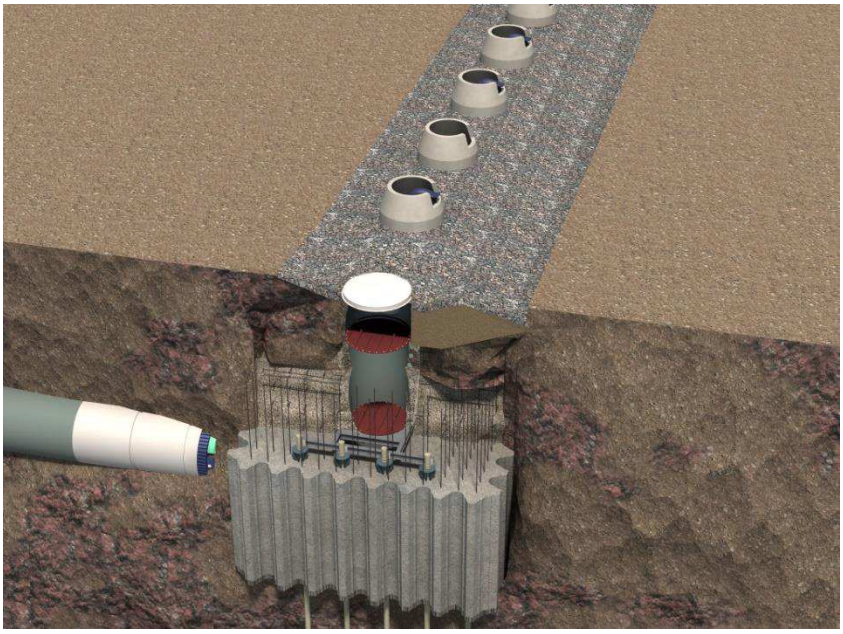
APPENDIX M
MEETING WITH DELTA FIRE AND EMERGENCY SERVICES

Annacis Island WWTP New Outfall System

Vancouver Fraser Port Authority
Project and Environmental Review Application



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SERVICES AND SOLUTIONS FOR A LIVABLE REGION

CDM Smith

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Meeting Minutes

Meeting with Delta Fire and Emergency Services (DFES)

Date: September 21, 2017
Time: 1:30 to 2:30 PM
Location: Delta Fire and Emergency Services, Meeting Room

Attendees: DFES: Steve Raby, Brad Wilson; MV: Ken Massé; CDM Smith: John Newby, Jeff Chen.

Meeting Objectives: Introduce Delta Fire and Emergency Services to the New Outfall System and Site Preparation Projects at the Annacis Island Wastewater Treatment Plant. The goal is to confirm coordination with DFES throughout the projects and incorporate any specific requirements.

No.	Agenda Topic / Discussion Items	Action By
1	**Background** A. MV and CDM Smith provided an overview of the project and planned construction activities. B. New outfall system designed to meet a design seismic event with a return period of 2,475 years (2% chance in 50 years) and a future flow capacity 25.3m^3/s. C. The project involves underground construction for the shafts and tunnels. All work will be performed per WorkSafeBC requirements and the contractor will be required to provide tunnel rescue teams that will be on-call during all periods when workers are in the shafts and tunnels. D. CDM Smith described general and tunnel specific health and safety, fire protection, and monitoring requirements contained in the draft specification requirements for the contractor. E. Objective of the meeting is to obtain information on Delta Fire and Emergency Services anticipated activities, requirements, and possible concerns. F. DFES confirmed that they have no responsibility for fire and rescue on the Fraser River – emergency services are provided by the Canadian Coast Guard	
2	**Project Safety** A. There is a lot of regulations governing underground work with Work Safe BC (Specified in the project safety specification). B. Worker access to the shafts and tunnels will be via stairways and crane man-lifts.	

No.	Agenda Topic / Discussion Items	Action By
	C. Work underground will be at atmospheric pressure. Ventilation will supply fresh air. D. Tunnel entry will require lock-out procedures. E. If hyperbaric work is required in the Tunnel Boring Machine (TBM) head, it will trigger another level of safety requirements. F. There is a site preparation project that will require the demolition of an existing building. DFES will be informed about the new fire suppression sprinkler system switch over to the remaining building. G. DFES provided their preferences for the remote fire connection. H. Contractor to have separate safety coordinator for the on-land and in-river work. I. Reviewed technical specifications safety requirements for tunneling. Specs left with DFES for review. J. Tunnel rescue team spec requires that anytime work is done in tunnel, rescue teams are required. There will also be a backup rescue team. Any additional backup might fall under DFES. K. Shaft work will likely be single work shifts, but tunnel maybe two shifts and one maintenance. Tunnel rescue will need to be available when activities happen. L. DFES wanted to make sure there was have adequate air supply capacity for rescue time in tunnel. There is no hardline air supply requirement. All air supply is provided by tanks with a 6-hour minimum supply for the rescue team. M. Air will be monitored in the tunnel and shaft at all times. N. Shaft excavation may have an excavator, so ventilation duct will be installed. O. There is no limit on number of people working during tunneling, but a minimum of 5 rescue team members are required. P. Typically for normal tunneling, injuries are associated with dropping equipment.	
3	**DFES Involvement** A. DFES would like to stay in contact during different construction phases and have staged familiarization during construction. Ideally, DFES would be included in communications with the Contractor's construction site safety coordinator to coordinate activities as appropriate.	

No.	Agenda Topic / Discussion Items	Action By
	B. Involvement in safety activities by DFES could include: 1) construction activity familiarization; 2) notification of safety organization and training sessions (with optional participation); 3) project site access for assistance with emergency response as necessary.	

Attachment:

1. Meeting Handout Slides
2. Draft Safety Related Specifications

Delta Fire and Emergency Services

Annacis Island Wastewater Treatment Plant
Transient Mitigation and Outfall - Consulting Engineering Services

Ken Massé (MV)
John Newby (CDM)
Jeff Chen (CDM)

Sept 20, 2017

CDM Smith

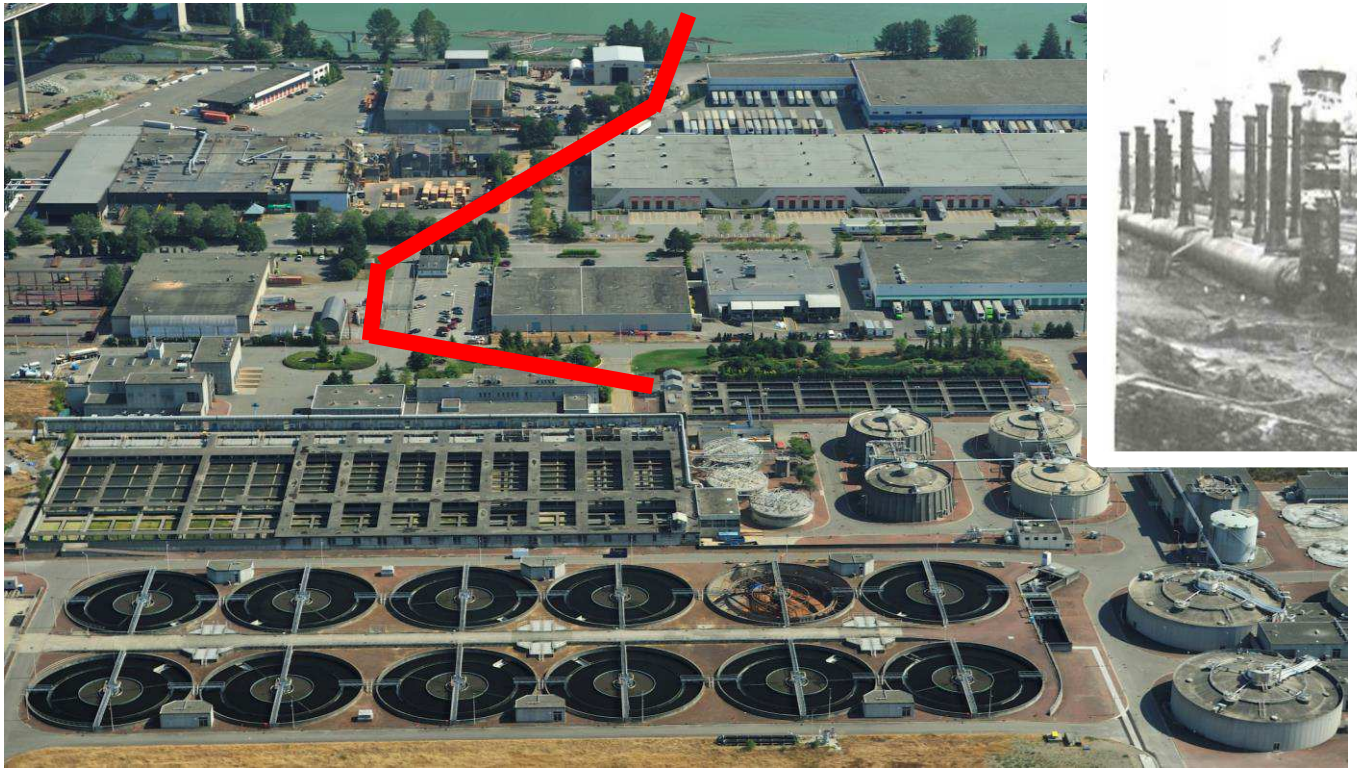
Agenda

- Provide an overview of the project and construction activities
- Describe general and tunnel specific health and safety, fire protection, and monitoring requirements
- Obtain information on Delta Fire and Emergency Services anticipated activities, requirements, and possible concerns

Metro Vancouver Regional District

Annacis Island Wastewater Treatment Plant

Existing Outfall

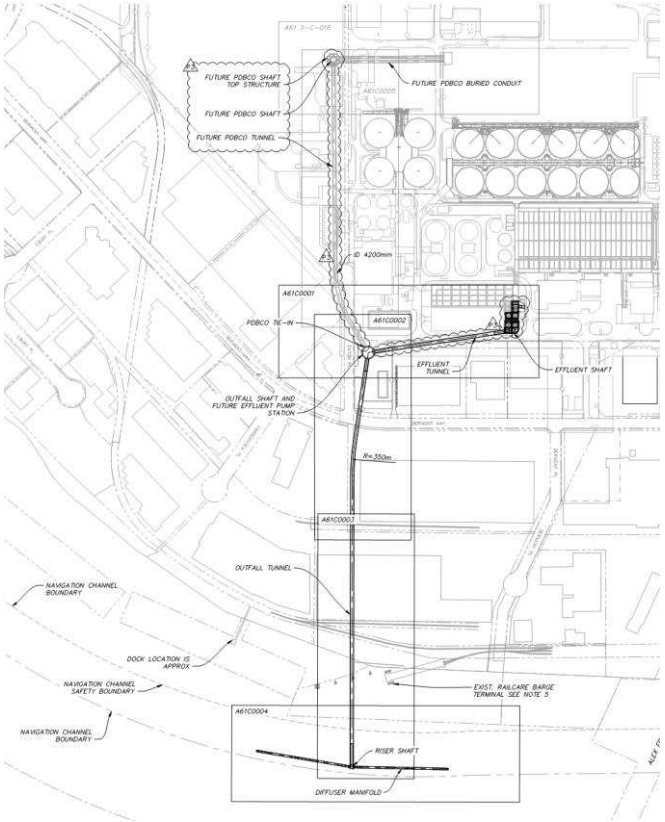


Outfall System Requirements

- Provide a total capacity of 25.3 m^3/s (i.e. Stage VIII PWWF) at a 200-year river level of 103.18 m GD.
- Achieve a minimum dilution ratio of 20:1 under slack water and low flows in the river
- Meet “Post Disaster” requirements in accordance with MV Seismic Design Criteria
- Meet all other standard requirements for MV facilities

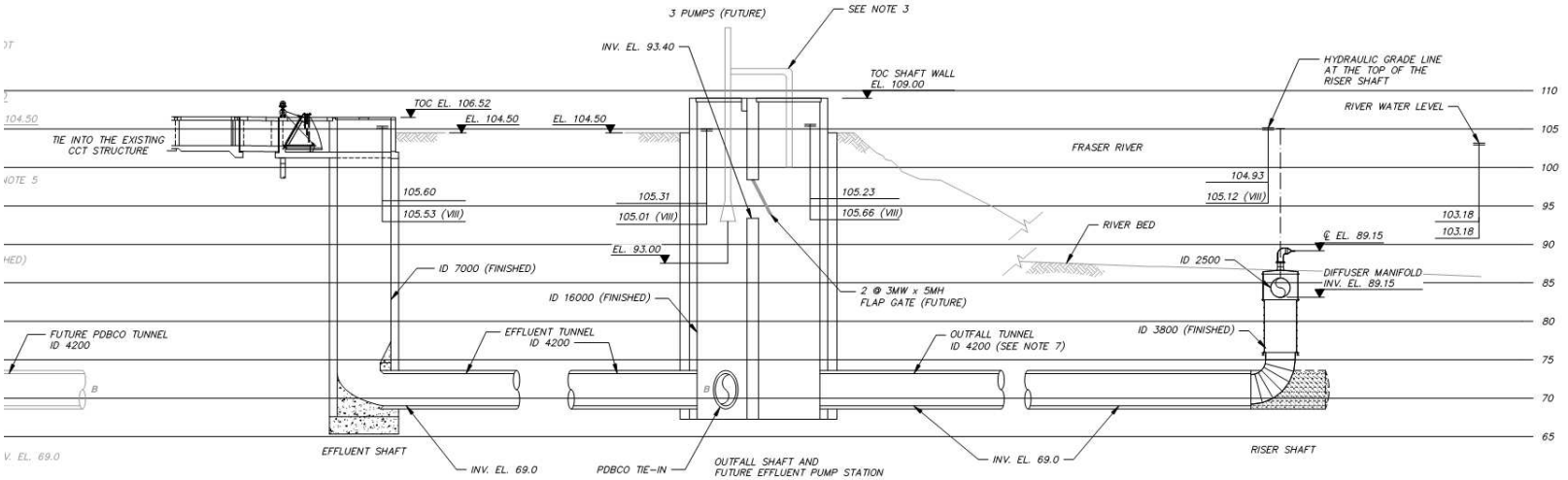
Project Overview

- Level Control Structure / Level Control Gates
- Effluent Shaft – 7m ID, 35m deep
- Effluent Tunnel – 4.2m ID, 216m long
- Outfall Shaft – 16m ID, 35m deep
- Outfall Tunnel – 3.82m ID Lining, 578m long
- PDBCO Tie-in
- Riser Shaft – 3.8m ID
- Diffuser Manifold – 2.5m ID, 240m long
- Future PDBCO Tunnel and Conduit
- Future Effluent Pump Station

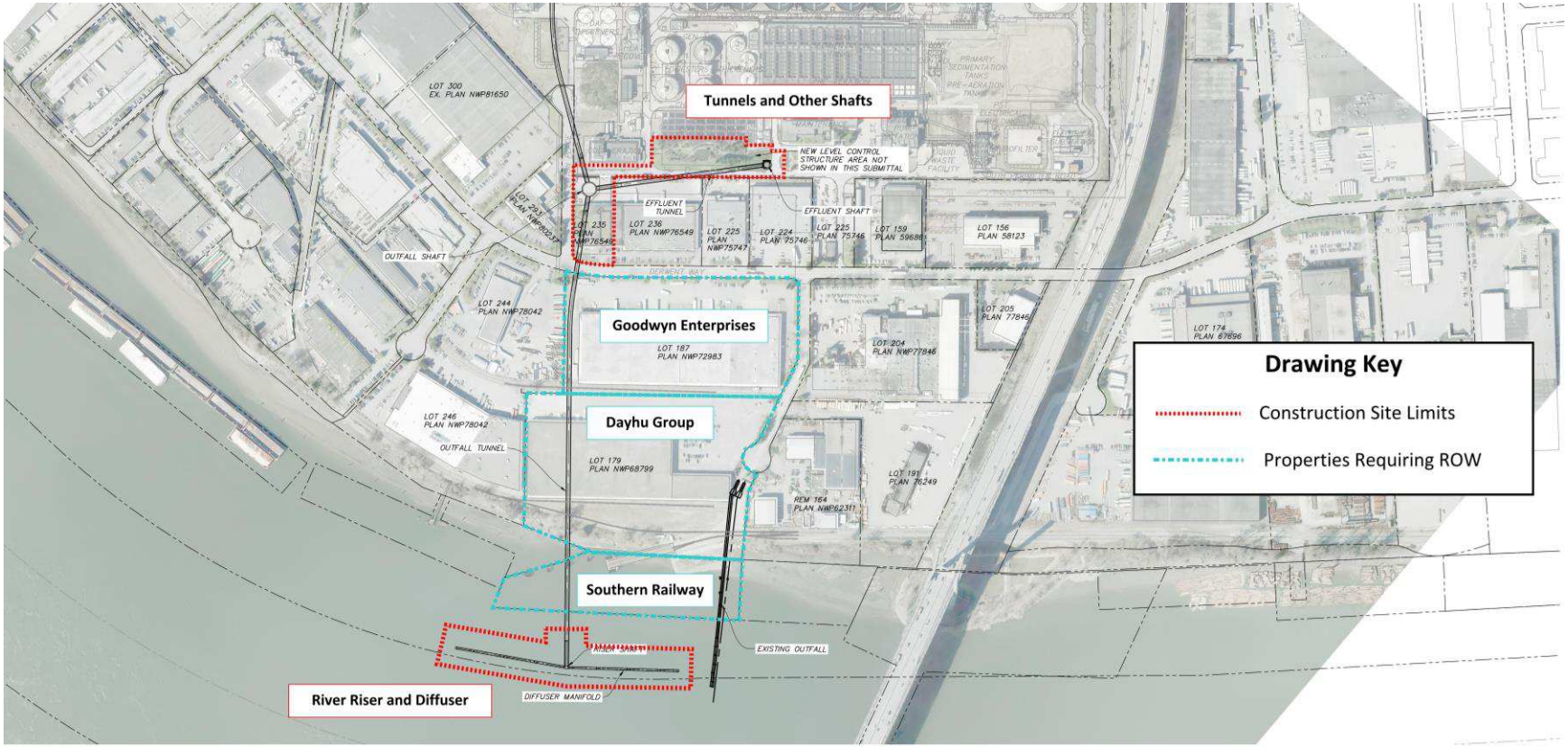


Overview of System Hydraulics

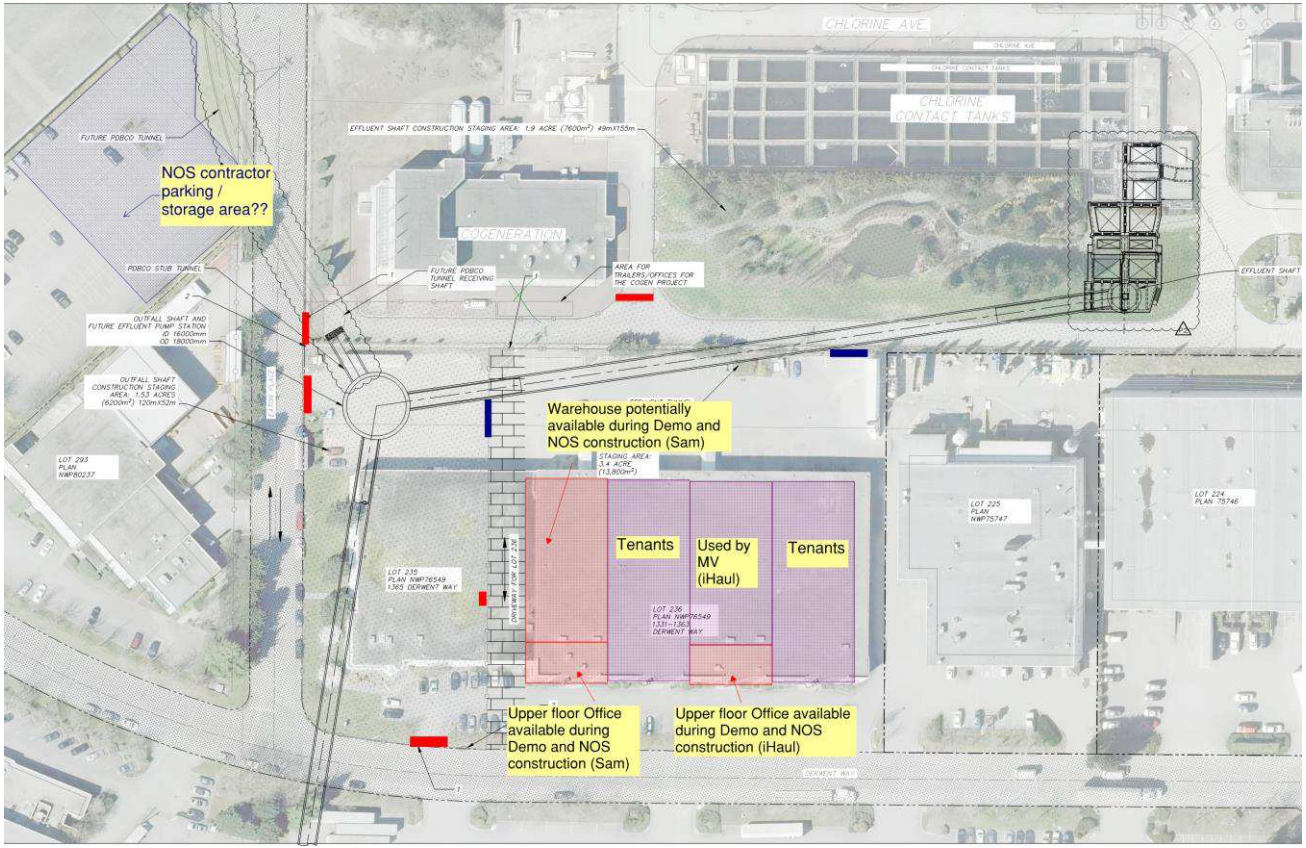
CCT Water Level 105.67 on upstream side of level control gates



Construction Work Areas



Site Preparation Contract



Shaft Details

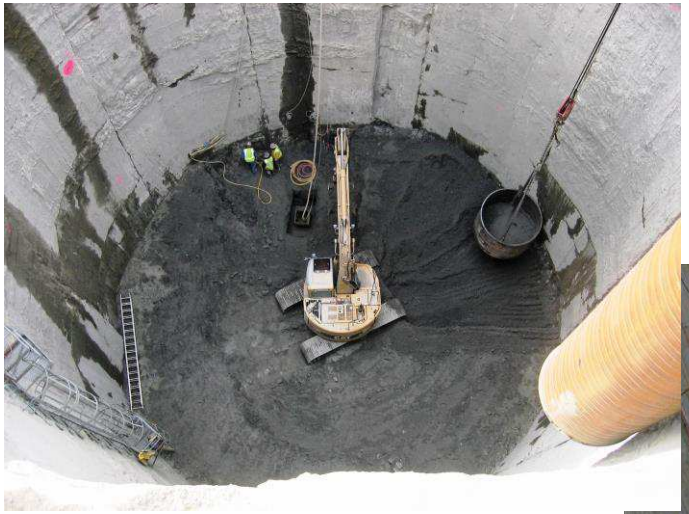
Outfall Shaft

- Serves as tunnel launch shaft
- 16 m final ID; 40.65 m deep
- 3.75 m thick base slab

Effluent and PDBCO Shafts

- Serve as tunnel receiving shafts
- 7 m final ID; 39.15 m deep
- 2.25 m thick base slab

Shaft Construction



Shaft Excavation Support

Water-tight (No GW drawdown allowed)

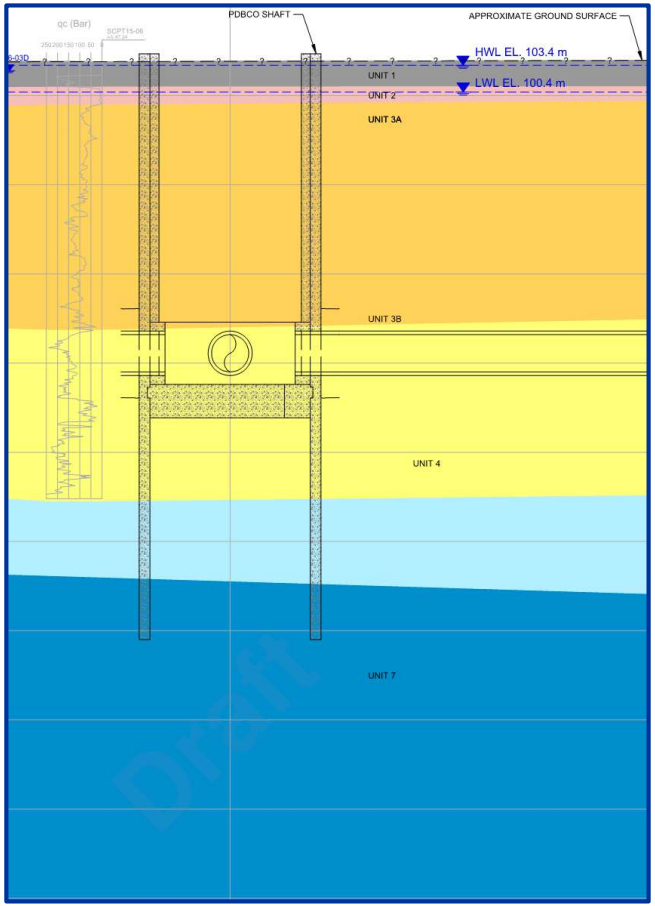
Independent of permanent structure

Slurry wall technology (assumed)

- ~ 1,220 by 3,000 mm panels
- 56.5 m total panel depth

Contractor options:

- Alternate support technologies
- Larger ID (> finished ID + 2 m)



Excavation and Base Slab

Excavation Method “In the Dry”

- Slurry wall depth selected for base stability
- Contractor to confirm suitability for alternate technology
- Contingency plan for tremie method, if conditions require

Base Slab / Breakout Structure

- Base slab reinforced with shear key into slurry walls
- Launch shaft design includes breakout structure
- External 12+ m ground improvement zone around tunnel alignment

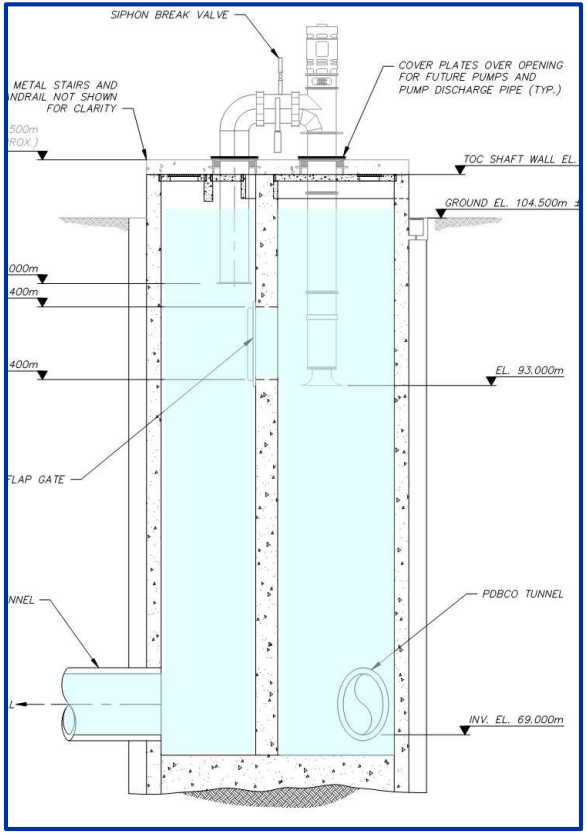
Final Lining and Top Structure

Reinforced Concrete Lining

- 1.0 m thick
- 1.5 m thick dividing wall in Outfall Shaft

Top Structure

- Level control structure above Effluent Shaft
- Buried conduit connection on PDBCO Shaft
- Pre-cast Panels on Outfall Shaft for future Effluent Pump Station



Tunnels

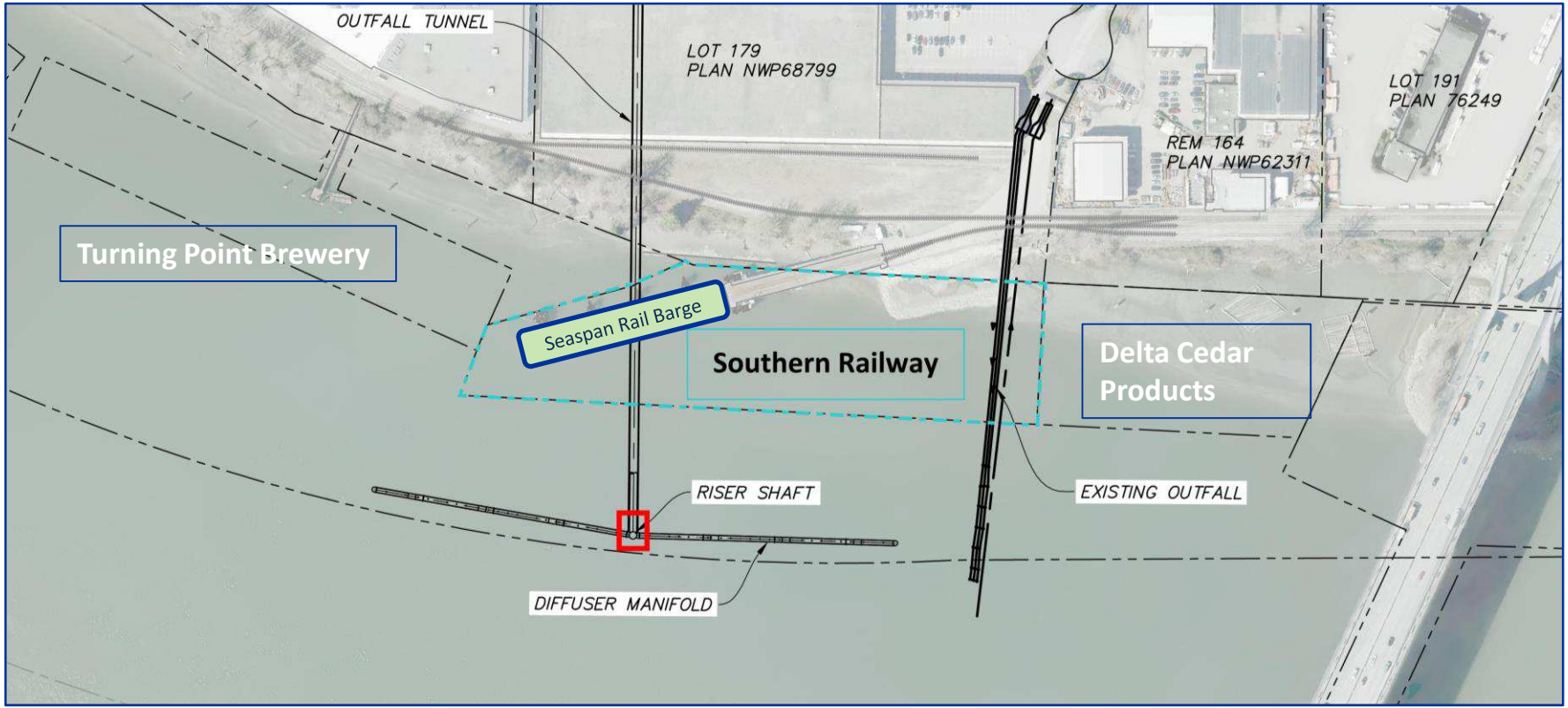
Tunnel Dimensions

- 4.2 m finish ID
- Effluent Tunnel (220 m)
- PDBCO Tunnel (410 m)
- Outfall Tunnel (580 m)

TBM Requirements

- Pressurize face (EPB or SPB)
- New or manufacturer reconditioned
- Allow for some oversize for machine selection

River Riser and Diffuser



Schedule

- Q1 – 2017: 60% Design Complete
- Q3 – 2017: RFQ Issued
- Q3 – 2017: 90% Design Complete
- Q1 – 2018: 100% Design Complete, RFP Issued, Site Preparation start
- Q4 – 2018: Site preparation complete
- Q1 – 2019: New Outfall System contract NTP

Section 01705 – Occupational Health and Safety

SPEC NOTE: This specification was updated 2015.04.15. Use this version until an approved (Controlled) version is available. Specifier is to select from the options shown in square brackets. Obtain approval from S. Sokalski before making any other project related changes.

PART 1 GENERAL

1.1 Scope

1.1.1 This section covers the establishment of workplace safety standards to ensure the health and safety of all persons at or near the workplace. It also outlines the duties of the Contractor, the Qualified Coordinator, the Corporation and its representatives.

1.2 References

1.2.1	Workers Compensation Act.	Government of British Columbia
1.2.2	Occupational Health and Safety Regulation (WorkSafeBC)	WorkSafeBC
1.2.3	British Columbia Electrical Safety Branch regulations	Government of British Columbia
1.2.4	GVRD Contractor Safety Management	Greater Vancouver Regional District

1.3 Submittals

1.3.1 All information submitted by the Contractor will be used by the Corporation to audit the activities of the Contractor against the Contractor's stated safety program, policy and safe work procedures, so as to allow the Corporation to assure itself that safe work practices and procedures are being followed.

1.3.2 Where the Contractor and the Corporation disagree on the compliance of the safety program, the Contractor, at his cost, shall retain a third party "Qualified Person" to review the safety program and confirm compliance to governing regulations.

SPEC NOTE: Select one of the two options shown in square brackets.

1.3.3 Before the Notice to Proceed can be issued, the Contractor shall submit to the Engineer, within [two weeks] [five days] of the award:

.1 A letter of clearance from WorkSafeBC for the Contractor and the Subcontractors;

.2 A set of safe work procedures designed to protect the health and safety of workers at the workplace, as required by WorkSafeBC OH&S Regulation, Part 20, 3(4)(c).

.3 A name of a qualified person or coordinator designated to be responsible for the Contractor's site health and safety activities;

.4 A copy of the Contractor's Occupational Health & Safety Program.

.5 A copy of all hazard assessments, for hazards generated by the Work activities.

.6 A copy of the Notice of Project if required by WorkSafeBC OH&S Regulation, Part 20, 2(1).

1.3.4 The Contractor shall submit to the Engineer, as the work progresses the following items:

.1 A copy of a valid certificate of inspection reports for all equipment and tools. All equipment whether owned, rented or subcontracted, must have the manufacturer's manual readily available.

.2 All Material Safety Data Sheets (MSDS) before the controlled product is used on site.

.3 Minutes of all the Contractor's weekly safety meetings (toolbox meetings).

.4 Near miss and incident investigation reports.

.5 Copy of formal weekly safety inspections.

.6 Copies of WorkSafeBC Inspection Reports and Notice of Compliance issued to the Contractor or any Subcontractors.

.7 Other safety and health related items as may be requested.

.8 Any changes to procedures or Health and Safety Program.

.9 The Contractor shall submit to the Engineer a monthly safety report summarizing all safety issues that occurred that month. The Contractor shall provide within seven days of month end.

1.4 Prime Contractor

1.4.1 As described in WCB Act, Section 118, the workplace is a multiple-employer workplace. The (successful tender) (Corporation) shall be the Prime Contractor and shall be solely responsible for the coordination of the health and safety activities at the worksite.

1.4.2 The Prime Contractor, shall be solely responsible for the development, implementation and maintenance of a safety program and all its components. The

purpose of the program is to ensure the safety of all persons and to safely coordinate all activities on the Work Site. This requirement shall apply continuously, and not be limited to normal working hours.

1.4.3 For construction projects, the Prime Contractor shall post a copy of the Notice of Project in prominent locations within the workplace to ensure that all other employers know that, as Prime Contractor, it has responsibility for coordinating the work activities related to occupational health and safety matters of all contractors.

1.5 Safety and Health Regulations

1.5.1 The Contractor shall comply with the WorkSafeBC OH&S Regulations, the British Columbia Electrical Safety Branch Regulations, the Corporation's Safety Management System Standards, Divisional Safety Programs and the regulations of other regulatory bodies. In the event of discrepancy between such provisions, the most stringent provision will apply.

1.6 Work Site Safety Program

1.6.1 The (Contractor) (Corporation) shall develop and be responsible for maintaining a project specific Work Site safety program, tailored specifically to the Work of the Contract, and shall be acceptable in all respects to WorkSafeBC.

1.6.2 In the development of the Work Site safety program the (Contractor) (Corporation) shall investigate thoroughly the nature and conditions of the project as well as the requirements of the job procedures. The Contractor should be prepared to, if warranted, implement a more comprehensive safety program than is required by WorkSafeBC regulations to protect the Health and Safety of all workers.

1.7 Work Site Joint Health and Safety Committee

1.7.1 As described in WCB Act, Section 125, when required, the Prime Contractor shall establish a Work Site Joint Health and Safety Committee to include representatives from the Contractor, Subcontractors, and other Contractors who will be on the Work Site.

1.7.2 When the Corporation is Prime the Contractor's attendance at the weekly tailboard meeting held by the Corporation is mandatory for the duration of the project.

1.8 Corporation Occupation Health & Safety Policy & Standards

1.8.1 It shall be the Contractor's responsibility to familiarize itself with these standards and programs and to incorporate where appropriate these standards and programs into its own safety program and safe work procedures in order to maintain safe

working conditions, including the safety of all persons and property during the performance of the Work.

1.8.2 Where the Contractor, through necessity to safely coordinate the Work, incorporates or adopts all or any portion of the Corporation's Safety Policies, and Standards or Divisional Programs, all costs for training Contractor's workers in such standards or programs, and the costs for any equipment required shall be borne by the Contractor.

1.8.3 The Contractor shall cooperate with the Engineer on any matter, interpretation, or application of the Corporation's Safety Management System Standards, or Standard Operating Procedures.

PART 2 PRODUCTS

2.1 Not used

PART 3 EXECUTION

3.1 General Requirements

3.1.1 The (Contractor) (Corporation) shall hold regular weekly 'tailboard' safety meetings, minutes of which shall be recorded and forwarded to the (Engineer) (Contractor).

3.1.2 The (Contractor) (Corporation) shall, require its Subcontractors, manufacturers and suppliers to provide current Material Safety Data Sheets (MSDS) for products considered hazardous to the environment or to persons, before the product is allowed on the Work Site. The (Contractor) (Corporation) shall comply with all requirements of the WorkSafeBC, WHMIS Regulations.

3.1.3 The (Contractor) (Corporation) shall ensure that each of its Subcontractors has a copy of their Occupational Health & Safety Program available for review prior to the Subcontractor commencing work onsite.

3.1.4 The (contractor) (Corporation) shall ensure that each of the Subcontractors submits the name of a qualified person designated to be responsible for that employer's site health and safety activities. This submission must be made prior to the Subcontractor commencing work

3.2 Work Site Safety Orientation

3.2.1 The (Contractor's) (Corporation's) Work Site specific safety program shall include site safety orientation of all personnel or employees of the Contractor, any

Subcontractor, vendor, supplier or consultant, or of the Corporation, the Engineer or any other visitor to the site.

3.2.2 The orientation must meet all WorkSafeBC OH&S Regulations and be made before their work, inspection or visit commences.

3.2.3 The orientation shall make everyone aware of the safety and security rules, regulations and requirements in effect at the Work Site.

3.3 Inspection of Work Site

3.3.1 The Contractor shall allow the Corporation the right of inspection and audit of Work Site safety conditions, and all pertinent health and safety performance records to measure adherence to safety and health objectives. Such inspection or audit may take place without warning or notice of intent.

3.3.2 If, in the opinion of the Corporation, the Contractor's Work or operations are hazardous, dangerous or unsafe in any way, the Corporation will shut down the Work until such conditions are corrected. Notification of Work shut down can be done verbally by the Corporation, effective immediately, with a letter following within 48 hours. No compensation, extension of time or payment will be made to the Contractor for any costs incurred by such shut down or corrective safety measures.

3.4 Qualified Coordinator (Workplace Safety Coordinator)

3.4.1 The Contractor shall designate a qualified individual to be responsible for safety on the Work Site and for the Contractor's health and safety activities and responsibilities.

3.5 Hazard Assessment

3.5.1 The Corporation will provide a list of hazards to the Contractor that are known or reasonably expected to exist at the Work Site. The Contractor shall ultimately be responsible for confirming all hazards on site.

3.5.2 No compensation, payment or extension of time will be made to the Contractor for any costs incurred by such stoppage of work or corrective safety measures. Any costs incurred by the Corporation as a result of the stoppage shall be borne by the Contractor.

END OF SECTION

Section 02305 – Tunnel Excavation by Tunnel Boring Machine

PART 1 GENERAL

1.1 Section Includes

1.1.1 This Section specifies requirements for the Tunnel Boring Machine (TBM) and tunnel excavations of the two tunnels of the New Outfall System (NOS). The two tunnels of the NOS project are the Effluent Tunnel between the Outfall Shaft and the Effluent Shaft, and the Outfall Tunnel between the Outfall Shaft and the Riser Shaft. Excavation of these tunnel are to be with a new or a refurbished TBM.

1.2 Related Requirements

1.2.1 This Section of the Specifications forms part of the Contract Documents and is to be read, interpreted and coordinated with all other parts.

1.2.2 Related sections

.1 Section 01330 – Submittal Procedures

.2 Section 02350 – Geotechnical Instrumentation and Monitoring

.3 Section 02337 – Ground Improvement

.4 Section 02302 – Slurry Walls

.5 Section 02450 – Tunnel Rescue Teams

.6 Section 02335 – Tail Void Grouting

.7 Section 02324 – Precast Concrete Tunnel Lining

.8 Section 02506 – Steel Pipe In-Tunnel Installation

1.3 Definitions

1.3.1 Abrasion: Detrimental wear of TBM and plant components from excavation and muck handling processes.

1.3.2 Action Level(s): See Section 02350 – Geotechnical Instrumentation and Monitoring.

1.3.3 Active Face Support: Application of internal pressure to counteract earth pressure and hydrostatic head at the tunnel face.

1.3.4 Boulder Stop: A stoppage of the TBM advance with worker entry into the Excavation Chamber to break and remove boulder(s).

1.3.5 Cutting Tools: Disc cutters, picks, drag tools, scrapers, and ripper tools mounted in the cutterhead for loosening, cutting, dislodging, and fracturing of materials.

1.3.6 Conditioners: Bentonite, foam, polymers, and other materials added to the excavated materials (cuttings) to reduce abrasion and improve flow characteristics of muck.

1.3.7 DTA: Design Tunnel Axis indicated in the Contract Documents by centerline in plan view and by invert elevation in profile view.

1.3.8 Earth Pressure Balance (EPB) TBM: A fully-shielded TBM with an active face support system consisting of a mechanical shield and mixing chamber kept under pressure.

1.3.9 Essential Services: Ventilation, emergency lighting, dewatering pumps, safety support systems, communication, data acquisition.

1.3.10 Excavation Chamber: The enclosed space directly to the rear of the cutterhead and ahead of the main bulkhead for the EPB TBM and ahead of the buffer wall in the Slurry TBM.

1.3.11 Extrados: See Section 02324 – Precast Concrete Tunnel Lining.

1.3.12 Factory Tests: Tests performed on equipment that certify that the equipment is in compliance with this Section in addition to the manufacturers' specified requirements.

1.3.13 Foam Expansion Ratio (FER): Ratio between the volume of the foam and the volume of foaming solution used.

1.3.14 Foam Injection Ratio (FIR): Ratio between the volume of foam injected at working pressure and the volume of the ground in place.

1.3.15 Ground Conditioning System (GCS): A system which permits the metered delivery of soil conditioners into the tool gap, excavation chamber, and screw conveyor of the TBM.

1.3.16 Guillotine Gate: Gate to close material flow conveyance, consisting either of one or two moveable gate components.

1.3.17 Hold Point: A point where work may not continue until a joint review of the activity to follow has been carried out by the Construction Manager and Contractor of methods, equipment, and personnel.

1.3.18 Hybrid EPB TBM: EPB TBM equipped with slurry injection facilities and alternative mucking methods.

1.3.19 Hyperbaric Intervention: TBM maintenance, TBM inspection, or event response work carried out in the Excavation Chamber under higher than atmospheric pressure.

1.3.20 Inspection Stop: A scheduled stoppage of the tunnel advance with worker entry into the Excavation Chamber to visually inspect condition of cutting tools, cutterhead, and other components and measure tool wear.

1.3.21 Intrados: See Section 02324 – Precast Concrete Tunnel Lining.

1.3.22 Lost Ground: Refer to Section 02335 – Tail Void Grouting.

1.3.23 Lost Ground Void: Refer to Section 02335 – Tail Void Grouting.

1.3.24 Muck: Excavated material consisting of a mixture of soil cuttings and water, that may include conditioner, bentonite, polymer, fragments of wood, cobbles, boulders, and ground improvement agents.

1.3.25 Open Mode Condition: A condition where the applied face support pressure is below the Required Support Pressure.

1.3.26 Pressurized Face TBM: EPB TBM, Slurry TBM, Hybrid EPB TBM.

1.3.27 Proof Grout: Refer to Section 02335 – Tail Void Grouting.

1.3.28 Reconciliation: Comparison of excavated and added materials with theoretical excavation by volume or weight for each ring of liner segments.

1.3.29 Refurbished TBM: Used TBM that is fully inspected, re-built, tested, with new main bearing and main bearing seals, with new articulation seal, certified by the original manufacturer or the parent company of the original manufacturer or another established TBM manufacturer and accompanied by complete documentation of detailed history of use.

1.3.30 Required Support Pressure: The pressure at the face that is required to fully counterbalance the hydrostatic head and earth pressure including appropriate safety factors and operation tolerances, to prevent lost ground.

1.3.31 Slurry TBM: A fully-shielded TBM with an active face support system consisting of low permeability material applied to the face under pressure.

1.3.32 Spoil: Material(s) removed when excavating a tunnel or other excavation.

1.3.33 Tail Void: Space between the extrados of the precast concrete segmental lining and the surrounding soil behind the tail shield formed by overcut of TBM cutterhead, thickness of the TBM shield, and clearance between the intrados of the shield and extrados of the segments.

1.3.34 Tail Void Grout: Refer to Section 02335 – Tail Void Grouting.

1.3.35 Tunnel Boring Machine (TBM): A shield with excavation, ground control, steering, lining assembly and propulsion equipment, including trailing gear and support equipment required for performing tunnel excavation.

1.3.36 Tunnel Eye: Feature that is formed or cut within the wall of the shaft ground support system to allow Tunnel Launch or Tunnel Reception.

1.3.37 Tunnel Launch: Exit of the TBM from a shaft through a tunnel eye.

1.3.38 Tunnel Reception: Entry of the TBM into a shaft through a tunnel eye or into a block of concrete backfill that marks the completion of TBM advance.

1.4 Reference Standards and Guidelines

1.4.1 American Petroleum Institute (API):

.1 API 13A, Drilling Fluids Materials.

1.4.2 American Society for Testing and Materials (ASTM):

.1 ASTM C109M, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 50 mm Cube Specimens).

.2 ASTM C150M, Standard Specification for Portland Cement.

.3 ASTM C494M, Standard Specification for Chemical Admixtures for Concrete.

.4 ASTM C827, Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens of Cementitious Mixtures.

1.4.3 Canadian Electrical Code (CEC) Hazardous Locations.

1.4.4 Canadian Standards Association (CSA):

.1 CSA Standard CAN/CSA-Z275.3-M86, Occupational Safety Code for Construction Work in Compressed Air.

.2 CSA Standard CAN/CSA-M421-00 (R2007), Use of Electricity in Mines.

1.4.5 European Standard (EN):

.1 EN ISO 13500, Petroleum and Natural Gas Industries Drilling Fluid Materials Specification and Tests.

1.4.6 International Tunneling and Underground Space Association/Association Internationale des Tunnels et de L'Espace Souterrain (ITA/AITES):

.1 ITAtech Guidelines on Rebuilds of Machinery for Mechanized Tunnel Excavation (ITAtech Report No. 5, No ISBN 978-2-9700858-9-8, May 2015.

1.4.7 National Fire Protection Association (NFPA):

.1 241 Safeguarding Construction, Alteration, and Demolition Operations.

1.4.8 WorkSafeBC Occupational Health and Safety Regulation:

.1 Part 22 Underground Workings.

.2 Part 20 Construction, Excavation, and Demolition.

1.5 Performance Requirements

1.5.1 Tolerances

.1 Line and Grade:

a) Control TBM position as required to permit installation of precast concrete segment linings in accordance with requirements indicated and the following:

- Horizontal alignment: Maximum 100 mm from indicated alignment centerline.
- Vertical alignment: Maximum 100 mm from indicated.
- Make corrections with due consideration of required tolerances for initial support, as specified in Section 02324 –Precast Concrete Tunnel Lining, and the steel pipe, as specified in Section 02506 – Steel Pipe In-Tunnel Installation, but do not correct out of tolerance line and grade at rate that exceeds 25 mm in 8 m.

.2 Heave and settlement per Section 02350.

.3 Groundwater seepage per Sections 02302 and 02324.

1.6 Submittals

1.6.1 Comply with the provisions of Section 01330, Submittal Procedures.

1.6.2 Tunnel Boring Machine (TBM): Detailed description of the proposed TBM to be used including preliminary drawings and plans within 90 calendar days of Notice to Proceed (NTP).

.1 General Arrangement Drawings from TBM manufacturer showing details of TBM and backup equipment layout including detailed scale drawings with sufficient vertical and horizontal sections at tunnel axis and cross sections to

clearly identify the different components of the TBM. Show the following features of the TBM:

a) Complete technical description and detailed general arrangement drawings of TBM and backup equipment, including cutters and cutterhead, conditioning system, thrust, articulation, and steering systems, drive system, muck system, main bearing and tail seals, guidance system, probe hole drilling system, segmental lining grouting system, gas monitoring system, fire suppression system, schematics of hydraulic and electrical systems, ventilation system, segment erector and the interface of TBM with the segmental lining system elements, muck and material transport and handling systems.

b) Provide detailed narrative supported with sketches demonstrating the suitability of the TBM, and backup for tunnelling in the ground conditions given in the Contract Documents.

.2 List and description of TBM spare parts as recommended by the TBM manufacturer giving storage location and condition.

1.6.3 At least 60 calendar days prior to Tunnel Launch submit in agreed formats method statements for the tunneling equipment, and the tunneling process and confirm schedule durations together with all relevant manufacturer's information sheets. Provide calculations and shop drawings stamped by a Professional Engineer registered in the Province of British Columbia:

.1 Preparation Plan: Detailed description and drawings of the launching and receiving shaft including, but not limited to, seals and supplemental supports and all installations required for the TBM launching and receiving operations.

.2 Working Plan: Detailed method statements on the tunnelling operations in the geologic conditions described in the Contract Documents including, but not limited to:

a) Launching and receiving operations

b) Tunnel excavation with face support application

c) TBM guidance

d) Segmental lining erection

e) Tail void grouting including details indicated in Section 02335.

f) TBM maintenance

g) Tunnel system monitoring.

.3 Muck Handling Plan:

a) For Slurry TBM:

- Slurry separation plant design and system layout showing the type and number of each process component used. Include details of system capabilities to deal with clay clogging potential and slurry separation of clay soils.
- Total plant slurry process rate.
- Process flow and tonnage capacity for each system component.
- Pipe sizing and piping network plan.
- Slurry pumping design including velocity requirements for soil transport.
- Slurry materials mix design and spoil loading capacity.
- Materials handling for slurry recirculation and waste disposal.
- Separated tunnel spoil solids containment and handling method.

b) For EPB TBM:

- In-tunnel muck handling facilities including rail and rolling stock or conveyor details.
- Surface muck handling and storage including supernatant or other water discharge from the muck.

.4 Provide support pressure calculations for entire tunnel drive for advancing and stoppages based on anticipated ground and groundwater conditions stamped by a Professional Engineer registered in the Province of British Columbia. Include with calculations:

a) Description of calculation method used including: definition of safety factors used; tolerance of face support control accounted for in the calculations; and, references used.

b) A table which includes a tunnel profile showing the Required Support Pressures and grouting pressures with depth across the tunnel face, and volumes and anticipated weights of excavated materials for each tunnel advance along the tunnel alignment. The tunnel advances may be simplified into reaches no longer than the distance between adjacent boreholes indicated in the Contract Documents.

.5 For EPB TBM:

a) Provide Ground Conditioning System settings for expected soil types as determined by systematic testing of the different soil types carried out such that the range of soil conditioning parameters including FER, FIR, types and concentrations of foam agents, polymers or other materials shall be known and ready to be applied when required.

.6 Provide a detailed description of the means and methods necessary to meet the specified requirements for the following:

a) Maintaining face stability

b) Work in the Excavation Chamber

c) Keeping ground movements at or below Action Levels

d) Measures for protection of adjacent property

e) Ventilation

f) Air Quality Monitoring

g) TBM fire suppression.

.7 Provide construction schedule, including:

a) Schedule for the design, manufacturing, shop erection and testing, dismantling, and shipment to Site of TBM and all backup equipment and systems.

b) Assembly time, start-up time, and on-site training period planned to reach routine tunnelling progress rates for execution of the Work.

c) Estimated average daily advance for tunnel excavation, in metres per day, for key increments of the tunnel. Any delays built into the estimated average advance rate are to be identified.

d) Estimated average liner erection rate in minutes per ring.

1.6.4 At least 60 calendar days prior to Tunnel Launch provide calculations of:

.1 Ventilation system flow and capacity

.2 Required Support Pressure, based on piezometric level information presented in the Contract Documents.

.3 Programmed unit weight of excavated material to be used to compare with actual excavated weights.

1.6.5 At least 60 calendar days prior to Tunnel Launch submit the following:

.1 Training Plan: Develop a comprehensive plan for orientation and training of all personnel based on all of the documents of the Tunnelling Excavation Plan.

.2 Tunnel Safety Plan:

a) Provide detailed descriptions of the health and safety equipment installations including those required for air quality monitoring, fire protection, gas detection, and certifications from manufacturers that equipment meets applicable regulatory requirements.

b) Include drawings and method statements for health and safety equipment described above.

.3 Tunnelling Quality Plan:

a) Include all required certifications and qualification documents including a detailed plan of the site organization and responsibilities of all planned personnel.

b) Field Quality Control: Details of TBM data acquisition including type of data, muck control and handling systems, ground movement monitoring, reporting, and documentation.

c) Product Quality Control: Product information, certifications, and details of any probing and testing program.

d) Remedial Plan: Detailed description of remedial plans including:

- Tunnelling modifications if excessive Lost Ground occurs.
- Corrective actions to be used for each Action Level associated with settlement and groundwater monitoring as indicated in Section 02350.
- Plans for protection of adjacent facilities and property if excessive Lost Ground occurs or ground movements exceed Action Levels indicated in Section 02350.
- Plans for sealing of groundwater inflows if the Tunnel Launch seal, Tunnel Reception seal, and tunnel lining seepage result in flow rates that exceed limits specified in Sections 02302 and 02324.
- Plans for repair of unacceptable segment off-sets, damage or segment spalling.

e) For EPB TBM: EPB pressure cell calibration.

f) For Slurry TBM: Slurry pressure sensor calibration.

.4 Compressed Air Work Plan

a) Prepared by the Contractor's hyperbaric consultant.

b) Requirements for compressed air work above one bar. To be used to obtain a variance from WorkSafeBC in accordance with CAN/CSA-Z275.3-M86.

c) Submittal review period does not include the time required to obtain the variance.

d) Include plant and equipment for the supply and use of compressed air and mixed gas, including but not limited to generator, stand-by equipment, air flow system control, air locks, medical locks, lighting, decompression chamber, and ventilation.

e) Include details of supervision, personnel entry, decompression, safety, and emergency procedures specific to work in compressed air.

f) Coordinate with the Project Safety Officer and Health and Safety Plan.

.5 For Slurry TBM:

a) Slurry transport and separation plant preventative maintenance plan.

.6 Hold Points

1.6.6 At least 60 calendar days prior to Tunnel Launch provide Contingency Plans with detailed descriptions of the actions and procedures for the following events:

.1 Lost Ground

.2 Groundwater or ground flowing into shafts if Tunnel Launch seal, Tunnel Reception seal, TBM seals or tunnel lining leakage results in flow rates that exceed limits indicated

.3 TBM outside DTA tolerance window

.4 Inundation events, including heading or shaft pump failures

.5 Power loss

.6 Loss of communication

.7 Fire

.8 Injury during a Hyperbaric Intervention

.9 Failure of main bearing

.10 Failure of main bearing seals

.11 Failure of articulation seal

.12 Gas alarm activation and TBM shutdown.

1.6.7 Prior to shipment of the TBM to site provide following certifications:

.1 Provide written certification from TBM manufacturer of full and complete design coordination between TBM manufacturer, backup equipment manufacturer and lining manufacturer. Include a written certification by the Contractor and manufacturers affirming the compatibility of TBM and backup equipment with lining systems, segment erector, and continuous backfill injection system.

.2 Provide documentation and certification for main bearing and for seal showing that they have been designed for the ground conditions indicated in the Contract Documents. Include calculations. Provide design life for the TBM main bearing.

.3 Provide written certification for air locks and compressed air equipment.

1.6.8 For Refurbished TBM provide prior to Tunnel Launch:

.1 Confirmation that TBM has been refurbished according to ITAtech Guidelines on Rebuilds of Machinery for Mechanized Tunnel Excavation (ITAtech Report No. 5, No ISBN 978-2-9700858-9-8, May 2015.)

.2 Year originally fabricated and released for operations

.3 Qualifications of the organization responsible for Refurbishment

.4 Operational record of TBM, including project names, types of ground excavated, performance, excavated diameter, total hours of operation, and records of any major rebuilt components.

.5 Machine Manufacturer or Refurbisher certifications stating that the new parts have been fitted according to the specifications herein:

a) Certification of installation of a new bearing and new main bearing seals.

b) Certification of installation of a new articulation seal.

.6 Results from non-destructive testing and inspection of cutterhead and main structural elements.

1.6.9 Provide Test Reports within five calendar days of completion for:

.1 TBM factory tests

.2 TBM site tests and re-calibration for TBM and backup systems

.3 Ground Conditioning System settings for expected soil types

.4 Tail void grouting preliminary suitability tests

.5 Slurry plant/slurry mix commissioning tests

.6 Grout plant/grout mix commissioning tests.

1.6.10 Pre-Tunnelling Meetings:

.1 Meeting agenda to include general information regarding:

a) Tunnelling methods, including equipment layout, TBM operation, and tunnelling process

b) Tunnelling operations

c) Break-out procedure

d) Means and methods

e) Orientation and training

f) Tunnelling health and safety

g) Access for maintenance and inspection

h) TBM data monitoring

i) Contingency plans.

.2 Meeting to be held not less than 30 calendar days prior to TBM launch, and to be attended by both Contractor and Construction Manager personnel.

1.6.11 Pre-Reception Meetings:

.1 Meeting agenda to include general information regarding:

a) TBM break-in and reception procedure

b) TBM retrieval or abandonment

c) Monitoring

d) Inspection and testing plans

e) Hold Points

f) Contingency plans.

.2 Meeting to be held not less than ten calendar days prior to TBM reception, and to be attended by both Contractor and Construction Manager personnel.

1.6.12 Daily submission of:

.1 Shift reports.

a) Submit shift reports, regardless of actual progress no later than the beginning of the following working day. Include:

- Number and type of equipment used.
- List of idle or inoperative equipment and reason for downtime.

.2 Ring Reports.

a) Ring reports submitted no later than the beginning of the following working day.

.3 Settlement monitoring and instrumentation reports as per Section 02350.

.4 TBM data logger records.

.5 Tail Void Grout Records:

a) Grout injection records for each segment

b) Mix type and batch number

c) Detailed grout injection records, broken down for each outlet by injected quantity, injection pressure and pumping rate.

.6 Muck samples and sampling report.

.7 Proof Grout Records

.8 Reconciliation Table:

a) Comparing excavated and added materials with the theoretical excavation by weight or volume for each ring of segmental liner; reconciliation table updates submitted no later than the beginning of the following working day.

1.6.13 Weekly Submission of:

.1 Electrical inspections records

.2 Ventilation performance records

.3 Muck hauling records including weight and volume details

.4 Weekly results of testing on tail void grout samples taken during production grouting.

1.6.14 Monthly Submission of:

.1 Calibration report for gas detectors.

1.6.15 Event submission within 24 hours:

.1 Inspection Stop documentation report

.2 Cutterhead maintenance report

.3 TBM maintenance report

.4 Lost ground reports

.5 Reports of combustible or toxic gas

.6 Documentation of actual excavated volumes exceeding theoretical volumes by more than five percent

.7 Report of emergency conditions.

1.6.16 Provide the following report 30 calendar days prior to Tunnel Reception at the Effluent Shaft:

.1 TBM Removal Plan at the Effluent Shaft

1.6.17 Provide the following reports prior to re-launching the TBM for the next TBM drive:

.1 Reports on TBM required and/or preventative maintenance and recalibrations performed following Tunnel Reception at the Effluent Shaft.

1.7 Quality Control

1.7.1 Qualifications

.1 TBM Manufacturer: Identify the manufacturer or refurbisher of the TBM proposed for use on the Project. Provide sufficient information to demonstrate that the manufacturer(s) have supplied no less than three Earth Pressure Balance or Slurry TBMs for projects in similar ground conditions within the last ten years.

a) TBM manufacturer's representative to be a senior technician with a minimum of ten years of experience training contractor personnel in all aspects of TBM operation and maintenance.

.2 Tunnel Superintendent: Minimum of two projects in the past ten years of on-the-job tunnel supervision experience with:

a) The type of TBM proposed for use on this Project

b) Tunnelling of similar size

c) Precast segmental lining consisting of bolted, gasketed, precast concrete segments.

d) Similar ground conditions

e) Tunnels driven through ground conditions similar to those indicated in the Contract Documents.

f) At least one of the projects to include TBM operation in pressures greater than 3.5 bar.

.3 Shift Foremen: Minimum of three years total on-the-job tunnel crew supervision experience with:

a) The type of TBM proposed for this Project

b) Tunnelling of similar size

c) Initial tunnel lining by bolted, gasketed, precast concrete segments

d) Similar ground conditions.

.4 TBM operators with at least two projects in the past five years operating and guiding the type of machine approved of similar size, with bolted, and gasketed precast concrete segments, and in similar ground conditions. At least one of these projects to include TBM operation in pressures greater than 3.5 bar.

.5 Hyperbaric consultant shall have experience on at least two projects in the past five years providing hyperbaric consulting and management services with personnel entry into a TBM excavation chamber using mixed gases at pressures up to 5.0 bar.

.6 If EPB TBM is selected:

a) Ground Conditioning Engineer: A specialist engineer with at least two projects in the past five years of preparing Ground Conditioning Plans for TBMs in similar ground conditions to those indicated in the Contract Documents.

.7 If Slurry TBM is selected:

a) Mud Engineer: A specialist engineer with at least two projects in the past five years of design and operation of Slurry Treatment Plants for TBMs in similar ground conditions to those indicated in the Contract Documents. On site for the first 300 metres of tunneling.

b) Slurry Plant Manufacturer's representative: A senior technician with a minimum of ten years experience training contractor personnel in all aspects of slurry treatment plant operation.

c) Slurry Plant operators: Have a minimum of five years experience and two projects operating slurry plants in similar ground conditions to those indicated in the Contract Documents.

1.8 Site Conditions

1.8.1 Geotechnical conditions to be anticipated are presented in the Contract Documents: Geotechnical Baseline Report (GBR) and the Geotechnical Data Report (GDR).

1.8.2 Hazardous Gas:

.1 Hazardous gas control measures specified herein are supplemental to WorkSafeBC requirements and are considered minimum additional measures.

.2 Assume sole responsibility for development and implementation of measures to control gas emissions and for proposing alternative or more stringent means, if necessary, to accomplish the objectives of these provisions.

1.9 Training

1.9.1 Foremen, shift engineers, TBM operators, and technicians shall be trained, qualified, and familiar with TBM, tunnel system and plant, and trained using the written procedures and work plans contained in the Tunnel Excavation Plan following the minimum training schedule:

.1 Initial training prior to TBM launch

.2 Start-up training

.3 Periodic re-training as required for changes to staff, equipment, or conditions

.4 Specialized preparation and training for compressed air workers.

PART 2 PRODUCTS

2.1 Owner-Supplied Products

Not Used

2.2 Materials

2.2.1 Oil and Grease: Flame resistant and biodegradable and accompanied by the manufacturers' certificate of compliance, compatible with segment gasket material and in accordance with TBM manufacturer recommendations

2.2.2 Proof Grout: Section 02335.

2.2.3 Tail Void Grout: Section 02335.

2.2.4 Slurry or EPB Soil Conditioners: Provide inert or biodegradable, accompanied by the manufacturers' certificate of compliance.

2.2.5 Tunnel Liner Precast Concrete Segments: Section 02324.

2.3 Equipment

2.3.1 General:

.1 The TBM to be capable of excavating the tunnel and erecting the bolted and gasketed precast concrete segmental lining while maintaining face stability and minimizing ground settlements in the geological conditions described in the Contract Documents.

2.3.2 Provide TBM, tunnel systems and plant that meets all federal and provincial regulations.

2.3.3 Fully assemble and integrate all TBM subsystems for the Factory Test of new or Refurbished TBM and trailing gear to be used in this Contract prior to shipment to site. Upon reassembly at site, re-test the TBM and all the components re-calibrated. Provide travel, accommodations, and meals for two persons from the Construction Manager team to attend factory tests.

2.3.4 Factory Test the Ground Conditioning System (GCS) integrated into the TBM and adjust so that all functions are within the manufacturer's recommendations prior to the TBM delivery. Tests carried out prior to integration on the TBM do not replace the integrated test requirement.

2.4 Tunnel Boring Machine (TBM)

2.4.1 General:

.1 New or Refurbished pressurized face TBM.

.2 Provide ability for drilling equipment to be mounted in the TBM. Drilling ports equipped with valves incorporated into the TBM shield so that drill casings can be sleeved through glands into ground when drilling ahead of the TBM. At a minimum include six ports that allow drilling around the periphery and two ports that allow drilling through the face.

2.4.2 Cutterhead and Tools:

.1 Design and configure the cutterhead with wear protection to enable efficient excavation of the ground indicated:

a) Cutting tool spacing to be sufficient to permit excavation of the material at the tunnel face and at Tunnel Launch and Tunnel Reception locations where

the ground has been modified by the Contractor.

2.4.3 Cutterhead Drive System and Main Bearing:

.1 Adequate torque and power to the cutterhead so that the machine is not torque limited while operating under any of the ground conditions indicated.

.2 Provide certification from the main bearing manufacturer that the bearing is suitable for the loads calculated by the TBM manufacturer, based on the ground conditions indicated and main bearing to a minimum bearing life of 10,000 operational hours.

.3 Oil lubricated main bearing with pumping and filtration circuits equipped with accessible sampling points.

.4 Provide new and replaceable main bearing that can be replaced from within the tunnel.

2.4.4 Face Support System:

.1 Design the TBM to allow operator controlled application of Active Face Support at all times:

a) EPB TBM:

- During TBM advance or extended stoppage by earth paste.
- At a minimum, six earth pressure sensors with minimum diameter of 75 mm within the Excavation Chamber: two sensors each near the crown, tunnel spring line and invert, replaceable from the atmospheric side of the main bulkhead at any time.

b) Slurry TBM:

- During TBM advance or extended stoppage by slurry.
- At a minimum, a total of four pressure sensors capable of measuring air and slurry pressure at crown level.
- Two sensors to be installed at the buffer wall within the excavation chamber.
- Two sensors to be installed at the bulkhead replaceable from the atmospheric side of the main bulkhead under the design operating conditions.
- Two additional redundant liquid level sensors at the bulkhead that utilize different sensor technology than the other four sensors. Provide sensor accuracy consistent with required face pressure control tolerances.

c) EPB and Slurry TBM:

- Provide pressure sensors with an accuracy of ±5 kPa and range of 0 to 1000 kPa.

2.4.5 Seals:

.1 The Main Drive sealing system shall incorporate the following:

a) New main bearing seals designed to handle maximum anticipated support pressure with minimum dynamic safety factor of 1.5.

.2 The articulation joint seals shall incorporate the following:

a) Designed for maximum hydrostatic head, earth pressure, and grouting pressure with a minimum safety factor of 1.25.

.3 The shield tail seal shall incorporate the following:

a) A grease fed wire brush sealing system capable of sealing hydrostatic, earth, and tail void grouting pressures and compatible with Sections 02324 and 02335.

b) Minimum of four rows of wire brush seals.

c) Spring steel sealing plates designed to prevent the steering gap from grout ingress.

d) Incorporate an inflatable safety seal deployable in an emergency where leakage cannot be controlled by any other means.

2.4.6 Propulsion and Steering System:

.1 Propulsion system that can advance the TBM under the combined maximum loads of tool, earth and hydrostatic pressure, shield friction, and trailing gear drag with a minimum safety factor of 1.5.

.2 Propulsion cylinder extensometers at four positions separated by 90 degrees.

.3 Ensure that maximum thrust contact pressure at any point and at any time on the precast segmental lining does not exceed 50 percent of the maximum permissible jacking load in the precast segmental lining design.

.4 Propulsion cylinder shoes or partial jacking rings designed to avoid crossing radial joints and as required to distribute thrust loads onto the leading edge of the pre-cast segment ring without developing eccentric loading on the segment ring for which the segments were not designed.

.5 Provide propulsion cylinder that are concentric with segmental ring centerline.

2.4.7 Shield Articulation:

.1 An active articulation joint(s) equipped with hydraulic cylinders to permit the TBM to follow the DTA.

.2 Sufficient injection ports around the circumference of the articulation joint(s) such that cleaning or other operations can be easily carried out.

.3 Extensometers at four positions on both the active and passive cylinders.

2.4.8 Operator Position:

.1 An ergonomic operator position which permits access to all controls, gauges, and monitoring devices to permit safe operation of the TBM.

.2 Displays for PLC input/output and continuous guidance system monitoring.

2.4.9 Construction Manager Position:

.1 A position near the operator's console for the Construction Manager permitting a view of excavation, grouting, and ring building activities, including access to the TBM gauges and monitoring devices.

2.4.10 Erector System:

.1 Assemble segments by an erector mechanism into rings under protection of the tail shield in the orientation and to the tolerance specified in Section 02324 without causing damage to the segments or gaskets.

.2 Provide erector system that is compatible with the TBM and precast segmental lining and meet the requirements specified in Section 02324.

a) The lifting and gripping mechanism to be designed to handle all loads with an adequate factor of safety in the axial, radial, and circumferential directions, and in the three articulation angles corresponding to the six degrees of freedom.

b) Sufficient rigidity and longitudinal travel to permit installation or removal of a segmental ring located on the wire brush seals.

c) Incorporate safety devices to ensure segments cannot be released during handling. In the event of a loss of power the erector will permit safe lowering of the segments.

d) The segment feeder to supply the erector with segments at the correct orientation and be capable of reverse operation for the removal of damaged or incorrect segments.

e) The segment erector arm to have sufficient capacity to ensure that the longitudinal joint gaskets are sufficiently compressed.

2.4.11 Grouting System:

.1 The TBM tail void grouting system are to be capable of continuous grouting with tail void grout during TBM advance through lines integrated in the tail shield in accordance with the following:

a) A minimum of four twinned grout injection lines shall be installed around the circumference of the shield and designed for continuous grout flow that will maintain filling and pressure with the maximum advance rate of the TBM.

- Each grout injection line used to be equipped with a pressure sensor

accurate to ±0.1 bar and manual stop valve at the tail shield connection.

- Provide a scale device and/or ultrasonic sensor for measuring weight and /or volume of grout injected and display at Operators' position and to data logger.

.2 Use computer controlled pumps pressure and volume measurement for each of the lines continuously to the TBM display and data logging system.

.3 Dedicate one pump to each injection line.

.4 A minimum of four grout injections lines must be used at all times.

.5 Equip pumps with water/bentonite connection to facilitate flushing.

.6 Drilling equipment and associated staging to enable recovery of tail void grout samples and proof grouting at any position around the ring.

2.4.12 Proof Grouting Equipment:

.1 General: Provide appropriate proof grouting pumping equipment and hoses to ensure continuous circulation of grout within the system.

.2 Mixer:

a) Use a high-speed colloidal-type mixer with a tangential return flow from the mixer pump capable of providing a homogenized mix.

b) Sized to ensure an uninterrupted supply of grout to the pump.

c) Provided with a means of accurately measuring and metering grout ingredients, including modifying the water/cement ratio.

.3 Agitator:

a) Equip with:

- Baffles to induce turbulence.
- Rotating paddles to assure thorough mixing of the grout prior to and during injection.

.4 Pumps:

a) Use an appropriate grout pump for the type volume and pressures specified.

b) Equip with a water connection to facilitate flushing the system.

c) Equip with a pressure gauge

2.4.13 Shield Grout Ports:

.1 Equip TBM shield with grout ports around its perimeter and provide with option to install additional grout ports after completion of TBM advance to allow filling the annular space around the shield extrados completely with proof grout as per paragraph 3.2.17.

2.4.14 Muck Handling System:

.1 Provide muck handling components designed for abrasion resistance and durability for the indicated ground conditions.

.2 EPB TBM:

a) The Ground Conditioning System (GCS) to be sized and configured as required to form a homogeneous conditioned soil suitable for control of Required Support Pressure for all ground conditions indicated in the Contract Documents. The system to be computer controlled with interactive parameter setting at the operator position.

b) Provide a dedicated foam generator with by-pass, pump, and flow measurement system to each outlet on the cutterhead.

c) Provide a reversible screw with primary and secondary sections which are equipped with dedicated drives and separated with a guillotine gate. Provide the capability for the automatic charging and releasing of excavated material from the secondary screw which will permit the controlled excavation of non-cohesive materials under the ground water pressure indicated.

d) Locate the screw conveyor inlet near the bottom of the Excavation Chamber and equip the inlet with bulkhead doors designed to isolate the screw conveyor from the Excavation Chamber. The screw conveyor are to be fitted with wear-resistant plate and be removable from the screw sleeve in the tunnel.

e) Fit screw outlet with a guillotine gate designed to operate and seal maximum hydrostatic and earth pressure in all soil types indicated.

f) Equip the screw conveyor sleeve with a minimum of two pressure sensors one located near the inlet and the other near the outlet.

g) Injection points along its length to permit the introduction of ground conditioners into the screw conveyor.

h) Removable inspection hatches fitted with valves to permit access to mechanical linkages and for the removal of blockages which may occur within the screw.

i) Equipment required to refill the Excavation Chamber.

j) Accumulator with automatic valve which will close the screw guillotine gate(s) in the event of a power failure.

k) Provide a weighing system consisting at a minimum of two belt weigh scales to monitor muck removal on a continuous basis ring by ring.

l) If a Hybrid EPB TBM with alternative mucking methods is used, provide equipment to measure weight and volume of the excavated material on a continuous basis ring by ring.

.3 Slurry TBM:

a) Provide slurry injection nozzles, both within Excavation Chamber and in the stone crusher/discharge inlet area within the Excavation Chamber.

b) Abrasion resistant closed circuit mucking system capable of discharging solids through a slurry discharge line and discharge pumps that are sized for the muck volume and advance rate anticipated. Include:

- Bypass line and associated valves.
- Hydraulic accumulators to ensure closure of all bulkhead flanges in case of power loss.

c) Equipment to measure weight and volume of the excavated material on a continuous basis ring by ring. unit length of tunnel basis:

- Flow and density meters in the supply and discharge slurry lines.
- Locate density meters in the return lines in the shaft and fitted to the vertical pipes carrying the slurry up to the separation plant.
- Bentonite slurry recharge flow meter.
- An operational status of the slurry plant including key pumps and level indicators and weight of discharged muck.

2.4.15 Active Face Support Pressure Control System:

.1 EPB TBM:

a) Equip the TBM with an automatic pressure compensation system for applying bentonite to the Excavation Chamber and Steering Gap in the event that the measured face pressure falls below the minimum Required Face Support Pressure.

b) Provide at least one dedicated bentonite feed line to the Excavation Chamber and a minimum of four lines thought the shield.

c) Continuously data log the bentonite consumed during TBM operation.

2.4.16 TBM Guidance System:

.1 TBM with a computerized laser-theodolite based guidance system.

.2 Capable of displaying the precise position and orientation of the TBM on a continuous basis with numerical and graphical display of horizontal and vertical deviation from the DTA and direction with respect to the DTA.

.3 Capable of displaying the position and orientation of the erected rings with the horizontal and vertical deviations from the DTA.

.4 The system to be capable of calculating and displaying correction curve data with interactive parameter setting.

.5 Monitor, record, and display:

a) Date, time, and tunnel station continuously.

b) Segment ring, DTA stationing values, as-driven coordinates and elevations, horizontal and vertical offsets from DTA.

c) The number and orientation of tapered segment rings required to achieve the desired alignment and the location of the axis of each ring relative to the axis of the tail shield.

d) Extensions of propulsion and active/passive articulation cylinders.

2.4.17 TBM Data Acquisition System:

.1 System for real-time continuous data monitoring and acquisition, storage, and display system for the following:

a) Propulsion cylinder stroke at a minimum of four positions. Pressure, average instantaneous advance rate and total thrust shown for all cylinders.

b) Extensions of propulsion and active/passive articulation cylinders at a minimum of four positions, pressure and total thrust.

c) Cutterhead rpm, direction, and torque.

d) Electric motor status and power consumption.

e) Main bearing and main bearing sealing system oil pressure, temperature, and flow.

f) TBM Guidance System data.

g) Face support pressure.

h) GCS data including water, polymer and foam solution flows and pressure, air flows and pressure, FIR and FER for each individual line.

i) Discharge system from Excavation Chamber including stone crusher on a slurry TBM and screw conveyor rotation speed and guillotine gate position indication on an EPB TBM.

j) Bulkhead valve status for the slurry TBM.

k) All gases included in the gas detection and monitoring system.

l) Pressures and volumes of shield tail grouting and tail seal grease.

m) Excavated weights by belt scale weighing system on an EPB TBM and by slurry flow and density meters on a Slurry TBM. Integrate with TBM PLC propulsion cylinder stroke measuring units to provide weight measurements for each segmental ring.

.2 Record data at maximum time intervals of ten seconds and display in real-time at:

a) TBM operator’s position

b) The Contractor's site office

c) The Construction Manager's site office.

.3 Store and record data for use by the Contractor and the Construction Manager via an automated acquisition system in digital form for later use and retrieval and supply the Construction Manager with the data on a continuous basis.

.4 Secure Internet-based access to real time and historical data for use by the Construction Manager in the Construction Manager's site office. Hardware and software shall ensure user friendly interface to access all required datasets.

.5 Maintain hardware and software necessary for recording and real time viewing of data at the Site. In the event of downtime due to hardware or software within the Contractor's control, notify the Construction Manager of the issue, repair hardware and/or software, and restore Internet-based access to real time data within four hours of hardware or software failure. Maintain recording of data at all times.

2.4.18 Spare Parts:

.1 Provide an on-site spare parts inventory for the duration of TBM excavation as recommended by the TBM Manufacturer including guidance system and data acquisition equipment.

.2 A spare main bearing and associated seals to be available on the Site within four weeks following the decision to replace the original bearing.

2.4.19 Tunnel Systems and Plant:

.1 Communication Systems:

a) Hard wired telephone communication system operable at all times, Include phones at TBM, along the tunnel alignment at intervals of 250 metres, at the shaft bottom, and at ground surface.

b) Wireless communication system on locomotives linked with shaft bottom and TBM.

c) Signaling system for trains entering the TBM back-up and shaft areas.

.2 Compressed Air Equipment:

a) Include all equipment required for applying face support by compressed air for worker access to the pressurized tunnel and Excavation Chamber in accordance with all applicable regulations.

b) Comply with requirements of CAN/CSA-Z275.3-M86.

c) A compressed air lock system for minimum three persons to permit safe access into the pressurized tunnel. The Excavation Chamber to be fitted within the main shield of the TBM, and designed to permit a maximum

working pressure of five bar.

d) Telephone within the compressed air lock and connection for telephone within Excavation Chamber.

e) Provide equipment capable of providing and maintaining compressed air pressure in the Excavation Chamber and the tunnel at any required level for the ground conditions indicated in the Contract Documents.

f) Provide sufficient airflow capacity to maintain air pressure in the Excavation Chamber and pressurized portion of the tunnel at the desired level during maximum expected air loss through lining and the face.

g) Equipment for oxygen decompression in the air lock.

h) Breathing masks with independent air supply for welding within the Excavation Chamber.

i) Utility hookups required for work under compressed air within the Excavation Chamber.

.3 Materials Handling for Working in the Excavation Chamber:

a) Provide appropriate materials handling equipment to permit the safe passage of excavation tools and other materials from the end of the segment feeder into the pressurized Excavation Chamber.

.4 Electrical System:

a) The TBM and trailing gear shall be designed according to CEC Class 1 Zone 2 standards and all other requirements set forth by WorkSafeBC and CSA Standard CAN/CSA-M421-93, Use of Electricity in Mines or other applicable regulatory agencies.

b) Design Essential Services to CEC Class 1 Zone 1 standards for gassy locations and all other requirements set forth by WorkSafeBC and CSA Standard CAN/CSA-M421-93.

c) The primary power distribution system to have means for limiting high-voltage fluctuations when starting up or shutting down the TBM.

d) An emergency standby generator with a capacity and configuration to automatically come on-line in the event of a power failure to operate ventilation, lighting, pumping, communications, and other safety support systems without interruption.

e) Provide power interrupt to automatically shut down power to the TBM and trailing equipment upon detection of an air quality event, such as explosive or toxic gas levels exceeding the regulation limits while maintaining power to Essential Services.

.5 Lighting Systems:

a) Primary lighting system for the entire length of the tunnel to CEC Class 1 Zone 2 standard.

b) Emergency lighting system for the entire length of the tunnel and TBM back up to CEC Class 1 Zone 1 standard.

c) Additional lighting in tunnel sufficient for inspection of construction operations by the Construction Manager.

d) Provide flashlights approved by WorkSafeBC as "permissible".

e) The use of flame safety lamps is prohibited.

.6 Water Pumping in Tunnel:

a) Provide pumping capacity in the TBM as required to remove accumulations of water from construction discharges and any groundwater inflows at the heading or through shield articulations or wire brush seals.

b) Provide sufficient intermediate pumping stations and pumping capacity along the tunnel as required to remove water accumulations from construction discharges and any groundwater seepage and to maintain accumulated water levels below tunnel railheads.

c) Provide sump, pump, and discharge lines at and from the TBM with sufficient capacity to remove water accumulations from construction discharges, groundwater seepage, and sudden water inflows.

.7 Slurry TBM Feed and Discharge Lines:

a) Design slurry lines, valves, and pumps to transport the materials indicated in the Contract Documents.

b) Provide sufficient intermediate pumps along the tunnel alignment for the slurry flow rate and pressure needed for Required Support Pressure and slurry discharge for the anticipated maximum TBM advance rate and tunnel length. Provide bypass valves at each feed booster pump and at 300 metres intervals in the feed line to permit flushing of slurry suction lines.

c) A minimum of two abrasion resistant pressure sensors along the slurry charge (feed) line segment and two additional abrasion resistant pressure sensors along the slurry discharge line which can be replaced under operating conditions.

.8 Slurry TBM Bentonite Mixing and Separation Plant:

a) Design slurry separation plant to separate bentonite slurry and the excavated soil material generated from tunnelling through the indicated conditions including areas of ground improvement.

- Capable of handling the anticipated volume rates, types, and quantities of materials anticipated.
- Capable of balancing the removal of solids from suspension with the Slurry TBM advance rate.

b) Recirculate the processed slurry and provide means of reconditioning and replacing lost slurry as required by ground conditions at heading.

- Ability to increase slurry density to counter slurry loss and to prevent face collapses.
- Ability to adjust and optimize dosage of slurry additives to provide efficient transport of spoils.
- Slurry suspension reserve with a minimum volume of 80,000 litres for use if a sudden, high flow rate slurry loss occurs during tunnelling in highly permeable soils.

.9 Transportation System:

a) For the transportation of material, supplies, persons, and injured persons with consideration of higher tunnel gradients at California switches and ramps.

b) Locomotives and rail cars to conform to the requirements of WorkSafeBC Section 22.

.10 Ventilation System:

a) To be in accordance with the CEC Class 1 Zone 1 specification and additional requirements of this Section.

b) To be fully reversible with ability to meet all performance and air quality criteria in exhaust or intake mode.

c) Main ventilation duct made of non-combustible materials.

d) Locate exhaust stacks of the ventilation system to prevent recirculation of exhaust air into the air intake shaft or shaft.

e) Design: Meet or exceed minimum requirements of WorkSafeBC regulations.

f) Power to the primary ventilation system is not be interrupted in the event of a gas detection system alarm.

2.4.20 Health and Safety Equipment:

.1 In addition to the health and safety requirements specified in other sections, features for equipment used in tunnelling work to meet the following requirements:

a) Equip TBM with integrated safety systems as described in this Section and in accordance with applicable regulatory requirements for underground construction equipment.

b) Rate all equipment for use in CEC Class 1 Zone 2 hazardous locations.

c) Provide eyewash stations.

.2 Minimum Fire Protection Requirements:

a) Fire suppression systems within TBM and along trailing gear for all electro-hydraulic installations, heat sources, and the TBM transformer.

b) A clear emergency escape way from the TBM along the trailing gear.

c) Fire suppression system on all locomotives.

d) Fire extinguishers at the TBM control panel, and at 8 metre intervals along the trailing gear.

e) A water curtain at the rear end of the trailing gear.

.3 All personnel entering the tunnel are to be equipped with portable oxygen re-breather type self rescuers.

.4 Air Quality Monitoring:

a) A CEC Class 1 Zone 1 compatible air quality monitoring and alarm system to monitor gas concentrations including, but not limited to, carbon monoxide, hydrogen sulfide, oxides of nitrogen, oxygen, methane, and airborne particulate concentrations in the tunnel atmosphere.

b) Continuous air quality monitoring on the TBM with readings captured by the TBM Data Acquisition System and recorded by the data logger at intervals of ten seconds or less.

c) Design the alarm system to disengage the TBM, at no more than 20 percent of LEL for methane or any other combustible gas.

d) Position sensors at locations that provide the most effective measurement of combustible and toxic gases. Do not place sensors within a fresh air stream.

e) Handheld multi-gas detectors including, but not limited to, carbon monoxide, hydrogen sulphide, oxygen, and methane used by properly trained personnel when entering the Excavation Chamber under free-air conditions.

2.5 Source Quality Control

Not Used

PART 3 EXECUTION

3.1 Preparation/Startup Operations

3.1.1 Training:

.1 Training Plan: A comprehensive plan for orientation and training of all personnel shall be developed based on all the documents of the Tunnelling Excavation Plan(s) for the two tunnels.

3.1.2 Before TBM launch and start-up operations, the following preparation and installations are required for each tunnel:

.1 Install and baseline geotechnical instrumentation: Before commencement of TBM launch, ensure that all specified geotechnical instrumentation has been installed, is functional, has been base lined and is being monitored, all as specified in Section 02350.

.2 Provide an on-site TBM manufacturer's representative to train the Contractor's personnel in the TBM operation and maintenance and for technical support during tunneling.

.3 Commission compressed air plant and related services required to supply the TBM.

.4 Prior to launch and start-up operation of an EPB TBM the required soil conditioner properties shall be determined in order that workable mixtures of soil and soil conditioners for the anticipated soil types may be determined.

a) Systematic testing of the soil types shall be carried out such that the range of soil conditioning parameters including FER, FIR, types and concentrations of foam agents, polymers or other materials shall be known and ready to be applied where required.

b) Calibration of the GCS shall be carried out in order to ensure consistent conditioner application.

.5 Prior to the launch and start-up operation of a Slurry TBM, the properties of the slurry to be used shall be determined and checked.

.6 Confirm that the Ground Improvement zones, specified in Section 02337– Ground Improvement, have been completed.

.7 Prior to launch and start up of the Slurry TBM, the properties of the slurry to be used shall be determined and checked.

.8 TBM Data Acquisition System is tested and fully operational.

.9 All site water discharge systems, including sump, pump, and discharge lines in the South shaft site, are tested and ready for operations that meet discharge requirements during tunnelling.

.10 Complete all necessary training for workers required to perform under compressed air.

.11 Verify correct operation of all safety equipment.

.12 Tunnel Recue Teams in place per Section 02450.

.13 Tunnelling Excavation Plan has been returned and accepted by the Construction Manager.

3.1.3 Launching each tunnel from the Outfall Shaft:

.1 Provide all installations in the shaft for TBM launch, start-up and tunnel operation, including installation of supplementary supports or bracing required for structural support, thrust abutment, and launch cradle.

.2 Provide shaft launch sealing structure for TBM launch which seals the gap between the shaft, soil and TBM and the gap between shaft and initial support.

.3 Fill Excavation Chamber with conditioned spoil or slurry during breakthrough into the break-out zone and maintain the chamber full through the zone.

.4 Complete the following before advancing the TBM cutterhead beyond the break-out zone:

a) Install at least two complete rings of segments and grout the tail void between the segments and shaft support wall to form a watertight seal.

b) Fill excavation chamber with conditioned soil or slurry and apply Required Support Pressure.

3.1.4 Provide Active Face support pressure calculations: as described in 1.6.3. (4).

3.1.5 Pre-Tunnelling Meetings:

.1 At least 30 calendar days prior to each TBM launch, conduct a meeting with the Construction Manager to discuss aspects of the tunnelling work relating to the monitoring, data acquisition and reporting, communications, testing plan, Hold Points, safety, quality procedures, and tunnel rescue teams.

3.1.6 Pre-Reception Meetings:

.1 At least 10 calendar days prior to each TBM reception, conduct a meeting with the Construction Manager to discuss aspects of the reception operations and subsequent TBM retrieval or abandonment relating to the monitoring, data acquisition and reporting, communications, inspection and testing plan, safety, quality procedures, and tunnel rescue teams.

3.2 Tunnelling

3.2.1 Excavation:

.1 Advance tunnel heading through all ground conditions encountered using Required Support Pressure to minimize lost ground as required to comply with ground movement limits.

.2 Operate TBM with Required Support Pressure during TBM advance; Open Mode operation is not permitted during TBM advance.

.3 Excavate the Effluent Tunnel from the Outfall Shaft, then excavate the Outfall Tunnel from the Outfall Shaft.

3.2.2 Face Support Application:

.1 Provide Active Face Support by pressurized soil or slurry at all times during tunnel excavation; adjust as appropriate within break-in and break-out zones adjacent to launching and receiving shaft.

.2 Control the Active Face Support pressure at or above the calculated target pressure to ensure face stability and minimize Lost Ground at all times and to comply with ground movement limits indicated in Section 02350.

a) Operate the TBM to keep Active Face Support pressure within the following operational tolerances of calculated target pressure:

- ±0.3 bar for face support with earth paste (EPB TBM);
- ±0.1 bar for face support by slurry (Slurry TBM).

.3 Adjust composition and properties of the slurry (for Slurry TBM) to the local ground conditions and properties of the make-up water in order to achieve a reliable Active Face Support including impacts from tunnelling through zones with high permeability ground.

3.2.3 Face Support during TBM Stoppage:

.1 Control and stabilize the tunnel face during inspection, maintenance, and boulder stops, and any other heading or excavation chamber work using compressed air.

.2 Prior to entry into the excavation chamber under compressed air, bentonite slurry shall be introduced into the tool gap via the GCS ports or flooded into the excavation chamber such that a substantial and continuous bentonite cake is formed on the tunnel face.

.3 Apply calculated target air pressure within excavation chamber with supplementary face support, when necessary.

.4 Prior to any work being carried out in the chamber a face stability assessment shall be carried by a competent person. The competent person shall immediately advise the Construction Manager of any changes in compressed air pressure or abandonment of the entry due to ground conditions.

.5 Maintain bentonite cake and supplementary face support during the excavation chamber entry.

.6 Air pressure and compressed air consumption shall be continuously controlled within a tolerance of ± 0.05 bar for face support by compressed air.

.7 Refill excavation chamber with earth paste or slurry and pressurize before restart of the TBM after Inspection Stops.

3.2.4 Support by Precast Concrete Segmental Lining:

.1 Refer to Section 02324.

3.2.5 Tail Void Grout Injection:

.1 In accordance with Section 02335.

3.2.6 Muck Handling:

.1 Handle and convey muck through excavation chamber and TBM to ground surface.

.2 Provide for legal off-site disposal of muck per the requirements of the Contract Documents.

.3 Submit copies of disposal records as requested by the Construction Manager.

3.2.7 Removal of Water:

.1 Remove all accumulating water and groundwater inflow from the TBM and tunnel using methods and equipment necessary to prevent damage to any portion of the work.

.2 Disposal of all water per regulatory permit conditions.

.3 Limit flows to requirements specified.

3.2.8 Prevention and Remediation of Lost Ground:

.1 Reconcile belt scale weights with stroke length and theoretical excavated weight on a ring by ring basis. Record in Reconciliation Table and submit daily updates of Reconciliation Table.

.2 Immediately notify the Construction Manager and modify face support pressure or muck handling system as necessary for better control and to minimize lost ground at face if excavated muck weight exceeds theoretical weight by greater than five percent per ring.

.3 Fill voids within four hours and repair any damage to underground utilities, surface structures, roadways, or any other features resulting from lost ground, settlement, and heave.

.4 Document lost ground void filling and submit lost ground records within four hours of completing remedial work.

.5 Work with the Construction Manager and owner of the structure or utility to determine what mitigation and repairs are required as a result of the lost ground.

3.2.9 Ventilation System:

.1 Operate the tunnel main ventilation system continuously 24 hours per day, seven days per week.

.2 Advance of the ventilation system shall be made continuously with the normal excavation cycle.

.3 Operate and maintain mechanical ventilation systems in tunnel and shaft excavations in which work of any kind is being performed.

.4 Monitor the performance of the ventilation system as required by WorkSafeBC, and as often as necessary to fully protect workers, but not less than once every seven calendar days to verify that it conforms to the minimum requirements.

a) Measure the flow rate of fresh air delivered by the ventilation system at the following minimum locations:

- Within the TBM shield in the ring build area.
- In the tunnel at a position eight tunnel diameters behind the back end of the TBM trailing gear.
- In the tunnel at a position eight tunnel diameters from the nearest open shaft.

b) Perform weekly smoke tube tests in the tunnel heading to identify air recirculation and areas of dead air. Modify or adjust the ventilation system as necessary to eliminate any deficiencies.

c) Air monitoring equipment:

- Check all with a known mixture of gas and calibrate, if necessary, at least once every 30 calendar days.
- Maintain in accordance with the manufacturer's recommendations.
- Maintain calibration records and make available to the Construction Manager on request.

d) Maintain records of all observations, and make available to the Construction Manager on request.

.5 Report indications of combustible or toxic gas in tunnels and shafts to the Construction Manager immediately.

.6 In the event of primary ventilation system failure for any reason, withdraw all persons from the tunnel. Permit limited access to those working to restore normal ventilation. Following restoration of ventilation flow, verify the air quality and modify ventilation system as required to meet WorkSafeBC requirements, prior to permitting re-entry of personnel.

.7 After the tunnel is holed through, maintain appropriate air flow and/or WorkSafeBC minimum requirements for the work activity being undertaken until all work in the tunnel is completed and accepted.

.8 Advise the Construction Manager before the main ventilation system is reversed.

3.2.10 Movement Monitoring System:

.1 Geotechnical instrument monitoring: Section 02350.

3.2.11 Tunnel Precast Segmental Lining:

.1 Installation and tolerances for Precast Segmental Lining: In accordance with Section 02324.

3.2.12 TBM Maintenance:

.1 Complete as often as necessary to keep the pressure sensors, muck handling equipment, and other TBM equipment in good operating condition, and as per manufacturers' recommendations.

.2 Hydraulic oil, seal oil, and bearing lubricating oil and grease shall be tested at least once per every 100 operating hours, monthly, or per manufacturer recommendations, whichever is most frequent. Maintain records of these tests and make available to the Construction Manager upon request. Clearly indicate the contaminant levels and overall condition including any changes since last testing and maintenance action indicated.

.3 Choose the appropriate cutting tool types as required for the ground conditions.

.4 Optimize cutting tools for best TBM performance with consideration of: production, cutter, and cutterhead wear, and fracturing of cobbles, boulders, and rock sufficiently at the heading for proper handling within the excavation chamber and mucking system.

.5 Sensors being logged by the data acquisition system shall be recalibrated, or replaced upon discovery of damage or the observation of erroneous readings and all sensors to be recalibrated at least twice over the length of the tunnel.

3.2.13 Boulder Removal:

.1 Shall be performed when a boulder is detected which cannot be ingested by the TBM.

.2 Blasting is prohibited. Use splitting, jack-hammering, sawing, chiseling, or other acceptable means for cutting, fracturing, and removal.

.3 Document observed face stability, groundwater inflows, and excavation chamber pressures for work completed during Boulder Stops.

3.2.14 Electrical System Monitoring:

.1 To remain acceptable for use in CEC Class 1 Zone 2 hazardous locations maintain electrical equipment as indicated:

a) Inspect as often as necessary to protect workers, but not less than once every seven days by a competent person.

b) Maintain in condition suited to its intended use.

c) Inspect explosion-proof enclosures for loose or missing screws, for damage to gaskets, threaded connections, covers, or seals, and for other impairments to a tight and sealed condition.

d) Inspect cables for cuts, abrasions, and other impairments.

.2 Maintain records of these inspections and make available to the Construction Manager on request.

3.2.15 Provide for safe access and egress of personnel to and from the heading. Include procedures for personnel working in all tunnel locations and include, as appropriate, separate walkways, refuges, personnel transfer equipment and authorization systems for working and walking on the track way.

3.2.16 Tunnel Reception for the Effluent Tunnel:

.1 Construct ground improvement for ground and groundwater control at the receiving shaft prior to the TBM breakthrough in accordance with Section 02337.

.2 Prepare the TBM breakthrough into the receiving shaft by forming the tunnel eye corresponding to the TBM breakthrough position. Pre-cutting is not permitted through the slurry wall panel until ground improvement for TBM breakthrough has been completed and required material properties have been achieved.

.3 Provide shaft reception sealing structure on the inside surface of the shaft for TBM reception which seals the gap between the shaft, soil and TBM tail shield.

.4 Advance the TBM through the shaft wall in accordance with paragraph 3.2.2 herein and into backfilled material, as applicable per Contractor's reception procedure.

.5 Grout and proof grout the last ring fully within the shaft wall once the TBM tail shield has passed through the shaft wall. Proof grouting in accordance with Section 02335, at least 24 hours following placement of the initial backfill grout.

.6 Remove backfill from the shaft and demobilize TBM and all associated equipment.

.7 Grouting shall be carried out to reduce ground water inflows to the specified limits.

3.2.17 Tunnel Reception for the Outfall Tunnel:

.1 Construct riser shaft concrete block as per Contract Drawings and remove any shaft excavation support system elements within the TBM advance path prior to the TBM break-in into the riser shaft concrete block.

.2 Confirm that the riser shaft concrete block has achieved the specified properties prior to the start of tunnel reception procedure.

.3 Advance the TBM for break-in into the riser shaft concrete block in accordance with paragraph 3.2.2 herein.

.4 Grout and proof grout the five rings immediately outside the riser shaft perimeter and all rings within the riser shaft perimeter. Proof grouting in accordance with Section 02335, at least 24 hours following placement of the initial backfill grout.

.5 Once the TBM shield is in its final position and the position has been confirmed by independent survey, fully replace the materials in the annular space around the shield with proof grout using pre-installed grout ports through the TBM shield.

.6 Abandon TBM shield in place to allow construction of riser shaft connection as per Contract Drawings.

3.2.18 Segment repair and clean-up prior to Welded Steel Pipe (WSP) installation: Section 02324, and Section 02506– Steel Pipe In-Tunnel Installation.

3.2.19 Prior to installation of the WSP, clean tunnel such that it is free of oils, greases, and loose debris, as agreed with the Construction Manager.

3.2.20 WSP Installation: Section 02506.

3.2.21 Daily Meetings: Conducted between the Contractor and the Construction Manager to discuss safety, quality, production, and submission of reports from previous day(s) production.

3.3 Tunnel Maintenance

3.3.1 Perform regularly scheduled tasks to:

.1 Clean the tunnel interior and invert muck, grout, debris, and other foreign materials.

.2 Maintain sumps, collection points, and pumps clear of trash and in good operating order.

.3 Maintain clear passage of the flow of personnel, equipment, and materials.

.4 Keep tunnel walkways and refuges clean to allow for safe access.

3.4 Site Quality Control

3.4.1 General:

.1 TBM Data: Review data transmitted real-time for TBM system monitoring and provide complete unaltered digital records in an agreed format directly to the Construction Manager.

.2 EPB Muck Control:

a) Use belt scales to determine the weight of muck for each ring and determine the actual weight and volume excavated with consideration of the materials added.

b) Promptly notify the Construction Manager and provide documentation if calculations indicate that actual weights and volumes for a ring advance exceed theoretical excavation by more than five percent.

.3 Slurry Muck Control:

a) Use measurements of flow rates and slurry densities in the slurry lines to and from the excavation chamber to determine and record the total weight of excavated material for each ring.

b) Record the total weight of the discharged material on a shift basis.

c) Record the total volume of bentonite slurry added to the system on a shift basis. Promptly report any bentonite losses in writing to the Construction Manager.

d) Promptly notify the Construction Manager and provide documentation if calculations indicate that actual volumes or weights for a shove exceed theoretical excavation by more than five percent.

.4 Daily Shift Reports during Tunnelling:

a) The daily shift reports shall be submitted to the Construction Manager by 10:00 a.m. the following working day in both an agreed digital and hardcopy format and shall include, but not be limited to, the following information:

- Date, location, shift, beginning and ending face station, list of personnel by name, classification, and function working that shift, list of the number and type of equipment, including amount of and reason for any idle or down time, list of all materials used in the work.
- Description of materials being excavated, volume of excavated materials using methods as mutually agreed when not otherwise specified.
- Description and locations of Lost Ground, water inflows and other events.

- Cutting tool and muck system component changes, including time and date of replacement, cutter or component position or number, and reason for change.

.5 Daily Excavation reports shall be submitted in both an agreed digital and hardcopy format and shall include, but not be limited to, the following:

a) Date, shift, ring number, beginning and ending face station, start and end time for excavation and ring erection, face support pressure, excavated weight and reconciled weight and volume, type and total weight and volume of conditioners injected, total volume of grout injected, bentonite injected, observed material density, and calculation of bulking factor.

b) Guidance system information, including present and predicted position, propulsion and articulation cylinder extensions, ring gap before and after ring erection, key position, and roll of ring.

c) Other information including observations and damage to precast segments or gaskets.

.6 Air quality monitoring report shall be submitted in both an agreed digital and hardcopy format and shall include, but not be limited to:

a) Records of air quality measurements and reports and make available to the Construction Manager upon request.

b) Indications of combustible or toxic gas in tunnels or shafts to the Construction Manager immediately when these indications occur.

.7 Survey:

a) Provide Construction Manager access and assistance as necessary for confirmation of the tunnel alignment and stationing.

b) Immediately initiate alignment corrections and alignment control changes if a survey error and out of tolerance alignments are identified. Notify the Construction Manager immediately upon discovery of TBM out of tolerance.

c) Be responsible for the accuracy of the work and for correcting it, as required.

3.4.2 Quality Control:

.1 Precast Concrete Segmental Lining: Section 02324.

.2 EPB TBM: During the excavation of the tunnel, the muck passing over the belt shall be observed for changes in its appearance.

a) A muck sample shall be taken directly from the conveyor when a change in appearance is noted by the Contractor or when directed by the Construction Manager.

b) At a minimum, a five-litre sample shall be taken once per shift each day of excavation. Identify samples by location and date. Sample shall be placed

within watertight plastic bag, and sealed. Bagged sample shall have location identified on bag. Provide bag sample to the Construction Manager.

c) GCS settings shall be noted along with stationing and other pertinent data.

.3 Slurry TBM:

a) Control the material properties of the slurry every time, fresh suspension is being mixed and once every shift.

b) Determine, monitor, and test material flow characteristics such as density, filtrate loss, viscosity, yield point and others as identified within the Submittal with Acceptable Disposition.

c) Maintain records on a shift basis of quality control tests including slurry density and volume of slurry and conditioner used and make available to the Construction Manager upon request.

3.5 Tunnel Safety

3.5.1 Whenever there is a condition which is likely to endanger the stability of the excavation or adjacent work or structures, notify the Construction Manager and work with a full crew for 24 hours per day including weekends and holidays without interruption until those conditions are mitigated.

3.5.2 Follow the Tunnel Safety Plan for tunnel evacuation and for tunnel re-entry in the event that the air monitoring system alarms or automatic power shutdown occurs. Post the evacuation and re-entry plans in a readily visible location at the shaft entrance.

3.5.3 Tunnel crews shall be given daily safety briefings and sufficient time at shift change hand-over to identify any hazardous conditions or safety issue that may exist and have not been corrected.

3.5.4 Notify the Construction Manager immediately upon:

.1 Encountering an emergency condition likely to endanger the tunnel integrity, including but not limited to: seepage with soil erosion or piping of fines at heading, tail seal seepage, precast concrete segment joint seepage, shaft seal seepage, excessive lining deformations, significant lining cracks and any other detrimental observations.

.2 Encountering an emergency condition likely to endanger structures adjacent to the tunnel axis.

.3 Any TBM or tunnel air quality alarm or warning.

END OF SECTION

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Section 02450 – Tunnel Rescue Teams

PART 1 GENERAL

1.1 Section Includes

1.1.1 This Section specifies the procedures, and training requirements for the Tunnel Rescue Teams (TRT). These provisions are intended to supplement and reinforce the requirements of WorkSafeBC Regulation Part 22 Underground Workings. In the event of conflict between this Section and the written requirements of Part 22, the more stringent requirement applies. The requirements of this Section are to be coordinated with local emergency response agencies and are subject to review of WorkSafeBC and the Construction Manager.

1.2 Related Requirements

1.2.1 Section 02305, Tunnel Excavation by Tunnel Boring Machine

1.2.2 Section 02506, Steel Pipe In-Tunnel Installation

1.3 References

1.3.1 WorkSafeBC Regulation Part 22 Underground Workings

1.4 Submittals for Review

1.4.1 Submittals are to comply with the provisions of Section 01300 – Submittals.

1.4.2 At least 90 calendar days before the start of tunnel excavation, provide a TRT Plan document consisting of the following:

.1 Qualifications of TRT Members and Training Course Instructors.

.2 Detailed statement describing the proposed method of compliance with the requirements for TRTs.

.3 Disclose whether the Contractor has independently provided TRTs or entered into an agreement for the services of professional TRTs.

.4 Include the name of the provider and the location of the services in the statement.

.5 Identification of all members of the primary and back-up TRTs for all underground work shifts.

.6 TRT Member Training Certification – see Article 1.7 herein.

.7 Rescue Notification Plan – see Article 1.9 herein.

1.5 Submittals for Information

Not Used

1.6 Submittals for Closeout

Not Used

1.7 Quality Assurance

1.7.1 Qualifications

.1 TRT Members:

a) Ensure each person has been employed in an underground tunnel construction project for a minimum of one year within the past five years.

b) Ensure workers, who are employed on the surface but work regularly underground, meet the experience requirement.

.2 Training Course Instructors:

a) Have been employed in an underground tunnel for a minimum of two years within the past five years and have received WorkSafeBC approval for tunnel rescue team training, or equivalent.

1.8 TRT Requirements

1.8.1 Availability of Tunnel Rescue Teams:

.1 TRT presence is required during all phases of tunnel construction operations. Tunnel construction operations are deemed to include tunnel excavation and support, and steel pipe installation and backfill within the tunnel.

.2 Compose each TRT of five members and one alternate, who are qualified, trained, and equipped for providing emergency tunnel rescue service.

.3 Establish at least two TRTs which are available at all times when workers are underground or enter into an arrangement for professional tunnel rescue services which assures that at least two TRTs are available at all times when workers are underground.

.4 Arrange, in advance, ground transportation for rescue teams and equipment to the tunnel construction sites to be served.

.5 Consider TRTs available where teams are capable of presenting themselves at the tunnel Work Site(s) in accordance with Article 1.7, herein, after notification of an occurrence that might require their services.

.6 Availability to Tunnel Launch Shaft:

a) Have the primary rescue team available at the tunnel launch shaft site or within a maximum of 30 minutes of travel time from the tunnel launch shaft.

b) Have the backup rescue team either at the tunnel launch shaft site or available within a maximum of two hours of travel time from the tunnel launch shaft.

1.8.2 Physical Requirements for TRT Members

.1 Verify that each member of the TRT is examined within thirty (30) days of appointment to the TRT and annually, by an occupational physician who certifies that each person is physically fit to perform tunnel rescue and recovery work for prolonged periods under strenuous conditions.

.2 It's required that a minimum of two members from each TRT pass the medical examination for compressed air work within 30 days of appointment to the TRT and then annually thereafter.

.3 A team member requiring corrective eyeglasses is not disqualified provided the eyeglasses can be worn securely within an approved face piece.

.4 In determining whether a worker is physically capable of performing tunnel rescue duties, verify that the physician takes the following conditions into consideration:

a) Seizure disorder.

b) Perforated eardrum.

c) Hearing loss without a hearing aid greater than 40 decibels at 400, 1,000 and 2,000 Hertz.

d) Repeated blood pressure (controlled or uncontrolled by medication) reading which exceeds 160 systolic, or 100 diastolic, or which is less than 105 systolic, or 60 diastolic.

e) Distant visual acuity (without glasses) less than 20/50 Snellen scale in one eye, and 20/70 in the other.

f) Heart disease.

g) Hernia.

h) Absence of a limb or hand.

i) Any other condition, which the examining physician determines, is relevant to the question of whether the tunnel worker is fit for TRT service.

.5 Complete documents (certifying medical fitness) signed by the examining physician for each TRT member and submit to the Construction Manager.

1.9 Training Requirements

1.9.1 Prior to serving on a TRT, ensure that each member completes, at a minimum, an initial 20-hour course of training as indicated in this Article 1.7 including instruction in the use, care, and maintenance of the type of breathing apparatus which is to be used by the TRT.

1.9.2 Upon completion of the initial training, verify that all team members receive at least 48 hours of refresher training annually. Provide this training at least four hours each month, or for a period of eight hours every two months.

1.9.3 Ensure that training is conducted in conditions that, as closely as practicable, resemble actual underground conditions.

1.9.4 Approximately eight hours of training is to be given at the tunnel Work Site(s).

1.9.5 Conduct the training courses required by qualified instructors.

1.9.6 Maintain a record of training for each team member on file at the tunnel rescue station for the duration of the underground works.

1.9.7 A TRT member will be ineligible to serve on a team if more than eight hours of training is missed during one year, unless additional training is received to make up for the time missed.

1.9.8 Include the following in the TRT member training program:

.1 Sessions underground at least once each month.

.2 The use, care, capabilities, and limitations of auxiliary tunnel rescue equipment, or a different breathing apparatus.

.3 Advanced tunnel rescue training and procedures.

.4 Tunnel map training and ventilation procedures.

.5 Instruction and demonstration in the use, care, and maintenance of self-rescue and respiratory devices used in the tunnel.

.6 Training in the use of self-contained self-rescue devices including complete donning procedures in which each person assumes a donning position, opens the device, activates the device, inserts the mouthpiece, or simulates this task while explaining proper insertion of the mouthpiece, and puts on the nose clip.

.7 Entering and leaving the tunnel; transportation; communications:

a) Instruction on the procedures in effect for entering and leaving the tunnel: The check-in and check-out system in effect at the tunnel; the procedures for riding on and in tunnel conveyances; the controls in effect for the transportation of tunnellers and materials; and the use of the tunnel communication systems, warning signals, and directional signs.

.8 Introduction to the work environment:

a) A visit and tour of the tunnel, or portions of the tunnel, which are representative of the entire tunnel.

b) A method of mining utilized at the tunnel is to be observed and explained.

.9 Tunnel Map:

a) A review of the tunnel map; the escape way system; the escape, firefighting, and emergency evacuation plans in effect at the tunnel; and the location of abandoned areas.

b) Introduction to the methods of barricading and the locations of the barricading materials, where applicable.

c) Use the program of instruction for escape ways and emergency evacuation plans for this course.

.10 Ventilation Plans:

a) Introduction to and instruction on the ventilation plan in effect at the tunnel and the procedures for maintaining and controlling ventilation.

.11 Health:

a) Instruction on the purpose of taking dust, noise, and other health measurements, and any health control plan in effect at the tunnel is to be explained.

b) Explain the health provisions of the WorkSafeBC Regulations and equipment warning labels.

.12 Hazard Recognition:

a) Include the recognition and avoidance of hazards present in the tunnel.

.13 Electrical Hazards:

a) Recognition and avoidance of electrical hazards.

.14 First Aid:

a) Instruction in first aid methods acceptable to WorkSafeBC Regulations.

.15 Tunnel Gases:

a) Instruction in the detection and avoidance of hazards associated with tunnel gases.

.16 Instruction in the health and safety aspects of the tasks to which a new TRT members will be assigned, including:

a) Mandatory health and safety standards pertinent to such tasks.

b) Information about the physical and health hazards of chemicals in the work area.

c) The protective measures a TRT member can take against these hazards.

.17 Include within the training plan methods, such as oral, written, or practical demonstration, by which the training is to be considered successfully completed. Administer the methods for determining such completion before assigning trainees to actual work duties.

1.10 Tunnel Rescue Station

1.10.1 Designate in advance of tunnelling the location of the Tunnel Rescue Station(s) serving the Project.

1.10.2 Locate TRT equipment at the tunnel construction site(s) to be served by the work.

1.10.3 Tunnel Rescue Stations are to be centralized, organized storage locations for TRT equipment designed to ensure equipment readiness for immediate use.

1.10.4 Provide each Tunnel Rescue Station with at least the following equipment:

.1 Twelve self-contained oxygen breathing apparatus, each with a minimum of two hours capacity, and any necessary equipment for testing such breathing apparatus.

.2 A portable supply of liquid air, liquid oxygen, pressurized oxygen, oxygen generating or carbon dioxide absorbent chemicals, as applicable to the supplied breathing apparatus and sufficient to sustain each team for 6 hours while using the breathing apparatus during rescue operations.

.3 One extra oxygen bottle (fully charged) for every six self contained compressed oxygen breathing apparatus.

.4 One oxygen pump or a cascading system, compatible with the supplied breathing apparatus.

.5 12 permissible cap lamps and a charging rack.

.6 Two gas detectors appropriate for each type of gas which may be encountered at the tunnel heading(s) served.

.7 Two oxygen indicators.

.8 One portable tunnel rescue communication system or a sound-powered communication system. Verify that the wires or cable to the communication system are of sufficient tensile strength to be used as a manual communication system. These communication systems are to be at least 300 m in length.

.9 Necessary spare parts and tools for repairing the breathing apparatus and communication system.

1.10.5 Maintain TRT apparatus and equipment in a manner that ensures readiness for immediate use.

1.10.6 Verify that a person trained in the use and care of breathing apparatus inspects and tests the apparatus at intervals not exceeding 30 days and certifies, by signature and date, that the inspections and tests were completed.

1.10.7 When the inspection indicates that a corrective action is necessary, make the corrective action and have the trained person record the corrective action taken.

1.10.8 Maintain the certification and the record of corrective actions at the tunnel rescue station and make available to the Construction Manager upon request.

1.11 Rescue Notification Plan

1.11.1 Provide a Rescue Notification Plan outlining the procedures required to call for the TRT in the event of an emergency.

PART 2 PRODUCTS

2.1 Owner-Supplied Products

Not Used

2.2 Source Quality Control

Not Used

PART 3 EXECUTION

3.1 General

3.1.1 Post a copy of the TRT Plan document at the tunnel site for the worker's information.

3.1.2 Post a copy of the Rescue Notification Plan separately at the tunnel site(s) for the worker's information.

3.2 Site Quality Control

3.2.1 Provide TRTs that meet the requirements of this Section, and make them available for service prior to performing any work in the tunnel.

3.2.2 Supplement the initial training requirements specified above by assembling the TRT as a group and reviewing access constraints, location of emergency equipment, availability of personal protective equipment, and other necessary information, prior to launching the TBM.

3.2.3 Coordinate all work and responsibilities of the TRT with the Workplace Safety Coordinator.

END OF SECTION

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CDM Smith

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