WATER STREET ENGINEERING LTD.

INFRASTRUCTURE PLANNING AND DESIGN

City of Vancouver
Burrard Sewage Pump Station
Condition Assessment

19 Jan 2018
Rev. 0

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City of Vancouver
Burrard Sewage Pump Station
Condition Assessment

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1. INTRODUCTION

1.1. Background

The City of Vancouver (the City) retained Water Street Engineering Ltd. (WSE) to complete an assessment, high-level scope of work, and cost estimate for refurbishing the Burrard Pump Station, located at 300 Burrard Street (below the Burrard and W. Cordova Street intersection).

The wastewater pump station was constructed in 1984. It is a wet-pit/dry-pit configuration with three submersible pumping units with a reported design capacity of 100 L/s each. In addition to the wet well, the station has a below-grade valve chamber housing the discharge control valves, and an above-grade building housing the controls, fans and air system.

This report assesses the current condition of the station, identifies opportunities for improving operation, safety controls and instrumentation, and making the station overall more resilient. This information can be used to inform future refurbishments and upgrade plans for the station.

1.2. Work Completed

The assessment included evaluations of the following:

- Operational (condition and capacity, safety and operability, and flood proofing)
- Structural/geotechnical (static evaluation and seismic resiliency)
- Mechanical (pumps, valves, piping, instrumentation, etc.)
- Electrical and controls (controls, PLCs, and standby power)

The options analysis identified and developed opportunities, and made recommendations for upgrades, in those areas based on the existing condition of components, occupational health and safety requirements, current industry practices, and efficiency improvement opportunities.

1.3. Definitions / Abbreviations

m geodetic	Metres above mean sea level
MCC	Motor Control Center
PCV	Pump Control Valve
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition

1.4. Study Team and Acknowledgements

This study was led by the following professionals:

- Allan Bronsro, MCIP, PEng, technical lead, Water Street Engineering Ltd.
- Helena Wiegand, PEng, geotechnical lead, Thurber Engineering Ltd. (Thurber)
- Adam Williams, PEng, structural lead, Gygax Engineering Associates Ltd. (GEA)
- David Black, PEng, electrical lead, PBX Engineering Ltd. (PBX)

The team acknowledges the help and contributions received from City of Vancouver staff, including but not limited to Wally Konowalchuk, PEng (Project Manager), Derek Bailey (Pump Stations System Controller), and Scott Clarke (Engineering Assistant, Wastewater Pump Stations).

2. DESCRIPTION OF PUMP STATION

2.1. General

The Burrard Sewage Pump Station was built in 1984. It is a wet-pit/dry-pit configuration with a nominal pumping capacity of 200 L/s. In addition to the wet well, the station has a below-grade valve chamber housing the discharge control valves and pump isolation valves, and an above-grade building housing the controls, fans and air system.

The station is located near the north-east corner of the Marine Building, under the intersection of Burrard Street and West Cordova Street, which are both on elevated guideways at this location. The building is located under the Burrard/Cordova bridge system, and is not accessible from those streets. Access is via a ramp at Granville Street. Vehicle traffic requires passing two gates between the ramp and the station. Normal pedestrian traffic is similarly limited by these gates, but the exclusion is not complete, as access is possible (albeit difficult) from the bridge deck.

2.2. Substructure

The substructure consists of two reinforced concrete chambers with a common wall. Their common roof at ground level is at 3.392 m geodetic (top of concrete). The bottom of the wet well is at -4.075 m geodetic (top of concrete), and the dry well at 0.040 m geodetic.

From the records provided, the substructure appears to be founded on bedrock.

Access to the wet well is via a manhole cast into the top slab (see below), and a ladder to an intermediate deck at -0.400 m geodetic.

2.3. Superstructure

The above-ground building is of reinforced masonry, and has three rooms: a main control room, a washroom, and a separate electrical room (with own entrance) housing the junction boxes for the pumping units.

The roof is flat, consisting of built-up roofing over steel decking.

2.4. Pumping Units

The station is provided with three identical Hydr-O-Matic Series S8L submersible pumping units with a duty point of 100 L/s (1,575 USgpm) at 22.3 m (73 ft.), and integral 50 HP, 575 VAC motor. These units have guide rails and hydraulic sealing flanges that permit them to be raised for servicing without the need for personnel to enter the wet well.

The pumping units can be lifted through hatches in the top slab, using a monorail built into the roof structure of the building.

2.5. Piping and Valves

Station piping is carbon steel. The riser pipes, valves and discharge headers are 250 mm diameter, and the forcemain is 300 mm. Check valves are not used. Each discharge header has a pneumatically actuated pump control valve (PCV), plus an isolation valve. The forcemain has a station isolation valve where it exits the valve chamber. All valves are Valmatic plug valves.

The PCV has a closing time of 30-40 s. A compressor on the main floor provides air for the valves.

2.6. Level Control

Originally equipped with a bubbler system, the station now has a redundant Milltronics EnviroRanger ERS500 ultrasonic system. The secondary level controller is in cold stand-by.

The level controllers send lead pump start/stop, lag pump start/stop, mixer call, and low and high level signals to the relay based pump control system.

2.7. Ventilation

On the dry side, air is drawn into the valve chamber by gravity, and exhausted by a wall fan located near the exterior door.

On the wet side, air is supplied to the wet well by a roof-mounted fan, and exhausted through a pipe vent by gravity.

The flows are not known.

2.8. Cranage

Three permanent monorail systems are provided:

- Over the wet well hatches, for removing the pumping units,
- In the valve chamber, and
- In the control room, for lifting items to/from the valve chamber.

2.9. Primary Electrical Distribution

The station is supplied from BC Hydro with a 347/600 VAC, 3-phase, 60 Hz supply. The primary distribution equipment is original to the station and is mounted on the north wall. It consists of a main incoming cable pull box, main breaker, metering current transformer compartment, BC Hydro metering cabinet, and a primary distribution panel board. A manual transfer switch and cable for connection to a mobile generator was added circa 2009, and ties into the system at the current transformer compartment.

The primary panel board distributes power to a 15 kVA, 100 A, 600-120/208 V transformer for general house loads, a power factor correction capacitor, the mixer motor starter, and a two-section Motor Control Center (MCC) containing the pumping unit starters and pump controls. The MCC and transformer are located on the west wall and are also original to the station.

A single line sketch of the primary distribution is provided in Appendix 2.

2.10. SCADA and Control System

The station SCADA and control system is composed of the following main elements:

- Pump Controls: A relay-based pump control system is located within a section of the MCC and contains relay logic to interpret signals from the station level sensors and control the starting and stopping of the pumps. A pump alternator module controls the selection of the lead and lag pumps by mechanically advancing the lead pump sequence based on shut-down of the operating lead pump.
- SCADA Cabinet: A wall-mounted SCADA cabinet contains a Motorola ACE 3600 RTU and Beijer HMI screen, and gathers site diagnostics information and relays it to the central SCADA system.

- Mixer Motor Control: A wall-mounted cabinet contains a relay module to control the mixer motor starter contactor.
- Air Compressor Control Cabinet: A wall-mounted cabinet contains relay logic for starting and stopping the air compressor unit used for actuation of the pneumatic PCVs.

2.11. General Electrical

A 15 kVA, 600-120/208 V transformer provides power to a 100 A, 120/208 V panel board for distribution to general electrical loads within the station. Power is distributed through surface-mounted armoured electrical cable and rigid metallic conduit. The general electrical loads are summarized in the panel schedule below.

<table>
<tr><th>Description</th><th>Bkr.</th><th colspan="2">Circuit No.</th><th>Bkr.</th><th>Description</th></tr>
<tr><td rowspan="3">Air Compressor 1</td><td rowspan="3">15A</td><td>1</td><td>2</td><td>15A</td><td>Tele System</td></tr>
<tr><td>3</td><td>4</td><td rowspan="3">30A</td><td rowspan="3">Heater No. 1</td></tr>
<tr><td>5</td><td>6</td></tr>
<tr><td rowspan="3">Air Compressor 2</td><td rowspan="3">15A</td><td>7</td><td>8</td></tr>
<tr><td>9</td><td>10</td><td rowspan="3">20A</td><td rowspan="3">Outside Receptacle Box</td></tr>
<tr><td>11</td><td>12</td></tr>
<tr><td>Outside Receptacle Box, GFCB</td><td>15A</td><td>13</td><td>14</td></tr>
<tr><td>Lighting</td><td>15A</td><td>15</td><td>16</td><td>15A</td><td>Sump Pump</td></tr>
<tr><td>Receptacles</td><td>15A</td><td>17</td><td>18</td><td>15A</td><td>Roof Fan</td></tr>
<tr><td>Hot Water Tank</td><td>15A</td><td>19</td><td>20</td><td>15A</td><td>Exhaust Fan</td></tr>
<tr><td>Mixer Control Power</td><td>15A</td><td>21</td><td>22</td><td>15A</td><td>Cathodic Protection</td></tr>
<tr><td>Generator Block Heater (23A)
Charger/Heater (23B)</td><td>15A
15A</td><td>23</td><td>24</td><td>15A</td><td>Pump Control Power</td></tr>
</table>

3. PUMP STATION ASSESSMENT

3.1. Summary

The City wishes to adopt a condition-based (as opposed to age-based) asset management system, and consequently has assessed the station and its equipment from that perspective where applicable.

3.2. Assessment Criteria

The standards against which the station was assessed include the following:

- The City of Vancouver *Sewage Pumping Requirements*, Sewers and Drainage Design Branch, v.0.2 Sep 2017 (referred to as the SPR).

- The British Columbia *Occupational Health and Safety Regulation* (the OHS Regulation).
- The City of Vancouver *Building Bylaw 10908.*
- The City of Vancouver *Flood Plain Standards and Requirements*, Jan 2015.

The City's SPR provides general guidance on most topics, rather than mandatory requirements, as it recognizes the need for specific criteria to be developed for each situation. There are some mandatory requirements, however, and these are referenced where appropriate.

Other references are cited in the text where appropriate.

3.3. Operational Assessment

Access Hatches

The wet well is equipped with hinged access hatches for pump removal, and a cast manhole cover for personnel access. The hatches are Hydr-O-Matic Pump Co. aluminum hatches for concrete installation

SPR 4.1.2 requires exterior hatches to be equipped with a locking mechanism, watertight slam-lock mechanism, and oversized recessed padlock hasp with a flush cover plate. It is not clear if the City would require such locking mechanisms on the heavy cast lid, but then the SPR does not envision such a lid for entry.

SPR 4.1.2 requires telescoping ladder extension safety posts to be installed at all personnel entry points to underground chambers. These are not provided. Fall protection grids within each service hatch opening are desired.

Wet Well

The wet well is adequately sized to prevent excessive pump cycling, and is generally in accordance with the requirements of SPR 4.2. Observed exceptions are noted.

SPR 4.2.6 requires that ladders be constructed of non-corrosive material, and platforms and handrails to be constructed of fiberglass where possible, and anchored using stainless steel fasteners. The ladder and the intermediate deck grating are made of mild steel. The record drawings indicate the deck is fastened to the wall with stainless steel inserts, while the ladder is fastened with Hilti Kwik-Bolts.

SPR 4.2.7 requires that concrete wet well walls be epoxy coated. The walls were not coated when the station was built, and it would not be practical to coat them now. This requirement should be considered to apply to new structures.

SPR 4.2.11 requires a sluice gate to be installed at the inlet to the wet well. During an upgrade in 2009, a gate valve was bolted to the wet well wall at the inflow location.

Wet Well Hydraulics. Although the volume is adequate for pump cycling, the hydraulics of the incoming sewer are not ideal. If the sump is not designed correctly, the hydraulic environment may affect the pump operation — resulting in diminished design performance and reduced pump life. To allow the pumps to operate in a suitable environment, some general points should be considered:

- Flow of water from the inlet of the wet well should be directed towards the pump inlet.
- The flow should be uniform without swirl or air entrainment.

- The walls should be designed to avoid stagnant regions in order to prevent the formation of air-entraining surface vortices and sediment accumulation.
- The water depth should be great enough to suppress surface vortices.
- Excessive turbulence or large eddies should be avoided, although a minor amount of turbulence helps to prevent the formation and growth of vortices.

In the Burrard station, the inlet sewer is situated in a way that creates a significant drop entering the wet well. Also, the flow enters parallel to the line of pumps, rather than being directed towards each individual unit. Among other issues, this can cause pre-swirl of the water entering the pumps. However, this is not particularly unusual in pump station design. In this case, no problems were noted or reported by the City. The City does not consider there is any evidence indicating hydraulic problems with the wet well.

Dry Well (Valve Chamber)

The valve chamber is considered by the City to be a confined space based on the OHS Regulation (Section 9.1) definition of a "confined space" as one that

a) is enclosed or partially enclosed,

b) is not designed or intended for continuous human occupancy,

c) has limited or restricted means for entry or exit that may complicate the provision of first aid, evacuation, rescue or other emergency response service, and

d) is large enough and so configured that a worker could enter to perform assigned work.

The confined space designation is based on two issues, namely poor ventilation and poor access. First, as noted in Section 2, air is drawn into the valve chamber by gravity, and exhausted by a wall fan located near the door. This means that ventilation is ineffectual when the door is open. Second, access is by means of a vertical ladder.

SPR 4.3.3 requires that adequate horizontal and vertical clearance be provided for removal of all equipment and for other maintenance purposes. As a subjective matter, the space in the chamber is considered very cramped. There is only about 700 mm clear between the discharge headers.

Odour Control

Odour control is not provided. SPR 1.4 requires only that odour control be considered “where required”.

Emergency Operation

Bypass Pumping. SPR 2.1 requires pumping stations to have provisions to allow temporary by-pass pumping around the station, and to isolate the forcemain by means of isolation valves. The station has these provisions.

Standby power. SPR 2.2 requires pumping stations to have provisions for supply of emergency power in the event of a power failure. The station has this provision by means of a manual transfer switch and cable for connection to a mobile generator. Note, however, that if the station does not contain an on-site generator, SPR 2.3.1 requires provision for a minimum of 2 hours’ storage during peak flow conditions (i.e., the peak flow the station is currently experiencing). The City periodically re-assesses the storage time at the station to determine if a genset is to be added to meet the city guidelines.

Storage. SPR 2.3 requires some storage to be provided. It suggests 2 hours but with the determination to be made by the designer. The station has approx. 41.5 m^3 of storage between the “lead pump on” and the overflow elevations. This would not provide 2 hours' storage at the rated capacity of the pumps, but appears to be adequate under known conditions. In addition to the wet well, the inflow pipe network also stores effluent, this is volume is estimated by the City to be 135 m^3.

The most recent reported storage timing trial performed by the City was in Nov 2015 during a morning peak inflow. During that test, the station reached the spill point 114 minutes after the pumps were turned off, that is, clos to 2 hours.

It is also noted that the station has an overflow to the storm system. This alleviates concern about sewer back-up and station flooding, but leaves potential concerns about sewage overflows to the environment.

Overflow. SPR 2.4 requires an overflow to the sanitary or storm system, which the station has; it also requires the overflow to have a submerged inlet to limit the escape of solids, floatables and scum into the storm manhole; it is not clear if the overflow is so equipped.

It is noted that a station failure occurred on 20 Oct 2017. Pump 1 and pump 2 failed to start due to a 'high temp' alarm. Due to the pump alternator arrangement noted in Section 3.6, the station also did not start pump 3. This required City operators to attend the site to reset the alarms to re-start the pumps. There was no apparent reason for the high temperature alarms. However, this condition occurred just after a 'brown out' alarm at the station (i.e., momentary power interruption). City staff suspected that a power surge caused an errant high temperature alarm in pump 1 and pump 2. There were power issues that evening due to a lightning strike.

Flood Protection

The station is not in a designated floodplain or wave effect area (reference *Flood Plain Standards and Requirements*). However, the main floor slab (at 3.39 m geodetic) is below the Flood Construction Level (FCL) of 4.6 m geodetic.

The station is not necessarily required to be built above the FCL as it is not used for "habitation, business or storage of goods" but it would be rendered inoperable by a flood to that level, as the electrical equipment would be wetted.

See below for assessment of specific affected systems.

3.4. Seismic and Structural Assessment

SPR 1.2.5 requires new stations to be designed and built to the appropriate codes for a post-disaster building. For a current structure, this would require structural design in accordance with the current Vancouver Building Bylaw (VBBL 2014), which has Part 4 structural provisions based on the 2012 British Columbia Building Code (BCBC 2012). Consequently, a new facility designed per SPR 1.2.5 would require design to the BCBC 2012 structural provisions and referenced codes, with the building classified as post-disaster.

Seismic Assessment

The results of a desktop seismic evaluation performed by Thurber Engineering Ltd. is attached as Appendix A.

The assessment indicates that the pump station substructure is founded on bedrock. Post-seismic settlement of the structure is expected to be negligible. However, seismic performance of the overhead viaduct and adjacent retaining wall present a potential risk to the pump station.

Description of Structural System

The structure consists of a reinforced concrete below-grade substructure and reinforced masonry superstructure, with a metal deck roof diaphragm.

The reinforced concrete substructure includes a 3.66 m x 2.9 m x 7.5 m deep wet well and adjacent 3.66 m x 3.35 m deep dry well (inside to inside dimensions) with 450 mm thick exterior and interior walls. The main floor slab over the wet and dry wells is at grade, elevation 3.392 m geodetic. All exterior walls are two-way spanning for out-of-plane loads, and per available drawings detailed with two layers of reinforcement each face, anchored at wall corners and intersections to provide rigid connections.

The structure is founded on sandstone bedrock and, per the available drawings, roughly the lower half of the wet well walls are cast directly against the rock sides.

The superstructure consists of a reinforced masonry single-storey structure, 3 m high and 4.57 m x 4.57 m in plan area (out to out), with a metal deck roof diaphragm. Blocks are nominal 200 mm wide, and reinforced and grouted vertically every 1.2 m and at corners and openings, with reinforced bond beams at the tops of walls. The roof buildup includes a metal deck diaphragm supported on either embedded plates cast into the bond beam (north-south walls) or on a steel beam in turn supported on an embedded plate into the bond beam (east-west walls). Metal deck connections (side laps and deck to supporting members) are not shown on the available drawings.

Current Structural Condition

Based on a visual inspection of the facility completed on 30 Sep 2017, review of structural record drawings, and discussions with City of Vancouver staff during the site visit, the existing structure generally appears to conform well with the available record drawings. City staff on site were not aware of any structural modifications being made since original construction, and no modifications were apparent.

The wet well was inspected with a visual inspection from the opened access hatches only. In general, the visible concrete appears sound with no sign of visible spalling or reinforcement corrosion, although concrete below the water line was not visible. There is no sign of any foundation or wall movement, and no cracks were observed to the visible upper portion of the concrete walls or slab.

The steel platform and ladders within the wet well are visibly corroded, even viewed from a distance. Per the available drawings, these were originally specified as galvanized steel, although it appears the galvanized coating is no longer present and the steel is corroded and may have section loss.

The concrete dry well appears to be in generally good condition. There is no sign of any corrosion of reinforcement or movement or deterioration to the concrete walls, other than some narrow shrinkage cracks visible to the dry well floor around the valve stands.

The masonry appears to be in good condition based on a visual inspection of accessible areas, with no sign of any movement, visible cracking or deterioration. Similarly, the steel roof beams, monorails, roof and visible bolted connections appear in good condition with no sign of corrosion.

The connections between the steel roof deck diaphragm and tops of walls are not shown on record drawings and were not visible during the inspection. These connections likely consist of puddle welds to the embedded steel plates cast into the top of the masonry as detailed on the record drawings, although size and spacing of welds, if present, have not been confirmed. As the structure contains asbestos in the insulation, and wall / ceiling coverings consequently are painted, it is not practical to inspect this area under the scope of this assessment.

There is no sign of any water ingress into the structure or issues with the building envelope, and the Cordova and Burrard Street viaducts above provide almost total protection from rainfall and snow.

Structural Assessment for Static (non-Seismic) Loads

For non-seismic load cases (gravity, wind, lateral earth pressure, flood, and imposed (live) loads from usage and pipe thrusts), based on the current structural condition as noted above, the structure is likely to still have similar structural capacity as when originally designed and constructed, as the structure is in close to original condition without significant modification.

As the structure was constructed in 1984, it was likely designed to environmental loads specified in the 1980 National Building Code / 1981 BC Building Code.

As the structure is essentially protected from snow and significant wind loads by the elevated guideways above and surrounding buildings, snow and wind loads are not assessed to be a concern, although post-disaster requirements mean that loads for the design of a new facility designed today would be about 25% greater than the loads used for the original design. Provided there are no plans to demolish the viaducts or surrounding buildings providing weather protection during the remaining life of the facility, the structure is assessed to be in conformance with the performance requirements for a new post-disaster facility for snow and wind loads.
The structure is located at a low elevation and is subject to potential flooding from sea water in an extreme event. However, calculations show that the structure has sufficient weight to resist potential uplift for flood levels up to the ground floor or above, with a factor or safety against uplift during flood of greater than 1.5 for flood with all doors sealed and the wet well empty to elevation 4.60 m, the designated design flood level for the City of Vancouver (per City of Vancouver Flood Plain Standards and Requirements). This flood level, however, exceeds the main floor slab and door sill elevation of EL. 3.4 m geodetic. See elsewhere for discussion of the effects of facility flooding on mechanical and electrical equipment.

Structural Resiliency Assessment for Seismic Loads

A structural resiliency assessment for seismic loads has been completed in accordance with the Tier 1 / Tier 2 procedures of ASCE 41-2013 “Seismic Evaluation and Retrofit of Existing Buildings”. This standard provides a performance-based, three-tier processes for seismic evaluation of existing buildings to a range of performance objectives.

The ASCE 41 code is used as it is the most comprehensive seismic evaluation and retrofit procedure in North America, and there is no equivalent Canadian code. The procedures in ASCE 41 or similar seismic evaluation guidelines are in general more appropriate for evaluating existing structures than new building codes, which typically include provisions that encourage or require designs with features important for good seismic performance such as regular configuration, structural continuity, ductile detailing and material requirements which may not be present in existing buildings.

The assessment was completed by using the Immediate Occupancy (S-1) Structural Performance Level and Position Retention (S-B) Non-Structural Performance Level, which are analogous to the Post-Disaster performance level of structures designed to VBBL 2014, and by using 1 in 2,475-year return period ground motions.

A Tier 1 screening assessment was performed for the pump station. This consisted of a series of simple analytical checks on key elements of the seismic force-resisting system and completing a series of checklists, based on the analytical checks, information on available record drawings, and field observations of the structures. This procedure allowed for a rapid identification of elements that either conform to the required performance level or are non-conformant and need to be evaluated further. Where elements were evaluated as Non-Compliant to Tier 1, and where there was sufficient information available to allow, a more detailed Tier 2 analysis of the Non-Compliant analysis was completed.

The Tier 1 and Tier 2 assessment to the Immediate Occupancy structural performance level under the 1 in 2,475-year ground motions shows that most structural components are in conformance with the requirements of this performance level. Although building code seismic loads and ductility requirements for new structures have increased between the time of original design and today, the pump station is a relatively small structure with a regular structure layout, short spans, few openings, and reinforcement and joint detailing that provides structural continuity through joints. Consequently, both the above-ground reinforced masonry structure and below-grade reinforced concrete wet and dry wells are expected to generally perform well in an earthquake.

Two items were flagged as potentially deficient from the seismic resiliency analysis:

1. The connection between the top of the masonry walls and the metal deck diaphragm is unknown. This connection detail is not fully detailed on the available drawings and is not readily accessible for visual inspection. This connection is required to be sufficiently strong to resist the out-of-plane seismic loads from the masonry wall and transfer them to the diaphragm. Preliminary analysis showed that the wall does not have sufficient out-of-plane capacity to resist such loads without this connection under a 1 in 2,475-year earthquake. It is possible that the actual connection consists of puddle welds from the diaphragm to an embedded plate cast into the top of wall and has sufficient strength, but further inspection is required to verify this. Inspection is complicated by the need to remove roof coverings, potentially involving removal of asbestos-containing material. If required, a simple retrofit can be provided by installing bolted connection brackets to the inside of the building between the steel deck and the wall.

2. The structures surrounding the pump station, including the Burrard Street overhead viaduct, the Cordova Street viaduct, and the steep soil slope and abutment behind the pump station that forms the abutment of the Burrard Street viaduct, have the potential to significantly damage or destroy the pump station if they exhibit structural failure during an earthquake. Detailed seismic assessment of these structures is outside this scope of work. For seismic resiliency purposes, the resiliency or performance level of the pump station should not be taken as greater than the return period of the seismic ground motions that surrounding structures have been assessed or designed to for a collapse prevention limit state. In addition, surrounding structures further away (such as the eastern extents of the Cordova viaduct or surrounding buildings), although unlikely to damage the pump station, may disrupt or prevent access to the pump station if they suffer significant damage during an earthquake.

Pumping Units and Other Equipment

The brief visual inspections undertaken for this report did not reveal any obvious concerns with seismic restraint of equipment. The main mechanical and electrical equipment (e.g., the compressor, the piping and the MCC) appear to be adequately attached. However, seismic loadings for equipment were not assessed in detail.

The submersible pumping units are protected from seismic forces primarily by proper anchorage of the discharge heads to the concrete floor slab. This was not checked but should be assessed as part of future design work.

Asbestos

The concrete block walls are reported to contain asbestos (vermiculite). The suspended ceiling tiles may also contain asbestos. The City's asbestos policy describes the precautions and processes to safely demolish and dispose of these materials.

3.5. Mechanical Systems Assessment

Pumping Units and Capacity

A design flow was not provided against which to assess the capacity of the station. As noted, the stated duty point of the pumps is 100 L/s (1,575 USgpm) at 22.3 m (73 ft.) (certified performance curves in the Operating Manual, reproduced in Appendix 3).

WSE performed a brief check of the system curves (also in Appendix 4). These curves show a capacity of 105 L/s and 154 L/s with one and two pumps operating, respectively. The firm capacity of the station would thus be 154 L/s. It is emphasized that these checks are approximate only, and based on assumptions, including those listed in the appendix. Information about the forcemain material, internal diameter, and lining, was not available. The relative flatness of the pump and system curves mean that small differences in assumption about friction lead to relatively larger differences in estimated capacities. The curves cannot be used to assess the capacity of the pumps; actual measurements should be used.

Measurements from SCADA data. The station has no flowmeter; pump discharge flows were estimated from SCADA data (on-off and wet-well level) for 28 and 29 Sep 2017, as follows:

Table 3-1: Measured Pump Capacities (from SCADA records)

Pump Number	Average Flow (L/s)	Minimum Flow (L/s)	Maximum Flow (L/s)
1	78	68	85
2	85	74	93
3	93	75	104
All	**85**	**68**	**104**

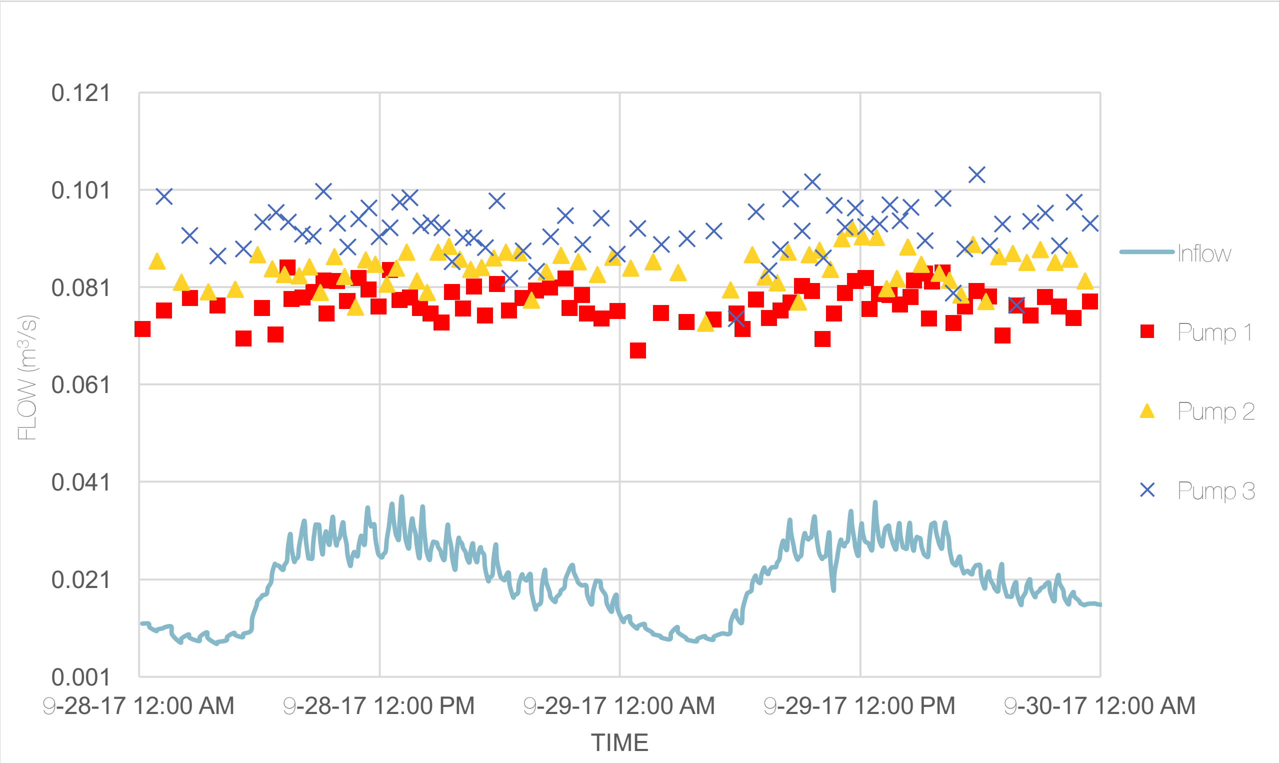
This method of flow measurement is subject to uncertainty of at least +/-15%. Because of the amount of time taken for the PCVs to open and close, the method tends to under-estimate the actual pump capacity (because the flow is restricted for a portion of the pumping cycle). On 29 Nov 2017, City staff performed manual pump-down testing with greater accuracy than was available from SCADA records, and measured the following discharge flows:

- Pump 1: average 93 L/s
- Pump 2: average 125 L/s
- Pump 3: average 108 L/s
- Pumps 1 and 3 together: 169 L/s

Although the measurements are approximate, they provide evidence that (i) there is variability among the individual pumps, and (ii) at least two of the pumps are operating below their theoretical performance.

The highest inflow estimated by the above method was 38 L/s. While this value does not represent a design flow, it provides some evidence that the station has plenty of capacity on days with moderate rainfall. September 28 was a dry day. September 29 had some rain in the morning, but not enough to constitute a design event for inflow and infiltration. While there was a clear diurnal pattern to the sewage inflows, there was no obvious difference between the two days, indicating that I&I was not significant during the event of 29 Sep. The City reports that the station rarely requires two pumps to operate together.

Figure 3-1: Estimated Inflows and Pumped Flows, 28-29 Sep 2017



Pump Condition

The current condition of the pumping units is not known. The City provided some maintenance records. The most recent comprehensive reports date from 2003, although the pumps have been serviced more recently. The equipment log at the station indicates that pump 3 was serviced in October 2010, pump 2 was sent in due to seal failure and cable blistering in January 2013, and pump 2 was sent in again for seal failure in July 2016.

Condition Reports. The last known comprehensive condition assessments and overhauls of all three pumping units were performed by Spears Sales and Service Ltd., Vancouver, in 2000 (Appendix 3). Records indicate that two of the units were also overhauled in 2003. No major failures were noted on either occasion. With some variations among the three units, the main issues found on those occasions include the following:

- Water and/or oil ingress into the seal chambers
- Leaks in the dry cap assemblies
- Worn or failed seals
- Power and/or sensor cords fraying
- Rotating parts out of balance
- Bent shafts
- Excessive clearance between the impellers and wear rings

Again, with some variations, the work done included the following (ignoring routine items such as fluid changes):

- Replacement of the mechanical seals (or just the lower seals)
- Repotting of the cable connections
- Balancing of rotating assemblies

- Straightening of shafts
- Replacement of at least the lower bearings
- Replacement and machining of the wear rings

The condition of the impellers varied among the units. The impellers do not appear to wear at the same rates. Some mechanical seals had failed in 2003 due to ingress of solids between the surfaces. It is likely that at least some of the stators will need to be re-wound, if they have not already been since the 2003 repairs.

Barring a major rebuild of the station, which would include replacement of all equipment, the decision to replace the pumps should be based on an economic analysis, balancing capital cost against pump efficiency (energy cost) and maintenance costs.

Maintenance Schedule. A typical maintenance program for medium-sized submersible pumping units would include items similar to the following:

> Monthly: take readings of flow, head (pressure), amperage, and running hours. Note any unusual or increased noise, chattering of vibration. Keep records to track trends. Measurements with a vibration meter are not practical but a monthly check should be done on the installation and look, sound and feel of the operation. For example, the guide bars may be chattering more than normal, or the discharge piping may be vibrating more than normal. All these may be symptoms of a pump being off balance due to plugging impeller, a chip out of the impeller, not sitting on discharge connection properly, rocks or settlement build-up in the bottom of the wet well, or a cable caught up in the suction. The operator may notice a drop in flow or pressure that would indicate some wear or other problem. These types of documented observations can greatly extend the service life of the bearings, stator, and inside mechanical seals.
>
> Annually or semi-annually: inspect the electrical circuits, including control circuits and contacts to eliminate nuisance control failures or more extreme failures such as single-phasing or grounding of the motor winding circuits.
>
> Every 3 to 5 years: pull the pumps for a full maintenance, typically including the items listed above, plus replacement of fluids and O-rings. The motors may need to be rewound.

Service Life. The critical parts of pumps do not wear at the same rates. This means that asset management of the pumps should be based on maintenance rather than ‘condition’ as such, or expected service life. The BOMA publication referenced in Section 3.6 provides estimated life of pumping units between 10 and 25 years but these are not necessarily applicable, for the reasons given above. Nevertheless, 30 years of service is considered high. While this is not in and of itself reason to replace the units, the difference in pumping rates at this time may indicate that replacement should be considered.

Other Concerns. The City notes that the guide rail system is problematic from a maintenance perspective. They tend to come apart and get in the way of the level controllers. The two rails for each pump are also spaced relatively far apart, making alignment with the pump installation more difficult.

Piping and Valves

No significant concerns were noted with respect to the piping.

SPR 3.3.5 requires the station to have indicating pressure gauges on each discharge header and on the main header pipe; and to have a pressure transmitter provided on the main header. These are not provided.

The plug valves and actuators in the station were observed visually but not internally. Maintenance records were not provided. The assessment of both the valves and actuators is dependent on past service and current service conditions, but below are guidelines to follow.

The seals on the valves should last for at least 10 years. Some leakage was observed from the seals of the PCVs. The manufacturer recommends that the valves be cycled at least once a month. It is recommended to keep a rebuild kit or spare valve on site.

The pneumatic actuators should be in acceptable condition since they are working satisfactorily. However, once air starts passing/leaking, they should be rebuilt.

Flow Measurement

SPR 4.6 requires a magnetic flow meter to be provided and connected to the SCADA system. This has not been done.

Flooding

Flooding to an elevation of 4.60 m geodetic would affect some mechanical equipment in the station. The submersible pumps, of course, would not be affected. See also Section 3.6 for the effects of flooding on motors and other electric and electronic equipment.

Air Compressor: The compressor powers the control valves and so is a critical piece of equipment. Its motor and controls would be damaged by flood water, but it would be a relatively simple matter to raise the assembly so these are above the FCL. A small portable work platform may be required for maintenance.

Valve Actuators: The pneumatic actuators should be able to be submerged for short periods without damage but they are not intended to operate submerged. They would require a complete disassembly and service following submersion.

Fans: These are above the FCL.

3.6. Electrical and Controls Systems Assessment

General Electrical

Most of the electrical equipment and distribution infrastructure in the pump station appears to be original. This includes the main incoming circuit breaker, the primary 347/600 V distribution equipment and panel board, the MCC lineup and pump starters, and the 600-120/208 V transformer and secondary 120/208 V panel board. Based on a visual assessment, this equipment appears to be in satisfactory condition, and there are no signs of excessive wear or corrosion, but it is over 30 years old. Failure of any one of these items would have a significant impact on the station operation and would likely render the station inoperable until repaired.

Lighting levels within the station are adequate, emergency backup lighting is present throughout, and there is evidence that it is regularly serviced and maintained.

Labelling of conduits, cables, and enclosures is ad-hoc and is not in accordance with the requirements of SPR 5.2.

The site main circuit breaker does not have an integral solid state type protective relay and there are no auxiliary contacts on the main circuit breakers tied to the PLC as stipulated in SPR 5.8.

The Building Owners and Managers Association (BOMA) International publication *Preventive Maintenance Guidebook – Best Practices to Maintain Efficient and Sustainable Buildings* provides expected average equipment useful life years based on regular preventive maintenance performed at prescribed frequencies. Per the publication, the average useful life of transformers, MCCs, panel boards, and circuit breakers is 30 years, and the average useful life of wire and cable is 40 years. It should be noted that many factors can affect the average useful life of equipment, and individual systems and components will have lifetimes that may vary far from average. Lifetimes can often be extended through robust maintenance programs that go beyond the norm.

Despite the foregoing limitations, the estimates can serve as general guides for future planning. The station primary distribution equipment is over 30 years old, is at the end of its expected useful life, and should be considered for upgrade.

Upgrading the primary distribution equipment would have the added benefit of bringing the circuit breakers and disconnect switches in alignment with SPR 5.8 with solid state type protective relays and auxiliary contacts for monitoring from the SCADA system.

Arc Flash

SPR 5.1.9 requires that an arc flash hazard assessment be completed as per the latest revision of CSA Z462.

Arc flash labels are present on all primary electrical distribution equipment, but the labels do not contain information regarding nominal system voltage, arc flash boundary, available incident energy, working distance, or site-specific level of PPE as required by CSA Z462.

If performing any distribution upgrades, it is recommended to also conduct an arc flash analysis in accordance with SPR 5.1.9.

Control System

The pump station control system is the original relay-based system. The pumps are controlled by redundant ultrasonic level sensors tied to a pump alternator module that controls interposing relay logic to turn the pumps on and off as required.

A hand-off-auto switch is provided for each pump. In the auto position the lead pump function will normally alternate sequentially between the three pumps. Whenever a pump is running, a green pilot light is on and an hour meter accumulates the operating time. The following alarms are provided for each pump and are indicated by a red pilot light on the MCC door: seal fail, overload trip, ground fault, high temperature, valve failure, and control power failure. The controls and indications are in compliance with SPR 5.7, but all logic behind the control and indications is via relay logic rather than PLC control.

The devices that comprise the control system are manufacturer agnostic and newly manufactured equivalent replacement components are readily available, but the control system is not in accordance with the requirements of SPR 5.3 and there are a number of notable shortcomings which are summarized below:

- SPR 5.3.3 requires redundant PLCs and DC power supplies with the secondary PLC and power supply set up in a cold standby configuration. The City of Vancouver sewage pump station pump control philosophy states that the controls shall be designed so that the failure of a single component will not prevent the operation of more than one pumping unit. The pump alternator module and a number of relays within the existing control system are single-point-of-failure components; failure of any one of these devices may cause a total station shutdown.

- SPR 5.3.4 requires a local operator interface complete with twin monitors setup in a cold standby configuration. No local operator interface is present.

- SPR 5.3.5 requires emergency stop buttons to be provided near the location of each pump control. There are no emergency stop buttons present at the station.

- SPR 5.9.3 requires provision for an uninterrupted power supply (UPS) hardwired into the control system, with 2 hours of run time to power all control, monitoring, and telemetry systems. There is no UPS present at the station.

- The pump alternator module is a mechanical switch device with three normal positions; Lead – Pump 1, Lag – Pump 2; Lead – Pump 2, Lag – Pump 3, or Lead – Pump 3, Lag – Pump 1. Relays within the level controllers send the lead run and lag run signals to the alternator, and the alternator only advances once the lead pump 'off' signal is received from the level controller. Should a pump fail to start, the station does not have the logic to start an alternate pump. In addition, if the lead pump and lag pump fail to start, the system will not advance to the third pump.

Upgrading the relay based control system to a PLC based control system designed to City of Vancouver standards would have a number of benefits. The shortcomings identified above would be rectified and a more robust and reliable system would be provided. Single-point-of-failure components would be eliminated and backup UPS power would be provided to allow the monitoring and telemetry systems to bridge short duration power outages. The mixer control module and air compressor control cabinet would be removed and integrated into the more reliable PLC system. Potential future station upgrades such as flow meters or VFD integration would be easier to deploy into the system with reduced engineering, testing, and commissioning requirements. In addition, thorough diagnostic information would be available for system operators and the need for call-outs to the station to investigate issues and reset components would be reduced.

SCADA

The SCADA control cabinet was installed in 2012 and is in accordance with the requirements of SPR 5.5.

Level Control

Redundant level controllers and transducers with the secondary system on cold stand-by are provided. In addition, a separate float switch is provided as a high-level alarm switch. This is in accordance with the level control requirements stipulated in SPR 5.6.

The Milltronics EnviroRanger ERS500 ultrasonic system is not to the City of Vancouver standard equipment specification, but no specific concerns were noted with regards to this equipment.

Power Monitoring

A digital power monitor is provided within the MCC lineup, but the monitor is end-of-life and is no longer available.

Flooding

Flooding to an elevation of 4.60 m geodetic would submerge critical station electrical equipment, including the distribution transformer, most of the MCC and control system, a portion of the RTU panel, and the main incoming distribution panel board and equipment. The station would be rendered inoperable by such a flood event.

Flood waters are contaminated and leave conductive, corrosive and/or flammable residues inside equipment that can produce shock and fire hazards. If wetted equipment were reconnected to its electrical source without proper evaluation or reconditioning, it would have the potential to fail immediately. Even if the equipment did not fail immediately, and seemed to operate normally, it is likely to fail later, causing damage or safety hazards. If thorough evaluations were done, some electrical systems may be reconditioned, tested, and reused, but in most cases, reconditioning is either not possible or is not economically feasible, and replacement will be the best option.

The following is a summary of the expected effects of flooding on the electrical equipment.

Circuit Breakers. Molded case circuit breakers and fuses are not designed to be serviceable, and would require replacement. Flooding would compromise the safety trip functions of the components.

Transformer. The dry-type transformer must be replaced because water would damage the insulation properties of the core and coil assemblies.

Distribution Panel Board and Switchgear. The MCC, distribution equipment, and distribution panel board contain active and passive components. Passive components include the structural metal framework and current-carrying bus structures, while active components consist of circuit breakers and fusible devices. Passive parts can usually be cleaned, tested, and reused. Active components should be replaced as the safety trip functions would be compromised.

Automation and Control. PLCs, relays, HMIs and other automation and control products are electronic devices that would almost certainly be destroyed by submersion or exposure to excessive moisture. Because these devices control the station, their operational integrity is imperative, and they would require replacement. This includes the RTU panel, the relay control panel, and the mixer control panel.

Given that most of the electrical equipment within the station is at or near its recommended end of life, if a flood occurred, total replacement of all affected electrical components is likely the most viable remediation action.

4. OPTIONS FOR IMPROVEMENTS

4.1. Introduction

Potential options for upgrading the station are developed in this section. For convenience, these options are grouped to align with the strategy for the existing building (i.e., retain or expand). Additional options involve upgrades to the wet well, and provision of standby power.

Options 1 and 2 are either/or options and dependent on the decision to retain the existing building or expand it. The pump replacement costs including discharge piping are considered essential and therefore included in Options 1 and 2. Options 3 and 4 are independent of upgrade approach and can be completed with Option 1 or Option 2 or not at all.

4.2. Option 1: Retain the Existing Building

A number of improvements could be implemented without significant changes to the existing building, primarily electrical and controls upgrades:

1. Building & Related Improvements
    a. Improve ventilation in valve chamber
2. Structural and Seismic Improvements
    a. Strengthen roof/wall connection
    b. Address asbestos in concrete block walls
    c. Add flexible connections to forcemain
3. Mechanical Systems Improvements
    a. Replace pumping units
    b. Replace control valves
    c. Add pressure transmitter
4. Electrical and Controls Systems Improvements
    a. See below

This option would not address the flooding issue, or access to the valve chamber.

Three levels of electrical upgrades are contemplated:

Option 1A. Replace existing relay-based control system with PLC. Use existing MCC section to house the PLC system.

Option 1B. Replace existing MCC, 347/600 V panel board, transformer, and 120 V panel board with a new MCC. Use across-the-line starters for pump control. New PLC system would be installed in a section of the MCC. To create room for the MCC, a new manual transfer switch would be installed in a kiosk outside the station.

Option 1C. Replace existing MCC, 347/600 V panel board, transformer, and 120 V panel board with a new MCC. Use VFDs for pump control (requires additional space). New PLC system would be installed in a section of the MCC. To create sufficient room for the VFDs, relocate the main incoming electrical feed, BC Hydro metering, and transfer switch to an electrical kiosk outside the station.

Discussion of Motor Controllers and Pump Control Valves

The essential difference between Options 1B and 1C is the addition of VFDs in the latter. This is discussed in more detail below.

The types of motor controllers used for the 50 HP pumping units, and the types of pump control valves used, are separate but related issues. Consideration was given to three types of motor controllers, in order of increasing cost:

- **Full-voltage non-reversing (FVNR) starters**, also called across-the-line (ATL), are three-phase motor controllers with one motor contactor. The contactor opens and closes the power circuit to turn the motor on and off. The existing MCC has FVNR starters, and these are also included in Option 1B. Their advantages include relatively low cost, and high efficiency. A main disadvantage for some applications is that FVNRs do not limit the inrush current on motor start, which is five or more times the operating current. Inrush current is a consideration, for example, in sizing standby gensets.
- **Soft-starters** are devices used, among other things, to limit the inrush current. They temporarily reduce the load and torque in the motor and pump during start-up. Most modern soft-starts are solid state, and various types are available. Most work by temporarily reducing the voltage or current output. The main application of soft-starts is for limiting the noted current and torque transients in motor-driven equipment that otherwise is intended to operate at constant speed.
- **Variable-frequency drives (VFDs)**, also called variable-speed drives, are a type of AC motor controller that adjusts speed and torque by varying the motor input frequency and voltage. Like soft-starts, they can control inrush current. Also like soft-starts, most modern types are solid state. They have a loss of efficiency compared to FVNRs since the solid-state controllers are always in line (unless bypass contactors are used). The main application of VFDs is for motor-driven equipment that is intended to operate at variable speed.

Neither soft-starts nor VFDs are intended to reduce pressure transients during pump starts, but they can be used for that purpose. They do not have any effect on pressure transients following sudden power failures, however, and sometimes separate surge relief valves are required.

The pump control valves are intended to control pressure surges on start and stop of pumps. The existing pneumatically actuated plug valves perform this function. Where surges are not a concern (for example, in some cases where soft-starts or VFDs are used), PCVs may not be required. Check valves would be used instead.

Option 1B involves replacing the existing controllers and control valves with like equipment:

- MCC lineup with FVNR starters
- Pneumatically actuated plug type pump control valves
- Compressor system

Option 1C involves replacing the existing motor controllers with VFDs, and the pump control valves with check valves:

- MCC lineup with VFSs
- Check valves

Finally, a third option would be similar to Option 1C but with soft-starts instead of VFDs. This is not considered as a separate option in the cost tables but is presented below for comparison:

Table 4-1: Comparison of Controller Options (Equipment Costs Only)

Item	FVNRs + Actuated Plug Valves (Option 1B)	Soft-Starters + Check Valves	VFDs + Check Valves (Option 1C)
MCC	$27,000	$43,000	$65,000
Valves	$6,000	$7,000	$7,000
Actuators	$14,000	n/a	n/a
Compressor	$5,000	n/a	n/a
Totals	**$52,000**	**$50,000**	**$72,000**

The soft-starts could be substituted for FVNRs in Option 1B with essentially no change in cost.

The use of VFDs for pump control is unlikely to provide significant advantages in terms of efficiency, since the potential control range would be very limited. This is shown by the curves in Appendix 4. Because most of the pump head is static head, the flow (and thus efficiency) falls off rapidly as the speed is reduced, reaching shutoff near 80% speed.

The above discussion is an overview only, and does not cover all aspects of controller and valve selection. In many cases the choice is affected by owner preference, and compatibility with equipment in other stations. Some other secondary but potentially important considerations should be made during the next phases of design:

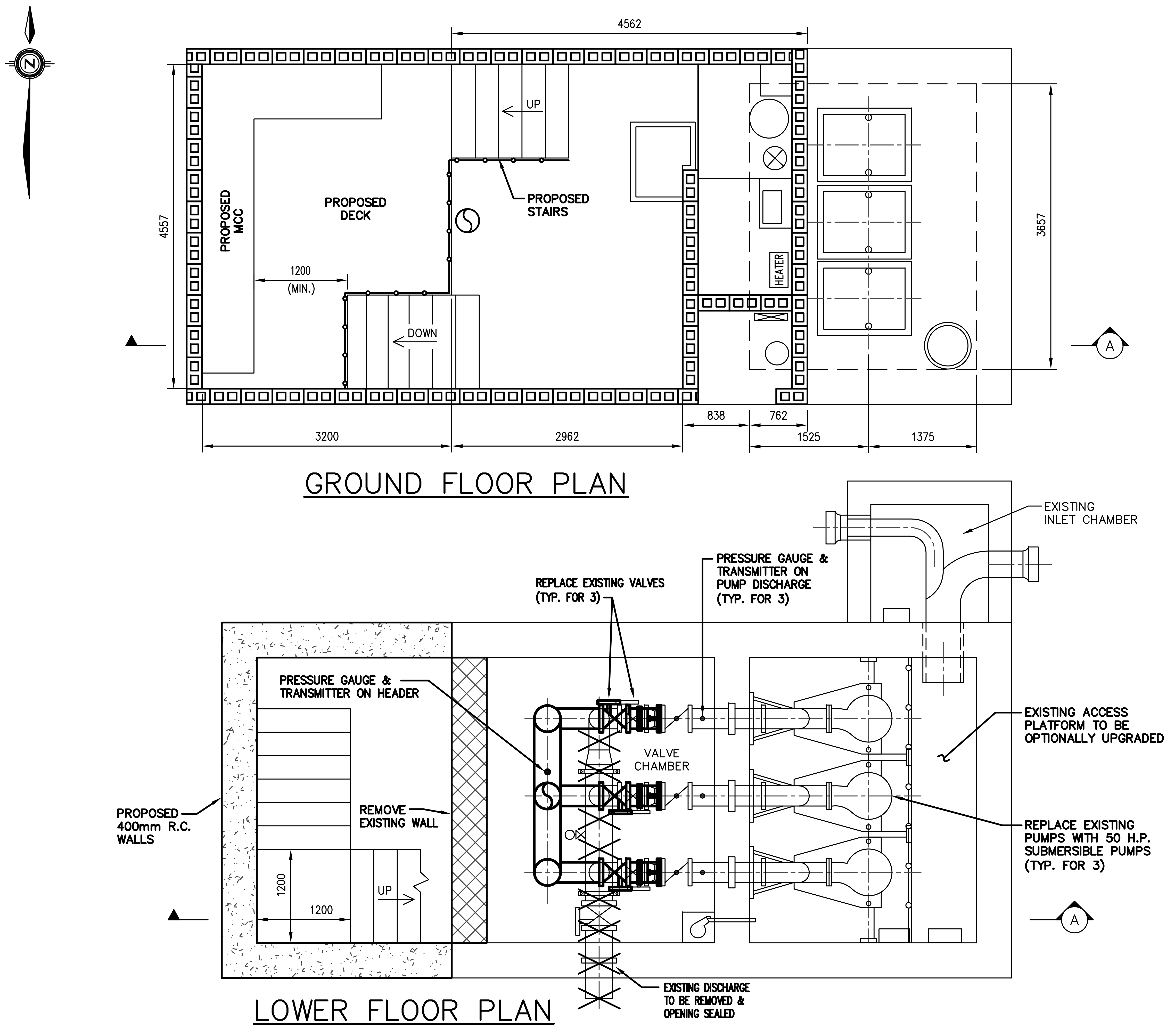
- If soft-starts or VFDs were used, the compressors could also potentially be eliminated, creating space in the building and reducing the complexity of the PLC logic and I/O points.
- Soft-starts and VFDs, as noted, are not intended to reduce pressure transients, and the extent to which they can be programmed to work satisfactorily is limited in that regard.
- In certain situations, the torque-limiting effects of soft-starts and VFDs can be problematical with sewage pumps, which may need to pass rags or solids immediately upon start-up to avoid clogging. However, some pump manufacturers are now providing “intelligent” sewage pumps with on-board VFD’s to optimize the speed the pump operates at so it is not uncommon for VFDs to be used in sewage applications. This functionality is less useful in this application for the reasons notes previously.
- Higher-end soft-starts and VFDs can provide other capabilities such as pump control logic and power factor correction.
- Pressure transients, and the potential need for pressure relief, should be considered.

4.3. Option 2: Expand the Building

This option would comprehensively address the main identified issues, aside from wet well and standby power upgrades, which are considered separately. Both the valve chamber and the above-ground building would be expanded to the west. The expanded part of the building would include an operating deck 1.2 m above the existing floor, which would contain all the electrical and mechanical equipment:

1. Building & Related Improvements
    a. Protect vital equipment against flooding
    b. Add stairs to make the valve chamber accessible (i.e., no longer confined space)
    c. Improve ventilation in valve chamber (same as Option 1)
2. Structural and Seismic Improvements
    a. Strengthen roof/wall connection (same as Option 1)
    b. Address asbestos in concrete block walls (same as Option 1)
    c. Add flexible connections to forcemain (same as Option 1)
3. Mechanical Systems Improvements
    a. Replace pumping units and control valves (same as Option 1)
    b. Add pressure transmitter (same as Option 1)
    c. Add flow meter in the expanded valve chamber
4. Electrical and Controls Systems Improvements
    a. Replace MCC using across-the-line starters for pump control
    b. Replace control system with a new PLC based control system housed in a section of the MCC
    c. Replace main incoming electrical feed, BC Hydro metering, and transfer switch
    d. Replace transformer, and 347/600 V and 120 V panel board
    e. Provide VFNR starters in conjunction with pneumatic control valves

This option is shown on Figures 4-1 and 4-2.



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CITY OF VANCOUVER

BURRARD WASTEWATER PUMP STATION

PUMP STATION EXPANSION FLOOR PLANS

FILE NO.	DATE	REVISION
87	JAN 16, 2018	0

Figure 4-1

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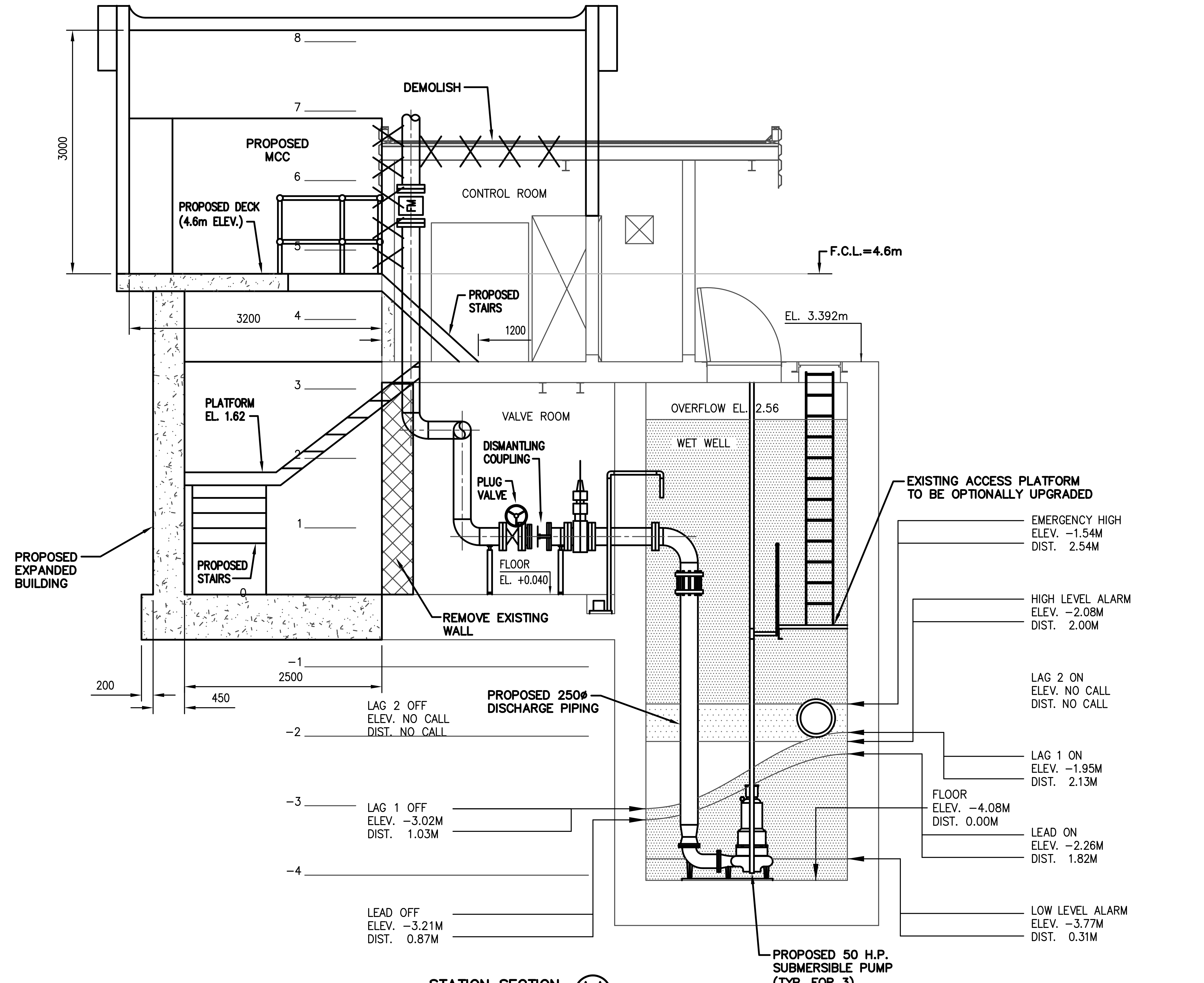

STATION SECTION (A–A / 1)
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CITY OF VANCOUVER

BURRARD WASTEWATER PUMP STATION

PUMP STATION EXPANSION SECTION

FILE NO.	DATE	REVISION
87	JAN 16, 2018	0

Figure 4-2

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4.4. Option 3: Upgrade the Wet Well

This option is independent of Options 1 and 2 (could be implemented or left out as a separate decision). The emphasis would be on addressing operational issues:

1. Improve access to wet well (add hatch stairs or ship ladder)
2. Improve fall protection (add fall grid on pump hatches)
3. Upgrade ladder and platform
4. Improve wet well hydraulics
5. Add odour control system

4.5. Option 4: Add Permanent Genset

This option is also independent of the previous options. A permanent genset on the site could be installed outside the building (to the west) on a fenced concrete pad. This could be elevated above the FCL, same as the operating deck in Option 2.

The manual transfer switch would be replaced with an automatic transfer switch.

5. COST ESTIMATES

5.1. Purpose and Level of Cost Estimates

Cost estimates were prepared for each option to assist the City with evaluation of the preferred options in the short term while also providing information for planning into the future.

The cost estimates, summarized in Table 5-1, are EGBC/ACEC-BC Class C estimates: ones prepared with limited site information and based on probable conditions affecting the project, representing the summation of all identified project costs, and typically used for program planning and preliminary project approval. The expected accuracy range is between a low of -25% and a high of +40% for a given scope. It is similar to an AACE International Class 4 estimate. This was considered to be an appropriate level of estimate for this assignment.

The detailed estimates for each option are in Appendix 5.

Estimate Preparation

The estimates are based on the options described in Section 4. They are based on the prepared drawings appended to this report, which are conceptual in nature.

The estimate was prepared by WSE, with estimates provided by GEA for structural work and PBX for the electrical scope (Divisions 26 and 48).

The estimate is based on unit costs for estimated quantities, combined with allowances where no quantities could be estimated. The unit rates are based on various methods, including budget quotes from suppliers, data from the literature (RSMeans *Construction Cost Data* and Hanscomb's *Yardsticks for Costing*), and the project team's judgment and experience.

Budget quotes were obtained for the following items:

- Pumping units (based on the lineup described in previous sections)
- Valves

Allowances have been added to the budget quotes for PST, delivery, spare parts, and contractor mark-up.

5.2. Assumptions and Exclusions

Major assumptions and exclusions include the following:

- Bonding, insurance, and mobilization/demobilization were added as factors of 1.5%, 0.5%, and 3.0%, respectively.
- No allowance has been made for architectural treatment.
- Heating is provided by electric unit heaters, and cooling by ventilation. No air conditioning is provided.
- Competent soils or bedrock are assumed. Nominal allowances have been made for dewatering. It is assumed that the subgrade will be competent.
- No allowance has been made for testing or disposing of any contaminated soils (but asbestos management is included).
- It is assumed that the excavation will not impact any adjacent structures.
- An allowance has been made for odour control equipment for Option 4, but no design criteria are available on which to base the allowance.
- The station contains the equipment described in Section 4 and/or listed in the table.
- No crane or lifting equipment has been included. The existing crane system is assumed to be adequate.
- No land acquisition costs are included.
- No permitting costs are included.
- A 10% contractor mark-up was applied on sub-trade work.
- It is assumed that all equipment, including pumping units and major valves, will be purchased by the contractor, not by separate supply contracts.
- Engineering and construction management was added as a factor of 20%.
- Global contingency was added as a factor of 30%.

It is assumed that all work will be done by a contractor. No allowance has been made for work by City forces. Similarly, any fees that the contractor is required to pay for City crews are not included.

5.3. Currency and Taxes

The estimates are prepared in 2017 Canadian dollars.

Provincial Sales Tax of 7% has been included on the major equipment listed in the table.

Goods and Services Tax has not been included.

5.4. Contingency

The global contingency referred to above is an amount added to the estimate to allow for items or conditions that could not be estimated with the current information, but which are expected to be required. These include but are not limited to minor estimating errors and omissions, minor price fluctuations (other than general escalation), design developments and changes within the scope, and variations in market and environmental conditions. Thus, the contingency is part of the budget, and is expected to be expended.

The contingency does not account for any of the following:

- major scope changes such as change in capacity, building size, construction type, architectural treatment, or project location
- extraordinary events such as strikes or legal actions
- escalation or currency effects
- market risk.

These and similar items should be considered risk factors, and these have not been included in the estimate.

5.5. Summary

The estimates for each option are summarized as follows from Table 5-1:

Table 5-1 - Summary of Estimates ($ millions)

	1A	1B	1C	2	3	4
Base estimate	0.70	0.80	0.80	1.40	0.10	0.20
Low estimate (-25%)	0.50	0.60	0.60	1.10	0.08	0.20
High estimate (+40%)	1.00	1.10	1.10	2.00	0.14	0.30

6. CLOSURE

WATER STREET ENGINEERING LTD.

Prepared by:

PROFESSIONAL PROVINCE OF A. BRONSRO #17424 BRITISH COLUMBIA ENGINEER
2018-01-19

Allan Bronsro, MCIP, PEng
Principal

Reviewed by:

Pádraig Harrington, PEng
Principal

AB/

Appendix 1: Geotechnical Report

THURBER ENGINEERING LTD.

October 18, 2017 File: 20628

Water Street Engineering Ltd.
#300 - 131 Water Street
Vancouver, B.C.
V6B 4M3

Attention: Allan Bronsro, MCIP, P.Eng.

BURRARD STREET SEWAGE PUMP STATION
VANCOUVER, B.C.
GEOTECHNICAL INPUT FOR SEISMIC EVALUATION

Dear Allan:

As requested, Thurber has completed a desktop study and site visit for the above noted project. This letter summarizes the results of the desktop study and site visit and provides our geotechnical input for seismic evaluation of the existing Burrard Street Sewage Pump Station.

It is a condition of this letter that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1. INTRODUCTION

The City of Vancouver (CoV) Burrard Street Sewage Pump Station is located under the Cordova Street and Burrard Street viaducts, south of the TransLink Expo Line. The pump station comprises a single storey pump house on top of underground wet well and valve chamber structures.

The CoV has retained Water Street Engineering to carry out an assessment of the existing pump station. As part of this, geotechnical input is required for seismic evaluation of the existing structure. The geotechnical seismic provided below is based on available information and follows current design procedures and seismic hazards. Thurber was provided with the documents listed below for our assessment.

- CoV Drawing DB 911, dated April 6, 1984 – Burrard Sewage Pumping Station, Site Plan and Access
- CoV Drawings PB-53, 6 sheets, dated March to July 1984 – Burrard Sewage Pumping Station
- CoV Drawing PB-54, dated October 30 1984 – Burrard Sewage Modification to Pipe – Header and Supports
- Cook Pickering & Doyle Ltd. Drawing 2-6802, rev. 1, dated February 1984 – Excavation Shoring – Burrard St. Pump Station
- Cook Pickering & Doyle Ltd. Drawing 10-5627, dated October 1981 – Drill Hole Location Plan – Cordova St. Extension
- Cook Pickering & Doyle Ltd. Test Hole Logs – DH25 and DH26

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thurber.ca

2. SUMMARY OF DESKTOP STUDY

Surficial geology mapping indicates that the project site is underlain by bedrock that may be overlain by glacial deposits and colluvium, and possibly fill, depending on the development history of the area. Historical test hole logs from Cook Pickering & Doyle confirm the presence of fill and that the site is underlain by bedrock. The test hole logs indicate that bedrock in the area comprises siltstone and sandstone and it is overlain by about 3.5 m of loose to compact silty, sand fill.

CoV's Underground Concrete Structure Drawing PB-53, sheet 5, indicates that the depth to bedrock at the pump station is about 2.5 m below grade and that the valve chamber and wet well structures are founded on bedrock. The drawing also notes that wet well walls were formed against the bedrock. There are no notes on backfill for portions of the pump station above bedrock.

Cook Pickering & Doyle's Excavation Shoring Drawing 2-6802, rev. 1, indicates that the south and west sides of the pump station excavation were shored. The north and east sides were vertical cuts in the bedrock and sloped in the overburden.

3. SITE OBSERVATIONS

A site visit was conducted by Thurber with the design team and representatives from the CoV on September 29, 2017. The following observations were made during the visit:

- The pump station structure showed no obvious signs of settlement (i.e. cracking or tilting).
- There were no signs of differential settlement between the pump station and surrounding grade or concrete pad north of the pump station.
- A steep shotcrete-covered slope (without anchors) was observed to the southwest of the pump station, below a retaining wall.
- Sandstone was exposed at the southwest corner of the pump station, where the grade was higher than elsewhere.

4. GEOTECHNICAL SEISMIC INPUT

Based on review of the available information and our observations made onsite, it is our opinion that it is reasonable to assume that the pump station is founded on bedrock. Following Table 4.1.8.4.A of the 2012 British Columbia Building Code, Site Class C can be used for preliminary seismic evaluation. If the rock is better quality, Site Class B could be more appropriate, this could be confirmed by conducting a geotechnical drill investigation. The output from 2010 NBCC seismic hazard calculator is attached for reference.

The elevation of the top of bedrock is uncertain and probably variable. The drawings provided indicate bedrock could be about 2.5 m below ground surface and historical test hole logs indicate it could be about 3.5 m below ground surface. Additionally, based on our site observations, bedrock is at the surface near the southwest corner of the pump station.

Based on the drawings provided, we understand that the underground structures were formed against the bedrock. Since the south and west sides of the pump station were shored, they probably were also blind formed. We assume that the material that was shored comprised a compact granular material. We also assume that where the excavation was sloped, the walls of the pump station were backfilled with compacted granular material. Our site observations indicate the fill surrounding the pump station is relatively competent, as signs of settlement were not observed.

There is no commonly applied standard method for determining seismic lateral earth pressures in cohesive materials, including bedrock. For the purposes this assessment, and without more detailed information on the quality of the rock, we have calculated seismic earth pressure coefficients in bedrock using the Mononobe-Okabe method with a friction angle of 45°. We assumed that the soil above the bedrock is compacted granular soil with a friction angle of 34°. The table below provides seismic lateral earth pressure coefficients that can be used for seismic assessment of the structure.

Design Earthquake Return Period (year)	Granular Fill K_{AE}	Bedrock K_{AE}
475	0.44	0.30
975	0.52	0.45
2475	0.67	0.46

The resultant of seismic earth pressures should be applied between the bottom third and middle of the wall, which is equivalent to applying earth pressures as hydrostatic or uniform pressure distributions, respectively. A soil unit weight of 20 kN/m^3 can be used for earth pressure calculations. It is important to note that surcharge loading due to the Burrard Street Viaduct abutment to the south of the pump station and adjacent retaining wall and slope have not been taken into account. For detailed seismic evaluation, loading from the adjacent infrastructure should be considered.

Post-seismic settlement of the pump station is expected to be negligible. However, seismic performance of the overhead viaduct and adjacent retaining wall present another risk to the pump station. We understand that a seismic assessment of the downtown viaducts will be completed in the next few years. The results of the assessment should be taken into consideration for future seismic evaluations of this pump station.

5. CLOSURE

We trust that this information is sufficient for your needs. Should you require clarification of any item or additional information, please contact us at your convenience.

Yours truly,
Thurber Engineering Ltd.
Steven Coulter, P.Eng.
Review Engineer

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
H. M. WIEGAND
44469
Oct. 18, 2017

Helena Wiegand, P.Eng.
Project Engineer

Attachments: Statement of Limitations and Conditions (1 page)
2010 NBCC Seismic Hazard Calculator Output (1 page)

THURBER

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

2010 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Requested by: ,

October 13, 2017

Site Coordinates: 49.2876 North 123.1162 West

User File Reference: Burrard Street, Vancouver, BC

National Building Code ground motions:
2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA (g)
0.917	0.635	0.332	0.172	0.454

Notes. Spectral and peak hazard values are determined for firm ground (NBCC 2010 soil class C - average shear wave velocity 360-750 m/s). Median (50th percentile) values are given in units of g. 5% damped spectral acceleration (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are tabulated. Only 2 significant figures are to be used. ***These values have been interpolated from a 10 km spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the calculated values.*** Warning: You are in a region which considers the hazard from a deterministic Cascadia subduction event for the National Building Code. Values determined for high probabilities (0.01 per annum) in this region do not consider the hazard from this type of earthquake.

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.2)	0.227	0.484	0.658
Sa(0.5)	0.154	0.330	0.450
Sa(1.0)	0.080	0.172	0.234
Sa(2.0)	0.040	0.087	0.120
PGA	0.115	0.241	0.326

References

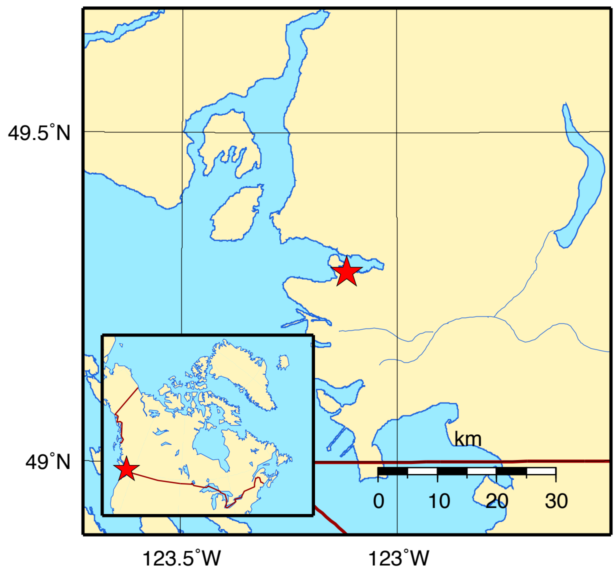
National Building Code of Canada 2010 NRCC no. 53301; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

User's Guide - NBC 2010, Structural Commentaries NRCC no. 53543 (in preparation)
Commentary J: Design for Seismic Effects

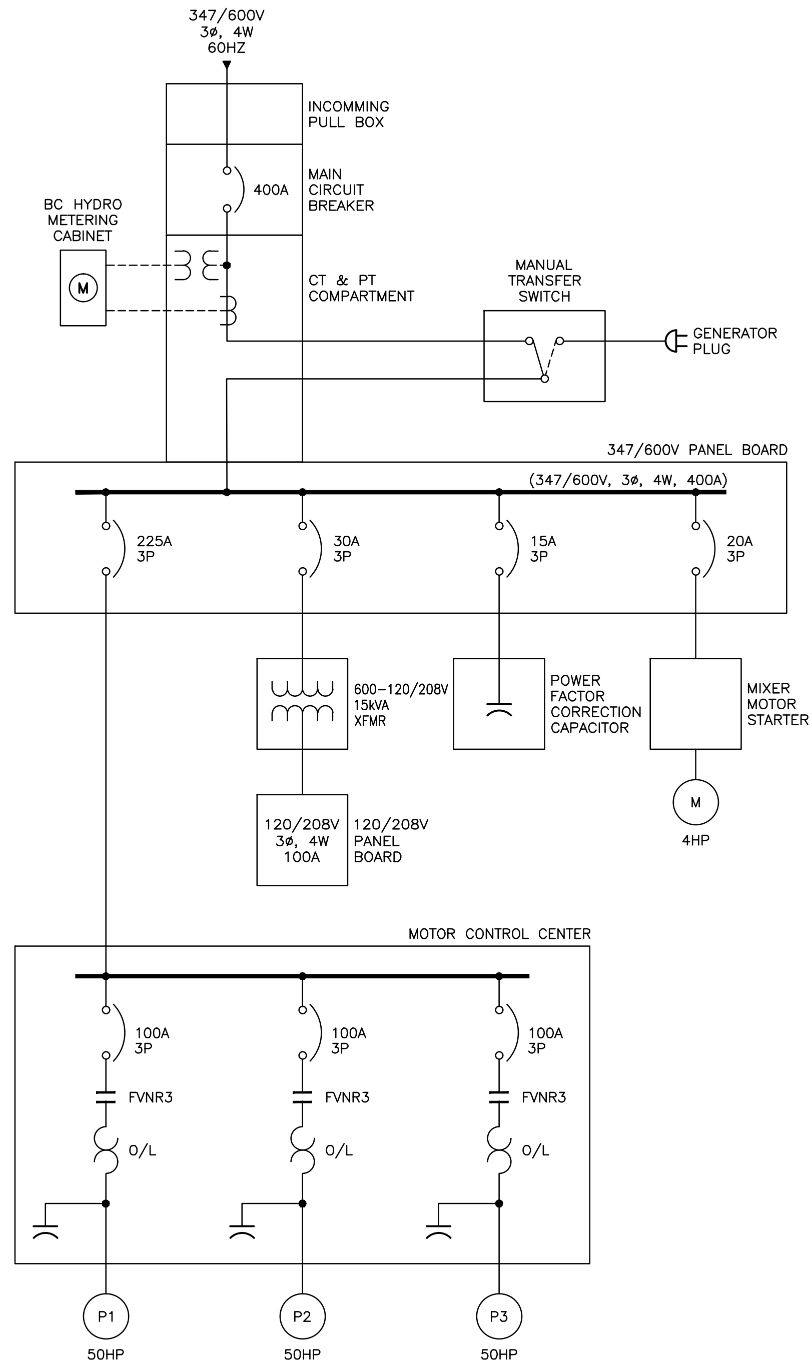
Geological Survey of Canada Open File xxxx
Fourth generation seismic hazard maps of Canada: Maps and grid values to be used with the 2010 National Building Code of Canada (in preparation)

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



Appendix 2: Single Line Sketch



PBX ENGINEERING

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www.pbxeng.com

CITY OF VANCOUVER
BURRARD WASTEWATER PUMP STATION
SINGLE LINE DIAGRAM

Appendix 3: Pumping Units – Technical Information

SPEARS SALES & SERVICE LTD.

3586 Commercial Street Vancouver BC V5N 4E9

Bus. (604) 872-7104 Toll free 1-800-663-6169 Fax (604) 872-7102

To: **Nelson Porter**
City of Vancouver
Sewage Operations Branch

From: **Geoff Mondor**
Spears Sales & Service

Re: **Final Report on the Repair of 3, 50hp, Hydromatic Submersibles Model #5 S8L5000 M6-6 84, Serial #'s 14280, 14281 & 14282**

These pumps were brought in for general service repairs. All three units arrived at our shop with no major internal failures mechanically or electrically. All documented deficiencies are listed with the individual pump reports.

The following is a breakdown of the results from the:

- Initial Inspection
- Tear Down Inspection
- Failure Analysis
- Final Assembly

The results are listed in respect to the individual pumps and the order they were brought in by. Following that is our recommendations for service intervals, expected repairs and replacement of parts to optimize the operating efficiency of your pump station. When considering the long and erratic lead times, this will allow us both to schedule and order the necessary parts and materials to better serve your needs.

Stephanie.
873 7224

gm

Final Report on the Repair of 3, 50hp, Hydromatic Submersibles
Model #5 S8L5000 M6-6 84, Serial #'s 14280, 14281 & 14282

Initial Inspection: Pump Serial # 14282

Date Received: February 4, 2000

The initial inspection of the unit indicated that the power cord was damaged and the sensor cord was split. The initial meter readings showed the pump seal chamber was meggering at 200MΩ (megohms), indicating water in the seal chamber. Through the cord the motor chamber was meggering at 750 MΩ (megohms). All phases of the motor winding have a balanced continuity of 0.5Ωs.

Though there was water present in the seal chamber, the motor housing oil had no indication of water contamination.

The test run prior to teardown indicated an imbalance of the rotating assembly. There was no bearing noise to attribute to bad bearings or housings and all of the amperages were within one ampere on each phase.

Test Voltage	Line 1	Line 2	Line 3
230V	9.5A	10A	9A

The lower test voltage was used because of the low megger readings from the stator.

gm

Final Report on the Repair of 3, 50hp, Hydromatic Submersibles
Model #5 S8L5000 M6-6 84, Serial #'s 14280, 14281 & 14282

Tear Down Inspection: Pump Serial # 14282

There was oil in the intermediate dry cap assembly indicating a breakdown of the epoxy that isolates the "dry" intermediate power connections from the oil in the motor chamber. The electrical connections in this dry cap assembly had started to degrade from the exposure to moisture and the submersible oil. This can lead to an increased voltage drop at the connection that would cause an under voltage condition at the motor.

The oil in the motor housing was clear not cloudy. There was debris found in the stator housing but nothing that would interfere with the stator windings or motor operation. The stator will be washed and surge tested to insure the windings are in good condition.

The cast iron impeller is showing signs of wear from normal operation. The impeller is pitting (*washing out*) on the inside of the vanes. The wear is not severe but should be noted since it does put an unbalanced load far enough outboard of the bearing to cause premature wear and a possible failure of the unit.

The tapered impeller shaft fit and keyway are in good shape.

The wear ring and eye of the impeller have a large clearance dimension of almost 1/4". The gap is large enough to allow the fluid to recirculate from the high-pressure area of the volute through the wear ring and back into the suction. This condition will reduce the overall operating efficiency of the unit.

All the shaft and housing bearing fits are within tolerance but the DE (*Drive End*) does show signs of damage to the shaft fit. Further inspection of the shaft runouts indicated the shaft is bent in the opposite direction of the DE shaft deficiency.

Both mechanical seals show even wear across the mated faces. There is some scoring on the outside seal indicating it was partially failing. This would account for the low megger readings through the sensor cord and the water found in the seal chamber.

The discharge flange hydraulic lip seal diaphragm was torn and generally worn-out.

gm

Final Report on the Repair of 3, 50hp, Hydromatic Submersibles
Model #5 S8L5000 M6-6 84, Serial #'s 14280, 14281 & 14282

Failure Analysis: Pump Serial # 14282

The unit was brought in for a general service repair because it was found to be kicking out on high temperature. From the teardown inspection it has been determined that this can be caused by a couple of scenarios.

The dry intermediate cap connections were degrading. This can cause a voltage drop at the connection that would then cause the motor of the pump to operate in an under voltage situation. Lower voltage at the motor will cause higher amperage during normal operation. This in turn causes a greater heating effect on the windings of the motor.

The increased tolerance at the wear ring and impeller eye can cause an artificial loss of head at the pump. The loss of head means more flow, more flow means more work therefore more horsepower is needed to do the work. The amperage again will increase causing the heating effect on the windings.

The surge test on the windings did not indicate any electrical deficiencies

The rotating motor assembly was found to have a bent shaft and a significant imbalance to the impeller.

Combine the possible low voltage condition and the artificial loss of head with the imbalance in the rotating assembly and the ingression of water, it would only be expected to see the motor working a bit harder. This would be enough to allow the panel to detect an increase in the operating temperature of the windings.

gm

Final Assembly: **Pump Serial # 14282**

All of the parts were sandblasted and/or cleaned and visually assessed to be free from any defects or anomalies in the castings or materials.

The cords were reassembled with new epoxy in both the cord and intermediate cap sections. The intermediate cap section was repotted with new, high temperature oil compatible leads. The power and sensor cords were rewired to match the incoming original connection to facilitate the ease of on-site reconnection of the circuits.

All the electrical circuits were tested for inconsistencies at different stages during the assembly process to eliminate problems in the final testing. The final megger readings were well over 2000MΩ (megohms) and into the infinite range of the meter.

The rotating assembly that includes the rotor of the motor and the impeller were dynamically balanced separately. This provides a better overall balance by correcting the imbalance of each rotating element.

The rotor shaft was restraightened to a runout of 0.001" at the seal. The D.E. bearing shaft fit was repaired to achieve the proper tolerance fit.

The motor was reassembled with all new bearings including an angular contact thrust bearing on the drive end. All the gaskets were replaced to match the original buna o-rings and gaskets including the discharge flange hydraulic lip seal diaphragm.

The eye of the impeller was re-trued after the shaft was restraightened, to clean up the wear ring clearance area. The new bronze wear ring was machined for a clearance of 0.020" to the impeller eye and installed in to the volute.

The new mechanical seals were of the same material make-up as the original incoming seals. Both the inside and outside seals have a carbon rotating face with a ceramic stationary seat. The rubber bellows and o-rings are made of buna rubber and the metal parts of the seal assemblies are all stainless steel.

The "No Load" test run of the motor showed smooth acceleration with very little electrical noise. There is also no significant vibration and the amperage at its operating voltage is balanced and steady.

Voltage	Line 1	Line 2	Line 3
600V	22.5A	23A	23.5A

gm

Initial Inspection: **Pump Serial #** 14281

Date Received: March 21, 2000

The initial inspection of this unit indicated that the power cord and the sensor cord were going soft and showing signs of abrasion from cord movement in the pit. The initial meter readings showed the motor chamber and seal chamber were meggering at around 1000MΩ (megohms), which is a good reading considering the amount of time it has been in service in the system. All phases of the motor winding have a balanced continuity of 0.25Ω's.

	Including Cord	Without Cord
Main Power Leads:	1000MΩ	2000MΩ
Sensor Cord Leads:	900MΩ	1000MΩ

The oil in the seal chamber had a slightly cloudy appearance indicating a small amount of water was present in the seal chamber even though the meter readings were good. The motor housing oil had no indication of water contamination.

The test run prior to teardown did not indicate any significant imbalance of the rotating assembly. Both housings gave no indication of increased tolerances during the test run and all of the amperages were fairly balanced between each phase.

Test Voltage	Line 1	Line 2	Line 3
600V	26.5A	27A	28A

gm

Tear Down Inspection: **Pump Serial** # 14281

The leads through the dry cap were swollen and mushy do to a failure in the epoxy that allowed oil to enter the intermediate dry cap assembly. The electrical connections in this dry cap assembly were in good shape.

The submersible oil in the motor housing of this pump was also clear. This stator will also be washed and surge tested to insure the winding insulation is in good condition.

The cast iron impeller is generally in good shape. It is also showing signs of wear from normal operation, but not as bad as the previous impeller. The tapered impeller shaft fit and keyway are in perfect shape. The wear ring and impeller eye do have an increased tolerance from normal operation.

Wear Ring I. D.	9.298"
Impeller Eye O. D.	9.185"
Difference	0.113"
Clearance	0.056"

The rotor shaft is bent and showing signs of wear. The runout at the taper is 0.014". The DE (Drive End) shaft fit is damaged and egg shaped, which can add to the shaft runouts. The inboard shaft seal area is worn and the outboard seal sleeve is grooved at the seal bellows fit, possibly from seal movement and shaft runouts. Both of the bearing housing fits are in great shape.

O. D. E. Shaft Fit	1.7718	**K6**	1.7724	to	1.7718
D. E. Shaft Fit	3.1495	**K6**	3.1504	to	3.1497
D. E. Damaged Area	3.1504	**Shaft fit is egg shaped**			

Both of these mechanical seals are in good shape and have even wear across the mated faces. The out side seal does show signs of debris getting between the seal faces that would allow water to seep inside.

The discharge flange hydraulic lip seal diaphragm is in tact but wearing on the sealing face.

gm

Final Report on the Repair of 3, 50hp, Hydromatic Submersibles
Model #5 S8L5000 M6-6 84, Serial #'s 14280, 14281 & 14282

Failure Analysis: Pump Serial # 14281

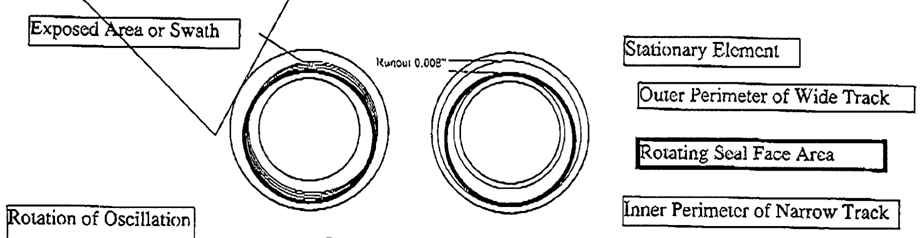
The unit had no major internal failures and was only brought in for a general service repair. The teardown inspection did indicate some deficiencies related to wear and tear during normal operation.

The dry intermediate cap did have oil present inside the assembly indicating a breakdown of the epoxy seal around the intermediate leads. The internal motor chamber pressures cause oil to be pushed up the leads through the epoxy barrier and into the dry cap assembly. This condition has caused the leads to go soft and mushy.

The tolerance at the wear ring and impeller eye were increasing but not enough to create a significant artificial loss of head at the pump.

The windings were surge tested and did not indicate any electrical deficiencies

The rotating motor assembly on this second unit was also found to have a bent shaft. The shaft runout at the impeller fit was 0.014"; the factory maximum seal runout tolerance is 0.002". Further inspection of the rotor shaft confirmed a runout of 0.008" at the seal area. This can cause premature seal failure because it allows the one side of the rotating seal face to make a wider track or swath that will then swipe across the narrow track taken by the opposite side. On the stationary element debris can collect on the exposed area of the swath left by the narrow track. Then the opposite side with the wider track will come around and clear the debris from the exposed area.



~ Drawing is for example only! ~

gm

Final Assembly: **Pump Serial # 14281**

All of the parts were sandblasted and/or cleaned and visually assessed to be free from any defects or anomalies in the castings or materials.

The cords were reassembled with new epoxy in both the cord cap and intermediate cap sections. The intermediate cap section was repotted with new, high temperature oil compatible leads. The power and sensor cords were rewired to match the incoming original connection to facilitate the ease of on-site reconnection of the circuits.

All the electrical circuits were tested for inconsistencies at different stages during the assembly process to eliminate problems in the final testing. The final megger reading for this unit were greater than 2000MΩ (megohms).

The rotating assembly, which includes the rotor of the motor and the impeller, were dynamically balanced separately. This provides a better overall balance by correcting the imbalance of each rotating element. This method also eliminates the need to rebalance the complete rotating assembly when only one of the elements are repaired or replaced. The rotor shaft was restraightened to a runout of 0.0005" at the seal.

The motor was reassembled with all new bearings including an angular contact thrust bearing on the drive end. All the gaskets were replaced to match the original buna o-rings and gaskets including the discharge flange hydraulic lip seal diaphragm.

The eye of the impeller was re-trued to clean up the wear ring clearance area. The new bronze wear ring was machined for a clearance of 0.020" to the impeller eye and installed in to the volute. This improves the operating capacity and overall efficiency of the pump by reducing the flow from the high-pressure areas of the volute that pass through the clearance of the wear ring and back into the suction.

The new mechanical seals were of the same material make-up as the original incoming seals. Both the inside and outside seals have a carbon rotating face with a ceramic stationary seat. The rubber bellows and o-rings are made of buna rubber. The metal parts of the seal assemblies are all stainless steel. A new stainless steel sleeve for the lower outside mechanical seal was also installed to replace the old one that was scored.

The "No Load" test run of the motor showed smooth acceleration with very little electrical noise. There is also no significant vibration and the amperage at its operating voltage is fairly balanced and steady.

Voltage	Line 1	Line 2	Line 3
600V	24.5A	25.5A	26A

gm

Final Report on the Repair of 3, 50hp, Hydromatic Submersibles
Model #5 S8L5000 M6-6 84, Serial #'s 14280, 14281 & 14282

Initial Inspection: Pump Serial # 14280

Date Received: July 5, 2000

The initial inspection of this unit indicated that both the power cord and the sensor cord were swollen.

The initial meter readings showed the motor chamber without the cord was meggering at around 600MΩ (megohms), which is fairly low and indicative to internal problems. The seal chamber was meggering out at 500MΩ (megohms), indicating water contamination. All phases of the motor winding have a balanced continuity of 0.5Ω's.

	Including Cord	Without Cord
Main Power Leads:	600MΩ	600MΩ
Sensor Cord Leads:	400MΩ	500MΩ

The oil in the seal chamber had a slightly cloudy appearance indicating a small amount of water was present in the seal chamber even though the meter readings were good. The motor housing oil had no indication of water contamination.

During the test run prior to teardown the unit ran quite smooth but the impeller was dragging on the body. The motor accelerated nicely with no bearing squawk or howl. The amperage draw was within the expected parameters and reasonably balanced between each phase.

Test Voltage	Line 1	Line 2	Line 3
230V	9.5A	9A	9A

The casting that the power and sensor cords are set in is very round on the edges. It appears the upper cast iron parts of the pump are getting soft. You can see where the bolts for the cap seated against the cast iron and all around the bolt head the cast iron is eroded away. This is due to the pumps exposure to the grease and oils present in the system combined with the movement of water, possibly under an infall pipe.

gm

Tear Down Inspection: **Pump Serial # 14280**

The dry cap assembly did have oil in the intermediate cap section due to a failure in the epoxy that allows oil to enter the dry cap. The electrical connections in this dry cap assembly were in good shape.

There was a small amount of water in the seal chamber but the motor chamber oil was clear with no indication of water contamination. Further inspection showed the main stator leads of the winding were starting to degrade and split, leaving exposed conductors inside the motor housing. This stator will be washed and tested to determine if the leads can be replaced or if a complete rewind will be needed.

This cast iron impeller is the worst of the three. It is also showing signs of washing out in the impeller vanes. The impeller is still usable but replacement in the next service interval should be expected. The impeller shaft fit taper was found to be 0.003" high on one side of the keyway. There are no signs of the impeller key beginning to roll over in the keyway. The wear ring and impeller eye do have an increased tolerance of over 1/8" from normal operation.

Wear Ring I. D.	9.308"
Impeller Eye O. D.	9.034"
Difference	0.274"
Clearance	0.137"

This rotor shaft is in rough shape. The runout at the taper is 0.007". The ODE (Opposite Drive End) shaft fit is out of round by 0.001". The DE (Drive End) shaft fit is damaged and also out of round by 0.0025". The bearing housing fits are both in good condition.

O. D. E. Shaft Fit	1.772	to	1.773	Out of round by 0.001"
D. E. Shaft Fit	3.150	to	3.1525	Out of round by 0.0025"

Both mechanical seals are in good shape and have even wear across the mated faces. This out side seal also shows signs of debris getting between the seal faces.

The discharge flange hydraulic lip seal diaphragm is in tact but marked up from debris between the sealing faces and normal wear and tear.

gm

Failure Analysis: Pump Serial # 14280

The unit had no major internal failures and was only brought in for a general service repair. The teardown inspection of this unit did indicate some shaft bearing fit deficiencies along with poor winding insulation integrity.

The dry cap assembly of this unit did have oil present inside the assembly indicating a breakdown of the epoxy around the intermediate leads. The main leads off the winding were starting to degrade and split exposing the main current carrying conductors. This condition could have caused a severe short to ground. The motor was isolated from the cord and oil and still meggered at 600MΩ (megohms). The stator windings barely passed the surge test.

The rotating motor assembly on this third unit had a couple of poor bearing fits but overall the shaft is all right. The shaft runout at the impeller fit was 0.004". Further inspection of the rotor shaft indicated a high spot at the taper fit that cocked the impeller to one side.

The wear ring and impeller eye clearance tolerance is over 1/8". It will start to let a lot more fluids and debris pass through, increasing the clearance area faster.

gm

Final Assembly: Pump Serial # 14280

All of the parts were sandblasted and/or cleaned and visually assessed. In the lower seal plate there are some casting flaws behind the outside stationary seal seat. There was no indication of exposure to water in that area or anywhere else on the chamber side of the casting that would indicate a breach. Even the back of the stationary seat is clean. Therefore the seal plate will be reused. All the other components are visually free from any defects or anomalies in the castings or materials.

Both the cord cap and intermediate cap sections were reassembled with new epoxy, and repotted with new, high temperature, oil compatible leads in the intermediate cap section. The cords were rewired to match the incoming original connection.

All the electrical circuits were tested for inconsistencies at different stages during the assembly process to eliminate problems in the final testing. The final megger reading for this unit is well into the *infinite* range of the meter.

The rotating motor assembly and the impeller were dynamically balanced separately. This provides a better overall balance and facilitates in the case of replacement or repair of the impeller without having to rebalance the rotating motor assembly. Both of the shaft bearing fits are restored and the rotor shaft was restraightened to a runout of 0.0005" at the seal.

The stator was rewound with an IRS type of conductor that is better suited for the submersible operating environment. The conductor has a tougher outer coating and an all around better product.

The motor was reassembled with all new bearings including an angular contact thrust bearing on the drive end. All the gaskets were replaced to match the original buna o-rings and gaskets including the discharge flange hydraulic lip seal diaphragm.

The eye of the impeller was re-trued to clean up the wear ring clearance area. The new bronze wear ring was machined for an impeller clearance of 0.020".

The new mechanical seals were of the same material make-up as the original incoming seals. Both the inside and outside seals have a carbon rotating face with a ceramic stationary seat. The rubber bellows and o-rings are made of buna rubber. The metal parts of the seal assemblies are all stainless steel.

The "No Load" test run of the motor showed very smooth acceleration operation with almost no electrical noise. The amperage at its operating voltage is fairly balanced and steady.

Voltage	Line 1	Line 2	Line 3
600V	23.5A	24A	22A

gm

Comments & Recommendations:

All of the pumps have been completely rebuilt and are in very good operating condition.

The bearing housings are in excellent condition. With the shaft bearing fits restored, the shafts restraightened and the rotating assemblies dynamically balanced, these pumps will provide you with a good service life for the future.

The impellers are still in fairly good shape. The impeller on the last pump repaired, Serial # 14280, will need to be replaced within the next service interval. We will monitor the condition of all the impellers throughout the future service intervals. If the impellers are replaced in the future, the new bronze wear rings which are machined to match the smaller old impeller eye dimensions can be easily remachined to match the larger new impeller eye dimensions.

If you are possibly considering replacing one of the units in the near future the pump, Serial # 14280 would make a good spare. The casting is quite soft and washing away in areas such as the upper cap assembly. This unit will provide you with many years of good service but you may want to consider having a spare.

A general service interval should be every two to three years. Where all the fluids should be drained and the lower mechanical seal changed. A general inspection of all the electrical circuits should be done every 6 months to a year. The control circuits and contacts should be checked to eliminate nuisance control related failures or more extreme failures such as single phasing of the motor winding circuits. This will provide closer monitoring of the overall operation of the system and greatly extend the service life of the bearings, stator and the inside mechanical seal.

gm

SPEARS SALES & SERVICE LTD.

3586 Commercial Street Vancouver BC V5N 4E9

Bus. (604) 872-7104 Toll free 1-800-663-6169 Fax (604) 872-7102

To: **Nelson Porter**
City of Vancouver
Sewage Operations Branch

From: **Geoff Mondor**
Spears Sales & Service

Re: **Report on the Seal Failures After Completed Rebuilds Installed**
All 3, 50hp, Hydromatic Submersibles
Model #5 S8L5000 M6-6 84, Serial #'s 14280, 14281 & 14282

We have now completed replacing all the lower mechanical seals in all three units.

The inspections all indicate debris related failures. The lower mechanical seals of the first two pumps originally repaired, Serial # 14281 & 14282 showed a definite grooving pattern in the carbon caused by an ingression of debris such as an abrasive. The last pump originally repaired, Serial # 14280 was the last one to go back into the system. So it is not surprising to see its seal having less wear when compared to the others but it is still worn on the carbon and ceramic.

All of the wear tracks appear to be even, proving the shaft runouts are within manufactures specifications. All the stationary ceramic seats were installed flat in the seat housings confirmed by the even wear on the carbon faces.

The ceramic seats were very clean around the o-ring area. So clean the ceramic side exposed to the pump seal chamber was perfectly white indicting there was no water leaking past the seat o-ring.

The o-ring sites are all free of defects such as nicks. The shaft areas where the bellows ride on the sleeves are free from defects and the internal sleeve to shaft o-rings are clean and intact. Inside the shaft sleeves there was no indication of water getting past the internal o-ring.

The impeller flush veins are mostly intact, some are better than the others but the one with the least amount of wear to the seal has the worst impeller.

Even if the pumps have seen a little salt water it would not have this effect on the seals. They were not attacked by a chemical, such as a corrosive, because the carbons were not etched.

gm

SPEARS SALES & SERVICE LTD.

3586 Commercial Street Vancouver BC V5N 4E9

Bus. (604) 872-7104 Toll free 1-800-663-6169 Fax (604) 872-7102

These seals all failed due to an abrasive getting between the seal faces.

I have inquired to all the seal suppliers to provide me with an unbiased report on the seal conditions, failure analysis, and the manufacturers of the three sets of seals provided. All the available reports are attached.

With the seals in this condition I cannot warranty a failure of this nature beyond our control. We will discuss what will happen at this point and a solution will be reached in a timely manner.

The following pages are the reports from the seal suppliers on the cause of the seal failures. Each report indicates the individual pump serial numbers for the seal that was inspected.

Please call me so we can set up a meeting at your earliest convenience.

Sincerely;

Geoff Mondor
Inside Services Technician
Spears Sale & Service Ltd.

gm

TOTAL P.01

Pump Ser# 14282

PROGRESSIVE SEALING
1698 W 75TH AVE
VANCOUVER,B.C
V6P 6G2
Phone: 604-263-1562
Fax: 604-263-8923

facsimile transmittal

To:	JEFF	Fax:	
From:	DAVID	Date:	09/27/00
Re:	FAILURE ANALYSIS	Pages:	1
CC:	SPEARS		

☐ Urgent ☐ For Review ☐ Please Comment ☐ Please Reply ☐ Please Recycle

AFTER INSPECTING THE STAT CER FACE I CONCLUDED THAT PARTICLES HAD MIGRATED ACROSS THE SEAL FACE WHILE IN OPERATION CAUSING SEAL FAILURE DUE TO SCORING.

IF YOU HAVE ANY QUESTIONS PLEASE CONTACT ME PH#230-7195

THANKS

gm

Seal Failure Analysis Worksheet

A.R. Thomson Group

Equipment Data

Customer: SPEAKS SALES

Tag No.: Pump Set # 14282

Location:

Seal Data

Manufacturer: ?

Type: T-21

Size: 3"

Material: CBN/CER/BUNA.

Date: AUG 31/00

By: RK.

W/O#:

Field survey attached Yes ☐ No ☑

All parts available Yes ☐ No ☑

Seal tampered with Yes ☐ No ☐

SEAL COMPONENTS	OK	Material Buildup	Worn	Eroded Corroded	Distorted	Fretted	Missing	Comments / Observations
Set Clips	N/A							
Clip Screws	N/A							
Set Screws	N/A							
Drive Collar	N/A							
Springs	N/A							
Bushings	N/A							
Bellows	N/A							
Sleeve	N/A							
Gland	N/A							
Other								

SEAL FACES	Material	Face Wear	Wear Track	Chipping ID/OD	Coking	Cracked Broken	Heat checked	Comments / Observations
~~O/B ROT~~								
~~O/B STN~~								
I/B STN	CER.	EVEN	EVEN	✓				
I/B ROT	CBN	EVEN	EVEN	✓ ON ID				ON BACK SIDE OF FACE
								SCORED ON FACE.

SECONDARY SEALS	Material	OK	Cut	Extruded	Swollen	Compression Set	Missing	Comments / Observations
~~O/B ROT~~								
~~O/B STN~~								
I/B STN	BUNA	✓						
I/B ROT	BUNA	✓						
Sleeve								
Gasket								
Other								

Recommendations / Action List

gm

MATERIAL / PRODUCT BUILD UP ON OD & ID OF CBN ROT FACE. SLIGHT CHIPPING ON BACK ID OF CBN ROT FACE. ORING GROOVE ON CERAMIC STAT DOES NOT APPEAR TO BE

TOTAL P.01

Pump Ser # 14281

Seal Failure Analysis Worksheet

A.R. Thomson Group

Equipment Data
Customer Spears ATTN: GEOFF
Tag No.
Location

Seal Data
Manufacturer John Crane
Type T-21
Size 3"
Material carbon / ceramic / Viton "O" Ring Stat.

Date Sept. 7/00.
By Warren Way
W/O# 00911

Field survey attached Yes ☐ No ☐
All parts available Yes ☐ No ☐
Seal tampered with Yes ☐ No ☐

SEAL COMPONENTS	OK	Material Buildup	Worn	Eroded Corroded	Distorted	Fretted	Missing	Comments / Observations
Set Clips								
Clip Screws								
Set Screws								
Drive Collar	✓							
Springs								
Bushings							✓	
Bellows			✓					
Sleeve								on ID.
Gland								
Other								
Retainer	✓							
Spring Holder							✓	

SEAL FACES	Material	Face Wear	Wear Track	Chipping ID / OD	Coking	Cracked Broken	Heat checked	Comments / Observations
O/B ROT								
O/B STN	ceramic	ok	even					
I/B STN								minor wear
I/B ROT	carbon	ok	even					minor wear.

SECONDARY SEALS	Material	OK	Cut	Extruded	Swollen	Compression Set	Missing	Comments / Observations
O/B ROT								
O/B STN	Viton							
I/B STN						✓		very slightly, minor wear
I/B ROT								
Sleeve								
Gasket								
Other								

Recommendations / Action List

No apparent cause of seal failure.

Pump Ser # 14280

EQUIPCO LTD.
Manufacturers Representatives
Unit 101 - 42 Fawcett Road, Coquitlam, BC V3K 6X9
Phone (604) 522-5590 • Fax (604) 522-0726
Toll Free Phone: (to BC from Alberta & Saskatchewan only) *1-888-522-1166*

Edmonton:
Phone (780) 486-1166
Fax (780) 486-1156
Calgary:
Phone (403) 201-4188
Fax (403) 201-4877

August 28, 2000

Spears Sales and Service Ltd.
3586 Commercial Street
Vancouver, BC V5N 4E9

Att: Geoff Mondor

Hydromatic Seal Failure - Cruise Ship Dock

I received and inspected the seal that had failed on the above project. The seal was worn evenly. This indicates that the seal was installed correctly. I also inspected the seal for cracking created by heat and there was nothing visible. This would indicate that the pump was run dry and this definitely did not happen.. The carbon face has some grooves worn into its face which would indicate that an abrasive material got lodged between the seal faces and caused the leakage. This is usually caused by infiltration of sand into the system. If you have any more questions please call.

Best regards,

gm

Pump Serial # 14280

EQUIPCO LTD.
Manufacturers Representatives

Memorandum

Date : September 12, 2000

To : Geoff

From : Terry Bowman

Subject : Hydromatic

The seals from Hydromatic are originally John Crane seals.

Terry Bowman

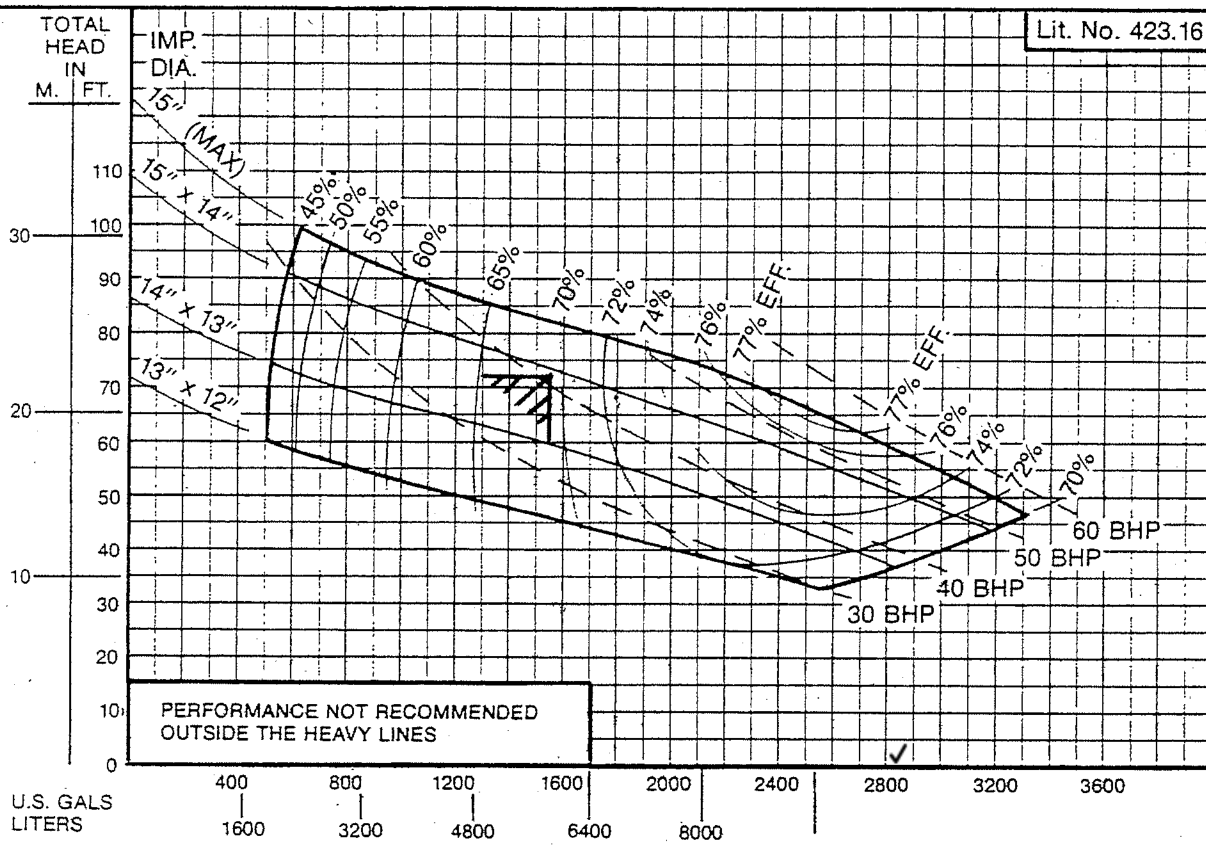
gm

BURRARD P.S.

HYDR-O-MATIC PUMPS

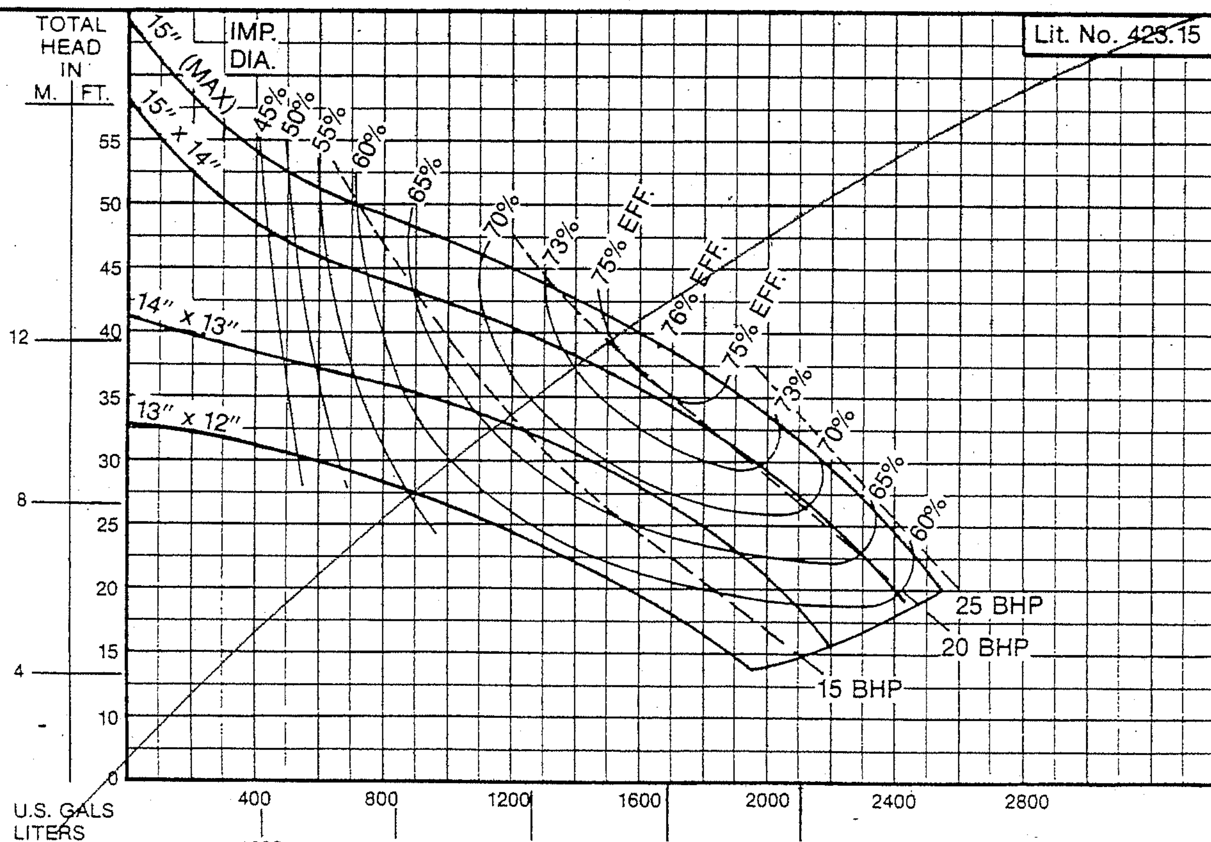
MODEL: S8L SUBMERSIBLE SEWAGE PUMP — MAX. SOLIDS: 4" SPHERE — 1150 RPM

Lit. No. 423.16 | 8940



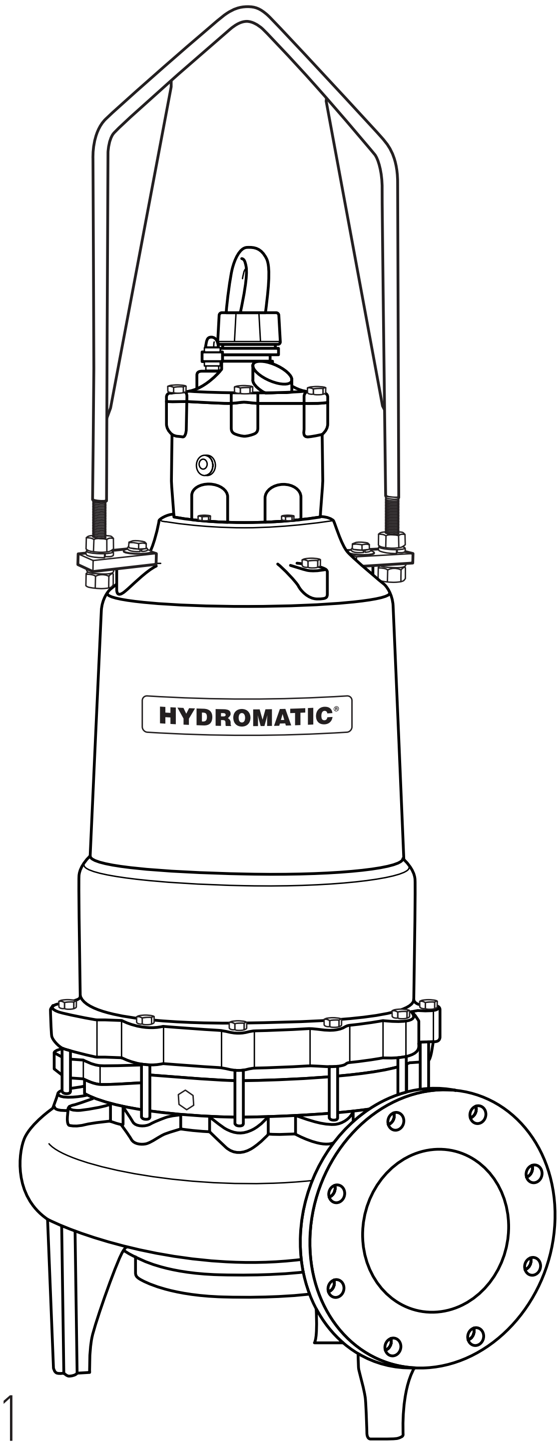
MODEL: S8L SUBMERSIBLE SEWAGE PUMP — MAX. SOLIDS: 4" SPHERE — 870 RPM

Lit. No. 423.15 | 8939



PENTAIR

HYDROMATIC®



MODELS S4T(X*), S8L(X*), S8LA(X*) and S12L(X*)

*Used in Hazardous Locations Class I, Division 1

SUBMERSIBLE SOLIDS HANDLING PUMP

INSTALLATION AND SERVICE MANUAL

For use with product built with USEM motor.

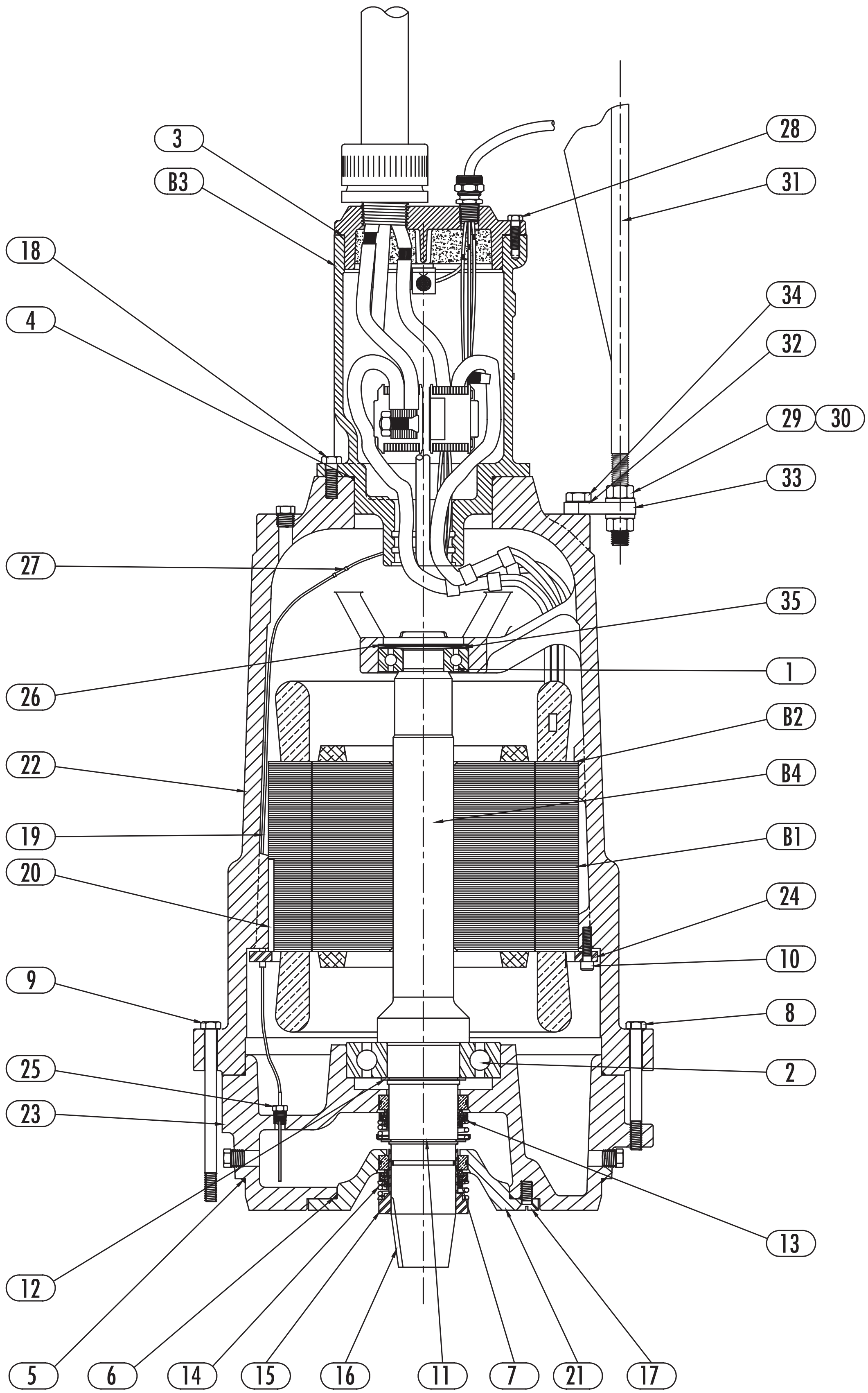
(*Hazardous Location Motor End)

FM APPROVED

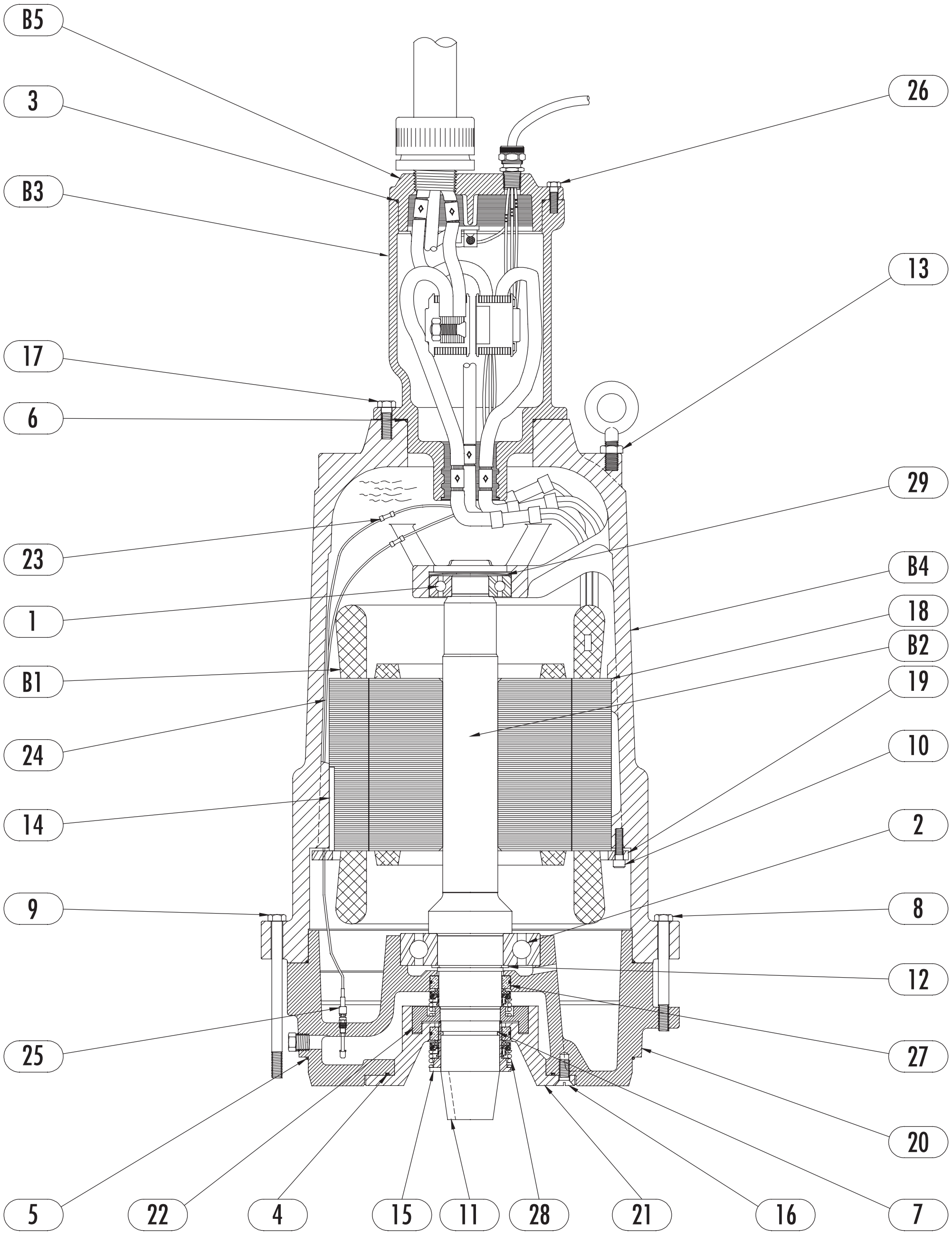
NOTE! To the installer: Please make sure you provide this manual to the owner of the equipment or to the responsible party who maintains the system.

Item # E-03-503 | 320 Frame | Part # 5625-503-1 | © 2014 Pentair Ltd. | 06/20/14

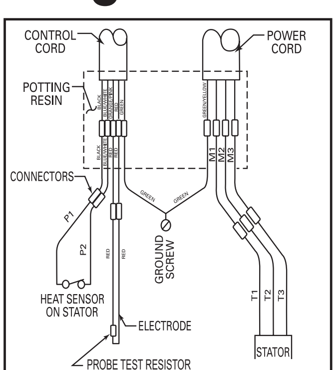
Standard Location
S4T, S8L, S8LA, S12L Motor End Components



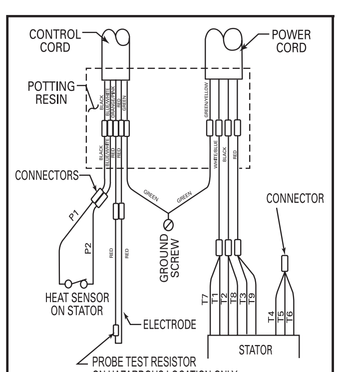
Hazardous Location
S4TX, S8LX, S8LAX, S12LX Motor End Components



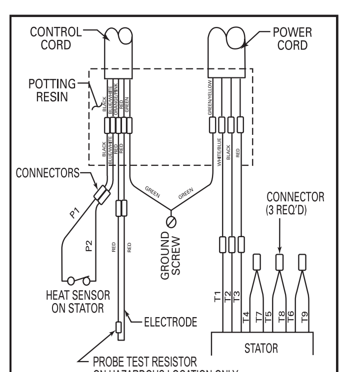
Wiring Diagrams



200 OR 575 VOLT – THREE PHASE



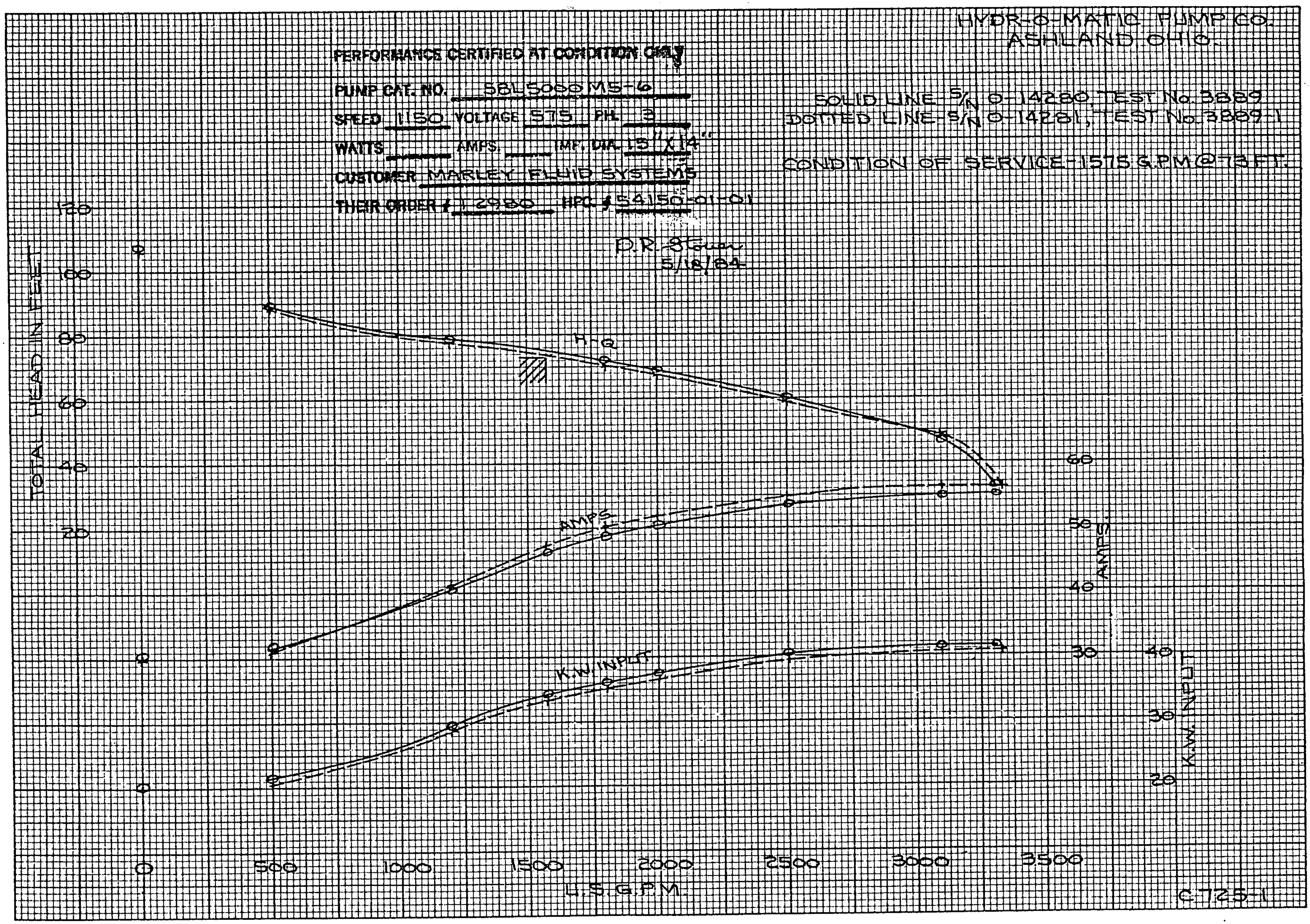
230 VOLT – THREE PHASE



460 VOLT – THREE PHASE

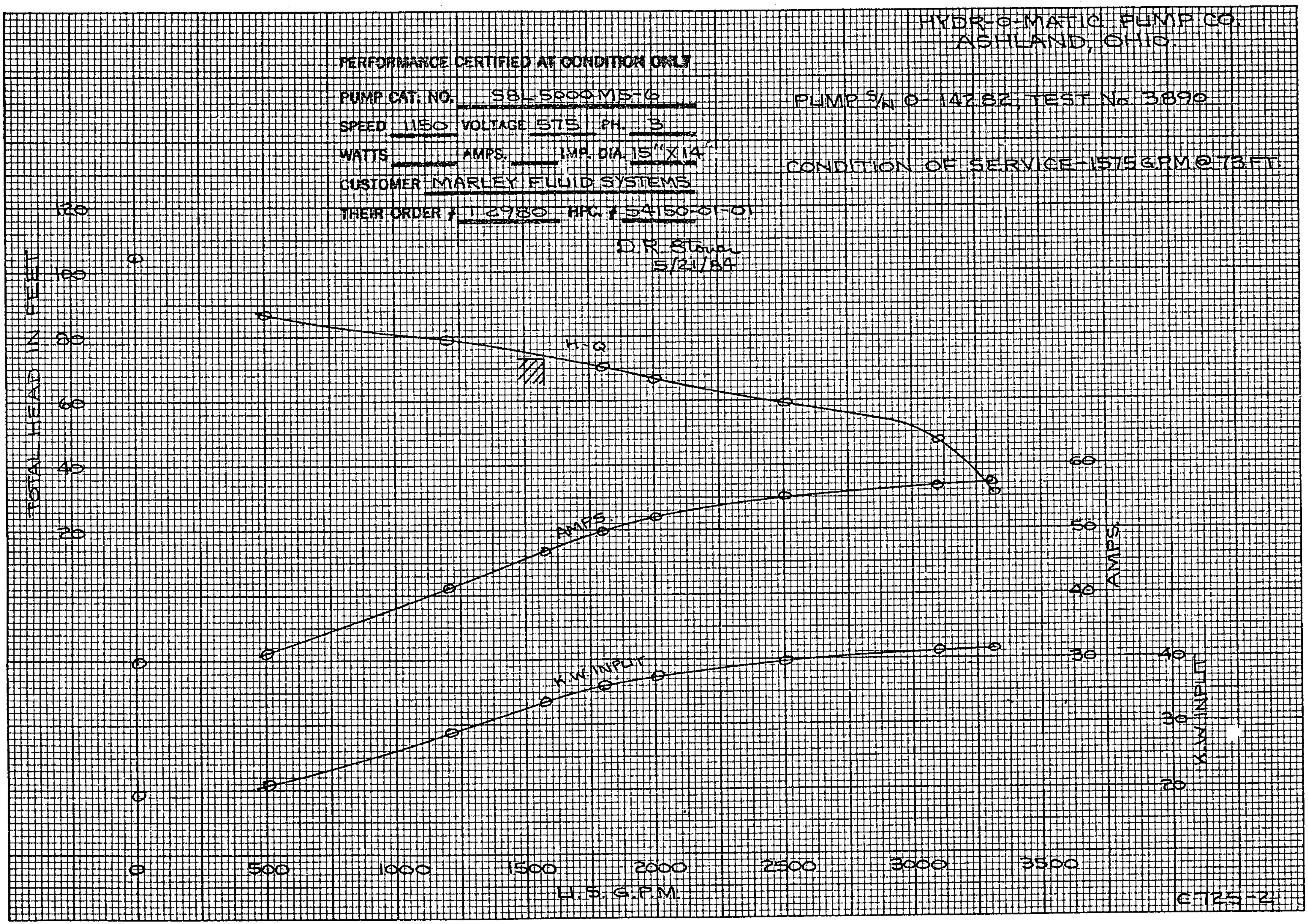
2301-TR15 10X10 TO ½ INCH
LITHO IN U.S.A.

TELEDYNE
NATIONAL TRACING PAPER
INDIANAPOLIS, INDIANA

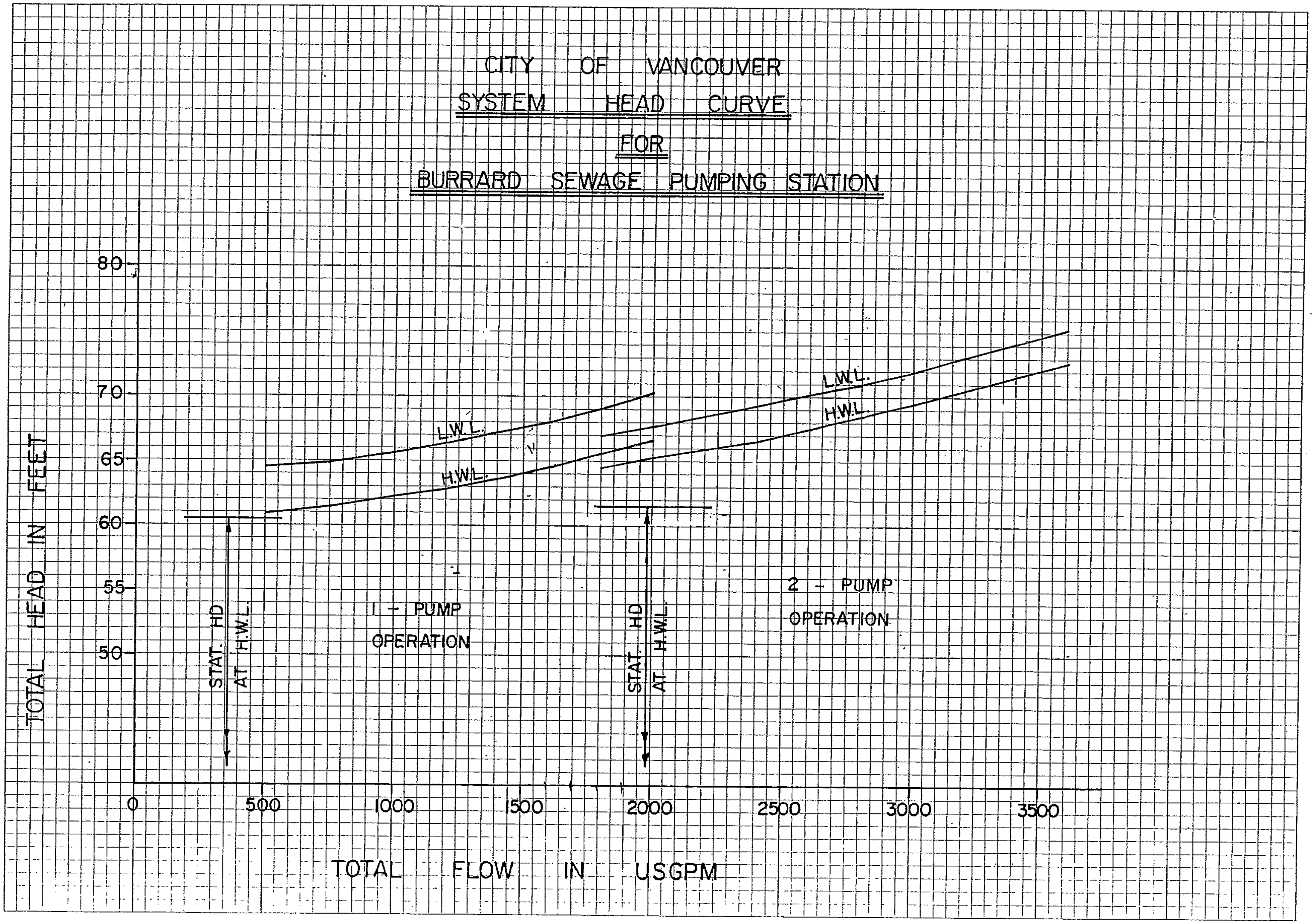


2301-TR15 10X10 TO ½ INCH
LITHO IN U.S.A.

TELEDYNE
NATIONAL TRACING PAPER
INDIANAPOLIS, INDIANA



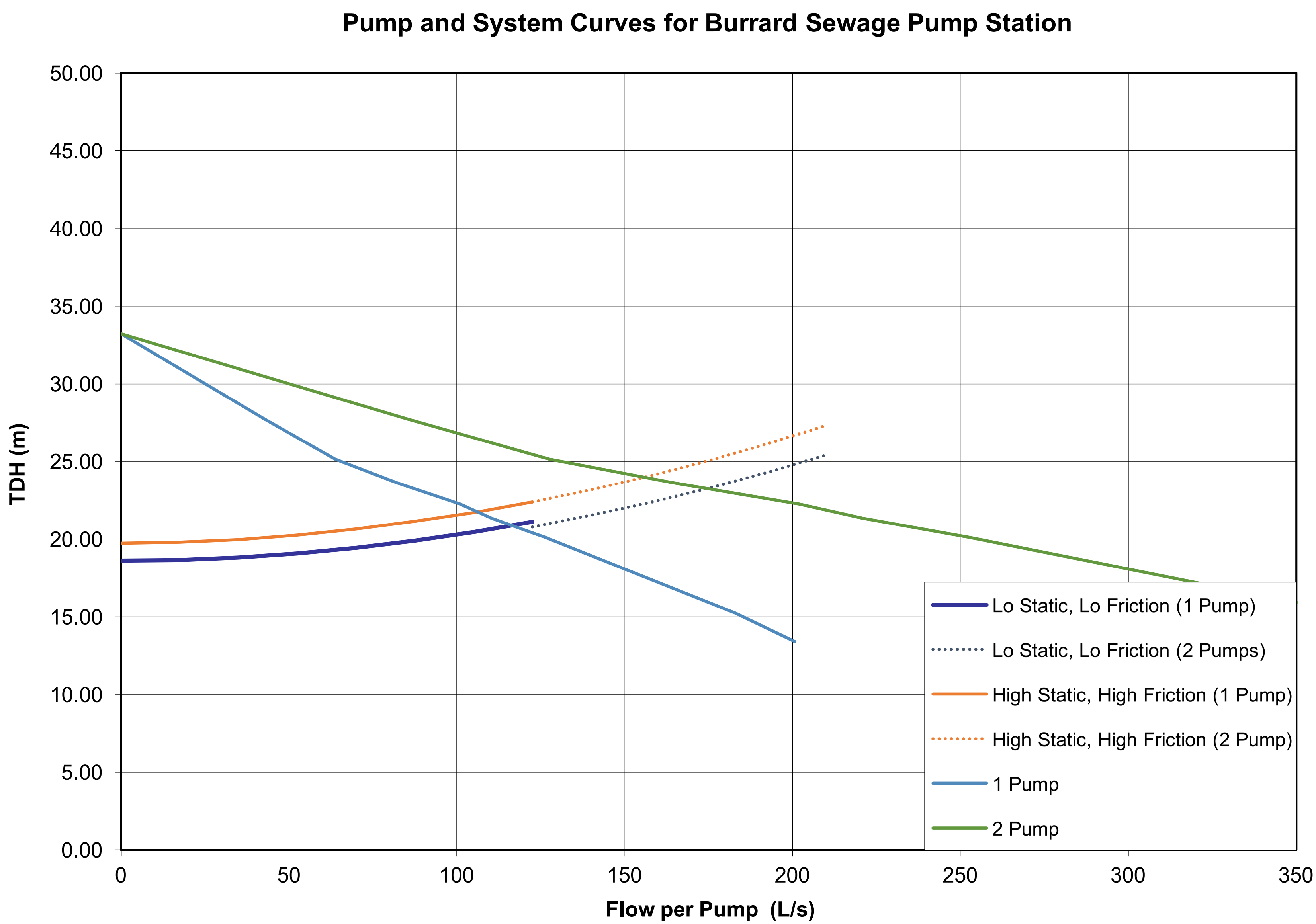
Appendix 4: Pump and System Curve

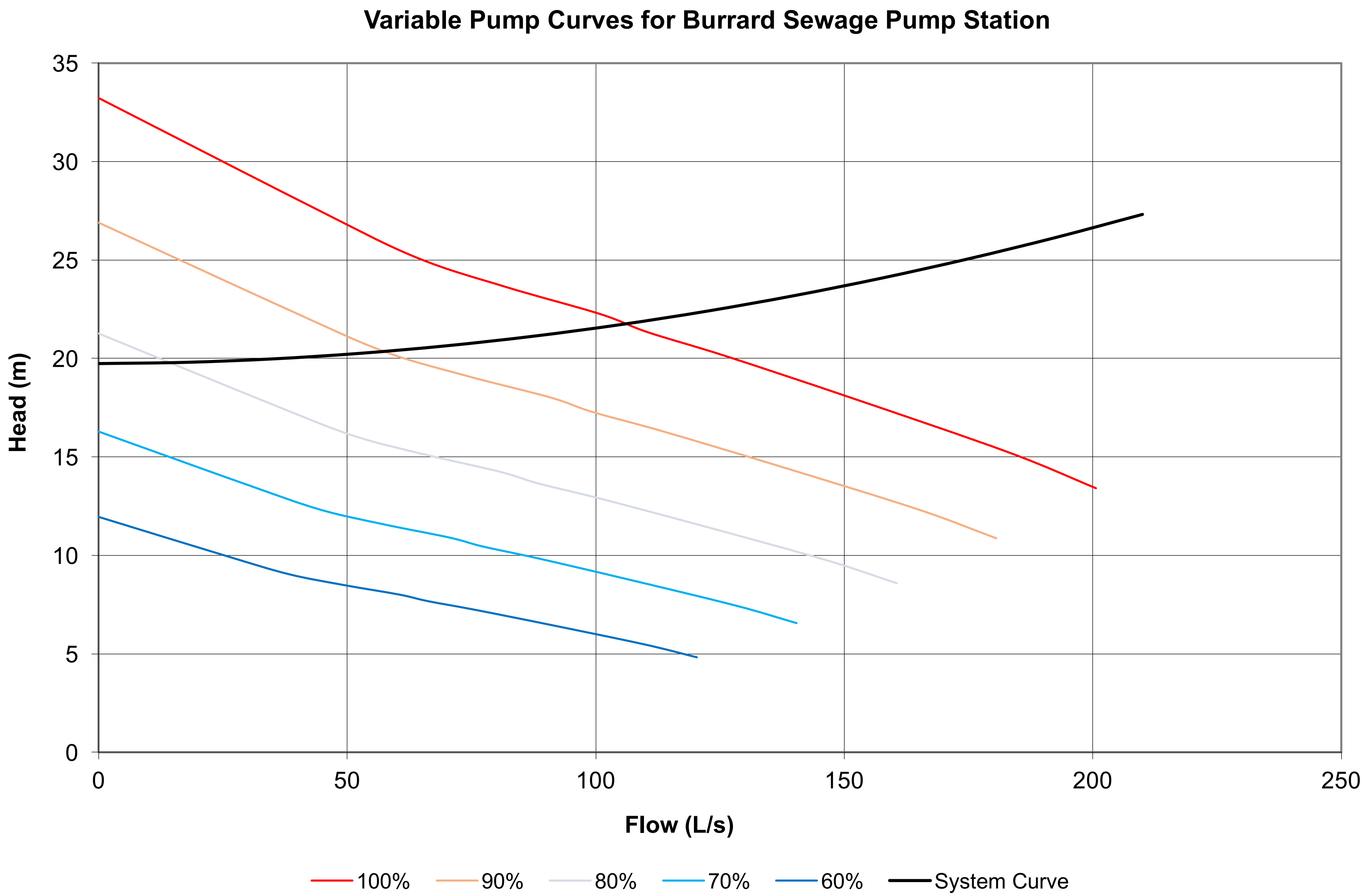


INITIALS OF SIGNING OFFICER

Selected Parameters for System Curve Calculation

FRICTION SCENARIO	Low	High	Low	High
NUMBER OF PUMPS OPERATING	1	1	2	2
STATIC HEAD (m)	18.6	19.7	18.3	19.7
HAZEN WILLIAMS FRICTION FACTOR (ASSUMED)	120	110	120	110
LENGTH OF FORCEMAIN (FROM WALL OF STATION - feet)	80	80	80	80
ASSUMED ID OF FORCEMAIN (mm)	310	310	310	310


Pump and System Curves for Burrard Sewage Pump Station
TDH (m)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
50
100
150
200
250
300
350
Flow per Pump (L/s)
Lo Static, Lo Friction (1 Pump)
Lo Static, Lo Friction (2 Pumps)
High Static, High Friction (1 Pump)
High Static, High Friction (2 Pump)
1 Pump
2 Pump


Variable Pump Curves for Burrard Sewage Pump Station
Head (m)
35
30
25
20
15
10
5
0
0
50
100
150
200
250
Flow (L/s)
100%
90%
80%
70%
60%
System Curve

Appendix 5: Cost Estimates

City of Vancouver
Upgrades
Class 'C' Cost Estimate **Option 1A: Retain Existing Building - Minor Upgrades and New PLC Controls**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
1	**General**				
1.01	Bonding	LS	463,488	1.50%	6,952
1.02	Insurance	LS	463,488	0.50%	2,317
1.03	Mob/demob	LS	463,488	3.00%	13,905
	Subtotal for Division				**23,174**
2	**Existing Conditions**				
2.01	Removal of asbestos containing materials	L.S.	1	10,000	10,000
	Subtotal for Division				**10,000**
5	**Metals**				
5.01	Strengthen Wall Roof Connection				
	Grade beams - cast-in place	kg	25	100	2,500
	Post installed anchor rods	ea	1	50	50
	Field welding incl. coating removal and replacement	lin.m	250	18	4,500
5.02	Misc pipe supports, misc metals	Allow	1	5,000	5,000
	Subtotal for Division				**12,050**
22	**Plumbing**				
2.01	Air compressor	L.S.	1	5,000	5,000
	Subtotal for Division				**5,000**
23	**HVAC**				
23.01	Chamber supply fan	ea	1	4,000	4,000
23.02	Ductwork & dampers	Allow	1	10,000	10,000
23.03	Wall penetration and louver	Allow	1	8,000	8,000
	Subtotal for Division				**22,000**
26	**Electrical**				
26.01	Controls & communications	LS	1	143,000	143,000
26.02	Electrical Equipment Removal	LS	1	1,920	1,920
26.03	Cabling and Wiring	L.S	1	5,560	5,560
26.04	Testing and Commissioning	L.S	1	1,920	1,920
26.05	General contractor's mark-up on electrical	%	150,480	10%	15,048
	Subtotal for Division				**167,448**
33	**Utilties**				
33.01	Excavation and backfill of forcemain connection	m3	18	200	3,600
33.02	Install two 12" couplings for seismic isolation	L.S	1	22,000	22,000
33.03	Dewatering	L.S.	1	5,000	5,000
33.04	Station Bypass	L.S.	1	11,000	11,000
33.05	Clean out wet well prior to pump install	L.S.	1	5,000	5,000
	Subtotal for Division				**46,600**
40	**Process Integration**				
	Piping				
40.01	Re-coat existing piping	lin.m	6	500	3,000
40.02	Field installation of valves, pumps and duct work	days	10	5,000	50,000

City of Vancouver
Upgrades
Class 'C' Cost Estimate **Option 1A: Retain Existing Building - Minor Upgrades and New PLC Controls**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
	Major Valves				
40.03	250mm Handwheel Operated Plug Valve	ea	3	2,852	8,556
40.04	250mm Actuated Plug Valve	ea	3	11,891	35,673
40.05	300mm Handwheel Operated Plug Valve	ea	1	3,437	3,437
40.06	Pressure transmitters	ea	4	800	3,200
40.07	Pressure guages (incl. snubbers)	ea	4	500	2,000
40.08	Hydrostatic testing	Allow	1	2,000	2,000
40.09	Commissioning	hrs.	8	500	4,000
40.10	General contractor's mark-up on mechanical	%	111,866	10%	11,187
	Subtotal for Division				**123,053**
43	**Process Liquid Handling Equipment**				
43.01	Pumps and appurtenances	ea	3	26,466	79,398
43.02	General contractor's mark-up on equipment	%	$ 79,398	10%	7,940
	Subtotal for Division				**87,337**
	Subtotal for Project				**496,663**
	Engineering & Construction Management	20%			99,333
	Contingencies	30%			148,999
	TOTAL AMOUNT (rounded, excl. GST)				**700,000**
	Low	-25%			**500,000**
	High	40%			**1,000,000**

Note: Refer to Basis of Estimate memo for assumptions and limitations.

City of Vancouver
Upgrades
Class 'C' Cost Estimate **Option 1B: Retain Existing Building - Minor Upgrades and New PLC Controls using VFNR starters**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
1	**General**				
1.01	Bonding	LS	515,424	1.50%	7,731
1.02	Insurance	LS	515,424	0.50%	2,577
1.03	Mob/demob	LS	515,424	3.00%	15,463
	Subtotal for Division				**25,771**
2	**Existing Conditions**				
2.01	Removal of asbestos containing materials	L.S.	1	10,000	10,000
	Subtotal for Division				**10,000**
5	**Metals**				
5.01	Strengthen Wall Roof Connection				
	Grade beams - cast-in place	kg	25	100	2,500
	Post installed anchor rods	ea	1	50	50
	Field welding incl. coating removal and replacement	lin.m	250	18	4,500
5.02	Misc pipe supports, misc metals	Allow	1	5,000	5,000
	Subtotal for Division				**12,050**
22	**Plumbing**				
2.01	Air compressor	L.S.	1	5,000	5,000
	Subtotal for Division				**5,000**
23	**HVAC**				
23.01	Chamber supply fan	ea	1	4,000	4,000
23.02	Ductwork & dampers	Allow	1	10,000	10,000
23.03	Wall Penetration and louver	Allow	1	8,000	8,000
	Subtotal for Division				**22,000**
26	**Electrical**				
26.01	Controls & communications	LS	1	143,000	143,000
26.02	Electrical Equipment Removal	LS	1	4,200	4,200
26.03	Cabling and Wiring	L.S	1	8,340	8,340
26.04	MCC/Distribution Equipment/Power Factor Correction	L.S	1	33,120	33,120
26.05	Manual Transfer Switch	L.S.	1	7,280	7,280
26.06	Building electrical modifications and hardware	L.S.	1	2,460	2,460
26.07	Generator Plug and Cable	L.S.	1	1,120	1,120
26.08	Testing and Commissioning	L.S	1	3,200	3,200
26.09	General contractor's mark-up on electrical	%	202,720	10%	20,272
	Subtotal for Division				**222,992**
33	**Utilities**				
33.01	Excavation and backfill of forcemain connection	m3	18	200	3,600
33.02	Install two 12" couplings for seismic isolation	L.S	1	22,000	22,000
33.03	Dewatering	L.S.	1	5,000	5,000
33.04	Station Bypass	L.S.	1	11,000	11,000
33.05	Clean out wet well prior to pump install	L.S.	1	5,000	5,000
	Subtotal for Division				**46,600**
40	**Process Integration**				
	Piping				

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Class 'C' Cost Estimate **Option 1B: Retain Existing Building - Minor Upgrades and New PLC Controls using VFNR starters**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
40.01	Re-coat existing piping	lin.m	6	500	3,000
40.02	Field installation of valves, pumps and duct work	days	10	5,000	50,000
	Major Valves				
40.03	250mm Handwheel Operated Plug Valve	ea	3	2,852	8,556
40.04	250mm Actuated Plug Valve	ea	3	11,891	35,673
40.05	300mm Handwheel Operated Plug Valve	ea	1	3,437	3,437
40.06	Pressure transmitters	ea	4	800	3,200
40.07	Pressure guages (incl. snubbers)	ea	4	500	2,000
40.08	Hydrostatic testing	Allow	1	2,000	2,000
40.09	Commissioning	hrs.	8	90	720
40.10	General contractor's mark-up on mechanical	%	108,586	10%	10,859
	Subtotal for Division				**119,445**
43	**Process Liquid Handling Equipment**				
43.01	Pumps and appurtenances	ea	3	26,466	79,398
43.02	General contractor's mark-up on equipment	%	$ 79,398	10%	7,940
	Subtotal for Division				**87,337**
	Subtotal for Project				**551,196**
	Engineering & Construction Management	20%			110,239
	Contingencies	30%			165,359
	TOTAL AMOUNT (rounded, excl. GST)				**800,000**
	Low	-25%			**600,000**
	High	40%			**1,100,000**

Note: Refer to Basis of Estimate memo for assumptions and limitations.

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Class 'C' Cost Estimate **Option 1C: Retain Existing Building - Minor Upgrades and New PLC Controls using VFD starters**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
1	**General**				
1.01	Bonding	LS	515,404	1.50%	7,731
1.02	Insurance	LS	515,404	0.50%	2,577
1.03	Mob/demob	LS	515,404	3.00%	15,462
	Subtotal for Division				**25,770**
2	**Existing Conditions**				
2.01	Removal of asbestos containing materials	L.S.	1	10,000	10,000
	Subtotal for Division				**10,000**
5	**Metals**				
5.01	Strengthen Wall Roof Connection				
	Grade beams - cast-in place	kg	25	100	2,500
	Post installed anchor rods	ea	1	50	50
	Field welding incl. coating removal and replacement	lin.m	250	18	4,500
5.02	Misc pipe supports, misc metals	Allow	1	5,000	5,000
	Subtotal for Division				**12,050**
23	**HVAC**				
23.01	Chamber supply fan	ea	1	4,000	4,000
23.02	Ductwork & dampers	Allow	1	10,000	10,000
23.03	Wall penetration and louver	Allow	1	8,000	8,000
	Subtotal for Division				**22,000**
26	**Electrical**				
26.01	Controls & communications	LS	1	143,000	143,000
26.02	Electrical Equipment Removal	LS	1	4,200	4,200
26.03	Cabling and Wiring	L.S	1	9,980	9,980
26.04	MCC/Distribution Equipment/Power Factor Correction	L.S	1	71,760	71,760
26.05	Outdoor Service Kiosk	L.S.	1	28,060	28,060
26.06	BC Hydro Feeder Modifications	L.S	1	2,760	2,760
26.07	Manual Transfer Switch	L.S.	1	7,280	7,280
26.08	Building electrical modifications and hardware	L.S.	1	2,460	2,460
26.09	Generator Plug and Cable	L.S.	1	1,120	1,120
26.10	Testing and Commissioning	L.S	1	4,480	4,480
26.11	General contractor's mark-up on electrical	%	275,100	10%	27,510
	Subtotal for Division				**302,610**
33	**Utilities**				
33.01	Excavation and backfill of forcemain connection	m3	18	200	3,600
33.02	Install two 12" couplings for seismic isolation	L.S	1	22,000	22,000
33.03	Dewatering	L.S.	1	5,000	5,000
33.04	Station Bypass	L.S.	1	11,000	11,000
33.05	Clean out wet well prior to pump install	L.S.	1	5,000	5,000
	Subtotal for Division				**46,600**
40	**Process Integration**				
	Piping				
40.01	Re-coat existing piping	lin.m	6	500	3,000
40.02	Field installation of valves, pumps and duct work	days	3	2,500	7,500
	Major Valves				

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Class 'C' Cost Estimate **Option 1C: Retain Existing Building - Minor Upgrades and New PLC Controls using VFD starters**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
40.03	250mm Handwheel Operated Plug Valve	ea	3	2,852	8,556
40.04	250mm Check Valves	ea	3	3,440	10,321
40.05	300mm Handwheel Operated Plug Valve	ea	1	3,437	3,437
40.06	Pressure transmitters	ea	4	800	3,200
40.07	Pressure guages	ea	4	500	2,000
40.08	Hydrostatic testing	Allow	1	2,000	2,000
40.09	Commissioning	hrs.	8	90	720
40.10	General contractor's mark-up on mechanical	%	40,734	10%	4,073
	Subtotal for Division				**44,807**
43	**Process Liquid Handling Equipment**				
43.01	Pumps and appurtenances	ea	3	26,466	79,398
43.02	General contractor's mark-up on equipment	%	$ 79,398	10%	7,940
	Subtotal for Division				**87,337**
	Subtotal for Project				**551,175**
	Engineering & Construction Management	20%			110,235
	Contingencies	30%			165,352
	TOTAL AMOUNT (rounded, excl. GST)				**800,000**
	Low	-25%			**600,000**
	High	40%			**1,100,000**

Note: Refer to Basis of Estimate memo for assumptions and limitations.

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Class 'C' Cost Estimate **Option 2: Expand Building (incl. VFNR starters)**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
1	**General**				
1.01	Bonding	LS	852,694	1.50%	12,790
1.02	Insurance	LS	852,694	0.50%	4,263
1.03	Mob/demob	LS	852,694	3.00%	25,581
	Subtotal for Division				**42,635**
2	**Existing Conditions**				
2.01	Demolition				
	Roof and block wall demolition incl. asbestos removal	L.S.	1	20,000	20,000
	Dry well wall saw cutting and removal incl. slab shoring	L.S.	1	9,000	9,000
	Remove existing pipe, pumps and valves	L.S.	1	7,500	7,500
	Subtotal for Division				**36,500**
3	**Concrete**				
3.01	Reinforced concrete chamber	m3	29	1,200	34,800
	Subtotal for Division				**34,800**
4	**Masonry**				
4.01	Masonry block walls incl. rebar and grout	m2	80	300	24,000
	Subtotal for Division				**24,000**
5	**Steel**				
5.01	Guardrails and stairs	kg	200	15	3,000
	Subtotal for Division				**3,000**
7	**Thermal and Moisture Protection**				
7.01	Roof build-up	m2	36	350	12,600
	Subtotal for Division				**12,600**
23	**HVAC**				
23.01	Chamber supply fan	ea	1	4,000	4,000
23.02	Ductwork & dampers	Allow	1	10,000	10,000
23.03	Louver and wall penetration	Allow	1	8,000	8,000
	Subtotal for Division				**22,000**
26	**Electrical**				
26.01	Controls & communications	LS	1	143,000	143,000
26.02	Electrical Equipment Removal	LS	1	4,200	4,200
26.03	Cabling and Wiring	L.S	1	8,340	8,340
26.04	MCC/Distribution Equipment/Power Factor Correction	L.S	1	33,120	33,120
26.05	Manual Transfer Switch	L.S.	1	7,280	7,280
26.06	Building electrical modifications and hardware	L.S.	1	2,460	2,460
26.07	Generator Plug and Cable	L.S.	1	1,120	1,120
26.08	Testing and Commissioning	L.S	1	3,200	3,200
26.09	General contractor's mark-up on electrical	%	202,720	10%	20,272
	Subtotal for Division				**222,992**
33	**Earthworks**				
33.01	Structural Excavation	m3	110	50	5,500
33.02	Structural Backfill	m3	10	100	1,000

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Class 'C' Cost Estimate **Option 2: Expand Building (incl. VFNR starters)**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
33.03	Shoring	m2	78	600	46,800
33.04	Install two 12" couplings for seismic isolation	L.S	1	10,000	10,000
33.05	Dewatering	L.S.	1	100,000	100,000
33.06	Station Bypass	L.S.	1	31,000	31,000
33.07	Clean out wet well prior to pump install	L.S.	1	5,000	5,000
	Subtotal for Division				**199,300**
40	**Process Integration**				
	Piping				
40.01	Re-coat existing piping	lin.m	42	2,100	88,200
40.02	Field installation of valves, pumps and duct work	days	15	5,000	75,000
	Major Valves				
40.03	250mm Handwheel Operated Plug Valve	ea	3	2,852	8,556
40.04	250mm Actuated Plug Valve	ea	3	11,891	35,673
40.05	300mm Handwheel Operated Plug Valve	ea	1	3,437	3,437
40.06	Pressure transmitters	ea	4	800	3,200
40.07	Pressure guages	Allow	4	500	2,000
40.08	Hydrostatic testing	Allow	1	2,000	2,000
40.09	Commissioning	hrs.	8	90	720
40.10	General contractor's mark-up on mechanical	%	218,786	10%	21,879
	Subtotal for Division				**240,665**
43	**Process Liquid Handling Equipment**				
43.01	Pumps and appurtenances	ea	3	26,466	79,398
43.02	300mm Flowmeter	ea	1	6,000	6,000
43.03	General contractor's mark-up on equipment	%	$ 79,398	10%	7,940
	Subtotal for Division				**93,337**
	Subtotal for Project				**931,829**
	Engineering & Construction Management	20%			186,366
	Contingencies	30%			279,549
	TOTAL AMOUNT (rounded, excl. GST)				**1,400,000**
	Low	-25%			**1,100,000**
	High	40%			**2,000,000**

Note: Refer to Basis of Estimate memo for assumptions and limitations.

City of Vancouver
Upgrades
Class 'C' Cost Estimate **Option 3: Wet Well Improvements**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
1	**General**				
1.01	Bonding	LS	45,500	1.50%	683
1.02	Insurance	LS	45,500	0.50%	228
1.03	Mob/demob	LS	45,500	3.00%	1,365
	Subtotal for Division				**2,275**
2	**Existing Conditions**				
2.01	Demolition				
	Removal of platform pumps and piping	L.S.	1	2,000	2,000
2.02	Removal of aesbestos containing materials	L.S.	1	10,000	10,000
	Subtotal for Division				**12,000**
6	**Wood, Plastics and Composites**				
6.01	FRP Platform including guardrail	kg	350	30	10,500
	Subtotal for Division				10,500
8	**Opening**				
8.01	Hatches	ea	2	4,000	8,000
8.02	Retrofit safety grid to existing pump hatches	ea	3	1,000	3,000
	Subtotal for Division				11,000
11	**Equipment**				
11.01	Odour Control	L.S.	1	10,000	10,000
	Subtotal for Division				10,000
23	**HVAC**				
23.01	Wet well fan	ea	1	4,000	4,000
23.02	Ductwork	Allow	1	10,000	10,000
	Subtotal for Division				**14,000**
	Subtotal for Project				**59,775**
	Engineering & Construction Management	20%			11,955
	Contingencies	30%			17,933
	TOTAL AMOUNT (rounded, excl. GST)				**100,000**
	Low	-25%			**80,000**
	High	40%			**140,000**

Note: Refer to Basis of Estimate memo for assumptions and limitations.

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Class 'C' Cost Estimate **Option 4: Permanent Genset**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
1	**General**				
1.01	Bonding	LS	127,538	1.50%	1,913
1.02	Insurance	LS	127,538	0.50%	638
1.03	Mob/demob	LS	127,538	3.00%	3,826
	Subtotal for Division				**6,377**
2	**Existing Conditions**				
2.01	Removal of asbestos containing materials	L.S.	1	10,000	10,000
	Subtotal for Division				**10,000**
3	**Concrete**				
3.01	Reinforced contrete genset pad	m3	3	750	2,250
	Subtotal for Division				**2,250**
5	**Metals**				
5.01	Chainlink fence	lin.m	14	150	2,100
5.02	Fence gate	ea	1	350	350
	Subtotal for Division				**2,450**
26	**Electrical**				
26.01	Electrical Equipment Removal	LS	1	640	640
26.02	Transfer switch	LS	1	11,420	11,420
26.03	Cabling wiring and ductt bank	LS	1	4,420	4,420
26.04	Grounding	LS	1	2,285	2,285
26.05	Building electrical modifications	LS	1	2,460	2,460
26.06	Testing and Commissioning	LS	1	2,070	2,070
26.07	General contractor's mark-up on electrical	%	21,225	10%	2,123
	Subtotal for Division				**25,418**
27	**Communications**				
27.01	SCADA connection	allow	1	25,000	25,000
	Subtotal for Division				**25,000**
31	**Earthworks**				
31.01	Excavation and foundation preparation	m3	3	50	150
	Subtotal for Division				**150**
48	**Electrical Power Generation**				
48.01	Stanby Genset	LS	1	65,700	65,700
48.02	General contractor's mark-up on equipment	%	$ 65,700	10%	6,570
	Subtotal for Division				**72,270**

City of Vancouver
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Class 'C' Cost Estimate **Option 4: Permanent Genset**

Div. / Item	Description	Unit	Quantity	Unit Rate	Line Total
	Subtotal for Project				**143,914**
	Engineering & Construction Management	20%			28,783
	Contingencies	30%			43,174
	TOTAL AMOUNT (rounded, excl. GST)				**200,000**
	Low	-25%			**200,000**
	High	40%			**300,000**

Note: Refer to Basis of Estimate memo for assumptions and limitations.