UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Secure Water Supply for UBC - Team 10

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CIVL 445

Themes: Water, Community, Land

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Executive Summary

GTEN Engineering Consultants are pleased to present the final technical design for the UBC Water Supply System in the following report. It is important to supply safe drinking water in all situations, especially with the growth of the UBC campus. Currently, the primary supply of water cannot be guaranteed in all emergency situations from the primary water mains connecting to the Sasamat Reservoir. The purpose of this report is to provide a technical design that meets all design criteria and requirements and provide the details required for the construction of the two water storage tanks.

In response to UBC's concerns, the objective is to secure the water supply in the event of a failure of the current supply system, and the demand for the future population growth by a introducing water storage solution. The key considerations and issues for developing designs include an increasing population, infrastructure constraints, soil geology, materials, technical guidelines, cost, environmental issues, and community impacts.

The final design of the Water Supply System consists of two separate storage tanks with capacities of 9,000,000 L and 6,125,000 L. The first tank is located under University Village field, and the second tank is located under Rashpal Dhillon Track and Field Oval. The storage capacity provides drinking water to 24,000 people for up to three days. Two separate tanks allow a more resilient life to the community. Construction will begin on April 23rd, 2018 and be completed by July 5th, 2018. The total cost of the project of the selected design is $5,200,000, which includes the cost of initial planning as well as the completion of construction.

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1.0 Introduction

The client, UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program is requesting for a secure water supply system. This system is designed to deliver potable water to the campus population in the event of a failure in the main water supply. UBC Vancouver has gradually developed into a small scale city over the years, and continues to grow as the campus expands as well as further development of residential buildings. The campus currently serves approximately 55,000 people per day with future growth planned to reach a peak of 70,000 people. UBC is generally self-sufficient in terms of its resource usage. However, the supply of water is still highly dependent on Metro Vancouver's two water mains. Currently, both of these water mains feed off of the Sasamat Reservoir, which is located in the Pacific Spirit Regional Park some distance away from the campus. A failure in the reservoir or the water mains would mean that UBC's water supply is stopped, since there is currently no backup plan for this situation.

1.1 Project Objectives

The objective of the project is to design a water supply system at the UBC Campus in case of failure of current infrastructure. The team will base the design over many constraints and issues, including population demand, existing infrastructure, soil geology, materials, technical guidelines, cost, environmental issues, and community impacts. The preliminary design framework was established in a previous communication, and the preferred option was selected and justified. The purpose of this report is to continue to build upon the selected design option by developing the its structural details based on the technical design criteria.

1.2 Scope of Work

The scope of work as presented in this report includes the following:

- Review of the key design criteria, both technical and non-technical
- Detailed design of a secure water supply system for the UBC campus in an event of failure of a existing system
- Explanation of the structural details of the key components in the system
- A draft construction plan highlighting the construction timeline and key tasks
- A maintenance plan over the design life
- An updated cost estimate broken down into design, construction, and commissioning
- Detailed structural drawings issued for construction

1.3 Methodology

The project is developed in several stages. Firstly, a concept design for solution is generated, where the decision between storage tanks on campus or reinforcement of the water pipelines was determined. Since the design team decided to go with storage tanks, their locations had to be chosen with site visits. The initial concept design involved researching codes and standards relevant to the design. The first proposal was developed in order to acquire the permits. A decision matrix was developed in order to choose the best option for the design. This report serves to further develop the best option. Detailed calculation for each part of the design was made from softwares such as SAP2000 and other design codes. The report also provides the technical details and engineering drawing. From the acquired technical details, the final cost and schedule is developed. The next step is to proceed with construction.

1.4 Team Contributions

Table 1. Summary of Contributions

Members	Contributions
Kevin Gu	An updated cost estimate and schedule, specifications and estimates of service-life maintenance plan
James Song	Top slab specification, column specification
Jordan Cheng	Soil capacity specification, Design criteria
Andy Hsu	Detailed design outputs shown in drawings
Carol Zhuang	A draft plan of construction work and a brief discussion on anticipated issues related to specific site conditions
Oyuna Garmaeva	Retaining wall specifications, Codes, Standards & Software

2.0 Summary of Key Components

The detailed design is based on the preferred option selected in the preliminary design report. Two water tanks make up the storage system. Their specifications are summarized in the table below:

Table 2: Summary of Tanks

	Tank 1	Tank 2
Location	Rashpal Dhillon Track and Field Oval	University Village
Dimension	60 x 50 x 3 m	35 x 35 x 5 m
Capacity	9,000,000 Liters	6,125,000 Liters
Soil Coverage	1 meter	1 meter
Wall Thickness	250 mm	370 mm
Top Slab Thickness	500 mm	500 mm
Foundation Thickness	1500 mm	1500 mm
Column	400 mm in diameter	400 mm in diameter

The water pipes attached to the tank make up the other major components for the system. A summary table of the pipes is attached below:

Table 3: Summary of Pipes

	Pipes Associated with Tank 1	Pipes Associated with Tank 2
Pressure Zone Supplied	Low-pressure Zone	High-pressure Zone
Diameter	12’’ (300mm)	24’’ (600mm)
Origin	Low-pressure Zone Supply Line (16th Avenue)	Main Pump Station Supply Line (University Boulevard)
Destination	Low-Pressure Zone directly	Pump Station, then High-Pressure Zone
Additional Lines	None	Hospital Supply Line (to UBC Hospital) Emergency Pump Station Supply Line (to the emergency line that also goes to pump station)

3.0 Design Criteria

The team was tasked to design a water supply system to meet the growing demands of the UBC population while meeting the design standards. An important criteria to the design is to have the capability to provide enough safe drinking water for a population of 24,000 people in case of an emergency. Therefore, water quality is an important consideration to the final design. The team used a projected year of 2041 as the standard for the demand volume to design the two water storage tanks with a total combined volume of 15,125,000 L of water in order to meet the requirements.

The design criteria includes not only the technical aspect of the project, but also to minimize the costs such as construction and maintenance, as well as societal impact. It is important to minimize the construction disruption to the residents as well as the students, which will be reflected in the project schedule. Environmental impact is an important topic for UBC and therefore, a key consideration in the design and construction of the water storage tanks. Appearance is a common issue discussed in stakeholder engagements for projects that involve large structures.

3.1 Design Life

Despite the projected demand of 25 years, the design life of the water storage tanks will be greater. Based on the standards for the materials and construction, the storage tanks will have an adopted design life of 50 - 60 years. The life of the tanks will depend on the materials being used such as:

- PVC
- Reinforced Concrete
- Other Materials
    - Sealants
    - Joints
    - Finishing Materials

Based on the ACI 350 [2] guideline and industry standards, it was found that PVC and reinforced concrete will have a typical design life of 50 years. These major components will be the determinant of the life of the tanks. Other materials such as sealants, joints, and other finishing materials that help to protect the tanks and the drinking water will only last about 10 - 15 years. These materials will be replaced in accordance to the maintenance plans.

3.2 Water Considerations

The water demand values have been calculated conservatively, meaning that the capacities are designed for redundancy. Therefore, demands will still be met 50 - 60 years from now. However, instead of providing the required water for 72 hours, there will be a minimum of 24 hours of water usage which is still adequate in emergency situations. Currently, the 72 hours of water usage from the 24,000 residents could be divided into 36 hours of usage with 6 hours of fire flow at a rate of 300 L/s. The fire flow is a requirement as obtained from the Surrey Design Manual [7], which allowed the team to estimate the amount of water required for fire fighting. Additional storage tanks could be installed to increase the capacity, or regulation of the water usage during an emergency could be an alternative. The current usage calculations are not limited to only drinking, which results in a high demand. Regulations such as limiting the water usage for drinking only, or limiting the amount of water allowed per household could be a solution to future plans 50 - 60 years from now. The projection of 50 - 60 years' time is difficult due to changes in variables such as the rate of development.

Water quality is important to the design of the supply system as the task is to provide drinking water for emergencies. Therefore, a storage tank design must consider stagnation as to not retain the same volume of water for more than seven days, as per the Surrey Design Manual [7]. Thus, the best solution is to design a continuously flowing system where the storage only occurs when there is no inflow of water. The chlorination of the water must be maintained at around 0.2 mg/L. However, the storage tanks may reduce the amount of chlorination required due to the additional time in which the water spends inside the tank before being distributed. This increases the contact time, and therefore, the dosage of chlorine may be reduced.

3.3 Design Loadings

With the construction of large structures like the water storage tanks, the loads must be computed in order to determine the capacity required in order to support the loads. The values as summarized in the table below are based on a combination of standards from the BC Building Code, as well as computed self-weights of the structure based on the design. The bearing and structural capacity will be discussed in more detail in section 5 of the report. The values as summarized in the table below are all factored loads which offer a more conservative design and resiliency against natural disasters, such as earthquakes. It is important for the design loads to be met since the water supply of UBC will be dependent on these two storage tanks to supply water for up to 72 hours.

Table 4: Summary of Design Loads

	Rashpal Dhillon Track and Field Oval Underground Tank	University Village Underground Tank
Dimensions (m^3)	60 x 50 x 3	35 x 35 x 5
Dead Load (kPa)	140.5	188.1
Live Load (kPa)	8.2	8.2
Earthquake Load (kPa)	54.8	114.4
Moment (kNm)	56.0	579.5

4.0 Technical Considerations

4.1 Codes

Design of the project shall obey the codes specified below in order to qualify for being constructed:

- B.C. Master Municipal Design Standards
- CSA Standards
- UBC technical guidelines
- UBC Environmental Protection Policy #6
- UBC Sustainability Development Policy #5
- UBC Emergency Response plan- Water Utility
- Water quality - Health Authorities

Our main codes to follow are CSA standards, B.C. M.M.D. standards and water quality. Since, the project objective is to create a resilient water communication on UBC Vancouver campus thus it has to obey UBC emergency plan and technical guideline, UBC is following SEED policy therefore environmental protection policy #6 and sustainable development policy #5 shall be satisfied.

Concerning construction part of the project , the materials and construction shall meet the following standards:

- National Building Code of Canada (NBCC)
- B.C. Building Code
- B.C. Plumbing Code

- B.C. Master Municipal Construction Documents (MMCD)
- B.C. Water & Waste Association (BCWWA)
- American Water Works Association (AWWA)

4.2 Standards

The project being designed based on ACI350 code, drawing specifications obey ACI318 code.

The main section to follow in ACI 350 are listed below:

- ACI350.6
- ACI350.7
- ACI350.8
- ACI350.9
- ACI350.14
- ACI350.21

The specifications cover from the pipe and pipeline connections to all of the design specification for the different parts of the underground tank.

4.3 Software

The design process required to use several different software, which are listed below in Table 5.

Table 5: Summary of Software Used

Software	Application
SAP2000	Moment distribution on the top slab of the tanks
AutoCAD	Engineering and design drawing of the tanks
Excel	Load calculation for the parts of the tanks
Eurocode 8	Earthquake load calculation

5.0 Detailed Design

The detailed design is built upon the preliminary design developed previously. This section of the report is primarily concerned with the structural details of the two major parts: storage tanks and water pipes. The design of the storage tanks will be discussed by the structural components independently.

5.1 Design of Storage Tanks

From the preliminary design stage, the UBC Water Supply Project consists of two separate storage tanks: one at University Village and the other at the Rashpal Dhillon Track and Field Oval. The two tanks are designed to hold approximately 15 million liters of water in total. Both tanks are rectangularly shaped. The capacity of the University Village water tank is 35x35x5m, and that of the Track and Field Oval tank is 60x50x3m. Although the tanks have different dimensions, the design procedure is similar. The tanks are primarily made of reinforced concrete. The design of the tanks will be broken down into the top slabs, columns, bearing walls, and foundation. The design of steel rebars will also be discussed in the respective sub-sections.

5.1.1 Top Slabs

The top slabs are the cover for the storage tanks. The dimension for each of the top slab will be equal to the base area of each of the storage tank plus the thickness of the bearing walls. The designed thickness for both slabs on the two tanks is 500 millimeters. The slab is subject to the following design loads:

- Dead load: self-weight of the reinforced concrete, calculated with an assumed unit weight of 24 kN/m^3
- Soil load: weight of the 1-meter soil cover on top of the slab. The soil type is assumed to be silty sand with unit weight of 16 kN/m^3
- Live load: load from the surface, such as trucks, people, and equipment. It is assumed to be 4.8 kPa from the UBC Technical Guidelines

The design loads are factored and combined using formulas found in ACI 350. The top slab is supported by bearing walls on the four sides and by columns in the interior. The columns are spaced at 5 meters in a square array, while the side columns are 2.5 meters from the sides. To analyze the moment reaction in the beam, the slab is modeled as a beam on SAP2000. The results show that the slab is mostly subject to positive bending moment (tension at bottom). The factored bending moment diagrams are quite similar across to two tanks. Rebars are installed throughout the bottom section of the slab in both directions. The selected steel rebars will be of size 25M, and they are spaced at 400mm. Positive bending moment (tension at top) occurs near the columns only, but the magnitude is higher than the negative moment at bottom. Therefore, the rebars at top only need to extend 2 meters around the columns The top rebars are still of size 25M, but they will be spaced at 200mm instead to account for the higher magnitude of bending moment. The rebar cover will be 50mm for both top and bottom in accordance with the standards specified by the ACI 350.

5.1.2 Columns

The columns are located inside the storage tank and they support the loadings from the top slab. As previously mentioned, the columns are spaced at 5 meters apart. The height of the columns are equal to the height of each of the storage tanks. The columns in the University Village tank are 5 meters tall, and the columns in the Rashpal Dhillon Track and Field Oval tank are 3 meters tall. The factored loads taken by each column are therefore calculated using a tributary area of 5x5 meters. Because both tanks use the same column arrangement, the factored compression load for every column in the two tanks is effectively the same. The columns are assumed to be short columns for the simplicity of the calculations, so buckling will not be considered.

The columns are designed to be circular in shape. The factored compression load is approximately 1300 kilo-newtons for each column. Both the concrete and the longitudinal rebars will take the load. After iterative calculations, the optimal diameter of the columns is determined to be 400mm. Six longitudinal steel rebars will run through the whole length of the columns. They are size 20M and are arranged in a hexagonal pattern. Horizontal circular ties are used to stabilize the longitudinal rebars. They are size 10M and spaced at 300mm vertically.

5.1.3 Retaining Wall

The retaining wall for the structure is calculated based on size of the tank, therefore, each of the tank has different thickness of the wall, since the height difference is substantial therefore the reinforcement pattern in the wall is different as well. The retaining wall is calculated based on the soil specific gravity and the fill on top of the tank. It is calculated to maximum load situation where the soil outside of the tank is filled and the water inside of the tank is empty, since the mechanics where the tank is full with water inside and soil outside is filled resulting the force on the retaining wall being partially cancelled out, making the retaining wall less likely to fail in this situation. The thickness of the wall is determined from the load it must sustain without failure with a minimum reinforcement ratio, consisting from dead load of the structure and soil and earthquake load which is calculated based on ACI350.21. The combined load calculation is based on ACI350.7. The maximum bending moment is determined based on combined load and allowing to calculate the thickness of the wall with the cover depending on the type. The Rashpal Dhillon Oval tank has thickness of 250mm and 3m height retaining wall and University Village having 370mm thick and 5m tall retaining wall. The rebar calculations are based on minimum reinforcement specified in ACI350.9. Table 6 below shows the distribution of the rebar in each of the retaining wall. The detailed drawings for the retaining wall with the reinforcement pattern distribution are located in Appendix A4.

Table 6: Summary of Reinforcement Components

Reinforcement Component		Rashpal Dhillon Track and Field Oval Underground Tank	University Village Underground Tank
Rebars	Bottom part of the wall	15mm @ 60mm c/c	20mm @ 50mm c/c
	Top part of the wall	10mm @ 240mm c/c	10mm @ 190mm c/c
	Throughout the wall	15mm @ 120mm c/c at every 0.8m vertically c/c	20mm @ 100mm c/c at every 1.135m vertically c/c
Steel Shear Plate		15mm @ 50mm from the inner wall surface	15mm @ 50mm from the inner wall surface

The cover of the concrete is 50mm since the requirement for the water storage as specified in ACI350 does not require special type of concrete and requires a rebar cover of 50mm minimum.

5.1.4 Soil Capacity

The soil capacity calculations are based on same soil conditions and concrete density assumptions as stated in section 5.1.1. The capacity is broken down into bearing and shear. The bearing capacity of the soil is the ability for the soil to support the vertical load above it. This includes the weight of the concrete, soil backfill, and the water in the storage tank. The shear capacity of the soil is the resistance of lateral forces which involves the horizontal equivalent forces of the soil and water, and earthquake loads. The calculated tank pressures are known as the demands - the load that needs to be supported by the soil.

The bearing capacity of the soil was dependent its properties. Based on the assumption that the soil conditions are dense and sandy, the allowable bearing capacity was found to be 200 kPa from literature. The shear capacity was calculated based on the shear formula, which depended on the bearing load. The shear formula is as follows:

$$\tau = \sigma tan(\phi)$$

Where:

τ = *shear capacity*
σ = *bearing load* (*normal stress*)
ϕ = *soil angle of repose* (*soil property*)

Table 7: Soil Capacity of Rashpal Dhillon Track and Field Oval

Rashpal Dhillon Track and Field Oval (60 x 50 x 3) m^3		
	Allowable Soil Pressure (kPa)	**Calculated Tank Pressure (kPa)**
Bearing Capacity	200	148.7
Shear Capacity	86.6	54.8

Table 8: Soil Capacity of University Village

University Village (35 x 35 x 5) m^3		
	Allowable Soil Pressure (kPa)	**Calculated Tank Pressure (kPa)**
Bearing Capacity	200	196.3
Shear Capacity	116.6	114.4

It is important to note that the the smaller footprint of the University Village storage tank results in a larger demand. Therefore, the smaller tank has a smaller buffer between allowable and actual loads. But since the capacity had already been factored, a small safety factor was already applied.

5.2 Pipes

The tank at the University Village supplies water to the high-pressure zone, which includes much of the main campus. Two lines, one input and one output, connect the tank to the main pump station supply line from University Boulevard is are 24-inch in diameter. This ensures water always flows through the tank. The tank intakes the supplied water from Sasamat Reservoir upstream, and then releases it into the original downstream alignment of the pump station supply line. The pump station, contained within the UBC Powerhouse, can then supply water to all buildings in both the high and low pressure zones.

In the case that the main pump supply line fails, the 20-inch diameter emergency pump station supply line will handle the water supply to the whole campus. Therefore, the design option also includes a connection between the storage tank and the emergency line. This backup pipe, which branches off the output line and joins the emergency line, is normally closed. Another branch connects the outlet line with the UBC hospital so that the hospital still receives continuous clean water in case of emergency.

The tank at Rashpal Dhillon Track & Field Oval supplies water to the low pressure zone, which includes the Wesbrook Village and many residences. The intake of this tank is from the 12-inch low pressure supply line. The tank releases water back into the same line so that it contains running water.

Detailed maps of the pipeline network can be found in the appendices.

6.0 Construction Plan

6.1 Construction Sequence

The construction sequence of the project is shown in Figure 1 below. The construction will begin on April 23, 2018, and it is estimated to be completed on July 5, 2018. The duration of the construction is a little more than two months. A brief summary of each tasks in the construction sequence is demonstrated in Table 9. The commissioning task needs to take place before the landscaping task. Since the water tanks are located underground, the water tightness test should be performed before placing backfill around the water tank in order to make observations and detections of leakage points. The water tightness test will be carried out by filling the water tanks with water. If the leakage problem occurs during the test period, the tanks should be emptied and the leakage need to be repaired before continuing. In addition, the concrete tank cannot be filled with water until all concrete components have achieved the designed compressive strength of the concrete (greater than 14 days). (General Technical Specifications for the Construction of Concrete Water Tanks, Palestinian National Authority)

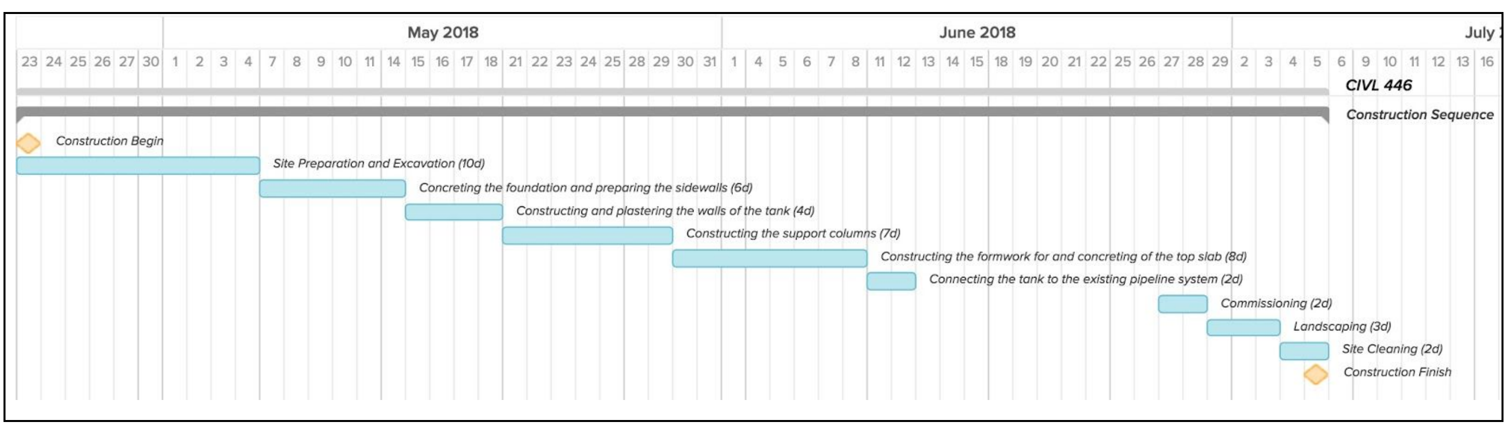


Figure 1: Construction Sequence of the Project

Table 9: Brief Summary of Each Tasks in the Construction

Tasks	Description
Site Preparation and Excavation	Clearing, grubbing, and grading; Removing existing plants, trees, shrubs and topsoil; Site excavation for the water tank and pipeline.
Foundation Work	Installing the concrete mat foundation and reinforced concrete bottom slab.
Retaining Walls	Installing the prefabricated concrete retaining wall, rebar and shear steel plate
Support Columns	Installing the prefabricated concrete support columns in the water tank with reinforcement
Top Slab	Installing the reinforced concrete top slab of the water tank and steel rebar
Pipe work	Connecting the water tank to the existing pipeline system; Pipe installation; Pipe testing.
Commissioning	Do the water tightness test for the water tanks by filling tank with water; Test the pipeline system, stability of the structure; Water tank and pipeline disinfection.
Landscaping	Backfilling and soil compaction; Installing the vegetation, plants, shrubs, gravel paths, etc.
Site Cleaning	Site clean-up, touch-ups and final walk-through

6.2 Work Breakdown Structure

Table 10 shows the hierarchy structure of the WBS. The project is divided into five main stages, which is initiation, design, execution, control and closeout. Figure 2 provides a visual representation of the WBS of the project. In addition, a much more detailed version of activities under each WBS code is provided in Appendix B.

Table 10: Work Breakdown Structure of the Project

Stages	Tasks
Initiation	1.1.1 Client Engagement 1.1.2 Obtaining Documents 1.1.3 Review Documents 1.1.4 Conceptual Design 1.1.5 Preliminary Design
Design	1.2.1 Detailed Design 1.2.2 Stakeholder Engagement 1.2.3 Finalized Design 1.2.4 Permits Obtained
Execution	1.3.1 Site Deconstruction 1.3.2 Site Excavation 1.3.3 Concreting the foundation 1.3.4 Bottom concrete slab installation 1.3.5 Constructing and plastering the retaining walls 1.3.6 Constructing the support columns 1.3.7 Constructing the formwork for and concreting of the top slab 1.3.8 Connecting the tank to the existing pipeline system 1.3.9 Landscaping
Control	1.4.1 Commissioning
Closeout	1.5.1 Site Cleaning

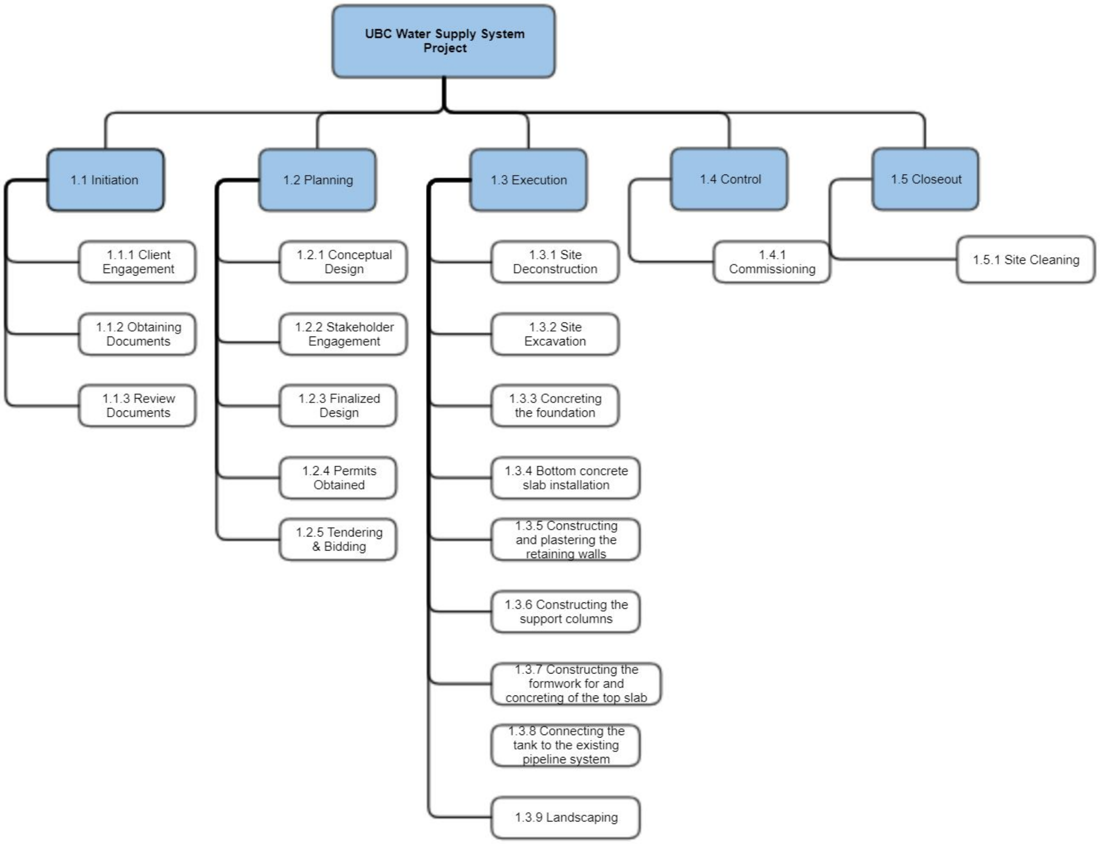


Figure 2: Organizational Chart of the Project Work Breakdown Structure

6.3 Anticipated Issues

During the construction of the proposed water supply system, some challenges will come up. It is important to anticipate some issues that may cause negative impacts on the project before the construction starts. This can give sufficient time for the project team to develop the mitigation strategies and an appropriate construction plan, which is critical for the overall success of the project. The following list provides the critical issues that may arise during the construction process:

- Risk of shoring collapse during excavation
- Leakage problem may occur when connecting to the existing pipeline systems
- Heat problem may arise since the construction takes place in the summer
- Concerns that there will be material or equipment delays or worker shortages that will drag the construction beyond the schedule
- Issues related to the parking disruption and redirection of traffic during the construction

6.4 Maintenance Details and Plans

The concrete water storage tanks are designed and constructed to serve and operate trouble free for an extended period of years; however, regular maintenance operations should still take place in order to prevent potential massive repair in the future due to issues such as gradual corrosion and water quality fluctuation. Regular maintenance activities should include the following:

Table 11: Maintenance Activities and Detailed Specifications

Maintenance Activity	Comment
Routine Inspection and Maintenance	Initial inspection take place 1-2 years after construction followed by inspections every 3-5 years, partially drain the tanks when inspecting and maintaining
Interior Coating Reapplication	Remove the existing coating and reapply new interior coating every 10-15 years
Exterior Overcoating	Wash the existing coating and apply penetrating sealer over the existing exterior coating, then apply new coating on top of it, perform overcoating for exterior every 15-20 years
Structural Analysis	Conduct structural and buckling analysis of the tanks and perform any necessary upgrades every 30 years

7.0 Cost Estimate

7.1 Work Breakdown

For this project, the first level of the work breakdown structure is broken down into three fundamental components: design, construction and commissioning. The Tank section is where the most of the sub categories are comprised with the detailed cost found in the below figures. The tank cost makes up the majority of the total cost due to the large volumes of concrete and steel. The total cost for the project is estimated to be approximately $5,200,000. The cost below does not include PST (7%) and GST (5%).

Table 12: General Project Cost

Scopes	Cost
Excavation	$40,000
Tank Cost	$3,282,125
Disinfection	$15000

Table 13: Pipeline Cost

Pipe properties	Amount Pipe used for project	Cost
PVC Pipe 20 Inch Diameter Wall Thickness: 0.59 Inches	(5760+5040) = 10800m	$853,200

Table 14: Labour Cost

Labour	$/hour
Superintendent	59
Project Manager	50
Project Coordinator	35

Safety Officer	50
Site Coordinator	36
Construction Worker	25
Total Cost for Project	$412,800

Table 15: Construction Cost

Type	Cost ($)
Earthwork	96,000
Backfill	15,730
Equipment Cost	33,730
Resurfacing / Replantation	116,000
Sum	**261,460**

Table 16: Permit Cost

Development Permits and Fees	Units	Cost (Dollars)
Minor Applications	1	1600.00
Planned Development Fee	1	1852.00
Unoccupied Commercial and Utility Construction	1	1362.00
Construction Inspection Fee	1	1643.00
	Subtotal	**4814.00**
Plumbing Permits	**Units**	**Cost (Dollars)**
Plant Plumbers	6	3,892.39
Installation of Fixture Permit	7	371.00
Alteration of Plumbing	2	496.00
	Subtotal	**4759.39**
Building Permit	**Units**	**Cost (Dollars)**
Fire Hydrant Permit	4	200.00

Tree Removal Permit	4	559.00
Sidewalk and Road Permit	1	200.00
Sign Permit	2	189.80
	Subtotal	**1148.8**
Utility Permit		700.00
Total Permit Cost		**13065.19**

7.1.1 Project Management Team

The roles associated with this project are as follows.

Table 17: Median Salary of Project Management Team

Roles	Work Tasks	Median annual salary in BC
Project Manager	Planning, procurement, and execution of project	$73,365
Construction Workers	Carry out task to construct the design	$40,000
Construction Manager	Expertise in construction cost and	$65,849
Civil Engineers	Perform analysis and validity of the project at hand	$65,849

7.1.2 Construction Team

Five main roles comprise in the construction team and are listed in the table below. Electrical, mechanical engineers, and civil engineers are included in the engineers section and the cost are broken down as follows in the table below.

Table 18: Median Salary of Construction Team

Roles	Work Tasks	Median Annual Salary in BC
Electrical Engineers	Design systems that uses electricity within the pipelines	$64,754
Civil Engineers	Perform analysis and validity of the project at hand	$65,849
Mechanical Engineers	Perform analysis and validity for plumbing, piping, heating for the pipeline system	$66,623

7.2 Disbursements

7.2.1 Minor Disbursements

Minor disbursements are charged at 8% of professional fee. These may include:

- Local communication costs (phone, cell phone, etc);
- Routine production of drawings and documents
- Local travel expenses from home to site and return
- Standard software and computer costs
- Offices supplies

7.2.2 Miscellaneous Costs

Table 19: Miscellaneous Costs Breakdown

Contractor Misc Cost	Cost ($)
Insurance	5,000
Temporary Power	2,300
Communication	700
Toilets	500

Waste Management	10,000
Electrical	6,000
Survey	11,000
Total	35,500

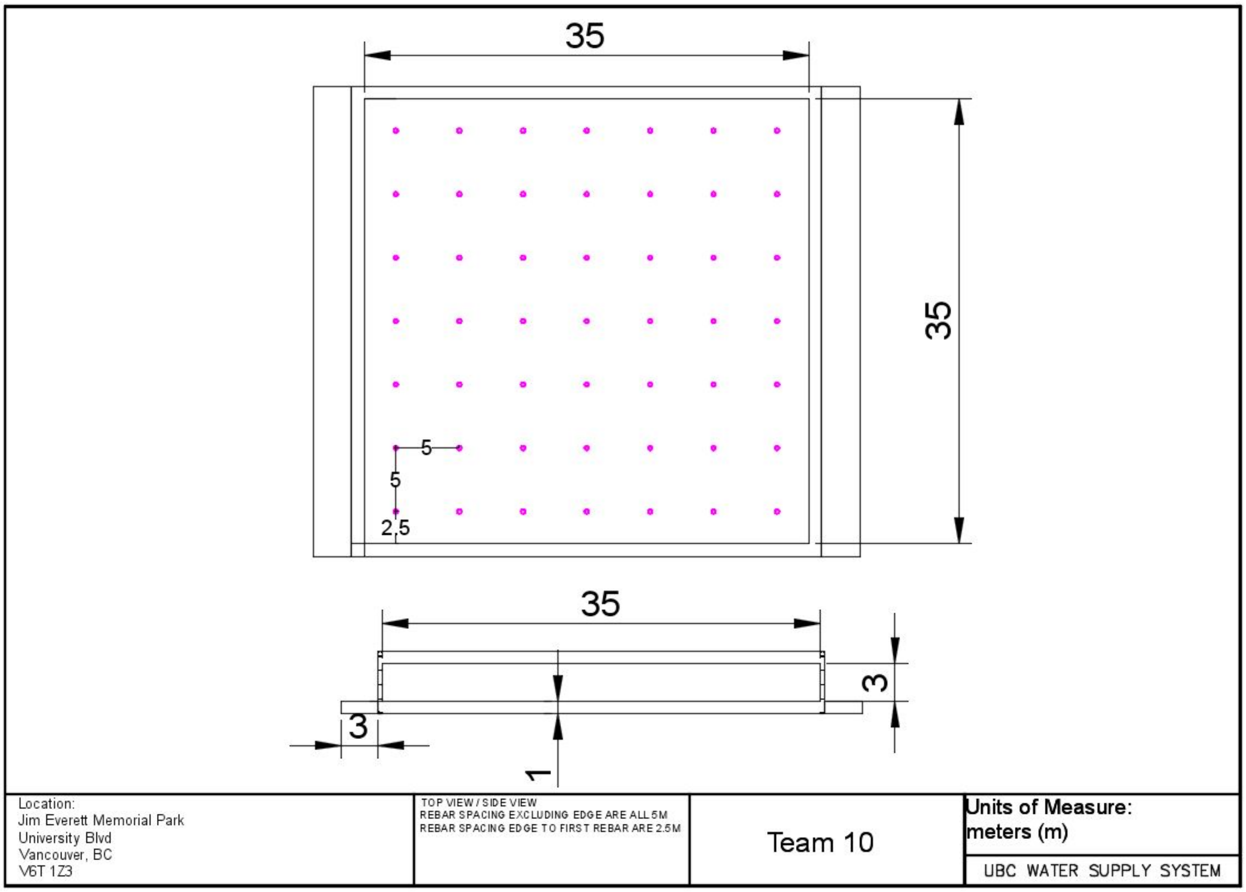
References

1. http://responsiblechoice.info/wp-content/uploads/Validation-of-long-life-of-PVC-pipes.pdf
2. http://www.technicalguidelines.ubc.ca/technical/structural_design_snow_loads.html#d
3. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/water/livestock-watering/590307-1_winter_considerations.pdf
4. https://www.eurocodeapplied.com/design/en1998/mononobe-okabe
5. http://www.civilengineeringbasic.com/mat-foundation-advantages-disadvantages/
6. City of Surrey, "City of Surrey," July 2016. [Online]. Available: https://www.surrey.ca/files/DesignCriteria.pdf. [Accessed January 2018].

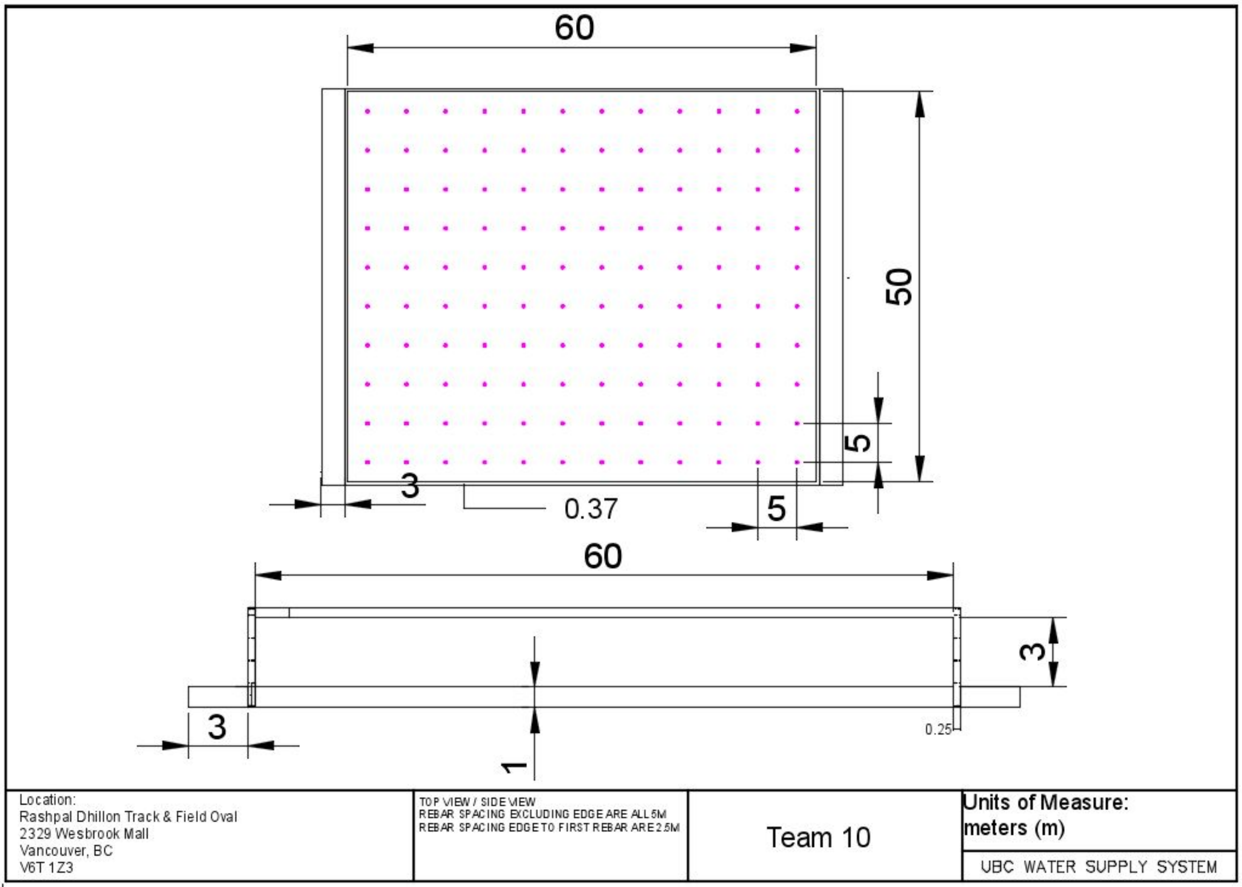
Appendices

Appendix A: Engineering Drawing for Storage Tanks

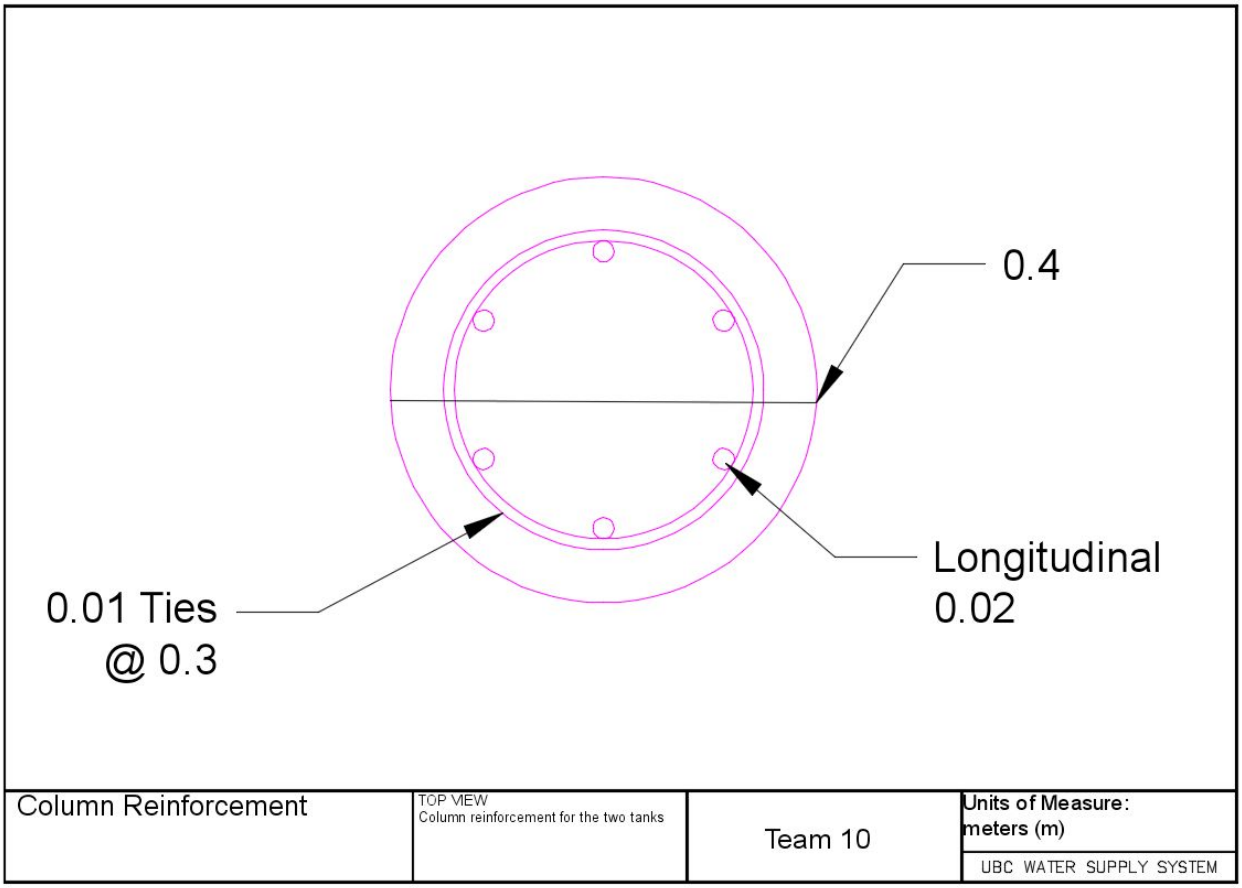
A1. Plan View of University Village Tank



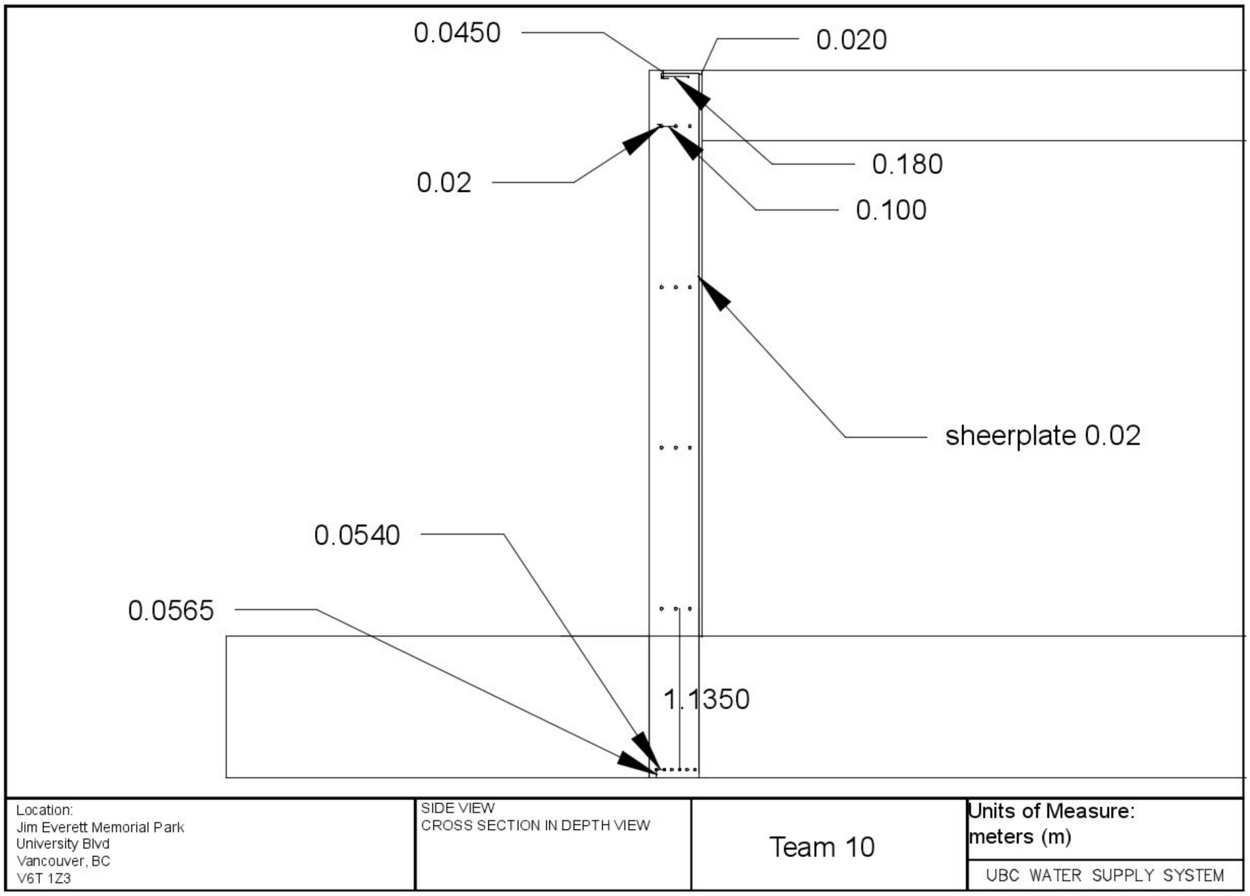
A2. Plan View of Track and Field Oval Tank



A3. Cross-sectional View of Column



A4. Cross Section View of University Village Tank



Appendix B: Detailed Work Breakdown Structure

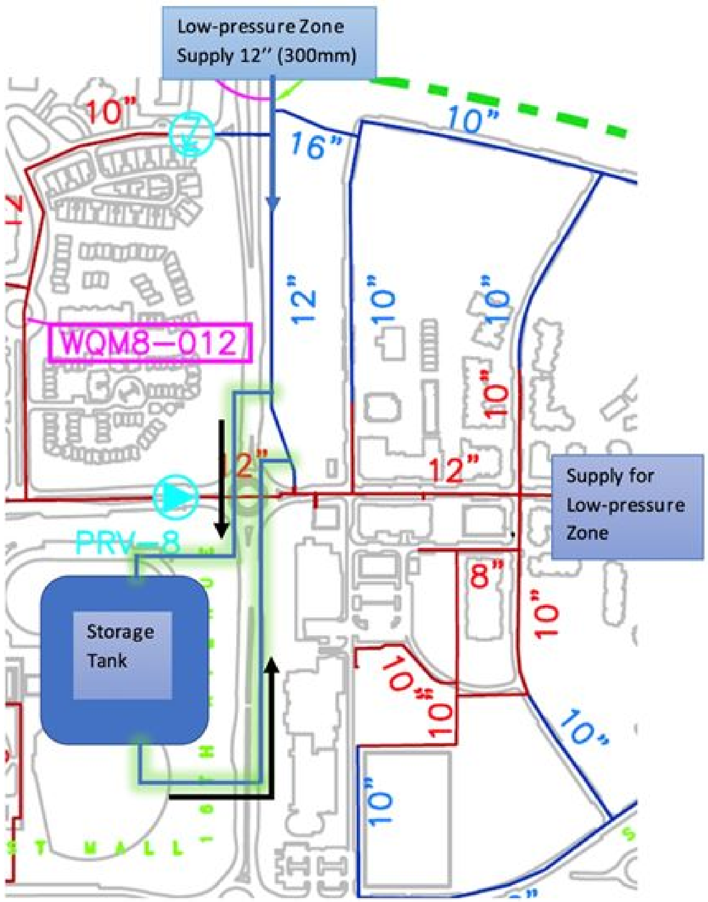
Level	WBS Code	Element Name	Description
1.1	1.1.1	Client Engagement	**Client:** Doug Doyle, P. Eng, Assoc. Direction, Infrastructure and Services Planning, UBC Campus and Community Planning David Gill, Program and Policy Planner, UBC SEEDS (Social Ecological Economic Development Studies) Sustainability Program, Campus and Community Planning **Program:** University of British Columbia-UBC SEEDS(Social Ecological Economic Development Studies) Sustainability Program
	1.1.2	Obtaining Documents	Obtain relevant information and technical requirements about the proposed area. e.g soil condition, contour, topographic, storm, water, etc.
	1.1.3	Review Documents	General review of documents mentioned above

1.2	1.2.1	Project Design	Project design includes conceptual, preliminary and detailed design: **Conceptual** - Present three different conceptual designs to clients and decide on one to progress with using a decision matrix. **Preliminary** – Prepare a report outlining the water tank with a decision matrix, Implementation schedule, cost estimation and relevant drawings/calculations. **Detailed** - Provide a detailed report with Detailed calculations on the dimensions of all components of the water tank with a more refined schedule and cost estimation. And also, detailed engineering drawings for all elements of water tank are developed.
	1.2.2	Stakeholder Engagement	Relevant stakeholders: · Client · Design team · Construction team · Neighborhood · UBC Campus (Students, Professors and workers, etc.)
	1.2.3	Finalized Design	Milestone
	1.2.4	Permits Obtained	Building and development permits approved
	1.2.5	Tendering & Bidding	Respond to the open Request for Proposal (RFP) through the tendering process.

1.3	1.3.1	Site Preparation and Excavation	Clearing, grubbing, and grading; Removing existing plants, trees, shrubs and topsoil; Site excavation for the water tank and pipeline.
	1.3.2	Foundation Work	Installing the concrete mat foundation and reinforced concrete bottom slab.
	1.3.3	Retaining Walls	Installing the prefabricated concrete retaining wall, rebar and shear steel plate
	1.3.4	Support Columns	Installing the prefabricated concrete support columns in the water tank with reinforcement
	1.3.5	Top Slab	Installing the reinforced concrete top slab of the water tank and steel rebar
	1.3.6	Pipe work	Connecting the water tank to the existing pipeline system; Pipe installation; Pipe testing.
	1.3.7	Commissioning	Do the water tightness test for the water tanks by filling tank with water; Test the pipeline system, stability of the structure; Water tank and pipeline disinfection.
	1.3.8	Landscaping	Backfilling and soil compaction; Installing the vegetation, plants, shrubs, gravel paths, etc.
	1.3.9	Site Cleaning	Site clean-up, touch-ups and final walk-through

Appendix C: Pipeline Network

C1. Pipes Associated with Low-pressure Zone



C2. Pipes Associated with High-pressure Zone