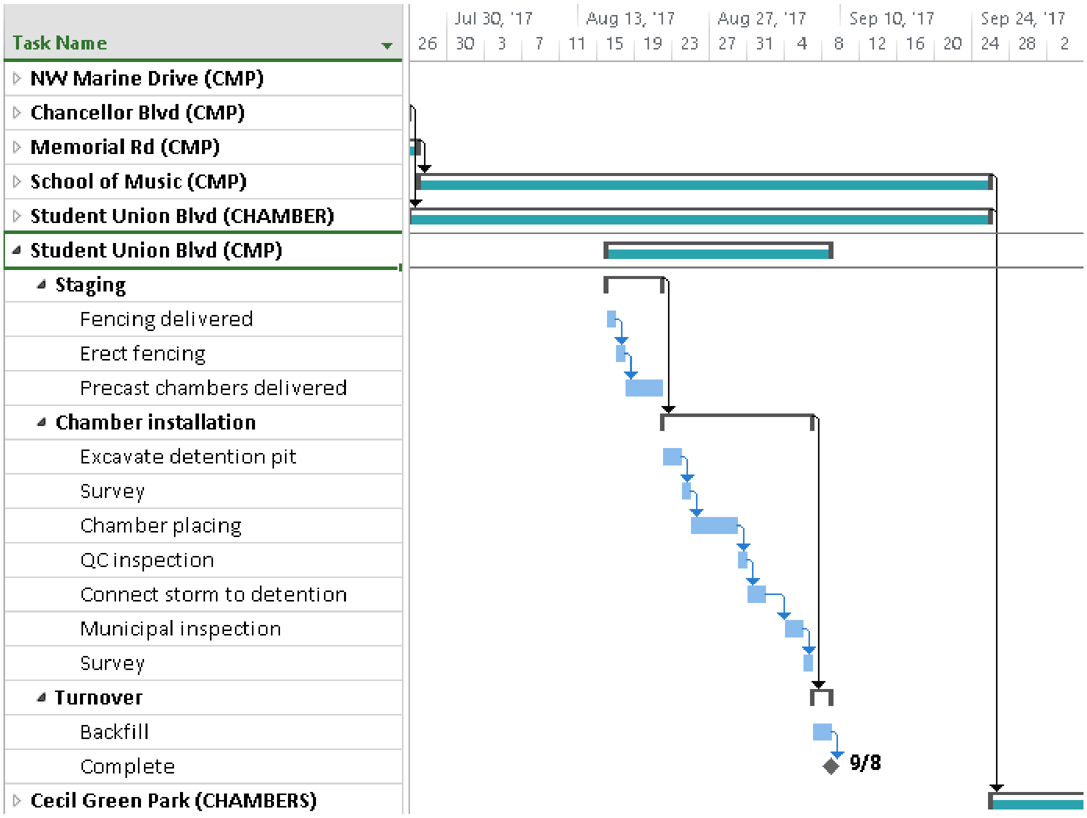
(School of Music Gantt Chart)



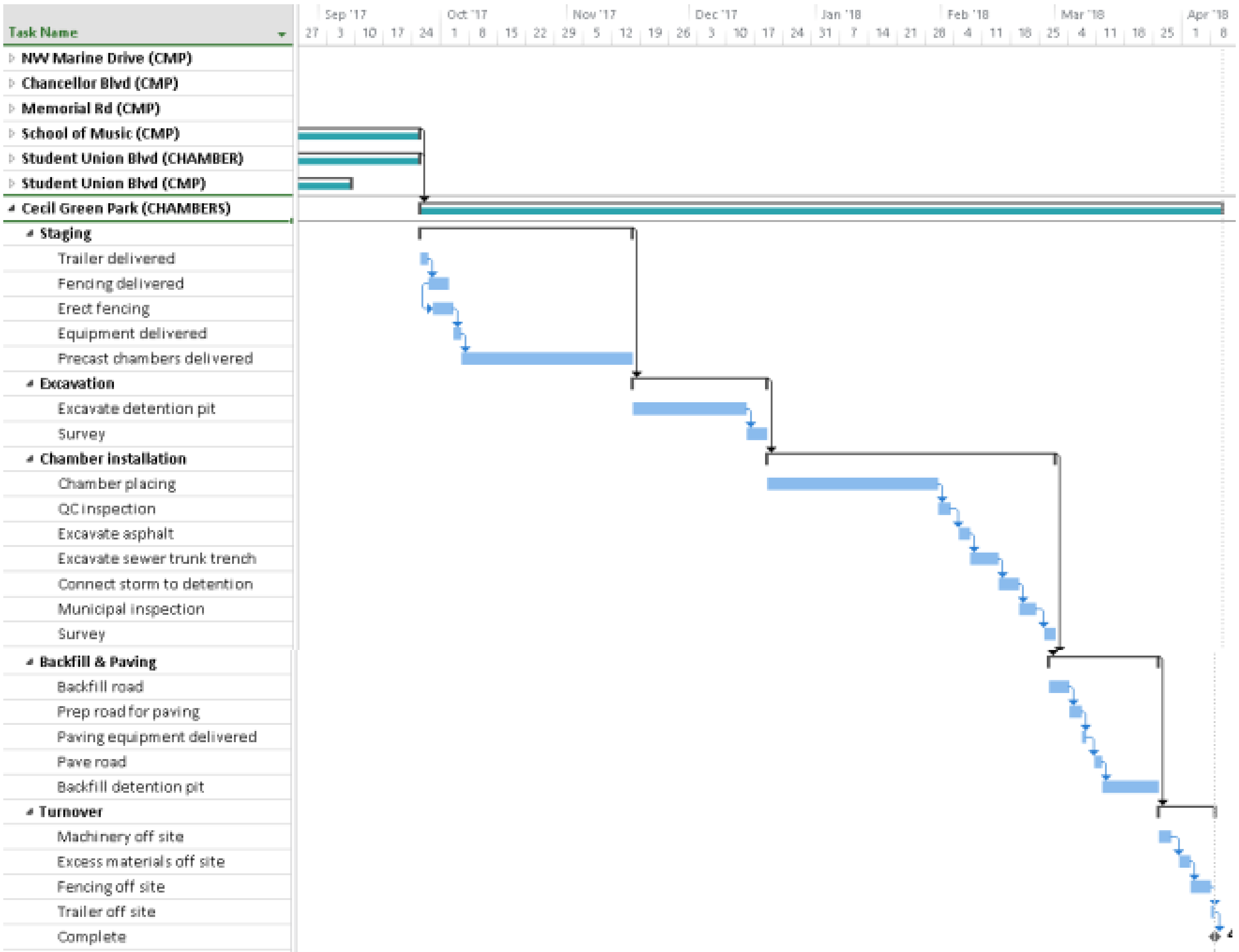
(Student Union Boulevard Chamber Gantt Chart)



(Student Union Blvd CMP Gantt Chart)



(Cecil Green Park Gantt Chart)


Task Name
Sep '17
Oct '17
Nov '17
Dec '17
Jan '18
Feb '18
Mar '18
Apr '18
27 3 10 17 24 1 8 15 22 29 5 12 19 26 3 10 17 24 31 7 14 21 28 4 11 18 25 4 11 18 25 1 8
NW Marine Drive (CMP)
Chancellor Blvd (CMP)
Memorial Rd (CMP)
School of Music (CMP)
Student Union Blvd (CHAMBER)
Student Union Blvd (CMP)
Cecil Green Park (CHAMBERS)
Staging
Trailer delivered
Fencing delivered
Erect fencing
Equipment delivered
Precast chambers delivered
Excavation
Excavate detention pit
Survey
Chamber installation
Chamber placing
QC inspection
Excavate asphalt
Excavate sewer trunk trench
Connect storm to detention
Municipal inspection
Survey
Backfill & Paving
Backfill road
Prep road for paving
Paving equipment delivered
Pave road
Backfill detention pit
Turnover
Machinery off site
Excess materials off site
Fencing off site
Trailer off site
Complete

Appendix E: Structural Analysis Calculations

Description	Symbol	Tank 1	Tank 2	Tank 3	
Base	L	36.000	30.000	30.000	m
Width	w	18.000	12.000	18.000	m
Height	h	4.500	4.500	2.000	m
Volume (initial)	Vi	2916.000	1620.000	1080.000	m^3
Collumns (l side)	NL	5.000	4.000	4.000	
Collumns (w side)	Nw	2.000	1.000	2.000	
C to C (l side)	Li	6.000	6.000	6.000	m
C to C (w side)	wi	6.000	6.000	6.000	m
Trib Area for col		36.000	36.000	36.000	m^2
b/w	Li/wi	1.000	1.000	1.000	
# of Cols	Nc	10.000	4.000	8.000	
Vol of Cols	Vc	7.200	4.500	4.000	m^3
Length of Beams	LB	162.000	78.000	132.000	m
Vol of Beams	Vb	51.840	24.960	42.240	m^3
Length of Walls	Lw	108.000	84.000	96.000	m
Volume of Walls	Vw	97.200	75.600	38.400	m^3
Volume of Slab (top	Vst	129.600	72.000	108.000	m^3
Volume of Slab (bottom)	Vsb	97.200	54.000	81.000	m^3
Volume of Pad Footings	Vp	20.000	8.000	16.000	m^3
Volume of Strip Footings	Vsf	24.300	18.900	21.600	m^3
Volume of Concrete	Vc	427.340	257.960	311.240	m^3
Contact Areas					
Slab (top)	CA st	658.800	368.400	549.600	m^2
Slab (bottom)	CA sb	8.100	6.300	7.200	m^2
Beam	CA b	324.000	156.000	264.000	m^2
Column	CA c	7.200	7.200	3.200	m^2
Wall	CA L	972.000	756.000	384.000	m^2
Pad Footing	CA p	20.000	8.000	16.000	m^2
Strip Footing	CA sf	64.800	50.400	57.600	m^2

Constant	Value
Phi s	0.850
Phi c	0.650
f'c	30.000
fy	400.000
alpha	0.800
beta	0.900

Yellow = Load

Green = Resistance

Loads

Dead Soil	D	10.000	10.000	10.000	Kpa
Snow	S	1.750	1.750	1.750	Kpa
Live Load	L	0.000	0.000	0.000	Kpa
Unfactored Load		11.750	11.750	11.750	Kpa
Load Case 3	Kpa	1.25 D + 1.5 S			
Factored Load	Kpa	15.125	15.125	15.125	Kpa

Beams (Flexure)

Length	L	6.000	6.000	6.000	m
Trib Area	A	18.000	18.000	18.000	mm^2
Idealized Area Height	h	3.000	3.000	3.000	m
Load	W	24.125	24.125	24.125	Kpa
Beam Weight	BW	19.200	19.200	19.200	Kpa
Factored Load	Wf	144.375	144.375	144.375	KN/m
Unfactored Load	W	114.450	114.450	114.450	KN/m
Factored Moment	Mf	649.6875	649.6875	649.6875	KNm
height (estimated)	hi	0.375	0.375	0.375	m
width (estimated)	bi	0.188	0.188	0.188	m
height	h	0.800	0.800	0.800	m
width	bi	0.400	0.400	0.400	m
cover	m	0.040	0.040	0.040	m
depth (estimated)	di	0.730	0.730	0.730	m
height (estimated)	hi	375	375	375	mm
width (estimated)	bi	188	188	188	mm
height	h	800	800	800	mm
width	b	400	400	400	mm

cover	m	40	40	40	mm
depth (estimated)	di	730	730	730	mm
Steel Area	As	2886.972	2886.972	2886.972	mm^2
Configuration		6-25M	6-25M	6-25M	
Bars	n	6.000	6.000	6.000	
Diameter	db	25.000	25.000	25.000	mm
Area	Ai	500.000	500.000	500.000	mm^2
Area Total	As	3000.000	3000.000	3000.000	mm^2
Ratio	max = 0.027	0.010	0.010	0.010	
effective Depth	d	737.500	737.500	737.500	mm
Spacing	Smin	35.000	35.000	35.000	mm
1.4db		35.000	35.000	35.000	mm
1.4Amax		28.000	28.000	28.000	mm
30		30.000	30.000	30.000	mm
Minimum Width	Bmin	390.000	390.000	390.000	mm
Minimum Steel Area		876.356	876.356	876.356	mm^2
Depth of compression	a	163.462	163.462	163.462	mm
Moment Resistance	Mr	668.885	668.885	668.885	KN*m

Beams (Shear)

Length	L	6.000	6.000	6.000	m
Factored Load	Wf	144.375	144.375	144.375	KN
Shear Force	V	343.350	343.350	343.350	KN
Factored Shear Force	Vf	433.125	433.125	433.125	KN
Effective Depth	d	737.500	737.500	737.500	mm
Effective Shear Depth	Dv	663.750	663.750	663.750	mm
Shear at Midspan	Vfmid	0.000	0.000	0.000	KN
Shear at Dv	Vf @ Dv	337.2960938	337.2960938	337.2960938	KN
Beta	B	0.18	0.18	0.18	
Concrete Shear Resistance	Vc	170.1417967	170.1417967	170.1417967	KN
Steel Resistance Required	Vs	167.1542971	167.1542971	167.1542971	KN
Stirrup Diameter	Ds	10	10	10	mm
Sitrrup Area	Ab	100	100	100	mm^2
Shear Area	Av	200	200	200	mm^2
Spacing	S	386	386	386	mm
Spacing Max	Smax	464.625	464.625	464.625	mm
Design Spacing	S	300	300	300	mm
Minimum Area	Avmin	98.59006035	98.59006035	98.59006035	mm^2
Max Shear Resistance	Vrmax	1294.3125	1294.3125	1294.3125	KN
Steel Shear Resistance (Design)	Vs	215.1435	215.1435	215.1435	KN
Shear Resistance (Total)	Vr	385.29	385.29	385.29	KN

Slabs (Flexure)

height of slab	hs	0.250	0.250	0.250	m
height of slab	hs	300.000	300.000	300.000	mm
Clear Span	Ln	6.000	6.000	6.000	m
Load		15.125	15.125	15.125	Kpa
Self Weight	p	24.000	24.000	24.000	KN/m^3
Dead Load (SW)	p	7.200	7.200	7.200	Kpa
Factored Load	Wf	24.125	24.125	24.125	Kpa
Factored Moment	Mf	108.5625	108.5625	108.5625	KN*m/m
Width	b	1.000	1.000	1.000	m
	b	1000.000	1000.000	1000.000	mm
Effective Depth (initial)	di	230.000	230.000	230.000	mm
Steel Area Required	As	1466.880	1466.880	1466.880	mm^2/m
	Db	20	20	20	mm
Bar Area	Ab	300	300	300	mm^2/m
Spacing	s	205	205	205	mm
Spacing Design	s	200	200	200	mm

Steel Area	As	1500.000	1500.000	1500.000	mm^2/m
Reinforcement Ratio	p	0.007	0.007	0.007	Max = 0.027
Effective Depth (actual)	d	250.000	250.000	250.000	mm
Gross Area	Ag	300000.000	300000.000	300000.000	mm^2
Compression Depth	a	32.692	32.692	32.692	mm
Moment Resistance	Mr	119.1634615	119.1634615	119.1634615	KN*m/m

Columns

Height of Column	Hc	4.500	4.500	2.000	m
Height of Column	Hc	4500.000	4500.000	2000.000	mm
Compression Load (service)	Ps	1373.4	1373.4	1373.4	KN
Compression Load (factored)	Pf	1732.5	1732.5	1732.5	KN
Area (required)	Ag	115500.000	115500.000	115500.000	mm^2
Width/Height (required)	b	339.853	339.853	339.853	mm
Width/Height	b	400.000	400.000	400.000	mm
Area	Ag	160000.000	160000.000	160000.000	mm^2
Reinforcement Ratio	p	0.010	0.010	0.010	
Steel Area (required)	Ast	1600.000	1600.000	1600.000	mm^2
Reinforcement Ratio		4-20M	4-20M	4-20M	
Number of Bars	n	4.000	4.000	4.000	
Diameter	Db	20.000	20.000	20.000	mm
Bar Area	Ab	300.000	300.000	300.000	mm^2
Steel Area	Ast	1200.000	1200.000	1200.000	mm^2
Comp Resistance Steel	Prs	408.000	408.000	408.000	KN
Comp Resistance Concrete	Prc	2477.280	2477.280	2477.280	KN
Compression Resistance	Pro	2885.280	2885.280	2885.280	KN
Compression Resistance (max)	Prmax	2308.224	2308.224	2308.224	KN
Transverse Ties Spacing	Smax	320.000	320.000	320.000	mm

Walls (Flexure)

Height of Wall	Hw	5	5	2	m
Pressure at top of Tank	Po	2.320	2.320	2.320	Kpa
Pressure at bottom of Tank	Po	21.000	21.000	9.320	Kpa
Factored Pressure @ Top	Pof	3.480	3.480	3.480	Kpa
Factored Pressure @ bottom	Pof	31.500	31.500	13.980	Kpa
Uniform Factored Pressure	Wf	19.230	19.230	10.470	Kpa
Slab weight	rho s	7.200	7.200	7.200	Kpa
Slab Load	Q	11.750	11.750	11.750	Kpa
Slab Load Factored	Qf	15.125	15.125	15.125	Kpa
Beam Shear Force @ end	V	433.125	433.125	433.125	KN/m
Dead Load from Slab	D	18.950	18.950	18.950	Kpa
Dead Load from Slab (factored)	Df	24.125	24.125	24.125	Kpa
Dead Load from Slab	D	37.900	37.900	37.900	KN/m
Dead Load from Slab (factored)	Df	72.375	72.375	72.375	KN/m
Beam Force Distributed over 6m	wf	72.188	72.188	72.188	KN/m
Beam Force Distributed over 6m	ws	57.225	57.225	57.225	KN/m
Load on Wall (non factored)	qs	95.125	95.125	95.125	KN/m
Load on Wall (vertical)	qf	144.563	144.5625	144.5625	Kn/m
Length of Wall	Lw	6.000	6.000	6.000	m
Horizontal Moment	Mmax	60.09375	60.09375	5.235	KN*m/m
Horizontal Shear	Vmax	48.075	48.075	10.47	KN/m
Shear Resistance of Concrete	Vc	384.501	384.501	384.501	KN/m
Minimum Thickness	tmin	190.000	190.000	80.000	mm
Design Thickness	t	200.000	200.000	200.000	mm
Bar Diameter	db	20.000	20.000	20.000	mm
Effective Depth	d	150	150	150	mm
Steel Area required	As	1277.739341	1277.739341	101.5374428	mm^2/m
Spacing required	Sreq	234.790	234.790	2954.575	mm
Spacing Maximum	Smax	500.000	500.000	500.000	mm
Spacing Design	S	200.000	200.000	200.000	mm

Steel Area	As	1500.000	1500.000	1500.000	mm^2/m
Reinforcement Ratio	p	0.010	0.010	0.010	
Min Reinforcing Area	Asmin	300.000	300.000	300.000	mm^2/m
Compression Depth	a	32.692	32.692	32.692	mm
Moment Resistance	Mr	68.163	68.163	68.163	Kn*m/m

Walls (Shear)

Horizontal Shear	Vmax	48.075	48.075	10.47	KN/m
Effective Shear Depth	Dv	144.000	144.000	144.000	mm
Beta	B	0.200	0.200	0.200	
Concrete Shear Resistance	Vc	102.534	102.534	102.534	KN/m
Avmin	Avmin	400.000	400.000	400.000	mm^2/m
Bar Diameter	Db	15.000	15.000	15.000	mm
Bar Area	Ab	200.000	200.000	200.000	mm
Spacing Required	Sreq	500.000	500.000	500.000	mm
Spacing Max	Smax	500.000	500.000	500.000	mm
Design Spacing	S	500.000	500.000	500.000	

Bottom Slab

Load on the Wall (factored)	qf	144.563	144.563	144.563	KN/m
Weight of the Wall	w	24.000	24.000	9.600	KN/m
Total Load (factored)	Wf	174.563	174.563	156.563	KN/m
Compression Load (column)	P	1732.500	1732.500	1732.500	KN
Weight of the Column	w	19.200	19.200	7.680	KN
Total Load Transferred from Column	P	1756.500	1756.500	1742.100	KN

Slabs (Flexure) bottom

Slab Thickness	h	150.000	150.000	150.000	mm
Gross Area	Ag	150000.000	150000.000	150000.000	mm^2/m
Minimum Reinforcement Area	Asmin	150.000	150.000	150.000	mm^2/m
Effective Depth	d	50.000	50.000	50.000	mm
Diameter Bar	db	15.000	15.000	15.000	mm
Area bar	Ab	200.000	200.000	200.000	mm^2
Spacing	sreq	1333.333	1333.333	1333.333	mm
Design Spacing	s	1000.000	1000.000	1000.000	mm

Pad Footings

Ultimate Bearing Pressure	qult	850.000	850.000	850.000	Kpa
Unfactored Load	Ps	1390.680	1390.680	1381.080	KN
Factore Load	Pf	1754.100	1754.100	1742.100	KN
Allowable Bearing Pressure	qall	425.000	900.000	900.000	Kpa
Area required	A	3.272	1.545	1.535	m^2
Width	B	1.809	1.243	1.239	m
Design Width	B	2.000	2.000	2.000	m
Area	A	4.000	4.000	4.000	m^2
Factored soil Pressure	qf	438.525	438.525	435.525	Kpa
Factored Shear	Vf	1754.100	1754.100	1742.100	KN
Concrete Shear Resistance	Vc	1352.875	1352.875	1352.875	Kpa
Concrete Shear Resistance (design)	Vc=Vf	1754.100	1754.100	1742.100	KN
	bo * d	1.297	1.297	1.288	m^2
Width	t	0.400	0.400	0.400	m
Quadratic constants	a	4.000	5.000	6.000	
	b	1.600	1.600	1.600	
	c	-1.297	-1.297	-1.288	
	d	0.403	0.374	0.349	m
	Vc 1	2.029	2.029	2.029	Kpa
	Vc 2	2.464	2.396	2.335	Kpa
Bar Diameter	Db	20.000	20.000	20.000	mm
Cover	c	75.000	75.000	75.000	mm

Thickness	h	488.443	458.774	433.740	mm
Design thickness	h	500.000	501.000	502.000	mm
Design d	d	415.000	416.000	417.000	mm
1 way Shear	Vf	337.66425	336.7872	333.61215	KN
Effective Shear Depth	dv	373.500	374.400	375.300	mm
Concrete Shear Resistance	Vc	398.920	399.881	400.843	KN
Factored Moment	Mf	280.656	280.656	278.736	KN*m
Moment Resistance	Mr	280.656	280.656	278.736	KN*m
Steel Area Required	As req	2006.662	2001.565	1982.456	mm^2
Gross Area	Ag	1000000.000	1002000.000	1004000.000	mm^2
Steel Area Minimum	Asmin	2000.000	2004.000	2008.000	mm^2
Design Reinforcement	Db	20.000	20.000	20.000	mm
Number of bars	n	8.000	8.000	8.000	
Area of bars	Ab	300.000	300.000	300.000	mm^2
Steel Area (design)	As	2400.000	2400.000	2400.000	mm^2
Spacing	s	257.143	257.143	257.143	mm
Required Development Length	Ld	569.210	569.210	569.210	mm
Length	L	1700.000	1700.000	1700.000	mm

Strip Footings

Ultimate Bearing Pressure	qult	473.000	473.000	473.000	Kpa
Unfactored Load	Ps	119.125	119.125	104.725	KN/m
Factored Load	Pf	148.906	148.906	130.906	KN/m
Allowable Bearing Pressure	qall	236.500	236.500	236.500	Kpa
Footing Width	l	0.504	0.504	0.443	m
Design Width	l	0.750	0.750	0.750	m
Length	b	1.000	1.000	1.000	m
Length	b	1000.000	1000.000	1000.000	mm
Area	A	0.504	0.504	0.443	m^2
Factored Soil Pressure	qf	295.625	295.625	295.625	Kpa
Cover	c	75	75	75	mm
Trial Thickness	h	300.000	300.000	300.000	mm
Diameter of bar	Db	15	15	15	mm
Area of Bar	Ab	200	200	200	mm^2
Number of Bars	n	3	3	3	
Effective depth	d	217.5	217.5	217.5	mm
Factored Shear Force	Vf	16.9984375	16.9984375	16.9984375	KN/m
Effective Shear Depth	Dv	216	216	216	mm
Beta	B	0.21	1.21	2.21	
Concrete Shear Resistance	Vc	161.4905189	930.4929896	1699.49546	KN/m
Factored Moment	Mf	11.17832031	11.17832031	11.17832031	KN/m
Steel Area Required	As	149.5442905	149.5442905	149.5442905	mm^2/m
Min Reinforcemenet Area	Asmin	600	600	600	mm^2/m
Steel Area Design	As	600.000	600.000	600.000	mm^2/m
Spacing	s	333.3333333	333.3333333	333.3333333	mm
Design Spacing	Sdes	300	300	300	mm
Longitdunail Gross Area	Ag	225000	225000	225000	mm^2
Asmin	Asmin	450	450	450	mm^2
Diameter of bar	Db	15	15	15	mm
Area of Bar	Ab	200	200	200	mm^2
Number of Bars	n	3	3	3	
Steel Area	As	600	600	600	mm^2

Appendix F: Geotechnical Analysis Calculations

Horizontal Soil/Water Load:

$$\sigma_H = K_a H * \gamma' + H y_w$$

$$K_a = \frac{1-\sin(38)}{1+\sin(38)} = 0.238$$

$$\sigma_{H(0.5)} = 2.32kPa$$

$$\sigma_{H(5.0)} = 23.2kPa$$

Vertical Loads:

$$\sigma_V = H * \gamma$$

$$\sigma_{(0.5)} = 0.5 * 19.6 = 10kPa$$

Factored Load:

$$L = 1.25 * DL + 1.75 * SL = 15.125kPa$$

Settlement:

$$S_e = C_1 C_2 (\bar{q} - q) \sum_0^{z_2} \frac{I_z}{E_s} \Delta z$$

where

I_z = strain influence factor
C_1 = a correction factor for the depth of foundation embedment = $1 - 0.5[q/(\bar{q} - q)]$
C_2 = a correction factor to account for creep in soil = $1 + 0.2 \log$ (time in years/0.1)
$\bar{q}$ = stress at the level of the foundation
$q = \gamma D_f$ = effective stress at the base of the foundation
E_s = modulus of elasticity of soil

4.5 m box square	
Df	0.5
σ	5.874
Nq	48.9
Nc	61.31
Ny	77.9
y	19.6
y'	9.79
B	2
dw	0
σ	5.874
Φ (degrees)	38
Φ (radians)	0.663225116

Layer	Depth (below footing)	Δz	Es	z (mid)	qz (mid)	Iz (avg)	Iz*Δz/Es
1	1m	1	100000	0.5	53.845	0.44096015	4.4096E-06
2	1m-4m	3	100000	2.5	73.425	0.39096015	1.17288E-05
						SUM	1.61384E-05

settlement	0.0098 m 9.8 mm

Bearing Capacity:

$$Hydrostatic\ Bearing\ Pressure = 5m * \frac{9.81kN}{m3} = \ 44kPa$$

$$Mass\ of\ Tank = 469728kg$$

$$Tank\ Bearing\ Pressure = \frac{469278kg *\ 9.81\ m/s^2}{30m * 12m} = 13kPa$$

$$Total\ Bearing\ Pressure = 57kPa$$

$$Allowable\ Bearing\ Pressure\ = 150kPa$$

$$FOS = \frac{150}{57} = 2.63$$

Sheet Pile Calculations:

Density (kg/m3)	2000	angle (deg)	38	
y (kN/m3)	19.6	angle (rad)	0.6632	
G (Mpa)	200	Ka	0.2379	
K (kPa)	2000	Kp	4.2037	
yw (kN/m3)	9.81	ko	0.3843	
Excavation Depth	6	m	FOS	1.5
Wall Depth	10	m	15 deg(rad)	0.262
Diff.	4	m		
anchor spacing	1.2	m		
load transfer	190	kn/m		
p	18.18	kN/m		
total load	109.10	Kn/m2		
# anchors	1			
H1	2			
pe	27.28			
loads				
Mb	17.51	kNm		
T1	59.60	kN		
R	13.13	kN		
x	1.96	m		
bond length				
D	74.05			
Bond Length	0.58	m		
unbonded length	From CAD			
Total Anchor Length				
Stability Checks				
T1	59.60	Pe	27.28	
R	13.13			
SUM	72.74	FOS	2.67	
0.5*Pp	164.62	R	13.13	
		Pa	93.16	
FOS	1.55	SUM	106.29	