UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

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Multiple Use Stormwater Detention Adjacent to UBC Centre for Comparative Medicine

FINAL DESIGN REPORT

April 08th, 2019

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EXECUTIVE SUMMARY

This Final Design Report provides information pertaining to Thunderbird Lake, a proposed stormwater wet pond facility for South UBC in Vancouver. This report consists of a table of contents, overview, introduction, design overview, design criteria, technical considerations, summary of software and standards used, construction planning, project cost estimate and appendices including construction specifications and detailed drawings. Thunderbird Lake was chosen as the preferred design for a number of reasons, namely, the existence of numerous precedent examples to similar systems, the high quality of effluent discharge released into the ocean, and promotion of green space for students, nearby residents, and visitors. Thunderbird Lake will be capable of safely handling a volume of 8,500 m^3 in the event of a 1/100 year rainfall event. Thunderbird Lake is a typical wet pond featuring a forebay for sediment settlement and a main pond for stormwater detention, separated by a concrete weir. The pond features continuous orifice flow into an outlet detention tank, as well as a pair of pipes that can be opened with a valve when the pond is to be drained. Other design criteria which were considered include the use of a water recirculation system, biofiltration mechanisms, serviceability, and aesthetics. Construction of the facility is expected to take approximately 8 months, with an anticipated start date of May 2019. Based on preliminary estimates, the total cost of the project is valued at $2,677,000.

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1.0 INTRODUCTION

Team 16 has been selected by the University of British Columbia (UBC) Social Ecological Economic Development Studies (SEEDS) Sustainability Program to design a stormwater detention system adjacent to UBC Center for Comparative Medicine (CCM). The goal of the project is to design a stormwater detention system that will collect runoff from South UBC campus and release the collected stormwater at a controlled rate to prevent erosion of the cliffs near Wreck Beach. The stormwater detention system must also serve as a multipurpose facility. Team 16 believes that a wet pond water retention system is the best option to meet the criteria of the project. A wet pond has been design and named "*Thunderbird Lake*". This report will detail the design and design process of Thunderbird Lake and provide details necessary for construction of Thunderbird Lake.

1.1 SITE DESCRIPTION

The UBC Centre for Comparative Medicine (CCM) is one of Western Canada's largest medical research facilities. Located in the south end of UBC campus next to the Tri-University Meson Facility (TRIUMF) and the National Research Council Institute for Fuel Cell Innovation, the protection of this area is a priority. The location of the CCM is shown in Figure 1.

Figure 1*: Location of the Centre for Comparative Medicine*

1.2 PROJECT OBJECTIVES

The UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program has identified the need for a stormwater detention facility adjacent to the CCM, at the intersection of SW Marine Drive and Wesbrook Mall. The primary objective of this facility is to detain stormwater flows resulting from a 1/100 year rainfall event. During the design rainfall event, the facility must safely control enough stormwater for the current drainage systems to function without failing. Nearby research centres are considered major stakeholders in this project, as flooding of this area could impact operations at these locations. The sustainability targets of UBC and Metro Vancouver encourage a design which limits environmental impact and provides additional functionality aside from only stormwater detention. The detention facility must also release stormwater of acceptable quality into the environment at a controlled rate, without damaging the cliffs surrounding Wreck Beach.

1.3 TEAM CONTRIBUTION

Team 16 is comprised of six individuals, each providing insight from their respective experiences. Below is a summary of each team member's contribution to the development of this report.

Table 1: Member Contribution Summary Table

Justin DeSiena	3D Modelling, Hydrological Considerations, Stormwater Collection System
Chris Irish	Hydrological Considerations, Stormwater Collection System
Sandeep Arcot	Geotechnical Considerations, Structural Design
Tarek Ghoul	Pond Hydraulic Design, Environmental Considerations
Matthew Munk	Construction Planning and Scheduling, Environmental Considerations
Jimmy Zhang	Cost Estimate, Drafting, Photovoltaic System

2.0 DESIGN OVERVIEW

The design overview describes all key components of Thunderbird Lake. Major elements of the design include stormwater collection, the wet pond, and water discharge system. A 3-D concept preview of the proposed design is shown in Figure 2.

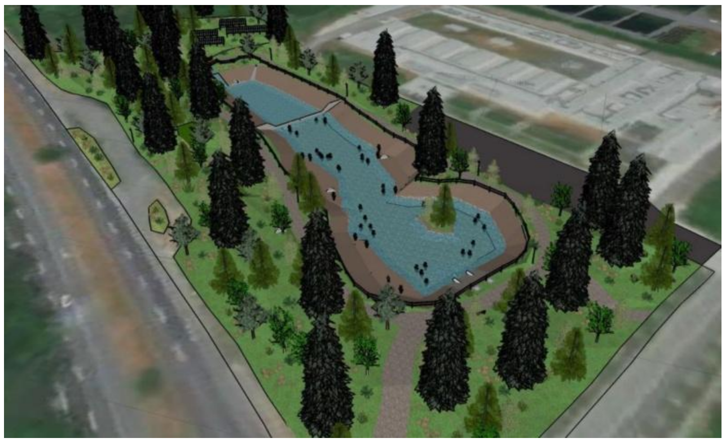

Figure 2*: 3-D Orthographic Projection Render of Thunderbird Lake Concept*

2.1 STORMWATER COLLECTION & DISCHARGE

To deliver stormwater to the wet pond facility, it must be collected from existing stormwater lines spanning parallel along Marine Drive and Wesbrook Mall. The pipes comprising this collection system must be adequately sized to convey flows resulting from the 1/100 year storm; Section 2.1 describes how the stormwater collection and discharge systems were designed for Marine Drive and Wesbrook Mall sub-catchments, and the pond outlet. All pipe sections are precast concrete with a Manning's "n" value of 0.013; nominal pipe diameters were selected based on the smallest size up from the required diameter. The invert elevation for the inlet structures of both Marine and Wesbrook Diversions is set to the permanent water elevation of 54.25 m.a.s.l in the forebay. A summary of pipe dimensions for the entire stormwater collection and discharge system is provided in Table 2. Specifications for the pipe sections can be found in Section 2 of *Appendix A - Standards and Specifications*.

Table 2: Stormwater Collection & Discharge Pipe Dimensioning

PIPE SEGMENT	LENGTH [m]	NOM. PIPE DIAMETER [mm]	SLOPE [%]	FLOW RATE [m^3/s]
Marine 1	**128.6**	**450**	**0.4**	**0.13**
Marine 2	**30.4**	**525**	**0.4**	**0.26**
Wesbrook 1	**52.8**	**1050**	**1.5**	**2.48**
Wesbrook 2	**75.4**	**1050**	**1.5**	**2.48**
Wesbrook 3	**166.8**	**1050**	**1.4**	**2.48**
Wesbrook 4	**71.3**	**1050**	**1.8**	**2.48**
Wesbrook 5	**172.0**	**1200**	**0.56**	**2.41**
Pond Outlet	**55.2**	**600**	**3.6**	**0.92**

2.1.1 MARINE

The Marine Drive sub-catchment delivers approximately 10% of the total flows to the wet pond facility resulting from the 1/100 year storm. The southernmost pipe inlet in the forebay, Marine Inlet, delivers stormwater to the wet pond facility via two collection pipes, namely, Marine Diversions 1 & 2. To maximize flow into the wet pond facility, pipe grades for the Marine sub-catchment were designed at the minimum value of 0.4% as stated in the Surrey Design Criteria. Marine Diversion 1 connects to an existing drainage pipe oriented approximately north-south; the connection features a contraction between the existing trapezoidal drainage ditch and Marine Diversion 1. Marine Diversion 2 connects to an existing gutter which follows the east side of SW Marine Dr; this pipe will span parallel to a paved accessibility path for entrance to the northeast corner of the park. The Marine inlet features a headwall structure with Marine Diversions 1 and 2 entering the facility independently.

2.1.2 WESBROOK

The Wesbrook Drive sub-catchment delivers approximately 90% of the total flows to the wet pond facility, resulting in a design flow rate of 2.48 m^3/s. The Wesbrook Diversion consists of 5 pipe segments that connect to two existing stormwater lines. The stormwater line which connects to Segment 5 conveys the vast majority of the flow to the Wesbrook Inlet, as it conveys flow from the existing stormwater line running parallel to Wesbrook Mall which drains a large portion of South UBC. The connection from the existing stormwater line to Segment 5 features an expansion from 1050 mm to 1200 mm.

The stormwater line which connects to Segment 4 drains the neighbouring Centre for Comparative Medicine (CCM) and contributes only 0.07 m^3/s to peak flows. The connection from the existing stormwater line to Segment 4 features an expansion from 250 mm to 1050 mm. Pipe grades for the Wesbrook Diversion were selected initially by assuming the minimum value of 0.4%, and the elevation of the *closest upstream* node for the Wesbrook stormwater line was found; the pipe grades were then adjusted to account for the increase in elevation difference between the node and the pond inlet. Segments 1, 2, 3 and 4 of the Wesbrook collection system feature a constant diameter of 1050 mm. Segments 4 and 5 are outside of the study area for the wet pond facility, and therefore permission need be obtained to lay and connect pipe to the existing stormwater system. The Wesbrook inlet features a headwall structure with the Wesbrook Diversion entering from approximately north.

2.1.3 POND OUTLET

The Pond Outlet pipe connects the outlet structure of the wet pond facility to the culvert which crosses under Wesbrook Mall. The pipe is designed to convey a flow rate of 0.92 m^3/s, as determined from analysis. As the elevation difference between the outlet and culvert is quite high, the Pond Outlet pipe is required to be built at a grade of 3.6%, causing the section to fail the necessary cover requirement as provided by the Surrey Design Criteria; to account for this, a small amount of fill will be placed above the shallow sections to ensure adequate pipe cover of 1.5 m. The relatively large slope also causes 1/100 year flows to become supercritical, therefore in-pipe energy dissipators will be used to reduce water speed and prevent erosion. The connection from the Pond Outlet pipe to the existing stormwater line features an expansion from 600 mm to 1200 mm.

2.2 INLET

The inlet system for the wet pond facility is comprised of to two intake structures; the Wesbrook Inlet and the combination of the two Marine Inlets. The structures are to be precast concrete wingwalls angled at 45 degrees with a footing and pipe intake centered at the permanent water level. The wingwall structure was designed using (LHV Precast, n.d.) as guidance for geometry and dimensions. Details and dimensions of the Wesbrook and Marine Inlets are provided in *Appendix D - Detailed Design Drawings*.

2.2.1 INLET PROTECTION

The Surrey Design Criteria warrants energy dissipation for supercritical inflows to reduce the scouring effects of high-velocity water. Using the Froude number and flow velocity, riprap aprons were designed according to the TP10 design guidelines used by the City of Auckland (2003). Both aprons consist of 0.25 m riprap and measure 8 m x 3.6 m x 0.5 m and 8 m x 5.6 m x 0.5 m for the Wesbrook Inlets and combined Marine Inlets, respectively. A single size riprap was used for homogeneity and logistic considerations; the greater diameter governed.

2.2.2 DEBRIS COLLECTION

The end of each intake pipe will be fitted with netted trash traps to collect large debris before they enter the forebay while allowing design flows to pass unimpeded. These traps will reduce equipment damage and pipe blockage, as well as facilitate easier cleaning and maintenance of the forebay.

2.3 FOREBAY

The purpose of the forebay is to provide a sedimentation process for stormwater entering the facility, dissipate the energy of flows into the main pond, and provide additional retention volume. Stormwater entering the facility will likely contain suspended sediments, which if not removed, may contribute to blockage of hydraulic features or contamination at the ocean outfall. The forebay is designed such that any particle larger than 0.05 mm will settle to the bottom of the pond by gravity before it reaches the weir and is discharged into the main pond.

The minimum water level required for sedimentation in the forebay is determined to be 0.6 m; to account for effective particle settlement and water loss due to evaporation, the permanent water level is designed to be 0.7 m. Due to the relatively shallow permanent water level, reservoir stratification can be ignored. The forebay is designed as a trapezoidal cross section with an average basin width of 9 m, depth of 3 m, slopes of 1:3 (California Stormwater), a total *permanent* stormwater volume of 295 m^3, and a full volume of approximately 2065 m^3 (including permanent volume and stormwater detention volume) detailed drawings are shown in *Appendix D - Detailed Design Drawings*.

To prevent stagnant water and improve water quality, a surface aerator will be used in the forebay. Due to the systems exposure to open surfaces and location in an area with significant anticipated sediment runoff, the facility will have to be drained and dredged every 2 - 3 years (Government of Canada, 2013). To accommodate this maintenance, a drainage mechanism has been designed which features a pipe connecting the forebay and the main pond via the weir. Natural drying cycles will allow for dredging to be performed in the summer. If it is to be performed during any other period, the main pond can be drained by opening the valves, then a valve at the bottom of the weir can be opened to drain the forebay. The project maintenance plan located in Section 4.7 of this report can be referenced for more information.

2.4 WEIR

To control flow between the forebay and main pond, a weir was designed to be placed between the two reservoirs. The weir will delay the overall time taken for stormwater to accumulate in the main pond, therefore providing more retention time for the system. The weir also improves the stormwater quality of the main pond by trapping sediment in the forebay. Team 16 recommends the use of a 1 m tall 0.3 m wide V-notch concrete weir with an angle of 160 degrees. The notch shall be located at the centre of the structure at a height of 0.7 m, directly above the permanent water level such that it allows water through during stormwater events. The structure will be made of reinforced concrete with riprap placed downstream of the weir opening to dissipate energy and prevent bed erosion.

Two 250 mm pipes with valves will be located 0.1 m above the forebay bed and shall be used to drain the forebay for maintenance purposes.

2.5 POND

The main pond will be 97 m long and will feature a vertical concrete retaining wall at the stormwater discharge outlet. The pond bed is located 0.3 m below the forebay's bed resulting in an elevation drop at the weir. A clay liner will be installed underneath and around the facility to prevent stormwater seepage and soil contamination. The trapezoidal cross section of the main pond is designed identically to that of the forebay, with a height of 3 m and horizontal distance of 9 m, yielding a 1:3 slope; a typical cross section as well as the width over the span of the length is shown in *Appendix D - Detailed Design Drawings*. The main pond has a minimum top width of 27 m, although the width varies across its 97 m length. The main pond features a total permanent stormwater volume of 1,164 m^3, and a full volume of 5,238 m^3 (including permanent volume and stormwater detention volume) The majority of stormwater held during a 1/100 year storm event will reside in the main pond with a detention volume of 5,800 m^3 including the forebay capacity.

The large design volume for the main pond is attributed to failsafe redundancy; the main pond was sized based on the assumption that the outlet for the facility may become blocked and cannot release stormwater, therefore requiring it to detain the entirety of the 1/100 year storm event. The operating depth of stormwater in the main pond is 1 m, although during a 1/100 year storm event the water level will rise to approximately 2.75 m. To prevent stagnant water and improve water quality, as with the forebay, aerators and circulators will be used. A summary table of the detention volumes of both the forebay and the main pond is presented below.

Table 3: Detention Pond Volume Summary Table

	PERMANENT VOLUME	DETENTION VOLUME	FULL VOLUME
Forebay	295	1770	2065
Main Pond	1164	4074	5238
Total	1459	5844	7303

2.6 OUTLET/ACCESS VAULT

Given the nature of this project and the significant risk to the environment and human life in the event of failure, this facility was designed with several redundancies; the facility features a three-tiered protection system to provide safety from failure.

The outlet of the facility is designed with two 250 mm orifices draining into the current stormwater system; the orifices are located at a height of 1.125 m from the pond floor, allowing for drainage when the water level rises. The orifices were sized to withstand flows generated from a design head of 2.9 m, which represents the head exerted on the system given no continuous drainage (hydrostatic condition). Given that in reality there will be continuous drainage from the outlet of the facility, the design includes a large factor of safety (FOS) for freeboard. The actual water level of the main pond is expected to rise to 2.7 m, and yield a maximum discharge outflow of ~0.4 m^3/s during the 1/100 year flood event. While excluding the runoff from subcatchments not diverted to the wet pond facility, the total flow through the conduit under Wesbrook Mall will be ~0.7 m^3/s, still significantly smaller than the maximum flow rate of ~1.2 m^3/s. Both outlets will feature filters that will prevent debris from entering the existing stormwater system as detailed in Section 2.5 of *Appendix A - Standards and Specifications*. Upon exiting the main pond, stormwater will be conveyed via pipes into a stormwater chamber which will consist of a 700 mm x 1000 mm x 2500 mm vault that is accessible through a manhole and will relieve pressure in the system. The manhole will allow access to the outlet to facilitate cleaning and maintenance operations. After flowing into the chamber, stormwater will be conveyed through two 250 mm pipes that connect to each other and then into the main 600mm concrete outlet pipe.

In the extremely unlikely event that both the stormwater tanks are blocked or otherwise cease to function, a parallel system has been devised consisting of two emergency discharge pipes with release valves. These discharge pipes will typically be used when draining the main pond for maintenance, although can still be used in emergency events if necessary. These 250 mm corrugated metal pipes were sized such that they can drain the main pond should the total head reach 2.9 m. The two failsafe mechanisms discussed in the preceding clauses were designed to be able to function simultaneously while limiting overland flows to below 1.2 m^3/s.

The third design redundancy is the volume of the facility itself; the pond is sized in such a way that it is able to detain the entire 1/100 year flood event without failure. While this potential outcome is undesirable due to concerns of stormwater quality, it acts as the 'last line of defense' in the entire system. This allotted contingency also protects the overall system from a situation where the outlets are blocked; the volume of the main pond is large enough that even if this catastrophic failure occurs, the pond is still able to detain the large flows and prevent the nearby sensitive areas from inundation.

2.7 FILL AND SOIL MATERIALS

Thunderbird Lake will be built with a variety of fill materials to form the side embankments, support slab foundations and to prevent seepage of stormwater. This section discusses the fill materials to be used in the construction of this facility.

2.7.1 EMBANKMENT FILL

The existing soil on site was found to be glacial till. The soil can be classified as a combination of silty sand, clayey sand, and silt based on the ASTM D-2487 classification system. Based on typical soil parameters and after conducting a slope stability analysis, the native soil was found to be suitable for use to form the embankments for Thunderbird Lake. Details regarding the site investigation and slope stability analysis can be found in Section 4.10 of this report. The specifications for the embankment fill can be found in Section 2 of *Appendix A - Standards and Specifications*.

2.7.2 ENGINEERED FILL AND GRAVEL

All the structural systems within the facility will be supported by slab-on-grade concrete foundations. In order to provide adequate support for the slab foundations, an engineered fill consisting of clean sand should be placed in areas where a slab foundation is to be constructed. On top of the engineered fill a layer of gravel and polyethylene moisture barrier will be installed to prevent any possible moisture migration. Details regarding the engineered fill and gravel can be found in Section 4.10 of this report and Section 2 of *Appendix A - Standards and Specifications*.

2.7.3 CLAY LINER

In order to prevent seepage of the pond water into the surrounding soil, a clay liner will be installed. With a clay liner the seepage of pond water will be minimal and any effects are deemed negligible. Details regarding clay liner and specifications can be found in Section 4.10 of this report and Section 2 of *Appendix A - Standards and Specifications*.

3.0 DESIGN CRITERIA

Many different factors were taken as design criteria for this project. As a multi-purpose facility, Thunderbird Lake was designed to handle floods, protect the environment, exist for future generations, and act as an accessible and aesthetic amenity on UBC campus.

3.1 EXTREME FLOOD EVENT

The wet pond facility is designed to maintain a permanent water level during typical storm events. As per the client's requirement, the pond is also appropriately sized to retain a 1/100 year flood volume.

3.2 ENVIRONMENTAL PROTECTION

3.2.1 CLIFF EROSION

Cliff erosion is an important issue within the scope of the wet pond design. Detainment and controlled release of the 1/100 year flood volume was required to minimize overland sheet flows and negative downstream impacts to the cliffs surrounding Wreck Beach.

3.2.2 GREEN SPACE

The maintenance of green space and promotion of nature habitat is a primary focus in the design of the wet pond facility. The site will facilitate biodiversity and sustainability; aligning with the client's and UBC's visions and environmental targets.

3.2.3 SEDIMENTATION

By consulting the Quebec Ministry of Agriculture's design standards regarding detention ponds, the forebay was adequately sized to settle all particles larger than coarse silt and most medium silts (0.035 mm) during a 1/100 year storm event. By calculating the horizontal particle speed compared to the vertical speed, it was calculated that a 38 m long forebay would be sufficient to achieve this consideration. During smaller storm flows (10% of the 1/100 year event), particles larger than fine silts will be settled.

The presence of a weir will further improve the systems ability to detain sediment and prevent it from entering the main pond as well as create a well defined area that can be cleaned every 2-3 years, thus preventing the buildup of significant amounts of sediment in the main pond.

3.3 DESIGN LIFE

Because this facility is designed to detain a 1/100 year storm, its design life must be long enough to make it a worthwhile effort. A project life of at least 50 years was considered when designing this project. Project materials were chosen to be durable and long lasting. Work required to preserve the functionality and extended life of the wet pond is prescribed in the maintenance plan, which can be found in Section 4.9 of this report; consideration of this plan will allow for the facility to function optimally throughout its life.

3.4 ACCESSIBILITY

Thunderbird Lake was designed to be a multipurpose facility, and as such, access to the public must be maintained. While the 30 m tree buffer exists and would deter members of the public from entering the facility, there are four entrances to the facility, each with their own gates. The gate from marine drive to the southwest would be accessible to vehicles and heavy equipment such as excavators for maintenance purposes. The location of the site is also critical when considering accessibility to the public. Given that there are bus stops on either side of Thunderbird Lake, the site is ideal for public access. With regards to accessibility within the Thunderbird Lake site, there is a scenic path around the lake with a fence preventing individuals from falling, allowing them to enjoy the park.

3.5 AESTHETICS

As the site is located on a major entrance to the UBC campus, aesthetic appeal is a significant criterion when designing the facility. The facility's tree buffer will enhance the natural appearance of the park and the campus itself.

3.6 MULTI-PURPOSE FACILITY

Thunderbird Lake will be surrounded with green space and walking pathways that can be utilized as leisure areas. Due to the proximity to TRIUMF, The CCM, and the Wesbrook residential area, it is anticipated the green space and leisure area will be utilized by residents from Wesbrook Village and workers from the nearby research facilities. Thunderbird Lake also serves the purpose of being a welcoming feature for UBC campus from the entrance near SW Marine Drive. Thunderbird Lake will act as welcoming feature for students and professor who commute to campus as well as visitors.

3.7 STAKEHOLDER ENGAGEMENT

Stakeholders and local First Nations groups relevant to this project must be consulted to ensure its success. UBC is located on unceded Musqueam land, therefore the Musqueam First Nation must be consulted, and their approval for the project must be received before construction. Nearby facilities such as The CCM and TRIUMF are stakeholders due to their proximity, and must also be consulted to ensure the project does not negatively impact them. UBC students will fund this project through tuition and may visit the area, thus making them stakeholders as well. Those entering campus by vehicle, bike, or on foot to Wesbrook Mall are considered stakeholders to the project, as Team 16 wishes to enhance the visual appeal of the corner property for public satisfaction, and to attract visitors.

4.0 TECHNICAL CONSIDERATIONS

Technical considerations were examined and used to perform calculations and design components of the project.

4.1 POND SIZING

The pond was sized with several factors in mind; the pond is to be able to settle all particles larger than fine silts, with all particles larger than coarse silts (0.05 mm) settling in the forebay during the 1/100 year event. During typical storms, the bulk of the fine silts (0.01 mm) are to be settled in the forebay which was sized accordingly. Sedimentation velocities were calculated using soil particle density and dimensions of the pond, The Agrireseau Quebec Retention Basin Guide was used to determine time for a given particle to fall to the bottom of the pond.

The pond was also sized with the maximum outflow of 1.2m3/s flow rate constraint. Detention pond outlet structures are typically sized to match the rainfall flow patterns, however due to this constraint, a worst case scenario was assumed and several redundancies were put in place to prevent a risk to public safety resulting from a collapse of the cliffs downstream. One of these redundancies was the size of the pond itself which is to accommodate 5844 m3 of water, which corresponds to the total amount of water assuming constant discharge below the 1.2 m3/s rate with a factor of safety to account for other overland flows that were not captured by the stormwater drainage system and accounting for the magnification resulting from the effects of global warming. This was calculated by creating a flow-balance hydraulic model with time steps of 1 s and modelling the effects of the expected flow rate on the overall system at any given time, accounting for the weir, the forebay, and the constant outflow.

4.2 EVAPORATION

Due to the historically dry summers in Vancouver, the effects of surface evaporation were considered for the wet pond facility. The Penman Formula was used to calculate the water loss due to evaporation based on temperature data retrieved from Environment Canada. The temperature data were selected for the 4-month period between May - August for the year 2017, as this drought season reported the highest average temperature on record for Vancouver. After application of the Penman Formula with an assumed dew point temperature of 10 C, a volume reduction of 1000 m^3 is estimated for the wet pond facility under the stated conditions. Although this volume is large, the wet pond facility will not dry completely as the permanent pond volume is 1459 m^3. Considering that there will be some inflow during this period, there is a low risk of the wet pond facility drying entirely.

4.3 SEICHING

Seiching was considered given the strong winds that may be experienced in Vancouver. Assuming a 140 km/hr windstorm, it was calculated that the pond would experience seiching in the order of 2.3 cm, thus marginally contributing to recirculation while still not resulting in a risk of spilling during the 1/100 year event.

4.4 PIPE SYSTEMS

Clause 5.4.2.5 of the SDC states that the minimum pipe grade is 0.4 %. To capture as much flow as possible into the wet pond facility, minimum slope requirements were used for both pipe segments connecting to the Marine Inlet. The steepest pipe grade in the system is 3.6 % for the pond outlet pipe, which is below the maximum of 15 % from the SDC. Clause 5.4.2.6 states that design velocities must be less than 3 m/s and subcritical; due to the required slope of the pond outlet pipe, the flow velocity in that section is super-critical during a 100-year event. This will be mitigated by placement of small rip-rap (diameter 0.25 m) at the pipe exit near the culvert under Wesbrook Mall. The smallest design velocity in the system is 0.8 m/s for the Marine 1 pipe segment, which is above the minimum velocity of 0.6 m/s from the SDC. To protect against acid attack and general pipe corrosion, the concrete pipe sections will be protected as per Section 3.2 in *Appendix A - Standards and Specifications*.

4.5 WEIR DESIGN

A V-notched weir was selected as it provides additional retention time, detains sediment in the forebay, and allows for the water level in the forebay to be maintained during smaller events, spilling over the weir during large stormwater events. This also serves to channel the flow to a smaller area that is covered with riprap, thus acting as a scour mitigation device.

A set of valves located at the bottom of the weir were placed to allow for drainage should the entire pond need to be drained during the wet season. In such a scenario, the main pond would be drained, followed by the forebay. The weir is made of rebar reinforced concrete, made of the proper exposure class. Specifications for the concrete can be found in Section 3.1 of *Appendix A - Standards and Specifications*.

4.6 RIPRAP SIZING

The size of the stones selected to be used as riprap (0.25 m) is chosen to satisfy both of the requirements of the inlet placement and weir placement as to reduce cost.

4.7 MAINTENANCE PLAN

Maintenance work must be done periodically throughout the life of the wet pond, to ensure optimal performance. Maintenance Specifications can be found in *Appendix B - Sample Calculations*.

4.7.1 DREDGING PLAN

To prevent the accumulation of sediment at the bed of the forebay, an excavator shall be used to dredge the pond at least once every three years or after a year with particularly strong storms comparable to the 1/100 year storm event. The pond will be dredged between June 1st and August 1st for safety purposes when the water level is lowest due to evaporation.

Excavators shall only access the forebay via the designated access route. The main pond does not need to be routinely dredged since the majority of the sediment will accumulate in the forebay.

4.7.2 WATERFOWL MANAGEMENT

Waterfowl such as geese and ducks are usually considered a nuisance in regards to lakes and other bodies of waters as their excrements may pollute the water and they may be aggressive to park users. To prevent waterfowl from gathering near the pond, 4 coyote scarecrows will be placed at various locations near the water to deter them. This will be coupled with a non-toxic goose repellent that shall also be periodically applied to grazing areas to keep away geese and other waterfowl.

4.7.3 PIPE CLEANING

All inlet and outlet pipes are to be routinely cleaned and inspected to prevent clogging during storm events. The grates and trashbags will over time accumulate debris.The emergency outlet pipes must be manually cleaned from the outside but the orifice outlet pipes may be cleaned through the access manhole.

4.7.4 CIRCULATOR AND AERATOR MAINTENANCE

During the winter where flows are expected to be high, the circulator systems will be turned off to prevent damage to the system. Aerators and Circulators should be inspected as per their user manuals every two years to ensure that they are working properly and are replaced when needed. Should the aerator and circulators fail, causing algae growth, commercial products such as Algaway and Green Clean can be used to treat the algae.

4.7.5 VEGETATION MAINTENANCE

At times plants may need to be replaced. Long droughts, harsh winters, or local wildlife could potentially kill off vegetation planted in the wet pond. It is recommended that the pond is inspected twice a year, in September and in March, to determine if any sections of vegetation must be replanted.

4.8 PARK LAYOUT

The overall site surrounding the main wet pond feature prioritizes the safety and comfort of its visitors. The walkway and ramps are designed to be compacted engineered fill to accommodate bicycles and wheelchairs as well as provide an appealing design from the street. The main pathway circling the facility will have standard park fencing between itself and the pond slopes with a vehicular access gate at the forebay (mentioned previously) and maintenance gates for technicians to service the outlet. The site is designed with standard park lighting for visitor safety.

The site includes a park area with picnic benches on the moderately sloped land and a pathway leading to the street. The steeper terrain is utilized as a solar farm to provide power of the facilities electrical components.

4.9 RENEWABLE SOLAR PHOTOVOLTAICS

A solar pathing analysis was conducted, and a shadow projection was produced. The results are summarized in Figure 3 and used to estimate the maximum number of solar photovoltaic panels that could be installed at the site without being in the shade cast by other panels and tall trees in the area. The angle of the sun used for the calculations is taken as the solar angles experienced on the winter solstice, as the sun is farthest to the earth during that time and the longest shadows are cast. An estimated 160 panels can be installed at our site, with an installation capacity of 41.6 kW. In the winter time, an average of 55 kWh of energy can be produced on a daily basis, while 203 kWh can be produced in the summer. This energy production is enough to power between 2 to 8 households at any given time and is sufficient to power all the recirculation and aeration devices and site lighting. The entire system is connected to the electrical grid so that excess power generated can be used to reduce the total load on the grid. The grid also serves as a backup to the site electricity demands when the solar panels undergo maintenance or at night when the panels cease to operate. Out of warranty and safety concerns, the panels are recommended to only be in operation between 9:00 AM and 4:00 PM such that panels ending up in the shade do not become dead loads in the system. The exact details and specifications of the technology used for the system may be found in Section 6 of *Appendix A - Standards & Specifications*.

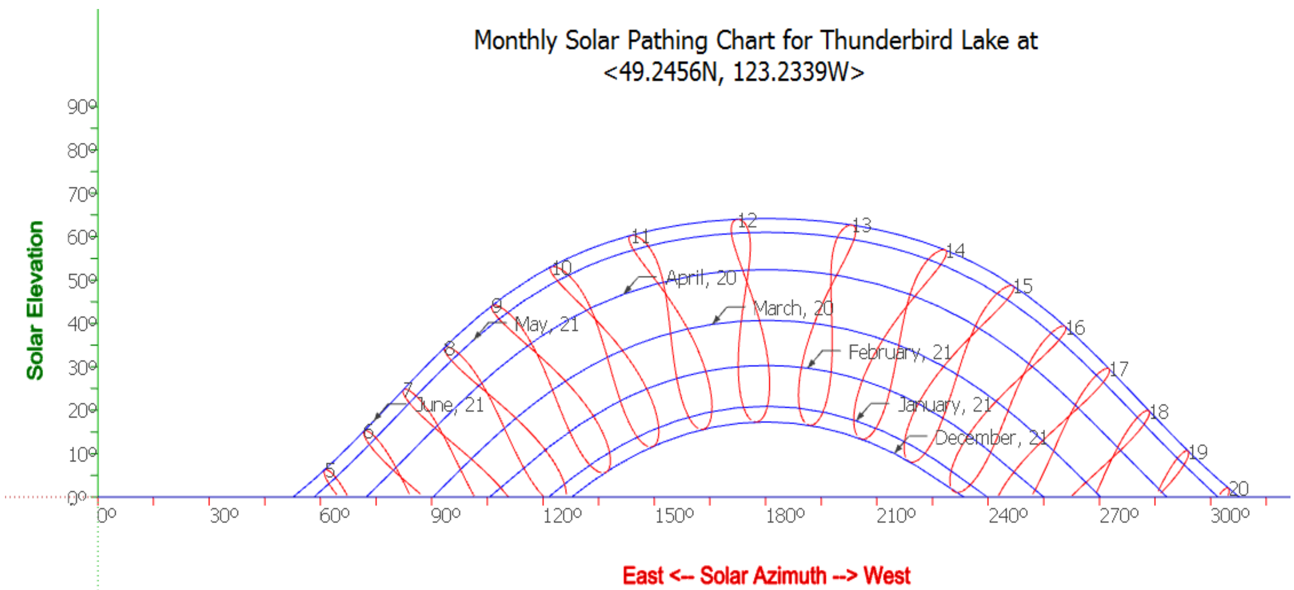

Figure 3: *Solar Altitude and Angle Summary Chart at Thunderbird Lake Site Location*

4.10 GEOTECHNICAL CONSIDERATIONS

The following section will discuss the site investigation that was conducted near the proposed facility, and further research conducted regarding geotechnical considerations for this project. The section will also provide design details and requirements dealing with geotechnical engineering relevant to the project.

4.10.1 SITE INVESTIGATION

The facility is to be situated adjacent to the UBC Centre for Comparative Medicine (CCM) in South UBC. Although no geotechnical investigation has been conducted at the exact site of the proposed project, a geotechnical site investigation report prepared by GeoPacific Consultants (GPC) is available for a multi-story development near 16th Avenue and Westbrook Mall. For the purposes of this report, it is assumed that the conditions reported by GPC are consistent with conditions found at the location for the proposed facility. Three auger test holes were drilled to depths between nine and eleven meters below surface level; a summary of findings relevant to the project provided from the GPC geotechnical assessment are provided in the sections below.

4.10.2 SUBSURFACE SOIL CONDITIONS AND SOIL PARAMETERS

The geology of South UBC was classified by GPC as Vashon Glacial deposits. This was done by utilizing Map 1484A from the Geological Survey of Canada (Government of Canada). The borehole data provided in the report shows that there is ~0.5 m of topsoil overburden spread across the site, after ~0.5 m of depth, there is ~9 m of glacial till; no further data is available regarding deeper soil layers. The glacial till matrix is described as a silty sand with trace gravel clasts and cobbles, exhibiting high density at shallow depths and higher density at deeper depths. Based on GPC’s soil description, the soil can be classified as a mixture of silty sand, clayey sand and silt based on the American Society for Testing and Materials (ASTM) D-2487 Classification System. The soil was classified using the ASTM D-2487 system primarily because most of the referenced standards and engineering guides utilized ASTM D-2487 as well.

As no soil parameters were provided by the report prepared by GPC, further research was conducted in order to produce a geotechnical analysis. An engineering guide titled "Introduction to Fill and Backfill for Structures" published by CED Engineering was referenced for soil parameters to be used in the geotechnical analysis. The guide listed typical soil parameters for various types of soil depending on the classification of soil based on the ASTM D-2487 classification system. Table 4 below summarizes the soil parameters selected for the native glacial till on site. Parameters for the clay liner were also selected using this guide. The clay liner will be discussed in the following sections.

Table 4: Selected Soil Parameters

MATERIAL	MAXIMUM DRY DENSITY (kN/m^3)	FRICTION ANGLE (Degrees)	COHESION (kPa)
Glacial Till	15	31	50
Clay Liner	15	28	86

4.10.3 GROUNDWATER CONDITIONS

The report prepared by GPC indicates the static groundwater table is expected to be far below ground level. Perched groundwater was found in isolated locations from the borehole data, occurring sporadically at depths ranging from 4 m - 5.5 m (GeoPacific Consultants). Due to the depth of the static groundwater level and only isolated incidents of perched groundwater being present, no specific considerations for groundwater effects were considered.

4.10.4 SEISMIC CONDITIONS

It was found that subsurface soils are not prone to ground liquefaction or other forms of ground softening induced by seismic events (GeoPacific Consultants). As a result, seismic effects were not considered for the design of Thunderbird Lake.

4.10.5 STORMWATER SEEPAGE CONTROL

In order to maintain water in the wet pond, many design guidelines for wet ponds suggest the installation of a clay liner. A clay liner may not be needed dependent on the permeability of the native soil on site. The report prepared by GPC provided no information regarding the permeability of the native soil on site. For conservative measures it was decided that a clay liner should be installed to prevent seepage of stormwater into the soil and maintain a water level for the pond.

An engineering guide prepared by National Estuarine Research Reserve (NERR) titled "Low Impact Development in Coastal South Carolina: A Planning and Design Guide" was referenced in order to design the stormwater seepage control system. It is suggested a clay liner be utilized to prevent seepage of pond water. The clay liner will have thickness of 0.3 meters and additional layer of compacted soil with a thickness of 0.3 meters will be place above the clay liner. The existing soil will be used as the additional layer of compacted soil. The specification for the clay liner can be found in Section 2 of *Appendix B - Sample Calculations*. Figure 4 below shows a typical pond cross section with the clay liner installed.

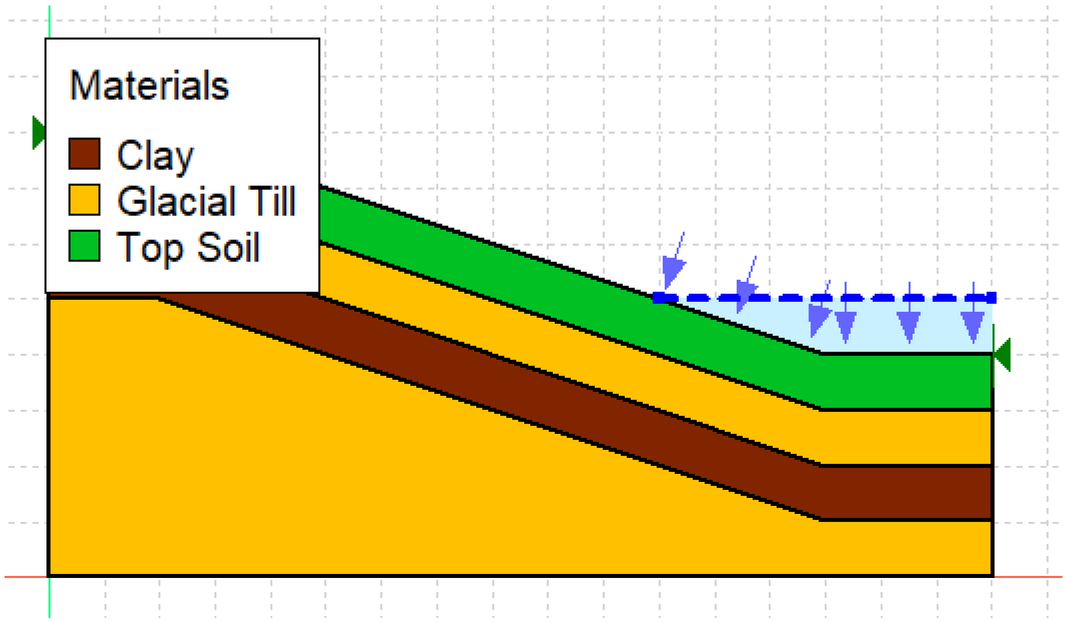

Figure 4: *Pond Cross Section*

4.10.6 SHORING AND EXCAVATION

Based on the report produced by GPC, temporary construction embankments may be designed to have a maximum ratio of 4V:3H (GeoPacific Consultants). All embankments and excavations should be performed in accordance with WorkSafe BC regulations unless otherwise directed by the geotechnical engineer.

4.10.7 SLOPE STABILITY

A slope stability analysis was performed using Slope/W by GeoStudio. Various design guidelines have advised an embankment slope of 1V:3H for stability purposes. The standard Slope/W model parameters were input into the analysis, including usage of the Morgenstern-Price method for slope stability. According to the site investigation conducted, the static groundwater table was not included in the model. The only scenario modelled in Slope/W was the critical setup characterized by a drained pond.

Soil parameters from Table 4 were input into the model. Seepage effects were not considered as the clay liner applied to the embankment will allow for negligible seepage into the underlying soil. After analyzing results from the model, the FoS for the critical slope failure mode was found to be 12.7. Figure 5 below shows the output from Slope/W with the critical failure slope and associated FOS.

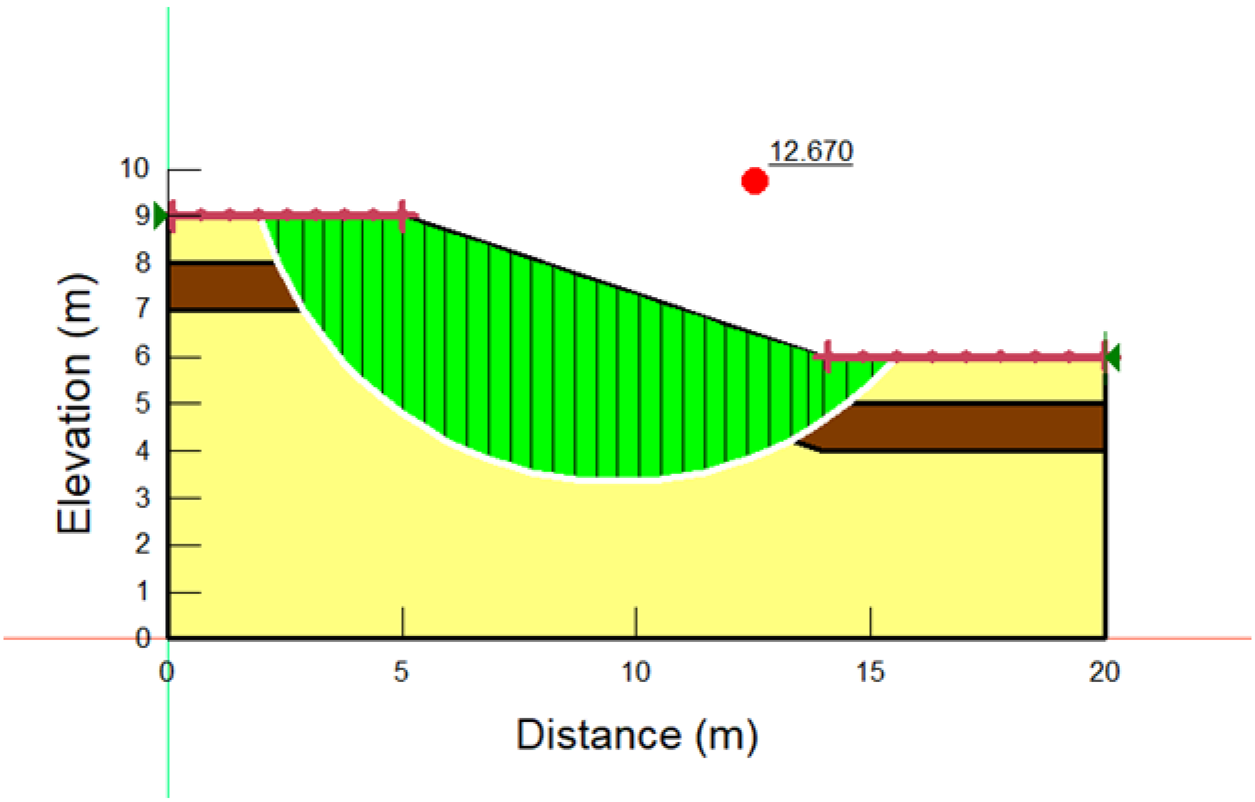

Figure 5: *Slope Stability Analysis Results*

Based on the results of the slope stability results and following an engineering guide regarding structural fill prepared by CED Engineering as previously mentioned, it was determined the native material is suitable to be used as fill material to form the proposed pond slopes of 1V:3H. Specifications and procedures needed to be undertaken to prepare the native soil material to form the embankments of the pond can be found in Section 2 of *Appendix A - Standards and Specifications*.

4.10.8 FOUNDATION DESIGN REQUIREMENTS

Thunderbird Lake will feature two foundation systems; both systems are concrete slab-on-grade foundations and are utilized at the outlet and weir structures. GeoPacific Consultants have outlined requirements for foundations which will be discussed below.

For adequate frost protection for foundation structures, the structures must be positioned at a minimum depth of 450 mm below grade (GPC). All foundation structures on site have been designed in accordance with this consideration.

The bearing capacity of the native soil is expected to be 575 kPa (GPC). The maximum pressure on the native soil under any foundation on site is expected to be 55 kPa which yields a FoS of 10, far greater than general requirements.

All foundation structures should be supported by an engineered fill. The proposed engineered fill material can be considered a clean sand. To prevent any potential upward migration of moisture, a polyethylene moisture barrier should be installed beneath the foundation along with gravel (GPC). Specifications for the engineered fill, polyethylene moisture barrier, and gravel can be found in Section 2 of *Appendix A - Standards and Specifications*.

Foundation settlements should be below 25 mm (GPC). No heavy loading is expected on site, and the heaviest additional load in comparison to existing conditions is expected to be an additional 5 kPa. Considering that the depth of glacial till is expected to be very large, settlement effects are considered negligible.

5.0 SOFTWARE AND STANDARDS

In this section the software and standards used to design the various project components are detailed.

5.1 SOFTWARE

Multiple softwares were used in this project for a variety of purposes. Table 6 below lists all software used in the development of the wet pond facility.

Table 6: *Software Used*

SOFTWARE	USE
GeoStudio Slope/W	Slope stability analysis of the pond embankments. A critical failure slope and associated factor of safety was calculated using the software
RSMeans	Estimate task durations for project schedule
Microsoft Project	Generate Gantt Chart of project Schedule
Microsoft Excel	Create a hydraulic model of head of the facility, size the collection and discharge pipes, and was used in conjunction with EPASWMM to model flow rates
AutoCAD	Scale dimensions and design the pond based on local right-of-ways and elevations
EPASWMM	Analyse the existing stormwater system and determine 1/100 year flow rates in pipe segments
SketchUp	Conceptualize and project a 3D rendering of the proposed wet pond facility

5.2 STANDARDS AND GUIDELINES

Multiple standards and guidelines were used in this project for a variety of purposes. Table 7 below lists all standards and guidelines used.

Table 7: *Standards and Guidelines Used*

STANDARD	USE
CSA A23-3 Concrete Design Code	Design of the concrete structure for the weir/forebay and outlet structure
NER Pond Design Guideline	Reference to design the pond embankments and clay liner
ASTM (American Society of Testing Materials)	Preparation of specification for fill material
Agriculture, Fisheries, and Food Canada- Water Storage and Sedimentation Guide	Sedimentation calculations and forebay sizing
Surrey Design Criteria (SDC)	Design of the stormwater collection and discharge system
Iowa DNR Stormwater Management Manual	Wet pond design constraints and sizing

6.0 CONSTRUCTION PLANNING

The construction process of this project has been outlined and all necessary tasks have been considered.

6.1 SCHEDULE

The schedule for this project begins on May 1st 2019, and ends on December 26th 2019; yielding a construction period of 172 working days, distributed over 8 months.

Construction for this project has been scheduled using Microsoft Project to create a Gantt Chart, which is attached in *Appendix C - Schedule Gantt Chart*. RSMeans was used to estimate job durations. Estimated float times were taken into account in the durations used in the Gantt Chart. Relationships between the different tasks were considered and taken into account. Certain tasks must be completed or started before others can be completed. For example, the laying of inlet piping must be done before the trench it lays in can be filled, but the entire length of the pipe does not need to be installed before backfilling begins. In the schedule, the piping is set to finish installation one day before the backfilling is completed. This can be seen in a section of the Gantt Chart shown in Figure 6 below.

ID	Task Mode	Task Name	Duration	Start	Finish
1		**Construction**	**177 days**	**Wed 19-05-01**	**Thu 20-01-02**
6		**Installation of Inflow Pipes**	**15 days**	**Fri 19-09-27**	**Thu 19-10-17**
7		**Piping from Wesbrook Stormwater**	**15 days**	**Fri 19-09-27**	**Thu 19-10-17**
10		Laying Pipe	12 days	Mon 19-09-30	Tue 19-10-15
11		Removing Shoring and Filling Trench	6 days	Wed 19-10-09	Wed 19-10-16

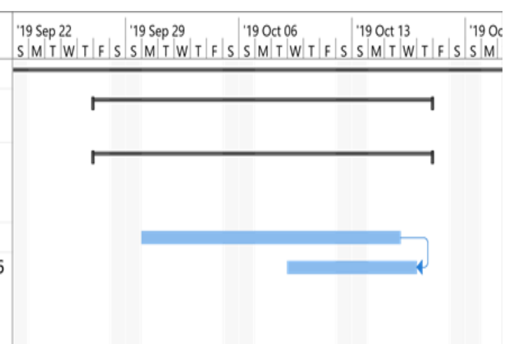

Figure 6: *Pipe Laying and Trench Filling*

6.2 CRITICAL PATH

The critical path for construction of this project is the rigid list of tasks which directly affects the schedule of the overall project; if one of these tasks is delayed, then the final completion date of the project will also be delayed. Tasks which are not considered part of the critical path feature flexibility for delays without affecting the entire project schedule. In the Gantt Chart schedule in *Appendix C - Schedule Gantt Chart*, critical path items are highlighted in red.

The first task that must be completed is the clearing and grubbing of existing vegetation; this is required to prepare the site for other works to occur. The next critical task is bulk excavation of the pond. After excavation is done, the embankments must be compacted. The clay liner can then be installed along the banks and base of the pond. Again, the embankments must be compacted. Backfilling soil above the clay liner can then be completed and soil can be compacted. Backfilling of a base material must be completed below the slab portion of the outlet structure before forming and rebar placement can be done. After the concrete of the outlet structure is poured and has cured for 2 weeks, the formwork can be removed. The precast concrete risers behind the outlet can then be installed, along with the outlet piping. Once these pipes are connected, they are buried with backfill. As this concludes the heavy earthworks to be done on site, landscaping is done next. The walkway is built, lighting is installed, and pond guardrails are assembled. Solar panel podiums are then constructed, and the panels installed. Finally, the site trailer is removed and the 30 m treeline buffer at the construction entrance is replanted.

6.3 ANTICIPATED SITE ISSUES

There is potential for construction to take longer than projected due to human error and adverse site conditions. In the construction schedule attached in *Appendix C - Schedule Gantt Chart*, it is assumed that no human errors are made, and site conditions are ideal. If soil stability is not as predicted, shoring and engineered backfill may become necessary. If unexpected perched groundwater is encountered, dewatering will be required. Any mechanical failures of equipment used during construction can also cause delays. As the facility is expected to be under construction for approximately one year, it will face a variety of weather conditions. Poor weather such as heavy rain or snow can result in work delays, whereas extreme weather conditions such as large storms could potentially damage works which have already been completed.

6.4 TRAFFIC MANAGEMENT PLAN

Due to the utility work involved in connecting Thunderbird Lake to the existing infrastructure, several roads will have to be closed. As such, Team 16 has created a traffic management plan to deal with the impacts of construction on nearby neighbourhoods, and to reroute traffic safely through the area without disrupting the operations of the nearby research centres.

6.4.1 WESBROOK DIVERSION

The Wesbrook diversion will result in a portion of the Wesbrook mall stormwater network getting severed and replaced with new pipes. While the pipes will run underneath the sidewalks away from the street, some manholes will have to be relocated and the roundabout would therefore need to be closed at night to allow work to proceed. The roundabout would be closed just north of the 41 bus stop at northbound Wesbrook Mall at the TRIUMF Centre. The bus is operational between 7:08 am to 11:40 pm, providing workers with a 6-hour window to perform the necessary work. The roundabout will also be closed north of Nursery Street and west of the road adjacent to TRIUMF, allowing traffic to circumvent the roundabout. Access to the nearby facility north of CCM will be temporarily restricted during this time. Figure 7 below shows the layout of the roads adjacent to the site.

Figure 7: *Roadways Adjacent to Project Site*

6.4.2 OUTLET CONNECTION

Following the Wesbrook diversion tie in and shut off, the outlet must be connected to the stormwater system. At this point, the roundabout will once again be fully operational and as a result, vehicles will be able to travel through this area. The southbound lane will be temporarily closed to allow for the tie-in. This would effectively create a one-way road, restricting vehicles from travelling southbound at Wesbrook mall after the parking lots and using them to allow traffic to circle back and return north to access SW Marine via Ross and W 16th Avenue. This would add 3 km to the journey given the lack of redundancies in the area. This however would not affect the ability of first responders to arrive at the scene given that the path to the closest hospital, UBC Hospital, will be unobstructed during this phase of construction.

During this phase of the construction process, the 41 travelling southbound on Wesbrook would be asked to collect and drop off commuters at TRIUMF, then use the roundabout to return northbound and access SW Marine Drive through Ross and W 16th Avenue for an average bus delay of 6-8 minutes. Buses travelling to UBC would travel instead along SW Marine, turning right at W 16th Avenue, right at Ross Street, right at Wesbrook Mall, then circling back after dropping off travellers at TRIUMF.

6.5 STAGING AREAS

During construction, a staging area will be required to store material and equipment to be used on site. This is also where the site trailer will be located. The area where the solar panels will eventually be installed directly to the northwest of the facility will be used as the staging area during construction. Because this is directly adjacent to the pond, and the solar panels are only installed after everything else has been completed, this is a good location for the staging area. Entrance to the site will be via a pull out lane on SW Marine Dr. Access paths will connect this entrance to the staging area and to the pond. These access paths can then be used during maintenance dredging throughout the life of the wet pond. A sketch of the layout is shown below in Figure 8.

Figure 8: *Staging Area Location*

7.0 PROJECT COST ESTIMATE AND SUMMARY

An estimate of all costs associated with construction and operation has been completed.

7.1 OPERATING COST

One of the reasons why the wet pond facility was selected as the preferred option is the fact that there are many precedent examples around the world for Team 16 to draw inspiration from. A report commissioned by the Bay Area Stormwater Management Agencies Association is used as a baseline for extrapolating the maintenance costs of this facility. The report surveyed and compiled the operation costs of various stormwater detention systems in over thirteen cities in the states of Washington, Oregon, and Texas. The typical detention pond incurred annual maintenance costs of between $500 to $2,600 USD (Minton, 2003). After adjusting for exchange rates and applying an inflation rate of 40.5% to account for the change in price indices between the release of the report in 2002 and present day, an estimated annual operating cost of $4,700 CDN is obtained. This amount is not included in the Project Cost Summary as it is not an upfront capital cost. In an effort to reduce the operation and maintenance costs, higher capital expenditure is exercised to include circulators and aerators as well as water purifying plants *Nuphar Polysepalum* and *Scirpus Validus* throughout the water body.

7.2 CAPITAL COST OVERVIEW

The costs associated with the wet pond facility are divided into two major sections, construction costs and development costs. The construction costs add up to $2,062,000, and the development costs add up to $258,000. This puts the total project cost, less contingency, at $2,320,000. After a 15% contingency is allotted to the project, the total project cost is expected to be approximately $2,677,000. The pie chart shown in Figure 9 displays the amount and percentage each division contributes to the total cost. For a more detailed breakdown into individual cost codes within each division, refer to the Thunderbird Lake Project Cost Summary in *Appendix E - Cost Summary* and Cost Calculations in *Appendix B - Sample Calculations*.

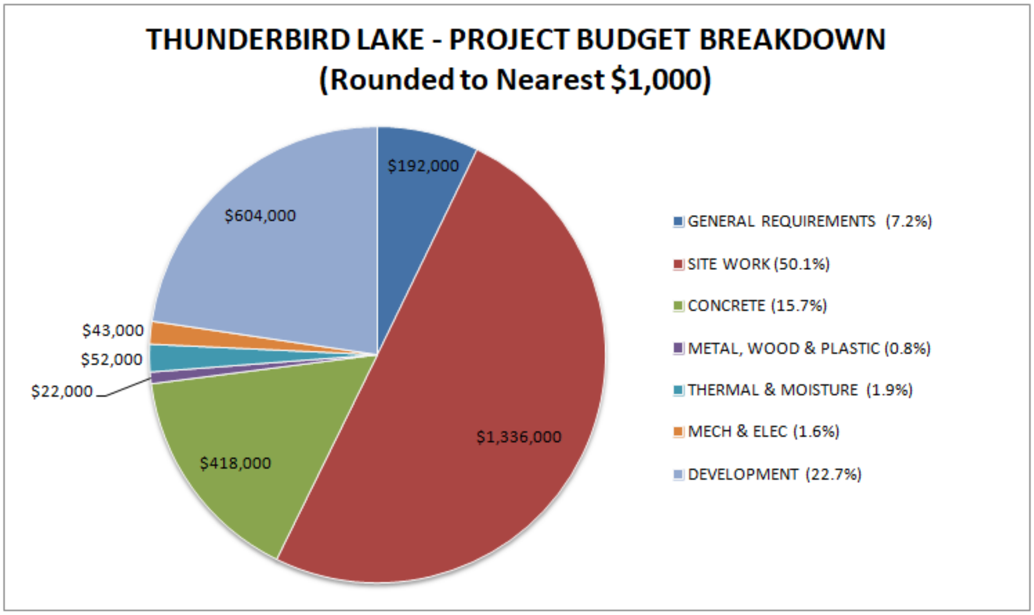

Figure 9: *Project Budget Breakdown*

7.3 FINANCIAL INTEREST RESERVE, LIABILITY INSURANCE, AND CONTINGENCY

Typical financial institutions require a contingency amount totaling no less than 5 % of remaining cost-to-complete items to secure further financing. In a phased project such as the wet pond facility, it is desirable to approach financing with a running mortgage account, such that only what is needed to be paid out is drawn on a monthly basis to avoid unnecessary financing fees and interest payments. A financial interest reserve fund is set aside at approximately 0.2% of the annual costs of the project, leaving $1,700 for the financing costs associated with the project. Since there is indication of perched aquifers in the geology of the site, a 15% contingency is utilized so that even if the potential issue is realized, there will still be sufficient contingency funds available to secure further financing. The worst-case scenario that must be avoided at all costs will be the rejection of financing due to depletion of funds, inclusive of contingency. This will ultimately put the project on hold indefinitely until separate financial injections are made, all the while accumulating further financing fees. The addition of the 15% contingency increases the total project budget by $347,000. The inclusion of liability insurance at benchmark market rates of 0.3 cents per at-risk value of the project is also included. This adds a further $7,000 to the budget.

7.4 SOURCES OF ERROR

Significant effort has been exercised in ensuring the accuracy of the preliminary budget, however, there remain many factors unaccounted for, which may result in the elimination or increase of certain cost items. Although firm quotes for various concrete and sitework items have been procured, the stipulated unit rates are still susceptible to being applied to incorrect quantities. Other sources of uncertainty are caused by the inability to predict the volatile commodities market and the immaturity of the preliminary design. Some original quotes secured during the preliminary design phase of the project have now expired following the start of 2019. Highly conservative cost values are considered to yield greater flexibility in the event of cost discrepancies.

8.0 CONCLUSION

After consideration of options for a stormwater detention facility for South UBC, due to the presence of many precedent examples and water quality concerns, a wet pond facility was selected. Thunderbird Lake is a typical wet pond featuring a forebay for sediment settlement and a main pond for stormwater detention, separated by a concrete weir. Thunderbird Lake will be capable of safely handling a volume of 8,500 m^3 in the event of a 1/100 year rainfall event. Construction of the facility is expected to take approximately 8 months, with an anticipated start date of May 2019. Based on preliminary estimates, the total cost of the project is valued at $2,677,000.

Team 16 proposes the enclosed designs for the stormwater detention facility, and sincerely hopes that the UBC is approving of the documents provided. Team 16 is represented by the undersigned below.

If there are any issues with the proposed designs and/or specifications, please do not hesitate to contact us for further processing.

Sandeep Arcot	Justin DeSiena	Tarek Ghoul
Chris Irish	Matthew Munk	Jimmy Zhang

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APPENDIX A - STANDARDS & SPECIFICATIONS

SECTION 1 - GENERAL REQUIREMENTS

1.1 Installation and Removal of Construction Facilities and Controls

1. Provide construction facilities and temporary controls in order to execute the work expeditiously.
2. Remove from site all such work after use.

1.2 Hoarding

1. Provide hoarding with prefabricated temporary steel-framed construction fence with mesh, 8'-0" high, with sections interlocked together and fence being self-supporting. Erect hoarding around entire perimeter of site to protect the public, workers, public and private property from injury or damage and to the approval of the authority having jurisdiction.
2. Provide lockable gates within hoarding for access to site by workers and vehicles. Ensure hoarding is completely secure when work is not in progress.
3. Locate all construction trailers, garbage bins, hoists, equipment, tools and the like, within the confines of the exterior hoarding.
4. Remove barriers prior to completion and final acceptance. Patch and repair surfaces to original condition damaged by erection of barriers.
5. All hoarding to be in compliance with WCB standards and Municipal regulations, whichever is more stringent.

1.3 Guard Rails and Barricades

1. Provide secure, rigid guard railings and barricades around deep excavations, open shafts, open stairwells, open edges of floors and roofs.
2. Provide as required by authority having jurisdiction.
3. Neatly assemble and firmly brace.
4. Maintain as required during construction period.
5. Remove barriers prior to completion and final acceptance. Patch and repair surfaces to original condition damaged by erection of barriers.

1.4 Hoisting

1. Provide, operate and maintain hoists and cranes required for moving of workers, material and equipment.
2. Operate hoists and cranes using qualified operators.

1.5 Scaffolding

1. Provide and maintain scaffolding, ramps, ladders, swing stages, platforms and temporary stairs.
2. Erect scaffolding independent of walls. Use scaffolding with the least possible interference with the Work. Construct and maintain scaffolding in rigid, secure and safe manner. Remove scaffolding promptly when no longer required. Erect and place scaffolding to permit convenient access to all levels for all workers,the authority having jurisdiction, the Consultant and the Owner.
3. Erect and dismantle scaffolding in accordance with all WCB standards.

1.6 Dewatering

1. Provide temporary drainage and pumping facilities to maintain excavations and site free of standingwater, to the approval of the authority having jurisdiction.
2. Keep excavations free of water while work is in progress.
3. Protect open excavations against flooding and damage due to surface runoff.
4. Dispose of water in a manner not detrimental to public and private property, or any portion of work completed or under construction.
5. Provide tanks, setting basins, or other treatment facilities to remove suspended solids or other materials before discharging to storm sewers, watercourses or drainage areas, in accordance with local authority requirements.
6. 6.Bear all costs for remedial work, and/or the cost to remove saturated material and install additional material to replace saturated material resulting from the failure to carry out the recommended dewatering techniques.

1.7 Access to Site

1. Maintain free and unimpeded access to and egress from site at all times.
2. Whenever interference with normal street and sidewalk traffic becomes necessary for proper and convenient performance of the work, and no satisfactory detour route exists,provide satisfactory detour, temporary bridge, or other proper facility for traffic to pass around or over interference, and maintain in satisfactory condition as long as interference continues. Provide before beginning interference.

1.8 Public Traffic Flow

1. Provide and maintain flag persons, traffic signals, barricades and flares/lights/lanterns as required to perform the Work and protect the public.
2. Maintain access to all portions of the site for fire fighting equipment to the satisfaction of the local Fire Department.

1.9 Sanitary Facilities

1. Provide sufficient portable sanitary facilities during the construction period for workers, in accordance with local health authorities.
2. Maintain in clean condition.
3. The use of the permanent washroom facilities will not be permitted.
4. Provide separate facilities, as required, for men and women, appropriately identified.

1.10 Equipment/Tool/Materials Storage

1. Provide and maintain, in a clean and orderly condition, lockable weatherproof sheds suitable for storage of tools, equipment and materials and to protect from weather or construction.
2. Locate materials required to be stored on site in a manner to cause the least interference with work activities.
3. All Owner/Contractor’s and Subcontractor’s tools and equipment must be in good physical condition.

1.11 Construction Sign

1. Provide and erect 8'-0" x 8'-0" project identification sign, including all necessary posts and framing.Maintain the sign in good condition for the duration of the Work. Clean periodically as required.Sign to be detailed as provided by the Consultant.

1.12 Site Safety

1. The Owner/Contractor is responsible for maintaining of discipline and general orderliness.
2. Provide adequate fire extinguishers on the premises during the course of construction of the types and sizes recommended by the authority having jurisdiction for control of fires resulting from the particular work being performed. Portable fire extinguishers must be visually checked daily, prior to commencement of Work to ensure the units is operational.
3. Maintain on site five (5) sets of CSA approved construction safety hats, and glasses for use of any authorized visitor to site. Visitors are responsible for their own CSA approved footwear.
4. Incorporate the W.H.M.I.S. (Workplace Hazardous Material Information System) and instruct all personnel handling, using and installing hazardous materials, in the proper and safe use of these materials. Hazardous materials are to be handled and used only by personnel trained and knowledgeable in their use and handling.

1.13 Project Close-Out and Warranty

1. Prior to the expiry of the Warranty period for the project or individually completed areas of the project, a review shall be carried out by the Consultant and the Contractor detailing the defective or unsatisfactory materials and/or workmanship. Carry out all remedial work required as observed by this review.

SECTION 2 - SITE WORK

2.0 Reference Standards

1. ASTM D698-91: "Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5 lb. (2.49 kg) Rammer and 12 in. (305 mm) drop."
2. ASTM D2167-84: "Test Method for Density and Unit Weight of Soil In Place by Rubber Balloon Method."
3. ASTM D2922-81: "Test Methods for Density of Soil and Soil Aggregate in Place by Nuclear Method (Shallow Depth)."
4. CSA-A23.1-M94, "Concrete Materials and Methods of Concrete Construction".
5. CSA A257.2, “Reinforced Concrete Culvert, Storm, and Sewer Pipe”

2.1 Site Preparation

1. Prior to construction all topsoil, organic material, debris, loose and unsuitable soil must be removed from the construction area.
2. All topsoil should be stored to be used later during the landscaping phase of the project.

2.2 Pond Embankments

1. Pond embankments to be formed using native glacial till soil.

2. Excavation must be done in a method to form the shape of desired pond as specified in the drawings.
3. Any excavated soil from site can be used as embankment fill material to form the desired shape of the pond as needed.
4. Any areas where native glacial till is used should be compacted 85% maximum dry density with associated water content based on ASTM D1557.

2.3 Engineered Fill and Foundation Requirements

1. Engineered fill should be placed underneath any slab foundations.
2. Engineered fill is defined as clean sand and should be compacted in 300 mm loose lifts to a minimum of 98% of the maximum dry density based on ASTM D698.
3. Moisture content should be within 2% of which is optimum for compaction.
4. The engineered fill will also serve as the material used to construct park pathways.
5. All slab foundations should be underlain with a polyethylene moisture barrier and 100 mm of ¾" gravel.

2.4 Riprap

1. Riprap shall be placed in the Wesbrook Inlet, Marine Combined Inlet, and the Weir.
2. The dimensions of each riprap apron can be found in *Appendix D - Detailed Design Drawings*.
3. The aggregates (riprap) should be placed with the longest dimension in the vertical orientation in areas where aggregate displacement is present.

2.5 Clay Liner

1. A clay liner will be installed covering the surface of the pond.
2. The thickness of the liner will be 300 mm.
3. Another 300 mm of compacted soil should be placed on top of the clay liner.
4. Native soil from excavation can be used to cover the clay liner.
5. The Table below shows specific specification required for the clay liner.

PROPERTY	TEST METHOD	UNIT	SPECIFICATION
Permeability	ASTM D-2434	Cm/sec	$1 * 10^{-6}$
Plasticity Index of Clay	ASTM D-423/424	%	Not less than 15
Liquid Limit of Clay	ASTM D-2216	%	Not less than 30
Clay Particles Passing	ASTM D-422	%	Not Less than 30
Clay Compaction	ASTM D-2216	%	95% of standard proctor density

2.6 Shoring and Excavation

1. Maximum temporary construction embankments may be designed to a have a maximum ratio of 4V:3H.
2. All excavation and shoring procedures should follow WorkSafeBC regulations unless otherwise directed by the geotechnical engineer on site.
3. Shoring protocols from WorkSafeBC Part 20.8 must be followed during all trench excavation on site.

2.7 Aeration and Circulation

1. A PondSeries 115V, PS20 System shall be used for pond aeration in the main portion of the pond. The air compression system shall be located at least 0.5 m higher than the 1 in 100 year flood water level. Please refer to the PS20 installation manual for more details on specifications and installation.
2. A 120V Kasco ½ HP 2400AF Surface Aerator shall be used in the forebay. This will be accompanied by a Kasco C-25 control panel which shall be located at least 0.5m above the 1/100 year flood water level. Please refer to the 2400AF specification sheet for additional information regarding specifications and installation.
3. A 120V ½ HP Kasco 2400CF Circulator shall be used to circulate water in the main portion of the pond. Please refer to the 2400CF specification sheet for additional information regarding specifications and installation.
4. All Circulator systems shall be turned off between the 1st of December and the 1st of March to minimize damage caused to components resulting from large storms.

2.8 Stormwater Collection and Diversion Pipes

*Design specifications adapted from Section 5.4 of SDC

1. The minimum pipe cover shall be 1.5 m for all pipe segments; where this is not possible with existing topography, fill shall be placed to achieve requirement.
2. The water velocities in the pipe segments shall not be less than or exceed 0.6 m/s, and 3 m/s, respectively.
3. The grade of the pipe segments shall not be less than or exceed 0.4 %, and 15 %, respectively.
4. The selected pipe diameters shall be the closest nominal diameter larger than the required diameter determined from analysis.
5. The pond outlet pipe invert shall be situated at EL 53.25 m.a.s.l, and the pond inlet pipe inverts shall be situated at EL 54.25 m.a.s.l.
6. All concrete pipes shall be the minimum of CLASS II 50-D as per ASTM C478-08.

2.9 Inlet System

Inlet specifications are for both Wesbrook Inlet and the combined Marine Inlet.

1. Concrete wingwalls and the head of each inlet will be precast concrete as per Section 3.2 of *Appendix A - Standards and Specifications*
2. The dimensions of the concrete wingwalls are found in *Appendix D - Detailed Design Drawings*.
3. The dimensions of the riprap apron are found in *Appendix D - Detailed Design Drawings* and shall be installed following Section 2.1 of *Appendix A - Standards and Specifications.*

4. Debris bags shall be installed to facilitate maintenance (see Section 4.2 of A*ppendix A - Standards and Specifications* for details) and prevent debris from entering the pond.

2.10 Outlet System

1. All concrete pipes to be minimum of CLASS II 50-D as per ASTM C478-08.
2. Corrugated steel pipes shall be used for the outlet system and shall lead into the 600 mm concrete outlet pipe in accordance to the Surrey Design Manual's requirements regarding corrugated steel pipes.
3. Refer to pre-cast concrete specifications for concrete design
4. Pipe guards shall be placed at each outlet point to prevent debris from entering the system. The pipe guard grates shall be round at the edges as is what is typical for high volume drainage applications.
5. Galvanized steel shall be used for the drainage grates citing its anti-corrosion properties.
6. The pipe grate shall be of standard shape for ease of cleaning. The grate thickness shall be at least 3.81 cm (1.5 ") The grate thickness shall not exceed 5.08 cm (2 ")

SECTION 3 - CONCRETE SPECIFICATIONS

3.0 Reference Standards

1. CAN3-A23.1 M77, "Concrete Materials and Methods of Construction".
2. ACI 303R-74, "A Guide to Cast-in-Place Architectural Concrete Practice".
3. National Standards of Canada, CAN/CSA A266.1-M (ASTM C494 Type D), water-reducing, set retarding and strength-increasing admixtures for concrete.
4. CSA-A3000-98: Cementitious Materials Compendium.
5. CAN/CSA-A23.1/A23.2-00: Concrete Materials and Methods of Concrete Construction/Methods of Test for Concrete.
6. CSA G30.5-M1983 (R1998): Welded Steel Wire Fabric for Concrete Reinforcement.
7. CAN/CSA-G30.18-M92 (R1998): Billet-Steel Bars for Concrete Reinforcement.
8. ASTM A185-01: Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete.
9. ASTM C260-01: Standard Specification for Air-Entraining Admixtures for Concrete.
10. ASTM C309-98a: Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete.
11. ASTM C494/C494M-99ae1: Standard Specification for Chemical Admixtures for Concrete.
12. ASTM D1751-99: Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Non extruding and Resilient Bituminous Types).

3.1 Cast in Place

1. All cast in place concrete is to be exposure class F1 per CSA A23.1 and follow all CSA requirements for this class.

2. All cast in place concrete is to be tested when poured on site for temperature, slump, and air content. Sample cylinders must also be taken for strength testing.
3. All cast in place concrete must reach a compressive strength of 30MPa, 28 days after being poured.

3.2 Precast Concrete

1. All precast concrete is to be exposure class F1 per CSA A23.1 and follow all CSA requirements for this class.
2. All precast concrete is to be inspected for damages before installation.
3. All precast concrete is to be reinforced with rebar.
4. All precast concrete pipes are to lined on the inner diameter by an anti-corrosion coating.

3.3 Rebar

1. 15M deformed reinforcing bars spaced at 300mm are to be used for all rebar in cast in place concrete.
2. Minimum cover for all rebar is to be 40mm.
3. All cast in place concrete slabs are to have longitudinal and latitudinal rebar reinforcement.
4. All cast in place concrete walls are to have one layer of rebar reinforcement.
5. When precast concrete slabs and walls intersect rebar from the slab is to be bent 90^o and used in the wall as well.

SECTION 4 - MAINTENANCE SPECIFICATIONS

4.0 Dredging Plan

1. An excavator shall be used to dredge the pond at least once every three years or after a year with particularly strong storms comparable to the 1/100 year storm event.
2. The pond may only be dredged between June 1st and August 1st for safety purposes when the water level is lowest due to evaporation. Excavators shall only access the forebay via the designated access route.

4.1 Waterfowl Management

1. To prevent waterfowl from accumulating near the pond, 4 coyote scarecrows will be used to scare them. Other non-chemical repellent techniques are permitted.
2. Non-toxic goose repellent with 14.5% Methyl Anthranilate shall also be periodically applied to grazing areas to keep geese and other waterfowl away as per the application instructions located at the back of the bottle.

4.2 Pipe Maintenance

1. The debris bags for the inlet structures shall be cleaned once every month during the wet season (October to April) and once every two months during the dry season (May to September).
2. The orifice trash racks at the outlet are to be cleaned once every month or after a major storm event.
3. The emergency release pipes at the outlet are to be inspected and cleaned once every 3 months

SECTION 5 - LANDSCAPING SPECIFICATIONS

5.0 General Specifications

1. Landscape mulch shall conform to Canadian Landscape Standards and be installed at depths specified under Canadian Landscape Standards, 7th edition. Mulch must be non-toxic. Mulch should be dark brown or black in colour; red coloured mulch is not permitted unless specified otherwise.
2. Filter fabric must be provided in any areas were drain rock is used as a mulch substitute or landscape feature, with the exception of drip strips (unless noted otherwise).
3. Site furnishings shall all be provided via shop drawing submittals through the submittal processes defined under the master specification.
4. All vegetation introduced to the site must be of naturally occurring native species.

5.1 Terrestrial Vegetation

1. A 30 m buffer of trees must be maintained between adjacent roads and the wet pond facility.
2. All trees planted on site must be Western Red Cedar (Thuja Plicata) or Douglas Fir (Pseudotsuga Menziesii).
3. An arborist report is to be submitted at the conclusion of landscaping work on site.

5.2 Aquatic Vegetation

1. Great Yellow Pond Lilies (Nuphar Polysepalum) are to be planted along the floor of the main pond.
2. Softstem Bulrush (Scirpus Validus) is to be planted along the slopes of the main pond.

5.1 Walkway

1. Walkway is to be constructed using engineered fill as specified in the earthworks specification
2. Grades is to be less than 3% in order for pathway to be wheelchair accessible
3. Cross slope is to be 2%
4. Path width is specified at 2 meters
5. Path to be inspected monthly to be cleared of debris and repaired in damaged areas

SECTION 6 - ELECTRICAL SPECIALTIES

6.0 Reference Standards

1. CSA C22.1 Canadian Electrical Code, Part I Safety Standard for Electrical Installations

6.1 Solar Photovoltaic Specifications

1. Minimum panel capacity of 260 watts, equivalent to or better than benchmark model [SL250-270TU-48M], regardless of monocrystalline, polycrystalline, or thin film structure.
2. All products must be certified as per IEC 61215, IEC 61730.
3. Manufacturing facility and supplier must be certified to ISO 9001 / ISO 14001 / OHSAS 18001 quality management system standards.
4. All products to carry 25 year limited power warranty, and 10 year limited product warranty.
5. All products to have operating range between -40 degrees celsius to 85 degrees celsius.

6.2 Low Voltage

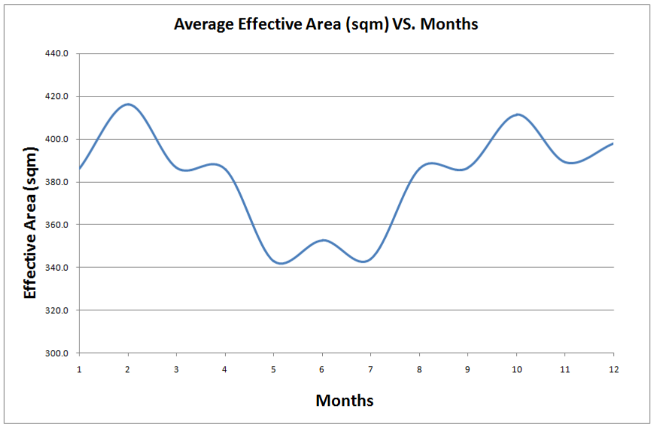
1. Low Voltage connections to utilize standard three-phase electrical power with wye, delta, or open delta connection methods at 120/208V, 347/600V, or 277/480V.
2. Inverter Box, Combiner Box, and Distribution Board required, Converter not required.
3. Maximum 21 panels to be combined into one (1) conduit to combiner box with six (6) inputs and six (6) outputs. Five (5) sets to be in operation at all times, 1 set to be kept as backup.
4. String model inverter box to not exceed 80 kW of installation capacity.
5. Separate electrical closet to be provided by Contractor, or provisions made to connect to existing facilities at UBC CCM adjacent to site.
6. Switch to be provided to maintain Solar operations between 9:00 AM to 4:00 PM.

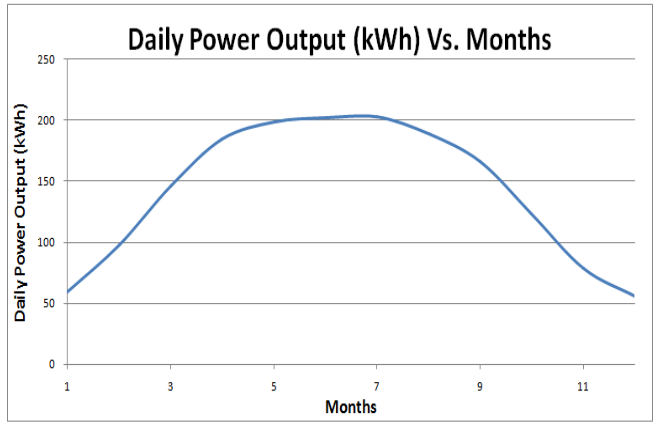
6.3 High Voltage

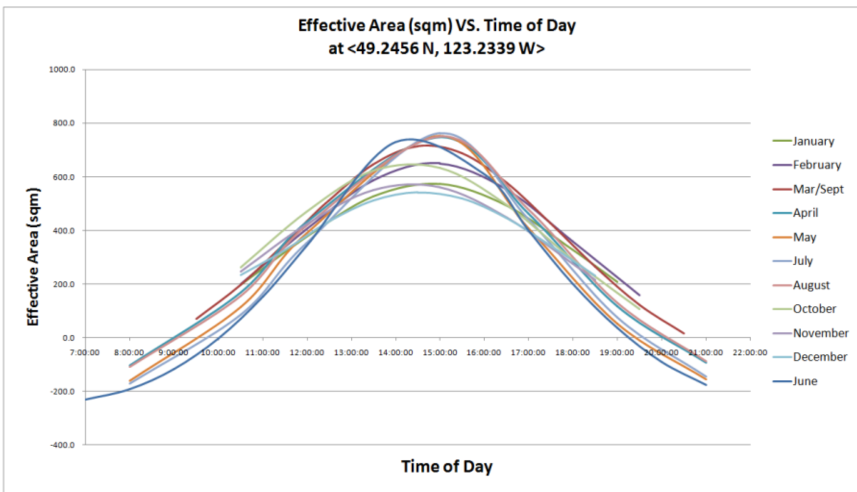
1. High Voltage connections (4000V and above) not allowed for this project.

APPENDIX B - DETAILED CALCULATIONS

Photovoltaic Calculations







Month	Solar Irradiance	Maximum Temp.	Panel Temp.	Loss	Daily Energy (kWh)	Monthly Energy (kWh)
1	1.44	11.3	16.2	-4.00%	60	1846
2	2.42	12.4	20.6	-6.00%	98	2734
3	3.7	13.3	25.8	-8.40%	146	4519
4	4.89	18.1	34.6	-12.30%	184	5533
5	5.53	25.1	43.8	-16.40%	199	6161
6	5.69	26.8	46	-17.50%	202	6061
7	5.79	28.6	48.1	-18.40%	203	6292
8	5.35	29	47	-17.90%	189	5848
9	4.6	27.1	42.6	-15.90%	166	4984
10	3.17	17.6	28.3	-9.50%	123	3828
11	1.95	15	21.6	-6.50%	78	2352
12	1.35	12.9	17.5	-4.60%	55	1720
					Annual	51878

Hydraulic Model Methodology

General Model

The general model used to determine the height of the water in the system was devised using the relationship between flow rate and volume. By taking timesteps of t = 1 s and considering a constant inflow of 3 m^3/s, the volume and height of water at any given point can be calculated. By performing this operation for multiple time steps and combining results with system specific flow formulas, the overall system can be modelled. This is done because the integral that is to be used is complicated and as such, riemann sums are a simpler method. The primary equation used for the iteration process is shown below.

$$Q * dt = dV,\ V_{n+1} = V_n + dV$$

Weir

The V-notch weir flow formula was used to compute the flow rate for any given weir height, h.

$$q = \frac{8}{15} C_d (2g)^{\frac{1}{2}} \tan\left(\frac{\theta}{2}\right) h^{\frac{5}{2}}$$

By using time steps of t = 1 s and multiplying by the net flow at any given time t, the volume in the system can be determined. Using this volume, a height can be computed; the height is then used to calculate the flow rate at any given point in time. A sample table used to perform this operation is shown below.

Time	Forebay Height	Volume in Forebay	Qin	Qout	Net
1	0.7000	466.2	3.0	0.00	3.0
2	0.7038	469.2	3.0	0.00	3.0
3	0.7076	472.2	3.0	0.00	3.0
4	0.7114	475.2	3.0	0.00	3.0
5	0.7152	478.3	3.0	0.00	3.0
6	0.7189	481.3	3.0	0.00	3.0
7	0.7227	484.3	3.0	0.00	3.0
8	0.7265	487.3	3.0	0.00	3.0
9	0.7302	490.3	3.0	0.00	3.0
10	0.7340	493.3	3.0	0.00	3.0
11	0.7377	496.3	3.0	0.00	3.0
12	0.7415	499.3	3.0	0.00	3.0
13	0.7452	502.4	3.0	0.00	3.0
14	0.7489	505.4	3.0	0.00	3.0
15	0.7526	508.4	3.0	0.00	3.0
16	0.7564	511.4	3.0	0.00	3.0
17	0.7601	514.4	3.0	0.00	3.0
18	0.7638	517.4	3.0	0.00	3.0
19	0.7675	520.4	3.0	0.00	3.0
20	0.7711	523.5	3.0	0.00	3.0
21	0.7748	526.5	3.0	0.00	3.0
22	0.7785	529.5	3.0	0.00	3.0
23	0.7822	532.5	3.0	0.00	3.0
24	0.7858	535.5	3.0	0.00	3.0

In this example, Q_{out} is a small value and reaches 3.0 m^3/s approximately 1300 s after the 1/100 year storm has started.

Height of the Main Pond and Outlet Calculations

By the principle of mass continuity, the flow out of the forebay was set to equal the flow into the pond. Using a method similar to that outlined in the forebay section, the height at any given time can be obtained based on taking time steps of t = 1 s and adding volume to the pond over time. However, since there is continuous flow out, the net flow must be used to determine volume changes. The net flow is Q_{in}-Q_{out}, this method was used to simulate the behaviour of the system over time as shown in the table on the following page. Since the reservoir is large, note that velocity head is considered negligible for ease of calculation.

Drainage Times:										
	Forebay						Pond			
Time	Forebay Height	Volume in Forebay	Qin	Qout	Net	dT	Pond Height	Volume in Pond	Qin	Qout with hL
1	0.7000	466.2	3.0	0.00	3.0		1	1620	0.00	0
2	0.7038	469.2	3.0	0.00	3.0	1	1	1620	0.00	0
3	0.7076	472.2	3.0	0.00	3.0	1	1	1620	0.00	0
4	0.7114	475.2	3.0	0.00	3.0	1	1	1620	0.00	0
5	0.7152	478.3	3.0	0.00	3.0	1	1	1620	0.00	0
6	0.7189	481.3	3.0	0.00	3.0	1	1	1620	0.00	0
7	0.7227	484.3	3.0	0.00	3.0	1	1	1620	0.00	0
8	0.7265	487.3	3.0	0.00	3.0	1	1	1620	0.00	0
9	0.7302	490.3	3.0	0.00	3.0	1	1	1620	0.00	0
10	0.7340	493.3	3.0	0.00	3.0	1	1	1620	0.00	0
11	0.7377	496.3	3.0	0.00	3.0	1	1	1620	0.00	0
12	0.7415	499.3	3.0	0.00	3.0	1	1	1620	0.00	0
13	0.7452	502.4	3.0	0.00	3.0	1	1	1620	0.00	0
14	0.7489	505.4	3.0	0.00	3.0	1	1	1620	0.00	0
15	0.7526	508.4	3.0	0.00	3.0	1	1	1620	0.00	0
16	0.7564	511.4	3.0	0.00	3.0	1	1	1620	0.00	0
17	0.7601	514.4	3.0	0.00	3.0	1	1	1620	0.00	0
18	0.7638	517.4	3.0	0.00	3.0	1	1	1620	0.00	0
19	0.7675	520.4	3.0	0.00	3.0	1	1	1620	0.00	0
20	0.7711	523.5	3.0	0.00	3.0	1	1	1620	0.00	0
21	0.7748	526.5	3.0	0.00	3.0	1	1	1620	0.00	0
22	0.7785	529.5	3.0	0.00	3.0	1	1	1620	0.00	0
23	0.7822	532.5	3.0	0.00	3.0	1	1	1620	0.00	0
24	0.7858	535.5	3.0	0.00	3.0	1	1	1620	0.00	0
25	0.7895	538.5	3.0	0.00	3.0	1	1	1620	0.00	0
26	0.7932	541.5	3.0	0.00	3.0	1	1	1620	0.00	0
27	0.7968	544.6	3.0	0.00	3.0	1	1	1620	0.00	0
28	0.8004	547.6	3.0	0.00	3.0	1	1	1620	0.00	0
29	0.8041	550.6	3.0	0.00	3.0	1	1	1620	0.00	0

For safety and redundancy purposes, two outlet systems have been devised. The first includes a set of orifices at the permanent water level height leading into two outlet detention tanks. The second is a set of two pipes located at the bottom of the pond with valves that is left closed and is only to be opened in case of an emergency.

For the purpose of calculations, the pipes and orifices were sized based on the “blocked” condition. The blocked condition assumes that the entire stormwater event is detained in the pond without continuous discharge, resulting in a maximum height of 2.74 m determined by dividing volume by the average cross sectional area. Bernoulli’s Equation was used as well as the Hazen-Williams Equation to determine the area of the pipe. A design flow of 0.5 m^3/s was chosen, accounting for run-off and an additional factor of safety. The following two formulas were solved to determine the minimum area required for each opening.

Maximum Orifice Formula

$$A = \frac{Q}{\left(2 * 9.81 * \left(h - h_{orifice}\right)\right)^{0.5}}$$

*Note that the manhole used brings the system to atmospheric pressure and that the velocity head of the water is negligible.

Pipe Calculations

$$h = \frac{\left(\frac{Q_{max}}{n}\right)^2}{2gA^2} * (1 + k_{minor}) + 10.59L * \frac{\left(\frac{Q_{max}}{n}\right)^{1.85}}{C^{1.85} * \left(\frac{4A}{pi}\right)^{0.5} + gh}$$

With an assumed a Hazen-Williams Coefficient (C) of 60 corresponding to corrugated steel, the equation above was solved for iteratively using the goal seek function. The above is derived from Bernoulli's Equation while ignoring surface velocity making it a conservative model.

Seiching

The following was used to determine the surface gradient resulting from wind forces. A wind speed of 140 km/hr was used as a worst case scenario to ensure the water does not spill over.

Surface wind setup

$$\frac{d\zeta}{dx} = \frac{\tau_s}{\rho g H} \quad \text{or similarly} \quad \frac{d\zeta}{dx} = \frac{u_*^2}{gH}$$

Stormwater Collection and Discharge

Hydraulic Radius, Rh [m] $$R_h = \frac{Area}{Wetted\,Perimeter} = \frac{(\frac{\pi}{4})D^2}{\pi D} = \frac{D}{4} \quad (1)$$

Manning Equation, v [m/s] $$v = (\tfrac{1}{n})R_h^{2/3}\sqrt{s} \quad (2)$$

(1) - (2) $$v = (\tfrac{1}{n})(\tfrac{D}{4})^{2/3}\sqrt{s} \quad (3)$$

Flow Continuity, Q [m^3/s] $$Q = vA = v(\tfrac{\pi}{4})D^2 \quad (4)$$

(3) - (4) $$D = (\tfrac{nQ}{k\sqrt{s}})^{3/8};\ where\ k = (\tfrac{\pi}{4})(\tfrac{1}{4})^{2/3} \quad (5)$$

Froude Velocity, v [m/s] $$v = F_r\sqrt{gy} = F_r\sqrt{gD} \quad (6)$$

Evaporation

Evaporation, E [mm/day] $$E = \frac{\frac{700T_m}{(100-A)} + 15(T-T_d)}{(80-T)};\ where\ A = latitude\ [deg] \quad (1)$$

$$T_d = dew\ point\ temperature\ [\,^oC]$$

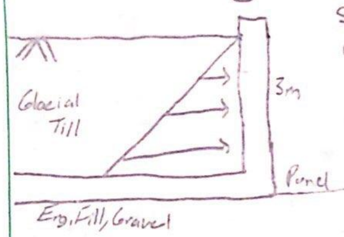
$$T_m = T + 0.006h;\ where\ h = elevation\ [m] \quad (2)$$

(1) - (2) $$E = \frac{\frac{700(T+0.006h)}{(100-A)} + 15(T-T_d)}{(80-T)} \quad (3)$$

Volume, V [m^3] $$V = (\tfrac{1\,m}{1000\,mm})(\Sigma_0^n E_n)A \quad (4)$$

Structural Calculations

Outlet Retaining Wall Design:



Soil Parameters:

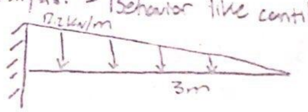
Glacial $\gamma = 12.75 kN/m^3$

$\phi = 31°$

$K_a = \frac{1-\sin\phi}{1+\sin\phi} = 0.32$

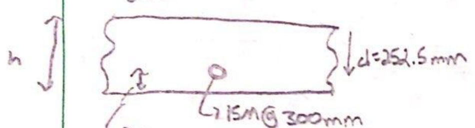
- Worst case scenario: Drained Pond
- Same design for weir
- Passive effects neglected
- 1.4 Load Factor
- Supporting slab to have same dimensions

Analysis: - Behavior like cantilevered beam



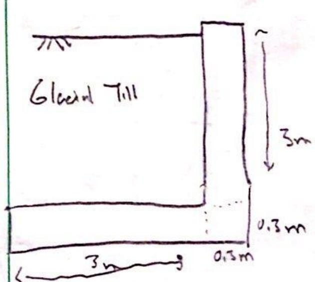
$M_f = 25 kN{\cdot}m$ $V_f = 25 kN$

Design:



- Spacing ≥ 300mm to accomodate pipe installation
- Minimum Steel requirements met
- $f'_c = 30 MPa$ - $f_y = 400 MPa$
- $M_r = \phi_s f_y A_s (d - a/2) = 50 kN{\cdot}m > M_f$
- $V_c = \phi_c\, 2/3 \sqrt{f'_c}\, b_w d_v = 169 kN > 25 kN$
- Serviceability: $h > \frac{l_n}{10}$ ✓

Retaining Wall Checks:



Minimum FoS:

Overturn: 2

Sliding: 1.5

Bearing: 2.5

Applied:

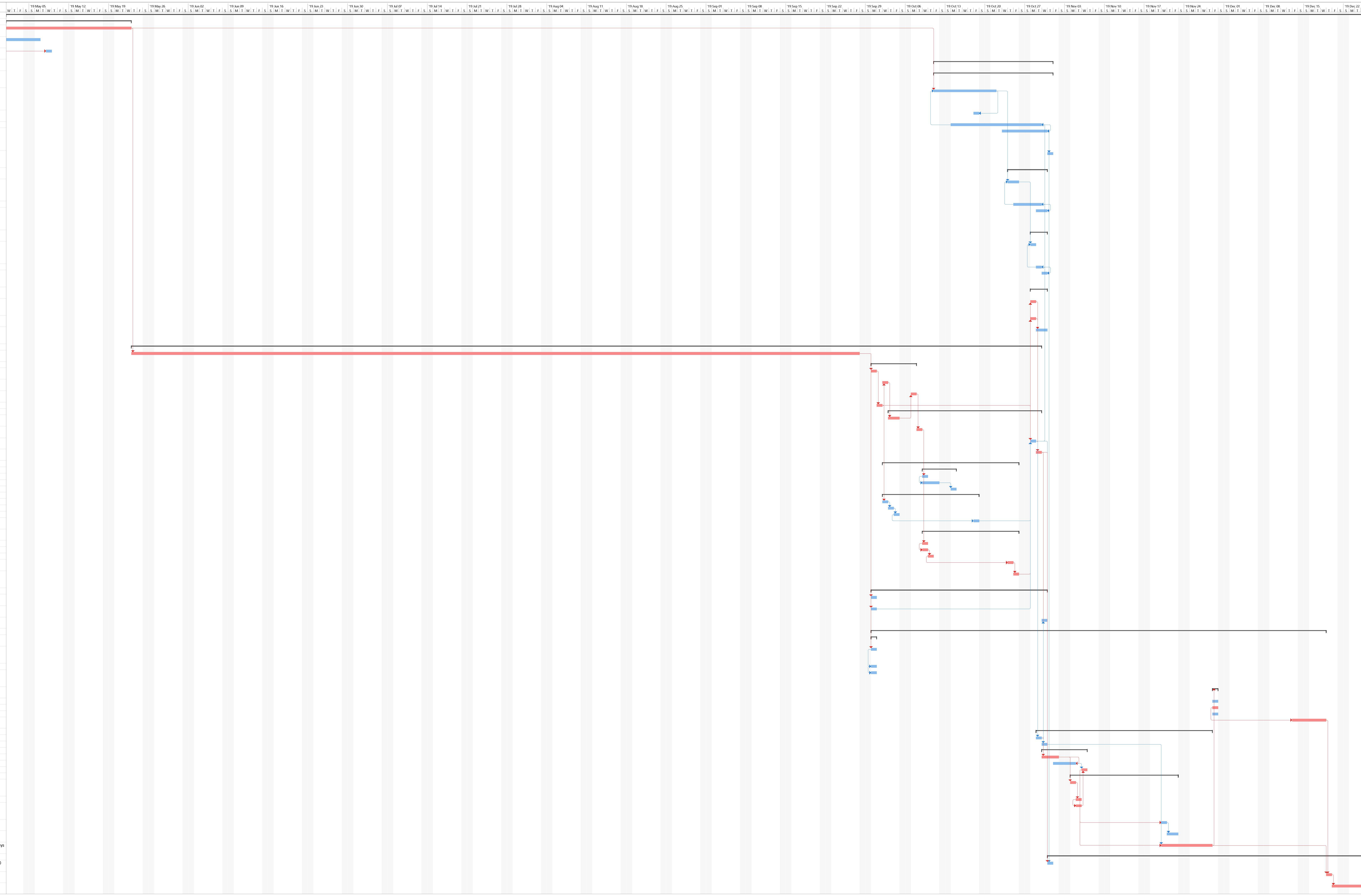
Overturning: 32.5 > 2

Sliding: 18 > 1.5

Bearing: 10 > 2.5

APPENDIX C - SCHEDULE GANTT CHART

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Construction**	**172 days**	**Wed 19-05-01**	**Thu 19-12-26**	
2	**Site Setup**	**16 days**	**Wed 19-05-01**	**Wed 19-05-22**	
3	Clearing and Grubbing	16 days	Wed 19-05-01	Wed 19-05-22	
4	Hoarding and Barricades	4 days	Wed 19-05-01	Mon 19-05-06	
5	Site Trailer Setup	1 day	Wed 19-05-08	Wed 19-05-08	3SS+5 days
6	**Installation of Inflow Pipes**	**15 days**	**Fri 19-10-11**	**Thu 19-10-31**	
7	**Piping from Wesbrook Stormwater**	**15 days**	**Fri 19-10-11**	**Thu 19-10-31**	
8	Excavating Trench and Installing Shoring	7 days	Fri 19-10-11	Mon 19-10-21	3,10SS-1 day
9	Removing Asphalt	1 day	Fri 19-10-18	Fri 19-10-18	8FF-1 day
10	Laying Pipe	12 days	Mon 19-10-14	Tue 19-10-29	35FF+1 day
11	Removing Shoring and Filling Trench	6 days	Wed 19-10-23	Wed 19-10-30	10FF+1 day
12	Repaving Wesbrook Mall	1 day	Thu 19-10-31	Thu 19-10-31	11
13	**Piping from Marine Drive**	**5 days**	**Thu 19-10-24**	**Wed 19-10-30**	
14	Excavating Trench and Installing Shoring	2 days	Thu 19-10-24	Fri 19-10-25	15SS-1 day,8
15	Laying Pipe	3 days	Fri 19-10-25	Tue 19-10-29	35FF+1 day
16	Removing Shoring and Filling Trench	2 days	Tue 19-10-29	Wed 19-10-30	15FF+1 day
17	**Piping from Center**	**3 days**	**Mon 19-10-28**	**Wed 19-10-30**	
18	Excavating Trench and Installing Shoring	1 day	Mon 19-10-28	Mon 19-10-28	19SS-1 day,14
19	Laying Pipe	1 day	Tue 19-10-29	Tue 19-10-29	35FF+1 day
20	Removing Shoring and Filling Trench	1 day	Wed 19-10-30	Wed 19-10-30	19FF+1 day
21	**Installation of Outflow Pipes**	**3 days**	**Mon 19-10-28**	**Wed 19-10-30**	
22	Installation of Emeragncy Pipes	1 day	Mon 19-10-28	Mon 19-10-28	52
23	Installation of Upper Pipes	1 day	Mon 19-10-28	Mon 19-10-28	52
24	Installation of Piping After Merge	2 days	Tue 19-10-29	Wed 19-10-30	22,23
25	**Earthworks**	**114 days**	**Thu 19-05-23**	**Tue 19-10-29**	
26	Bulk Excavation	92 days	Thu 19-05-23	Fri 19-09-27	3
27	**Compaction**	**6 days**	**Mon 19-09-30**	**Mon 19-10-07**	
28	After Excavation	1 day	Mon 19-09-30	Mon 19-09-30	26
29	After Clay Liner	1 day	Wed 19-10-02	Wed 19-10-02	31
30	After Backfill	1 day	Mon 19-10-07	Mon 19-10-07	33
31	Clay Liner	1 day	Tue 19-10-01	Tue 19-10-01	28
32	**Backfill**	**19 days**	**Thu 19-10-03**	**Tue 19-10-29**	
33	Above Clay Liner	2 days	Thu 19-10-03	Fri 19-10-04	29
34	Fill Below Slabs	1 day	Tue 19-10-08	Tue 19-10-08	30
35	Pond Slope	1 day	Mon 19-10-28	Mon 19-10-28	46,52,55,31
36	Behind Outlet	1 day	Tue 19-10-29	Tue 19-10-29	22,23
37	**Concrete**	**18 days**	**Wed 19-10-02**	**Fri 19-10-25**	
38	**Forebay Pad**	**4 days**	**Wed 19-10-09**	**Mon 19-10-14**	
39	Forming	1 day	Wed 19-10-09	Wed 19-10-09	34
40	Rebar	3 days	Wed 19-10-09	Fri 19-10-11	39SS
41	Pouring	1 day	Mon 19-10-14	Mon 19-10-14	40
42	**Weir**	**13 days**	**Wed 19-10-02**	**Fri 19-10-18**	
43	Forming	1 day	Wed 19-10-02	Wed 19-10-02	31
44	Rebar	1 day	Thu 19-10-03	Thu 19-10-03	43
45	Pouring	1 day	Fri 19-10-04	Fri 19-10-04	44
46	Form Removal	1 day	Fri 19-10-18	Fri 19-10-18	45SS+10 days
47	**Outlet Structure**	**13 days**	**Wed 19-10-09**	**Fri 19-10-25**	
48	Forming	1 day	Wed 19-10-09	Wed 19-10-09	34
49	Rebar	1 day	Wed 19-10-09	Wed 19-10-09	48SS
50	Pouring	1 day	Thu 19-10-10	Thu 19-10-10	49
51	Form Removal	1 day	Thu 19-10-24	Thu 19-10-24	50SS+10 days
52	Installing Concrete Manhole	1 day	Fri 19-10-25	Fri 19-10-25	51
53	**Aeration System**	**23 days**	**Mon 19-09-30**	**Wed 19-10-30**	
54	Power Installation	1 day	Mon 19-09-30	Mon 19-09-30	26
55	Airline Installation	1 day	Mon 19-09-30	Mon 19-09-30	26
56	Difuser Installation	1 day	Wed 19-10-30	Wed 19-10-30	68
57	**Solar Panels**	**58 days**	**Mon 19-09-30**	**Wed 19-12-18**	
58	**Connecting to Electrical Grid**	**1 day**	**Mon 19-09-30**	**Mon 19-09-30**	
59	Shallow Trench Digging	1 day	Mon 19-09-30	Mon 19-09-30	26
60	Wire Laying	1 day	Mon 19-09-30	Mon 19-09-30	59SS
61	Shallow Trench Filling	1 day	Mon 19-09-30	Mon 19-09-30	60SS
62	**Installing Podiums**	**1 day**	**Fri 19-11-29**	**Fri 19-11-29**	**80**
63	Forming	1 day	Fri 19-11-29	Fri 19-11-29	
64	Rebar	1 day	Fri 19-11-29	Fri 19-11-29	
65	Pouring	1 day	Fri 19-11-29	Fri 19-11-29	
66	Installing Panels	4 days	Fri 19-12-13	Wed 19-12-18	64SS+10 days
67	**Landscaping**	**23 days**	**Tue 19-10-29**	**Thu 19-11-28**	
68	Riprap	1 day	Tue 19-10-29	Tue 19-10-29	35
69	Plants in Pond	1 day	Wed 19-10-30	Wed 19-10-30	68
70	**Walkway**	**6 days**	**Wed 19-10-30**	**Wed 19-11-06**	
71	Forming	3 days	Wed 19-10-30	Fri 19-11-01	36
72	Rebar	2 days	Fri 19-11-01	Mon 19-11-04	71FF+1 day
73	Pouring	1 day	Wed 19-11-06	Wed 19-11-06	72,77
74	**Lighting**	**15 days**	**Mon 19-11-04**	**Fri 19-11-22**	
75	Shallow Trench Digging	1 day	Mon 19-11-04	Mon 19-11-04	71
76	Wire Laying	1 day	Tue 19-11-05	Tue 19-11-05	75
77	Shallow Trench Filling	1 day	Tue 19-11-05	Tue 19-11-05	76SS
78	Lamp Post Base Prep	1 day	Wed 19-11-20	Wed 19-11-20	73SS+10 days
79	Lamp Post Installation	2 days	Thu 19-11-21	Fri 19-11-22	78
80	Pond Guardrail	7 days	Wed 19-11-20	Thu 19-11-28	69,73SS+10 days
81	**Site Cleanup**	**41 days**	**Thu 19-10-31**	**Thu 19-12-26**	
82	Extra Fill Removal	1 day	Thu 19-10-31	Thu 19-10-31	36,35,11,16,20
83	Trailer Removal	1 day	Thu 19-12-19	Thu 19-12-19	80,66
84	Fixing Treeline	5 days	Fri 19-12-20	Thu 19-12-26	83



Project: Detailed Project Schedu
Date: Fri 19-04-05

Task · Split · Milestone · Summary · Project Summary · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · External Tasks · External Milestone · Deadline · Critical · Critical Split · Progress · Manual Progress

APPENDIX D - DETAILED DESIGN DRAWINGS

GENERAL NOTES

1. ALL ONSITE CIVIL WORKS SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE LATEST EDITIONS OF THE BRITISH COLUMBIA'S BUILDING CODES AND PLUMBING CODES, MASTER MUNICIPAL CONSTRUCTION DOCUMENTS (MMCD) PLATINUM EDITION, THE UBC BUILDING OPERATIONS'S DESIGN CRITERIA MANUAL, THE UBC BUILDING OPERATIONS'S STANDARD CONSTRUCTION DOCUMENTS (GENERAL CONDITIONS, SUPPLEMENTARY SPECIFICATIONS AND SUPPLEMENTARY STANDARD DRAWINGS) AND ALL OTHER APPLICABLE MUNICIPAL BYLAWS AND POLICIES, UNLESS NOTED OTHERWISE.

2. ALL EXISTING UNDERGROUND WORKS AND SERVICES SHOWN ARE APPROXIMATE ONLY AND ARE BASED ON AS-CONSTRUCTED RECORDS PROVIDED BY THE UBC BUILDING OPERATIONS AND BC ONE CALL. PRIOR TO CONSTRUCTION AND ORDERING OF MATERIALS, THE CONTRACTOR SHALL EXPOSE AND VERIFY INVERTS, LOCATIONS, MATERIAL TYPES AND SIZES OF ANY AND ALL EXISTING UNDERGROUND WORKS AND SERVICES AT TIE-IN AND CROSSING POINTS AND ADVISE CONSULTANTS IMMEDIATELY OF ANY DISCREPANCIES.

3. ALL DIMENSIONS, OFFSETS, SIZES AND ELEVATIONS ARE IN METRIC AND TO GEODETIC DATUM, UNLESS NOTED OTHERWISE.

4. A TREE CUTTING PERMIT AND AN EROSION & SEDIMENT CONTROL PERMIT SHALL BE OBTAINED PRIOR TO ANY WORKS COMMENCING ONSITE.

5. TEMPORARY TREE PROTECTION BARRIER FENCES SHALL BE CONSTRUCTED AND INSPECTED BY THE UBC BUILDING OPERATIONS'S PARKS DEPARTMENT AS PER THE LOCATIONS AND INSTRUCTIONS IN THE ARBORIST REPORT AND LANDSCAPING DRAWINGS PRIOR TO ANY WORKS COMMENCING ONSITE.

6. ALL EXISTING BUILDINGS, SHEDS, FOUNDATIONS, SEPTIC SYSTEMS, DRIVEWAYS, FENCES, TREES, SHRUBS, ETC. LOCATED ONSITE SHALL BE REMOVED AND DISPOSED OFFSITE.

7. A PLUMBING PERMIT AND ALL OTHER APPLICABLE APPROVALS AND PERMITS SHALL BE OBTAINED PRIOR TO ANY UNDERGROUND CIVIL WORKS COMMENCING ONSITE. THE CONTRACTOR SHALL ARRANGE AND PAY FOR ALL PERMIT FEES FOR OBTAINING THE REQUIRED PERMITS.

8. PRIOR TO CONSTRUCTION, THE CONTRACTOR SHALL ARRANGE FOR A PRECONSTRUCTION MEETING ONSITE WITH CONSULTANTS TO REVIEW AND DISCUSS THE CIVIL DESIGN DRAWINGS, CONSTRUCTION METHODS, GENERAL COORDINATION BETWEEN TRADES, TIMING, SITE REVIEWS, TESTING PROCEDURES, TESTING RESULTS, ETC.

9. ALL CONSTRUCTION WORKS SHALL BE COMPLETED IN SUCH A MANNER SO AS TO PREVENT THE RELEASE OF ANY CONSTRUCTION WATER, SILT, CONCRETE LEACHATE AND ANY OTHER DELETERIOUS SUBSTANCES SHALL BE DISPOSED OF OR PLACED IN SUCH A MANNER AS TO PREVENT IT'S ENTRY INTO ANY STORM SEWER SYSTEM, WATER COURSE, RAVINE OR RESTRICTIVE COVENANT AREA.

10. THE OWNER AND CONTRACTOR ARE RESPONSIBLE FOR SWEEPING OF THE EXISTING ROADWAYS FREE OF ANY DIRT AND SEDIMENT CAUSED BY CONSTRUCTION ACTIVITY ON A DAILY BASIS.

11. THE CONTRACTOR SHALL REINSTATE ALL DISTURBED WORKS TO PRE-CONSTRUCTION CONDITION OR BETTER AND TO CURRENT MMCD AND UBC BUILDING OPERATIONS'S STANDARDS AND TO THE SATISFACTION OF CONSULTANTS

12. ALL NEW ONSITE ELECTRICAL AND TELECOMMUNICATIONS SERVICES AND CONNECTIONS SHALL BE LOCATED UNDERGROUND. REFER TO THE ELECTRICAL SITE PLAN AND BC HYDRO DRAWINGS FOR DETAILS.

13. ALL WORKS CONSTRUCTED BY CIVIL CONTRACTOR SHALL BE SITE REVIEWED BY CONSULTANTS AND UBC BUILDING OPERATIONS PRIOR TO ANY BACKFILLING. FAILURE TO DO SO MAY RESULT IN THE CIVIL CONTRACTOR EXPOSING SUCH WORKS AND SERVICES FOR VISUAL SITE REVIEW AT THE CIVIL CONTRACTOR'S EXPENSE.

14. ANY DAMAGE TO EXISTING SURVEY POSTS AND/OR MONUMENTS (DESTROYED OR DAMAGED DURING CONSTRUCTION) SHALL BE REPLACED BY A B.C. LAND SURVEYOR AT THE CONTRACTOR'S EXPENSE.

15. 48 HOURS NOTICE SHALL BE PROVIDED BY THE DEVELOPER'S CIVIL CONTRACTOR TO CONSULTANTS AND THE UBC BUILDING OPERATIONS'S PLUMBING INSPECTOR PRIOR TO INITIAL CONSTRUCTION COMMENCEMENT.

16. THE CONTRACTOR SHALL COMPLY WITH ALL THE ARBORIST RECOMMENDATIONS IN THE ARBORIST REPORT. THE CONTRACTOR SHALL COMPLY WITH THE GEOTECHNICAL RECOMMENDATIONS IN THE GEOTECHNICAL REPORT.

17. UPON SUBSTANTIAL CONSTRUCTION COMPLETION, THE CIVIL CONTRACTOR'S SURVEYOR (B.C.L.S. OR P.ENG.) SHALL SUBMIT TO CONSULTANTS AS-BUILT SURVEY INFORMATION FOR THE PROPOSED WORKS AND SERVICES SHOWN ON THE SITE GRADING PLAN AND THE SITE SERVICES PLANS PREPARED CONSULTANTS FOR REVIEW.

EROSION AND SEDIMENT CONTROL

1. ALL EROSION AND SEDIMENT CONTROL WORKS SHALL BE UNDERTAKEN IN COMPLIANCE WITH THE APPROVED EROSION & SEDIMENT CONTROL PLANS, EROSION & SEDIMENT CONTROL DETAILS AND UBC BUILDING OPERATIONS BYLAW.

2. THE CONTRACTOR SHALL COMPLETE ALL CONSTRUCTION WORKS FOR THE ENTIRE DURATION OF THE PROJECT IN SUCH MANNER AS TO PREVENT THE RELEASE INTO ANY CATCH BASIN, STORM SEWER, WATER COURSE OR DRAINAGE SYSTEMS OF ANY SEDIMENT LADEN WATER THAT CONTAINS A TOTAL SUSPENDED SOLIDS (T.S.S.) IN EXCESS OF 25 MILLIGRAMS PER LITER (mg/L) DURING THE DRY WEATHER SEASON AND EXCEEDING 75 MILLIGRAMS PER LITER (mg/L) DURING THE WET WEATHER SEASON AND A PH BETWEEN 6.0 AND 9.0.

3. A SIGNIFICANT RAINFALL EVENT IS 25mm OR GREATER OF TOTAL RAINFALL DEPTH IN A 24 HOUR TIME PERIOD.

ONSITE STORM SEWER NOTES

1. ALL ONSITE CIVIL WORKS SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE LATEST EDITIONS OF THE BRITISH ALL ONSITE CIVIL WORKS SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE LATEST EDITIONS OF THE BRITISH COLUMBIA'S BUILDING CODES AND PLUMBING CODES, MASTER MUNICIPAL CONSTRUCTION DOCUMENTS (MMCD) PLATINUM EDITION, AND ALL OTHER APPLICABLE MUNICIPAL BYLAWS AND POLICIES, UNLESS NOTED OTHERWISE.

2. ALL DIMENSIONS, OFFSETS, SIZES AND ELEVATIONS ARE METRIC AND TO GEODETIC DATUM, UNLESS NOTED ALL DIMENSIONS, OFFSETS, SIZES AND ELEVATIONS ARE METRIC AND TO GEODETIC DATUM, UNLESS NOTED OTHERWISE.

3. PRIOR TO CONSTRUCTION AND ORDERING MATERIALS, THE CIVIL CONTRACTOR SHALL EXPOSE AND VERIFY THE PRIOR TO CONSTRUCTION AND ORDERING MATERIALS, THE CIVIL CONTRACTOR SHALL EXPOSE AND VERIFY THE LOCATION, MATERIAL TYPE, SIZE AND INVERT OF THE EXISTING STORM SEWERS AND SANITARY SEWERS AT POINTS OF TIE-IN'S AND CROSSINGS AND THE CIVIL CONTRACTOR SHALL REPORT ANY DISCREPANCIES TO CONSULTANTS IMMEDIATELY.

4. PRIOR TO CONSTRUCTION AND ORDERING OF MATERIALS, THE CIVIL CONTRACTOR SHALL CONFIRM FINAL LOCATIONS, PRIOR TO CONSTRUCTION AND ORDERING OF MATERIALS, THE CIVIL CONTRACTOR SHALL CONFIRM FINAL LOCATIONS, INVERTS AND SIZES OF STORM SEWER AND SANITARY SEWER

5. TRENCH BACKFILL UNDER ROADWAYS, DRIVEWAYS AND SIDEWALKS SHALL BE 100mm IMPORTED GRANULAR MATERIAL TRENCH BACKFILL UNDER ROADWAYS, DRIVEWAYS AND SIDEWALKS SHALL BE 100mm IMPORTED GRANULAR MATERIAL COMPACTED TO 95% MPMDD.

6. MANHOLE BENCHING SHALL BE REQUIRED FOR ALL NEW MANHOLES TO MMCD STANDARDS. IF REQUIRED, MANHOLE BENCHING SHALL BE REQUIRED FOR ALL NEW MANHOLES TO MMCD STANDARDS. IF REQUIRED, MANHOLE REBENCHING SHALL BE REQUIRED FOR ALL NEW TIE-IN'S TO EXISTING MANHOLES TO MMCD STANDARDS.

7. ALL STORM SEWER PIPE (REGARDLESS OF PIPE MATERIAL) SHALL BE CONSTRUCTED WITH 0.45m OF COVER OR ALL STORM SEWER PIPE (REGARDLESS OF PIPE MATERIAL) SHALL BE CONSTRUCTED WITH 0.45m OF COVER OR MORE, UNLESS NOTED OTHERWISE.

8. THE CIVIL CONTRACTOR SHALL INSTALL ALUMINUM TRAPPING HOODS ON ALL STORM WATER CATCH BASIN OUTLETS THE CIVIL CONTRACTOR SHALL INSTALL ALUMINUM TRAPPING HOODS ON ALL STORM WATER CATCH BASIN OUTLETS AND LAWN DRAIN OUTLETS.

9. ALL STORM SEWER SERVICE CONNECTIONS SHALL BE CONSTRUCTED AT 2.0% MINIMUM GRADE.

10.INSTALL A TEMPORARY 2x4 POST STUB PAINTED GREEN FOR STORM SEWER CAPS AND RED FOR SANITARY SEWER CAPS EXTENDED ABOVE THE FINISHED GROUND SURFACE AT THE LOCATION OF THE TEMPORARY CAP.

11. ALL STORM SEWER AND SANITARY SEWER JOINTS SHALL BE CLOSED JOINTS.

12. ALL MANHOLE COVERS, CLEANOUT COVERS, VALVE COVERS, ETC. SHALL BE CONSTRUCTED FLUSH WITH FINISHED SURFACE GRADE.

SITE GRADING

1. ALL ONSITE CIVIL WORKS SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE LATEST EDITIONS OF THE BRITISH COLUMBIA'S BUILDING CODES AND PLUMBING CODES, MASTER MUNICIPAL CONSTRUCTION DOCUMENTS (MMCD) PLATINUM EDITION, SUPPLEMENTARY SPECIFICATIONS AND ALL OTHER APPLICABLE MUNICIPAL BYLAWS AND POLICIES, UNLESS NOTED OTHERWISE.

2. ALL DIMENSIONS, OFFSETS, SIZES AND ELEVATIONS ARE METRIC AND TO ALL DIMENSIONS, OFFSETS, SIZES AND ELEVATIONS ARE METRIC AND TO GEODETIC DATUM, UNLESS NOTED OTHERWISE.

3. ALL ROAD ELEVATIONS ARE FINISHED SURFACE PAVEMENT AND FINISHED ALL ROAD ELEVATIONS ARE FINISHED SURFACE PAVEMENT AND FINISHED SURFACE GUTTER LINE ELEVATIONS.

4. CHANGES IN GRADE LINES SHALL BE FORMED BY SMOOTH CURVES.

5. ADJUST ALL EXISTING AND PROPOSED RIMS, I.C.'s AND COVERS FLUSH WITH FINISHED SURFACE GRADES (UNLESS NOTED OTHERWISE).

6. TIE-IN ALL PROPOSED SURFACE WORKS TO EXISTING SURFACE WORKS WITH A SMOOTH TRANSITION.

7. EXISTING SUB-GRADE SHALL BE PREPARED AS PER GEOTECHNICAL RECOMMENDATIONS AND APPROVED BY THE GEOTECHNICAL ENGINEER PRIOR TO PLACEMENT OF IMPORTED SUB-BASE AND BASE MATERIALS. SUB-BASE AND BASE MATERIALS SHALL BE INSTALLED AND COMPACTED AS PER THE RECOMMENDATIONS APPROVED BY THE GEOTECHNICAL ENGINEER PRIOR TO COMMENCING ASPHALT PAVING.

8. ALL LOOSE AND/OR ORGANIC MATERIAL WITHIN THE ROADWAY SHALL BE OVER EXCAVATED AS DIRECTED BY THE GEOTECHNICAL ENGINEER AND SHALL BE REPLACED WITH APPROVED ENGINEERED FILL AS PER GEOTECHNICAL RECOMMENDATIONS AND APPROVAL.

9. SURFACE WATER PONDING IS NOT PERMITTED AND IS SUBJECT TO REMOVAL AND REPLACEMENT AT THE CONTRACTOR'S EXPENSE.

10. REFER TO LANDSCAPE DRAWINGS FOR DECORATIVE SURFACE TREATMENT DETAILS AND REFER TO LANDSCAPE DRAWINGS FOR DECORATIVE SURFACE TREATMENT DETAILS AND SPECIFICATIONS AND THEY SHALL MEET H20 TRAFFIC LOADING SPECIFICATIONS.

11. PRIOR TO INSTALLATION OF CONCRETE AND HOT-MIX ASPHALT, THE CONTRACTOR SHALL OBTAIN WRITTEN SIGN OFF APPROVAL FROM THE ELECTRICAL CONSULTANT AND UBC BUILDING OPERATIONS THAT ALL THE UNDERGROUND ELECTRICAL AND TELECOMMUNICATIONS SERVICES HAVE BEEN INSTALLED AND ARE ACCEPTABLE.

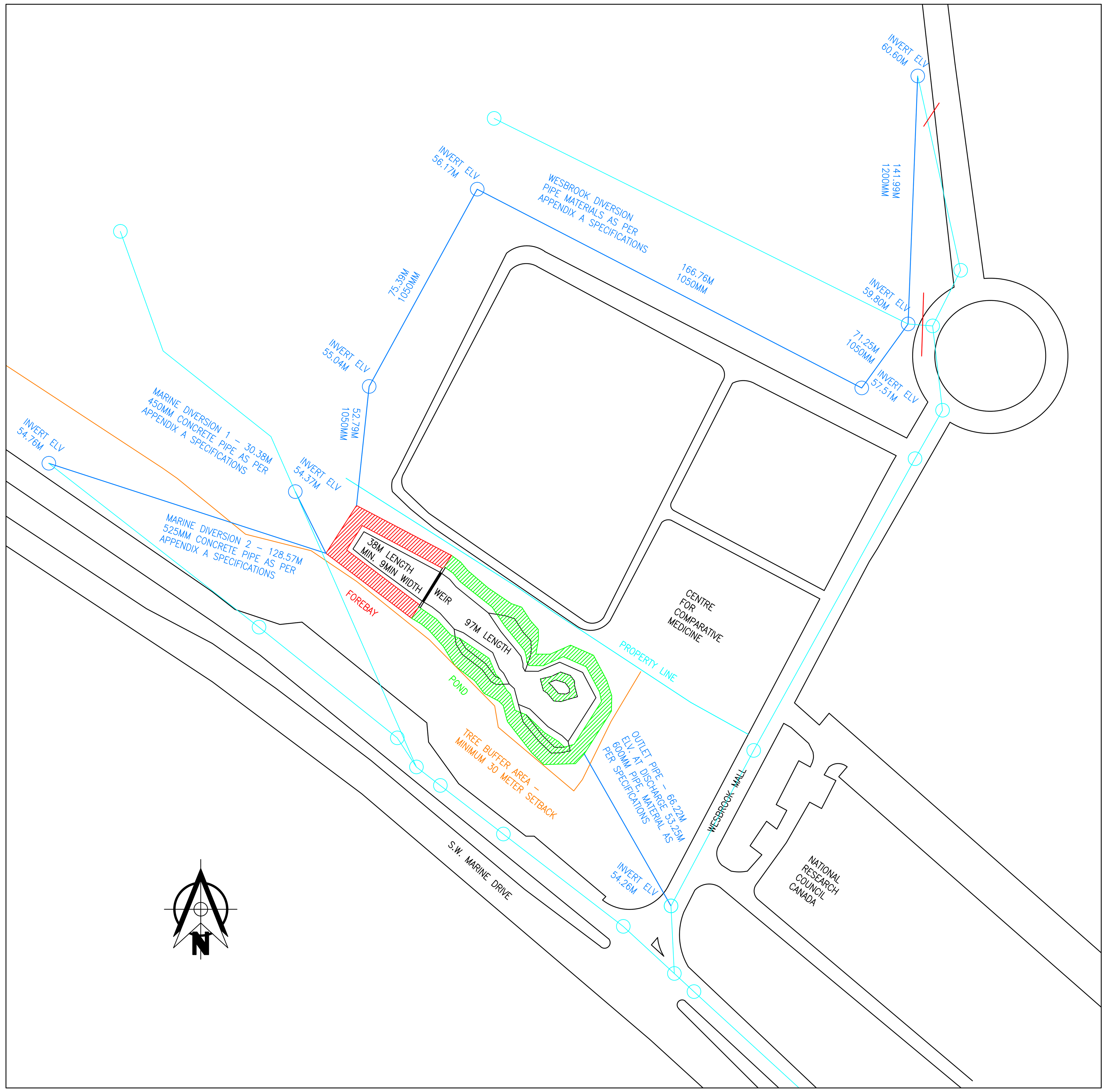
12. THE OWNER SHALL EMPLOY THE SERVICES OF A GEOTECHNICAL ENGINEER FOR FIELD REVIEWS AND CERTIFICATIONS RELATED TO STRIPPING DEPTHS, SUB-GRADE EXCAVATION, SUB-GRADE PREPARATION, ENGINEERED FILL, BACKFILL MATERIALS WITHIN TRENCHES, SHORING, ROAD STRUCTURE MATERIALS, COMPACTION, ASPHALT MIX DESIGN, ASPHALT CORE TESTING, ASPHALT COMPACTION TESTING, ETC.

BENCHMARK / LEGAL	No.	REVISIONS / SUBMISSIONS	DATE	CLIENT	DEVELOPMENT MANAGEMENT	PROJECT NAME	SEAL	UNIVERSITY OF BRITISH COLUMBIA
				UBC SEEDS SUSTAINABILITY PROGRAM 2210 WEST MALL VANCOUVER, BC V6T 1Z4 PHONE: 604-822-8228 FAX: 604-822-6119	UBC CIVIL ENGINEERING CIVL 446 TEAM 16	THUNDERBIRD LAKE 4145 Wesbrook Mall, V6T 1W5 VANCOUVER, BC	APRIL 6TH, 2019	THUNDERBIRD LAKE GENERAL NOTES

DESIGN:	JD	DRAWING NUMBER	TLAKE-00
DRAWN:	JZ		
CHECKED:	N/A	HOR. SCALE	
ENGINEER:	N/A	VER. SCALE	REV. 0

DESTROY ALL PRINTS BEARING PREVIOUS REVISION NUMBER

THUNDERBIRD LAKE – STORM SEWER NETWORK



EXISTING STORM SEWER MAINS

NEW DIVERSIONS TO SEWER MAINS

STORM SEWER SEVER POINTS

PRE-EXISTING MANHOLE/INVERT

NEW MANHOLE/INVERT

0m 10m 20m 30m 40m 50m

SCALE: 1:50

ISSUED FOR CONSTRUCTION

REGULAR NET VOLUME: 1164 CUBIC METERS
1:100 FLOOD NET VOLUME: 5800 CUBIC METERS

MAXIMUM FLOW IN = 3.0 CUBIC METERS PER SECOND

MAXIMUM FLOW OUT = 0.98 CUBIC METERS PER SECOND (MAX ALLOWABLE = 1.2)

FOREBAY CONCRETE AREA: 1135.8 SQUARE METERS
FOREBAY CONCRETE VOLUME: 340.7 CUBIC METERS

WEIR CONCRETE AREA: 468.0 SQUARE METERS
WEIR CONCRETE VOLUME: 234.0 CUBIC METERS

OUTLET CONCRETE AREA: 202.5 SQUARE METERS
OUTLET CONCRETE VOLUME: 243.0 CUBIC METERS

CONCRETE SPEC NO LESS THAN 32MPA 20MM 5–8%
MINIMUM EXPOSURE CLASS C–2
SLUMP 80+–20 MM

MANHOLE AND CONCRETE PIPE NO LESS THAN ASTM CLASS II 50–D

ALL STORM SEWER COMPONENTS TO ABIDE BY APPENDIX A – STANDARDS AND SPECIFICATIONS OF DETAIL DESIGN REPORT

CUT VOLUME: 14415 CUBIC METERS
FILL VOLUME: 25650 CUBIC METERS

IMPORTED FILL TO BE ENGINEERED FILL AS PER APPENDIX A – STANDARDS AND SPECIFICATIONS

FOREBAY NORTHWEST CORNER ELV: 61M
FOREBAY SOUTHWEST CORNER ELV: 58M
POND NORTHEAST CORNER ELV: 58M
POND SOUTHEAST CORNER ELV: 55M
INLET ELV: 54.25M
OUTLET ELV: 53.25M
MINIMUM 1:3 SLOPE FOR FOREBAY & POND

ALL DIMENSIONS IN METERS

BENCHMARK / LEGAL	No.	REVISIONS / SUBMISSIONS	DATE	CLIENT	DEVELOPMENT MANAGEMENT	PROJECT NAME	SEAL	UNIVERSITY OF BRITISH COLUMBIA
				UBC SEEDS SUSTAINABILITY PROGRAM 2210 WEST MALL VANCOUVER, BC V6T 1Z4 PHONE: 604-822-8228 FAX: 604-822-6119	UBC CIVIL ENGINEERING CIVL 446 TEAM 16	THUNDERBIRD LAKE 4145 Wesbrook Mall, V6T 1W5 VANCOUVER, BC	APRIL 6TH, 2019	THUNDERBIRD LAKE - PLAN VIEW

DESIGN:	JD	DRAWING NUMBER	TLAKE-01
DRAWN:	JZ		
CHECKED:	N/A	HOR. SCALE	1:50
ENGINEER:	N/A	VER. SCALE	REV. 0

DESTROY ALL PRINTS BEARING PREVIOUS REVISION NUMBER

WEIR DETAILS FOUND AT DWG. NO. WEIR 1 & WEIR 2, TYP. V-NOTCH 0.3 METER DEPTH IF SHEET METAL, MAXIMUM THICKNESS TO NOT EXCEED 12 GAUGE BEFORE BEVELING REQUIRED

160 QIXIN 260W PV SOLAR PANELS, 41.6 KW INSTALLATION CAPACITY TO BE HOOKED UP TO GRID VIA LOW VOLTAGE CONNECTION THROUGH 80 KW STRING INVERTER INTO COMBINER BOX AS PER STANDARDS & SPECIFICATIONS AND PART I OF CANADIAN ELECTRICAL CODE.

SEPARATE STATUTORY RIGHT-OF-WAY TO BE OBTAINED FROM UBC BUILDING OPERATIONS AND COMPARATIVE CENTRE FOR MEDICINE

PARKING SPACE TO INTEGRATE PRE-EXISTING PARKING AT UBC CCM, EASEMENT PROVISIONS TO BE OBTAINED VIA PROFESSIONAL LAND ASSEMBLY SOLICITOR OFFICE

ISSUED FOR CONSTRUCTION

0m 10m 20m 30m 40m 50m

SCALE: 1:15

INLET SEE DWG. NO. INLET 1-2 FOREBAY & POND BOTTOM WIDTH MINIMUM 9M, MAXIMUM 17M. TOP WIDTH AND OUTLINE ARBITRARY, SUBJECT TO LANDSCAPE ARCHITECT

TREES TO BE NATIVE PSEUDOTSUGA MENZIESII [FIR] AND THUJA PLICATA [RED CEDAR]; WATER PLANTS TO BE NUPHAR POLYSEPALUM AND SCIRPUS VALIDUS.

BRUSHES SUBJECT TO ARBORIST CHOICE, ARBORIST TO HAND PICK WATER PLANTS FROM NURSERY.

OUTLET DETAILS FOUND AT DWG. NO. OUTLET STRUCTURE 1-2, OUTLET 0-4. ELEVATION SEE DWG. NO. TLAKE-01

PATH MINIMUM WIDTH 3M CONSTRUCTION TO FOLLOW DETAIL DESIGN REPORT AND APPENDIX A STANDARDS AND SPECIFICATIONS

BENCHMARK / LEGAL	No.	REVISIONS / SUBMISSIONS	DATE	CLIENT	DEVELOPMENT MANAGEMENT	PROJECT NAME	SEAL
				UBC SEEDS SUSTAINABILITY PROGRAM 2210 WEST MALL VANCOUVER, BC V6T 1Z4 PHONE: 604-822-8228 FAX: 604-822-6119	UBC CIVIL ENGINEERING CIVL 446 TEAM 16	THUNDERBIRD LAKE 4145 Wesbrook Mall, V6T 1W5 VANCOUVER, BC	APRIL 6TH, 2019

UNIVERSITY OF BRITISH COLUMBIA

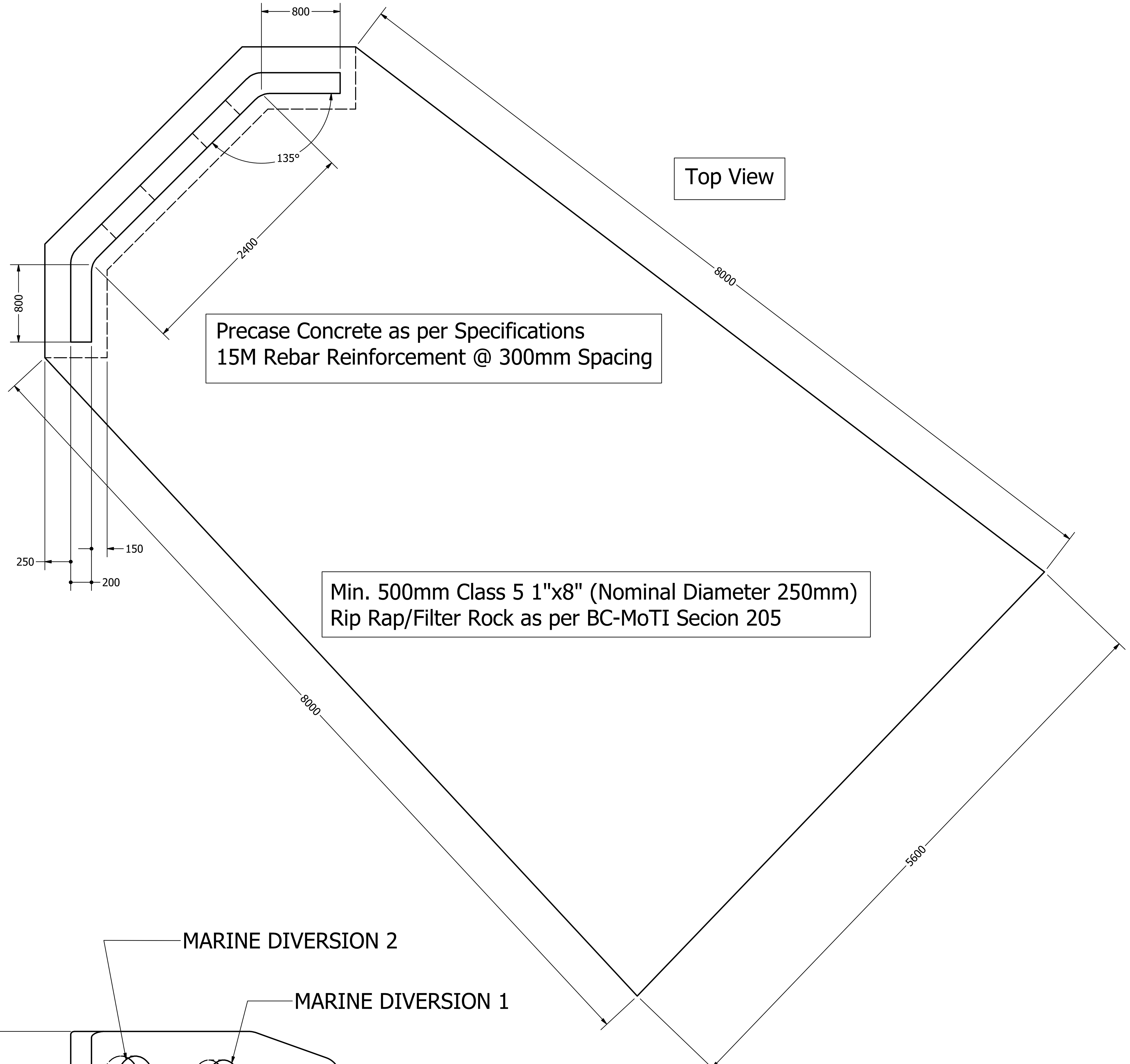
THUNDERBIRD LAKE - LANDSCAPE

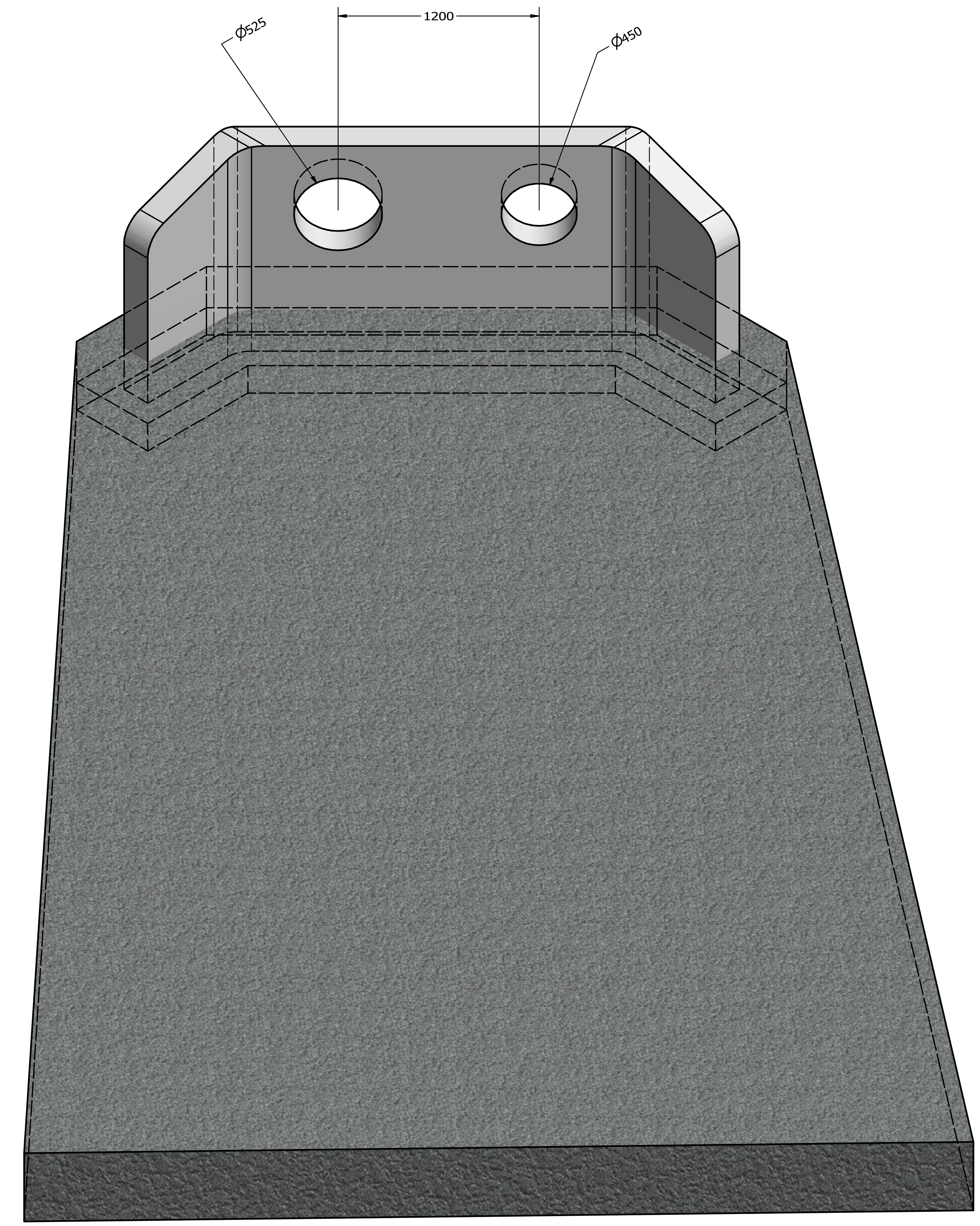
DESIGN:	JD	DRAWING NUMBER	TLAKE-02
DRAWN:	JZ		
CHECKED:	N/A	HOR. SCALE	1:15
ENGINEER:	N/A	VER. SCALE	1:15

REV. 0

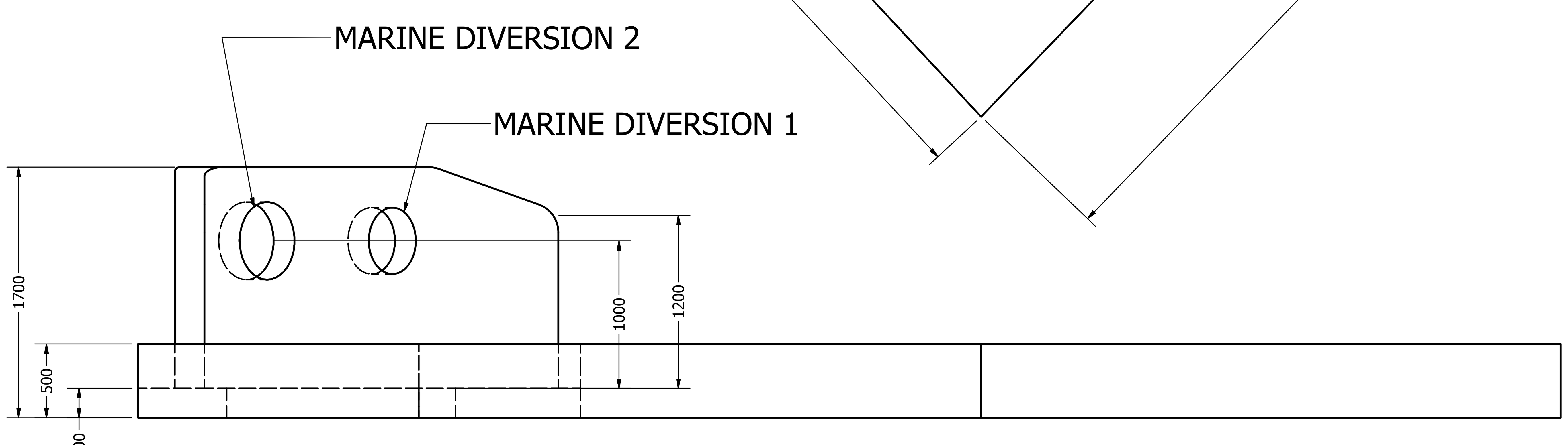
DESTROY ALL PRINTS BEARING PREVIOUS REVISION NUMBER

Top View





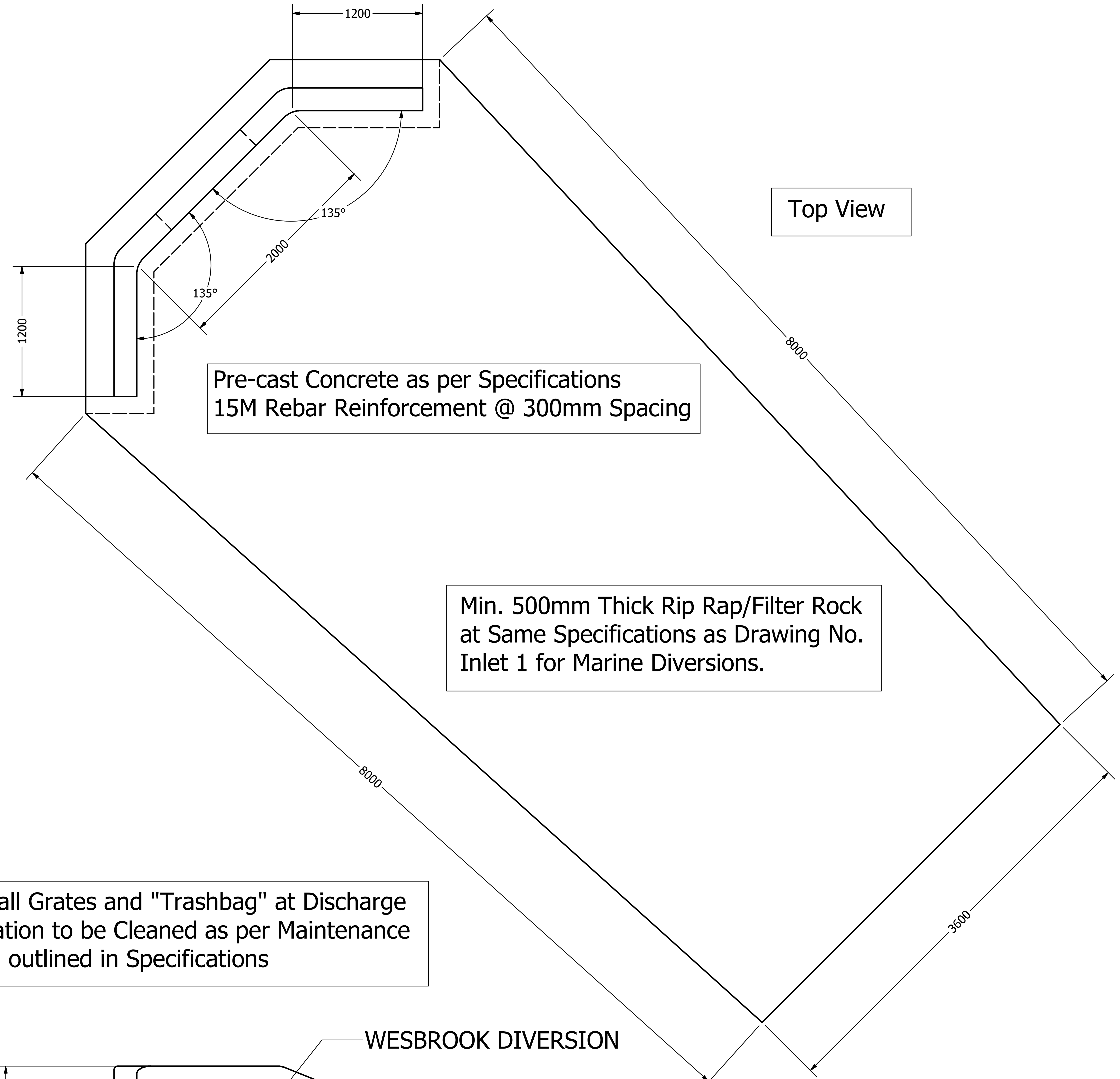
Rip Rap Lining Top of Soil as per X-Sec in Drawing No. Weir 2 and Native Soils



Elevation View

All dimensions in mm

DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16	
CHECKED		TITLE	
QA		Thunderbird Lake - Marine Diversion Inlet	
MFG			
APPROVED			
		SIZE D	DWG NO Inlet 1 REV
		SCALE 1 / 25	SHEET 1 OF 1

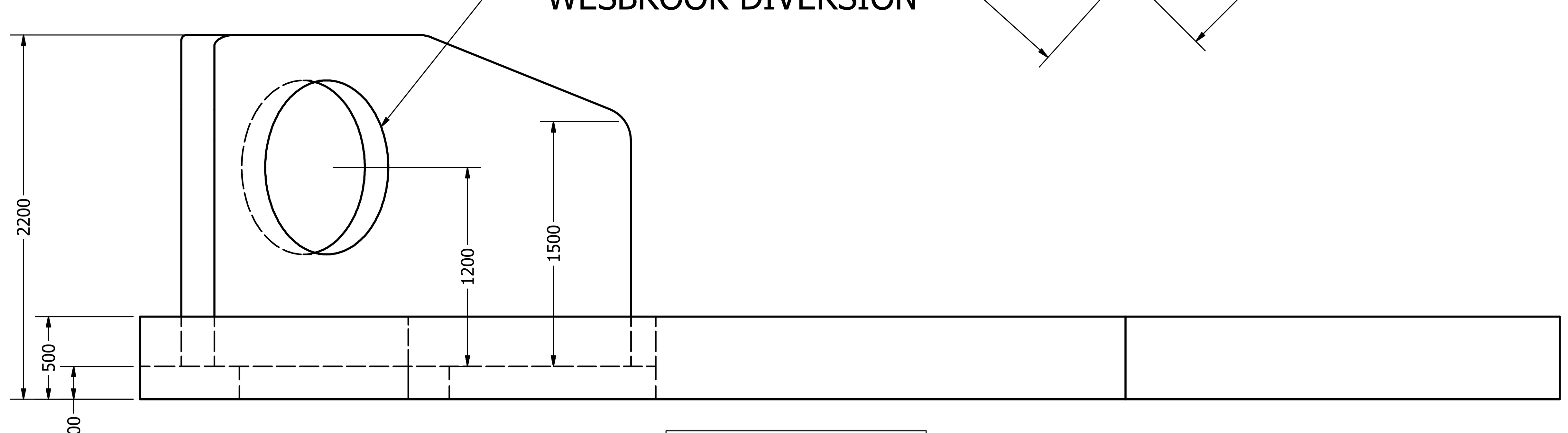


Top View

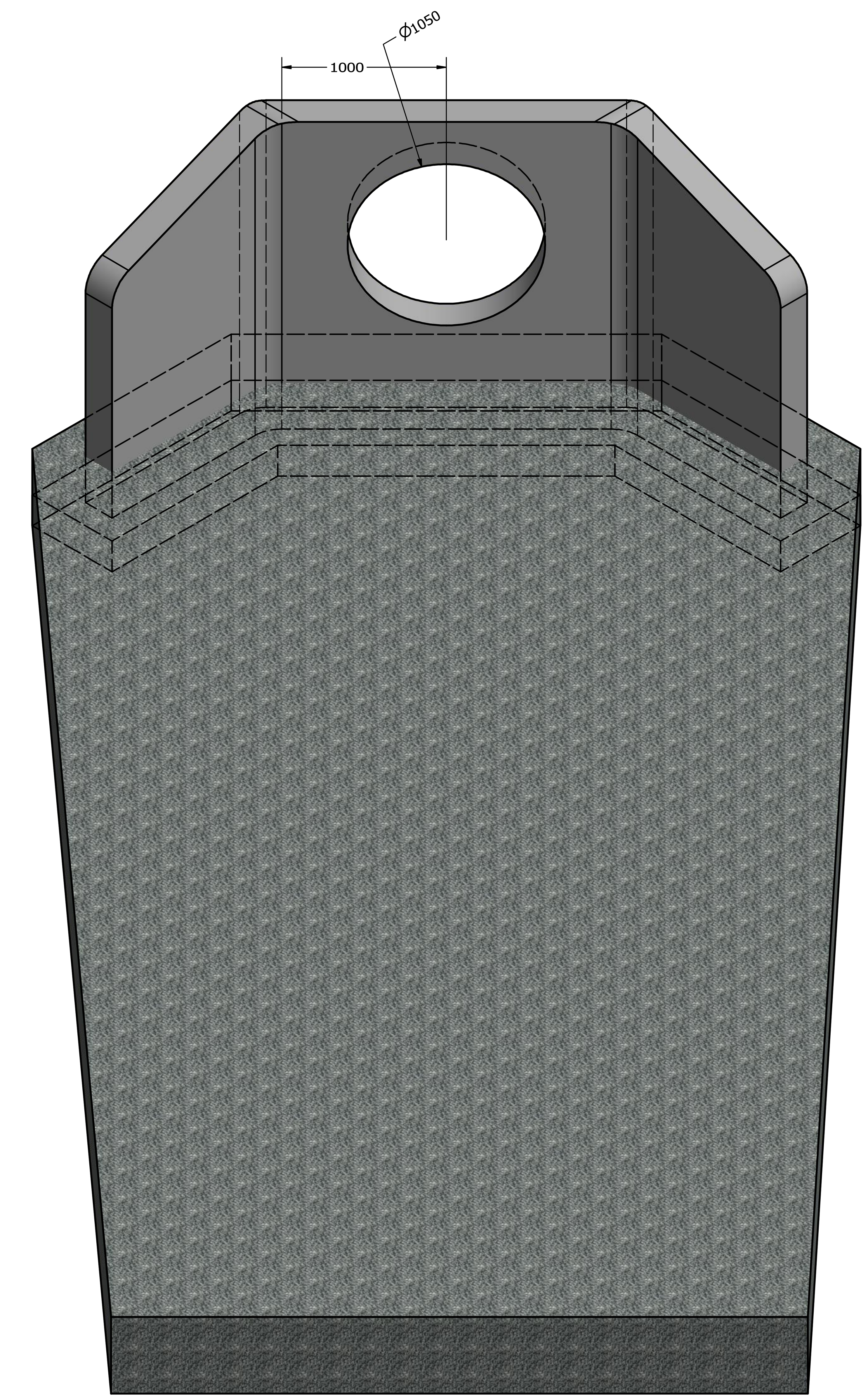
Pre-cast Concrete as per Specifications
15M Rebar Reinforcement @ 300mm Spacing

Min. 500mm Thick Rip Rap/Filter Rock at Same Specifications as Drawing No. Inlet 1 for Marine Diversions.

Install Grates and "Trashbag" at Discharge Location to be Cleaned as per Maintenance Plan outlined in Specifications



Elevation View

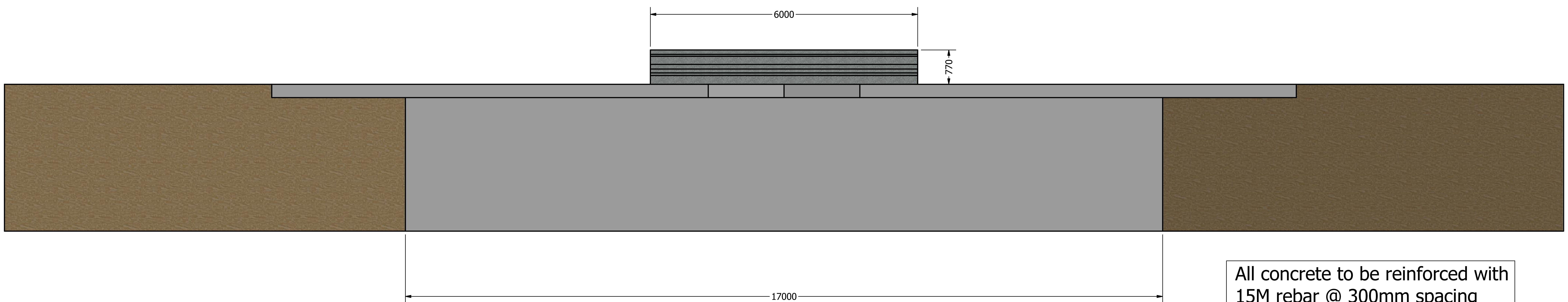


Soil Conditions to Mimic Drawing No. Inlet 1

All dimensions in mm

DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16
CHECKED		TITLE
QA		Thunderbird Lake - Wesbrook Diversion Inlet
MFG		
APPROVED		SIZE D · DWG NO Inlet 2 · REV
		SCALE 1 / 25 · SHEET 1 OF 1

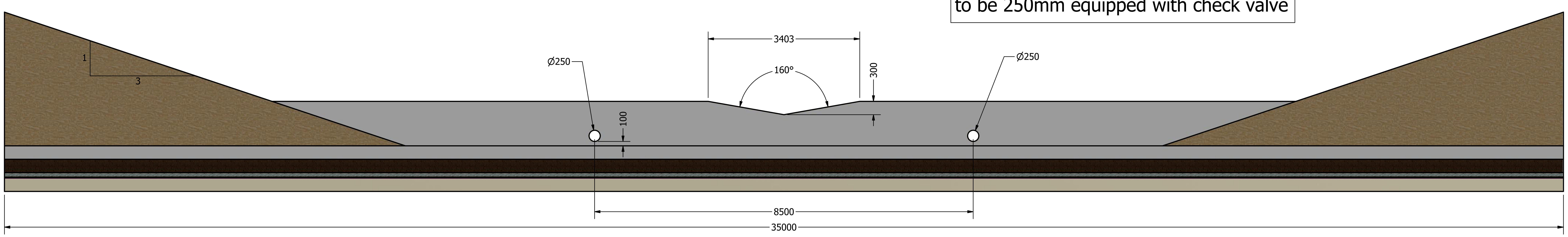
TOP VIEW



All concrete to be reinforced with
15M rebar @ 300mm spacing
in accordance to Specifications

BASE VIEW

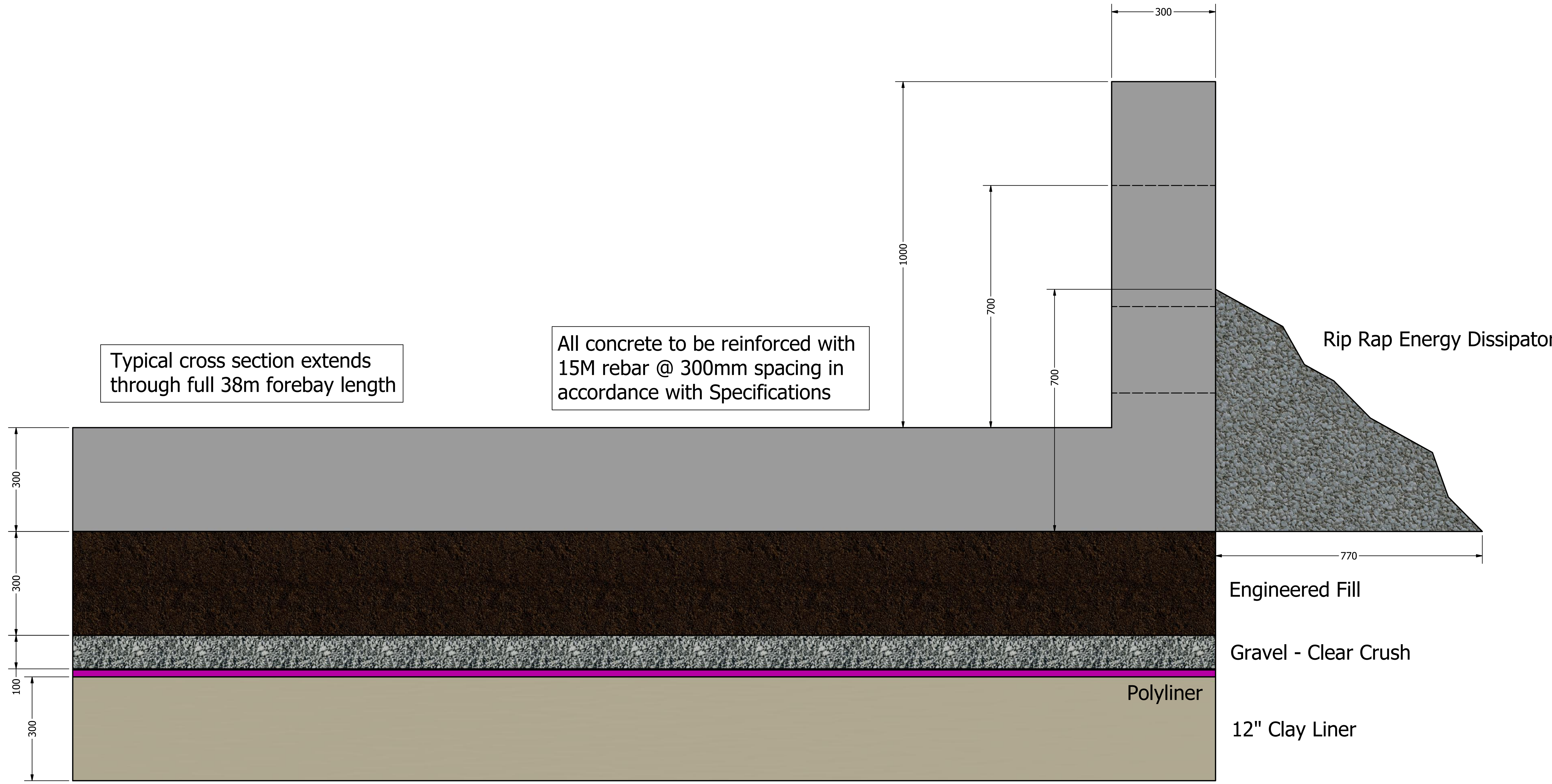
Emergency/Maintenance release orifice
to be 250mm equipped with check valve



See detailed soil cross sections
in Drawing No. Weir 2

All dimensions in mm

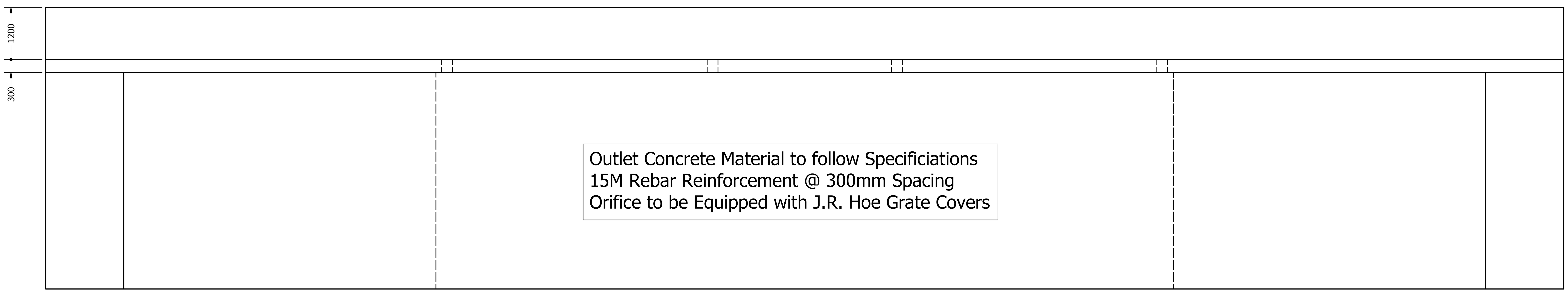
DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16
CHECKED		TITLE
QA		Thunderbird Lake - Weir Base Specifications
MFG		
APPROVED		SIZE D / DWG NO Weir 1 / REV
		SCALE 1 / 50 / SHEET 1 OF 1



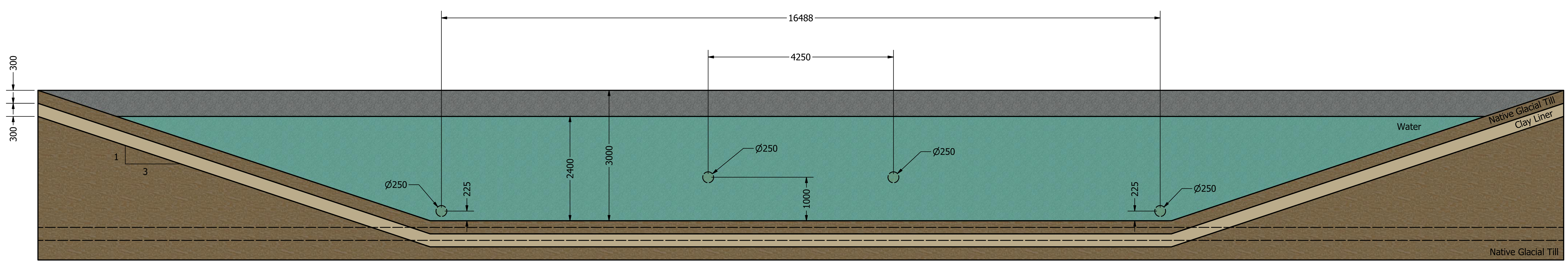
To be read in conjunction with Drawing No. Weir 1

All dimensions in mm

DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16
CHECKED		TITLE
QA		Thunderbird Lake - Weir Soil Cross Section
MFG		
APPROVED		SIZE D — DWG NO Weir 2 — REV
		SCALE 1 / 7 — SHEET 1 OF 1



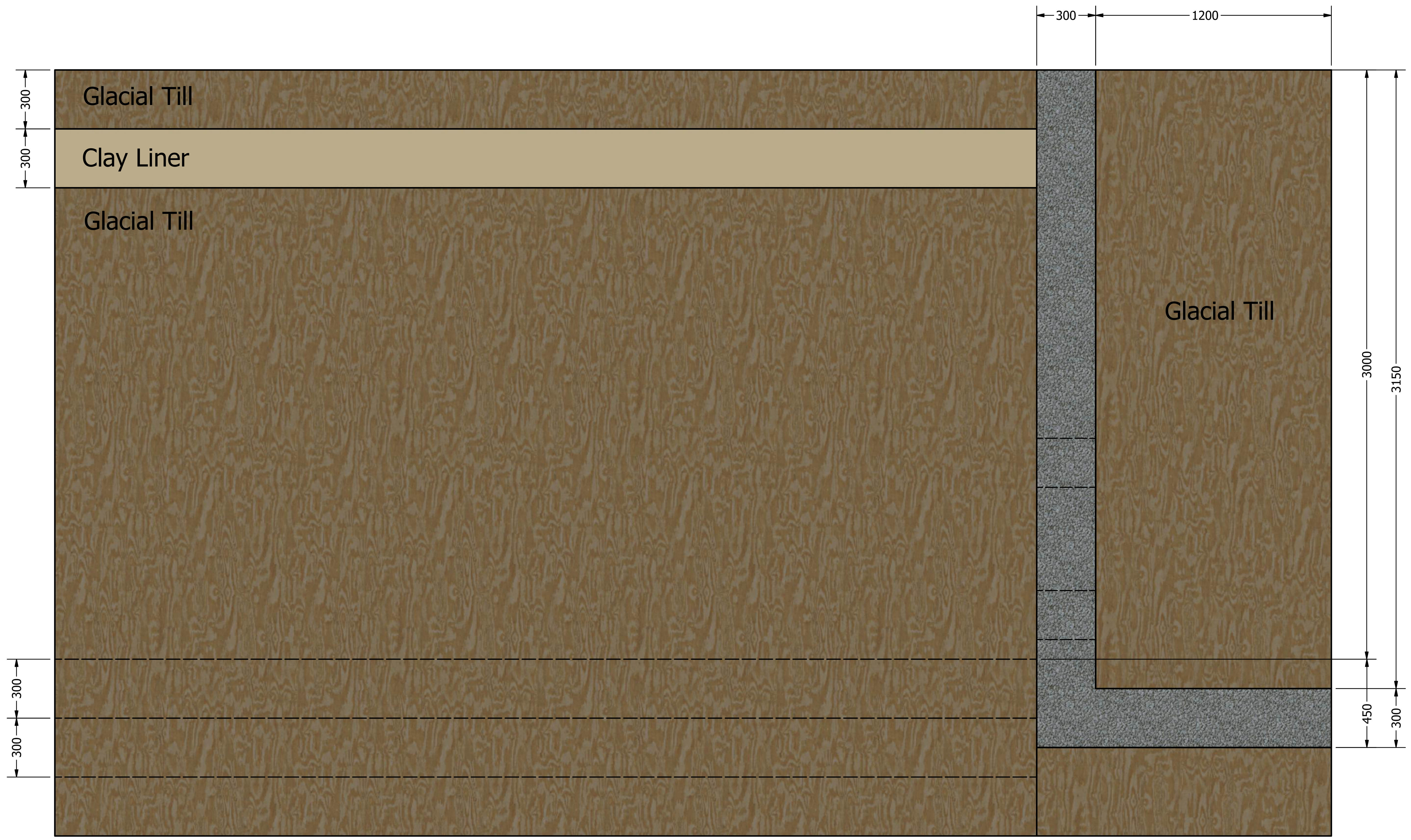
Outlet Concrete Material to follow Specificiations
15M Rebar Reinforcement @ 300mm Spacing
Orifice to be Equipped with J.R. Hoe Grate Covers



Maximum Water Level 2.4m Above Lakebed
Emergency Release Values 0.1m Above Lakebed
with Check Valves. Normal Orifice at 1.0m, to be
Connected to Service Manholes as per Drawing No.
Outlet 0

All dimensions in mm

DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16
CHECKED		TITLE
QA		Thunderbird Lake - Outlet Structure
MFG		
APPROVED		SIZE D · DWG NO Outlet Structure 1 · REV
		SCALE 1/50 · SHEET 1 OF 1



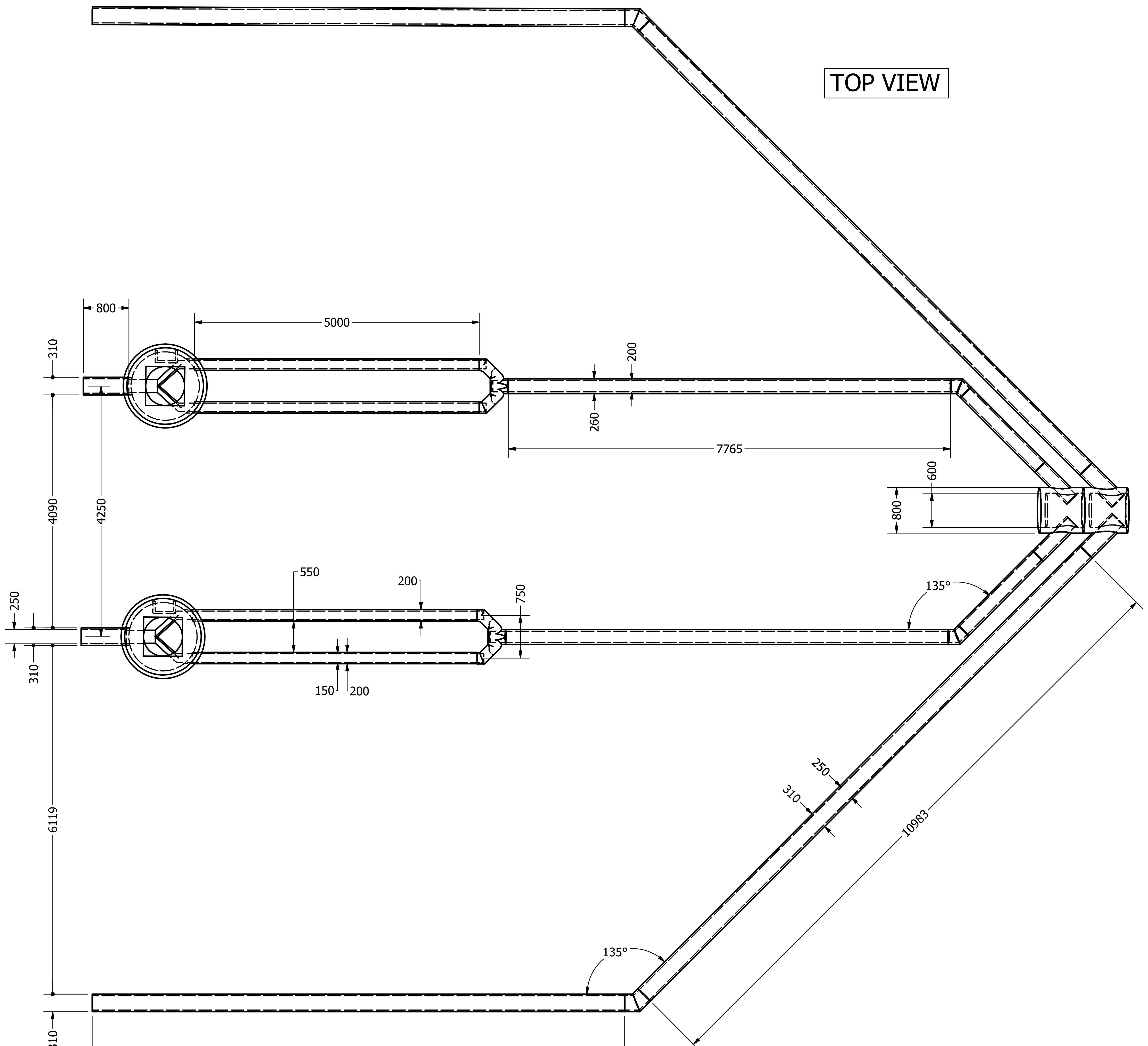
Outlet Discharge Orifices to be Connected to Outlet Pipe Structure as per Drawing No. Outlet 0

15M Rebar Reinforcement @ 300mm Spacing
Minimum Overlap of 150mm at 90 deg. Bend

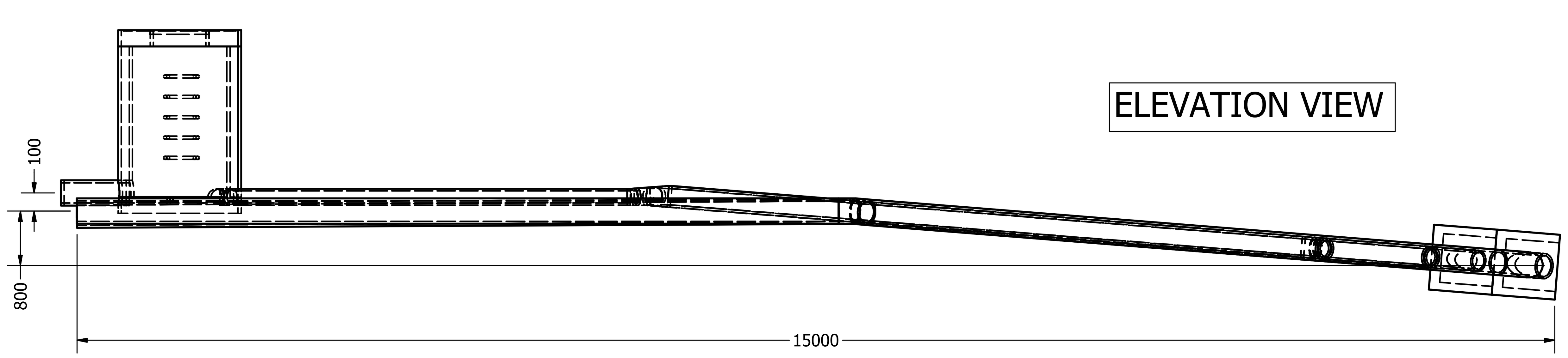
Cross Section Application to Entire Length of Pond, From Outlet Structure to Weir Structure.

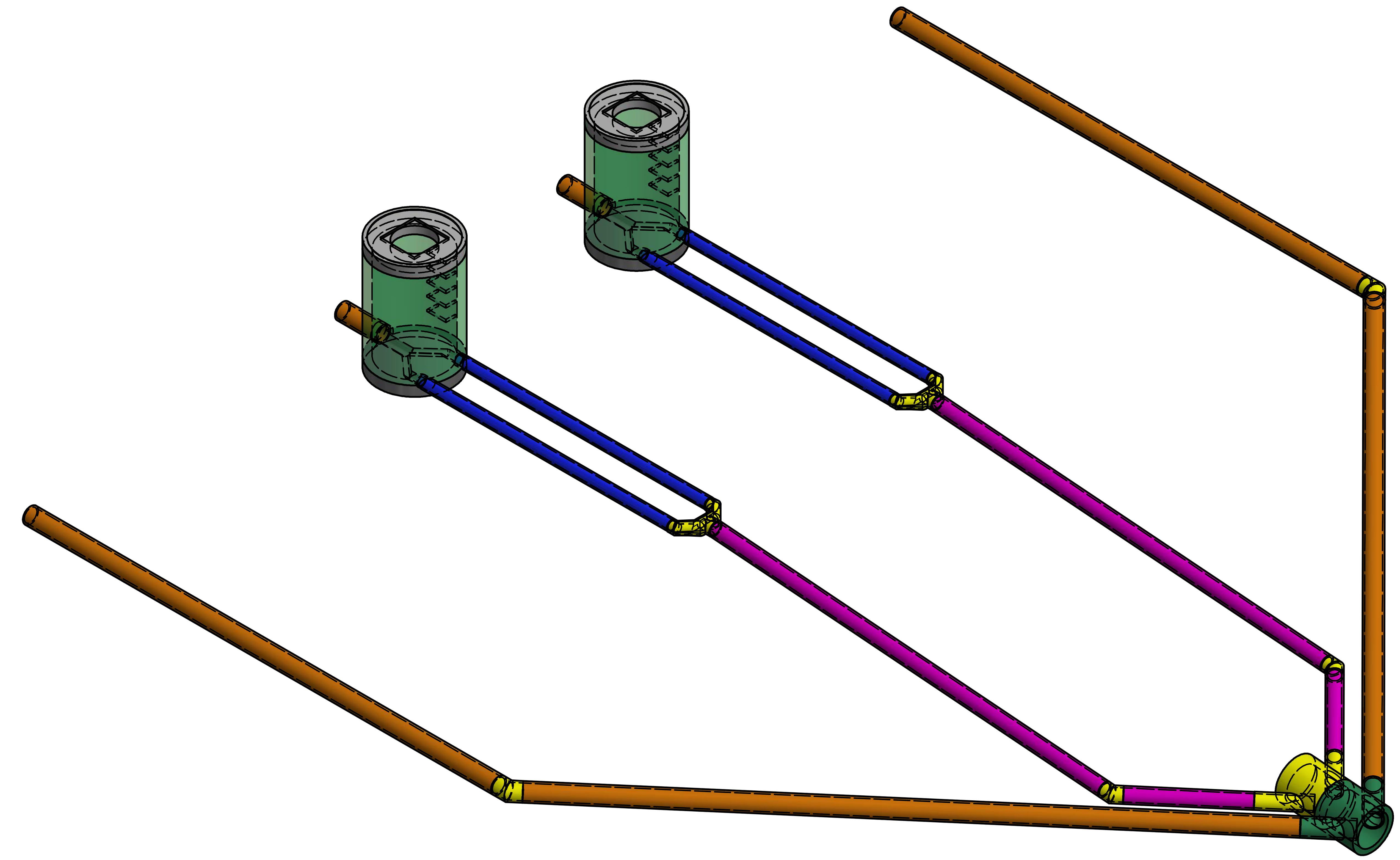
DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16
CHECKED		TITLE
QA		Thunderbird Lake - Outlet Cross Section
MFG		
APPROVED		
		SIZE D / DWG NO Outlet Structure 2 / REV
		SCALE 1/15 / SHEET 1 OF 1

TOP VIEW



ELEVATION VIEW

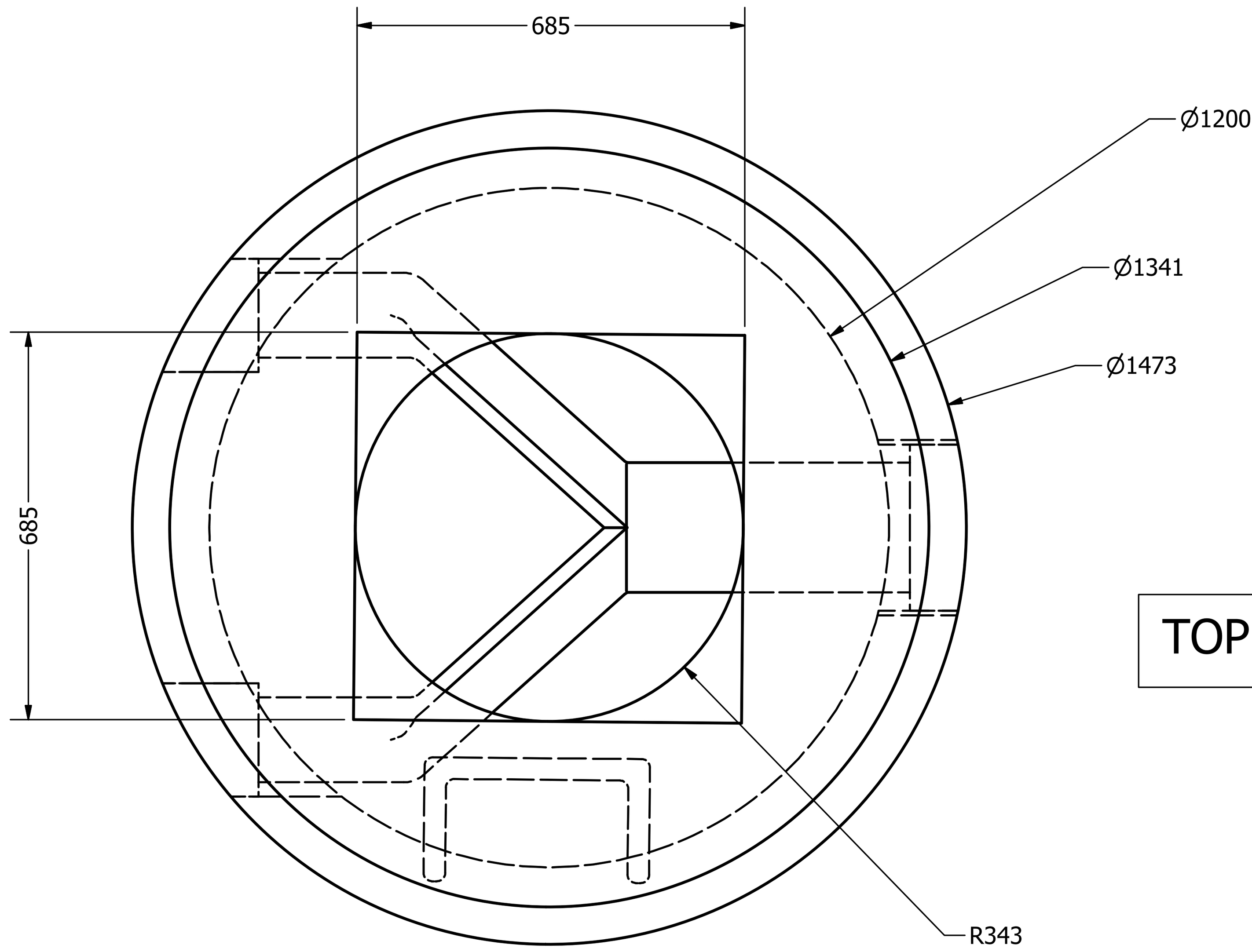




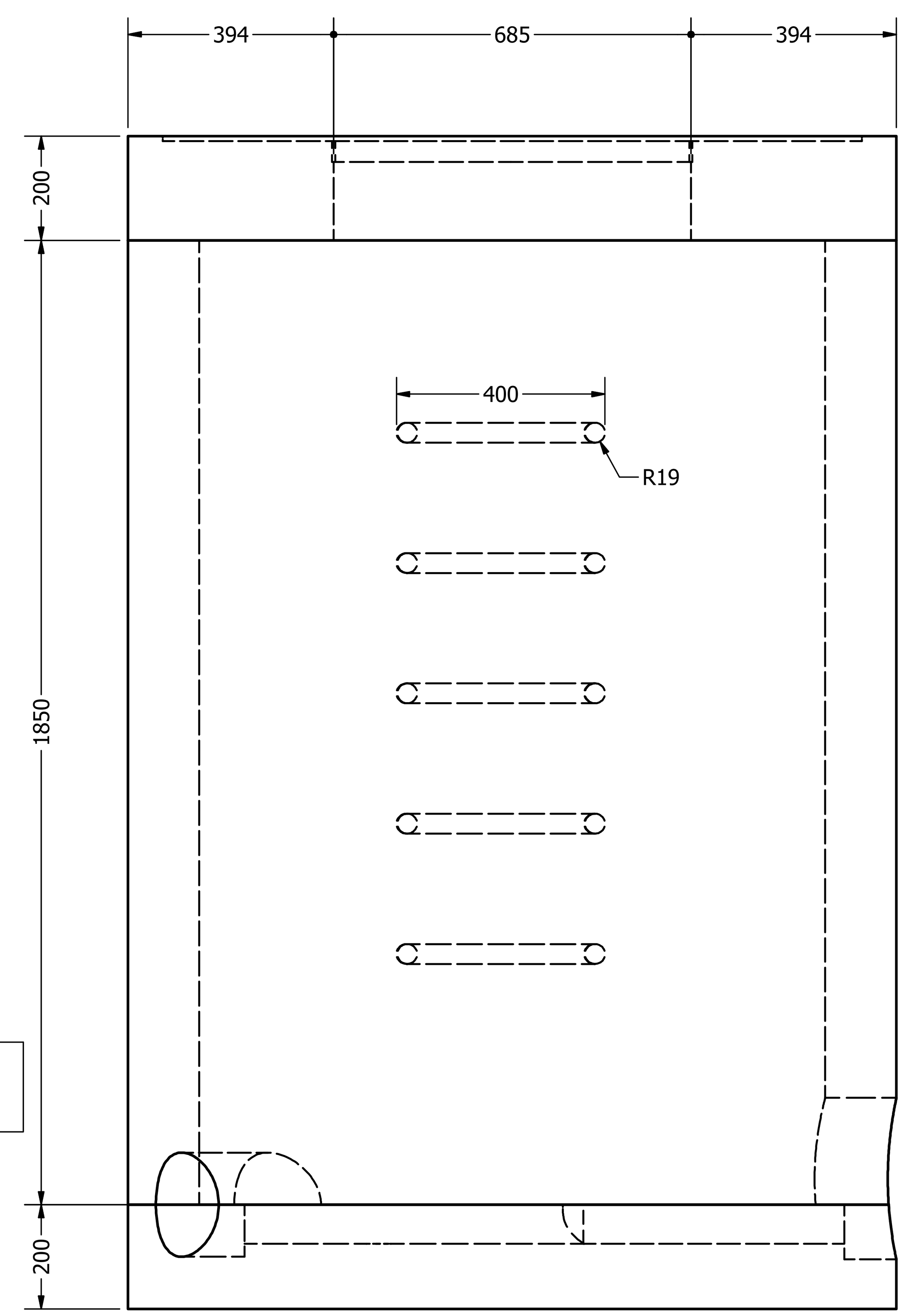
Manhole Details See Drawing Outlet 1
200mm to 250mm Connection See Outlet 2
45 Degree Bends see Outlet 3
Junction into 600mm See Outlet 4

All dimensions in mm

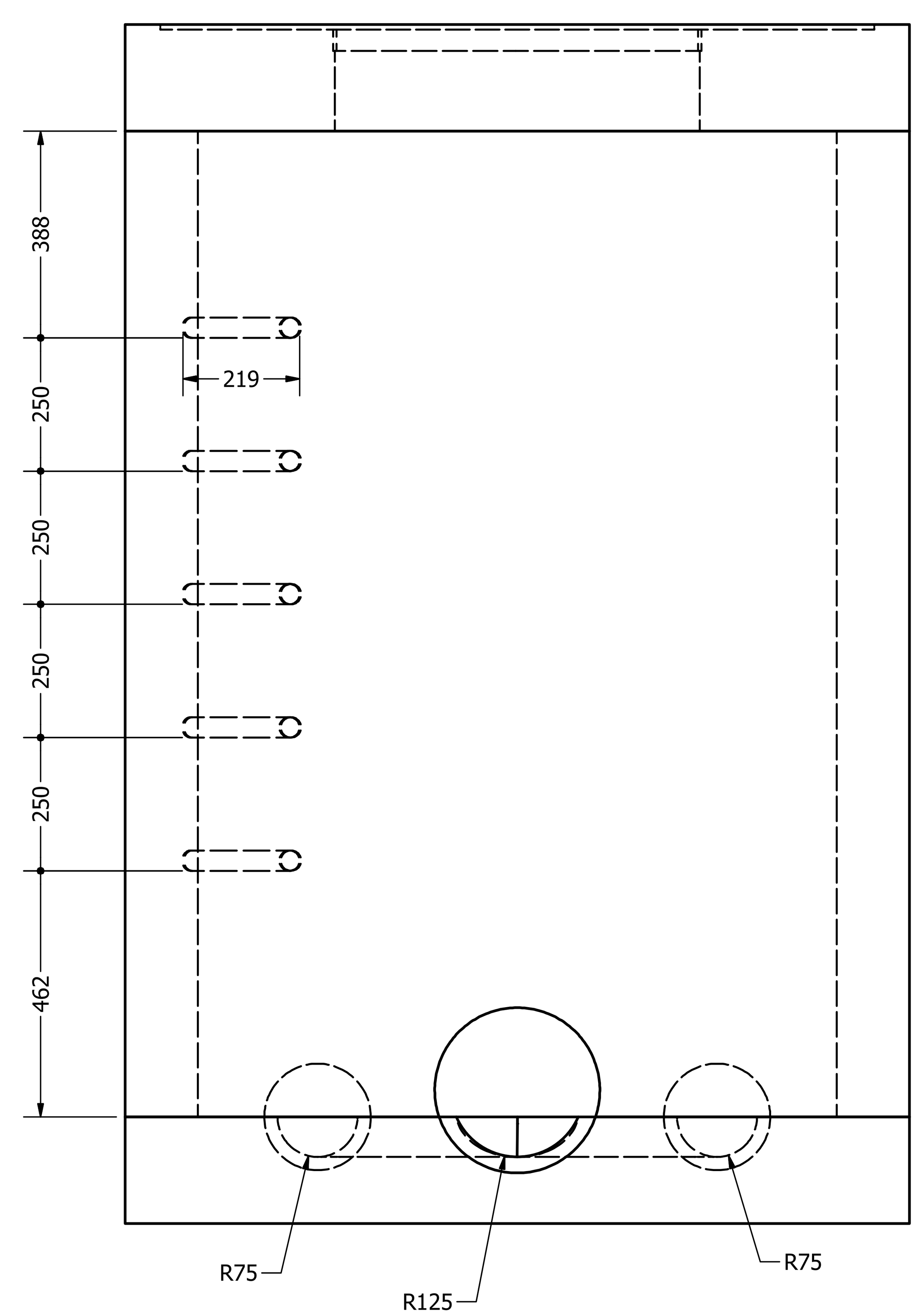
DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16
CHECKED		TITLE Thunderbird Lake - Outlet Structure
QA		
MFG		
APPROVED		SIZE D / DWG NO Outlet 0 / REV
		SCALE 1 / 50 / SHEET 1 OF 1



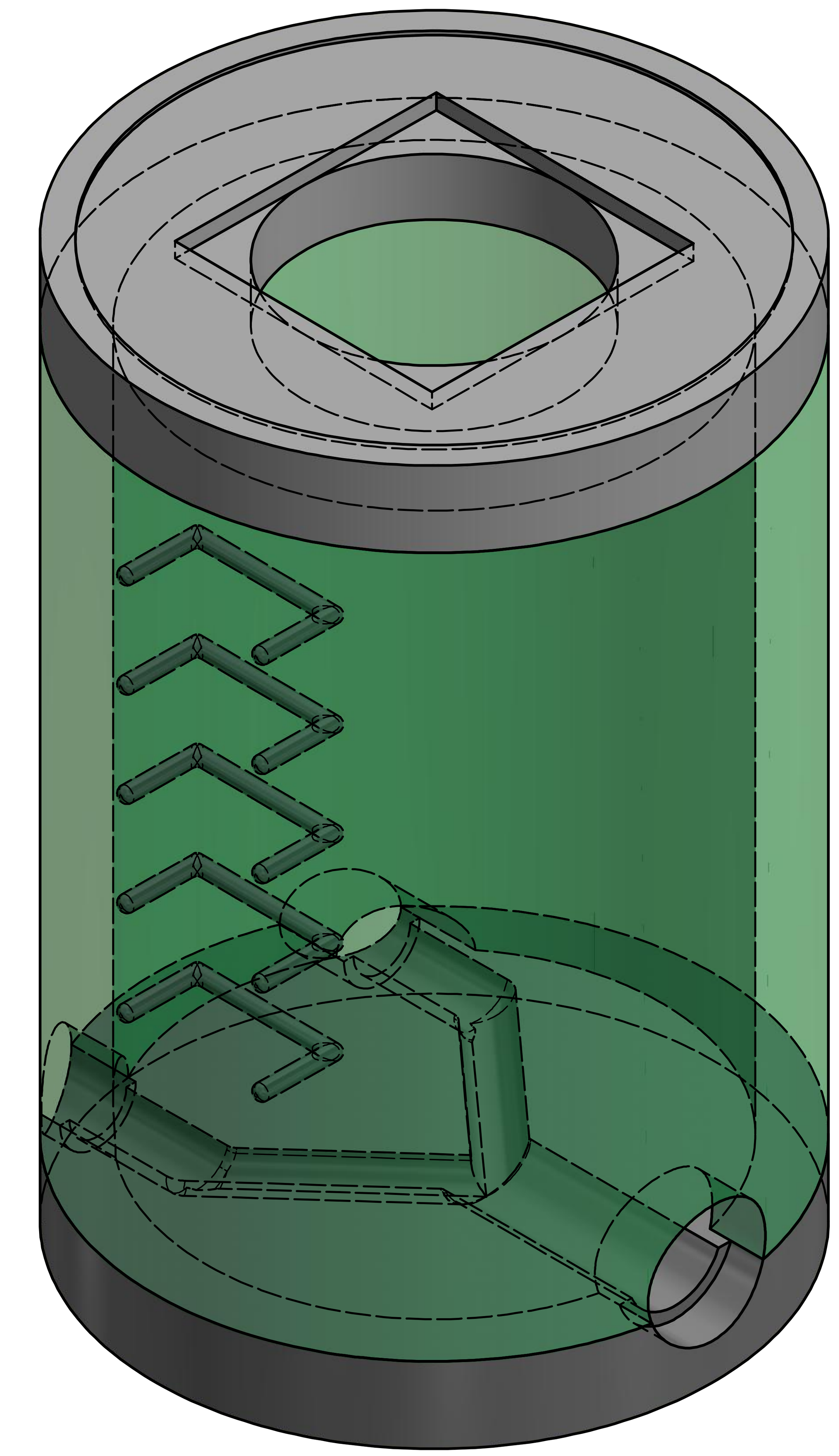
TOP VIEW



FRONT VIEW



SIDE VIEW

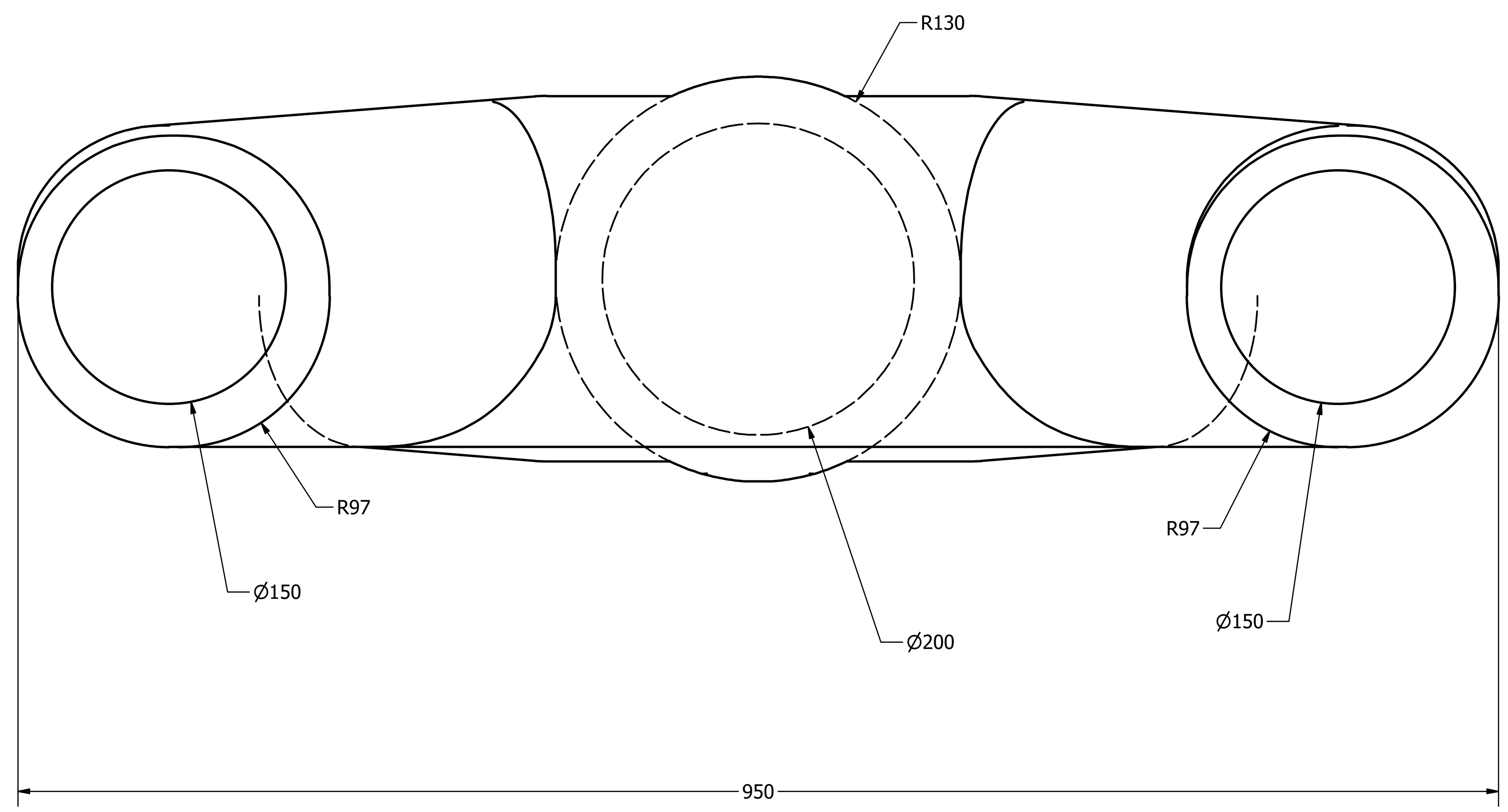


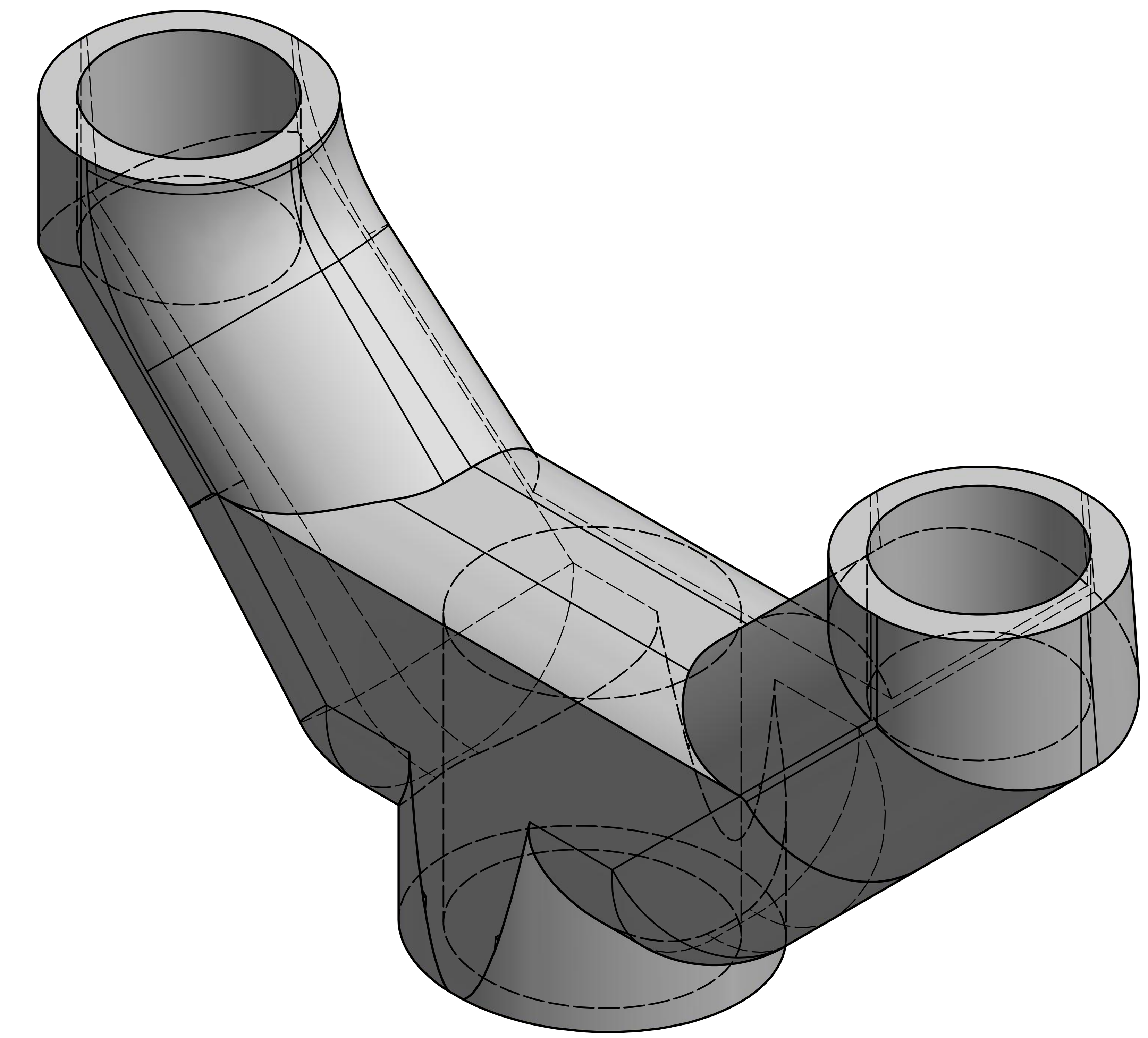
Pre-benched Class II 50-D Concrete Service Manhole
Typical Access Lid and Handles

All dimensions in mm

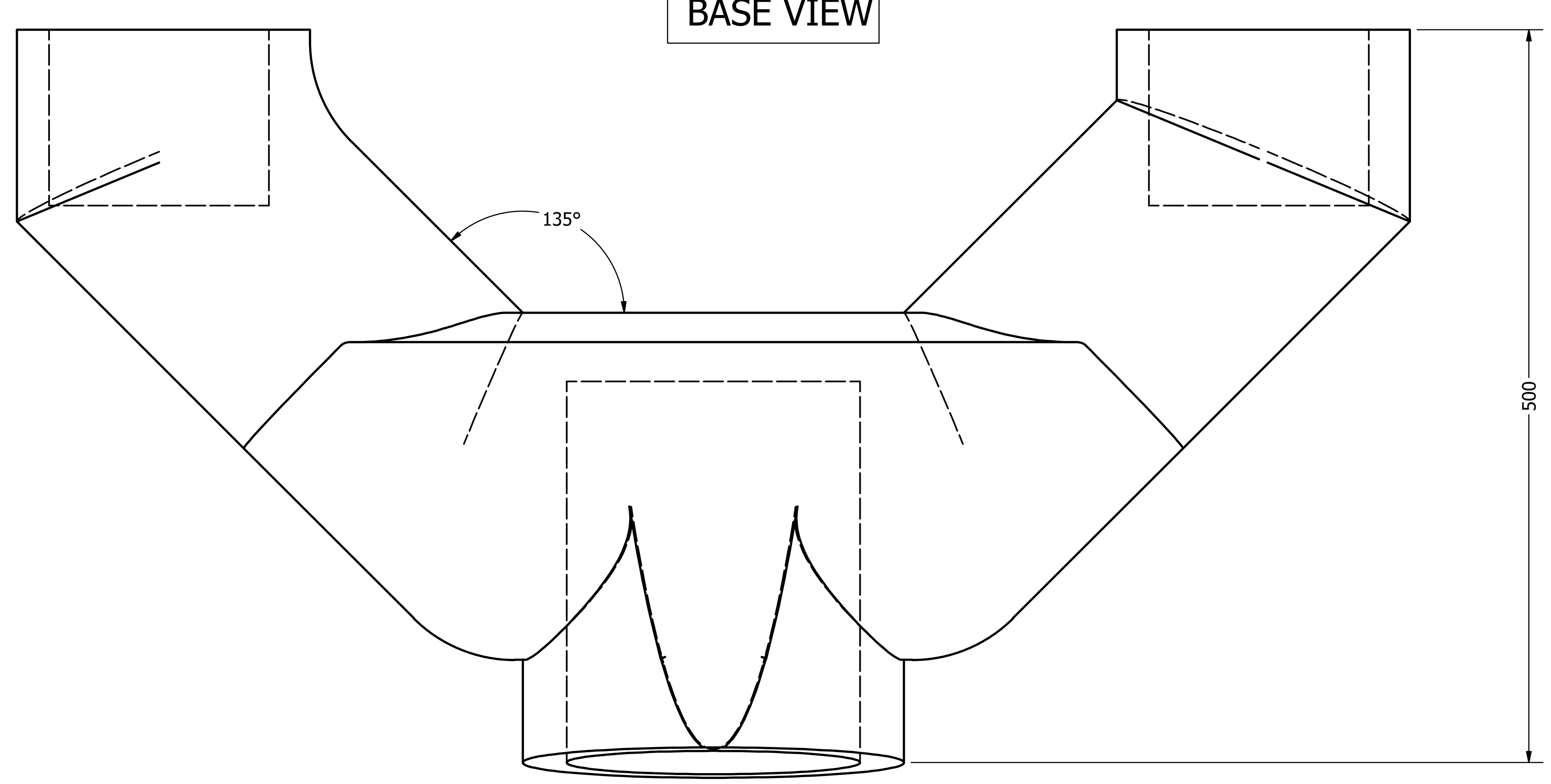
DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16
CHECKED		TITLE
QA		Thunderbird Lake - Outlet Manhole
MFG		
APPROVED		SIZE D / DWG NO Outlet 1 / REV
		SCALE 1:10 / SHEET 1 OF 1

TOP VIEW

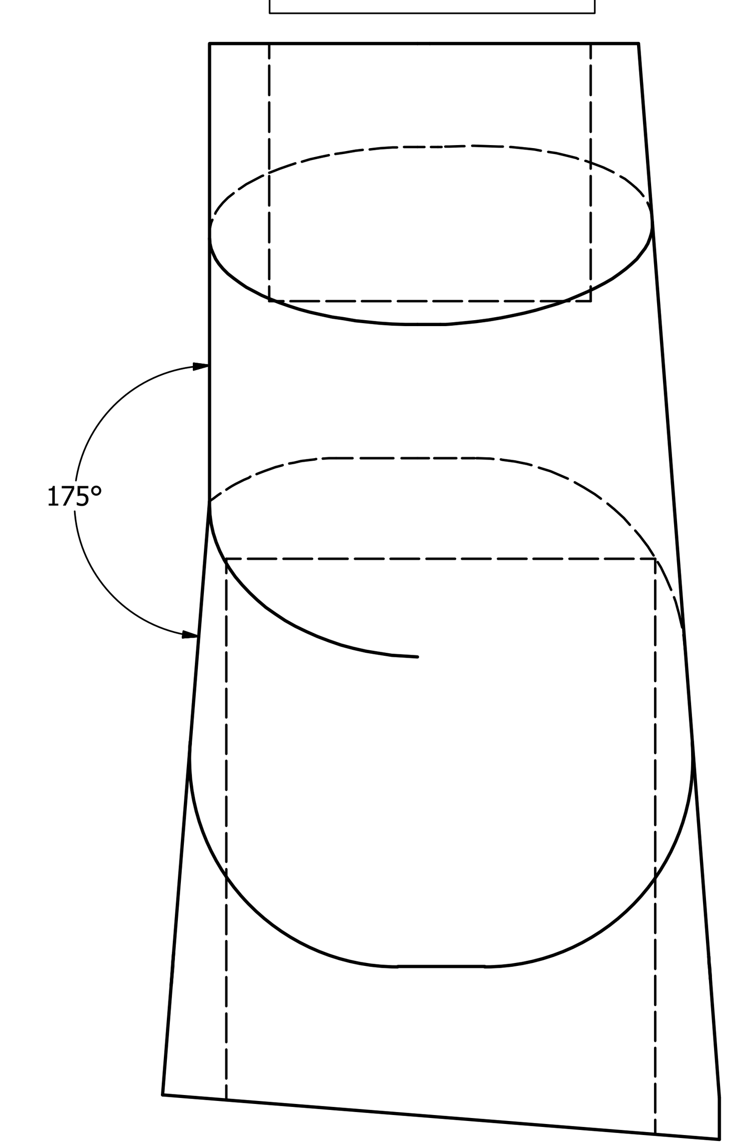




BASE VIEW



SIDE VIEW

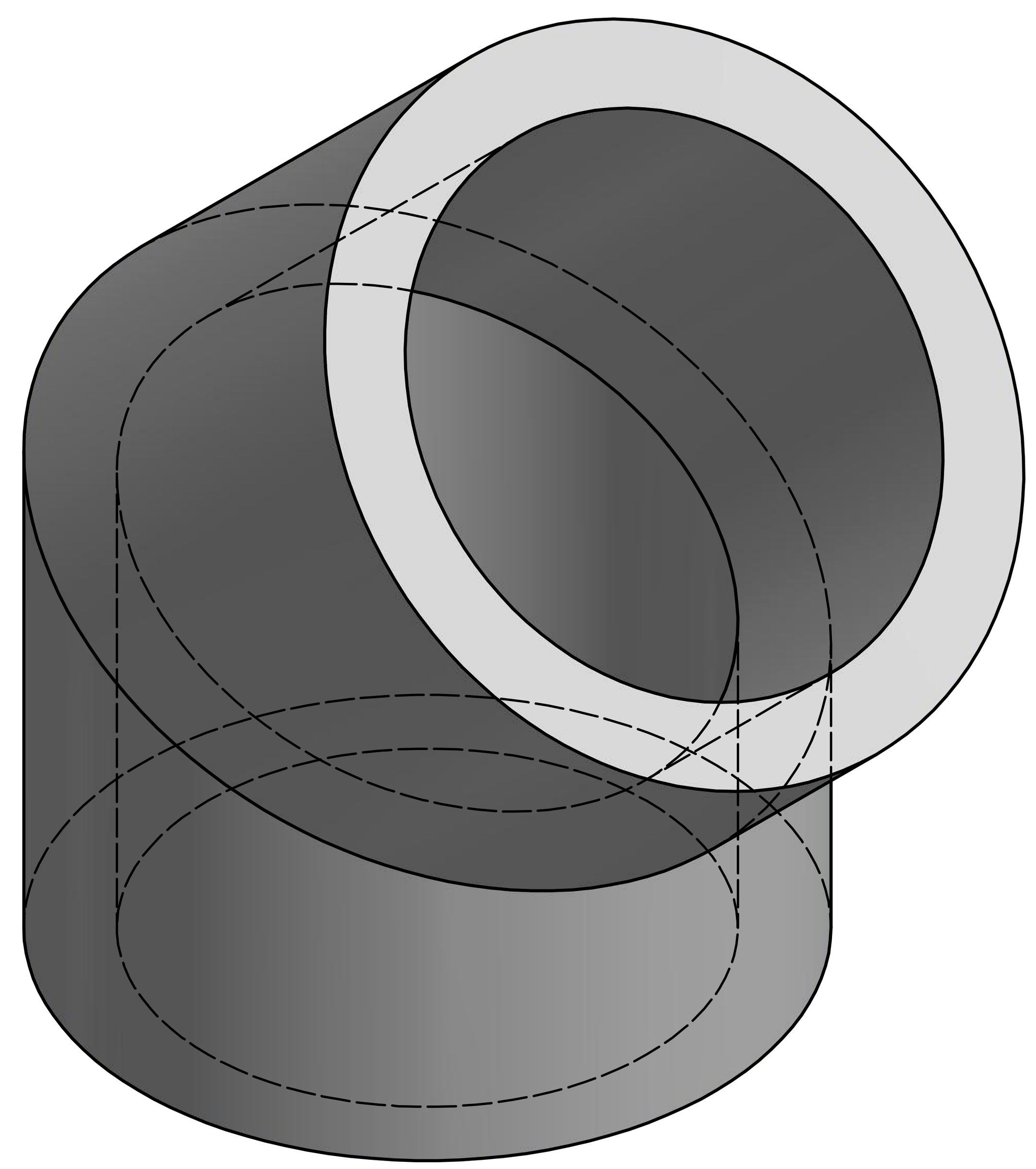


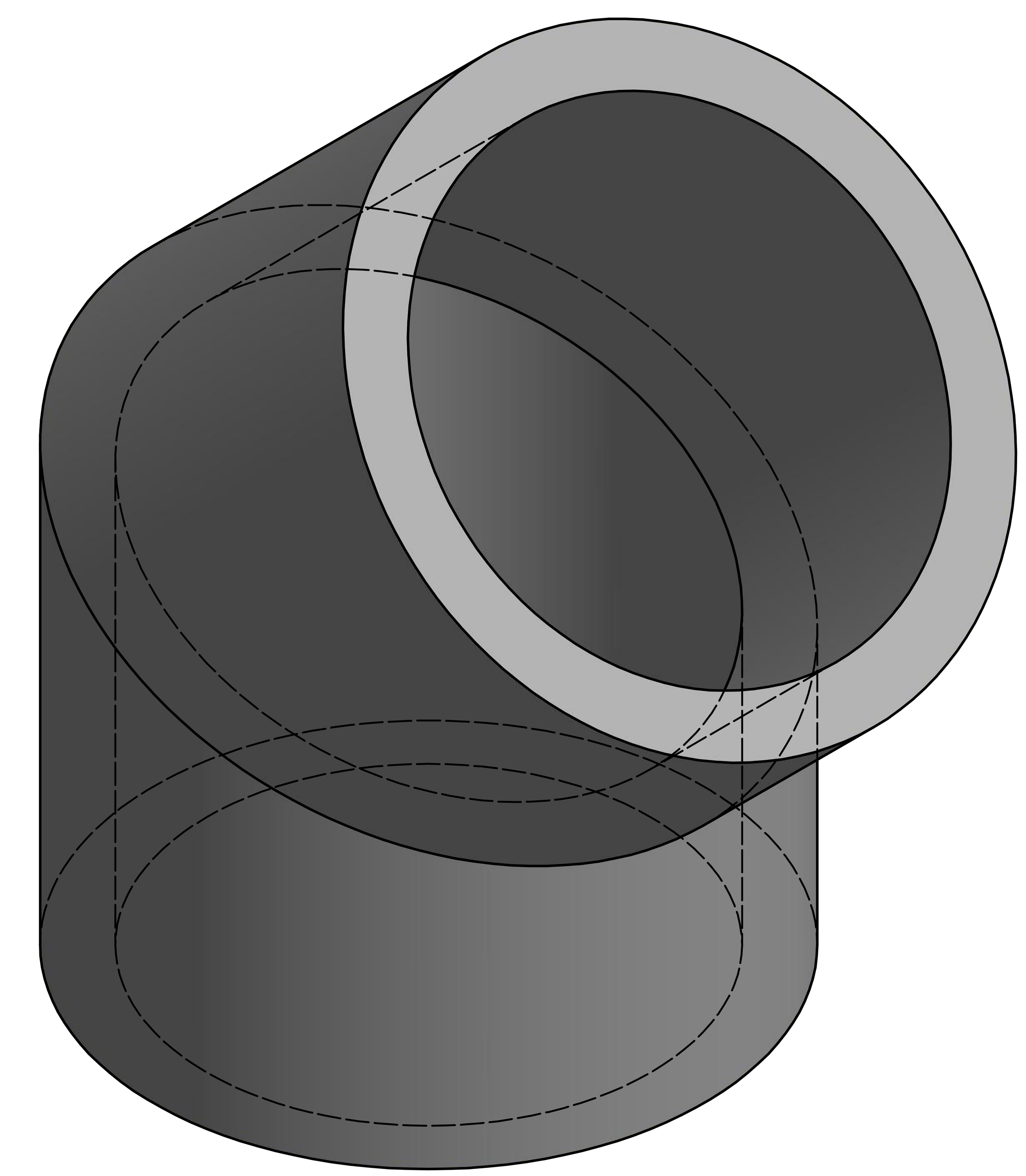
Material to match 150mm and 200mm piping

All dimensions in mm

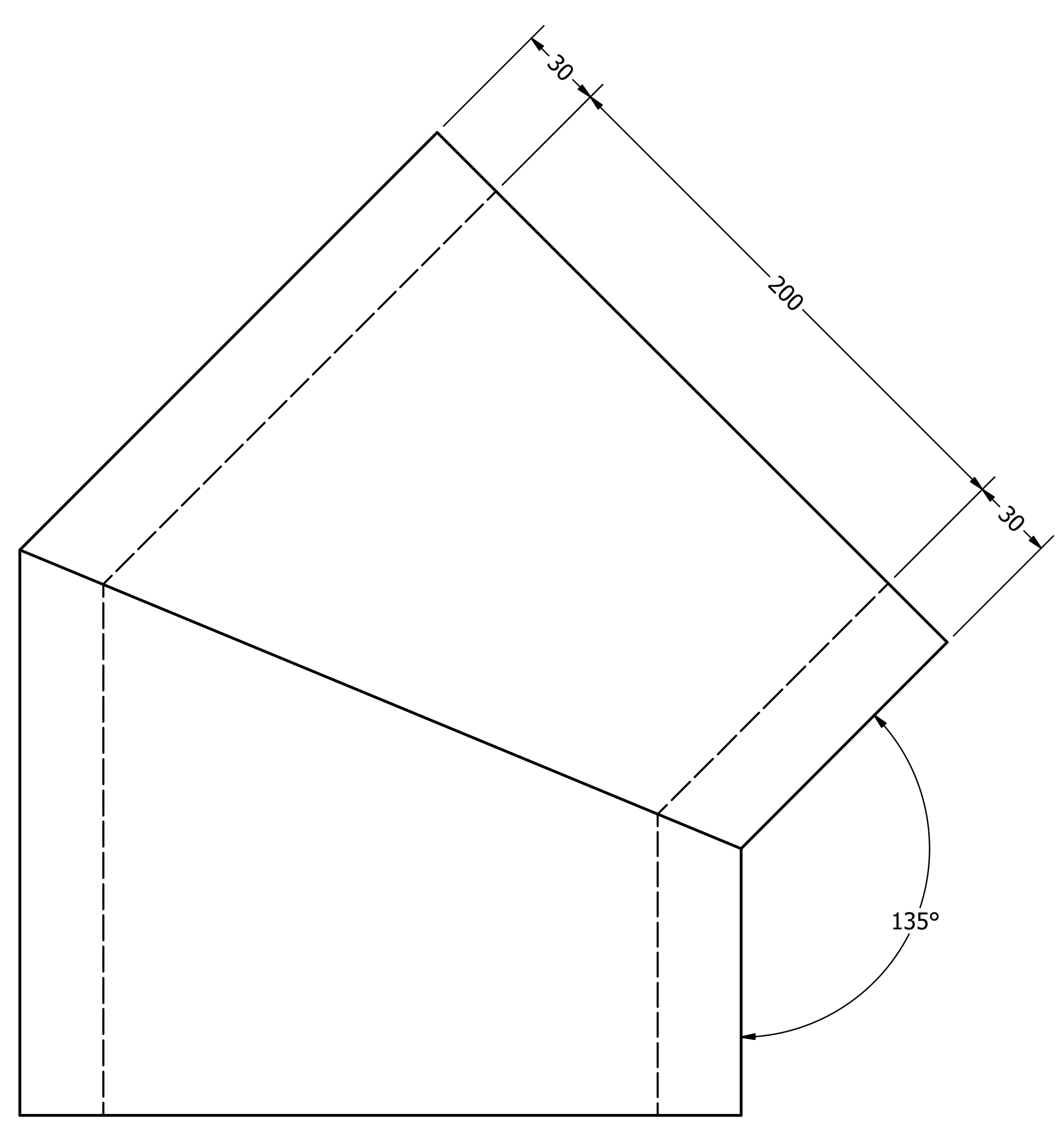
DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16	
CHECKED		TITLE Thunderbird Lake - Outlet 150mm to 200mm Wye Connection	
QA			
MFG			
APPROVED		SIZE D	DWG NO Outlet 2
		SCALE 1/3	SHEET 1 OF 1

REV

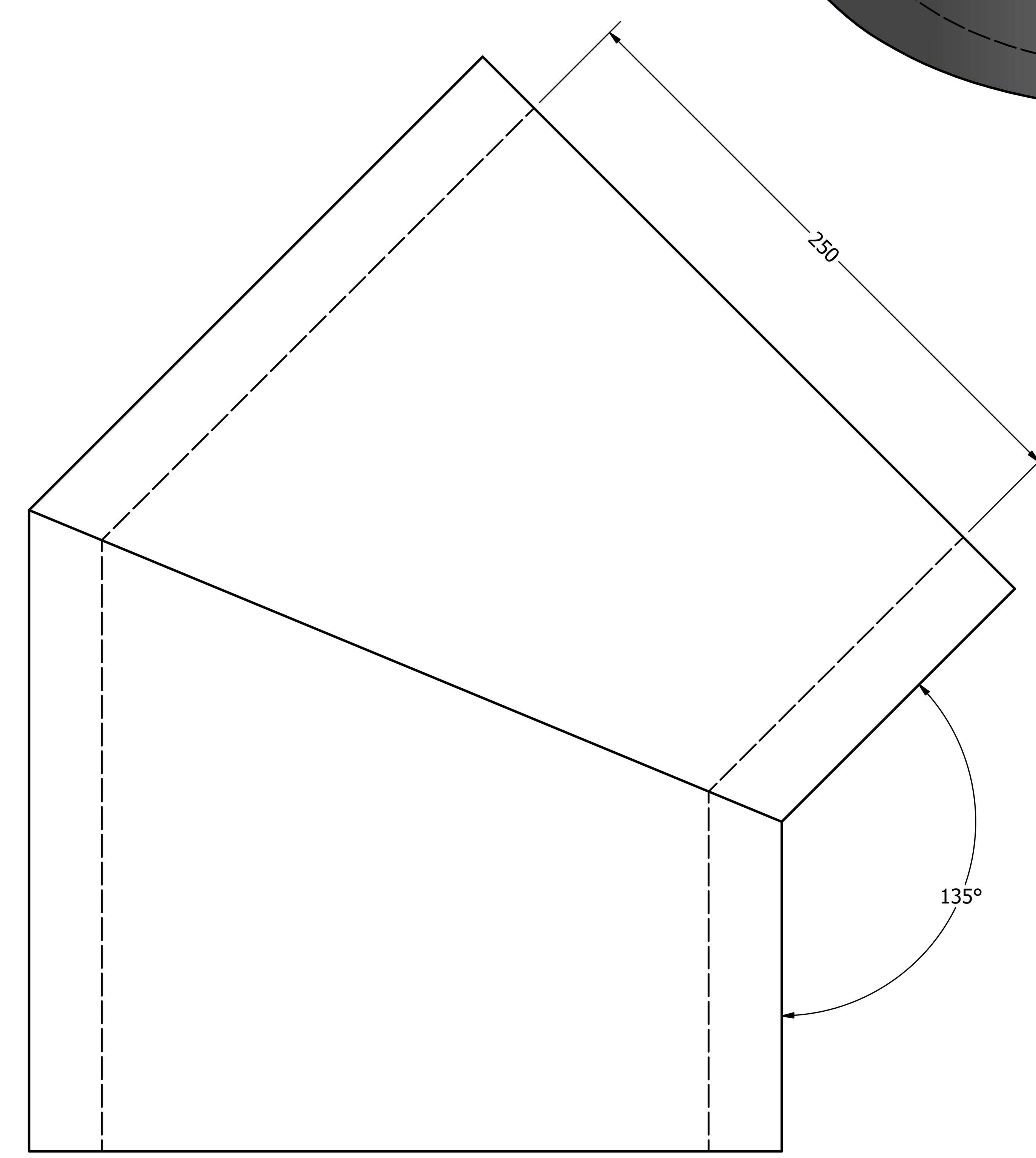




200mm 45 Deg. Bend



250mm 45 Deg. Bend



All dimensions in mm

DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16
CHECKED		TITLE Thunderbird Lake - Outlet 45 Degree Bends for 200mm and 250mm Pipe
QA		
MFG		
APPROVED		SIZE D, DWG NO Outlet 3, REV
		SCALE 1 / 2, SHEET 1 OF 1

All dimensions in mm

DRAWN Jimmy	2019-03-31	UBC CIVL 446 Team 16
CHECKED		TITLE Thunderbird Lake - 200mm and 250mm into 600mm Pipe Junction
QA		
MFG		
APPROVED		SIZE D / DWG NO Outlet 4 / REV
		SCALE 1:7 / SHEET 1 OF 1

APPENDIX E - COST ESTIMATE

THUNDERBIRD LAKE PROJECT COST SUMMARY

SUMMARY OF TOTAL PROJECT COSTS

DETAILED DESIGN BUDGET ESTIMATE DATE - March 30th, 2019

PREPARED FOR: UBC SEEDS

	(1)	(4)	(5)
COST CODE	**DESCRIPTION OF WORK**	**BUDGET**	**NOTES & ASSUMPTIONS**
0100	GENERAL REQUIREMENTS	192,020	
0200	SITE WORK	1,335,782	Revised for excavation and pipes
0300	CONCRETE	417,618	Revised for weir expansion
0400	MASONRY	0	
0500	METALS	5,000	
0600	WOOD & PLASTIC	17,060	
0700	THERMAL & MOISTURE	52,006	Revised for weir expansion
0800	DOORS & WINDOWS	0	
0900	FINISHES	0	
1000	SPECIALTIES	0	
1100	EQUIPMENT	0	
1200	FURNISHINGS	0	
1300	SPECIAL CONSTRUCTION	0	
1400	CONVEYING SYSTEMS	0	
1500	MECHANICAL	13,000	Revised for addition of aeration sys.
1600	ELECTRICAL	29,960	Revised for addition of Solar
	TOTAL CONSTRUCTION	**2,062,446**	
1700	CONSULTANTS	232,644	
1800	LAND	0	
1900	MUNICIPAL LEVIES	20,000	
2000	FINANCING	4,616	
2100	SALES COSTS	0	
2200	CONTINGENCIES	347,324	Target 15%, min. 5% for financing
	TOTAL DEVELOPMENT	**604,584**	
	TOTAL PROJECT COSTS	**2,667,031**	
0101	Field Supervision	90,000	15000/month
0102	Site Coordinator/CSO	48,000	8000/month
0107	Truck Allowance/Employee Travel	6,000	1000/month
0110	Concrete Testing	3,000	500/month
0115	Site Phones	1,800	allow $300/month
0116	Documentation & Deliveries	1,400	As per proposal
0117	Site Consumables	1,800	allow $300/month
0119	Temporary Site Office	4,800	800/month site trailer
0120	Temporary Toilets	4,020	670/month for 3 toilet + pumping
0121	Temporary Power	3,000	500/month
0126	Hoarding & Barricades	600	$100 per month
0131	Rubbish Removal	5,400	$900/month
0134	Street Cleaning	5,200	$1300/month during rain season (4 month)
0136	Security	12,000	$2000/month
0196	Mobilization	5,000	As per proposal
0100	**GENERAL REQUIREMENTS**	**192,020**	
0210	Demolition & Clearing	40,000	20k/acre

THUNDERBIRD LAKE PROJECT COST SUMMARY

SUMMARY OF TOTAL PROJECT COSTS

DETAILED DESIGN BUDGET ESTIMATE DATE - March 30th, 2019

PREPARED FOR: UBC SEEDS

	(1)	(4)	(5)
COST CODE	**DESCRIPTION OF WORK**	**BUDGET**	**NOTES & ASSUMPTIONS**
0220	Excavation & Imported Fill	790,435	$7/ton, $500/trip, 27 tons/trip
0255	Onsite Servicing	400,000	Altus 2018 + Finalized pipe length
0280	Landscaping	105,346	Allow $12/sqft
0200	**SITE WORK**	**1,335,782**	
0310	Formwork Material	11,661	$0.6/sqft ($20 7/16 4x8 OSB)
0311	Formwork Labour	134,096	Allow $6.90/sqft
0320	Concrete Reinforcing	151,907	Allow $0.75/ft
0330	Concrete Supply	106,301	$130/m^3 (retaining wall/footing)
0331	Concrete Pumping	13,653	$200/hr, $3 per m pumped (40M 5" pump)
0300	**CONCRETE**	**417,618**	
0550	Metal Fabrications/Misc. Metals	5,000	Weir allow appropriate gauge steel
0500	**METALS**	**5,000**	
0610	Rough Carpentry Material	17,060	Allow $20/ft for 48' guardrail/fencing
0600	**WOOD & PLASTIC**	**17,060**	
0705	Dampproofing	52,006	Allow $3/sqft for forebay/weir/outlet
0700	**THERMAL & MOISTURE**	**52,006**	
1590	Mechanical Controls	13,000	2x PS20 and 1x Forebay Floater
1500	**MECHANICAL**	**13,000**	
1610	Solar Photovoltaics	24,960	Allow $0.60 per Watt installed
1650	Light Fixtures	5,000	Allow 5k exterior lighting
1600	**ELECTRICAL**	**29,960**	
1702	Project/Construction Manager	120,000	Allow 10k/month Cost Plus
1704	Geotechnical Engineer		
1708	Structural Engineer	41,800	As per proposal
1716	Civil Engineer		
1715	Environmental Consultant	20,000	Allow 20k LOA
1711	Surveyors	30,000	Assume 10k/month first 3 months
1720	Accountant	6,000	Allow 1.5k quarterly
1722	Liability Insurance	6,924	Standard construction insurance (0.003)
1780	Consultant Disbursements	7,920	As per proposal + 10%
1700	**CONSULTANTS**	**232,644**	
1903	UBC Fees	20,000	As per proposal
1900	**MUNICIPAL LEVIES**	**20,000**	
2001	Financing Fees	4,616	~0.002 of total cost per annum
2000	**FINANCING**	**4,616**	
2201	Construction Contingency	347,324	15% of total project
2200	**CONTINGENCIES**	**347,324**	

Detailed Design Cost Estimate - Major Cost Contributors Calculations & Breakdown

/This sheet only serves to supplement the Project Cost Summary; straight forward values reasonably inferrable from the summary sheet will not be calculated here; mainly focuses on Divisions 2 and 3/

Assumptions:
>Rebar weight at 1.556 kg/m

>Thumb Rule Method yields 130 kg of reinforcement required per cubic meter of concrete for retaining structures, 100 kg/cubic meter for forebay slabs
>Dampproofing/Waterproofing requires only Tremco Liquid spray and Delta MS membrane
>Typical 40 meter length concrete pump with 5in diameter is used
>One truck trip (27 tonnage) to bring in imported fill can also leave with load of spoil
>Every truck requires $400 to mobilize + $125 per hour on the road, effectively $1000 per trip (Fairway quote), $500 per trip after 800 trips (scaling)
>Soil conditions at site resembles density values of ~20 kN per cubic meter
Parameters (not exactly as per drawings due to conservative estimation practice): *Areas are contact area to be used for formwork labour takeoffs, not total surface area*
>Forebay Concrete Area: 1135.8 sqm; 12219.6 sqft
>Forebay Concrete Volume: 340.7 cubic meters
>Weir Concreted Area: 54 sqm; 290.6 sqft
>Weir Concrete Volume: 27 cubic meters
>Outlet Concrete Area: 202.5 sqm; 2179.7 sqft
>Outlet Concrete Volume: 243 cubic meters
>Cut/Fill Net Volume: 1620 cubic meters

Required Reinforcement (Thumb Rule Method)
[(27+243)*130+340.7*100]/1.556*3.28 = 145817.6 ft

Required Imported Fill Trucking Trips
1620*20/9.8/27 = 122 trips

Original Budget Estimate

Division	Cost Code	Item	Quantity	Unit	Unit Rate	Extension
2	0200	Excavation & Imported Fill	122.0	trips	$ 1,000.00	$ 122,000.00
2	0200	Excavation & Imported Fill	3306.1	tons	$ 17.00	$ 56,203.70
2	0280	Landscaping	8778.9	sqft	$ 12.00	$ 105,346.80
3	0310	Formwork Material	14980.5	sqft	$ 0.60	$ 8,988.30
3	0311	Formwork Labour	14980.5	sqft	$ 6.90	$ 103,365.45
3	0320	Concrete Reinforcement	145817.6	ft	$ 0.75	$ 109,363.20
3	0330	Concrete Supply	610.7	cubic m	$ 130.00	$ 79,391.00
3	0331	Concrete Pumping	32	hours	$ 200.00	$ 6,400.00
3	0331	Concrete Pumping	610.7	cubic m	$ 3.00	$ 1,832.10

Revisions for changes between CIVL445 and CIVL446; added cost to complete items

Division	Cost Code	Item	Quantity	Unit	Unit Rate	Additional Cost
2	0255	600mm Concrete Pipe	55.2	m	$ 148.70	$ 8,211.21
2	0255	525mm Concrete Pipe	128.6	m	$ 110.50	$ 14,206.99
2	0255	450mm Concrete Pipe	30.4	m	$ 101.30	$ 3,078.51
2	0255	1050mm Concrete Pipe	128.2	m	$ 525.50	$ 67,357.12
2	0255	1200mm Concrete Pipe	380.0	m	$ 658.60	$ 250,268.00
2	0220	Excavation	29418	tons	$ 7.00	$ 205,926.00
2	0220	Imported Fill	22905	tons	$ 7.00	$ 160,335.00
2	0220	Trucking	726.0	trips	$ 500.00	$ 363,000.00
3	0311	Concrete Pumping	24.0	hours	$ 200.00	$ 4,800.00
3	0311	Concrete Pumping	207.0	cubic m	$ 3.00	$ 621.00
3	0330	Concrete Supply	207.0	cubic m	$ 130.00	$ 26,910.00
3	0320	Concrete Reinforcing	56725.4	ft	$ 0.75	$ 42,544.05
3	0311	Formwork Labour	4453.7	sqft	$ 6.90	$ 30,730.53
3	0310	Formwork Material	4453.7	sqft	$ 0.60	$ 2,672.22