University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

UBC Groundwater Emergency Supply

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Prepared for:

Course Code: CIVL 446

University of British Columbia

Date: 16 April 2021

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Executive Summary

Clean water is provided to the UBC Point Grey campus by Metro Vancouver through two water mains. The potential for failure of these pipes makes the system vulnerable in the event of an emergency. An alternate water supply that takes advantage of the groundwater in the aquifers below the campus has been designed on the request of the client, UBC SEEDS Sustainability Program. Key issues to consider while developing this design include determining how to most efficiently extract and deliver the water considering the features of the site, as well as determining the necessary water volumes and treatment. Methodology used for developing the detailed design involved implementing current best practices for the desired components while ensuring that the structure will be resilient enough to survive a potential seismic event. The team has prepared this detailed design report to present the detailed specifications and final construction plans for the project.

The detailed design process was initiated once feedback was received from the client for the preliminary design report. The design of the project has now been updated and finalized; drawings and management plans are attached to this report. The main components of the detailed design are the eight groundwater wells that will be installed at the north end of campus, as well as the pipes, connections and pumps that need to be constructed to convey the groundwater into the system. The water treatment specifications and the structural designs for the storage and treatment facilities will be done by a sub-consultant, but the preliminary designs and criteria have been specified in this report. Additional considerations include the service life maintenance plan, the environmental impact assessment, permitting processes and the stakeholder engagement plan.

Provided the construction starts in May 2021, the project is expected to be completed by November 15th, 2021. A draft construction work plan has been outlined and focuses primarily on ensuring that the construction is safe and efficient. A detailed cost estimate has been conducted and based on that, the project will cost approximately $9.07M, including construction costs and design fees.

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1 Introduction

The University of British Columbia ("the University", "UBC") is situated on the Point Grey Peninsula of Vancouver, British Columbia on the traditional, ancestral and unceded territory of the Musqueam people. It typically has a daily population of 55,000 people, but that number is expected to increase in the coming years. In addition to drinking water and plumbing demands, the campus also supports academic and scientific research that requires the use of water. Water is sold to the campus and distributed by Metro Vancouver using two water mains from the Sasamat Reservoir and running through the University Endowment Lands via West 16th Ave. In the event of water main failure, the campus would be in a challenging situation. The campus sits above the Quadra Sand layer, which has been found to be a viable source of drinking water. Further discussion of the site is included in later sections.

To increase the resilience of the UBC campus and avoid significant interruptions in the event of a seismic event or water system failure, alternate water sources have been explored. UBC SEEDS Sustainability Program has contracted the team to explore the feasibility of using the groundwater present in the Quadra Sand layer as an emergency water supply. The overarching objective of this project was to develop an appropriate design that considers all relevant issues and criteria while delivering an efficient and effective system. The system should be engineered to act reliably after a seismic event of reasonable severity, and be optimized to reduce any negative social, economic, and environmental effects throughout its life cycle.

Initial research was conducted by the team to study the project site and learn from precedent examples. Emergency water demands, hydrogeological assessments, well yields, and necessary water treatment protocols were then established. The feasibility of groundwater wells and reservoirs was assessed based on the initial research and projected water demands for 2041, and conceptual and preliminary design processes were conducted.

After receiving feedback on the preliminary design at the beginning of 2021, the team began the detailed design process for the project. Further hydrotechnical modelling had to be conducted in order to determine specifications, and detailed design drawings had to be produced to complete the design. Specifications had to be updated and finalized, detailed management plans had to be established, and design drawings had to be created. As a result of those processes, the team has prepared the following detailed design report for an emergency groundwater supply. Figure 1 below displays the general site layout.

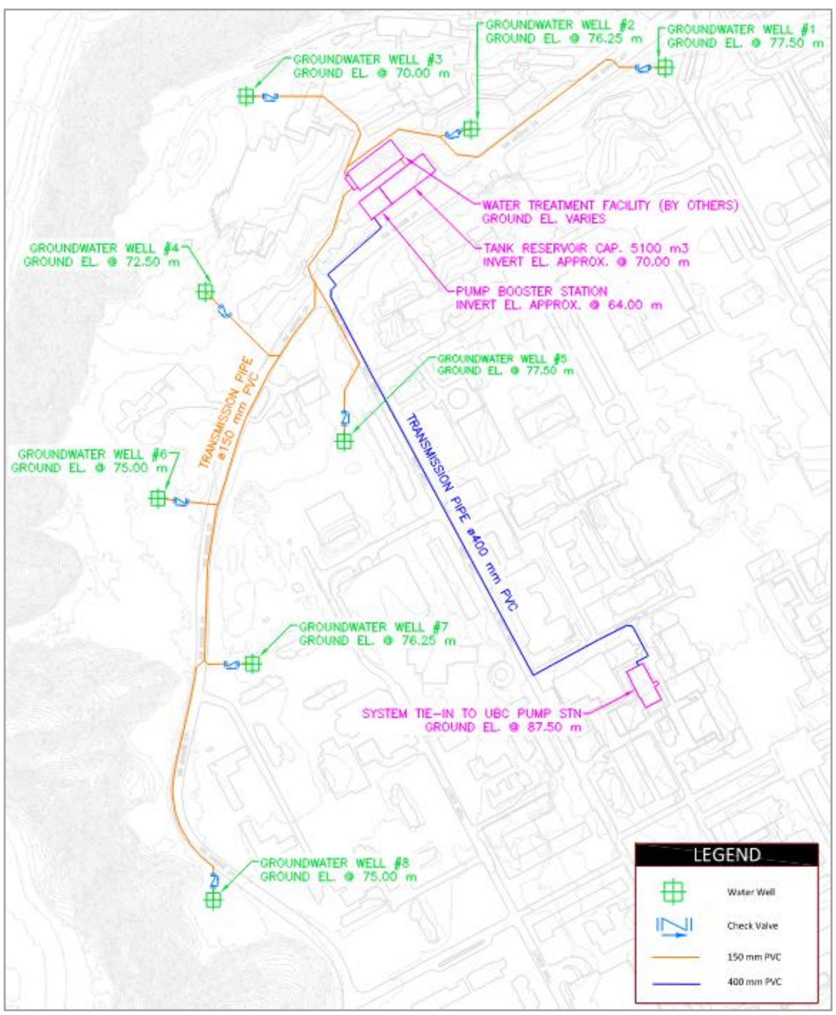


Figure 1: General Site Layout of the UBC Emergency Groundwater Supply System

1.1 Member Contributions

Table 1 below summarizes the contribution of each member during the development of this report. All members were also involved in editing and reviewing all sections of the report. Note that this table of contributions only includes the focus of each group member and is not a comprehensive list of roles or responsibilities.

Table 1: Member Contributions

Member	Contributions
Member 1	Service Life Maintenance Plan, Pipe & Connection Design, Restraint Detail Drawing
Member 2	Executive Summary, Introduction, Stakeholder Engagement Plan, Construction Work Plan, Project Schedule
Member 3	Pumps & Pump Station, Water Treatment, Structural Design of Facilities, Pump Station Layout Drawing, Structures General Layout Drawing, Pump Specifications Drawing
Member 4	Environmental Impact Assessment, Cost Estimate, Design Software & Codes, P&ID Diagram Technical Drawing
Member 5	Drafting, design and analysis of wells, geotechnical considerations, traffic management plans and permitting
Member 6	Site Layout, Reservoir, Water Treatment and Design Outputs of Drawings

2 Site Assessment

2.1 Geotechnical Evaluation

The following section outlines the team's geotechnical evaluation of the site. This includes information on subsurface soil and water conditions, preliminary liquefaction and seismic design comments, and horizontal and foundation recommendations. This information is based on field work conducted and reported by Piteau Associates Engineering in "UBC Properties Trust: Hydrogeological and Geotechnical Assessment of Northwest Area UBC Campus, Vancouver".

2.1.1 Soil Characterization

According to Piteau's report, two sonic drill holes (TH01-01 & TH01-03) and two mud rotary drill holes (BH2-67 and BH3-67) were located within the vicinity of our proposed infrastructure. Soil conditions were logged, and representative disturbed samples were collected for further classification and laboratory testing. Furthermore, a review of published geological information indicated the study site is underlain by the geological formations presented in Table 2. The storage tank, water filtration system, and Well 1 and 2 are situated in Vashon drift and Capilano sediments while Wells 3-8 are placed within the pre-Vashon deposits and Capilano sediments.

Table 2: Geological Formations Underlaying the Site

Geological Formation	Description of Formation
Vashon Drift and Capilano Sediments (VCb)	Comprising lodgment and minor flow till, lenses and interbed of sub stratified glaciofluvial sand and gravel and lenses of interbeds of glaciolacustrine laminated stony silt
Pre-Vashon Deposits (PVa)	Quadra fluvial channel fill and floodplain deposits, cross bedded sand containing minor silt and gravel lenses
Capilano Sediments (Cb)	Raised beach medium to coarse sand

A generalized site subsoil profile is provided below. TH01-01 was given precedence over TH01-03 due to its higher frequency of permeability testing. The study area is predominantly underlain by sand. This allows for greater drainage and recharge in and out of the unconfined aquifer. According to Piteau's sieve analysis, over 81% of all material is considered to be sand. The presence of sand is also proven through laboratory tests conducted by Smith (1981). According to Piteau Associates' testing of the Quadra Sand Unit, a porosity of 0.42 was adopted. Furthermore, a hydraulic conductivity of $8.5*10^{-5}$ was selected from TH01-01 to reflect the soil conditions at the well's base. Table 2.2 in Freeze and Cherry (1979) specifies that the above-referenced data correlated with clean sand.

Table 3: Subsoil Profile Near Project Location

Depth (m)	Soil Descriptions
0 -2.9	loose to compact, gravelly sand to silty sand fill
2.9-3.8	grey to brown, compact to stiff, silty sand, some gravel
3.8-11.6	brown-grey, loose to dense, silty sand to sand & gravel
11.6-27.4	grey to grey-brown, loose to dense, silty sand to sand, trace to some gravel, trace to some silt: dense interlayers between 15.9 to 17.8 m, 20.4 to 20.6 m, and 21.3 to26.4 m
27.4-55.8	grey to brown, loose to dense sand to slightly silty sand, trace gravel
55.8-66.1	grey to grey-brown, loose sand to very stiff clayey SILT, trace to some gravel: interbedded layers of dark brown, dense, organic PEAT

66.1-75.6	grey, dense to very dense sand to very stiff SILT, trace to some gravel: brown below 74.2m, loose SAND & SILT between 72.5 to 73.9m

Figure 2: Geological Map of Site

2.1.2 Liquefaction & Seismic Design

Liquefaction refers to a sudden reduction in shear strength due to repeated loading from seismic events (Nazhat, 2020). This occurs with increased water presence, leading to elevated pore water pressure and soil voids. Larger gaps in the soil structure results in reduced effective strength, thus escalating settlement, bearing capacity failure and landslide risks. In addition, common triggers for liquefaction includes cohesionless, loose, saturated, and undrained soils. As a result, soil between 3.8 - 11.6 m underground poses the greatest liquefaction risk. This is critical since our water storage facility has a design embedment of 5 m.

Based on the information above, a Rapid Impact Compaction method is recommended for liquefaction improvement. RIC is a form of dynamic compaction, consisting of a 9-ton weight that is hydraulically dropped at specified heights (Menard). The hammer apparatus is also mounted on a tracked excavator. The team proposes that RIC be carried out using a grid system over the water storage tank. This approach increases uniformity in densification, thus decreasing differential settlement. RIC can achieve an influence depth between 5 to 7 m. As a result, the loose sand material will have increased liquefaction and shear resistance. However, vibrations induced by dynamic compaction may disturb surrounding structures and utilities. If adopted, a vibration and pre-construction monitoring plan must be completed.

The benefits of uniform compaction outweigh the vibrational risks that may occur. To accurately evaluate seismic induced liquefaction, a site-specific response spectrum is recommended for future works. This is magnified since the rock slope north of the project site is considered to be an area of recorded landslides. In the absence of shear wave velocity data, the subject site was deemed to be Site Class D. Peak Ground Acceleration and correlative site coefficients were also found from the ATC Hazard website and are displayed in Appendix V – Seismic Response Spectrum and Data.

3 Design Description and Criteria

3.1 Well Design Components and Loads

Eight water supply wells are utilized to pump groundwater into a reservoir for treatment. Five of these wells are situated south-east of the Museum of Anthropology (MOA), along NW Marine Drive, two are north of MOA and the other is west of the UBC Department of Sociology. These wells will be fed into an in-ground treatment and water storage tank, feeding into the existing water main infrastructure. The following sections describe the design specifications, construction methods, maintenance, and environmental concerns associated with our wells.

3.1.1 Geohydrological Conditions

UBC has two aquifers located approximately 55-60 m and 70-85 m below ground. The upper aquifer is bounded by a very thin aquitard, which allows some groundwater to flow to the bottom aquifer. Both aquifers are also sloped towards the north-west. As water is pumped, the groundwater table is lowered and forms a cone of depression about the well (Margulis, 2017). If spaced too closely, groundwater drawdown may interfere with neighbouring wells.

As a result, a radius of influence of 90 m was established by using Kusakin's formula presented below (Aravin & Numerov, 1953). The equation was a function of hydraulic conductivity (K), porosity (n_e) and aquifer thickness (h_0) (indicated in Section 2.2.1) and the time after pumping starts (t). The latter assumed peak flow is 1.5 times the average flow for 6 hours per day for 21 days. As a result, only 51.3 m^3/h of flow is required.

$$R = 1.9 * \sqrt{\frac{h_0 K t}{n_e}}$$

A well drawdown of 11 m was tabulated via the Theis solution presented below. This is a function of flow rate (Q) and aquifer transmissivity (T). U represents a non-dimensional parameter which depends on water density, water and aquifer compressibility, porosity and the radius of influence. The first three values were found in established hydrological publications (Freeze and Cherry, 1979) and assumed that the soil is dense fine sand. Since water is not pumped continuously, it was assumed that a flow rate of 51.3 m^3/h was used for drawdown calculations rather than the flow capacity of 71.5 m^3/h. All hydrological calculations are found in Appendix II – Calculations.

$$s(r,t) = \frac{Q}{4T\pi} * (\ln\left(\frac{1}{u}\right) - 0.5772)$$

3.1.2 Well Placement

Well locations were contingent on UBC's terrain, hydrological properties, and setback regulations. Based on available contour plots, the university is sloped towards the northwest. This is why runoff is routed towards a spiral drain north of MOA, which is ultimately discharged over Point Grey Cliff. To ensure maximum aquifer recharge, the team narrowed the proposed location to the north-west section of campus. The next step is to confirm aquifer thickness variations by looking at cross-section views from Piteau Associate's Report. The consultants noted that the lower aquifer increases towards the south and east. However, the rate of increase plateaus beyond the Point Grey Cliff. Lastly, wells must be a certain distance away from utilities to avoid groundwater degradation. According to the 2017 BC Groundwater

Protection Regulations, sewage pipes, having a maximum flow rate of 22.7 m^3/day, must be at least 30 m away. To avoid cross contamination with saline, all wells must be 50 m away from the shoreline. However, even wells 500 m away from sea are at risk. As a result, electrical conductivity should be inspected on an annual basis. If encountered, it is recommended to seal certain sections of the well. When incorporating all three factors, it is evident that regions southeast and northwest of MOA, along NW Marine drive are ideal for groundwater well construction.

3.1.3 Well Construction

All wells are installed using a mud rotary drilling method. The auger rapidly rotates and cuts in-situ soil into pieces (EPA, 2018). Discarded material is removed by pumping water down the auger rods and up the annulus between the auger and borehole. Final well depths are contingent on the elevation of lower aquifers and are displayed in Appendix III – Drawings. This aquifer was selected since the aquitard underlaying the upper aquifer is semi permeable. As a result, water from the top aquifer will seep into the deeper, yet larger lower aquifer.

Drilled construction proves to be advantageous over alternative methods such as dug wells. For instance, a rotary drill rig can reach depths up to 300 m (Ontario, 2019). Dug wells, on the other hand, extend to a maximum depth of 15 m. Shallow wells have the disadvantage of quicker drawdown rates. Since the UBC lower aquifer elevations range between 62.5 to 82.5 m below grade, longer holes are necessary to obtain adequate yield. In addition, drilled wells consume a smaller cross-sectional area. As a result, less land is subjected to soil disturbances, clean-up procedures and contamination risks. Pollutants and particulates are also restricted in drilled wells through the use of screens, specified in Section 3.1.7. By contrast, dug wells have a larger probability of containing contaminated water. This is because most impurities, similar to dug wells, are situated at shallow depths. Lastly, mud rotary drilling is versatile in cold weather and geology, is widely available and has been previously implemented within the project vicinity by Piteau Associate in 2002.

An area of concern for drilled construction is the high initial costs. This is attributed to the significant depths and safety measures, such as additional sealant, prescribed in drilled wells. In addition, skilled, yet expensive, well drillers must be retained to safely operate the rotary drill rig. However, the cost of long drilled wells are offset by their high well yields and marginal contamination risks. Additional care is also required to ensure pumped water does not interfere with native soil formations.

3.1.4 Surface Casing

As the drill auger advances to the design embedment, loose sand at the top may slough into the hole, creating groundwater contamination risks. A simple solution is to install a temporary SCH-40, 14-inch thermoplastic surface casing up to 12 m deep. This length reflects the loosest region in the soil profile, as specified in Section 2.1.1. Furthermore, the casing's diameter was selected to accommodate a protective sealant around the final production casing. The surface casing is removed prior to the sealant's placement.

3.1.5 Production Casing

After drilling the well hole to its respective depth, a SCH-40 10-inch thermoplastic production casing is advanced. The overall casing comprises three 90 ft pipes connected using simple flush threaded joints. This system offers a barrier against varmints, containments and debris from entering the well. The well diameter was determined from an established correlation between pumping rate and well diameter (Smith, 1962). Our pumping rate of 19 L/s suggests a diameter between 8 to 10 inches is appropriate. Thermoplastic was selected due to its inert properties and resiliency against changing environments (Singh, 2017). These qualities provide stable housing for our submersible pumps. Concrete pipes were not considered due to its low ductility under seismic events. Steel casings were also avoided due to construction delays with welding. In addition, production casings protect pumped water from poorer quality groundwater found in lower elevations.

3.1.6 Filter Pack

Artificial filter packs are recommended if the natural formation surrounding a well is fine sand. Piteau Associates' TH01-01 sieve analysis suggest nearly all soils below 55 m are fine sand, implying the need for filter packs. The team recommends placing uniform, well sorted, well-rounded coarse silica sand after the well screen is installed. Silica prevents materials from dissolving over time due to contamination. Sand acts as a filter for suspended particulates such as silt, pathogens or pollutants in water. Silica sand has a uniform particle size of 2.4 mm to avoid screen blockages from well graded soils. Well-rounded material is preferred as it promotes water movement, which correlated to elevated hydraulic conductivity and greater well yield. Before installation, the filter pack is chlorinated to remove impurities and increase its design life. Afterwards, the filter pack is placed 2 feet above the well's bottom up to a length of 18 ft using a tremie pipe (Department of Interior Geological Survey, 1966).

3.1.7 Well Screen

Following the placement of production casing, a 6-inch diameter continuous stainless-steel screen is recommended to regulate soil particulates from entering the well. Continuous well screens are welded rods wrapped in wiring to provide strength and durability against contamination and clogging. Well screen length was established via a study at the University of Florida, suggesting well screens are only required for 70% of the aquifer thickness (Boman et. al, 2015). Since all proposed wells end at the lower aquifer, approximated to be 8.5 m thick, a screen length of 6m was chosen. Well sizes were matched with the appropriate intake area to determine an appropriate screen opening. Since the intake area is only 18.8 in^2/ft and the smallest area on the table was 25 in^2/ft, the latter was used to determine a screen opening of 0.01 inch. Each opening was V-shaped to prevent a residual clogging of small particles.

Based on Table 5.4.2 from Walton, 1962, aquifer hydraulic conductivity is correlative to the entrance velocity through a screen. Consequently, an entrance velocity of 0.6 m/min is anticipated. According to a paper published by the Government of Michigan, lower velocity results in lower headloss, which minimized the amount of energy the submersible pump expends. It also causes less encrustation relative to alternative screens, leading to decreasing pump abrasion and smaller maintenance expenses.

3.1.8 Bentonite Slurry Sealant

To minimize well movement within the loose sand region, a 2-inch thick bentonite slurry sealant is placed 10 m below grade using a tremie pipe. The slurry has a bentonite to water ratio of 1:3 (Knodel et. al, 1992). Sodium 8/25 granular bentonite is used due to local accessibility and its capacity to form a very dense clay mass. This balances the flexibility of the thermoplastic casing to provide a well structure that is stiff, yet ductile during a seismic event. Furthermore, the irregular shapes of the bentonite granules offer extra friction to form a tight and impermeable seal. This also prevents chemicals and contaminants from entering the well. During construction, field engineers must monitor bentonite slurry for slump. If too wet, the bentonite slurry may swell too quickly. Polymer additives should be used as a result (Hunt, 2000). Bentonite slurry was implemented over Portland Cement as the latter is more susceptible to corrosion.

3.1.9 Submersible Pumps

A submersible pump will be used for each of the 8 groundwater wells and will feature a multi-stage centrifugal pump in a ring-section design with 150 mm (6”) PVC piping and a well casing with a minimum diameter of 250 mm (10”). Benefits of this pump type include high operating reliability and long service life due to features such as lift check valves with stainless-steel investment castings that provide anti-corrosive properties. In addition, the multi-stage configuration will allow for sufficient head to transport the groundwater to the proper elevation without compromising pump flow rate. Referencing the pump performance curve of the KSB UPA 200B with a total of 4 stages, a pump flow rate of approximately 74.2 m^3/h can be delivered with a total head of 80.2 m enough to satisfy the minimum required flow rate of

71.5 m^3/h per well. At this rated flow rate, pump efficiency at each well pump is expected to be around 75% with a required NPSH of 4.2 m.

3.1.10 Well Bowls

A 6 inch, 6MM8V well bowl series is attached above the pump motor to convert mechanical power from pump vanes into an output power. According to the bowl manufacturer, Wolf Pumps, the bowl has a capacity of 500 GPM (31.5L/s) and a pump efficiency of 87%. This is achieved through closed bronze impellers, typically used when pump efficiencies are high and NPSH is low, as is the case for our submersible pumps. As a result, head and well capacity can be delivered more effectively.

3.1.11 Check Valves

Check valves are implemented to hold water pressure in the system when the submersible pump stops. As a result, backspin and water hammer are minimized, increasing the pump's life span (Nelson, 2019). The team recommends two Model 80DIX ductile iron check valves be placed along the distribution pipe and above the well bowls. Alternative check valves such as the swing type check valve were not considered due to slow reaction times, leading to sudden velocity changes and water hammer.

3.1.12 Torque Arrestor

A torque arrestor is a device which minimizes pump and well casing damage by absorbing energy produced from motor start-up torque (McEwen, 2019). The device is 11.75-inch long and comprises two thermoplastic molds clamped on each end by stainless steel gear clamps. The torque arrestor is specified to be 2 ft above the submersible pump to account for vertical displacements during seismic events.

3.1.13 Pumping Pipe & Pitless Adapter

Groundwater is delivered from the pumping system to the distribution main via a 2-3/8-inch SCH 80 thermoplastic pumping pipe. The pipe is connected to a MBNL250 model pitless adapter at the frostline to protect water from freezing and permitting convenient access to the well. The pitless adapter also allows the pumping pipe to seamlessly transition to the 6-inch distribution pipe.

3.1.14 Well Cap

Once the pumping system is installed, a WCC-A10 aluminum conduit well cap is placed at a stick-up length of 0.3 m. This offers additional safeguards against contamination found at the top of the well. WCC-A10 well caps are also configured to permit instrumentation wiring from pumps and test equipment to exit the water wells. Aluminum materials was chosen to resist corrosion from buried metals. This is relevant since silty materials have greater corrosion potential and are found in the first 3.8 m of our geotechnical model. Due to aluminum's availability and recyclability, well caps can be easily replaced if subjected to damage.

3.1.15 Backfill

The last step in the water well system is to remove surficial vegetation and existing fill up to a depth of 1m and replace it with engineered fill. This comprises well-graded sand, free of deleterious substances and having a maximum particle size of 75 mm with less than 5% fines (percent passing No. 200 sieve). Excavated material from the site may be reused as fill provided that any unsuitable material (organic clays) and any building rubble or deleterious material is excluded. The engineered fill, and any excavation backfill where subgrade support is required, should be compacted in layers of not greater than 300 mm loose thickness, to a density ratio of 95% of Standard Maximum Dry Density (SMDD). Dense sand fill helps to reduce compressibility and void ratio, while providing extra friction for shear strength. The absence of fine-grained material promotes greater rainfall infiltration and thus recharge into the lower aquifer.

Density tests should be regularly carried out on the fill in accordance of CSA A23.1 standard to confirm the above specifications are achieved. The density test frequency should be at least one test per well.

3.1.16 Well Development

Before a well is deemed operational, it must undergo well development to remove clay and silt material within the vicinity of the well screen and behind the filter packs (Aller et. al, 1991). Since contamination is a core technical consideration for this project, the team avoided the use of jetting or air pumping for well development. These techniques have potential to displace and/or entrain air in the filter packs, leading to reduced permeability and susceptibility of chemical infiltration. It is recommended to use overpumping for well development, provided bridges are avoided through surging. Overpumping works by using an external pump, operating at higher capacity then the well, to cause quick movement of particulates towards the pumping well. This performs especially well in clean sand formations, which was identified in Section 2.1.1. Overpumping is also easy to organize and cost-effective compared to alternative options such as surge blocking and bailing (Aller et. al, 1991).

3.2 Pipes & Connections

The system supply pipes have three major components: piping, connections, and restraints. The components, their technical specifications and design criteria are covered below.

3.2.1 Pipes

The pipes being used to convey water through the system are NAPCO CIOD PC 235 (DR18) in two nominal diameters – 150 mm and 400 mm. These are bell and spigot pipes with double seal gasket joints on either end. They comply with both relevant AWWA and CSA standards. They were chosen for both their corrosion resistance as well as their ease of installation. Being made of PVC makes the pipes strong and durable, they are impact test rated to up to 240 J of impact force. These pipes allow for adequate flow volumes through the system under all operating conditions and they are pressure rated up to 350 psi (design pressures in system do not exceed 110 psi). These factors make them both economical and durable, needing minimal maintenance and having a low probability of needing major replacement through their design life.

3.2.2 Connections

The system pipes will be restrained two ways: conventional tie-rod connections, and wedge action restraints.

The tie-rods will be used for most of the connections in the system. They are easier and less expensive to install than wedge action restraints and have a lower unit cost. They consist of two pipe clamps on either side of the joint fixed together using eight high strength steel bolts arranged around the pipe threaded onto the clamps.

Wedge action restraints will only be used where required, primarily in high pressure zones near and inside the pump station and the well heads. Wedge action restraints can provide stronger connections than simple tie-rods. These restraints have a number of wedges or teeth located around the exterior circumference of the pipe. When screws placed above the wedges are tightened, the teeth on the bottom of each wedge lock onto the pipe surface locking it in place. A pair of wedge action restraints can then be bolted together to create a strong bond fixing the joint in place.

3.2.3 Joint Restraints

The primary method of restraining the system through large angle turns (above 20 degrees) both vertical and horizontal will be thrust blocks. Thrust blocks prevent the mains from displacing under loads from high pressure turns and possible transient events. They will be constructed using 25 MPa concrete to resist design pressures of between 70 and 90 psi depending on the location. They have been designed with a factor of safety of 2 and will have a bearing area of between 0.60 m^2 and 1.1 m^2, respectively assuming soil consisting primarily of sands and gravels will be used during the placement of the restraints. Each thrust block will displace between 1 to 5 cubic meters of soil depending on the size of block required. They shall be fully covered by at least 250 mm of topsoil once installed. Sample calculations for the restraints can be found in the Appendix.

3.3 Pumps & Pump Station

3.3.1 Groundwater Well Pumps

To simplify the groundwater pump selection process, a trial-and-error method was used to identify configuration and specifications for the 8 groundwater well pumps that will be constructed along the norther portion of the study area. An initial estimated water demand of 71.5 m^3/h, which was based on future water demand calculations, and a total dynamic head of 75 m, were used to start the trial-and-error selection method. Various multi-stage vertical centrifugal pumps were tested in conjunction with the selected horizontal centrifugal pumps for the booster station using EPANET. It was determined that the Model UPA 200B 80 with a minimum well diameter of 200 mm, a best efficiency point at 80 m^3/h, and 4 vertical centrifugal stages can sufficiently meet the system's flow rate demands of 572.0 m^3/h at the inlet chamber of the water treatment facility while ensuring that pressures at junction nodes throughout the transmission pipes do not exceed 100 psi (70.3 m WC). Groundwater pump specifications and dimensioning for Model UPA 200B 80, referenced from manufacturer data sheets provided by KSB, can be found in Appendix III – Drawings.

Table 4: Summary of Groundwater Well Pump Specifications

Summary of Groundwater Well Pump Specifications	
Pump Specification	Vertical Multi-Stage Centrifugal
Number of Stages per Pump	4
Minimum Flow Rate, per pump	71.5 m^3/h
Total Dynamic Head at Minimum Flow	80.2 m
Impeller Speed	$n \leq 2900$ rpm
Max. Permissible Sand Content of Fluid	50 g/m^3
Outlet Pipe, diameter	150 mm (6")
Well Casing, internal diameter	250 mm (10")

3.3.1 Booster Station Pumps

To deliver the total minimum flow and head required to convey the treated groundwater to the tie-in at the UBC Pump Station, 4 dry-installed volute casing centrifugal pumps in parallel will be used. A total minimum flow of 572.0 m^3/h was used as a base-criteria to select the pump configuration and specification, within an operating range from a low pressure of 20.0 psi (14.1 m WC) to a high pressure of 80.0 psi (56.3 m WC). The minimum flow was determined using population equivalent projections to the design year and a base demand of 50 L/capita-day. To develop the system curve for the transmission pipes from the outlet of the pump booster station at a minimum suction HGL of 65.0 m to the tie-in with a discharge HGL of 87.5 m, the Hazen-Williams equation for head loss in pipes was used with a roughness coefficient C of 140 for smooth PVC pipes. To minimize head losses in the transmission pipes, a larger pipe with a nominal diameter of 400 mm and a mean internal diameter of 390 mm was used. This resulted in a total head loss of 3.51 m and considers head losses from connections such as 90-degree and 45-degree pipe connections. Example head loss calculations and a summary of results can be found in Appendix II – Calculations. Pump model specifications can be referenced in Appendix III – Drawings.

An inlet header pipe with an outside diameter of 1000 mm will connect the water tank reservoir to the pump booster station. Each pump will include a suction pipe of 350 mm diameter, a 400 mm discharge pipe, a check valve to prevent backflow, and gate valves at both suction and discharge ends to ensure easy operation and maintenance. Pumps should be constructed on concrete equipment pads that can sufficiently reduce impacts of mechanical vibrations on surrounding foundational soil and concrete structures. A detailed layout of the pump station, including pipe specifications and valves can be found in Appendix III – Drawings.

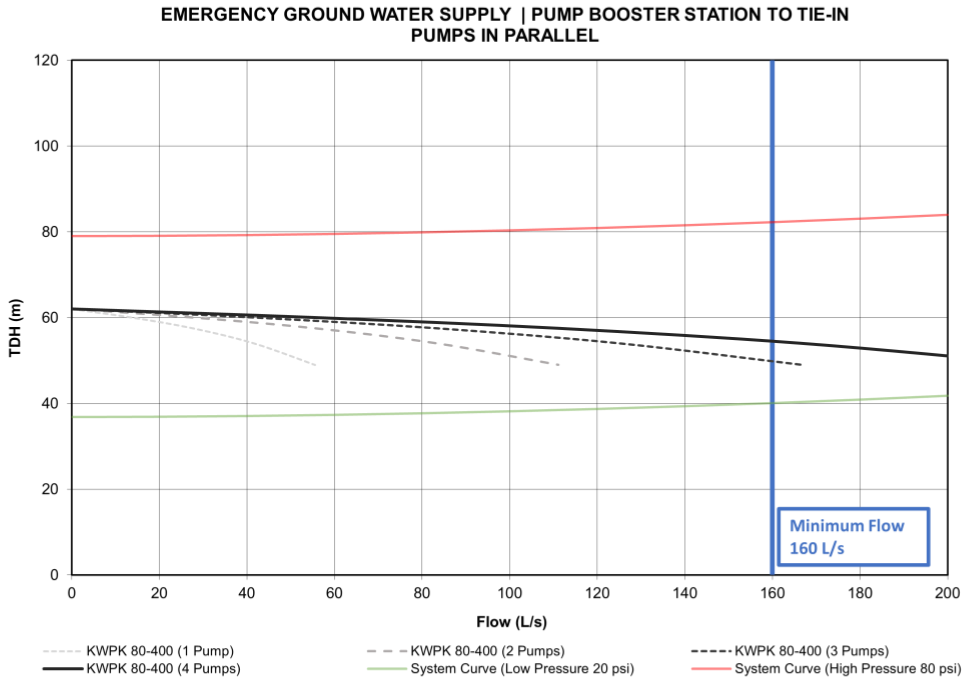


Figure 3: Pump Performance Curve for Booster Pumps in Parallel

Comparison of the performance curves of 4 centrifugal pumps in parallel with the system curve of the transmission pumps indicate that the KWPK 80-400 model is sufficient in supplying the minimum total flow while staying within the acceptable pressure ranges. Further analysis of this pump model was done using EPANET in conjunction with the selected groundwater well pumps to ensure a balanced hydraulic model that can meet flow demand at the tie-in. A summary of the booster pump specifications is provided in Table 5 below.

Table 5: Summary of Booster Pump Specifications

Summary of Booster Pump Specifications	
Pump Specification	Horizontal Centrifugal
Number of Pumps	4 in Parallel
Estimated Operating Flow, per pump	143.8 m^3/h
Total Dynamic Head at Operation Flow	58.0 m
Impeller Speed	n = 1450 rpm
Net Positive Suction Head, Allowable	14.7 m
Net Positive Suction Head, Required	2.5 m (at a flow of 150 m^3/h)

3.4 Water Treatment

Detailed process design of the water treatment facility is being contracted to Water Street Engineering in consideration of the process and quality specifications listed in the subsequent sections. It is recommended to maintain the flow of the treatment facility at a rate similar to the total inflow rate from the groundwater wells, which is approximately 572.0 m^3/hr, to minimize the footprint requirements of the underground tank reservoir and sufficiently meet the water demands at the tie-in at the UBC pump station. Similar to the underground tank reservoir and pump booster station, the detailed structural design of the water treatment facility will also be provided by aDB Engineering.

3.4.1 Water Treatment Process Specifications

Filtration and chlorination are the two main processes specified by the team for Water Street Engineering to include in their detailed design of the water treatment process to sufficiently meet the water quality specifications outlined by UBC's Water Drinking Guidelines. It is also required that Water Street Engineering complies with the 4-3-2-1-0 drinking water guidelines put forward by the Canadian Drinking Water Quality Guidelines. The chlorination and filtration systems to be proposed by Water Street Engineering are also required to maintain a treatment flow rate of 572.0 m^3/hr.

3.4.1 Water Quality Specifications

Key criteria for drinking water include Aesthetic Objectives (AO) and Maximum Acceptable Concentrated (MAC) as stated in the B.C. Ministry of Environment and Climate Change Strategy (2020). The water quality specifications to be fully considered by the external design consultant are listed in Table 6 below. The client has indicated that the groundwater being extracted from the upper aquifer is of high quality. However, consideration for contaminants infiltrating from surface runoff, nearby sewer systems, as well as contaminants from the surrounding soil stratigraphy, should still be considered in the design of the water treatment process.

Table 6: Drinking Water Quality Values Based on B.C. Ministry of Environment and Climate Change Strategy

Water Quality Parameter	Type	Guideline
Coliforms Fecal, Total	MAC	≤ 10 CFU/100 mL
Escherichia Coli, Total	MAC	≤ 10 CFU/100 mL
Free Chlorine Residual, Total	MAC	≥ 0.4 mg/L; ≤ 2.0 mg/L
Haloacetic Acids (HAAs), Total	MAC	≤ 0.08 mg/L
Trihalomethanes (THMs), Total	MAC	≤ 0.1 mg/L
Vinyl Chloride, Total	MAC	≤ 0.002 mg/L
Iron, Total	AO	≤ 0.3 mg/L
Manganese, Total	MAC	≤ 0.12 mg/L
	AO	≤ 0.12 mg/L
Lead, Total	MAC	≤ 0.005 mg/L
Zinc, Total	MAC	≤ 5 mg/L
	AO	≤ 3 mg/L
Copper, Total	MAC	≤ 2 mg/L
	AO	≤ 1 mg/L
Dissolved Solids, Total	MAC	≤ 300 mg/L
Turbidity, Total	AO	≤ 1 NTU

3.5 Structural Design of Facilities

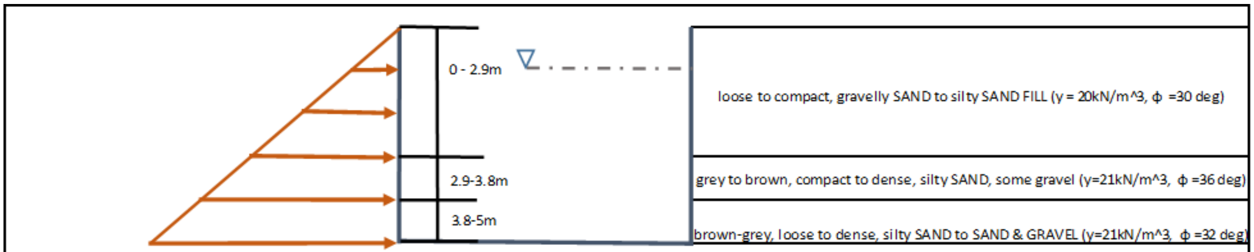
The detailed structural designs for the water treatment facility, underground tank reservoir, and pump station are being contracted out to aDB Engineering. The reservoir structure will require a floor elevation of 69.75 m and requires a minimum capacity of 5,100 m^3 with a high-head HGL of 74.75 m and a low-head HGL of the tank reservoir no less than 69.75 m. A 250 mm free-board above the high-head HGL will be required. As the tank reservoir is to be placed underground, tank walls are required to be able to resist lateral earth pressures acting on the structure from both saturated and dry soil conditions. The structure will also need to resist a uniformly distributed load of 2.4 kPa (NBCC 2015) in addition to the structure self-weight and weight of detained water volume at max capacity of 5,100 m^3. Furthermore, the structure will require consideration for ventilation to a ground elevation of 76.25 m to allow excess air or vapour pressure to exit the tank reservoir and prevent the integrity of the structure from being compromised. The reservoir is recommended to have a minimum 2% sloped floor to ensure that detained water can feed into the 1000 mm diameter inlet header for the pump booster station. The underground tank will be constructed using reinforced concrete and lined with an impervious membrane to prevent seepage of potentially harmful contaminants from the parking and roadway infrastructure above the reservoir, as well as the surrounding soil stratigraphy. Additional considerations for the tank reservoir design include water stops along construction joins of the base slab and tank walls and sealants around any openings. Table 7 below outlines the specifications with which the structural design consultant is required to comply. A general site layout of the main structures, including the treatment facility, underground tank reservoir, and pump station can be found in Appendix III – Drawings.

Table 7: Underground Tank Reservoir Specifications

Underground Tank Reservoir Specifications	
Dimensions of Underground Tank Reservoir Structure	
Width, Exterior Structure	22.0 m
Length, Exterior Structure	52.0 m
Height, Exterior Structure	6.0 m
Minimum Volume Capacity	5100 m^3
Invert Elevation (top of slab)	69.75 m (geodetic)
Minimum thickness, base slab	1.0 m
Minimum thickness, tank walls	0.5 m
Minimum thickness, cover slab	0.25 m
Structural Loading Specification	
Uniformly Distributed Load	2.4 kPa (NBCC 2015)
Process Requirements of Tank Reservoir	
High-Head HGL	74.75 m (geodetic)
Low-Head HGL	69.75 m (geodetic)

3.5.1 Lateral Pressure of Reservoir

Since the proposed water supply reservoir is underground, in-situ soil will impose lateral pressure on the walls. The following diagram illustrates how pressure is applied to the structure and the calculations to determine base pressure. The team used the Equivalent Fluid Method, where the pressure envelope is triangular, to perform our assessment (Keystone, 2003). Soil unit weights and friction angles are derived from established literature (Nazhat, 2020). In addition, Piteau Associates' 2001 hydrogeological report suggests groundwater conditions begin at 0.41 m.



$$P_a = 0.5 * k_a * \gamma * H^2$$

$$P_a = 0.5 * \left(((2.9 * 20) + (0.9 * 21) + (1.2 * 21) - (1 * 9.81)\right) * 0.41) * 5$$

$$P_a = 94.6 \frac{kN}{m^3}$$

Figure 4: Lateral Loading of Reservoir

3.5.2 Foundation Design of Reservoir

The proposed water storage system is subjected to a combination of heavy concrete, variable traffic loading and hydraulic forces. Table 8 details the contributions of each load type to the overall applied forces. Load factors of 1.5 and 1.25 are added to live and dead loads, respectively. Additional forces such as lateral seismic loading will be considered in the detailed design, prepared by aDB Engineering.

Table 8: Foundation Loading

Dead load		Live Load	
Concrete Weight	38000kN	**Parking Lot Traffic**	2450kN
Rebar Weight	1260kN	**Storage Water**	46600kN

3.5.2.1 Mat Foundation

A mat foundation is a continuous slab extending over the entire water storage footprint. A larger foundation area decreases the applied load felt by the bearing soil. The reservoir's foundation experiences a bearing pressure of 141 kPA and is resisted by a bearing resistance of 7500 kPA. Bearing pressure is also deemed the primary mode of failure. The bearing capacity is much higher comparatively to the structural loads due to its large width and length, correlating to high bearing and shape factors.

Furthermore, mat foundations are more economical than footings. This is because the floor slab acts as a self-sustaining foundation, leading to less concrete, formwork, and workmanship. Furthermore, a wide foundation is also beneficial in minimizing differential settlement. When water supply wells are activated, groundwater is lowered, resulting in aquifer compaction (USGS). As a result, overlaying soil may shift. A mat foundation ensures this disturbance does not occur non-uniformly. Continuous concrete construction also certifies a smaller probability of uneven consolidation, air entrainment and slump within the floor slab. Continuity allows heavy concrete and hydraulic loads to be distributed to the soil.

However, erosion hazards are of concern near the foundation's edges. This is because the location of maximum shear occurs at the floor slab's ends (Tabsh, El-Emam, Partazian, 2020). The result is greater difficulties in reservoir wall load transfer into the floor slab. As a remedy, French Drains are recommended around the perimeter of the storage tank. A drainage system allows pore pressure to be diverted away from the floor slabs. Nevertheless, consistent monitoring is required to measure debris clogging, and changes in water diversion.

3.6 Modelling Software

A successful engineering design team is one with open lines of communication and the correct tools for the job. Especially in a socially distanced engineering design process, software has taken a significant role to facilitate project team communication and document management. Additionally, numerous technical analysis and design tools were utilized to ensure accurate and reliable design results. Software used by the design team in the production of the detailed design of the UBC Emergency Groundwater project in Table 9.

Table 9: Software Used

Software Purpose	Software
Technical Drawings & Visual Aids	AutoCAD, Civil 3D, Adobe Photoshop CC, Adobe Illustrator CC, Google Earth
Reports, Presentations & Calculations	Microsoft Word, Microsoft Excel, Microsoft PowerPoint
Team Communication, File Management	Microsoft Teams, Facebook Messenger, Zoom
Hydrotechnical Analysis	EPANET

3.7 Design Codes & Guidelines

The team provides clients with reliable and cost-effective infrastructure solutions. Within the design process, careful research was undertaken to ensure proposed solutions meet or exceed local, regional, Provincial, and National design codes and guidelines. For each project component, designers first considered legally mandated requirements. In the lack of legal design codes for specific project components, industry standards and design best practices were followed.

As the emergency source of drinking water for the population of the UBC community, the safety and cleanliness of supplied water is of paramount concern for this project. As such, every precaution was taken to ensure the production, treatment, and conveyance of water within the project would meet or exceed regulations and design codes. When designing water infrastructure of the project, the following documents were utilized for guidance and compliance.

Table 10: Hydrotechnical Standards

Drinking Water	• BC Drinking Water Regulation
	  ○ Drinking Water Protection Act
	  ○ Drinking Water Protection Regulation
	• Canadian Drinking Water Regulation
	  ○ Guidelines for Canadian Drinking Water Quality
	  ○ Canadian Drinking Water Quality Guideline Technical Documents
	• BC Ministry of Environment Climate Change Strategy
	• Aesthetic Objectives (AO)
	• Maximum Acceptable Concentrations

Groundwater	• BC Groundwater Protection Regulations
Water Distribution Design	• American Water Works Association Design Manuals

Apart from the design of water infrastructure on the UBC Emergency Groundwater Project, other codes and guidelines were followed to ensure legal compliance and engineering best practices were maintained. Other codes and guidelines utilized throughout the design process include:

Table 11: Structural Standards

Concrete Structures	• CSA A23.1 - Concrete Materials & Methods of Concrete Construction • CSA A23.2 - Test Methods & Standard Practices for Concrete • CSA A23.3 - Design of Concrete Structures • National Building Code of Canada
Other	• Other Relevant CSA Standards • City of Vancouver Roadwork Requirements

4 Additional Considerations

4.1 Service Life Maintenance Plan

A plan has been created outlining suggested maintenance and operation procedures of the system to ensure full functionality and safety in an emergency. The plan includes procedures to sustain the performance of the system during and before operation, mitigate deterioration of the system and its components, achieve the full-service life of the system, and suggested timelines for repairs and inspections. Approximate costing of this maintenance regime is approximately $8,500 per year.

Table 12: Service Life Maintenance Plan

Item	Frequency	Description	Remarks
Well Development	**First 24 hours*	Check the following: • Original water level • Water level after pumping • Aquifer permeability • Well efficiency	*Monitor well status during first 24 hours of operation
Water Quality Tests	**Daily*	Check the presence of the following in water supply: • Ecoli • Fecal coliforms • Viruses See section 2.4 for more information on water quality	*Check daily during operation, *annually* otherwise

Right-of-way Inspection	Annually	Check system right-of-way and well caps for the following: • Presence of potentially disruptive vegetation like trees or shrubs • Growth of new vegetation around well cap impeding access • Unauthorized construction in or around right-of-way • Encroachment of water bodies	
Well Inspection	Annually	Inspect the well cap and well casing for signs of the following: • Deterioration and excessive wear to casing including cracking, root infiltration or leaks • Presence of foreign debris in well	Well casing inspection may require use of cameras or other special equipment
Submersible Pump Inspection	Annually	Remove submersible pumps to inspect: • Motor condition • Pressure sensor condition • Impeller condition	
Water Reservoir Inspection	Annually	Inspect reservoir for the following: • Presence of sediment or algal growth on interior of reservoir • General condition of concrete • Presence of any exposed reinforcing steel • Concrete spalling • Condition of seal around access hatch • Functionality and structural integrity of access hatch	Will require personnel trained in confined space safety procedures
Water Treatment and Pump House Inspection	Annually	Check Water Treatment Facility and Pump House for the following: • Condition of pump motors • Condition of pump impellers • Condition of treatment equipment • Integrity of vessels used for chemical storage	
System Pipe Flushing	Annually	Run system at full capacity for approximately 1 hour to flush system of sediment and contaminants	
System Pipe Inspection	Tri - Annually	Inspect all pipes for the following: • Structural integrity of the pipes • Signs of cracks, leaks, or root infiltration • Condition of pipe joints • Condition of all valves	Will require use of specialized cameras and other equipment along lengthy system shutdown

4.2 Environmental Impact Assessment

From onset of the UBC Emergency Groundwater Project, the engineering team has taken strong measures to ensure that the proposed infrastructure imparts a minimal impact on the natural environment of the University of British Columbia. As part of the responsibility of an engineering consultancy, the team has undertaken a project-wide Environmental Impact Assessment (EIA) to identify, classify, and mitigate potential environmental impacts resulting from the construction and operation of the proposed facilities. The purpose of Environmental Impact Assessment, as defined by the United Nations Environment Program, is to "to facilitate the systematic consideration of environmental issues as part of development decision-making", "[taking] place before major decisions are taken and, ideally, while feasible alternatives and options to a proposed action are still open" (Abaza 40). As such, the design team undertook the first steps of the EIA in the initial phases of project design to ensure that all future decision-making was completed with the consideration of site-specific environmental issues.

During the project's initial design phase, three potential design philosophies were explored to best suit the client-provided design criteria. The three design options each met or exceeded client objectives. As part of the process to identify the option best suited to successfully meet the design objectives, a number of criteria were considered; among other key performance indicators (KPIs) identified for the project including operational resiliency and capital cost, environmental impact was a heavily weighted decision-making criterion in the selection of the proposed system.

4.2.1 Wells

With an understanding of well-spacing requirements due to aquifer drawdown and the proximity to the ocean, placement of wells within the project site was carefully considered to maximize hydraulic efficiency and minimize impact to the UBC environment. When choosing location of the wells, a number of specific factors were considered. First, well-drilling requires large, powerful rigs. To access to proposed locations, construction access roads are required, requiring removal of large trees and other plant-life. To mitigate this, well locations were chosen to minimize the length of these roads where possible while maintaining required well-spacing limits. Upon completion of the project, a comprehensive re-planting program will be undertaken to restore and rehabilitate the impacted natural lands. Another environmental factor of well construction is the impact of operations on groundwater. In the design process, team members conducted a significant desktop study of the supply aquifer to determine the impacts of the proposed demand. If, in the case that design demands exceeded the capacity of the aquifer, groundwater levels would be significantly reduced, harming plant life and potentially destabilizing the nearby Wreck Beach cliffs. The results of the desktop study concluded that the large size of the aquifer and proposed spacing limits were sufficient to mitigate potential impacts, especially given the emergency-use nature of the water supply system.

4.2.2 Piping

The proposed piping network connects the well systems to the treatment, storage, and distribution systems of the project. Pipe installation varies across the project depending on the location; forested areas require different environmental mitigation than installation under roads. Piping from the well locations in forested areas, similar to the well drilling process, requires sizable machinery and space to work. Proposed pipe paths will follow the access routes created for well access, mitigating requirements for further removal of local plant-life. Pipe depths will also be reduced to minimum requirements to keep excavation activities at a minimum. Where possible, distribution pipe networks (ie along South-West Marine Drive) have been placed to minimize repaving of roads. Placement of project piping under roads, where required, will follow a strict environmental protection program, in part comprised of sediment control bags at storm catch basins and regular street cleaning to mitigate chemical spills and sediment entering the stormwater systems. All construction equipment will be required to utilize spill trays to further reduce oil or chemical spills into the environment.

4.2.3 Storage Tank

Of the proposed infrastructure developments entailed in the UBC Emergency Groundwater Supply Project, the cast-in-place concrete storage tank is the largest undertaking with the greatest disturbance to the natural environment. The construction procedure of the tank involves bulk excavation; geotechnical earth preparations; forming, placing, finishing, and stripping of the concrete structure; backfill of the excavation; and site finishing works. Selection of the tank location was deliberate and carefully considered. Given the value of land at UBC and to avoid impact to undeveloped regions of the campus, the tank was chosen to be installed underneath the existing UBC Museum of Anthropology parking lot. The design engineers undertook consideration of structural materials for the tank with the effort of minimizing production and installation emissions while maximizing the operating lifetime of the facility. Reinforced concrete was determined to be the most well-rounded structural material to use when considering the size and calculating loading of the tank. During concreting activities, strict environmental measures will be undertaken by the contractor to mitigate the risk of chemical spills leeching into the groundwater supply.

4.3 Permitting

Permit acquisition is a key component in ensuring all project activities adhere to municipal and provincial guidelines. The following is a comprehensive list of permits and licenses obtained by the team for the purpose of this project.

4.3.1 BC One Call

Any drilling or trench work requires the preparation of a BC One Call. This outlines the type of work, duration, and location of the proposed project. Once received, issuing officials will provide available schematic drawings of municipal utilities, FortisBC gas mains and any underground telephone or BC Hydro lines. This allows consultants to adjust well and watermain locations to avert utility damage.

4.3.2 Construction Permits

Prior to constructing the eight-well system, a construction permit is required by Vancouver Coastal Health to satisfy water quality guidelines specified in Canadian Drinking Water Quality Guideline and Drinking Water Protection Act. Permit applications must include construction plans that detail how water is pumped from the wells into the distribution main and storage tank. It also contains water quality data, well logs, pump tests and setbacks between sanitary and storm sewers.

4.3.3 Operating Permits

As per the BC Ministry of Health, an Operating Permit must be granted by an "issuing official" to operate the water well, treatment and reservoir system. This supplements the Construction Permit and provides best practice documentation on performance monitoring and preventive measures on saline water intrusion. The application should outline the impact of water treatment strategies on users, especially those from vulnerable populations. Lastly, the permit ensures the water distribution system is overseen by an EOCP certified senior operator.

4.3.4 Water Supply Well Registration

All eight wells in the proposed distribution system must be registered with the BC government. This is completed by preparing a Well Identification Report, illustrating the well's owners, their locations and their identification plate numbers (provided the well construction report is complete). Once approved, all provided information will be processed in the Provincial WELLS Database.

4.3.5 Water Licenses

A Water Licence is mandatory for any party wishing to store or distribute groundwater. It is reviewed and approved by the Ministry of Forests, Lands, Natural Resource Operations and Rural Developments (FLNR). The application consists of background project information, reservoir dimensions, construction drawings and anticipated water demand. All hydrological data must comply with the BC Water Sustainability Act.

4.4 Stakeholder Engagement Plan

The design of the emergency water supply has required consultation with many stakeholders. A website was created that contained graphics and information about the project, and a feedback form for the public to contact the design team. Live presentations were held on the website, the recordings of which were updated. Meetings were also conducted with representatives of the main stakeholder and land rights holder groups, which are as follows:

- Metro Vancouver
- Integrated Land & Resource Registry
- Musqueam Nation
- Department of Fisheries and Oceans
- Local Business Operators
- City of Vancouver
- Pacific Spirit Regional Park
- University of British Columbia
- Environmental Action Groups
- Local Residents

In addition, the construction and successful operation of the system will require ongoing stakeholder engagement. Campus users will need to be notified in an effective and accurate manner as to how construction will affect them, especially in areas where access will be severely impacted throughout the duration of construction. The team will prepare documents outlining the proposed online and in-person notification strategies, including social media posts and bulletin board postings.

Building managers will provided with materials that outline how operation of the system will function in an emergency and will be responsible for making sure that that information is distributed among residents and frequent users. Essential staff on campus will be invited to information sessions regarding emergency operations, and the campus emergency operation plans will be updated to include the maintenance and operation of the system.

5 Construction Work Plan

An important part of creating a detailed design is considering the sequence and method of construction. The following section is a draft construction work plan, that will be revised and finalized by the general contractor prior to construction.

As soon as detailed design is completed and the clients have reviewed the report and drawings, procurement and construction start up can commence. Materials, labour, and equipment will be procured, and the site can be setup and mobilized. A construction trailer will be setup and remain on-site for the entire duration of the project. A critical aspect of the site setup is establishment of the safety protocols. The general contractor will come up with a set of safety rules to follow while on site, and it is the responsibility of everyone to ensure that they are followed.

Once construction can commence on May 21st after procurement is complete, ground improvement will begin for the detention tank and water treatment structures. As discussed in Section 2.1.2, Rapid Impact Compaction (RIC) is the preferred method and involves a 9-ton weight that is hydraulically dropped at specified heights. The dynamic compaction significantly reduces the risk of compaction in the event of an earthquake.

5.1 Wells

Concurrent to the ground improvements is the installation of the groundwater wells. First, well locations will be prepared for drilling. This includes surveying, staking and additional preparation measures like installation fencing and providing a power source. Three rotary drills must be procured as the wells will be drilled concurrently in groups of two or three. All eight wells will be drilled over a period of 10 days beginning at the end of May. Once the holes are drilled, the thermoplastic well casing will be installed, followed by grouting, installation of well screens, and installation of the submersible pumps and check valves. To complete the well construction, the piping to the main well junction will be installed, then well caps and landscaped can be configured. As the wells are being constructed concurrently in order to keep construction efficient, this whole process is expected to be complete by the beginning of July, after which a few days of QA/QC work will be undertaken.

5.2 Storage Tank & Treatment Facility

While the wells are being installed, construction of the groundwater detention tank and treatment structure will be ongoing. Staking and excavation of the sites will begin May 21st, followed by shoring and anchoring of the excavation. In order to most efficiently make use of crews and equipment, the excavation/shoring as well as all reinforced concrete construction will be done first for the detention tank, then immediately followed by work done on the water treatment structure. The slab formwork, reinforcement, and concrete will be put in place in that sequence from June 18th to July 15th. Following that, the same sequence will be done for walls, then the roof of the tank, which will be complete at the end of August, once QA/QC has been done and the site engineer is satisfied everything has been done as per the drawings. The waterproof membrane and access hatches will be installed and the ground will be level complete construction in this area.

5.3 Piping

Installation of the pipe connection from Junction A to the reservoir will begin in mid-June and will end in mid-July, coinciding with the installation of the wall formwork for the reservoir. Installation of the pipe connections from the reservoir to the main water distribution system will begin in mid-August. Piping installation will involve staking, excavation, lay-down of the pipe, and system tie-in, followed by backfilling and repaving.

5.4 Project Schedule

A simplified project schedule that identifies key milestones can be found in Figure 5 below. The detailed project schedule is included in Appendix VI – Project Schedule.

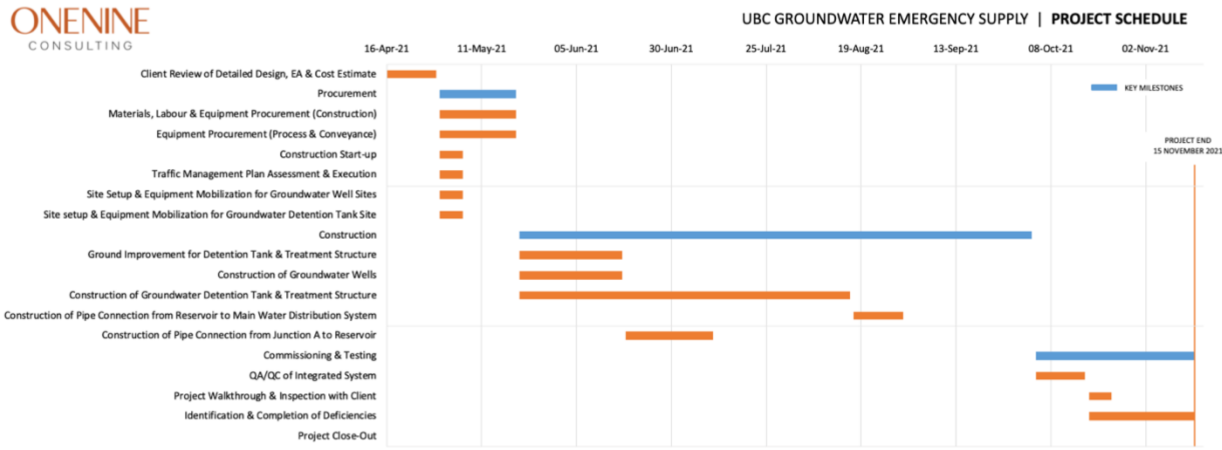


Figure 5: Simplified Project Schedule

5.5 Anticipated Issues

As with any major construction project, there is an expectation that a variety of issues might occur. There is still a degree of uncertainty of the quality of the soil at the site that will not be resolved until excavation occurs and further testing can be done. The quality of the water brings up the same concern. The sub-consultants have already started on the design of the water treatment facilities and storage tank, and are expected to completed in time prior to procurement. There is a risk that they will not be completed in time, which would delay construction.

At any stage in construction there might be delays due to unexpected conditions or lack of resources, but as long as it does not occur with tasks in the critical path, significant delays can be avoided. As the site is located on campus, issues will occur if significant construction is still occurring once school starts again in-person in September. The schedule is designed so that the bulk of construction occurs before then, but delays might affect that. The number of people on campus will increase significantly as well as the demands on the roads and walking paths, so more effort will be needed to keep the public away from the site.

6 Project Cost Estimate

Within the design scope of the UBC Emergency Groundwater Project, the team of design engineers has prepared a Class A cost estimate for the design, construction, and commissioning of the proposed works. Careful consideration was undertaken to ensure accurate quantities and unit prices were utilized to calculate cost. The principal guiding document for the project cost estimate was RSMeans cost data. Further, industry professionals were contacted to provide more accurate unit prices for numerous scopes. The total cost for the project, as calculated by the team, is estimated to be $9,071,457.61. The provided price includes the cost of supply and installation of all project components, public consultation, permitting, mobilization and demobilization, quality control testing, system commissioning, indirect costs, contingency, and engineering design fees. Significant cost of $2.7M is attributed to the construction activities proposed for the storage tank, which is considered expected by the design team given the large scope. Other significant scopes include well construction at $784,000 and water treatment facility at $635,500. A complete copy of the project cost report can be viewed in Appendix VII – Cost Estimate.

Appendices

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Appendix II – Calculations

Peaking Factor: $f_d = 3.9 (P^{-0.0752})$

Where P = population

Per Capita Method (to estimate future water demand): $P = P_0 * e^{rt}$

P = population after time t (in years)

P_0 = initial population

r = % rate of growth

t = time (years)

Population Breakdown

Category	P_0	Data Year	Design Year	t	r	P
Students	55,990	2020	2041	21	0.0200	75,000
Staff	10,736	2020	2041	21	0.0200	16,340
Faculty	5,711	2020	2041	21	0.0200	8,692
UEL	15,890	2016	2041	25	0.0200	26,198
West-Point Grey	13,065	2016	2041	25	0.0133	18,218
Dunbar Southlands	21,425	2016	2041	25	0.0133	29,876
Total	122,817					174,324

Water Demand Calculations

Peaking Factor (f_d):	1.62			
Average Water Demand:	50	L/per capita day		
Future Peaking Factor (f_d):	1.57			
Anticipated Future ADD:	8,716,223	L/day	8,716	m^3/day
Anticipated Future MDD:	13,716,484	L/day	13,716	m^3/day
Flow Required:	158.7555988	L/s	572	m^3/h
Flow per Well:	19.84444985	L/s	71.4	m^3/h
Tank Required Capacity:	5143.68	m^3		

Summary of Head Loss Calculations (using Hazen-Williams Equation)

CIVL 446 | Emergency Groundwater Supply
Pump Booster Station to UBC Tie-in

High Head		
Pumps Operating	4	
Flow	160.0	L/s
Discharge HGL=	87.50	m
Suction HGL=	65.00	m
Hazen-Williams C Value	140.00	
I.D. mm	390.00	

Flow in L/s, head in m

		No. of Pumps			
	26.01	1	2	3	4
Flow (L/s)	0	23	23	23	23
	20	23	23	23	23
	40	23	23	23	23
	60	23	23	23	23
	80	24	23	23	23
	100	24	23	23	23
	120	25	23	23	23
	140	25	23	23	23
	160	26	23	23	23
	180	27	24	23	23
	200	28	24	23	23
	200	28	24	23	23
	200	28	24	23	23
	200	28	24	23	23
	200	28	24	23	23
	200	28	24	23	23
	200	28	24	23	23

Element	Dia (nom) in	I.D. mm	Total Flow L/s	Flow in Element L/s	Length m	"C"	"K"	"CV"	Velocity m/s	Delta H m
Pump Station Exit			160	160.00						
90 degree bend		390	160	160.00			0.60		1.34	0.0548598
PC 235 (DR18) PVC Pipe		390	160	160.00	0.5	140			1.34	0.0018615
Swing check valve		390	160	160.00				4600	1.34	0.2136673
Gate valve		390	160	160.00			0.30		1.34	0.0274299
PC 235 (DR18) PVC Pipe		390	160	160.00	5.0	140			1.34	0.0186149
90 degree bend		390	160	160.00			0.60		1.34	0.0548598
PC 235 (DR18) PVC Pipe		390	160	160.00	13.0	140			1.34	0.0483987
90 degree bend		390	160	160.00			0.60		1.34	0.0548598
PC 235 (DR18) PVC Pipe		390	160	160.00	57.3	140			1.34	0.2133268
90 degree bend		390	160	160.00			0.60		1.34	0.0548598
PC 235 (DR18) PVC Pipe		390	160	160.00	28.5	140			1.34	0.1059560
90 degree bend		390	160	160.00			0.60		1.34	0.0548598
PC 235 (DR18) PVC Pipe		390	160	160.00	8.7	140			1.34	0.0323899
45 degree bend		390	160	160.00			0.20		1.34	0.0182866
PC 235 (DR18) PVC Pipe		390	160	160.00	10.6	140			1.34	0.0394636
45 degree bend		390	160	160.00			0.20		1.34	0.0182866
PC 235 (DR18) PVC Pipe		390	160	160.00	365.61	140			1.34	1.3611589
90 degree bend		390	160	160.00			0.60		1.34	0.0548598
PC 235 (DR18) PVC Pipe		390	160	160.00	91.8	140			1.34	0.3417696
45 degree bend		390	160	160.00			0.20		1.34	0.0182866
PC 235 (DR18) PVC Pipe		390	160	160.00	8.0	140			1.34	0.0297838
45 degree bend		390	160	160.00			0.20		1.34	0.0182866
PC 235 (DR18) PVC Pipe		390	160	160.00	30.0	140			1.34	0.1116894
90 degree bend		390	160	160.00			0.60		1.34	0.0548598
PC 235 (DR18) PVC Pipe		390	160	160.00	15.4	140			1.34	0.0573339
90 degree bend		390	160	160.00			0.60		1.34	0.0548598
PC 235 (DR18) PVC Pipe		390	160	160.00	8.6	140			1.34	0.0320176
Minor Losses		390	160	160.00			3		1.34	0.2742989
Exit		390	160	160.00			1.00		1.34	0.0914330
Total Head Losses (m)										**3.51**
Static Head										22.50
Total Dynamic Head (m)										26

Sample Calculations for Head Loss in Pipe:

$$H = \frac{10.583\ LQ^{1.85}}{C^{1.85}D^{4.87}}$$

Where:
H = Headloss (m)
L = Length of pipe (m)
Q = Flow in pipe (m^3/s)
C = Hazen-Williams roughness coefficient; C = 140 for smooth PVC pipes
D = Internal diameter of pipe (m)

Given:
L = 365.61 m
Q = 160 L/s = 0.160 m^3/s
C = 140
D = 390 mm = 0.390 m

$$H = \frac{10.583\ \times (365.61\ m) \times (0.160\ \frac{m^3}{s})^{1.85}}{140^{1.85} \times (0.390\ m)^{4.87}} = 1.36\ m$$

Sample Calculation for Head Loss in Fitting:

$$H = K\frac{v^2}{2g}$$

Where:
K = Minor losses coefficient (unitless)
v = Velocity in pipe (m/s)
g = Gravitational constant

Given:
K = 0.60 (for a 90-degree bend)
C = 140
D = 390 mm = 0.390 m
$v = \frac{Q}{A} = \frac{0.16\ m^3}{0.119\ m} = 1.34\ \frac{m}{s}$

$$H = K\frac{v^2}{2g} = 0.60 \times \frac{(1.34\ \frac{m}{s})^2}{2 \times (9.8\ \frac{m}{s^2})} = 0.549\ m$$

Sample thrust block calculation:

$$A_T = \frac{2Pasin\left(\frac{\theta}{2}\right)}{q_{all}} = \frac{2(90psi)asin\left(\frac{90°}{2}\right)}{70\ kpa} = 1.1\ m^2$$

Given		
k = Hydraulic Conductivity	8.10E-05	m/s
θ = Porosity	0.42	
L = Lower Aquifer Thickness	9	m
α = Water Compressibility (from Freeze & Cherry, 1979)	4.4E-10	m^2/N
β = Aquifer Compressibility	0.000000001	m^2/N
p = Density of Water	1000	kg/m^3
g = Gravity	9.81	m/s^2
Calculated		
Q = flow (based on water demand)	74.2	m^3/h
	2.06E-02	m^3/s
T = Aquifer Transmissivity = L*k	7.29E-04	m^2/s
S = Specific Storage = pg(α + θβ)	8.44E-06	m^-1
A = Aquifer Storativity = S*L	7.59E-05	
t = Time After Pumping Starts	1.32E+06	s
u = Non-Dimensional Parameter = (Sr^2)/(4Tt)	1.81286E-05	
s(r,t) = Drawdown = (Q/(4Tπ))*(LN(1/u)-0.5772)	23.3	m
r= Radius Away From the Well	90.8	m

Sample Calculations for Mat Foundation:

Geometric & Weight Calculations		
Depth of the Foundation Base (Df)	5.00	m
Concrete Wall Area Parallel to NW Marine Drive	255	m^2
Concrete Wall Thickness	0.50	m
Concrete Slab Thickness	1.00	m
Concrete Wall Area Perpendicuar to NW Marine Drive	75.0	m^2
Concrete Cover/ Floor Area	1020	m^2
Total Concrete Volume	2350	m^3
Concrete Weight (assume concrete density = 23.5kg/m^3)	55200	kN
Concrete Weight Transferred to Base (99% cuz of rebar)	54.1	kPa
Rebar Volume (assume 1% of total concrete self-weight)	13.5	m^3
Rebar Weight (assuming rebar density of 77kg/m^3)	1040	kN
Rebar Weight Transferred to Base	1.02	kPa

Structural Loads		
Live Load From Parking Lot Vehicles	2.40	kPa
Hydraulic Volume (assuming a full tank of water)	4750	m^3
Hydraulic Weight (assuming a water density of 9.81kg/m^3)	46600	kN
Hydraulic Live Load (water weight in tank is not constant)	45.7	kPa
Total Load = 1.25D+1.5L	141	kPa
γ*Df = Overburden Pressure	99.7	kPa
po = Total Effective Load	41.4	

Soil Bearing Capacity			
qo' = Overburden Pressure	240.8	kPa	**** Values different from word doc since tank is close to TH01
Nq=Bearing Capacity Factor	20.63		**** Assumed a weighted average of 31 degree of
sc = Shape Factor			
sq = Shape Factor	1.24		**** Excel converts TAN to radians automatically, so I calculated by hand
sγ = Shape Factor	0.84		
Nγ = Bearing Capacity Factor	26.0		
L = Foundation Length	52.0		
B = Foundation Width	21.0		
dc = Depth Factor			
dq = Depth Factor	1.07		
dγ = Depth Factor	1.00		
Nc = Bearing Capacity Factor			**** cohesion was zero
qu = Bearing Resistance	7500	kPa	
qu > po?	YES		

UBC GROUNDWATER EMERGENCY SUPPLY SYSTEM

1. ELEVATIONS REFER TO SEA LEVEL DATUM.

2. CONDUIT GRADE ON PROFILE IS APPROXIMATE ONLY. FINISHED GRADE WILL BE SUBJECT TO LOCATION OF EXISTING UNDERGROUND UTILITIES.

3. MINIMUM COVER CONDUIT 0.61 m ALL SECTIONS EXCEPT WHERE OTHERWISE NOTED. MANHOLE ROOF 0.46 m.

4. ALL DUCTS TO BE HDPE (ORANGE) UNLESS OTHERWISE NOTED.

5. ALL MANUFACTURED BENDS TO BE 0.91 m RADIUS UNLESS OTHERWISE NOTED.

6. MAINTAIN A MINIMUM CONDUIT COVER 1.0 m WHEN WORKING UNDER ROADS.

7. CONTRACTOR IS TO PROVE THE LOCATIONS OF ALL EXISTING UNDERGROUND UTILITIES AND SERVICES AFFECTED BY CONSTRUCTION BY M-SCOPE OR HAND EXCAVATION.

8. FOR CABLE TROUBLE OR REPAIR INFORMATION, CONTACT TELUS LOCAL NETWORK DISTRICT MANAGER.

9. TEMPORARY/PERMANENT RESTORATION IN ALL PAVED/SIDEWALK AREAS TO BE DONE IN ACCORDANCE WITH ALL APPROVING AUTHORITIES SPECIFICATIONS AND APPROVAL.

10. PERMANENT SIDEWALK AND CURB REPAIRS TO BE DONE BY CONTRACTOR. PERMANENT ROAD REPAIRS TO BE DONE BY CONTRACTOR.

11. PERMANENT BOULEVARD RESTORATION TO BE DONE BY CONTRACTOR.

12. ALL LANDSCAPE RESTORATION IN LAWN BOULEVARDS MUST BE DONE BY USING SUITABLE GRASS SOD.

13. CONTRACTOR TO CONTACT THE APPROPRIATE GAS COMPANY RECORDS DEPARTMENT 24 HOURS PRIOR TO STARTING WORK.

14. CONTRACTOR TO CONTACT THE CITY/MUNICIPAL WORKS INSPECTOR 48 HOURS PRIOR TO STARTING WORK.

15. CONTRACTOR TO CALL BC ONE CALL 48 HOURS PRIOR TO DIGGING.

16. ALL BACKFILL MATERIAL AND COMPACTION TO BE IN ACCORDANCE WITH ALL APPROVING AUTHORITIES SPECIFICATIONS.

17. ALL DIRECT BURIED SYSTEMS 2-WAY AND LARGER TO BE BUNDLED AND STRAPPED.

18. TELUS CONTRACTOR TO SUPPLY AND PLACE AN ENCLOSED PLYWOOD BOX OVER SAC PAD DUCTS AND SECURED TO FRAME.

19. BREAK OUT EXISTING CONCRETE ENCASED DUCTS: ANY JACK-HAMMERING OR USE OF POWER TOOLS TO BE CARRIED OUT BY CONTRACTOR. ALL HAND STRIPPING OF DUCTS, BREAKING OF DUCTS AND/OR HANDLING OF CABLES TO BE DONE BY TELUS FORCES.

20. EXISTING CONDUIT TO BE RELOCATED IF REQUIRED TO ENSURE SPECIFIED ENTRANCE LOCATIONS INTO MANHOLE/VAULT. CONTRACTOR TO PROVIDE EXCAVATION, BACK-FILLING AND RESTORATION IF RELOCATION BECOMES NECESSARY.

21. ORANGE TELUS MARKER TAPE TO BE PLACED ON CENTERLINE OF DUCT BANK @ 300mm BELOW FINAL GRADE.

22. CONTACT TELUS 10 DAYS BEFORE PROJECT START TO ARRANGE PICKUP LOCATION OF TELUS SUPPLIED MATERIAL.

23. SUBGRADE & DIRECT BURIED MATERIAL WHERE APPLICABLE SHALL BE 20mm MINUS CRUSHED AGGREGATE.

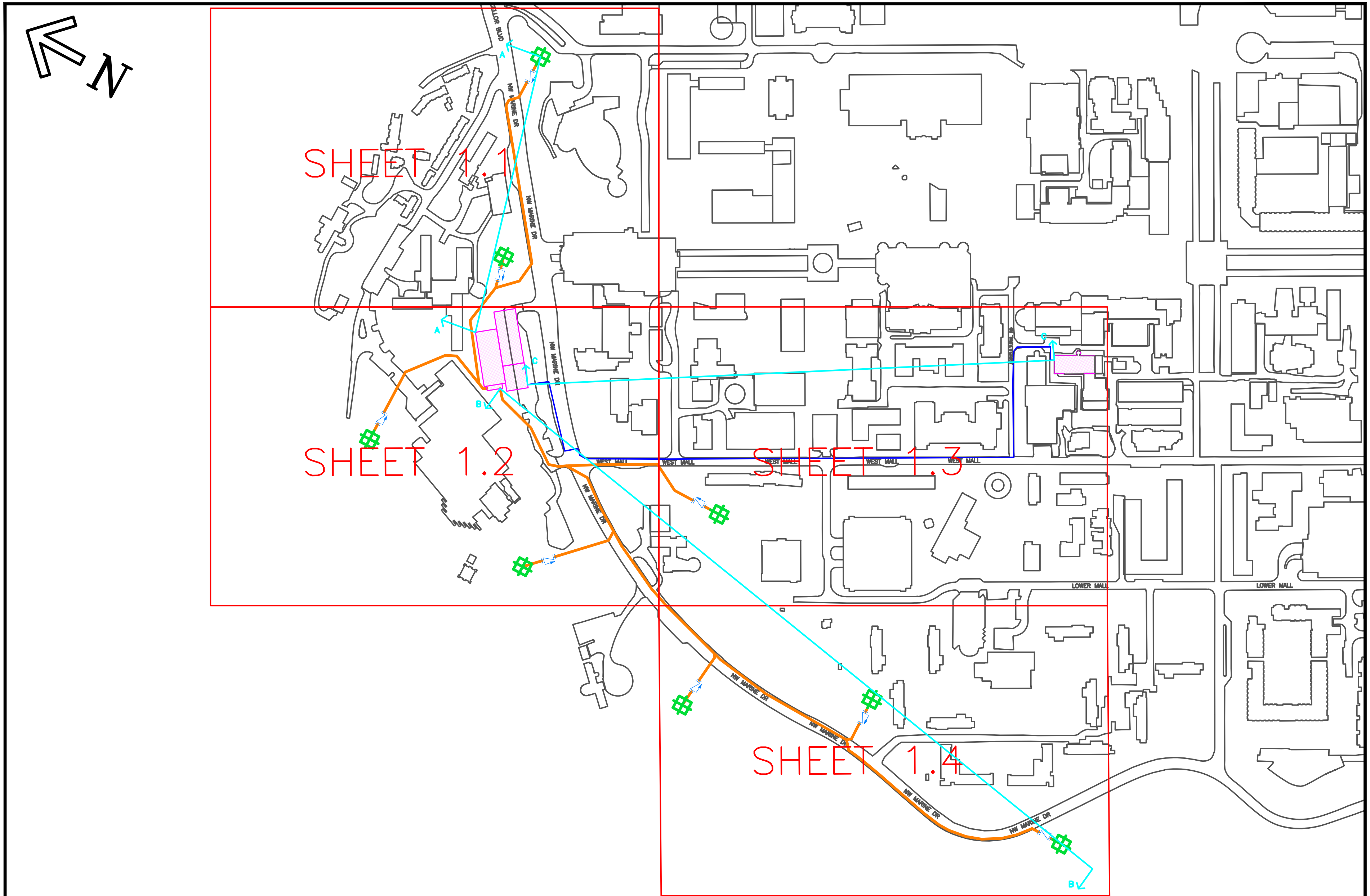
24. BACKFILL MATERIAL SHALL BE:
    IN ROADWAYS/TRAVELLED AREAS 20 mm

25. CONTRACTOR TO PULL IN A TELUS SUPPLIED MEASURING TAPE THRU ONE DUCT IN EACH RUN AFTER MANDRELLING, LOCATION TO BE DETERMINED BY TELUS.

26. MINIMUM SEPARATION FROM ALL UTILITIES TO BE 300mm.

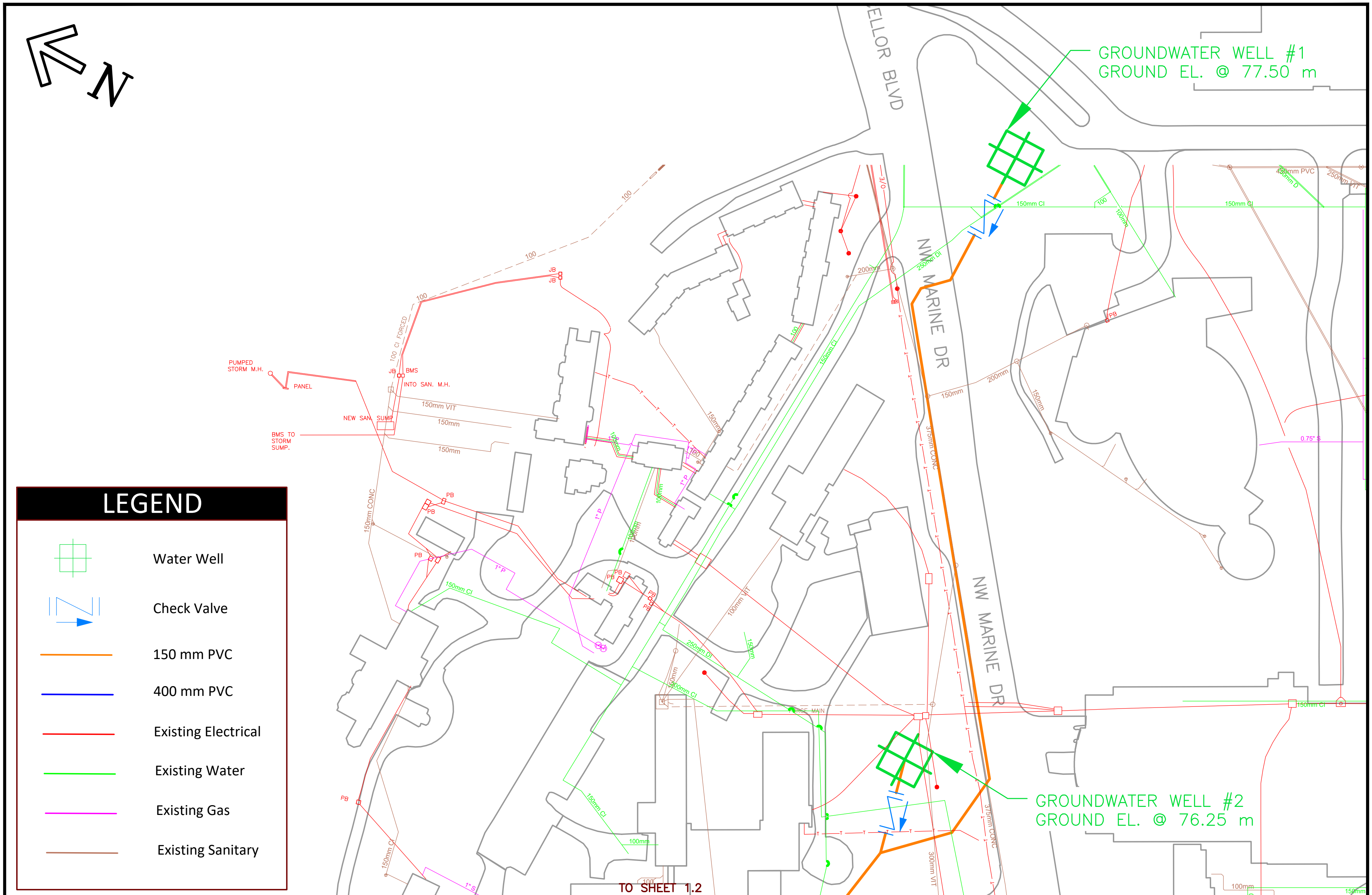
Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program				Title	GENERAL NOTES	
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus						
Project no.	-	Drawn OQ	Design OQ	Checked AL	Date April 16, 2021	Scale NTS	Drawing no. 0.1



Client	UBC SEEDS Sustainability Program
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus
Title	SITE LAYOUT
Project no.	-
Drawn	OQ
Design	OQ
Checked	AL
Date	April 16, 2020
Scale	NTS
Sheet	0.2

Notes:
1. All units in metres unless noted otherwise.

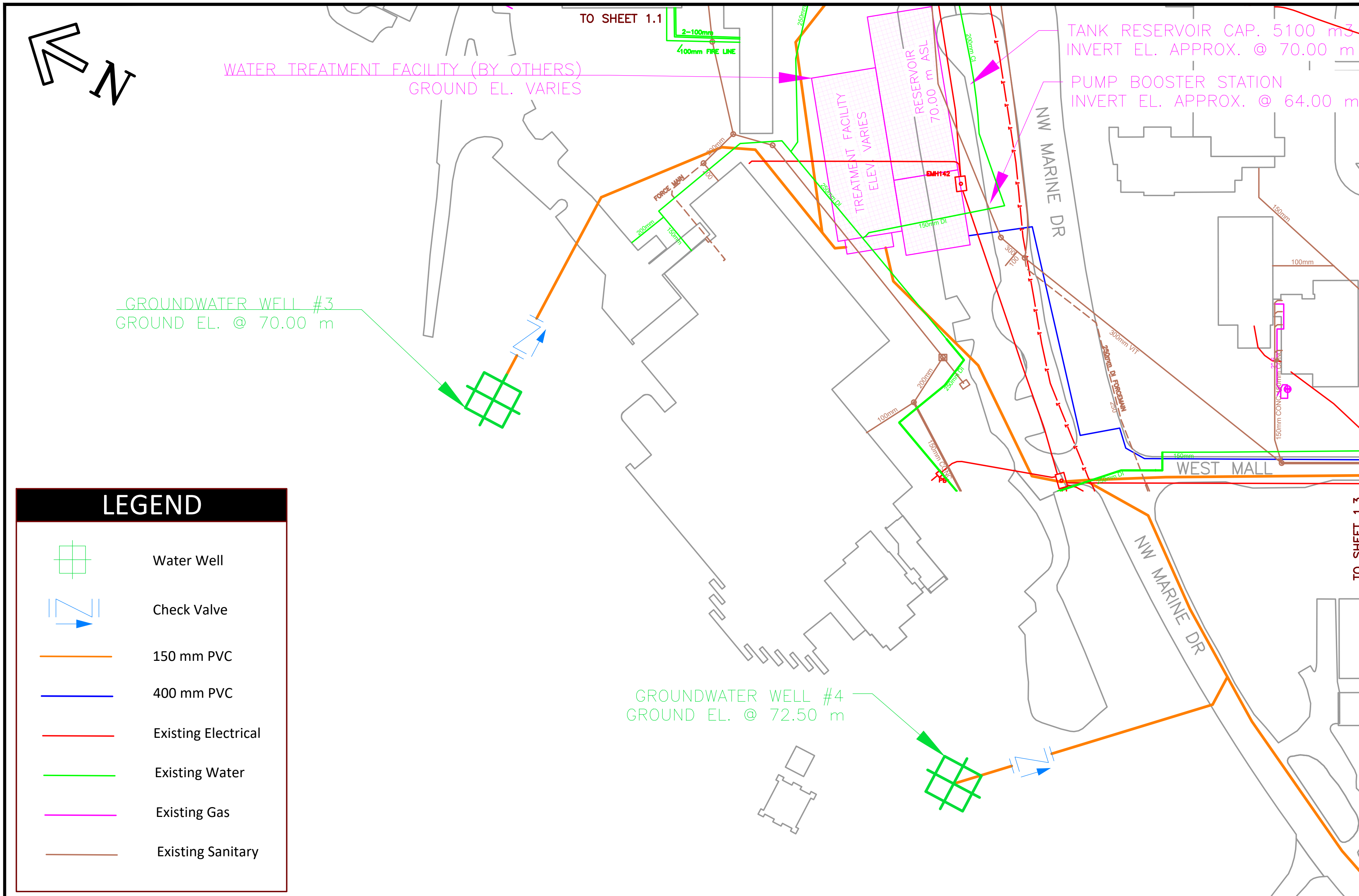


LEGEND

- Water Well
- Check Valve
- 150 mm PVC
- 400 mm PVC
- Existing Electrical
- Existing Water
- Existing Gas
- Existing Sanitary

Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus
Title	PLAN VIEW - NORTH
Project no.	-
Drawn	OQ
Design	OQ
Checked	AL
Date	April 16, 2020
Scale	1:10
Sheet	1.1

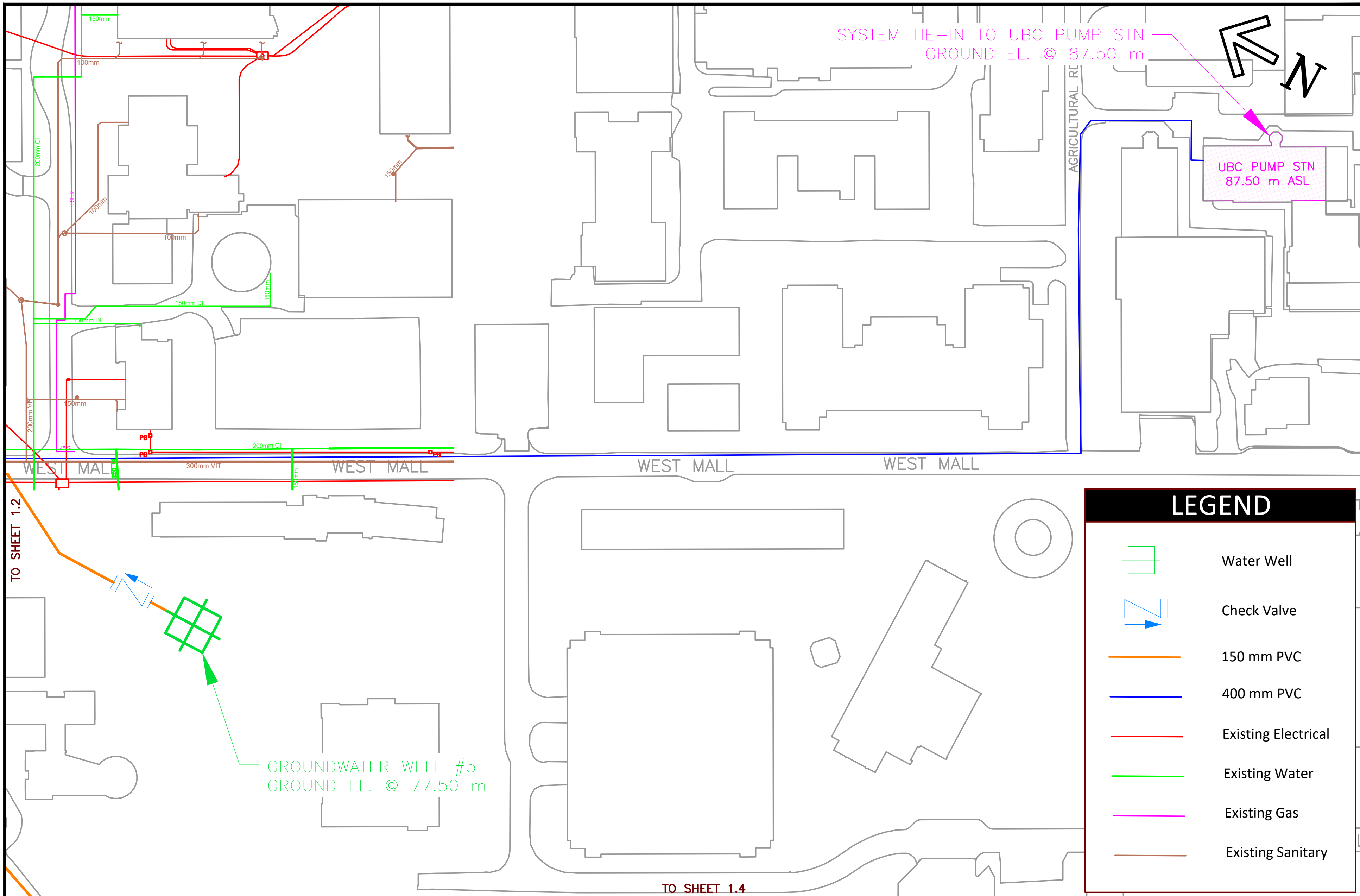


LEGEND

	Water Well
	Check Valve
	150 mm PVC
	400 mm PVC
	Existing Electrical
	Existing Water
	Existing Gas
	Existing Sanitary

Notes:
1. All units in metres unless noted otherwise.

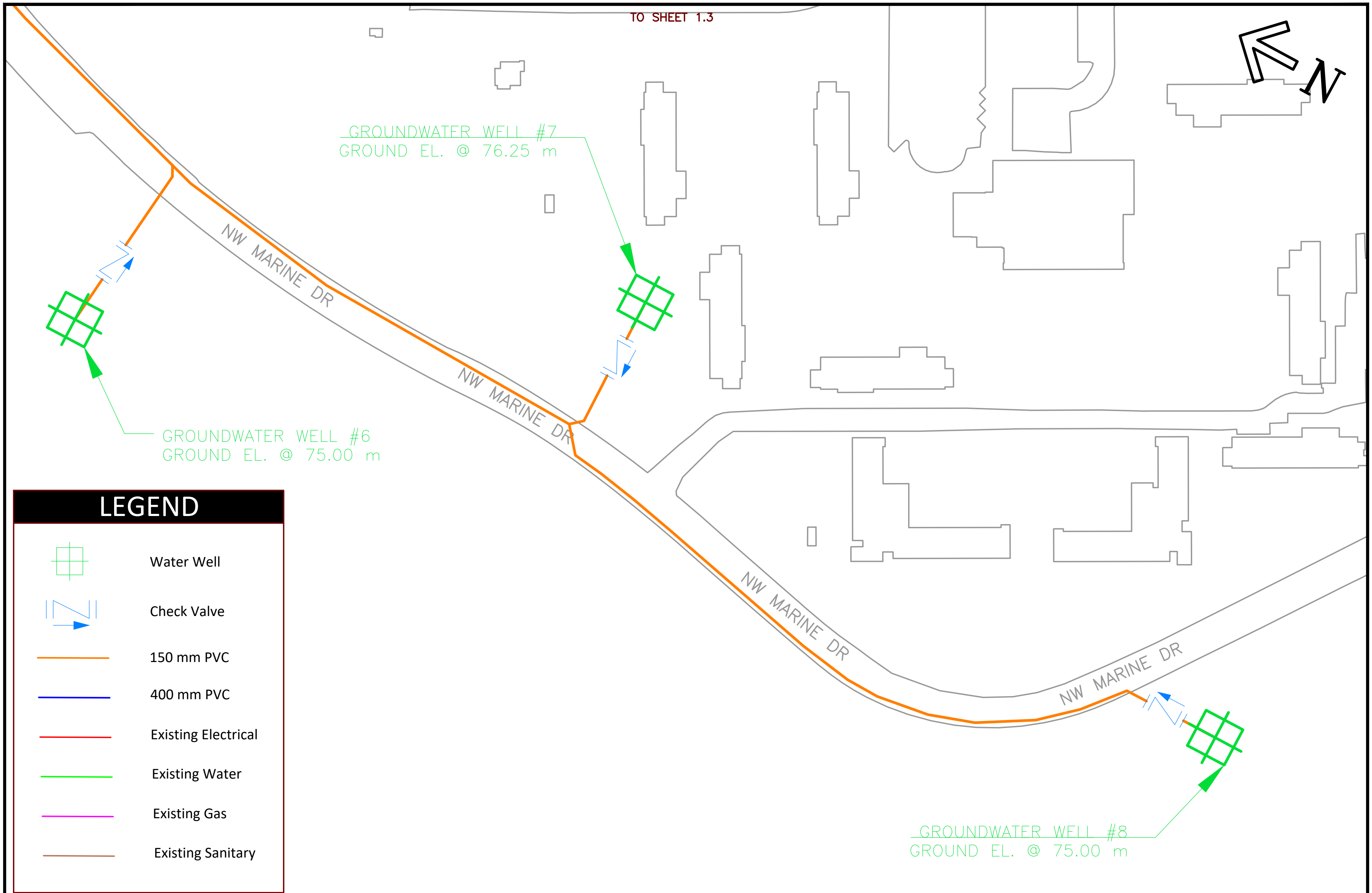
Client	UBC SEEDS Sustainability Program
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus
Title	PLAN VIEW - SOUTH WEST
Project no.	-
Drawn	OQ
Design	OQ
Checked	AL
Date	April 16, 2020
Scale	1:10
Sheet	1.2



Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus
Title	PLAN VIEW - SOUTH EAST

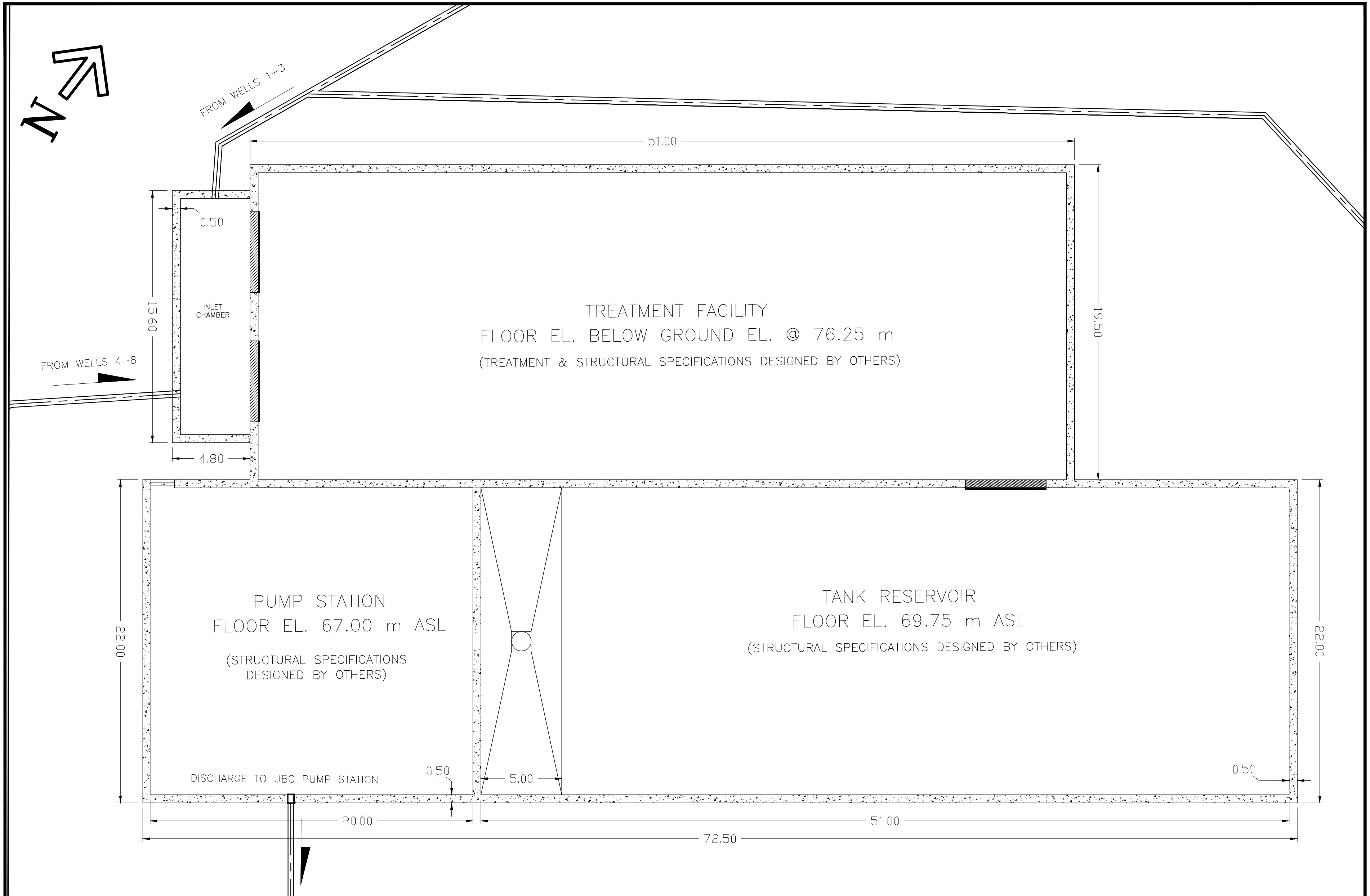
Project no.	Drawn	Design	Checked	Date	Scale	Sheet
-	OQ	OQ	AL	April 16, 2020	1:10	1.3



Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program			
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus			
Project no. -	Drawn OQ	Design OQ	Checked AL	

Title	PLAN VIEW - SOUTH	
Date April 16, 2020	Scale 1:10	Sheet 1.4



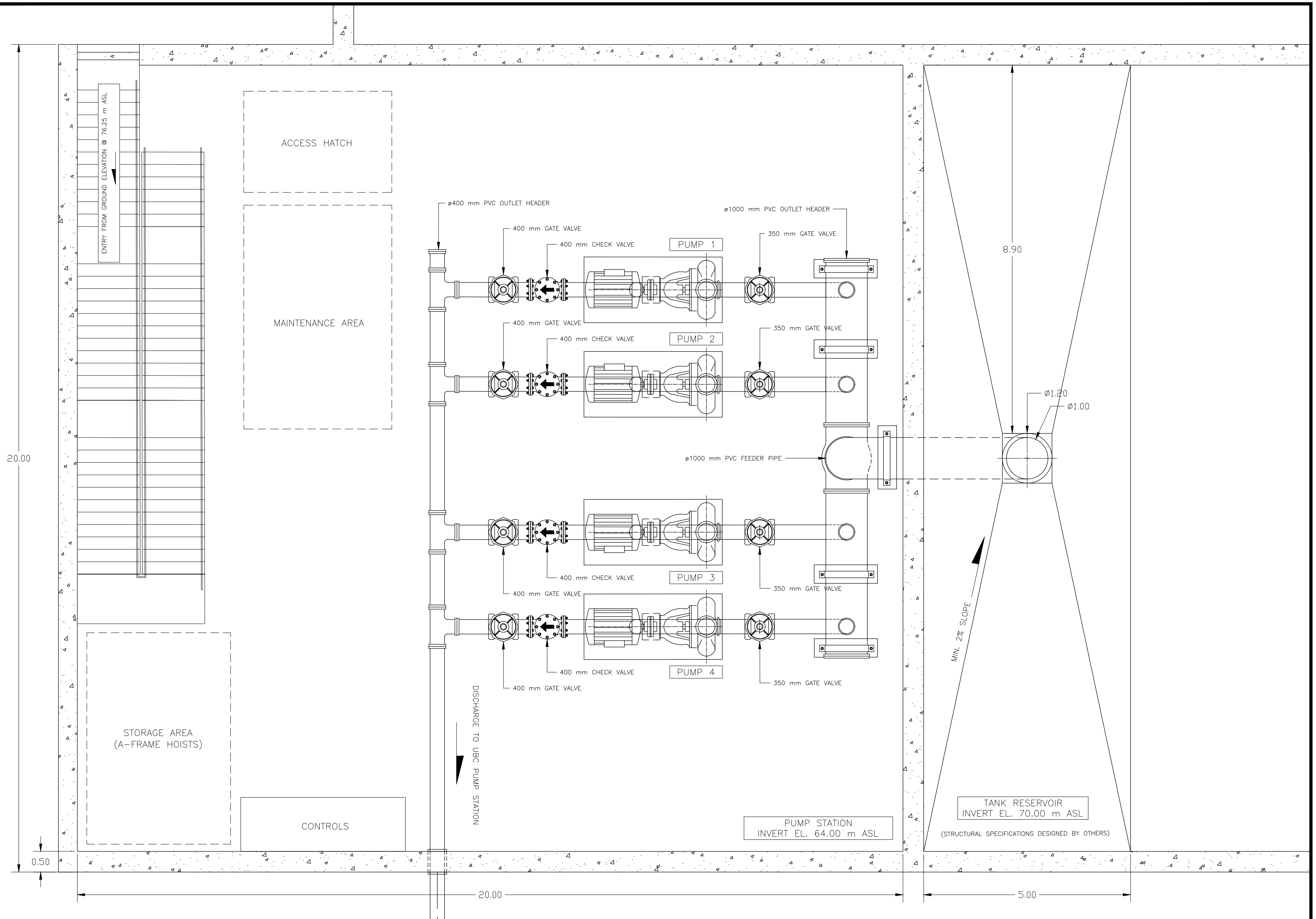
Notes:
1. All units in metres unless noted otherwise.

Client: UBC SEEDS Sustainability Program

Project: UBC Groundwater Emergency Water Supply
UBC Vancouver Campus

Title: STRUCTURES - GENERAL LAYOUT

Project no.	Drawn	Design	Checked	Date	Scale	Drawing no.
-	AL	AL	AM	April 16, 2021	NTS	1.5



Notes:
1. All units in metres unless noted otherwise.

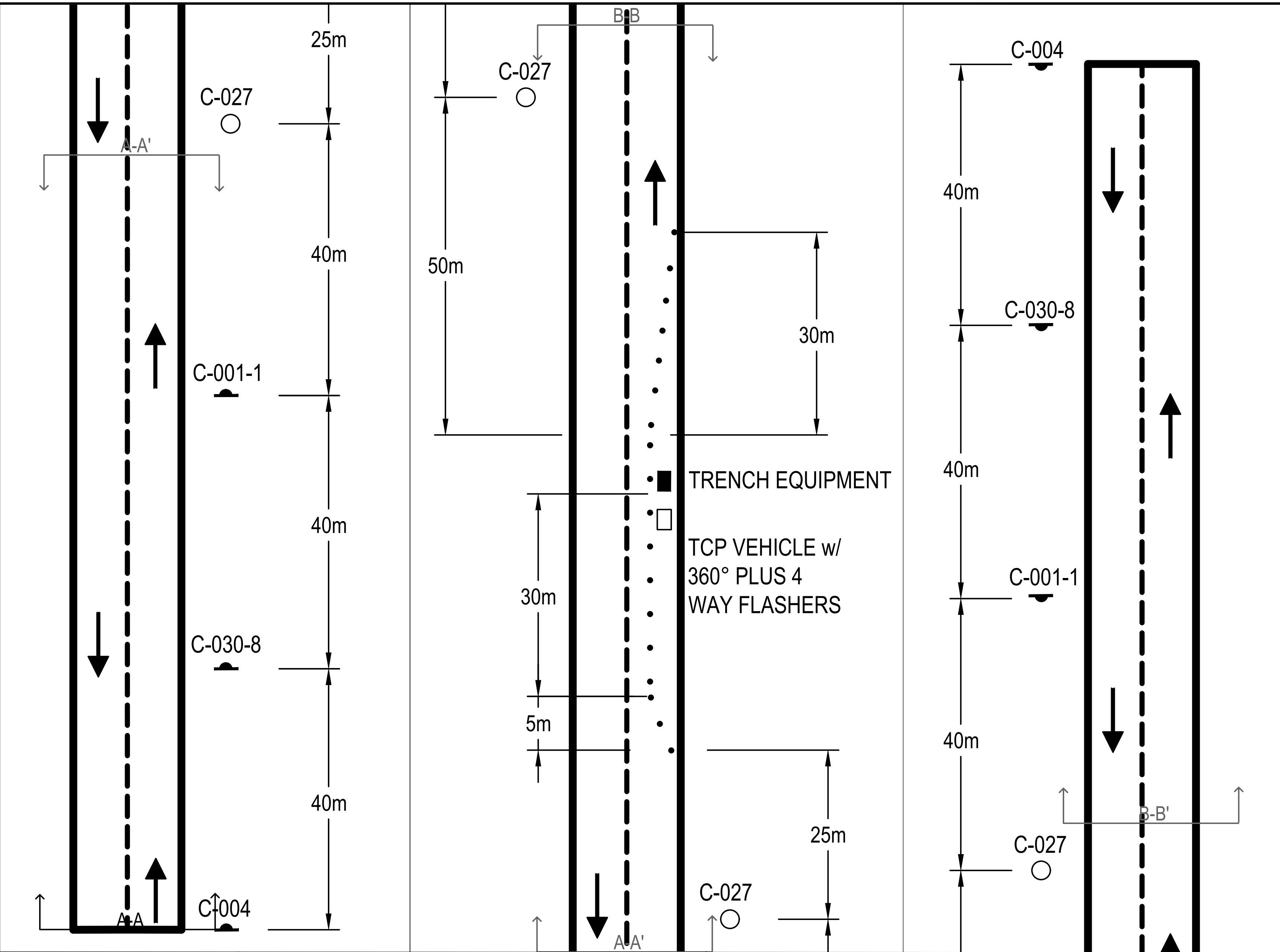
Client	UBC SEEDS Sustainability Program
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus
Title	PUMP STATION - PLAN VIEW
Project no.	-
Drawn	AL
Design	AL
Checked	AM
Date	April 16, 2021
Scale	NTS
Drawing no.	1.6

1. NEW WATERMAIN IS ON SB LANE
2. BUS STOPS NOT AFFECTED
3. DRIVEWAYS AND BIKE LANES TO REMAIN ACCESSIBLE
4. LENGTHS BETWEEN TRAFFIC SIGNS ARE FROM SECTION 17 OF BC TRAFFIC MANUAL

SPEED LIMIT 50 km/h

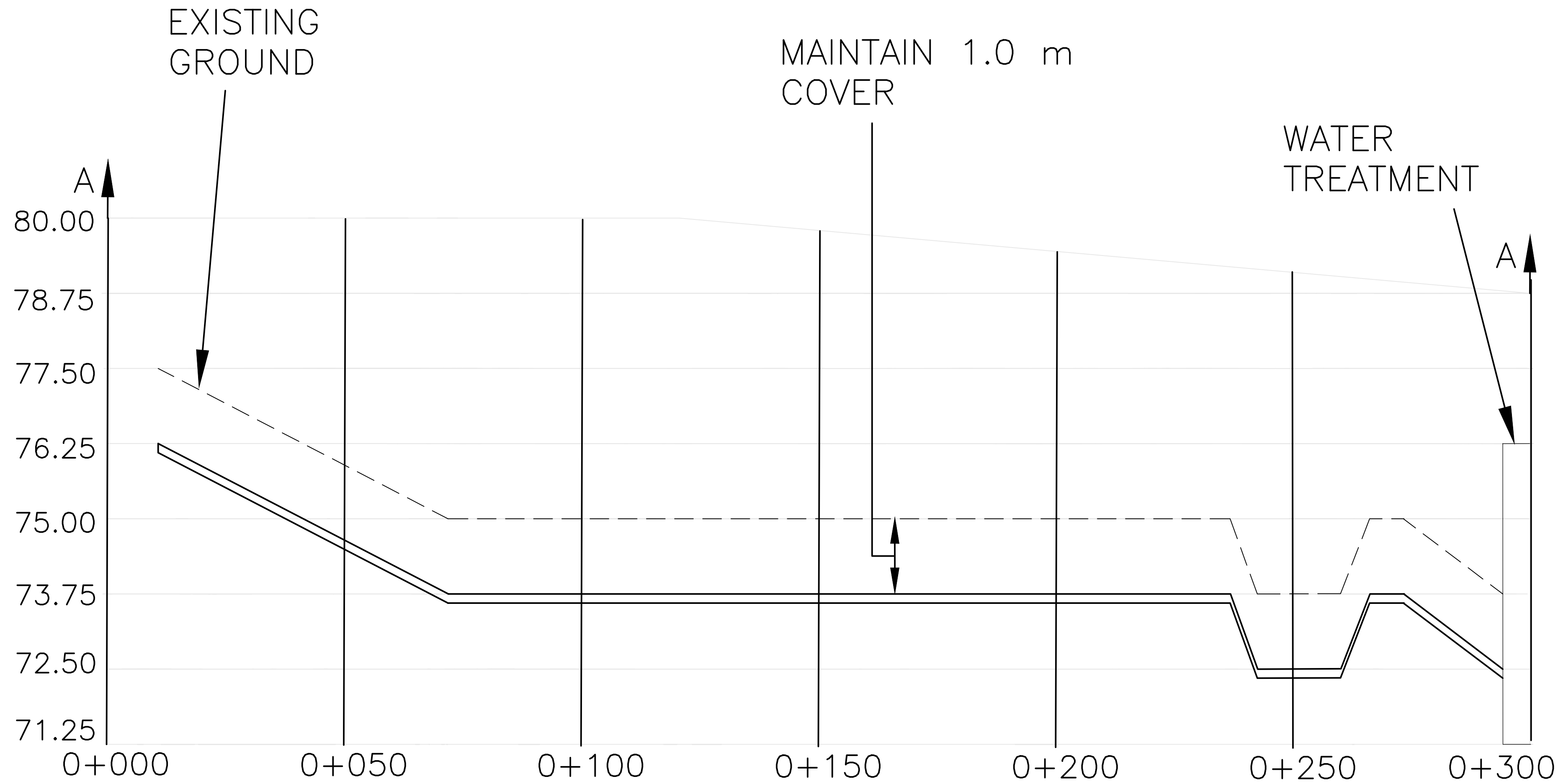
LEGEND

- • DELINEATORS
- ○ TCP
- C-001-1 TCP AHEAD
- C-030-8 SINGLE LANE TRAFFIC
- C-004 CREW WORKING AHEAD
- C-029 PREPARE TO STOP AHEAD



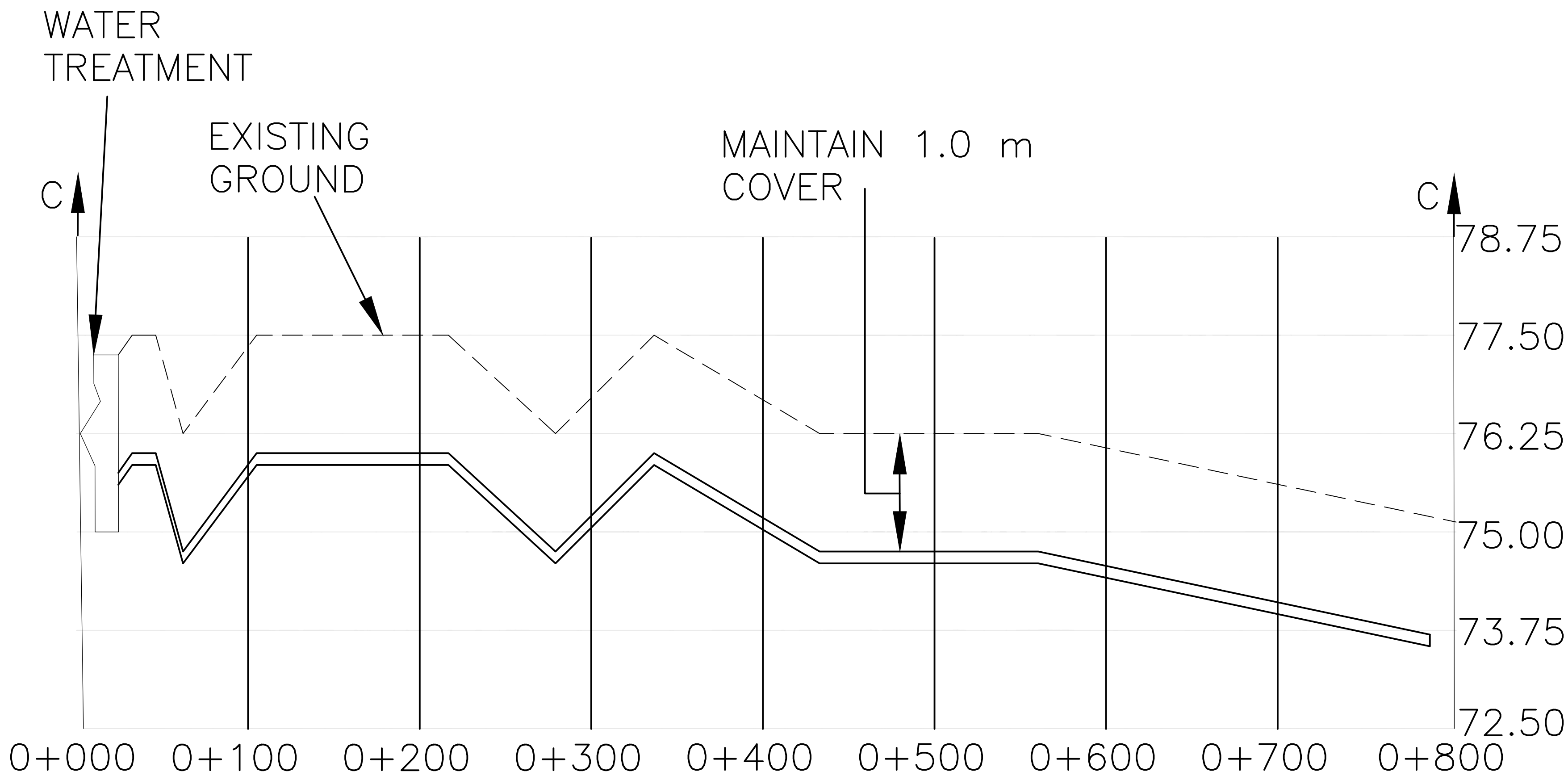
Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus
Title	TRAFFIC MANAGEMENT PLAN
Project no.	-
Drawn	SP
Design	SP
Checked	OQ
Date	April 16, 2021
Scale	1:1400
Drawing no.	1.7



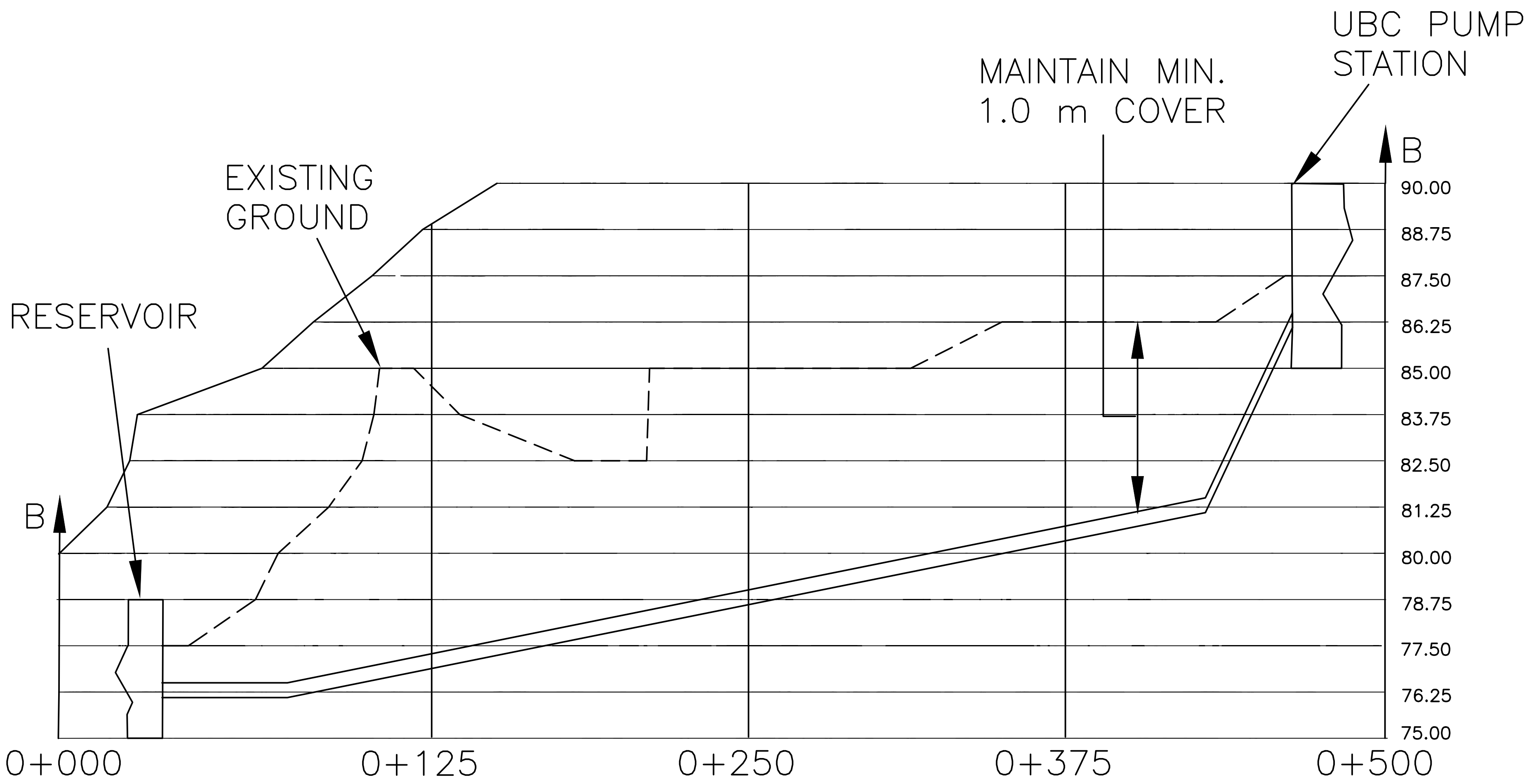
Notes:
1. All units in metres unless noted otherwise.

Client: UBC SEEDS Sustainability Program				Title: WELL 1 TO TREATMENT PROFILE
Project: UBC Groundwater Emergency Water Supply UBC Vancouver Campus				
Project no.: -	Drawn: OQ	Design: OQ	Checked: AL	Date: April 16, 2020 / Scale: NTS / Sheet: 2.1



Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program					
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus					
Title	TREATMENT TO WELL 8 PROFILE					
Project no.	Drawn	Design	Checked	Date	Scale	Sheet
-	OQ	OQ	AL	April 16, 2020	NTS	2.2



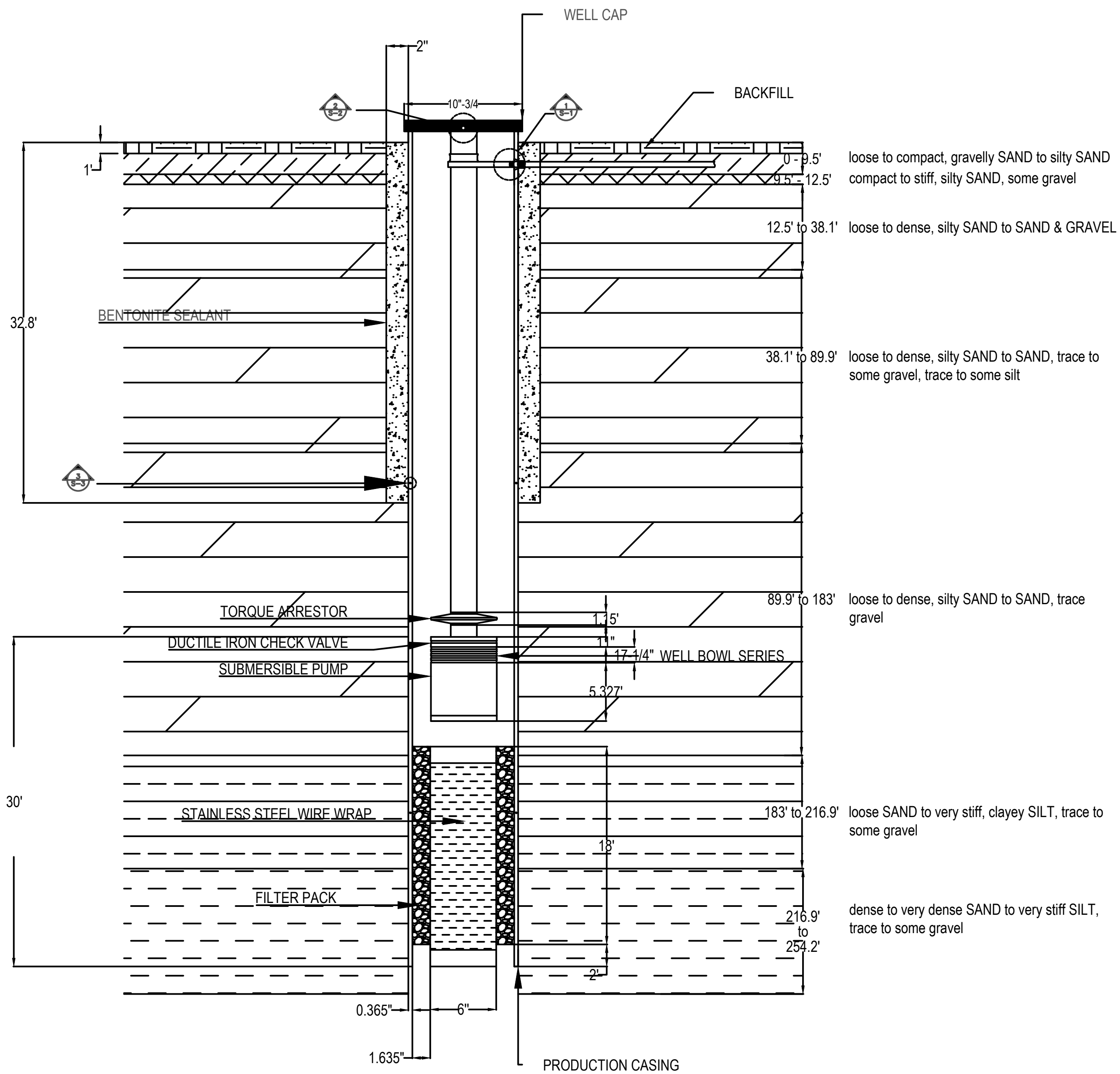
Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus
Title	RESERVOIR TO UBC PUMP STATION PROFILE
Project no.	-
Drawn	OQ
Design	OQ
Checked	AL
Date	April 16, 2020
Scale	NTS
Sheet	2.3

1. SEE SECTION S-1 FOR PITLESS ADAPTER DETAILS

2. SEE SECTION S-2 FOR PLAN VIEW

3. SEE SECTION S-3 FOR PIPE THREADED FLUSH-JOINT



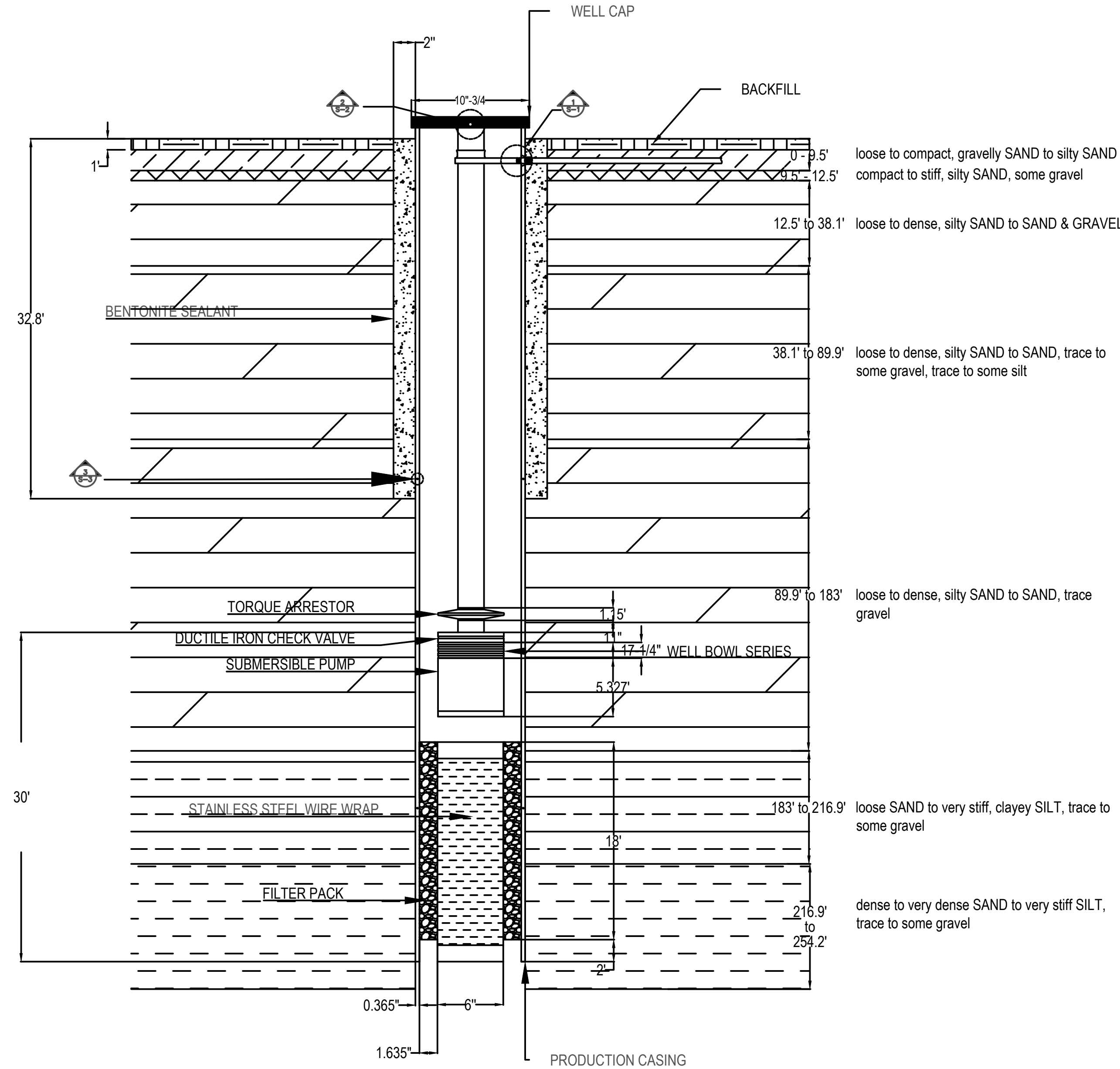
Notes: 1. All units in metres unless noted otherwise.	**Client** UBC SEEDS Sustainability Program				**Title** WELL #1 ELEVATION VIEW	
	Project UBC Groundwater Emergency Water Supply UBC Vancouver Campus					
	Project no.	**Drawn** SP	**Design** SP	**Checked** OQ	**Date** April 16, 2021	**Scale** NTS

Drawing no. 3.1

1. SEE SECTION S-1 FOR PITLESS ADAPTER DETAILS

2. SEE SECTION S-2 FOR PLAN VIEW

3. SEE SECTION S-3 FOR PIPE THREADED FLUSH-JOINT

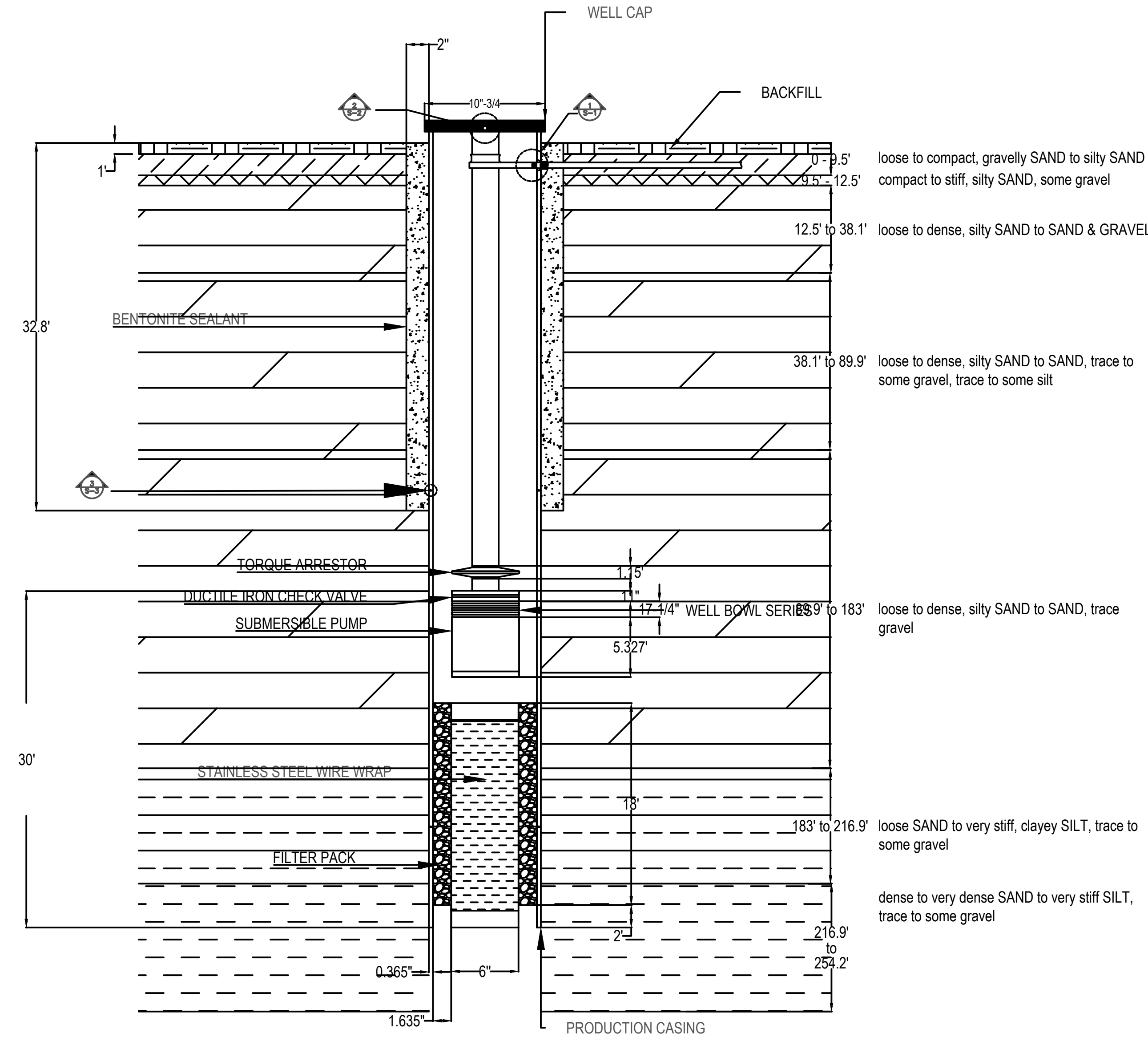


Notes: 1. All units in metres unless noted otherwise.	**Client** UBC SEEDS Sustainability Program			**Title** WELL #2 ELEVATION VIEW	
	Project UBC Groundwater Emergency Water Supply UBC Vancouver Campus				
	Project no.	**Drawn** SP	**Design** SP	**Checked** OQ	
	Date April 16, 2021	**Scale** NTS	**Drawing no.** 3.2		

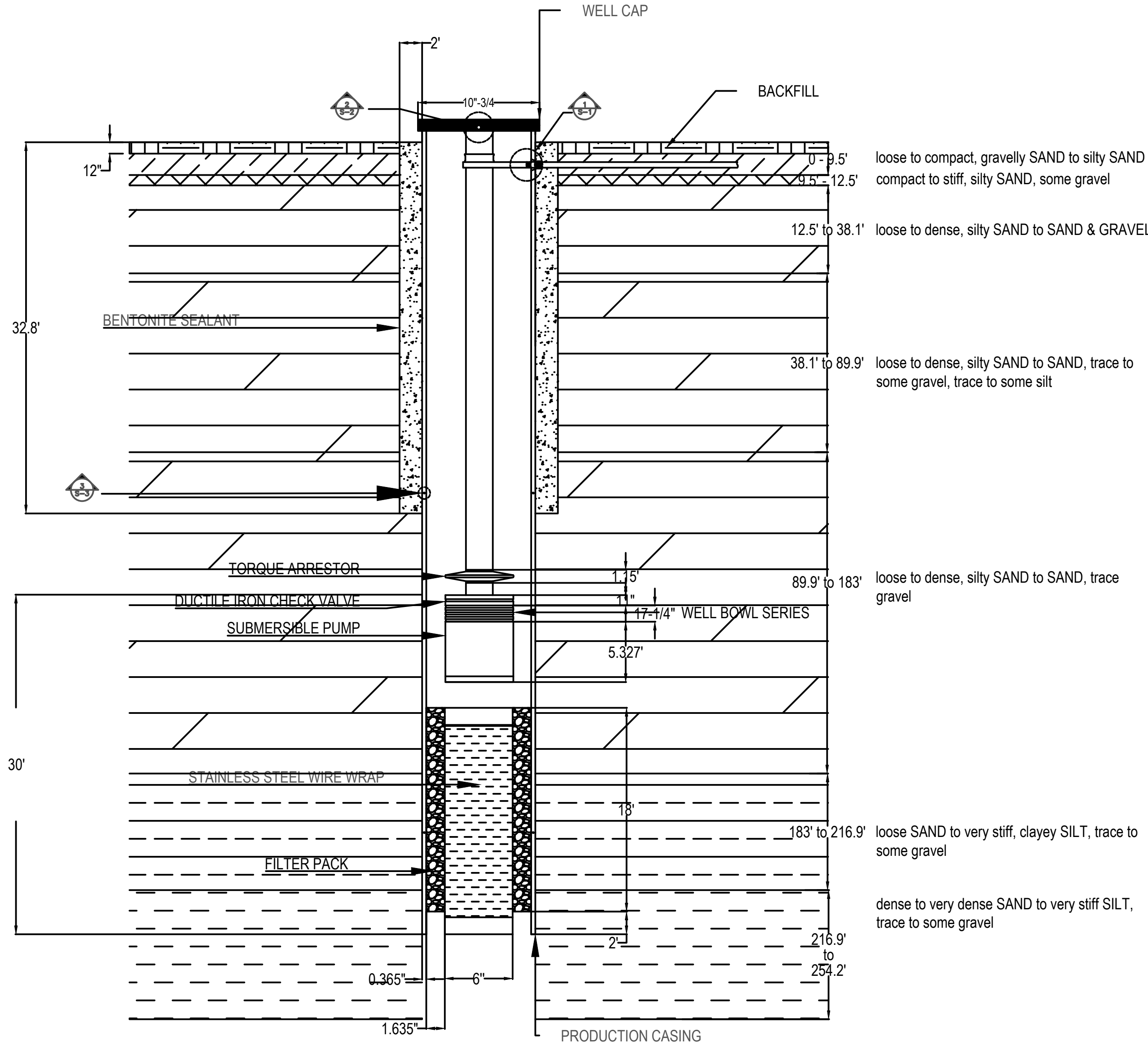
1. SEE SECTION S-1 FOR PITLESS ADAPTER DETAILS

2. SEE SECTION S-2 FOR PLAN VIEW

3. SEE SECTION S-3 FOR PIPE THREADED FLUSH-JOINT



Notes: 1. All units in metres unless noted otherwise.	Client: UBC SEEDS Sustainability Program				Title: WELL #3 ELEVATION VIEW			
	Project: UBC Groundwater Emergency Water Supply UBC Vancouver Campus							
	Project no.	Drawn: SP	Design: SP	Checked: OQ	Date: April 16, 2021	Scale: NTS	Drawing no.: 3.3	



1. SEE SECTION S-1 FOR PITLESS ADAPTER DETAILS

2. SEE SECTION S-2 FOR PLAN VIEW

3. SEE SECTION S-3 FOR PIPE THREADED FLUSH-JOINT

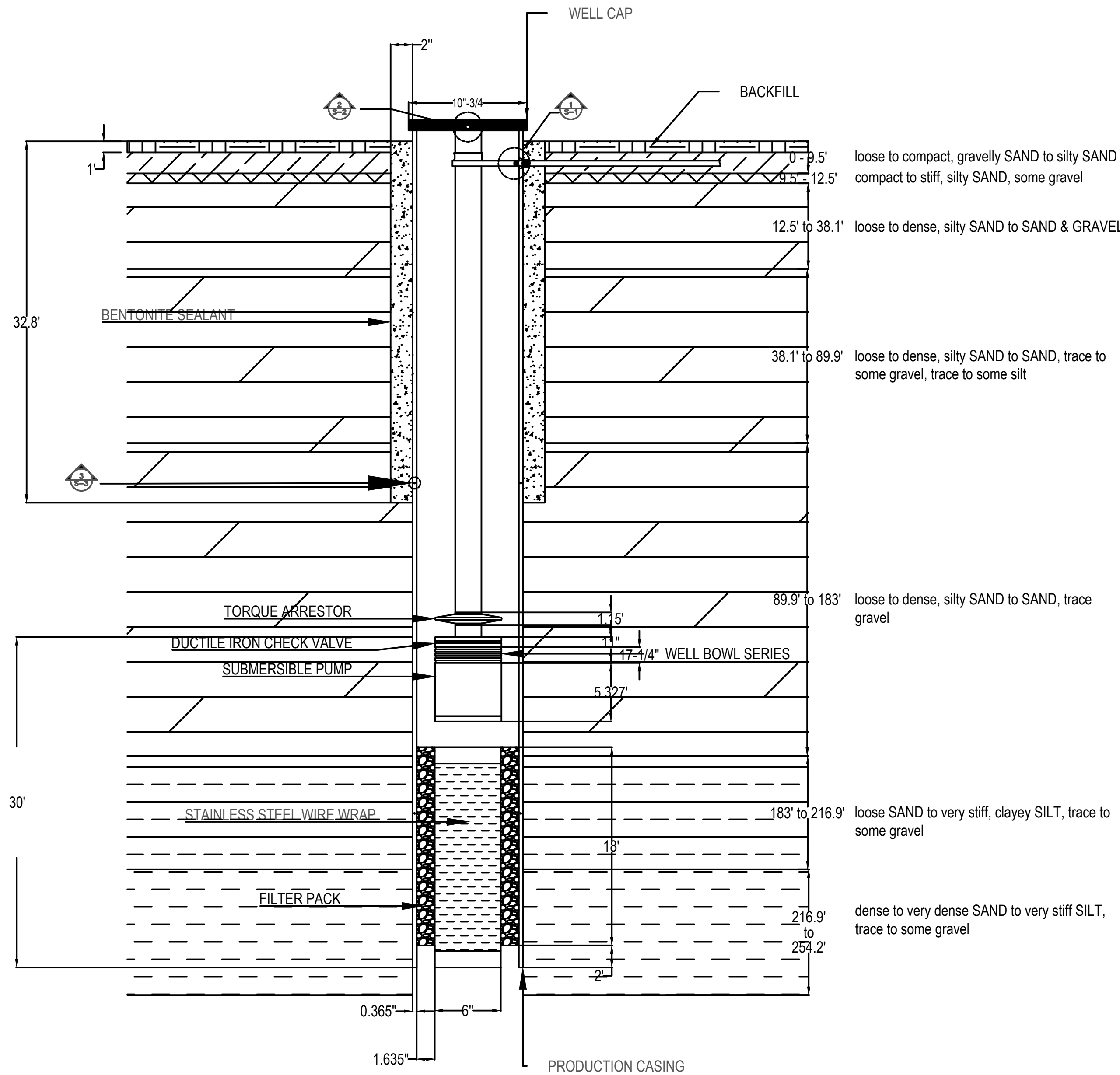
Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus
Title	WELL #4 ELEVATION VIEW
Project no.	
Drawn	SP
Design	SP
Checked	OQ
Date	April 16, 2021
Scale	NTS
Drawing no.	3.4

1. SEE SECTION S-1 FOR PITLESS ADAPTER DETAILS

2. SEE SECTION S-2 FOR PLAN VIEW

3. SEE SECTION S-3 FOR PIPE THREADED FLUSH-JOINT

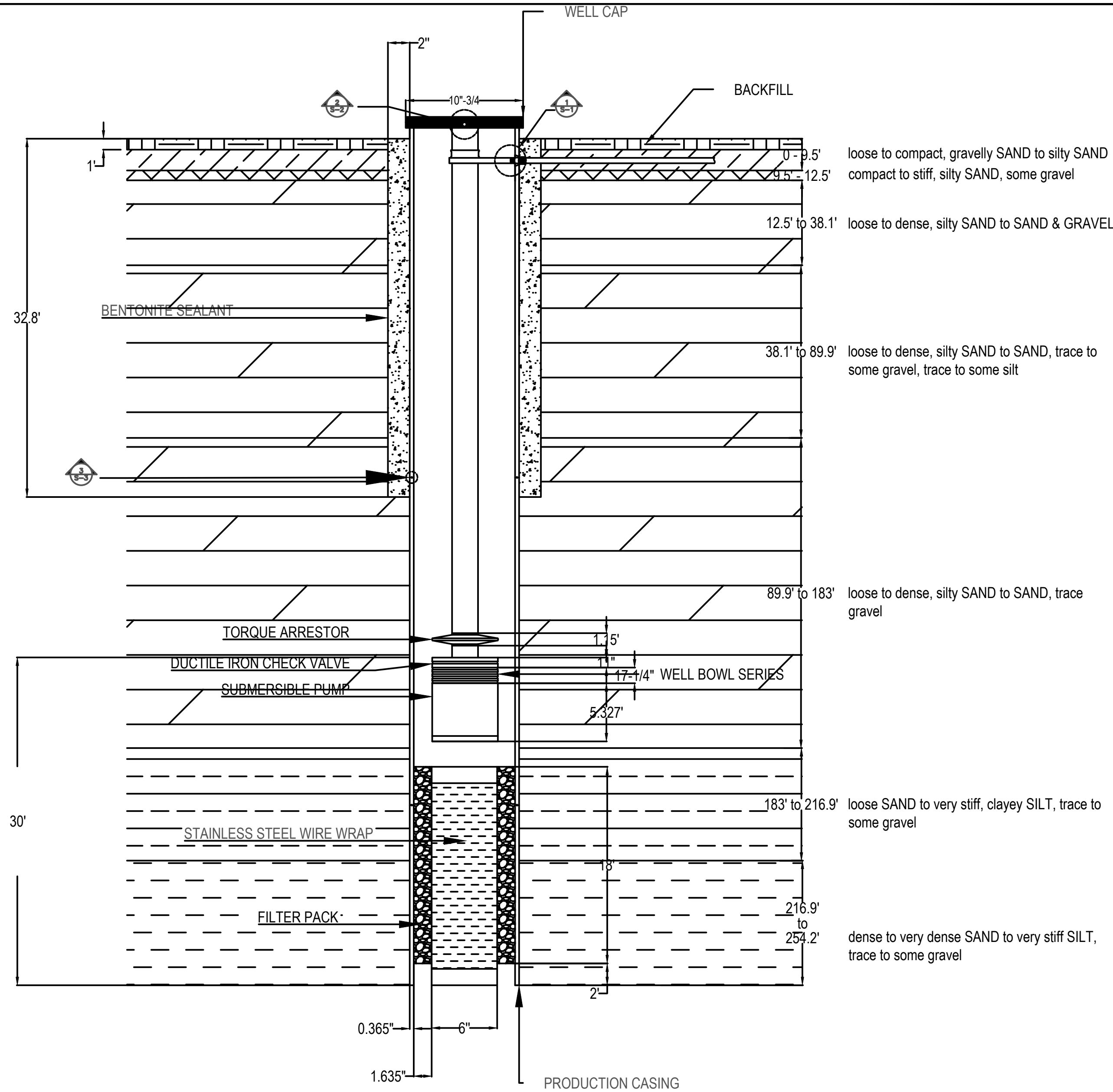


Notes: 1. All units in metres unless noted otherwise.	**Client** UBC SEEDS Sustainability Program			**Title** WELL #5 ELEVATION VIEW	
	Project UBC Groundwater Emergency Water Supply UBC Vancouver Campus				
	Project no.	**Drawn** SP	**Design** SP	**Checked** OQ	**Date** April 16, 2021
	Scale NTS	**Drawing no.** 3.5			

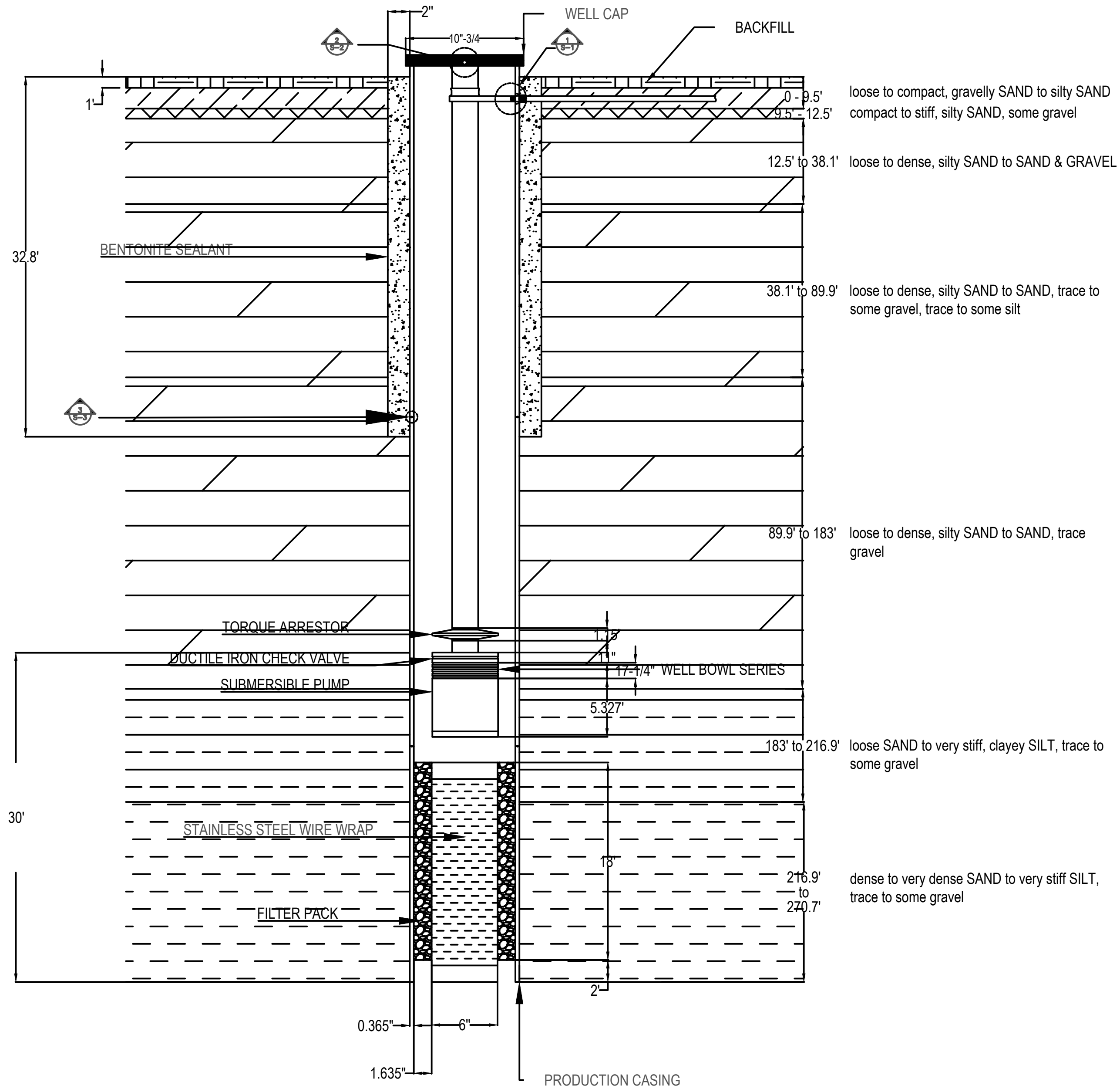
1. SEE SECTION S-1 FOR PITLESS ADAPTER DETAILS

2. SEE SECTION S-2 FOR PLAN VIEW

3. SEE SECTION S-3 FOR PIPE THREADED FLUSH-JOINT



Notes: 1. All units in metres unless noted otherwise.	Client: UBC SEEDS Sustainability Program				Title: WELL #6 ELEVATION VIEW		
	Project: UBC Groundwater Emergency Water Supply UBC Vancouver Campus						
	Project no.	Drawn: SP	Design: SP	Checked: OQ	Date: April 16, 2021	Scale: NTS	Drawing no.: 3.6



1. SEE SECTION S-1 FOR PITLESS ADAPTER DETAILS

2. SEE SECTION S-2 FOR PLAN VIEW

3. SEE SECTION S-3 FOR PIPE THREADED FLUSH-JOINT

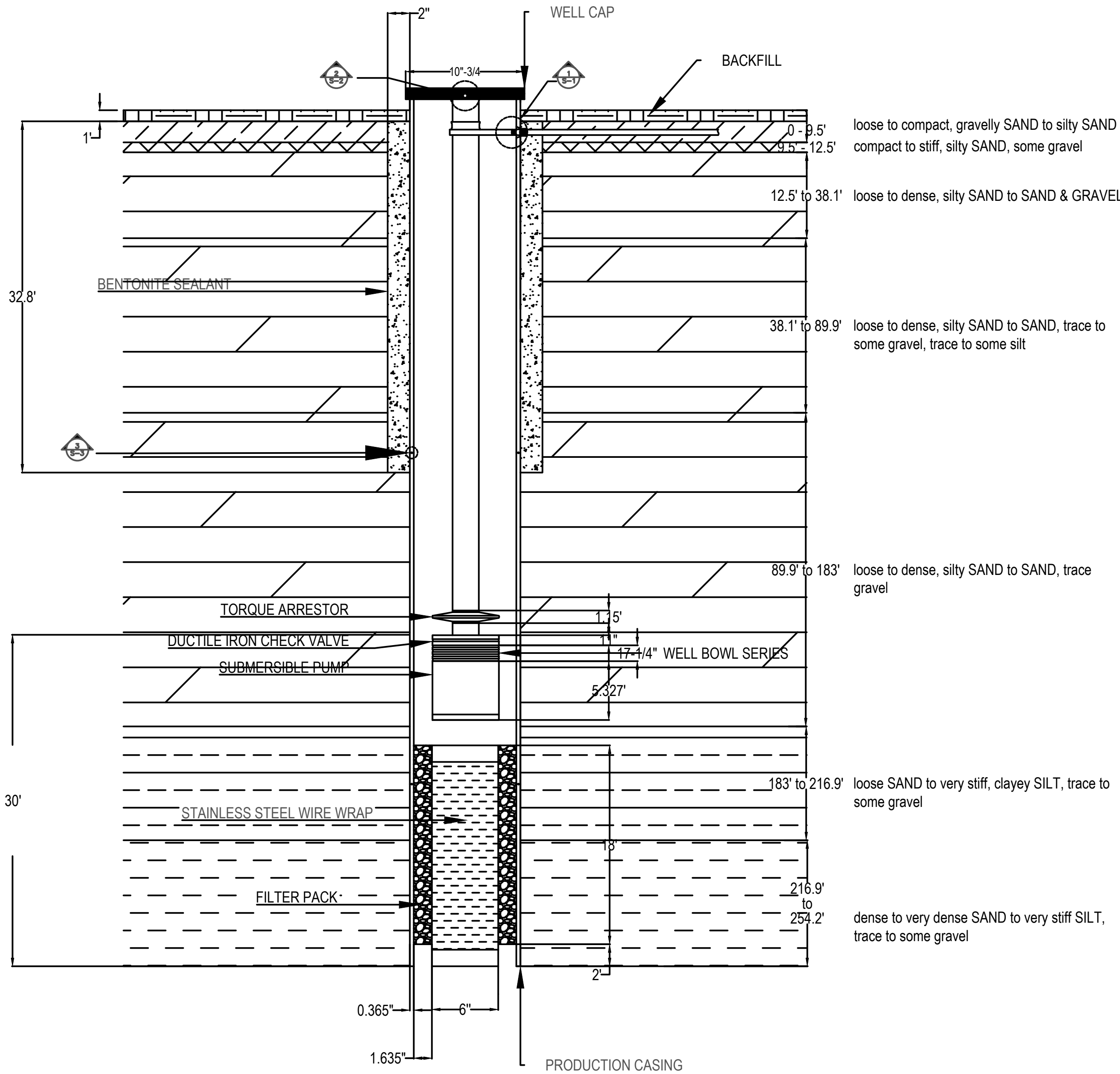
Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program			Title	WELL #7 ELEVATION VIEW		
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus						
Project no.	Drawn: SP	Design: SP	Checked: OQ	Date: April 16, 2021	Scale: NTS	Drawing no.: 3.7	

1. SEE SECTION S-1 FOR PITLESS ADAPTER DETAILS

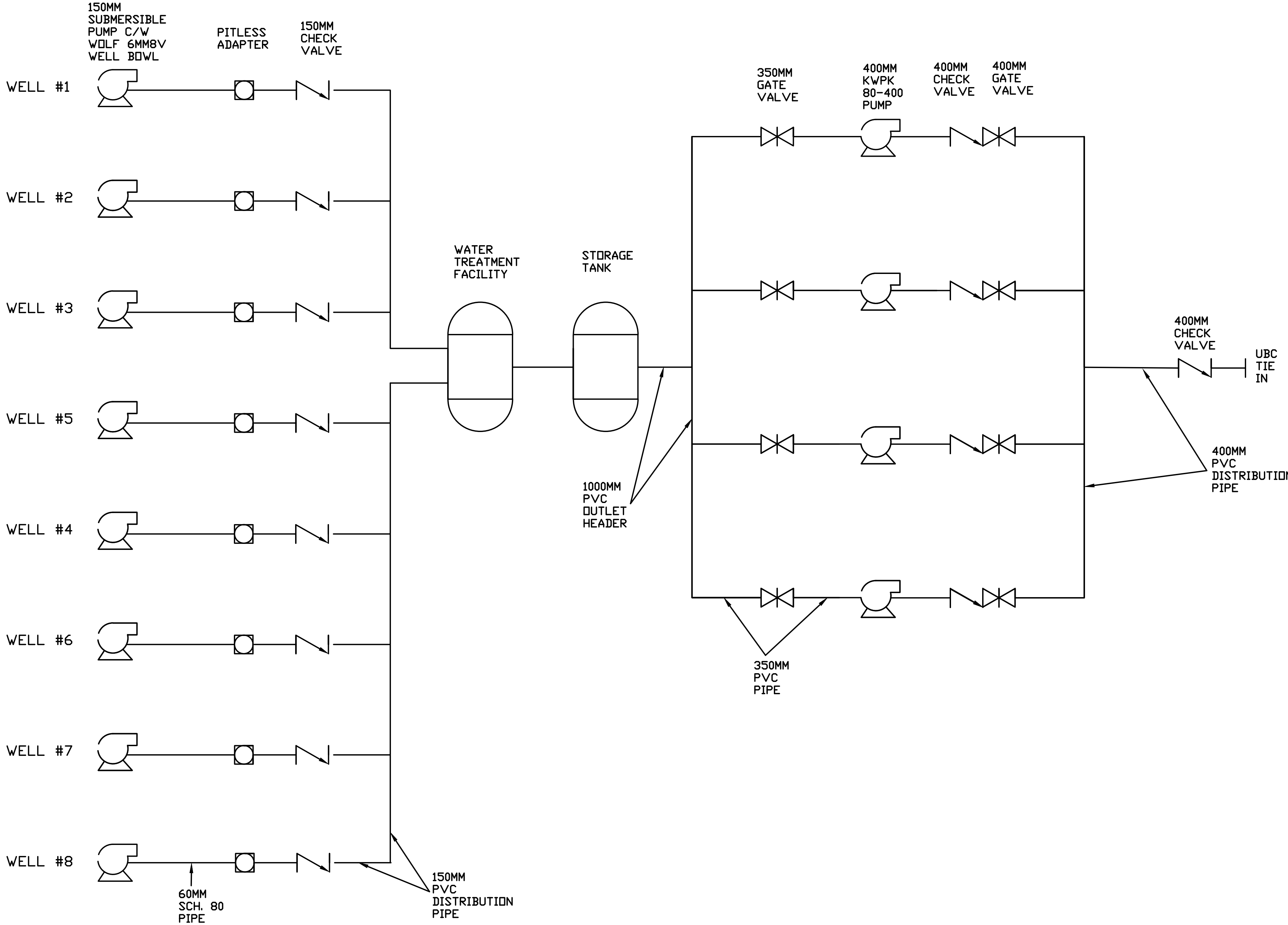
2. SEE SECTION S-2 FOR PLAN VIEW

3. SEE SECTION S-3 FOR PIPE THREADED FLUSH-JOINT



Notes:
1. All units in metres unless noted otherwise.

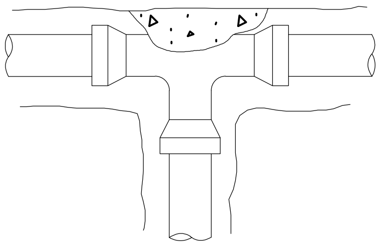
Client	UBC SEEDS Sustainability Program
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus
Title	WELL #8 ELEVATION VIEW
Project no.	
Drawn	SP
Design	SP
Checked	OQ
Date	April 16, 2021
Scale	NTS
Drawing no.	3.8



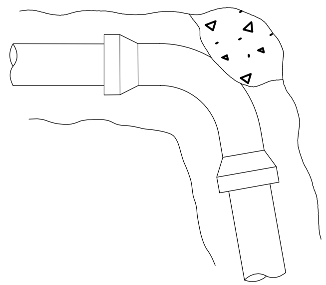
Notes:
1. All units in metres unless noted otherwise.

Client: UBC SEEDS Sustainability Program				Title: P&ID DIAGRAM
Project: UBC Groundwater Emergency Water Supply UBC Vancouver Campus				
Project no.: -	Drawn: AM	Design: AM	Checked: AL	Date: April 16, 2021
Scale: NTS	Drawing no.: 4.1			

Typ. Tee Junction or Dead End

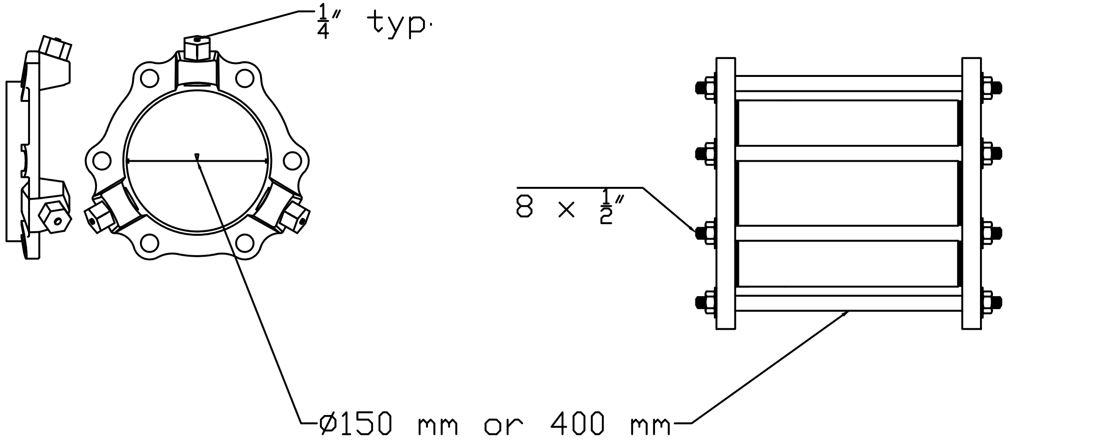


Typ. Bend



Typ. Wedge Action Restraint

Typ. Tie Rod Connection



DIMENSION TABLE

PIPE DIAM.	TEST PRESSURE (PSI)	BEND ANGLE	CONCRETE VOLUME M^3	FACE SIZE M^2
150 mm	90	11.25° 22.5° 45°	1.1 2.1 3.6	0.4 0.5 0.6
400 mm	90	11.25° 22.5° 45°	2.9 4.0 5.3	0.8 0.9 1.1

BEARING TABLE

Soil Type	Safe Bearing Load kPa
Mud, Peat, Liquefiable soil	0
Soft clay	45
Sand	95
Sand and gravel	140
Rock	475

NOTES:

1. CONTRACTOR TO PROVIDE BLOCKING ADEQUATE TO WITHSTAND FULL TEST PRESSURE.

2. DIVIDE THRUST BY SAFE BEARING LOAD TO DETERMINE REQUIRED AREA OF CONCRETE TO DISTRIBUTE LOAD.

3. AREAS TO BE ADJUSTED FOR OTHER PRESSURE CONDITIONS.

4. ALL PIPE FITTINGS TO ADHERE TO RELEVANT MATERIAL QUALITY STANDARDS

5. CONTRACTOR TO BE RESPONSIBLE FOR ADEQUATE INSTALLATION OF PIPE FITTINGS/ RESTRAINTS

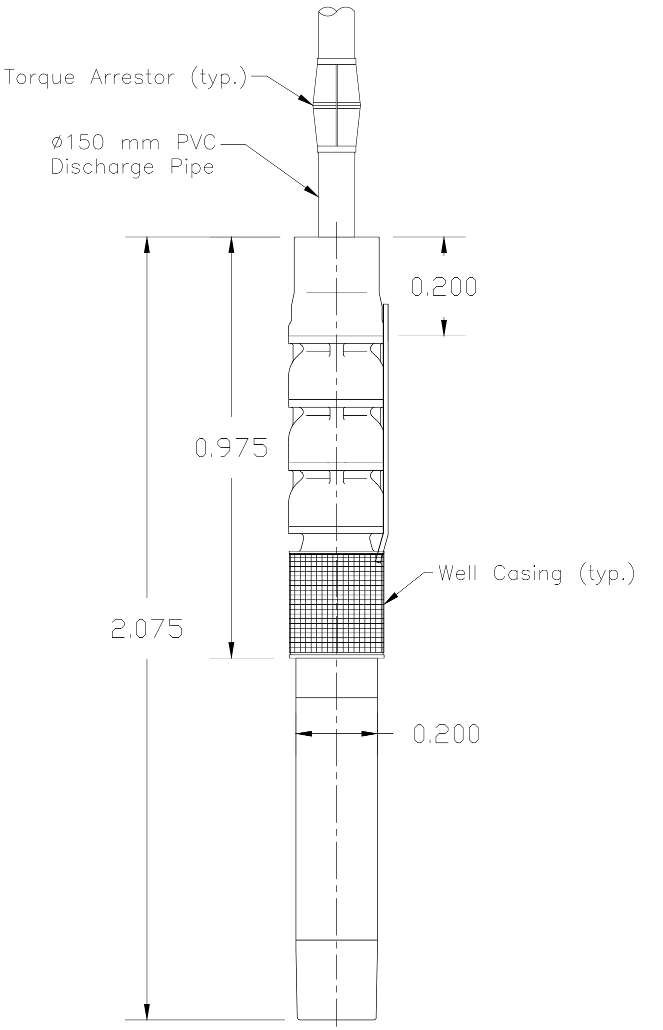
Notes:
1. All units in metres unless noted otherwise.

Client: UBC SEEDS Sustainability Program

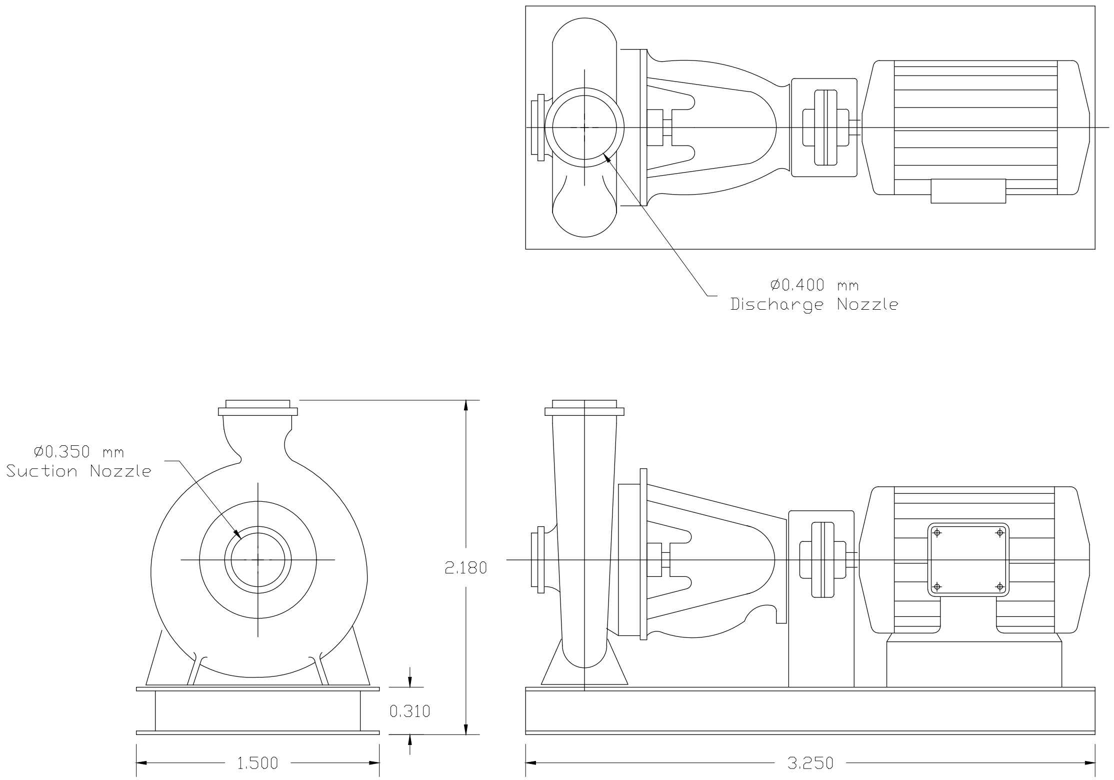
Project: UBC Groundwater Emergency Water Supply
UBC Vancouver Campus

Title: PIPE CONNECTIONS & RESTRAINTS

Project no.	Drawn	Design	Checked	Date	Scale	Drawing no.
-	DB	DB	AL	April 16, 2021	NTS	4.2



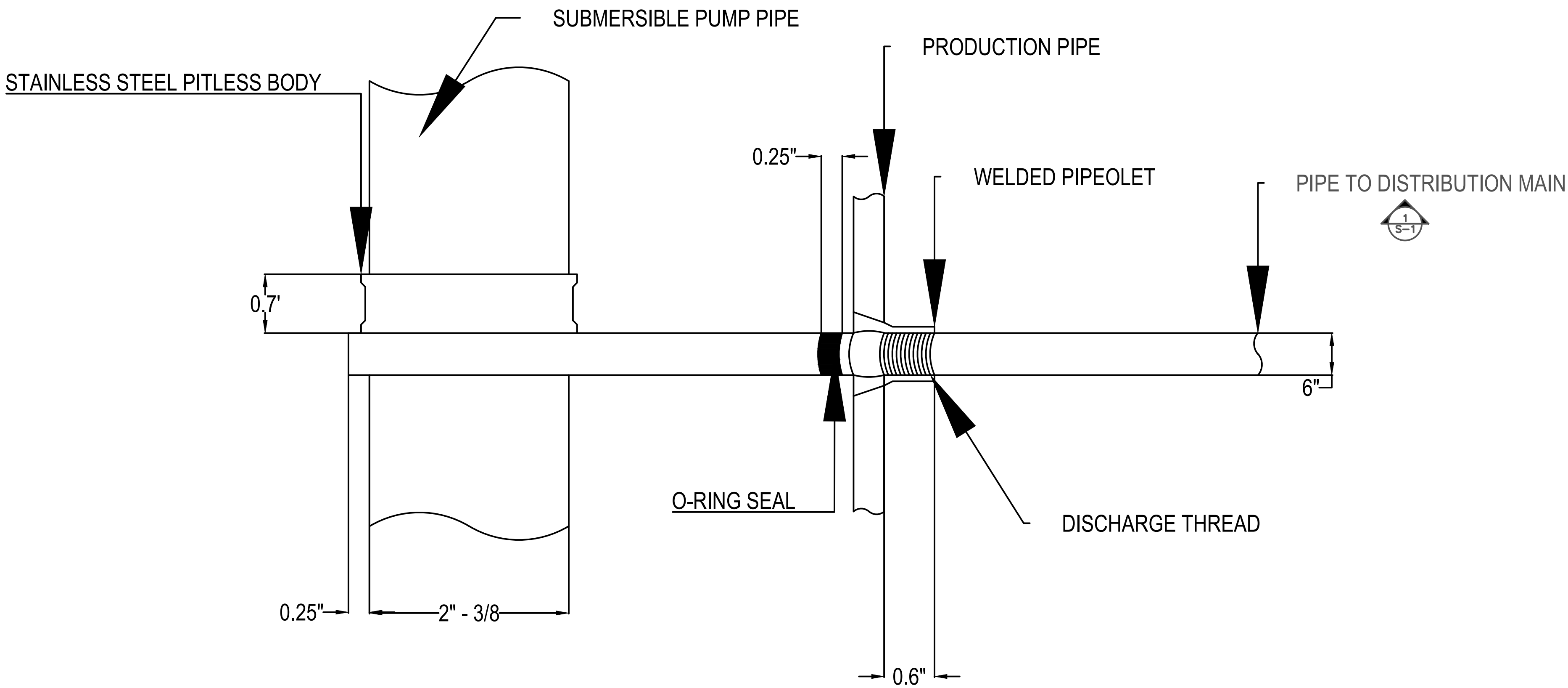
KSB UPA 200B-80 4e Stages
(Submersible Multi-Stage Centrifugal Pumps)



KSB KWP 80-400
(Horizontal Centrifugal Volute Casing Pumps)

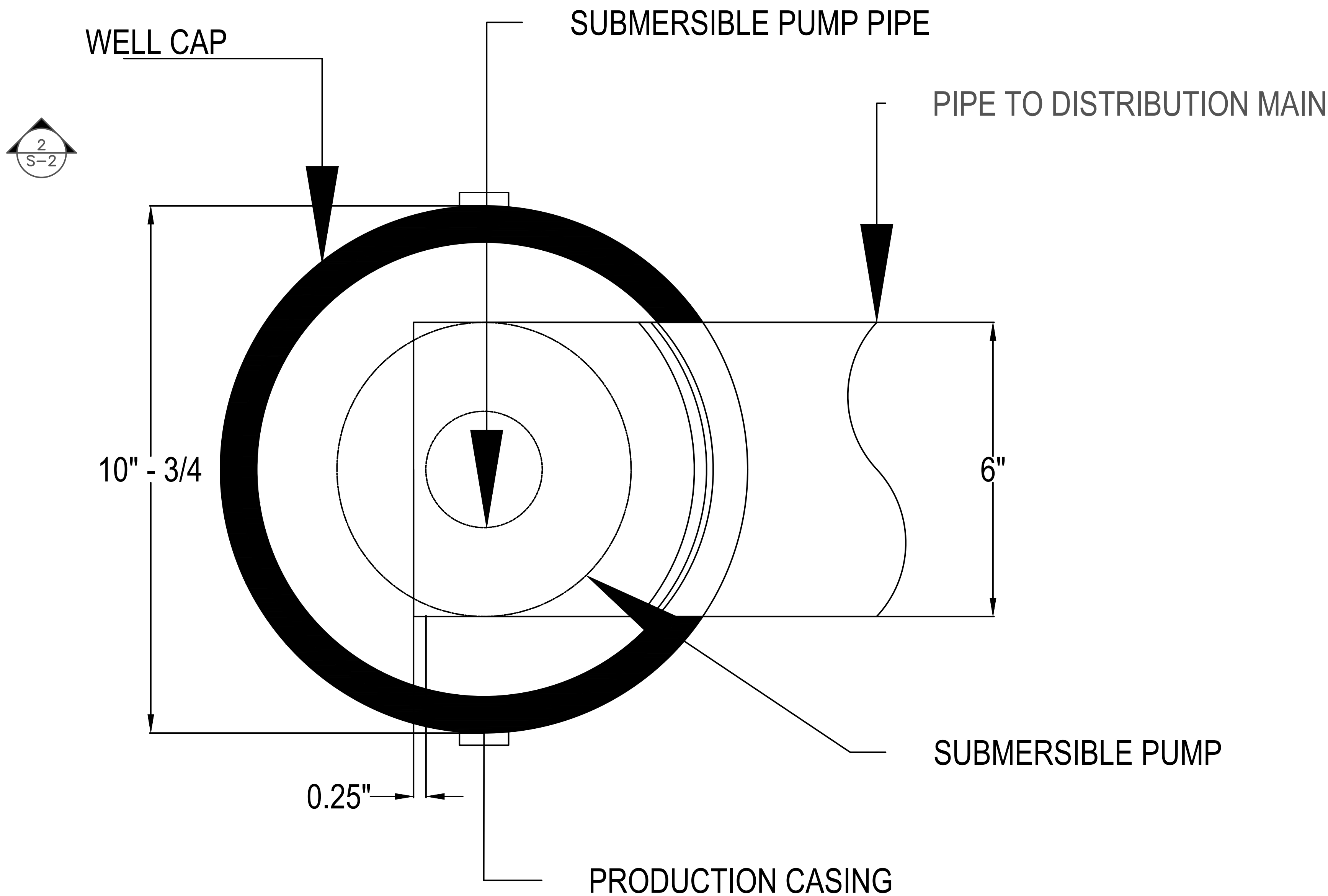
Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program				Title		
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus				PUMP SPECIFICATIONS		
Project no.	-	Drawn: AL	Design: AL	Checked: AM	Date: April 16, 2021	Scale: NTS	Drawing no.: 4.3



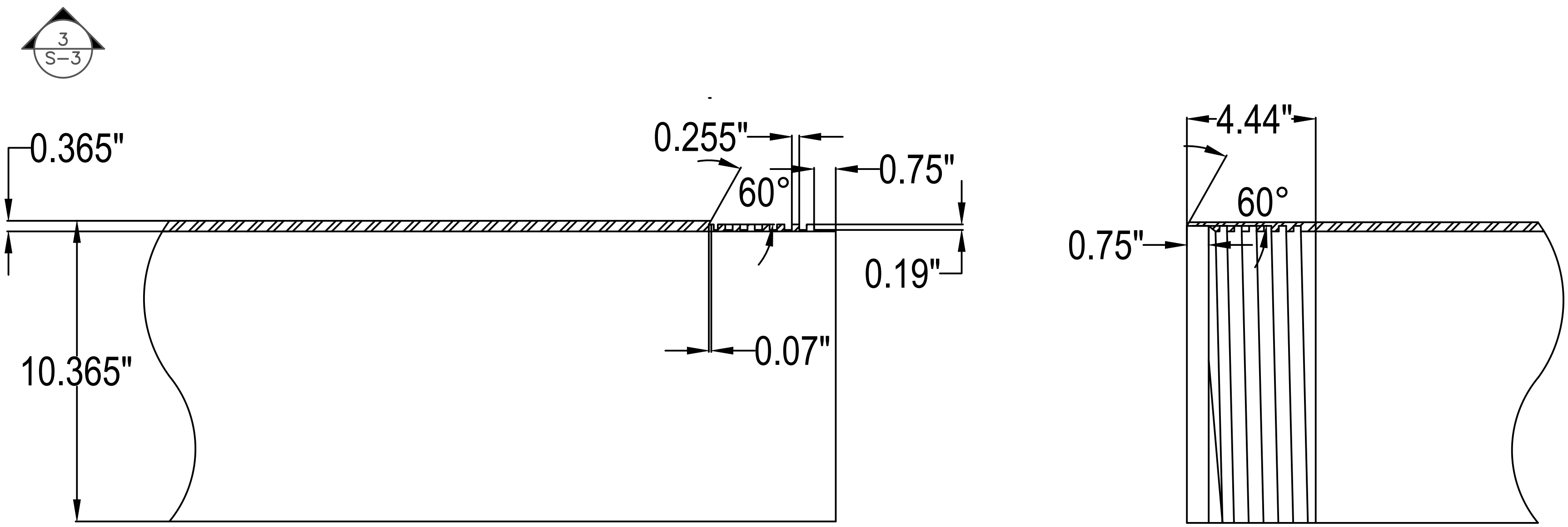
Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus
Title	WELL PITLESS ADAPTER CONNECTION
Project no.	
Drawn	SP
Design	SP
Checked	OQ
Date	April 16, 2021
Scale	H - 1:0.2 V - 1:5
Drawing no.	S-1



Notes:
1. All units in metres unless noted otherwise.

Client	UBC SEEDS Sustainability Program			Title	TYPICAL WELL PLAN VIEW
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus				
Project no.	Drawn: SP	Design: SP	Checked: OQ	Date: April 16, 2021	Scale: 1:0.5
				Drawing no.	S-2

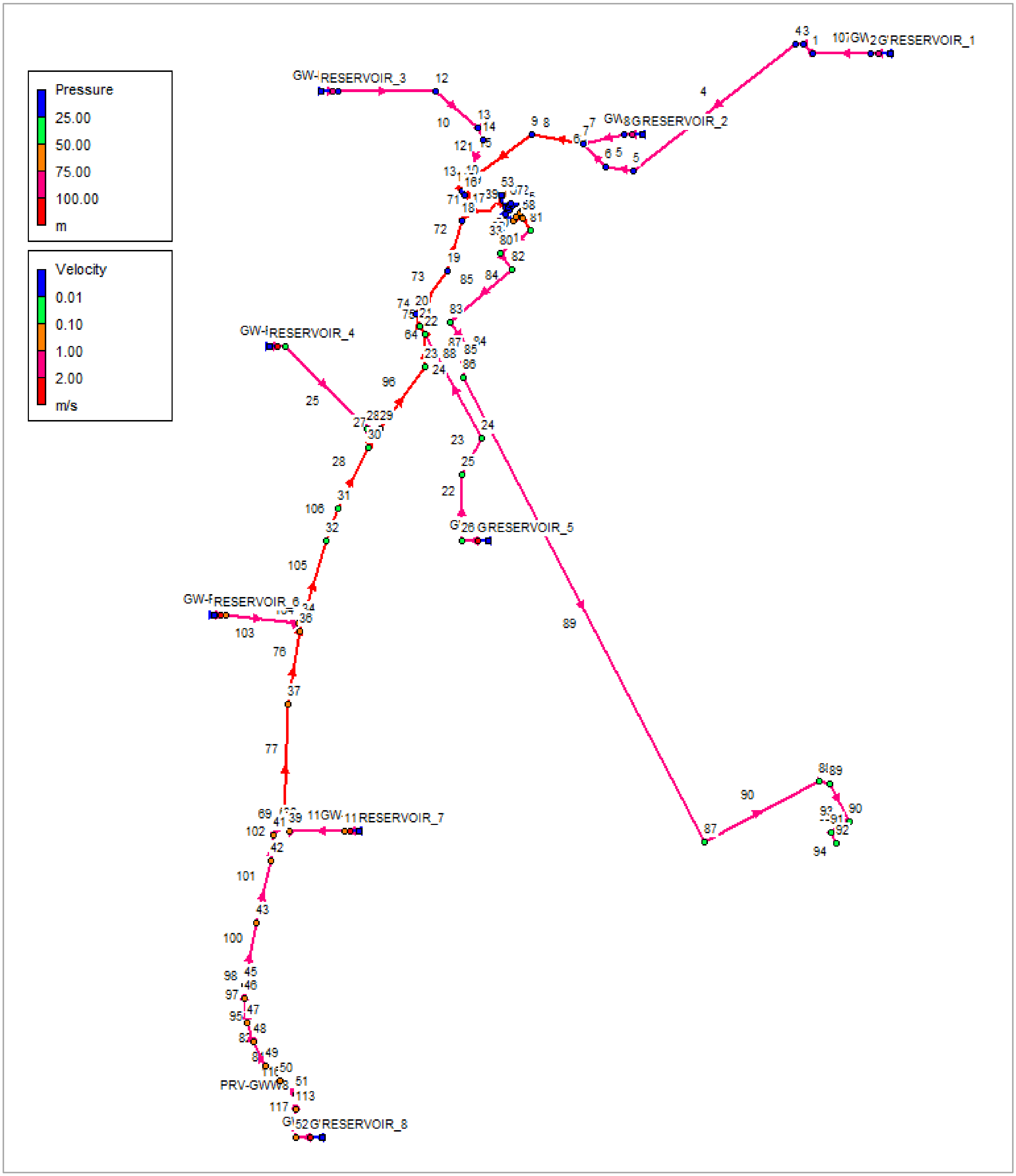


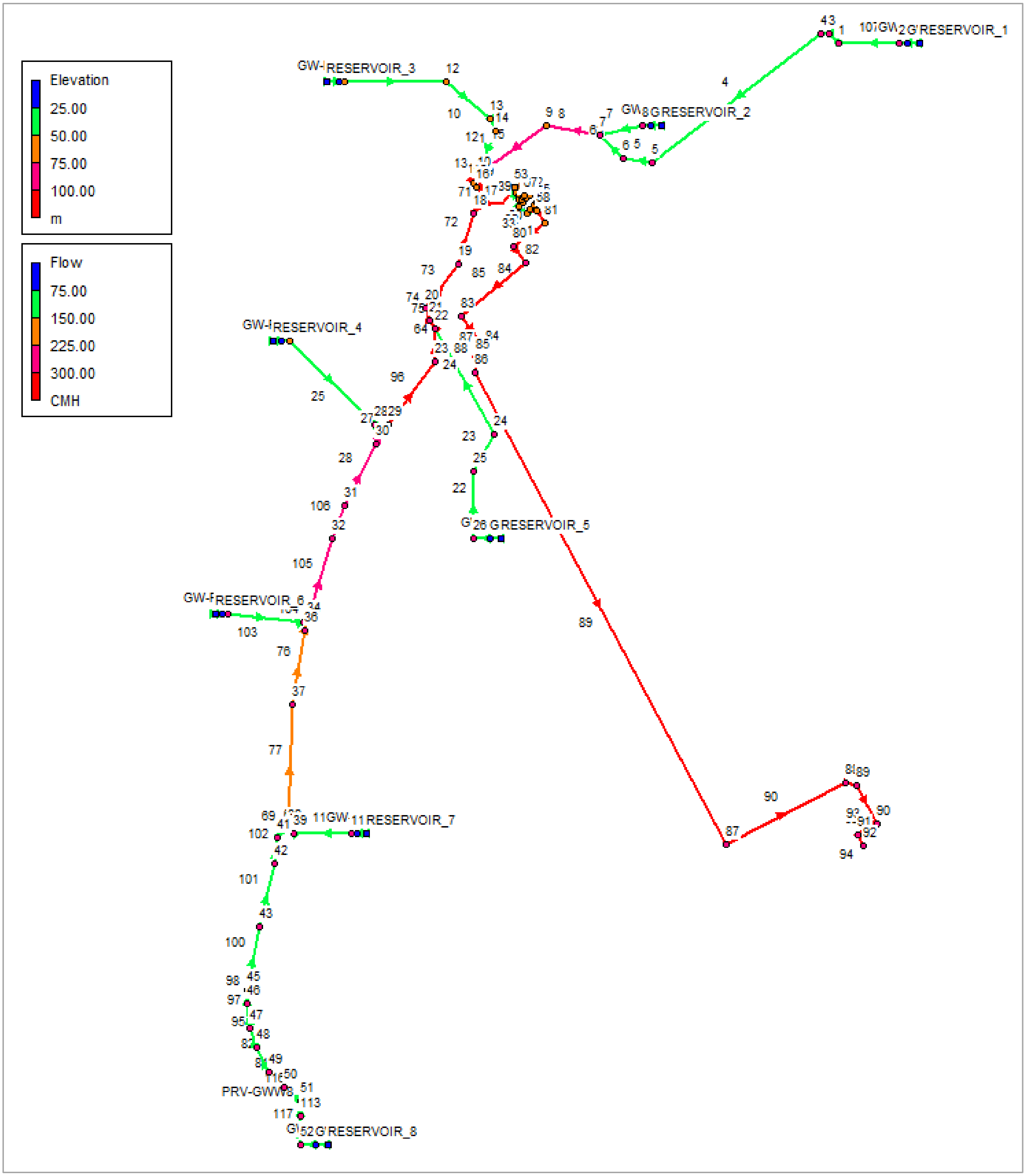
Notes:
1. All units in metres unless noted otherwise.

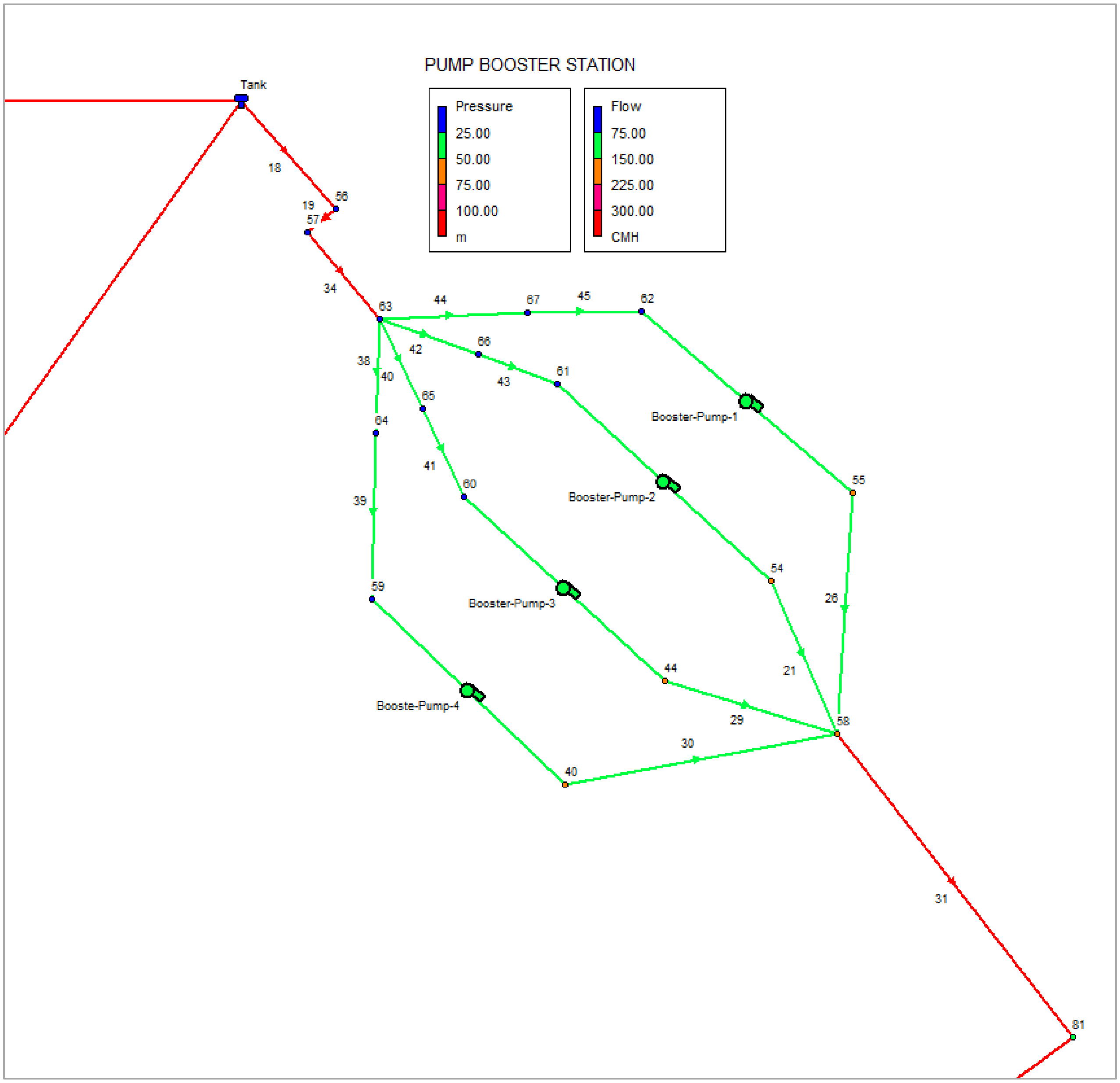
Client	UBC SEEDS Sustainability Program	Title	WELL THREADED FLUSH JOINT
Project	UBC Groundwater Emergency Water Supply UBC Vancouver Campus		

Project no.	Drawn	Design	Checked	Date	Scale	Drawing no.
	SP	SP	OQ	April 16, 2021	1:1	S-3

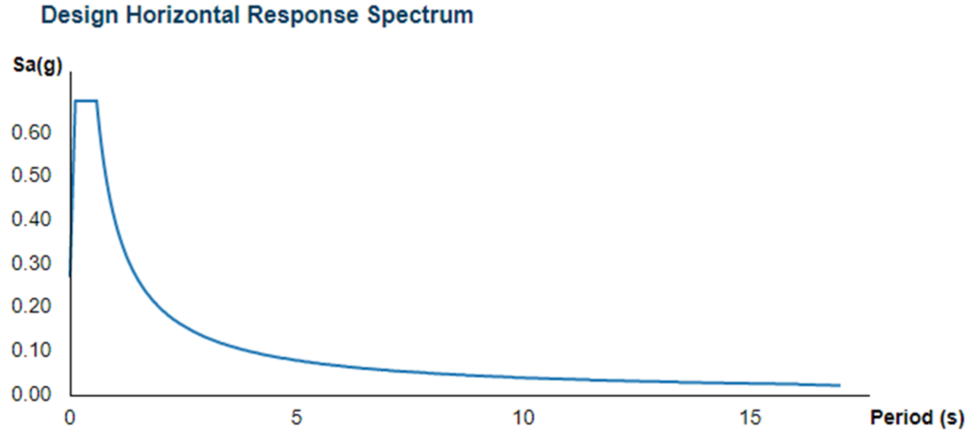
Appendix IV – EPANET Model Results




Elevation
25.00
50.00
75.00
100.00
m
Flow
75.00
150.00
225.00
300.00
CMH
RESERVOIR_1
RESERVOIR_2
RESERVOIR_3
RESERVOIR_4
RESERVOIR_5
RESERVOIR_6
RESERVOIR_7
RESERVOIR_8


PUMP BOOSTER STATION
Pressure
25.00
50.00
75.00
100.00
m
Flow
75.00
150.00
225.00
300.00
CMH
Tank
18
56
19
57
34
63
44
67
45
62
42
66
43
61
38
40
65
64
Booster-Pump-1
41
60
Booster-Pump-2
55
39
54
26
59
Booster-Pump-3
44
21
Booste-Pump-4
29
58
30
40
31
81

Appendix V – Seismic Response Spectrum and Data



Basic Parameters

Name	Value	Description
S_S	0.882	MCE_R ground motion (period=0.2s)
S_1	0.35	MCE_R ground motion (period=1.0s)
S_{MS}	1.012	Site-modified spectral acceleration value
S_{M1}	0.595	Site-modified spectral acceleration value
S_{DS}	0.674	Numeric seismic design value at 0.2s SA
S_{D1}	0.397	Numeric seismic design value at 1.0s SA

Additional Information

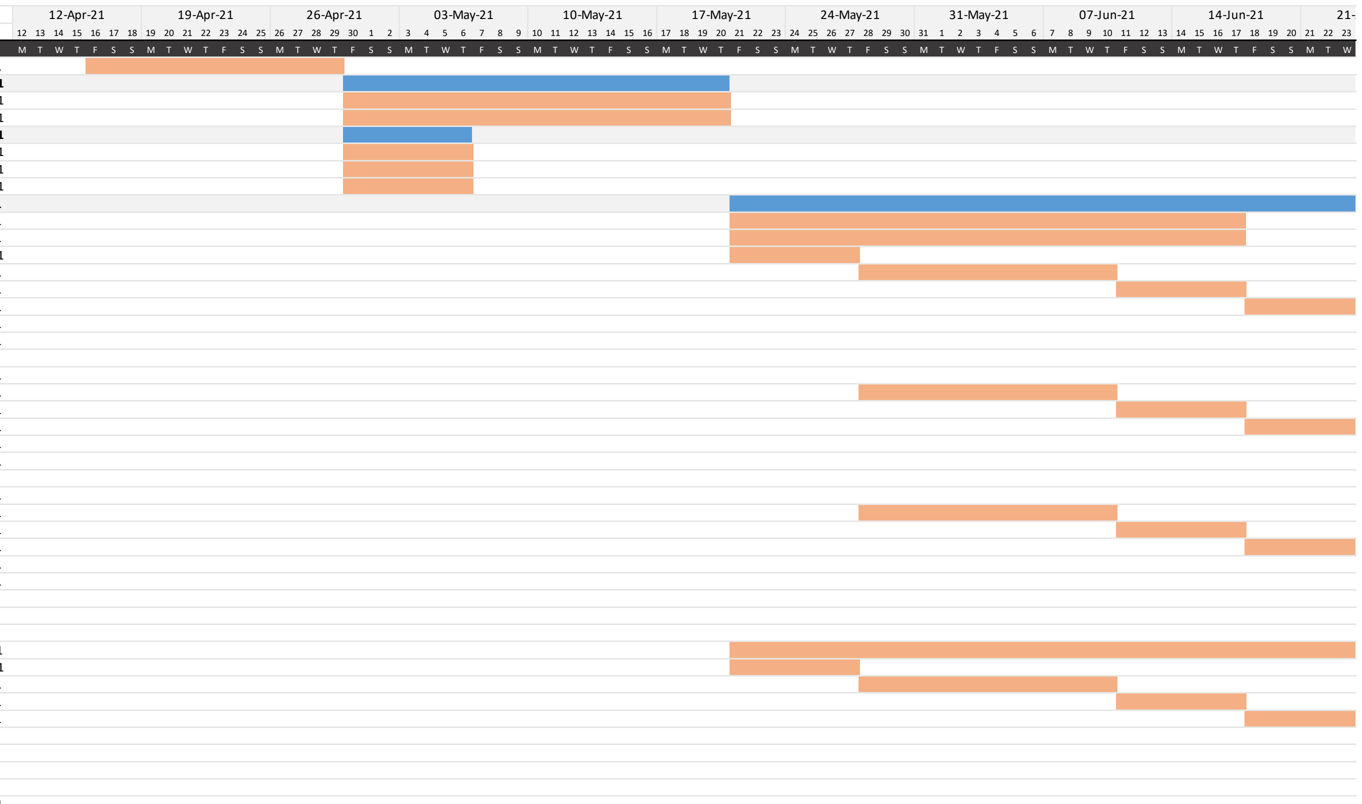
Name	Value	Description
SDC	D	Seismic design category
F_a	1.147	Site amplification factor at 0.2s
F_v	1.7	Site amplification factor at 1.0s
CR_S	0.948	Coefficient of risk (0.2s)
CR_1	0.914	Coefficient of risk (1.0s)
PGA	0.377	MCE_G peak ground acceleration
F_{PGA}	1.123	Site amplification factor at PGA
PGA_M	0.423	Site modified peak ground acceleration
T_L	16	Long-period transition period (s)
SsRT	0.882	Probabilistic risk-targeted ground motion (0.2s)
SsUH	0.93	Factored uniform-hazard spectral acceleration (2% probability of exceedance in 50 years)
SsD	1.5	Factored deterministic acceleration value (0.2s)
S1RT	0.35	Probabilistic risk-targeted ground motion (1.0s)
S1UH	0.383	Factored uniform-hazard spectral acceleration (2% probability of exceedance in 50 years)
S1D	0.6	Factored deterministic acceleration value (1.0s)
PGAd	0.6	Factored deterministic acceleration value (PGA)

Appendix VI – Project Schedule

UBC GROUNDWATER EMERGENCY SUPPLY | PROJECT SCHEDULE

Last Updated: Tue, 13-Apr-2021

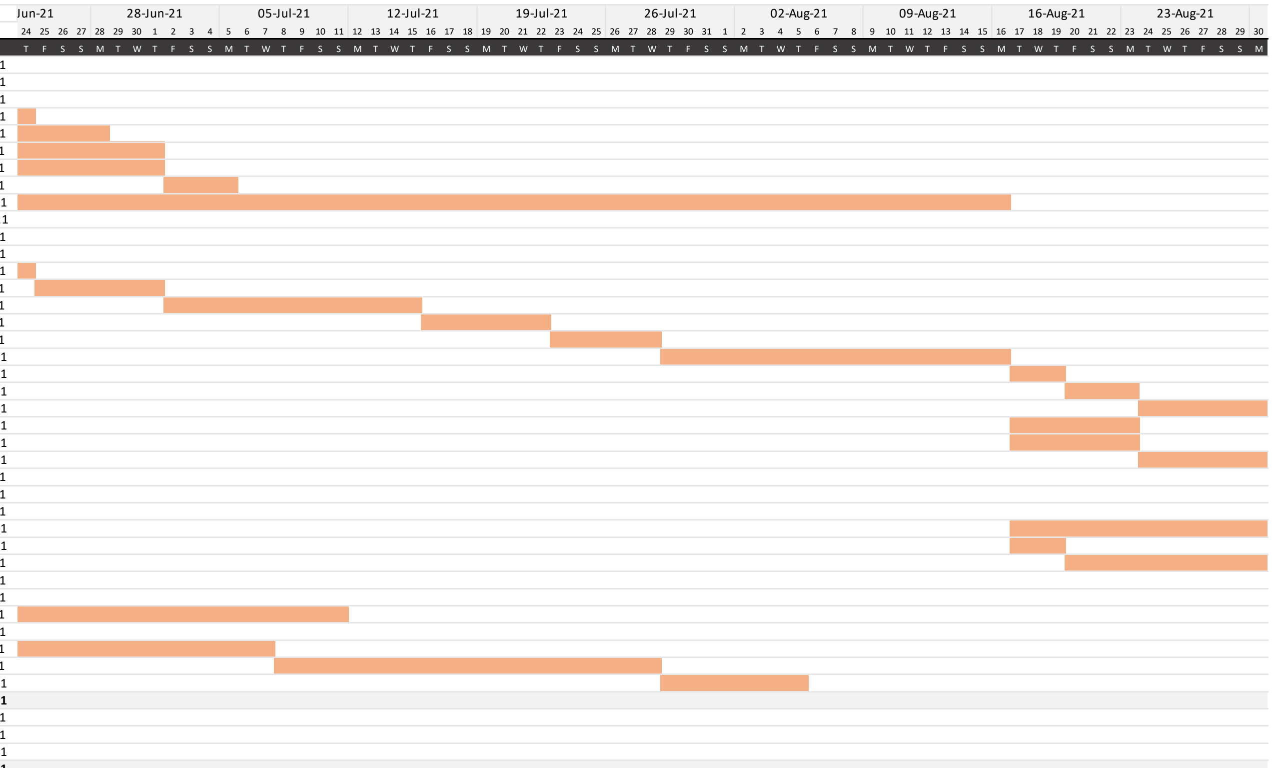
Category	ID #	Task	Dependancy	Duration	Start	End
Task	2.11.0	Client Review of Detailed Design, EA & Cost Estimate	2.10.0	10	16-Apr-21	29-Apr-21
Set	**3.0.0**	**Procurement**		**15**	**30-Apr-21**	**20-May-21**
Task	3.1.0	Materials, Labour & Equipment Procurement (Construction)	2.11.0	15	30-Apr-21	20-May-21
Task	3.2.0	Equipment Procurement (Process & Conveyance)	2.11.0	15	30-Apr-21	20-May-21
Set	**4.0.0**	**Construction Start-up**		**5**	**30-Apr-21**	**06-May-21**
Task	4.1.0	Traffic Management Plan Assessment & Execution	2.11.0	5	30-Apr-21	06-May-21
Task	4.2.0	Site Setup & Equipment Mobilization for Groundwater Well Sites	2.11.0	5	30-Apr-21	06-May-21
Task	4.3.0	Site setup & Equipment Mobilization for Groundwater Detention Tank Site	2.11.0	5	30-Apr-21	06-May-21
Set	**5.0.0**	**Construction**		**93**	**21-May-21**	**03-Oct-21**
Task	5.1.0	Ground Improvement for Detention Tank & Treatment Structure	3.1.0	20	21-May-21	17-Jun-21
Task	5.2.0	Construction of Groundwater Wells	3.1.0	20	21-May-21	17-Jun-21
Sub-Task	5.2.1	Site Survey, Staking & Preparation for Groundwater Well Drilling	3.1.0	5	21-May-21	27-May-21
Sub-Task	5.2.2	Rotary Drilling of Groundwater Well A, B & C	5.2.1	10	28-May-21	10-Jun-21
Sub-Task	5.2.3	Installation of Thermoplastic Well Casing A, B & C	5.2.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.2.4	Grouting of Well A, B & C	5.2.3	4	18-Jun-21	23-Jun-21
Sub-Task	5.2.5	Installation of Well Screen A, B & C	5.2.4	1	24-Jun-21	24-Jun-21
Sub-Task	5.2.6	Installation of Submersible Pump & Check Valve for Well A, B & C	5.2.4	3	24-Jun-21	28-Jun-21
Sub-Task	5.2.7	Installation of Well A, B & C Pipe Connection to Junction A	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.8	Installation of Well Cap A, B & C & Site Landscaping	5.2.4	2	24-Jun-21	27-Jun-21
Sub-Task	5.2.9	Rotary Drilling of Groundwater Well D, E & F	5.2.1	10	28-May-21	10-Jun-21
Sub-Task	5.2.10	Installation of Thermoplastic Well Casing D, E & F	5.2.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.2.11	Grouting of Well D, E & F	5.2.3	4	18-Jun-21	23-Jun-21
Sub-Task	5.2.12	Installation of Well Screen D, E & F	5.2.4	1	24-Jun-21	24-Jun-21
Sub-Task	5.2.13	Installation of Submersible Pump & Check Valve for Well D, E & F	5.2.4	3	24-Jun-21	28-Jun-21
Sub-Task	5.2.14	Installation of Well D, E & F Pipe Connection to Junction A	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.15	Installation of Well Cap D, E & F & Site Landscaping	5.2.4	2	24-Jun-21	27-Jun-21
Sub-Task	5.2.16	Rotary Drilling of Groundwater Well G & H	5.2.1	10	28-May-21	10-Jun-21
Sub-Task	5.2.17	Installation of Thermoplastic Well Casing G & H	5.2.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.2.18	Grouting of Well G & H	5.2.3	4	18-Jun-21	23-Jun-21
Sub-Task	5.2.19	Installation of Well Screen G & H	5.2.4	1	24-Jun-21	24-Jun-21
Sub-Task	5.2.20	Installation of Submersible Pump & Check Valve for Well G & H	5.2.4	3	24-Jun-21	28-Jun-21
Sub-Task	5.2.21	Installation of Well G & H Pipe Connection to Junction A	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.22	Installation of Well Cap G & H & Site Landscaping	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.23	QA/QC for Groundwater Wells A, B, C, D, E, F, G & H	5.2.22	2	02-Jul-21	05-Jul-21
Task	5.3.0	Construction of Groundwater Detention Tank & Treatment Structure	3.1.0	60	21-May-21	16-Aug-21
Sub-Task	5.3.1	Staking & Excavation Layout for Groundwater Detention Tank	3.1.0	5	21-May-21	27-May-21
Sub-Task	5.3.2	Excavation for Detention Tank & Treatment Structure	5.3.1	10	28-May-21	10-Jun-21
Sub-Task	5.3.3	Shoring & Anchoring for Major Excavation	5.3.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.3.4	Installation of Slab Formwork	5.3.3	5	18-Jun-21	24-Jun-21
Sub-Task	5.3.5	Installation of Slab Reinforcements	5.3.4	4	25-Jun-21	01-Jul-21
Sub-Task	5.3.6	Concrete Pour for Tank Slab	5.3.5	10	02-Jul-21	15-Jul-21
Sub-Task	5.3.7	Installation of Wall Formwork	5.3.6	5	16-Jul-21	22-Jul-21
Sub-Task	5.3.8	Installation of Wall Reinforcements	5.3.7	4	23-Jul-21	28-Jul-21
Sub-Task	5.3.9	Concrete Pour for Tank Walls	5.3.8	12	29-Jul-21	16-Aug-21



UBC GROUNDWATER EMERGENCY SUPPLY | PROJECT SCHEDULE

Last Updated: Tue, 13-Apr-2021

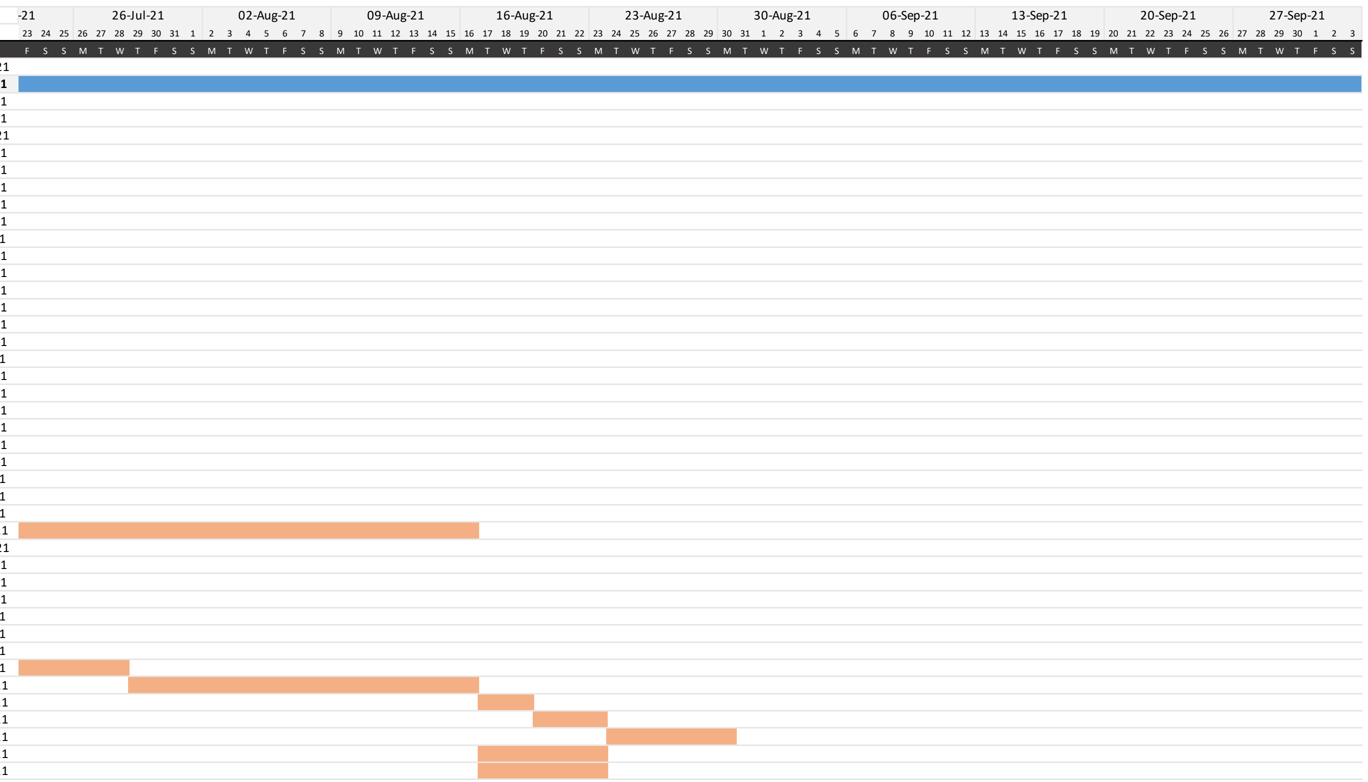
Category	ID #	Task	Dependancy	Duration	Start	End
Sub-Task	5.2.16	Rotary Drilling of Groundwater Well G & H	5.2.1	10	28-May-21	10-Jun-21
Sub-Task	5.2.17	Installation of Thermoplastic Well Casing G & H	5.2.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.2.18	Grouting of Well G & H	5.2.3	4	18-Jun-21	23-Jun-21
Sub-Task	5.2.19	Installation of Well Screen G & H	5.2.4	1	24-Jun-21	24-Jun-21
Sub-Task	5.2.20	Installation of Submersible Pump & Check Valve for Well G & H	5.2.4	3	24-Jun-21	28-Jun-21
Sub-Task	5.2.21	Installation of Well G & H Pipe Connection to Junction A	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.22	Installation of Well Cap G & H & Site Landscaping	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.23	QA/QC for Groundwater Wells A, B, C, D, E, F, G & H	5.2.22	2	02-Jul-21	05-Jul-21
Task	5.3.0	Construction of Groundwater Detention Tank & Treatment Structure	3.1.0	60	21-May-21	16-Aug-21
Sub-Task	5.3.1	Staking & Excavation Layout for Groundwater Detention Tank	3.1.0	5	21-May-21	27-May-21
Sub-Task	5.3.2	Excavation for Detention Tank & Treatment Structure	5.3.1	10	28-May-21	10-Jun-21
Sub-Task	5.3.3	Shoring & Anchoring for Major Excavation	5.3.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.3.4	Installation of Slab Formwork	5.3.3	5	18-Jun-21	24-Jun-21
Sub-Task	5.3.5	Installation of Slab Reinforcements	5.3.4	4	25-Jun-21	01-Jul-21
Sub-Task	5.3.6	Concrete Pour for Tank Slab	5.3.5	10	02-Jul-21	15-Jul-21
Sub-Task	5.3.7	Installation of Wall Formwork	5.3.6	5	16-Jul-21	22-Jul-21
Sub-Task	5.3.8	Installation of Wall Reinforcements	5.3.7	4	23-Jul-21	28-Jul-21
Sub-Task	5.3.9	Concrete Pour for Tank Walls	5.3.8	12	29-Jul-21	16-Aug-21
Sub-Task	5.3.10	Installation of Roof Formwork	5.3.9	3	17-Aug-21	19-Aug-21
Sub-Task	5.3.11	Installation of Roof Reinforcements	5.3.10	2	20-Aug-21	23-Aug-21
Sub-Task	5.3.12	Concrete Pour for Tank Roof	5.3.11	5	24-Aug-21	30-Aug-21
Sub-Task	5.3.13	Installation of Pumping System for Detention Tank	5.3.9	5	17-Aug-21	23-Aug-21
Sub-Task	5.3.14	Installation of Treatment Equipment	5.3.9	5	17-Aug-21	23-Aug-21
Sub-Task	5.3.15	QA/QC for Detention Tank & Treatment Structure (Process)	5.3.11	5	24-Aug-21	30-Aug-21
Sub-Task	5.3.16	Installation of Waterproof Membrane & Access Hatches	5.3.15	2	31-Aug-21	01-Sep-21
Sub-Task	5.3.17	Backfill of Excavation & Ground Elevation Leveling	5.3.16	2	02-Sep-21	06-Sep-21
Sub-Task	5.3.18	Installation of Access Roads & Security Fencing	5.3.17	3	07-Sep-21	09-Sep-21
Task	5.4.0	Construction of Pipe Connection from Reservoir to Main Water Distribution System	5.3.0	10	17-Aug-21	30-Aug-21
Sub-Task	5.4.1	Staking & Excavation Layout for Pipe Connection	5.3.0	3	17-Aug-21	19-Aug-21
Sub-Task	5.4.2	Excavation for Pipe Connection	5.4.1	10	20-Aug-21	02-Sep-21
Sub-Task	5.4.3	Installation of Pipe (PVC or HDPE options) & Tie-Ins to Distribution System & Tank	5.4.2	15	03-Sep-21	26-Sep-21
Sub-Task	5.4.5	Backfill of Pipe Connection Excavation	5.4.3	5	27-Sep-21	03-Oct-21
Task	5.5.0	Construction of Pipe Connection from Junction A to Reservoir	5.2.0	15	18-Jun-21	11-Jul-21
Sub-Task	5.5.1	Staking & Excavation Layout for Pipe Connection	5.2.0	3	18-Jun-21	22-Jun-21
Sub-Task	5.5.2	Excavation for Pipe Connection	5.5.1	10	23-Jun-21	07-Jul-21
Sub-Task	5.5.3	Installation of Pipe (PVC or HDPE options) & Tie-Ins to Distribution System & Tank	5.5.2	15	08-Jul-21	28-Jul-21
Sub-Task	5.5.4	Backfill of Pipe Connection Excavation	5.5.3	5	29-Jul-21	05-Aug-21
Set	**6.0.0**	**Commissioning & Testing**		**30**	**04-Oct-21**	**15-Nov-21**
Task	6.1.0	QA/QC of Integrated System	5.0.0	10	04-Oct-21	17-Oct-21
Task	6.2.0	Project Walkthrough & Inspection with Client	6.1.0	5	18-Oct-21	24-Oct-21
Task	6.3.0	Identification & Completion of Deficiencies	6.1.0	20	18-Oct-21	15-Nov-21
Set	**7.0.0**	**Project Close-Out**		**-**	**15-Nov-21**	**15-Nov-21**



UBC GROUNDWATER EMERGENCY SUPPLY | PROJECT SCHEDULE

Last Updated: Tue, 13-Apr-2021

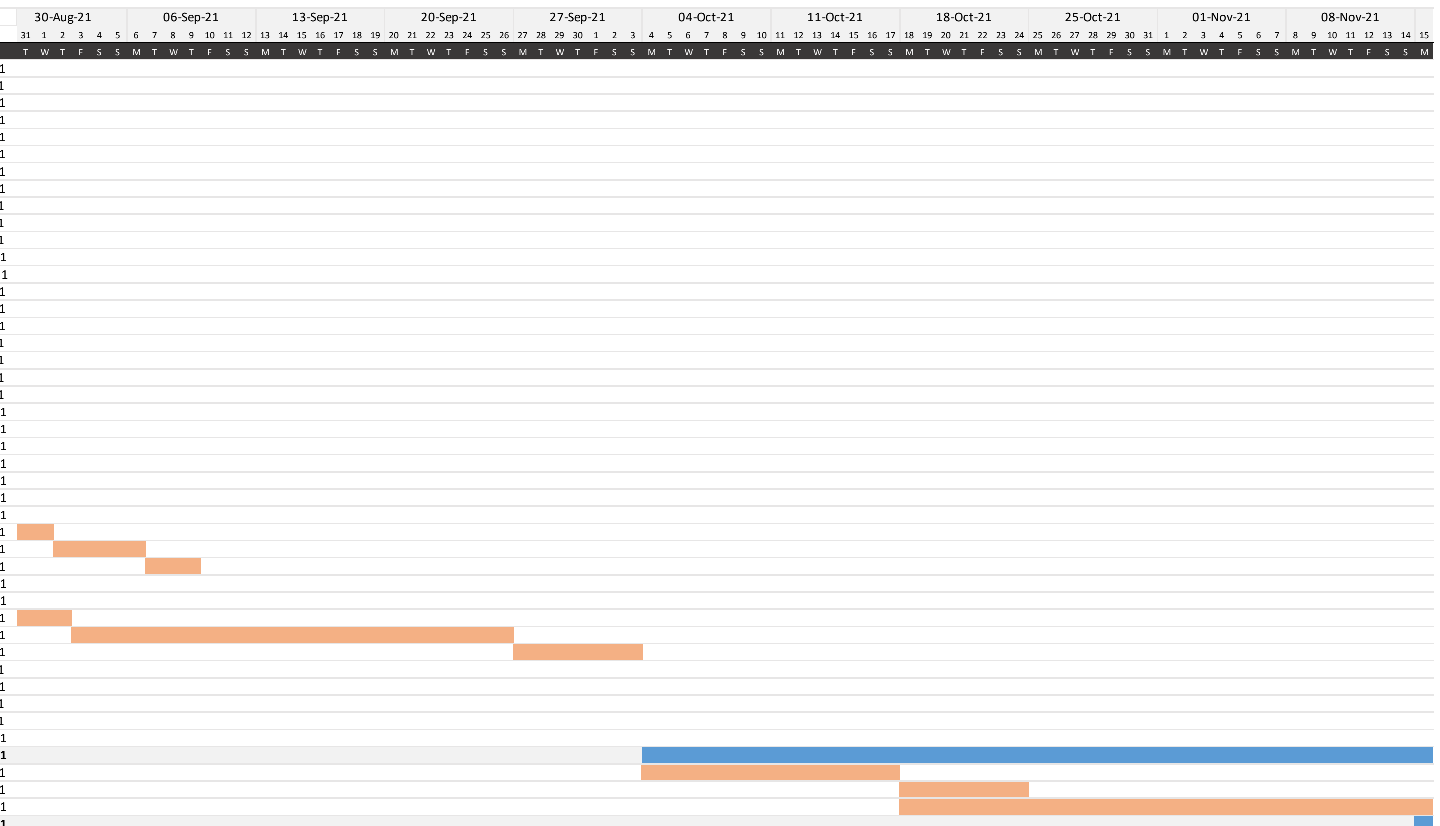
Category	ID #	Task	Dependancy	Duration	Start	End
Task	4.3.0	Site setup & Equipment Mobilization for Groundwater Detention Tank Site	2.11.0	5	30-Apr-21	06-May-21
Set	**5.0.0**	**Construction**		**93**	**21-May-21**	**03-Oct-21**
Task	5.1.0	Ground Improvement for Detention Tank & Treatment Structure	3.1.0	20	21-May-21	17-Jun-21
Task	5.2.0	Construction of Groundwater Wells	3.1.0	20	21-May-21	17-Jun-21
Sub-Task	5.2.1	Site Survey, Staking & Preparation for Groundwater Well Drilling	3.1.0	5	21-May-21	27-May-21
Sub-Task	5.2.2	Rotary Drilling of Groundwater Well A, B & C	5.2.1	10	28-May-21	10-Jun-21
Sub-Task	5.2.3	Installation of Thermoplastic Well Casing A, B & C	5.2.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.2.4	Grouting of Well A, B & C	5.2.3	4	18-Jun-21	23-Jun-21
Sub-Task	5.2.5	Installation of Well Screen A, B & C	5.2.4	1	24-Jun-21	24-Jun-21
Sub-Task	5.2.6	Installation of Submersible Pump & Check Valve for Well A, B & C	5.2.4	3	24-Jun-21	28-Jun-21
Sub-Task	5.2.7	Installation of Well A, B & C Pipe Connection to Junction A	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.8	Installation of Well Cap A, B & C & Site Landscaping	5.2.4	2	24-Jun-21	27-Jun-21
Sub-Task	5.2.9	Rotary Drilling of Groundwater Well D, E & F	5.2.1	10	28-May-21	10-Jun-21
Sub-Task	5.2.10	Installation of Thermoplastic Well Casing D, E & F	5.2.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.2.11	Grouting of Well D, E & F	5.2.3	4	18-Jun-21	23-Jun-21
Sub-Task	5.2.12	Installation of Well Screen D, E & F	5.2.4	1	24-Jun-21	24-Jun-21
Sub-Task	5.2.13	Installation of Submersible Pump & Check Valve for Well D, E & F	5.2.4	3	24-Jun-21	28-Jun-21
Sub-Task	5.2.14	Installation of Well D, E & F Pipe Connection to Junction A	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.15	Installation of Well Cap D, E & F & Site Landscaping	5.2.4	2	24-Jun-21	27-Jun-21
Sub-Task	5.2.16	Rotary Drilling of Groundwater Well G & H	5.2.1	10	28-May-21	10-Jun-21
Sub-Task	5.2.17	Installation of Thermoplastic Well Casing G & H	5.2.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.2.18	Grouting of Well G & H	5.2.3	4	18-Jun-21	23-Jun-21
Sub-Task	5.2.19	Installation of Well Screen G & H	5.2.4	1	24-Jun-21	24-Jun-21
Sub-Task	5.2.20	Installation of Submersible Pump & Check Valve for Well G & H	5.2.4	3	24-Jun-21	28-Jun-21
Sub-Task	5.2.21	Installation of Well G & H Pipe Connection to Junction A	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.22	Installation of Well Cap G & H & Site Landscaping	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.23	QA/QC for Groundwater Wells A, B, C, D, E, F, G & H	5.2.22	2	02-Jul-21	05-Jul-21
Task	5.3.0	Construction of Groundwater Detention Tank & Treatment Structure	3.1.0	60	21-May-21	16-Aug-21
Sub-Task	5.3.1	Staking & Excavation Layout for Groundwater Detention Tank	3.1.0	5	21-May-21	27-May-21
Sub-Task	5.3.2	Excavation for Detention Tank & Treatment Structure	5.3.1	10	28-May-21	10-Jun-21
Sub-Task	5.3.3	Shoring & Anchoring for Major Excavation	5.3.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.3.4	Installation of Slab Formwork	5.3.3	5	18-Jun-21	24-Jun-21
Sub-Task	5.3.5	Installation of Slab Reinforcements	5.3.4	4	25-Jun-21	01-Jul-21
Sub-Task	5.3.6	Concrete Pour for Tank Slab	5.3.5	10	02-Jul-21	15-Jul-21
Sub-Task	5.3.7	Installation of Wall Formwork	5.3.6	5	16-Jul-21	22-Jul-21
Sub-Task	5.3.8	Installation of Wall Reinforcements	5.3.7	4	23-Jul-21	28-Jul-21
Sub-Task	5.3.9	Concrete Pour for Tank Walls	5.3.8	12	29-Jul-21	16-Aug-21
Sub-Task	5.3.10	Installation of Roof Formwork	5.3.9	3	17-Aug-21	19-Aug-21
Sub-Task	5.3.11	Installation of Roof Reinforcements	5.3.10	2	20-Aug-21	23-Aug-21
Sub-Task	5.3.12	Concrete Pour for Tank Roof	5.3.11	5	24-Aug-21	30-Aug-21
Sub-Task	5.3.13	Installation of Pumping System for Detention Tank	5.3.9	5	17-Aug-21	23-Aug-21
Sub-Task	5.3.14	Installation of Treatment Equipment	5.3.9	5	17-Aug-21	23-Aug-21



UBC GROUNDWATER EMERGENCY SUPPLY | PROJECT SCHEDULE

Last Updated: Tue, 13-Apr-2021

Category	ID #	Task	Dependancy	Duration	Start	End
Sub-Task	5.2.13	Installation of Submersible Pump & Check Valve for Well D, E & F	5.2.4	3	24-Jun-21	28-Jun-21
Sub-Task	5.2.14	Installation of Well D, E & F Pipe Connection to Junction A	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.15	Installation of Well Cap D, E & F & Site Landscaping	5.2.4	2	24-Jun-21	27-Jun-21
Sub-Task	5.2.16	Rotary Drilling of Groundwater Well G & H	5.2.1	10	28-May-21	10-Jun-21
Sub-Task	5.2.17	Installation of Thermoplastic Well Casing G & H	5.2.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.2.18	Grouting of Well G & H	5.2.3	4	18-Jun-21	23-Jun-21
Sub-Task	5.2.19	Installation of Well Screen G & H	5.2.4	1	24-Jun-21	24-Jun-21
Sub-Task	5.2.20	Installation of Submersible Pump & Check Valve for Well G & H	5.2.4	3	24-Jun-21	28-Jun-21
Sub-Task	5.2.21	Installation of Well G & H Pipe Connection to Junction A	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.22	Installation of Well Cap G & H & Site Landscaping	5.2.4	5	24-Jun-21	01-Jul-21
Sub-Task	5.2.23	QA/QC for Groundwater Wells A, B, C, D, E, F, G & H	5.2.22	2	02-Jul-21	05-Jul-21
Task	5.3.0	Construction of Groundwater Detention Tank & Treatment Structure	3.1.0	60	21-May-21	16-Aug-21
Sub-Task	5.3.1	Staking & Excavation Layout for Groundwater Detention Tank	3.1.0	5	21-May-21	27-May-21
Sub-Task	5.3.2	Excavation for Detention Tank & Treatment Structure	5.3.1	10	28-May-21	10-Jun-21
Sub-Task	5.3.3	Shoring & Anchoring for Major Excavation	5.3.2	5	11-Jun-21	17-Jun-21
Sub-Task	5.3.4	Installation of Slab Formwork	5.3.3	5	18-Jun-21	24-Jun-21
Sub-Task	5.3.5	Installation of Slab Reinforcements	5.3.4	4	25-Jun-21	01-Jul-21
Sub-Task	5.3.6	Concrete Pour for Tank Slab	5.3.5	10	02-Jul-21	15-Jul-21
Sub-Task	5.3.7	Installation of Wall Formwork	5.3.6	5	16-Jul-21	22-Jul-21
Sub-Task	5.3.8	Installation of Wall Reinforcements	5.3.7	4	23-Jul-21	28-Jul-21
Sub-Task	5.3.9	Concrete Pour for Tank Walls	5.3.8	12	29-Jul-21	16-Aug-21
Sub-Task	5.3.10	Installation of Roof Formwork	5.3.9	3	17-Aug-21	19-Aug-21
Sub-Task	5.3.11	Installation of Roof Reinforcements	5.3.10	2	20-Aug-21	23-Aug-21
Sub-Task	5.3.12	Concrete Pour for Tank Roof	5.3.11	5	24-Aug-21	30-Aug-21
Sub-Task	5.3.13	Installation of Pumping System for Detention Tank	5.3.9	5	17-Aug-21	23-Aug-21
Sub-Task	5.3.14	Installation of Treatment Equipment	5.3.9	5	17-Aug-21	23-Aug-21
Sub-Task	5.3.15	QA/QC for Detention Tank & Treatment Structure (Process)	5.3.11	5	24-Aug-21	30-Aug-21
Sub-Task	5.3.16	Installation of Waterproof Membrane & Access Hatches	5.3.15	2	31-Aug-21	01-Sep-21
Sub-Task	5.3.17	Backfill of Excavation & Ground Elevation Leveling	5.3.16	2	02-Sep-21	06-Sep-21
Sub-Task	5.3.18	Installation of Access Roads & Security Fencing	5.3.17	3	07-Sep-21	09-Sep-21
Task	5.4.0	Construction of Pipe Connection from Reservoir to Main Water Distribution System	5.3.0	10	17-Aug-21	30-Aug-21
Sub-Task	5.4.1	Staking & Excavation Layout for Pipe Connection	5.3.0	3	17-Aug-21	19-Aug-21
Sub-Task	5.4.2	Excavation for Pipe Connection	5.4.1	10	20-Aug-21	02-Sep-21
Sub-Task	5.4.3	Installation of Pipe (PVC or HDPE options) & Tie-Ins to Distribution System & Tank	5.4.2	15	03-Sep-21	26-Sep-21
Sub-Task	5.4.5	Backfill of Pipe Connection Excavation	5.4.3	5	27-Sep-21	03-Oct-21
Task	5.5.0	Construction of Pipe Connection from Junction A to Reservoir	5.2.0	15	18-Jun-21	11-Jul-21
Sub-Task	5.5.1	Staking & Excavation Layout for Pipe Connection	5.2.0	3	18-Jun-21	22-Jun-21
Sub-Task	5.5.2	Excavation for Pipe Connection	5.5.1	10	23-Jun-21	07-Jul-21
Sub-Task	5.5.3	Installation of Pipe (PVC or HDPE options) & Tie-Ins to Distribution System & Tank	5.5.2	15	08-Jul-21	28-Jul-21
Sub-Task	5.5.4	Backfill of Pipe Connection Excavation	5.5.3	5	29-Jul-21	05-Aug-21
Set	**6.0.0**	**Commissioning & Testing**		**30**	**04-Oct-21**	**15-Nov-21**
Task	6.1.0	QA/QC of Integrated System	5.0.0	10	04-Oct-21	17-Oct-21
Task	6.2.0	Project Walkthrough & Inspection with Client	6.1.0	5	18-Oct-21	24-Oct-21
Task	6.3.0	Identification & Completion of Deficiencies	6.1.0	20	18-Oct-21	15-Nov-21
Set	**7.0.0**	**Project Close-Out**		**-**	**15-Nov-21**	**15-Nov-21**



Appendix VII – Cost Estimate

	Item	Quantity	Unit	Unit Cost	Extended Cost
Wells					
	Drilling	8	EA	$ 37,500.00	$ 300,000.00
	Grouting	8	EA	$ 11,800.00	$ 94,400.00
	Testing	8	EA	$ 14,500.00	$ 116,000.00
	Misc. Well Materials & Install	8	EA	$ 20,000.00	$ 160,000.00
	Submersible Pumps	8	EA	$ 5,250.00	$ 42,000.00
	Riser Pipes (71.5m Stainless Steel each)	8	EA	$ 5,000.00	$ 40,000.00
	Well Check Valves - 150mm	8	EA	$ 3,935.00	$ 31,480.00
	150mm Stainless steel PVC adapters	8	EA	$ 65.00	$ 520.00
Distribution Pipes from Wells to Treatment Facility					
	150mm DR18 PVC	2015	LM	$ 35.00	$ 70,525.00
	150mm Tie-rod Restraint	336	EA	$ 45.00	$ 15,120.00
	1.5m Trench Excavation, Backfill, & Compact	2015	LM	$ 125.00	$ 251,875.00
	150mm DR18 PVC Wye	6	EA	$ 65.00	$ 390.00
	150mm DR18 PVC 45 Elbow	16	EA	$ 55.00	$ 880.00
	150mm DR18 PVC 90 Elbow	2	EA	$ 55.00	$ 110.00
	Road Crossing Sawcut	394	LM	$ 8.50	$ 3,349.00
	Road Crossing Paving	197	M2	$ 95.00	$ 18,715.00
	Road Crossing Sidewalk Reinstate	9	EA	$ 425.00	$ 3,825.00
Water Treatment					
	Bulk Excavation - Deep	3150	M3	$ 90.00	$ 283,500.00
	Water Treatment Equipment - S&I	1	EA	$ 225,000.00	$ 225,000.00
	Backfill & Compact excavated material	500	M3	$ 15.50	$ 7,750.00
	Disposal Of Excavated Material	2650	M3	$ 45.00	$ 119,250.00
Reservoir					
	Excavation + Prep				
	Bulk excavation - 54x23x7m	8694	m3	$ 90.00	$ 782,460.00
	Excavation Disposal	7824.6	m3	$ 45.00	$ 352,107.00
	Ground Improvement	1	EA	$ 200,000.00	$ 200,000.00
	Slab				
	Slab Concrete Supply	1092	M3	$ 200.00	$ 218,400.00
	Slab Rebar Supply & Install	87.36	MT	$ 1,900.00	$ 165,984.00
	Slab Formwork Supply & Install	146	M2	$ 14.50	$ 2,117.00
	Place Slab Concrete	1092	M3	$ 27.50	$ 30,030.00
	Finish Slab Concrete	1092	M2	$ 15.00	$ 16,380.00
	Walls				
	Walls Concrete Supply	365	M3	$ 200.00	$ 73,000.00
	Walls Rebar Supply & Install	29.2	MT	$ 1,900.00	$ 55,480.00
	Walls Formwork Supply & Install	740	M2	$ 107.00	$ 79,180.00
	Place Walls Concrete	365	M3	$ 51.00	$ 18,615.00
	Finish Walls Concrete	740	M2	$ 8.60	$ 6,364.00
	Roof				
	Roof Concrete Supply	278.25	M3	$ 200.00	$ 55,650.00
	Roof Rebar Supply & Install	22.26	MT	$ 1,900.00	$ 42,294.00
	Roof Formwork Supply & Install	2646	M2	$ 129.00	$ 341,334.00
	Place Roof Concrete	1370.25	M3	$ 28.00	$ 38,367.00
	Finish Roof Concrete	2646	M2	$ 12.50	$ 33,075.00
	Finishing				
	Backfill & Compact	869.4	M3	$ 15.50	$ 13,475.70
	Repave	1375	M2	$ 125.00	$ 171,875.00

Distribution Pump Station					
	600mm PVC Feeder	10	LM	$ 294.71	$ 2,947.08
	System Distribution Pumps - KSB KWP 80-404	4	EA	$ 21,500.00	$ 86,000.00
	1040mm PVC Intake Header	30	LM	$ 787.20	$ 23,616.00
	1040mm PVC 90 Elbow	1	EA	$ 4,200.00	$ 4,200.00
	350mm PVC	12.5	LM	$ 96.24	$ 1,202.94
	350mm PVC Flange Adapters	16	EA	$ 368.00	$ 5,888.00
	400mm PVC	25	LM	$ 121.82	$ 3,045.48
	400mm PVC Flange Adapters	16	EA	$ 475.00	$ 7,600.00
	400x400x400mm PVC Tee	5	EA	$ 655.00	$ 3,275.00
	350mm Gate Valve	4	EA	$ 16,658.00	$ 66,632.00
	400mm Check Valve	4	EA	$ 13,500.00	$ 54,000.00
	400mm Gate Valve	3	EA	$ 19,485.00	$ 58,455.00
Booster Station to UBC Distribution Pump Centre along West Mall					
	400mm DR18 PVC	750	LM	$ 121.82	$ 91,364.40
	400mm DR18 PVC 90 Elbow	6	EA	$ 1,100.00	$ 6,600.00
	400mm DR18 PVC 45 Elbow	4	EA	$ 1,100.00	$ 4,400.00
	2.0m Trench Excavation, Backfill, & Compact	750	LM	$ 197.00	$ 147,750.00
	Traffic Control	5	Days	$ 1,500.00	$ 7,500.00
	Pavement Sawcut	1500	LM	$ 8.50	$ 12,750.00
	Repave	700	M2	$ 125.00	$ 87,500.00
	Distribution Tie In	1	EA	$ 16,750.00	$ 16,750.00
	Thrust Blocks	6	EA	$ 2,800.00	$ 16,800.00
Electrical System					
	Controls System Supply & Install	1	EA	$ 125,000.00	$ 125,000.00
	Emergency Power Supply Generator System	1	EA	$ 150,000.00	$ 150,000.00
Infrastructure Maintenance		50	YR	$ 8,500.00	$ 425,000.00
Public Consultation					$ 10,000.00
Permitting					$ 100,000.00
Mob/Demob					$ 150,000.00
QC Testing - 2% of Direct Costs					$ 109,283.05
System Commissioning					$ 250,000.00
Indirects - 20% estimate					$ 1,301,687.13
Contingency - 15%					$ 1,171,518.42
Engineering Design Fees - 1%					$ 89,816.41
				Total	**$ 9,071,457.61**