UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

UBC Secure Potable Water Supply System - Team 9

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University of British Columbia

CIVL 445

Themes: Water, Community, Land

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Executive Summary

Team 9 & Associates has been retained by the University of British Columbia's Social Ecological Economic Development Studies to create issue for construction drawings and detail specification to perform the construction of a secure water supply system for UBC and the surrounding community. The intent of this document is to provide an overview of the detailed design being undertaken for UBC's secure water supply – specifically the design of the underground tank and distribution system, an updated Class B 'Substantive' cost estimate, detailed construction schedule and a service life and maintenance plan. This will extend the previous findings and recommendations from the summary report issued by Team 9 on March 2, 2018.

This report outlines the design inputs, methods, models, and outputs that have been used by Team 9 in the process of producing a final design. A summary of design recommendations are as follows:

<u>(1) Underground Storage Reservoir:</u>

Geotechnical Considerations – floating foundation design

Structural Design Elements – loading conditions: (a) empty tank condition, (b) standing waves.

Envelope – Concrete mix as per ACI standards, waterproofing from Kryton International

<u>(2) Distribution System:</u>

Pipe Design – 450 mm dia. class 50 ductile iron main with 1.0 m cover, minimum

Pump Requirements – 5 vertical in-line centrifugal pumps in parallel

<u>(3) Construction Schedule:</u>

Schedule – 30 days for watermain and 147 days for storage tank

<u>(4) Class B 'Substantive' Cost Estimate:</u>

Life cycle cost – total life cycle cost (capital and O&M) over 50 years is estimated at $7.25 million.

Issue for construction (IFC) drawings, the primary deliverable of this report can be found in Appendix I.

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Disclaimer

This document has been prepared by Team 9 & Associates in accordance with generally accepted engineering and geoscientist practices and is intended for the exclusive use and benefit of UBC SEEDS.

Definitions and Terminology

Metro Vancouver water supply line (supply line)	The main water pipe connecting UBC's water distribution system to Metro Vancouver's. It runs from Sasamat reservoir on West 16th Avenue, to the UBC campus.
Water demand/level of service estimate	The estimated amount of water required by UBC and the surrounding community, during and emergency event.
Potable water	Water that is safe to drink
Service population and service period	The amount of people that are using the emergency water supply and for how long they are using it
Factor of Safety (FOS)	An engineering term used to measure additional capacity of a design, to properly address safety concerns
Distribution point/station	A predetermined location where users can go to access potable water during and emergency
Net present value	The value of something in today's money, in contrast to it's future value
BEP	Best efficiency point
Pump Working Point	As per system curve diagram – working point refers to the pump head (TDH) and flow rate (Q)
TDH	Total dynamic head
O&M	Operations and maintenance
DI	Ductile iron
NBCC	National Building Code of Canada

1 Introduction

In the event of an emergency or a system malfunction - there is the potential for Metro Vancouver's water supply line to UBC to fail, leaving roughly 68,000 students, faculty, staff and residents on campus without potable water. The University of British Columbia Social Ecological Economic Development Studies (UBC SEEDS) wishes to address the need for infrastructure resiliency on campus and design an emergency system that provides access to potable water during such an event.

Previously, Team 9 completed the preliminary design of the secure water supply system – which resulted in: (1) a water demand estimate for the campus and surrounding area (in an emergency event) of approximately 13,700 m^3; (2) calculation of existing storage capacity at UBC's Aquatic Centre; (3) a below-grade storage tank under the existing Rashpal Dhillon track and field oval – in addition to a distribution system to fulfill the estimated water demand; and (4) a building integrated water tower located at the Marine Drive residence. The remainder of this report provides detailed design deliverables to carry-forth with construction of the recommended system, as well as provide details on the operations and maintenance over its lifecycle.

1.1 Methodology

Team 9 & Associates' previously completed the preliminary design of UBC's secure water supply system project. Team 9 has taken the preliminary design and produced detail drawings and technical specifications issued for construction. This was done by combing technical expertise, design standards and guidelines, and engineering modelling/calculations. The roles and responsibilities of Team 9 personnel to deliver these detailed design outputs for the final report submission are shown below in Table 1-1.

Table 1-1: Team Roles and Responsibilities

TEAM MEMBER	PROJECT ROLE	SECTIONS COMPLETED
Bradley Jenks - EIT	Water Resources Engineer	Pump energy, distribution system hydraulics, cost estimate
Brennan Jay - EIT	Project Manager/Design Team Lead	Storage Tank: geotechnical considerations, CAD drawings, scheduling, construction methods
Brian Tingley - EIT	Materials Engineer (Concrete Specialist) and Estimator	Storage Tank: building envelope, CAD drawings, cost estimate
Jason Morden - EIT	Graphics Design Engineer/Water Sustainability Liaison	Storage Tank: structural design, CAD drawings and public awareness considerations
Karm Poonian - EIT	Land Development Engineer/Business Lead	Distribution: network characteristics and civil drawings
Sony (Yudong) Fu - EIT	Structural Engineer	Storage Tank: structural design calculations and CAD drawings
Viraj Mann - EIT	Mechanical Systems Engineer and Scheduler	Distribution: pump house detailing and civil drawings

1.2 Scope of Work

The extents of the project are delineated by two main sections: (1) storage tank design, and (2) the distribution system – in addition to a combined cost estimate and construction schedule.

Storage Tank Scope:

- Site description – previous usage
- Geotechnical assessment and design
- Detailed design drawings (dimensions, plan view, section view
- Structural loading conditions and design (reinforced concrete walls, footings and foundation)
- Building envelope (waterproofing/sealant)

Distribution System Scope:

- Computer modelling of system demands
- Design of a pump configuration to fulfill demand
- Pipe system design for both connection to existing system and temporary lines
- Pump house design

It is to be noted that this report strictly conveys the inputs and outputs of the detailed design for UBC's secure and resilient water supply system (as per list above).

2 Stakeholder Analysis

The emergency water supply and distribution system for the UBC campus will have considerable impact on the surrounding areas and the various stakeholders – identified in Table 2-1. A measure of success on any project considers the satisfaction of all its stakeholders. Consequently, an effective stakeholder engagement strategy must be employed during the detailed design phase.

A successful stakeholder engagement strategy begins with building an early relationship with the members involved. Therefore, Team 9 will first inform the stakeholders about changes to their neighborhood that may affect them before, during and after the construction of the new system, and give them an opportunity to influence these decisions. To ensure these criteria are met, a community liaison officer (CLO) will be appointed, which will act as a communication channel from stakeholders to management, and vice versa. The CLO duties will include implementing stakeholder engagement strategies, policies and procedures and ensuring that stakeholder interests and expectations are analyzed and maintained throughout the delivery of the project. The CLO will also look after tracking and monitoring progress and outcomes of stakeholder engagement activities. For this project, Dr. Yahya Nazhat will be appointed as CLO.

Table 2-1: Project Stakeholders

- Local Shops/Business – Water user
- First Nations – Water user, environmental protectors
- Metro Vancouver – Water suppliers
- UBC Properties Trust – Land usage
- Students/Faculty/Residents – Water user
- Funder/Donors – Financiers
- UBC Building Operation – O&M
- UBC Board of Governors

3 Project Overview

Team 9 & Associates' developed a preliminary report to address the issue of securing potable water access on campus during an emergency event – such as an earthquake. Two main objectives communicated with UBC SEEDS in the design of a resilient supply system are:

1. Access to clean potable water during an emergency event at the University of British Columbia
2. Develop a feasible way of water storage and distribution on campus

2.1 Key Design Components

Team 9 and Associates proposes a below-grade concrete tank - storing 8,800 m3 of potable water. Which, alongside the UBC Aquatic Center, will satisfy the requirement for potable water storage of approximately 13,700 m^3 determined in the preliminary report. Specifically, two different components were used to address the total required storage volume:

Design 1 – Below-grade storage tank ~ 8,800 m^3

Design 2 – UBC Aquatic Centre swimming pool water supply ~ 4,900 m^3

The location of the storage tank and pump house will be below the athletics track at Thunderbird Park, in conjunction with the UBC Aquatic Centre located in the north section of campus (Figure 3-1). Please note that Team 9 did not move forward with the building integrated water tower (BIWT) – as proposed in the preliminary report. This was previously agreed upon with UBC SEEDS due to its insignificant increase in storage volume, yet substantial increase in cost.

Figure 3-1: Proposed System Overview

Regarding the distribution of water to users in an emergency event, the proposed system will consist of:

1. Pump house capable of lifting water to locations indicated in Figure 3-1,
2. 450mm ductile iron (DI) main connecting to UBC's existing system (Scenario A),
3. Temporary distribution conduit used in Scenario B and C to distribution points

2.2 Design Criteria & Constraints

Due to the nature of the project, design constraints were combined with design criteria to create a framework of goals for the preliminary and detailed design. Both technical and non-technical aspects are discussed below.

2.2.1 Technical Criteria

(1) Resiliency – Given that the system designed must remain functional during an emergency, a resilient design is an imperative.

(2) Environmental Responsibility – Mitigation of impact to the environment is considered throughout the entire life of the system, from construction to decommissioning.

(3) Constructability and Permitting - The design requires conformance to all applicable standards and codes to ensure a smooth permitting process. Furthermore, the design needs to be considerate of common construction practices as well as the impact to the surrounding community.

2.2.2 Non-technical Criteria

(1) Life-cycle Cost – Economics must be considered at every stage of the systems life. By considering this in the design process, UBC SEEDS can avoid unforeseen future costs.

(2) Aesthetics – Creating an aesthetically pleasing design for all users and stakeholders.

(3) Public Awareness – Ensuring all users of potable water at UBC are aware of the three (3) demand scenarios, the water restrictions that encompass them, and where to access their allotted quantity.

4 Below-grade Storage Tank

The primary design element pertaining to storage is the below-grade water storage tank located at Thunderbird Park. The tank is responsible for the storage of 8,800 m^3 of potable water, must have a resilient and durable design, and must be able to facilitate operation and maintenance over its lifespan. The preliminary plan and section drawings for the tank are shown in Figure 4-1. The large mass concrete storage tank provided unique design challenges including standing wave analysis and constructability. Team 9's multi-disciplinary design team has produced a comprehensive design solution to meet the design criteria in an efficient and effective manner.

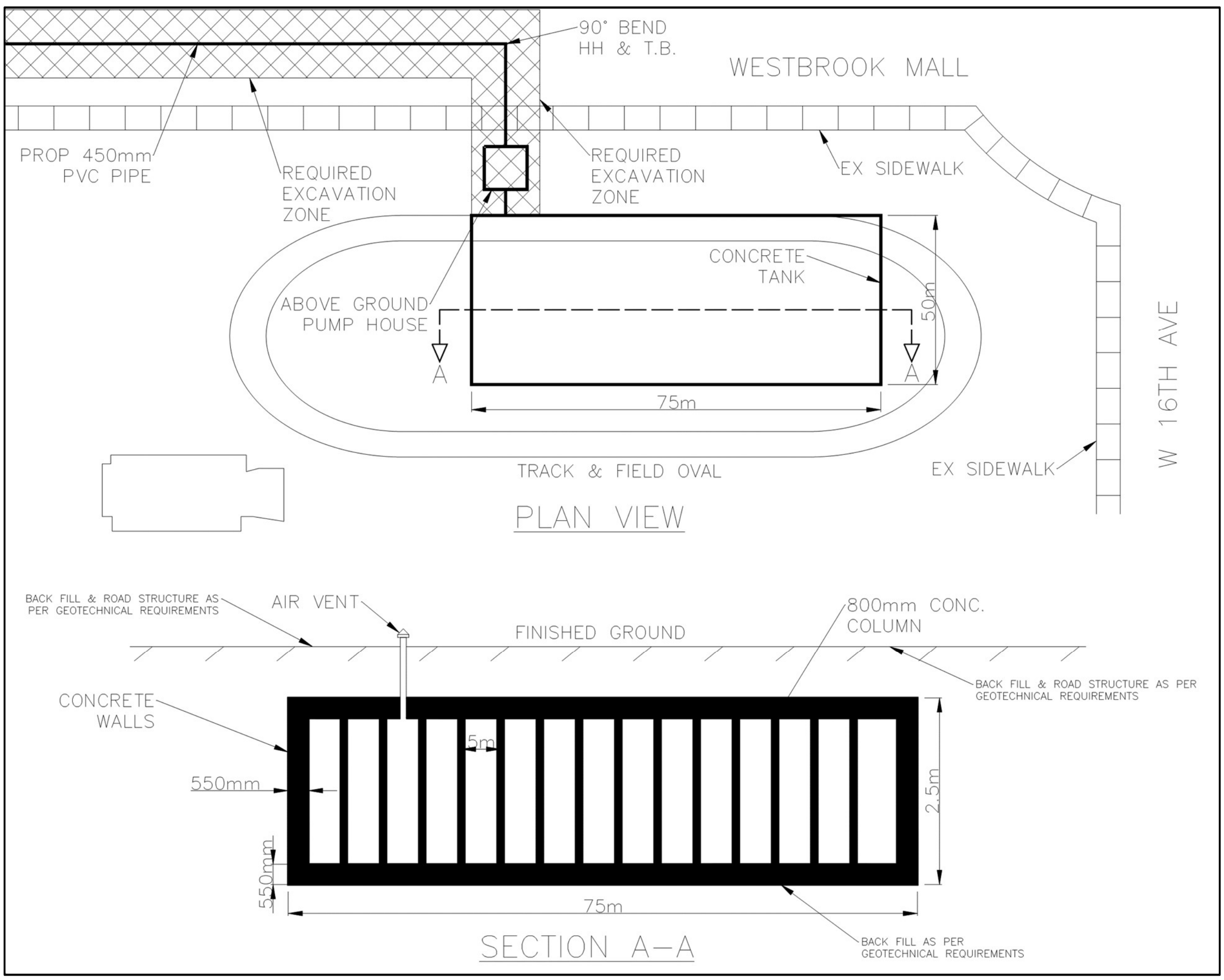

Figure 4-1: Conceptual Underground Tank Plan and Section View

4.1 Design Criteria

The underground tank's primary design criteria include the following:

- Have the capacity to hold the estimated amount of potable water.
- Require a feasible amount of operation and maintenance demand over its stated 50-year design life.
- Hold paramount a resilient design to ensure UBC has a secure source of water supply after an emergency event.
- Uphold the highest quality of water standards to provide to student, faculty, staff and the surrounding communities.

The three principal design aspects are geotechnical, structural, and building envelope. Design strategies, procedures, checks and outputs are described in the following sections.

4.2 Standards & Modelling Software

Notable design standards referenced for the tank design include:

- UBC Building & Excavation Permit
- Canadian Standards Association (CSA)
- NBCC – Section 9
- American Concrete Institute (ACI)

Figures displayed in this section of the report and IFC drawings in Appendix I were prepared using Civil 3D and Bluebeam software.

4.3 Technical Considerations & Design Outputs

4.3.1 Geotechnical

To achieve cost and time savings, Team 9 undertook a floating foundation design, which would require minimal site investigation. The floating foundation design was carried out in accordance with the CIVL 410 design guidelines (Nazhat, 2017). The floating foundation design is ideal for a number of reasons, shown below in Table 4-1.

Table 4-1: Floating Foundation Design Advantages

Floating Foundation Design Advantages	
1.	While minor testing is recommended to confirm the level of the water table, a full-scale investigation is not required,
2.	The assumed dense sand soil conditions will experience minor swelling,
3.	The below grade tank will have exceptionally uniform structural loading, so foundation tilting is not expected to be a concern,
4.	The shallow depth of excavation minimizes the chance of bottom heave or foundation wall collapse.

The inputs to this design method include the foundation depth below grade of 4.65m, the soil density, and undrained shear strength. The design checks were carried out using an assumed soil density from the Piteau Report (provided by UBC), in conjunction with appropriate assumptions made by Team 9.

Design Procedure

The basis of the design is that the weight of the soil material removed from the site is approximately equal to the weight of the new structure and its loadings once constructed. An overview of the design procedure is shown below (Figure 4-2), in addition to detailed sample calculations in Appendix V.

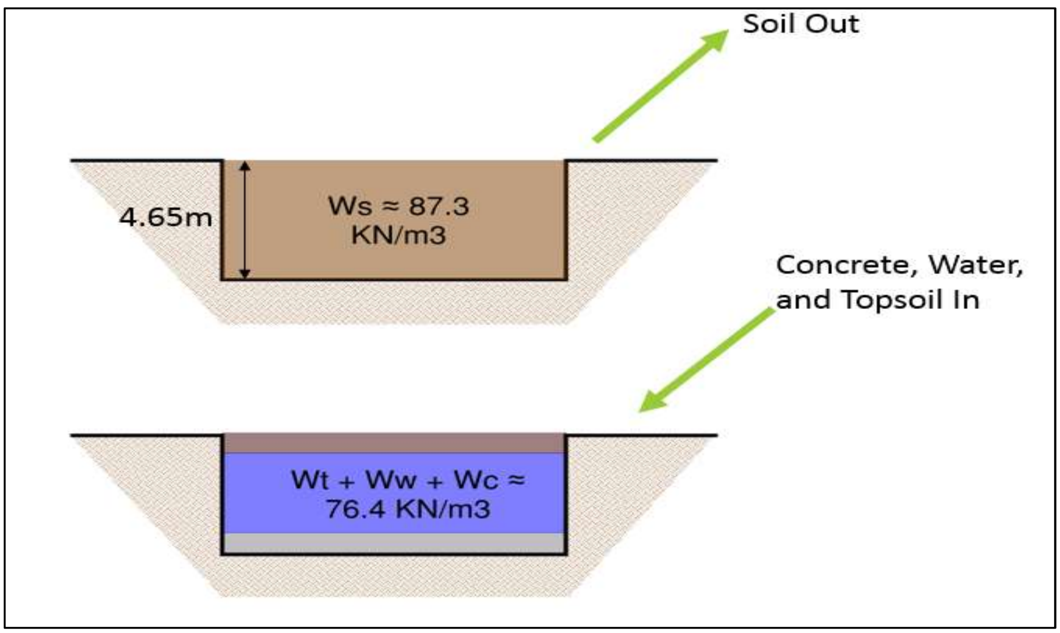

Figure 4-2: Floating Foundation Method

Displaced Soil Weight = Weight of New Tank

- Ws = Wt + Ww + Wc

- Ws – Weight of Displaced Soil
- Wt – Weight of Topsoil and Landscaping
- Ww – Weight of Water
- Wc – Weight of Concrete

The percentage difference in the material weights is approximately 9% - which is within the acceptable range.

Liquefaction

As resiliency in the event of a disaster such as an earthquake is a key aspect of the below-grade tank design, a liquefaction assessment was carried out. A maximum ground acceleration of 4.0g and a magnitude 7 earthquake was used for the assessment. The results of the assessment are displayed in Figure 4-3 below. The factor of safety method was used.

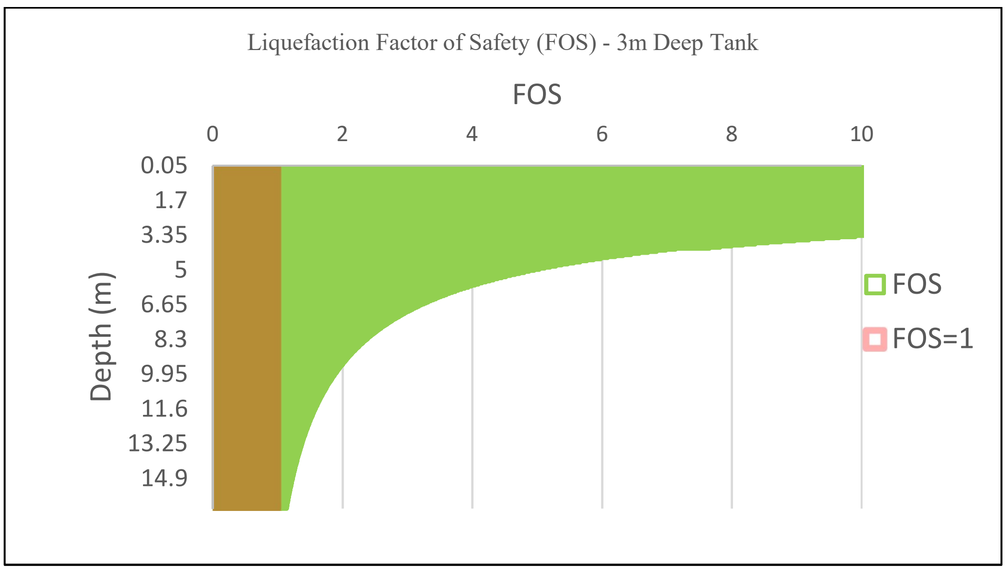

Figure 4-3: Liquefaction Assessment

As seen in the above figure, the factor of safety for liquefaction exceeded 1 for the depth of 15m below the bottom of the below grade tank. This is shown by the green region of the chart being above the red region of the chart. These results can be expected due to the dense nature of the sand, and the drained conditions assumed.

4.3.2 Structural

The tank walls are designed to be foundation walls to support the vertical loadings from a one-story building with vertical and horizontal reinforcement placed based on the loading listed below:

Table 4-2: Loading Parameters

Live Load	Dead Load	Load from Soil Layer Above
200 kg/m^2	360 kg/m^2	15kPa

The overall dimensions were selected to satisfy the required loading conditions. The structural elements were designed as follows (see Appendix V for details).

Foundation Walls – determined in accordance to NBCC Table 9.15.4.2 and CSA 23.3 design criteria

- The walls are subject to lateral forces from the surrounding soil and from stored water and ground water with design considerations of corrosion and seepage effects,
- Two loading conditions are considered: the tank being empty as well as additional loading from standing waves caused by oscillation and ground movement from earthquakes,

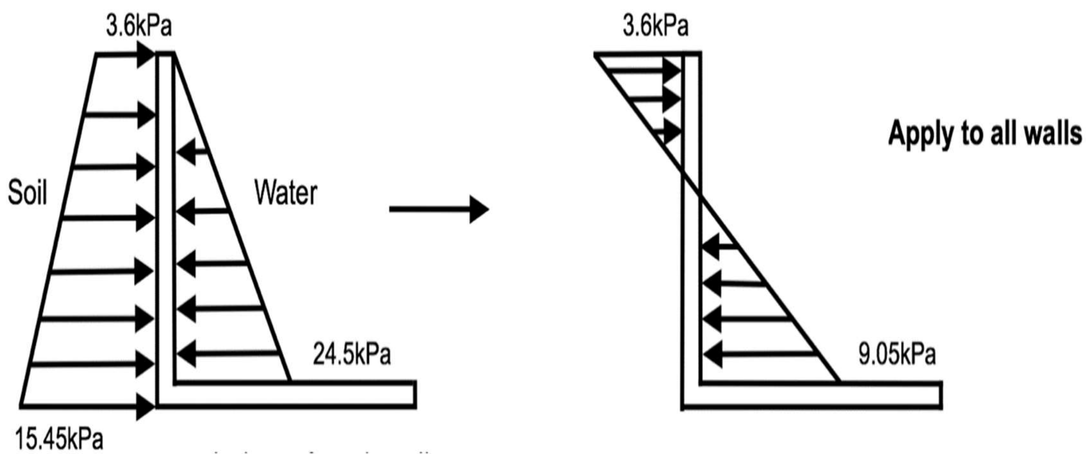

Figure 4-2: Foundation Wall Loadings

T-shaped Footings:

- 400mm joists spacing was used for top slab with a 3000mm span. Joists spans transfer loads to the footings and additional rebar cages and bending rebar were installed at the connections in accordance to CSA 23.3 Standard Structural Design Guidelines,

- Footing widths and areas were decided based on the loads from the joists and the wall thickness, refer to NBCC section 9.17.6. Solid Concrete Columns,

Interior Columns:

- Interior columns are spaced at 3000mm on center in both directions within the tank to support the top slab and provide stability for the tank structure,
- Slenderness checks were performed along with the consideration of lateral impact forces due to standing oscillations, see Appendix V: column slenderness check sample calculations,

Interior Separation Wall:

- One Interior Wall was designed to divide the tank in to two compartments for service and redundancy purposes, please refer to 3.3.4 Envelope Design.
- The wall has the same structural design and specifications. However, it has double sided water impermeable layers to prevent seepage and potential corruption issues.

Table 4-3: Rebar Design Schedule

	Size	**Strength**	**Reinforcing**
Corner Columns	300*300mm	40MPa	4-15M vertical with 10M at 300 Ties
Foundation Walls	300*300mm	40MPa	1-15M Vertical with 10M at 400 Ties
Interior Columns	250*250mm	35MPa	4-15M Vertical with 10M at 300 Ties
Interior Walls	300*300mm	40MPa	4-15M vertical with 10M at 300 Ties

Additionally, in the event of an earthquake, standing waves could be produced inside the basin, which can affect the structural equilibrium of the tank. Through the application of standing wave theory, it was concluded there would be a maximum additional pressure of 15 kPa exerted at the base of the foundation wall, while the water surface would exert a maximum negative pressure of 12 kPa - Figure 4-4.

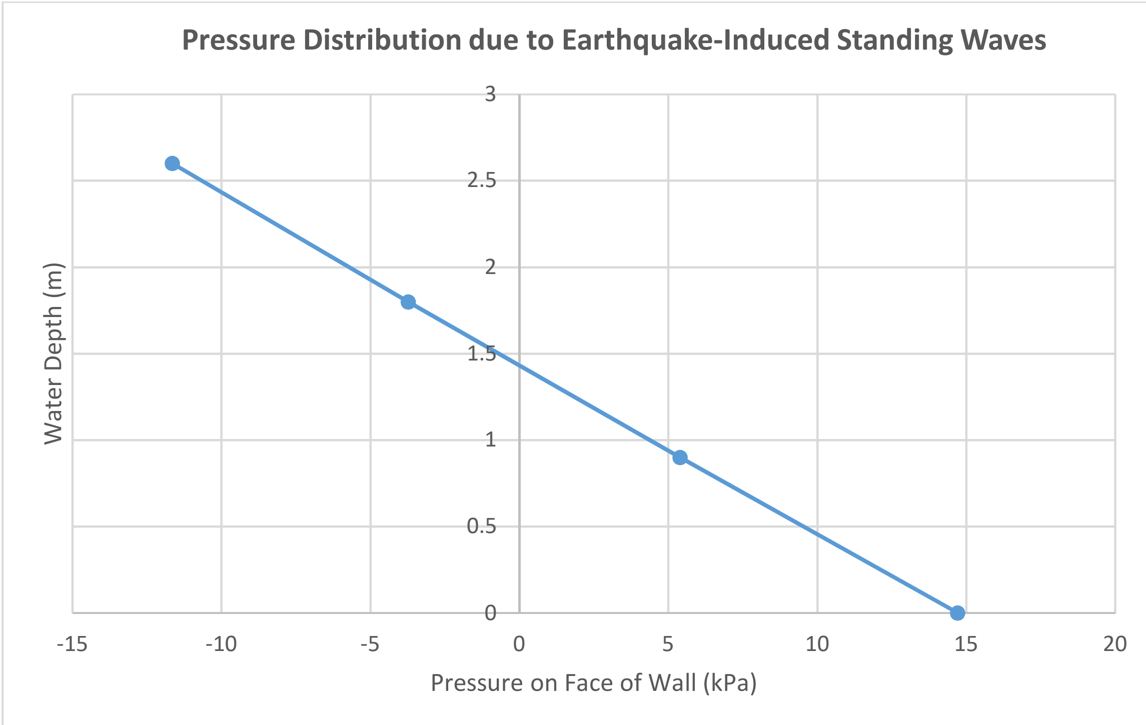

Figure 4-4: Standing Wave Analysis below summarizes the storage tank design outputs explained above.

Table 4-4 below summarizes the storage tank design outputs explained above.

Table 4-4: Structural Design Summary Table

Structural Components	Designed Dimensions
Footing Width and Area	$1150 \times 1150mm$
Foundation Wall Thickness	$300mm$
Interior Column Size	$250\times 250mm$
Interior Column Spacing	$3000mm$
Bottom Slab Thickness	$250mm$

4.3.3 Concrete Mix Design

Concrete Mix design was developed through ACI Manual of Concrete Practice 2000, Part 1: Materials and General Properties of Concrete as well as CSA A23.1 Tables 1 through 17. Necessary properties of design are governed by structural design and exposure classes: 15MPa compressive strength and exposure to freeze/thaw conditions. The code specifies the following mix design for the design parameters:

Table 4-5: Concrete Mix Design

Concrete Mix Design	
Material	**Content (kg/m3)**
Water	193
Cement	482.5
Coarse Aggregate	933
Fine Aggregate	636

The specified mix design yields a compressive strength of 40 MPa, with an air content of 5%. Admixtures and other supplementary cementitious materials such as superplasticizer and fly ash can be used, but proportions of base mix design must be reconsidered. Self-sealing admixture, Kryton's Krystol Internal Membrane (KIM) will be dosed at 2% by weight of cement because of waterproofing considerations.

4.3.4 Envelope Design

The envelope design of the storage tank puts importance on a durable design with a water-tight seal. Considerations in design include but are not limited to: water intrusion/retention, water quality, and drainage. The triple-protection design at cold joints as well as double-protection from cracks along the wall surface are highlighted in

Table 4-6.

Table 4-6: Wall Assembly

Wall Assembly		
Layer	**Specification**	**Thickness (mm)**
Exterior		
Drain-Rock	¾" aggregate size used around perforated pipes	Approximately 300mm
Filter Fabric and Drain-Mat	SopraDrain 10-G	10mm
Discrete Waterproofing Membrane	Soprema Colphene Flam 180	3mm
Specialized Integral Concrete	Concrete base-mix batched with Kryton KIM^{TM}(PRAH-rated)	300mm
Waterstop Cementitious Slurry	$Krystol\ Waterstop\ Treatment^{TM}$ using internal swelling method of application	Along surface of cold joints
Swelling Waterstop	$Krytonite^{TM}$ with resistance greater than 0.8 MPa of hydrostatic head	N/A

The prescribed design is able to withstand up to 0.8 MPa of hydrostatic head from interior of the tank, and any cracks that will form will be sealed through Kryton technology. This will minimize maintenance costs and limit the disruption of Thunderbird Field located above. Figure 4-5 and Figure 4-6 below illustrates the typical waterproofing measures located at the slab to column interface.

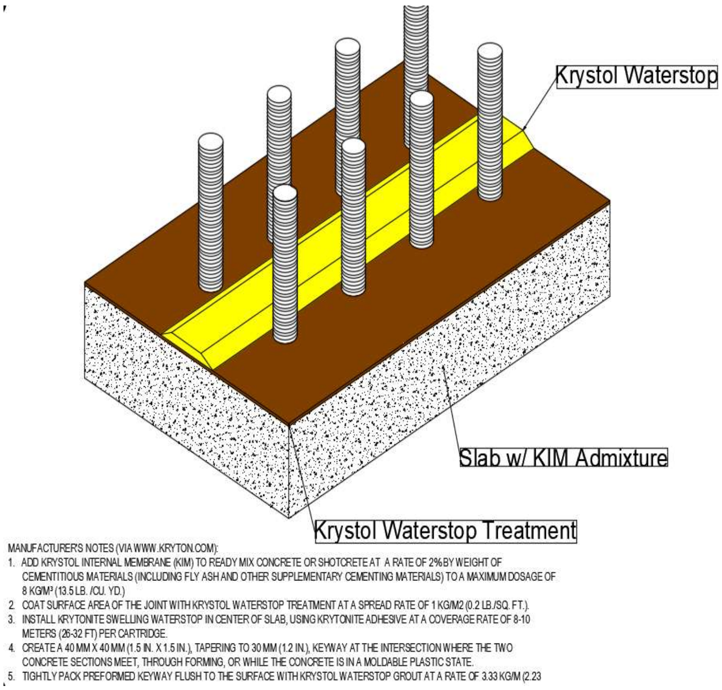

Figure 4-5: Slab to Column Interface

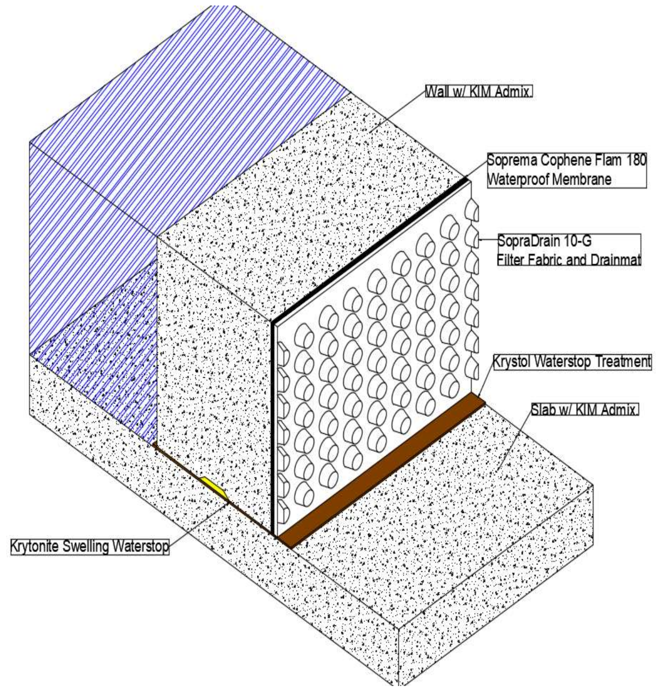

Figure 4-6: Exterior Wall Detail

Application of the building envelope will be monitored by waterproofing professionals to ensure the successful application of the waterproof membrane, along with all Kryton products throughout the structure. Applicators will follow application instructions given by membrane distributors and the Kryton's Application Instructions. Application instructions for all components of the building envelope can be found in the specification sheets on the provided IFC drawings (Appendix I).

5 Distribution System

The preliminary report generated by Team 9 (CIVL 445) outlined three scenarios (A, B, & C) for water demand during an emergency event at the University of British Columbia. Each scenario represented a different event, with "A" being the least severe, to "C" having the most significant impacts on potable water supply and access. Subsequently, an EPANET static hydraulic model was generated to provide demand estimates and correctly size the distribution network to meet design standards. Two demand scenarios (A and B) governed to address distribution constraints for the proposed system. The proposed distribution system alignment is displayed in (Figure 5-1) – an excerpt of the detailed design drawings.

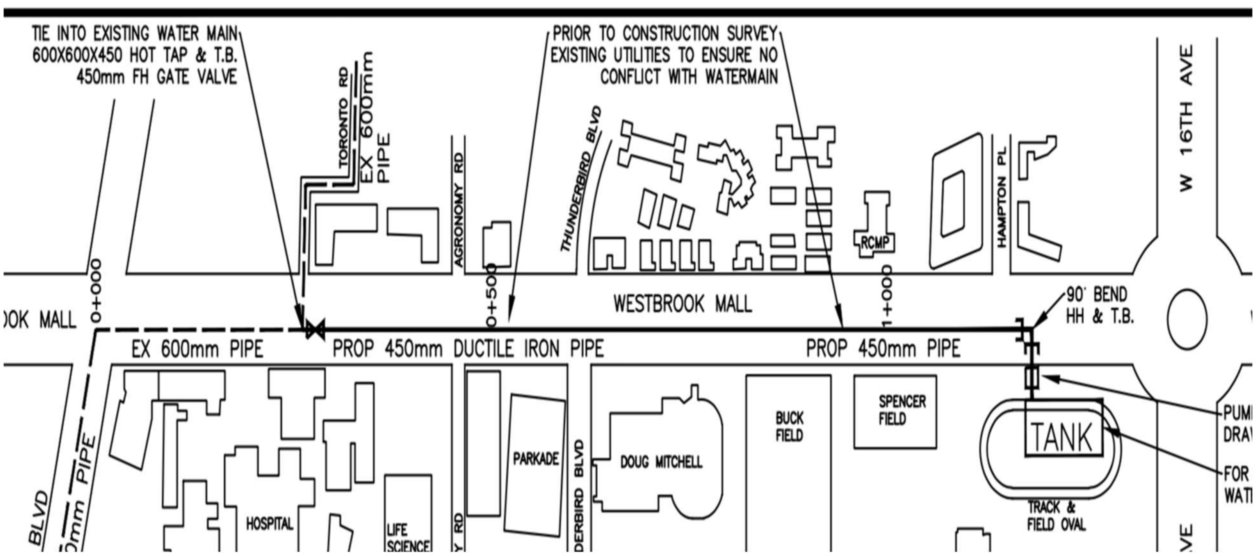

Figure 5-1: Distribution System Alignment

5.1 Design Criteria

Design criteria to be met by the distribution system is detailed in two separate components – pump requirements and distribution design. The pumping demand for Scenario A and B – the governing design cases – is detailed below:

Scenario A: The main operating constraint is to deliver approximately 6.0 m of net positive suction head (NPSH) to UBC's existing pump house, through means of a proposed tie-in 450mm dia. line (Table 5-1).

Table 5-1: Scenario A Demand Characteristics

Flow (L/s)	Pipe Material	Pipe Diameter (mm)	Pipe Length (m)	Unit Headloss (m/km)	UBC Pump House NPSH (m)
240	Ductile Iron	450	980	22	6

Scenario B: This situation represents conditions where the existing distribution system is down, thus temporary lines and faucet stations are prepared to convey potable water to meet the stated demands (Table 5-2).

Table 5-2: Scenario B Demand Characteristics

Distribution Point	Flow (L/s)	Pipe Material	Diameter (mm)	Length (m)	Unit Headloss (m/km)	Distribution Pressure (PSI)
A	5.79	Rubber conduit	150	1130	1.56	25
B	2.90		75	260	12.70	31

The anticipated design life of the pump configuration – as per industry standards – is approximately twenty (20) years.

The distribution system design must meet the standards discussed next in Section 4.2. UBC utilities specifications are held paramount to design outputs communicated through the IFC drawings in Appendix I. The distribution system will be designed for an anticipated lifetime of 50-years – which is consistent with the tank structure and typical estimates within industry. The main design criteria for the design of the distribution system are listed below:

- Ability to convey demand stated in Table 5-1 and Table 5-2 while meeting pressure standards depicted in the City of Surrey Design guidelines (2016)
- Ability to withstand earthquake forces and act as an independent system from UBC's existing network

5.2 Standards & Modelling Software

As previously noted – EPANET was utilized to generate pump requirements and pipe sizing for the proposed system. Additionally, AutoCAD Civil 3D was used to produce the IFC drawings found in Appendix I.

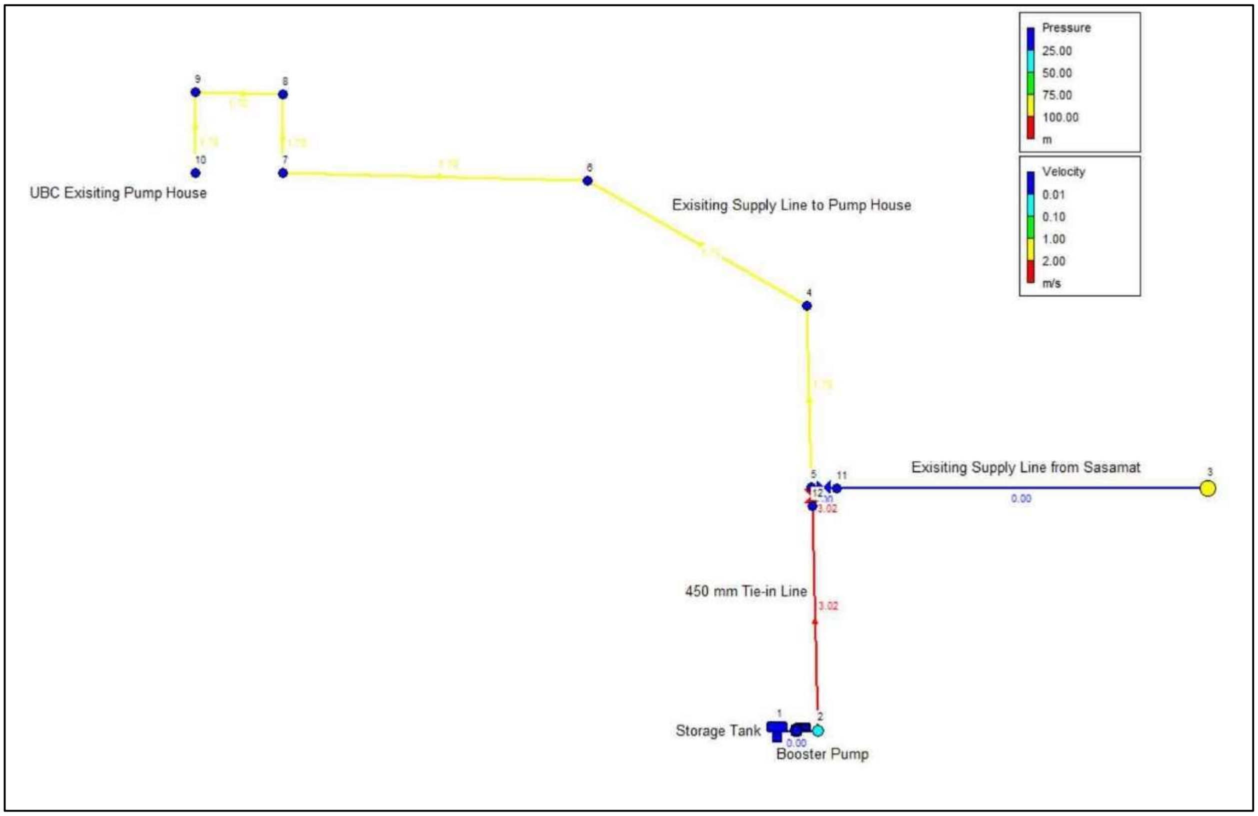

Figure 5-2: EPANET Output

Design standards referenced for the distribution system include:

- UBC Building & Excavation Permit
- Master Municipal Construction Documents (MMCD)
- UBC Technical Guidelines – Section 33 Water Utilities
- American Water Works Association (AWWA)

5.3 Technical Considerations & Design Outputs

5.3.1 Pump House

Typical water distribution utilities in the lower mainland require that maximum and minimum system pressures be met (20 psi and 150 psi, respectively), in addition to maximum velocities – thus, pumping head is required to fulfill the established demand stated in Section 5.1. Figure 5-3 below depicts the pump and system curves for the range of operating conditions discussed.

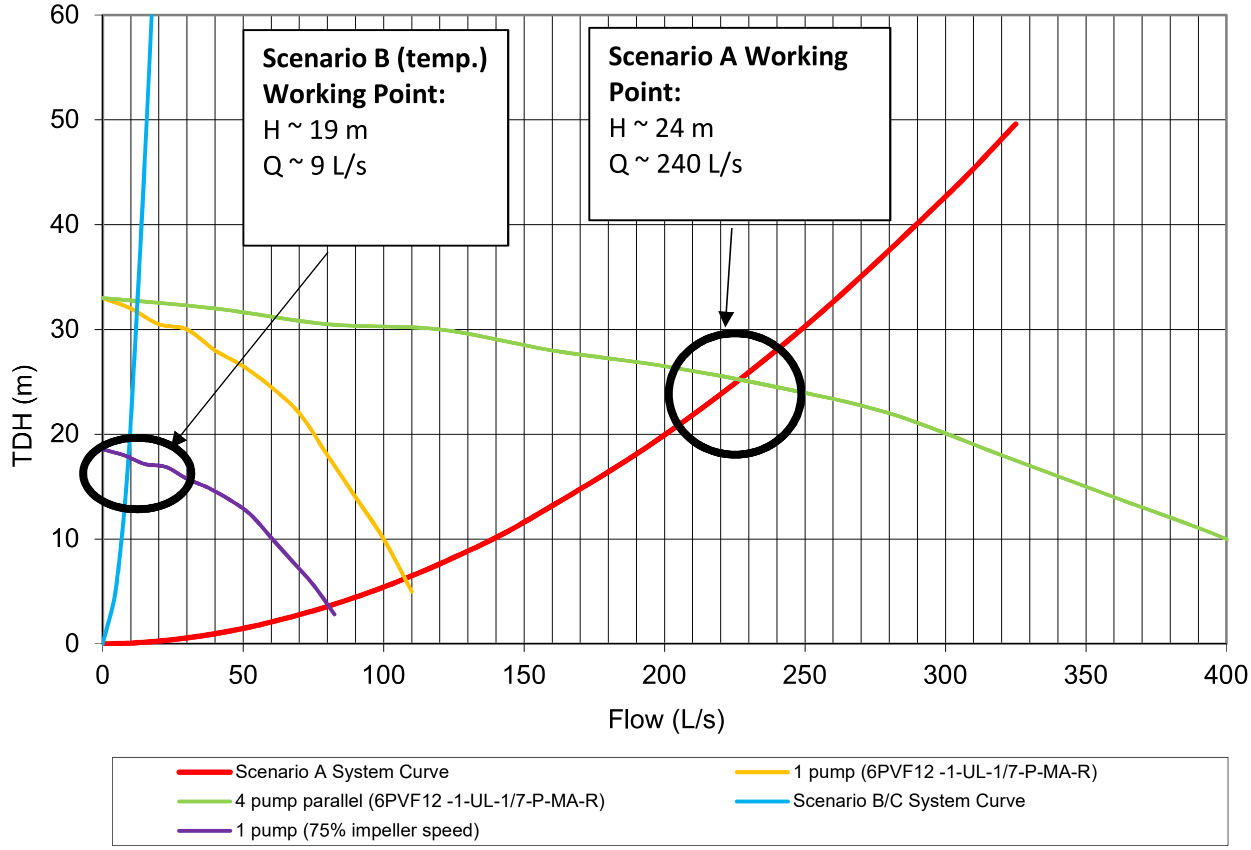

Figure 5-3: System & Pump Curve(s)

The pump chosen is a Vertical In-Line Centrifugal Pump (6PVF12-1-UL-1/7-P-MA-R) with a 60 Hz, 30 HP motor and 10-inch impeller. The specifications were obtained from the Grundfos database (grundfos.com, 2018). Pump affinity laws were utilized to configure the pumps to meet the working points from the system curves, as well as near proximity to the best efficiency point (BEP). The pump house will have five (5) pumps in parallel (with an additional pump for redundancy purposes). Scenario A will utilize 4 pumps in parallel and Scenario B and C will utilize 1 pump with a variable frequency drive (VFD). Please see IFC design drawings of the proposed pump house in Appendix I and supplementary pump information in Appendix II.

Furthermore, energy utilization of the pumps is displayed in

Table 5-3 for each emergency scenario developed. However, these values do not include routine pump maintenance of the system, which will be delved into in Section 7.2.

Table 5-3: Pump Energy Expenditure

Demand Scenario	Pump Working Point		Pump Impeller Speed	Pump Efficiency	Pump Energy Consumption (kW)	Duration (hrs.)	Total Power Cost
	H (m)	Q (L/s)					
A	~24	~240	100 %	73.2 %	80	24	$ 288
B/C	~19	~9	75 %	45.0 %	3.6	168	$ 92
C	~19	~9	75 %	45.0 %	3.6	504	$ 275

Assumptions in the calculation of energy requirements include: an electricity price of $0.15 per kWh from BC Hydro's website, and a flat loading pattern with no significant peaks.

5.3.2 Distribution Main

Based on the EPANET outputs of Scenario A, Team 9 designed a 450mm ductile iron pipe for 980 lineal meters, which connects the proposed water tank to the existing 600mm watermain (see previous XX). The list below outlines the major design considerations; which follow all codes and bylaws stated in Section 5.2, notably MMCD, AWWA and UBC Utilities – Section 33:

- ***Pipe material*** **-** Pipe shall be Class 50 ductile iron pipe manufactured to AWWA C151
- ***Depth of watermain*** **-** Minimum cover over any water main pipe shall be 1.0m to the finished grade.
- ***Max/min slope*** **-** Min slope shall be 0.1%. When slope exceeds 10%, the pipe must be anchored
- ***Thrust block*** **-** Place concrete thrust blocks between valves, tees, wyes, bends and undisturbed soil
- ***Separation from existing utilities*** **-** min 3 m horizontal clearance required from sewer piping.
- ***Valve placement*** **-** Maximum distance between isolating distribution valves to be 100 m.
- ***Joints*** **-** Shall be restrained and have a single rubber gasket for push-on bell and spigot type joints. In addition, all joints should be restrained with concrete reinforcement
- ***Backfill/compaction/bedding*** **-** For trench backfill native backfill material may be used.
- ***Cleaning/flushing & disinfection-*** Perform disinfection procedure and chlorine test and flush pipe.
- ***Min pressure*** **-** Minimum design pressure for piping must be greater than 20 psi

In addition to typical water utility design standards, all pipe joints shall be restrained with concrete joints to prevent the separation of the pipe and fittings caused by the thrust forces and earthquake loading. The purpose of using concrete restrained joints was to increase the resiliency of the pipe network. Further details and calculations can be seen on the design drawing package. Furthermore, please see Appendix I for the complete package of IFC design drawings, in which a plan-profile drawing summarizes the proposed distribution system.

5.3.3 Temporary Distribution System

Based on EPANET outputs, the temporary distribution lines connecting the tank to distribution point A and B is displayed in Figure 5-4: Temporary Distribution Point Layout. Table 5-4: Temporary Distribution System Characteristics below details the system characteristics.

Table 5-4: Temporary Distribution System Characteristics

Distribution Point	Conduit Length (m)	Pipe O.D. (mm)
A	1130	150
B	260	75

Rubber pipes are suggested because of the materials convenience to be easily stored, and because of its ability to be easily bent around buildings when routing.

Assuming that during scenario B and C, 25% of the population will be dependent on pool water, the temporary distribution pipes have been designed to service 75% of the expected population. It is expected that during scenario B and C the per capita demands will be much lower as water will primarily be used for drinking and sanitation purposes only, therefore no peaking factor was used.

Figure 5-4: Temporary Distribution Point Layout

Figure 5-5: Conceptual Distribution Point Tap

6 Public Awareness Program

With the construction of this new water storage and distribution system, it is important to educate the public about its purpose and how it will best be used. This may be done by distributing information pamphlets in the residence buildings as well as a few other high traffic UBC buildings, such as the Nest. These pamphlets would educate people on how the emergency system works, and what to do in the case of an emergency. Additionally, the pamphlets provide tips on how to conserve water, which could potentially lower water demand, making the system more conservative. Upon completion of the project, it would also be advisable to have a mass email sent to all UBC students. This email would provide people with a brief overview of the system and let them know where to find more information. Ultimately, all people who would be using the system should be educated on a specific list of things to do in the case of an emergency. This list is as follows:

1. Stay calm. Emergencies like this have been prepared for.
2. Reduce water consumption. This can be done by not showering every day, not flushing the toilet frequently, not letting the tap run extra water when washing dishes and not doing laundry for the specified period.
3. If water is not available in your building, you will have to go to the nearest distribution station to receive your emergency ration. Please consult the map to see which station is the closest. When you arrive there, staff will be giving directions. Follow their directions and do not panic. Upon receiving your water ration, vacate the distribution station area in order to avoid overcrowding.

In addition to education, it is also important to actively manage people when the emergency water system is in use. Steps need to be taken to ensure that users behave in a calm and orderly manner when collecting their ration of emergency water. This factor is most applicable to a large scale natural disaster, where there would likely be a higher sense of panic among users on the UBC campus. All water distribution stations should have staff directing people in their collection of water rations. This staff should be equipped with megaphones to give people directions/explanations, and to reassure people that there is enough water for everyone. To avoid users overcrowding the distribution stations, it is advised to have a temporary fence erected around each distribution station. People would line up and only a set number would be allowed inside the fence at one time. This would ensure fast and orderly distribution of the water.

7 Service-life Maintenance Plan

The service-life maintenance plan for the proposed secure water supply system consists of a detailed description of the lifecycle servicing required (subsequent sections), in addition to a lifecycle cost.

7.1 Storage Tank

Maintenance of the storage tank can include the following: concrete crack repair/structural repair, re-passivation of corroded rebar, and repair of seals and penetrations. The process of any type of repair must start with access to the inside of the tank. With a partition wall located in the center of the tank, perpendicular to the longest dimension, maintenance is possible. Once the valve is closed in the partition wall, one side is able to be repaired. Measures against major maintenance have been taken, such as seal-sealing cementitious products, cold joint protection, and exterior membranes with drain mats (warranties will be provided from distributors for up to 20 years); however, in the case of needing maintenance, Team 9 has set-up a detailed maintenance plan to use.

Crack repair of concrete walls and slabs are highlighted in Figure . Generally, the crack will be chiseled and filled with a repair mortar with high bond strength properties as well as fiber reinforcement. Applicators can check if the repair is satisfactory when there is no water present 48 hours after application. Wall penetrations from service pipes routing to the pump station can be repaired in a similar manner if visible leaks are present.

In the case of major repair from a structurally-catastrophic event, Team 9 advises to contact a registered structural engineer to assess and provide a strategy for repair.

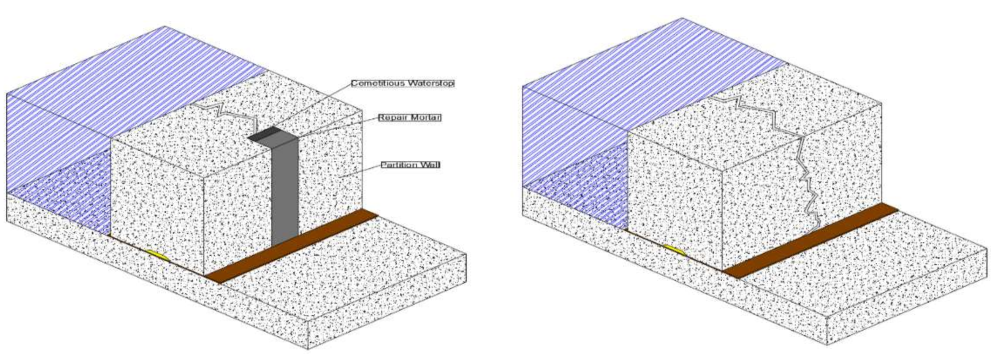

Figure 7-1: Repair Strategy for Crack Repair

7.2 Distribution System

Maintenance over the service-life of the distribution system includes:

1. Semi-annual pump inspection of each pump in the five (5) parallel configuration detailed (each respective pump taken offline one at a time) – as per manufacturers website
2. Semi-annual system turnover – replace stagnant water with fresh water from Sasamat reservoir, and test distribution valves and components

Furthermore, maintaining an adequate chlorine residual will be the primary disinfectant to prevent microbial growth in the tank. Chlorine levels in the tank and distribution system will be assessed on a weekly basis using a water quality testing device – as displayed in Figure 7-2 (dHgate.com, n.d.).

Figure 7-2: Water Quality Testing Device

Moreover, a monthly flush-out routine will consist of recycling the storage volume into the existing system – through the operation of the tie-in valve connecting to the 600-mm supply line. The retention time of the tank (time to recycle the water) is approximately 15 hours.

Unless specified by the owner – UBC SEEDS – no maintenance of the 450mm ductile iron distribution pipe itself is required.

8 Detailed Construction Schedule

8.1 Overview of Gantt Chart

The construction is broken down into two parts. First is the construction of the tank which is anticipated to last form May 1, 2018 to November 21, 2018 and governs the overall schedule, and second is the construction of the water main which happens in parallel and lasts from May,1 2018 to June 12, 2018. For a detailed breakdown of the schedule please refer to Appendix III (Gantt Chart).

8.2 Anticipated Construction Complications & Risks

Considering the construction of new a major infrastructure system at UBC demands some foresight of potential issues that could be encountered during construction. The principal issue will be maintaining the utility of the rest of the sports fields, as well as minimizing the impact to the surrounding traffic and community. The table below summarizes potential construction difficulties and possible approaches to address them.

Table 8-1: Construction Complications

Potential Construction Difficulties	Complications Presented	Proposed Solution
1. Storage of excavated soil/backfill	Space constraints	Arrange for coordination with a site that needs preload material, excavated soil can be transported immediately off site
2. Groundwater and surface water	Upward pressures on tank foundation	Construction a sump pump in the excavation the facilitate dewatering during construction
3. Routing of traffic during water main installation	Road shutdowns and delays	Complete comprehensive traffic management plan – contact Team 9 for further details
4. Proximity to sports field users, particularly children, during tank construction	Safety issues involving open excavations, heavy machinery, and dangerous materials	Pay special attention to site security, signage, and safety fences
5. Construction Noise	Close proximity to in use sports field presents safety issues and disruptions	Coordinate noise intensive activities with schedule of adjacent sports field, alternatively perform tests to ensure construction noise will not be harmful or disruptive

9 Class B 'Substantive' Cost Estimate

9.1 Lifecycle Cost

A Class B (substantive) cost estimate was developed for the project. The total lifecycle cost, detailed below is approximately $7.25 million (CAD) – in 2018 dollars, adjusted for future interest and inflation.

The capital cost, including design fees, permitting, environmental aspects, management and construction is estimated to be approximately $3,190,000. It is to be noted that all line items are inclusive of material, labour and equipment. Figure 9-1 depicts the anticipated breakdown of capital cost for the project.

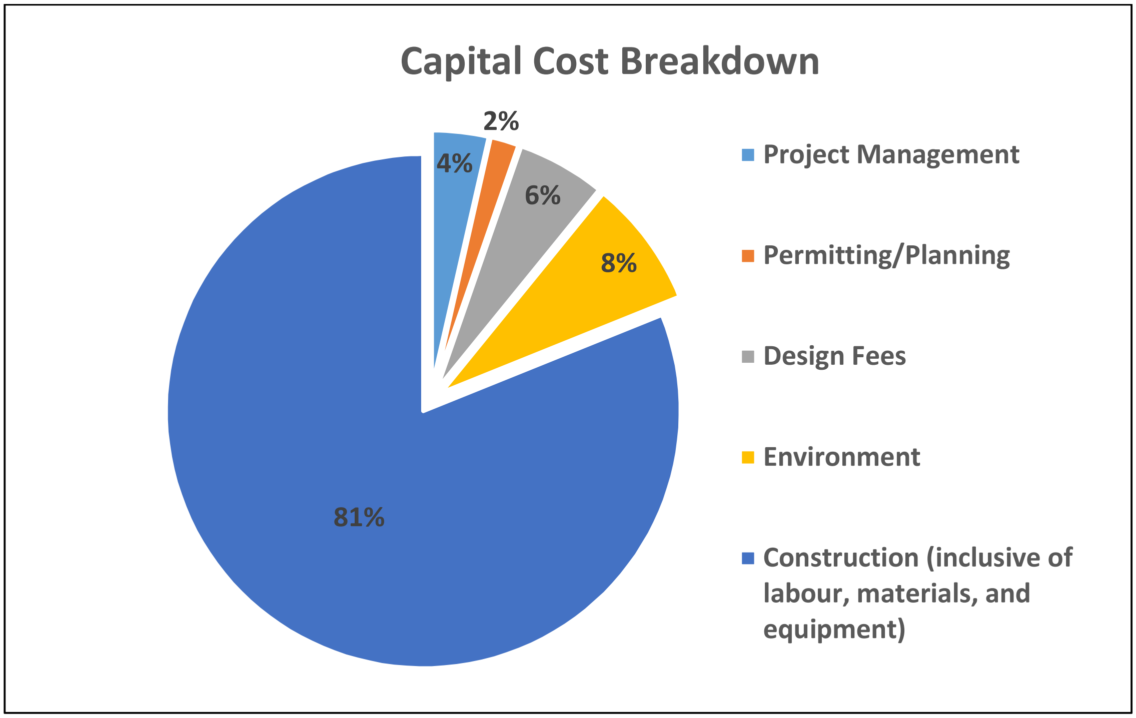

Figure 9-1: Capital Cost Breakdown

Furthermore, the operation and maintenance (O&M) costs over the assumed 50-year service lifespan include maintenance, pump replacement/rehabilitation, chlorine testing and water turnover in the system. Therefore, the present value of operating costs, using a real rate of interest of -1.0% (interest accounting for inflation), and a lifetime of 50-years, equals approximately $3,720,000. This was done using the net present value (NPV) analysis tool (Equation 9-1), utilizing lifecycle time (t), yearly cashflow (C), and a real interest rate (r). The real interest rate was calculated with the following parameters: nominal interest rate (n) = 1.0%, and inflation (i) = 2.0% - detailed in Equation 9-2:

Equation 9-1: Net Present Value

$$NPV = C\frac{(1-(1+r)^{-t})}{r}$$

Equation 9-2: Real Interest Rate

$$n = \left((1+r)*(1+i)\right)-1$$

Table 9-1 summarizes (to the nearest $10,000) the complete Class B cost estimate found in Appendix IV.

Table 9-1: Lifecycle Cost Summary

Real rate of interest (i) ~ -1.0%, Lifecycle (n) = 50 years

Cost Item	Contingency	Yearly Cash Flow (Annuity)	Present Value (PV) over 50-year lifecycle
Capital Costs:			
Design and Project Management	20%	N/A	$290,000
Environmental Considerations	30%	N/A	$260,000
Permitting & Planning	20%	N/A	$60,000
Construction			
Site Preparation & Mobilization	10%	N/A	$110,000
Storage Tank	10%	N/A	$1,360,000
Pump House	10%	N/A	$100,000
Distribution System	10%	N/A	$820,000
		Sub Total:	**$3,190,000**
Operations and Maintenance (O&M) Costs:			
Storage Tank Inspection & Water Quality Testing	20%	$32,000	$2,120,000
Distribution System Maintenance and Pump Replacement	20%	$25,000	$1,600,000
		Sub Total:	**$3,720,000**
		GST (5%)	$350,000
		Total Lifecycle Projected Cost:	**$7,250,000**

N/A = not applicable

9.2 Project Cost Justification

Based on UBC's 2017/2018 operations budget (vpfo.ubc.ca, 2017), approximately 121 million is allocated to capital spending. Assuming 10% goes towards utilities, and approximately 4% will be spent on the proposed tank and distribution system, the total budget per year amounts to $484,000. A simple payback period using the yearly budget for the project is 15 years. The additional social and environmental benefits UBC receives from the project also plays a major role to justify the design. The tank and distribution system will restore resiliency to UBC's critical infrastructure for the foreseeable future.

10 Triple Bottom Line Assessment

Team 9 and Associates has employed the triple bottom line assessment to ensure UBC SEEDS meets the environmental, social, and economic goals of the project. Addressing and evaluating the triple bottom line will be a valuable metric for the overall success of the project over its lifecycle.

10.1 Environmental

During the construction of the emergency water supply system, the use of LEED certified, sustainable materials presents an opportunity to minimize the overall carbon footprint and environmental impact of the project. In addition, Team 9 has sought after local construction materials for the design and respective cost estimate.

In addition, a high level Environmental Impact Assessment (EIA) was established by Team 9. The five pillars of an EIA, and how they may affect the project are listed below in Table 10-1.

Table 10-1: Environmental Impact Assessment Pillars

EIA Pillar	Project-Specific Considerations
Health	- Uncovering of hazardous soils during excavation - Potential of soil contamination during construction process
Heritage	- Possibility of uncovering sensitive artifacts belonging to First Nations
Environmental	- Greenhouse gases (GHG) emitted during construction
Social	- Disruption of major routes leading to UBC and campus recreation facilities for an extended period - Noise pollution from construction
Economic	- Cost of project burdened on stakeholders (UBC, Vancouver)

10.2 Social

By implementing this design, UBC will become a leader in sustainable infrastructure innovations. Other universities and institutions, as well as surrounding communities throughout Metro Vancouver, will view UBC as a model for their own sustainable emergency infrastructure.

On a local scale, the community will have the peace of mind associated with the outstanding improvement to the resiliency of UBC's water distribution system. Concurrent with the design and construction of the system, there is an opportunity to raise awareness regarding responsible water use in the surrounding community.

10.3 Economic

The environmental and social benefits of the recommended secure potable water supply system design features strong synergy with both long and short term economic considerations. In the short term, the below-grade tank leaves on grade land free for further use and expansion. In the long term, major or minor emergency events can incur significant costs, both direct and indirect (fires, hospital failures, etc.). With the addition of a resilient emergency water supply, some of these costs are mitigated or eliminated completely.

11 Conclusion

Team 9 & Associates' has completed the detail design of a secure emergency water supply system for the University of British Columbia. The results of the detail design were (1) design of the underground tank and distribution system, (2) an updated Class B 'Substantive' cost estimate, (3) detail construction schedule and (4) service life and maintenance plan. The overall objective of the project put forth by UBC SEEDS was to design a resilient emergency water supply system to provide UBC a secure source of water in the event the connection to Metro Vancouver is severed.

In summary, the detail design outputs outlined in this report are the following:

1) Below Grade Storage Tank – dimensions of 50x70x2.5m giving 8800m^3 of storage volume, floating foundation design, T shaped footing, 250x250mm interior columns 3m O.C., 300mm interior separation wall, concrete to ACI standards and waterproofing as per Kryton Krystol.
2) Distribution system – 450mm Class 50 ductile iron water main, 5 vertical in-line centrifugal pumps in parallel, concrete thrust block, all joint restrained with concrete reinforcement, 6x10x2.5m concrete below grade pump house, temporary distribution for scenario B & C via temporary pipes and trucking
3) Construction scheduling - start date of May 1, 2018 and project completion for Nov 21, 2018. 30 days to complete water main installation and 147 days to complete storage tank
4) Class B Cost Estimate - The capital costs to construct and commission the secure water supply system is approximately $3.19 million (CAD). 50-year lifecycle O&M costs for the recommended design is nearly $3.72 million (CAD). Total lifecycle cost will be $7.25 million (CAD).

After review and consideration of Team 9's detail design report by UBC SEEDS, it is expected that the project will move into the construction phase.

12 References

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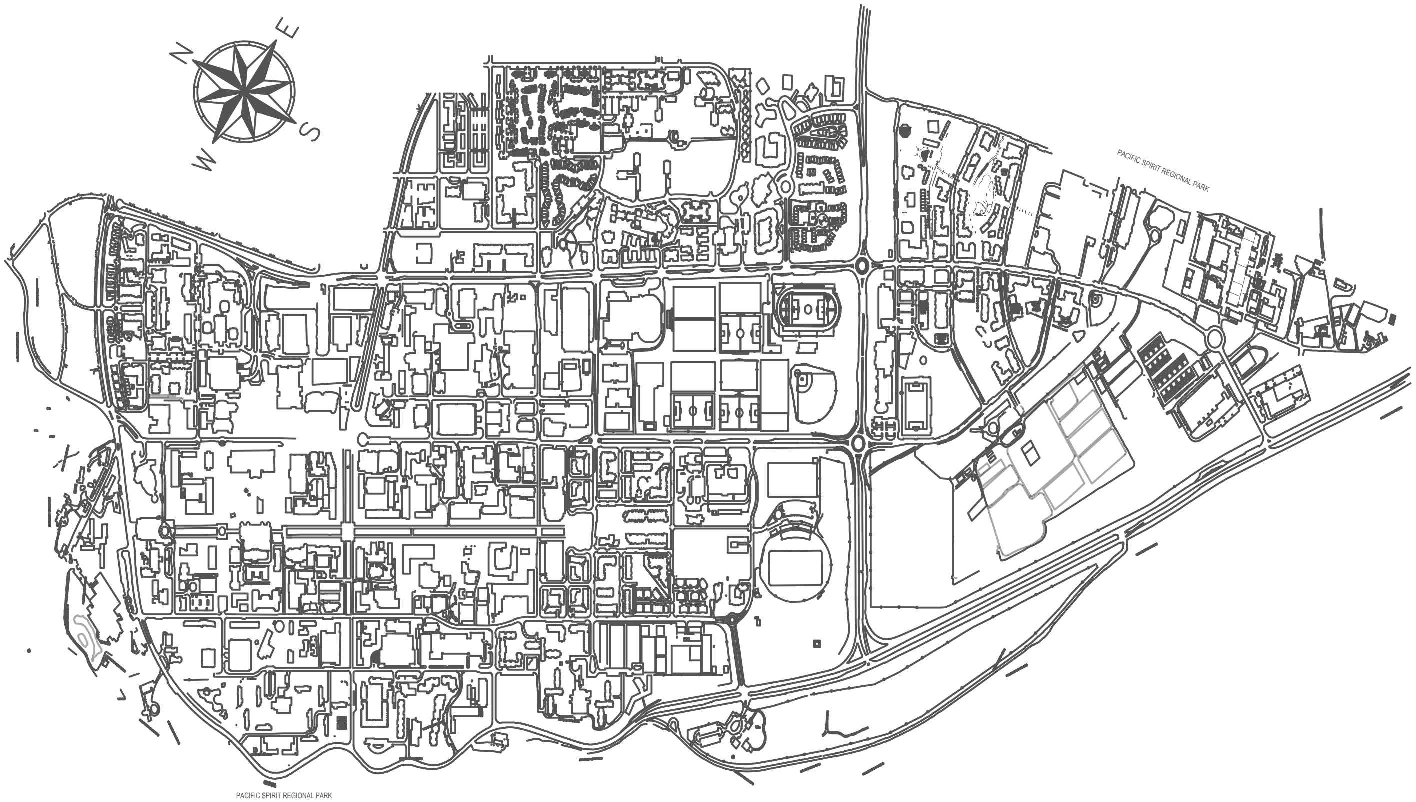
Appendix I – IFC Drawings Package

2329 WESTBROOK MALL, VANCOUVER
SECURE WATER SUPPLY FOR UBC CAMPUS
LOT 22, DISTRICT LOT 6469, GROUP 1

a place of mind

UBC



UBC LOCATION MAP

NTS

MARCH 2018

INDEX OF DRAWING SHEETS

DRAWINGS SHEET TITLE	DRAWING SHEET NO.
COVER SHEET	18001-COV
GENERAL NOTES AND DETAILS	18001-01
WATER TANK COMPOSITE UTILITY PLAN	18001-02
WATER TANK SECTION A-A DETAIL	18001-03
WATER TANK PLAN VIEW	18001-04
WATER TANK REBAR SPECIFICATION	18001-05
WATERMAIN PLAN/ PROFILE STA. 0+000 TO 1+200	18001-06
PUMP HOUSE	18001-07
WATER TANK WALL TO SLAB DETAIL	18001-08
WALL TO SLAB WATER PROOFING TANK DETAIL	18001-09
TANK FOOTING WATERPROOFING DETAILS	18001-10
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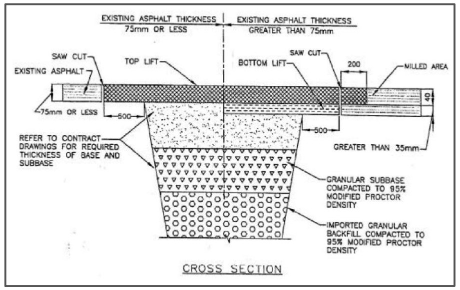
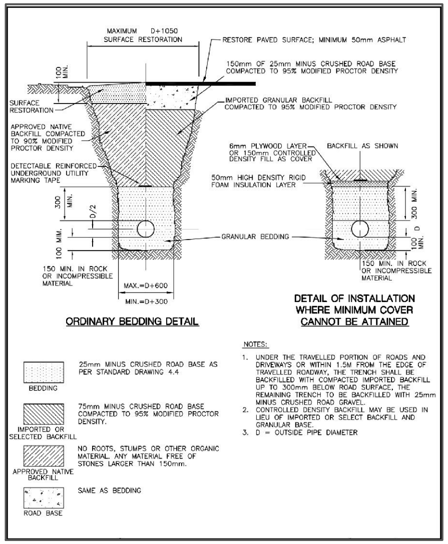
TEAM 9 & ASSOCIATES FILE NO. 18001



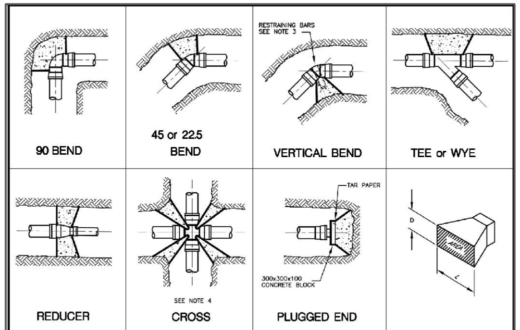
ASPHALT RESTORATION

Waterproofing Product	Instruction
Krystol Waterstop Treatment	Application Instruction 4.16 (Kryton)
Krytonite Swelling Waterstop	Application Instruction 4.16 (Kryton)
Krystol Waterstop Grout	Application Instruction 5.32 (Kryton)
Krystol Internal Membrane	Application Instruction 1.11 (Kryton)
Soprema Colphene Flam 180 Waterproofing Membrane	Technical Data Sheet provided on www.Soprema.ca
SopraDrain 10-G Filter Fabric and Drainmat	Technical Data Sheet provided on www.Soprema.ca

WATERPROOFING INSTRUCTIONS



WATERMAIN BEDDING DETAIL

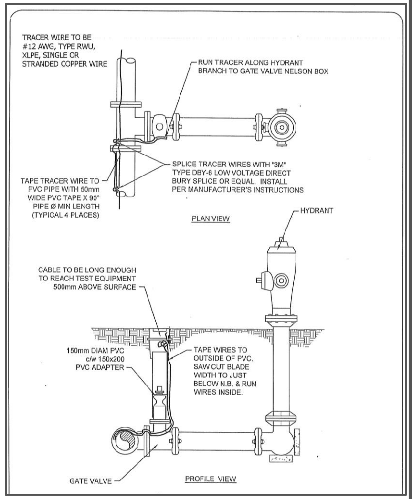


MINIMUM THRUST AREA BASED ON WATER PRESSURE OF – 1000KPa (150psi) & SOIL BEARING CAPACITY OF – 100KPa (2000psf)

FITTING	PIPE SIZE	AREA SQ. METERS	L x D AT FACE	FITTING	PIPE SIZE	AREA SQ. METERS	L x D AT FACE
90° BEND	100	0.2	0.7 x 0.3m	22.5° BEND	100	0.1	0.5 x 0.2m
	150	0.4	1.0 x 0.4m		150	0.2	0.7 x 0.3m
	200	0.7	1.2 x 0.6m		200	0.2	0.7 x 0.3m
	250	1.1	2.0 x 0.6m		250	0.3	0.8 x 0.4m
	300	1.6	2.0 x 0.8m		300	0.5	1.0 x 0.5m
45° BEND or WYE	100	0.2	0.7 x 0.3m	CAPPED END OR TEE	100	0.2	0.7 x 0.3m
	150	0.3	1.0 x 0.3m		150	0.3	0.8 x 0.4m
	200	0.4	1.0 x 0.4m		200	0.5	1.0 x 0.5m
	250	0.6	1.0 x 0.6m		250	0.8	1.2 x 0.7m
	300	0.9	1.5 x 0.6m		300	1.1	1.4 x 0.8m

NOTES:
1. SOIL BEARING CAPACITY USED IS THAT FOR SOFT CLAY, FOR SOFTER SOILS THRUST BLOCKS SHALL BE DESIGNED BY THE ENGINEER.
2. THRUST BLOCKING FOR FITTINGS LARGER THAN 300 ø SHALL BE DESIGNED BY THE ENGINEER.
3. VOLUME OF CONCRETE IN VERTICAL BEND ANCHORS TO BE DETERMINED BY THE ENGINEER. USE 2–20M RETAINING BARS PER CUBIC METRE.
4. FOR CROSSES USE VALUE FOR 45° BEND IN EACH QUADRANT.
5. WHERE PIPE SIZE DIFFERS IN ANY ONE FITTING USE VALUE FOR LARGEST SIZE.
6. CONCRETE NOT TO ENCROACH ON PIPE BARREL, BUT TO BEAR ON FITTING ONLY.
7. CONCRETE TO BE 20MPa (3000psi) COMPRESSIVE STRENGTH.

THRUSTBLOCK DETAIL



TRACER WIRE DETAIL

GENERAL NOTES

- THE CONTRACTOR SHALL BE RESPONSIBLE FOR LAYOUT FROM DIGITAL INFORMATION. ACCURACY FROM DIGITAL FILES IS NOT GUARANTEED. LAYOUT TO CONFORM TO DISTANCES AND OFFSETS AS SHOWN ON THE CONTRACT DRAWINGS. CONTRACTOR TO CONFIRM THE ACCURACY OF THE LAYOUT PRIOR TO CONSTRUCTION, AND CONTACT THE ENGINEER IN REGARDS TO ANY DISCREPANCIES THAT ARE APPARENT BEFORE CONTINUING WITH INSTALLATION OF WORKS.
- THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL NECESSARY PERMITS FOR CONSTRUCTION & ARRANGING FOR DISPOSAL OF GROUND WATER AS REQUIRED. – THE CONTRACTOR SHALL COORDINATE ALL TESTING REQUIRED WITH THE TESTING FIRM SPECIFIED BY THE ENGINEER.
- INITIAL TESTING COSTS TO BE BORN BY THE DEVELOPER WITH THE COST OF RETESTS OF FAILED TESTS BORN BY THE CONTRACTOR.
- THE POSITION OF POLE LINES, CONDUITS, WATERMAINS, SEWERS, UNDERGROUND, ABOVEGROUND UTILITIES & STRUCTURES IS NOT NECESSARILY SHOWN ON THE CONTRACT DRAWINGS. WHERE SHOWN, THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED. BEFORE STARTING WORK, THE CONTRACTOR SHALL INFORM HIMSELF OF THE EXACT LOCATION OF SUCH UTILITIES AND STRUCTURES, AND SHALL ASSUME ALL LIABILITY FOR DAMAGE TO THEM.
- THE CONTRACTOR SHALL EXERCISE EXTREME CAUTION WHEN WORKING AROUND LEGAL PINS TO AVOID DISTURBANCE. IF THE CONTRACTOR IS UNABLE TO AVOID DISTURBANCE OF ANY PIN BECAUSE OF PHYSICAL CONSTRAINTS OF THE SITE, THE ENGINEER SHALL BE NOTIFIED PRIOR TO DISTURBING THE SURVEY PIN. ANY SURVEY PIN DISTURBED WITHOUT NOTIFYING THE ENGINEER, SHALL BECOME THE CONTRACTOR'S RESPONSIBILITY.
- ALL HYDRO AND COMMUNICATION INSTALLATION TO CONFORM TO INDIVIDUAL UTILITY COMPANY STANDARDS
- SEE UTILITY COMPANY DRAWINGS FOR DETAILED INSTALLATION PLANS
- ONSITE AND OFFSITE SEWER & STORM LINES TO BE TESTED AND VIDEO CAMERA INSPECTED
- THE CONTRACTOR SHALL ADJUST ALL EXISTING MANHOLES, HYDRANTS, SERVICE BOXES, ETC. TO MATCH FINAL GRADES.
- PROVIDE CATHODIC PROTECTION FOR ALL BURIED METALLIC FITTINGS TO MITIGATE CORROSION AS PER SOIL RESISTIVITY REPORT AND AS PER MMCD
- WATER SERVICE CONNECTIONS TO HAVE 2X4 MARKERS @ INVERTS OF PIPES TO ABOVE GROUND SURFACE WITH MARKER TO SHOW DEPTH TO INVERT.
- ALL WORK TO CONFORM TO THE LATEST EDITION OF M.M.C.D. AND UBC TECHNICAL GUIDELINES & APPLICABLE PLUMBING CODE UNLESS OTHERWISE AS EXPLICITLY NOTED ON THE DRAWING.
- THE CONTRACTORS SURVEYOR SHALL PROVIDE AS BUILT INFORMATION TO THE ENGINEER IN AUTOCAD FORMAT AND SHALL CERTIFY IT TO BE CORRECT
- ROAD RESTORATION AS PER CITY SUPPLEMENTAL SECTION 31 23 01S 7.5.1 TO 7.5.9
- THE CONTRACTOR AND CONSULTANT ARE TO COMPLETE ALL TIE–INS AND DISCONNECTIONS OF UBC WASTEWATER IN THE PRESENCE OF UBC PERSONNEL.
- THE CONTRACTOR SHALL NOTIFY THE ENGINEER TO REVIEW THE STRING LINE OR FORM WORK FOR CURBING 24 HOURS PRIOR TO POURING CONCRETE.

BACFILL/COMPACTION/BEDDING REQUIREMENTS

- FOR TRENCH BACKFILL NATIVE BACKFILL MATERIAL MAY BE USED IN BOULEVARD AND EASEMENT AREAS IF FREE OF ROCK GREATER THAN 25 MM
- FOR PIPE BEDDING USE CLEAN GRANULAR PIPE BEDDING, GRADED GRAVEL, 19 MM (–), MMS TYPE 1. BOTTOM THICKNESS SHALL BE A QUARTER OF PIPE DIAMETER, OR MINIMUM 100 MM THICK. TOP SHALL BE MINIMUM 300 MM THICK. SIDES SHALL BE MINIMUM 225 MM TO MAXIMUM 300 MM THICK.
- MINIMUM SOIL COVER TO BE 1.0 M
- USE IMPORTED BEDDING WHEN PROPOSED WORK IS INSTALLED UNDER THROUGH PAVED AREAS, WHEN UTILITIES MECHANICAL ENGINEER DEEMS NATIVE MATERIAL UNSUITABLE FOR BACKFILL, OR WHEN TRENCH HAS BEEN EXCAVATED IN ROCK. OTHERWISE FOR TRENCH BACKFILL, NATIVE BACKFILL MAY BE USED IF FREE OF ROCK GREATER THAN 25 MM AND LOCATED IN BOULEVARDS OR EASEMENTS. APPROVAL BY UBC ENERGY & WATER SERVICES IS REQUIRED.

CLEAN/FLUSHING & DISINFECTION PROCEDURE

- PERFORM DISINFECTION PROCEDURE AND RESIDUAL CHLORINE TEST IN PRESENCE OF MECHANICAL DISTRIBUTION ENGINEER
- MAINTAIN WATER CHLORINATING LEVEL (FREE CHLORINE CONCENTRATION MM. 25 MG/L) IN NEW PIPING FOR MINIMUM 24 HOURS
- BEFORE CONNECTION TO UBC WATER SYSTEM, FLUSH PIPING CLEAN UNTIL MAXIMUM FREE CHLORINE CONCENTRATION IS LESS THAN 0.3 MG/L. ANY FLUSHED WATER ON OR SOUTH OF AGRONOMY ROAD MUST BE DE–CHLORINATED IN A MANNER THAT IT DOES NOT POSE THREAT TO AQUATIC LIFE IN BOOMING GROUND CREEK.
- AFTER DISINFECTION AND FLUSHING, THE NEW MAIN IS FILLED WITH POTABLE WATER AND SAMPLED FOR TOTAL COLIFORM AND E. COLI BACTERIA (BUG TEST) EVERY 350 M

SEPARATION FROM EXISTING UTILITIES

- A MINIMUM 3 M HORIZONTAL CLEARANCE IS REQUIRED FROM EITHER SANITARY SEWER OR STORM SEWER PIPING, WHEN THEY RUN PARALLEL TO WATER MAIN.
- IF THIS CLEARANCE CANNOT BE MET, WATER PIPING CAN BE INSTALLED CLOSER WITH PRIOR APPROVAL FROM UBC ENERGY & WATER SERVICES. REFER TO MMCD DESIGN GUIDELINE MANUAL SECTION 1.4, AND VANCOUVER COASTAL HEALTH'S WATER SUPPLY SYSTEM CONSTRUCTION PERMIT GUIDELINES AND APPLICATION FORM (SEE 2.1.4 THIS SECTION).
- INSTALLATION MAY BE APPROVED PROVIDED WATER PIPE IS INSTALLED ABOVE SANITARY OR STORM SEWER PIPING WITH MINIMUM VERTICAL CLEARANCE 0.5 M AND WATER MAIN JOINTS ARE WRAPPED.
- WHEN CROSSING SANITARY SEWERS AT 90° ANGLE, THE WATER PIPE SHALL BE ENCASED WITH 20 MPA CONCRETE OF MINIMUM THICKNESS 150 MM. IF CONCRETE IS NOT DESIRABLE, JOINTS OF THE WATER MAIN CAN BE WRAPPED WITH HEAT SHRINK PLASTIC OR PACKED WITH COMPOUND AND WRAPPED WITH PETROLEUM TAPE IN ACCORDANCE WITH THE LATEST VERSION OF THE AWWA STANDARDS C217, AND C214 OR C209.

CONCRETE RESTRAINED PIPE JOINTS

- CONCRETE RESTRAINED PIPE JOINTS WILL BE USED FOR ALL PIPE JOINTS TO PREVENT THE SEPARATION OF THE PIPE AND FITTINGS CAUSED BY THE THRUST FORCES AND ANY EARTHQUAKE LOADING.
- RESTRAINED JOINTS ONLY SYSTEM METHOD USES THE FRICTION BETWEEN THE SOIL AND THE SPECIFIED LENGTH OF RESTRAINED PIPE TO RESIST THE THRUST FORCE. NO PASSIVE SOIL RESISTANCE AT THE FITTING AND/OR PIPE SHALL BE CONSIDERED.
- THE TOTAL FRICTION FORCE CALCULATED SHALL BE AT LEAST 1.5 TIMES THE FULL THRUST FORCE (P × A). USE THE FOLLOWING EQUATION FOR DETERMINING THE REQUIRED RESTRAINED LENGTH.

$$L_{REQUIRED} = (F \times SF) \div ((2WE + WP + WW) \times \tan(\Delta))$$

- L = MINIMUM LENGTH OF PIPE TO BE RESTRAINED (RESTRAINED LENGTH FOR EACH LEG IN THE CASE OF A BEND)
- F = THRUST FORCE=PXA
- P = DESIGN PRESSURE
- A = CROSS SECTIONAL AREA OF PIPE (USING OD OF PIPE WHICH EQUALS THE SEALING DIAMETER)
- SF = FACTOR OF SAFETY (1.5)
- WE = EARTH PRISM LOAD (PER FOOT LENGTH OF PIPE) *
- WP = WEIGHT OF PIPE (PER FOOT LENGTH OF PIPE) *
- WW = WEIGHT OF WATER IN PIPE (PER FOOT LENGTH OF PIPE)
- Δ = FRICTION ANGLE BETWEEN DISSIMILAR MATERIALS

MMCD STANDARD DRAWINGS

WATERWORKS

STD. W3 GATE VALVE INSTALLATION
STD. W5 TEST POINT INSTALLATION

CATHODIC PROTECTION

STD. W100 CATHODIC PROTECTION AND FINK BOX INSTALLATION

WATERMAIN GENERAL NOTES

- CONTRACTOR TO HOLD A SITE MEETING PRIOR TO STARTING WORK. NOTIFY UBC AND ENGINEER TWO WORKING DAYS PRIOR TO THE MEETING. CONTRACTOR TO ARRANGE FOR PIPE MANUFACTURE TO ATTEND, AND TO PROVIDE THE UBC INSPECTION POLICY AT THE SITE MEETING.
- ALL WATERMAIN TO BE INSTALLED AS PER MANUFACTURES RECOMMENDATIONS AND INSTRUCTIONS. CARE TO BE TAKEN TO ELIMINATE OVER DEFLECTION OF JOINTS, CONTRACTOR TO INSTALL PIPES TO ½ THE MANUFACTURES DEFLECTION ALLOWANCE. CARE TO BE TAKEN TO ELIMINATE OVER INSERTION OF PIPE JOINTS. INSERTION LINES MUST BE VISIBLE FOR ALL JOINTS. PRIOR TO ANY WORK BEING UNDERTAKEN CONTRACTOR TO OBTAIN A COPY OF MANUFACTURES GUIDELINES AND IS TO PROVIDE A COPY TO THE ENGINEER.
- CONTRACTOR TO PROVIDE ASBUILT LOCATION OF ANY UNDERGROUND FITTINGS (X,Y & Z COORDINATES) AND LOCATION OF ANY CUT SECTIONS OF PIPE.
- ALL UNDERGROUND METALLIC JOINTS, VALVES AND FITTINGS SHALL BE PROTECTED BY DENSO PASTE AND TAPE. CATHODIC PROTECTION
- 12 GUAGE TRACER WIRE TO BE INSTALLED ALONG THE WATERMAINS, ALONG THE SERVICES BETWEEN THE MAIN AND CURB STOPS (FOR SERVICES WHICH ARE NOT INSTALLED PERPENDICULAR TO THE PROPERTY LINES). PICKUP POINTS TO BE INSTALLED AT LINE AND HYDRANT VALVES. MULTIPLE VALVE ASSEMBLIES NEED ONLY ONE PICKUP POINT. TRACER WIRE CONNECTORS TO BE WATERTIGHT, DESIGNED AND RATED FOR BURIED APPLICATION (I.E. 3M DBR OR COMPARABLE).
- UTILITY TIE–INS TO BE COMPLETED BY THE CONTRACTOR, USING CONTRACTOR SUPPLIED MATERIALS AND EQUIPMENT. TIE–IN TO BE COORDINATED WITH UBC PROJECTS SUPERVISOR, MINIMUM 48 HOURS (WORKING DAYS) NOTICE IS REQUIRED AS GEID REPRESENTATIVE MUST BE PRESENT.
- A SCHEDULE MUST BE PROVIDED TO UBC A MINIMUM OF ONE WEEK PRIOR TO ANY WORKS WHICH MAY CAUSE SERVICE DISRUPTIONS.
- ALL THRUST BLOCKS TO BE INSTALLED AS PER APPROPRIATE STANDARD DRAWINGS. CONTRACTOR TO OBTAIN COPY OF AND KEEP A COPY ON SITE FOR REVIEW DURING CONSTRUCTION. THE CONTRACTOR IS TO ENSURE THAT A INSPECTOR BE NOTIFIED AND IS PRESENT TO DOCUMENT CONSTRUCTION OF KEY ITEMS SPECIFIC
- WATERMAINS TO BE TESTED AND DISINFECTED TO UBC AND AWWA STANDARDS PRIOR TO TIE–IN.
- 450mm MINIMUM VERTICAL SEPARATION BETWEEN WATERMAINS AND STORM & SANITARY MAINS WHEN CROSSING, WATERMAIN SHALL BE ON TOP, IF 450mm CLEARANCE CANNOT BE ACHIEVED USE MMCD STANDARD G6.
- ALL WATERMAINS TO BE CLASS 50 450MM DUCTILE IRON AS NOTED ON THE DESIGN DRAWINGS.
- ALL DESIGN CURVATURES ARE BASED ON IPEX PIPE GUIDELINES.
- ALL FILL WITHIN 300mm OF VALVE RISERS AND SERVICE BOXES TO BE CLEAN SAND.
- ALL CURB BOXES IN SIDEWALK & DRIVEWAYS TO BE PLACED IN BROOKS BOXES. ALL CURB BOXES IN ROADWAY TO BE PLACED IN NELSON BOX
- ALL CURB BOXES, VALVES, WATERMAINS, OR HYDRANTS TO BE A MINIMUM OF 1.5m FROM ANY RETAINING WALLS OR PHYSICAL STRUCTURES.

General Notes

ISSUE FOR CONSTRUCTION

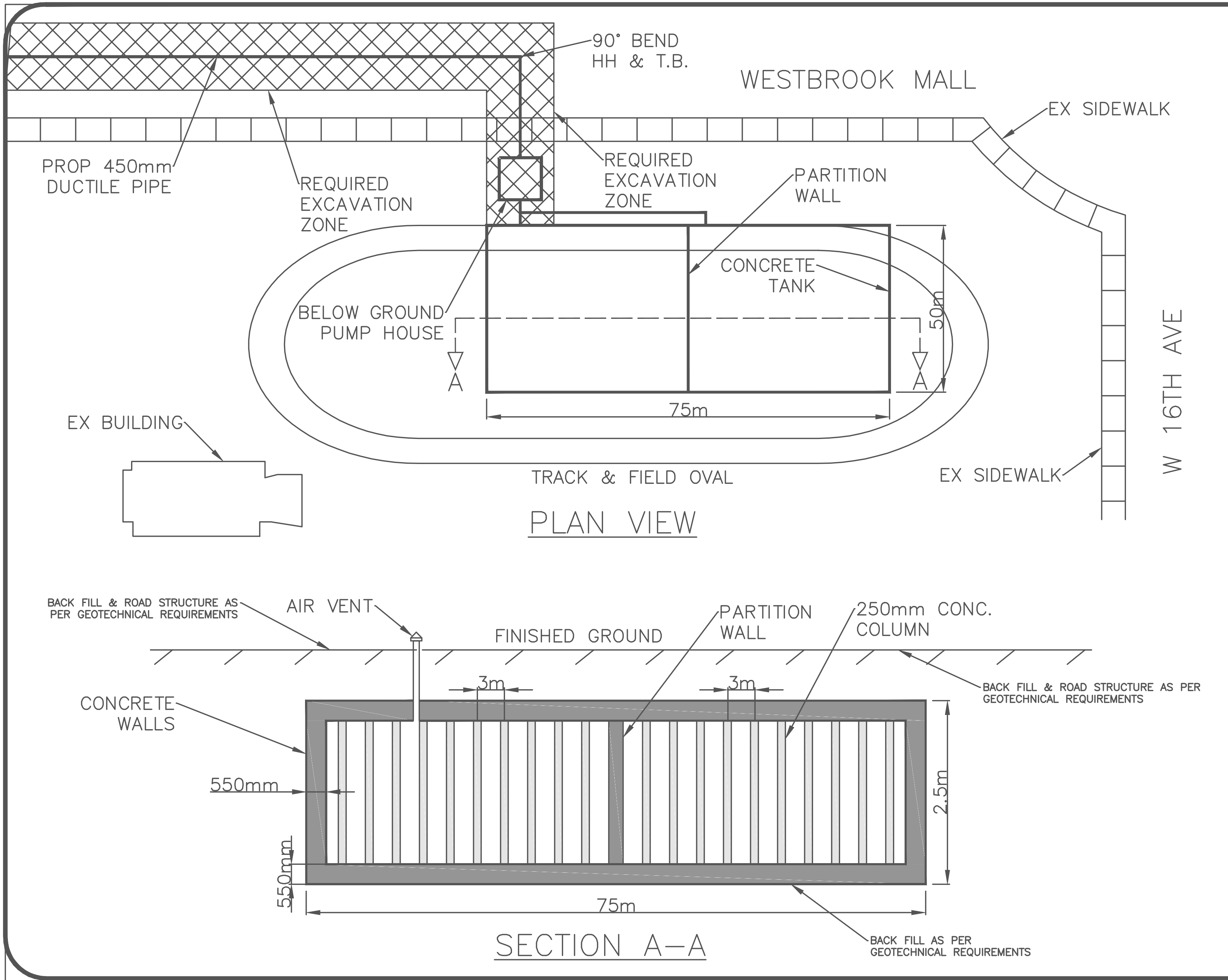
No.	Revision/Issue	Date

Firm Name and Address
TEAM 9 & ASSOCIATES

Project Name
GENERAL NOTES AND DETAILS

Project 18001–01
Date MAR 10 2018
Scale NTS
Sheet #1

Final dwg.dwg 14.10.2003



General Notes

ISSUE
FOR
CONSTRUCTION

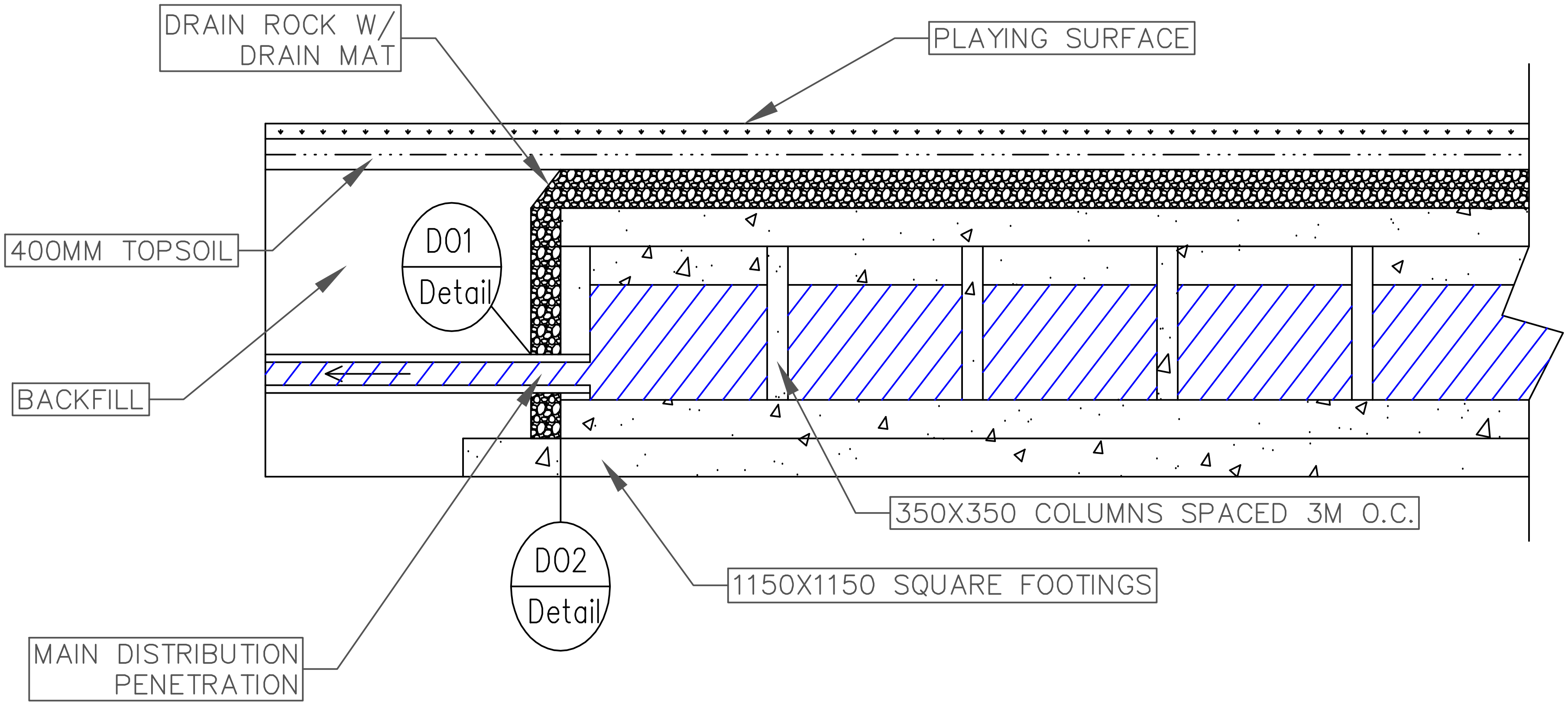
No.	Revision/Issue	Date

TEAM 9 & ASSOCIATES

WATER TANK
COMPOSITE UTILITY
PLAN

Project: 18001–02
Date: MAR 15 2018
Scale: NTS
Sheet: #2

Section A–A Ref



General Notes

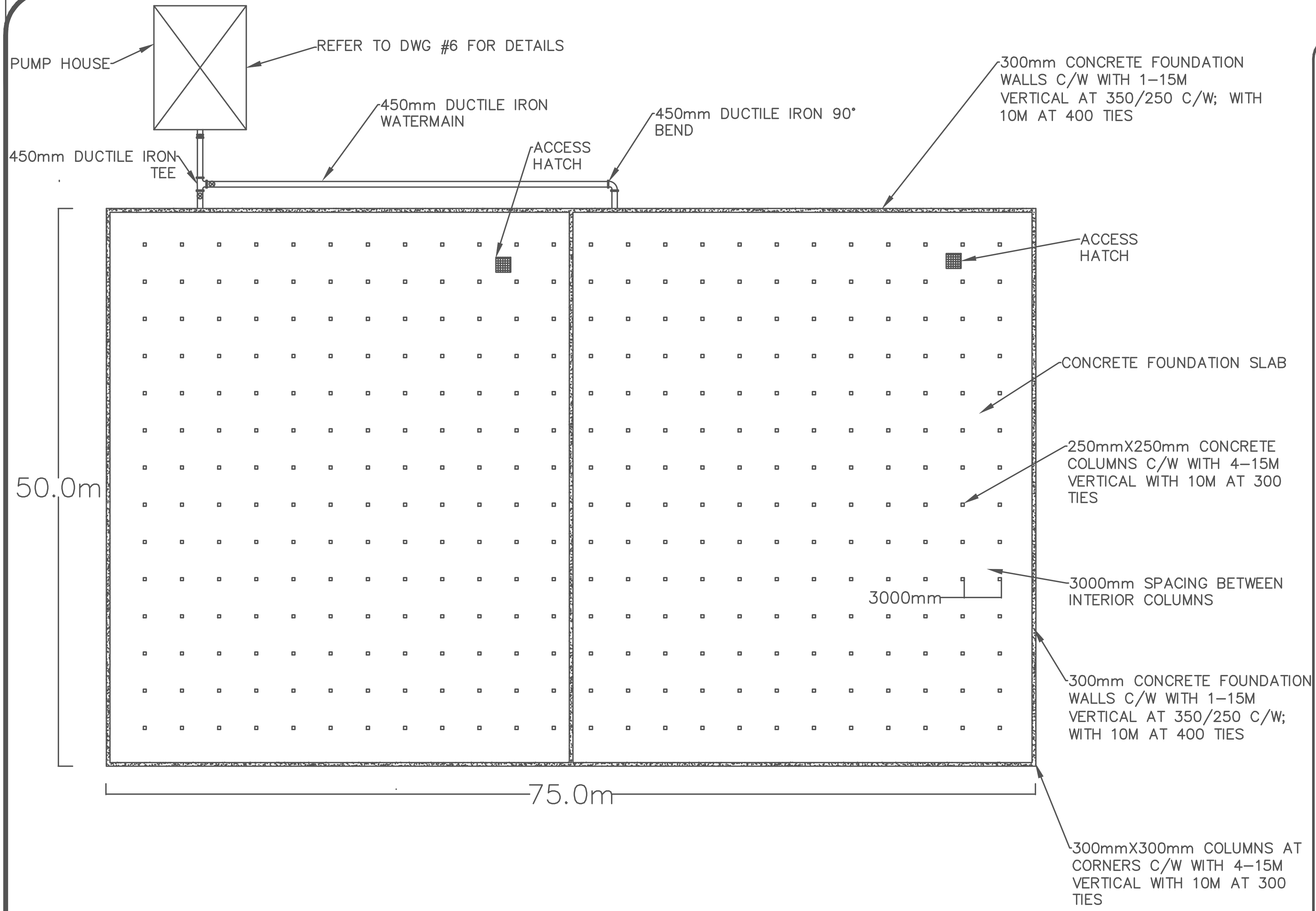
ISSUE FOR CONSTRUCTION

No.	Revision/Issue	Date

Firm Name and Address
TEAM 9 & ASSOCIATES

Project Name
WATER TANK SECTION A–A DETAIL

Project: 18001–03
Date: MAR 15 2018
Scale: NTS
Sheet: #3



Storage Tank Plan View

General Notes

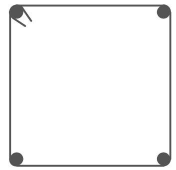
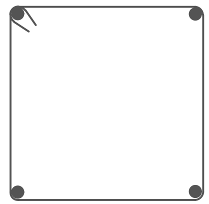
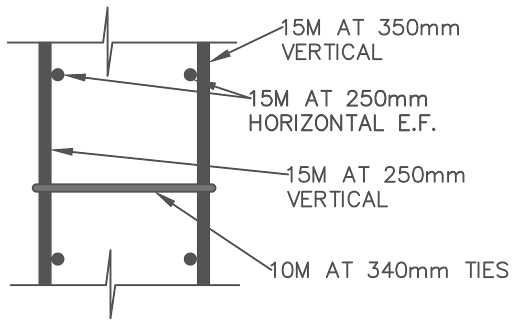
ISSUE FOR CONSTRUCTION

No.	Revision/Issue	Date

Firm Name and Address: TEAM 9 & ASSOCIATES

Project Name: WATER TANK PLAN VIEW

Project: 18001–04
Date: MAR 15 2018
Scale: NTS
Sheet: #4

COMPONENT	SIZE AND COVER	STRENGTH	REINFORCING	SCHEMATIC
INTERIOR COLUMN	250X250mm WITH 20mm CLEAR COVER ON ALL SIDES	35 MPa	4–15M VERTICAL WITH 10M AT 300mm TIES	
CORNER COLUMN	300X300mm WITH 50mm CLEAR COVER ON EXTERIOR	40 MPa	4–15M VERTICAL WITH 10M AT 300mm TIES	
FOUNDATION WALL	300mm THICK WITH 20mm CLEAR COVER ON INTERIOR AND 50MM CLEAR COVER ON EXTERIOR	40 MPa	1–15M VERTICAL AT 350/250 C/W; WITH 10M AT 400mm TIES	

WATER TANK REBAR SPECIFICATIONS

General Notes

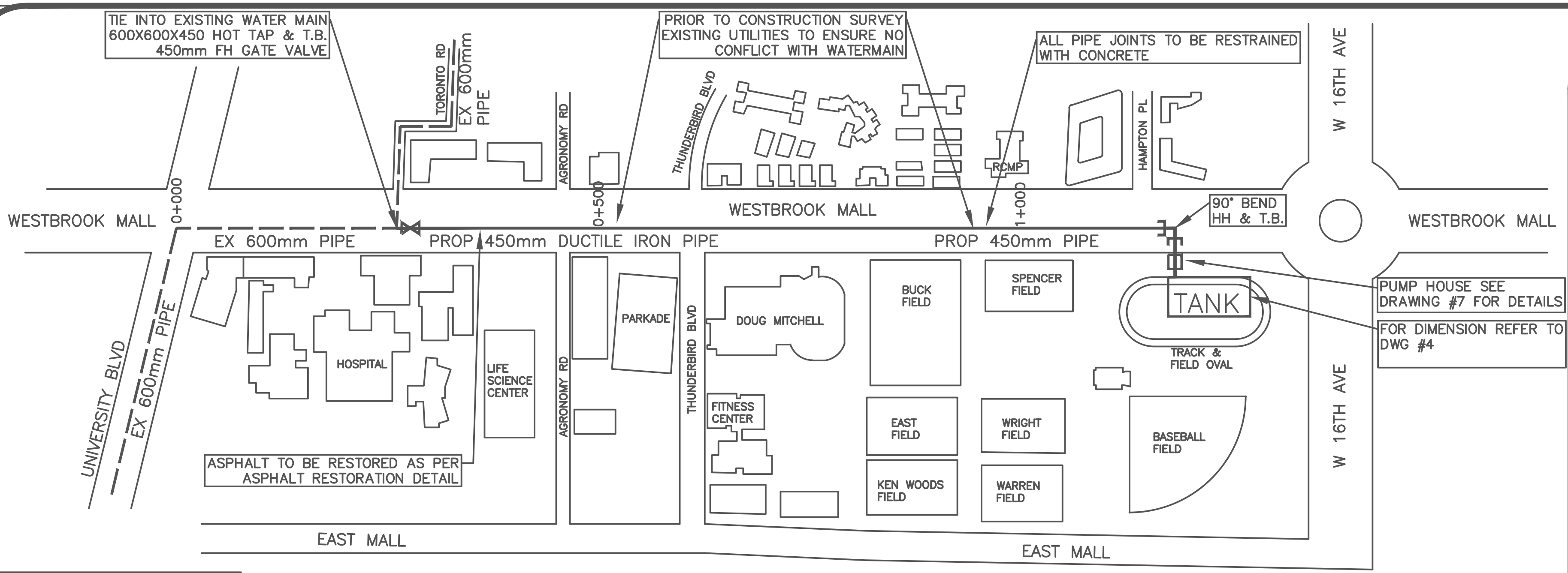
ISSUE FOR CONSTRUCTION

No.	Revision/Issue	Date

Firm Name and Address
TEAM 9 & ASSOCIATES

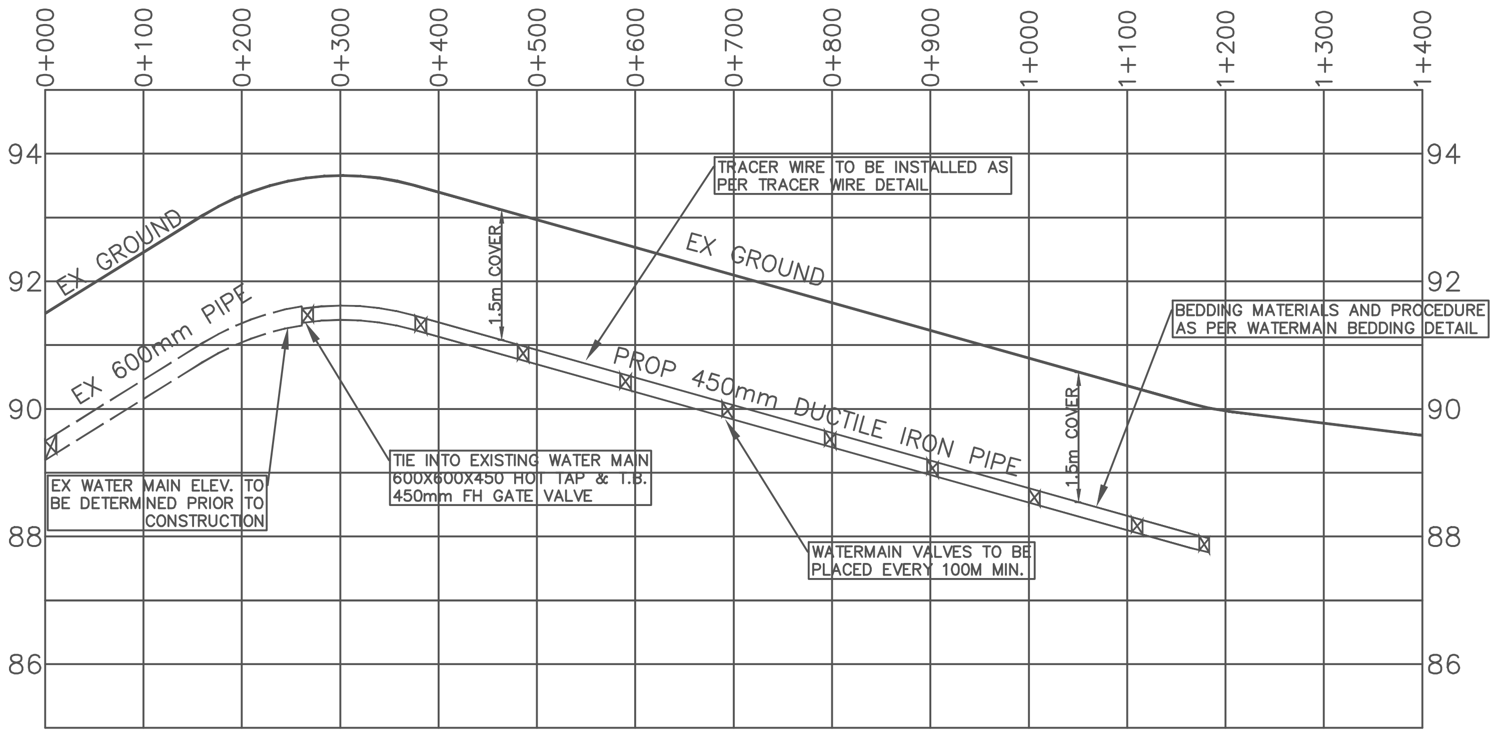
Project Name
WATER TANK REBAR SPECIFICATION

Project 18001-05
Date MAR 15 2018
Scale NTS
Sheet #5



ALL WATERMAINS TO BE CLEAN/FLUSHED AND DISINFECTED

PLAN VIEW



General Notes

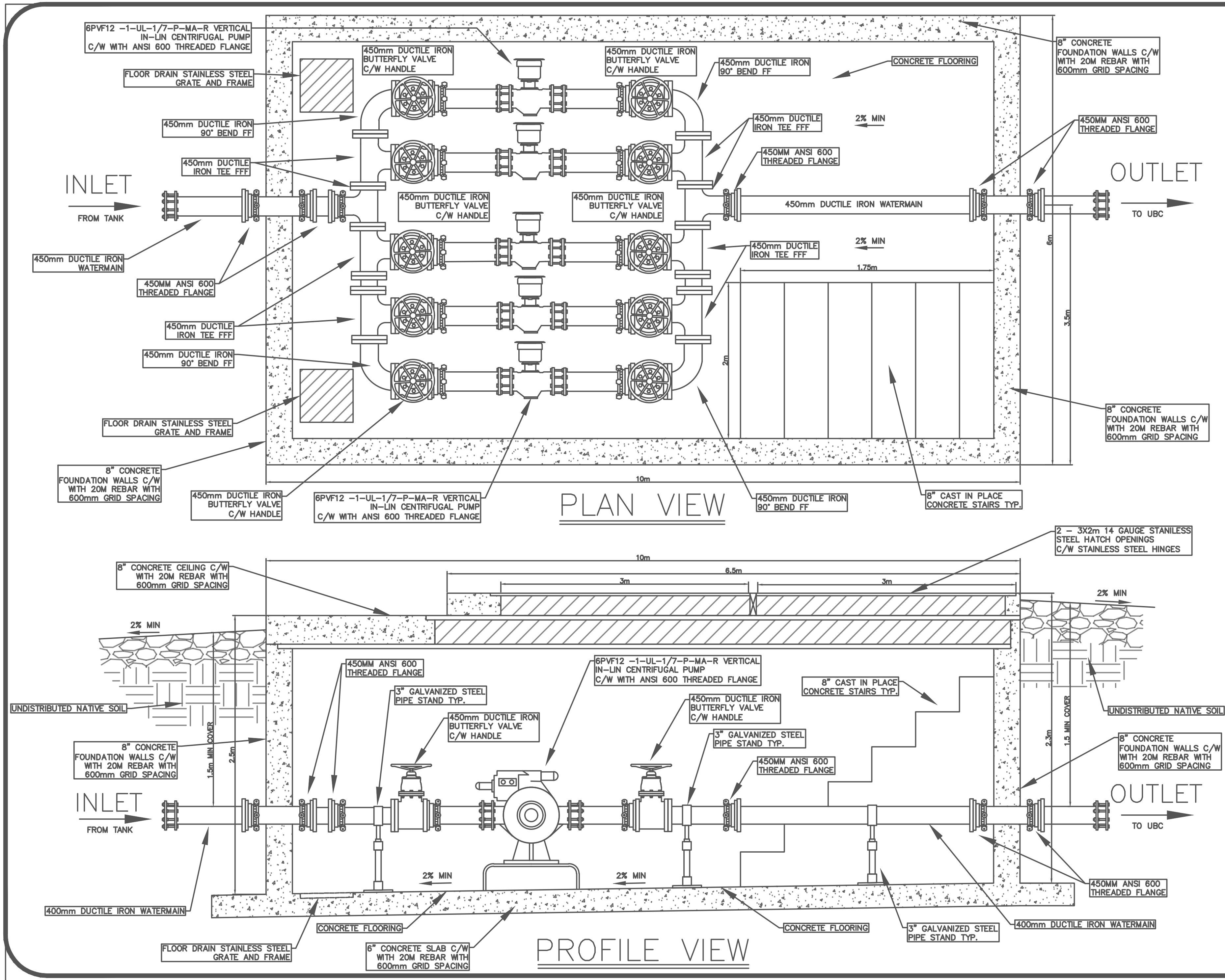
ISSUE FOR CONSTRUCTION

No.	Revision/Issue	Date

Firm Name and Address
TEAM 9 & ASSOCIATES

Project Name
WATERMAIN PLAN/PROFILE

Project: 18001-06
Date: MAR 10 2018
Scale: NTS
Sheet: #6



General Notes

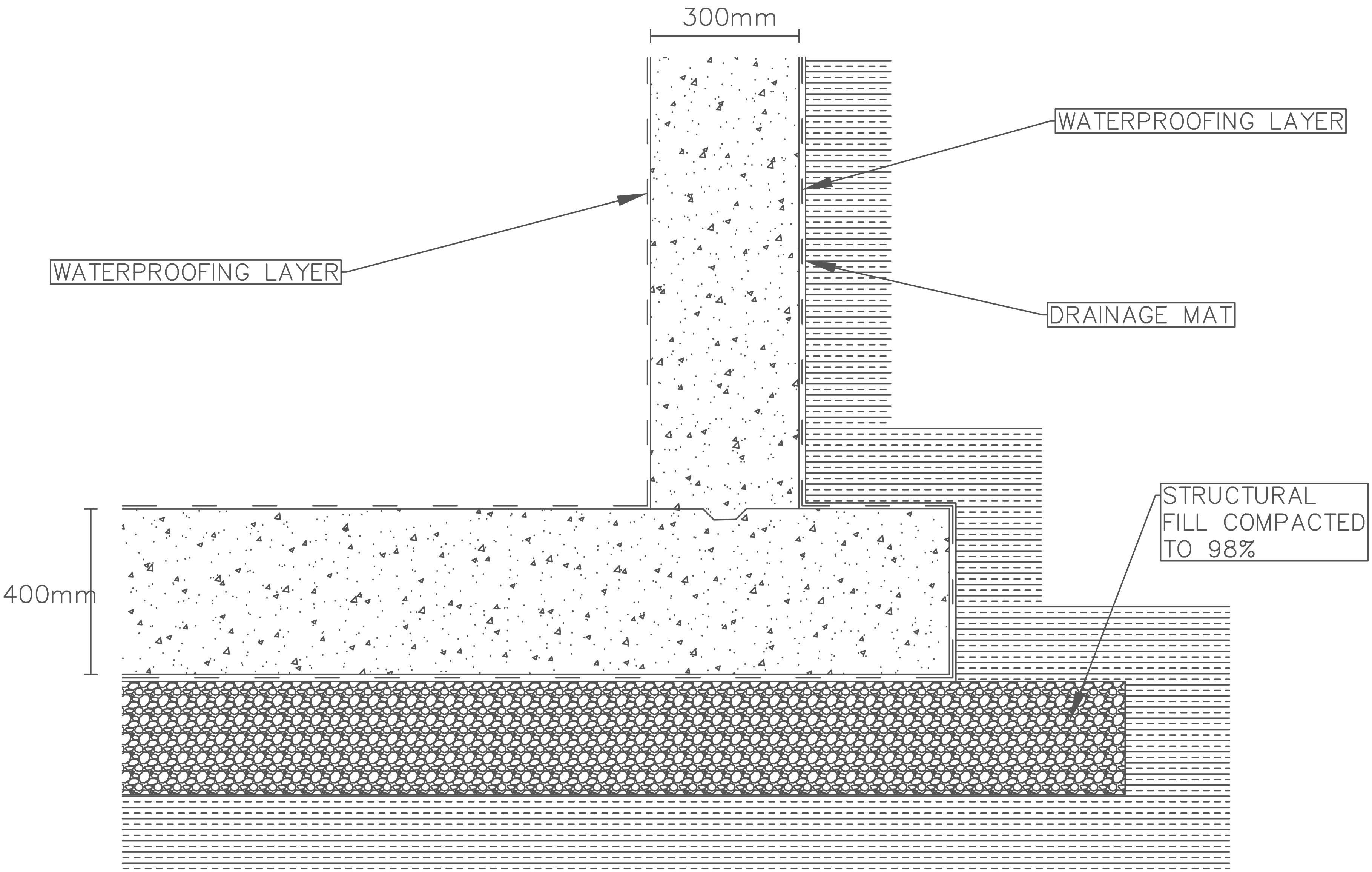
ISSUE FOR CONSTRUCTION

No.	Revision/Issue	Date

Firm Name and Address
TEAM 9 & ASSOCIATES

Project Name
PUMP HOUSE PLAN/PROFILE

Project: 18001-07
Date: MAR 20 2018
Scale: NTS
Sheet: #7



Tank Wall to Slab Detail

General Notes

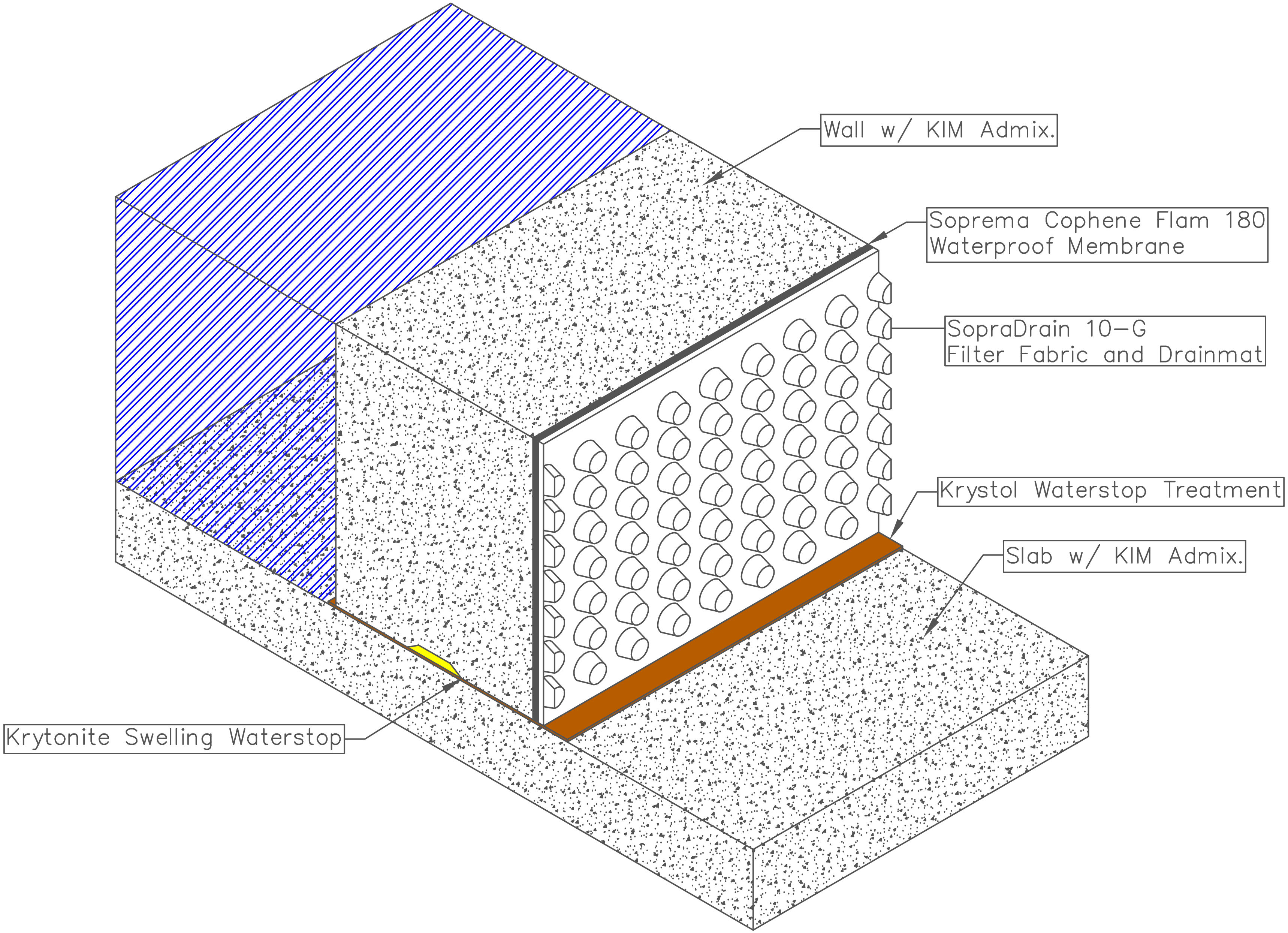
ISSUE FOR CONSTRUCTION

No.	Revision/Issue	Date

Firm Name and Address
TEAM 9 & ASSOCIATES

Project Name
TANK WALL TO SLAB DETAIL

Project 18001–08	Sheet #8
Date MAR 28 2018	
Scale NTS	



General Notes

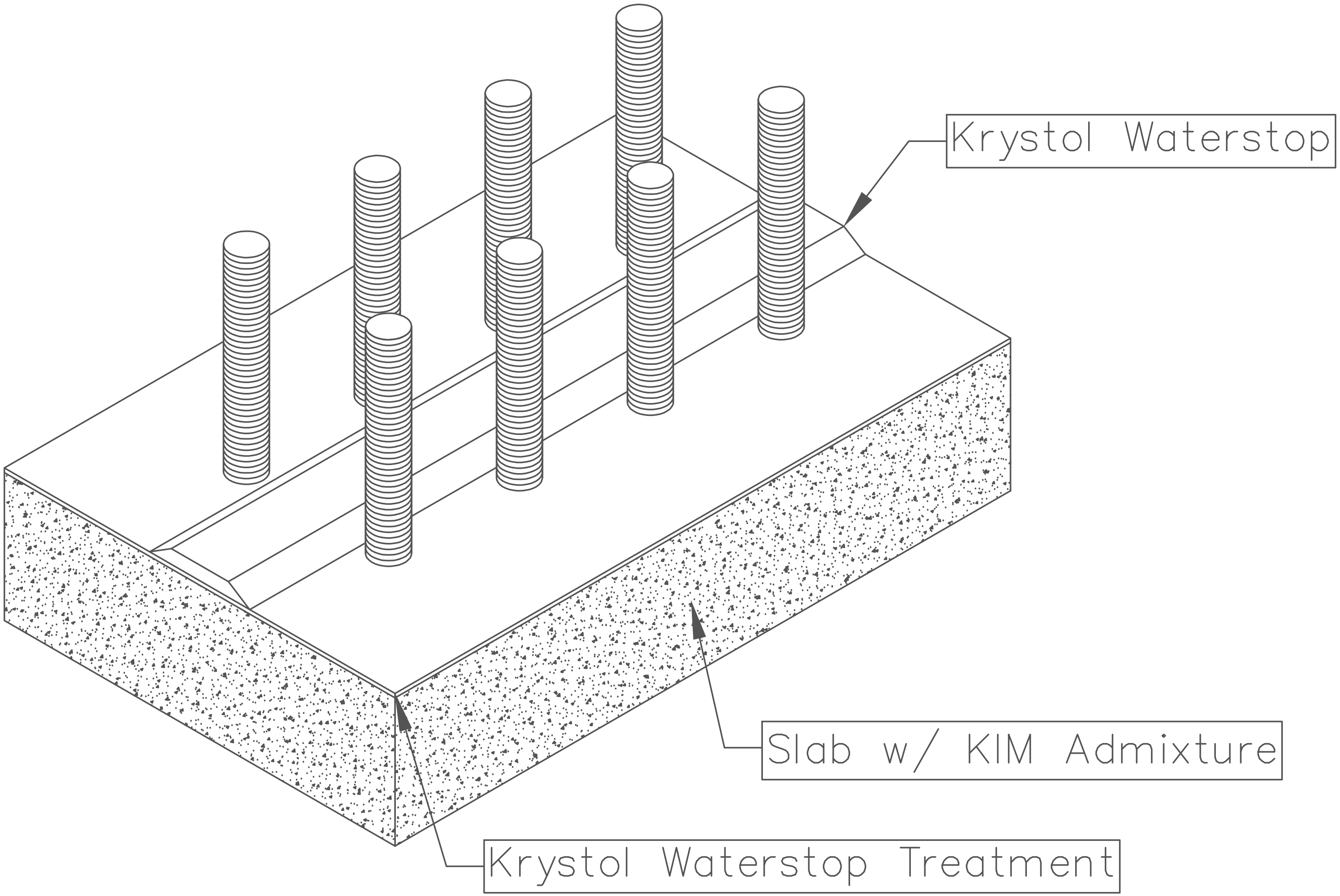
ISSUE FOR CONSTRUCTION

No.	Revision/Issue	Date

Firm Name and Address
Team 9 and Associates

Project Name and Address
Overview of Slab to Wall Detail using Waterproofing Products

Project: 18001-09
Date: 11.06.17
Scale: N/A
Sheet: #9



MANUFACTURER'S NOTES (VIA WWW.KRYTON.COM):

1. ADD KRYSTOL INTERNAL MEMBRANE (KIM) TO READY MIX CONCRETE OR SHOTCRETE AT A RATE OF 2% BY WEIGHT OF CEMENTITIOUS MATERIALS (INCLUDING FLY ASH AND OTHER SUPPLEMENTARY CEMENTING MATERIALS) TO A MAXIMUM DOSAGE OF 8 KG/M³ (13.5 LB. /CU. YD.)
2. COAT SURFACE AREA OF THE JOINT WITH KRYSTOL WATERSTOP TREATMENT AT A SPREAD RATE OF 1 KG/M2 (0.2 LB./SQ. FT.).
3. INSTALL KRYTONITE SWELLING WATERSTOP IN CENTER OF SLAB, USING KRYTONITE ADHESIVE AT A COVERAGE RATE OF 8-10 METERS (26-32 FT) PER CARTRIDGE.
4. CREATE A 40 MM X 40 MM (1.5 IN. X 1.5 IN.), TAPERING TO 30 MM (1.2 IN.), KEYWAY AT THE INTERSECTION WHERE THE TWO CONCRETE SECTIONS MEET, THROUGH FORMING, OR WHILE THE CONCRETE IS IN A MOLDABLE PLASTIC STATE.
5. TIGHTLY PACK PREFORMED KEYWAY FLUSH TO THE SURFACE WITH KRYSTOL WATERSTOP GROUT AT A RATE OF 3.33 KG/M (2.23 LB./FT.)

General Notes

ISSUE
FOR
CONSTRUCTION

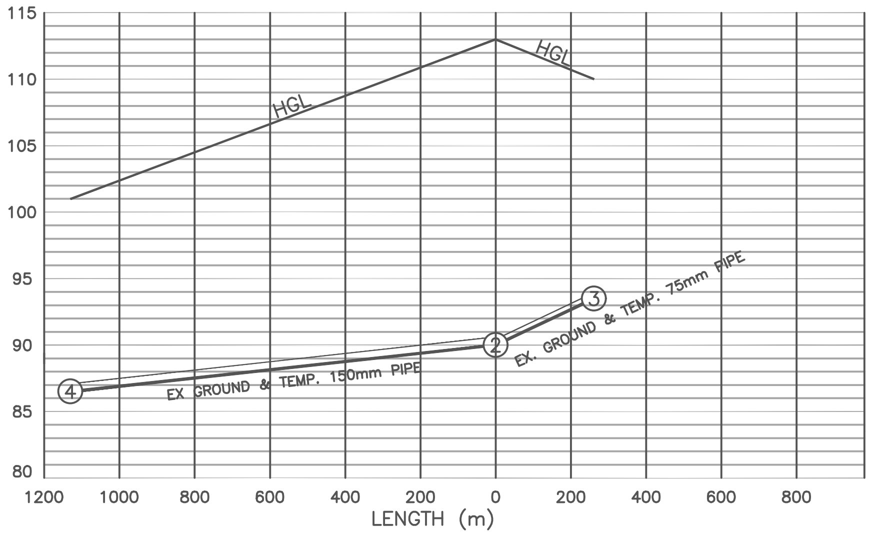
No.	Revision/Issue	Date

Firm Name and Address
Team 9 and Associates

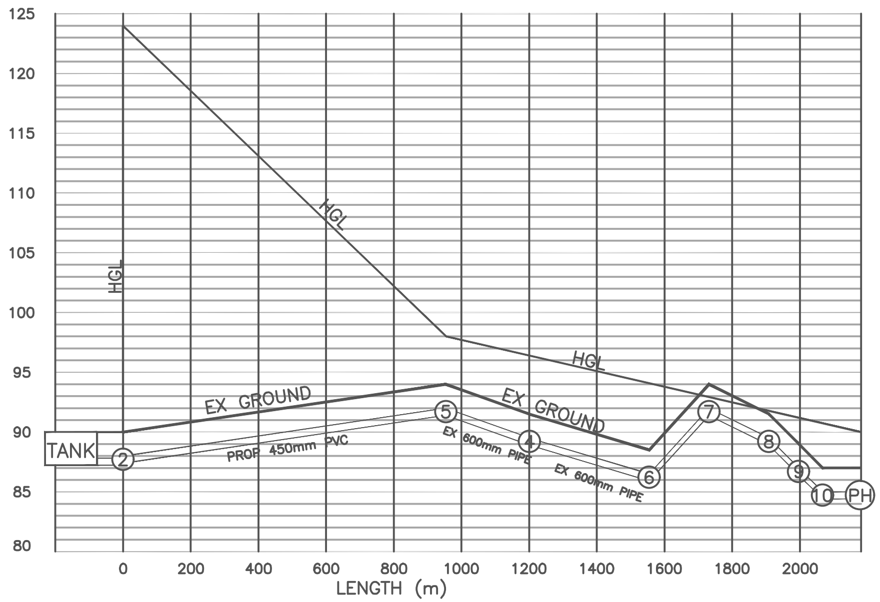
Project Name and Address
Overview of Footing to Wall Detail using Waterproofing Products

Project 18001–10	Sheet #10
Date 11.06.17	
Scale N/A	

SCENARIO B



SCENARIO A



General Notes

ISSUE FOR CONSTRUCTION

No.	Revision/Issue	Date

Firm Name and Address
TEAM 9 & ASSOCIATES

Project Name
SCENARIO A & B HGL

Project: 18001-11
Date: NOV 9 2017
Scale: NTS
Sheet: #11

Appendix II – Supplementary Pump Information

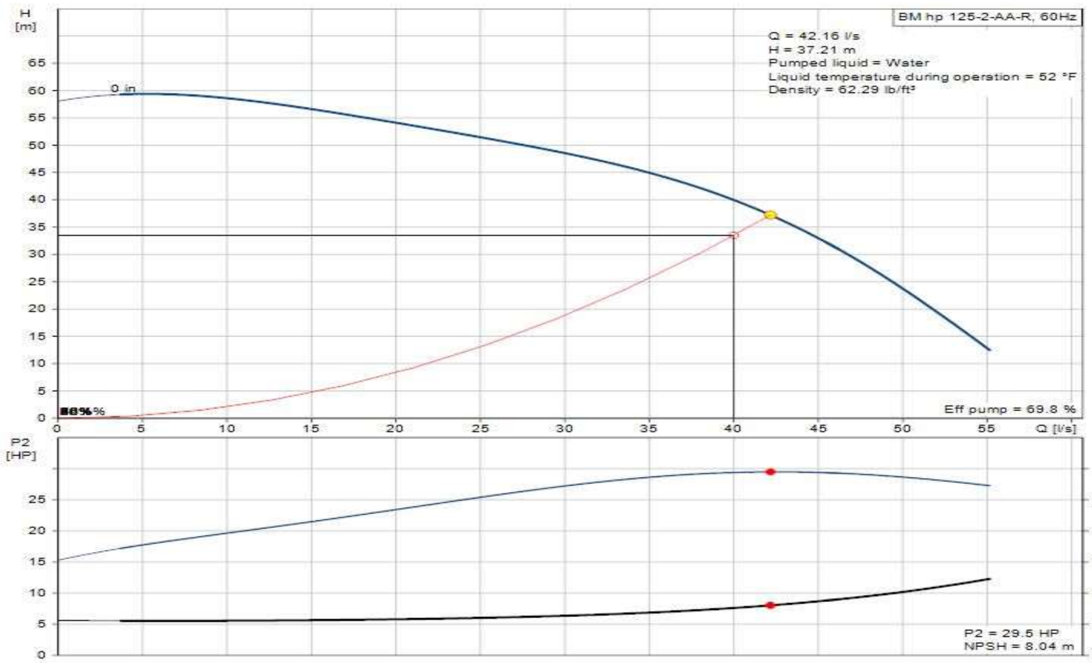
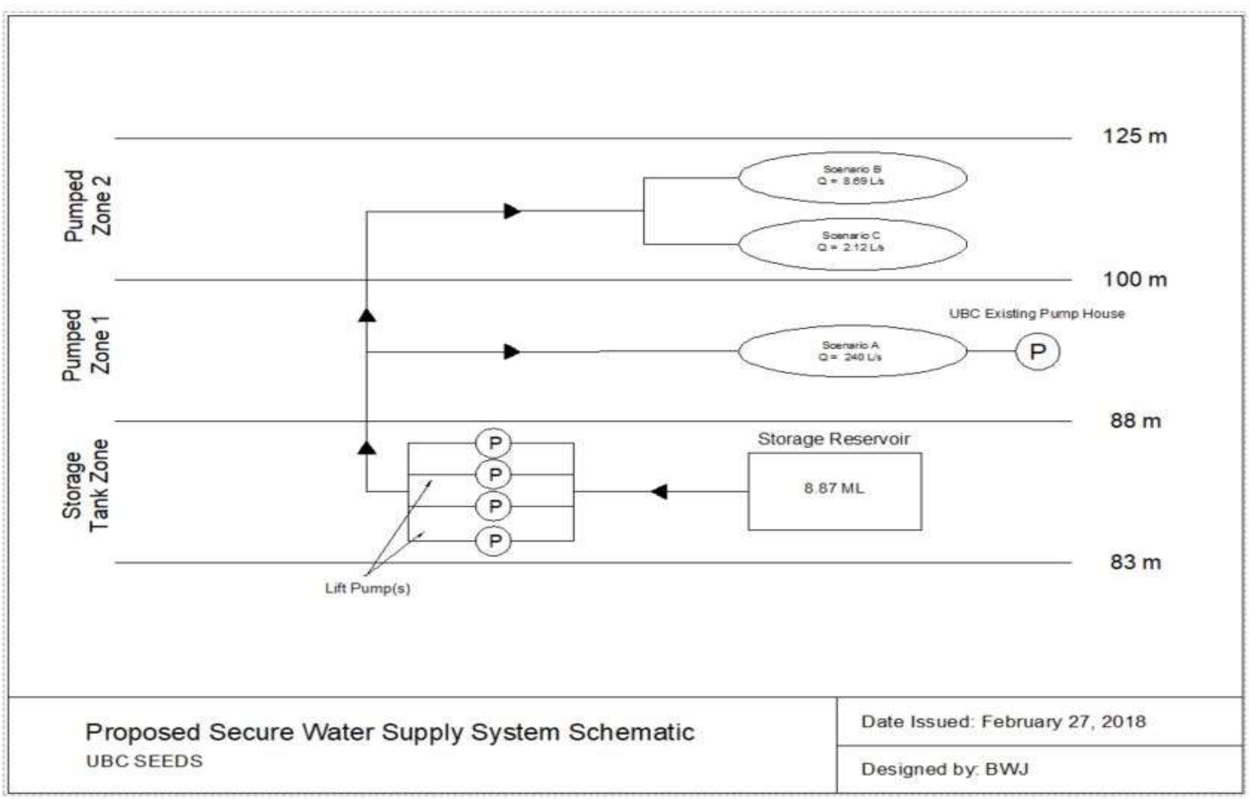
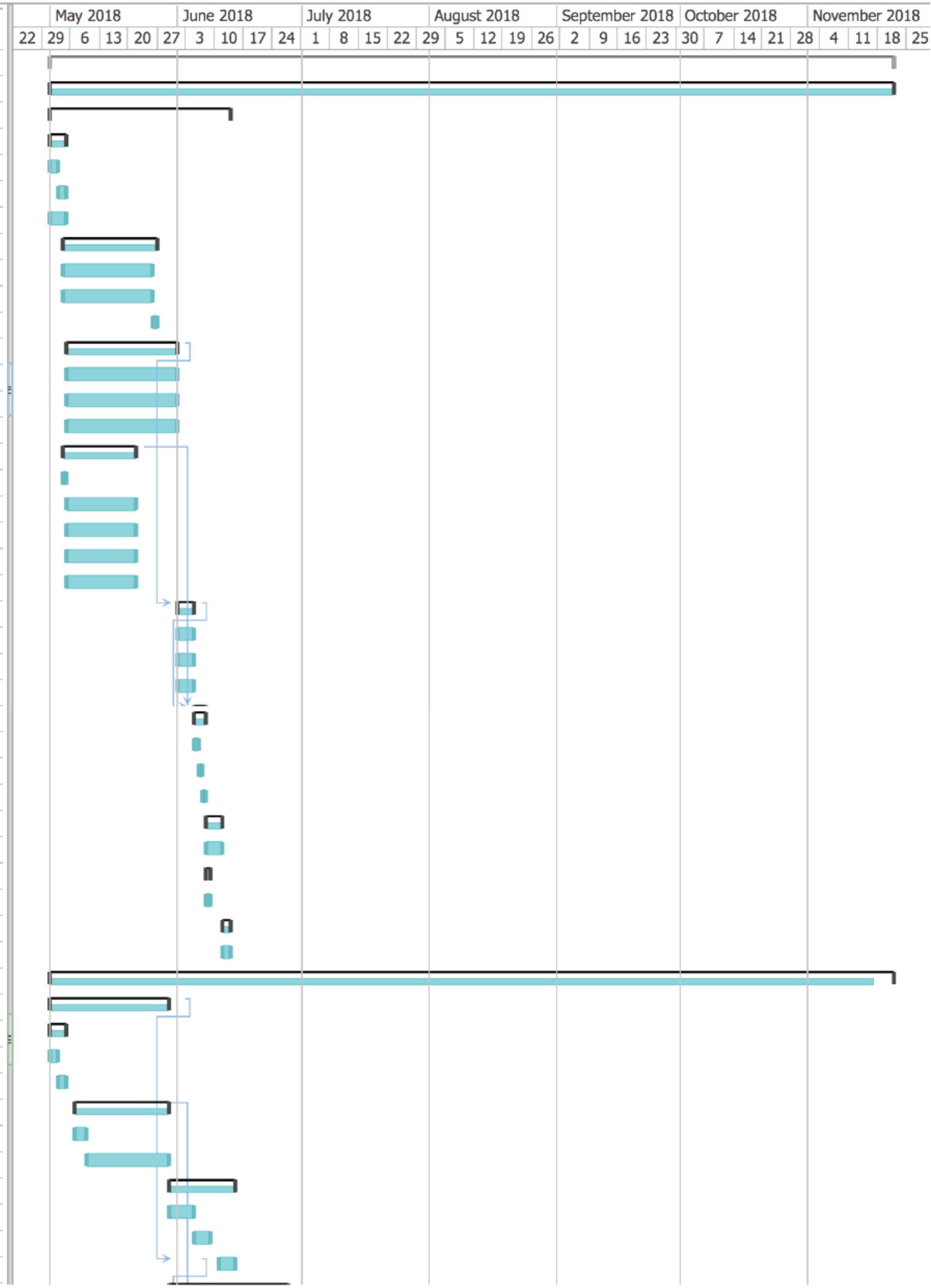


Figure A-0-1: 6PVF12-1-UL-1/7-P-MA-R Pump Curve (Grundfos, 2018)

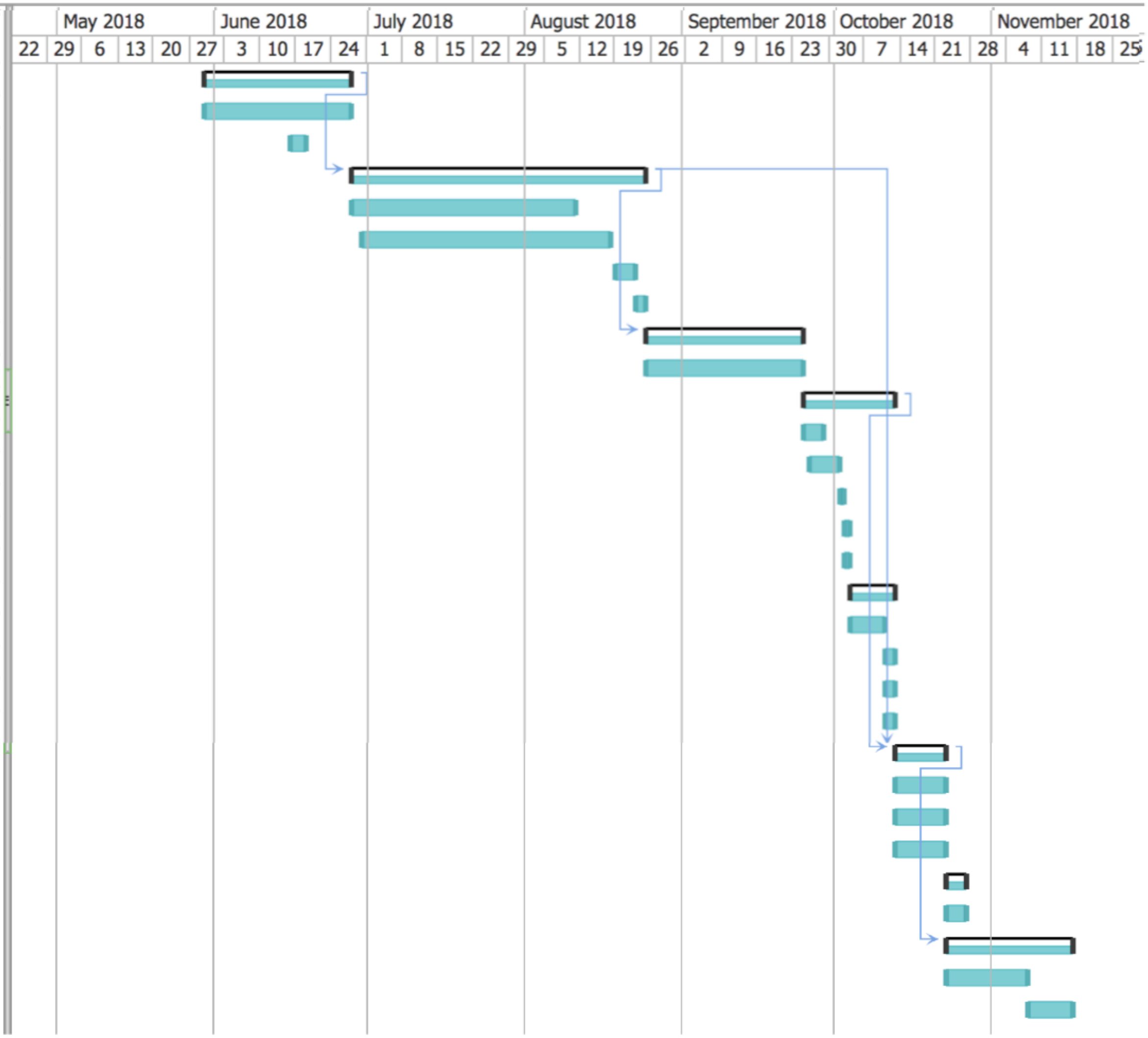


Appendix III – Proposed Construction Gantt Chart

ID ↑	Task Name	Duration	Start	Finish
0	**Water Tank and Distribution Main construction**	**147d**	**5/1/2018**	**11/21/2018**
1	**Secure Water Storage and Distribution Syster**	**147d**	**5/1/2018**	**11/21/2018**
2	**Distribution Line Construction**	**32d**	**5/1/2018**	**6/13/2018**
3	**Site Preparation**	**4d**	**5/1/2018**	**5/4/2018**
4	Initial Site Survey	2d	5/1/2018	5/2/2018
5	Existing Utility Identification	2d	5/3/2018	5/4/2018
6	Mobilization (equipment, site office, labour)	4d	5/1/2018	5/4/2018
7	**Earthworks**	**17d**	**5/4/2018**	**5/26/2018**
8	Asphalt Removal	16d	5/4/2018	5/25/2018
9	Excavation	16d	5/4/2018	5/25/2018
10	Material Disposal	1d	5/26/2018	5/26/2018
11	**Backfill**	**20d**	**5/5/2018**	**5/31/2018**
12	Placing (Base and Top)	20d	5/5/2018	5/31/2018
13	Compaction	20d	5/5/2018	5/31/2018
14	Testing	20d	5/5/2018	5/31/2018
15	**Pipe Laying**	**12d**	**5/4/2018**	**5/21/2018**
16	Transport	1d	5/4/2018	5/4/2018
17	Laying	12d	5/5/2018	5/21/2018
18	Aligning	12d	5/5/2018	5/21/2018
19	Connecting	12d	5/5/2018	5/21/2018
20	Thrust Block	12d	5/5/2018	5/21/2018
21	**Resurfacing**	**2d**	**6/1/2018**	**6/4/2018**
22	Asphalt restoration	2d	6/1/2018	6/4/2018
23	Testing	2d	6/1/2018	6/4/2018
24	Landscaping	2d	6/1/2018	6/4/2018
25	**Pipe Testing**	**3d**	**6/5/2018**	**6/7/2018**
26	Water Pressurization Testing	1d	6/5/2018	6/5/2018
27	Flush out	1d	6/6/2018	6/6/2018
28	Microbial Growth/ Bacteria Test	1d	6/7/2018	6/7/2018
29	**Connection**	**2d**	**6/8/2018**	**6/11/2018**
30	Connection to existing main	2d	6/8/2018	6/11/2018
31	**Approval**	**1d**	**6/8/2018**	**6/8/2018**
32	Approval by Engineer	1d	6/8/2018	6/8/2018
33	**Demobilizing**	**2d**	**6/12/2018**	**6/13/2018**
34	Demobilizing equipment	2d	6/12/2018	6/13/2018
35	**Underground Tank**	**147d**	**5/1/2018**	**11/21/2018**
36	**Site Investigation**	**21d**	**5/1/2018**	**5/29/2018**
37	**Survey**	**4d**	**5/1/2018**	**5/4/2018**
38	Topographic Survey	2d	5/1/2018	5/2/2018
39	Legal Survey	2d	5/3/2018	5/4/2018
40	**Geotechnical Investigation**	**17d**	**5/7/2018**	**5/29/2018**
41	Borehole	3d	5/7/2018	5/9/2018
42	Site Classification and Verification of Geote	14d	5/10/2018	5/29/2018
43	**Site Preparation**	**12d**	**5/30/2018**	**6/14/2018**
44	Fence Setup	4d	5/30/2018	6/4/2018
45	Site Utilities (Power, sanitary, waste disposal)	4d	6/5/2018	6/8/2018
46	Signange	4d	6/11/2018	6/14/2018



ID ↑	Task Name	Duration	Start	Finish
47	**Earthworks**	**21d**	**5/30/2018**	**6/27/2018**
48	Excavation	21d	5/30/2018	6/27/2018
49	Compaction	2d	6/16/2018	6/18/2018
50	**Tank Constuction**	**42d**	**6/28/2018**	**8/24/2018**
51	Rebar and formwork	32d	6/28/2018	8/10/2018
52	Concrete pour	36d	6/30/2018	8/17/2018
53	Concrete Settling	4d	8/19/2018	8/22/2018
54	Stripping	2d	8/23/2018	8/24/2018
55	**Tank Enclosure/Waterproofing**	**22d**	**8/25/2018**	**9/24/2018**
56	Membrane	22d	8/25/2018	9/24/2018
57	**Pumphouse**	**14d**	**9/25/2018**	**10/12/2018**
58	Rebar and Formwork	4d	9/25/2018	9/28/2018
59	Concrete Pour	4d	9/26/2018	10/1/2018
60	Formwork Stripping	1d	10/2/2018	10/2/2018
61	Steel hatch insallation	1d	10/3/2018	10/3/2018
62	utility placement	1d	10/3/2018	10/3/2018
63	**Piping/Connections**	**7d**	**10/4/2018**	**10/12/2018**
64	Pump Installation	5d	10/4/2018	10/10/2018
65	Connection to tank	2d	10/11/2018	10/12/2018
66	Connection to New Water Main	2d	10/11/2018	10/12/2018
67	Temporary Distribution Connection Intallat	2d	10/11/2018	10/12/2018
68	**Backfill**	**7d**	**10/13/2018**	**10/22/2018**
69	Side and Top placement	7d	10/13/2018	10/22/2018
70	Compaction	7d	10/13/2018	10/22/2018
71	Testing	7d	10/13/2018	10/22/2018
72	**Demobalization**	**4d**	**10/23/2018**	**10/26/2018**
73	Demobilizing equipment	4d	10/23/2018	10/26/2018
74	**Landscaping**	**19d**	**10/23/2018**	**11/16/2018**
75	Track	12d	10/23/2018	11/7/2018
76	Sodd	7d	11/8/2018	11/16/2018



Appendix IV – Class B Cost Estimate

UBC Secure Water Supply System Class B Cost Estimate
CIVL 446 - Project No. II

Cost Element Worksheet

CAPITAL COST

Cost Element	Quantity	Unit	Unit Price	BASE ESTIMATE	CONTINGENCY %	CONTINGENCY $	Total	COMMENTS
Project Management								
~3.5% of Design, Environmental, and Construction Costs				$ 94,080	20%	$ 18,816	**$ 112,896**	
Permitting/Planning								
~2.0% of Construction Costs				$ 46,760	20%	$ 9,352	**$ 56,112**	Additional ~1.0% added for permitting costs
Design Fees								
Detailed Design Services				$ 150,000	20%	$ 30,000	$ 180,000	
Design Total				**$ 150,000**	**20%**	**$ 30,000**	**$ 180,000**	
Environment								
Environmental Compensation				$ 200,000	30%	$ 60,000	$ 260,000	
Environment Total				**$ 200,000**	**30%**	**$ 60,000**	**$ 260,000**	
Construction (inclusive of labour, materials, and equipment)								
Site Preparation/Mobilization								
Survey layout and asbuilt records	*1*	*LS*	*$ 20,000*	$ 20,000	10%	$ 2,000	$ 22,000	
Mobilization and demobilization	*1*	*LS*	*$ 12,000*	$ 12,000	10%	$ 1,200	$ 13,200	
Traffic Control	*1*	*LS*	*$ 12,000*	$ 12,000	10%	$ 1,200	$ 13,200	
Insurance	*1*	*LS*	*$ 6,000*	$ 6,000	10%	$ 600	$ 6,600	
Material Payment and Performance Bonding	*1*	*LS*	*$ 20,000*	$ 20,000	10%	$ 2,000	$ 22,000	
Bid Bond	*1*	*LS*	*$ 30,000*	$ 30,000	10%	$ 3,000	$ 33,000	
Below Grade Tank								
Tank Construction								
Field removal	*3,744*	*m^2*	*$ 6*	$ 20,592	10%	$ 2,059	$ 22,651	
Excavation	*11,232*	*m^3*	*$ 9*	$ 101,088	10%	$ 10,109	$ 111,197	
Concrete								
Corner Columns	*0.4*	*m^3*	*$ 90*	$ 32	10%	$ 3	$ 36	
Foundation Walls	*186.3*	*m^3*	*$ 90*	$ 16,767	10%	$ 1,677	$ 18,444	
Interior Columns	*21.0*	*m^3*	*$ 90*	$ 1,890	10%	$ 189	$ 2,079	
Top Slab	*874.0*	*m^3*	*$ 90*	$ 78,660	10%	$ 7,866	$ 86,526	
Bottom Slab	*874.0*	*m^3*	*$ 90*	$ 78,660	10%	$ 7,866	$ 86,526	
Partition Wall	*34.7*	*m^3*	*$ 90*	$ 3,123	10%	$ 312	$ 3,435	
Footings	*2.7*	*m^3*	*$ 90*	$ 243	10%	$ 24	$ 267	
Concrete Waste	*199.3*	*m^3*	*$ 18*	$ 3,587	10%	$ 359	$ 3,946	
Rebar								
10-M	*50*	*Tonnes*	*$ 2,320*	$ 114,840	10%	$ 11,484	$ 126,324	
15-M	*92*	*Tonnes*	*$ 2,320*	$ 212,976	10%	$ 21,298	$ 234,274	
Formwork	*3,211*	*m^3*	*$ 85*	$ 272,935	10%	$ 27,294	$ 300,229	
Exterior Membrane	*780*	*m^2*	*$ 45*	$ 35,100	10%	$ 3,510	$ 38,610	

CAPITAL COST								
Cost Element	Quantity	Unit	Unit Price	BASE ESTIMATE	CONTINGENCY %	CONTINGENCY $	Total	COMMENTS
24"x36" Steel Access Hatch	*2*	*ea*	*$ 1,600*	$ 3,200	110%	$ 3,520	$ 6,720	
Field Restoration								
Track Installation	*3,744*	*m^2*	*$ 30*	$ 112,320	10%	$ 11,232	$ 123,552	
Landscaping	*1*	*LS*	*$ 10,000*	$ 10,000	10%	$ 1,000	$ 11,000	
Approvals & Testing								
QA/QC	*1*	*LS*	*$ 50,000*	$ 50,000	10%	$ 5,000	$ 55,000	
Water Quality Testing	*1*	*LS*	*$ 2,400*	$ 2,400	110%	$ 2,640	$ 5,040	
Owner/bylaw officer approval	*1*	*LS*	*$ 5,000*	$ 5,000	10%	$ 500	$ 5,500	
Distribution System								
Civil Works								
Asphault removal	*1,960*	*m^2*	*$ 30*	$ 58,800	10%	$ 5,880	$ 64,680	
Excavation	*2,940*	*m^3*	*$ 55*	$ 161,700	10%	$ 16,170	$ 177,870	
450 mm dia. C900	*980*	*m*	*$ 200*	$ 196,000	10%	$ 19,600	$ 215,600	
450 x 450 x 150 mm dia. Tee and thrust block	*2*	*ea*	*$ 1,000*	$ 2,000	10%	$ 200	$ 2,200	
450 mm dia. Gate Valve	*10*	*ea*	*$ 1,400*	$ 14,000	10%	$ 1,400	$ 15,400	
450 mm dia. 90 deg bend and thrust blocks	*2*	*ea*	*$ 850*	$ 1,700	10%	$ 170	$ 1,870	
Hydrants	*10*	*ea*	*$ 4,500*	$ 45,000	10%	$ 4,500	$ 49,500	
450 mm to 600 mm hot tap tie-in	*1*	*LS*	*$ 15,000*	$ 15,000	10%	$ 1,500	$ 16,500	
Structural filll and compact	*2,940*	*m^3*	*$ 50*	$ 147,000	10%	$ 14,700	$ 161,700	
Surface Restoration								
50mm Asphalt	*1,960*	*m^2*	*$ 30*	$ 58,800	10%	$ 5,880	$ 64,680	
Roadworks delineation	*1*	*LS*	*$ 3,000*	$ 3,000	10%	$ 300	$ 3,300	
Landscaping	*1*	*LS*	*$ 10,000*	$ 10,000	10%	$ 1,000	$ 11,000	
Approvals & Testing								
Flush-out	*1*	*LS*	*$ 4,000*	$ 4,000	10%	$ 400	$ 4,400	
Water pressurization test	*1*	*LS*	*$ 4,000*	$ 4,000	10%	$ 400	$ 4,400	
Owner/bylaw officer approval	*1*	*LS*	*$ 5,000*	$ 5,000	10%	$ 500	$ 5,500	
Temporary Distribution Set-up								
150mm Rubber Conduit	*580*	*m*	*$ 8*	$ 4,640	10%	$ 464	$ 5,104	
75mm Rubber Conduit	*460*	*m*	*$ 6*	$ 2,760	10%	$ 276	$ 3,036	
Pre-fabricated Tap Structure	*2*	*ea*	*$ 6,000*	$ 12,000	10%	$ 1,200	$ 13,200	
Pump House								
Excavation	*40*	*m^3*	*$ 30*	$ 1,200	10%	$ 120	$ 1,320	
Pre-fab underground building	*1*	*LS*	*$ 25,000*	$ 25,000	10%	$ 2,500	$ 27,500	
Pumps (6VPF12 1-UL-1/7-P-MA-R) In-line	*5*	*ea*	*$ 5,000*	$ 25,000	10%	$ 2,500	$ 27,500	
Electrical systems	*1*	*LS*	*$ 10,000*	$ 10,000	10%	$ 1,000	$ 11,000	
Conections/detailing	*1*	*LS*	*$ 15,000*	$ 15,000	10%	$ 1,500	$ 16,500	
Architectural features	*1*	*LS*	*$ 10,000*	$ 10,000	10%	$ 1,000	$ 11,000	
Construction Supervision	*1*	*LS*	*$ 180,000*	$ 180,000	10%	$ 18,000	$ 198,000	
Construction Total				**$ 2,338,006**		**$ 239,401**	**$ 2,577,406**	
CAPITAL COSTS SUB-TOTAL							**$ 3,186,415**	

OPERATIONS AND MAINTENANCE (O&M) - Lifecycle Cost								
COST ELEMENT	**Quantity**	**Units**	**Unit Price**	**Annual Cost**	**CONTINGENCY**		**NPV (50-year Lifecycle)**	**COMMENTS**
					%	**$**		
Storage Tank								
Inspection	*1*	*LS*	*$ 5,000*	*$ 5,000*	20%	$ 1,000	$ 391,740	
Water Quality Monitoring								
Chlorine Dosing	*12*	*Monthly*	*$ 1,500*	*$ 18,000*	20%	$ 3,600	$ 1,410,264	
Testing	*4*	*Quarterly*	*$ 1,000*	*$ 4,000*	20%	$ 800	$ 313,392	Real rate of interest = -1.0%, timeline = 50 years Contingency 20% due to an unforseen future
Distribution System & Pumps								
System Flush-out	*4*	*Quarterly*	*$ 250*	*$ 1,000*	20%	$ 200	$ 78,348	
Pump Inspection	*1*	*LS*	*$ 10,000*	*$ 10,000*	120%	$ 12,000	$ 1,436,380	
Pump Replacement	*0.2*	*year*	*$ 5,500*	*$ 1,100*	20%	$ 220	$ 86,183	
O&M COSTS SUB-TOTAL							**$ 3,716,307**	
Tax						GST @ 5%	$ 345,136	
TOTAL PROJECT LIFECYCLE COST							**$ 7,247,858**	

Cost Estimating Sources
"Protech Consulting"
RS Square Means
City of Nanaimo - Cost Sheets

Appendix V – Sample Calculations

Geotechnical:

Floating Foundation Design Check	
Material Out	Material In
$w_o = w_s = B_s \times \gamma_s$	$w_i = w_c + w_w + w_t$
$w_s = 3m \times 18\frac{kN}{m^3} = 83.7\frac{kN}{m^3}$	$w_i = \left(2m \times 21.6\frac{kN}{m^3}\right) + \left(1.55m \times 9.81\frac{kN}{m^3}\right) + \left(1.1m \times 16.3\frac{kN}{m^3}\right) \approx 76.4\frac{kN}{m^3}$
$\%Djff = 100 \times \frac{83.7 - 76.4}{83.7} = 8.8\%$	
$w_o - Weight\ of\ Material\ Removed$ $w_s - Weight\ of\ Soil\ Removed$	$w_i = Weight\ of\ New\ Material$ $w_c - Weight\ of\ Concrete$ $w_w - Weight\ of\ Water$ $w_t - Weight\ of\ Topsoil\ and\ Landscaping$

Foundation Depth Check	
F_s against bottom failure for an excavation of depth D is $F_s = N_c \frac{Su}{\gamma D + p_s}$ where, N_c is the bearing capacity factor P_s is the surcharge load.	$F_s = (42.14) \times \frac{10kP_a}{18\frac{kN}{m^3} \times 3m} = 7.8$

Liquefaction Assessment	
Liquefaction Factor of Safety: $FOS = \frac{CRR(K_\sigma * K_m * K_a)}{CSR} > 1$ $CRR = Cyclic\ Resitance\ Ratio$ $CRR = Cyclic\ Stress\ Ratio$	$K_m = Magnitude\ Factor\ (magnitude\ 7)$ $K_a = Slope\ Factor\ (not\ applicable)$ $K_\sigma = Overburden\ Factor\ (0.75m)$

Structural:

Slenderness check for $250\times 250mm$ interior columns:

$$f_y = 400\text{MPa} \rightarrow K_s = 66{,}000 \, {}^{KN}/_{m^3}$$

$$K_f = K_s \times I_f = 66{,}000 \times \frac{1}{12} \times 250^4 \times 10^{-12} = 21.48KN$$

For Columns:

$$\frac{4EI}{l_c} = \frac{4\times\frac{1}{12}\times250^4\times0.7}{0.5\times2600} = 0.7 \times 10^6 N \cdot mm$$

$$\psi_{bottom} = \frac{15.78}{9.62} = 1.64$$

$$\psi_{top} = 0.2$$

K=0.7($from\ Fig.N10.15.1\ Effective\ Factors$)

$$\frac{KL}{r} = \frac{0.7 \times 2600}{0.3 \times 250} = 24.3 > \frac{25 - 10 \times 0.5}{\sqrt{\frac{216}{25 \times 250 \times 250}}} = 17.1$$

No slenderness check is needed.

9.15.3.4. Basic Footing Widths and Areas

1) Except as provided in Sentences (2) and (3) and in Articles 9.15.3.5. to 9.15.3.7., the minimum footing width or area shall comply with Table 9.15.3.4.

2) Where the supported joist span exceeds 4.9 m in *buildings* with light wood-frame walls, floors and roofs, footing widths shall be determined according to
a) Section 4.2., or
b) the following formula

W = w • [Σ sjs/ (*storeys* • 4.9)]

where
W = minimum footing width,
w = minimum width of footings supporting joists not exceeding 4.9 m, as defined by Table 9.15.3.4.,
Σ sjs = sum of the supported joist spans on each *storey* whose load is transferred to the footing, and
storeys = number of *storeys* supported by the footing.
(See Note A-9.15.3.4.(2).)

3) Where a *foundation* rests on gravel, sand or silt in which the water table level is less than the width of the footings below the *bearing surface*,
a) the footing width for walls shall be not less than twice the width required by Sentences (1) and (2), and Articles 9.15.3.5. and 9.15.3.6., and
b) the footing area for columns shall be not less than twice the area required by Sentences (1) and (2) and Article 9.15.3.7.

Division B

Table 9.15.4.2.-A
Thickness of Solid Concrete and Unreinforced Concrete Block Foundation Walls
Forming Part of Sentence 9.15.4.2.(1)

Type of *Foundation* Wall	Minimum Wall Thickness, mm	Maximum Height of Finished Ground Above *Basement* Floor or Crawl Space Ground Cover, m			
		Height of *Foundation* Wall Laterally Unsupported at the Top(1)(2)	Height of *Foundation* Wall Laterally Supported at the Top(1)(2)		
		≤ 3.0 m	≤ 2.5 m	> 2.5 m and ≤ 2.75 m	> 2.75 m and ≤ 3.0 m
Solid concrete, 15 MPa min. strength	150	0.8	1.5	1.5	1.4
	200	1.2	2.15	2.15	2.1
	250	1.4	2.3	2.6	2.5
	300	1.5	2.3	2.6	2.85
Solid concrete, 20 MPa min. strength	150	0.8	1.8	1.6	1.6
	200	1.2	2.3	2.3	2.2
	250	1.4	2.3	2.6	2.85
	300	1.5	2.3	2.6	2.85
Unreinforced concrete block	140	0.6	0.8	—	—
	190	0.9	1.2	(3)	(3)
	240	1.2	1.8	(3)	(3)
	290	1.4	2.2	—	—

9.15.4.3.

Table 9.15.4.2.-B
Reinforced Concrete Block Foundation Walls Laterally Supported at the Top(1)
Forming Part of Sentence 9.15.4.2.(4)

Maximum Height of Finished Ground Above Basement Floor or Crawl Space Ground Cover, m(2)	Size and Spacing of Continuous Vertical Reinforcement, M at mm o.c.					
	190 mm Minimum Wall Thickness			240 mm Minimum Wall Thickness		
	Foundation Wall Height			Foundation Wall Height		
	≤ 2.5 m	≤ 2.75 m	≤ 3.0 m	≤ 2.5 m	≤ 2.75 m	≤ 3.0 m
0.8	(3)	(3)	(3)	(3)	(3)	(3)
1	(3)	1-15M at 1 800	1-15M at 1 800	(3)	(3)	(3)
1.2	(3)	1-15M at 1 600	1-15M at 1 600	(3)	1-20M at 2 000	1-20M at 2 [illegible]
1.4	1-15M at 1 600	1-15M at 1 600	1-15M at 1 600	(3)	1-20M at 1 800	1-20M at 1 [illegible]
1.6	1-15M at 1 400	1-15M at 1 400	1-15M at 1 400	(3)	1-20M at 1 600	1-20M at 1 [illegible]
1.8	1-15M at 1 400	1-15M at 1 400	1-15M at 1 200	(3)	1-20M at 1 600	1-20M at 1 [illegible]
2	1-15M at 1 200	1-15M at 1 000 or 1-20M at 1 200	2-15M at 1 200	1-20M at 1 600	1-20M at 1 600	1-20M at 1 [illegible]
2.2	2-15M at 1 200	2-15M at 1 000	2-15M at 1 000	1-20M at 1 400	1-20M at 1 400	1-20M at 1 4[illegible]
2.4	2-15M at 1 000	2-15M at 1 000	2-15M at 800	1-20M at 1 400	1-20M at 1 400	1-20M at 1 2[illegible]
2.6	n/a	2-15M at 800 or 1-25M at 1 000	2-15M at 800 or 1-25M at 1 000	n/a	1-20M at 1 000	1-20M at 1 [illegible]
2.8	n/a	n/a	1-20M at 600	n/a	n/a	1-20M at [illegible] or 2-15M at 1 [illegible]
3	n/a	n/a	1-20M at 400 or 1-25M at 600	n/a	n/a	2-15M at [illegible]

Notes to Table 9.15.4.2.-B:

Table 9.15.4.5.-A
Vertical Reinforcement for 140 mm Flat Insulating Concrete Form Foundation Walls
Forming Part of Sentence 9.15.4.5.(2)

Max. Height of Finished Ground Above Finished *Basement* Floor, m	Minimum Vertical Reinforcement		
	Maximum Unsupported *Basement* Wall Height		
	2.44 m	2.75 m	3.0 m
1.35	10M at 400 mm o.c.	10M at 400 mm o.c.	10M at 400 mm o.c.
1.6	10M at 400 mm o.c.	10M at 380 mm o.c.	10M at 380 mm o.c.
2	10M at 380 mm o.c.	10M at 380 mm o.c.	10M at 380 mm o.c.
2.2	10M at 250 mm o.c.	10M at 250 mm o.c.	10M at 250 mm o.c.
2.35	n/a	10M at 250 mm o.c.	10M at 250 mm o.c.
2.6	n/a	10M at 250 mm o.c.	10M at 250 mm o.c.
3	n/a	n/a	15M at 250 mm o.c.

Concrete Mix Design:

Mix Design Check	
Given from ACI Manual of Concrete Practice 2000, Part 1: Materials and General Properties of Concrete	Volume Fraction of Water: 0.193 Volume Fraction of Cement: 0.15 Volume Fraction of Coarse Aggregate: 0.58 Volume Fraction of Air Content: 0.05
Calculation of Fine Aggregate Proportion	$Vf\ Fine\ Agg = 1 - Vf(water) - Vf(cement) - Vf(CA) - Vf(Air)$ $Vf\ Fine\ Agg = 1 - (0.193) - (0.15) - (0.58) - (0.05) = 0.27$
Calculation of Weight Proportions of Materials, (kg/m^3)	$Weight\ Proportion, kg/m^3 = Volume\ Fraction\ x\ Density\ (kg/m^3)$ $Weight\ Proportion\ of\ Water, kg/m^3 = 0.193\ \ x\ 1000\ kg/m^3 = 193\ kg/m^3$

Standing Wave Design:

Standing Wave Pressure Check	
Given through dimensional parameters	Length 1 = 75m Length 2 = 45m Depth, D = 2.6m Wave Period = 29.7 seconds Wave Height, H = 1.5m (worst-case)
Find Standing Wave Pressure at Water Surface	Therefore, at water surface, S = 2.6m KD, found through tables = 0.351 $Pressure, Pa = (1000\ x\ g\ x\ h) + (1000\ x\ g\ x\ H)x(cosh(KS))/(cosh(KD))$ $Pressure, Pa = (1000\ x\ 9.81\ x\ 0) + (1000\ x\ 9.81\ x\ 1.5)x(cosh(0.351)) /(cosh(0.351)) = 14715\ Pa$

Water Distribution:

Water Network Design	
Head Loss (Hazen-Williams) $H.L. = \frac{10.59L}{C^{\beta} D^{4.87}}$	EPANET software used to model system, thus no calculations required.

Pumping Power (Scenario A)	
Power Required: $P = (Q * \rho * g * h)/eff$ where Q – flow rate, rho equals density, g is gravitational constant, and h = head, eff = pump efficiency	Therefore, for one pump operating at its working point (see below figure): Q = 0.043 m^3/s ρ = 1000 kg/m^3 g = 9.81 m/s^2 h = ~37 m eff = 0.7 thus, $P = \frac{0.043 * 1000 * 9.81 * 37}{0.7} = \mathbf{22.3\ kW}$

Pump Energy Costs (Scenario A)	
Pump Energy $Energy\ cost = Power * \#pumps * duration * price\ per\ kWh$	Therefore, Power = 22 kW/pump # of pumps = 4 Duration = 24 hours Price per kWh = $0.15 $Energy\ cost = 22kW * 4 * 24\ hrs * \$0.15 =$ **$288**