

UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

**UBC Emergency Water Supply System - Team 13**

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**CIVL 445**

**Themes: Water, Community, Land**

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## **Executive summary**

The objective of this project is to design a water supply system for the University of British Columbia (UBC) Vancouver campus in the event of a failure of the system that supplies everyday water to the campus area. The proposed design for this project includes an underground storage tank (having a volume of approximately 7.7 ML), an onsite pump station, and a secondary water main supply. The underground storage tank and pump station is to be located under an existing rugby field, Ken Woods Field, that is west of Wesbrook Mall and south of Thunderbird Boulevard. When developing the concept of the underground tank, the team considered the adaptability in usage, utilization of space, visual aesthetics and minimizing environmental impacts. Moreover, in calculating the water demand, the team considered the future populations of UBC Vancouver and residents within an hour's walking distance, totalling approximately 175,000 people. Additionally, emergency water in case of a fire was also included in the storage tank volume. A pump station was designed to accommodate the flow requirements during emergency situations. The Grundfos online tool was applied when choosing the required pump for achieving the population's system demand. Likewise, a secondary water main will run under University Boulevard and connect to the existing water main at Blanca Street. This secondary water main will provide another water source connection from the greater Vancouver water district to the UBC campus area. Bentley WaterCAD was utilized to provide modelling results for this project. The proposed design will increase the resiliency of UBC's water supply in the short and long term and provide an adequate water supply during crisis periods.

A structural design was completed for the underground storage tank, which utilized the CSA design standards. The proposed underground tank will be constructed from reinforced concrete and a waterproof membrane will be wrapped around the exterior to reduce infiltration, contamination and leakage issues. Due to the geological profile of the site, a concrete mat foundation overlying a layer of compacted granular fill was considered. One metre of clearance from the top of the tank to the ground level is designed to provide

insulation for the stored water to prevent the water from freezing and to help protect the storage tank. The interior dimensions of the tank are 45m (length) x 35m (width) x 5m (height). A combined factored load, including live load and dead load, was used for design purposes. The ceiling slab for the tank was calculated to have a 300mm thickness. Additionally, 350mm thick concrete walls around the perimeter of the tank and 48 reinforced concrete columns (having a diameter of 500mm) were studied to support the ceiling slab and combined factored load. The Mononobe-Okabe Theory was used to ensure that the walls could withstand earthquake scenarios. Strip footings and a mat foundation were utilized in the design to accommodate the weight of the entire structure and combined factored load.

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## 1.0 Introduction

The purpose of this report is to design a secondary water supply system for the University of British Columbia (UBC) to alleviate potable water concerns when the main water source for the University is compromised. The design includes an onsite storage tank, a pump station, and a secondary water main to act as a secondary water supply source for the campus. All engineering components, including engineering materials and structural, hydrotechnical, geotechnical, and environmental engineering will be included in the design.

UBC Vancouver requires a potable water supply for a peak population of 55,000 people per day with a long-term population growth of 70,000 people per day. Potable water requirements for UBC Vancouver include drinking water, research applications, equipment cooling, and other water uses. The supplier of potable water for the UBC Vancouver area is Metro Vancouver. Currently, potable water comes from the Greater Vancouver Water District Sasamat Reservoir in Pacific Spirit Park and travels through two separate water main pipes through the University Endowment Lands (UEL). If there is a failure of the water supply east of this location, UBC Vancouver would be without potable water. This would force the campus to shut down, and would be a health concern to the residents in the UBC area. Additionally, UBC Vancouver would likely become a refugee location for people within a one-hour walking distance during emergencies; therefore, the University would need to supply water to over 70,000 people per day. The project would also need to accommodate the water demand for the permanent residents and faculty of UBC Vancouver.

There are also two pressure zones in the area, a high-pressure and a low-pressure zone. The high-pressure zone supplies water to the north side of the UBC Vancouver area, primarily supplying water to the academic and residential buildings. The low-pressure zone supplies water to the south side of the UBC Vancouver area, primarily supplying water for residential uses.

## **1.1 Purpose**

The purpose of this project is to design a water supply system for the UBC Vancouver campus in the event of a failure of the system that normally supplies water to the campus. In the event that there is a failure of the primary water supply from Sasamat Reservoir, the campus area would be without potable water. The lack of potable water would force the campus to shut down and would be a health concern to the residents in the UBC campus area. Additionally, nearby residents would likely take refuge in the UBC campus area during an emergency (i.e. after a major earthquake); therefore, the campus would need to accommodate the water demand for residents within a one-hour walking distance as well.

## **1.2 Scope**

The project design must accommodate an emergency potable water supply to the UBC Vancouver campus and the population within a one-hour walking distance of the storage tank location. The water demand must also include storage requirements for fire flow in the event of an emergency. The scope for the detailed design of this project includes design components for the underground water storage tank, the secondary water main and the pump station. A detailed structural design for the water tank was also completed. Hydrotechnical modelling for the project was also done using a WaterCAD modelling program. Furthermore, road rehabilitation and erosion and sediment control was also examined and will be discussed in this report.

## **1.3 Site Description**

The Rugby field (Ken Woods Field) adjacent to the thunderbird arena near Wesbrook mall was the selected location for the storage tank. This location is outside of the high density academic section of UBC Vancouver. As shown in Figure 1, the proposed site is a clear, level field. The site has no obstructions for construction activities and has easy access to

Wesbrook Mall. This site is between the high and low pressure zone areas that are serviced by the existing water system of UBC Vancouver. Some benefits of having the storage tank at this location are:

1. Direct access to the primary water main
2. Easy access to the storage site
3. Easily accessible to fire tenders for onsite filling
4. Convenient access to the bulk fill users

After construction of the storage tank is completed, the rugby field will be reconstructed for continued use.



*Figure 1: Storage Tank Site*

Furthermore, the secondary water main is to be installed under University Boulevard. This roadway is one of the primary roads that gains access to UBC Vancouver. The section of road where the secondary water main is to be installed includes a vegetated median and has large elevation changes. Access to this site will be easily accessible; however, traffic control may be necessary in some areas during construction.



## **1.4 Design Overview**

The location of the design maximizes land use and visual aesthetics, while minimizing environmental impacts. An underground concrete storage tank is recommended to be constructed under the existing soccer fields near Westbrook Mall and Thunderbird Boulevard. The tank is designed to be unnoticed from the surface and the rugby field will remain in use after construction is complete. The project was designed to be resilient and sustainable. A proposed water main will run underneath University Boulevard and will provide a secondary water supply source; thereby, increasing the resiliency of the UBC Vancouver water supply system. The storage tank was designed to accommodate the current and future water demands while minimizing environmental impacts; thereby, creating a sustainable final product. In addition to the potable water supply, fire flow storage capable of accommodating a four-hour fire event needed to be accommodated. A pump station was also designed to accommodate the required flow rates during regular and emergency uses. The size of the storage tank was also determined in concurrence with the water demand (outflow) and supply (inflow) of the tank to ensure that peak and hourly demands would be met. The primary construction materials for the storage tank will include reinforced concrete and a waterproofing membrane installed around the exterior of the tank. The tank will be constructed on a mat foundation and will be covered by topsoil to avoid frost issues and help protect the tank. When the primary water source fails, the storage tank will accommodate immediate water demands and the secondary water main will replenish the storage tank when the water demand is low.

## **1.5 Methodology**

As described in the preceding sections, this project aims to provide an emergency water supply to UBC's water service area in the event of water supply failure from Sasamat reservoir. The design team assessed the population to be serviced in such an event (i.e. future UBC population as well as the population in a one-hour walking distance). From the

calculated service population and the emergency water servicing loading rate (18 L/ca/d) the base water storage volume was assessed for different emergency durations. In addition to the base water storage, fire storage was assessed based on the land-use zoning of the campus. The pump station was designed to have redundancy (spare pump, backup power, etc.) and the ability to service the highest service elevation while delivering emergency water supply as well as the fire flows. After significant brainstorming, the design team shortlisted three options in the preliminary report: an above ground tank with a secondary water supply source, an underground tank with a secondary supply source, and a large underground storage tank without a secondary supply. The underground tank with a secondary water supply source was selected based on the project cost, land utilization, system redundancy, and the aesthetics of the infrastructure.

The size of the tank was designed based on the volume of water needed for the two-day emergency water supply for the required population demand. Cylindrical columns were chosen to support the slab, soil and the live load on top. This column type was chosen because less erosion issues from water are expected when compared to square columns. To support the retaining wall, the team designed strip footings and a flat plate mat foundation for the support of the columns and the weight of the water. In the design calculations for the top slab, columns, and the foundation, the team followed the Concrete Handbook and the CSA 23.3 standards within. The “Design Recommendations for Storage Tanks and Their Supports with Tanks and Emphasis on Seismic Design” textbook was used for the retaining wall design

## **1.6 Key Issues and Benefits**

The main issue that was considered during the preliminary phase was the effectiveness and resiliency of the design. Simply building a storage tank will provide the water demand during emergency cases, but only for a limited time. After the water storage depletes, another water

source would be needed to replenish the water storage. Therefore, a secondary water main is essential in making the water system more resilient. The main purpose of the secondary water source is for emergency purposes; however, it can also be activated in the future as a support to the primary line when the water demand increases due to future population growth. Another issue was how to integrate the design within the UBC lands. Installing the tank under an existing soccer field was favourable because it maximizes land use and is visually appealing when compared to above ground storage tank options.

During the design phase of the storage tank, determining the earthquake load proved to be challenging. Different techniques were studied on how to include earthquake load and ultimately Mononobe-Okabe (MO) theory was used. This is a safe assumption since the MO theory is widely used in seismic earth pressures for retaining walls. Lastly, the decision of making a concrete pad foundation was discussed extensively. Each column needed a square footing foundation and the walls required a strip footing to distribute the load from the column to the soil beneath. All the footings are to be constructed with one concrete pour, instead of adding another layer, to make the tank a closed system. The thickness of the pad was increased; however, this reduced the amount of material needed without compromising the stability of the structure.

## 1.7 Contributions

This section discusses the contributions that each team member had for this project. These contributions are summarized in the table below.

*Table 1: Contribution Table*

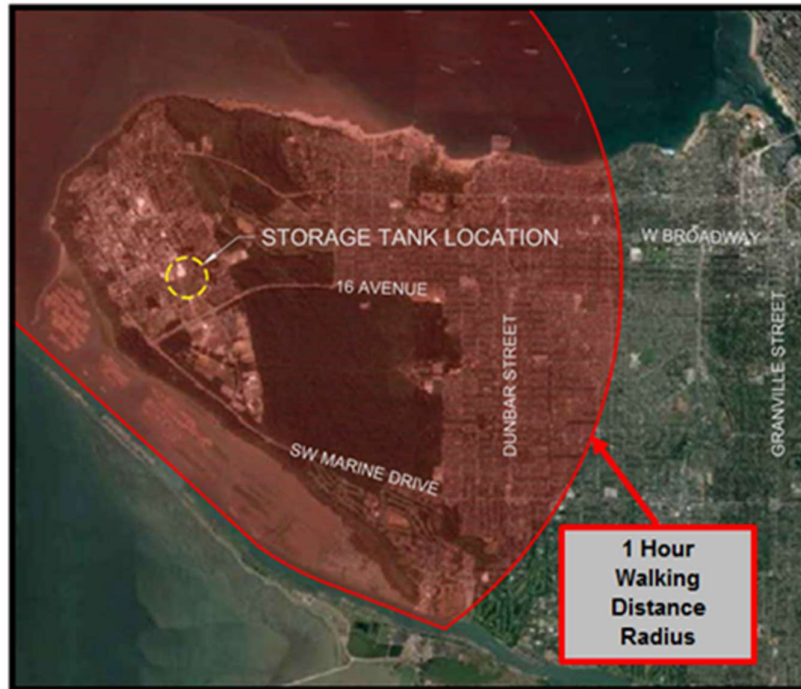
Team Member Contribution Table	
Team Member	Contribution
1	Hydrotechnical design, methodology, storage tank volume, WaterCAD modelling, emergency response plan
2	Hydrotechnical design, site visit, introduction, purpose, project scope, site description, determining population demand, secondary water main design, erosion and sedimentation control, final editing and formatting
3	Structural design, site visit, column design write up, retaining wall design write up, tank size calculation, waterproof membrane discussion, contribution table
4	Hydrotechnical design, pump station design, hydrotechnical write up, cost estimate
5	Structural design, cost estimate, project schedule, resolution planning for project issues, tank size calculation, key issues and benefits, discussion
6	Structural design, structural drawings, table of contents, title page, methodology, load combination and geotechnical, tank size calculation
7	Structural design, memo, slab design calculation and write up, foundation and strip footing design write up, design summary

## **2.0 Hydrotechnical Design**

For the hydrotechnical design of this project, the population demand had to first be determined. Once the population demand was determined, the storage tank was then sized and hydrotechnical modelling was then done using WaterCAD. From the results of the WaterCAD modelling, the pumps for the pump station and the secondary water main were then designed. This section describes the hydrotechnical aspects required for this project.

### **2.1 Population Demand**

The population demand used to calculate the capacity requirements for the storage tank was based on a combination of the UBC Vancouver population and the population of Vancouver residents within a one-hour walking distance of the storage tank location. Currently, the UBC population is approximately 55,000 people; however, this population is expected to grow to approximately 70,000 people in the future. To create a more resilient and sustainable final product, a UBC Vancouver population of 70,000 people was used for design purposes. Additionally, a population of approximately 27,000 was considered for the future projection of permanent residents and faculty of UBC Vancouver. The one-hour walking distance was based on an average walking speed of 1.5 m/s (Dean, 2000). From this walking speed, the one-hour walking distance was determined to be 5.4 km. Refer to Figure 2 for an aerial picture of this walking distance. The one-hour walking distance population was based on population statistics and zoning from the City of Vancouver. Two different calculation methods were used to determine the one-hour walking distance population.



*Figure 2: One-Hour Walking Distance Radius from Storage Tank Location*

The first method was used to determine the population density for one and two-family dwelling districts. For this method, a population of people per hectare was determined based on existing zoning and population statistics. According to a population projection report prepared by Metro Vancouver, the average population per dwelling for one and two-family districts in 2006 was 3 and is projected to decrease to 2.73 by 2041 (Metro Vancouver, 2011). Since the storage tank is expected to be used in the near and projected future, a conservative number of 3 people per dwelling was used for design purposes. From the existing zoning maps for the area, Google maps (to determine how many existing lots there are) and a population of 3 people per dwelling, the population density for one and two-family dwellings was calculated to be 46 people per hectare. When multiplying this population density by the area within a one-hour walking distance, a total population of approximately 64,000 people was estimated to live within a one-hour walking distance of the storage tank location. Refer to Figure 3 for the zoning map used for the population estimation.

The second method was used to determine the population density for multiple dwelling districts. For this method, the total number of people living in multiple dwelling districts in Vancouver (174,635 people in 2016) (City of Vancouver, 2017) was divided by the total area within Vancouver zoned as a multiple dwelling district to get a population density of 397 people per hectare. Note that this value included high rise and low rise apartments and is expected to be a conservative estimate. A total of approximately 14,000 people, living in multiple dwelling districts, are estimated to live within a one-hour walking distance of the storage tank location.

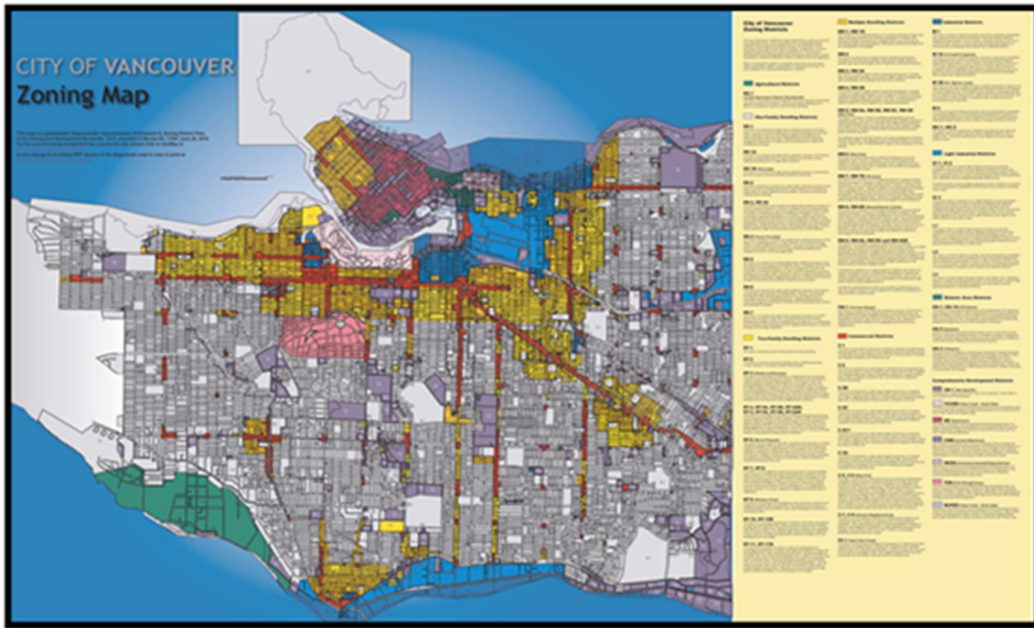


Figure 3: City of Vancouver Zoning Map (City of Vancouver, 2016)

## 2.2 Storage Tank Volume

The sizing of the emergency storage tank depended on the population serviced, loading rate for assigning demand, fire storage volume, and the duration of emergency servicing. Since UBC has few commercial developments, a fire flow of 150 L/s and a fire event of 4 hours was used to calculate the fire storage volume (2.16 ML). Based on the AWWA manual for servicing during an event of emergency, a loading rate of 18.9 L/ca/day was used to service

approximately 175,000 people in the event of emergency. In calculating the total water demand, the design included a consumption that was based on the loading rate discussed above and fire storage (total demand = fire storage volume + base consumption volume). For the final design, a 48-hour emergency service duration was selected for sizing the reservoir and had a base emergency water consumption of 5.6 ML. The total design volume of the emergency storage tank was assessed at 7.7 ML.

In a scenario where there is a secondary supply main (under University Boulevard), the supply line will aid in filling the tank during the low demand period (night hours) and will also directly service some areas in the pumped zone. The feasibility for the secondary main depends on the following factors:

- Capacity of Vancouver's water system at the point of connection
- The extent of damage experience by Vancouver's water distribution system
- The available hydraulic grade line (HGL) at the point of connection

During normal operation, to over turn the tank volume it is recommended to use the storage tank water for peak hour consumption and irrigation purposes. UBC's water system has a maximum daily demand (MDD) of 300 L/s (i.e. 7 hours is the tank overturn time at MDD flows). It is recommended to operate the tank on the daily basis during Peak Hour Demand (PHD) to prevent water quality deterioration.

## **2.3 WaterCAD Modelling**

Bentley WaterCAD was used as the hydraulic modelling software for analyzing various scenarios based on the model "UBC-WAT-Model-Final - October 24 2012" provided by the client. The water system was modelled under the following boundary conditions:

1. Physical system for year 2020



2. PRV settings of the MDD 2020 scenario
3. The ground elevation for the proposed tank and pump station location was 92 m
4. The primary supply from the Sasamat reservoir was closed
5. Existing pump station was out of service

After analyzing the ground elevations of the existing water supply network, the highest elevation of 101.4 m was recorded in the pumped zone. The pump station was designed to supply an HGL of 135 m at 33 L/s of emergency service flow. The pump station also has the ability to deliver the fire flow of 150 L/s at the same HGL. The proposed pump station comprises of a service pump, an emergency pump and a fire pump. This station will also have a standby power generator of 75kW for normal duty and 355kW for fire flow. A bulk station will also be constructed at the site to facilitate water service to people from the surrounding areas and to the fire trucks.

As shown in figure 4, the lowest pressure of 48 psi is recorded at the highest service elevation. The lowest pressure recorded in the service area is well above the minimum required pressure of 40 psi. The PRV station at Blanca Street and University Boulevard was designed with two pressure reducing valves and to have a pressure setting of 44 psi. All the PRVs in the water distribution system are summarized in Table 2. Appendix G shows the model used for this project.

**Table 2: PRV Station Overview**

Station #	PRV	Diameter (mm)	Elevation (m)	Hydraulic Grade Setting (m)	Pressure Setting (psi)
<b>Existing PRV Stations</b>					
1	PRV-1	150	79	123	63
	PRV-1 Domestic	100	79	125	65
2	PRV-2	150	80	126	65
	PRV-2 Domestic	100	80	128	67
3	PRV-3	300	85	129	62
4	PRV-4	200	84	130	65
5	PRV-5	200	94	129	50
6	PRV-6	300	94	127	47
7	PRV-7	250	91	126	50
8	PRV-8	200	88	136	68
	PRV-8 Domestic	150	88	139	72
9	PRV-9	250	81	123	59
	PRV-9 Domestic	100	81	126	64
<b>Proposed PRV Station</b>					
10	PRV-10	200	92	120	40
	PRV-10 Domestic	100	92	123	44

As shown in Figure 4, in an event where both the existing primary supply main and the proposed water main are out of service, the emergency storage tank can service the population for 66 hours at the assessed emergency service rate of 33 L/s. Therefore, this is the available time window that one of the two supply mains need to be restored. If the secondary supply main is operational, continuous emergency water supply can be provided without any disruption.

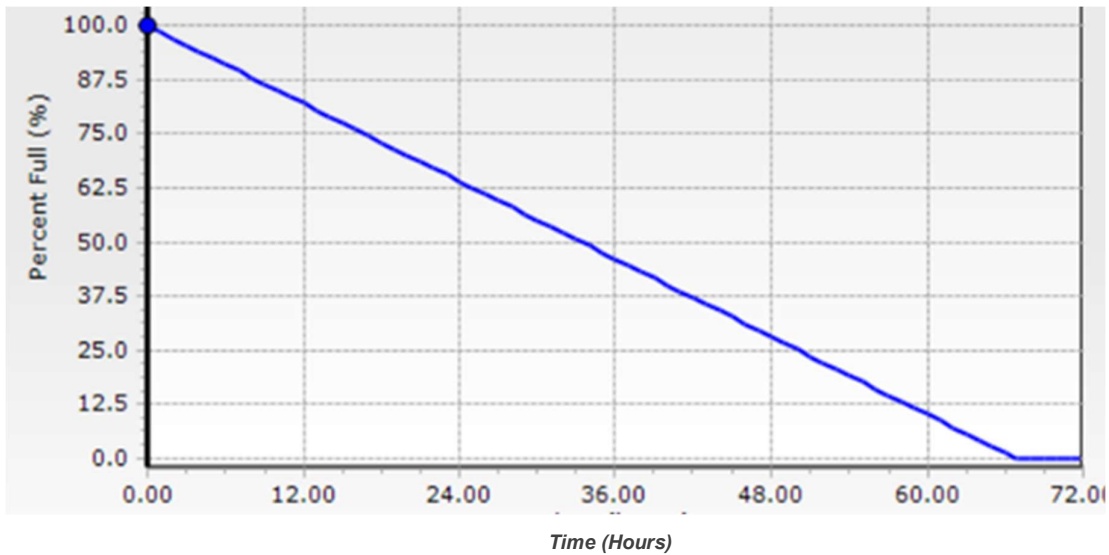


Figure 4: Extended Period Simulation of the Storage Tank in an Emergency Conditions

## 2.4 Pump Station

Based on the tank size calculations, the team determined the various required water flow rate requirements for lower emergency water demand, higher emergency water demand and the minimum fire flow rate. The calculated flow rates can be found in Table 3 below. The minimum fire flow rate was calculated and referenced from Table A-6.5.3.6 found in the British Columbia Fire Code using a 200mm diameter pipe.

Table 3: Flow Rate Requirements

Scenario	Flow Rate Required
Lower Emergency Flow Rate	32.3247 L/s
Higher Emergency Flow Rate	128.9914 L/s
Minimum Fire Flow Rate (200mm Pipe)	96.6667 L/s

### 2.4.1 Pump Design Criteria

An on-site pump station was required near the proposed underground storage tank to enhance the pumping resiliency of the existing system. The pump station would maintain the

required pressure and service the higher elevations of the UBC Vancouver water distribution system, as well as during fire event scenarios. The pump station would be built on top of a precast concrete ground-level floor in a suitable location where it does not disturb the use of the soccer field and would also be easily accessible to the public as the pump station would have an option to build a bulk fill station on site. Based on the parameters of population, loading rate, fire requirements and the duration of the servicing, the proposed pump capacities were determined and are outlined below.

- One fire pump of 150L/s capacity
- One normal duty pump of 35L/s capacity
- One standby parallel pump of 35L/s capacity

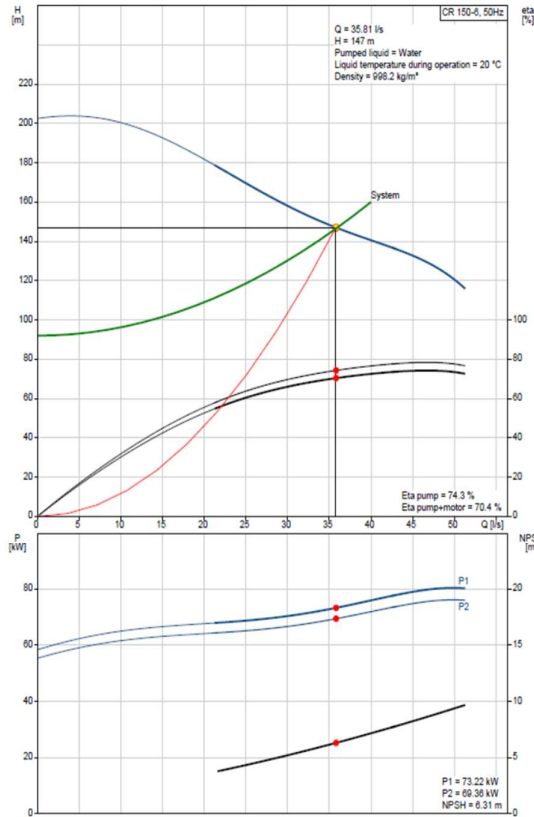
The pump station will include a normal duty service pump, a standby pump, a fire pump, AC motors, an electrical generator and variable frequency drives installed on the pumps. Aside from the tank storage calculations, it was significant to estimate the hourly demand to accurately choose and design the suitable pumps, considering the morning peak hours from 6:00 AM to 9:00 AM with the mandatory fire flow requirements. The three pumps are configured in a parallel system and for the fire pump there will be an optional underground hook up installed above ground for fire truck access in case of a fire pump failure. The normal duty pump is intended to supply daily water demand, and the standby pump would only be activated for an emergency failure of the other operating pump. The detailed drawings of the pump station layout can be found in the Appendix A and D.

### **2.4.2 Pump curves**

From the online Grundfos tools based on the drinking water distribution pump applications and selections, the selected fire pump was NKG 200-315.1/335 50Hz, and the CR 150-6 50Hz pump was selected for the normal duty pumps. When choosing these two models, the team made a conservative engineering assumption that the temperature of the water during

operation would be approximately 20 degrees celcius with a density of  $998.2\text{kg/m}^3$ . A hydraulic grade line of 135m is required to supply the water from the underground storage tank to the highest elevation point in the UBC distribution system. At the operating point for the fire pump, a flow rate of 149.7L/s, a net positive suction head (NPSH) of 7.09m, a total head of 143.8m and an efficiency of 70.9% is expected. At the operating point for the normal duty pump, a flow rate of 35.81L/s, a net positive suction head of 6.31m, a total head of 147.0m and an efficiency of 74.3% is expected. The pump curves, system curves and corresponding results are illustrated in figure 5 below. Furthermore, from the WaterCad analysis, it was confirmed that the chosen pumps are free from suction cavitations by meeting the NPSH requirements of the system. However, regular maintenance involving checking the pumps, valves and water meters is required to ensure that the pumps are free of clogs to avoid potential cavitation issues. Lastly, the chlorine residual samples would be taken from the water once a week and to a lab for water quality testing to fulfill the provincial drinking water quality requirements.

95922381 CR 150-6 50 Hz



NKG 200-150-315.1/335 50 Hz

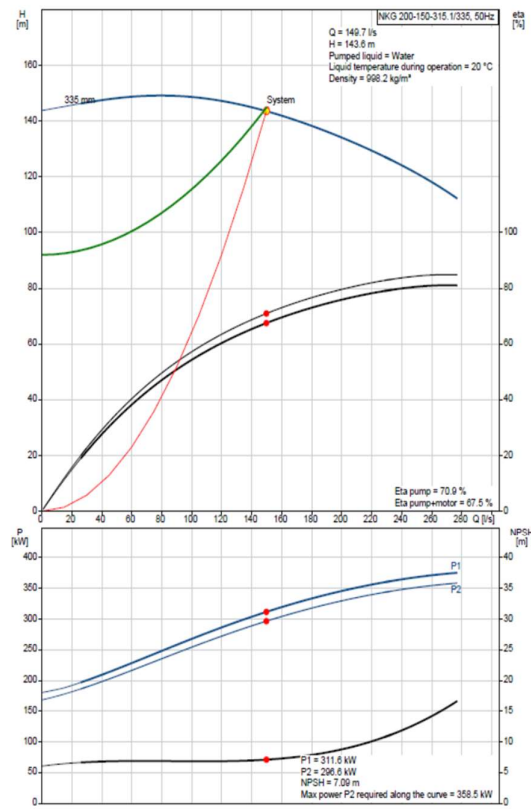


Figure 5: Pump Curves for Fire and Normal Duty Pumps

## 2.5 Secondary Water Main

The secondary water main will be installed under University Boulevard from the UBC connection to Blanca Street. This section will describe details about the design and rehabilitation that is necessary for the secondary water main. Construction drawings for the secondary water main can be found in Appendix B.

### **2.5.1 Water Main Design**

The secondary water main is to be installed 1.5m into the median of University Boulevard and is to extend from Blanca Street to approximately 1,100 m west where it will connect to the existing UBC water main. The east side of the secondary water main will connect to the existing 200mm diameter water main that runs under Blanca Street. The west side of this water main will connect to the existing 641 mm diameter water main that supplies water to UBC from Sasamat Reservoir. Since the area is earthquake prone, all pipe material shall be ductile iron (class 52) and all water main joints are to have wedge action restrained joints. The inside diameter of the pipe shall be 300mm. Valves are to be installed at a spacing of no more than 300m to allow for more efficient maintenance in the future. The extra valve installations will allow a section of the water main to be closed off and drained to reduce possible future maintenance/repair times, rather than requiring the entire secondary water main to be drained to conduct repairs. Since the City of Vancouver requires 300mm diameter water mains to have a minimum of 1.07 m of cover above the pipe, the pipe will be installed 1.1m below finished grade (City of Vancouver, n.d.). Also, as per the City of Vancouver engineering standards, all valve installations are to be resilient-seated gate valves. Air valves are also to be installed at all high points in the water main to allow air to leave the system. By introducing air valves, issues like water hammer, and therefore pipe leakage, can be reduced. The air valves will also alleviate low water pressure concerns.

### **2.5.2 Roadway and Landscape Rehabilitation**

Where it is necessary to install water mains under the road surface, the pipe trench shall be compacted to 100% proctor density (after installation of the water main) and the new road structure shall match the existing road structure. The existing road structure is to be confirmed during construction, since this information is not currently available. The final road rehabilitation is to meet the satisfaction of the site engineer. Where pipe construction and road rehabilitation is necessary at the Blanca Street and University Boulevard intersection, it

will be the contractor's responsibility to ensure that a minimum of one lane of traffic in all directions remains flowing at all times. Additionally, since the secondary water main is to be installed 1.5 m into the grassed median of University Boulevard, landscape rehabilitation will be necessary after the pipe installation and trench compaction has been completed. A minimum of 0.15 m of topsoil shall be placed at the surface of the trench and grass seed is to be spread over the trench to ensure that grass will grow back and the median will regain its original aesthetics.



### 3.0 Structural Design of Underground Water Tank

The design for the underground storage tank required a structural design to be completed. This section will discuss the structural design components required for the design and will provide details on the construction materials required for the tank. Structural calculations and construction drawings for the tank can be found in Appendix C and D, respectively.

#### 3.1 Load Combination & Geotechnical

All the geotechnical data used in the design of the storage tank was derived from the “Hydrological and Geotechnical Assessment of Northwest Area” report. The report includes borehole information of certain locations throughout the UBC campus. Due to the lack of borehole studies at the location of the storage tank, the team selected four boreholes around the campus. Boreholes numbered 11, 12, 44, and 74 were taken into consideration as they were most closely located to the rugby field. The four borehole data were then interpolated to estimate the soil composition at the water storage tank location. The depth and composition is listed in table 4 below.

*Table 4: Composition at the Location of the Storage Tank*

Soil Type	Depth measured [m]
Topsoil	0.1
Pure till	5.5
Mostly till with possibility of silt	7.0
Mostly till with possibility of sand	10.0

Therefore, the general ground composition of the rugby field was determined to be composed mostly of till with some silt. Density of the soil was taken as 2000 kg/m<sup>3</sup>, and the friction angle and shear modulus used for design purposes were 30 degrees and 200 MPa, respectively.

For the calculation of the structural components of the tank, the load combinations were determined to calculate the total load of the soil. The dead load included the soil weight and the self weight of the concrete. The live load was taken as a full size bulldozer weighing 8 tons, which assumes that the live load after construction would not exceed the weight of the bulldozer. From the reinforced concrete handbook the two load combinations were as follows:

$$\text{Total Load} = 1.25 * (\text{Dead Load}) + 1.5 * (\text{Live Load}) = 33.8 \text{ kPa}$$

$$\text{Total Load} = 1.4 * (\text{Dead Load}) = 37.8 \text{ kPa}$$

For the calculation of the top slab of the storage tank, the load of the soil on top was governed by the second equation and taken as 37.8 kPa. For the calculation of the columns and the retaining wall, the self weight of the top slab was taken into consideration, which has a density of 2500 kg/m<sup>3</sup>.

## **3.2 Slab Design**

A top slab, having dimensions of 45.7 m x 35.7 m (including retaining wall dimensions), was designed to support a combination of dead load and live load on top of the slab. The dead load included the weight of a 1 m soil depth and the slab self weight. The weight of the construction equipment was considered as the live load. Since the dead load was much heavier than the live load, the factored design load had to be 1.4 times the dead load. The top slab was designed as a two-way slab. The slab was only supported by columns in the middle and retaining walls at the edges. Therefore, the uniformly distributed loads carry in both directions. As a result, a two-way slab with reinforcement in both directions was necessary. Based on design requirements in the CSA standards, the slab thickness required

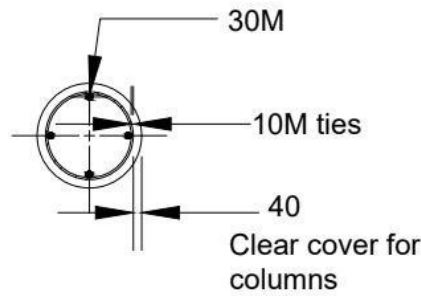
was 300mm. The tributary area of each column was 5 m x 5 m. Therefore, the column strip (which is on top of every column) was 2.5 m with 15M reinforcement at the top of the slab and had a spacing of 150 mm in both directions. Also, the middle strip (which is between two columns) was 2.5 m with 15M reinforcement at the top and bottom of the slab and had a spacing of 330 mm in both directions. Appendix D shows detail drawings of the slab construction. A small increment of clear cover for rebar was used to prevent corrosion due to water. To connect the top slab and columns, the rebars in the columns were extended and bent at the top of the slab.

### **3.3 Column Design**

Columns are one of the most common structural element to support the vertical load of a reinforced concrete storage tank. Since the tank is 45m in length and 35m in width, using a 5m x 5m square tributary area for each vertical column would allow for symmetry. This yielded to a total of 48 columns: 8 evenly spaced lengthwise and 6 evenly spaced crosswise. Circular columns with a diameter of 500mm were used rather than rectangular or square columns to provide better corrosion protection. Columns with edges would corrode easily under shifting water. The columns were determined to be “short columns” based on the ratio of the maximum unsupported length ( $L_u$ ) over column diameter ( $D$ ). The tributary area would resist a dead load of 26.978 KPa from the weight of the top slab and 1m deep soil, and a live load of 3.13 KPa from the weight of a dozer. An analysis of the load combinations was made based on the 2015 National Building Code of Canada, with all the varying cases considered and the governing value was calculated to be 961kN (38.431kPa); therefore, this was the load applied to each column for design purposes.

After calculating the total load, axial and flexural load resistance of concentration load applied to the short column would be determined. Figure 6 shows that each short column is reinforced with 30M longitudinal rebar with 10M ties, and a 40mm clear cover for each

column. The total area of longitudinal steel ( $A_{st} = 2,800 \text{ mm}^2$ ) and the gross cross-sectional area ( $A_g = 196,350 \text{ mm}^2$ ) were calculated first to determine the axial load resistance. The factored axial load resistance of concrete and longitudinal reinforcement were found to be 4,026 kN and 952 kN respectively, based on the CSA A23.3 standard guideline. As a result, the calculated total factored axial load resistance was 4,978 kN for each reinforced concrete short column. As required by CSA A23.3, the final maximum axial load resistance should be decreased with the reduction factor 0.85 for spiral columns; thus, was equal to 4,231 kN. This is the load resistance for each column, and is larger than the applied load, which means the design satisfied the loading requirements.



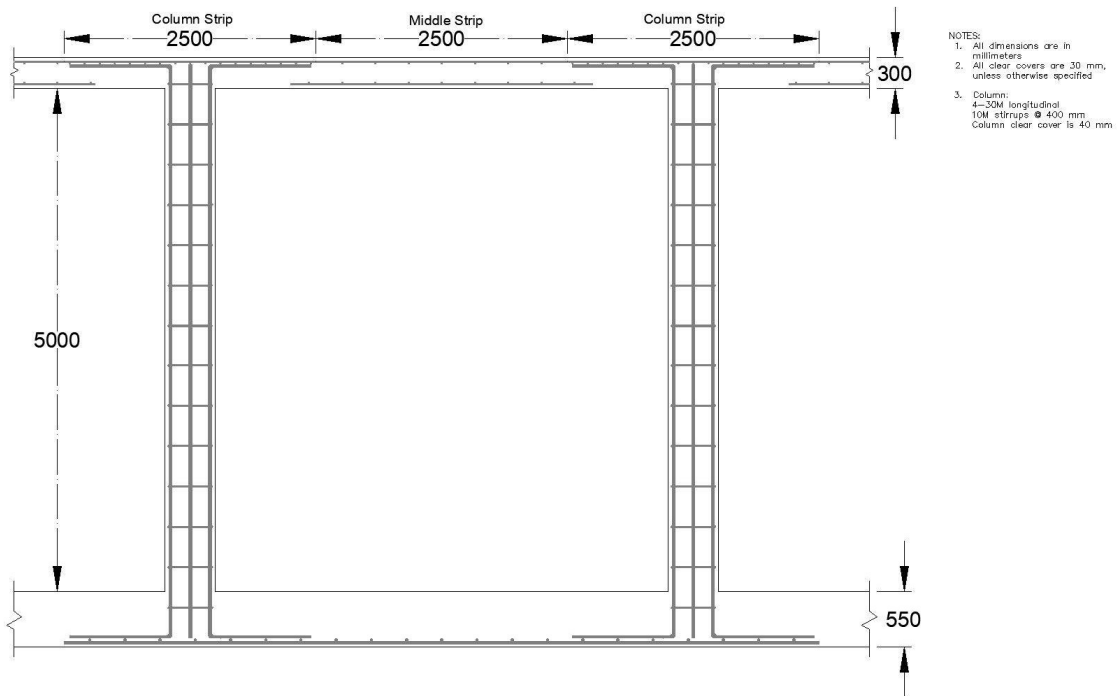
**Figure 6: Top View of a Typical Column**

To finalize the complete design summary, a few of the components needed to be checked, as outlined by CSA A23.3 column design requirements. The following table lists the results of the longitudinal reinforcement ratio, minimum bar spacing, and maximum tie spacing.

Figure 7 provides the column design summary in the elevation view.

**Table 5: CSA A23.3 Column Design Requirements**

Criteria	Requirement
Longitudinal Reinforcement Ratio (%)	1.43 (Max: 1.57)
Minimum Bar Spacing (mm)	42
Maximum Tie Spacing (mm)	480



*Figure 7: Column Design Summary*

### 3.4 Retaining Wall Design

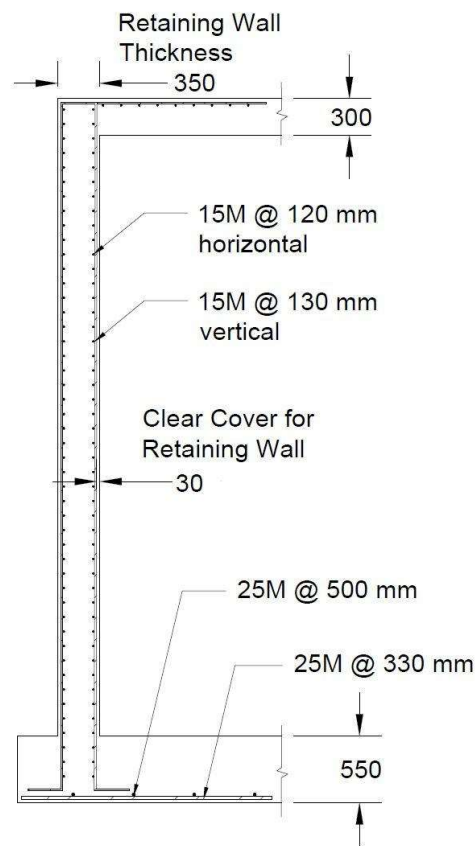
Since the storage tank will be underground, the retaining walls should be able to resist the lateral earth pressure from the soil and the axial loads from the top slab. The wall design followed the CSA A23.3 standard. The three main calculations in designing retaining walls were bending moments and shear forces applied to the wall, concentrated effects of flexure and axial loads, and shear reinforcements.

To determine the bending moments and shear forces, soil and seismic loads are both considered. Applying Mononobe-Okabe theory, the combined total bending moments were determined to be 165 kN (top) and 169 kN (bottom) and the combined shear forces were 195 KN/m (top) and -205 KN/m (bottom).

Considering the combined effects of flexural and axial loads, the thickness of wall was obtained as 350mm. The calculated effective depth was 310mm by using 15M reinforcement bars and 30mm clear cover. The area of steel bars was calculated to be 1645mm<sup>2</sup> and the

bar spacing was 130mm in vertical direction, which complies with the CSA standard bar spacing limit. Both tension reinforcement ratio and gross cross-sectional area satisfy the CSA requirement as well.

The entire retaining wall design and analysis for shear follows the CSA A23.3 standard and all of the key components conform with the requirements. The effective depth was used in calculating the concrete shear resistance, yielding to shear reinforcement being not required. However, CSA requires the prevention of minimum horizontal reinforcements in the walls regardless of design calculation. Two layers of 15M bars were used for the vertical reinforcement with 120mm bar spacing. Figure 8 illustrates the details of the retaining wall design. The reinforcement rebars were extended to the top slab and to the strip footings as shown in the final design scenario.



**Figure 8: Retaining Wall Design Summary**

### **3.5 Foundation and Strip Footing Design**

Two types of foundations were used in the storage tank design: strip footings and a mat foundation. The strip footings were designed to support the retaining walls and resist the soil pressure. By using the CSA standards, the strip footing and mat foundation designs required a thickness of 550 mm. Specifically, the design thickness for strip footing is slightly less than the mat foundation; however, to make construction easier, one thickness was used in both cases. The reinforcement for the strip footing was 25M rebar, spaced at 330 mm in the transverse direction and 25M rebar, spaced at 500 mm in the longitudinal direction.

The mat foundation supports the columns, the weight of the water inside the storage tank, and resists soil pressure. A square footing was initially designed for each column; however, a mat foundation was later designed because the square footings required were very close together. Therefore, instead of designing another slab underneath the square footings, all the square footings now essentially connect to each other and form a mat foundation. Based on the CSA standards, a mat foundation, having a 550 mm thickness was required. The reinforcement required in the mat foundation was 25M rebar, spaced 350 mm in both transverse and longitudinal directions.

Appendix D shows detail drawings for both the strip footings and the mat foundation. To connect the retaining walls and columns to the strip footings and the mat foundation, the same type of connection for the slab and columns was designed. The rebars in the retaining walls and columns were extended and bent at the bottom of the strip footings and mat foundations.

### **3.6 Waterproof Membrane**

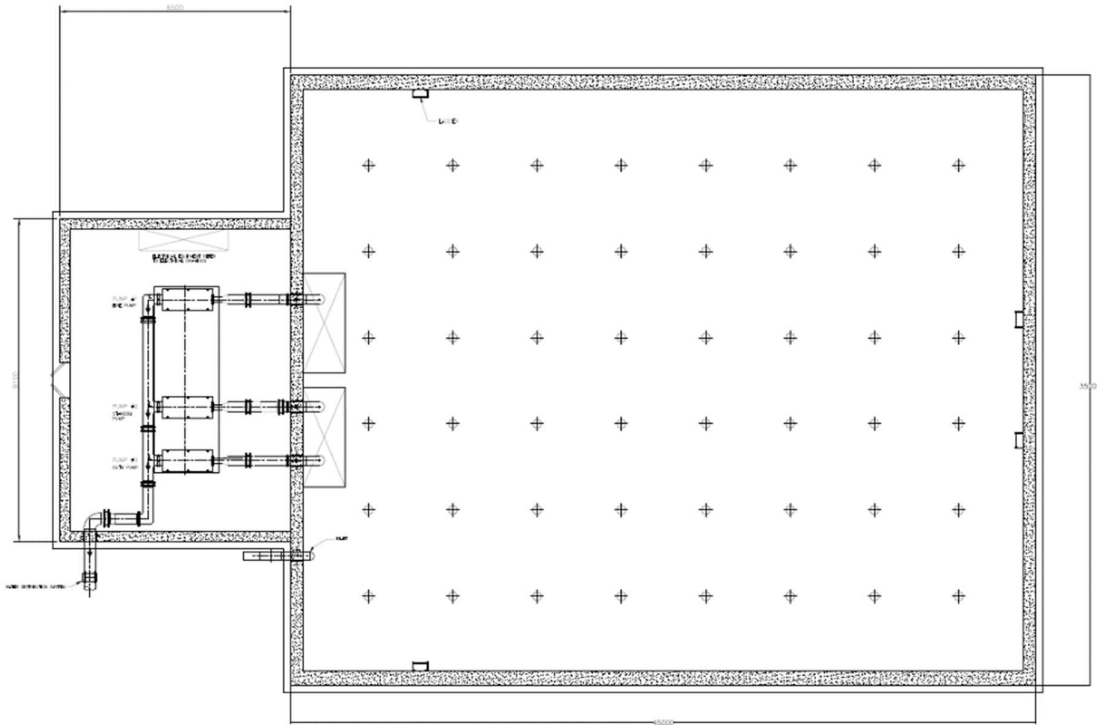
The waterproof membrane was a vital item needed for the concrete storage tank to inhibit infiltration of unwanted water and pathogens from contaminating the stored water. The team

recommends providing a water proof membrane on all exterior walls and above the top slab of the storage tank, totalling an area of 2,375m<sup>2</sup>. The details of the quantity and unit cost of the waterproof membrane will be discussed later in the cost estimate section of this report.



## 4.0 Design Summary

The concrete storage tank will be located under the existing rugby field, and the on-site pump station will be built above ground beside the tank. There will be inflow and outflow pipes located near the top and bottom of the north tank wall, respectively. The inflow pipe will connect to the existing water main underneath Wesbrook Mall. The outflow pipes will connect to the pump station and will be distributed throughout the water network within the UBC area. The figure below shows the configuration of the storage tank and pump house and can also be found in the construction drawings in Appendix D.



**Figure 9: Storage Tank Configuration with Pump Station**

## **5.0 Erosion and Sedimentation Control**

The construction of the underground water tank will require an erosion and sedimentation control plan to reduce environmental issues. A gravel pad of 0.20 m thickness, 9 m width, and 15 m length shall be placed at the site access location. The purpose of the gravel pad is to remove the clay soil from truck and equipment tires prior to the vehicle leaving the site. This will minimize the amount of soil from the site that is tracked onto Wesbrook Mall. Additionally, catch basin socks will be installed at all catch basins along Wesbrook Mall within 100 m of the site location and at the first 2 catch basin locations downhill of the site location. The catch basin socks will reduce the amount of sedimentation that enters the sewer system; thereby, decreasing negative effects to fish health and the aquatic habitat in the receiving waters of the sewer system. Silt fences will also be installed at the edge of the site where the ground slopes downward towards the existing ground. The silt fences will further prevent sedimentation from leaving the site.

## 6.0 Resolution Planning for Project Issues

An action plan to immediately deal with project issues can be critical to prevent adverse impacts on project tasks. The table below outlines possible problems that can be encountered during the construction phase and suggested solutions to mitigate these problems.

*Table 6: Resolution Table*

<b>Issues</b>	<b>Cause</b>	<b>Action Plan</b>
<b>Soil Erosion and sedimentation</b>	<b>Deep excavation</b>	<ul style="list-style-type: none"> <li>• Tapered edges of the excavation (using 2 to 1 ratio)</li> </ul>
	<b>Heavy rain / Dust Control</b>	<ul style="list-style-type: none"> <li>• Applying soil erosion &amp; sedimentation control such as geotextiles</li> </ul>
<b>Unexpected Costs</b>	<b>Poor soil condition</b>	<ul style="list-style-type: none"> <li>• Additional expenses due to poor soil condition (if occurs) is included in the proposed costs</li> <li>• Check the borehole logs to determine expected soil type</li> </ul>
<b>Project Delays</b>	<b>Incorrect Custom Order</b>	<ul style="list-style-type: none"> <li>• If the specifications are similar, may use the material to avoid delays</li> <li>• Reorder the correct material but will delay the project</li> </ul>
	<b>Mistake due to outdated blueprints</b>	<ul style="list-style-type: none"> <li>• Make sure all blueprints are dated and documented properly</li> <li>• Always provide the contractors with the most recent drawings</li> </ul>
<b>Loss of Equipment and Materials</b>	<b>Theft/Burglary</b>	<ul style="list-style-type: none"> <li>• Material stockpiles should be monitored either by a security patrol or closed-circuit cameras</li> <li>• Equipment should be stored in a safeguarded area</li> </ul>

<b>Safety and Welfare</b>	<b>Accidents</b>	<ul style="list-style-type: none"><li>• Workers should always wear protective gears (hard hat, steel-toe shoes, laminated vest, eyewear and others)</li><li>• Safety signs should be provided for people passing by</li><li>• Report accidents immediately</li><li>• Report near-misses to Project Manager so preventive measures can be taken</li><li>• Could hire a safety officer for daily/weekly Safety Meetings</li><li>• Semi-permanent scaffoldings should be checked regularly</li></ul>
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## 7.0 Project Schedule

This project is estimated to last 89 days, provided that there are no unforeseen major delays happening. The project is divided into two components: the construction of the secondary water source (Phase A), and the construction of the storage tank (Phase B). Phase B is further divided into three stages: stage 1 is the connection of the primary tank to the storage tank, stage 2 is the construction of the tank, and stage 3 is the post storage tank construction, which includes from backfilling to site clean up. Phase A and Phase B were planned to be constructed simultaneously to reduce the timeline of the project. It is assumed that the construction takes place during the summer because of reduced traffic flow from students and to minimize disturbances caused by noise and redirection of road traffic.

For materials delivery, it is advised that the materials come to site at least 7 days early to avoid delays. This will give enough time for inspection, material testing, and reorder if changes occur. A problem that could delay the timeline is the presence of peats and organics in situ. Soil analysis of nearby sites were available, and these data were extrapolated to predict the soil composition of where the storage tank will be constructed. However, even if small, there is still a possibility that the soil contains peats and organics. As discussed in the resolution planning, deep soil mixing, or jet grouting could solve this problem. However, this will cause a 3 - 5 day delay, depending on the preparedness of the crew. The detailed schedule for this project is shown in Appendix E.

## 8.0 Cost Estimate

The project is expected to cost \$4,494,485, with an operating and maintenance annual cost of \$70,650. As expected, the bulk of the cost comes from building the storage tank (including materials and labour), and construction of the pump station. The volume of the required materials was rounded up to ensure there is enough supplies on site and avoid delays due to orders and transport. This cost also includes miscellaneous expenses such as traffic control and soil erosion control. There is also a 10% increase on the overall cost as a contingency.

The operating and maintenance costs are for the water tank, pump station, and the water lines. This assumes that 3 hours a week is needed for maintenance. The structure and infrastructure installed for this project is expected to have a minimum design life of 100 years. The detailed breakdown for the cost is found in Appendix F.

## 9.0 Emergency Response Plan

In the event of an emergency, where both the supply mains to the University of British Columbia are compromised (i.e. the existing primary supply from the Sasman Reservoir and the proposed secondary supply from the Vancouver Water System via University Boulevard), the following emergency plan shall be followed by the Water Operations Department of UBC:

1. Isolate the break
2. Check with the City of Vancouver about the performance of their distribution system
3. Issue a low water usage warning and inform operations to shutoff all the fountains and irrigation lines
4. Operate the new proposed pump station to deliver the emergency service volume
5. Assess the system for any breaks and continue to isolating any breaks found

## 10.0 Discussion

The construction of a storage tank and a secondary water main line is an effective solution in providing a resilient water source to UBC and its surrounding area in case of disruptions on the main water line. This upgraded water system will have an underground storage tank located under a rugby field near Wesbrook Mall, a secondary water main line that runs under University Boulevard, a pump station near the storage tank, and a PRV station along the secondary water line to control flow. The addition of the secondary water supply source was deemed necessary to add resiliency to the design. It will be beneficial in the future when population grows, and the main line cannot supply the water demand anymore. If both water mains fail, the storage tank takes over in supplying water to the residence. The tank will be able to supply water that lasts 66 hours. Therefore, this layered design provides a solution to short and long-term problems. To ensure success of the project during the construction period, it is recommended that the contractors should review the resolution planning and project issues outlined in section 6 of this report.



## References

Amirzehni, E. (2016). *Seismic assessment of basement walls in British Columbia*.

Vancouver: University of British Columbia.

Brzev, S., & Pao, J. (2016, 3rd Edition). *Reinforced Concrete Design*. New York : Pearson.

Cement Association of Canada (2012, 3rd Edition). *Concrete Design Handbook*. Ottawa:

Cement Association of Canada.

The City of Vancouver (2016) Utilities Design and Construction Manual, Engineering

Services. Retrieved from

<http://vancouver.ca/files/cov/UtilitiesDesignConstructionManual.pdf> [Accessed 2 Nov, 2017]

The City of Vancouver. (2017). *Housing Characteristics Fact Sheet*. Vancouver, British

Columbia, Canada: City of Vancouver. Retrieved from:

<http://vancouver.ca/files/cov/housing-characteristics-fact-sheet.pdf> [Accessed 16 Oct, 2017].

City of Vancouver. (n.d.). *SECTION 2: WATER DESIGN AND CONSTRUCTION*

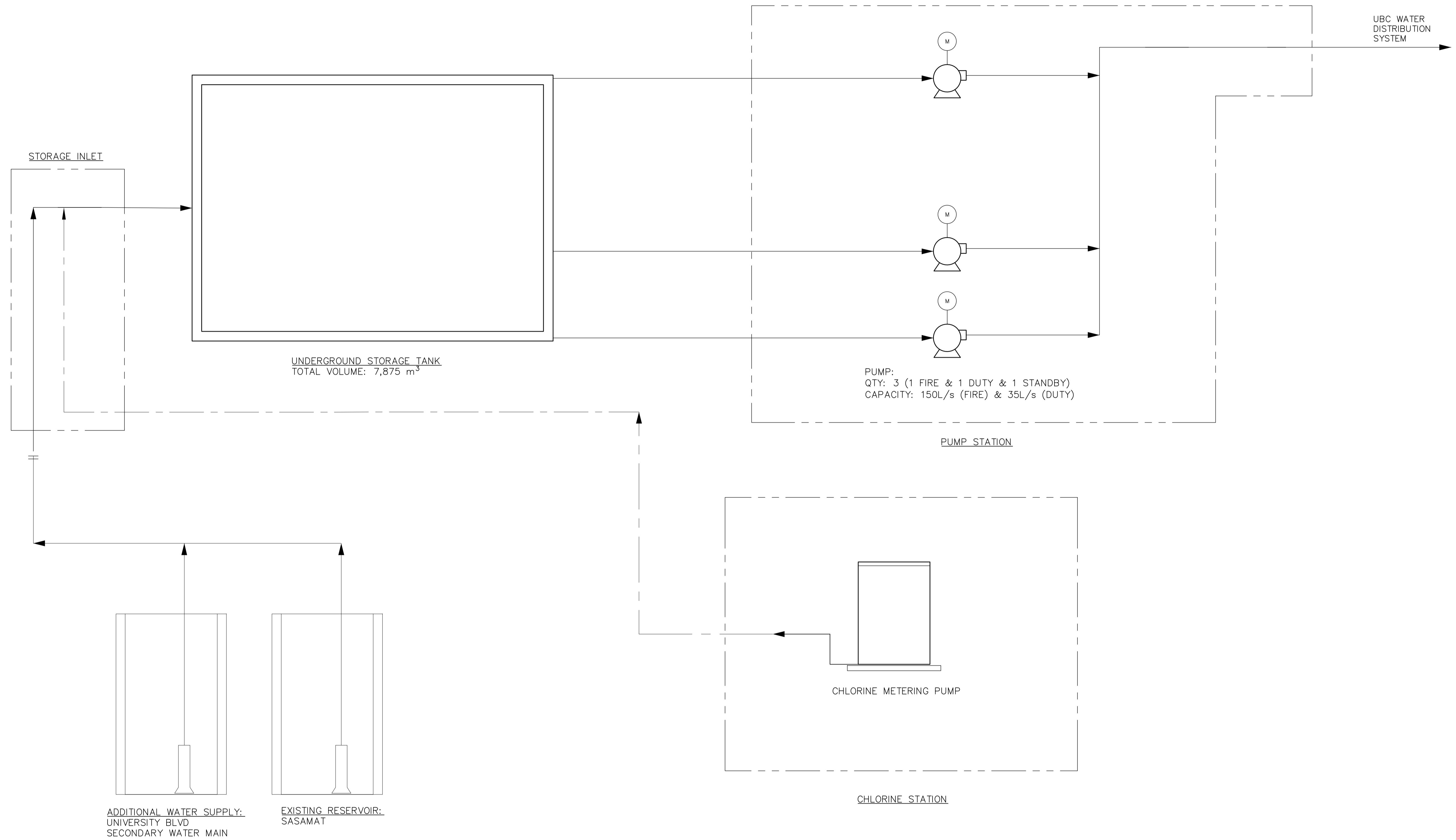
*REQUIREMENTS*. Retrieved January 15, 2018, from City of Vancouver:

[https://www.cityofvancouver.us/sites/default/files/fileattachments/public\\_works/page/11852/section2\\_2017\\_watergeneralreq\\_final.pdf](https://www.cityofvancouver.us/sites/default/files/fileattachments/public_works/page/11852/section2_2017_watergeneralreq_final.pdf)

- Dean, C. (2000). Walking speed over 10 metres overestimates. *Clinical Rehabilitation*, 417.  
Retrieved from: <https://www.ncbi.nlm.nih.gov/pubmed/11518442> [Accessed 1 Nov, 2017].
- Fire Underwriters Survey (1999). *Water Supply for Public Fire Protection*. CGI Group Inc.
- Grundfos Product Center (2018). *Find products and solutions*. Retrieved from  
<https://product-selection.grundfos.com/front-page.html?qcid=342651142>
- Metro Vancouver. (2011). *Regional Growth Strategy Projections: Population, Housing, and Employment*. Vancouver: Metro Vancouver.
- Nakashima, M. (2010). *Design Recommendation for Storage Tanks and Their Supports with Tanks and Emphasis on Seismic Design*. Japan: ARCHITECTURAL INSTITUTE OF JAPAN.
- Office of the Fire Commissioner Ministry of Municipal Affairs (1998). *The British Columbia Fire Code*. Retrieved from:  
<http://www.qp.gov.bc.ca/testing/wlap/firecode.htm> [Accessed 1 Nov. 2017].
- Piteau Associates Engineering Ltd. (2002). *UBC Properties Trust: Hydrogeological and Geotechnical Assessment of Northwest Area UBC Campus, Vancouver*. Vancouver.
- Properwinston (2017, July 16). *Back to Post: Underground Water Storage Tanks for Homes*. Retrieved from: <http://properwinston.com/underground-water-storage-tanks-for-homes/fire-protection-tanks-denton-greeley-water-storage-tanks-inside-underground-water-storage-tanks-for-homes/> [Accessed 1 Nov. 2017].

# **Appendix A:**

## **Pump Station Layout**



DRAWING: PUMP STATION LAYOUT DWG SOURCE: CUSTOMER'S DESIGN AND SPECIFICATIONS

**UBC SEEDS  
UBC WATER SUPPLY  
PUMP STATION LAYOUT**

DRAWING  
**001-001**

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A	18	03	18							

PERMIT ENGINEER

# **Appendix B:**

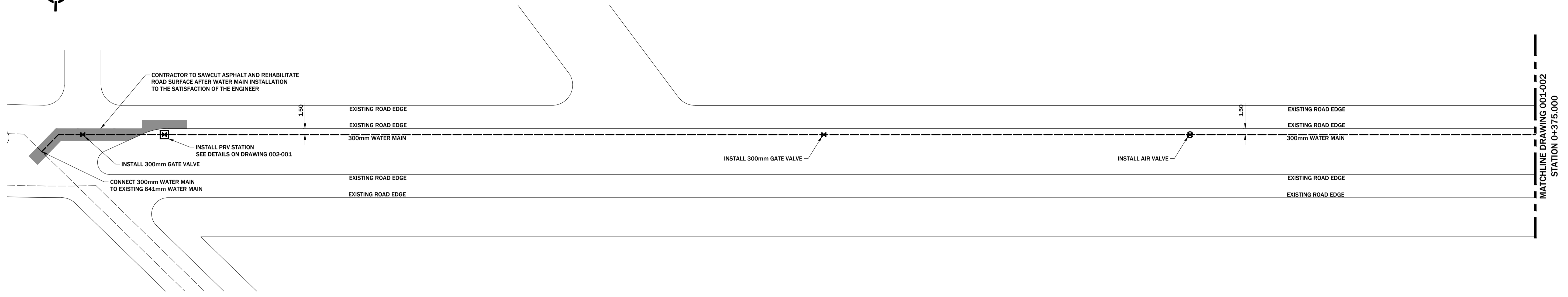
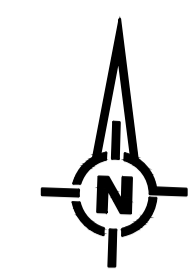
## **Secondary Water Main Design**

### **Drawings**

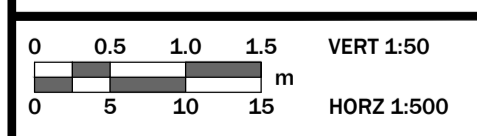
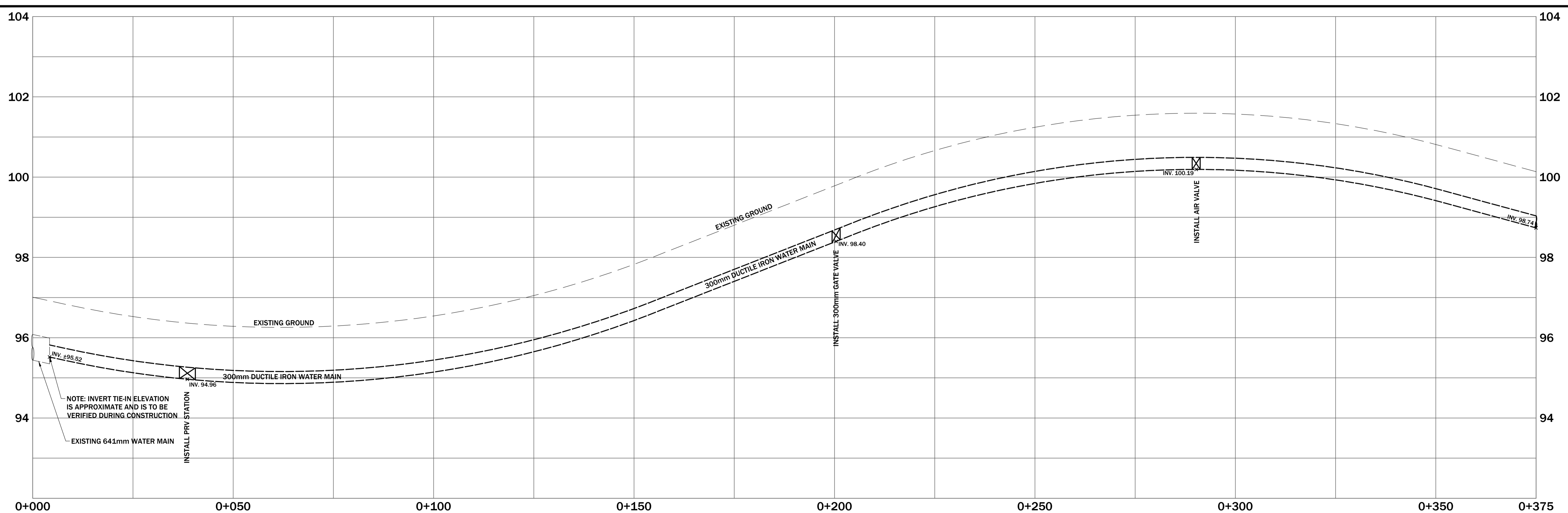
**LEGEND**

- 200 mm WATER MAIN
- - - EXISTING 200 mm WATER MAIN
- ⊗ GATE VALVE
- ⊙ AIR VALVE
- ▬ ROAD REHABILITATION AREA

- NOTES:**
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS.
  2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
  3. ALL NEW WATER MAIN PIPE MATERIAL IS TO BE DUCTILE IRON.
  4. LANDSCAPE REHABILITATION ABOVE THE NEW WATER MAIN INSTALLATION IS TO BE GRASS SEEDED AND A MINIMUM OF 0.15m OF TOPSOIL IS TO BE PLACED UNDER THE GRASS SEED.
  5. ALL NEW ASPHALT REHABILITATION IS TO MATCH THE EXISTING ROAD STRUCTURE.
  6. ALL REHABILITATED AREAS ARE TO MEET THE SATISFACTION OF THE SITE ENGINEER.
  7. ALL VALVES ARE TO BE RESILIENT-SEATED GATE VALVES.
  8. ALL PIPE JOINTS ARE TO HAVE WEDGE ACTION RESTRAINTS.



# UNIVERSITY BOULEVARD



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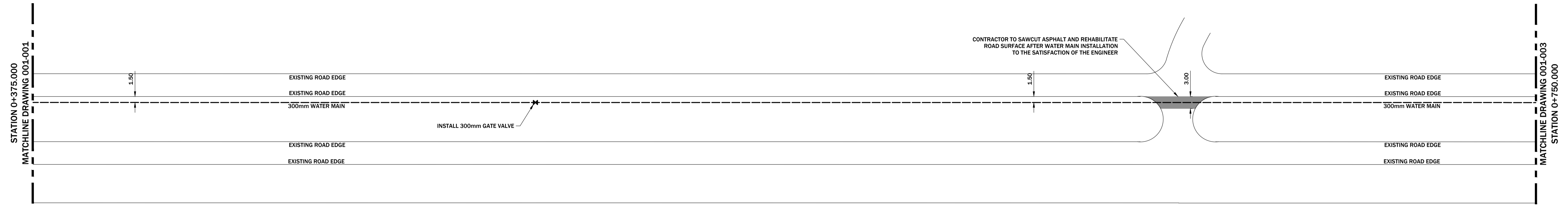
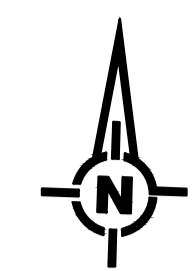
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**UBC WATER SUPPLY**  
**SECONDARY WATER MAIN**  
**UNIVERSITY BOULEVARD**  
**STATION: 0+000.000 TO 1+375.000**

DRAWING  
**001-001**

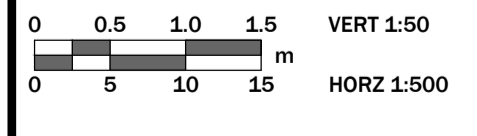
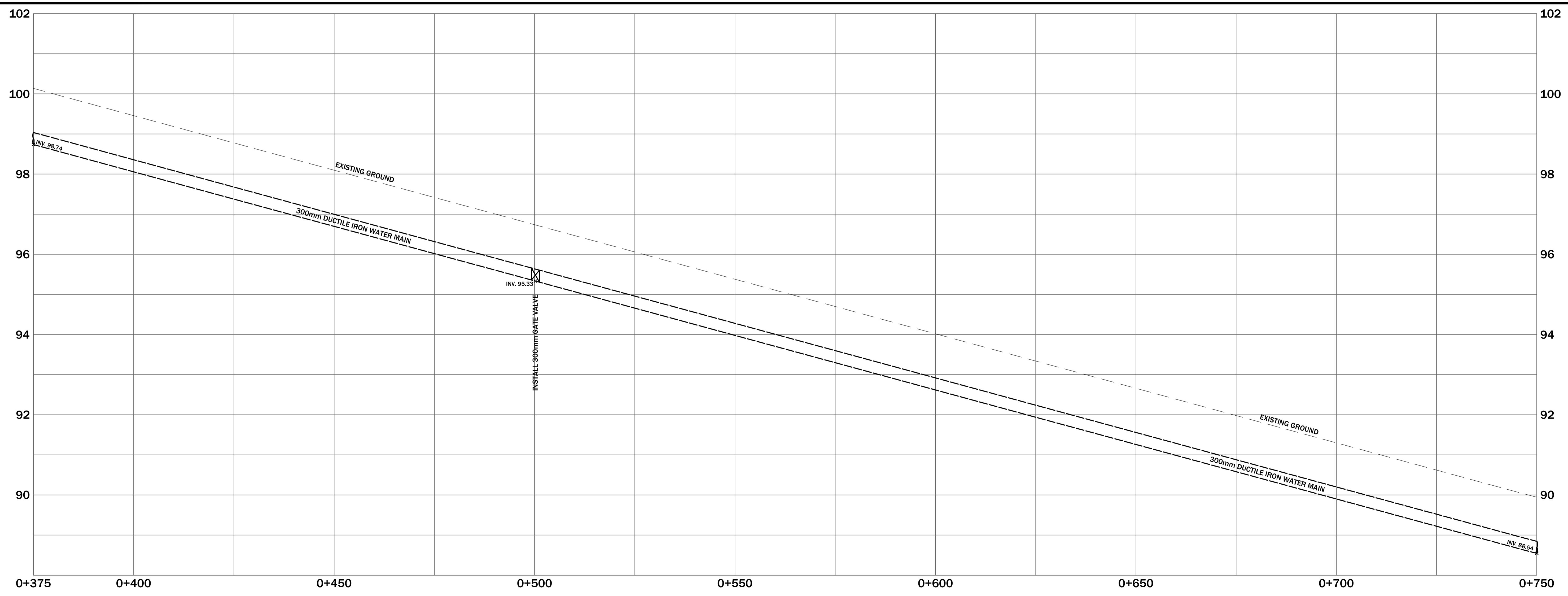
**LEGEND**

	200 mm WATER MAIN
	EXISTING 200 mm WATER MAIN
	GATE VALVE
	AIR VALVE
	ROAD REHABILITATION AREA

- NOTES:**
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# UNIVERSITY BOULEVARD



PERMIT

ENGINEER

REV	Y	M	D	REVISION DESCRIPTION	DRN	SUPV	DES	CHK	ENG	APP
A	18	04	09	ISSUED FOR APPROVAL						

**UBC SEEDS**  
**UBC WATER SUPPLY**  
**SECONDARY WATER MAIN**  
**UNIVERSITY BOULEVARD**  
**STATION: 0+375.000 TO 0+750.000**

DRAWING  
**001-002**

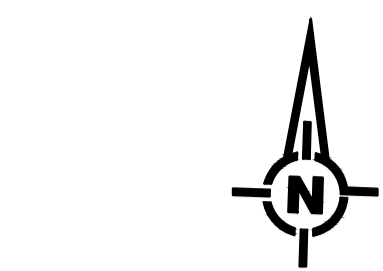
LEGEND

- 200 mm WATER MAIN
- EXISTING 200 mm WATER MAIN
- ⊠ GATE VALVE
- ⊙ AIR VALVE
- ROAD REHABILITATION AREA

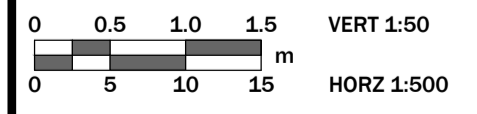
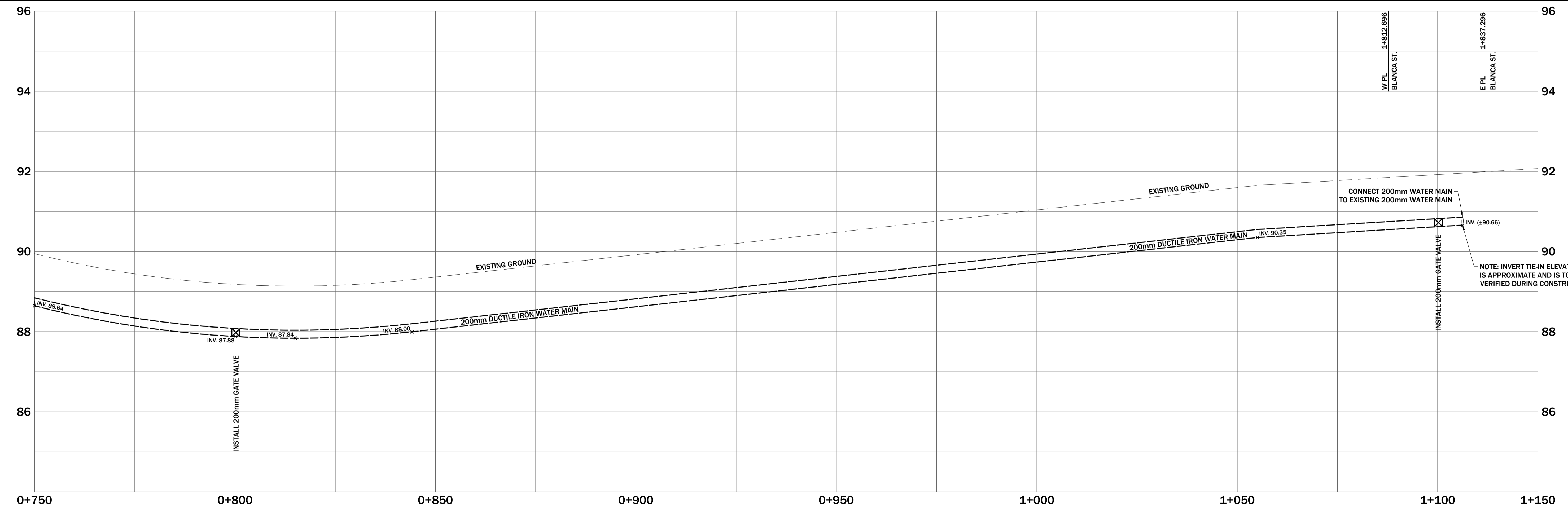
NOTES:

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS.
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. ALL NEW WATER MAIN PIPE MATERIAL IS TO BE DUCTILE IRON.
4. LANDSCAPE REHABILITATION ABOVE THE NEW WATER MAIN INSTALLATION IS TO BE GRASS SEEDING AND A MINIMUM OF 0.15m OF TOPSOIL IS TO BE PLACED UNDER THE GRASS SEED.
5. ALL NEW ASPHALT REHABILITATION IS TO MATCH THE EXISTING ROAD STRUCTURE.
6. ALL REHABILITATED AREAS ARE TO MEET THE SATISFACTION OF THE SITE ENGINEER.
7. ALL VALVES ARE TO BE RESILIENT-SEATED GATE VALVES.
8. ALL PIPE JOINTS ARE TO HAVE WEDGE ACTION RESTRAINTS.

NOTE:  
WHEN CONDUCTING WORK IN THE UNIVERSITY BOULEVARD AND BLANCA STREET INTERSECTION, THE CONTRACTOR IS TO ENSURE THAT A MINIMUM OF ONE LANE OF TRAFFIC IN ALL DIRECTIONS IS MAINTAINED



# UNIVERSITY BOULEVARD



PERMIT	ENGINEER
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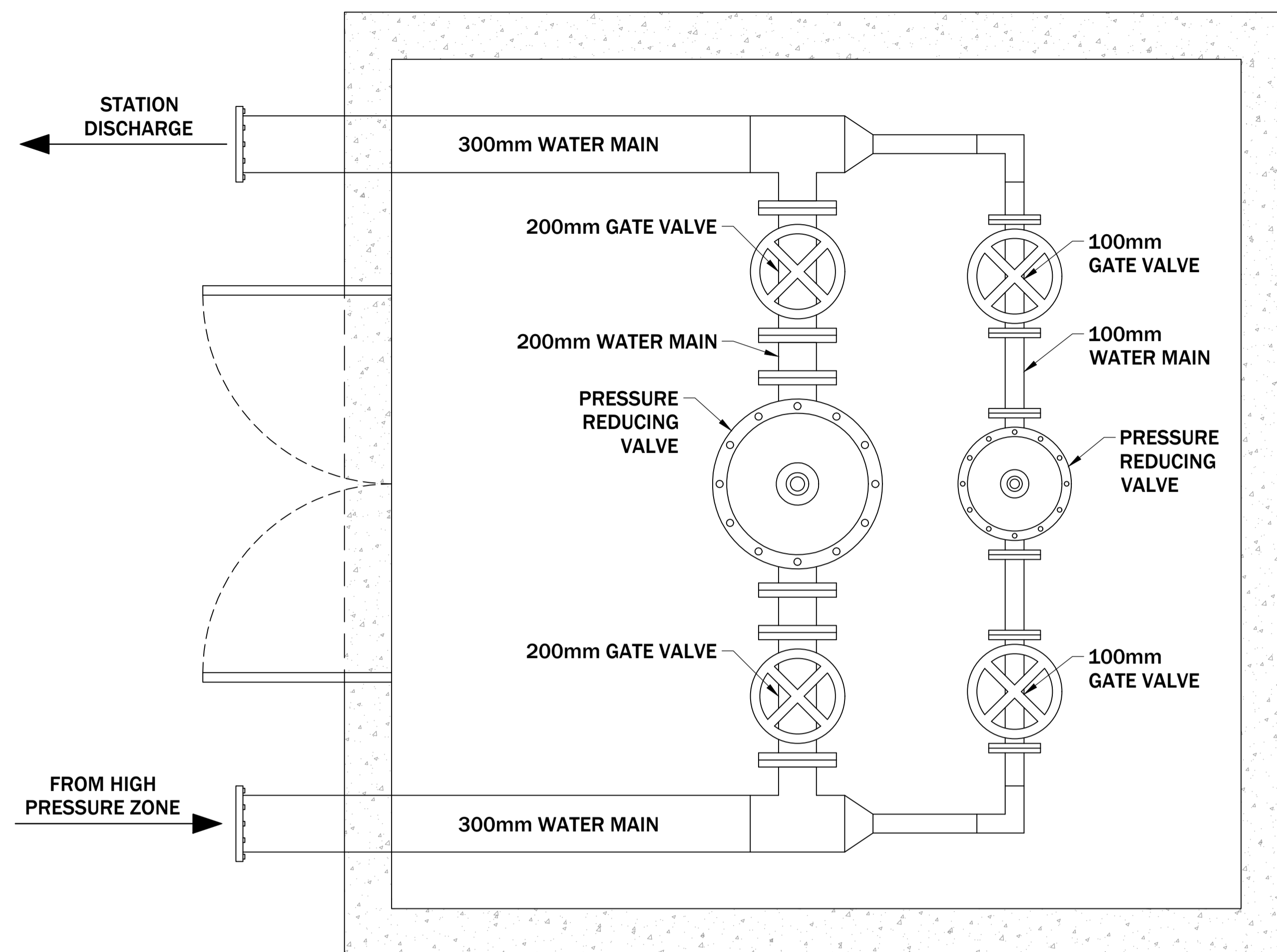
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UBC SEEDS  
UBC WATER SUPPLY  
SECONDARY WATER MAIN  
UNIVERSITY BOULEVARD  
STATION: 0+750.000 - 1+150.000

DRAWING  
**001-003**



- NOTES:**
1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS SPECIFIED OTHERWISE.
  2. ALL NEW WATER MAIN PIPE MATERIAL IS TO BE DUCTILE IRON.
  3. ALL VALVES ARE TO BE RESILIENT-SEATED GATE VALVES.
  4. ALL PIPE JOINTS ARE TO HAVE WEDGE ACTION RESTRAINTS.



**PRV STATION DETAIL**

SCALE: N.T.S.

0 0.5 1.0 1.5 VERT 1:50  
 0 5 10 15 m  
 HORZ 1:500

PERMIT

ENGINEER

REV	Y	M	D	REVISION DESCRIPTION	DRN	SUPV	DES	CHK	ENG	APP
A	18	04	09	ISSUED FOR APPROVAL						

**UBC SEEDS**  
**UBC WATER SUPPLY**  
**SECONDARY WATER MAIN**  
**UNIVERSITY BOULEVARD**  
**PRV STATION DETAILS**

DRAWING

**002-001**

**Appendix C:**

**Structural Design Calculations for**

**Storage Tank**

## Sample Calculation

### Soil

Density = 2000 kg/m<sup>3</sup>  
Top Height = 1 m  
g = 9.81 N/kg  
Soil Weight = 30901500 N  
30901.5 kN

### Tank Dimension

Height = 5 m  
Length = 45 m  
Width = 35 m  
Tributary Area = 1575 m<sup>2</sup>

### Dozers

Weight = 8 tons/dozer  
78.48 kN

### Concrete and Rebar Properties

f'<sub>c</sub> = 40 MPa  
f<sub>y</sub> = 400 MPa  
φ<sub>c</sub> = 0.65  
φ<sub>s</sub> = 0.85  
Assume Density = 2500 kg/m<sup>3</sup>  
λ = 1 for normal concrete  
α = 0.8 for normal concrete  
ρ<sub>b</sub> = 0.022

### Two Way Slab Design

The slab actually is 45.7m x 35.7m (including the thickness of retaining wall).

Assume 0.5 m as diameter of cylinder column

Assume 48 columns

=> 8 columns in length x 6 columns in width

Tributary Area for Each Column in Middle of Tank (Worse Case)

Length = 5 m

Width = 5 m

Clear Span, L<sub>n</sub> = 4.5 m

Min t = 150 mm (clause 13.2.3)

t = 300 mm

### Load Combination

Dead Load - Soil Weight      Fraction = 1.25  
30901.5 kN                              1.4  
19.620 kPa

Dead Load - Slab Weight  
7.358 kPa

Total DL = 26.978 kPa

Live Load = Dozers Weight      Fraction = 1.5  
78.48 kN  
0.050 kPa

### Load Combination

$$\text{Case 1} = 1.25 \times \text{DL} + 1.5 \times \text{LL} \\ 33.797 \text{ kPa}$$

$$\text{Case 2} = 1.4 \times \text{DL} \\ 37.7685 \text{ kPa}$$

$$\text{Total Load} = 37.7685 \text{ kPa}$$

$$\begin{aligned} \text{Slab Volume} &= 7.5 \text{ m}^3 && \text{for one column} \\ \text{Slab Weight} &= 183.9 \text{ kN} && \text{for one column} \end{aligned}$$

$$\begin{aligned} \text{Try } & 15 \text{ M rebar} \\ & 30 \text{ mm cover} && \text{(from table A.2)} \\ \text{Abar} &= 200 \text{ mm}^2 \\ d &= 255 \text{ mm} \end{aligned}$$

### Factored Moment

$$L_n = 4.5 \text{ m}$$

$$M_f = 478 \text{ kN}\cdot\text{m}$$

% $M_f$	$M_{\text{design}}$	
0.35	167 $\text{kN}\cdot\text{m}$	for positive $M_f$
0.65	311 $\text{kN}\cdot\text{m}$	for internal negative $M_f$

(Table 13.1)

### Column Strip

$$\begin{aligned} \text{Total Bending Moment} &= 311 \text{ kN}\cdot\text{m} \\ \text{Bending Moment for Column Strip} &= 0.59M_f = 282 \text{ kN}\cdot\text{m} \\ \text{Column Strip Width} &= 2500 \text{ mm} \end{aligned}$$

#### Within $b_b$

$$\begin{aligned} \text{Bend Width } b_b &= 1400 \text{ mm} \\ \text{Design Moment } M_f &= 104 \text{ kN}\cdot\text{m} \\ \text{Required Reinforcement Area } A_s &= 1207 \text{ mm}^2 && \text{Ok} \\ \text{Min Reinforcement Area } A_{s \text{ min}} &= 840 \text{ mm}^2 \\ \text{Required Spacing } s &= 232 \text{ mm} && \text{Ok} \\ \text{Max. Spacing} &= \text{Min}(1.5h_s \text{ or } 250) = 250 \text{ mm} \\ \text{Design Reinforcement (area in mm}^2) &= 6.03 - 15\text{M} @ && 232.03 \\ &&& \text{using 7-15M @ 220 (1400)} \end{aligned}$$

$$\rho = 0.00392 < \rho_b = 0.022 \quad \text{Ok}$$

### Outside bb

Bend Width $b_b$ =	1100 mm	
Design Moment $M_f$ =	178 kN*m	
Required Reinforcement Area $A_s$ =	2159 mm <sup>2</sup>	Ok
Min Reinforcement Area $A_{s \text{ min}}$ =	660 mm <sup>3</sup>	
Required Spacing $s$ =	102 mm	Ok
Max. Spacing = Min(1.5 $s$ or 250) =	250 mm	
Design Reinforcement (area in mm <sup>2</sup> ) =	10.80 - 15M @	101.89
	using 12-15M @ 95 (2400)	

Use 15M @150mm OC for column strip reinforcement

### Middle Strip

Middle Strip Width =	2500 mm	
Design Moment $M_f$ =	29 kN*m	
Required Reinforcement Area $A_s$ =	326 mm <sup>2</sup>	
Min Reinforcement Area $A_{s \text{ min}}$ =	1500 mm <sup>3</sup>	
Required Spacing $s$ =	1533 mm	
Max. Spacing = Min(3 $s$ or 500) =	500 mm	
Design Reinforcement (area in mm <sup>2</sup> ) =	7.50 - 15M @	333.33
	using 8-15M @ 330 (1600)	

Use 15M @330mm OC for middle strip reinforcement

### Slab Integrity Reinforcement

Considered Load	
Soil =	19.620 kPa
Slab = 2 x Slab Weight =	14.715 kPa
Design Load =	19.620 kPa
$V_{se}$ =	491 kN
$A_{sb}$ =	2453 mm <sup>2</sup>
Required Reinforcement =	12.26 -15M
	using 14-15m, 7-15m in each direction

## Circular Column Design

### Load Combination

Dead Load (Soil) = 19.620 kPa  
Live Load = 3.139 kPa

Slab Volume = 7.5 m<sup>3</sup> for one column  
Slab Weight = 183.9 kN  
Dead Load (Slab) = 7.358 kPa

DL = 26.978 kPa  
LL = 3.139 kPa

### Load Combination

Case 1 = 1.25 x DL + 1.5 x LL  
38.431 kPa

Case 2 = 1.4 x DL  
37.769 kPa

Total Load = 38.431 kPa  
Pf = 961 kN

### Column Arrangement

Assume 0.5 m as diameter of cylinder column

Assume 48 columns

=> 8 columns in length x 6 columns in width

### Tributary Area for Each Column in Middle of Tank (Worse Case)

Length = 5 m

Width = 5 m

Thickness of slab = 0.3 m

Lu = 5 m

Lu/D = 10 Short Column

Assume 30 M rebar

40 mm Cover

A<sub>bar</sub> = 700 mm<sup>2</sup>

# of bar = 4

A<sub>st</sub> = 2800 mm<sup>2</sup>

A<sub>g</sub> = 196350 mm<sup>2</sup>

Pro, c =	4026 kN	
Pro, s =	952 kN	
Pro =	4978 kN	
Pro, max =	4231 kN	Ok

CSA A23.3 Column Design Requirements

Longitudinal Reinforcement Ratio =	$A_{st} / A_g =$	1.43%
Max reinf. ratio = $0.08 * A_g =$	1.57%	

Minimum number of longitudinal reinforcement = 4 for columns for circular ties

Minimum bar spacing =	42 mm	governs
	28 mm	
	30 mm	

Tie sizing should be 30% of the biggest longitudinal reinforcement b

Max tie spacing =	480 mm	governs
	480 mm	
	500 mm	

Design stirrup spacing = 400 mm

## Retaining Wall Design

$K_v = 0.5 * K_h =$	0.23
$K_h =$	0.46
$K =$	0.597
$\theta =$	0.539
$\phi =$	38 degrees
$\delta =$	15 degrees
$K_{ea} =$	0.868
$P_{ea} =$	0.084 N/mm <sup>2</sup> 84.367 KN/m <sup>2</sup>

Given:

Thickness =	350 mm
Cover =	30 mm
Base width =	1000 mm
$\gamma_s =$	20 kN/m <sup>3</sup>
$k_0 =$	0.5
$f'_c =$	40 MPa
$f_y =$	400 MPa
$\phi_c =$	0.65
$\phi_s =$	0.85

	15M bar
Diameter	15 mm
Area	200 mm <sup>2</sup>

a) Determining the design bending moment and shear forces

$h_w =$	5 m
$b =$	1000 mm
$\gamma_0 =$	10 kN/m <sup>3</sup>
$P_0 =$	50 kN/m <sup>3</sup>
P of Soil =	75 kPa
P of Seismic =	85 kPa

$w_1 =$	75 kN/m <sup>2</sup>
$w_2 =$	10 kN/m <sup>2</sup>
$l =$	5 m
$x =$	2.5



<b>Bending Moment</b>		<b>Shear</b>	
Rectangle (w1)			
M max =	156.250 kN	V max (pos) =	187.5 kN/m
M midpoint =	78.125 kN	V max (neg) =	-187.5 kN/m
Triangle (w2)			
M 1 =	8.333 kN	V 1 =	7.5 kN/m
M 2 =	12.50 kN	V 2 =	17.5 kN/m
M midpoint =	5.208 kN		
Total (w1+w2)			
M 1 =	164.583 kN	V 1 =	195.0 kN/m
M 2 =	168.750 kN	V 2 =	-205.0 kN/m
M midpoint =	83.333 kN		

b) Design the wall for concentrated effects of flexure and axial loads

hu =	5000 mm		
CIP Foundation =	190 mm		
Wall height >4m =	300 mm		
	200 mm		
Governs	300 mm		
DL	67.4 kN/m		
LL	31.4 kN/m		
E	212.5 kN/m		
Mf = Mr	168.75 kN m		168750000 N mm
Factored Axial Load			
1.25DL+1.5LL	131.35 kN/m		
1.0DL+1.0E	280 kN/m		
Govern	280 kN/m		
Effective Depth =	312.5 mm		
Use	310 mm		
Total Steel Area =	1645 mm <sup>2</sup>		
Spacing =	121.6156 mm		
Use	130 mm		
Check allowed spacing			
3t =	1050 mm		
s max =	500 mm		
Govern	500 mm		
>		130 mm	Okay

$p =$	0.005	<	$p_b =$	0.034	Okay
				* $p_b$ from table A.4	
$A_g =$	350000 mm <sup>2</sup>				
$A_{min} =$	525 mm <sup>2</sup>		$A_s =$	3289 mm <sup>2</sup>	Okay
	<				

**\*15M@130 Vertical**

c) Design for shear

	$V_f =$	205 kN/m		
$d_v =$	$0.9d =$	279 mm		
	$0.72t =$	252 mm		
	Governs	279 mm		
	$\beta =$	0.180		
	$V_c =$	206.255 kN/m		
Check	$V_f =$	205 kN/m		
	<	$V_c =$	206.2552 kN/m	Okay
	$A_h \text{ min} =$	700 mm/m		
	Required Bar Spacing =	122 mm		
	Use	120 mm		

Check allowed spacing

$3t =$	1050 mm
$s \text{ max} =$	120 mm
Governs	120 mm

**\*Use 15M@120 horizontal**

Since  $t=350\text{mm} > 210\text{mm}$ , use 2 layers

Stirrup =	10 mm
Spacing =	255 mm

## Strip Footings Support Walls

### Allowable Soil Pressure

$c'$ =	0
Height of soil =	6.3 m
Unit Weight of Soil =	20 kN/m <sup>3</sup>
Depth of GWT =	6.6 m
Unit Weight of Water =	9.81 kN/m <sup>3</sup>
Effective Stress =	126 kPa
Gamma =	13.133
$\phi$ =	30 degree
$N_c$ =	37.16
$N_q$ =	22.46
$N_{\gamma}$ =	19.7
$Q_{ult}$ =	2959.320 kPa
FS =	3
$Q_{all}$ =	986.440 kPa

Not in practical, so use reasonable number  $Q_{all} = 250$  kPa

### 1.) Determining the footing width

DL =	67.4 kN/m
LL =	31.4 kN/m
$Q_{all}$ =	250 kPa
unit length =	1 m
$B \geq$	0.3952 m
use	1 m

### 2.) Determining the factored soil pressure

A =	1 m <sup>2</sup>
Factored Soil Bearing, $Q_f$ =	131.35 kPa
Use	130 kPa
Cover =	30 mm
Wall thickness, t =	350 mm

### 3.) Determining the required footing thickness based on shear

Assume Strip Depth =	300 mm
Use	550 mm
Using 15M rebar	
$d_b$ =	15 mm
d = effective depth =	262.5 mm
$d_v$ = shear depth =	236.25 mm
$V_f$ =	11.5375 kN per unit length

$$\begin{aligned}
 \beta &= 0.21 \\
 \phi_c &= 0.65 \\
 \lambda &= 1 \\
 f'_c &= 40 \text{ MPa} \\
 V_c &= 203.955 \text{ kN per unit length} \\
 V_f < V_c & \quad \text{Ok}
 \end{aligned}$$

#### 4.) Determining the flexural reinforcement based on the flexural design requirements

$$\begin{aligned}
 M_f &= 6.866 \text{ kN}\cdot\text{m} \\
 &\text{Use } 7 \text{ kN}\cdot\text{m} \\
 M_r &= 7 \text{ kN}\cdot\text{m} \\
 A_s &= 77 \text{ mm}^2
 \end{aligned}$$

#### 5.) Minimum Reinforcements

$$\begin{aligned}
 A_g &= 300000 \text{ mm}^2 \\
 A_{s \text{ min}} &= 600 \\
 A_s < A_{s \text{ min}} & \quad \text{Not Ok} \\
 &\text{Use } 600 \text{ mm}^2
 \end{aligned}$$

#### 6.) Determin Spacing

$$\begin{aligned}
 A_{\text{bar}} &= 200 \text{ mm}^2 \quad \text{for 15M bar} \\
 S &= 333 \text{ mm} \\
 S_{\text{max}} &= 500 \text{ mm} \\
 S < S_{\text{max}} & \quad \text{Ok} \\
 &\text{Use } 330 \text{ mm}
 \end{aligned}$$

#### 7.) Design Minimum Reinforcement in the longitudinal direction

$$\begin{aligned}
 A_g &= 300000 \text{ mm}^2 \\
 A_{s \text{ min}} &= 600 \text{ mm} \\
 \# \text{ of bars} &= 3 \\
 S_{\text{max}} &= 500 \text{ mm}
 \end{aligned}$$

#### Summary

Longitudinal Reinforcement 25M@500  
 Flexural Reinforcement 3-25M@330

## Square Footing for Column

Tributary Area = 25 m<sup>2</sup>

### Load Per Column

DL = 26.978 kPa 674.438 kN

LL = 3.139 kPa 78.48 kN

### Weight of the Column

Diameter = 0.5 m

Cross section = 0.196 m<sup>2</sup>

Height = 5 m

Volume = 0.982 m<sup>3</sup> Per column

Conc Density = 2500 kg/m<sup>3</sup>

Unit Weight = 24.525 kN/m<sup>3</sup>

Column Weight = 24.08 kN Per column

# of Column = 48

Total Column Volume = 47.124 m<sup>3</sup>

Total Column Weight = 1155.713 kN

### Weight of Water

Total Water Volume = 7827.876 m<sup>3</sup>

Water Density = 1000 kg/m<sup>3</sup>

Total Water Weight = 76791.465 kN

Water Weight = 48.756 kPa

Water Weight = 1218.912 kN Per column

### Load Combinatioin

Total DL = 1917.427 kN

Total LL = 78.48 kN

1.25DL + 1.5LL = 2514.504 kN

1.4DL = 2684.398 kN

Total Load = 2684.398 kN

### Property

lamda = 1 for normal concrete

phi c = 0.65

phi s = 0.85

f'c = 40 MPa

fy = 400 MPa

### 1. Determine the footing plan dimensions

qall = 250 kPa

A = P/qall = 7.984 m<sup>2</sup>

b = SQRT(A) = 2.826 m

use 3 m

A = 9 m<sup>2</sup>

## 2. Determine the factors soil pressure

$$q_f = P_f / A = 298.266 \text{ kPa}$$

## 3. Determine the required footing thickness

### Requirement of 2-way slab

$$\begin{aligned} V_f &= P_f = 2684.398 \text{ kN} \\ v_c &= 1.562 \text{ MPa} \\ V_c &= v_c \times b_o \times d = V_f = 2684.398 \text{ kN} \\ b_o \times d &= V_c / v_c = 1.718 \text{ m}^2 \\ b_o &= 4 \times (t + d) \\ b_o \times d &= 4dt + 4d^2 = V_c / v_c \\ t &= 0.5 \text{ m} \quad \text{column diameter} \\ d &= 0.451 \text{ m} \\ \text{use } & \quad \quad \quad 0.5 \text{ m} \\ \text{check } 4dt + 4d^2 &= 2 \quad \text{OK} \\ b_o &= 3.806 \text{ m} \\ \text{Beta } c &= t/t = 1 \\ v_c &= 2.343 \text{ MPa} \\ \alpha_s &= 4 \text{ for interior column} \\ v_c &= 2.732 \text{ MPa} \\ \text{Min } v_c &= 1.562 \text{ assumption was correct} \end{aligned}$$

use 15M rebar

$$\begin{aligned} d_{bar} &= 25 \text{ mm} \\ A_{bar} &= 500 \text{ mm}^2 \\ \text{cover} &= 30 \text{ mm} \\ h &= 542.5 \text{ mm} \\ \text{use } & \quad \quad \quad 550 \text{ mm} \\ d &= 507.5 \text{ mm} \\ \text{use } & \quad \quad \quad 500 \text{ mm} \end{aligned}$$

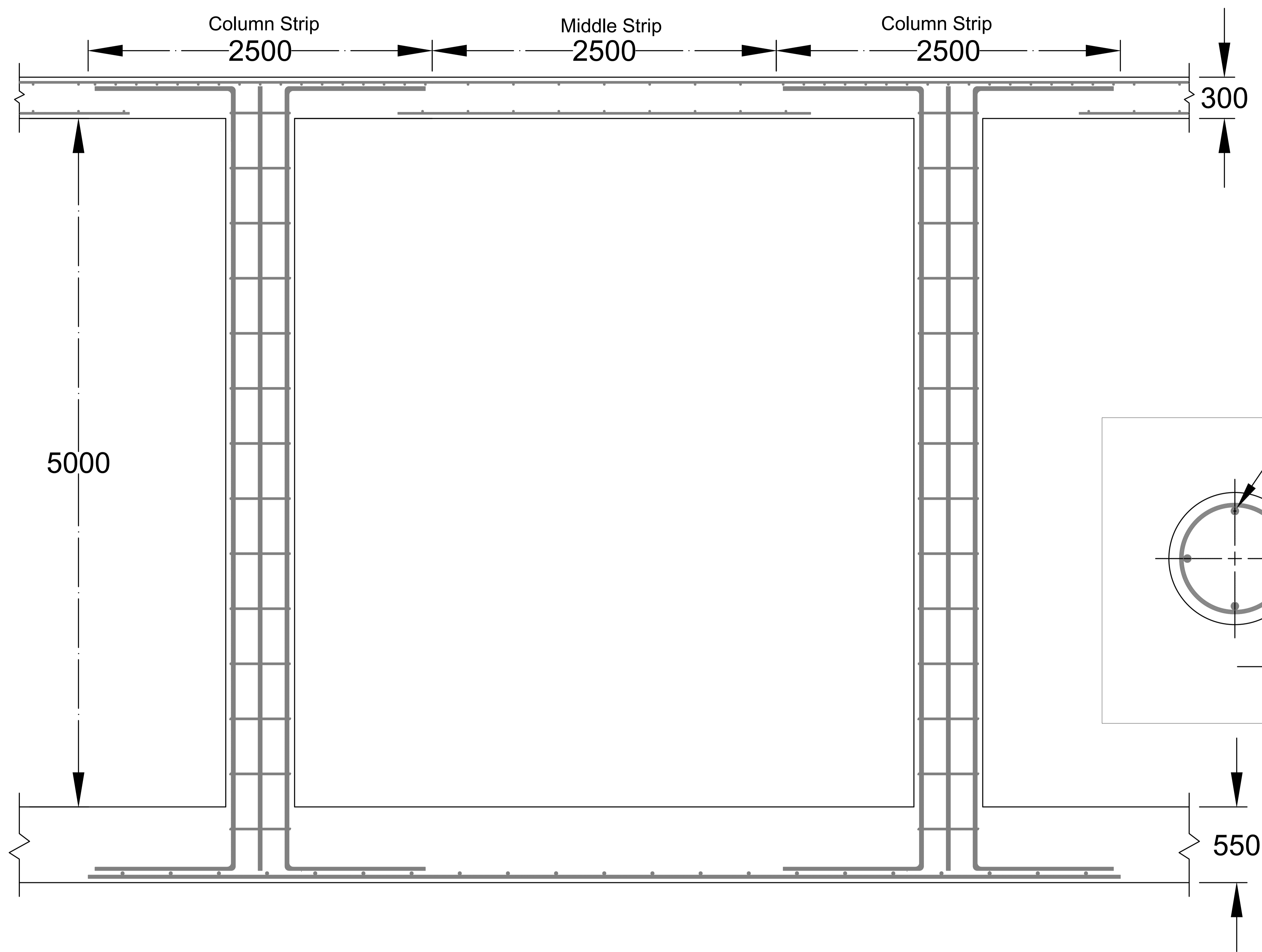
### Requirement of 1-way slab

$$\begin{aligned} d_v &= 450 \text{ mm} \\ V_f &= q_f \times b \times ((b-t)/2 - d_v) = 715.839 \text{ kN} \\ \beta &= 0.16 \\ V_c &= 880.313 \text{ kN} \\ V_f &< V_c \quad \text{OK} \end{aligned}$$

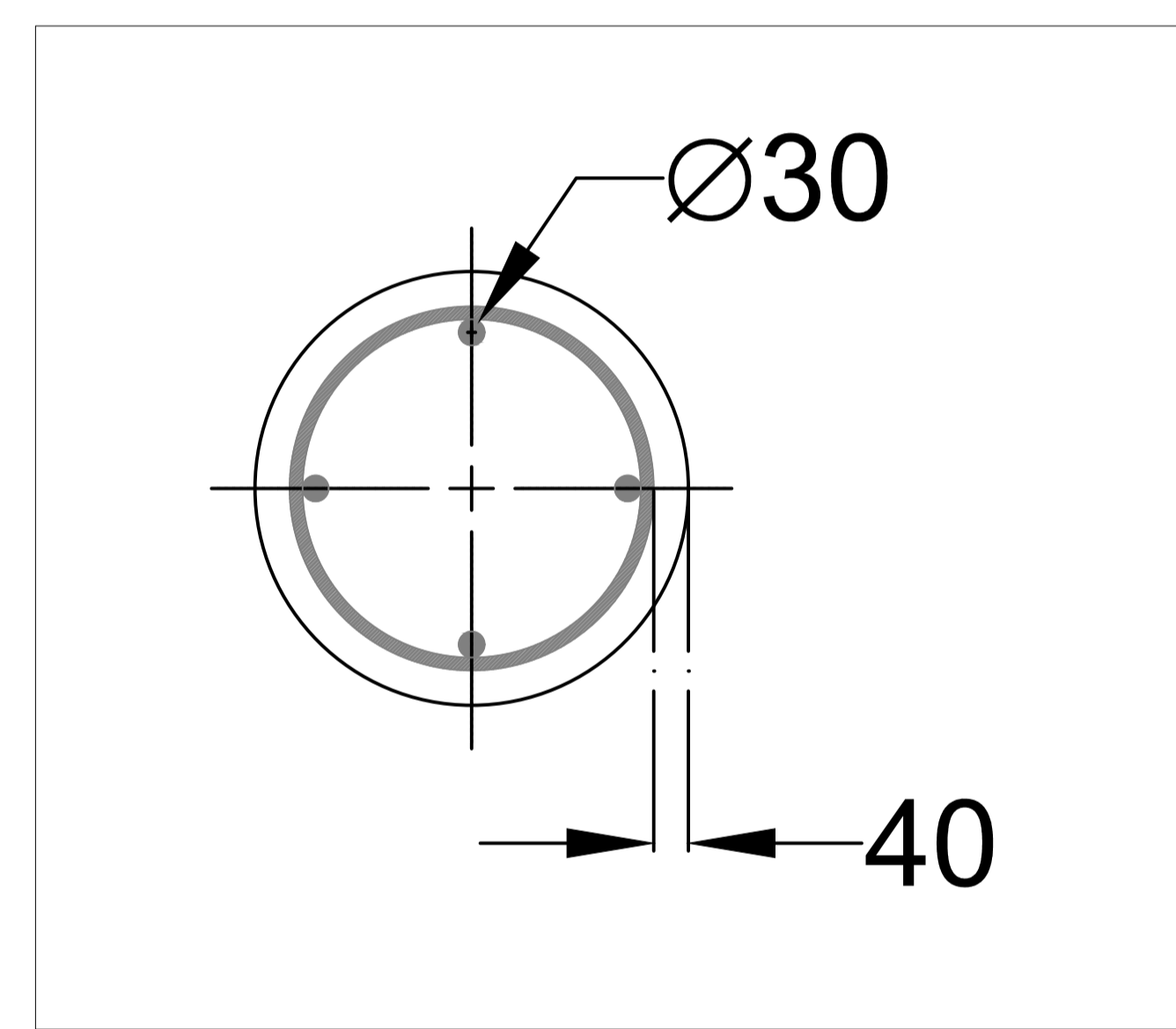
**Appendix D:**

**Structural Design Drawings for**

**Storage Tank**



- NOTES:
- 1. All dimensions are in millimeters
  - 2. All clear covers are 30 mm, unless otherwise specified
  - 3. Reinforcement Specs:  
Slab Column Strip:  
15M @ 150 mm top  
  
Slab Middle Strip:  
15M @ 330 mm top&bottom
  - 4. Column:  
30M longitudinal  
10M stirrups @ 400 mm  
Column clear cover is 40 mm



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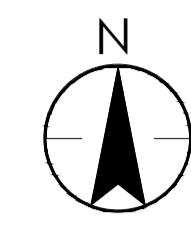
UBC SEEDS  
UBC WATER STORAGE TANK  
TYPICAL COLUMN CROSS SECTION

DRAWING  
003 - 001

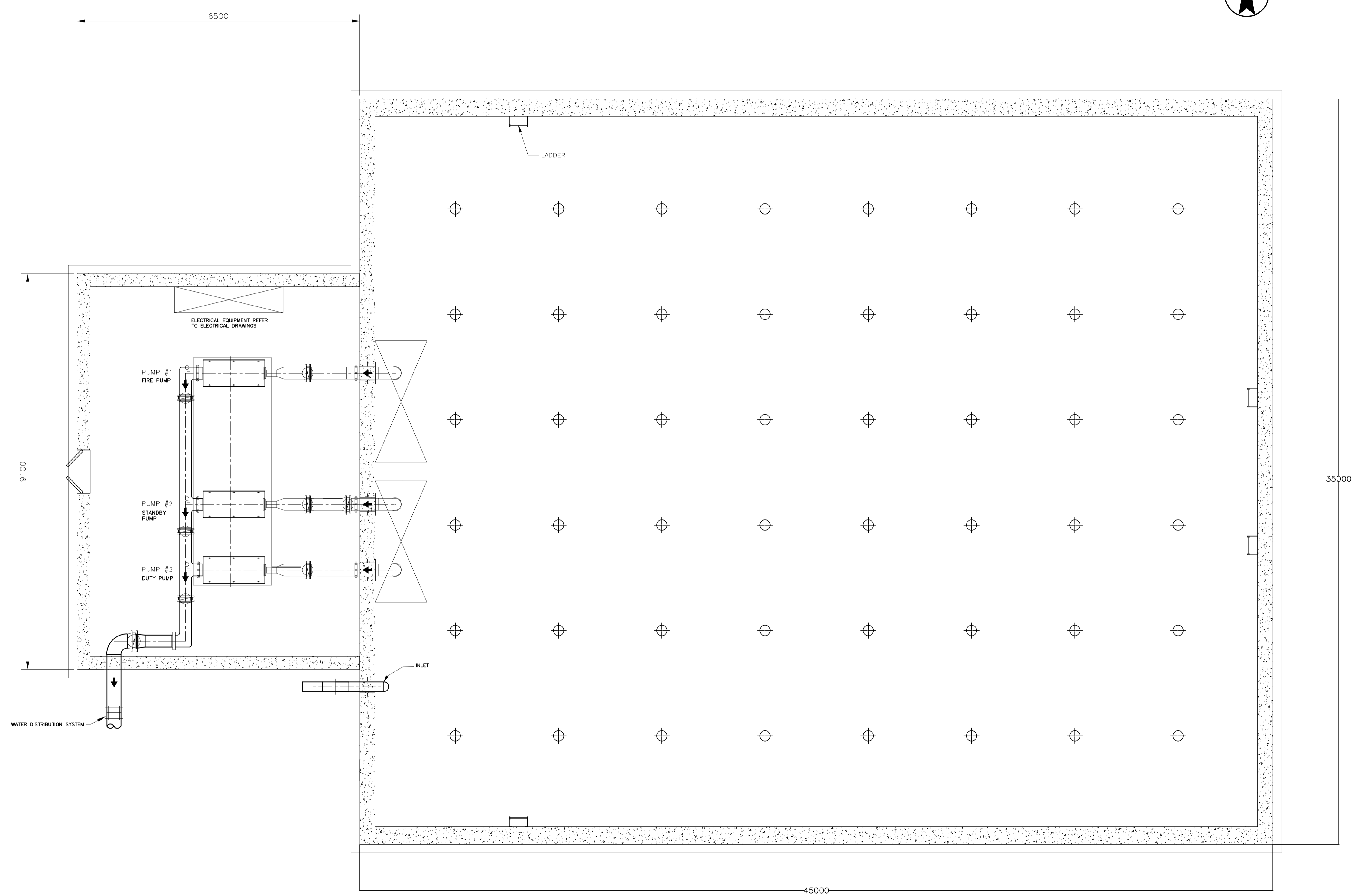








- SHOP DRAWING NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS
  2. A PRE-CONSTRUCTION MEETING WILL BE HELD PRIOR TO START OF CONSTRUCTION
  3. SITE MEETING START-UP MEETING REQUIRED WITH APPROPRIATE CONSULTANTS
  4. THE CONTRACTOR SHALL NOTIFY THE ENGINEER AND ARCHITECT FOR FIELD REVIEWS



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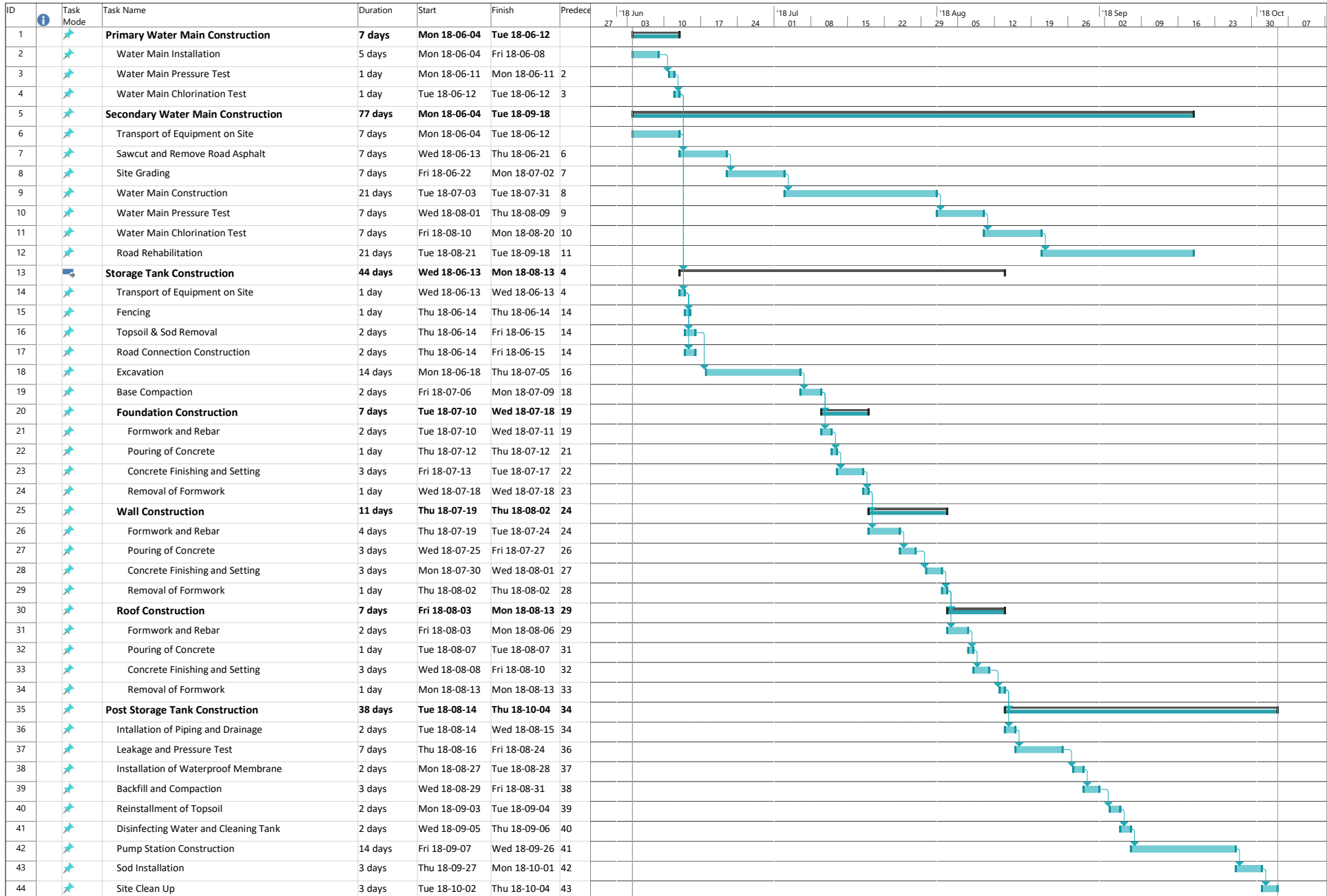
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A	18	03	18							

**UBC SEEDS  
UBC WATER SUPPLY  
PUMP STATION DETAILED**

DRAWING  
**001-002**

**Appendix E:**

**Project Schedule**



Project: Civil 445 Sched.mpp  
Date: Sat 18-03-31

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

## **Appendix F:**

# **Project Cost Estimate**

# UBC WATER SUPPLY - CONSTRUCTION COST ESTIMATE

## SCHEDULE 'A' - Site Grading

ITEM NO.	DESCRIPTION	UNIT OF MEASURE	QUANTITY	UNIT PRICE	COST
1.	Topsoil removal and haul to designated truck dump location	m3	1,820	\$4.50	\$8,190.00
2.	Common Excavation (clay soil) - Site Cuts to designated truck dump location	m3	28,960	\$5.00	\$144,800.00
3.	Clay soil relocation from designated truck dump location to be placed on top of finished storage tank (complete with compaction to 95% SPD)	m3	19,200	\$5.00	\$96,000.00
4.	Topsoil relocation from designated truck dump location to be placed on top of finished storage tank	m3	1,820	\$4.50	\$8,190.00
5.	Sod installation (Including labour)	m2	6,060	\$27.00	\$163,620.00
				TOTAL =	\$420,800.00

Note: Topsoil depth is assumed to be 0.30m

## SCHEDULE 'B' - Watermains

ITEM NO.	DESCRIPTION	UNIT OF MEASURE	QUANTITY	UNIT PRICE	COST
1.	300 mm Ductile Iron (Class 50) Water Main (Including All Fittings and labour)	m(lin)	1150	\$550.00	\$632,500.00
2.	Gate Valves c/w Box, Stem and Final Grade Adjustments - 300 mm (Including labour)	ea.	8	\$4,100.00	\$32,800.00
3.	Manual Air Valve	ea.	1	\$5,000.00	\$5,000.00
4.	Pressure Reducing Valve Station	ea.	1	\$200,000.00	\$200,000.00
5.	Connection to Existing Pipe - All Water Main sizes (Including labour)	ea.	3	\$2,500.00	\$7,500.00
6.	Pressure Test	Labour Hr.	50	\$50.00	\$2,500.00
7.	Chorination Test	Labour Hr.	50	\$150.00	\$7,500.00
				TOTAL =	\$887,800.00

Note: Labour price for chlorine has been inflated to account for cost of chlorine

### SCHEDULE 'C' - Road Rehabilitation

ITEM NO.	DESCRIPTION	UNIT OF MEASURE	QUANTITY	UNIT PRICE	COST
1.	Sawcut of removal of existing asphalt	Labour Hr.	8	\$100.00	\$800.00
2.	Granular Base Course - 3-20A Gravel (Assume 300mm Depth) (Including labour)	m2	350	\$31.00	\$10,850.00
3.	Asphalt Base Course (Assume 85mm Depth) (Including labour)	m2	350	\$37.00	\$12,950.00
4.	Asphalt Surface Course (Assume 35mm Depth) (Including labour)	m2	350	\$22.00	\$7,700.00
5.	Contingency for addition asphalt rehabilitation	m2	1000	\$90.00	\$90,000.00
				TOTAL =	\$122,300.00

Note: Asphalt structures are approximate and are to be verified during construction

### SCHEDULE 'D' - Storage Tank

ITEM NO.	DESCRIPTION	UNIT OF MEASURE	QUANTITY	UNIT PRICE	COST
1.	Granular Base Course - 3-20A Gravel (Assume 300mm Depth) (Including labour)	m2	7000	\$31.00	\$217,000.00
2.	Concrete	m3	1900	\$271.00	\$514,900.00
3.	Steel Reinforcement				
	30M	m	1000	\$5.60	\$5,604.90
	25M	m	9100	\$4.00	\$36,431.85
	15M	m	33000	\$1.60	\$52,846.20
	10M	m	700	\$0.80	\$560.49
4.	Formwork	lump sum	1	\$17,500.00	\$17,500.00
5.	Waterproof Membrane	m2	2375	\$23.00	\$54,625.00
6.	Labour				
	Formwork	hrs	420	\$40.00	\$16,800.00
	Pouring of Concrete	hrs	480	\$40.00	\$19,200.00
	Waterproof membrane installation	hrs	120	\$40.00	\$4,800.00
	Steel Bars	hrs	240	\$40.00	\$9,600.00
	Site Preparation Labour (transport, fencing, excavation, etc)	hrs	1,320	\$80.00	\$105,600.00
	Post Tank Construction Labour (pressure test, backfill, etc)	hrs	960	\$80.00	\$76,800.00
				TOTAL =	\$1,132,268.44

Note: Use 25M steel rebars; Storage Tank Dimension: 45m\*35m\*5m  
Labour price for pre and post construction are inflated to account for extra machineries used



SCHEDULE 'E' - Pump House

ITEM NO.	DESCRIPTION	UNIT OF MEASURE	QUANTITY	UNIT PRICE	COST
1.	Pump Station	Lump Sum	1	\$ 1,500,000.00	\$ 1,500,000.00
					TOTAL = \$ 1,500,000.00

SCHEDULE 'F' - Miscellaneous

ITEM NO.	DESCRIPTION	UNIT OF MEASURE	QUANTITY	UNIT PRICE	COST
1.	Traffic Control	Lump Sum	1	\$10,000.00	\$ 10,000.00
2.	Erosion and Sedimentation Control	Lump Sum	1	\$15,000.00	\$ 15,000.00
					TOTAL = \$25,000.00

SUMMARY OF SCHEDULES

ITEM NO.	DESCRIPTION	COST
1.	SCHEDULE 'A' - Site Grading	\$420,800.00
2.	SCHEDULE 'B' - Watermains	\$887,800.00
3.	SCHEDULE 'C' - Road Rehabilitation	\$122,300.00
4.	SCHEDULE 'D' - Storage Tank	\$1,132,268.44
5.	SCHEDULE 'E' - Pump House	\$1,500,000.00
6.	SCHEDULE 'F' - Miscellaneous	\$25,000.00
7.	10% CONTINGENCY	\$406,316.84
		TOTAL = \$4,494,485.28

# UBC WATER SUPPLY - ANNUAL OPERATION COST ESTIMATE

ITEM NO.	DESCRIPTION	UNIT OF MEASURE	QUANTITY	UNIT PRICE	COST
1.	Annual Labour Hours	hr.	156	\$80.00	\$12,480.00
TOTAL =					\$12,480.00

Note: Annual labour hours assumes that 3 hours per week is necessary for maintenance




## SCHEDULE 'X' - Pump Station Operation & Maintenance

ITEM NO.	DESCRIPTION	UNIT OF MEASURE	QUANTITY	UNIT PRICE	COST
1.	Water Treatment and Pumping Station Operation	day	365	\$114.00	\$41,610.00
2.	Chlorine residual samples taken in the water once per week	week	52	\$110.00	\$5,720.00
3.	Maintain a daily record book at the water treatment plant, record and enter data in the log book	day	365	\$16.00	\$5,840.00
4.	Check routine maintenance on equipment including pumps, valves and water meters	lump sum	1	\$5,000.00	\$5,000.00
TOTAL =					\$58,170.00
Operation and Maintenance =					\$70,650.00

# **Appendix G:**

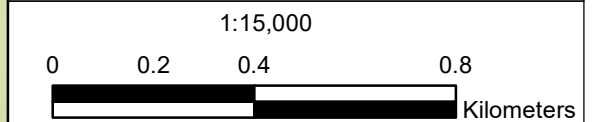
## **Water Network Model**

# TEAM 13

-  Storage Tank
-  Existing PRV Stations
-  Pump Station
- Pressure (psi)**
- <= 40
- 41 - 60
- 61 - 90
- > 90
- Proposed Secondary Supply Main
- Existing Pipeline Network

Note:

- Supply HGL of 135 m from new Pump Station
- 33 L/s emergency water supply from the storage tank
- Existing Pump Station inactive
- Break in both primary supply mains
- Secondary supply main not in operation
- Storage tank is the only emergency supply in this scenario
- Highest service elevation is 101.4 m

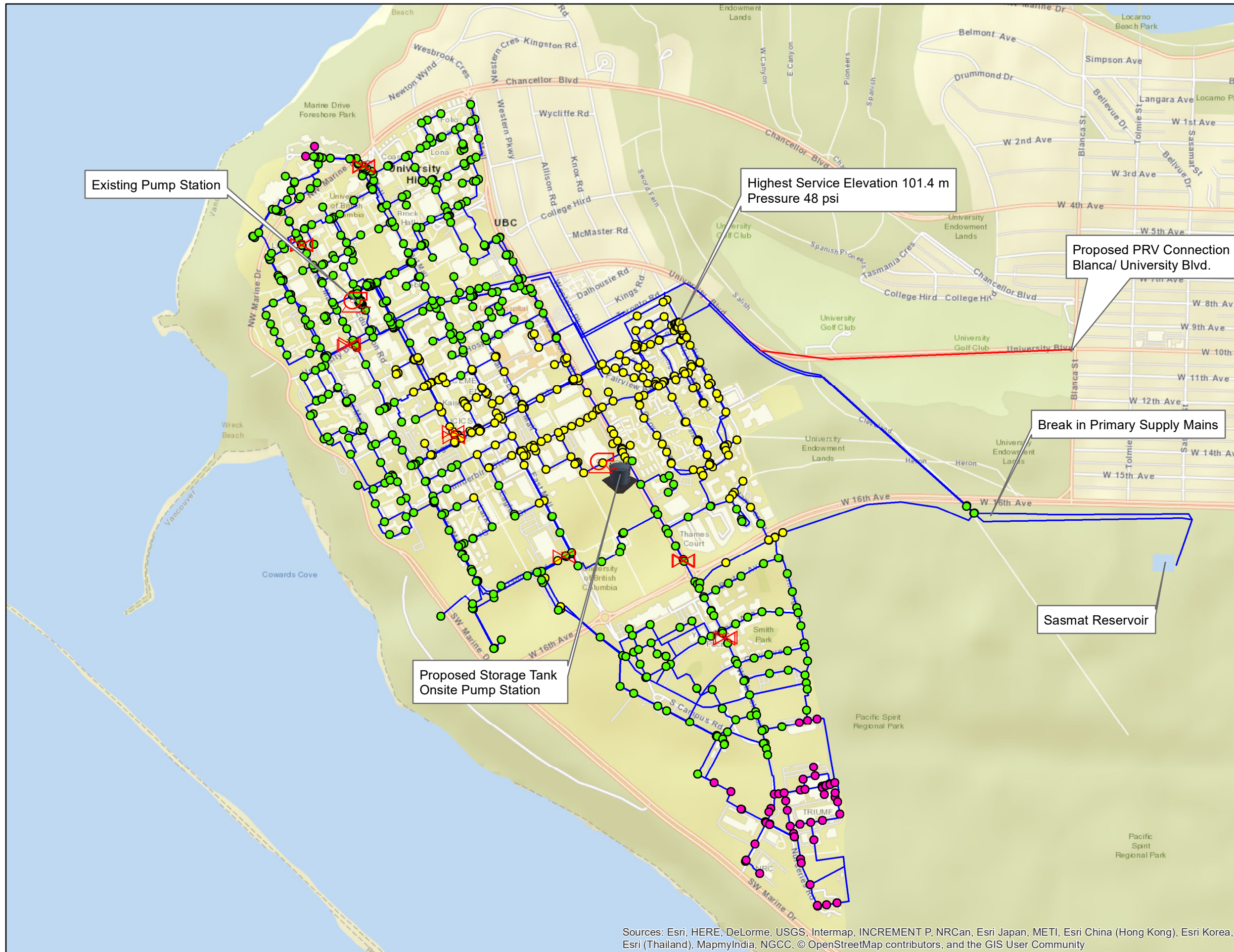


 **Faculty of Applied Science**  
THE UNIVERSITY OF BRITISH COLUMBIA

**University of British Columbia  
Supply Arrangement**

**University of British Columbia  
Emergency Pressures**

PROJECT NO. 446-2	DATE FEB. 23, 2018	REVISION 0
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