University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

UBC Groundwater Emergency Supply Detailed Design Report

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Executive Summary

UBC currently receives its water supply from the Metro Vancouver water system, which is reliant on two distribution pipes that direct the water through the University Endowment Lands. In the event of an emergency, these pipes may fail and leave UBC and the surrounding areas without a water supply. SEEDS (Social Ecological Development Studies) is exploring options for UBC's on-site emergency water supply system,

by evaluating the water demand during an emergency and utilizing groundwater wells, an emergency storage system, or a combination of the two to meet the demand. The Most Civil Engineering Consultants has created a detailed design to provide UBC with an emergency water supply solution.

The detailed design provides an emergency water supply to meet the demands of UBC's population and communities within a 1-hour walking distance. The total population considered was estimated to be 164,500 people. The water demand per capita was assessed, and a design was conceptualized that would meet the average flow demand that was calculated to be 3000 L/min and a 3-hour fire demand of 14,000 L/min.

The site is on the south-east section of the campus, next to Library PARC, and will include four artesian wells, one 4.2 million liter water tank, and a main water distribution pipe along SW Marine Drive to the UBC pump house with a branch to UBC Farms. The project is estimated to cost $14.94 million CAD. Construction is planned to begin on May 2021 and with a duration of approximately 10 months. The cost breakdown and construction schedule included may be modified upon unforeseeable circumstances during construction. The performance, reliability, costs, environmental impact, and aesthetics all contributed to the decision-making process and development of the detailed design.

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1 Introduction

The main objective of this report is to outline the detailed design for an emergency water supply system for UBC and the surrounding areas. The goal of the emergency system is to provide potable water when the main water source has been compromised due to a possible seismic event, power failure, or other failure systems. If this happens, UBC will need to self-supply water for all the students, residence, staff, crucial activity (i.e., research studies), projects, and possibly for people who live within 1-hour walking distance of campus. The system will also need to be able to provide adequate water supply for fire suppression systems. This report contains a final design, providing a detailed layout of the design components and criteria, design inputs, water tank design, well design, pump and distribution network design, class 'A' cost estimate, and the schedule.

1.1 Exclusion of Liability

This report has been prepared exclusively for the use and purposes of UBC SEEDS and The Most Civil Engineering Consultants in regards to UBC's emergency water supply system. No other use of this report is permitted without the express written consent of The Most Civil Engineering Consultants. The designs here are intended for construction or tender.

1.2 Stakeholder Engagement

The project has two main groups of stakeholders outside of the client and engineering firm. Those who reside, study, and work on UBC Vancouver campus as well as the xʷməθkʷəy̓əm (Musqueam) people. Those who reside, study, and work on and near UBC's Vancouver campus are most likely to be concerned with aesthetics, cost, and reliability. For example, designs that include large tanks in main parts of campus would severely degrade the overall aesthetics of the campus. As these people will likely be contributing financially to the upfront and ongoing cost of the project, the associated cost of the project is likely a concern for them. In the event of an emergency, these stakeholders are going to use the water from this project. Having enough reliable water to continue their daily activities normally is crucial. As UBC's Vancouver campus is on the traditional lands of the Musqueam people, they have a vested interest in this project. Based on the experience of The Most Civil Engineering Consultants, the Musqueam people's main concerns are typically related to environmental protection and sustainability.

1.3 Description of Key Components

The design features four flowing artesian wells, equipped with solenoid valves, that will be naturally pressurized. The four wells will be pumping the water into a large reinforced concrete storage tank which will be located behind UBC PARC library. From the tank site, the potable water will be distributed through a resilient welded iron pipe distribution system. Finally, this system will be merged into UBC's existing pipe infrastructure at the existing pump house. Filtration, controls, and sensors have all been subcontracted out with their design requirements clearly listed in their applicable subsections.

1.4 Contributions

The table below contains a detailed breakdown of each team member's contributions.

Table 1: Team Member List and Contributions

Team Member Numbers	Contributions
1	Detailed Construction Steps and Processes, Gantt Chart and List of the Anticipated Issues and Final Editing
2	Fire Flow and Water Demand Calculations, Description of Distribution Network and Pipe Drawings
3	Storage Tank Design and Specifications, Tank Drawings and Conclusion
4	Pump House and Distribution Section, Overview of Water Treatment and Controls and Design Criteria
5	Title Page, Executive Summary, Well Design, Well Drawings, Standards Used and Technical Components and Final Review of Report
6	Table of Contents, Class A Cost Estimate, Description of the Key Components of the Design and Final Review of Report

2 Design Criteria

UBC SEEDs commissioned the designing of an emergency potable water supply for UBC. The criteria provided stated that the system was for an emergency scenario, such as an earthquake, where the UBC campus would be cut off from Metro Vancouver's potable water supply. The Most Civil Engineering Consultants will specify the demand, supply and storage methods, filtration methods, means of distribution, and the site location.

2.1 Criteria Used

For this project, the system needed to be capable of providing water for UBC residences, those who commute to UBC, and residents who live within a 1-hour walking distance to UBC; estimated to be 164,500 people. From this amount of people and the various types of water usage of each group, an average water demand of 3,000 L/min and a peak flow of 4,800 L/min was determined to be the emergency water demand. Allowances were also made for a 3-hour fire flow of

14,000 L/min which was based on a typical 10-storey concrete building with sprinklers. Please refer to Appendix B for detailed fire flow calculations.

As this system is to provide potable water during an emergency event, it was assumed that Metro Vancouver would take approximately a month to restore services to UBC campus. This is because an earthquake would likely cause extensive damage to all of Metro Vancouver and the Fraser Valley. If it was known that UBC had a reliable supply of potable water, then it is possible that Metro Vancouver would prioritize fixing the lines in areas which do not have an emergency water supply.

As UBC's potable water infrastructure is mainly ductile iron pipe, it is assumed that the potable water distribution system will be operational in the event of an earthquake, and any damages will be minor and repairable by UBC maintenance.

It was also assumed that if the emergency water supply was provided to the UBC pump house at the required flow rate(s) and at 60 PSI (42 mH2O), the infrastructure at UBC pumphouse would be able to deliver the water to the end users on campus.

This design does not take into consideration any additional backup electricity sources. It was assumed that electricity services will be operational or UBC will have additional emergency power systems that could be used.

3 Artesian Wells

3.1 Assumed Hydrogeological Model

Artesian wells are highly dependent on the correct hydrogeological conditions, to produce a flowing well without the assistance of pumps. For the purposes of design, a precedent example, and existing data from Piteau Associates'

Hydrogeological and Geotechnical Study were considered in the assumed Hydrogeological model.

The precedent example considered was an artesian well that was mistakenly created on 7084 Beechwood St, when inexperienced builders drilled for a geothermal system (CBC News, CBC.com). The builders were not aware of the presence of the Artesian Aquifer located at 25 m below grade, and this resulted in an uncontrolled flow of 950 L/min. It was also recorded that the drillers encountered dense glacial till before the aquifer was penetrated, suggesting that the aquifer is confined by the overburden layer and the artesian aquifer is located roughly 16 m in elevation. This example was located 5.7 km from the proposed location of the project site. Considering this is the nearest example of an artesian well from the same aquifer, a yield of 950 L/min will be assumed will be achievable by adding an above ground booster pump. One booster pump per well will be located in the pumphouse upstream of the water treatment. See Appendix E for exact details of the location in the schematic drawing. These booster pumps will handle the difference in head required based on the difference in elevation from the precedent example and our site (14 m), plus additional head required to push the water through the water treatment system and into the top of the tank. This was estimated to be 30 mH2O (~42.5 PSI) at the flow rate of 950 L/min. For this, the Gould's 66SV10GK4E60 was selected (see Appendix D for the pump curves and details).

Cross sections from Piteau Associates report found in Appendix A, show the upper aquifer at approximately 22 m elevation and the lower aquifer at 7 m elevation. These cross sections do not represent the artesian aquifer; however, they can be used to approximate the drill depth to the confined aquifer. Considering the precedent example and cross-section drawings, it was assumed that the artesian aquifer is at an elevation of 15 m. Since the site location is at an elevation of roughly 55 m, the wells must be drilled approximately 40 m. The drill depth to the upper confining layer will be assumed to be 30 m, and the remaining 10 m will be to the artesian aquifer.

3.2 Pre-Assessment

Pre-assessment of the site must be thorough and extensive, to accurately determine the hydrogeological profile of the site and the depth of drilling required. Pre-assessment will be subcontracted with the following criteria, referencing Groundwater Protection Regulation in the Water Sustainability Act of BC, Schedule 1:

- Pre-assessment report is required before construction is commenced
- A report must be written outlining the artesian flow management plan and details of the artesian wells such as material information, timeline, evaluation of risks, and a summary of professionals involved with the construction
- Reports must be written and approved by the local Ministry of Environment office

It is also advised that extensive testing should be completed to confirm the assumed Hydrogeological model. Experienced Well Contractors are recommended for artesian wells.

3.3 Quantity of Wells

As outlined in Section 3.1, the assumed well yield will be 950 L/min based off research of precedent examples. Since the average demand for water was assumed to be 3000 L/min, the number of wells needed is four. This flow will be sufficient for equalization of the tank to meet demand during peak hours. In the event of a fire, the storage tank has been sized to adequately meet fire flow demand.

Since four wells will be utilized, the wells will be equally placed surrounding the tank, as seen in Appendix E. This will maximize the space between the wells and will also minimize piping needed to direct flow into the filtration/chlorination system. Currently, there are no existing restrictions outlined in the Groundwater Protection Regulation in the Water Sustainability Act of BC for well spacing. Additionally, the Government of Ontario's, Water Supply Wells – Requirements and Best Management Practices, which is referenced by BC standards, does not require minimum spacing for wells. In lieu of this, the Canadian Mortgage and Housing Corporation recommends a minimum of 30 m spacing for pumped wells (Canadian Mortgage and Housing Corporation, 2003). Since flowing wells will be utilized, draw cones are not a major concern for the design. However, each well will still be spaced 30 m as a precaution.

3.4 Well Construction

The construction of the wells will need to be completed with caution, and must follow British Columbia well construction standards, which references the Government of Ontario's, Water Supply Wells – Requirements and Best management Practices. As described in Section 3.1, the precedent example was found to be confined by a dense glacial till layer. Since these conditions are assumed to be prevalent in the proposed location for the wells, the drilled hole must have multiple casings with weighted material as outlined in the Water Supply well requirements. Specific material requirements include:

- Outer Steel Casing: ASTM A252 or ASTM A500
- Inner Steel Casing: ASTM A-53 Grade B, ASTM A589 Grade B, or ASTM A500 Grade B or C
- Sealant: Must be a heavy slurry, such as Neat Cement with Accelerator. Recommended to use Neat cement grout with a density of 1.8 kg/L with weight additives.

Other requirements for the well construction include:

- Drilling to be done using rotary (mud, air, reverse), duel rotary, or cable tool for flowing wells with barite to control flow
- Venting must be installed in the upper end of the casing, to allow for equalization of pressures between inside of well casing and atmosphere

The chosen design for the wells will make use of a Flowing Well Pitless Unit-Spool Type system, which is recommended by the Ontario Well Manual for high-pressure flowing wells. It is also recommended to use weld-on drive shoes at the end of the inner pipe due to the high-pressure environment. Solenoid valves will also be utilized in the design to control flow of the wells if needed. Detailed well drawings and specifications can be found in Appendix E.

4 Water Treatment

The complete and detailed design and specification of the water treatment will be subcontracted. The subcontracted design will conform to the details outlined in this section of the design report.

It was determined that the ideal location for the main water treatment is to occur between the wells and the concrete storage tank. This reduces the total volume of water that the system is required to treat at any given time. Each well water line will be treated separately to add additional layers of redundancy and flexibility when servicing the wells and water treatment equipment. The water treatment equipment for each well must have the capacity to handle the flow rate of 950 L/min.

It will be ensured that the well water is free from contaminants, viruses, and bacteria such as E. coli. In the case the water does contain trace amounts of iron, it is not a concern for human health in a temporary use case such as in an emergency water system.

4.1 Filtration

Rapid sand filters will be used to provide basic treatment that ensures a low level of sediment and the captures iron. These filters will be located between the wells and storage tank.

4.2 Chlorination

At distribution, “between 0.4-2.0 mg/L of free chlorine” (“British Columbia Guidelines (Microbiological) On Maintaining Water Quality In Distribution Systems”, 2016) shall be added to the potable water. This is standard practice to treat any contaminates that may be present in the distribution line between the storage tank, UBC pump house, and UBC farms. This is required since dirt entering the line during construction, repairs, or leaks may contain contaminates.

The free chlorine will be injected into the distribution line using a dosing pump and chlorine reservoir tank. This will be synchronized with the PLC controller to ensure that the dosing increases or decreases with the amount of water being pumped out.

4.3 Ultraviolet (UV)

It is anticipated that there will be no bacteria such as E. coli present, therefore UV treatment will not be required.

4.4 Additional Requirements

The water treatment design shall also conform to the following requirements:

- Conform to all applicable Canadian codes, standards, guidelines, and best practices such as:
    - BC's Drinking Water Protection Act
    - BC Approved Water Quality Guidelines
    - Guidelines for Canadian Drinking Water Quality
- All water must be acceptable for human consumption for up to consecutive 2 months
- All water must be acceptable for use in crop irrigation and for general farm use

5 Electrical, Controls, and Sensors

The electrical/control design, specification, programming, and commissioning of the system will be subcontracted. The design shall conform to the requirements within this section.

All controls and sensors for the water treatment system shall be run by a single PLC controller in a NEMA 4 enclosure that has built in cellular data and ethernet data connections. The controller program must be complete with user manual and training for the end user(s).

The controller must automatically turn the well pumps on and off based on the concrete storage tank level. The level must be determined by two means: a series of four float valves and one ultrasonic volume level. The float valves shall be at 5 m, 4.5 m, 3 m, and 1 m from the base of the tank. Each will relay a signal to the controller to enact the well pumps. At 5 m, this will signal the controller to turn off all well pumps as the tank is full. At 4.5 m, this will signal the controller to turn on one well pump. At 3 m, this will signal the controller to turn on a total of three well pumps until it reaches the 5 m level. At 1 m, the controller will turn on all well pumps until the level reaches the 5 m level sensor and send a warning signal via email and/or text message to the end user. This will allow the end user to inform the appropriate parties at UBC in order to restrict water usage even more. The controller will log the ultrasonic level sensor level. This log and a live reading of the current tank level must be accessible remotely by the end user.

The distribution pumps must also be automatically turned on and off by the PLC controller. A pressure sensor located in the distribution pipe approximately 10 m downstream of the distribution pumps will be used to determine the water demand. A target pressure of 160 PSIG (110 mH2O) will be used as a minimum maintained pressure. To achieve this, the distribution pumps may be installed with variable frequency drives or HOA (Hand, Off, Auto) starters. The controls for the distribution pumps must be configured in such a way (automatically by the controller) so that the pumps run within 15% of their optimal efficiency.

5.1 Safety and Maintenance

All starters for pumps must have an electrical disconnect with lock out. In the controller or on the starter for each pump, there must be a way to manually stop each pump. The controller must be able to automatically detect and notify if any pump is electrically disconnected and remove it from the operation.

The controller must log the number of times each pump starts, stops, and total run time. Allowances must be included to notify the end user if a pump has run for more than a set amount of run time or has been in service longer than a set amount of time. These settings must be configurable by the end user.

5.2 Additional Requirements

The controls design, programing and implementation shall also conform to the following requirements:

- Canadian standards, codes, and best practices which include:
  - CSA C22.2 No. 14 - Industrial Control Equipment
  - CSA C22.2 No. 286 - Industrial Control Panels and Assemblies
- All wiring, sensors, and other electrical equipment located within the water tank shall be watertight and electrically sealed
- All equipment shall be grounded and bonded

6 Distribution

The 400 mm ductile iron pipe distribution line will run approximately 3700 m (see Appendix E for a typical cross section) from the storage tank located behind Library PARC, along SW/NW Marine Drive 3 m below grade, to the UBC Pumphouse near the UBC Sauder building. The pipe joints will be connected using ball joints, this will prevent the pipes from separating if there is any ground movement. A branch also goes to UBC Farm to supply water during non-emergency times. This allows water in the tank to be circulated to prevent stagnation and at the same time reduces the on-going demand of water from Metro Vancouver. The routing is detailed in Figure 1.

Figure 1: Distribution Layout

6.1 Distribution Pumps

To size the pumps, the systems total head loss and flowrate must be determined. As the fire flow was determined to be 14,000 L/min and the average water demand is 3000 L/min; a maximum flow rate used in the design was 17,000 L/min at 42.5 mH2O (~60 PSI). It was assumed that the UBC pump house or individual buildings have booster pumps to provide higher than 42.5 mH2O (~60 PSI) to distribute potable water to UBC campus if required. Please refer to Appendix B for head loss, water demand, and fire flow calculations. From these calculations, it was determined that the distribution pumps must be capable of 111.6 mH2O (~160 PSI) head pressure at a flow rate of approximately 2000 L/min (~525 USGPM). Nine pumps in parallel will be required to achieve the maximum demand while only one to three pumps will be required to handle typical daily demand. The distribution pumps will be located in the pump house behind Library PARC. The Gould's 92SV40GT4E60 was selected for the distribution pumps (see Appendix D for the pump curves and details).

6.2 Pump House

The pump house will be located as shown in the detailed drawings in Appendix E. It will be constructed on reinforced concrete with a length of 40 ft and a width 15 ft. The pump house will be built according to the standards set out in CSA A23.3-14. This will create sufficient space to access the pumps and possibly hoist them with a forklift or other equipment as required for initial installations and maintenance. The pump house will also contain a 2000 BTU gas fired heater, floor drains, the controllers, and space for the water treatment equipment.

7 Tank Design

Referencing the EXP Services Inc. geotechnical report for the UBC MacLeod Building renewal/seismic upgrade issued December 9th 2019, it was concluded that a very dense sand and gravel (glacial till) layer is likely found 1 m below grade overlain by topsoil. The following serviceability limit state (SLS) and factored ultimate limit state (ULS) soil bearing resistance are expected for the very dense sand and gravel subgrade layer:

- SLS 500 kPa
- ULS 750 kPa

The geotechnical engineer should review the foundation subgrade prior to construction to confirm the soil bearing resistances given are appropriate for the subgrade. Any disturbed material and ponding water must be removed prior to pouring concrete.

Referencing the above mentioned geotechnical reports, it was determined that site “Class C” (referencing ASCE 7-98/02 and ASCE 7-05) may be used for determining response to seismic events. The soils underlying the site are not expected to liquify under seismic conditions.

The site is located approximately 1 km from where the above-mentioned report was conducted. Additional geotechnical investigations must be done at specific site location prior to excavation. A utility locator must also confirm there are no utilities underlying the site prior to excavation.

7.1 Construction Details

A 36 m diameter by 5 m tall cylindrical partially above ground reinforced concrete 4200 m^3 storage tank will be constructed on the area currently used as a composting mound, adjacent to Library PARC. The current landfill will be excavated down to the very dense sand and gravel layer underlying the proposed construction site. The layer is expected to be about 1 – 2 m below grade. The concrete base and wall footings will be constructed on the sand and gravel layer. The storage tank will be constructed in accordance with CSA A23.3-14, using reinforced concrete.

The tank dimensions are shown in Table 2. The main purpose for the reinforcing steel will be to control cracking in the concrete and to tie into the walls of the tank to resist the lateral pressure caused by the water in the filled tank. The walls must resist a maximum moment of 61.25 kNm at the base of the tank. The slab will be constructed directly on the subgrade mentioned earlier in this section. The tank will have strip footings which the walls of the tank will rest on and one pad footing which the base of the tank will rest on. The tank will then be backfilled to the existing grade. See Appendix B for detailed calculations.

The total mass of the concrete used will be approximately 3300 kg and the mass of the reinforcing steel will be 660 kg. The total pressure on the ground once the tank is full will be about 80 kPa which is well below the ULS bearing capacity given to the glacial till layer underlying the tank.

The inside of the water tank must also be lined with a waterproof layer/membrane which can be chosen by the contractor but must be approved by the engineer prior to construction. Detailed drawings of the storage tank can be found in Appendix E.

Table 2: Concrete Storage Tank Details

Tank Section	Thickness (m)	Concrete Strength (MPa)	% of Steel
Base	1	20	0.2
Wall	0.5	20	0.2
Roof	0.5	20	0.2

8 Construction Process

The construction of the project will be completed in three key components. These are the construction of the tank, the construction of the distribution system and the installation of the flowing wells. The first steps of the construction are the excavation processes. This involves the excavation of the organic matter at the tank site as well as excavating for the distribution line. Once excavation is completed, the construction of the tank and pump house will begin. Simultaneously, the construction of the distribution line will take place.

The construction of the tank and pumphouse will begin with the foundation. The foundation will be poured together for the two structures. This will ensure that if there is any movement during an earthquake, any pipes running through the structures will stay intact. All the concrete components of this project will require 14 days to set before any loads are applied. The standards that must be followed when constructing the tank and pumphouse can be seen in Sections 6.2 and 7.1. Once the foundation is constructed and has had enough time to cure, the walls of the tank and pumphouse will be built. Following this, any pipes that need to go into the tank will be installed. Once the pipes are installed a waterproof barrier will be placed on the inside of the tank. Finally, the top of the tank and pumphouse will be constructed.

The construction of the distribution line will begin once excavation is complete. All the dirt that was excavated from the distribution line site will be stored and used as backfill. The installation of the distribution line will begin with laying down the pipe between the tank, UBC Farm and the existing UBC pumphouse. Once the pipes are laid down, they will be connected with ball joints. After the joints are installed, the distribution line will be tested to ensure there are no leaks and then will be backfilled.

The flowing wells will be one of the final components of the project to be installed. This is because the water coming from the wells will be under high pressures so any damage to the wells can result in water flooding the construction site. To avoid this, all other major components will be installed first. The four wells will be installed one at a time at the four points surrounding the well. The wells will be constructed as outlined in Section 3.4. As the wells are being constructed, the treatment equipment and pumps will begin to be installed in the pump house. Once all the wells and treatment equipment are installed, the whole system will be tested before being commissioned.

8.1 Anticipated Issues

During construction there are a few issues that may arise that may affect the schedule and budget of the project. These issues include delays due to weather as well as damages to existing structures and structures under construction.

During construction, there may be times when the weather can negatively affect the project. During the excavation process heavy rainfall may make it difficult for the machinery to operate in the muddy conditions. This can result in delays to the project. This can be avoided by monitoring the weather and ensuring the weather during the excavation period will be suitable. It is also important to monitor the weather when the concrete for the tank and pumphouse are being poured. It is essential that the temperature remains above 5 degrees Celsius while the concrete cures to ensure it reaches the desired strength. If the temperature is expected to be below this, the project may need to be delayed or supplementary cementitious materials or admixtures will need to be added.

Another issue that may arise during construction is that previously installed components may be damaged by machinery or workers. This can result in length delays as well as budget overruns. It is essential to ensure everything is protected once installed and constructed. This can be done by fencing off areas to prevent machinery from getting too close. Also, equipment such as pumps and treatment equipment can be protected by ensuring that those working with or close to the equipment are properly trained and informed of the risks.

If any of the above-mentioned issues arise, they can lead to budget overruns and project delays. If these are significant, they may jeopardize the completion of the project. To mitigate any further issues with the project, delays, and cost overruns should be brought to the attention of the budgeting committee as soon as they are known. This gives the committee time to ensure additional funds can be allocated to the project if needed without having to shut down construction.

9 Cost Estimate

9.1 Design Implementation Costs

After the detailed design was completed, a class 'A' project cost estimate was performed, and the total cost of the project was determined to be $14.94 million. The total cost of this project is comprised of the costs of the concrete storage tank, four artesian wells, pumphouse, major distribution system, drilling and excavation. Other associated costs include all related testing, operating and maintenance as well as insurance and contingency fees. The costs for all of the major project components can be seen in Table 3. A detailed breakdown, including relevant calculations, of all costs can be found in Appendix: C. Finally, summaries of the different cost components can be found in the applicable subsections.

Table 3: Total Detailed Cost Breakdown

Major Project Component	Cost
Testing and Design Hours	$407,000
Concrete Storage Tank	$3,200,000
Artesian Wells	$843,000
Distribution Water Main	$5,840,000
Drilling/Excavation for Water Main	$2,100,000
Filtration and Chlorination	$100,000
Pumphouse	$80,000
Distribution Pumps and Starters	$224,000
Maintenance Fee	$62,000
Excavation and Dumping of Compost	$80,000
Bonding and Insurance	$664,000
Contingency Fee	$1,328,000
Grand Total	**$14,938,000**

9.2 Testing Costs

Testing is an integral part of our project task approach and must be implemented continuously during all critical stages of construction to ensure consistency. Tests that are to be specifically considered include hydrotechnical, geotechnical, and material. Geotechnical testing involves determining the sufficiency of all collected soil samples, hydrotechnical testing will ensure that all water being supplied is free of contaminants and abides by all water regulations and specifications. Finally, material testing will be completed on the concrete storage tank to ensure structural integrity is being achieved. A total cost for all testing was determined to be $187,000. Cost estimates of these testing procedures can be seen in Table 4 below.

Table 4: Total Testing Costs

Testing Considered	Cost of Testing
Geotechnical	$95,000
Hydrotechnical	$72,000
Material (Concrete)	$15,000

9.3 Storage Tank and Flowing Wells Costs

A single 4200 m^3 concrete tank will be constructed and will cost $3.2 million to build. This includes the raw costs of mixing/pouring of concrete, forms and finishing, reinforcement bars (25M rebar), excavation, labour and inspections needed. Also considered, were the subbase, grading as well as all site preparation and pre-compaction. A detailed breakdown of the cost can be seen in Table 5 below. This design will also implement the use of four artesian flowing wells. The cost associated with these wells will include the drilling needed for the wells, proper steel encasing and well pumps, starters, and controls. The cost of the solenoid valves was also factored into the estimate. The price for the four artesian wells was determined to be $843,000. A detailed breakdown of the cost can be seen in Table 6.

Table 5: Concrete Storage Tank Costs

Concrete Component	Cost of Component
Material, Subbase, Pouring, Forms and Finishing	$1,500,000
Reinforcement Bars	$120,000
Excavation, Grading and Landscaping	$580,000
Labour and Inspections	$1,000,000

Table 6: Artesian Well Cost Breakdown

Well Component	Cost of Component
Drilling	$331,800
Casing	$210,000
Well Capping	$218,000
Grouting	$51,000
Pumps and Starters	$28,744
Solenoid Valves	$3,500

9.4 Distribution System, Filtration and Pumphouse Costs

The distribution system tying into the existing UBC water mains will comprise much of the project cost. A total cost of $5.84 million will be assessed to the client which includes 3.7 km of 400 mm diameter welded iron pipe that will be used to distribute the emergency supply of potable water. The cost for vertical drilling for the water main was determined to be $2,145,000. Other associated fees with the distribution system will include the cut and fill excavation for the trenches where the piping will be laid, welding, integration with the existing features, as well as general labour and installation costs. A cost of $100,000 will be charged for filtration and chlorination of the water system. This includes sand and microparticle filters, dosing pumps and chlorination storage and mixing tanks. Finally, a cost of $80,000 has been assessed for the design and construction of a pumphouse which will help the water supply to reach UBC's existing distribution system. A cost of $224,000 was determined for nine distribution pumps and starters. Costs associated with the distribution system can be found below in Table 7.

Table 7: Distribution System, Filtration and Pump House Costs

Component	Cost of Component
Water Main	$5,840,000
Drilling/Excavation for Water Main	$2,145,000
Filtration and Chlorination	$100,000
Pumphouse	$80,000
Distribution Pumps and Starters	$224,000

9.5 Operating and Maintenance Costs

Regular inspection and maintenance will be required for this project as the emergency system must always be ready to operate. This will protect against possible leakage and contaminants affecting the water distribution system to UBC.

The concrete storage tank is expected to have an average lifespan of one-hundred years while the distribution system is anticipated to last approximately eighty years. To ensure that these systems reach their expected lifespan, there will be site inspections conducted semi-annually to ensure the integrity of the system. The operational and maintenance fee was assessed at $62,000. Additionally, any necessary excavation, landscaping and dumping of compost at the site of the concrete storage tank will cost $45,000.

9.6 Contingency, Design and Permitting Costs

There will also be a flat percentage rate applied to the cost of this project which will cover all insurance and contingency fees. A five-percent insurance rate and ten-percent contingency rate will be charged to the client. A cost of $225,000 will be assessed for all applicable design hours charged to this project as well as any necessary permitting that is required.

10 Schedule

The proposed construction schedule can be seen below in Figure 2. The project is planned to start in May, 2021 and will take approximately 10 months to complete. The tasks will be completed in the order described above in Section 8.

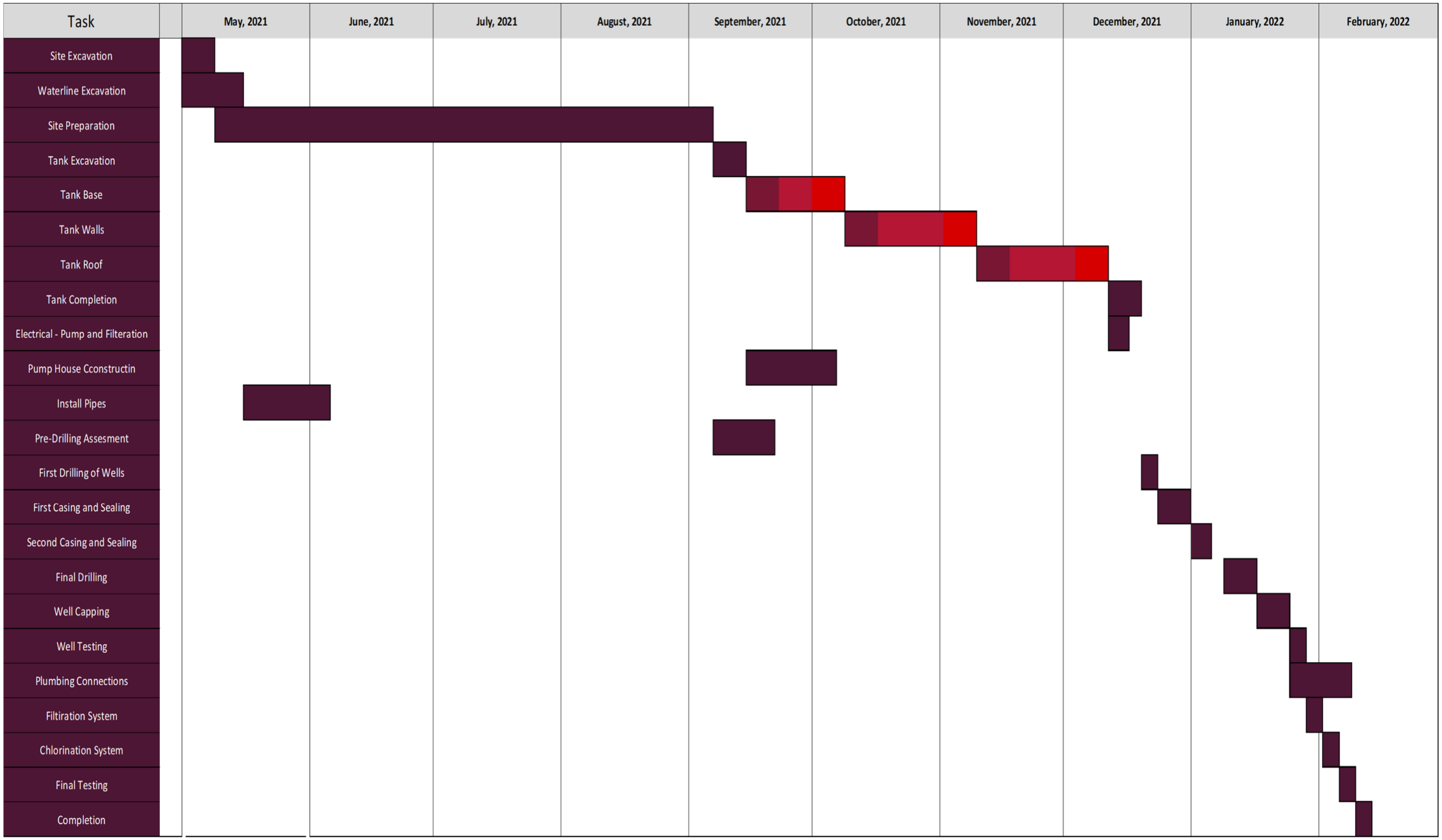

Figure 2: Proposed Project Schedule

11 Conclusion

The above report outlines The Most Civil Engineering Consultants' final design of an emergency water supply system for UBC's Vancouver campus. The use of the Artesian Aquifer, as a source of water, became the predominant design choice due to its reduced number of wells and complexity. The design met all the design criteria by having low environmental impact, meeting aesthetic standards, being economically friendly, and providing reliability.

As mentioned in the preliminary design report, issued by The Most Civil Engineering Consultants, all necessary tests and consultations have been completed and the outlined design is recommended to proceed to the implementation phase. The class 'A' cost estimate for the project, is $14.94 million CAD. The project will begin May, 2021 and will take approximately 10 months to complete.

To ensure the project is completed on time and on budget, the report highlights some key issues that must be accounted for. Spot checks and tests will be completed by The Most Civil Engineering Consultants to ensure the contractor(s) are building with conformance to the design. Any issues that may arise during the project construction phase, must be communicated to The Most Civil Engineering Consultants as soon as possible

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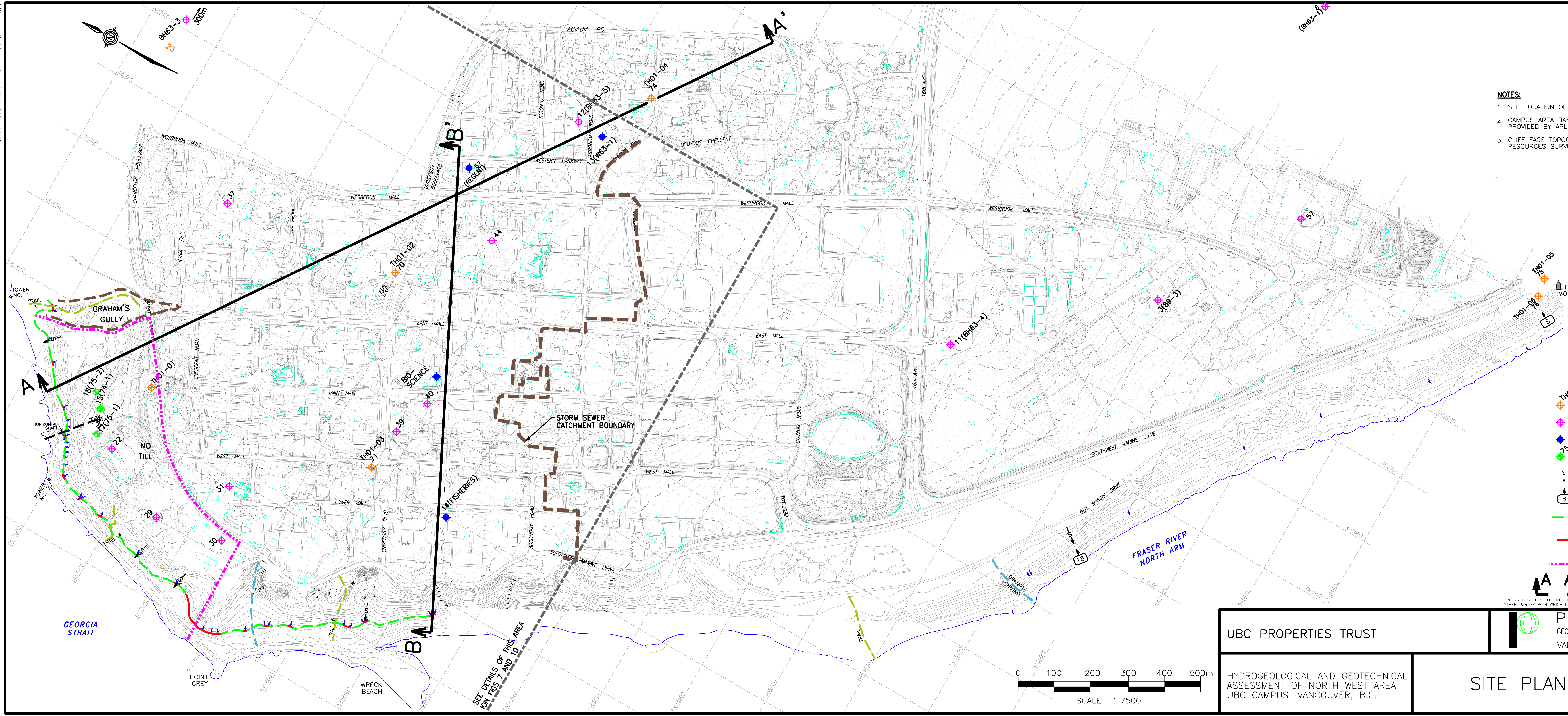
Appendix A: Cross-Sections from Piteau Associates' Report



NOTES:

1. SEE LOCATION OF MAP ON FIG. 1
2. CAMPUS AREA BASE MAP, WITH 0.5m CONTOUR INTERVAL WAS PROVIDED BY APLIN & MARTIN CONSULTANTS LTD.
3. CLIFF FACE TOPOGRAPHY WAS MODIFIED FROM BURNET RESOURCES SURVEYS LTD. 2.5m COUNTOUR INTERVAL MAPPING.

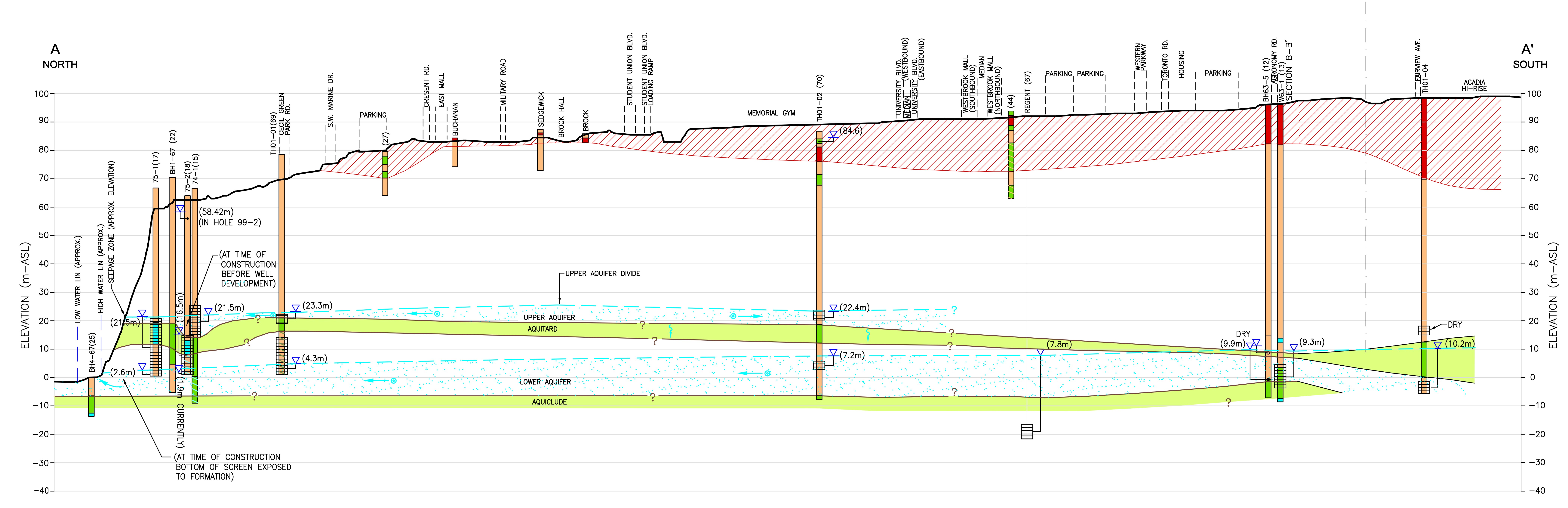
LEGEND

- TH01-01 — PITEAU ASSOCIATES ENGINEERING LTD. TEST HOLE DRILLED 2001
- DRILL HOLES GREATER THAN 30m DEEP
- PRODUCTION OR TEST WELLS
- 75-1 — DRAINHOLE
- SLIDE AREA
- 8 — PHOTO NUMBER 8
- INFERRED CONTACT BETWEEN QUADRA SAND Q1 AND SILT UNIT Q2
- CONFIRMED CONTACT BETWEEN QUADRA SAND Q1 AND SILT UNIT Q2
- NORTH OF MARINE DRIVE STUDY AREA
- A A' — HYDROGEOLOGICAL SECTION (SEE FIGS 8 & 9)

UBC PROPERTIES TRUST	PITEAU ASSOCIATES GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS VANCOUVER LIMA		
HYDROGEOLOGICAL AND GEOTECHNICAL ASSESSMENT OF NORTH WEST AREA UBC CAMPUS, VANCOUVER, B.C.	SITE PLAN	BY: RAD/cz APPROVED:	DATE: AUG. 02 FIG: 3

DWG. NUMBER: /PROJECT/2154/CADD/2154-008vx.DWG

Well ID		12	13	15	17	18	22	25	27	Buchanan	Sedgewick	Brock	44	67	TH01-01	TH01-02	Fairview
Offset (m)		65	10	115	165	60	220	69	145	155	345	23	156	55	115	115	20
Orientation		NNE	NNE	SSW	SSW	SSW	SSW	SSW	SSW	SSW	SSW	SSW	SSW	NNE	SSW	SSW	SSW
Depth (m-BGL)		103.9	105.5	76.2	66.4	63.4	76.2	13.4	15.2	9.2	15.2	5.2	30.5	113.4	75.6	93.9	n/a
Water (m-asl)	Piezo A	9.9	9.9	22.0	21.5	15.3								7.8	4.9	7.3	
	Piezo B	dry													23.3	22.6	
Yield (L/s)			1.58	1.64										6.31			
Date		Mar 63	Apr 63	Apr 74	Jul 75	Jul 75	Jun 67	Apr 67	Jan 93	Feb 95	Jun 69	Nov 89	Sep 65	Dec 86	Jun 01	Jul 01	Jul 01



SOIL UNITS

- TILL
- SAND (WITH TRACE CLAY OR SILT)
- SILT (OR SILTY SAND OR LAYERS)
- CLAY
- SANDSTONE

SYMBOLS

- WATER LEVEL
- DRILLED WELL
- WELL SCREEN
- PIEZOMETER

INFERRED LITHOLOGIC CONTACT

INFERRED GROUNDWATER FLOW RELATIVE TO THE PLANE OF THE SECTION:

- PARALLEL
- IN TO
- OUT OF

AQUIFER PIEZOMETRIC ELEVATION

LOW PERMEABILITY UNITS (AQUITARD AND/OR AQUICLUDE)

SURFACE TILL UNIT

WATER BEARING SAND WITH OCCASIONAL GRAVEL (AQUIFER)

VERTICAL LEAKAGE THROUGH AQUITARD

NOTES:

1. SEE TEST HOLE LOCATIONS ON FIGURE 2 & 4.
2. REPRESENTATIVE WATER LEVELS AT TIME OF CONSTRUCTION.

0 40 80 120 160 200m

HORIZONTAL SCALE 1:4000
VERTICAL EXAGGERATION = 4x

UBC PROPERTIES TRUST

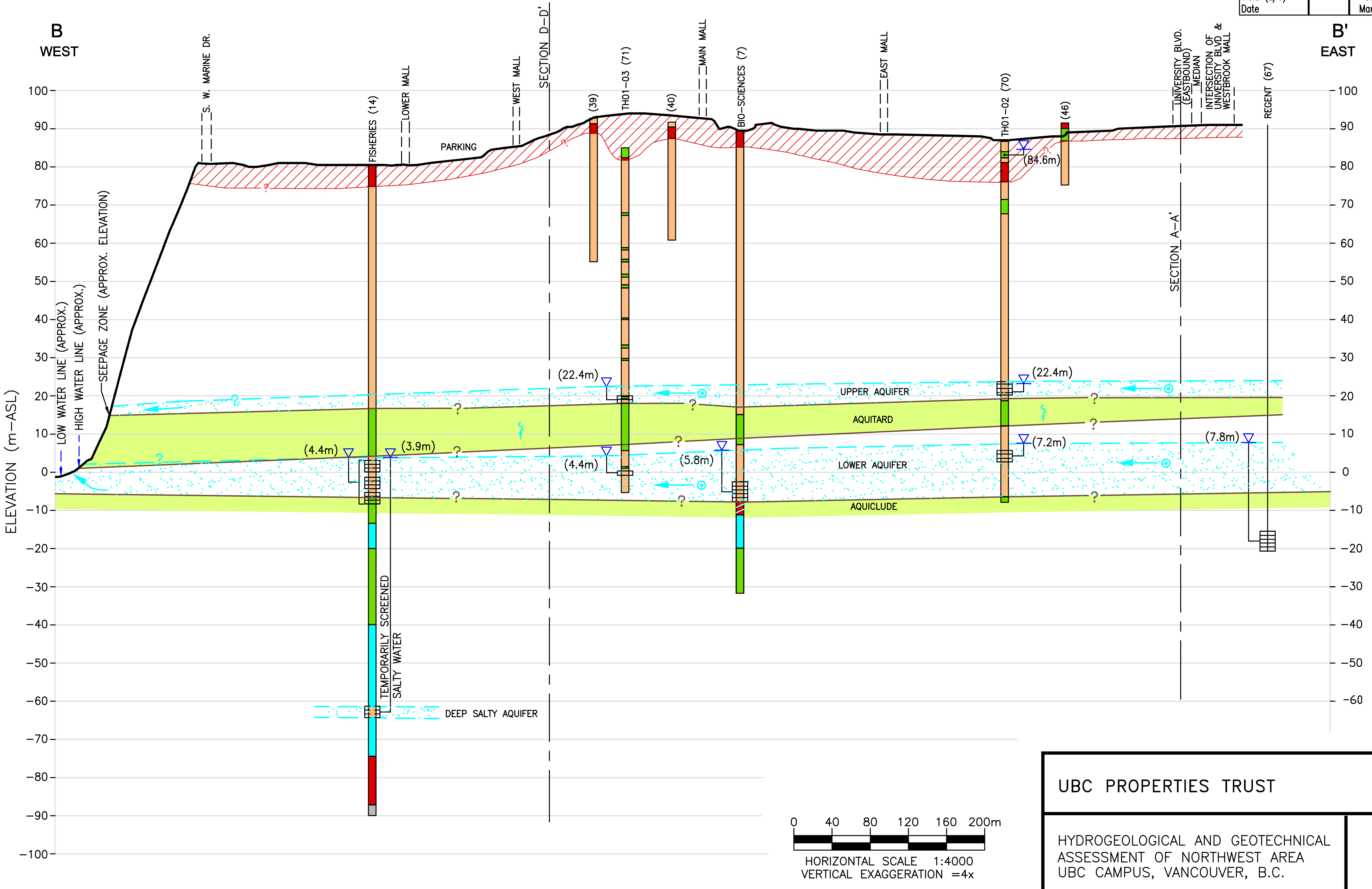
PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS
VANCOUVER LIMA

HYDROGEOLOGICAL AND GEOTECHNICAL ASSESSMENT OF NORTHWEST AREA UBC CAMPUS, VANCOUVER, B.C.

HYDROGEOLOGICAL SECTION A-A'

BY:	DATE:
RAD/cz	JAN. 02
APPROVED:	FIG: 8

Well ID		7	14	39	40	46	67	TH01-2	TH01-03
Offset (m)		115	65	126	43	61.5	60	165	10
Orientation		SSW	NNE	NNW	NNW	SSE	SSW	SSW	NNE
Depth (m-BGL)		121.9	170.7	36.9	30.8	15.2	113.4	93.9	90.5
Water (m-asl)	Piezo A	4.2	3.9				7.8	7.3	4.2
	Piezo B							22.6	22.5
Yield (L/s)		3.15	2.27				6.31		
Date		Mar 66	Mar 67	Jun 60	Jun 60	Sep 65	Dec 86	Jul 01	Jul 01



SOIL UNITS

- TILL
- SAND (WITH TRACE CLAY OR SILT)
- SILT (OR SILTY SAND OR LAYERS)
- CLAY
- SANDSTONE

SYMBOLS

WATER LEVEL
DRILLED WELL
WELL SCREEN
PIEZOMETER

LOW PERMEABILITY UNITS (AQUITARD AND/OR AQUICLUDE)

SURFACE TILL UNIT

WATER BEARING SAND WITH OCCASIONAL GRAVEL (AQUIFER)

INFERRED LITHOLOGIC CONTACT

INFERRED GROUNDWATER FLOW RELATIVE TO THE PLANE OF THE SECTION:
PARALLEL
IN TO
OUT OF
AQUIFER PIEZOMETRIC ELEVATION

VERTICAL LEAKAGE THROUGH AQUITARD

NOTES:

1. SEE TEST HOLE LOCATIONS ON FIGURE 1.
2. REPRESENTATIVE WATER LEVELS AT TIME OF CONSTRUCTION.

UBC PROPERTIES TRUST

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS
VANCOUVER LIMA

HYDROGEOLOGICAL AND GEOTECHNICAL ASSESSMENT OF NORTHWEST AREA UBC CAMPUS, VANCOUVER, B.C.

HYDROGEOLOGICAL SECTION B-B'

BY:	DATE:
RAD/cz	JAN. 02
APPROVED:	FIG: 9

DWG. NUMBER: /PROJECT/2154/CADD/2154-010vx.DWG

Appendix B: Calculations

Storage Tank Calculations:

$$W = \text{Distributed Weight of Water on Storage Tank Walls}$$

$$W = \gamma_w \times L \times W$$

$$W = 9.81\ kN/m^3 \times 5\ m \times\ 1\ m$$

$$W =\ 49\ kN/m$$

$$M_{max} = \text{Maximum Moment of Concrete Walls}$$

$$M_{max} = \frac{W \times L^2}{20}$$

$$M_{max} = \frac{49\ kN/m \times 5\ m^2}{20}$$

$$M_{max} =\ 61.25\ kNm$$

Head Loss Calculations:

$$H_{Total} = H_{minor} + H_{major} + H_{elevation} + H_{pressure}$$

$$Hminor\ assumed\ =\ 0\ as\ length\ of\ pipe\ >>\ 1000\ m$$

$$Hmajor\ =\ f\ * \frac{Length\ of\ pipe}{diameter\ of\ pipe}\ * \frac{(velocity\ of\ water)^2}{2 * gravity}$$

$$(f\ =\ 0.014\ by\ assuming\ Re > 10^8 and\ from\ the\ Moody\ Diagram)$$

$$=\ 0.014\ * \left(\frac{3700m}{0.4m}\right)\ * \frac{\left(2.25\frac{m}{s}\right)^2}{2 * 9.81\frac{m}{s^2}}\ =\ 33.6\ m$$

Check to see if the Re assumption is correct:

$$Re = \frac{\rho * v * L}{\mu} = \frac{1000\frac{kg}{m^3} * 2.25\frac{m}{s} * 3700m}{10^{-3}\frac{Ns}{m^2}} = 8.34 * 10^9 > 10^8 \text{ It is!}$$

$$H_{total} = H_{major} + H_{elevation} + H_{pressure} = 33.6m + 36m + 42m = 111.6m\ (\cong 160\ PSI)$$

Water Demand Calculations:

Sample Area:

- Area within a 1-hour walking distance of all access routes to UBC Campus
- Average Human Walking Speed = 1.42 m/s

$$1.42\frac{Meters}{Sec} + 3600 \text{ Sec} = 5112 \text{ Meters} = 5.11\ Km$$

Sample Population:

- UBC's Future Population
    - Daytime Population = 70,000 people
    - Overnight Population = 25,500 people
    - Residents within a 1-hour walking distance to UBC

Using Google Maps, the total area within 5.11 km was determined to be approximately 12.57 km. This value was then multiplied with the City of Vancouver's average density of 5493 people/ km2 (Canadian Census, 2016) which yielded approximately 69,000 people.

$$12.57\ km^2 x\ 5493 Peaple/km^2 \approx 69{,}000 \text{ People}$$

$$70{,}000 + 25{,}500 + (69{,}000 \text{ x } 0.75) = 147{,}250 \text{ People}$$

Assumptions:

- 25% of The City of Vancouver's residence encompassed in the, will have access to water and will not need to depend on UBC during a crisis.
- Each resident would require 2 laundry days per week, 4 toilet flushes per day, 26

L/day for water and cooking, and a 5-minute shower which allocates them 90 L/day

- For commuters, it was assumed they have a source of water at home and therefore would only require 2 toilet flushes and 4 L for drinking/food per day while on campus for a total of 10 L/day.
- People walking to campus would only need 22 L/day
- 186,500 L/day were then allowed for UBC projects in the design requirements.
- expected that for the beginning periods the rationing of water may need to be stricter, but as water is restored in different parts of Metro Vancouver, less and less demand will be from other users who may be walking to campus.

This yielded a flow demand of approximately **3000 L/min**.

Fire Flow Calculations:

Fire Flow Equation:

$$F = 220C\sqrt{A}$$

Where,

F = Required Fire Flow in Liters Per Minute
C = Construction Coefficient

C Values,

Wood Frame Construction C = 1.5
Ordinary Construction C = 1.0
Non-combustible Construction C= 0.8
Fire Resistive Construction C = 0.6

A = Sum of Floor Area's in Square Meters

For the Purpose of this report, A typical 10-story concrete building of 40m x 40m floor area with sprinklers will be used as for the fire flow calculations. (Note: This is as per Dr. Nazhat's instruction)

$$C = 0.8$$
$$A = 10\ x\ (40\ x\ 40) = 16{,}000\ m2$$

$$F = 200C\sqrt{A} = 200\ x\ 0.8\ x\ \sqrt{16{,}000} = 20{,}238.58\ Liters\ per\ Minute$$

Round to the Nearest 1,000 Liters per Minute,

$$F = 20{,}000\ Liters\ per\ Minute$$

30% Reduction due to Sprinklers Minus,

$$Reduction = 0.3\ x\ 20{,}000 = 6{,}000\ Liters\ per\ Minute$$

Final Fire Flow Value:

$$F = 20{,}000 - 6{,}000 = 14{,}000\ Liter\ per\ Minute = 3{,}761.43\ Gallons\ Per\ Minute$$

From Tables (see below):

$$Average\ Area\ Per\ Hydrant = 9{,}500\ m2$$
$$Fire\ Flow\ Duration = 3\ Hours$$

TABLES

STANDARD HYDRANT DISTRIBUTION	
Fire Flow Required (litres per minute)	Average Area per Hydrant (m^2)
2,000	16,000
4,000	15,000
6,000	14,000
8,000	13,000
10,000	12,000
12,000	11,000
14,000	10,000
16,000	9,500
18,000	9,000
20,000	8,500
22,000	8,000
24,000	7,500
26,000	7,000
28,000	6,500
30,000	6,000
32,000	5,500
34,000	5,250
36,000	5,000
38,000	4,750
40,000	4,500
42,000	4,250
44,000	4,000
46,000	3,750
48,000	3,500

REQUIRED DURATION OF FIRE FLOW	
Fire Flow Required (litres per minute)	Duration (hours)
2,000 or less	1.0
3,000	1.25
4, 000	1.5
5,000	1.75
6,000	2.0
8000	2.0
10,000	2.0
12,000	2.5
14,000	3.0
16,000	3.5
18,000	4.0
20000	4.5
22,000	5.0
24,000	5.5
26,000	6.0
28,000	6.5
30,000	7.0
32000	7.5
34,000	8.0
36,000	8.5
38,000	9.0
40,000 and over	9.5

Appendix C: Class 'A' Cost Estimate

Class 'A' Detailed Cost Estimate	Qty.	Unit Cost	Total
Concrete Storage Tank:			
4,200,000L Circular Concrete Tank (4,200 m^3) **36m diameter and 5m high.**			
500mm-1000mm thick walls (0.750m)*(2xPIxrxh+2*PI*r^2 = 2 * pi * 18m *5m + 2 * pi * 18^2) = 28000 ft ^2 * 1.968 ft = 55104 ft ^ 3 = 2040 yd^3			
2040 yd^3 35 Mpa, kim crystal, admixtures conc, $4.29/ft^2 reinforcement, $5.00 / ft^2 forms and finishing			
Concrete Material, Mixing, Pouring Cost:	2,040	$613	$1,250,000
Subbase Costs ($53.92/yd^3)	2,040	$53.92	$110,000
Reinforcement Costs ($4.29 CAD/ ft^2) Total Square Footage: 28000 ft ^2	28,000	$4.29	$120,000
Forms and Finishing Costs ($5.00 CAD/ ft^2) Total Square Footage: 28000 ft ^2:	28,000	$5.00	$140,000.00
Excavation, Grading and Landscaping	1	$245,000.00	$580,000.00
Labour and Inspections	1	$1,000,000.00	$1,000,000.00
Total Concrete Storage Tank Cost:	1	$3,200,000	$3,200,000
4 Artesian Aquifer Wells (65m drilling, casing, installation of well system, 213.2') 60$/ft USD = $78.76 CAD/ft			
Drilling (additional 60' added to make up for oversized drill hole)	4	$82,950	$331,800
Casing (steel casing $55 CAD/ft, assume 20m until unconsolidated confining bed)	4	$52,500	$210,000
Grouting ($245/m^3)	4	$12,750	$51,000
Capping	4	$54,500	$218,000
Well Pump and Starter	4	$7,186	$28,744
Solenoid Valves	4	$875	$3,500
Total Artesian Well Cost:	4	$210,761	$843,044
Distribution System:			
3.75km of welded steel piping 600 mm dia (24") 0.5" wall thickness, 250.71 lb/ft			
$3000 USD / 2000 lbs (metric ton)			
3750m = 12300 ft * 250.71 lb/ft =3,083,733 lbs /2000 lbs = 1541.8665* $3000 USD = $4,625,600 USD to $5,821,109 CAD + $20,000 for any losses	1	$5,840,000	$5,840,000
Pipe Drilling and Installation Cost $174.9 * ft = 174.9*12300 = 2,145,000	1	$2,145,000	$2,145,000
Filtration and Chlorination	1	$100,000	$100,000
Distribution Pumps and Starters	9	$24,885	$223,965
Pumphouse	1	$80,000	$80,000
Total Distribution System, Filtration and Pumphouse Costs:	1	$8,388,965	$8,388,965
Design Hours, Testing and Permitting			
EIT (Hours charged to project)	750	$140	$105,000
P.Eng (Hours charged to project)	550	$218	$120,000
Geological Testing Per Site, includes Assessment and Report	1	$95,000	$95,000
Concrete Testing	1	$15,000	$15,000
Hydrotechnical Testing	1	$72,000	$72,000
Total Design Hours, Testing and Permitting Costs:	1	$407,000	$407,000
Operational and Maintenance (Deficiencies) Fees	1	$62,000	$62,000
Excavation & Dumping Compost	1	$45,000	$45,000
Subtotal			**$12,946,009**
Bonding & Insurance (5%)			$ 664,000.00
Contingency (15%)			$ 1,328,000.00
Total Detailed Design Cost			**$ 14,938,009.00**

Appendix D: Pump Curves and Technical Details

GOULDS WATER TECHNOLOGY
a xylem brand

Customer		Date	15.04.2021
Contact		Project	
Phone number		Project no.	
Email			

92SV40GT4E60

Operating data

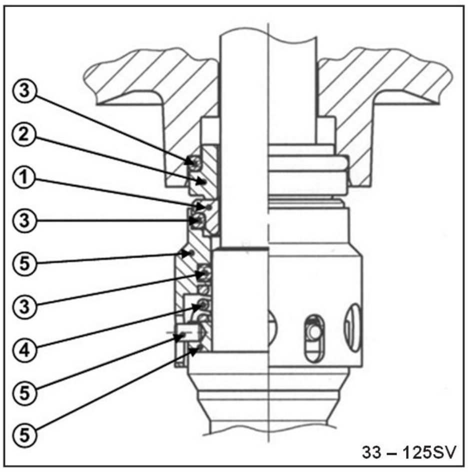
Pump type		Multi-Stage Pumps	Fluid		Water
No. of pumps / Reserve		1 / 0	Operating temperature t A	°F	39.2
Nominal flow	US g.p.m.	524.8	pH-value at t A		7
Nominal head	ft	370.1	Density at t A	lb/ft³	62.4
Static head	ft	0	Kin. viscosity at t A	ft²/s	1.689E-5
Inlet pressure	psi	0	Vapor pressure at t A	psi	14.5
Environmental temperature	°F	68	Solids		0
Available system NPSH	ft	0	Altitude	ft	0

Pump data

Make		Goulds Water Technology		Nominal	US g.p.m.	527.2	(527.2)
Speed	rpm	3500	Flow	Max-	US g.p.m.	621.1	
No. of stages		4		Min-	US g.p.m.		
Max pressure rating	psi	362		Nominal	ft	373.2	
Head H(Q=0)	ft	600	Head	at Qmax	ft	292.4	
Weight	lb	1249		at Qmin	ft	603	
Efficiency	%	76.6	Shaft power		hp	66.7	(66.7)
NPSH 3%	ft	23.3	Max. shaft power		hp	68	
Inlet pressure + zero gpm pressure	psi	261.5	Shutoff TDH		ft	605	
Pump Flange Rating		Class 250 / 300					

Shaft Seal

Single Seal	Xylem
Mechanical Seals	
1 - Rotating Face	Carbon
2 - Stationary Face	Silicon Carbide Graphite Filled
3 - Elastomers	Viton
4 - Spring	316SS
5 - Metal Components	316SS



Motor data

Manufacturer	Baldor	Electric voltage	575 V	Speed	3500 rpm	Insulation class	F
Specific design	3ph TPE			Frame size	365TSC	Colour	RAL 5010
Type	575V 365TSC (X20A32H5BP2S)			Degree of protection	TEPE		
Rated power	75 hp	Electric current	64.6 A				

Remarks:

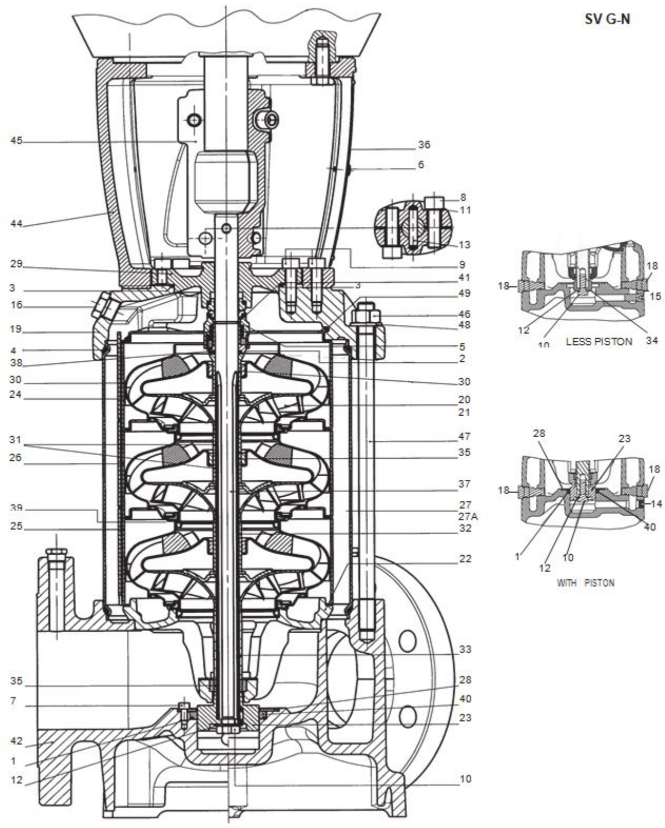
Customer Contact Phone number Email	Date 15.04.2021 Project Project no.

92SV40GT4E60

Construction Data

Pump Materials

1 - O-Ring, Piston Seal	Viton (std) EPDM (opt)
2 - O-Ring, Mechanical Seal Sleeve	Viton (std) EPDM (opt)
3 - O-Ring, Seal housing	Viton (std) EPDM (opt)
4 - O-Ring, Sleeve	Viton (std) EPDM (opt)
5 - Mechanical Seal	Refer Mechanical Seals
5A - Cartridge Seal	Refer Mechanical Seals
6 - Screw, Guard	Stainless Steel (A193-304)
7 - Screw, Piston Holding Disc	Stainless Steel (A193-316)
8 - Screw, Coupling	Zinc Plated Steel (B633)
9 - Screw, MA and Seal Housing	Zinc Plated Steel (B633)
10 - Screw, Impeller	Stainless Steel (A193-316)
11 - Washer, Coupling	Carbon Steel (A108)
12 - Washer, Impeller	Stainless Steel (A193-316)
13 - Pin, Coupling	Carbon Steel (A108)
14 - Plug, with Piston	Stainless Steel (A193-316)
15 - Plug, without Piston	Stainless Steel (A193-316)
16 - Plug, Fill	Stainless Steel/O-Ring (A193-316)
17 - Plug, Vent	Stainless Steel/O-Ring (A193-316)
18 - Plug, Drain	Stainless Steel/O-Ring (A193-316)
19 - Pump Head	Cast Iron (A48 Class 35)
20 - Impeller, Full Diameter	Stainless Steel (A193-316L)
21 - Impeller, Reduced Diameter	Stainless Steel (A193-316L)
22 - Lower Bearing Assembly	SS/Cast Iron (A193-316L/A48 Class 3
23 - Piston	Duplex SS (A182-F51)
24 - Diffuser, Final	Stainless Steel (A193-316L)
25 - Diffuser with Carbon Bushing	Stainless Steel (A193-316L)
26 - Diffuser with Tungsten Bushing	Stainless Steel (A193-316L)
27 - Outer Sleeve, 25 Bar	Stainless Steel (A193-316L)
27A - Outer Sleeve, 40 Bar	Stainless Steel (A193-316L)
28 - Holding Disc, Piston Seal	Stainless Steel (A193-316L)
29 - Seal Housing	Cast Iron (A48 Class 35)
30 - Spacer, Impeller Final	Stainless Steel (A193-316)
31 - Spacer, Shaft Bushing	Stainless Steel (A193-316)
32 - Spacer, Impeller	Stainless Steel (A193-316)
33 - Spacer, Impeller Lower (66-92SV	Stainless Steel (A193-316)
34 - Bushing, Non-Piston	Stainless Steel (A193-316)
35 - Tungsten Carbide Bushing	Tungsten carbide
36 - Coupling Guard	Stainless Steel (A193-304)
37 - Shaft	Duplex SS (A182-F51)
38 - Mechanical Seal Shaft Sleeve	Stainless Steel (A193-316)
39 - Wear Ring, Impeller	PPS Glass Filled
40 - Piston Seal	Impregnated Carbon
41 - Stop Ring, Impeller	Stainless Steel (A193-316)
42 - Pump Body	Cast Iron (A48 Class 35)
43 - Motor Adapter Plate	Cast Iron (A48 Class 25)



Remarks:

GOULDS WATER TECHNOLOGY
a xylem brand

Customer		Date	15.04.2021
Contact		Project	
Phone number		Project no.	
Email			

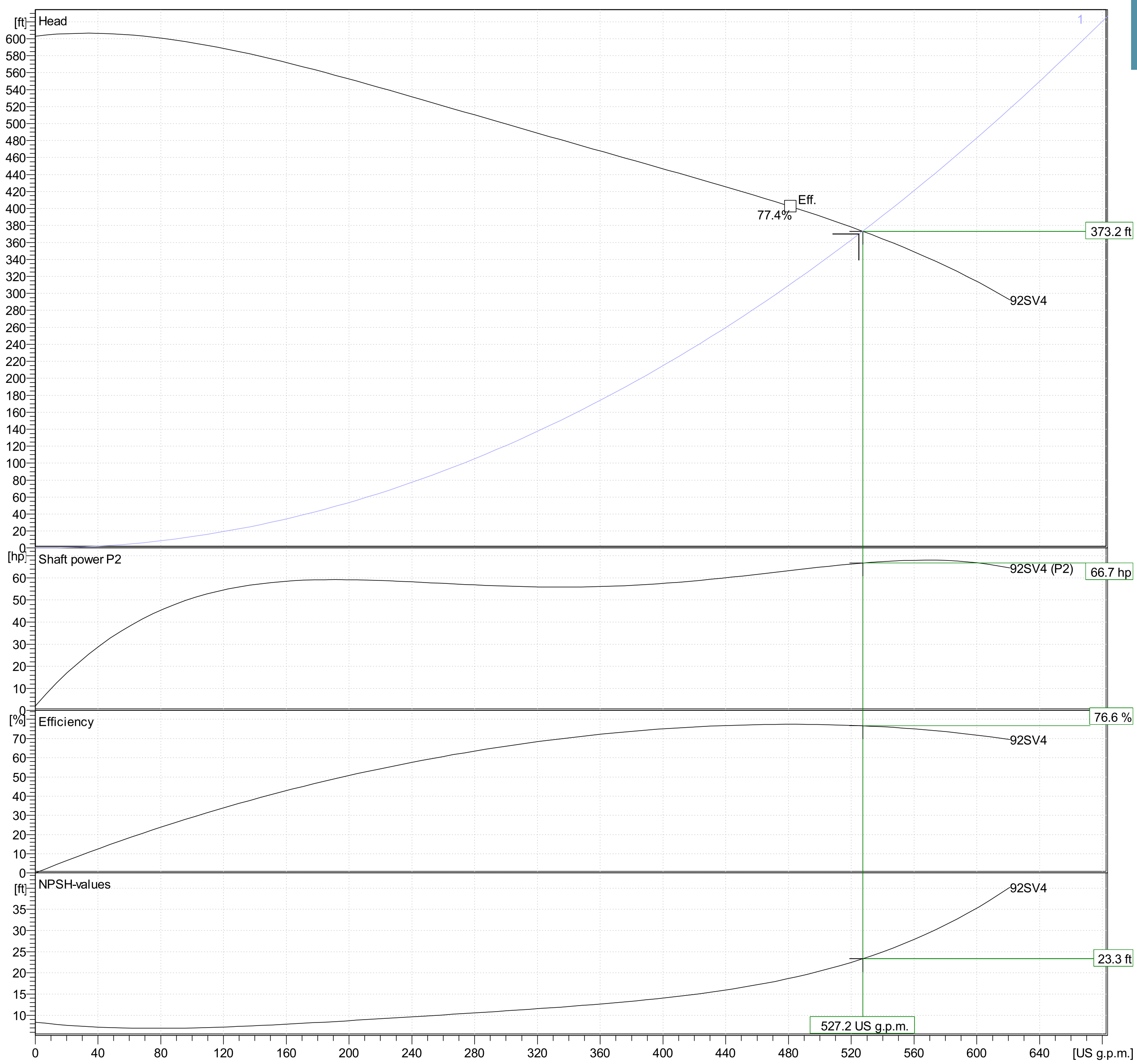
92SV40GT4E60

Tender Hydraulic

Hydraulic Data

Operating Data Specification		Hydraulic data (duty point)		Impeller design	
Flow	525 US g.p.m.			Impeller R	0 inch
Head	370 ft	Flow	527 US g.p.m.	Frequency	60 Hz
Static head	0 ft	Head	373 ft	Speed	3500 rpm

Power data referred to:
Water [100%] ; 39.2°F; 62.4lb/ft³; 1.69E-5ft²/s
Performance according to ANSI/HI 14.6 - Grade 2B

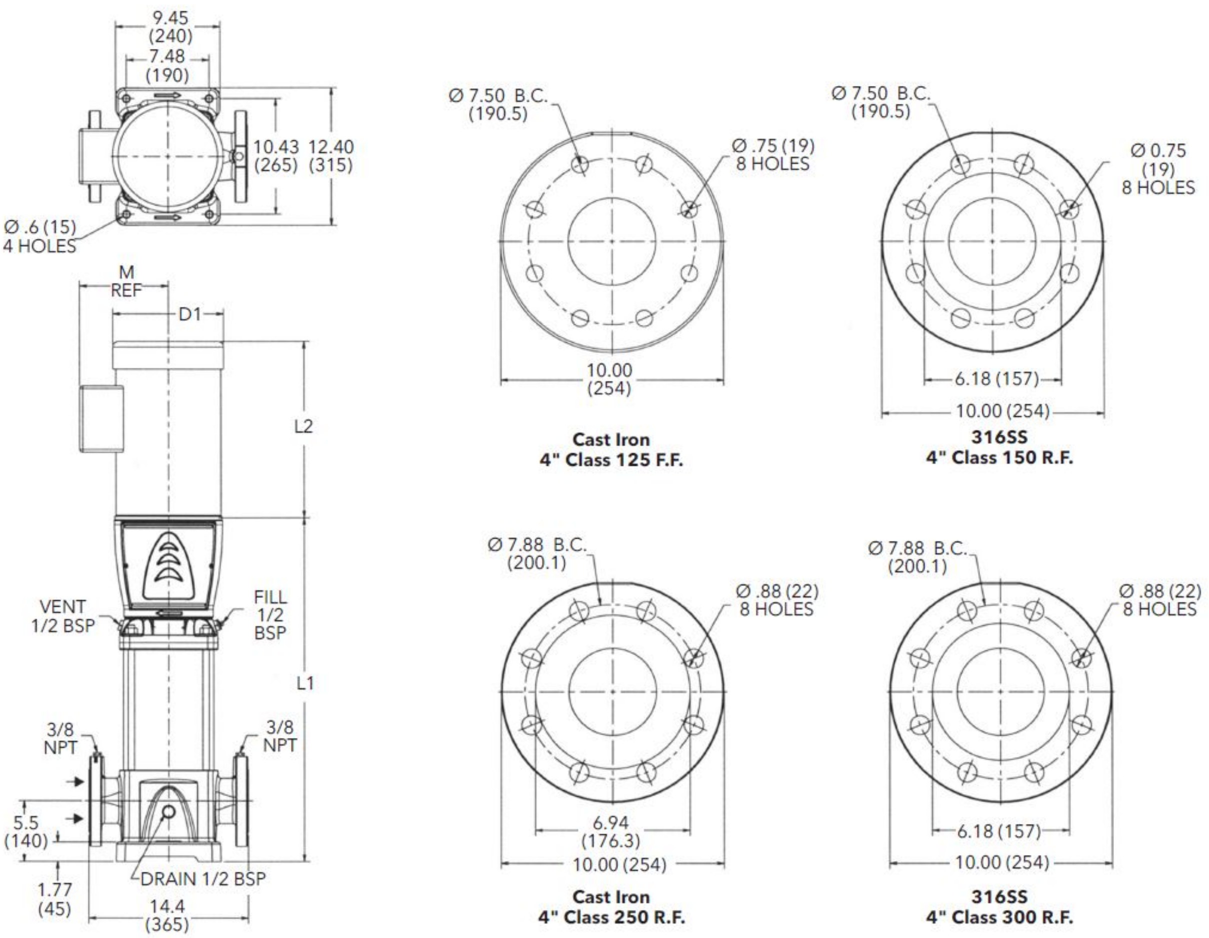


GOULDS WATER TECHNOLOGY
a xylem brand

Customer	Date	15.04.2021
Contact	Project	
Phone number	Project no.	
Email		

92SV40GT4E60

Drawing



All dimensions are in inches (mm).

Dimensions inch

D1 max D2 L1 L2 M.Ref NEMA Frame	$20\frac{1}{4}$ $13\frac{1}{4}$ $34\frac{7}{8}$ $30\frac{5}{16}$ $18\frac{13}{16}$ 365TSC					Weight 1249 lb

Customer		Date	15.04.2021
Contact		Project	
Phone number		Project no.	
Email			

66SV10GK4E60

Operating data

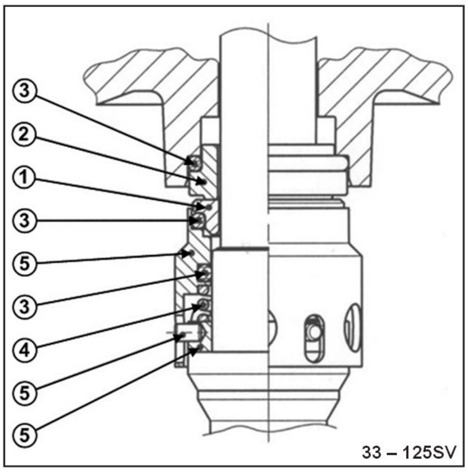
Pump type		Multi-Stage Pumps	Fluid		Water
No. of pumps / Reserve		1 / 0	Operating temperature t A	°F	39.2
Nominal flow	l/min	950	pH-value at t A		7
Nominal head	ft	92.26	Density at t A	lb/ft³	62.4
Static head	ft	0	Kin. viscosity at t A	ft²/s	1.689E-5
Inlet pressure	psi	0	Vapor pressure at t A	psi	14.5
Environmental temperature	°F	68	Solids		0
Available system NPSH	ft	0	Altitude	ft	0

Pump data

Make		Goulds Water Technology		Nominal	l/min	1042.6	(1042.6)
Speed	rpm	3500	Flow	Max-	l/min	1677.3	
No. of stages		1		Min-	l/min		
Max pressure rating	psi	362		Nominal	ft	111.1	
Head H(Q=0)	ft	140	Head	at Qmax	ft	74.7	
Weight	lb	449		at Qmin	ft	137.7	
Efficiency	%	71.34	Shaft power		hp	10.5	(10.5)
NPSH 3%	ft	10	Max. shaft power		hp	12.2	
Inlet pressure + zero gpm pressure	psi	59.7	Shutoff TDH		ft	142	
Pump Flange Rating		Class 125 / 150					

Shaft Seal

Single Seal	Xylem
Mechanical Seals	
1 - Rotating Face	Carbon
2 - Stationary Face	Silicon Carbide Graphite Filled
3 - Elastomers	Viton
4 - Spring	316SS
5 - Metal Components	316SS



Motor data

Manufacturer	Baldor	Electric voltage	575 V	Speed	3500 rpm	Insulation class	F
Specific design	3ph TPE			Frame size	254TC	Colour	RAL 5010
Type	575V 254TC (V13A32H5BK2S)			Degree of protection	TEPE		
Rated power	15 hp	Electric current	13.8 A				

Remarks:

Customer	Date 15.04.2021
Contact	Project
Phone number	Project no.
Email	

66SV10GK4E60

Construction Data

Pump Materials

1 - O-Ring, Piston Seal	Viton (std) EPDM (opt)
2 - O-Ring, Mechanical Seal Sleeve	Viton (std) EPDM (opt)
3 - O-Ring, Seal housing	Viton (std) EPDM (opt)
4 - O-Ring, Sleeve	Viton (std) EPDM (opt)
5 - Mechanical Seal	Refer Mechanical Seals
5A - Cartridge Seal	Refer Mechanical Seals
6 - Screw, Guard	Stainless Steel (A193-304)
7 - Screw, Piston Holding Disc	Stainless Steel (A193-316)
8 - Screw, Coupling	Zinc Plated Steel (B633)
9 - Screw, MA and Seal Housing	Zinc Plated Steel (B633)
10 - Screw, Impeller	Stainless Steel (A193-316)
11 - Washer, Coupling	Carbon Steel (A108)
12 - Washer, Impeller	Stainless Steel (A193-316)
13 - Pin, Coupling	Carbon Steel (A108)
14 - Plug, with Piston	Stainless Steel (A193-316)
15 - Plug, without Piston	Stainless Steel (A193-316)
16 - Plug, Fill	Stainless Steel/O-Ring (A193-316)
17 - Plug, Vent	Stainless Steel/O-Ring (A193-316)
18 - Plug, Drain	Stainless Steel/O-Ring (A193-316)
19 - Pump Head	Cast Iron (A48 Class 35)
20 - Impeller, Full Diameter	Stainless Steel (A193-316L)
21 - Impeller, Reduced Diameter	Stainless Steel (A193-316L)
22 - Lower Bearing Assembly	SS/Cast Iron (A193-316L/A48 Class 3
23 - Piston	Duplex SS (A182-F51)
24 - Diffuser, Final	Stainless Steel (A193-316L)
25 - Diffuser with Carbon Bushing	Stainless Steel (A193-316L)
26 - Diffuser with Tungsten Bushing	Stainless Steel (A193-316L)
27 - Outer Sleeve, 25 Bar	Stainless Steel (A193-316L)
27A - Outer Sleeve, 40 Bar	Stainless Steel (A193-316L)
28 - Holding Disc, Piston Seal	Stainless Steel (A193-316L)
29 - Seal Housing	Cast Iron (A48 Class 35)
30 - Spacer, Impeller Final	Stainless Steel (A193-316)
31 - Spacer, Shaft Bushing	Stainless Steel (A193-316)
32 - Spacer, Impeller	Stainless Steel (A193-316)
33 - Spacer, Impeller Lower (66-92SV	Stainless Steel (A193-316)
34 - Bushing, Non-Piston	Stainless Steel (A193-316)
35 - Tungsten Carbide Bushing	Tungsten carbide
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38 - Mechanical Seal Shaft Sleeve	Stainless Steel (A193-316)
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42 - Pump Body	Cast Iron (A48 Class 35)
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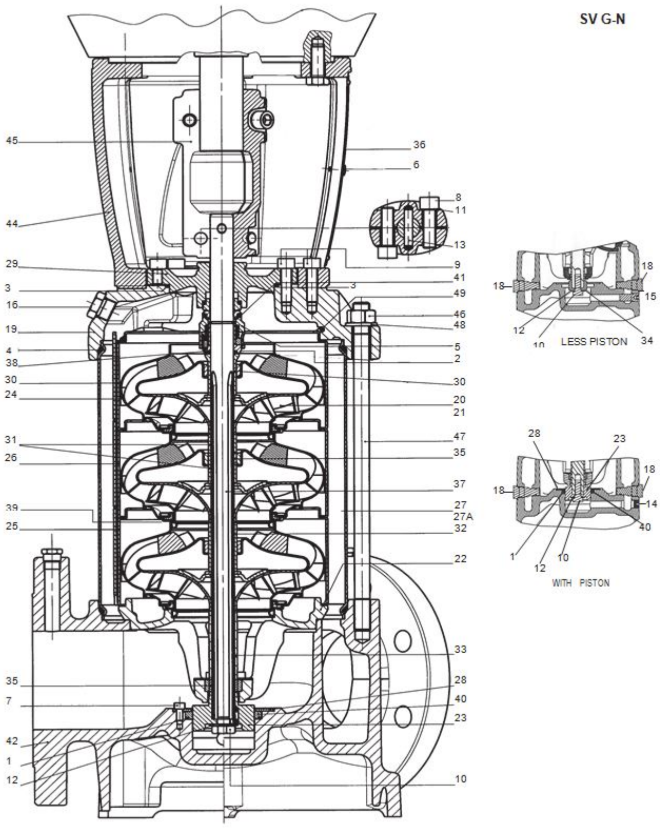


Remarks:

GOULDS WATER TECHNOLOGY
a xylem brand

Customer		Date	15.04.2021
Contact		Project	
Phone number		Project no.	
Email			

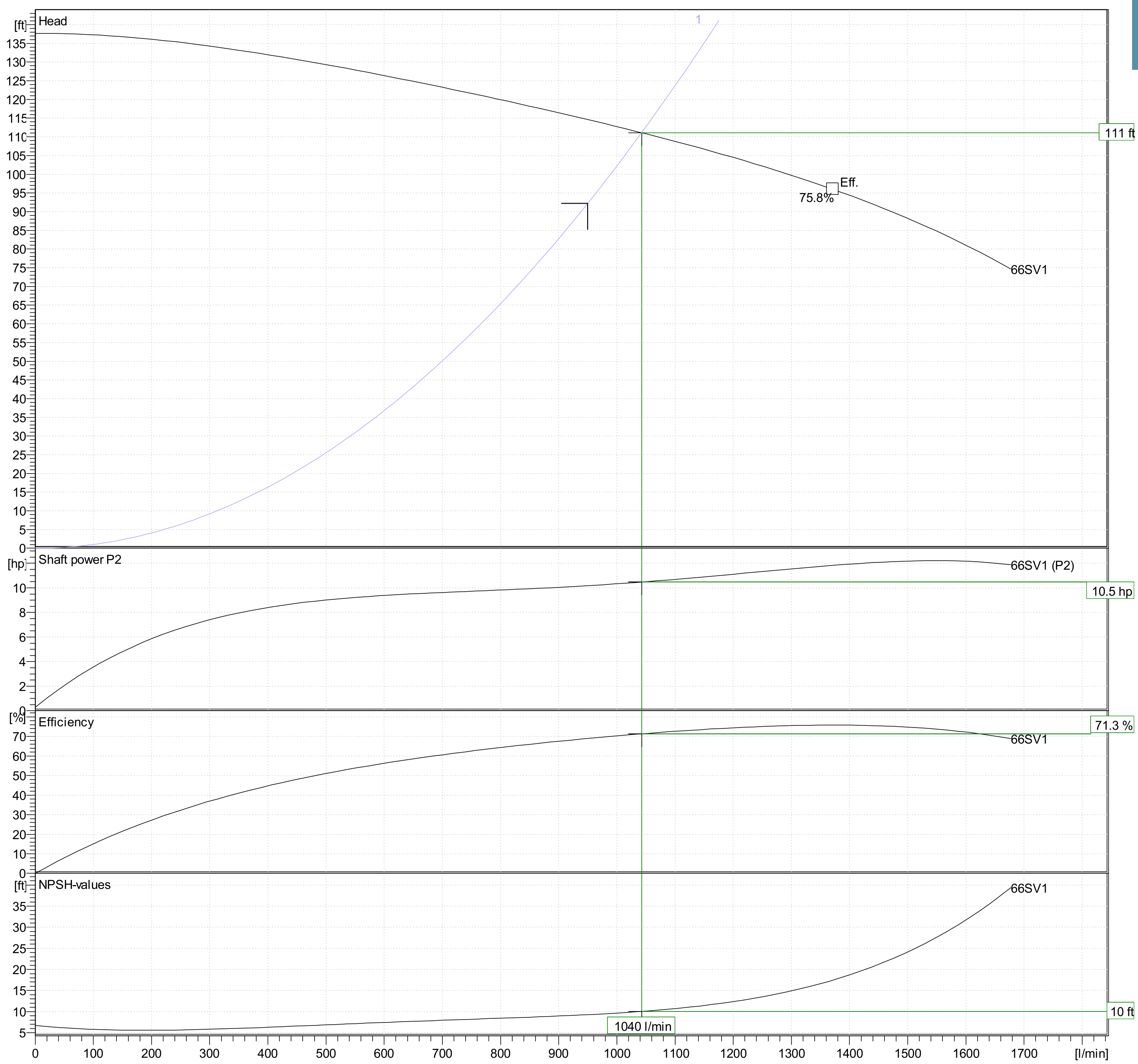
66SV10GK4E60

Tender Hydraulic

Hydraulic Data

Operating Data Specification		Hydraulic data (duty point)		Impeller design	
Flow	950 l/min			Impeller R	0 inch
Head	92.25 ft	Flow	1040 l/min	Frequency	60 Hz
Static head	0 ft	Head	111 ft	Speed	3500 rpm

Power data referred to:
Water [100%] ; 39.2°F; 62.4lb/ft³; 1.69E-5ft²/s
Performance according to ANSI/HI 14.6 - Grade 2B



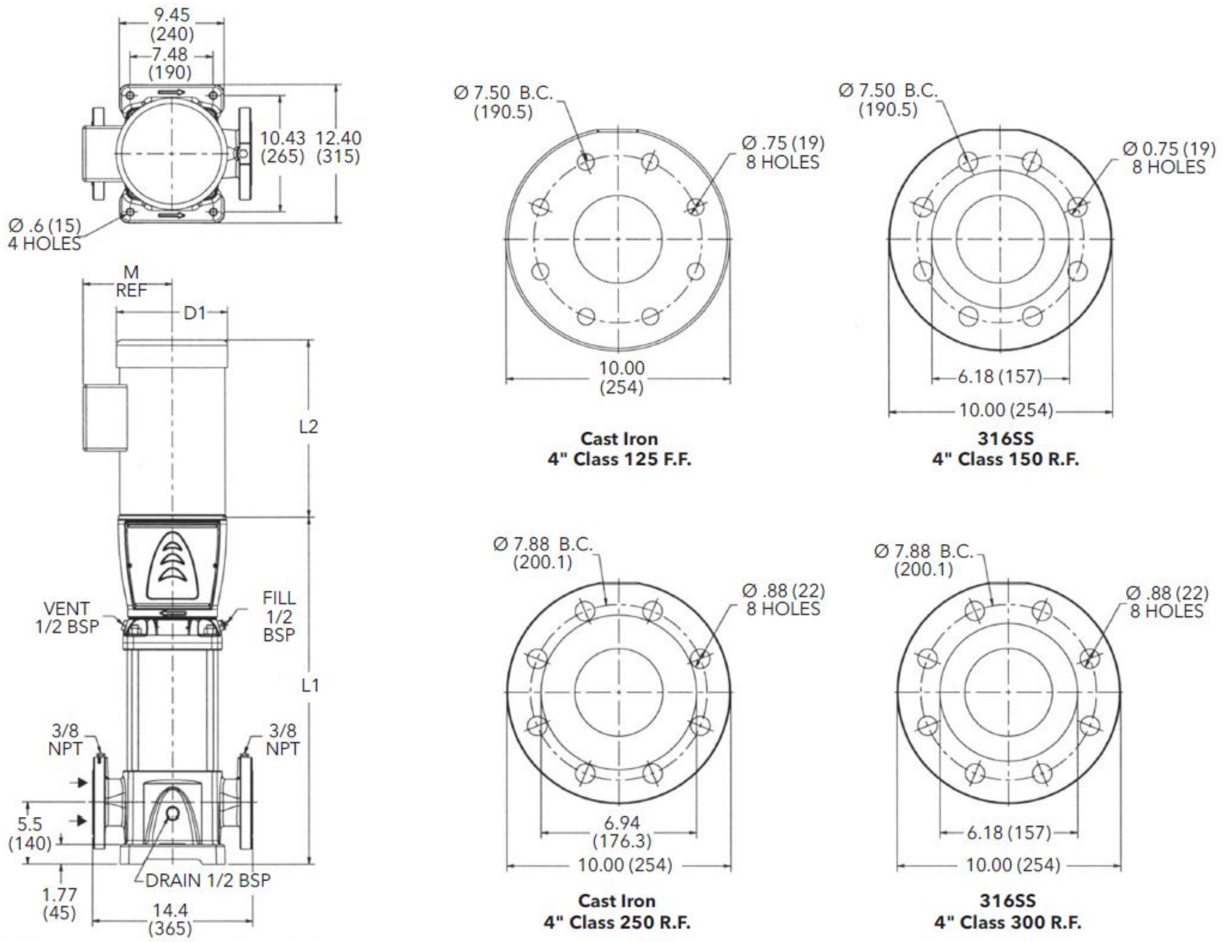
GOULDS WATER TECHNOLOGY
a xylem brand

Customer Contact Phone number Email	Date Project Project no.	15.04.2021

66SV10GK4E60

Dimensional Data

Drawing

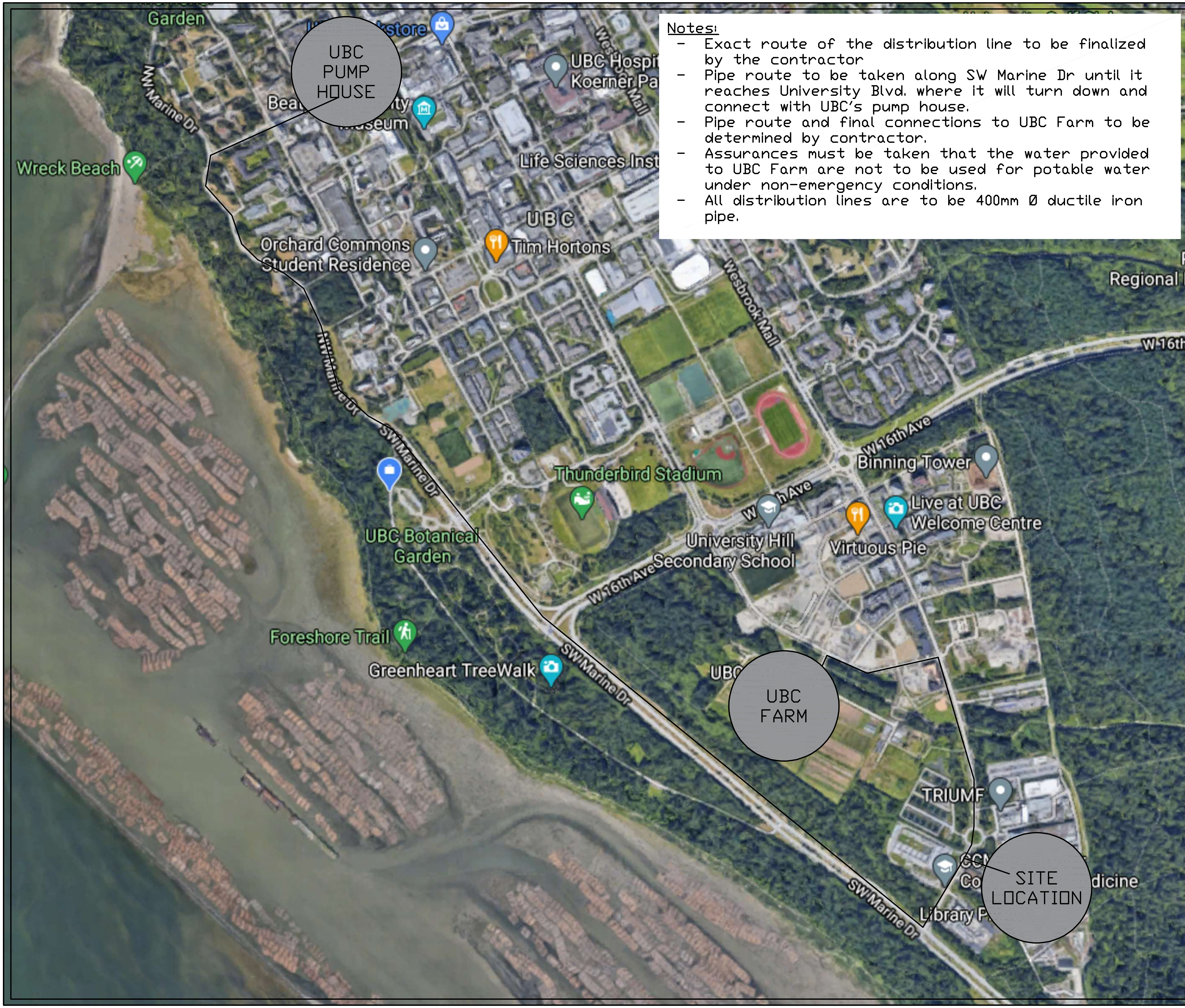


All dimensions are in inches (mm).

Dimensions inch

D1 max D2 L1 L2 M.Ref NEMA Frame	13 1/4 9 1/16 23 3/16 22 1/16 9 1/2 254TC					Weight 449 lb

Appendix E: Detailed Drawings



Notes:

- Exact route of the distribution line to be finalized by the contractor
- Pipe route to be taken along SW Marine Dr until it reaches University Blvd. where it will turn down and connect with UBC's pump house.
- Pipe route and final connections to UBC Farm to be determined by contractor.
- Assurances must be taken that the water provided to UBC Farm are not to be used for potable water under non-emergency conditions.
- All distribution lines are to be 400mm Ø ductile iron pipe.

The Most Civil Engineering Consultants

REV.	DESCRIPTION	DATE
1	ISSUED FOR REVIEW	2020-12-04
2	ISSUED FOR CONSTRUCTION	2021-04-16

PROJECT:

UBC EMERGENCY WATER SUPPLY

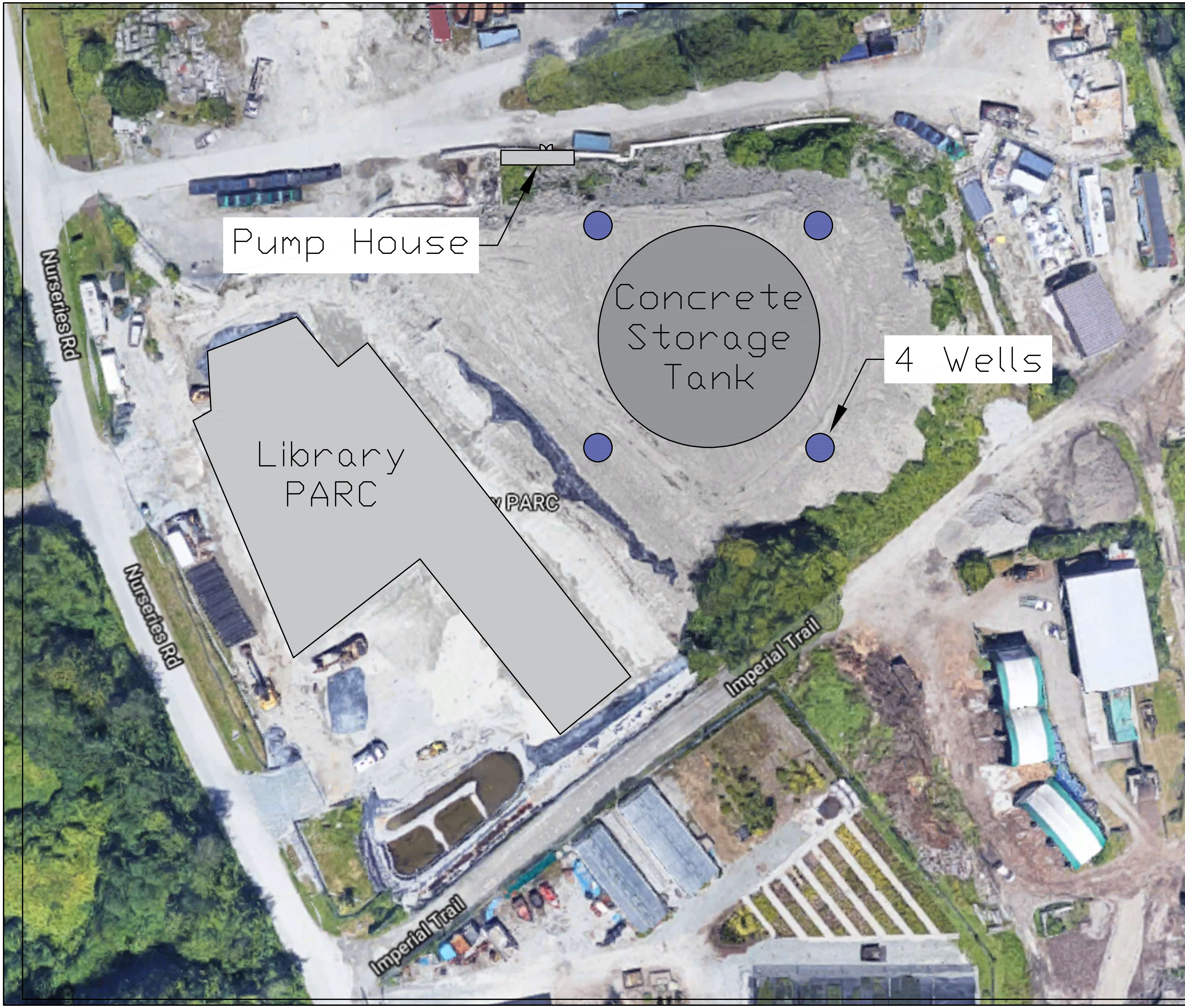
TITLE:

UBC CAMPUS OVERVIEW

DRAWN BY:	BG
REV'D BY:	BG
DATE:	2020-12-05
SCALE:	NOT TO SCALE

DWG#:

01



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REV.	DESCRIPTION	DATE
1	ISSUED FOR REVIEW	2020-12-04
2	ISSUED FOR CONSTRUCTION	2021-04-16

PROJECT:

UBC EMERGENCY WATER SUPPLY

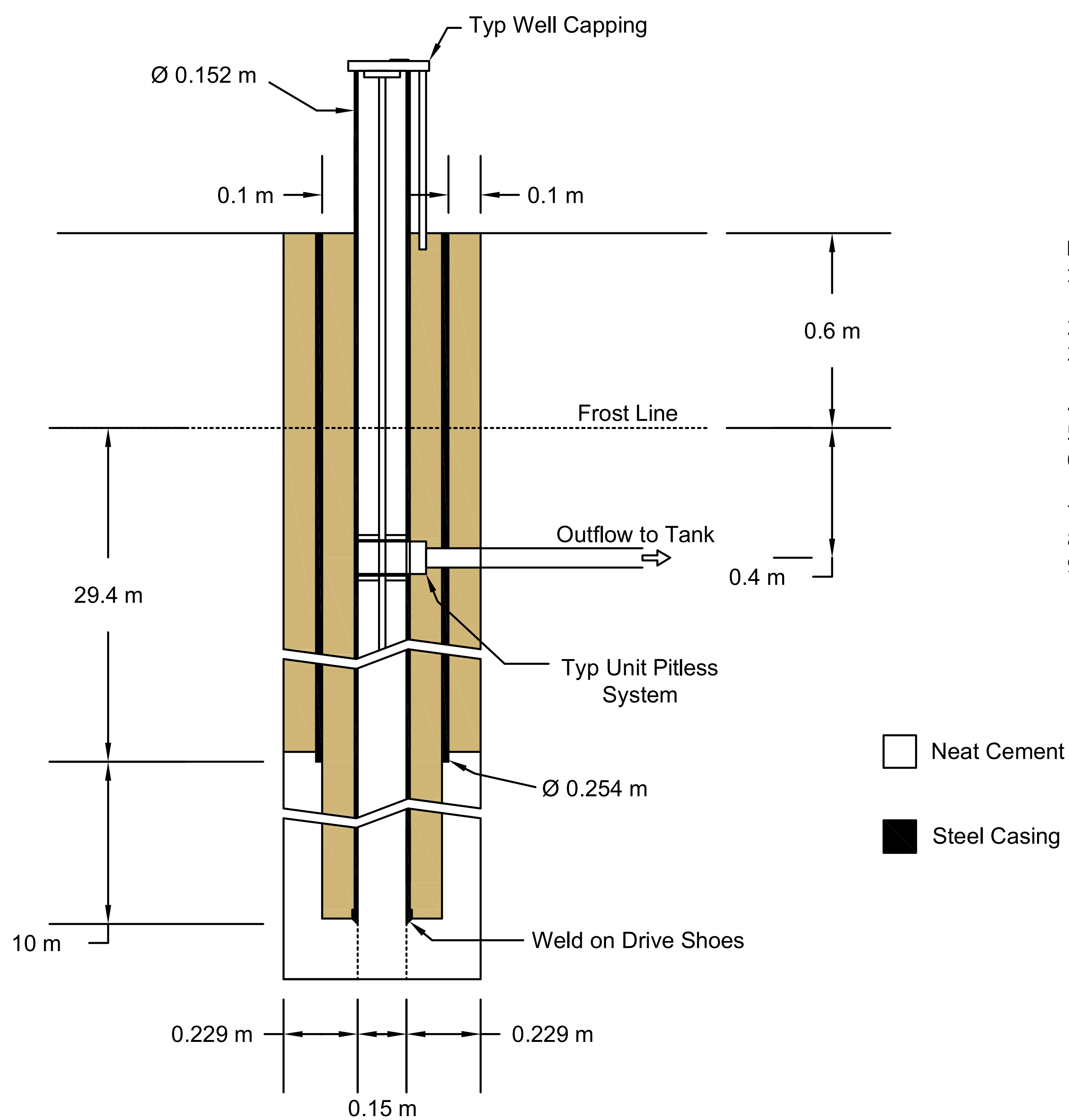
TITLE:

SITE OVERVIEW

DRAWN BY:	BG
REV'D BY:	BG
DATE:	2020-12-05
SCALE:	NOT TO SCALE

DWG#:

02



Notes:

1. Drilling is recommended with mud rotary drilling, barite or other dense fluids may be used to control flow during drilling.
2. Outer steel casing must conform to ASTM A252 or ASTM A500
3. Inner steel casing must conform to ASTM A-53 Grade B, ASTM A589 Grade B, or ASTM A500 Grade B or C.
4. Drive shoes will be welded onto the pipe
5. Unit well pitless system from Baker Water Systems
6. Grouting to be Neat Cement with accelerator, with a density of 1.8 kg/L with weight additives
7. Typical Well Capping System to be used, must include ventilation
8. Typing Unit Pitless System, with Solenoid valve
9. Drill parameters are subject to change during construction phase

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REV.	DESCRIPTION	DATE
1	ISSUED FOR REVIEW	2020-12-04
2	ISSUED FOR CONSTRUCTION	2021-04-16

PROJECT:

UBC EMERGENCY WATER SUPPLY

TITLE:

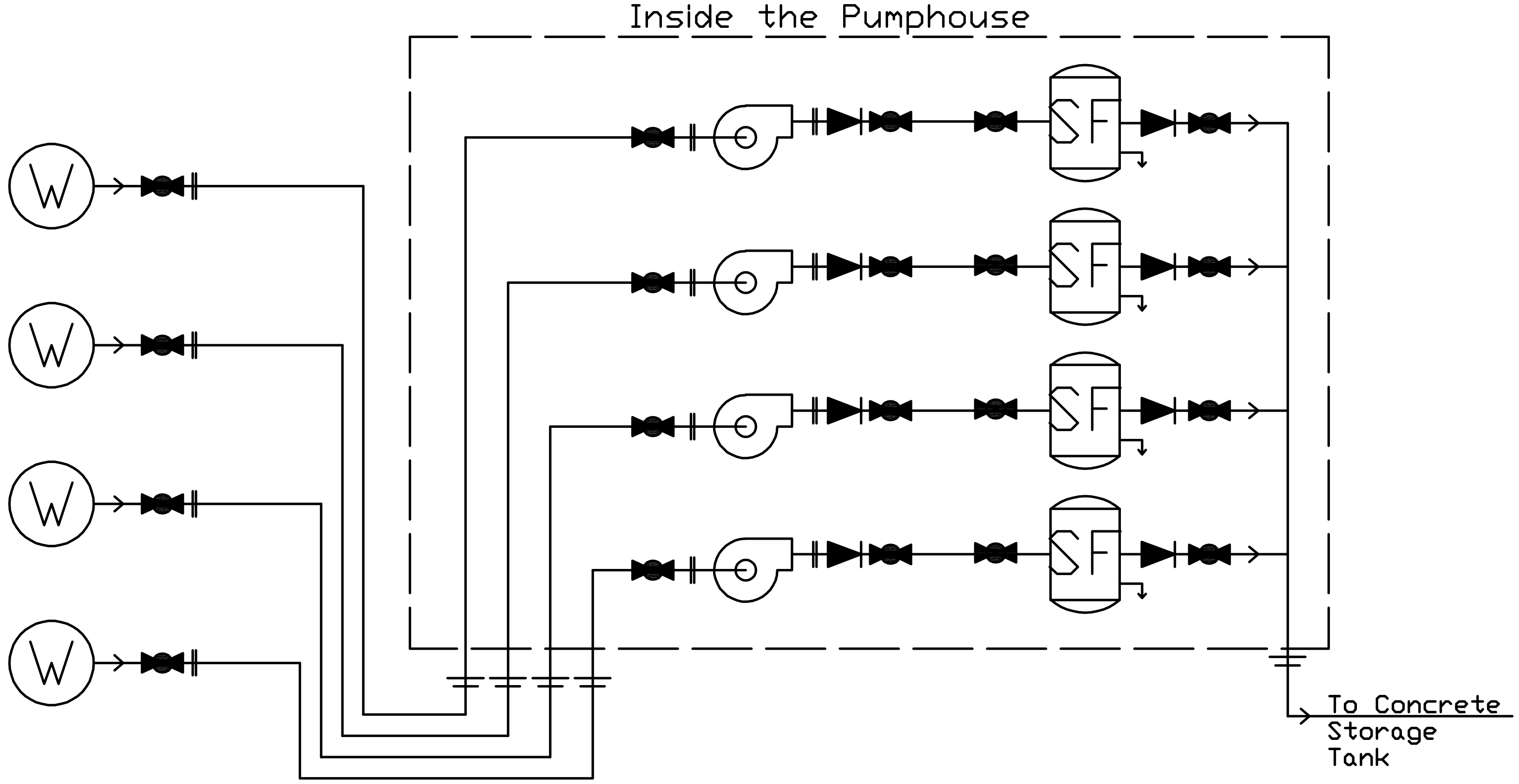
WELL DIAGRAM

DRAWN BY:	BS
DATE:	4-12-2020
SCALE:	NOT TO SCALE

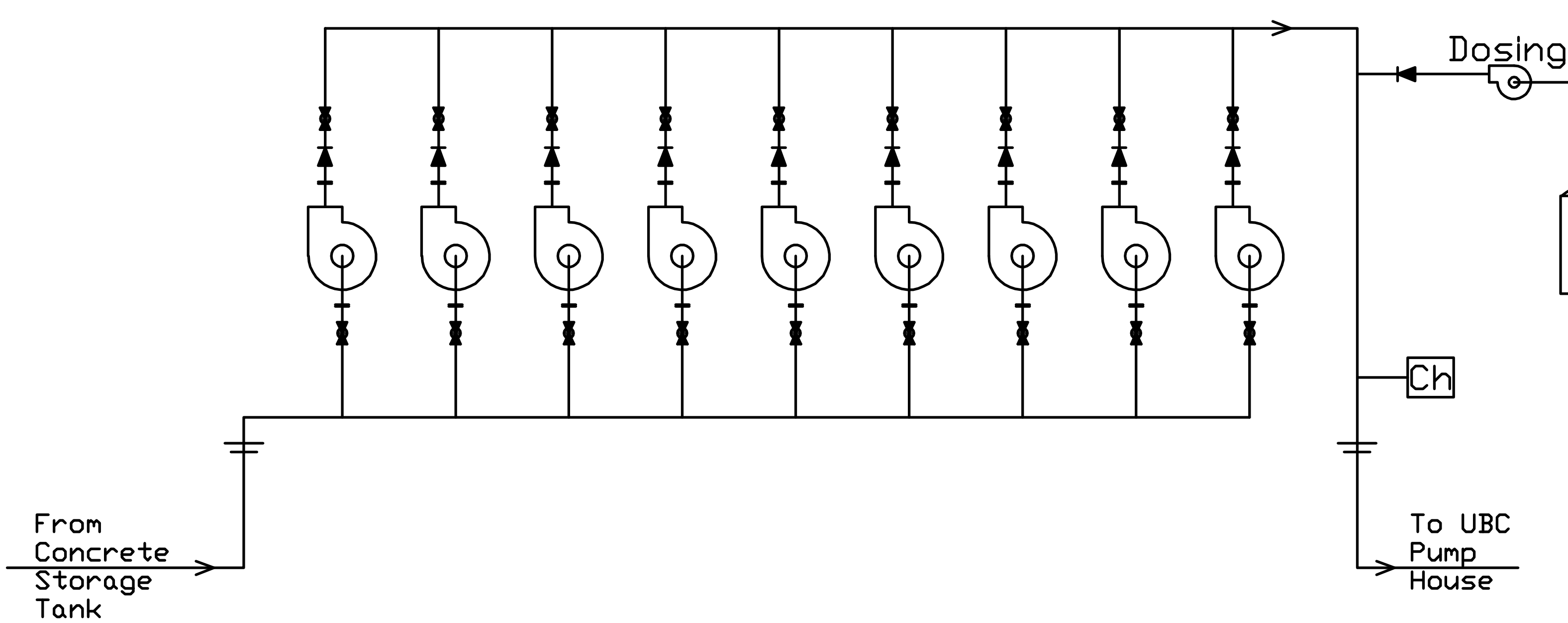
DWG#:

03

Well Water Pipe Schematic



Distribution Water Pipe Schematic



Legend	
Dosing	Chlorine Dosing Pump
	Water Pump
Ch	Free Chlorine Sensor
	Slow Acting Check Valve
	Ball Valve
	Flange
Ch	Chlorine Storage Tank
	Floor Level inside the Pump House
	Direction of Flow
SF	Sand Filter with Reverse Flow Cleaning
W	Direction of Flow

Pipe Sizes - Well Water:

- Consolidated line downstream of filters to Storage Tank: 100mm Ø
- Otherwise: 50mm Ø

Pipe Sizes - Distribution:

- Immediately before or after a pump: 75mm Ø
- Otherwise: 400mm Ø

All Pipe is to be welded ductile iron except the Chlorine Dosing Tubing which is to be opaque 12.5mm Ø reinforced PVC Tubing

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REV.	DESCRIPTION	DATE
1	ISSUED FOR REVIEW	2020-12-04
2	ISSUED FOR CONSTRUCTION	2021-04-16

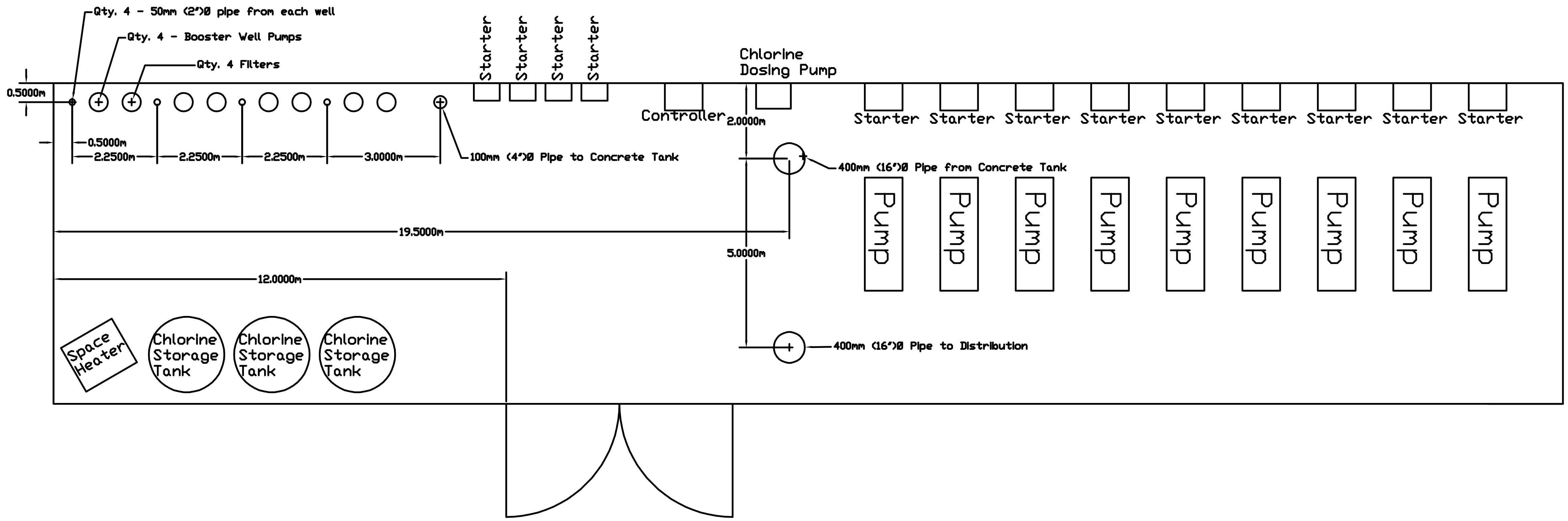
PROJECT:
UBC EMERGENCY WATER SUPPLY

TITLE:
FLOW DIAGRAM

DRAWN BY:	BG
REV'D BY:	BG
DATE:	2020-12-05
SCALE:	NOT TO SCALE

DWG#:
04

Pump House Layout



Notes:

- Pump and distribution pipe layout are suggestions. Final pump and distribution pipe layout to be specified by the contractor in accordance with the Distribution Water Pipe Schematic.
- Water treatment pipe layout and water treatment equipment locations/layout are suggested. Final water treatment pipe layout and equipment location/layout are to be specified by the subcontracted engineers.
- Controller wiring and starter wiring to be finalized and specified by subcontracted engineers.
- All electrical plans are to be specified by Controls-R-Us Engineering.
- The Space Heater is a 2000 BTU natural gas space heater with a thermostat control near the controller. Natural gas line runs and location to be provided by the contractor.
- The starters for the four well pumps shall be located next to the controller as shown. The starters for the nine distribution pumps shall be located on the wall behind the distribution pumps.

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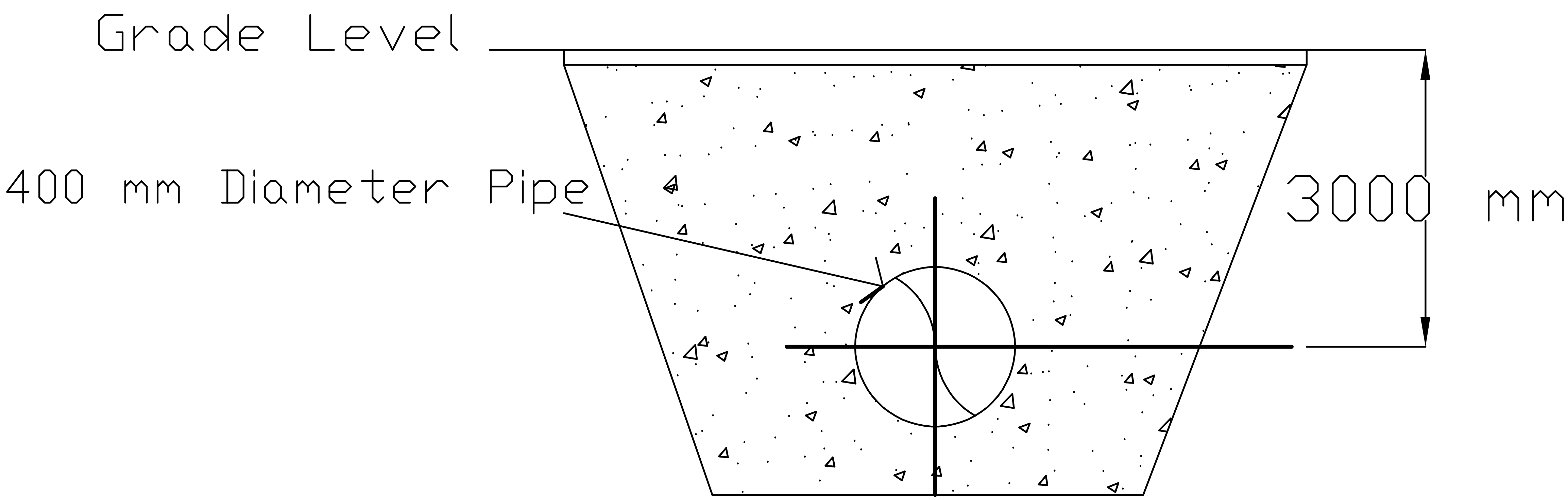
REV.	DESCRIPTION	DATE
1	ISSUED FOR REVIEW	2020-12-04
2	ISSUED FOR CONSTRUCTION	2021-04-16

PROJECT: **UBC EMERGENCY WATER SUPPLY**

TITLE: **FLOW DIAGRAM**

DRAWN BY:	BG
REV'D BY:	BG
DATE:	2020-12-05
SCALE:	NOT TO SCALE

DWG#: **05**



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REV.	DESCRIPTION	DATE
1	ISSUED FOR REVIEW	2020-12-04
2	ISSUED FOR CONSTRUCTION	2021-04-16

PROJECT:

UBC EMERGENCY WATER SUPPLY

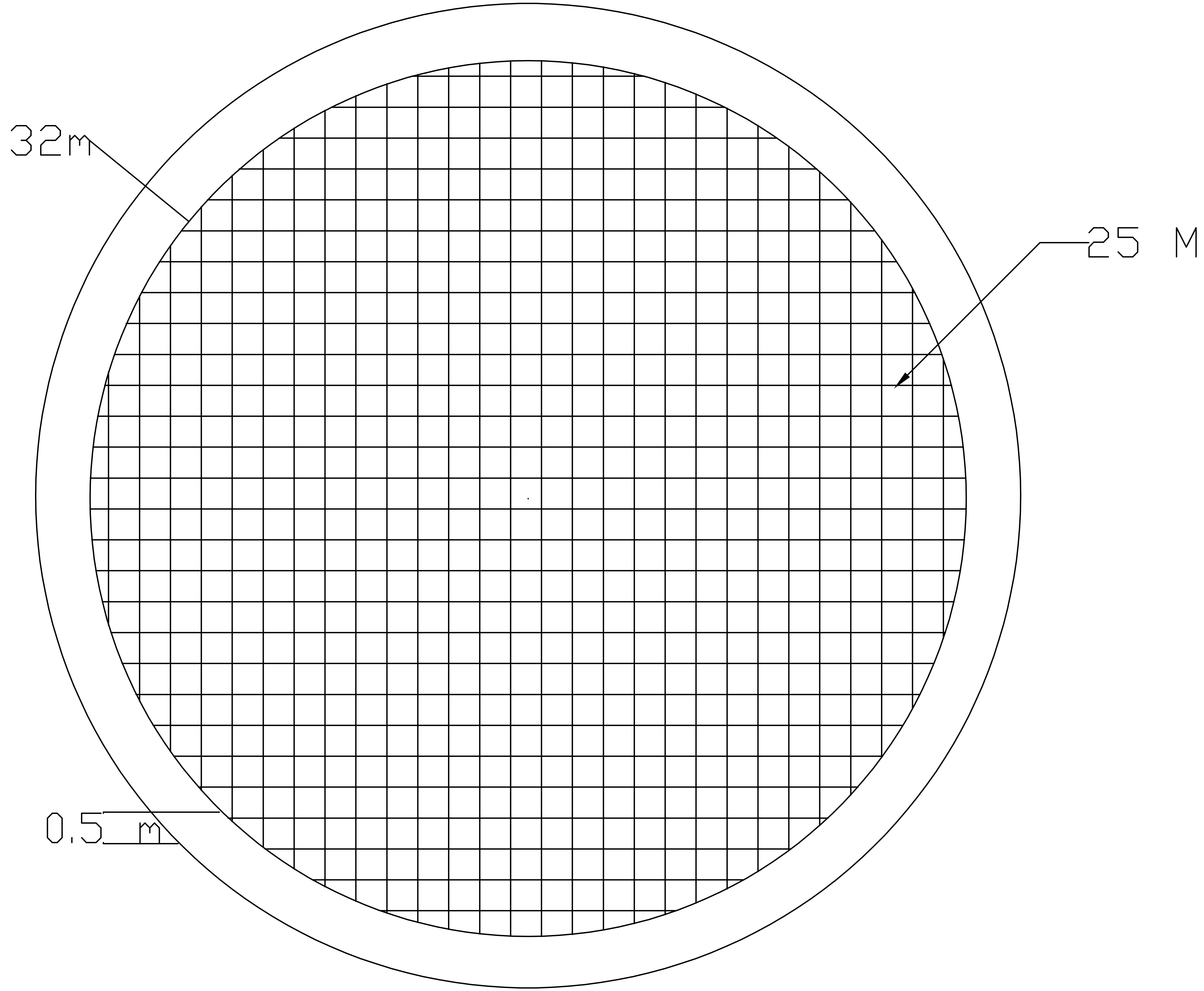
TITLE:

TYPICAL DISTRIBUTION LINE CROSS SECTION

DRAWN BY:	AF
REV'D BY:	AF
DATE:	2020-12-05
SCALE:	NOT TO SCALE

DWG#:

06



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REV.	DESCRIPTION	DATE
1	ISSUED FOR REVIEW	2020-12-04
2	ISSUED FOR CONSTRUCTION	2021-04-16

PROJECT:

UBC EMERGENCY WATER SUPPLY

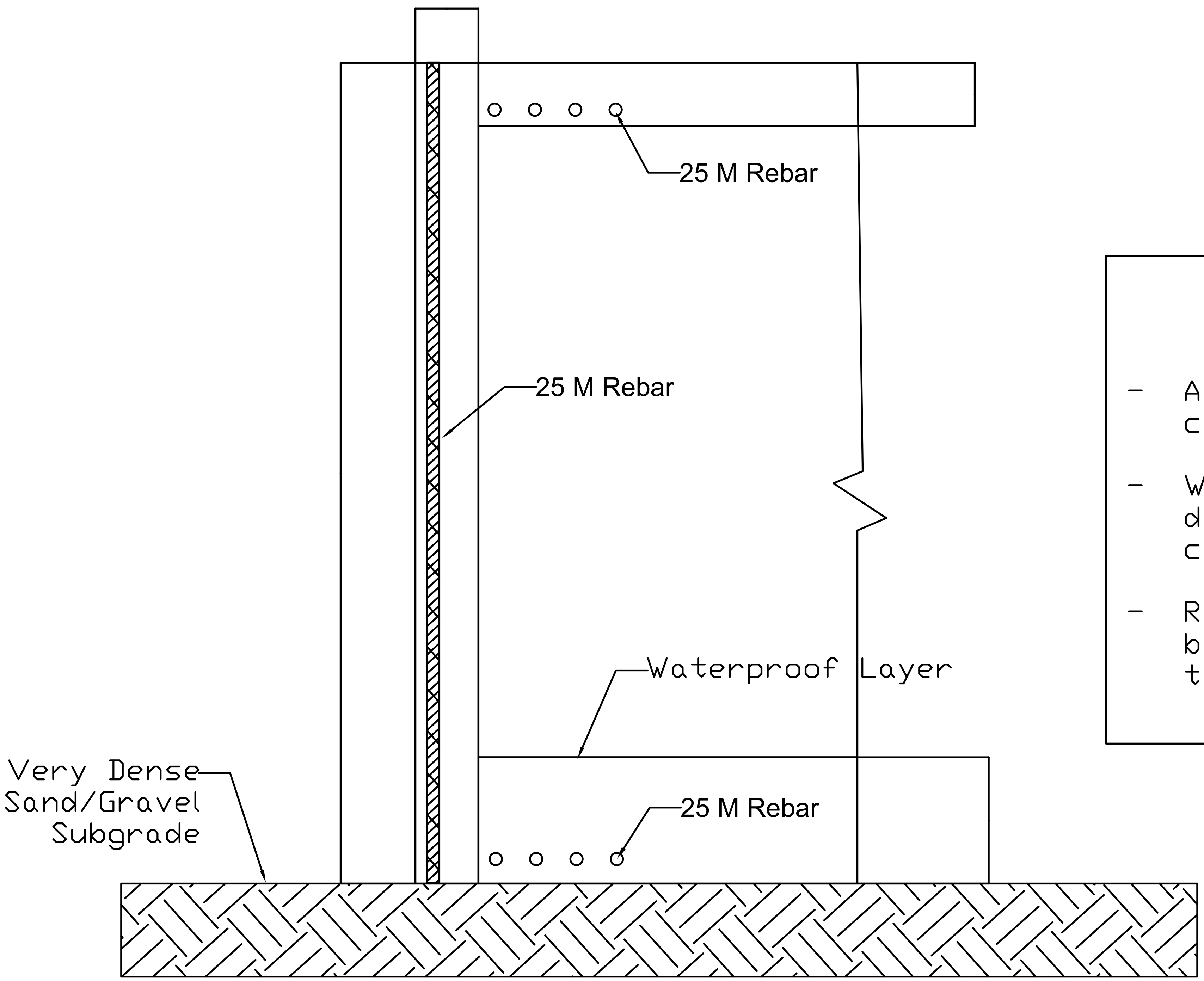
TITLE:

STORAGE TANK

DRAWN BY:	MG
REV'D BY:	MG
DATE:	2020-12-05
SCALE:	NOT TO SCALE

DWG#:

07



Notes:

- All concrete 20 MPa compressive strength
- Waterproof layer decided by contractor
- Rebar spacing for base and roof of tank 250 mm

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REV.	DESCRIPTION	DATE
1	ISSUED FOR REVIEW	2020-12-04
2	ISSUED FOR CONSTRUCTION	2021-04-16

PROJECT:

UBC EMERGENCY WATER SUPPLY

TITLE:

STORAGE TANK CROSS SECTION

DRAWN BY:	MG
REV'D BY:	MG
DATE:	2020-12-05
SCALE:	NOT TO SCALE

DWG#:

08