Eagle Mountain
Woodfibre Gas Pipeline Project

Water Management Plan

Rev. 1

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EXECUTIVE SUMMARY

FortisBC Energy Inc. (FortisBC) submitted a Pipeline Permit application to the British Columbia (BC) Oil and Gas Commission (BC OGC) for the tunnel component of the Eagle Mountain – Woodfibre Gas Pipeline (EGP) Project (EGP Tunnel) on November 1, 2019 (AA# 100084403). During the review of the Pipeline Permit application, the BC OGC determined that a Water Licence under the *Water Sustainability Act* is required for the EGP Tunnel due to the potential impacts to groundwater aquifers and surface streams from construction activities as well as operation activities, assuming permanent groundwater discharge will occur.

As part of the Water Licence application, the BC OGC recommended that FortisBC develop a Water Management Plan to consolidate relevant water-related information for all EGP Project phases. To comply with this requirement, FortisBC engaged McMillen Jacobs Associates, Tetra Tech Canada Inc., and Jacobs Consultancy Canada Inc. to conduct the required technical studies.

The Water Management Plan presented herein is based on the "Considerations for Water Management Plan" technical guidance document received on December 2019 from the BC OGC, the Water Licence Application Manual, and the Provincial Environmental Flow Needs (EFN) Policy.

PROJECT OVERVIEW

FortisBC received Environmental Assessment Certificate (EAC) No. E16-01 for the EGP Project from the British Columbia Environmental Assessment Office on August 9, 2016, for the EGP Project. The EGP Project will involve the construction of approximately 47 kilometres (km) of Nominal Pipe Size 24 (610 millimetres [mm] outside diameter) pipeline beginning north of the Coquitlam Watershed and ending at the Woodfibre Liquefied Natural Gas Ltd. (WLNG) Production Facility (WLNG Site) on the northwestern shore of Howe Sound. The EGP Tunnel was identified as a solution for the last 9 km of the alignment of the EGP Project to address Indigenous and public concerns regarding impacts to the sensitive Squamish River Estuary, as well as to avoid steep, difficult terrain in the area of Monmouth Ridge.

FortisBC has selected a Design-Build (DB) procurement approach for the EGP Tunnel. The Design-Build Contractor (DB Contractor) will be provided with a Reference Design**.**

Geology and groundwater conditions for the EGP Tunnel can be analyzed in three reaches:

1) Soft ground reach under the estuary (Soft Ground Tunnel)
2) Estuary-rock transition reach (Interface Zone)
3) Hard rock reach, which extends from the estuary-rock transition to the West Portal (Hard Rock Tunnel)

In the Reference Design, the Hard Rock Tunnel has been sized nominally at 3.5 metres (m) in diameter at depths ranging from approximately 30 to 500 m below ground surface.

OVERVIEW OF PROPOSED WATER MANAGEMENT ACTIVITIES

Water Use and Waste Water Discharge

Tunnel construction activities will require the extraction of water as well as the disposal of treated water. Tunnelling operations require water for the tunnel boring machine (TBM) cooling system, tunnel cleaning, grouting, probe drilling, and for general construction site use. FortisBC applied to the BC OGC for a Short-Term Use approval to withdraw 415 cubic metres/day from the Squamish River Estuary for the East Shaft at the BC Rail Properties Ltd. site (BC Rail Site). This volume was based on the technical requirements of the TBM as well as experience on projects of similar scope. Water for the West Portal will be supplied by WLNG.

Water used in tunnel operations becomes process water (after it leaves the source) and could become contaminated with sediment, dust, oil and grease, amongst others. Process water is typically treated on-site (sediment removed, grease skimmed) and discharged. FortisBC is planning to submit a Waste Discharge Authorization under the *Environmental Management Act* to the BC OGC to discharge treated water to a non-fish bearing stream at the WLNG Site. Treated water from construction activities at the BC Rail Site will be discharged to the Squamish River or to a surface water drainage system on-site. FortisBC will obtain all necessary permits and approvals for water discharge at the BC Rail Site.

The 4.96-km-long Hard Rock Tunnel slopes down toward the Soft Ground Tunnel. At the western end of the Soft Ground Tunnel, but within the adjacent Hard Rock Tunnel, a water-tight bulkhead will be constructed. Therefore, once the Hard Rock Tunnel is completed and backfilled, and depending on the DB Contractor proposed design, accumulated groundwater may be discharged at the West Portal during pipeline operation activities. FortisBC is planning to submit a Waste Discharge Authorization under the *Environmental Management Act* to the BC OGC to discharge water during operation activities onto a non-fish bearing stream at the WLNG Site at the same location as the construction phase.

The Soft Ground Tunnel crosses under the Squamish River Estuary at a slope of 0.05 percent. The Soft Ground Tunnel will be constructed from the BC Rail Site and will be supported with a precast bolted and gasketed segmental lining. No groundwater seepage or discharge is anticipated to occur for the Soft Ground Tunnel during pipeline operations. As such, the information included in the following sections is specific to the Hard Rock Tunnel.

Any potential water discharge from the EGP Tunnel will be conducted in accordance with regulatory requirements and Best Management Practices. Prior to discharge, the water will be sampled, tested, and treated (if required) to verify that it meets BC Approved Water Quality Guidelines.

Potential for Impacts to the Surficial Groundwater System

Upon completion of construction of the Hard Rock Tunnel, the pipeline will be installed, and the tunnel will be partially or completely backfilled. The DB Contractor will be responsible for preparing a detailed procedure and specifications for installing and backfilling the pipeline inside the Hard Rock Tunnel based on applicable codes and standards, sound engineering practice, local regulations, the performance requirements included in the Request for Proposal, and subject to FortisBC acceptance.

One of the potential scenarios is that once the Hard Rock Tunnel is completed and backfilled, seepage and groundwater inflow could potentially occur into the Hard Rock Tunnel along discrete discontinuities within the rock mass (such as, joints, shears, and fractures). Given that a large section of the Hard Rock Tunnel is essentially "underwater" and under internal pressure, the flow during pipeline operations at the West Portal will be less than when the EGP Tunnel is initially constructed and "dry."

It is anticipated that water could be continuously discharged at the West Portal during pipeline operation activities. However, mitigation measures (that is, grouting) will be implemented to reduce the quantity of the water that will be discharged.

CONCEPTUAL HYDROGEOLOGY MODEL

A Conceptual Hydrogeology Model (CHM) was developed to allow field data to be interpreted more readily and to simplify and visualize the geometry and hydraulics of water inflow into the Hard Rock Tunnel. Both a Regional Scale and a Tunnel Scale CHM are presented. The CHM was prepared and used to aid in the development of an analytical model to estimate groundwater inflow rates into the Hard Rock Tunnel.

Regional Scale Conceptual Hydrogeology Model

Groundwater flow in mountainous terrain is generally controlled by topography. Recharge of the groundwater system generally occurs at higher elevations, and results in generally downward hydraulic gradients. Groundwater discharge occurs in valley bottoms, or in this particular case Howe Sound.

Fracture zones occurring in the granitic bedrock coincide with surficial lineaments which range from 2 to 15 m wide. Groundwater flow in fractured granitic bedrock predominantly occurs via discontinuities (such as, joints, faults, or fracture zones). A greater amount of groundwater flow (hence inflow into the Hard Rock Tunnel) will occur through faulted areas due to a higher degree of interconnectivity of discontinuities compared with the unfaulted rock mass. Streams occur along or cross many of the lineaments and the surface water is likely hydraulically-connected with underlying saturated overburden.

Tunnel Scale Conceptual Hydrogeology Model

The Tunnel Scale CHM was based upon geological and geotechnical surface mapping, observations of seepage from the rock faces at surface, and hydraulic conductivity testing conducted in 2016.

In the field, 21 specific lineaments have been identified, mapped, and characterized. These lineaments are surface geomorphological expressions of underlying fracture zones in the bedrock which are likely to be the zones of highest groundwater flow within the granitic rock mass. Conceptually, when the Hard Rock Tunnel intersects a hydraulically-conductive discontinuity (that is, an open joint or well-interconnected fracture zone), there will be an initial high rate of inflow into the tunnel. This flow will diminish exponentially with time as the water stored within the discontinuity is released from storage and piezometric heads equilibrate.

Based on the site observations and testing carried out to-date, two types of potential discontinuities intersected by the Hard Rock Tunnel have been defined. Type I discontinuities are non-connected or weakly-connected discontinuities in fairly massive rock. These discontinuities are thought to have a low-hydraulic conductivity. Due to their limited connectivity, water inflows from Type I discontinuities are not anticipated to be high.

Type II discontinuities are well-connected and persistent within a localized zone of other closely-spaced discontinuities. Type II discontinuities include the fracture zones underlying the surface lineaments observed in 24 streams, associated catchments, and 11 lineaments of concern (Study Area). Based on the hydraulic conductivity tests conducted, these features are considered to have much higher hydraulic conductivity than surrounding massive bedrock. As a result, the highest water inflows to the Hard Rock Tunnel are expected from Type II discontinuities. Andesite dike contacts are also included as Type II discontinuities.

ENVIRONMENTAL FLOW NEEDS ASSESSMENT

The purpose of the EFN Assessment is to determine if water inflow to the Hard Rock Tunnel from fracture zones could potentially deplete water from overlying streams and cause an EFN concern as defined in the Provincial EFN Policy. As such, the EFN Assessment was conducted to determine the anticipated annual loss of stream water compared with the stream's mean annual discharge (MAD).

The Study Area results indicate that five catchments (I, J, L, S, and T) have no intersections with any of the 11 lineaments of concern. A total of 101 lineament/stream intersections were evaluated across the remaining 19 catchments. The calculated total streamflow depletion as a percentage of MAD was low, ranging from <0.1 percent (Catchment F) up to 2.9 percent (Catchment B), with an average depletion of 1.04 percent of MAD.

Based on analysis, the potential streamflow depletion due to ungrouted fracture zone inflows to the Hard Rock Tunnel are considered to be low. As these calculated depletions are <15 percent and it is understood that the streams are non-fish bearing, the effects of Hard Rock Tunnel dewatering on streamflow in the Study Area would likely be considered as an EFN Risk Management Level 1 (lowest concern). Furthermore, since it is intended to grout the fracture zones found within the Hard Rock Tunnel (generally with forward probing, prior to excavation), the potential streamflow depletion is anticipated to be significantly reduced.

ESTIMATED WATER BUDGETS

A water balance was developed to estimate expected annual volumes of precipitation, surface runoff, infiltration to groundwater, and losses to evapotranspiration within the watersheds draining across the Hard Rock Tunnel alignment. The primary purpose of this balance is to estimate the annual recharge to groundwater upgradient to the proposed Hard Rock Tunnel.

A single water budget reflective of all 7.4 square kilometres (km^2) of drainage area was prepared utilizing precipitation data obtained from Squamish Airport and the results of the runoff coefficient and evapotranspiration calculations. The budget can be further broken down for individual watercourses with linear scaling based on watershed areas. The estimated annual water budget for the watershed area (7.4 km^2) draining through the Hard Rock Tunnel is included in Table ES-1.

Table ES-1. Annual Water Budget for Watershed(s) Draining through Hard Rock Tunnel

Watershed Area	Annual Precipitation		Runoff Coefficient	Annual Runoff		Evapotranspiration		Infiltration to Groundwater	
(km^2)	(mm)	(mm^3)		(mm)	(mm^3)	(mm)	(mm^3)	(mm)	(mm^3)
7.4	2,532	18.7	0.82	2,076	15.4	224	1.7	231	1.7

Notes:
mm^3 = cubic millimetre(s)

Through the high-level assessment, an annual groundwater recharge volume of 1,720,000 cubic metres (m^3) is projected within the Hard Rock Tunnel Watershed, which is equivalent to 9.2 percent of the annual precipitation in the area.

Construction Flow Estimate

The results of the predicted inflows to the Hard Rock Tunnel during construction based on hydrogeological calculations and sensitivity analysis by applying the methods presented in Table ES-2.

Table ES-2. Results of Calculated Inflows to the Hard Rock Tunnel during Construction

Method	Head Condition	Low-Hydraulic Conductivity			High-Hydraulic Conductivity			Geometric Mean Hydraulic Conductivity		
	%	m^3/s	Lps	Lpm	m^3/s	Lps	Lpm	m^3/s	Lps	Lpm
El Tani	NA	0.02	15.5	932	1.133	1,133	67,950	0.23	225.6	13,535
Moon and Fernandez	25[a]	0.003	3.5	207	0.256	256	15,367	0.051	50.8	3,048
	10[a]	0.001	1.4	83	0.103	103	6,151	0.0203	20.3	1,220

Sources: El Tani, M. 2003. Circular tunnel in a semi-infinite aquifer. Journal of tunnelling and underground space technology. Vol 18, pp. 49-55.

Moon, J. and Fernandez, G. 2010. Effect of excavation-induced groundwater level drawdown on tunnel inflow in a jointed rock mass. Engineering Geology, 110, 33–42.

[a] reduced piezometric head, as % of initial head acting on the tunnel springline

Notes:

m^3/s = cubic metre(s) per second
Lps = Litres per second
Lpm = Litres per minute

The above groundwater inflow calculations consider that no remedial measures are applied to reduce the groundwater inflow during and/or post advancement of the Hard Rock Tunnel. It is typical practice during tunnelling operations to grout zones that produce relatively high quantities of groundwater. In this instance, it is anticipated that the portions of the Hard Rock Tunnel that will produce the highest volumes of groundwater will be those which are highly fractured, relatively high-hydraulic conductivity, well-interconnected, and with connectivity to surface. The fracture zones underlying lineaments which intersect the Hard Rock Tunnel likely meet most, if not all, of these criteria; other yet to be identified structures may also produce relatively high quantities of groundwater.

The anticipated groundwater inflow for the full Hard Rock Tunnel was re-evaluated based upon the effect of grouting of the fracture zones. These results are included in Table ES-3 and show that grouting the fracture zones would approximately halve the groundwater inflow into the Hard Rock Tunnel.

Table ES-3. Results of Calculated Inflows to the Hard Rock Tunnel with Remedial Grouting

Method	Head Condition	Low-Hydraulic Conductivity			High-Hydraulic Conductivity			Geometric Mean Hydraulic Conductivity		
	%	m^3/s	Lps	Lpm	m^3/s	Lps	Lpm	m^3/s	Lps	Lpm
El Tani	N/A	0.0049	4.9	294	0.668	668	40,088	0.11	111	6,635
Moon and Fernandez	25[a]	0.001	1.2	73	0.167	167	10,024	0.028	28	1,659
	10[a]	0	0.49	29.4	0.067	67	4,010	0.011	11	664

Sources: El Tani, M. 2003. Circular tunnel in a semi-infinite aquifer. Journal of tunnelling and underground space technology. Vol 18, pp. 49-55.

Moon, J. and Fernandez, G. 2010. Effect of excavation-induced groundwater level drawdown on tunnel inflow in a jointed rock mass. Engineering Geology, 110, 33–42.

[a] reduced piezometric head, as % of initial head acting on the tunnel springline

Post-construction Flow Estimate

Pending the detailed design and backfill procedures to be determined by the DB Contractor, upon completion of construction activities, it is anticipated that seepage and groundwater inflow could occur into the Hard Rock Tunnel along discrete discontinuities within the rock mass (such as, joints, shears, and fractures). Given that a large section of the Hard Rock Tunnel is essentially “underwater” and under internal pressure, the flow during pipeline operations at the West Portal will be less than when the EGP Tunnel is initially constructed and “dry.” It is estimated that following water filling, approximately 1,000 Lpm of water could be discharged at the West Portal. However, continual monitoring of inflows and water quality will be conducted by taking flow measurements from observed seepage sources within the Hard Rock Tunnel during construction. These measurements will help determine if additional grouting is required to impede groundwater inflows. Should a high groundwater inflow occur from a particular feature, the DB Contractor will grout the feature to prevent groundwater ingress. It is considered that by grouting the five to ten critical water-bearing features expected in the Hard Rock Tunnel, the actual inflow could be reduced to approximately 500 Lpm.

MITIGATION MEASURES

As part of the specifications included in the Request for Proposal, the DB Contractor is expected to adhere to the directions provided in the EAC Condition Management Plans (CMPs) and will provide an EGP Tunnel-specific Environmental Protection Plan (EPP) that shall meet or exceed the standards outlined in the CMPs. The EPP will be submitted to FortisBC for review and acceptance. The EGP Tunnel-specific EPP developed by the DB Contractor will be prepared in advance of construction and will be submitted to the BC OGC.

Preliminary mitigation measures to manage water quality and quantity during construction and operation of the EGP Tunnel have been included in performance specifications included in the Request for Proposal package. The main mitigation measure to reduce the quantity of produced water will be the implementation of a grouting program that will consist of drilling a series of advance boreholes and injecting cementitious grout at high pressure into the lineaments of concern.

ENGAGEMENT SUMMARY

FortisBC sent a consultation package containing an EGP Project description letter and maps to Indigenous Groups whose Traditional Territories are affected by the proposed activities, including the following:

- Squamish Nation
- Tsleil-Waututh Nation
- Musqueam Indian Band

FortisBC will include a summary of the consultation conducted as part of the application submission.

A search of water users within the Study Area was conducted on February 25, 2020 to identify potentially affected water users including water licensees, water licence applicants and domestic water users. Based on the results of this search, the construction and operation of the Hard Rock Tunnel is not anticipated to have any potential effects on water users. As such, no right holder engagement activities were required.

CONTENTS

Appendixes

Tables

Figures

ACRONYMS AND ABBREVIATIONS

ARD	acid rock drainage
BC	British Columbia
BC EAO	British Columbia Environmental Assessment Office
BC OGC	British Columbia Oil and Gas Commission
BC Rail Site	BC Rail Properties Ltd. site
CHM	Conceptual Hydrogeology Model
CMP	Condition Management Plan
DB	Design-Build
DB Contractor	Design-Build Contractor
EAC	Environmental Assessment Certificate
ECCC	Environment and Climate Change Canada
EFN	environmental flow need
EGP Project	Eagle Mountain – Woodfibre Gas Pipeline Project
EGP Tunnel	tunnel under the Squamish River Estuary
EMP	Environmental Management Plan
EPP	Environmental Protection Plan
FortisBC	FortisBC Energy Inc.
Jacobs	Jacobs Consultancy Canada Inc.
K	hydraulic conductivity
km	kilometre(s)
km^2	square kilometre(s)
Lpm	litre(s) per minute
Lps	litre(s) per second
MAD	mean annual discharge
m	metre(s)
m/s	metre(s) per second
m^3	cubic metre(s)
m^3/s	cubic metre(s) per second
MJA	McMillen Jacobs Associates

ML	metal leaching
mm	millimetre(s)
mm^3	cubic millimetre(s)
R.F.	reduction factor
Study Area	24 streams, associated catchments, and 11 lineaments of concern
TBM	tunnel boring machine
Tetra Tech	Tetra Tech Canada Inc.
UPI	UniversalPegasus International
WHA	Wildlife Habitat Area
WLNG	Woodfibre Liquefied Natural Gas Ltd.
WLNG Site	Woodfibre Liquefied Natural Gas Ltd. Production Facility
WMA	Wildlife Management Area
WSC	Water Survey of Canada

1. INTRODUCTION

FortisBC Energy Inc. (FortisBC) submitted a Pipeline Permit application to the British Columbia Oil and Gas Commission (BC OGC) for the tunnel component of the Eagle Mountain – Woodfibre Gas Pipeline (EGP) Project (EGP Tunnel) on November 1, 2019 (AA# 100084403). During the review of the Pipeline Permit application, the BC OGC determined that a Water Licence under the *Water Sustainability Act* is required for the EGP Tunnel due to potential impacts to groundwater aquifers and surface streams from construction activities as well as operation activities, assuming permanent groundwater discharge will occur.

As part of the Water Licence application, the BC OGC recommended that FortisBC develop a Water Management Plan to consolidate relevant water-related information for all EGP Project phases. To comply with this requirement, FortisBC engaged McMillen Jacobs Associates (MJA), Tetra Tech Canada Inc. (Tetra Tech), and Jacobs Consultancy Canada Inc. (Jacobs) to conduct the required technical studies. Where relevant, technical memoranda, figures, and calculations have also been appended.

The Water Management Plan presented herein is based on the “Considerations for Water Management Plan” technical guidance document received on December 2019 from the BC OGC, the Water Licence Application Manual (BC OGC 2019), and the Provincial Environmental Flow Needs (EFN) Policy (BC MOE and BC MFLNRO 2016). The information presented includes the following:

- Sections 2 and 3: EGP Project overview and summary of proposed water management activities
- Section 4: Conceptual Hydrogeology Model (CHM) to determine potential impacts on the groundwater regime from construction and operation of the Hard Rock Tunnel
- Section 5: EFN Assessment for hydraulically-connected streams
- Section 6: Estimated water budgets for construction and post-construction activities
- Section 7: Mitigation measures for the management of water quality and quantity during construction and operation activities
- Section 8: Indigenous Groups and Right Holders Engagement Summary
- Section 9: Conclusions
- Section 10: References

2. PROJECT OVERVIEW

FortisBC received Environmental Assessment Certificate (EAC) No. E16-01 from the British Columbia Environmental Assessment Office (BC EAO) on August 9, 2016, for the EGP Project. The EGP Project will expand FortisBC's existing natural gas transmission system to supply natural gas to the proposed Woodfibre Liquefied Natural Gas Ltd. (WLNG) Production Facility (WLNG Site).

The EGP Project will involve the construction of approximately 47 kilometres (km) of Nominal Pipe Size 24 (610 millimetres [mm] outside diameter) pipeline beginning north of the Coquitlam Watershed and ending at the WLNG Site on the northwestern shore of Howe Sound. The EGP Project also involves the construction of the EGP Tunnel and the installation of associated facilities and ancillaries.

The EGP Tunnel was identified as a solution for the last 9 km of the alignment of the EGP Project to address Indigenous Groups and public concerns regarding impacts to the sensitive Squamish River Estuary, as well as to avoid steep, difficult terrain in the area of Monmouth Ridge. The ultimate purpose of the EGP Tunnel is to enclose the permanent pipeline. Much like other trenchless construction methods (such as, horizontal directional drilling), tunnelling will allow the installation of the pipeline while minimizing surface disturbance.

For the EGP Project specifically, tunnelling avoids surface disturbance within the Skwelwil'em Squamish Estuary Wildlife Management Area (WMA) and avoids other environmental sensitivities along the north shore of Howe Sound. The pipeline will carry high pressure sweet natural gas at a pressure of 14.890 megapascals. The EGP Tunnel pipeline will connect with the cross-country portion of the pipeline at a point to be determined within the BC Rail Properties Ltd. site (BC Rail Site), to the west of the existing rail tracks.

FortisBC has selected a Design-Build (DB) procurement approach for the EGP Tunnel. FortisBC has retained MJA as Owner's Engineer for the tunnel and has retained UniversalPegasus International (UPI) as Owner's Engineer for the remainder of the pipeline for the EGP Project. The Design-Build (DB) Contractor (DB Contractor) will be provided with a Reference Design (**Appendix A**) developed by MJA and specified design requirements prepared by FortisBC, MJA, and UPI, and will determine the final alignment within the prescribed corridor as well as the final tunnel and pipeline design.

The current Reference Design for the EGP Tunnel shows an alignment starting from a shaft located in the BC Rail Site just west of Industrial Way in Squamish (East Shaft) and terminates in a portal structure at the WLNG Site, northeast of the future Liquefied Natural Gas plant (West Portal or Woodfibre Portal). The eastern portion of the tunnel alignment crosses under the Squamish River Estuary. In this portion, the surface generally consists of low-lying, flat ground and braided river channels. The western portion of the tunnel alignment crosses under steep, rugged mountainous terrain. These mountains climb steeply from the estuary valley margin, reaching elevations of over 800 metres (m) above sea level. Geology and groundwater conditions can be analyzed in three reaches:

1) Soft ground reach under the estuary (Soft Ground Tunnel)
2) Estuary-rock transition reach (Interface Zone)
3) Hard rock reach, which extends from the estuary-rock transition to the West Portal (Hard Rock Tunnel)

For a detailed description of the overall geology refer to Phase II Geology Mapping: Updated Geology Mapping Report (Wood 2019a). In the Reference Design, the Hard Rock Tunnel has been sized nominally at 3.5 m in diameter at depths ranging from approximately 30 to 500 metres below ground surface.

The Reference Design includes construction of the East Shaft at the BC Rail Site such that excavation of the tunnel can start from the required depth for clearance under the Squamish River Estuary; however, the DB Contractor may elect to construct a decline as an alternative to the shaft. The West Portal will consist of a soil and rock cut as well as a graded site for construction staging. The EGP Tunnel includes laydown areas at the BC Rail Site and WLNG Site to support the tunnelling and pipe installation operations.

The proposed alignment for the EGP Tunnel as outlined in the Reference Design included in Appendix A is shown on Figure 1.

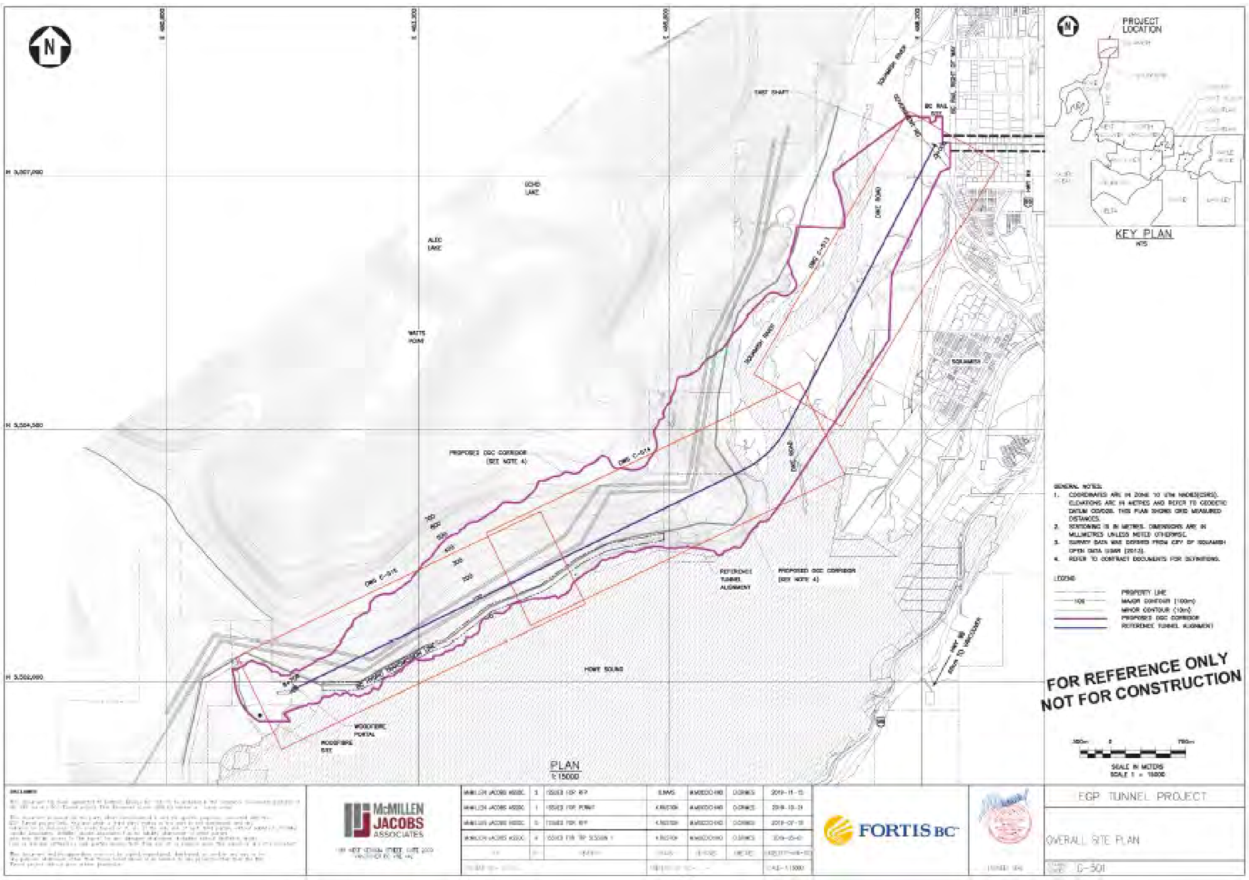

Figure 1. EGP Tunnel Alignment
Source: MJA 2019

3. OVERVIEW OF PROPOSED WATER MANAGEMENT ACTIVITIES

Water Demand

Tunnel construction activities will require the extraction of water as well as the disposal of treated water. Tunnelling operations require water for the tunnel boring machine (TBM) cooling system, tunnel cleaning, grouting, probe drilling, and for general construction site use. Water storage tanks will be required at the BC Rail Site to create a capacity buffer for the tunnelling operations and to compensate for limitations in the water network during high demand periods. The total storage capacity required is estimated to be 500 cubic metres (m^3). Water supply will also be required to provide sanitary working conditions. This includes changing house(s), bathrooms, and general site services for a crew of approximately 70 persons per day.

A portion of the water is dissipated into the ground surrounding the tunnel (bentonite slurry injection, probe drilling), transformed into cementitious material (tail void grout), or evaporated in the cooling system. FortisBC applied to the BC OGC for a Short-Term Use approval to withdraw 415 cubic metres per day from the Squamish River Estuary for the East Shaft at the BC Rail Site. This volume was based on the technical requirements of the TBM as well as experience on projects of similar scope. Water for the West Portal will be supplied by WLNG.

Waste Water Discharge

The water used in tunnel operations becomes process water and could become contaminated with sediment, dust, oil and grease, amongst others. Process water is typically treated on-site (sediment removed, grease skimmed) and discharged. FortisBC is planning to submit a Waste Discharge Authorization under the *Environmental Management Act* to the BC OGC to discharge treated water a non-fish bearing stream at the WLNG Site. Treated water from construction activities at the BC Rail Site will be discharged to the Squamish River or to a storm water drainage system on-site. FortisBC will obtain all necessary permits and approvals for water discharge at the BC Rail Site.

The 4.96-km Hard Rock Tunnel slopes down toward the Soft Ground Tunnel. At the western end of the Soft Ground Tunnel, but within the adjacent Hard Rock Tunnel, a water-tight bulkhead will be constructed. Therefore, once the Hard Rock Tunnel is completed and backfilled, and depending on the DB Contractor proposed design, accumulated groundwater is anticipated to discharge at the West Portal. It is presently considered unlikely that the natural groundwater inflows into the EGP Tunnel will require any ongoing treatment prior to discharge. However, a water quality monitoring program will be implemented during excavation activities to understand the quality of the natural water inflows and confirm that any discharge meets Provincial discharge criteria. FortisBC is planning to submit a Waste Discharge Authorization under the *Environmental Management Act* to the BC OGC to discharge treated water during operation activities onto a non-fish bearing stream at the WLNG Site at the same location as the construction phase.

The eastern Soft Ground Tunnel crosses under the Squamish River Estuary at a slope of 0.05 percent. The Soft Ground Tunnel will be constructed from the BC Rail Site and will be supported with a precast bolted and gasketed segmental lining as shown in Figure 2. Notwithstanding that the precast concrete segmental liner installed to support the Soft Ground Tunnel will have rubberized gaskets to prevent leakage or seepage, it is considered that the Soft Ground Tunnel will eventually fill with water. One option available to the DB Contractor is to fill the Soft Ground Tunnel with fresh water to help the stability and prevent inflow/seepage of potentially saline water. Given that the elevation of the East Shaft collar is higher than the Soft Ground Tunnel elevation and the water-tight bulkhead, the water within the completed Soft Ground Tunnel will be in a static condition with nowhere to flow to.

As such, no groundwater seepage or discharge is anticipated to occur during operations. Since no groundwater inflow or discharge is anticipated to occur for the Soft Ground Tunnel, the information included in the following sections is specific to the Hard Rock Tunnel.

Figure 2. Fully-assembled Precast Concrete Segmental Tunnel Liner Installed as the TBM Advanced

Any potential water discharge from the EGP Tunnel will be conducted in accordance with regulatory requirements and Best Management Practices. Prior to discharge, the water will be sampled, tested, and treated (if required) to verify that it meets British Columbia (BC) Approved Water Quality Guidelines.

Potential for Impacts to the Surficial Groundwater System

During construction and excavation of the Hard Rock Tunnel, groundwater inflows will be directed to sumps that will be excavated below the tunnel invert or floor and then pumped out of the EGP Tunnel for treatment, recycling or discharge, as required.

Upon completion of construction of the Hard Rock Tunnel, the pipeline will be installed, and the tunnel will be partially or completely backfilled. The DB Contractor will be responsible for preparing a detailed procedure and specifications for installing and backfilling the pipeline inside the Hard Rock Tunnel based on applicable codes and standards, sound engineering practice, local regulations, the performance requirements included in the Request for Proposal, and subject to FortisBC acceptance. One of the potential scenarios is that once the Hard Rock Tunnel is completed and backfilled, seepage and groundwater inflow could occur into the Hard Rock Tunnel along discrete discontinuities within the rock mass (such as, joints, shears, and fractures). Given that a large section of the Hard Rock Tunnel is essentially “underwater” and under internal pressure, the flow during pipeline operations at the West Portal will be less than when the EGP Tunnel is initially constructed and “dry.”

It is estimated that water could be continuously discharged at the West Portal during pipeline operation activities. However, mitigation measures (that is, grouting) will be implemented to reduce the quantity of the water that will be discharged. The following sections include the description of a CHM developed to estimate water budgets for watersheds overlying the Hard Rock Tunnel, as well as potential groundwater inflow rates during construction and post-construction under both grouted and ungrouted conditions. This Water Management Plan also includes an assessment to determine hydraulic connectivity with surface streams, an EFN Assessment as well as mitigation measures to manage the quality and quantity of water discharges during construction and operation activities.

4. CONCEPTUAL HYDROGEOLOGY MODEL

A CHM was developed to allow field data to be interpreted more readily and to simplify and visualize the geometry and hydraulics of water inflow into the Hard Rock Tunnel. Both a Regional Scale and a Tunnel Scale CHM are presented.

The CHM was primarily based upon observations from a 560-m-long subhorizontal investigation borehole (BH2016-09H), field mapping, a study based on water inflow into a nearby tunnel in similar geological conditions (Moalli et al. 2008; Wallis 2009), and the results of in-situ hydraulic testing in BH2016-09H. The results of the hydraulic testing provided estimates of the hydraulic conductivity (K) within sections of intact rock, as well as fractured and faulted rock. The field mapping identified the location of both 'massive' rock (relatively free of fractures) and 'fractured' rock (associated with fault/shear zone lineaments). To help calibrate the CHM, a back-analysis of inflow into a nearby tunnel within similar rock provided a global estimate of the hydraulic conductivity. The CHM was then prepared and used to aid in the development of an analytical model to estimate groundwater inflow rates into the Hard Rock Tunnel, presented further as follows.

4.1 REGIONAL SCALE CONCEPTUAL HYDROGEOLOGY MODEL

Groundwater flow in mountainous terrain is generally controlled by topography. Recharge of the groundwater system generally occurs at higher elevations, and results in generally downward hydraulic gradients. Groundwater discharge occurs in valley bottoms, or in this particular case, Howe Sound.

Where groundwater discharges to surface, upward hydraulic gradients are typically observed. For the EGP Tunnel, groundwater will be recharged generally to the north and west of the Hard Rock Tunnel alignment with deep groundwater discharge being to Howe Sound. Described as follows, perched groundwater likely exists in overburden above the bedrock along the Hard Rock Tunnel. Locally, discharge from this perched groundwater may enter mountain streams before they discharge into Howe Sound.

Recharge is seasonally influenced with most occurring due to snow melt and rainfall in spring and fall, respectively. Annual precipitation is approximately 1,400 mm (rain and snow equivalent) in Squamish, BC. The contribution to regional groundwater recharge from Alec and Echo Lakes (3 km north of the Hard Rock Tunnel alignment) is open to conjecture. These lakes are at 1,050 m and 900 m elevation, and 600 m and 900 m in length, respectively. Based on their size, location, and elevation, they may contribute to regional groundwater recharge.

In general, recharge is limited during winter due to snow cover, while recharge is limited in summer due to the relatively low precipitation rates and seasonally high evapotranspiration rates. The seasonality of the recharge/discharge relationship results in seasonal fluctuations in groundwater elevations (both in perched and deeper bedrock groundwater), with the strongest fluctuation suspected for perched groundwater. At a basin scale, the groundwater surface can be assumed to be a subdued replica of topography, but with greater depths to groundwater at higher elevations and shallower groundwater at lower elevations. Due to the steep terrain, it was assumed that groundwater divides coincide with surface water divides in the Hard Rock Tunnel. Groundwater flow within the bedrock along the Hard Rock Tunnel is inferred to flow to the south-southwest toward Howe Sound.

Surficial soils along the Hard Rock Tunnel generally consist of a thin layer of organic material overlying a veneer of silt-rich, low-hydraulic conductivity overburden. Surficial materials underlying high-energy mountain streams in the 24 streams, associated catchments, and 11 lineaments of concern (Study Area) are expected to be coarser and have higher hydraulic conductivity values than adjoining overburden. Underlying bedrock is mainly intact, very low-hydraulic conductivity granitic rock except where vertical or sub-vertical faults or fracture zones occur (Wood 2019c; MJA 2019a; Tetra Tech 2019). Surficial materials in most places, are expected to be hydraulically disconnected from the deeper, regional, bedrock groundwater system due to the contrast of higher hydraulic conductivity overburden above much lower hydraulic conductivity intact bedrock. Therefore, it is likely that a perched groundwater system exists in the overburden overlying the bedrock.

Fracture zones occurring in the granitic bedrock coincide with surficial lineaments which range from 2 to 15 m wide. Groundwater flow in fractured granitic bedrock predominantly occurs via discontinuities (such as, joints, faults, or fracture zones). A greater amount of groundwater flow (hence inflow into the Hard Rock Tunnel) will occur through faulted areas due to a higher degree of interconnectivity of discontinuities compared with the unfaulted rock mass. Streams occur along or cross many of the lineaments and the surface water is likely hydraulically-connected with underlying saturated overburden. This is discussed in more detail in Section 5.

For sections of the Hard Rock Tunnel that will extend below sea level, there is a potential during construction for Hard Rock Tunnel dewatering to induce saltwater intrusion into the Hard Rock Tunnel (especially along ungrouted high permeability fracture zones). On the basis of the hydraulic head difference between sea level and the Hard Rock Tunnel below sea-level (but under the land of the mountain side), under static conditions, a freshwater/saltwater interface would extend down into the subsurface at a steep angle toward the land from a marine shoreline area. When pumping occurs on the freshwater side (that is, during dewatering of the Hard Rock Tunnel), this interface could migrate toward the Hard Rock Tunnel. In mild cases, only brackish water may enter. Under strong hydraulic gradient, saltwater may be induced to enter. Mitigation of salt water intrusion is discussed in Section 7.

4.2 HARD ROCK TUNNEL SCALE CONCEPTUAL HYDROGEOLOGY MODEL

The Tunnel Scale CHM was developed using geological and geotechnical surface mapping, observations of seepage from the rock faces at surface and hydraulic conductivity testing conducted in 2016 (Wood 2019b).

It was interpreted that recharge to groundwater within the rock mass principally occurs by infiltration from the overlying overburden soils beneath the ridge that forms Watts Point. The overburden consists of colluvium, talus, till, and topsoil in varying thicknesses. The geotechnical mapping carried out in 2019 (MJA 2019a) shows that there is very little weathering of the rock underlying the soil deposits (99.4 percent of bedrock joints unweathered or only slightly weathered). An evaluation of the Rock Mass Rating for the bedrock shows that over 90 percent is classified as good to very good rock. Given the relatively higher hydraulic conductivity of the overburden, and the little-weathered, intact nature of the bedrock, it is inferred that the majority of shallow groundwater flow occurs above the soil/bedrock interface. Groundwater discharge from overburden will contribute to the flow in drainages and streams which cross the Hard Rock Tunnel alignment and drain into Howe Sound.

Groundwater flow in fractured crystalline rocks occurs primarily within discontinuities (secondary porosity) such as fractures, joints, faults, and shears, as the primary porosity of the rock mass is very low. The quantity of flow is dependent on the total groundwater head, the aperture between the discontinuity planes, and the number, persistence, and connectivity of discontinuities.

In terms of groundwater flow between two discrete points, the orientation of discontinuities relative to the plane of interest is also important. Open discontinuities aligned parallel to the direction of groundwater flow will act as conduits, while discontinuities perpendicular to the groundwater flow direction will not. Observations have shown that the bedrock along the Hard Rock Tunnel route is generally massive with few joint sets (that is, groups of parallel joints with similar geological history). However, the joint sets that do occur are very persistent over 10 m to 20 m or more in length. It is these joints that are thought to be most significant for groundwater flow.

The most persistent joint sets often align with lineaments that have been identified across the site and above the Hard Rock Tunnel alignment. In the field, 21 specific lineaments have been identified, mapped, and characterized (MJA 2019b). These lineaments have formed geomorphological zones of surface weakness, and as a consequence streams often align with the lineaments. Not all 21 lineaments identified are considered to intersect the Hard Rock Tunnel. Figure B-1 (**Appendix B**) presents the conceptual development of lineament streams. These lineaments are surface geomorphological expressions of underlying fracture zones in the bedrock which are likely to be the zones of highest groundwater flow within the granitic rock mass. An overall plan of the Hard Rock Tunnel alignment presenting the most critical lineaments and all streams and creeks is presented as Figure C-1 (**Appendix C**). These fracture zones are persistent and continuous features that potentially connect to other joint sets within the rock mass. It is expected that fracture density is greatest within fracture zones (directly underlying the lineaments), diminishing with distance perpendicular to the fracture zones. The majority of lineaments strike in a north-northeast to south-southwest direction (generally with a bearing of approximately 020° from true north) and the underlying fracture zones are sub-vertical to vertical.

Figure B-2a (**Appendix B**) shows a schematic diagram of perched groundwater within the overburden, developed due to a contrast in hydraulic conductivity between the overburden and bedrock. Figure B-2b (**Appendix B**) shows a schematic diagram of the likely direct hydraulic connection between perched groundwater in saturated overburden and an underlying saturated fracture zone. It is likely that the hydraulic conductivity of the overburden and the fracture zones are of the same order of magnitude (both higher than the hydraulic conductivity of bedrock).

Figure B-3 (**Appendix B**) shows a schematic diagram of the predicted changes in piezometric conditions in a saturated fracture zone intersecting the Hard Rock Tunnel and the overlying saturated overburden and lineament stream (discussed further in Section 5).

Groundwater flow may also be controlled by the orientation of intrusive andesitic dikes within the granitic rock. These dikes are related to surface volcanics that have been mapped by Wood (2019a) as part of the Monmouth Creek Volcanic Complex. Within the headland (Watts Point), these dikes are thought to be feeder structures for the extrusive andesite and volcaniclastic breccias that have been found and mapped on surface. The contribution of the andesitic dikes to regional groundwater flow is open to conjecture. MJA (2019a and 2019b) observed one andesite dike exposure on the shoreline, 0.5 to 1 m wide and oriented at 78°/097° (dip/dip direction). The dike was fractured but internally showed no signs of groundwater flow. Some seepage was observed at the contact between the granite and the dike. Rock at the contact may have been exposed to different thermal cooling regimes, forming a chilled margin with a higher degree of fracturing and higher permeability. It is inferred that such dike contacts may form groundwater conduits wherever they occur throughout the EGP Project area.

Conceptually, when the Hard Rock Tunnel intersects a hydraulically-conductive discontinuity (that is, an open joint or well-interconnected fracture zone), there will be an initial high rate of inflow into the tunnel. This flow rate will diminish exponentially with time as the water stored within the discontinuity is released from storage and piezometric heads equilibrate. How quickly piezometric heads reduce from their initial conditions to the new steady state condition depends on the hydraulic conductivity of the discontinuity that is intersected, the length or persistence of this discontinuity, and the interconnections made with other discontinuities. A large degree of interconnectivity between discontinuities results in a larger volume of rock draining into the Hard Rock Tunnel.

Based on the site observations and testing carried out to-date, two types of discontinuities that might be intersected by the Hard Rock Tunnel have been defined. Type I discontinuities are non-connected or weakly-connected discontinuities in fairly massive rock. These discontinuities are thought to have a low-hydraulic conductivity and, due to their limited connectivity, water inflows from Type I discontinuities are not anticipated to be high.

Type II discontinuities are well-connected and persistent within a localized zone of other closely-spaced discontinuities. Type II discontinuities include the fracture zones underlying the surface lineaments observed in the Study Area. Based on the hydraulic conductivity tests conducted, these features are considered to have much higher hydraulic conductivity than surrounding massive bedrock. As a result, the highest water inflows to the Hard Rock Tunnel are expected from Type II discontinuities. Andesite dike contacts are also included as Type II discontinuities.

4.3 HYDRAULIC CONDUCTIVITY TESTING

Hydrogeological packer testing was conducted within borehole BH2016-09H (Wood 2019b). In total, 28 staged packer tests were conducted. After screening suspect test results, the resulting hydraulic conductivity results are summarized as follows (MJA 2019b):

- Type I discontinuities (representing relatively homogeneous granite) - geometric mean of K = 1.6 by 10-7 metres per second (m/s), with a maximum of 9.8 by 10-7 m/s and a minimum of 3.4 by 10-9 m/s.
- Type II discontinuities (representing faults and fracture zones) - geometric mean of K = 4.5 by 10-6 m/s, with a maximum of 1.4 by 10-5 m/s and a minimum of 5.1 by 10-7 m/s.

4.3.1 SUMMARY OF HYDROGEOLOGICAL CONDITIONS WITHIN GEOTECHNICAL DOMAINS

The geotechnical model for the site has identified three geotechnical domains (Western, Central, and Headland Domains) where similar geological, geomechanical, and geotechnical conditions exist. Hydrogeological conditions inferred to exist within these geotechnical domains displayed in Figure 3 are summarized as follows.

Western Domain

Categorized by good quality rock with generally medium-spaced, planar, Type I discontinuities within a competent rock mass. Within the Western Domain, 12 lineaments (representing a Type II hydrogeological discontinuity) have been identified that might intersect the Hard Rock Tunnel. The aggregate intersection length of these Type II lineaments along the Hard Rock Tunnel is estimated to be 144 m. The average depth from surface to the Hard Rock Tunnel is 112 m. As a result, hydraulic pressure head from groundwater acting on the Hard Rock Tunnel is considered to be comparatively moderate compared with the other domains.

Central Domain

Categorized by fairly massive, good to very good quality rock, with widely-spaced, planar, Type I discontinuities. Within the Central Domain, three lineaments (Type II hydrogeological discontinuities) have been identified that might intersect the Hard Rock Tunnel. The aggregate intersection length of these Type II along the Hard Rock Tunnel is estimated to be 30 m. The average depth of the Hard Rock Tunnel from the ground surface is 207 m. As a result, hydraulic pressure head acting from groundwater on the Hard Rock Tunnel is considered to be moderate to high compared with other domains.

Headland Domain

Categorized by fairly massive, very good quality rock with generally widely-spaced, planar, Type I discontinuities. Only one lineament has been identified that might intersect the Hard Rock Tunnel. Within this rock mass, intrusions of andesitic dikes may be encountered. The average depth of the Hard Rock Tunnel from the ground surface is 324 m. As a result, hydraulic pressure head acting from groundwater on the Hard Rock Tunnel is considered to the highest of all three domains.

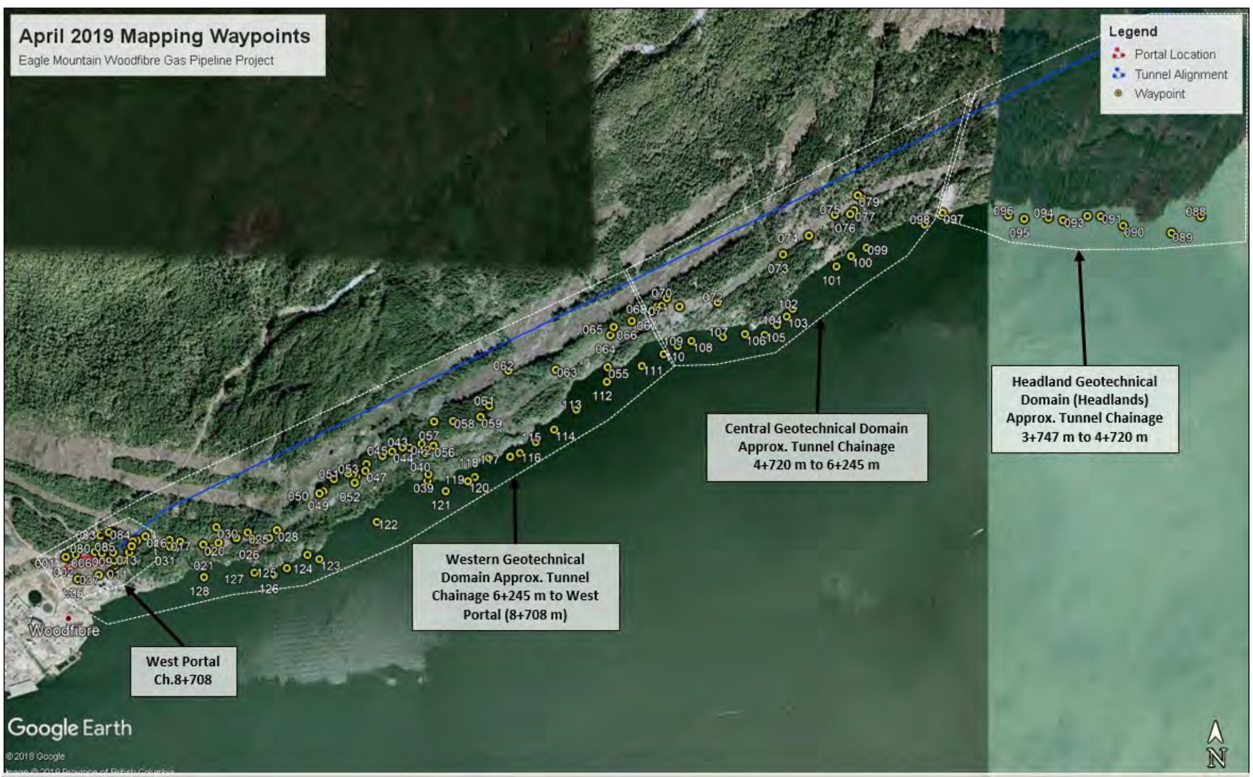

Figure 3. Location Plan of Geotechnical Domains Along Hard Rock Tunnel
Aerial image ©2018 Google. Annotation ©2019 FortisBC.

5. ENVIRONMENTAL FLOW NEEDS ASSESSMENT

The EFN in relation to a stream is defined as the volume and timing of water flow required for proper functioning of the aquatic ecosystem. Section 15 of the *Water Sustainability Act* requires the completion of an assessment of the EFN of streams that are reasonably likely to be hydraulically-connected with a groundwater application area.

As described in the CHM, a series of fracture zones intersect the proposed Hard Rock Tunnel and are anticipated be the largest contributors of groundwater inflow. These fracture zones are expressed at the surface as linear, preferentially-eroded, geomorphological surface traces (that is, lineaments). A total of 21 lineaments have been mapped, based on earth images and ground-truthing (Wood 2019a; MJA 2019a), and were ranked for the potential of their underlying fracture zones to contribute inflow to the Hard Rock Tunnel. The purpose of this section is to determine if water inflow to the Hard Rock Tunnel from fracture zones could potentially deplete water from overlying streams and cause an EFN concern as defined in the Provincial EFN Policy.

5.1 MEAN ANNUAL DISCHARGE

The objective of this EFN Assessment is to determine the anticipated annual loss of stream water compared with the stream's mean annual discharge (MAD). The objective of this analysis is to confirm that the expected withdrawal (draining) of the potentially impacted streams is less than 15 percent of the MAD (natural flow). This would classify the required risk management for the streams as Level 1. As defined in the Provincial EFN Policy, a stream, or specific flow periods, deemed to be at Risk Management Level 1 from withdrawals means that there is sufficient natural water availability for the proposed withdrawal period and that cumulative water withdrawals are below the specified threshold described in the Environmental Risk Management Framework. While Level 1 does not indicate a risk, supplementary information is likely not needed, unless species or habitat-specific sensitivities are identified.

5.1.1 METHODOLOGY

No site-specific hydrometric data are available for the small catchments that are potentially in hydraulic connection with the Hard Rock Tunnel; therefore, the estimate of MAD for the potentially impacted streams was based on an assessment of regional reference streams with available hydrometric data. Using the streamflow data from these reference steams, a relationship between annual precipitation and annual runoff was developed. This relationship is then used to generate an estimate of runoff from the catchment areas crossed by the Hard Rock Tunnel using the annual average precipitation. Further details on the approach used is provided in the following sections.

The main assumption of this approach is that for the small catchment areas of the EGP Tunnel site streams, the MAD is primarily a function of annual precipitation – site topography, soil cover, geology, and temperature are expected to have only minor effect, if any, on the MAD estimates and these parameters have not been considered in the analysis.

5.1.2 ESTIMATING MEAN ANNUAL DISCHARGE IN STREAMS INTERSECTING LINEAMENTS

Several small streams that intersect lineaments crossing the Hard Rock Tunnel were identified along the alignment. As hydrometric data were not available for any of these streams, data from reference hydrometric stations were used to estimate MAD based on precipitation data and catchment areas. This desktop analysis provides an approximation of MAD suitable for an initial flow sensitivity classification but would require field verification and data collection if a more in-depth analysis is required.

5.1.3 RELATIONSHIP BETWEEN DISCHARGE AND PRECIPITATION

A list of potential hydrometric reference stations was obtained by identifying Water Survey of Canada (WSC) hydrometric stations within 30 km of the EGP Tunnel site (WSC 2020), as nearby streams are more likely to have similar topography, climate, and geology. Only hydrometric stations with more than 10 years of continuous data and with catchment areas less than 150 square kilometres (km^2) were selected for analysis. Discharge estimates prepared by others for streams within the Study Area were also included in the reference hydrometric dataset. These included discharge estimates for Mill Creek and Woodfibre Creek (Golder 2015) and mean annual runoff for the EGP Tunnel site. Figure 4 shows the locations of the reference hydrometric stations used for the assessment.

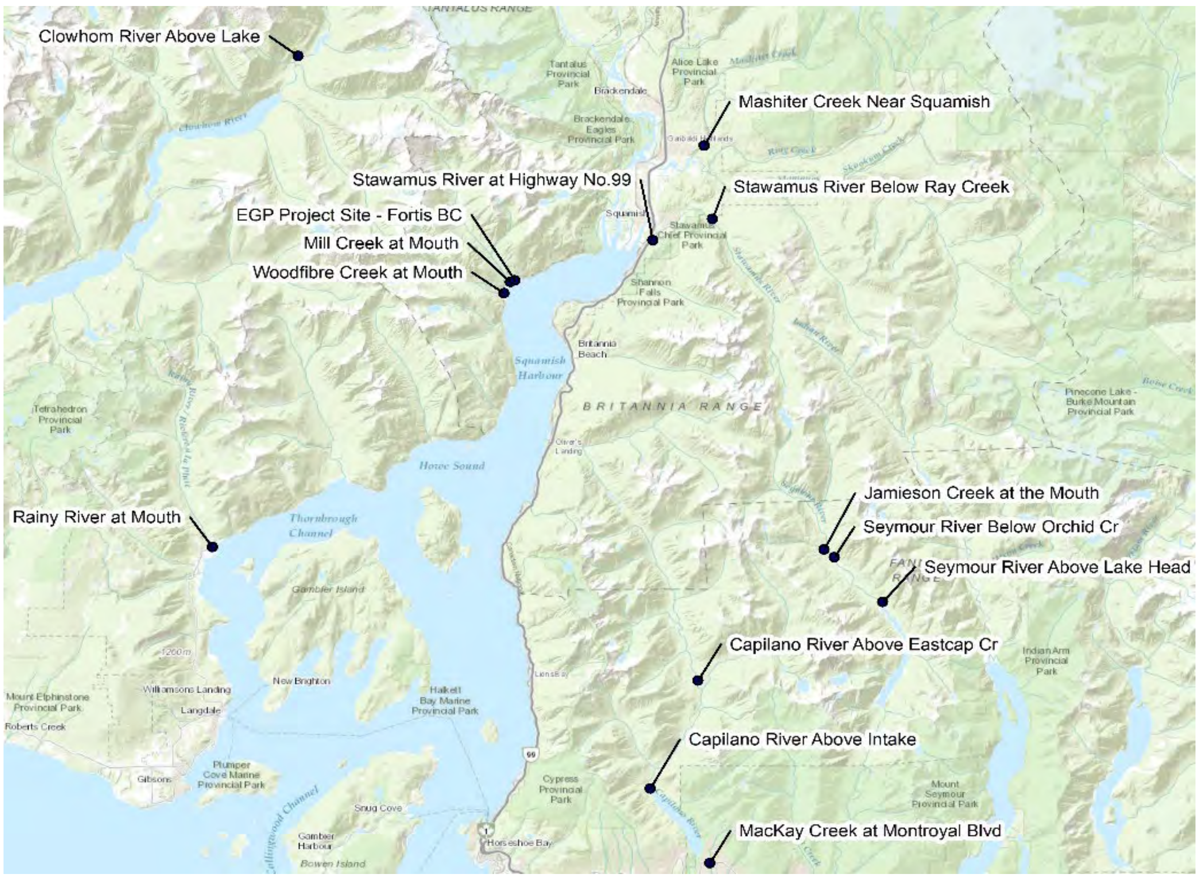

Figure 4. Reference Hydrometric Stations

The mean annual precipitation for each reference hydrometric station was estimated using data from the nearest Environment and Climate Change Canada (ECCC) meteorological station with more than 10 years of monthly precipitation data that coincided with the years of the hydrometric record (ECCC 2020). The mean annual precipitation volume was then calculated by multiplying the mean annual precipitation by the catchment area.

A summary of the catchment area, precipitation volume and MAD for each reference hydrometric station is presented in Table 1.

Table 1. Hydrometric and Meteorological Data for Reference Hydrometric Stations

Hydrometric Station ID	Hydrometric Station Name	Latitude	Longitude	Catchment Area (km²)	Mean Annual Discharge (m³/s)	Mean Annual Precipitation (mm)	Mean Annual Precipitation Volume (m³)
08GA010	Capilano River Above Intake	49°23'46" N	123°8'45" W	173	20.2	2,519	435,701,581
08GA020	Rainy River at Mouth	49°31'28" N	123°29'3" W	69.4	8.71	2,255	156,492,247
08GA064	Stawamus River Below Ray Creek	49°42'4" N	123°5'54" W	40.4	3.6	2,110	85,226,270
08GB013	Clowhom River Above Lake	49°47'16" N	123°25'13" W	149.4	16	2,344	350,202,017
08GA026	Capilano River Above Eastcap Creek	49°27'14" N	123°6'33" W	69.9	9.9	2,519	176,043,587
08GA057	Mashiter Creek Near Squamish	49°44'26" N	123°6'18" W	38.9	2.6	2,110	82,061,928
08GA062	Jamieson Creek at the Mouth	49°31'27" N	123°0'43" W	2.85	0.3	2,203	6,278,133
08GA076	Stawamus River at Highway 99	49°41'23" N	123°8'41" W	52.8	3.9	2,582	136,329,600
08GA077	Seymour River Below Orchid Creek	49°31'12" N	123°0'14" W	63	6.6	2,147	135,260,827
08GA079	Seymour River Above Lake Head	49°29'46" N	122°58'0" W	82.9	9.0	3,041	252,072,316
08GA061	MacKay Creek at Montroyal Boulevard	49°21'22" N	123°5'59" W	3.63	0.2	2,500	9,075,000
Estimated (Golder 2015)	Mill Creek at Mouth	49°40'2" N	123°15'18" W	39	3.4	2,356	91,884,000
Estimated (Golder 2015)	Woodfibre Creek at Mouth	49°39'40" N	123°15'35" W	23	2.0	2,356	54,188,000
Estimated	EGP Project Site - Fortis BC	49°40'5" N	123°15'5" W	6.4	0.4	2,532	16,204,800

Notes:

m^3/s = cubic metre(s) per second

Regression analysis was used to quantify the relationship between mean annual precipitation volume and MAD at the reference hydrometric stations. The results of the regression analysis are presented in Figure 5. A strong positive relationship was found between MAD and mean annual precipitation volume, as indicated by a Pearson correlation coefficient (R^2) of 0.96. The p-value of the regression model was 1 by 10^{-11}, indicating the relationship was strongly significant.

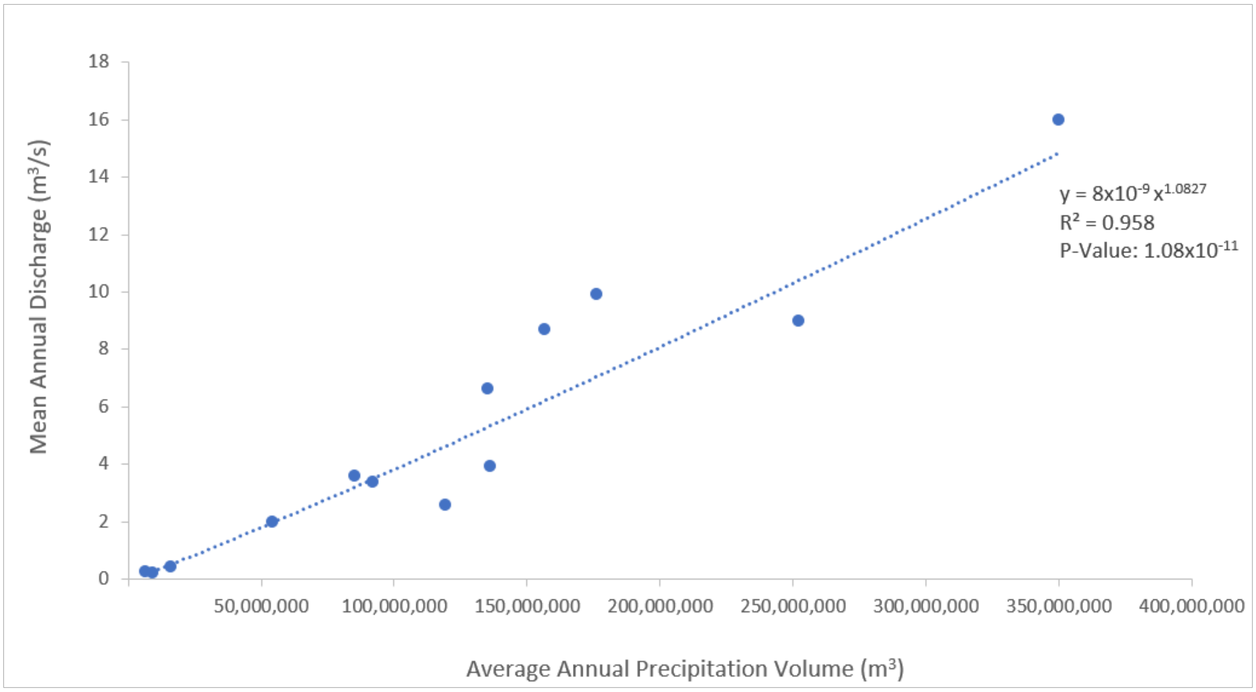

Figure 5. Relationship between Mean Annual Stream Discharge and Average Annual Precipitation Volume at Reference Hydrometric Stations using Regression Analysis

The relationship between mean annual precipitation volume and MAD is defined by the following equation:

$$Q = 8 \cdot 10^{-9} \cdot {P_v}^{1.0827}$$

where Q is mean annual discharge in m^3/s and P_v is mean annual precipitation volume in m^3.

5.1.4 MEAN ANNUAL DISCHARGE CALCULATIONS

The stream drainage paths were modelled using Global Mapper software and the catchment areas were delineated using the ArcGIS Watershed tool with 1 m elevation contours. The modelled drainages with catchment area boundaries are presented on Figure 6.

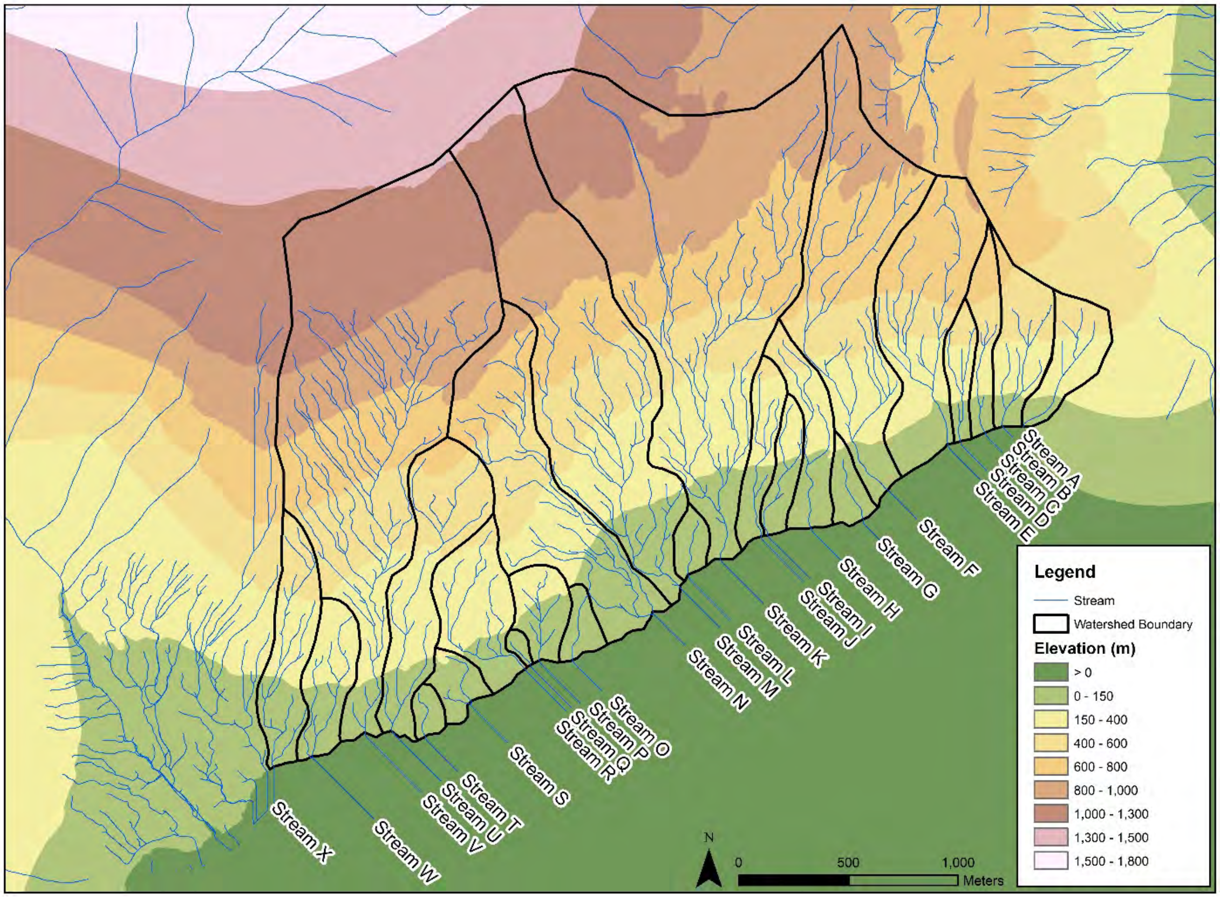

Figure 6. Study Streams and their Catchment Areas (watersheds) on the EGP Project Site
Source: Jacobs

The mean annual precipitation volume for each stream in the Study Area was calculated by multiplying the catchment area for the stream by the mean annual precipitation depth of 2,532 mm observed at the Squamish Airport meteorological station, the nearest ECCC meteorological station at a similar elevation to the Study Area with 10 years of continuous precipitation data (Table 2). MAD was then derived from mean annual precipitation volume using the equation presented previously.

Table 2. Stream and Watershed Characteristics for Study Streams on the EGP Project Site

Stream Number	Catchment Area (km^2)	Mean Annual Precipitation Volume (m^3)[a]	Mean Annual Discharge (m^3/s)	Runoff Coefficient
A	0.08	190,232	0.004	0.66
B	0.18	457,412	0.011	0.76
C	0.10	243,946	0.005	0.65
D	0.07	166,087	0.004	0.76
E	0.41	1,042,842	0.026	0.79
F	0.65	1,635,467	0.043	0.83

Table 2. Stream and Watershed Characteristics for Study Streams on the EGP Project Site

Stream Number	Catchment Area (km^2)	Mean Annual Precipitation Volume (m^3)[a]	Mean Annual Discharge (m^3/s)	Runoff Coefficient
G	0.05	129,003	0.003	0.73
H	0.14	359,591	0.008	0.70
I	0.07	179,155	0.004	0.70
J	0.10	264,358	0.006	0.72
K	1.56	3,942,095	0.111	0.89
L	0.04	103,260	0.002	0.61
M	0.95	2,394,262	0.065	0.86
N	0.52	1,325,466	0.034	0.81
O	0.04	111,535	0.002	0.57
P	0.09	234,994	0.005	0.67
Q	0.01	31,449	0.001	1.00
R	0.20	502,940	0.012	0.75
S	0.06	146,380	0.003	0.65
T	0.03	73,522	0.001	0.43
U	0.32	801,226	0.020	0.79
V	1.48	3,736,485	0.104	0.88
W	0.14	342,299	0.008	0.74
X	0.20	499,699	0.012	0.76
Combined Catchment	7.49	18913705	0.494	0.82

[a] Calculated based on a mean annual precipitation of 2,532 mm measured at ECCC meteorological station number 10476F0, Squamish Airport (ECCC 2020)

The MAD runoff coefficients for the individual catchment areas are presented in Table 2 and range from 0.66 to 1.0 with a runoff coefficient of 0.82 for the combined catchment area.

5.2 ENVIRONMENTAL SETTING

This section provides a description of Stream Characteristics, fish habitat, and wildlife and vegetation within the Study Area. Environmental constraints within the Study Area are included in Figure 7.

Stream Characteristics

Jacobs assessed several streams along the Monmouth Ridge in 2014. Jacobs traversed a previously proposed pipeline route that overlapped portions of the existing FortisBC Nominal Pipe Size 10 pipeline right-of-way, located between approximately 100 and 700 m upslope of the Hard Rock Tunnel alignment.

Nine watercourses with continuously defined bed and banks were identified during this assessment, along with several ephemeral drainages. Three of these watercourses had channel widths greater than 3 m. A subsequent traverse of the lower slope was conducted in June 2016 by Amec Foster Wheeler, UPI, and Jacobs, covering approximately 3 km of the proposed Hard Rock Tunnel alignment. This traverse was conducted along a previous pipeline alignment that was located between approximately 100 and 300 m downslope of the Hard Rock Tunnel alignment and ending near the WLNG Site. Approximately four large watercourses (>2 to 3 m channel width) were identified along this section of the slope (AFW 2016).

The streams flow south down steep (30 to 100 percent) slopes toward Howe Sound. Shallow flows (<0.3 m) were observed during spring runoff conditions, and most streams are expected to be ephemeral. Catchment areas are limited by relatively short distances to the height of land and there are no prominent bowls at their upper ends (AFW 2016). Most streams had bedrock channels with cobbles and boulders within the banks, though some had floodplains. Channel gradients were generally steep, with step-pool, cascade, and bedrock-controlled morphologies noted during the assessments. Debris flow deposits were found in several of the streams (AFW 2016). Debris flows involve rapid, channelized downstream movement of sediment and woody debris, often triggered by high flows causing bedload movement and debris mobilization or from materials sliding into the channel (AFW 2016).

Fish Habitat

Fish habitat potential along the Hard Rock Tunnel was determined from information collected during the field programs discussed under Stream Characteristics, above, and from a desktop assessment. The Hard Rock Tunnel is located within the Howe Sound sub-basin located adjacent to the District of Squamish.

After the crossing of the Squamish River and associated estuarine fish habitats, the Hard Rock Tunnel traverses under steep south-to-southeast facing slopes of Monmouth Ridge. Several unnamed watercourses and drainages were identified during the field assessments, none of which were determined to have fish habitat potential due to barriers to fish access before entering Howe Sound, including steep slopes and drops/falls. No upstream fish population sources (that is, lakes) were identified. Desktop assessment also reveals steep slopes at the Howe Sound interface which are expected to prevent fish migration and use of the stream’s lower reaches. Fish habitat values in the marine environment of Howe Sound, and the Squamish River and tidal tributaries, are discussed in the Aquatic Assessment Technical Report in the EAC application for the Project (Volume 2, Appendix 1H) (CH2M 2015).

Wildlife and Vegetation

The Hard Rock Tunnel is located within the Coastal Western Hemlock biogeoclimatic zone, with vegetation dominated by Douglas fir and western hemlock trees. Riparian and estuarine vegetation such as cottonwood, red alder, and western redcedar dominate in and around the Squamish River Estuary. None of the forest along the Hard Rock Tunnel is within Old Growth Management Areas (legal or non-legal) (BC MFLNRO 2009a, 2009b). No known plant species at risk or ecological communities at risk are present along the tunnel route (BC ENV 2020).

The Hard Rock Tunnel route is aligned beneath Critical Habitat for marbled murrelet (*Brachyramphus marmoratus)*. This Critical Habitat was designated by The Recovery Strategy for the Marbled Murrelet (*Brachyramphus marmoratus*) in Canada (Environment Canada 2014). The biophysical attributes necessary for marbled murrelet nesting may not be present in identified Critical Habitat which overlaps with the Hard Rock Tunnel route. The Hard Rock Tunnel route also overlaps with Wildlife Habitat Area (WHA) 2-517, a Managed Future Habitat Area for spotted owl (*Strix occidentalis*) (BC MOE and Ministry of Forest and Range 2009). Spotted owl surveys were completed in 2014 and 2015 and yielded no detections. The Hard Rock Tunnel will pass under the Skwelwil’em Squamish Estuary WMA with no disturbance to the surface (BC MFLNRORD 2018). Desktop review indicates that the Hard Rock Tunnel route is not located within an Important Bird Area (Bird Studies Canada 2020), Ungulate Winter Range (BC MFLNRORD 2019), park, ecological reserve, or protected area (BC ENV 2019).

Figure 7. Environmental Constraints along The Hard Rock Tunnel Study Area

Insert Figure 7:

https://extranet.fortisbc.com/projects/EGP/TunnelEng/03.%20Technical%20Reports%20and%20Documentation/30_GENERAL/EGP_ConstraintsMap_20200414%20(002).pdf

5.3 DETERMINATION OF STREAM FLOW DEPLETION

Tetra Tech conducted an assessment to determine the potential stream flow depletion from fracture zones that intersect the Hard Rock Tunnel and could cause an EFN concern. The Study Area is included in Figure 8.

The results indicate that five catchments (I, J, L, S, and T) have no intersections with any of the 11 lineaments of concern. A total of 101 lineament/stream intersections were evaluated across the remaining 19 catchments. The calculated total streamflow depletion as a percentage of MAD was low, ranging from <0.1 percent (Catchment F) up to 2.9 percent (Catchment B), with an average depletion of 1.04 percent of MAD as shown in Table 3.

Table 3. Summary of Fracture Zone/Stream Depletion Analysis

Catchment	Lineaments of Concern	No. of Intersections	MAD (m^3/s)	MAD (Lpm)	Total Streamflow Depletion as % of MAD
A	17	2	0.004	240	1.20
B	17, 19	6	0.011	660	2.94
C	17	1	0.005	300	2.42
D	17	2	0.004	240	1.18
E	17, 18	6	0.026	1,560	1.56
F	17	1	0.043	2,580	0.05
G	17	1	0.003	180	0.74
H	17	1	0.008	480	0.29
I	None of concern	0	0.004	240	0
J	None of concern	0	0.006	360	0
K	13, 16B	7	0.111	6,600	0.25
L	None of concern	0	0.002	120	0
M	7, 8, 11, 12, 13	16	0.065	3,900	0.29
N	7, 8, 11, 12, 13	21	0.034	2,040	0.5
O	13	1	0.002	120	0.59
P	11, 12	3	0.005	300	2.08
Q	12	1	0.001	60	0.96
R	6, 7, 8, 11	10	0.012	720	2.05
S	None of concern	0	0.003	180	0
T	None of concern	0	0.001	60	0
U	4, 6, 7, 8	11	0.02	1,200	1.29
V	4, 6, 7	6	0.104	6,240	0.09
W	4	3	0.008	480	0.76
X	4	2	0.012	720	0.53
Totals	**11 lineaments of concern**	**101**		**Avg.**	**1.04**
				max	**2.94**
				min	**0.05**

Notes:
MAD values and Streamflow Depletion in ungrouted conditions.
Lpm = litre(s) per minute

Based on analysis, the potential streamflow depletion due to ungrouted fracture zone inflows to the Hard Rock Tunnel are considered to be low. As these calculated depletions are <15 percent and it is understood that the streams are non-fish bearing (as indicated in subsection 5.2), the effects of Hard Rock Tunnel dewatering on streamflow in the Study Area would likely be considered as an EFN Risk Management Level 1 (lowest concern). Furthermore, since it is intended to grout the fracture zones found within the Hard Rock Tunnel (generally with forward probing, prior to excavation), the potential streamflow depletion is anticipated to be less than that stated in Table 3.

Tetra Tech's technical memorandum on streamflow depletion with detailed intersection information and calculations is included in **Appendix C**.

Insert figure:
https://extranet.fortisbc.com/projects/EGP/TunnelEng/03.%20Technical%20Reports%20and%20Documentation/30_GENERAL/VGEO03612-01_Figure1_Catchments.pdf

Figure 8. Hard Rock Tunnel Alignment with Stream Catchments and Lineaments of Concern

5.4 LIMITATIONS

Limitations to the approach used for this EFN Assessment include the following:

- The regression analysis does not include topography, geology, or temperature in the catchments; however, given the strong correlation between MAD and annual precipitation (R2 = 0.96), incorporating these additional parameters into the analysis is unlikely to significantly change the MAD estimates.
- The stream catchment areas used in the analysis are all smaller (<1.61 km^2) than the reference hydrometric station catchments (>2.85 km^2).

The uncertainty introduced to the MAD estimates by these limitations, and other limitations of the estimate approach, could be reduced by implementing a stream gauging program in a small gauged watershed within the Study Area. However, for the purpose of stream sensitivity classification using MAD in streams that intercept lineaments along the Hard Rock Tunnel alignment, the approach taken is considered appropriate.

6. ESTIMATED WATER BUDGETS

A water balance was developed to estimate expected annual volumes of precipitation, surface runoff, infiltration to groundwater, and losses to evapotranspiration within the watersheds draining across the Hard Rock Tunnel alignment on the west side of Howe Sound. The primary purpose of this balance is to estimate the annual recharge to groundwater upgradient to the proposed Hard Rock Tunnel.

Given the absence of site-specific hydrological and hydrogeological data, and the complexity of surface water-groundwater interactions in general, this water balance is only intended to serve as a high-level estimation of the recharge rate possibly occurring at site.

The balance was completed by evaluating streamflow data of two gauged watercourses to concurrent precipitation data recorded in the vicinity of the subject watersheds. Runoff coefficients representing the fraction of precipitation within a watershed which occurs as surface runoff were calculated by comparing the total volume of water conveyed through the hydrometric station over a set timeframe to the total volume of precipitation within the watershed over that same period (calculated as rainfall depth multiplied by watershed area). The remaining fraction of precipitation is assumed to be the quantity of water lost through evapotranspiration or through infiltration to deep groundwater. The quantity of water infiltrating to deep groundwater was then isolated by subtracting approximated evapotranspiration losses.

Watershed Delineation Along Hard Rock Tunnel

As presented in Section 5, the total watershed area draining across the proposed Hard Rock Tunnel alignment is delineated by topography to be 7.4 km^2. This total area is comprised of numerous individual streams draining directly into Howe Sound, each with watershed areas under 1.0 km^2.

Given the steep topography, it was assumed that the groundwater catchment for the EGP Project site to be identical to this 7.4 km^2 delineated from topography.

Runoff Coefficient

As presented in Table 2 of Section 5, a runoff coefficient of 0.82 is assumed for the combined watershed areas draining across the Hard Rock Tunnel alignment.

Evapotranspiration

Compensation for evapotranspiration was approximated through evaluation of hydrometric data collected by WSC on the Stawamus River. This station is situated approximately 10 km away from the EGP Project site in a similar topographic setting. The majority of this watercourse's drainage area is situated in high-gradient mountainous headwaters while the station itself is installed within a low-gradient reach of the river prior to its confluence with Howe Sound. Given this topographic setup, a broad assumption that all groundwater within the watershed will have exfiltrated back to the surface prior to reaching the hydrometric station was made. Therefore, any precipitation loses observed within the Stawamus Watershed are assumed to be reflective of annual evapotranspiration in the area.

Runoff coefficients were calculated for each complete year of hydrometric data available at this station using elevation-adjusted annual precipitation recorded at Squamish Airport. Table 4 presents the results of this analysis, yielded an average runoff coefficient of 0.913 for the Stawamus Watershed. The remaining 8.7 percent of precipitation (224 mm per year) is estimated to be a reasonable proxy of annual evapotranspiration in the area.

Table 4. Stawamus River, Runoff Coefficient by Year

Year	Runoff Volume (m^3)	Rainfall Depth (mm)	Precipitation Volume (m^3)	Runoff Coefficient
1992	97,963,312	2,316	122,267,402	0.801
1993	86,502,470	1,932	101,999,904	0.848
1994	109,186,618	2,473	130,577,435	0.836
1995	141,149,174	3,047	160,855,678	0.877
1998	113,727,377	2,771	146,310,400	0.777
1999	159,472,296	3,122	164,823,612	0.968
2000	102,375,274	1,956	103,277,444	0.991
2001	112,809,197	2,540	134,125,369	0.841
2002	120,563,942	2,513	132,702,790	0.909
2003	130,592,131	2,926	154,509,272	0.845
2004	109,997,136	2,116	111,723,100	0.985
2005	121,783,306	2,505	132,268,261	0.921
2006	121,405,133	2,977	157,167,901	0.772
2007	166,956,941	3,281	173,228,550	0.964
2010	118,780,646	2,663	140,628,138	0.845
2011	137,343,082	2,625	138,603,709	0.991
2012	141,787,584	2,494	131,670,625	1.077
2013	101,731,766	1,900	100,338,887	1.014
2015	111,546,634	2,665	140,691,080	0.793
2016	158,784,192	2,632	138,953,931	1.143
2017	132,127,200	2560	135,150,142	0.978
Average:	123,646,924	2,572	135,803,506	**0.913**

Study Area Water Budget

A single water budget reflective of all 7.4 km^2 of drainage area was prepared utilizing precipitation data obtained from Squamish Airport and the results of the runoff coefficient and evapotranspiration calculations in Tables 4 and 5. The budget can be further broken down for individual watercourses with linear scaling based on watershed areas.

Table 5. Annual Water Budget for Watershed(s) Draining through Hard Rock Tunnel

Watershed Area	Annual Precipitation		Runoff Coefficient	Annual Runoff		Evapotranspiration		Infiltration to Groundwater	
(km^2)	(mm)	(mm^3)		(mm)	(mm^3)	(mm)	(mm^3)	(mm)	(mm^3)
7.4	2,532	18.7	0.82	2,076	15.4	224	1.7	231	1.7

Note:
mm^3 = cubic millimetre(s)

Through the high-level assessment, an annual groundwater recharge volume of 1,720,000 m^3 is projected within the Hard Rock Tunnel Watershed, which is equivalent to 9.2 percent of the annual precipitation in the area.

These values come with a degree of uncertainty which could be alleviated through monitoring of hydrology and hydrogeology within the EGP Tunnel footprint.

6.1 CONSTRUCTION FLOW ESTIMATE

To calculate groundwater inflow into the Hard Rock Tunnel excavation, a closed form calculation was used. Katibeh and Aalianvari (2012) reviewed five approximations of estimating water inflow into a tunnel based on the work of El Tani (2003). The authors report that for large values of r/h (tunnel radius divided by hydraulic head acting on the tunnel), the El Tani approximation was closest to the actual water inflow encountered, while the relative differences of other methods (such as, those by Goodman, Karlsrud, Heuer and Lee) were considerable.

Su et al. (2017) also provided a review of various analytical methods for estimating the groundwater inflow rate into a tunnel. They identified the limitations of many prominent methods (including Goodman and El Tani) particularly with respect to the groundwater head applied. Methods which maintain the initial groundwater head in the prediction of tunnel inflow (that is, Goodman and El Tani), over-estimated groundwater inflow, while those which consider a decrease in the piezometric head (Moon and Fernandez 2010) under-estimated inflow. In order to bound the predicted groundwater inflow rates, both the El Tani and Moon and Fernandez methods were used.

The El Tani equation for water inflow into a tunnel is:

$$Q = 2\pi k\left(\frac{\lambda^2-1}{\lambda^2+1}\right)\left(\frac{h}{\ln\lambda}\right), \text{ and } \lambda = \frac{h}{r} - \sqrt{\frac{h^2}{r^2} - 1} \qquad \text{Eq. 1}$$

Where:

Q = groundwater flow into the tunnel (m^3/s per m of tunnel length),
h = head of water above the tunnel springline (m),
K = the equivalent hydraulic conductivity of the jointed rock mass around the tunnel (m/s), and
r = the tunnel radius (m).

Equation 1 pertains to cases where the initial piezometric surface in the rock mass is drawn down to the Hard Rock Tunnel due to dewatering. It was assumed this will be the case during construction for the Hard Rock Tunnel.

The Moon and Fernandez equations for water inflow into a tunnel are:

$$Q = \frac{k(2R_Z H - H^2)}{(R_x - a)}$$ (Shallow Tunnel; where r/H > 0.2 and drawdown (s)/H = 1) Eq. 2

$$Q = \frac{2\pi k H'}{ln(\frac{2H}{a})}$$ (Deep Tunnel; where r/H < 0.2 and s/H ≤ 0.5) Eq. 3

Where:

Q = inflow into the tunnel (m^3/s per m of tunnel length),
K = equivalent hydraulic conductivity for the jointed rock mass around the tunnel (m/s),
RZ = vertical influence distance of groundwater drawdown from initial groundwater level (m),
Rx = horizontal influence distance of groundwater drawdown from centre of tunnel (m)
H = initial hydraulic head over tunnel springline (m),
H' = lowered hydraulic head over tunnel springline (m), and
a = tunnel radius (m).

Dynamic Hydraulic Processes During Tunnel Construction

When driving a tunnel, the removal of rock causes stress concentrations around the tunnel which act to close fracture apertures in the rock mass close to the tunnel. As water flow through a fracture is proportional to the cube of the fracture aperture, any reduction in apertures causes a profound decrease in permeability through fractures in the rock mass, and a decrease in overall seepage inflow into the tunnel. This self-sealing effect is as if a water-tight liner was placed within the tunnel, hence it has been referred to as the lining-like effect (Moon and Fernandez 2010). A lining-like zone of lowered rock mass permeability can extend several to tens of metres into the rock mass. This is a strong basis to conclude that actual water inflows will tend to be on the lower end of predicted ranges (discussed further as follows).

In addition to stress concentrations, when a tunnel encounters a water-bearing discontinuity or fracture zone, there will be an initial flush of water rapidly draining into the tunnel from storage in the fractures. The extent, density and interconnectivity of fractures and fracture zones will control how long this initial flush will last. The initial flush inflow will taper off exponentially with time as storage depletes by gravity drainage, and normal groundwater flow toward the tunnel becomes predominant. Fracture zones hydraulically-connected to overlying saturated overburden (such as, Figure B-2b) may drain in this manner for longer periods since there is more interconnected saturated material to drain during the initial flush. The rates and duration of initial gravity-driven drainage of water-filled fractures is not considered in this assessment. It is presumed this would be managed through normal tunnel dewatering and grouting.

The pore pressure at the tunnel wall will be zero as an open tunnel is at atmospheric pressure. The reduction of pore pressure at the tunnel wall compared to pre-tunnel hydrostatic conditions also acts to relax and further close fracture apertures, further reducing fracture permeability near the tunnel and inducing a drop in piezometric head above the tunnel.

Tunnel Inflow Under Reduced Piezometric Head Conditions

One of the challenges of groundwater inflow assessment is the head reduction that might occur. Su et al. (2017) present results of numerical calculations on the reduction in head caused by drawdown into a circular tunnel at depth. They presented the following formula for the reduction in head.

h'E = m.(r/h)n . h Eq. 4

Where:

h'E = the reduced head (m),
r = the radius of the tunnel (m),
h = the initial head above the tunnel springline (m), and
m and n = coefficients derived from curve fitting (m=0.3 and n =-0.014r – 0.22).

Mohsen (2017) presents a more practically based assessment of the reduction in initial head from the observations of driving the Karaj tunnel; this has been used herein given its relative simplicity in comparison to the method presented by Su et al. (2017). At the Karaj tunnel the initial groundwater head in boreholes above the tunnel was observed to be very high (up to 400 m head) whereas heads in piezometers installed inside the tunnel were very low (5 m head). Back-analysis of the measured water inflow into the tunnel showed that water head was within 25 to 50 percent of the observed water head in the tunnel boreholes. Experience from other tunnelling projects within granitic rock has shown that significant head reduction occurs following the tunnel intersecting a water-bearing feature. Therefore, a reduction from initial head to 10 percent was also assessed.

Calculation of Inflows to the Hard Rock Tunnel During Construction

In order to calculate the water inflow into the Hard Rock Tunnel per metre, the following steps were conducted:

- The piezometric heads measured during the in-situ testing of the test borehole were used to develop a relationship between surface elevation and depth to the piezometric elevation. This relationship was used to extrapolate piezometric heads for the Hard Rock Tunnel beyond the borehole length drilled.
- The Hard Rock Tunnel was split into one metre increments and an appropriate hydraulic conductivity applied based on the foregoing discussion defining hydraulic conductivity for Type I or II conditions, rock quality designation, and rock type. For the portion of the Hard Rock Tunnel where data was not available Type I or II conditions were applied based upon surface mapping.
- For both Type I and Type II zones, the lowermost and uppermost hydraulic conductivity values estimated from the in-situ test were used. The geometric mean of each data set was also used. These hydraulic conductivity values were used to estimate the potential range of groundwater inflow into the Hard Rock Tunnel using the El Tani method (Equation 1) and the Moon and Fernandez method (Equations 2 or 3 depending on tunnel depth). The radius of tunnel was assumed to be 1.75 m (for a 3.5 m diameter tunnel).
- Inflows were also calculated using reduced piezometric heads in the form of a reduction factor (R.F.) per the method outlined above from Mohsen (2017). This was based on the percentage of expected head reduction from its original value (that is, if H = 10 m then with an R.F. = 0.3, H' = 3 m).

Results of Predicted Inflows to the Hard Rock Tunnel During Construction

The results of the hydrogeological calculations and sensitivity analysis are presented in Table 6. In order to compare the results, the total inflow along the length of the rock tunnel has been reported (in terms of Lpm).

Table 6. Results of Calculated Inflows to the Hard Rock Tunnel during Construction

Method	Head Condition	Low-Hydraulic Conductivity			High-Hydraulic Conductivity			Geometric Mean Hydraulic Conductivity		
	%	m^3/s	Lps	Lpm	m^3/s	Lps	Lpm	m^3/s	Lps	Lpm
El Tani	NA	0.02	15.5	932	1.133	1133	67,950	0.23	225.6	13,535
Moon and Fernandez	25[a]	0.003	3.5	207	0.256	256	15,367	0.051	50.8	3,048
	10[a]	0.001	1.4	83	0.103	103	6,151	0.0203	20.3	1,220

Sources: El Tani 2003; Moon and Fernandez 2010

[a] reduced piezometric head, as % of initial head acting on the tunnel springline

Lps = litre(s) per second

The best estimate of groundwater inflow is considered to be derived from the geometric mean hydraulic conductivity value with the drained head range, relative to the initial head, of 10 to 25 percent (Moon and Fernandez method). A reasonable estimate of total water inflow is therefore considered to be in the range of 1,220 to 3,048 Lpm as a steady state groundwater inflow. As shown in Table 6, the full range of predicted inflows is quite large, from a low of 83 Lpm (low-hydraulic conductivity and 10 percent head condition) up to 15,367 Lpm (high-hydraulic conductivity and 25 percent head condition).

The maximum total steady state inflow will not occur until the rock tunnel excavation is complete. This should allow the DB Contractor to observe actual flow rates and compare them to the predicted values allowing changes to be made to the water management and infrastructure using adaptive management.

Figure 9 shows the cumulative groundwater inflow along the Hard Rock Tunnel chainage for two analysis methods. Distinct steps in the inflow rate are predicted at lineament locations, where groundwater inflow is concentrated.

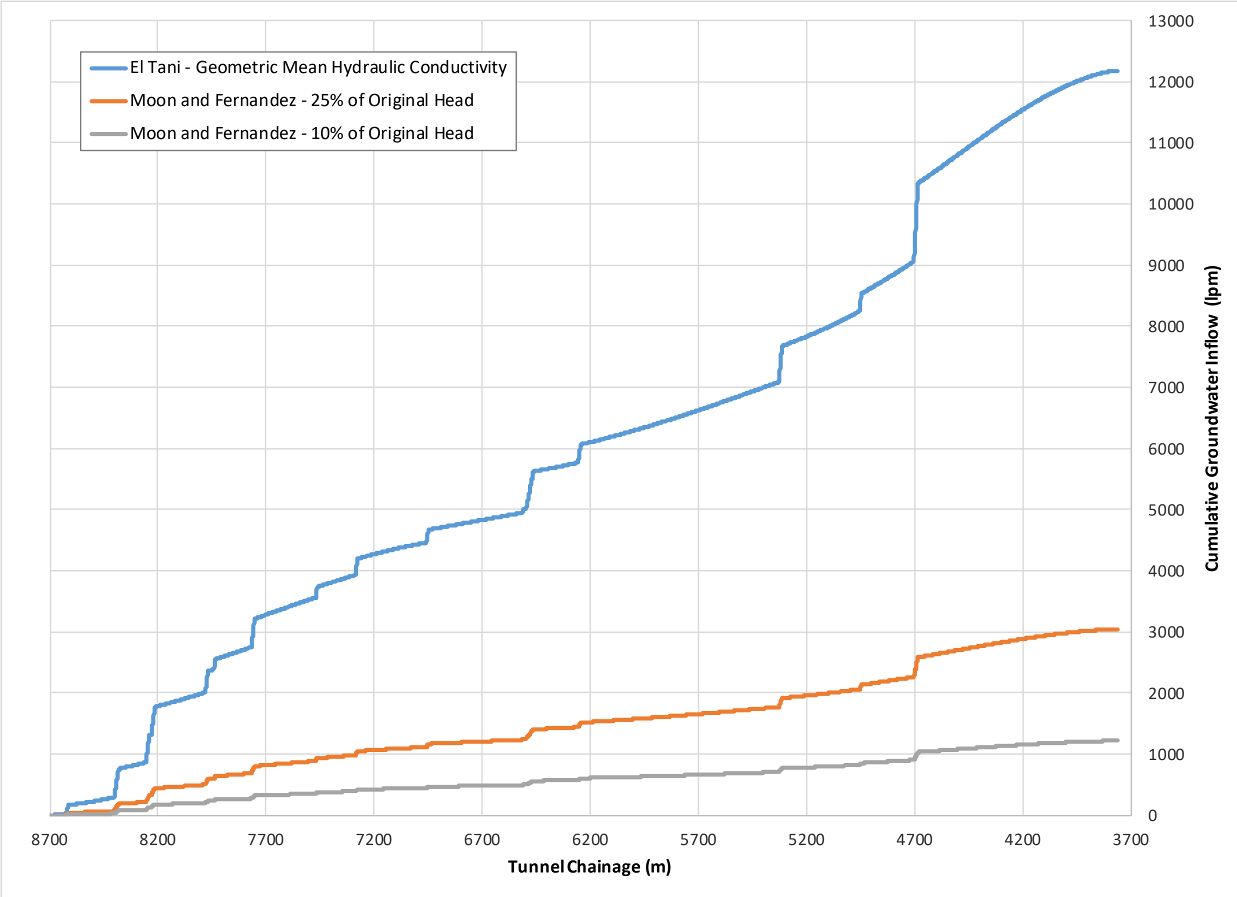

Figure 9. Cumulative Hard Rock Tunnel Inflow During Construction

Calculations of Anomalous Flows in Fracture Zones

An additional calculation was conducted to examine the anomalously high inflows from critical fracture zones intersecting the Hard Rock Tunnel. The most critical fracture zone is considered to underlie Lineament 18, intersecting the Hard Rock Tunnel at approximately Chainage 5+250. At this location, it was assumed that 85 percent of the total initial head would act within the fracture zone. This is due to its large size and likely interconnection with saturated overburden materials near the surface. Under these conditions, the maximum calculated inflow rate for that fracture zone was approximately 590 Lpm, over the full lineament width of 15 m (using either Moon and Fernandez or El Tani methods). There are five fracture zones in total where the results indicate that anomalous flows might exceed 200 Lpm using the same head assumptions.

The relatively large incremental contributions to total Hard Rock Tunnel inflow from fracture zones is shown by the step-wise increases in inflow on Figure 9.

Remedial Grouting of Fracture Zones

The above groundwater inflow calculations consider that no remedial measures are applied to reduce the groundwater inflow during and/or post advancement of the Hard Rock Tunnel. It is typical practice during tunnelling when a zone is encountered which produces relatively high quantities of groundwater it is grouted. In this instance, it is considered that the portions of the Hard Rock Tunnel which will produce the highest volumes of groundwater will be those which are highly fractured, relatively high-hydraulic conductivity, well-interconnected, and with connectivity to surface. The fracture zones underlying lineaments which intersect the Hard Rock Tunnel likely meet most, if not all, of these criteria; other yet to be identified structures may also produce relatively high quantities of groundwater. Consequently, the above analysis was re-evaluated by applying a lower hydraulic conductivity value to the fracture zones to represent their hydraulic properties post-grouting.

The most important fracture zones with respect to potential groundwater inflow to the Hard Rock Tunnel are those listed in Table 7. These fracture zones were chosen due to their Relative Importance Rating provided by MJA 2019b (Table 7-1). Table 7 compares the calculated predicted inflows from each of the most important fracture zones by applying both the El Tani (2003) and Moon and Fernandez (2010) methods. The analysis was performed by applying the geometric mean for the Type II discontinuities for each lineament. This represents the condition where no remedial grouting is applied. The analysis was also performed by applying a hydraulic conductivity value of 1 by 10-7 m/s to the fracture zones representing the grouted condition.

The value of 1 by 10-7 m/s was chosen based upon values reported by the United States Army Corps of Engineers (US ACE 2017) as follows:

> "Whereas a reasonable target for hydraulic conductivity of a grouted zone for a high-quality, single-line curtain might be 10 Lugeons, a multiple-line program of the same quality might reasonably be expected to produce a grouted zone hydraulic conductivity in the range of 1.0 Lugeon."

and

> "If the approach of best practice is carefully adhered to for every factor of the program, then design values for normal applications can be selected at the lower end of the achievable ranges (such as, in the range of 5 Lugeons or less)."

Note that one Lugeon is equivalent to a K of 1.3 by 10-7 m/s.

Additionally, more specialized grouting methods could be applied which would include more controls on the mixing and grouting procedure and potentially the use of microfine cement. Alternatively, additional grout lines could be conducted until flow observed to slow down to an appropriate or reasonable rate. Therefore, the application of 1 by 10-7 m/s is considered reasonable.

Table 7 shows that grouting of fracture zones (underlying their corresponding lineaments) will reduce the inflow from the fracture zones by between approximately 1 to 2 orders of magnitude.

Table 7. Lineament Inflow for Grouted and Non-Grouted Conditions

Lineament (Fracture Zone) No.	*Hard Rock Tunnel Intersection Chainage*	*El Tani (2003)*				*Moon and Fernandez (2010): Head = 25% of initial*				*Moon and Fernandez (2010): Head = 10% of Initial*			
		Inflow Ungrouted		**Inflow Grouted**		**Inflow Ungrouted**		**Inflow Grouted**		**Inflow Ungrouted**		**Inflow Grouted**	
		Geometric Mean Hydraulic Conductivity		**Grouted Zone K = 1E^{-7} m/s**		**Geometric Mean Hydraulic Conductivity**		**Grouted Zone K = 1E^{-7} m/s**		**Geometric Mean Hydraulic Conductivity**		**Grouted Zone K = 1E^{-7} m/s**	
From Table 7-1 (MJA 2019a) for all 3+ importance rating	**From Table 7-1 (MJA 2019a)**	**(m^3/s)**	**(Lpm)**	**(m^3/s)**	**(Lpm)**	**(m^3/s)**	**(Lpm)**	**(m^3/s)**	**(Lpm)**	**(m^3/s)**	**(Lpm)**	**(m^3/s)**	**(Lpm)**
4	8+320.00	9.5E-03	570	2.1E-04	13	2.4E-03	143	5.3E-05	3	9.5E-04	57	2.1E-05	1
6	7+902.00	6.7E-03	402	1.5E-04	9	1.7E-03	100	3.7E-05	2	6.7E-04	40	1.5E-05	1
7	7+865.00	3.1E-03	186	6.8E-05	4	7.7E-04	46	1.7E-05	1	3.1E-04	19	6.8E-06	0
8	7+688.00	8.7E-03	522	1.9E-04	11	2.2E-03	130	4.8E-05	3	8.7E-04	52	1.9E-05	1
11	7+394.00	3.3E-03	198	7.2E-05	4	8.1E-04	49	1.8E-05	1	3.3E-04	20	7.2E-06	0
12	7+210.00	5.1E-03	306	1.1E-04	7	1.3E-03	77	2.8E-05	2	5.1E-04	31	1.1E-05	1
13	6+882.00	4.0E-03	240	8.9E-05	5	1.0E-03	61	2.2E-05	1	4.0E-04	24	8.9E-06	1
16b	6+441	1.1E-03	66	2.4E-05	1	2.7E-04	16	5.9E-06	0	1.1E-04	6	2.4E-06	0
17	4+623 (E)	2.2E-02	1320	4.9E-04	29	5.5E-03	333	1.2E-04	7	2.2E-03	133	4.9E-05	3
18	5+250.00 (C)	1.1E-02	660	2.4E-04	14	2.7E-03	163	6.0E-05	4	1.1E-03	65	2.4E-05	1
19	4+879.00 (C)	5.0E-03	300	1.0E-04	6	1.2E-03	75	2.7E-05	2	5.0E-04	30	1.1E-05	1

The flow for the full Hard Rock Tunnel was re-evaluated based upon the grouting of the fracture zones. These results are shown in Figure 10 and Table 8. The results in Figure 9 (ungrouted) compared with those in Figure 10 (grouted) show that grouting the fracture zones would approximately halve the groundwater inflow into the Hard Rock Tunnel.

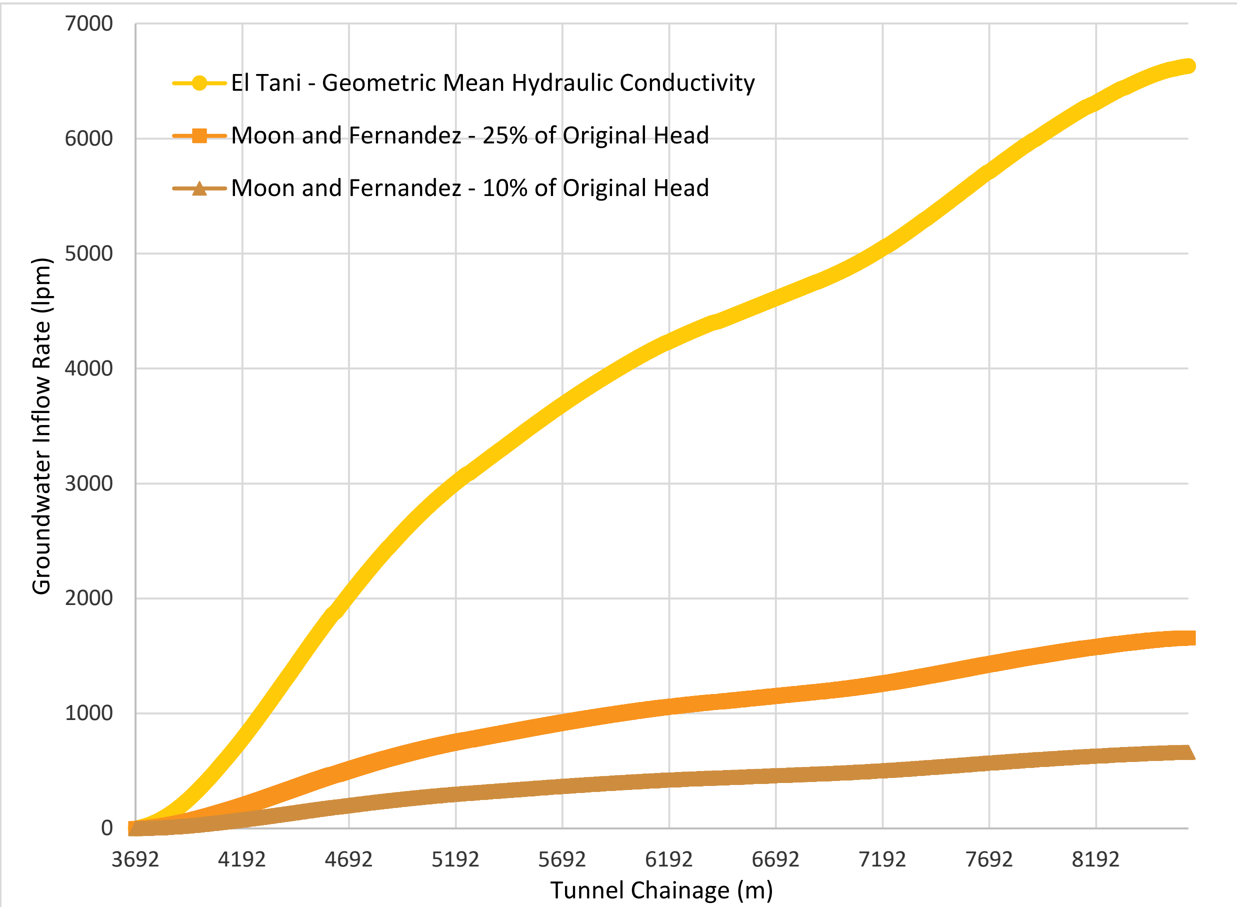

Figure 10. Cumulative Hard Rock Tunnel Inflow During Construction (Fracture Zones Grouted)

Table 8. Results of Calculated Inflows to the Hard Rock Tunnel with Remedial Grouting

Method	Head Condition	Low-Hydraulic Conductivity			High-Hydraulic Conductivity			Geometric Mean Hydraulic Conductivity		
	%	m^3/s	Lps	Lpm	m^3/s	Lps	Lpm	m^3/s	Lps	Lpm
El Tani	N/A	0.0049	4.9	294	0.668	668	40,088	0.11	111	6,635
Moon and Fernandez	25[a]	0.001	1.2	73	0.167	167	10,024	0.028	28	1,659
	10[a]	0	0.49	29.4	0.067	67	4,010	0.011	11	664

[a] reduced piezometric head, as % of initial head acting on the tunnel springline

Empirical Comparison with Inflows in Nearby Existing Tunnel

Given the recognized uncertainties with respect to the hydrogeological conditions, a back-analysis was conducted on the reported inflow of groundwater into the Ashlu Tunnel following construction. The Ashlu Tunnel is located North West of Squamish, 28 km north of the WLNG Site. Assessments of inflow (Moalli et al. 2008; Wallis 2009) were based on the reported outflow of 264 to 302 Lpm, for the 4.08 m diameter tunnel which is 4,400 m-long has an average depth of 475 m.

Accordingly, the geometric mean hydraulic conductivity value for the Ashlu Tunnel was adjusted using the Moon and Fernandez method until a water inflow of approximately 300 Lpm was achieved under a head range of 20 to 25 percent of the initial groundwater head (conservatively assumed at 5 m below ground surface). The back-calculated hydraulic conductivity value for the Moon and Fernandez method was 8.5 by 10-9 m/s.

The hydraulic conductivity value was then applied to the Hard Rock Tunnel of the EGP Tunnel Reference Design being 4,962 m-long, diameter of 3.5 m and an average depth below surface of 184 m. The result under a similar range of head pressures (20 to 25 percent) gave a total water inflow under static conditions of between 144 to 189 Lpm. While this range is within the overall range of predicted values, it is an order of magnitude below the range (1,220 to 3,048 Lpm) predicted using the closed form analytical calculations for the ungrouted Hard Rock Tunnel. For the grouted Hard Rock Tunnel, the predicted inflow is closer to the observed Ashlu Tunnel values, however the analytical solutions still predict more groundwater inflow into the grouted Hard Rock Tunnel (664 to 1,659 Lpm).

Discussion of Predicted Values of Inflow

It should be stressed that this analysis is an estimate of predicted inflows with a number of uncertainties (such as, detailed distribution and characteristics of water-bearing fractures along the full Hard Rock Tunnel length, exact piezometric head acting over the Hard Rock Tunnel, the degree of head reduction, and values of hydraulic conductivity to represent the equivalent fractured rock mass).

The hydraulic conductivity values used in the analytical calculations have a strong effect on the results. Equations 1, 2, and 3 all show that Q (flow rate) is directly proportional to K (hydraulic conductivity). Hydraulic conductivity values are mainly derived from packer test results in the 560-m-long test borehole, and hydraulic conductivity values were extrapolated for the remaining section of the Hard Rock Tunnel. In addition, some of the packer test results were rejected due to data irregularities, and it was suspected that some of the test intervals were hydraulically jacked open during testing, leading to overestimate of hydraulic conductivity values (in turn, leading to overestimation of inflows).

These factors, plus the hydraulically limiting effect of a lining-like zone, and comparison with a close analog tunnel near to the site suggests that lower range inflows (that is, on the order of a few hundred to 1,000 Lpm) are likely for the Hard Rock Tunnel during construction.

6.2 POST-CONSTRUCTION FLOW ESTIMATE

The EGP Tunnel Reference Design includes construction of a water-tight bulkhead close to the Interface Reach (around elevation -23 m) and allowance for the Hard Rock Tunnel to fill with water, such that it discharges at the Woodfibre Portal (elevation +50 m). The steady state water outflow from the Hard Rock Tunnel was assessed considering the flooded conditions. To conduct this analysis, the head acting on the Hard Rock Tunnel was calculated as the pressure head due to water above the tunnel minus the pressure head of water within the tunnel (elevation of Woodfibre Portal above any given point in the tunnel).

After reaching steady state, the outflow of water (and hence the total inflow of water to the flooded tunnel) is predicted to be approximately 1,000 Lpm with ungrouted fracture zones. Compared to the range presented for ungrouted inflows during construction (1,200 to 3,048 Lpm), this is a 17 to 67 percent reduction in total inflow to the Hard Rock Tunnel and reflects the changed net head condition into the flooded tunnel, as compared to a pumped 'dry' tunnel. With the fracture zones grouted (as planned), a second analysis was conducted for the flooded tunnel post bulkhead construction under steady state conditions by changing the hydraulic conductivity of the lineaments to 1 by 10^{-7} m/s. The result was that the water outflow at the Woodfibre Portal reduces to 500 Lpm.

In summary, during tunnelling the most hydraulically-conductive zones (the lineaments) will be grouted. The bulkhead at the Interface Zone will force Hard Rock Tunnel water to discharge at the Woodfibre Portal (at elevation +50 m). Given this reduced head of water acting in the tunnel, and grouted lineaments, it is anticipated that for long-term planning purposes, 500 Lpm of water will out flow at the Woodfibre Portal.

7. MITIGATION MEASURES

An Environmental Management Plan (EMP) has been developed by FortisBC and approved by the BC EAO for the EGP Project. In addition, Condition Management Plans (CMPs) are being developed as part of the BC EAO approval. The CMPs will ensure that the commitments made in the EMP communicate environmental procedures and mitigation relevant to the scope of the EGP Tunnel.

FortisBC has initiated consultation with Indigenous Groups and other specified agencies for the development of the CMPs. Mitigation measures described in the CMPs will be implemented during construction of the EGP Tunnel to avoid or reduce potential adverse effects on the environment. The DB Contractor for the EGP Tunnel is expected to adhere to the directions provided in the CMPs and will provide an EGP Tunnel-specific Environmental Protection Plan (EPP) that shall meet or exceed the standards outlined in the CMPs for review and subject to FortisBC acceptance. The EGP Tunnel-specific EPP developed by the DB Contractor will be prepared in advance of construction and will be submitted to the BC OGC.

This section includes a description of preliminary mitigation measures to manage the quantity and quality of water discharge from tunnel construction and operations.

7.1 MANAGEMENT OF WATER QUANTITY

In order to avoid flooding of the Hard Rock Tunnel works and to facilitate a functionally dry working area, grouting of fracture zones will be carried out during construction.

Continual monitoring of inflows and water quality will be conducted by taking flow measurements from observed seepage sources within the Hard Rock Tunnel. These measurements will help determine if additional grouting is required to impede groundwater inflows. Should a high groundwater inflow occur from a particular feature, the DB Contractor will grout the feature to prevent groundwater ingress. It is considered that by grouting the five to ten critical water-bearing features expected in the Hard Rock Tunnel, the actual inflow will be substantially reduced.

As part of the Request for Proposal package for the EGP Tunnel, Specification 01 11 23 Supplementary Requirements for Design, contains the following wording:

Water Tightness: Rock Tunnel

1. The first 10 m of tunnel west of the Interface Reach a maximum overall potentially saline water infiltration rate of 1 Lpm per metre of the tunnel with no identifiable or visible flow of water into the tunnel.
2. Soil or rock particles must not enter into the tunnel through water ingress.
3. Where water inflow from a lineament is greater than 100 Lpm (as measured in a probe hole or having excavated through a lineament), grouting of the rock mass surrounding the tunnel will be undertaken to reduce water inflow to less than 1 Lpm, from the lineament under consideration (measured downstream along the tunnel irrespective of lineament orientation). The grouting will be conducted in accordance with this Section.

Table 7 in Section 6 shows that grouting of fracture zones (underlying their corresponding lineaments) will reduce the inflow from the fracture zones by between approximately 1 to 2 orders of magnitude.

Figure 11 shows borehole drilling and grouting operations performed by a TBM of the type anticipated to be used for construction of the Hard Rock Tunnel. During the course of construction, and particularly when the TBM is approaching close to anticipated lineaments, the DB Contractor will pause the TBM to drill and probe in advance of the TBM face to determine conditions. Information received will include rock lithology, physical properties, and rate of water inflow. In the event a lineament with significant water inflow is encountered, TBM progress will be halted and a grouting program will be instituted.

The grouting program will consist of drilling a series of advance boreholes and injecting cementitious grout at high pressure into the lineament. Once the grout has solidified, measurement of water inflows will be repeated to confirm that flows are at an acceptable level. If the anticipated inflows are not at an acceptable level, additional drilling and grouting will be performed. If the anticipated inflows are at an acceptable level, the TBM continues to mine through the grouted lineament, pausing in advance of the next lineament to repeat the process.

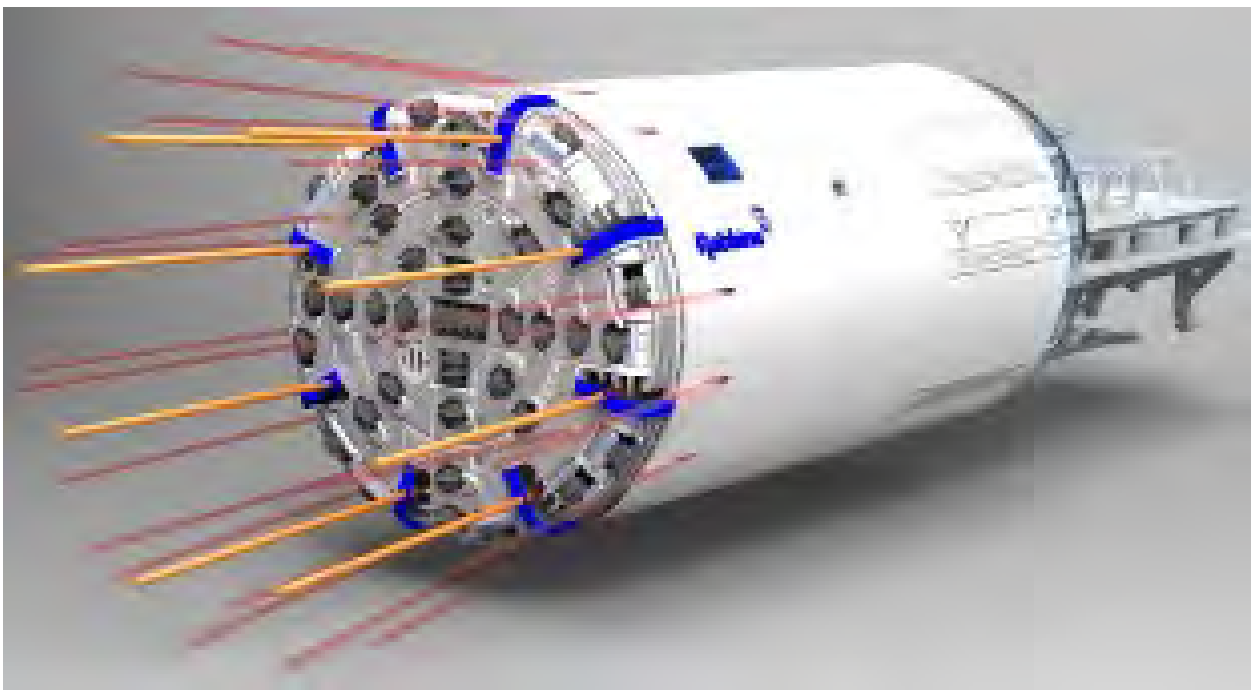

Figure 11. Grouting Operations Performed by a Tunnel Boring Machine
Source: TunnelTalk 2017

7.2 MANAGEMENT OF WATER QUALITY

As part of the Request for Proposal package for the EGP Tunnel, the following specifications have been developed for the management of water quality:

- Section 02 71 00 – Water Treatment and Disposal
- Section 31 23 19 – Groundwater Management

The Water Treatment and Disposal specification includes minimum requirements for collecting, handling, treating, sampling, testing, and disposing of all groundwater and stormwater encountered in accordance with all applicable regulatory requirements.

The DB Contractor must submit a Water Treatment Plan for collecting, handling, treating, measuring, and disposing of groundwater and other waste water generated from construction activities. The Water Treatment Plan must include drawings and designs, treatment goals, and detailed process descriptions with a corresponding flowchart. All treatment measures to be implemented must not exceed the applicable BC Approved Water Quality Guidelines for discharge of treated water to the environment. The Water Treatment Plan must include details on the means and methods of treatment, frequencies of monitoring water quality to check compliance with regulatory requirements prior to discharge, a water quality monitoring program, and contingency plans, amongst others.

The Groundwater Management Specification includes requirements for designing, documenting, and furnishing all labour, materials, tools, equipment, and incidentals for installation, maintenance, operation, and removal of temporary dewatering systems and water handling systems associated with controlling water infiltration during construction activities. The DB Contractor will be required to prepare a Groundwater Management Work Plan for each dewatering system.

To manage potential salt water intrusion, the salinity of seepage water into the tunnel sections that are below sea level will be continuously monitored. If salinity monitoring indicates the appearance of brackish or saline water in inflowing groundwater, then steps will be taken to grout that section of the Hard Rock Tunnel to reduce or eliminate saline water incursion.

The requirement for ongoing treatment of post-construction water discharge is uncertain at this point and will be evaluated and confirmed during construction based on actual water quality analysis. However, any potential water discharge from the EGP Tunnel will be conducted in accordance with regulatory requirements and Best Management Practices. Prior to initial discharge, the water will be sampled, tested, and treated (if required) to verify that it meets BC Approved Water Quality Guidelines.

Acid Rock Drainage and Metal Leaching

Multiple studies have been conducted along the EGP Tunnel to identify the potential for Acid Rock Drainage (ARD) and Metal Leaching (ML) based on samples collected during geotechnical investigations. Humidity cell kinetic testwork studies are currently underway to identify the potential for long-term ARD/ML. The results of this testwork will assist in identifying potential water quality issues during construction and over the long-term. This information will be used to inform monitoring and management plans for the Hard Rock Tunnel including the development of a detailed ARD Construction Response Plan to be incorporated into the EGP Tunnel EPP.

FortisBC's Construction Management Team will actively monitor construction activities to ensure the regulatory requirements are being met and the ARD Construction Response Plan is being successfully implemented. The DB Contractor will also have a full-time team of dedicated staff to control, manage and inspect the works continually. Active monitoring will be conducted to ensure the tunnel spoil is constantly monitored for signs or traces of sulphide mineralization and staining, as well as to conduct mapping of the tunnel sidewalls to assess ARD/ML potential. At locations where ARD/ML rock is suspected to occur, samples will be taken as required and sent for testing to an approved laboratory to accurately determine ARD/ML classification.

7.3 EROSION AND SEDIMENT CONTROL

The EPP to be prepared by the DB Contractor will include measures for erosion and sediment control during construction and dewatering activities. Erosion and sediment control measures included in the EMP approved by the BC EAO for the EGP Project include the following requirements that have been included in the Groundwater Management Specification for dewatering activities.

- The DB Contractor must accomplish dewatering in a way that prevents the loss of fines from excavation sidewalls, will maintain stability of excavated slopes and bottom of excavations, and will result in construction operations being conducted in the dry to the extent required to complete the work.
- Keep all water entering excavations sufficiently controlled to develop a workable subgrade and control groundwater levels as specified to facilitate construction.
- Provide and construct all necessary intercepting ditches, barriers, sedimentation basins, holding ponds, or other acceptable means, as necessary, to prevent muddy water, eroded materials, and other undesirable constituents from being discharged.
- Mechanized equipment, except equipment associated with water handling and treatment, must not be operated in flowing surface water. The DB Contractor's methods of dewatering, excavating, and stockpiling excavated materials (to the extent allowed) must include preventative measures to control silting and erosion.
- Water from excavations, drilling, grouting, or similar construction operations must not enter flowing or dry watercourses without the use of water treatment to achieve compliance with regulatory requirements.
- Dewatering system construction, operation, and monitoring must be performed in the presence of the a FortisBC representative, who must be allowed unrestricted access.
- Observe and record the flow rate and time of the operation of each dewatering system used daily and in accordance with any additional requirements.
- Monitor and record groundwater levels surrounding all excavations to ensure groundwater levels are maintained in accordance with applicable regulatory requirements and seasonal fluctuations.
- Repair all damage to adjacent properties, structures, or utilities and restore surfaces and finishes to the original ground state or better.
- Remove and dispose of all excavated material and other construction debris in compliance with applicable regulatory requirements.
- Keep the site clean and do not obstruct access to equipment.

8. ENGAGEMENT SUMMARY

The following sections provide a summary of the engagement with Indigenous Groups as well as potentially affected water users and rights holders conducted as part of the Water Licence application.

8.1 INDIGENOUS GROUPS

FortisBC sent a consultation package in accordance with the requirements in the BC OGC Water Licence Application Manual to Indigenous Groups whose Traditional Territories are affected by the proposed activities, including the following:

- Squamish Nation
- Tsleil-Waututh Nation
- Musqueam Indian Band

The pre-engagement materials including the letters and maps sent are included in **Appendix D.**

8.2 WATER USERS AND RIGHTS HOLDERS

A search of water users within the Study Area shown in Figure 8 was conducted on February 25, 2020 to identify potentially affected water users including water licensees, water licence applicants, and domestic water users. A search of the groundwater well database and eLicensing database showed no active groundwater wells (Government of British Columbia Water Licences Query 2020 and Government of British Columbia Natural Resource Online Service 2020). A search of iMap BC showed no active Water Rights Licences, Water Rights Applications, and Short-Term Water Use Proposed (Government of British Columbia Web Based Mapping 2020). Finally, a search of active and permitted Short-Term Water Use and Changes in and About a Stream applications showed several applications submitted by FortisBC (Government of British Columbia Data Catalogue 2020).

Based on the results of this search, the construction and operation of the Hard Rock Tunnel is not anticipated to have any potential effects on water users.

9. CONCLUSIONS

Fracture zones occurring in the granitic bedrock coincide with surficial lineaments along the Hard Rock Tunnel. Streams occur along or cross many of the lineaments and the surface water is likely hydraulically-connected with underlying saturated overburden and rock mass. The results of the EFN Assessment indicate that the calculated total streamflow depletion as a percentage of MAD was low, with an average depletion of 1.04 percent of MAD.

As these calculated depletions are <15 percent and it is understood that the streams are non-fish bearing, the effects of Hard Rock Tunnel dewatering on streamflow in the Study Area would likely be considered as an EFN Risk Management Level 1 (Iowest concern). Furthermore, since it is intended to grout the fracture zones found within the Hard Rock Tunnel, the potential streamflow depletion is anticipated to be significantly reduced.

The results of the predicted inflows to the Hard Rock Tunnel during construction activities indicate that the implementation of remedial grouting of the fracture zones would approximately halve the groundwater inflow into the Hard Rock Tunnel. Similarly, during post-construction activities, it is anticipated that the estimated water volume that could be discharged into the West Portal could be reduced from 1,000 Lpm to 500 Lpm with the implementation of the grouting program.

Detailed mitigation measures will be developed by the DB Contractor and approved by FortisBC to manage water quality and quantity during construction and operation of the EGP Tunnel including the development of a monitoring program.

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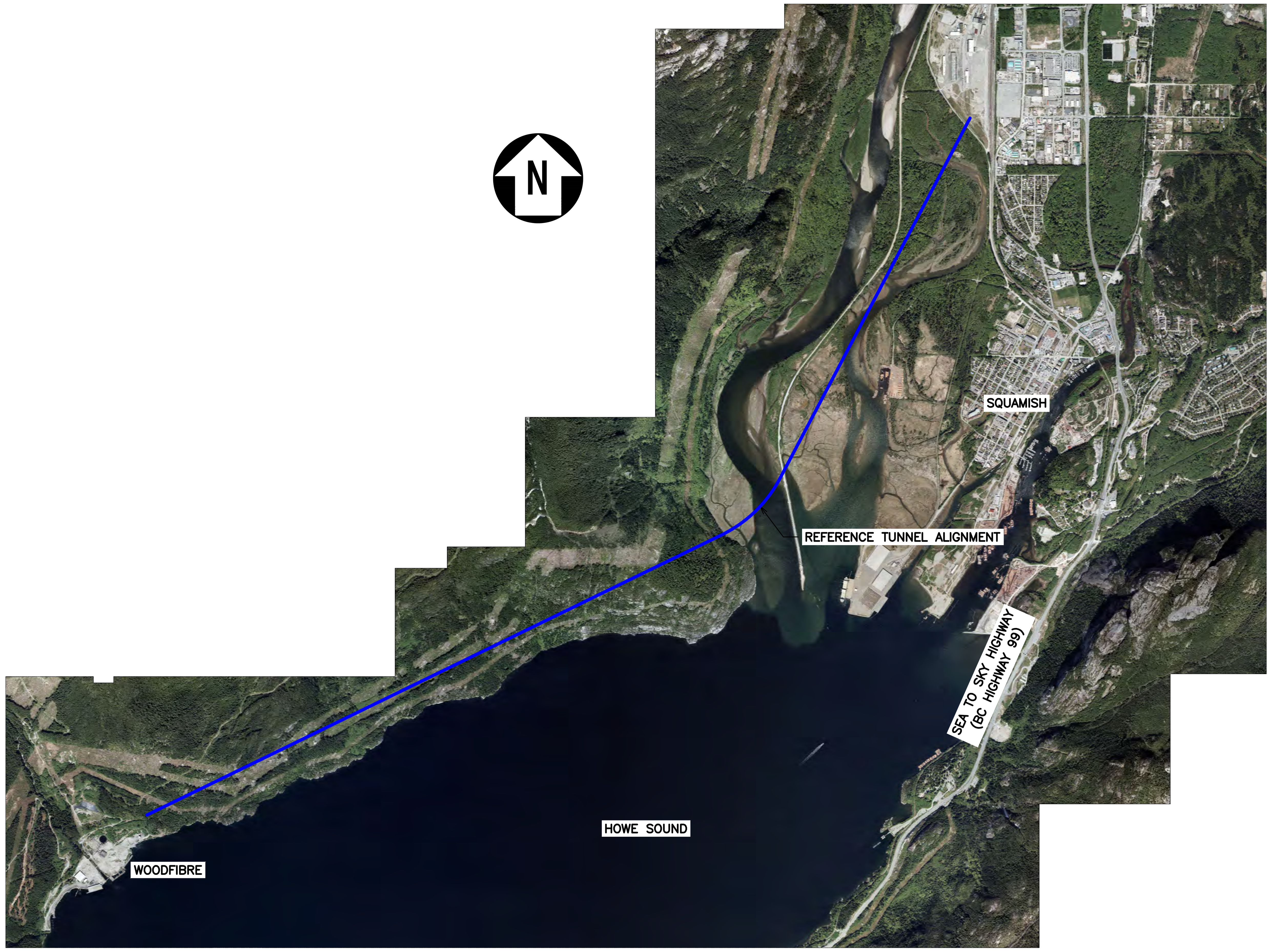
Appendix A
EGP Tunnel Reference Design Drawings

EAGLE MOUNTAIN WOODFIBRE GAS PIPELINE PROJECT

EGP TUNNEL – REFERENCE DESIGN

INDEX OF DRAWINGS

DRAWING NO.	DESCRIPTION
G–500	DRAWING INDEX
G–501	OVERALL SITE PLAN
C–500	BC RAIL PROJECT LAND
C–502	EAST SHAFT SLURRY WALL – APPROACH
C–503	EAST SHAFT TYPICAL BACKFILL – PLAN / SLURRY WALL – APPROACH
C–504	EAST SHAFT SLURRY WALL – APPROACH
C–505	EAST SHAFT SLURRY WALL – APPROACH – BACKFILL SECTION
C–510	WOODFIBRE PORTAL EXISTING SITE PLAN
C–511	WOODFIBRE PORTAL PROJECT LAND
C–512	WOODFIBRE PORTAL – PORTAL SECTIONS
C–513	TUNNEL PLAN AND PROFILE – REFERENCE ALIGNMENT C4 – SHEET 1
C–514	TUNNEL PLAN AND PROFILE – REFERENCE ALIGNMENT C4 – SHEET 2
C–515	TUNNEL PLAN AND PROFILE – REFERENCE ALIGNMENT C4 – SHEET 3
C–520	SOFT GROUND TUNNEL TYPICAL SECTIONS
C–521	SOFT GROUND TUNNEL SEGMENTAL LINING LAYOUT
C–523	INDICATIVE PERMANENT PROTECTION AND SUPPORT OF NPS24 PIPE
C–525	INTERFACE REACH – INDICATIVE APPROACH – PLAN AND PROFILE



SITE PLAN
SCALE: NTS

McMILLEN JACOBS ASSOCIATES
1188 WEST GEORGIA STREET, SUITE 2000
VANCOUVER BC V6E 4A2

BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY–MM–DD)
McMILLEN JACOBS ASSOC.	1	ISSUED FOR RFP	O.NAAS	M.MOCCICHINO	D.GRIMES	2019–11–15
McMILLEN JACOBS ASSOC.	0	ISSUED FOR PERMIT	O.NAAS	M.MOCCICHINO	D.GRIMES	2019–10–21

PROJECT NO.– 5372.3 | PREVIOUS DR. NO.– – | SCALE– NTS

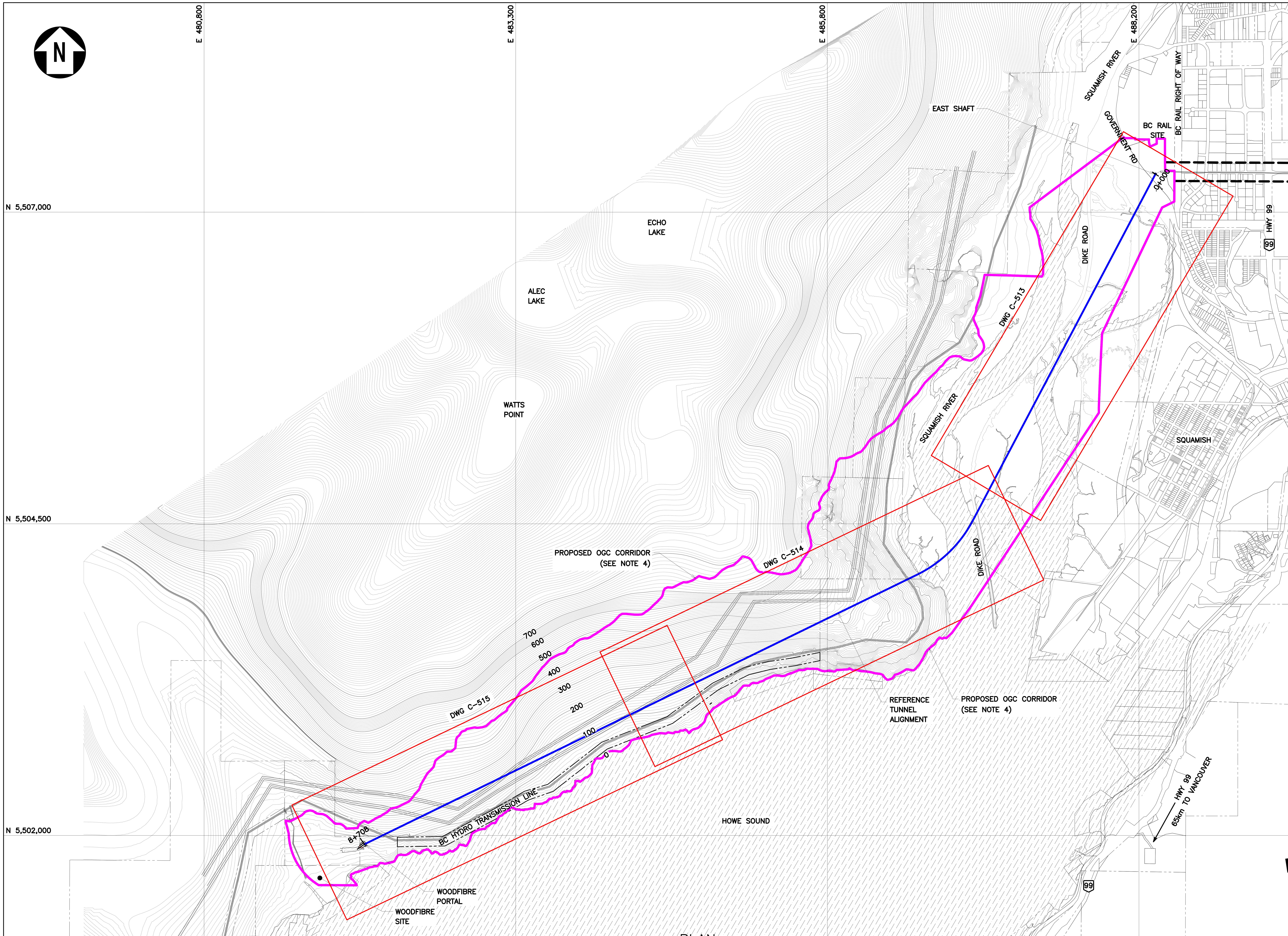
FORTIS BC™

ENGINEER SEAL

EGP TUNNEL PROJECT

DRAWING INDEX

DRAWING NUMBER G–500



PLAN
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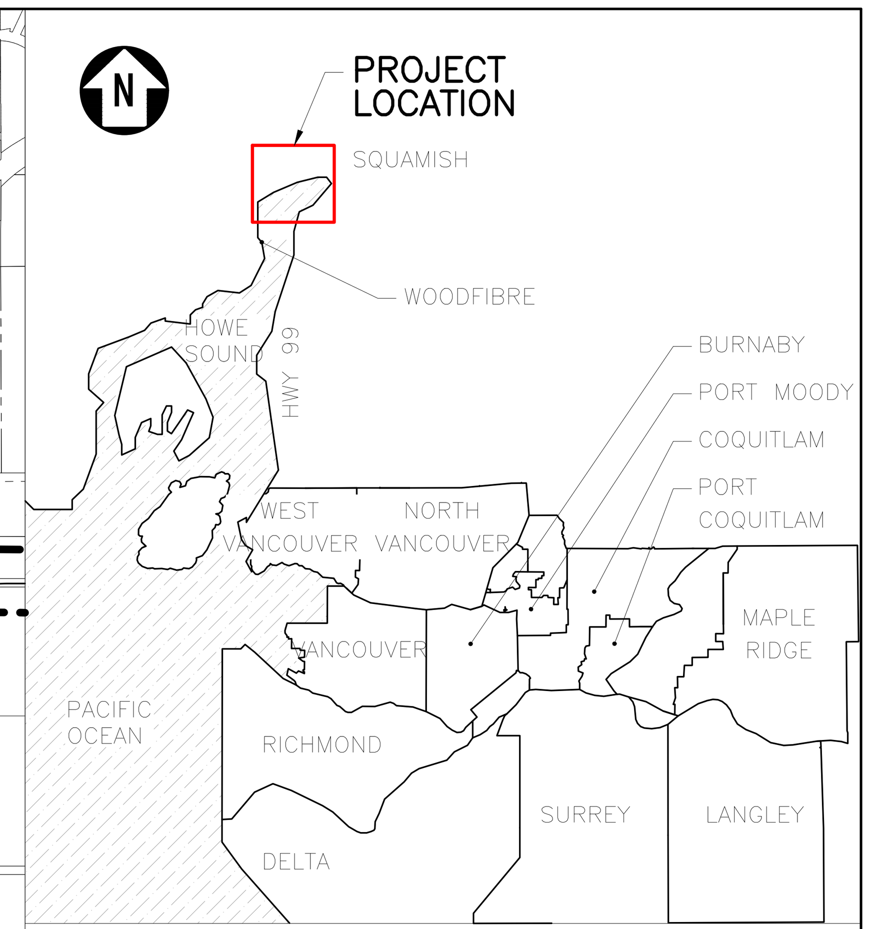

KEY PLAN
NTS

GENERAL NOTES:

1. COORDINATES ARE IN ZONE 10 UTM NAD83(CSRS). ELEVATIONS ARE IN METRES AND REFER TO GEODETIC DATUM CGVD28. THIS PLAN SHOWS GRID MEASURED DISTANCES.
2. STATIONING IS IN METRES. DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.
3. SURVEY DATA WAS DERIVED FROM CITY OF SQUAMISH OPEN DATA LIDAR (2013).
4. REFER TO CONTRACT DOCUMENTS FOR DEFINITIONS.

LEGEND

PROPERTY LINE
100 MAJOR CONTOUR (100m)
MINOR CONTOUR (10m)
PROPOSED OGC CORRIDOR
REFERENCE TUNNEL ALIGNMENT

FOR REFERENCE ONLY
NOT FOR CONSTRUCTION

300m 0 750m
SCALE IN METERS
SCALE 1 = 15000

DISCLAIMER

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BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY-MM-DD)
McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	M.MOCCICHINO	D.GRIMES	2019-11-15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-10-21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	A	ISSUED FOR TRP SESSION 1	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-05-01

PROJECT NO.- 5372.3
PREVIOUS DR. NO.- -
SCALE- 1:15000

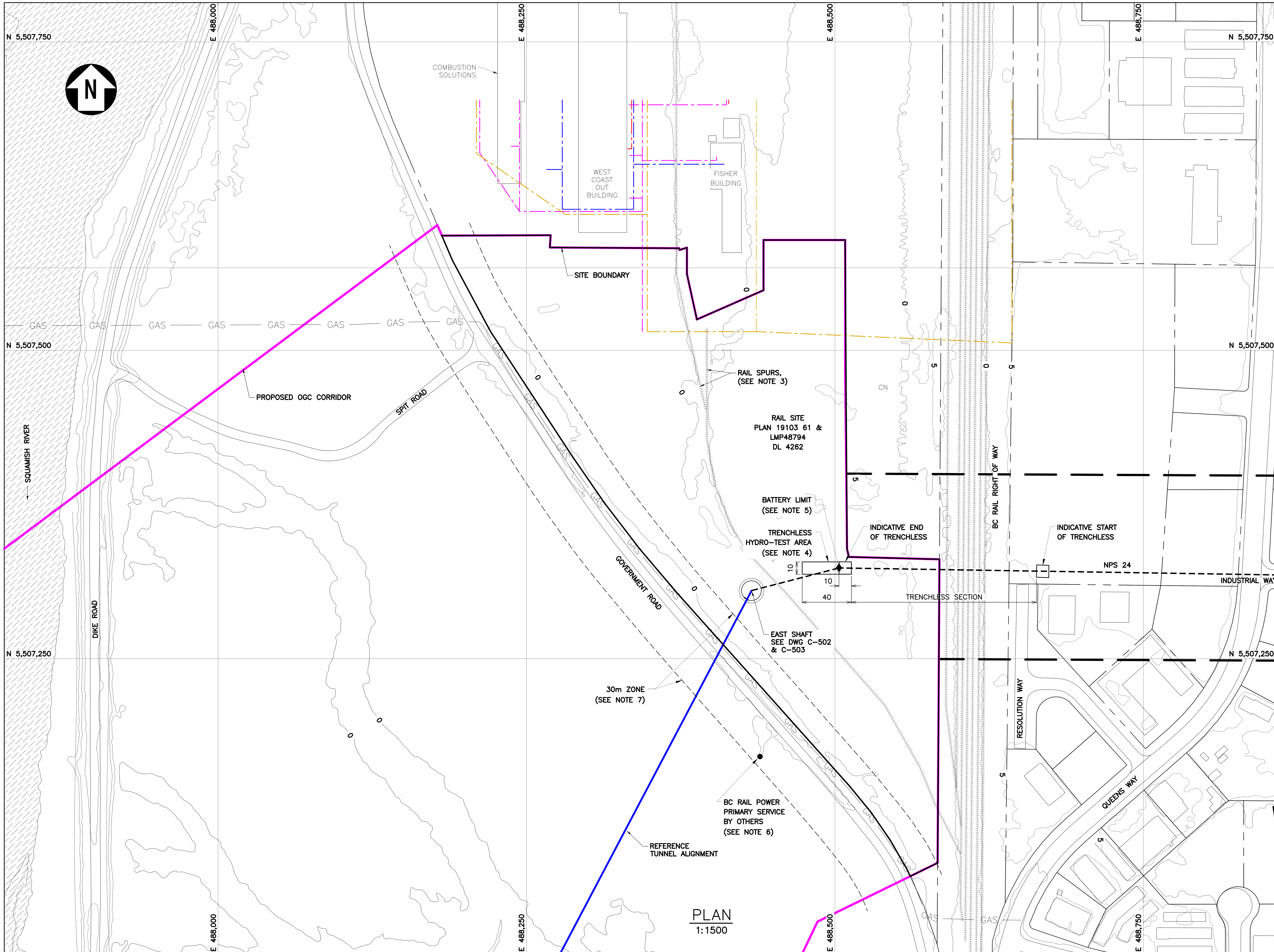
FORTIS BC

ENGINEER SEAL

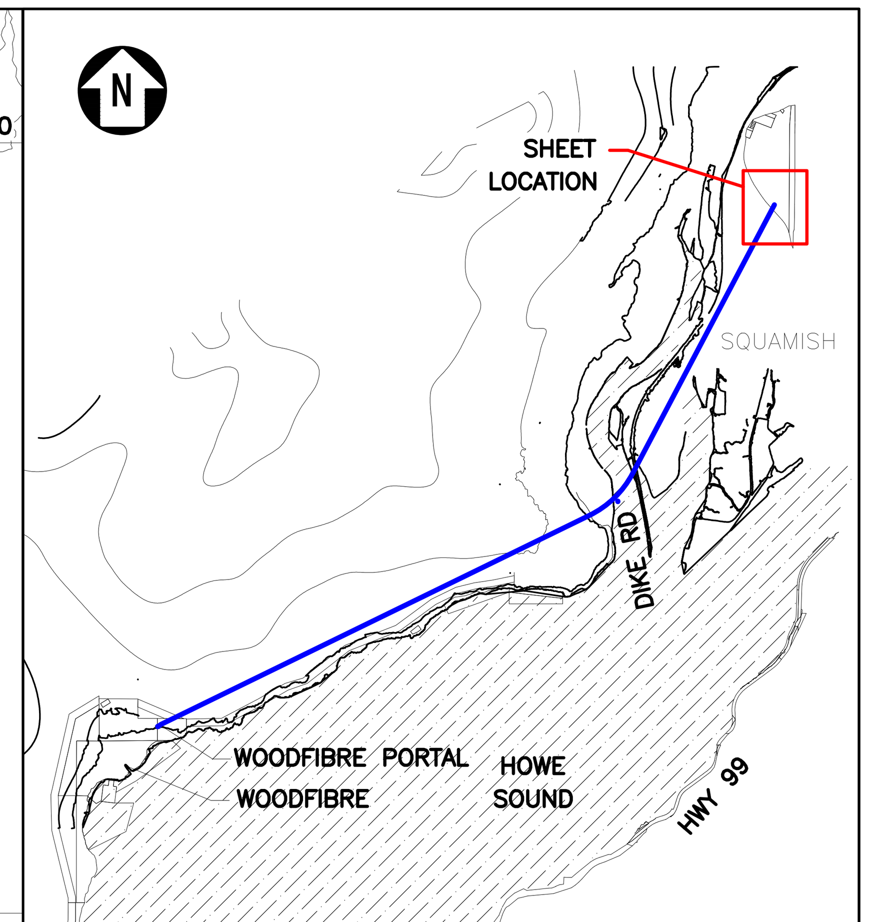
EGP TUNNEL PROJECT

OVERALL SITE PLAN

DRAWING NUMBER G-501



PLAN
1:1500



KEY PLAN
NTS

NOTES:

1. FOR GENERAL NOTES SEE DRAWING G-501.
2. FOR REFERENCE DESIGN ALIGNMENT COORDINATES SEE DWG C-513, C-514, AND C-515.
3. TO BE REMOVED DURING CONSTRUCTION AND REINSTATED AFTER WORK COMPLETION.
4. DESIGN BUILDER TO ALLOW ACCESS AS DETERMINED BY CONTRACT DOCUMENTS.
5. REFER TO SPECIFICATIONS FOR NATURAL GAS PIPELINE BATTERY LIMITS.
6. REFER TO SPECIFICATIONS FOR TEMPORARY POWER.
7. LOCATION OF CONCRETE BULKHEAD(S), OR EQUIVALENT SOLUTION THAT PREVENTS THE POTENTIAL COLLAPSE OF THE SEGMENTAL LINING – REFER TO SPECIFICATIONS.

LEGEND

- PROPERTY LINE
- 5 — CONTOUR (5m)
- EXISTING RAIL TRACKS
- NAME — EXISTING BUILDING
- GAS — EXISTING GAS TRANSMISSION PRESSURE LINE
- SITE BOUNDARY
- EXISTING UTILITY WATER
- EXISTING UTILITY STORMWATER
- EXISTING UTILITY HYDRO
- NPS 24

FOR REFERENCE ONLY
NOT FOR CONSTRUCTION

40m 0 100m
SCALE IN METERS
SCALE 1 = 1500

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McMILLEN JACOBS ASSOCIATES
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VANCOUVER BC V6E 4A2

BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY-MM-DD)
McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	M.MOCCICHINO	D.GRIMES	2019-11-15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-10-21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	A	ISSUED FOR TRP SESSION 1	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-05-01

PROJECT NO.– 5372.3
PREVIOUS DR. NO.– –
SCALE– 1:1500

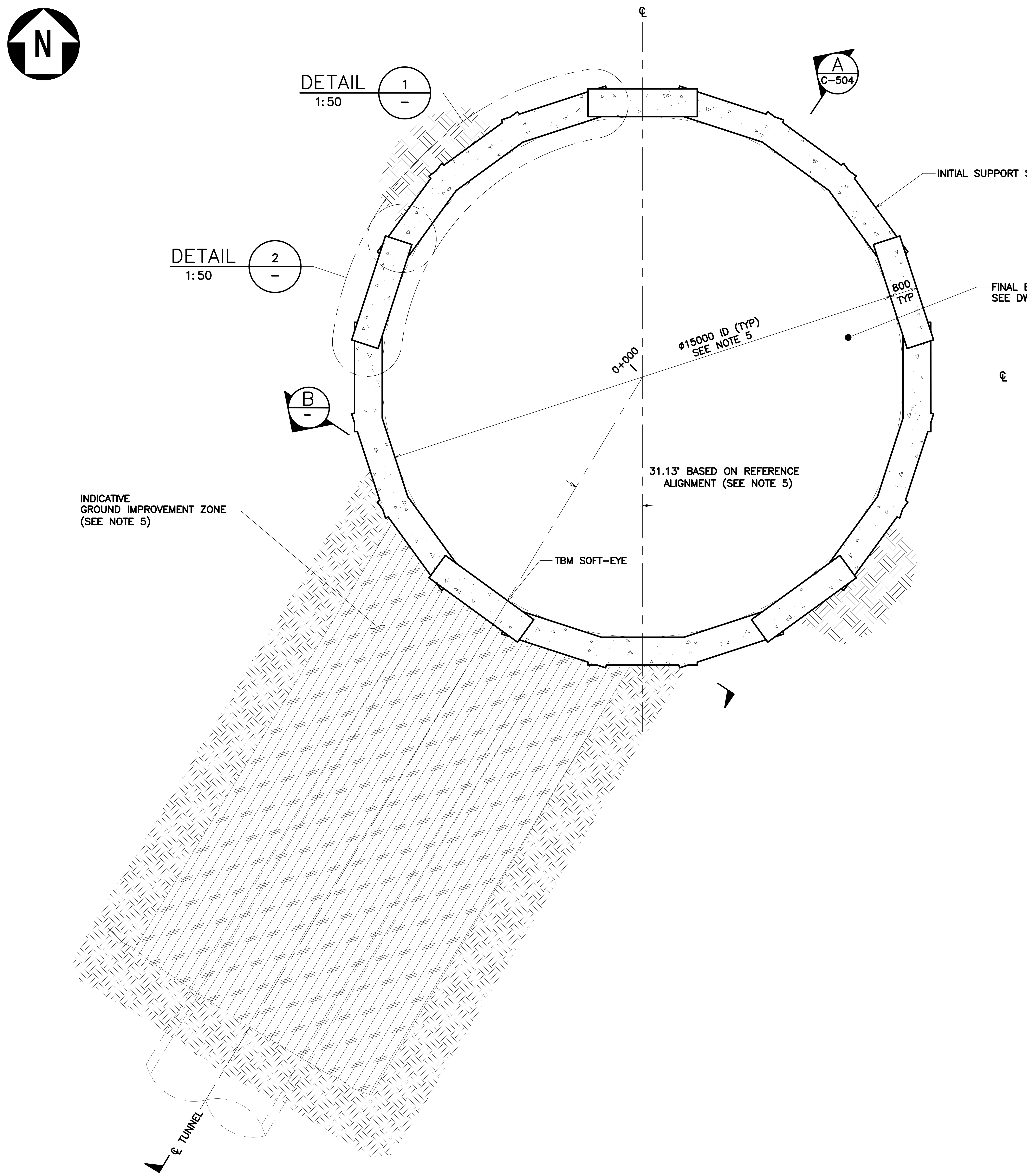
FORTIS BC

ENGINEER SEAL

EGP TUNNEL PROJECT

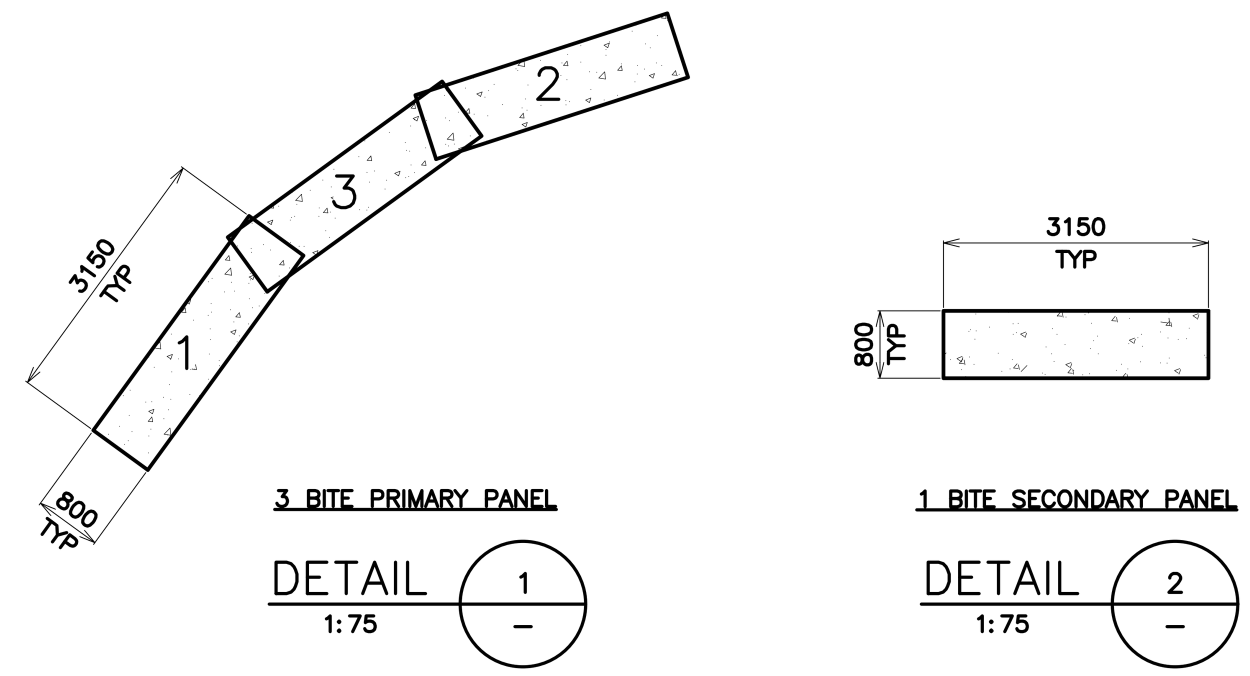
BC RAIL
PROJECT LAND

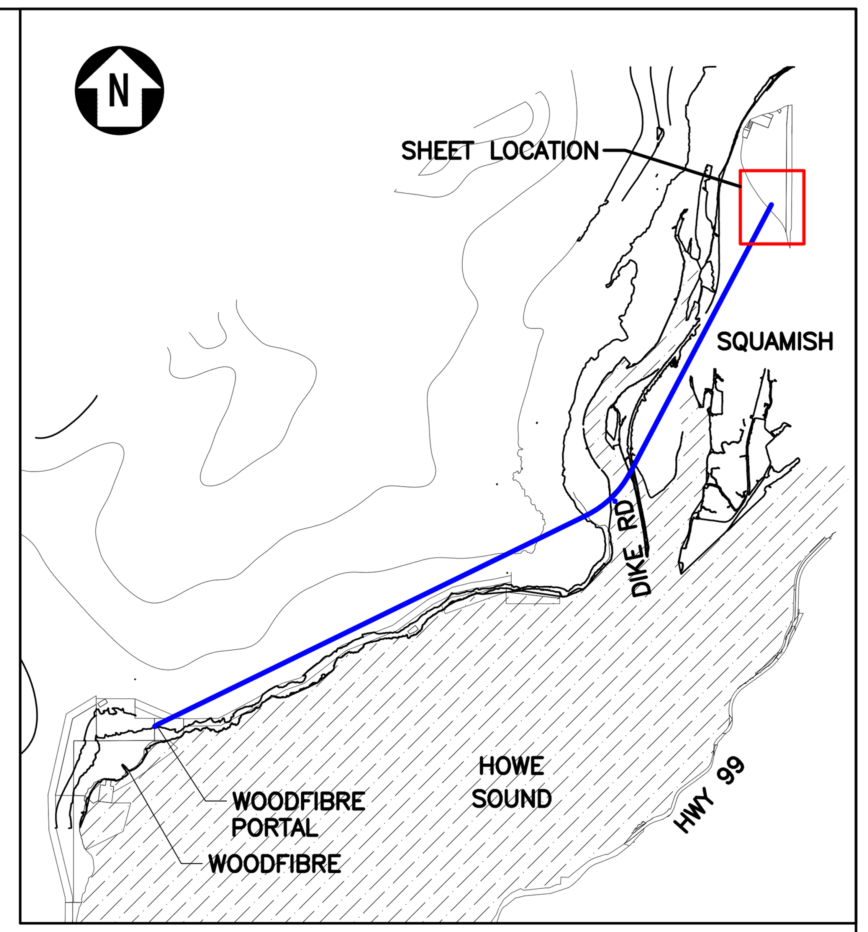
DRAWING NUMBER C-500



EAST SHAFT SLURRY WALL APPROACH

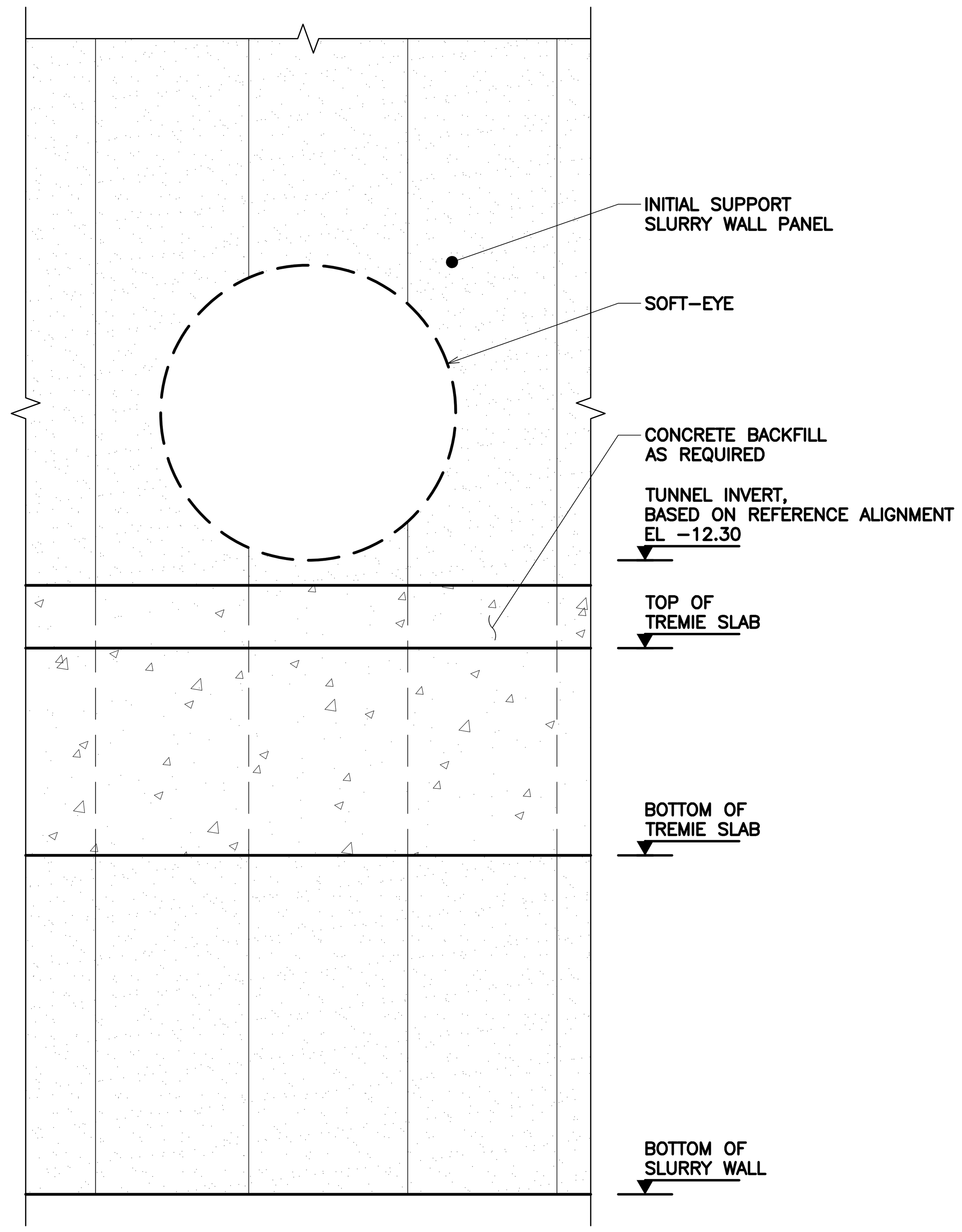
SCALE 1:75





KEY PLAN

NTS



SECTION B 1:75

NOTES:

1. SEE DRAWING G-501 FOR GENERAL NOTES.
2. SEE DRAWING C-513 FOR EAST SHAFT AND TUNNEL COORDINATES.
3. AN EXAMPLE PANEL LAYOUT AND EXCAVATION SEQUENCE IS SHOWN (DETAIL 1).
4. SLURRY WALL PANEL TOLERANCES NOT SHOWN.
5. REFER TO SPECIFICATIONS AND DESIGN BUILDER TO DETERMINE SLURRY WALL GEOMETRY AND DEPTH, SHAFT DIAMETER, THICKNESS, AND DETAILS OF TREMIE SLAB, GEOMETRY OF GROUND IMPROVEMENT, AS APPLICABLE.

FOR REFERENCE ONLY
NOT FOR CONSTRUCTION

2m 0 5m

SCALE IN METERS

SCALE 1 = 75

McMILLEN JACOBS ASSOCIATES

1188 WEST GEORGIA STREET, SUITE 2000
VANCOUVER BC V6E 4A2

BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY-MM-DD)
McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	M.MOCCICHINO	D.GRIMES	2019-11-15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-10-21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	A	ISSUED FOR TRP SESSION 1	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-05-01

PROJECT NO.- 5372.3 | PREVIOUS DR. NO.- - | SCALE- 1:75

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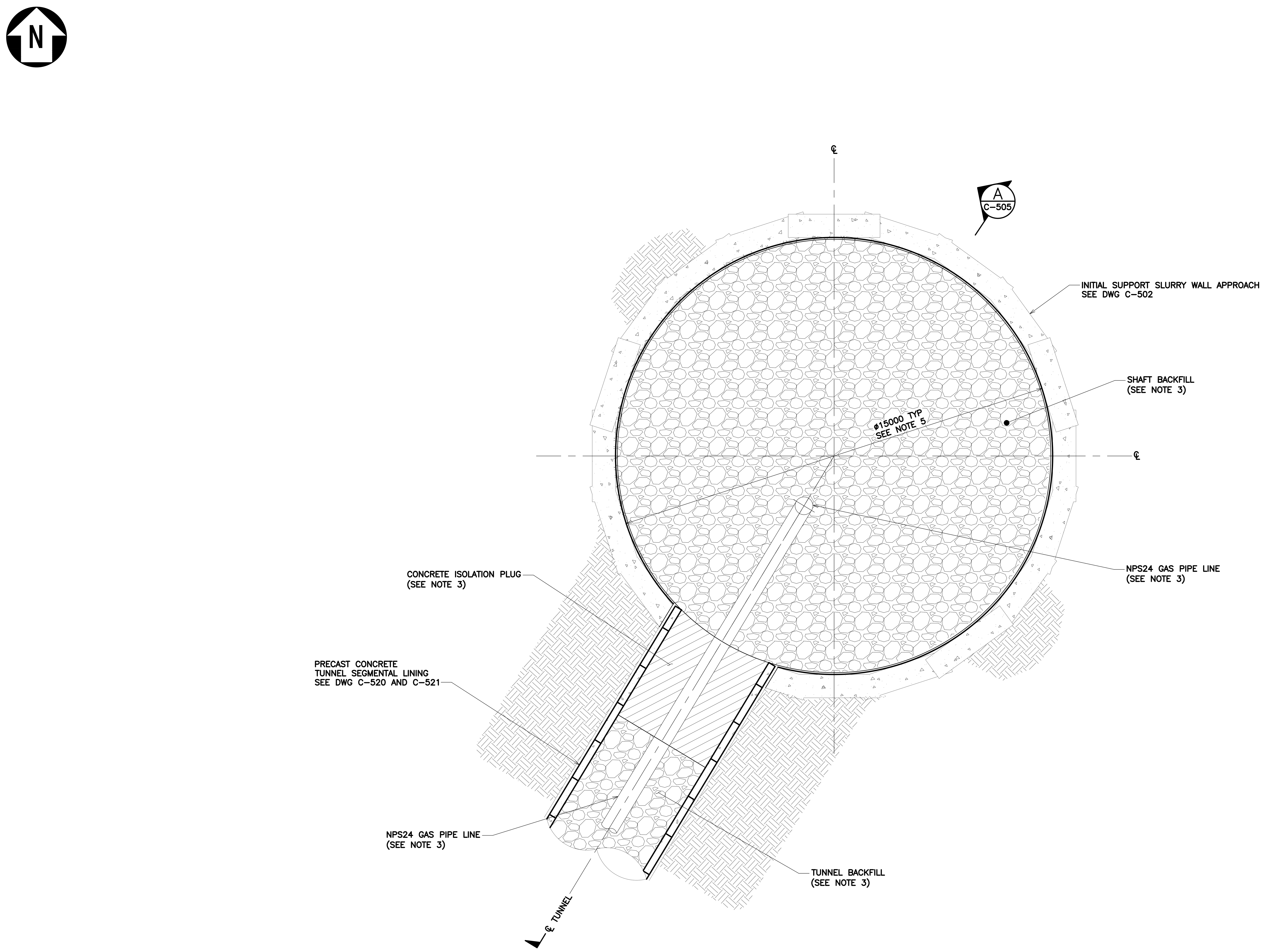
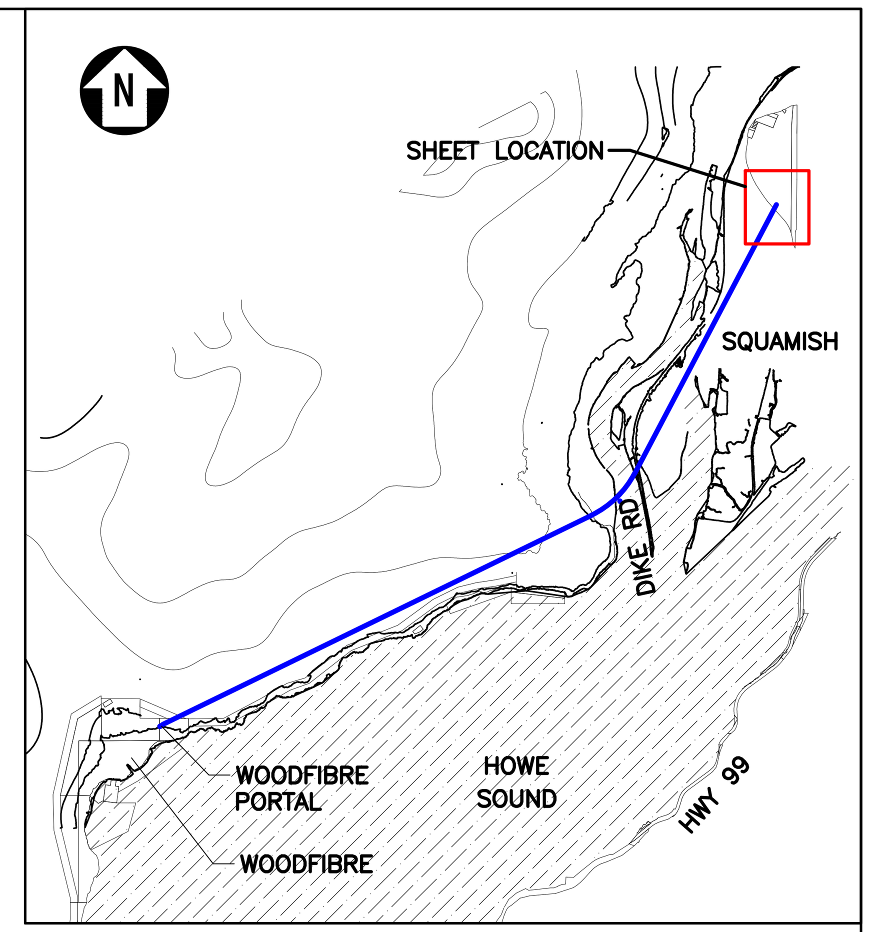
EGP TUNNEL PROJECT

EAST SHAFT
SLURRY WALL - APPROACH

DRAWING NUMBER C-502



EAST SHAFT FINAL LINING
SCALE 1:75



KEY PLAN
NTS

NOTES:

1. SEE DRAWING G-501 FOR GENERAL NOTES.
2. SEE DRAWING C-513 FOR EAST SHAFT AND TUNNEL COORDINATES.
3. REFER TO SPECIFICATIONS AND DESIGN BUILDER TO DETERMINE:
   - 3.1. ALIGNMENT AND LAYOUT OF NATURAL GAS PIPELINE IN THE TUNNEL, IN THE SHAFT, AND FROM THE SHAFT UP TO THE BATTERY LIMIT
   - 3.2. CONFINEMENT PIPELINE AND BACKFILL OF THE TUNNEL AND OF THE SHAFT
   - 3.3. GEOMETRY OF THE CONCRETE BULKHEAD
4. ELECTRO-MECHANICAL SYSTEMS NOT SHOWN FOR CLARITY.
5. SHAFT DIAMETER TO BE DETERMINED BY CONTRACTOR.
6. REFER TO SPECIFICATIONS AND DESIGN BUILDER TO DETERMINE SLURRY WALL GEOMETRY AND DEPTH, SHAFT DIAMETER, THICKNESS, AND DETAILS OF TREMIE SLAB, GEOMETRY OF GROUND IMPROVEMENT, AS APPLICABLE.

FOR REFERENCE ONLY
NOT FOR CONSTRUCTION

2m 0 5m
SCALE IN METERS
SCALE 1 = 75

McMILLEN JACOBS ASSOCIATES
1188 WEST GEORGIA STREET, SUITE 2000
VANCOUVER BC V6E 4A2

BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY-MM-DD)
McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	M.MOCCICHINO	D.GRIMES	2019-11-15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-10-21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	A	ISSUED FOR TRP SESSION 1	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-05-01

PROJECT NO.- 5372.3 | PREVIOUS DR. NO.- - | SCALE- 1:75

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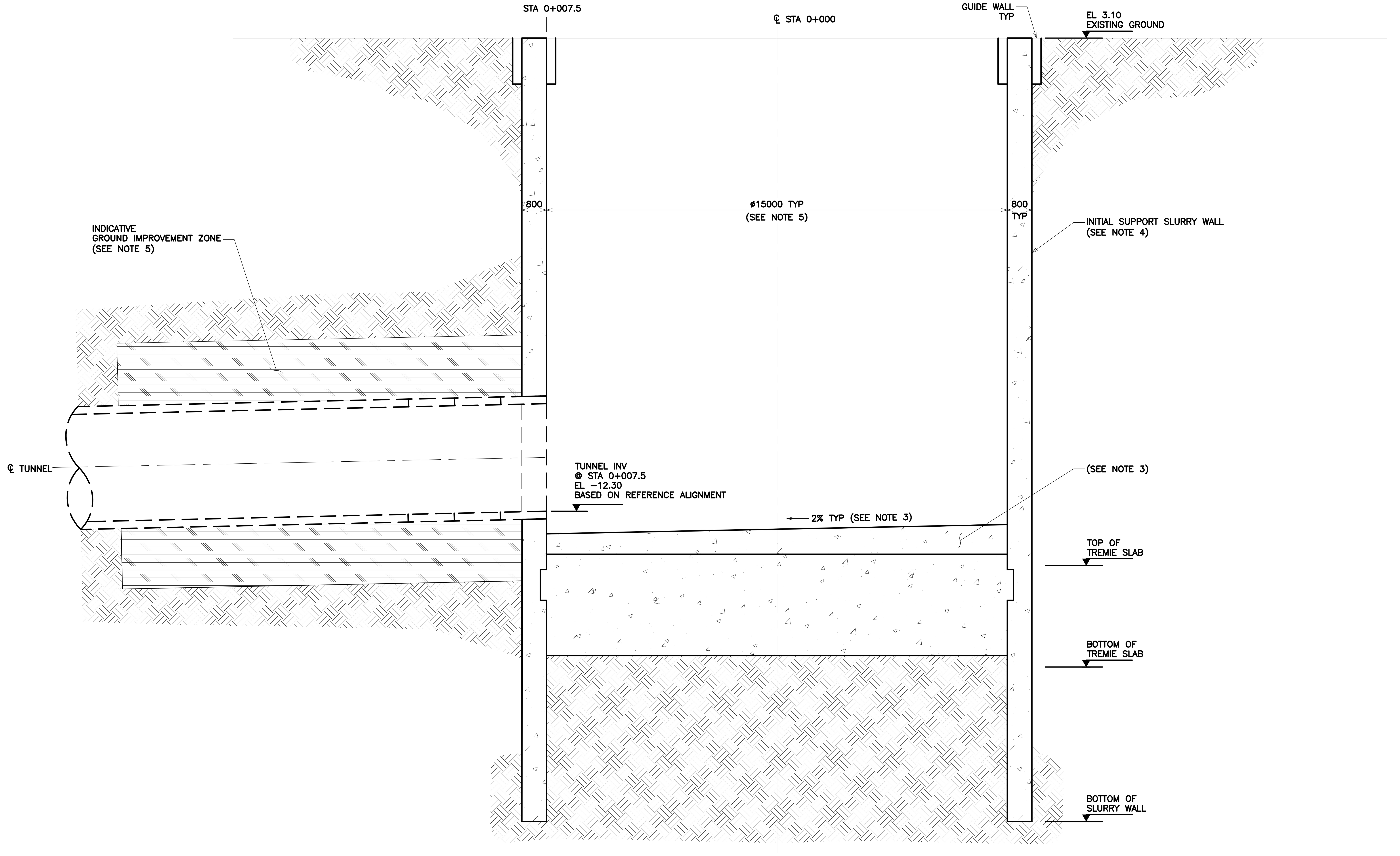
EGP TUNNEL PROJECT

EAST SHAFT
TYPICAL BACKFILL
PLAN / SLURRY WALL - APPROACH

DRAWING NUMBER C-503



SECTION A 1:75 C–502

NOTES:

1. FOR GENERAL NOTES SEE DRAWING G–501.
2. SLURRY WALL PANELS ARE UNREINFORCED CONCRETE UNLESS NOTED OTHERWISE.
3. DESIGN BUILDER TO DETERMINE CONCRETE BACKFILL AND SLOPE ADDITIONAL TO TREMIE SLAB, AS PER DESIGN BUILDER'S MEANS AND METHODS.
4. SLURRY WALL VERTICALITY TOLERANCE TO BE DETERMINED BY DESIGN BUILDER.
5. REFER TO SPECIFICATIONS AND DESIGN BUILDER TO DETERMINE SLURRY WALL GEOMETRY AND DEPTH, SHAFT DIAMETER, THICKNESS, AND DETAILS OF TREMIE SLAB, GEOMETRY OF GROUND IMPROVEMENT, AS APPLICABLE.

FOR REFERENCE ONLY
NOT FOR CONSTRUCTION

2m 0 5m
SCALE IN METERS
SCALE 1 = 75

McMILLEN JACOBS ASSOCIATES
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BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY–MM–DD)
McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	M.MOCCICHINO	D.GRIMES	2019–11–15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019–10–21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019–07–19
McMILLEN JACOBS ASSOC.	A	ISSUED FOR TRP SESSION 1	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019–05–01

PROJECT NO.– 5372.3 | PREVIOUS DR. NO.– – | SCALE– 1:75

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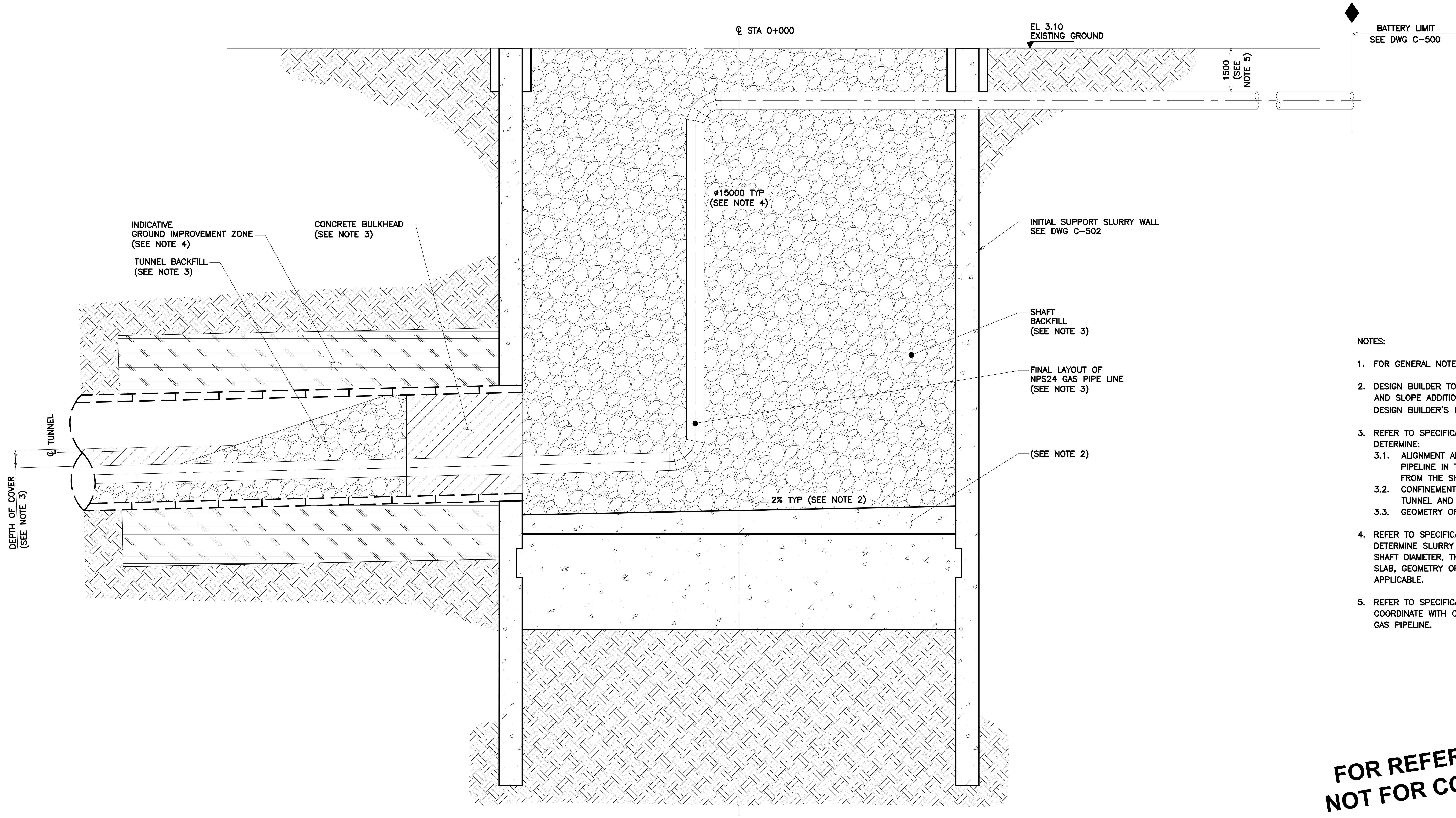
ENGINEER SEAL

EGP TUNNEL PROJECT

EAST SHAFT
SLURRY WALL – APPROACH

DRAWING NUMBER C–504



SECTION A
1:75 C-503

NOTES:

1. FOR GENERAL NOTES SEE DRAWING G-501.
2. DESIGN BUILDER TO DETERMINE CONCRETE BACKFILL AND SLOPE ADDITIONAL TO TREMIE SLAB, AS PER DESIGN BUILDER'S MEANS AND METHODS.
3. REFER TO SPECIFICATIONS AND DESIGN BUILDER TO DETERMINE:
   - 3.1. ALIGNMENT AND LAYOUT OF NATURAL GAS PIPELINE IN THE TUNNEL, IN THE SHAFT, AND FROM THE SHAFT UP TO THE BATTERY LIMIT
   - 3.2. CONFINEMENT PIPELINE AND BACKFILL OF THE TUNNEL AND OF THE SHAFT.
   - 3.3. GEOMETRY OF THE CONCRETE BULKHEAD
4. REFER TO SPECIFICATIONS AND DESIGN BUILDER TO DETERMINE SLURRY WALL GEOMETRY AND DEPTH, SHAFT DIAMETER, THICKNESS, AND DETAILS OF TREMIE SLAB, GEOMETRY OF GROUND IMPROVEMENT, AS APPLICABLE.
5. REFER TO SPECIFICATIONS AND DESIGN BUILDER TO COORDINATE WITH COMPANY FOR DEPTH OF NATURAL GAS PIPELINE.

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NOT FOR CONSTRUCTION

2m 0 5m
SCALE IN METERS
SCALE 1 = 75

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BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY-MM-DD)
McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	M.MOCCICHINO	D.GRIMES	2019-11-15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-10-21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	A	ISSUED FOR TRP SESSION 1	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-05-01

PROJECT NO.- 5372.3 | PREVIOUS DR. NO.- - | SCALE- 1:75

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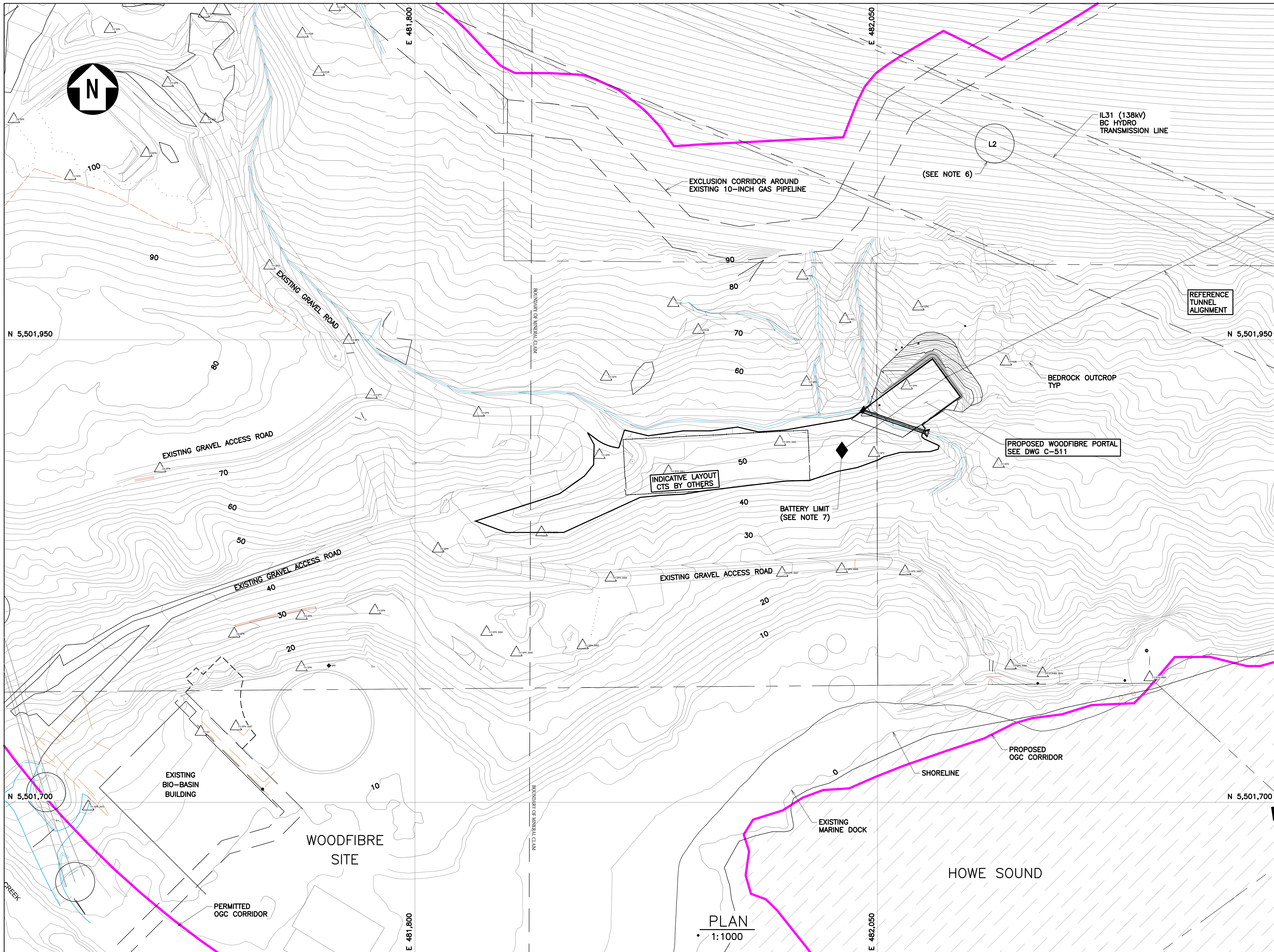
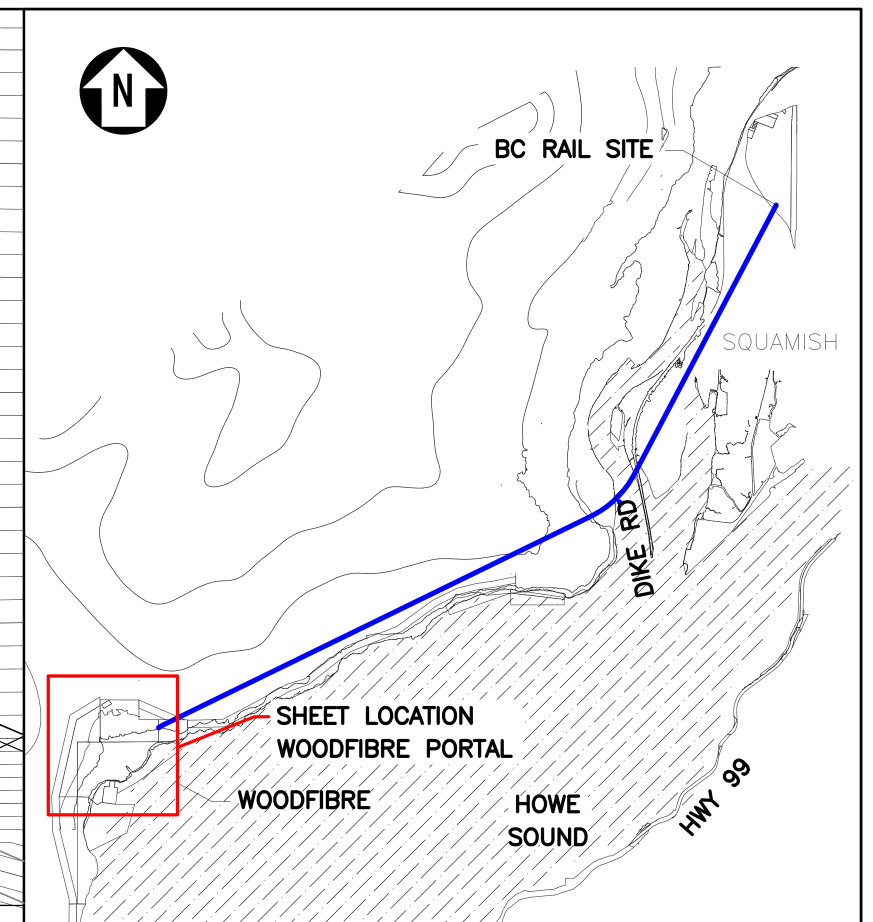
EGP TUNNEL PROJECT

EAST SHAFT
SLURRY WALL - APPROACH
BACKFILL SECTION

DRAWING NUMBER C-505



PLAN
1:1000



KEY PLAN
NTS

NOTES:

1. SEE DRAWING G-501 FOR GENERAL NOTES.
2. TOPOGRAPHIC INFORMATION SHOWN ON THIS DRAWING IS BASED ON MAY 2019 FIELD SURVEY RECEIVED FROM SOLARIS MANAGEMENT CONSULTANTS INC.
3. ELEVATIONS ARE IN METRES AND ARE REFERRED TO GEODETIC DATUM CGVD28 USING GEOID MODEL HTV2.0. THIS PLAN SHOWS GRID MEASURED DISTANCES.
4. SEE DRAWING C-511 FOR WOODFIBRE PORTAL EXCAVATION.
5. SEE DRAWING C-512 FOR WOODFIBRE PORTAL CROSS SECTIONS.
6. "L2" IS NEAREST BC HYDRO TRANSMISSION TOWER TO THE WOODFIBRE PORTAL.
7. REFER TO SPECIFICATIONS FOR NATURAL GAS PIPELINE BATTERY LIMITS.

LEGEND

PROPERTY LINE
RIGHT OF WAY
50 MAJOR CONTOUR (10m)
MINOR CONTOUR (2m)
PROPOSED LAYDOWN AREA/SPOILS DISPOSAL
EXISTING CREEK
SURVEY SPIKE

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20m 0 50m

SCALE IN METERS
SCALE 1 = 1000

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McMILLEN JACOBS ASSOCIATES
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VANCOUVER BC V6E 4A2

BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY-MM-DD)
McMILLEN JACOBS ASSOC.	3	UPDATED LAYDOWN AREA	K.RUSTON	C.HUNT	D.GRIMES	2020-01-23
McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	C.HUNT	D.GRIMES	2019-11-15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	C.HUNT	D.GRIMES	2019-10-21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	C.HUNT	D.GRIMES	2019-07-19

PROJECT NO.- 5372.3 | PREVIOUS DR. NO.- - | SCALE- 1:1000

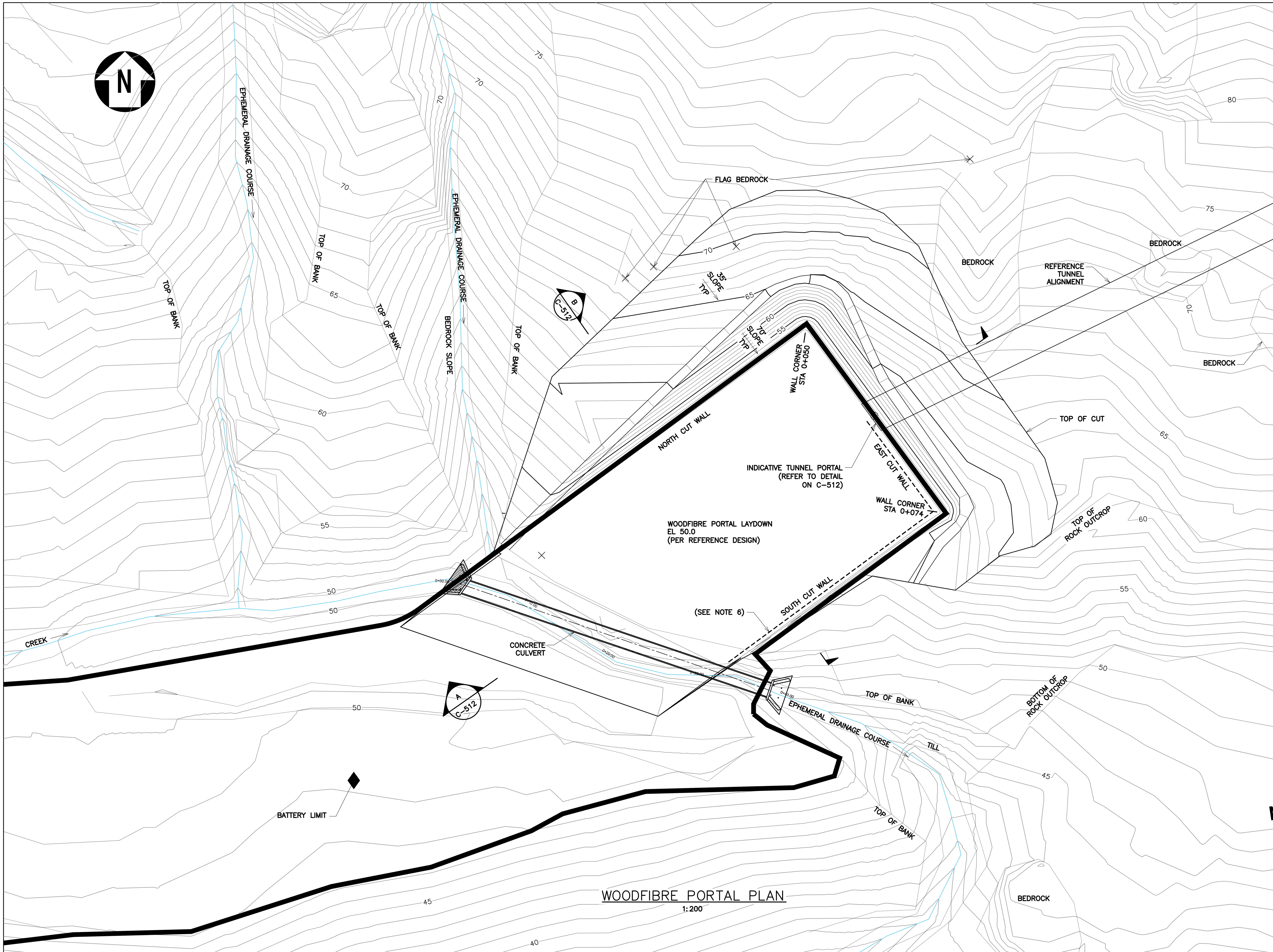
FORTIS BC™

ENGINEER SEAL

EGP TUNNEL PROJECT

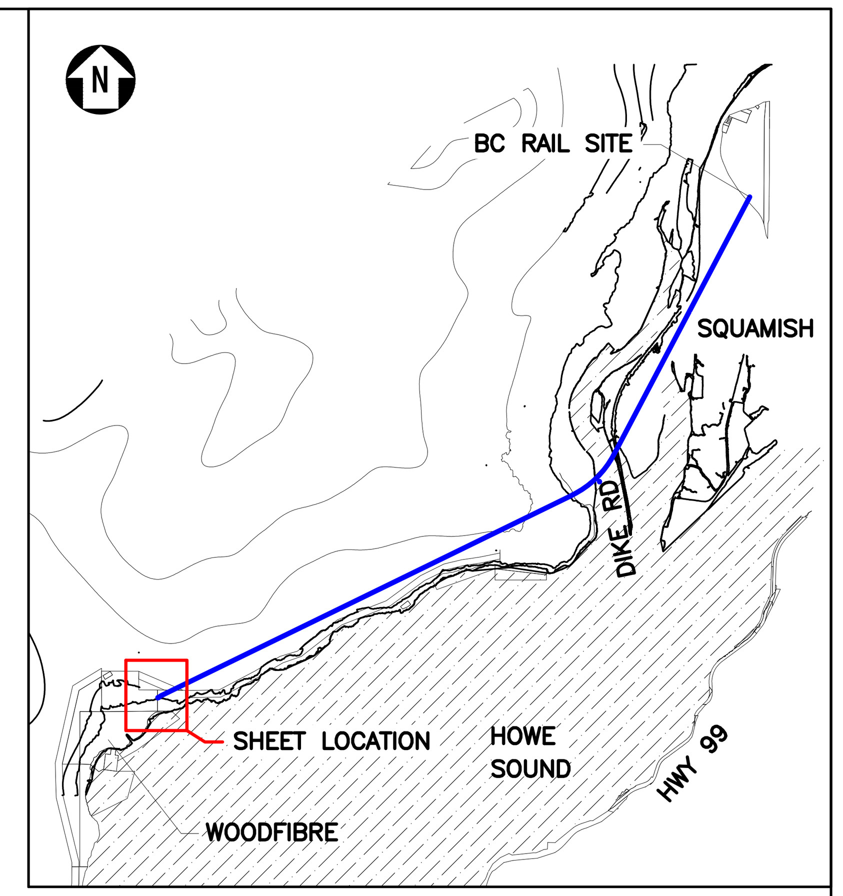
WOODFIBRE PORTAL
EXISTING SITE PLAN

DRAWING NUMBER C-510



WOODFIBRE PORTAL PLAN

1:200



KEY PLAN

NTS

NOTES:

1. FOR GENERAL NOTES SEE DRAWING G-501.
2. FOR TUNNEL COORDINATES SEE DRAWING C-513, C-514, AND C-515.
3. SEE DRAWING C-512 FOR CUT SLOPE WALL PROFILE.
4. CONTOURS SHOWN ARE EXISTING TOPOGRAPHY OUTSIDE OF PORTAL CUT.
5. ACTUAL BEDROCK SURFACE AND ALL SLOPE DESIGN WILL BE DETERMINED BY DESIGN BUILDER.
6. REFER TO SPECIFICATION ON PERMANENT DRAINAGE FROM TUNNEL (IF REQUIRED, WATER TREATMENT WILL BE BY OTHERS).
7. SLOPE ANGLES ARE INDICATIVE AND SHOULD BE CHANGED BASED ON EXPOSED GROUND CONDITIONS.

LEGEND

- 10 MAJOR CONTOUR (5m)
- MINOR CONTOUR (1m)
- PROPOSED LAYDOWN AREA

FOR REFERENCE ONLY NOT FOR CONSTRUCTION

4m 0 10m

SCALE IN METERS

SCALE 1 = 200

McMILLEN JACOBS ASSOCIATES

1188 WEST GEORGIA STREET, SUITE 2000
VANCOUVER BC V6E 4A2

BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY-MM-DD)
McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	C.HUNT	D.GRIMES	2019-11-15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	C.HUNT	D.GRIMES	2019-10-21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	C.HUNT	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	B	ISSUED FOR TRP SESSION 2	K.RUSTON	C.HUNT	D.GRIMES	2019-06-07

PROJECT NO.- 5372.3 PREVIOUS DR. NO.- - SCALE- 1:200

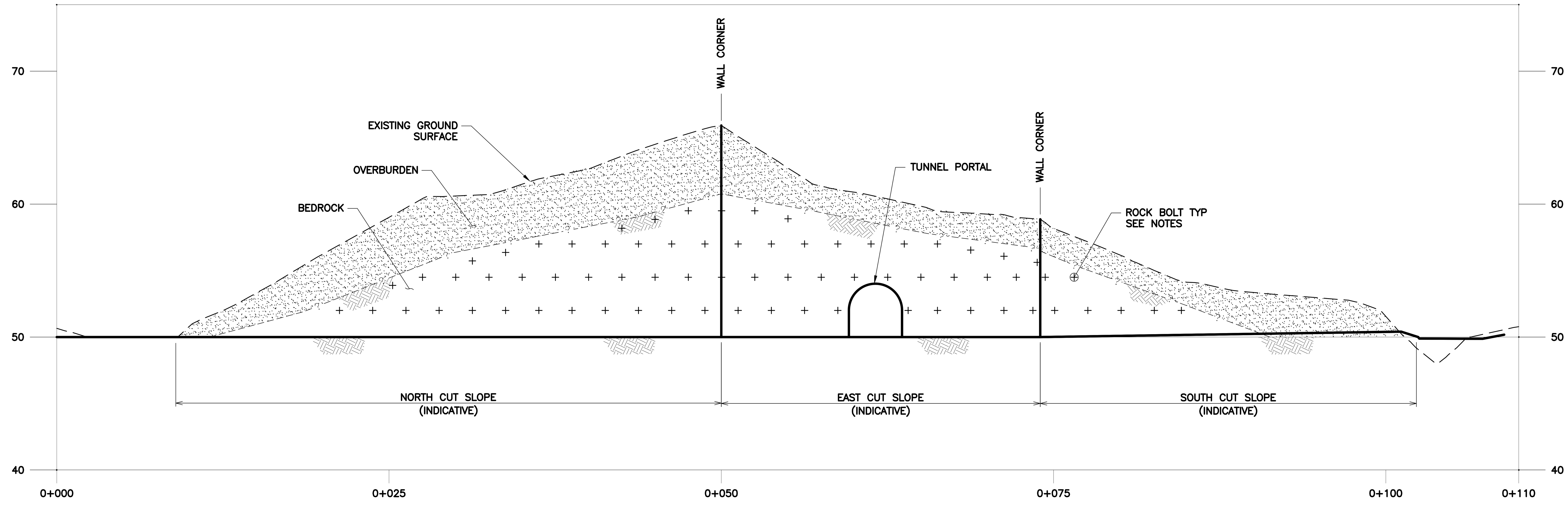
FORTIS BC

ENGINEER SEAL

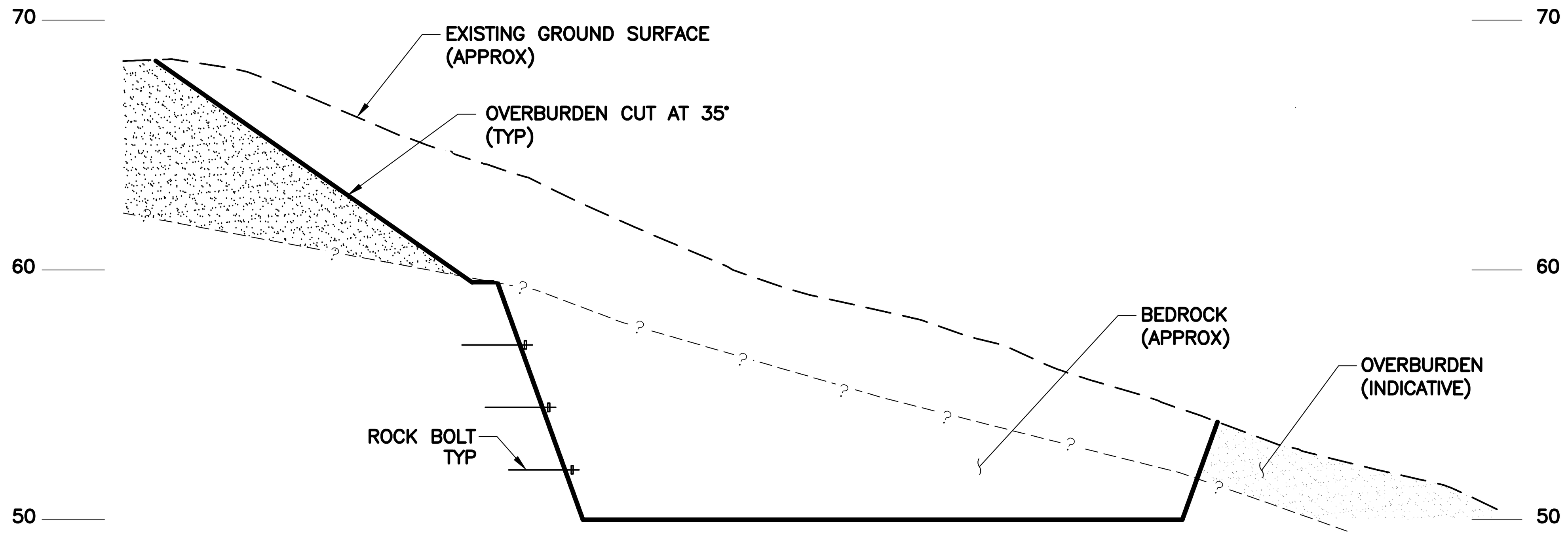
EGP TUNNEL PROJECT

WOODFIBRE PORTAL PROJECT LAND

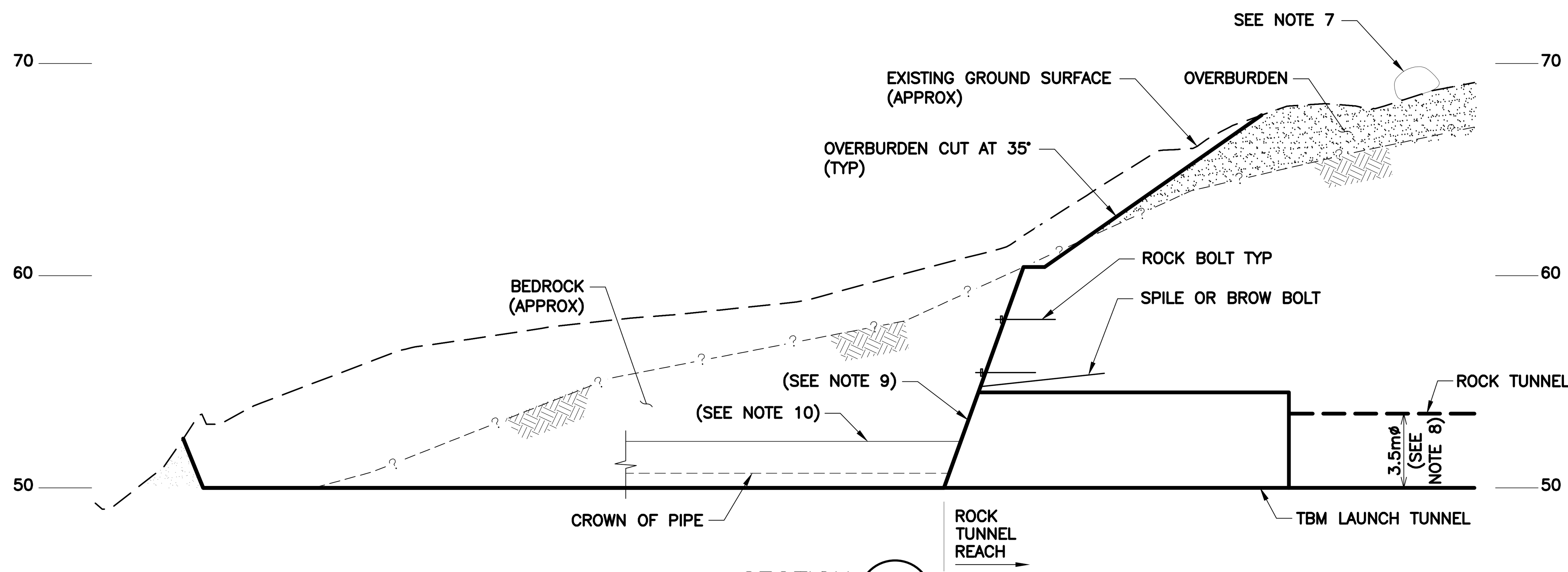
DRAWING NUMBER C-511



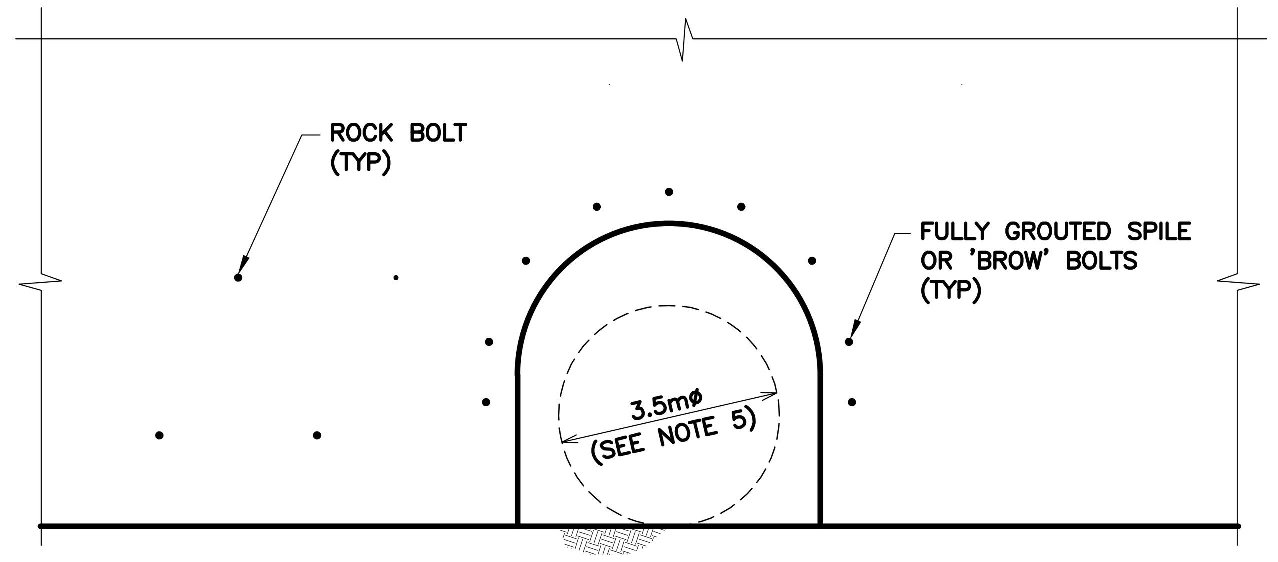
WOODFIBRE PORTAL – CUT WALL DEVELOPED ELEVATION
1:200



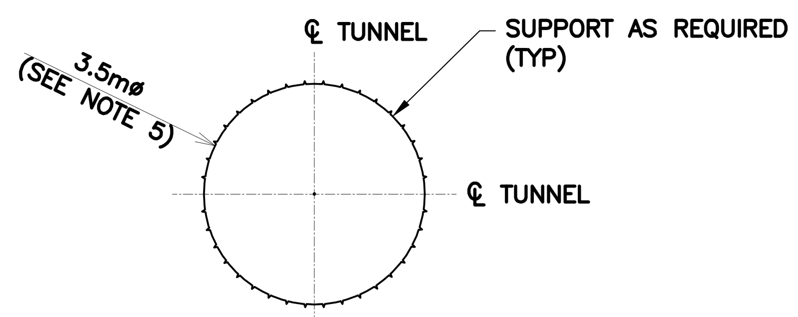
SECTION B
1:200 C-511



SECTION A
1:200 C-511



WOODFIBRE PORTAL – TBM LAUNCH TUNNEL PORTAL
1:100



ROCK TUNNEL – TYPICAL SECTION
1:100

NOTES:

1. FOR GENERAL NOTES, SEE DWG G-501.
2. MAXIMUM PPV AT BC HYDRO TOWER FOUNDATION AND 10 INCH GAS PIPELINE IS 50mm/SEC. MAXIMUM OVER AIR PRESSURE AT SHORELINE OF HOWE SOUND IS 100kPa.
3. FOLLOWING STRIPPING, CONFIRM BEDROCK PROFILE AND ELEVATIONS.
4. DRAINAGE HOLES TO BE DRILLED INTO SLOPE AS REQUIRED.
5. DESIGN BUILDER TO DETERMINE ROCK TUNNEL DIAMETER.
6. ROCK SLOPE SUPPORT SHALL BE CONFIRMED ON SITE FOLLOWING MAPPING AND GEOTECHNICAL ASSESSMENT.
7. ROCKFALL MESH SHOULD BE CONSIDERED AS SHOULD ROCKFALL HAZARD OUTSIDE OF EXCAVATION (BOULDERS).
8. DRAINAGE HOLES TO BE LOCATED IN THE FIELD AS REQUIRED.
9. FOLLOWING COMPLETION OF THE WORKS, THE PIPELINE WILL EXIT FROM THE TUNNEL PORTAL, A GRILLAGE OR SIMILAR WILL BE PLACED TO PREVENT ACCESS TO THE TUNNEL.
10. PIPE SHOULD BE BURIED BY 1.5m OF SOIL FROM THE PORTAL TO THE BATTERY LIMIT (REFER TO SPECIFICATIONS). EXACT PIPE ELEVATION AT THE BATTERY LIMIT IS TO BE DETERMINED BY DESIGN-BUILDER FOLLOWING SITE REGRADING.

FOR REFERENCE ONLY
NOT FOR CONSTRUCTION

2m 0 5m
SCALE IN METERS
SCALE 1 = 100

4m 0 10m
SCALE IN METERS
SCALE 1 = 200

McMILLEN JACOBS ASSOCIATES
1188 WEST GEORGIA STREET, SUITE 2000
VANCOUVER BC V6E 4A2

BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY-MM-DD)
McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	C.HUNT	D.GRIMES	2019-11-15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	C.HUNT	D.GRIMES	2019-10-21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	C.HUNT	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	B	ISSUED FOR TRP SESSION 2	K.RUSTON	C.HUNT	D.GRIMES	2019-06-07

PROJECT NO.- 5372.3 | PREVIOUS DR. NO.- - | SCALE- AS SHOWN

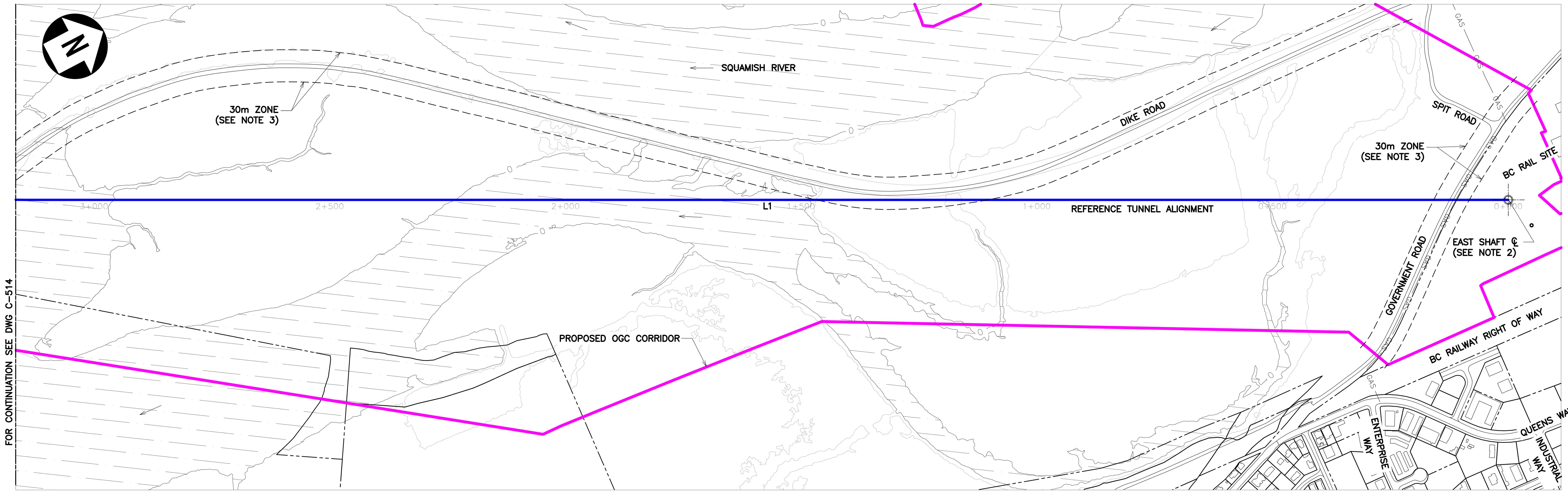
FORTIS BC

ENGINEER SEAL

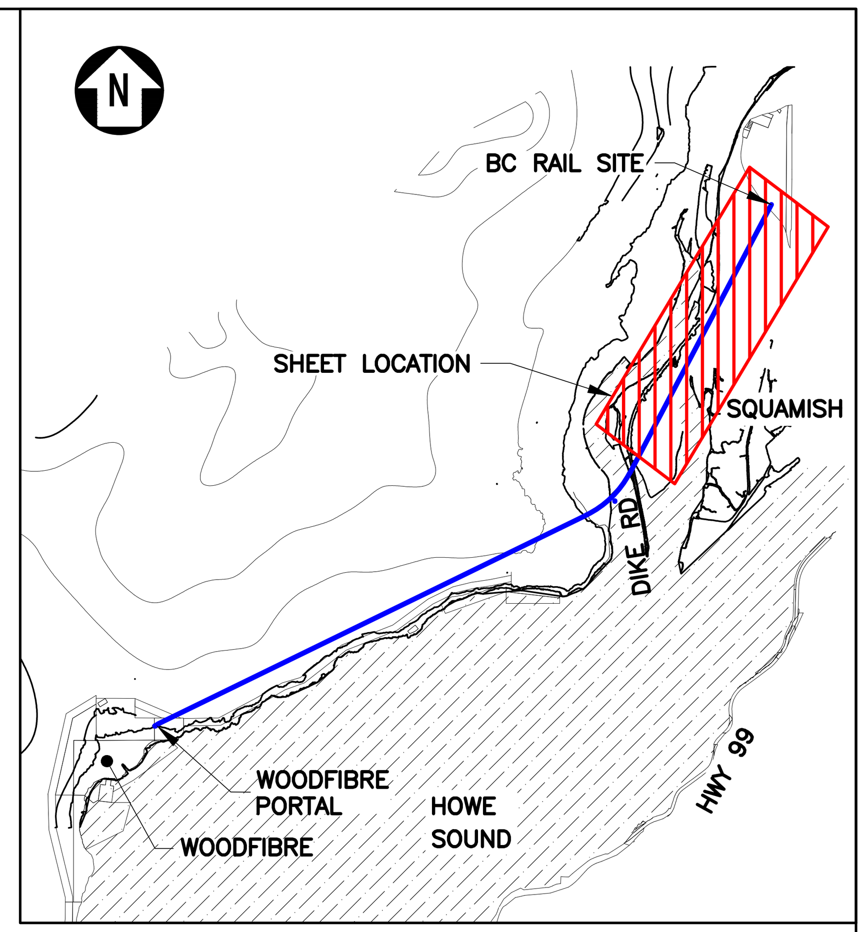
EGP TUNNEL PROJECT

WOODFIBRE PORTAL
PORTAL SECTIONS

DRAWING NUMBER C-512

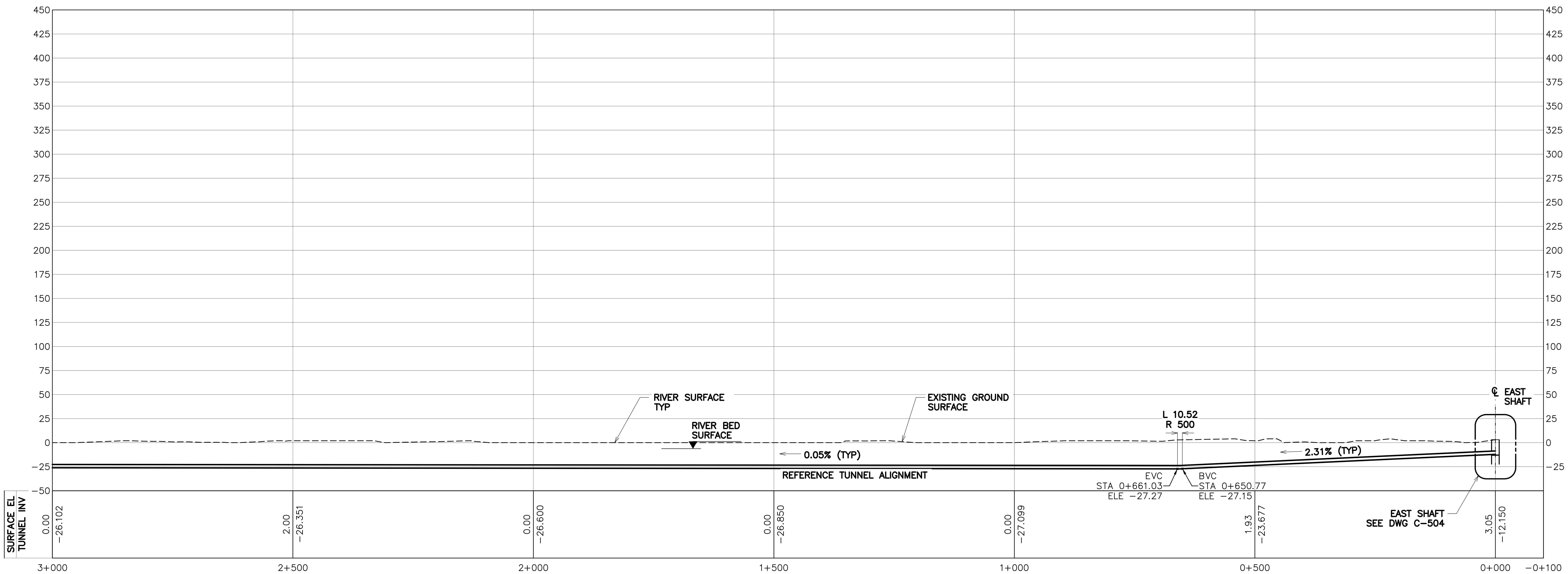


PLAN
1:5000



KEY PLAN
NTS

LINE TABLE (INDICATIVE DESIGN)						
LINE #	DISTANCE	BEARING	START NORTHING	START EASTING	END NORTHING	END EASTING
L1	3144.05m	S27°48'04"W	5507305.12	488432.40	5504234.85	486813.55



PROFILE
HOR 1:5000
VERT 1:2500

NOTES:

1. FOR GENERAL NOTES SEE DRAWING G-501.
2. ℄ COORDINATES OF EAST SHAFT AT STA 0+00
   N 5507305.12
   E 488432.40
3. LOCATION OF CONCRETE BULKHEAD(S), OR EQUIVALENT SOLUTION THAT PREVENTS THE POTENTIAL COLLAPSE OF THE SEGMENTAL LINING – REFER TO SPECIFICATIONS.

LEGEND

- PROPERTY LINE
- 0 — MAJOR CONTOUR (50m)
- 10 — MINOR CONTOUR (10m)
- GAS — EXISTING GAS TRANSMISSION PRESSURE LINE
- PROPOSED OGC CORRIDOR
- REFERENCE TUNNEL ALIGNMENT

FOR REFERENCE ONLY
NOT FOR CONSTRUCTION

80m 0 200m
SCALE IN METERS
HOR SCALE 1 = 5000

40m 0 100m
SCALE IN METERS
SCALE 1 = 2500

McMILLEN JACOBS ASSOCIATES
1188 WEST GEORGIA STREET, SUITE 2000
VANCOUVER BC V6E 4A2

BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY-MM-DD)
McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	M.MOCCICHINO	D.GRIMES	2019-11-15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-10-21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	B	ISSUED FOR TRP SESSION 2	O.NAAS	M.MOCCICHINO	D.GRIMES	2019-06-07

PROJECT NO.– 5372.3 | PREVIOUS DR. NO.– – | SCALE– AS SHOWN

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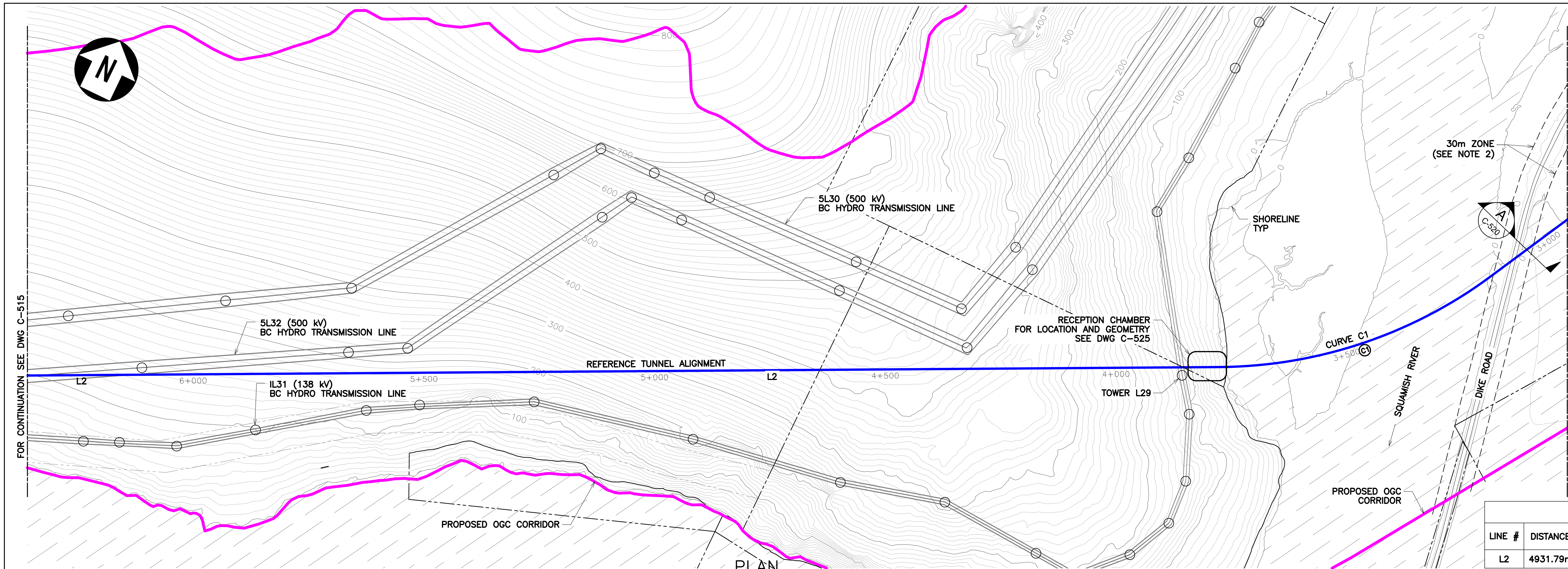
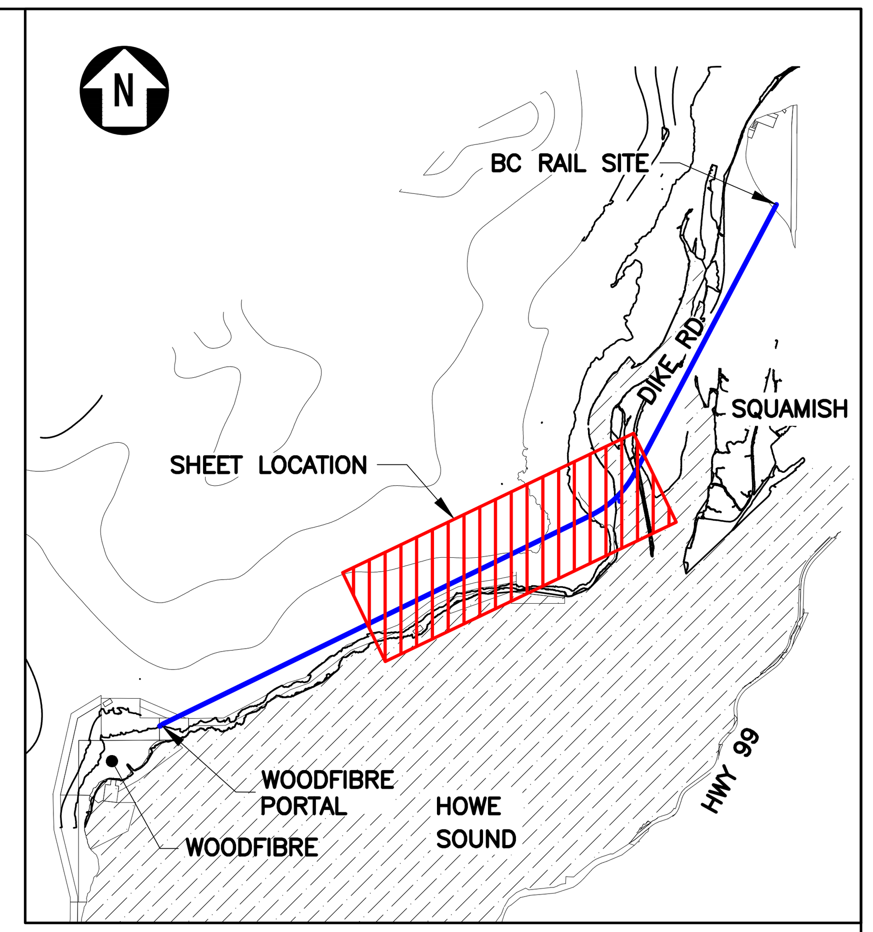
EGP TUNNEL PROJECT

TUNNEL PLAN AND PROFILE
REFERENCE ALIGNMENT C4 – SHEET 1

DRAWING NUMBER C-513



PLAN
1:5000



KEY PLAN
NTS

LINE TABLE (INDICATIVE DESIGN)						
LINE #	DISTANCE	BEARING	START NORTHING	START EASTING	END NORTHING	END EASTING
L2	4931.79m	S64°00'07"W	5504234.85	486813.55	5501929.76	482087.03

CURVE TABLE (INDICATIVE)						
CURVE #	RADIUS	LENGTH	CHORD BEARING	CHORD LENGTH	PI NORTHING	PI EASTING
C1	1000.00m	631.82m	S45°54'05"W	621.37m	5504234.85	486813.55

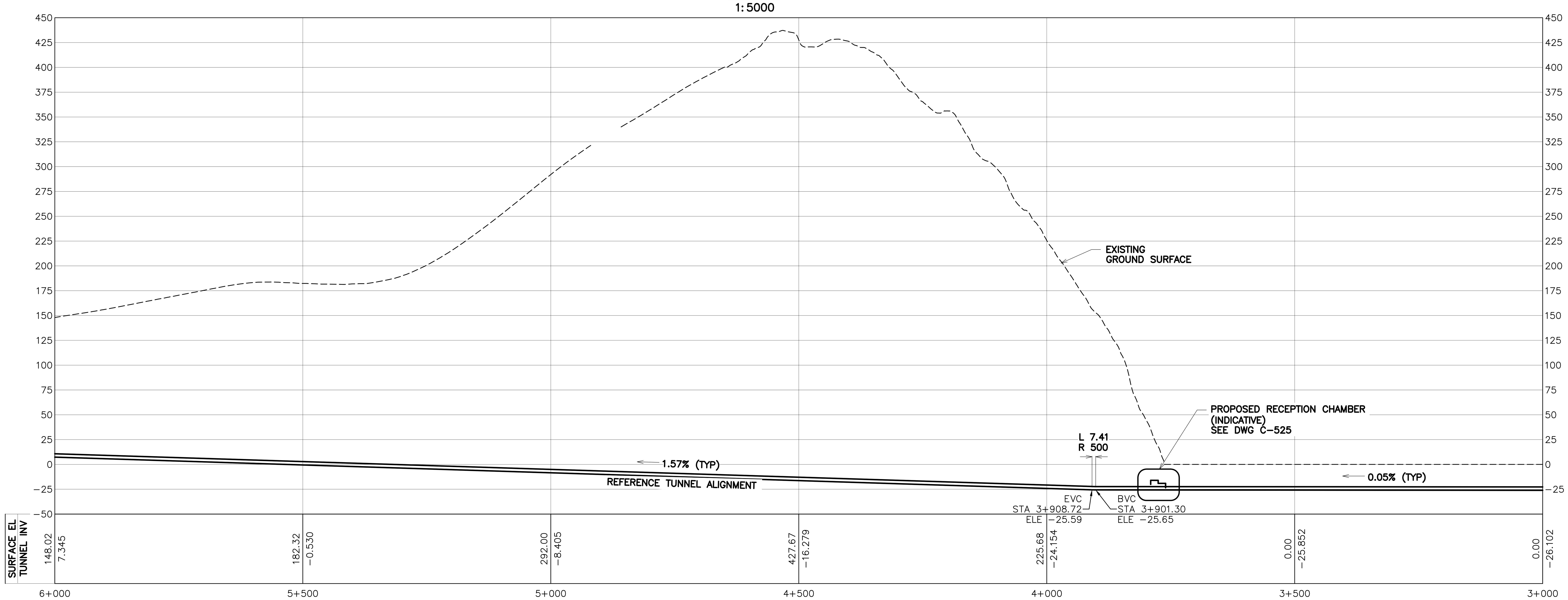
NOTES:

1. FOR GENERAL NOTES SEE DRAWING G-501.
2. LOCATION OF CONCRETE BULKHEAD(S), OR EQUIVALENT SOLUTION THAT PREVENTS THE POTENTIAL COLLAPSE OF THE SEGMENTAL LINING – REFER TO SPECIFICATIONS.

LEGEND

- PROPERTY LINE
- 0 MAJOR CONTOUR (50m)
- 10 MINOR CONTOUR (10m)
- GAS EXISTING GAS LINE (TRANSMISSION PRESSURE)
- PROPOSED OGC CORRIDOR
- REFERENCE TUNNEL ALIGNMENT
- BC HYDRO TRANSMISSION LINE TOWER

**FOR REFERENCE ONLY
NOT FOR CONSTRUCTION**



PROFILE
HOR 1:5000
VERT 1:2500

80m 0 200m
SCALE IN METERS
HOR SCALE 1 = 5000

40m 0 100m
SCALE IN METERS
SCALE 1 = 2500

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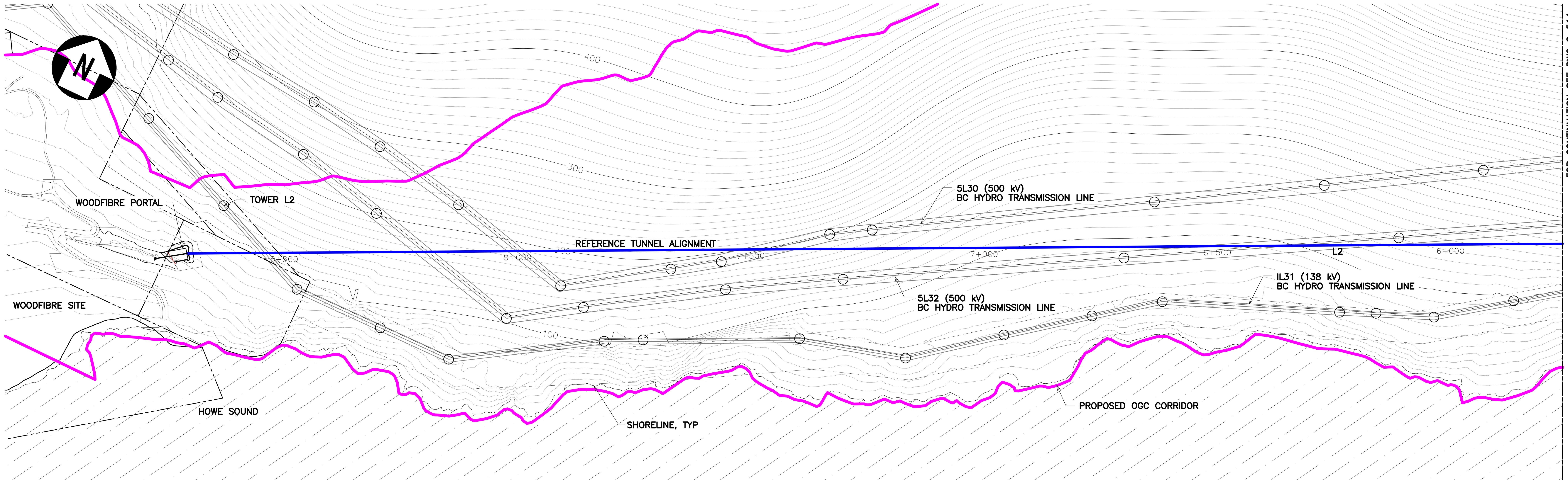
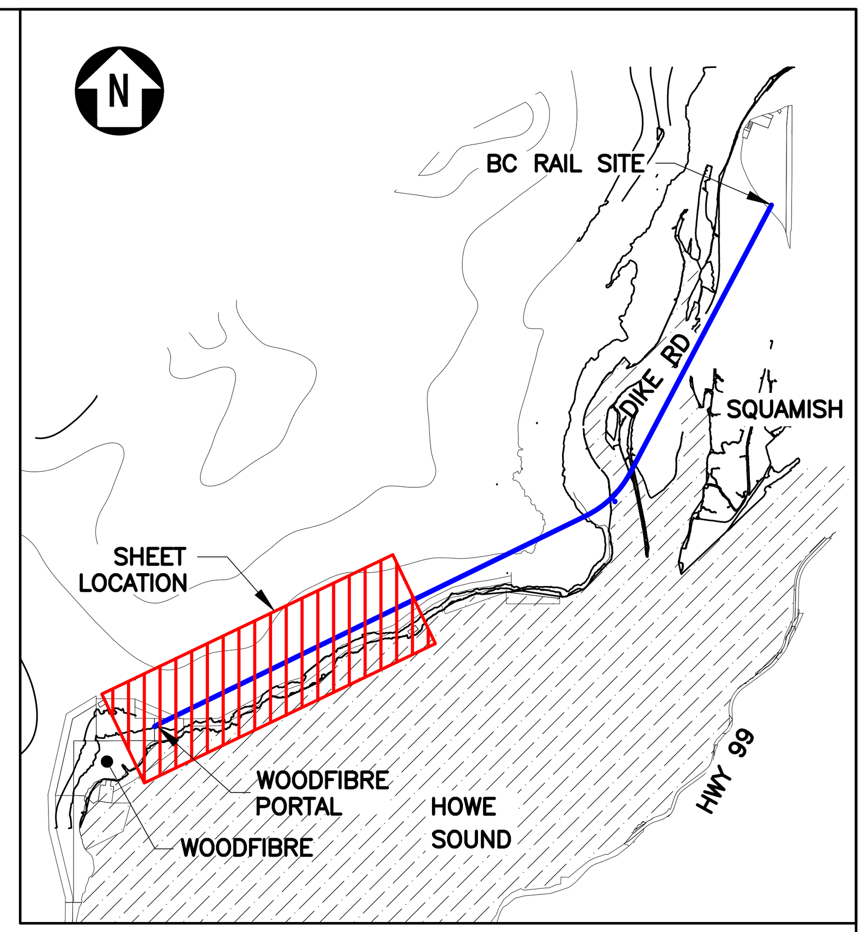
TUNNEL PLAN AND PROFILE
REFERENCE ALIGNMENT C4 – SHEET 2

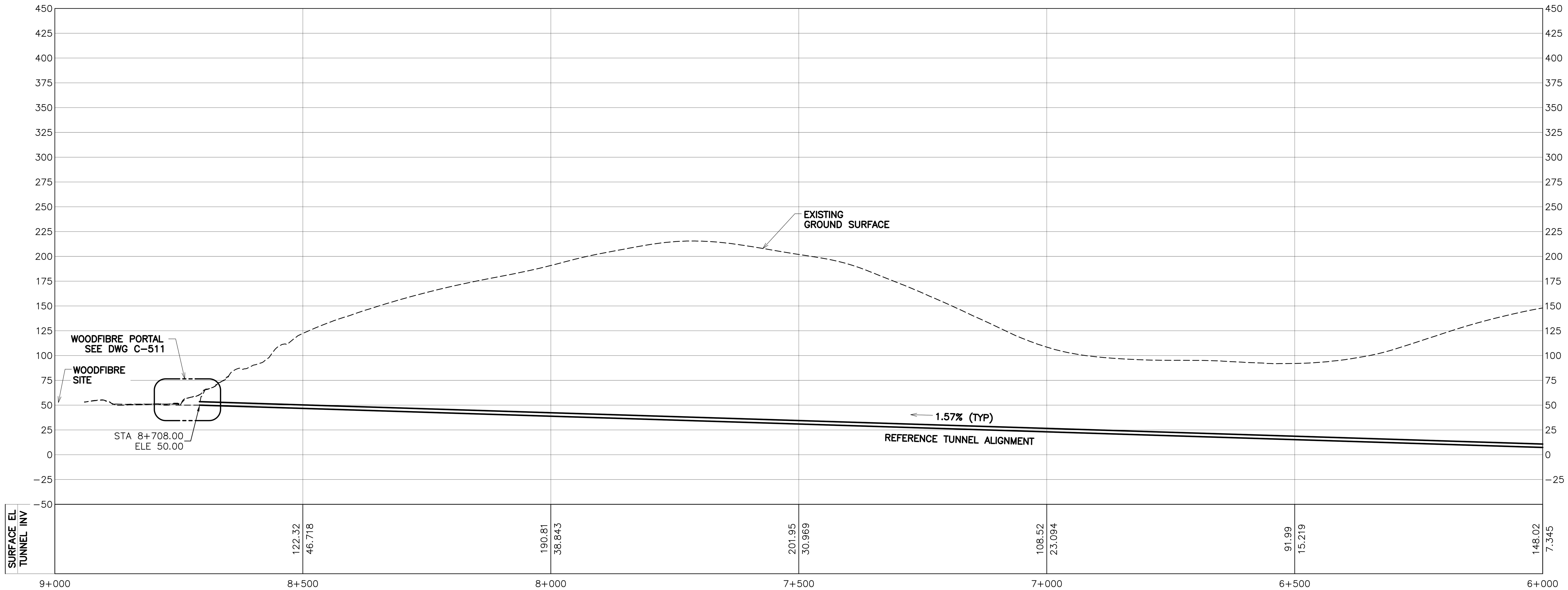
DRAWING NUMBER C-514



PLAN
1:5000



KEY PLAN
NTS



PROFILE
HOR 1:5000
VERT 1:2500

NOTE:

1. FOR GENERAL NOTES SEE DRAWING G-501.

LEGEND

- PROPERTY LINE
- 0 MAJOR CONTOUR (50m)
- 10 MINOR CONTOUR (10m)
- GAS EXISTING GAS LINE (TRANSMISSION PRESSURE)
- PROPOSED OGC CORRIDOR
- REFERENCE TUNNEL ALIGNMENT
- BC HYDRO TRANSMISSION LINE TOWER

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NOT FOR CONSTRUCTION

80m 0 200m
SCALE IN METERS
HOR SCALE 1 = 5000

40m 0 100m
SCALE IN METERS
SCALE 1 = 2500

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McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	B	ISSUED FOR TRP SESSION 2	O.NAAS	M.MOCCICHINO	D.GRIMES	2019-06-07

PROJECT NO.- 5372.3 PREVIOUS DR. NO.- - SCALE- AS SHOWN

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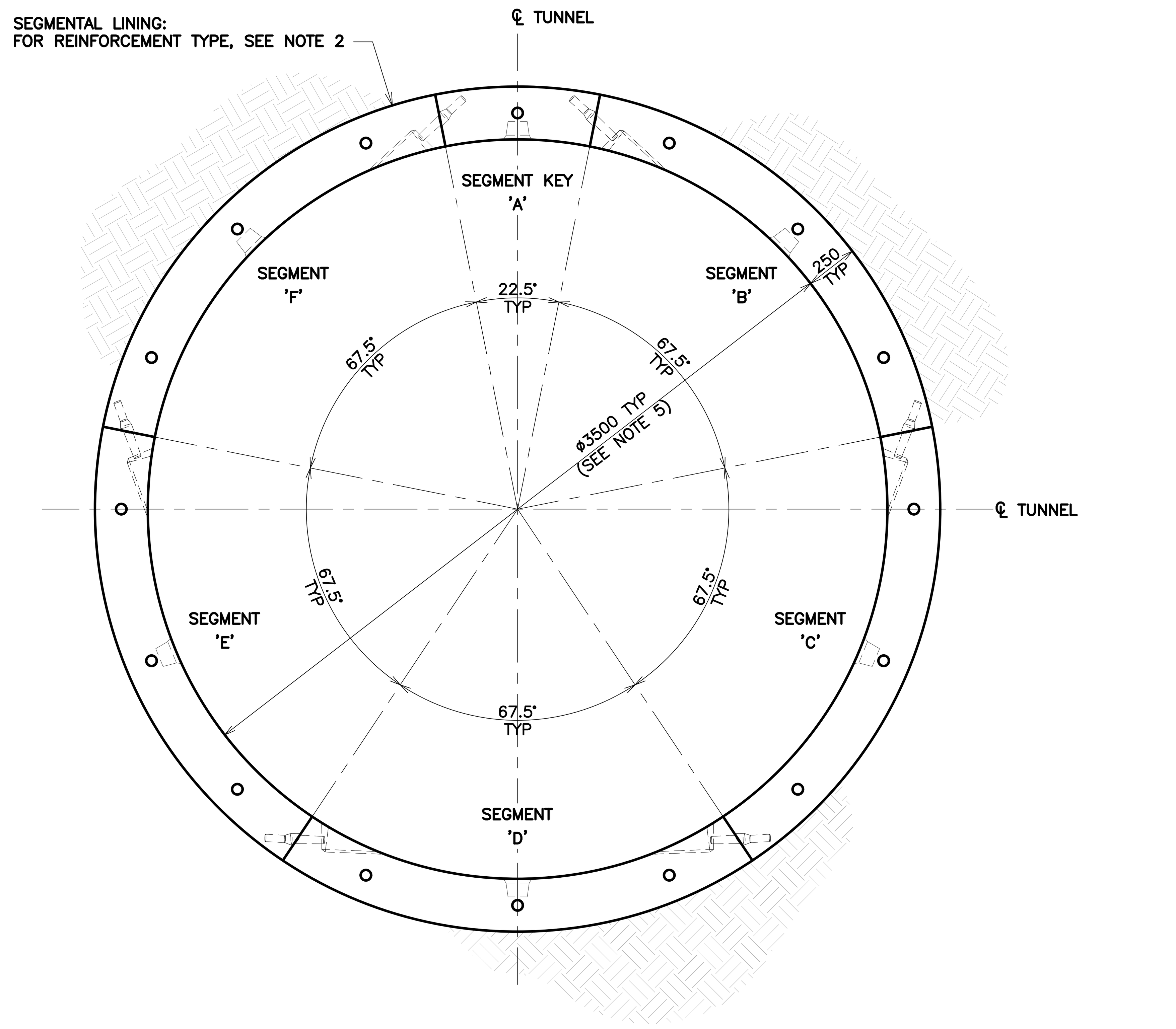
EGP TUNNEL PROJECT

TUNNEL PLAN AND PROFILE
REFERENCE ALIGNMENT C4 - SHEET 3

DRAWING NUMBER C-515

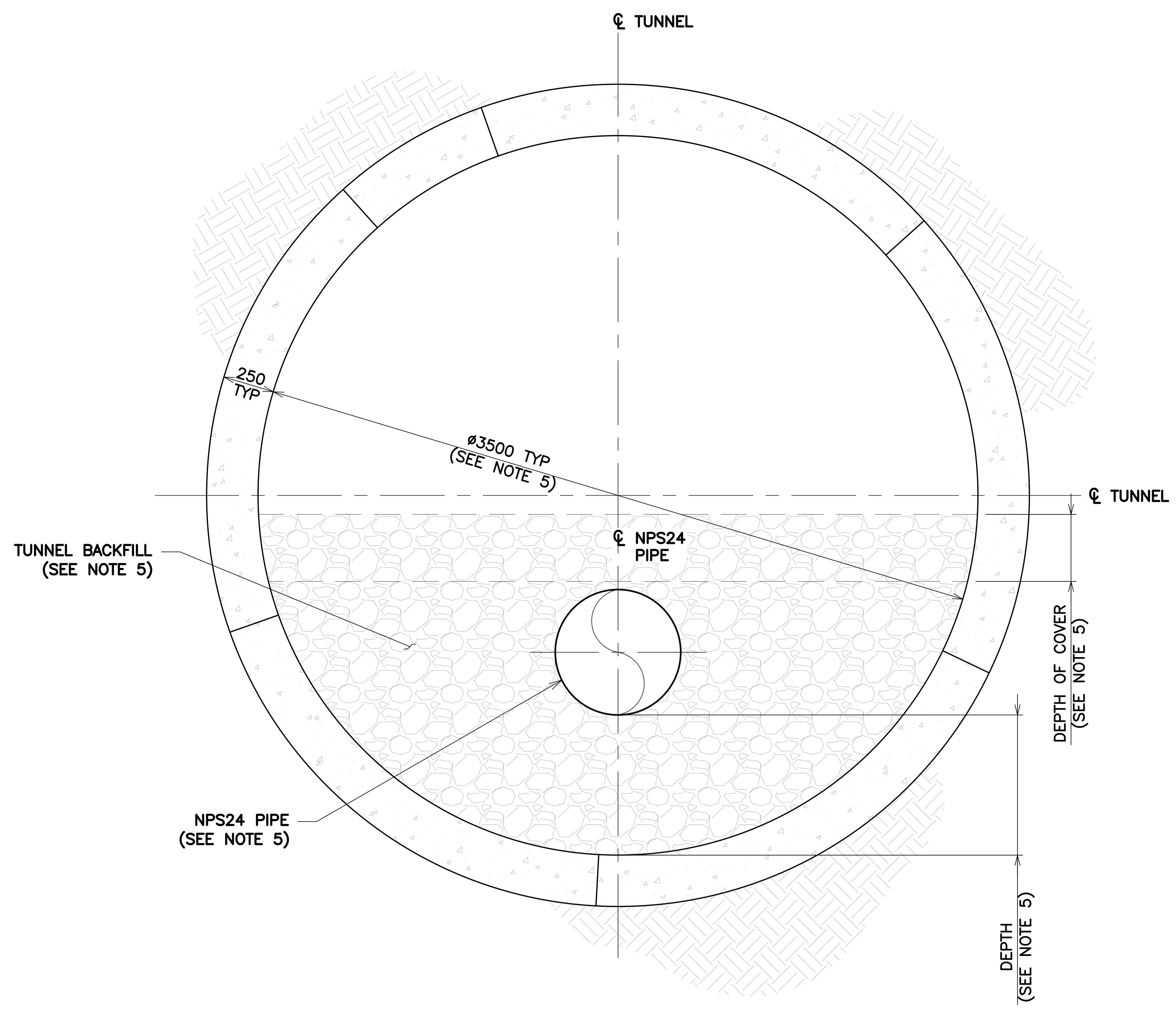
NOTES:

1. FOR GENERAL NOTES SEE DRAWING G-501.
2. REFER TO SPECIFICATIONS.
3. TUNNEL SECTION IS FROM STA 0+008 UP TO END OF SOFT GROUND TUNNEL.
4. SUPPORTS FOR NATURAL GAS PIPE INSTALLATION ARE NOT SHOWN FOR CLARITY.
5. REFER TO SPECIFICATIONS. DESIGN BUILDER TO DETERMINE THE SEGMENTAL LINING INTERNAL DIAMETER AND THICKNESS, THE CONFIGURATION AND THE CONFINEMENT OF THE NATURAL GAS PIPELINE IN THE TUNNEL.



TYPICAL SOFT GROUND TUNNEL SEGMENTAL LINING SECTION (UNIVERSAL RING)

SECTION A / C-513
1:20



TYPICAL SOFT GROUND TUNNEL CROSS SECTION

SECTION A / C-513
1:20

FOR REFERENCE ONLY
NOT FOR CONSTRUCTION

0.50m 0 1m
SCALE IN METERS
SCALE 1 = 20

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BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YYYY-MM-DD)
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McMILLEN JACOBS ASSOC.	A	ISSUED FOR TRP SESSION 1	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-05-01

PROJECT NO.- 5372.3
PREVIOUS DR. NO.- -
SCALE- 1:20

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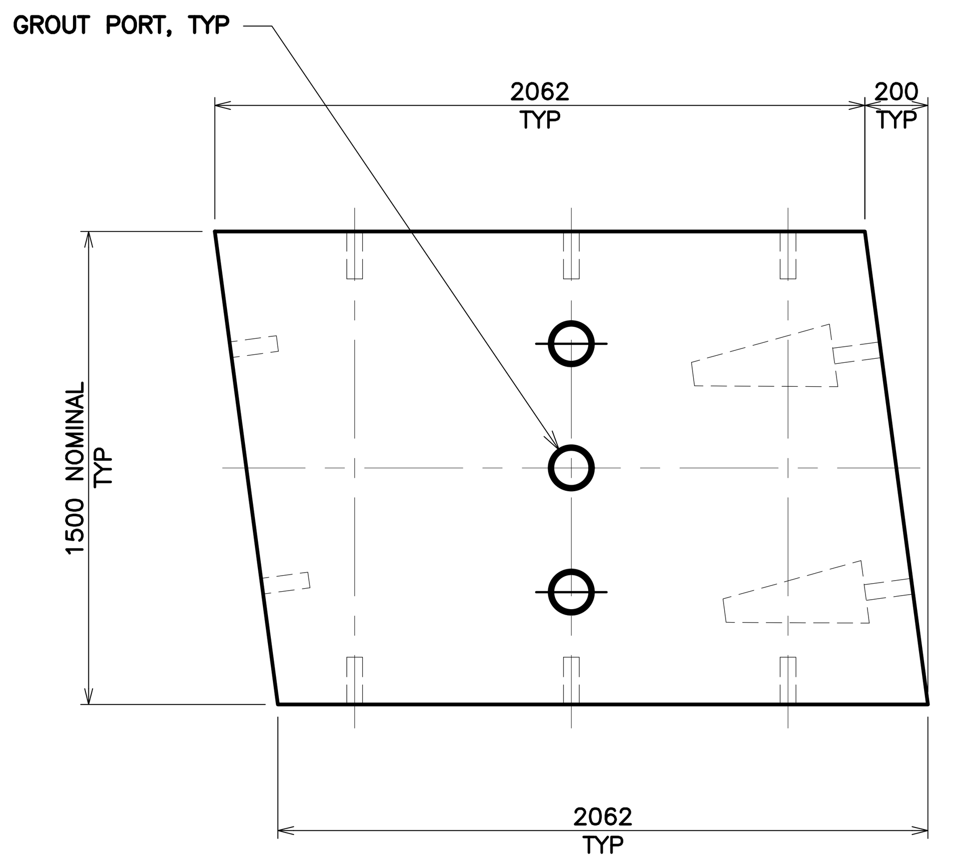
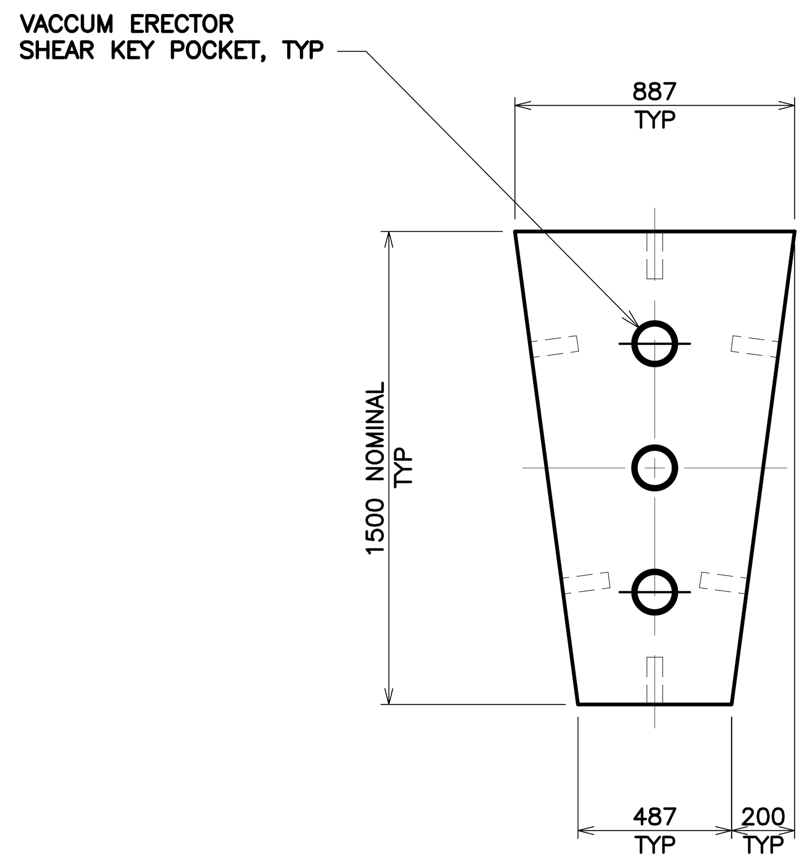
EGP TUNNEL PROJECT

SOFT GROUND TUNNEL
TYPICAL SECTIONS

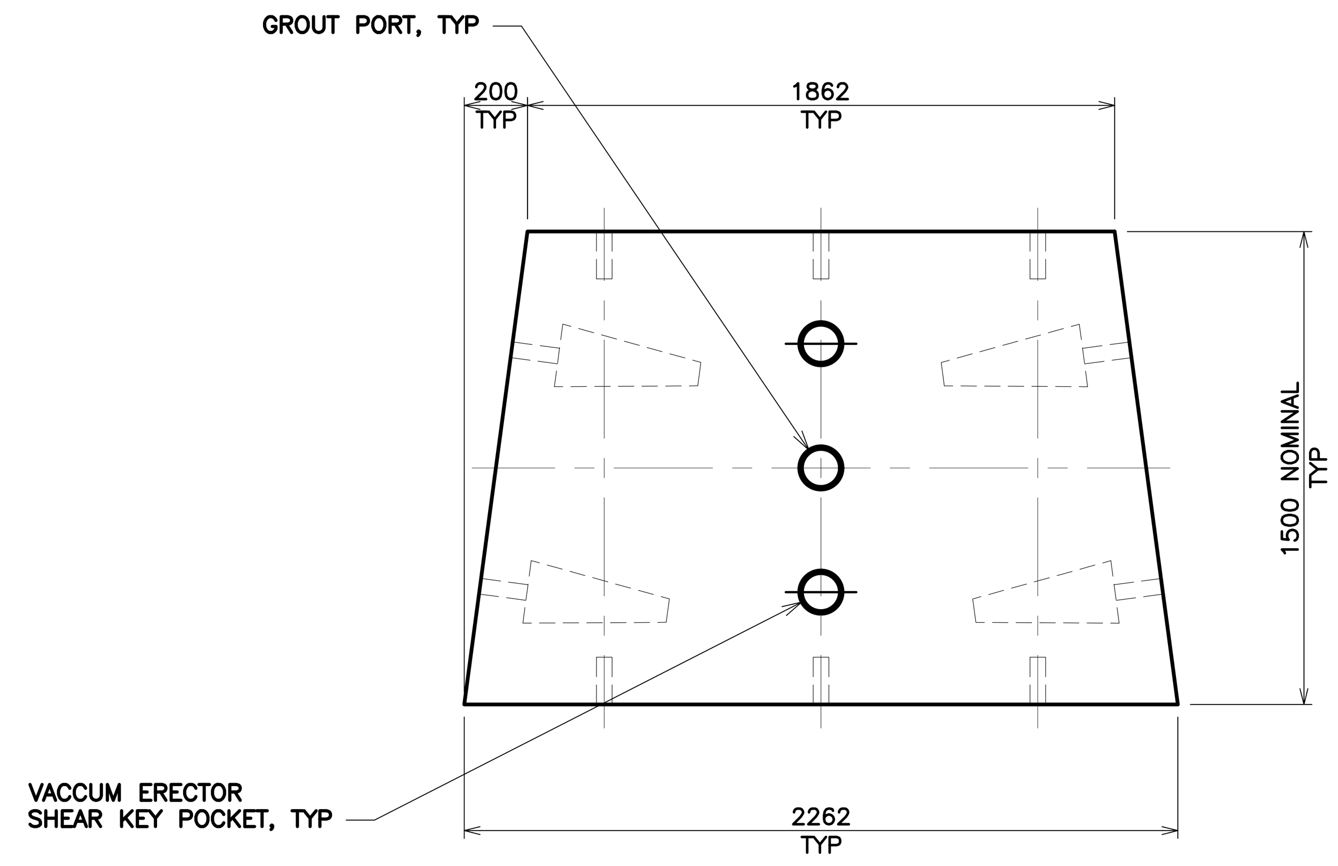
DRAWING NUMBER C-520



DEVELOPED PLAN SEGMENT E AND F (B AND C SIMILAR), INTRADOS FACE
SCALE 1:20



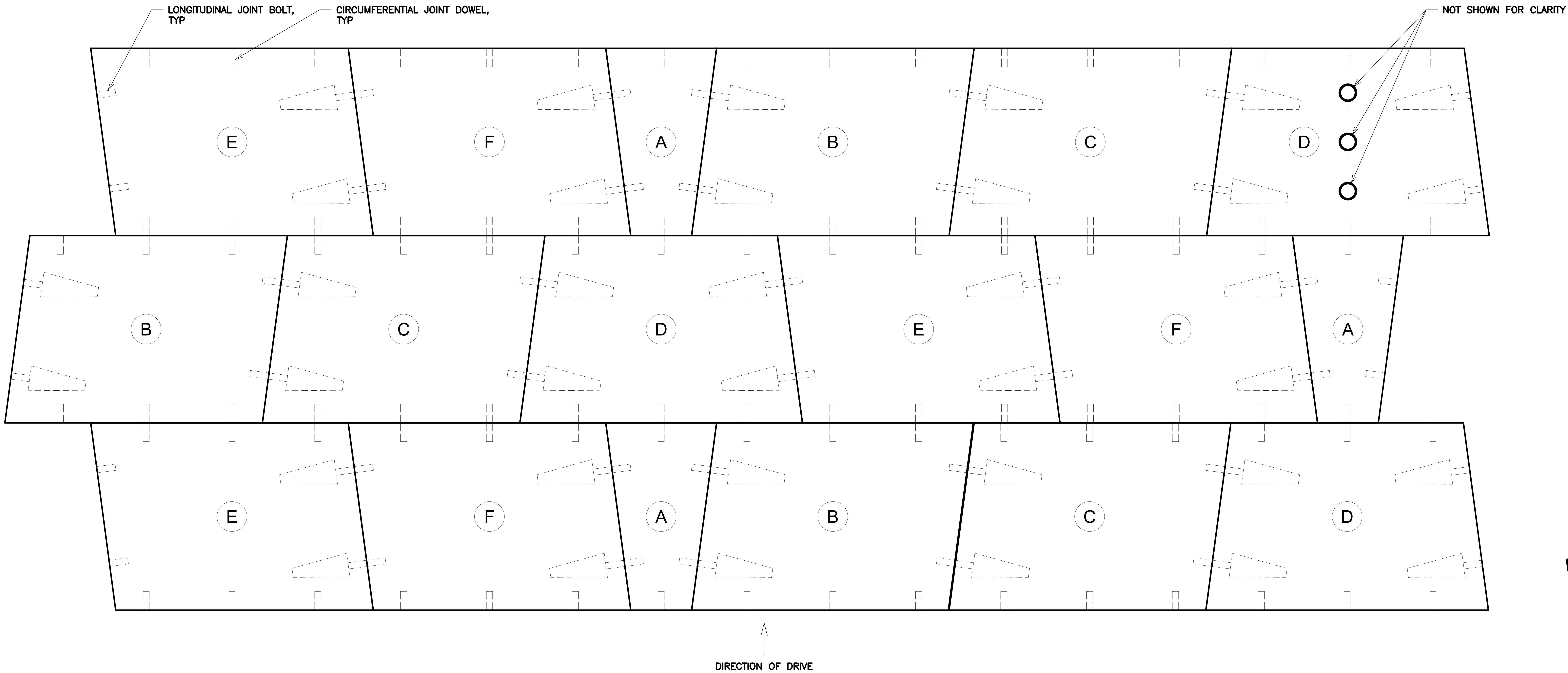
DEVELOPED PLAN SEGMENT A, INTRADOS FACE
SCALE 1:20



DEVELOPED PLAN SEGMENT D, INTRADOS FACE
SCALE 1:20

NOTES:

1. FOR GENERAL NOTES SEE DRAWING G-501.
2. TAPER NOT SHOWN FOR CLARITY.
3. DESIGN BUILDER TO DETERMINE UNIVERSAL RING TAPER BASED ON DESIGN BUILDER'S FINAL ALIGNMENT.
4. FINAL DESIGN JOINT DETAIL TO INCLUDE EPDM GASKET.



SOFT GROUND TUNNEL SEGMENTAL LINING LAYOUT
SCALE 1:20

FOR REFERENCE ONLY
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0.50m 0 1m
SCALE IN METERS
SCALE 1 = 20

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McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	A	ISSUED FOR TRP SESSION 1	K.RUSTON	M.MOCCICHINO	D.GRIMES	2019-05-01

PROJECT NO.- 5372.3
PREVIOUS DR. NO.- -
SCALE- 1:20

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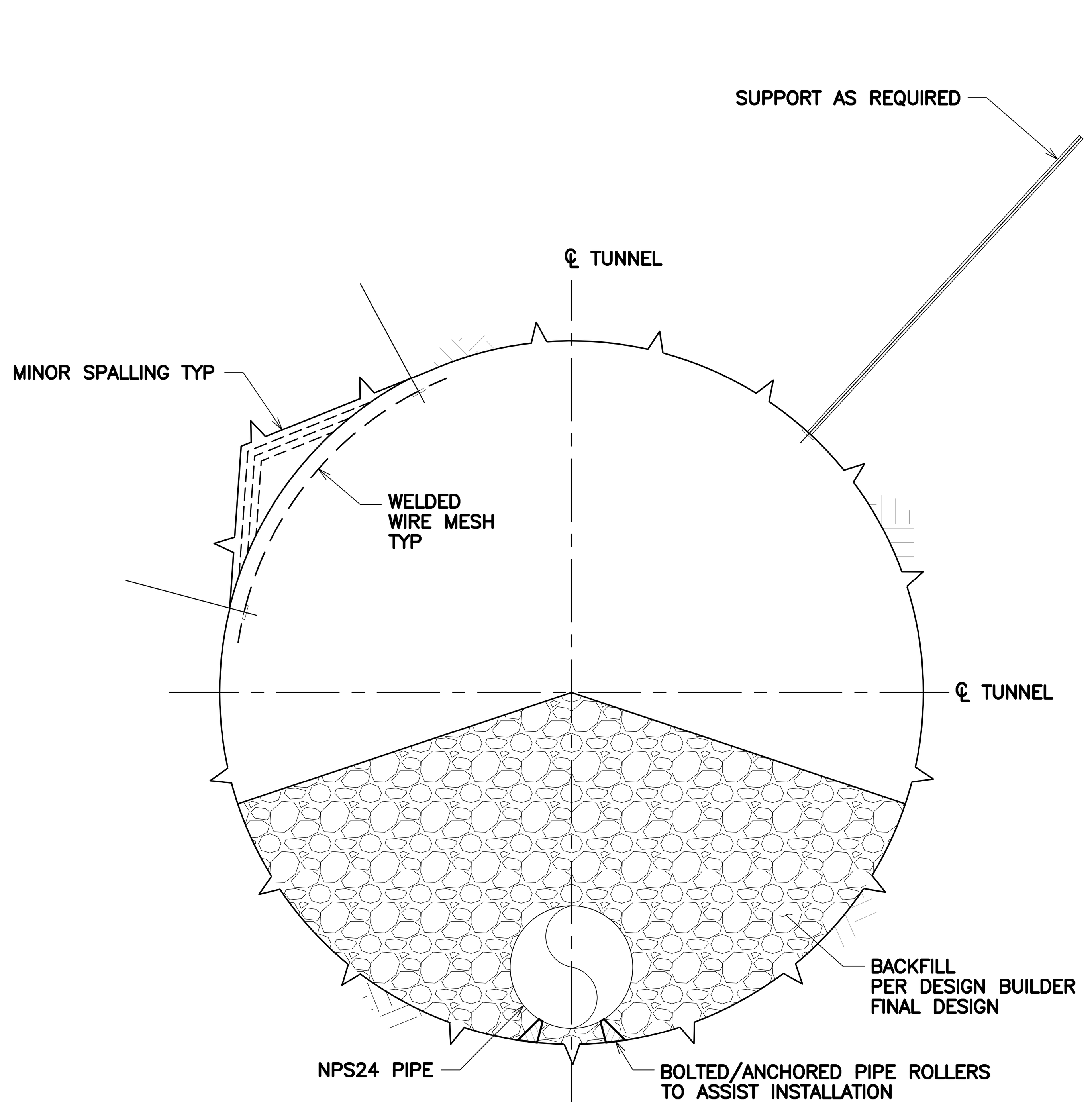
EGP TUNNEL PROJECT

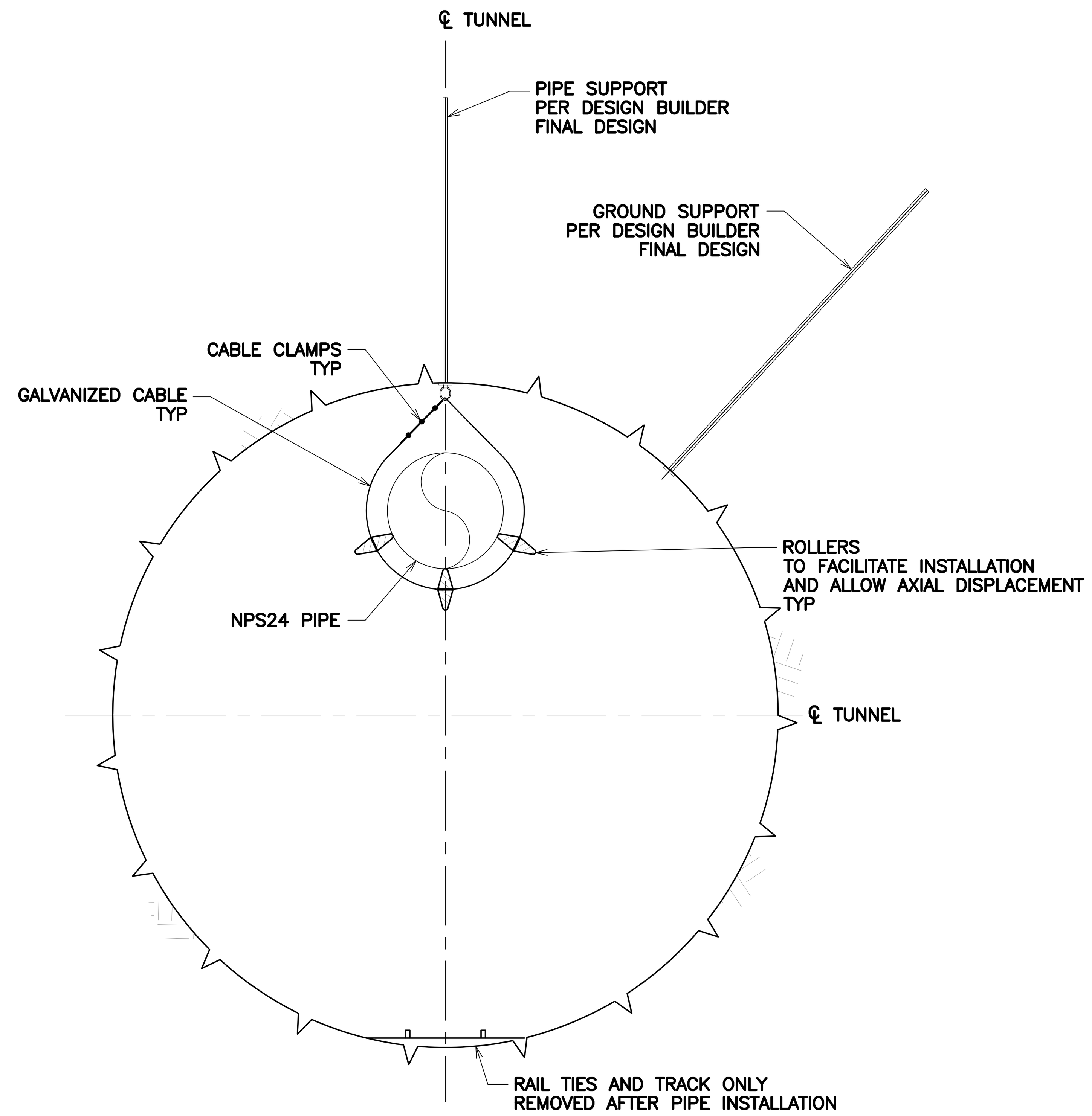
SOFT GROUND TUNNEL
SEGMENTAL LINING LAYOUT

DRAWING NUMBER C-521

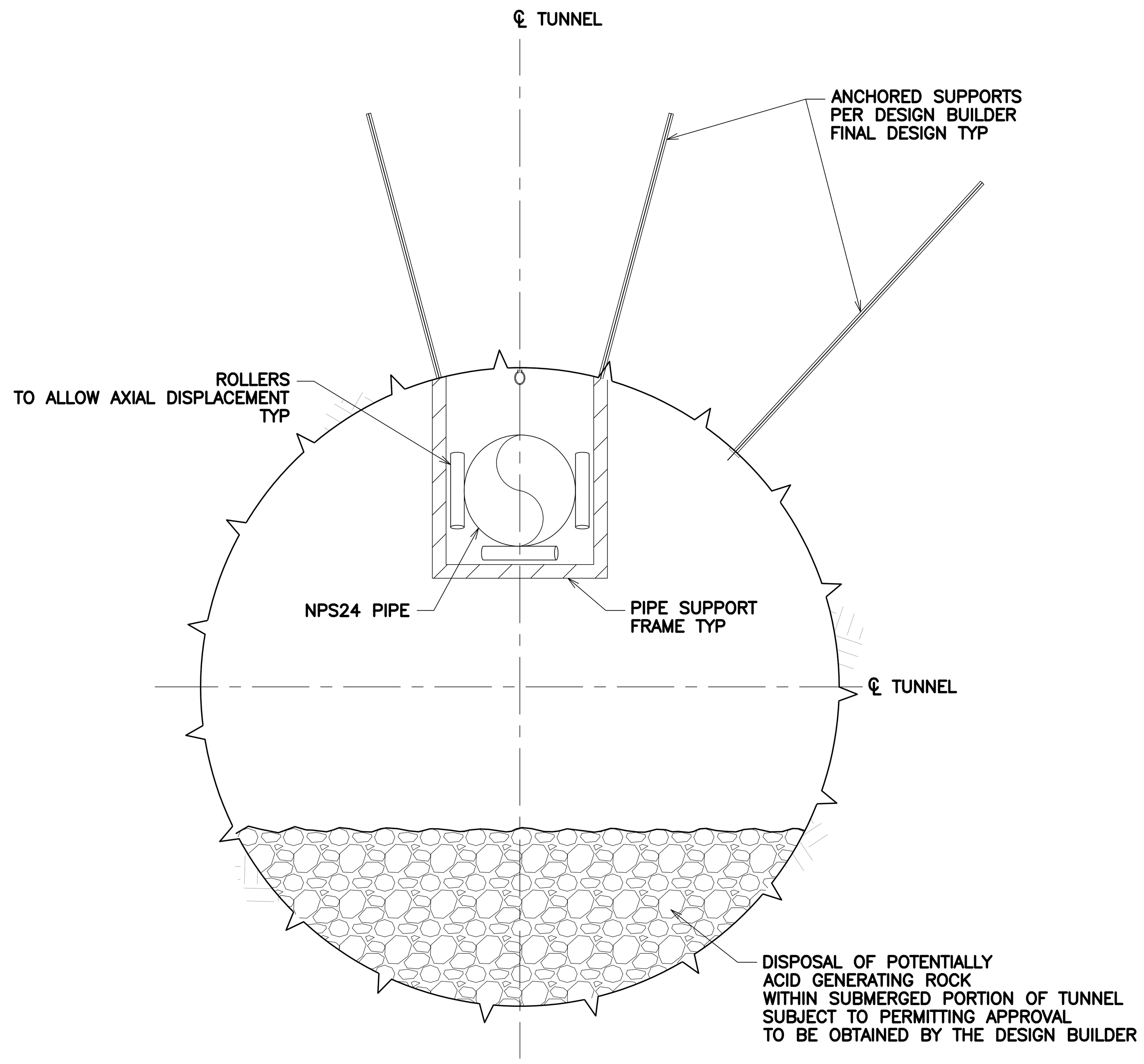
OPTION A
(BACKFILL–TEMPORARY ROCK SUPPORT)
SCALE 1:25



OPTION B
(PERMANENT ROCK SUPPORT)
SCALE 1:25



OPTION B – ALTERNATIVE
(PERMANENT ROCK SUPPORT)
SCALE 1:25



NOTE:

1. DESIGN BUILDER TO DETERMINE PIPE SUPPORT, PERMANENT ROCK SUPPORT, TEMPORARY ROCK SUPPORT (REFER TO SPECIFICATIONS) INCLUDING ROCK TUNNEL BACKFILL IF USED.

FOR REFERENCE ONLY
NOT FOR CONSTRUCTION

0.50m 0 1m
SCALE IN METERS
SCALE 1 = 25

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McMILLEN JACOBS ASSOC.	2	ISSUED FOR RFP	O.NAAS	C.HUNT	D.GRIMES	2019-11-15
McMILLEN JACOBS ASSOC.	1	ISSUED FOR PERMIT	K.RUSTON	C.HUNT	D.GRIMES	2019-10-21
McMILLEN JACOBS ASSOC.	0	ISSUED FOR RFP	K.RUSTON	C.HUNT	D.GRIMES	2019-07-19
McMILLEN JACOBS ASSOC.	A	ISSUED FOR TRP SESSION 2	K.RUSTON	C.HUNT	D.GRIMES	2019-06-07

PROJECT NO.– 5372.3 | PREVIOUS DR. NO.– – | SCALE– 1:25

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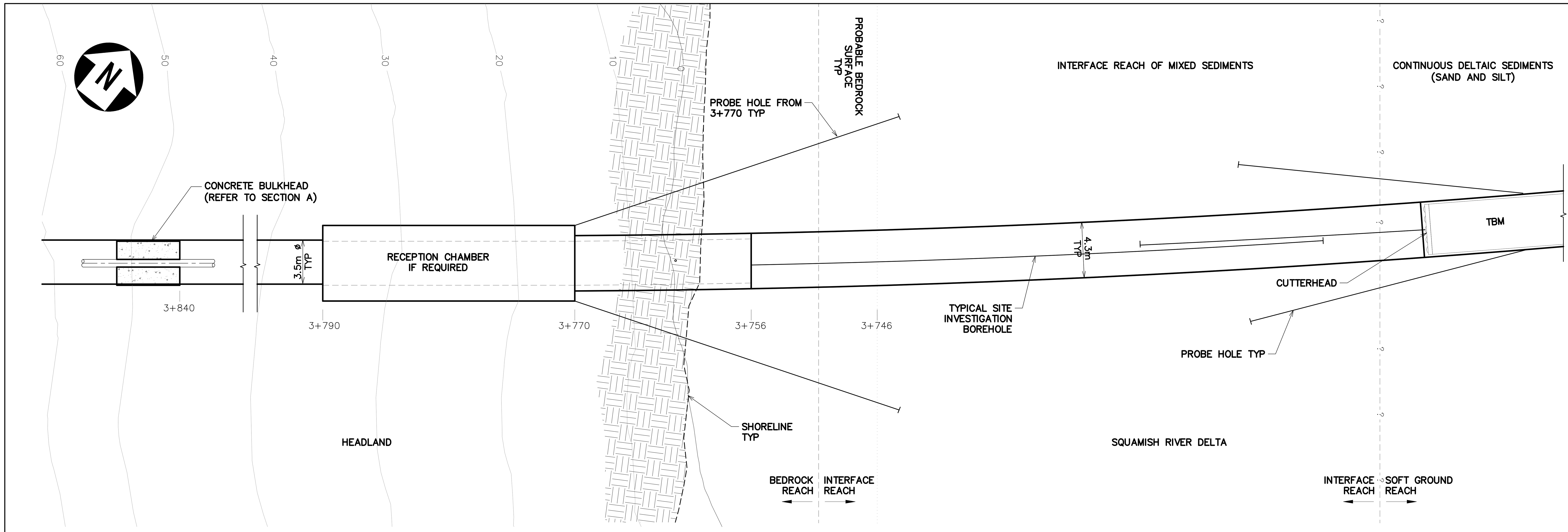
EGP TUNNEL PROJECT

INDICATIVE PERMANENT PROTECTION AND SUPPORT OF NPS24 PIPE

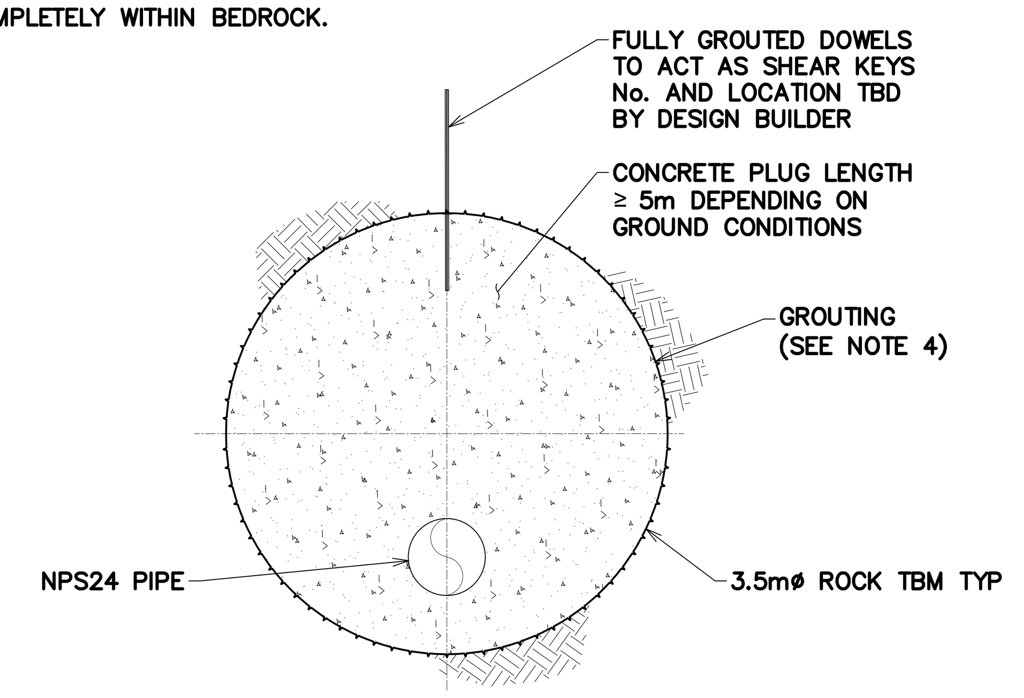
DRAWING NUMBER C–523

NOTES:

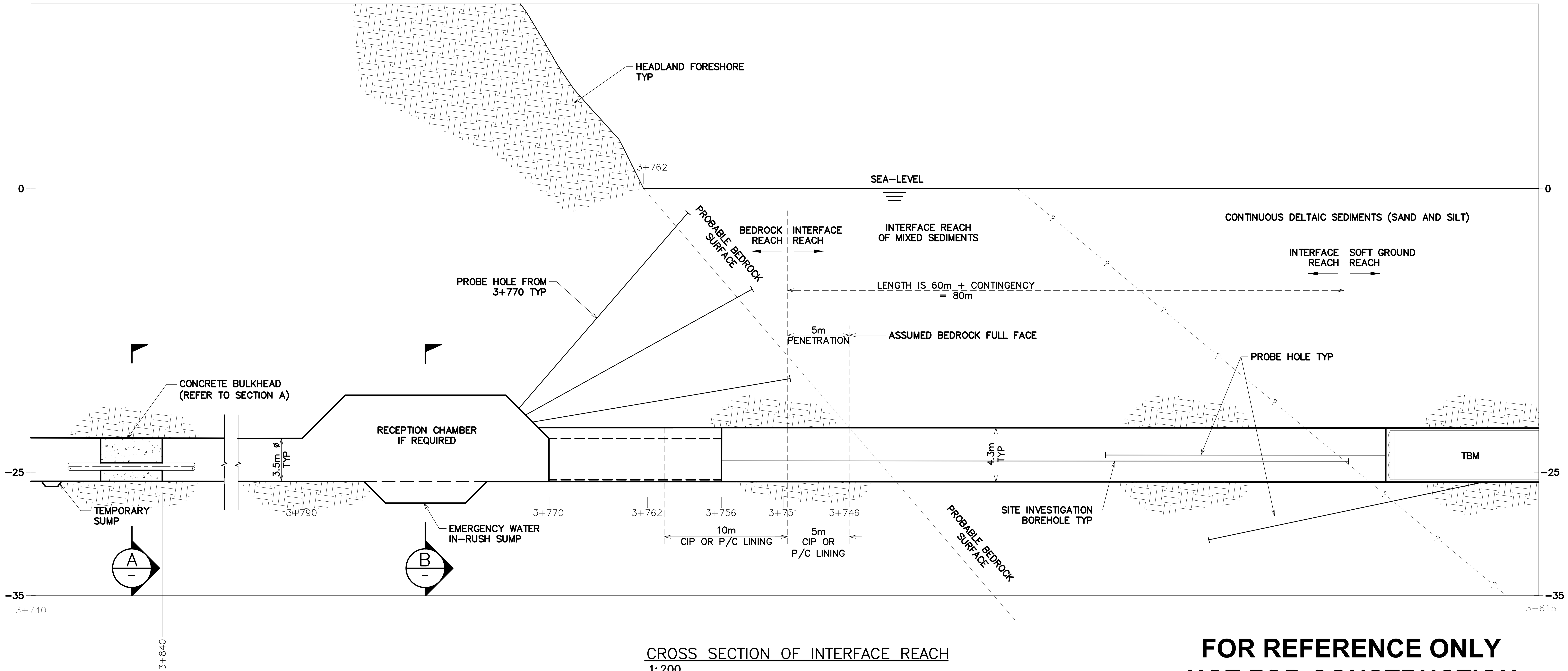
1. FOR GENERAL NOTES SEE DRAWING G-501.
2. EXCAVATION SUPPORT SHOWN SCHEMATICALLY FOR REFERENCE ONLY AND THEREFORE THE DIMENSIONS, SIZE AND TYPE OF SUPPORT ELEMENTS AND ELEVATIONS SHOWN ARE APPROXIMATE. THE CONSTRUCTION SEQUENCE AND DESIGN OF THE EXCAVATION SUPPORT SYSTEM TO BE DETERMINED DURING FINAL DESIGN BY THE DESIGN BUILDER, FOLLOWING SITE INVESTIGATION.
3. IF REQUIRED, THE RECEPTION CHAMBER IS TO BE POSITIONED WITHIN COMPETENT GRANITE.
4. CONTACT AND CONSOLIDATION GROUTING LOCATIONS ARE TO BE DETERMINED AROUND BULKHEAD.
5. ALL STATIONS OF TYPICAL SECTIONS ARE BASED ON THE REFERENCE DESIGN ALIGNMENT.
6. GEOTECHNICAL INSTRUMENTATION TO BE DETERMINED BY THE DESIGN BUILDER.
7. IT IS ENVISAGED THAT INTERFACE REACH WILL BE INVESTIGATED FROM BOTH SIDES AND ON THE BASIS, DEPENDING ON WHICH TBM GETS TO THE INTERFACE REACH FIRST, A STRATEGY FOR EXCAVATION WILL BE DEVELOPED.
8. LINED TUNNEL WILL CONTINUE 15m TOWARDS WOODFIBRE FROM WHERE TUNNEL IS COMPLETELY WITHIN BEDROCK.



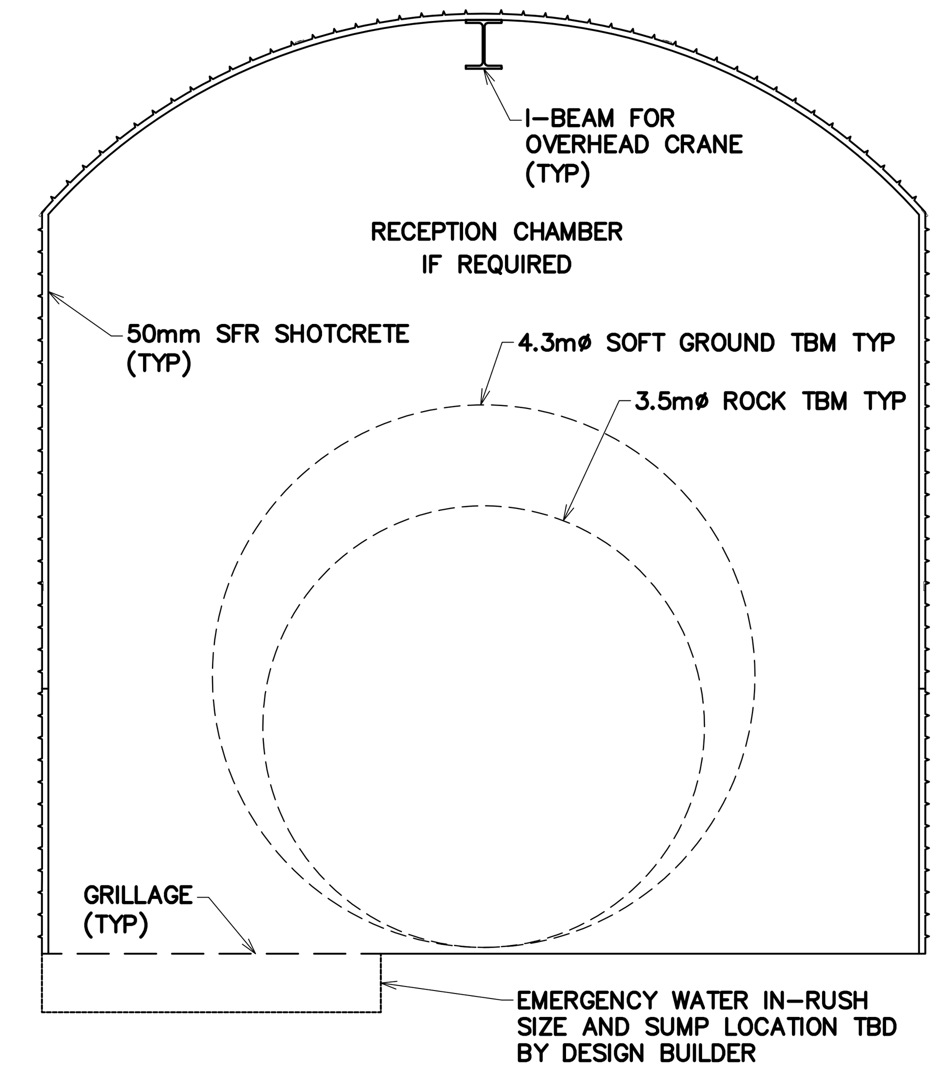
PLAN OF INTERFACE REACH
1:200



SECTION A
1:50



CROSS SECTION OF INTERFACE REACH
1:200



SECTION B
1:50

STA 3+790 TO 3+770 TYPICAL SUPPORT IN ROCK

1m 0 2m
SCALE IN METERS
SCALE 1 = 50

4m 0 10m
SCALE IN METERS
SCALE 1 = 200

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PREVIOUS DR. NO.- - SCALE- AS SHOWN

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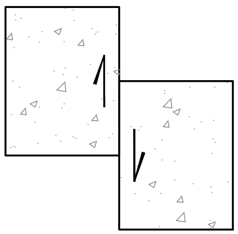
EGP TUNNEL PROJECT

INTERFACE REACH
INDICATIVE APPROACH
PLAN AND PROFILE

DRAWING NUMBER C-525

Appendix B
Conceptual Hydrogeologic Model Figures

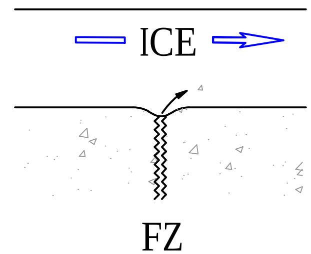
a)



FAULT IN GRANITIC ROCKS

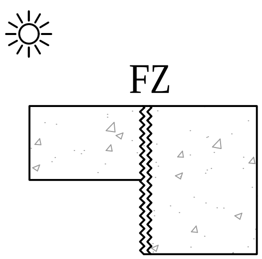
(BRITTLE FRACTURING SHOWS SHALLOW DEPTH ; e.g., 1-2 km DEEP)

c)



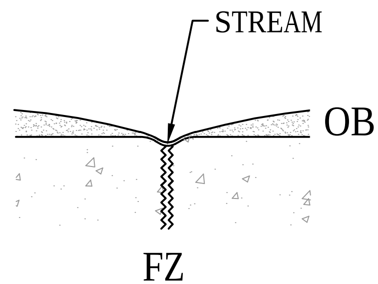
PREFERENTIAL EROSION OF BRECCIATED FZ ROCKS BY GLACIATION AND GLACIO -FLUVIAL SCOUR

b)



UPLIFT AND EROSION, EXPOSING FRACTURE ZONE (FZ)

d)



DEVELOPEMENT OF OVERBURDEN (OB)

(TILL/OUTWASH, COLLUVIUM, FLUVIAL DEPOSITS)

NOTES

SCALE : NOT TO SCALE

CLIENT

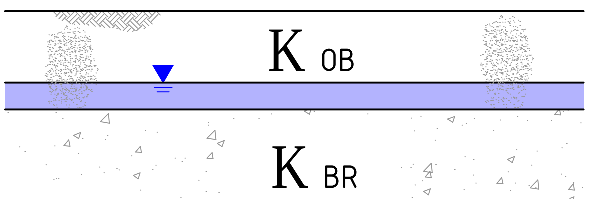
TETRA TECH

EGP TUNNEL PROJECT

CONCEPTUAL DEVELOPMENT OF LINEAMENT STREAMS

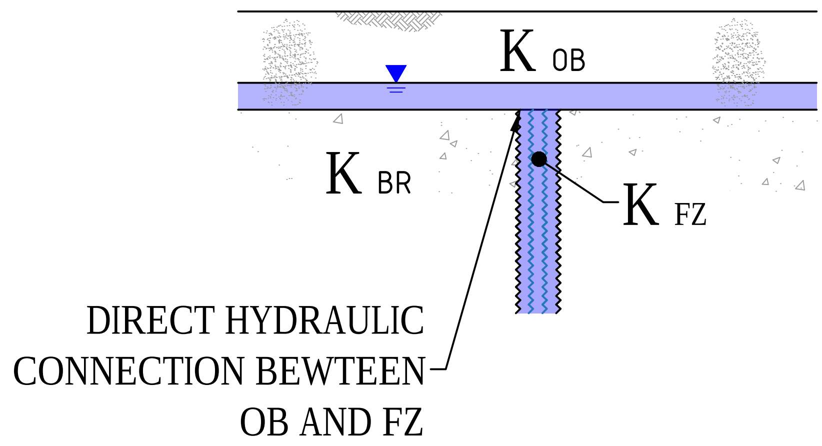
PROJECT NO.	DWN	CKD	REV	
ENG.VGEO03612	MJK	HSS	A	Figure 1
OFFICE	DATE			
VANC	January 22, 2020			

a) NO FRACTURE ZONE



$$K_{OB} \gg K_{BR}$$

b) FRACTURE ZONE PRESENT



$$K_{OB} \approx K_{FZ} \gg K_{BR}$$

NOTES

SCALE : NOT TO SCALE

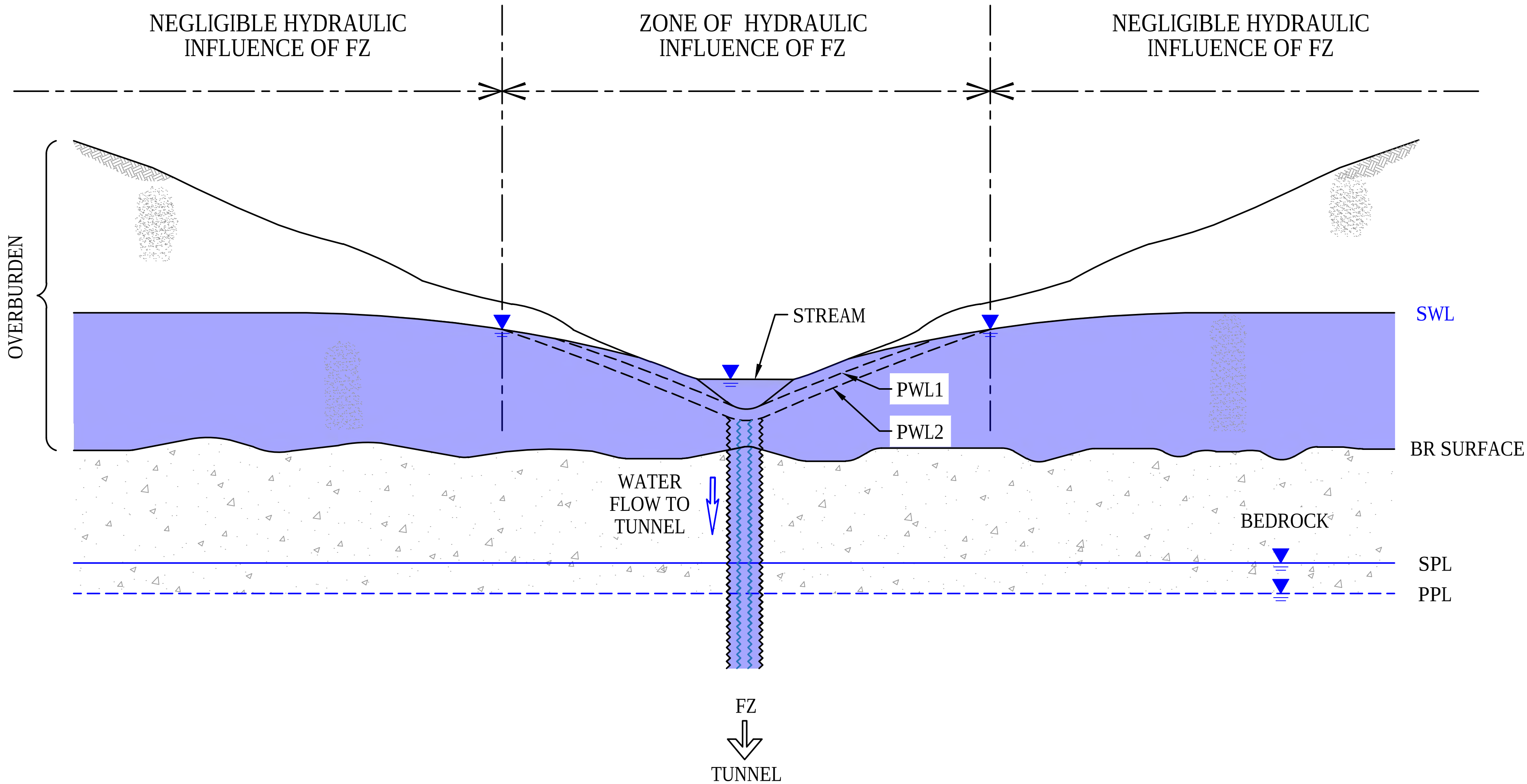
CLIENT

TETRA TECH

EGP TUNNEL PROJECT

THE RELATIONSHIP OF HYDRAULIC CONDUCTIVITY (K) IN OVERBURDEN AND BEDROCK OUTSIDE OF AND WITHIN FRACTURE ZONE

PROJECT NO.	DWN	CKD	REV	
ENG.VGEO03612	MJK	HSS	A	Figure 2
OFFICE	DATE			
VANC	January 22, 2020			



NOTES

SCALE : NOT TO SCALE

FZ = FRACTURE ZONE
SPL = STATIC PIEZOMETRIC LEVEL IN BR AT TUNNEL DEPTH
PPL = PUMPING PIEZOMETRIC LEVEL IN BR AT TUNNEL DEPTH
SWL = STATIC WATER LEVEL IN PERCHED WATER TABLE
PWL1 = PUMPING WATER LEVEL (SMALL DRAW-DOWN)
PWL2 = PUMPING WATER LEVEL (LARGE DRAW-DOWN)

CLIENT

TETRA TECH

EGP TUNNEL PROJECT

PREDICTED CHANGES IN PIEZOMETRIC CONDITIONS
DUE TO DEWATERING OF TUNNEL

PROJECT NO.	DWN	CKD	REV
ENG.VGEO03612	MJK	HSS	A
OFFICE: VANC	DATE: January 22, 2020		

Figure 3

Appendix C
Tetra Tech Technical Memorandum on Potential Stream Flow Loss

TETRA TECH

TECHNICAL MEMO

ISSUED FOR USE

To:	Doug Grimes, McMillen Jacobs Associates	**Date:**	April 24, 2020
c:		**Memo No.:**	TM 2020-01A
From:	Scott Schillereff, P.Geo., Tetra Tech Lara Reggin, P.Geo., Tetra Tech	**File:**	704-ENG.VGEO03612
Subject:	Determination of Potential Streamflow Loss due to Dewatering of Fracture Zones in the Proposed EGP Tunnel – Rev 2		

Note: This Technical memo replaces the previously issued for use (IFU) Technical Memo issued on March 30, 2020. Incidental changes were made based on additional client review, and this revised IFU version supercedes the original IFU doc.

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) is pleased to present this memorandum to McMillen Jacobs Associates (MJA), summarizing a high-level desktop study of the potential for streamflow loss due to dewatering of underlying fracture zones with respect to the construction and operation of the tunnel component of the Eagle Mountain – Woodfibre Gas Pipeline (EGP) Project (EGP Tunnel). Tetra Tech's understanding of the scope of work is based on a meeting between MJA and Tetra Tech on January 23, 2020, and a follow-up conference call between MJA, Jacobs Consultancy Canada Inc. (Jacobs), FortisBC Energy Inc. (FEI) and Tetra Tech on February 18, 2020.

This work was undertaken as a follow-up to earlier works which involved the development of a conceptual hydrogeological model and analysis of groundwater inflow into the tunnel (MJA, 2019), and evaluation of potential environmental impacts from EGP Tunnel (Tetra Tech, 2019).

Additional information provided by others and used in the analysis and calculations below includes:

- Table of stream and watershed characteristics and Mean Annual Discharge (MAD) values for steams in the EGP Project study area provided to Tetra Tech by Jacobs on Feb. 24, 2020.
- Figure of EGP Project Site Watershed with Streams (Watersheds_No_Lineaments.jpg) provided to Tetra Tech by Jacobs on Feb 24, 2020.

The analysis completed by Tetra Tech is based on the MJA Reference Design for the EGP Tunnel. FEI is planning to use the Design Build project delivery model for the EGP Tunnel and therefore the analysis may need to be updated to reflect the Design Build Contractors design and work plan.

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2.0 DETERMINATION OF POTENTIAL STREAMFLOW LOSS DUE TO DEWATERING OF FRACTURE ZONES IN PROPOSED TUNNEL

The purpose of this study is to determine if water inflow to the proposed EGP Tunnel from fracture zones could potentially deplete water from overlying streams and cause an Environmental Flow Needs (EFN) concern.

2.1 Setting and Terminology

A series of vertical or near-vertical fracture zones (FZs) intersect the proposed EGP Tunnel and are anticipated be the largest contributors of groundwater inflow. These FZs are expressed at the surface as linear, preferentially eroded, geomorphological surface traces (*lineaments*). A total of 21 lineaments have been mapped, based on earth images and ground-truthing (Wood, 2019 and MJA, 2019). MJA (2019, Table 7-1) summarized the locations and orientations of lineaments in the study area, and the lineaments were ranked based on the potential impact to the tunnel (0 - negligible up to 9 - substantial). Tetra Tech assigned inflow potentials based on lineament rankings by MJA (Table 1). For this analysis, only lineaments with scores of 3 or higher were carried forward for evaluation (11 total; nos. 4, 6, 7, 8, 11, 12, 13, 16B, 17, 18 and 19). These lineaments of concern are shown on Figure 1, along with the 24 drainage catchments (labelled A through X from east to west) identified by Jacobs.

2.2 Rationale to Consider Environmental Flow Needs

Table 1 below presents a summary of the 11 lineaments of concern, and their calculated inflows to the tunnel under ungrouted and grouted conditions, using three different analytical solutions (El Tani (2003) method, and Moon and Fernandez (2010) method with head reductions during tunnel dewatering equal to 25% and 10% of initial heads over the tunnel). As agreed during the February 18, 2020 conference call, the equivalent hydraulic conductivity (K) for the rock mass where FZs are grouted was set to 1 x 10^{-7} m/s, for purposes of this analysis.

Table 1 – Summary of Calculated Fracture Zone Inflows to the Tunnel under Ungrouted and Grouted Conditions

Lineament No.	Tunnel Intersection Chainage	El Tani (2003)				Moon and Fernandez (2010): Head = 25% of initial				Moon and Fernandez (2010): Head = 10% of initial			
		Inflow Ungrouted		Inflow Grouted		Inflow Ungrouted		Inflow Grouted		Inflow Ungrouted		Inflow Grouted	
		Geometric Mean Hydraulic Conductivity		Grouted Zone K = 1E-7 m/s		Geometric Mean Hydraulic Conductivity		Grouted Zone K = 1E-7 m/s		Geometric Mean Hydraulic Conductivity		Grouted Zone K = 1E-7 m/s	
From Table 7-1 (MJA, 2019) for all 3+ importance rating.	From Table 7-1 (MJA, 2019)	(m^3/s)	(L/m)	(m^3/s)	(L/m)	(m^3/s)	(L/m)	(m^3/s)	(L/m)	(m^3/s)	(L/m)	(m^3/s)	(L/m)
4	8+320.00	9.5E-03	570.0	2.1E-04	12.6	2.4E-03	144.0	5.3E-05	3.2	9.5E-04	57.0	2.1E-05	1.3
6	7+902.00	6.7E-03	402.0	1.5E-04	9.0	1.7E-03	102.0	3.7E-05	2.2	6.7E-04	40.2	1.5E-05	0.9
7	7+865.00	3.1E-03	186.0	6.8E-05	4.1	7.7E-04	46.2	1.7E-05	1.0	3.1E-04	18.6	6.8E-06	0.4
8	7+688.00	8.7E-03	522.0	1.9E-04	11.4	2.2E-03	132.0	4.8E-05	2.9	8.7E-04	52.2	1.9E-05	1.1
11	7+394.00	3.3E-03	198.0	7.2E-05	4.3	8.1E-04	48.6	1.8E-05	1.1	3.3E-04	19.8	7.2E-06	0.4
12	7+210.00	5.1E-03	306.0	1.1E-04	6.6	1.3E-03	78.0	2.8E-05	1.7	5.1E-04	30.6	1.1E-05	0.7
13	6+882.00	4.0E-03	240.0	8.9E-05	5.3	1.0E-03	60.0	2.2E-05	1.3	4.0E-04	24.0	8.9E-06	0.5
16b[1]	6+441	1.1E-03	66.0	2.4E-05	1.4	2.7E-04	16.2	5.9E-06	0.4	1.1E-04	6.6	2.4E-06	0.1
17	4+623 (E)	2.2E-02	1320.0	4.9E-04	29.4	5.5E-03	330.0	1.2E-04	7.2	2.2E-03	132.0	4.9E-05	2.9
18	5+250.00 (C)	1.1E-02	660.0	2.4E-04	14.4	2.7E-03	162.0	6.0E-05	3.6	1.1E-03	66.0	2.4E-05	1.4
19	4+879.00 (C)	5.0E-03	300.0	1.0E-04	6.0	1.2E-03	72.0	2.7E-05	1.6	5.0E-04	30.0	1.1E-05	0.7

[1]Lineament 16b was not recorded in the field but was observed as a significant feature from aerial imagery.

Table 1 shows that the El Tani (2003) method produced the highest calculated inflows and that, in general, calculated inflows for grouted FZs are nearly two orders of magnitude lower than ungrouted values. Tetra Tech understands that all substantial FZs encountered during tunnelling are typically grouted. Given the very low calculated inflows for grouted FZs (maximum grouted inflow for an individual FZ of 4.9E-04 m^3/s), there would be no plausible substantial depletion of overlying streamflow due to tunnel inflows from fully and properly grouted FZs.

For this evaluation, however, a conservative assumption of ungrouted conditions was used to evaluate potential EFN concerns caused by streamflow depletion from inflow to the tunnel through FZs. For this reason, we understand that Fortis has opted to proceed with this desktop study of potential effects of FZ inflow on streamflow loss, in the context of an EFN evaluation under British Columbia's EFN Policy. This will show the upper range of potential FZ inflow, and whether ungrouted FZ inflows would cause an EFN concern.

2.3 Conceptual Approach

Figure 2 (attached) shows a schematic diagram (not to scale) of a FZ plane extending from the rock mass around the tunnel to the bedrock surface. The FZ is hydraulically connected with overlying saturated overburden and, in turn, with surface water in the overlying stream. The length of the lineament overlying the FZ is shown as L. The conceptual flow lines show water in the FZ originating mainly from saturated overburden and, to a lesser extent, from the stream channel. It is unrealistic to conceive that *all* of the water in a FZ originates only from an overlying stream. Most of the water induced to flow down into a FZ during tunnel dewatering would likely originate from saturated overburden materials, not from streamflow.

In this analysis, water flowing into a FZ (and ultimately into the tunnel) was partitioned between overburden and stream channel sources based on the lineament/stream *intersection width* as a proportion of the *total lineament length.* Based on the rigor of the lineament mapping, we have relied on the plotted lineament location and length on Figure 1 in this analysis.

With Q_{inflow} representing the ungrouted inflow for a given FZ of concern, the potential depletion of streamflow ($Q_{stream\ loss}$) can be calculated as:

$$Q_{stream\ loss} = (W'/L) \times Q_{inflow} \qquad \text{Eq. 1}$$

where,

W' = lineament/stream intersection width (m), and

L = total lineament length (representing the contact length between a FZ in bedrock and overlying saturated overburden) (m).

For streams crossed by multiple lineaments, the total streamflow loss would be the sum of losses at each individual lineament (FZ) intersection.

For this analysis, it was assumed that the average stream channel width (W) is 2 m. All streams shown on Figure 1 have not been ground-truthed to confirm this, but Tetra Tech considers this to be a conservative assumption based on the physical setting. In addition, field observations of the study area during the geotechnical assessment indicated that average stream width ranges from 1 to 2 m (Pers. Comm. Charles Hunt, 2020). The intersection width (W') for a lineament crossing a stream perpendicularly would therefore be 2 m. W' for a lineament crossing obliquely (at an angle x taken between the lineament and the stream axis) would be

$$W' = 2/\sin(x) \qquad \text{Eq. 2}$$

For example, W' for a lineament crossing a stream at a 60-degree angle would be 2 m/sin60 = 2.31 m.

Jacobs has determined MAD values for the streams in each of the 24 catchments on Figure 1. EFN concerns as per the Provincial EFN Policy, are managed, in part, based on the relative depletion of streamflow as a percentage of its MAD value. Accordingly, in this analysis, Tetra Tech compiled the location and intersection angle between each lineament of concern (total of 11) and all of the stream channels crossed by them in each catchment (shown on Figure 1). For each intersection, we determined a $Q_{stream\ loss}$ value using Equations 1 and 2. Then, for each catchment, Tetra Tech totalled the $Q_{stream\ loss}$ values and divided the total by the MAD value for the catchment (multiplying the result by 100 to express as a percentage of MAD). Diagrams showing all intersections through different catchments are shown in Appendix B, and detailed calculations of depletion are presented in an Excel worksheet (Appendix C).

2.4 Assumptions

This conceptual approach included the following assumptions:

1. All the streams as shown on Figure 1:

   a. exist (currently the drainage pattern is based only on topography; the existence of all these stream channels has not yet confirmed by ground-truthing);

   b. flow permanently (i.e., provide a continuous source of water year-round);

   c. are on average 2 m wide; and

   d. are gaining streams (i.e., continuously receive groundwater discharge along their length. This may not, in fact, be the case on upper parts of the hillslope where a stream channel may be higher than the top of the saturated overburden).

2. All water entering a FZ originates only from overburden or stream sources and ultimately reports to the tunnel (regardless of lateral distance between a lineament/stream intersection and the tunnel alignment). This infers a steady state condition of tunnel dewatering, as well as no-flow boundaries at the sides and bottom edges (i.e., underneath the tunnel) of the FZs in the rock mass.

3. Ungrouted Q_{inflow} values were used, based on the El Tani (2003) equation. As mentioned above, FZs will be grouted when encountered during tunnelling, so using ungrouted inflows is a very conservative assumption. In addition, the El Tani (2003) method tends to over-estimate tunnel inflows.

2.5 Results

Table 2 shows a summary of results. Of the 24 catchments, five (I, J, L, S and T) had no intersections with any of the 11 lineaments (FZs) of concern. A total of 101 lineament/stream intersections were evaluated across the remaining 19 catchments. The calculated total streamflow depletion as a percentage of MAD was low, ranging from 0.05% (Catchment F) up to 2.94% (Catchment B), with an average depletion of 1.04% of MAD.

Table 2 – Summary of Fracture Zone/Stream Depletion Analysis

Catchment	Lineaments of concern	No. of intersections	MAD (m^3/s)	MAD[2] (L/m)	Total Streamflow Depletion as % of MAD
A	17	2	0.004	240	1.20
B	17, 19	6	0.011	660	2.94
C	17	1	0.005	300	2.42
D	17	2	0.004	240	1.18
E	17, 18	6	0.026	1,560	1.56
F	17	1	0.043	2,580	0.05
G	17	1	0.003	180	0.74
H	17	1	0.008	480	0.29
I	None of concern	0	0.004	240	0
J	None of concern	0	0.006	360	0
K	13, 16B	7	0.111	6,600	0.25
L	None of concern	0	0.002	120	0
M	7, 8, 11, 12, 13	16	0.065	3,900	0.29
N	7, 8, 11, 12, 13	21	0.034	2,040	0.50
O	13	1	0.002	120	0.59
P	11, 12	3	0.005	300	2.08
Q	12	1	0.001	60	0.96
R	6, 7, 8, 11	10	0.012	720	2.05
S	None of concern	0	0.003	180	0
T	None of concern	0	0.001	60	0
U	4, 6, 7, 8	11	0.020	1,200	1.29
V	4, 6, 7	6	0.104	6,240	0.09
W	4	3	0.008	480	0.76
X	4	2	0.012	720	0.53
Totals	11 lineaments of concern	101		Avg.	**1.04**
				max	2.94
				min	0.05

[2] MAD estimated under ungrouted conditions

2.6 Conclusions

Based on Tetra Tech's analysis, the potential streamflow depletion due to ungrouted fracture zone inflows to the tunnel is low (average 1% of MAD). Since these calculated depletions are <15% of MAD, and Tetra Tech understands that the streams are non-fish bearing, tunnel dewatering effects on streamflow in the study area would likely be considered as an EFN Risk Management Level 1 (lowest concern). Furthermore, since it is intended to grout the FZs found within the tunnel (generally with forward probing prior to excavation), the actual depletion may be as much as an order of magnitude less than that stated here (i.e., ~0.1% MAD).

3.0 LIMITATIONS OF REPORT

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4.0 CLOSURE

We trust this technical memo meets your present requirements. If you have any questions or comments, please contact Lara Reggin.

Respectfully submitted,
Tetra Tech Canada Inc.

PROFESSIONAL PROVINCE OF H.S. SCHILLEREFF # 28467 BRITISH COLUMBIA GEOSCIENTIST

H. Scott Schillereff
Apr 24, 2020

704-ENG.VGEO03612

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/tak

Enclosure:

- Figure 1 – Tunnel Alignment with Stream Catchments and Lineaments of Concern
- Figure 2 – Conceptual Model for Source Areas of Water in a Fracture Zone Discharging to the Tunnel
- Appendix A – Tetra Tech's Limitations on the Use of this Document
- Appendix B – Marked Catchment Work Sheets Showing All Intersections
- Appendix C – Fracture Zone/Stream Depletion Evaluation

REFERENCES

El Tani, M. 2003. Circular tunnel in a semi-infinite aquifer. Journal of tunneling and underground space technology. Vol 18, pp. 49-55.

McMillen Jacobs Associates. 2019. Rock Tunnel Design and Interpretative Report. Rev. 0. July 2019.

Moon, J. & Fernandez, G. 2010. Effect of excavation-induced groundwater level drawdown on tunnel inflow in a jointed rock mass. Engineering Geology, 110, 33–42.

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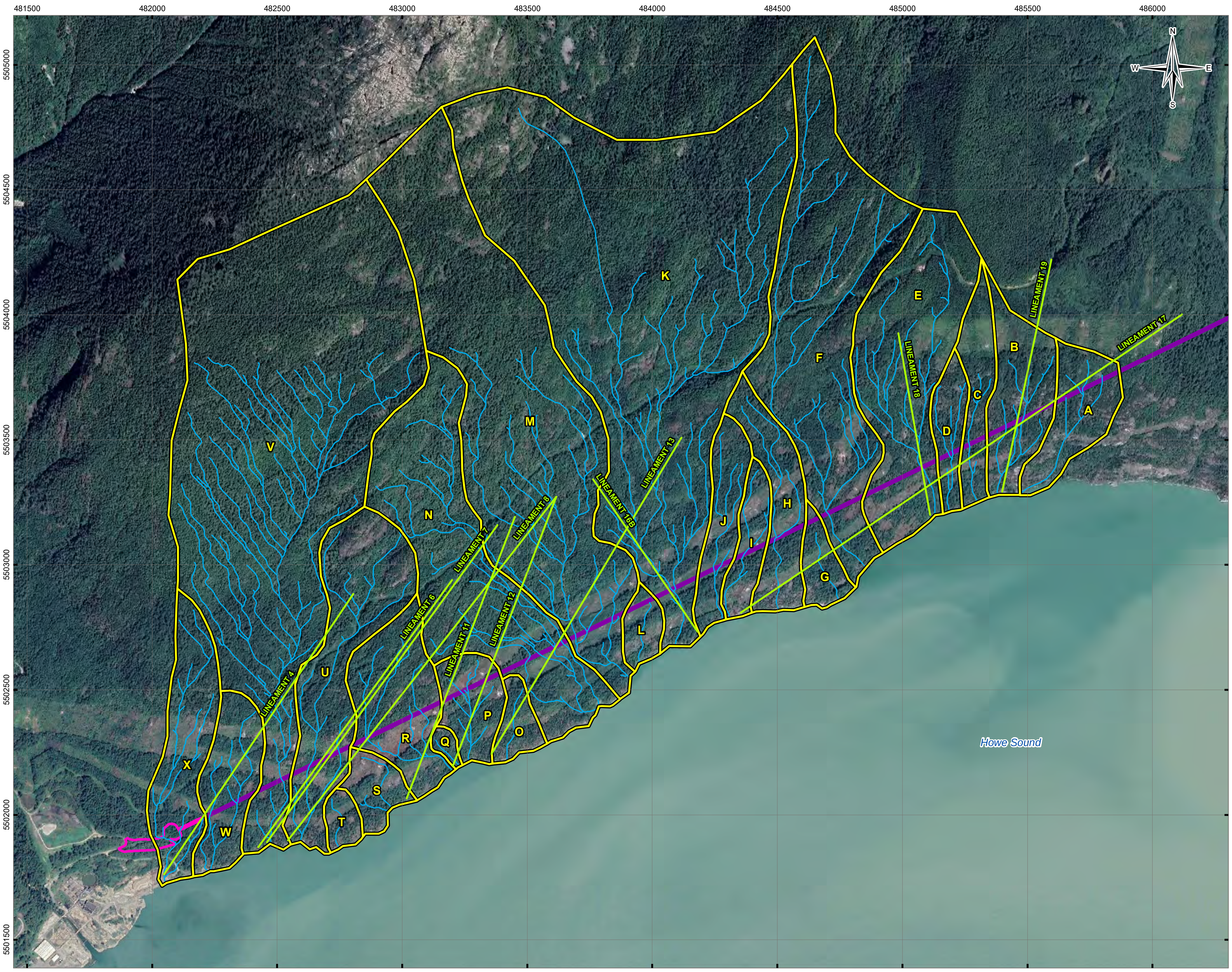
Wood. 2019. Phase II Geology Mapping: Updated Geology Mapping Report. Prepared for Fortis Energy Inc. 12 June 2019.

FIGURES



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LEGEND

- Study Stream (Jacobs 2020)
- Study Catchment (Jacobs 2020)
- Lineament of Concern (Wood 2019, MJA 2019)
- Tunnel Alignment (MJA 2019)
- Woodfibre Portal Area

NOTES
Base data source:
Imagery from Google (Aug 2019).

STATUS
ISSUED FOR USE

EGP TUNNEL PROJECT

Tunnel Alignment with Stream Catchments and Lineaments of Concern

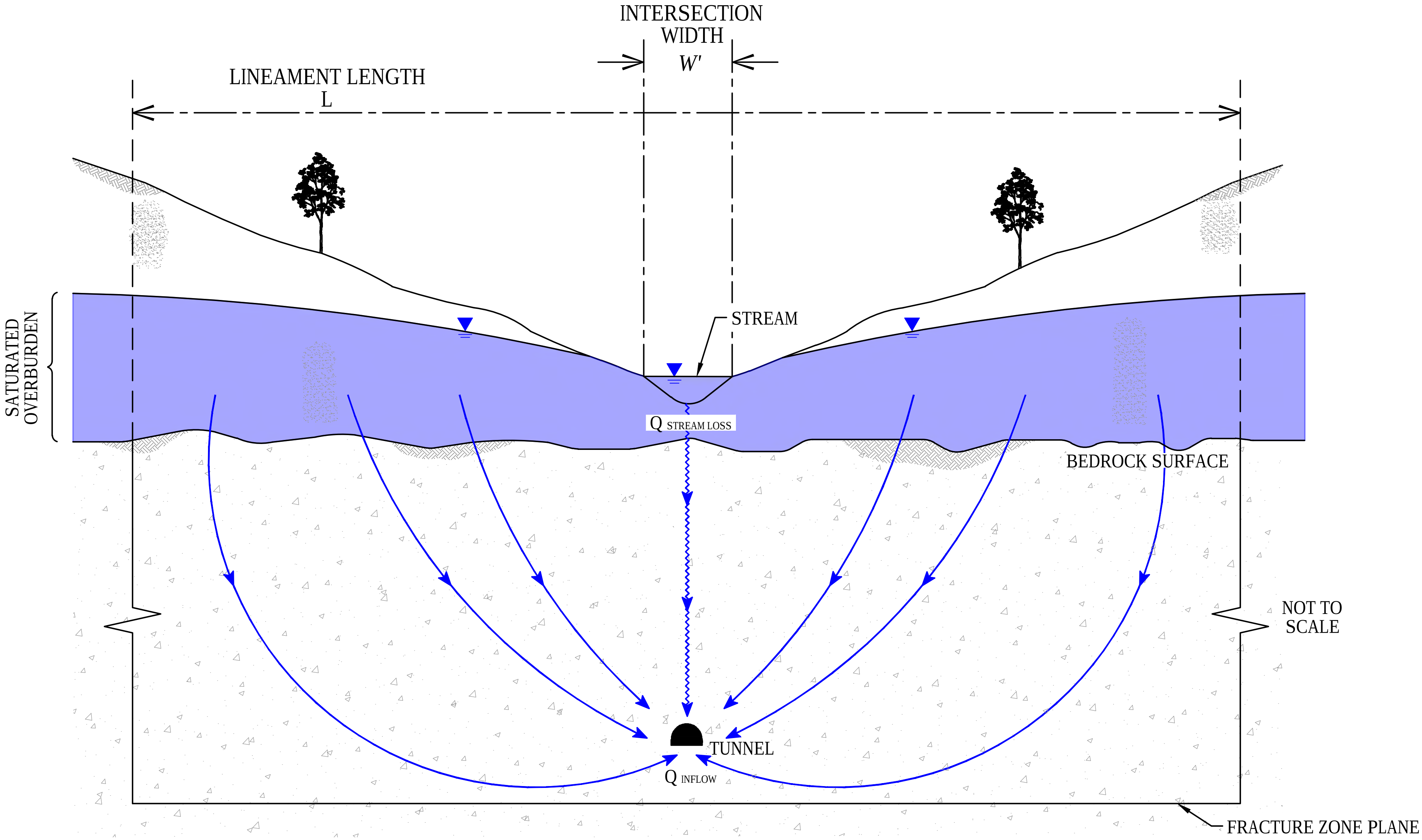
PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	FORTIS BC

Scale: 1:15,000
200 100 0 200
Metres

TETRA TECH

FILE NO.				
VGEO03612-01_Figure1_Catchments.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	YL	LR	0
DATE	PROJECT NO.			
April 20, 2020	ENG.VGEO03612-01			

Figure 1



CLIENT

FORTIS BC™

TETRA TECH

EGP TUNNEL PROJECT

CONCEPTUAL MODEL FOR SOURCE AREAS OF
WATER IN A FRACTURE ZONE
DISCHARGING TO THE TUNNEL

PROJECT NO.	DWN	CKD	REV
ENG.VGEO03612	MJK	HSS	A
OFFICE	DATE		
VANC	April 20, 2020		

Figure 2

APPENDIX A

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

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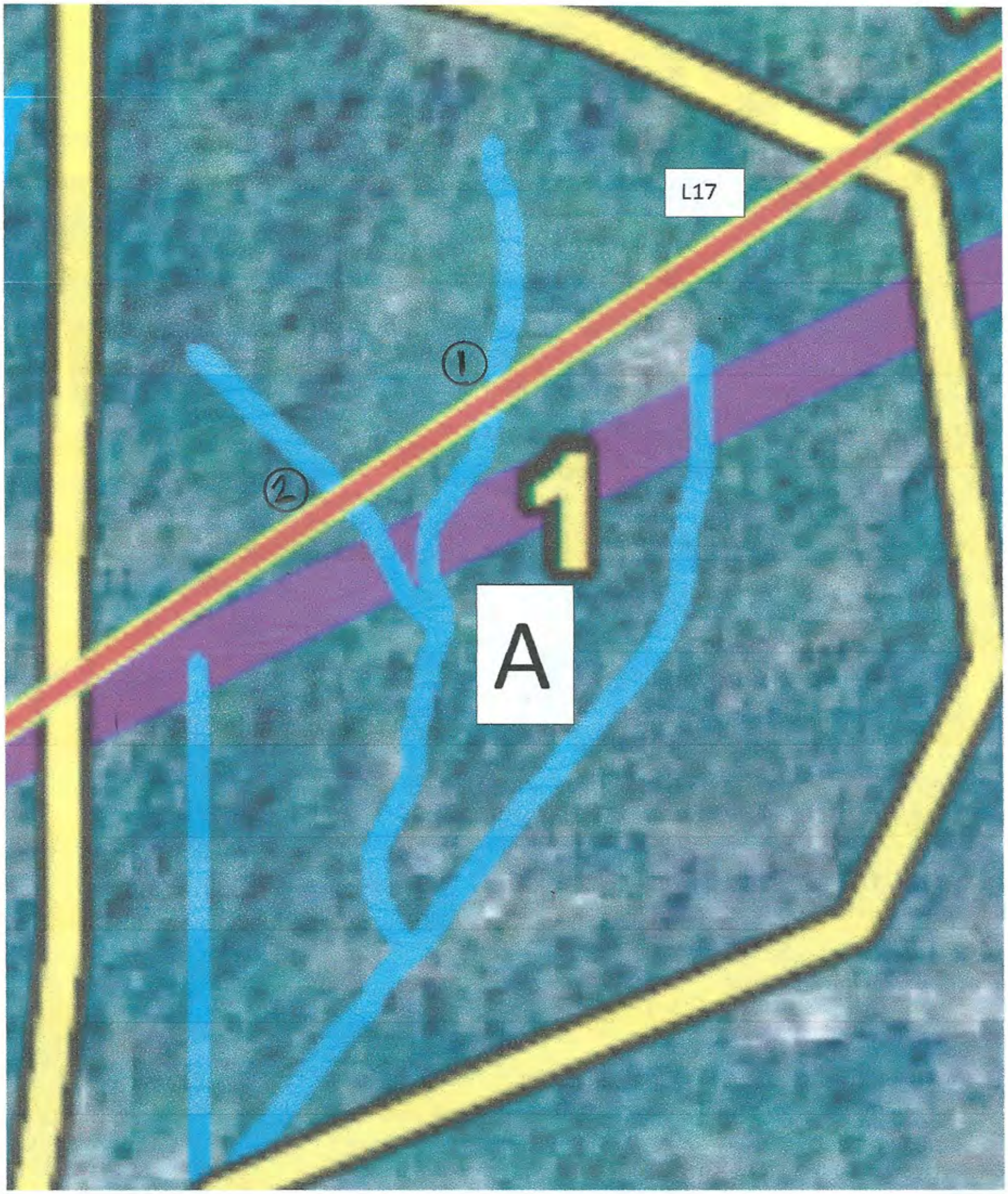
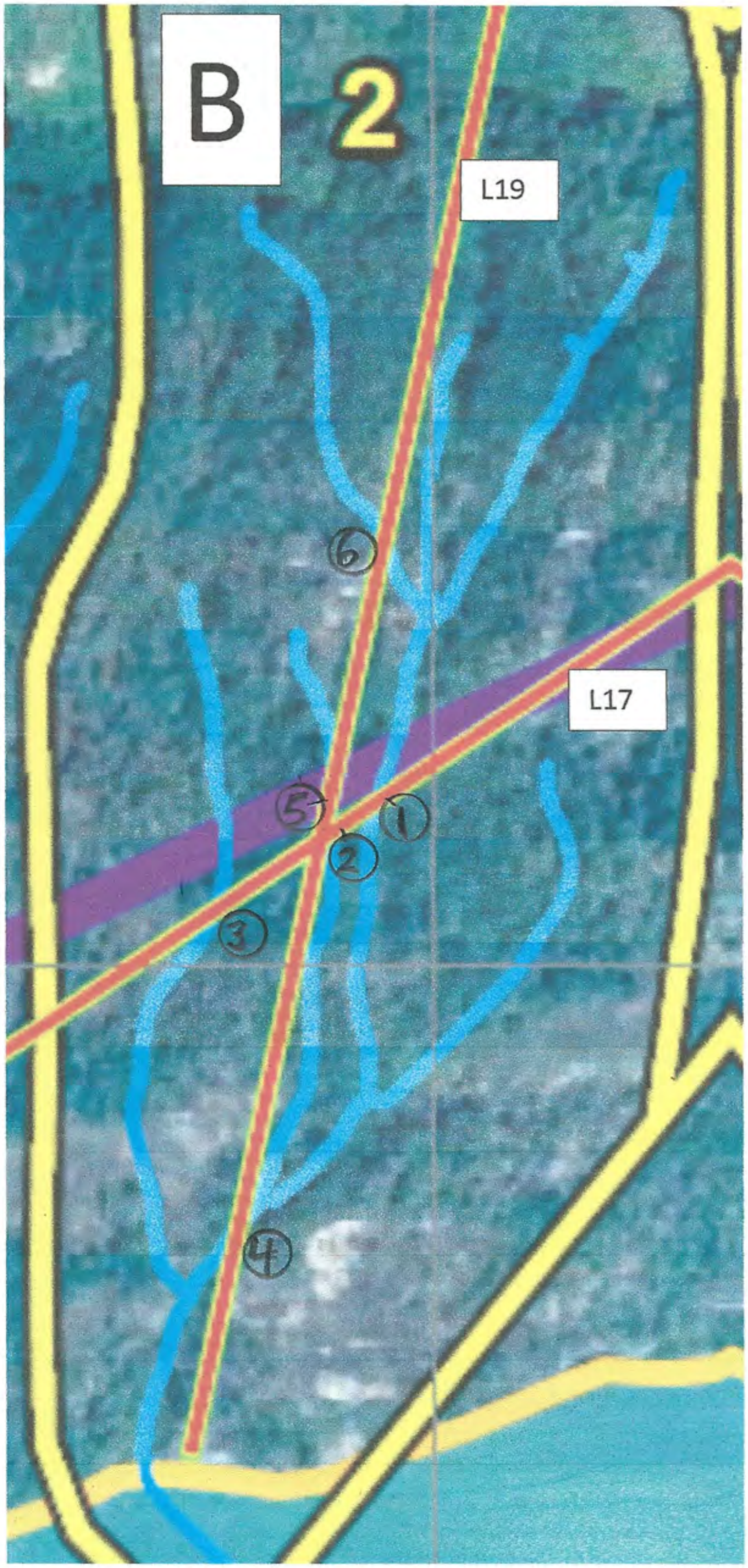
APPENDIX B

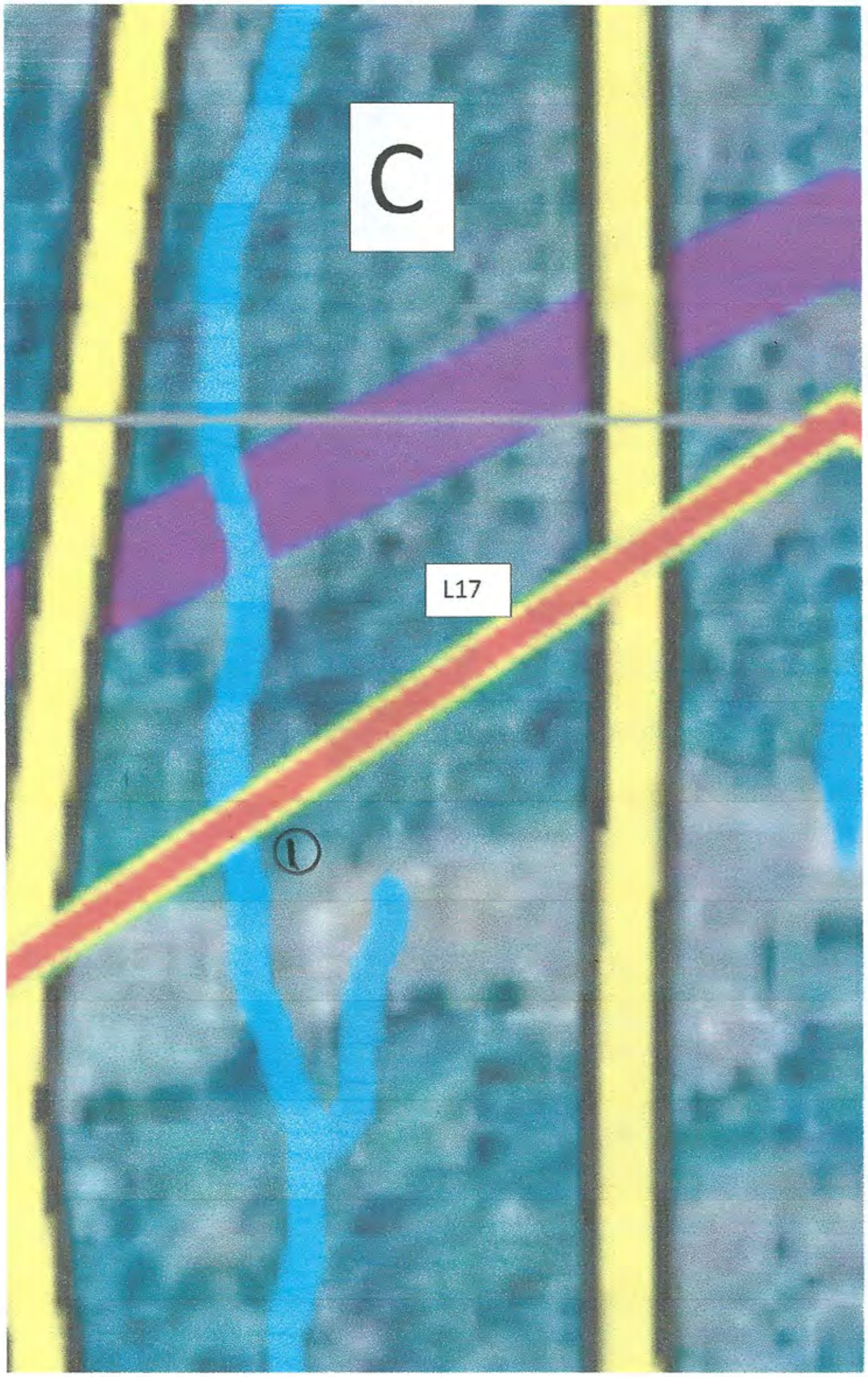
MARKED CATCHMENT WORK SHEETS SHOWING ALL INTERSECTIONS



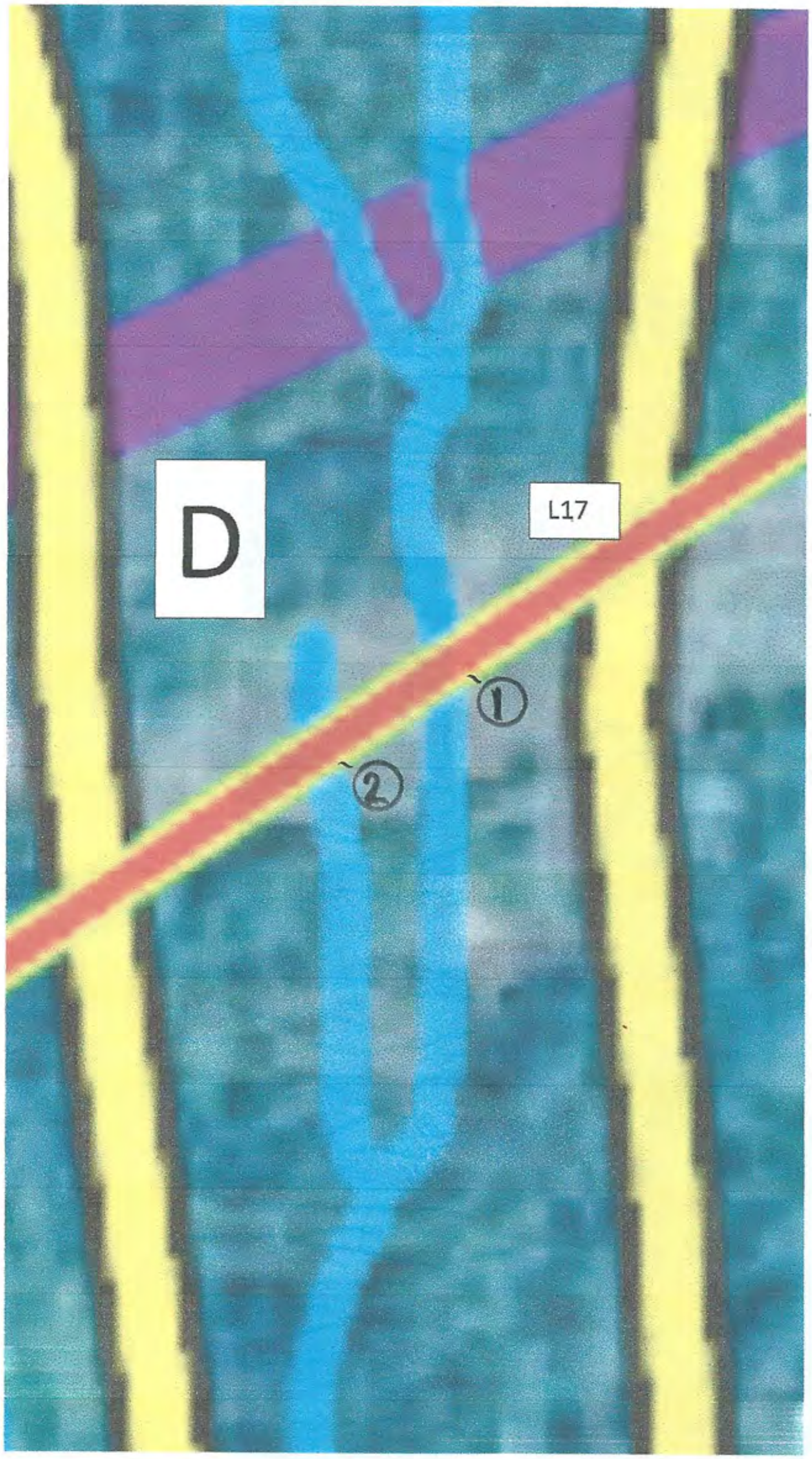
L17 crossing A (1)



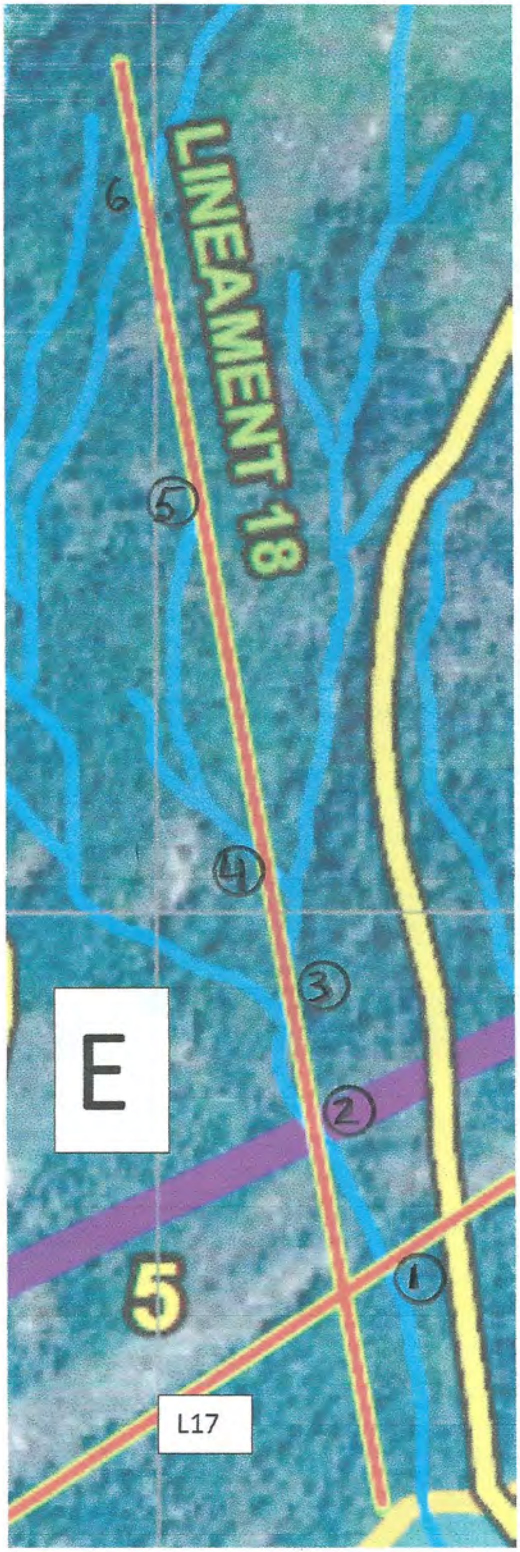
L17 and L19 crossing B (2)



L17 crossing C (3)

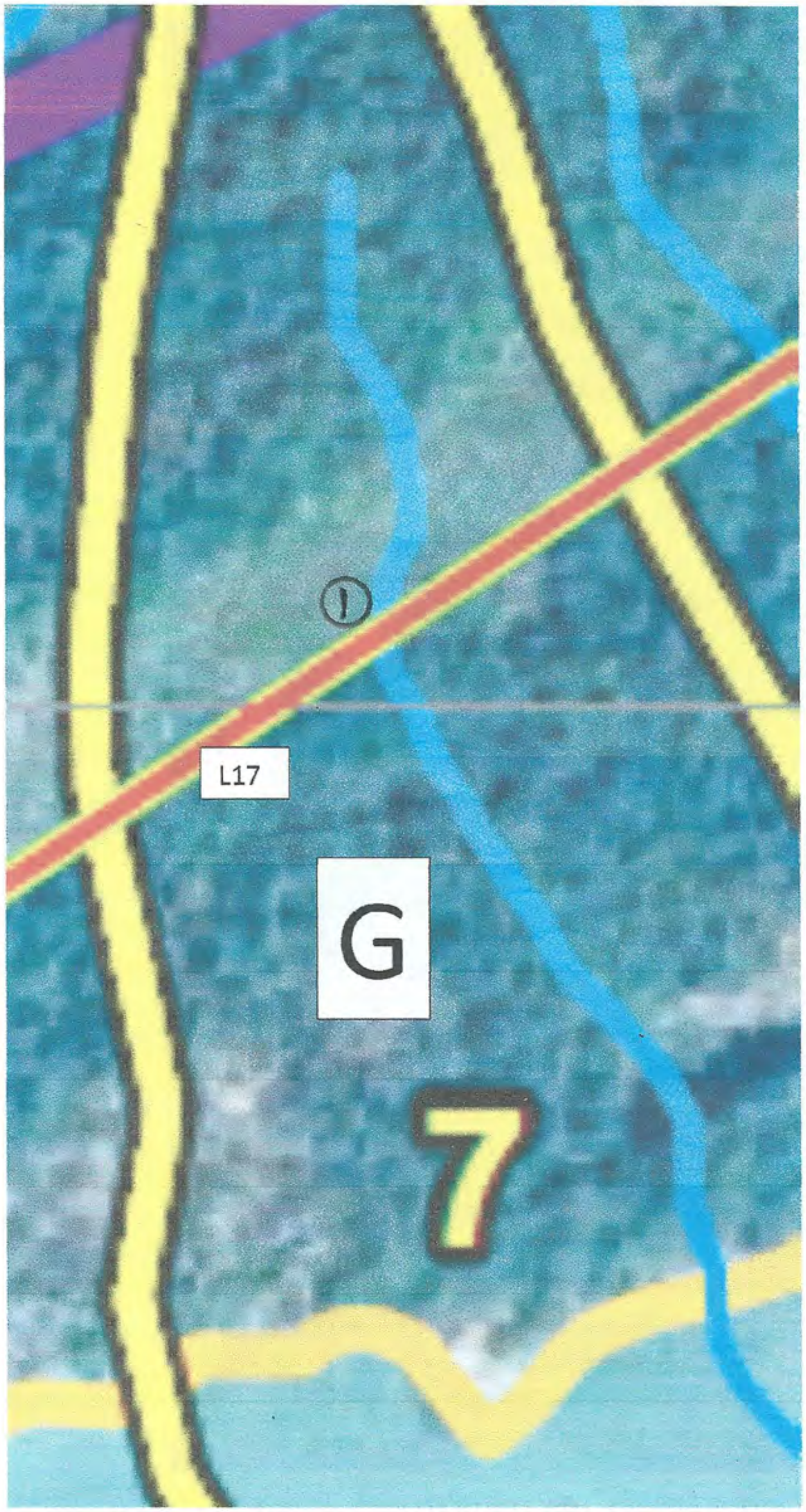


L17 crossing D (4)

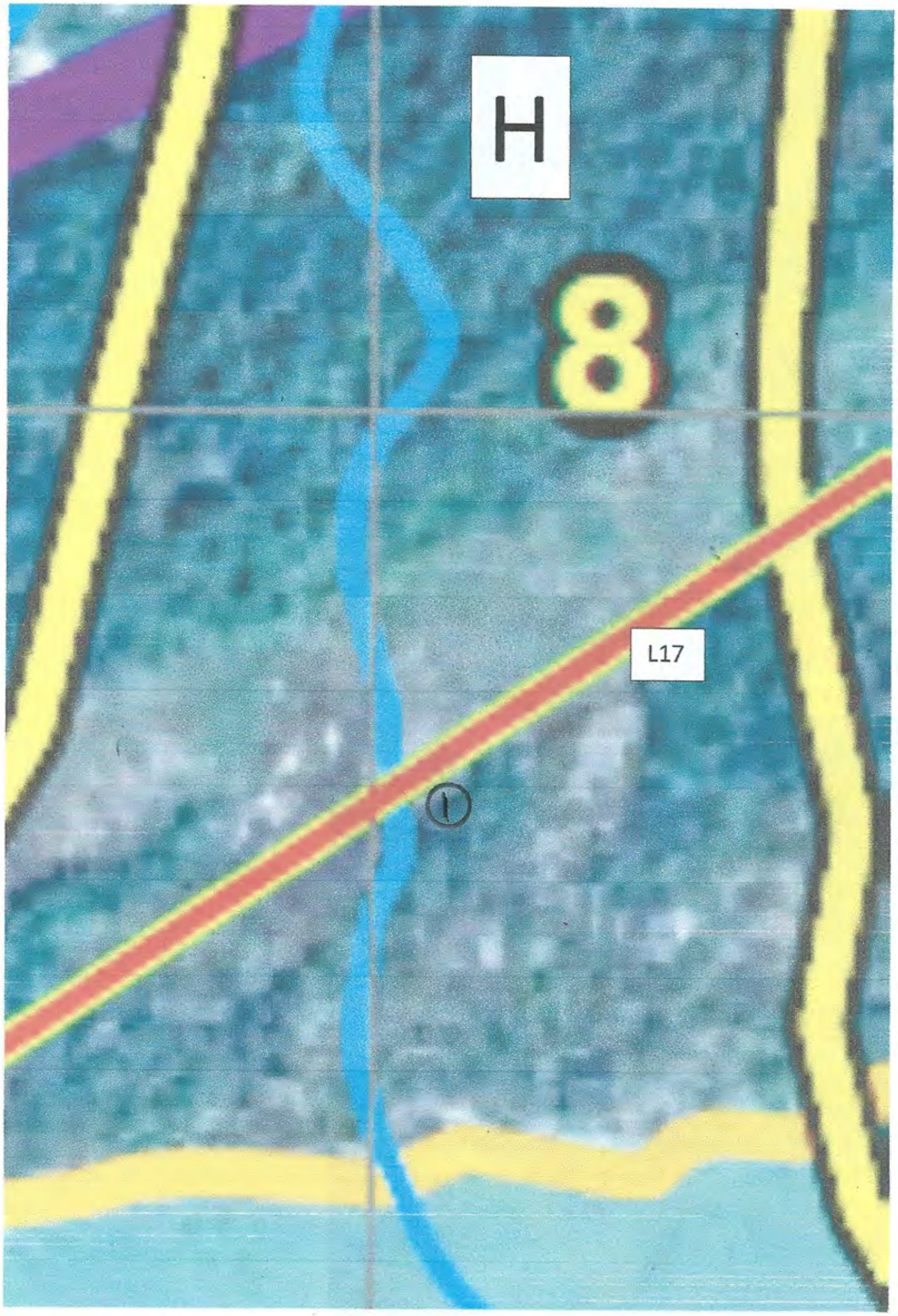


L17 and L18 crossing E (5)

L17 crossing F (6)

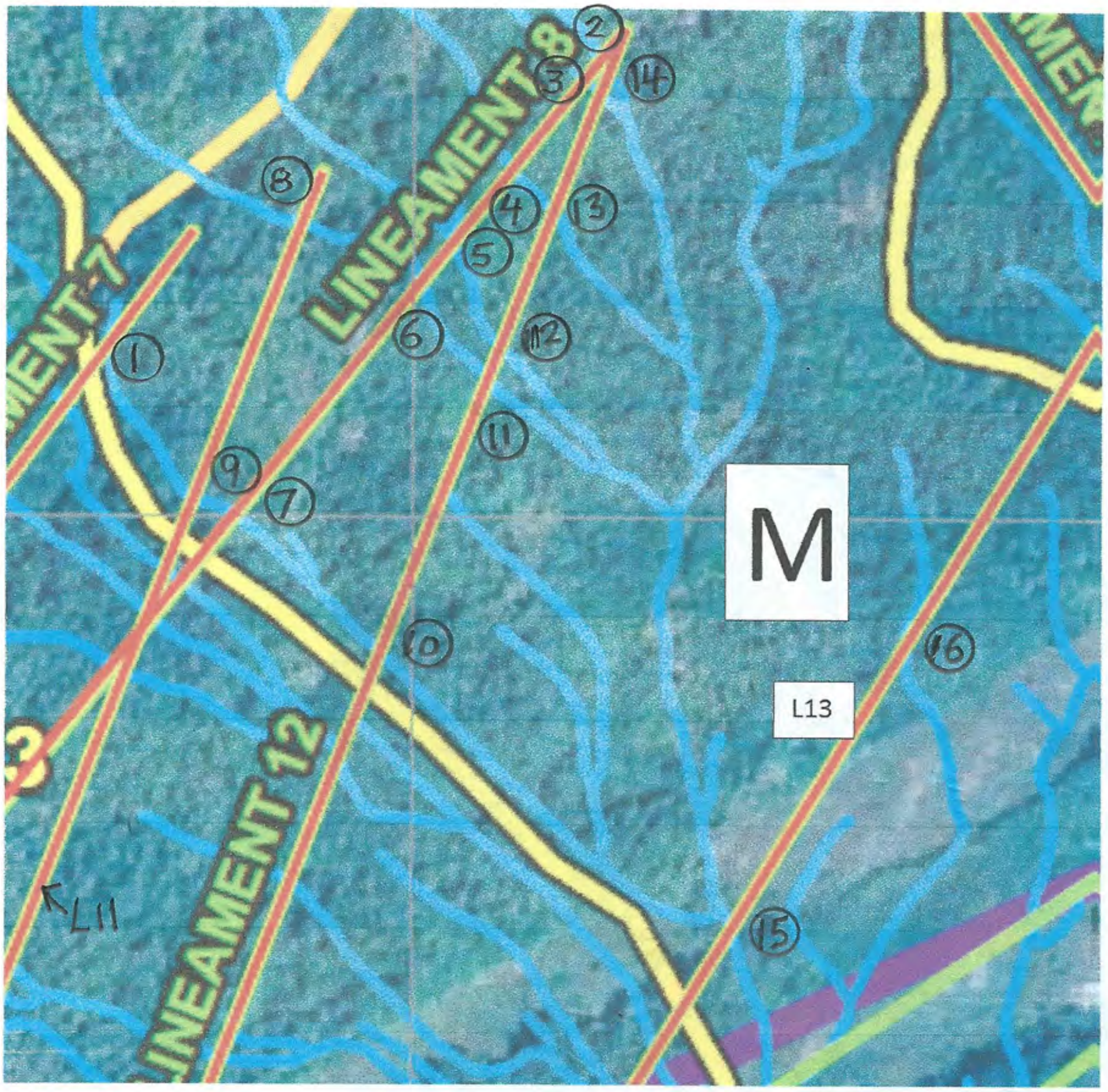


L17 crossing G (7)

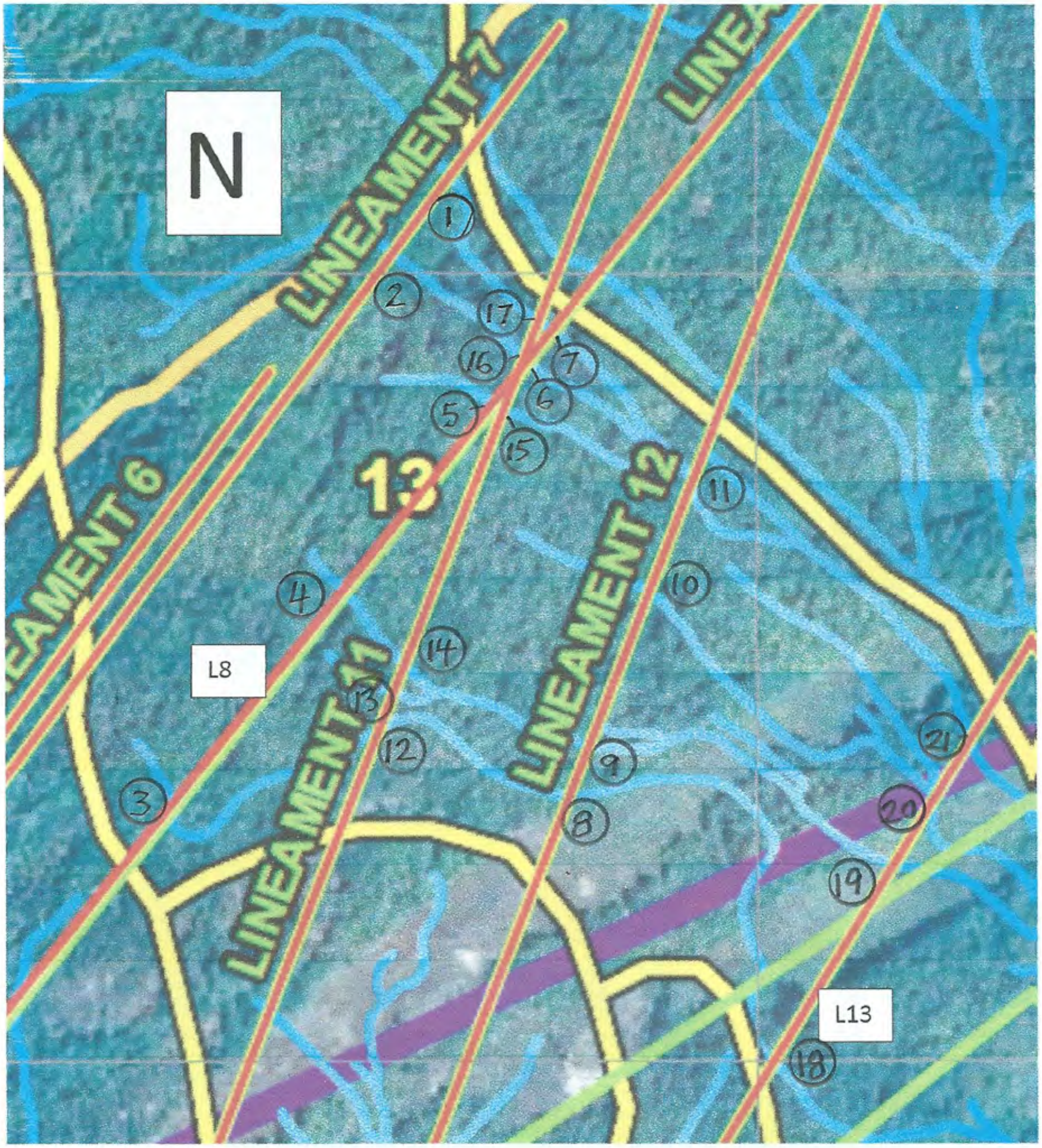


L17 crossing H (8). ***NOTE*** **no intersections in ~~I~~ J (9) with lineaments of concern**

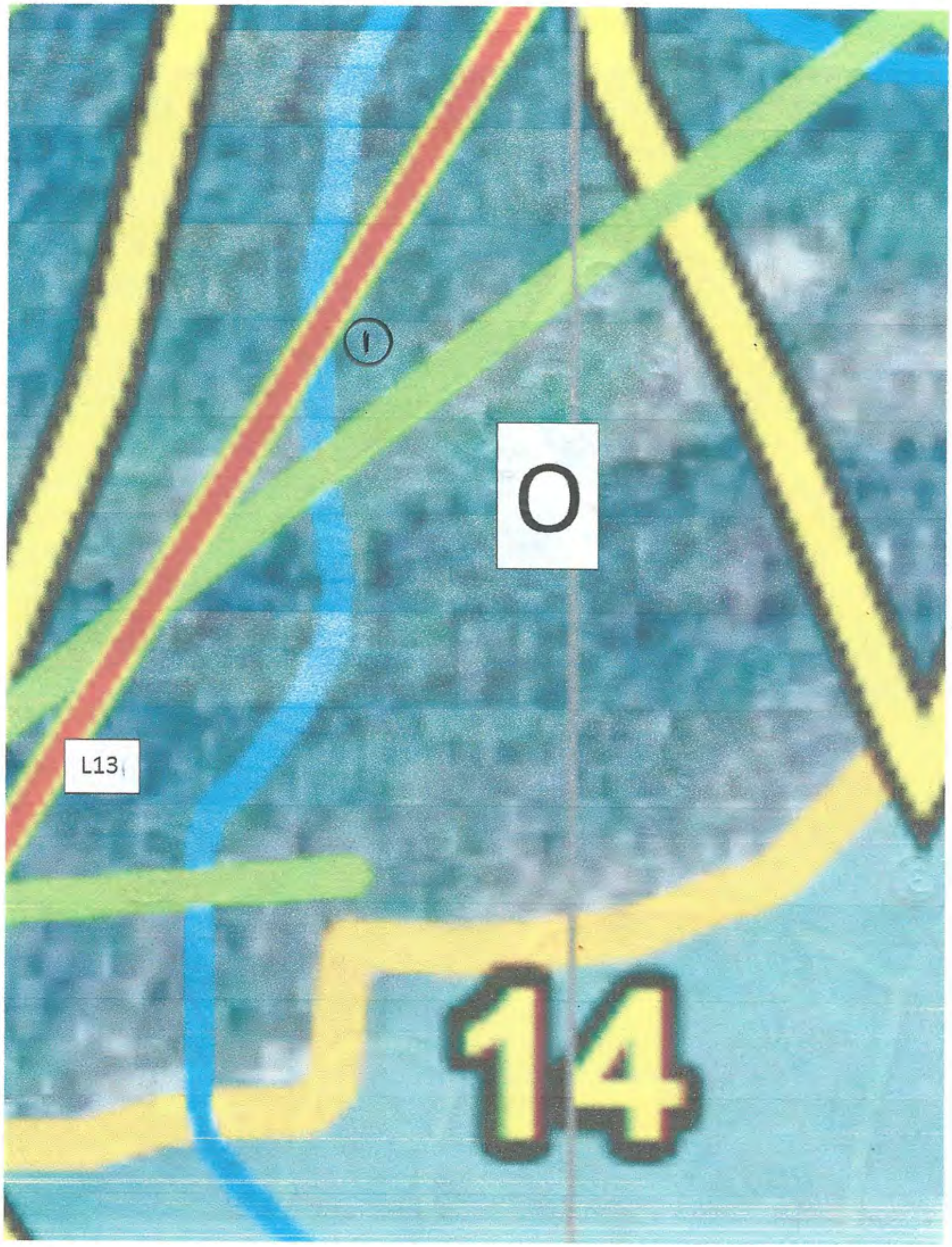
L13 and L16B crossing K (10). *****NOTE*** no intersections in L (11) with lineaments of concern**



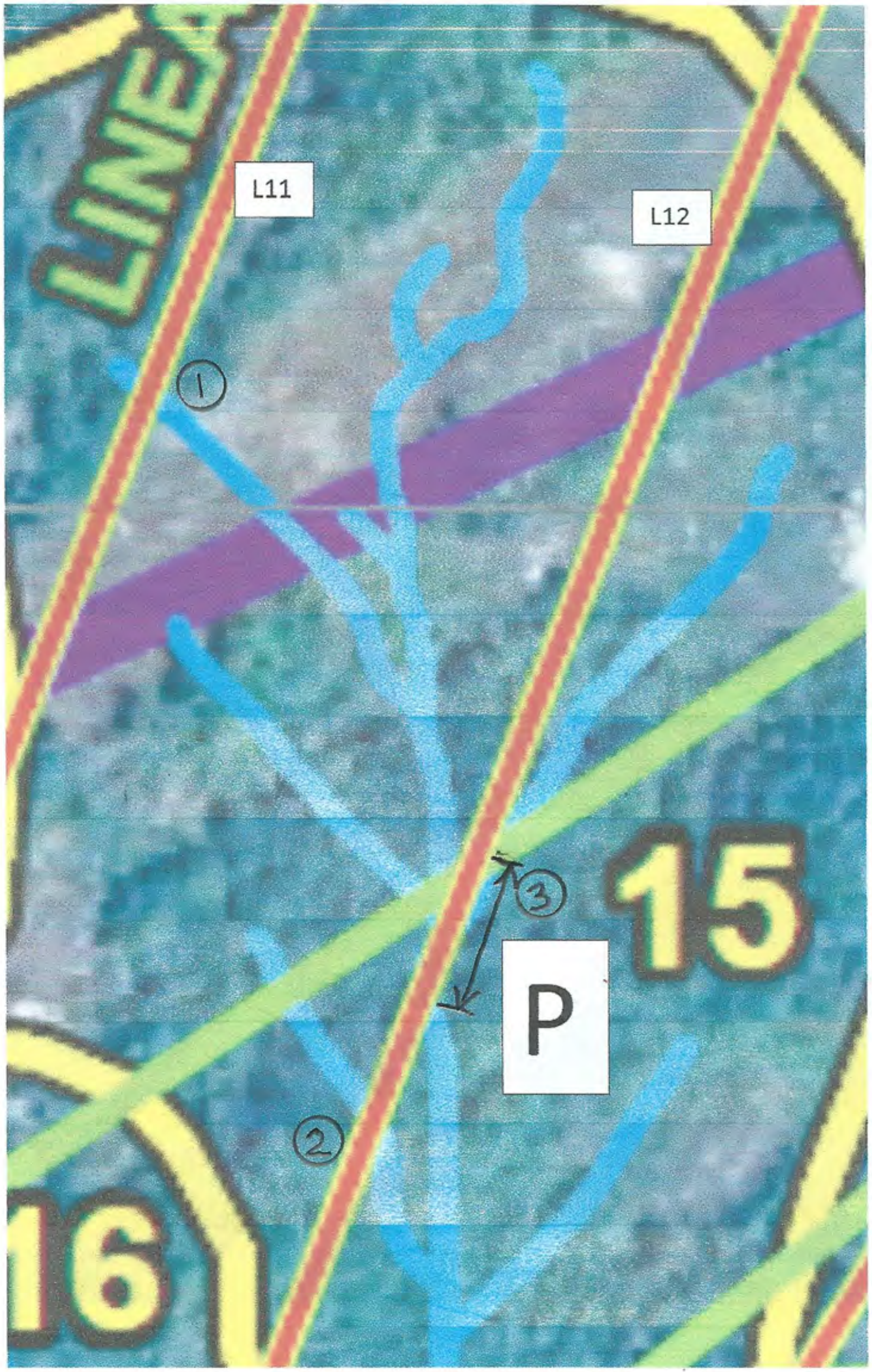
L7, L8, L11, L12 and L13 crossing M (12)



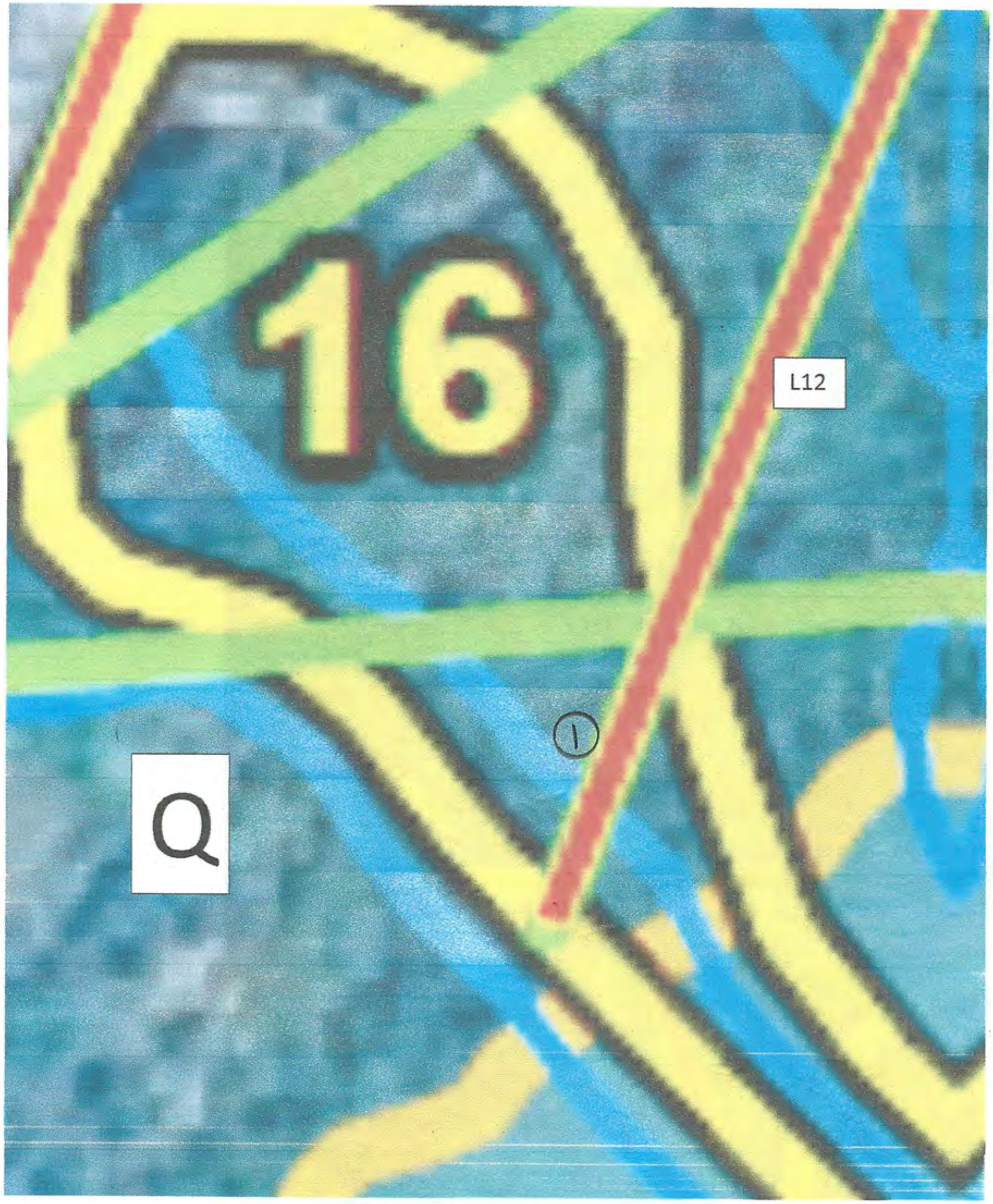
L6, 7, 8, 11, 12 and 13 crossing N (13)



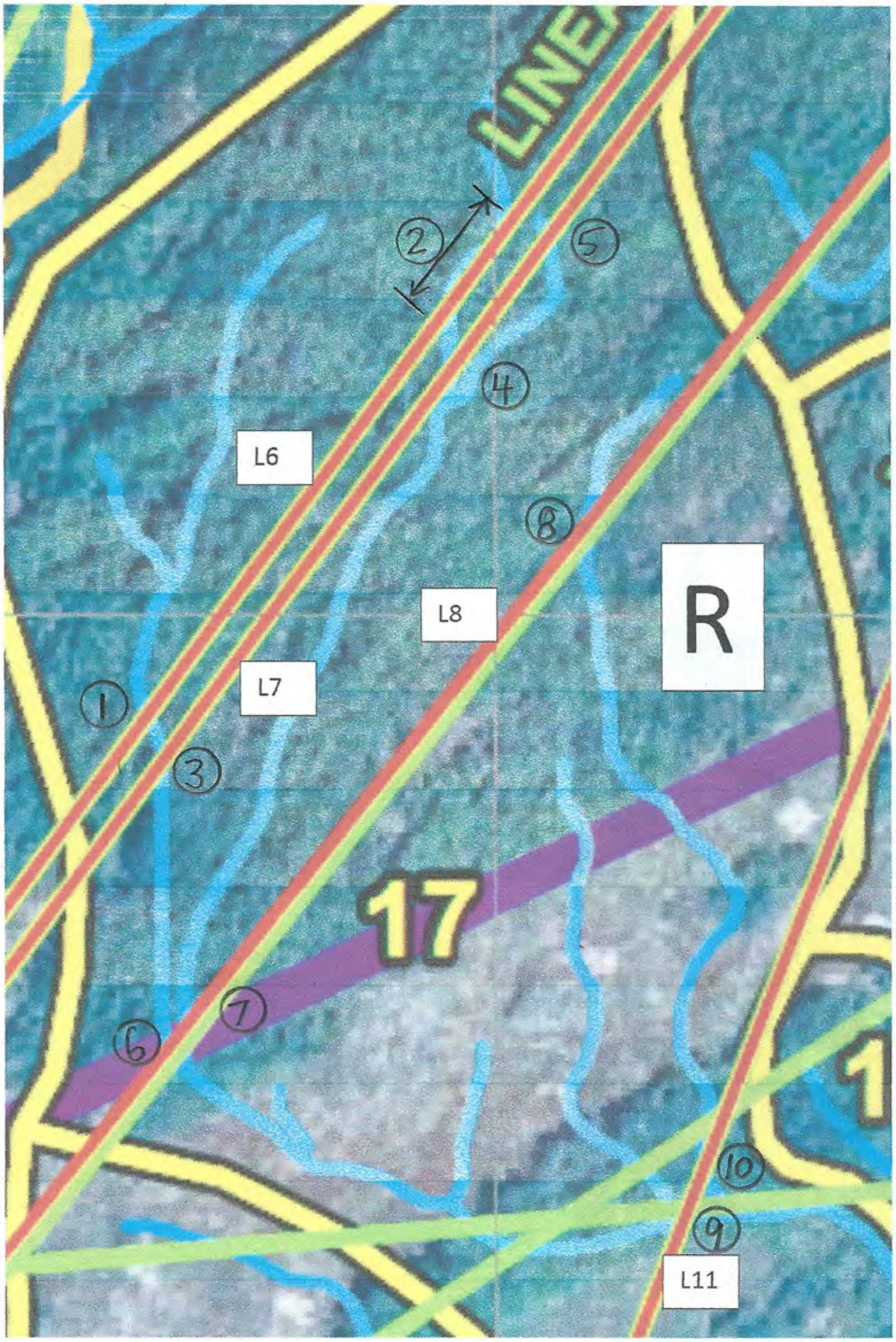
L13 crossing O (14)



L11 and L12 crossing P (15)

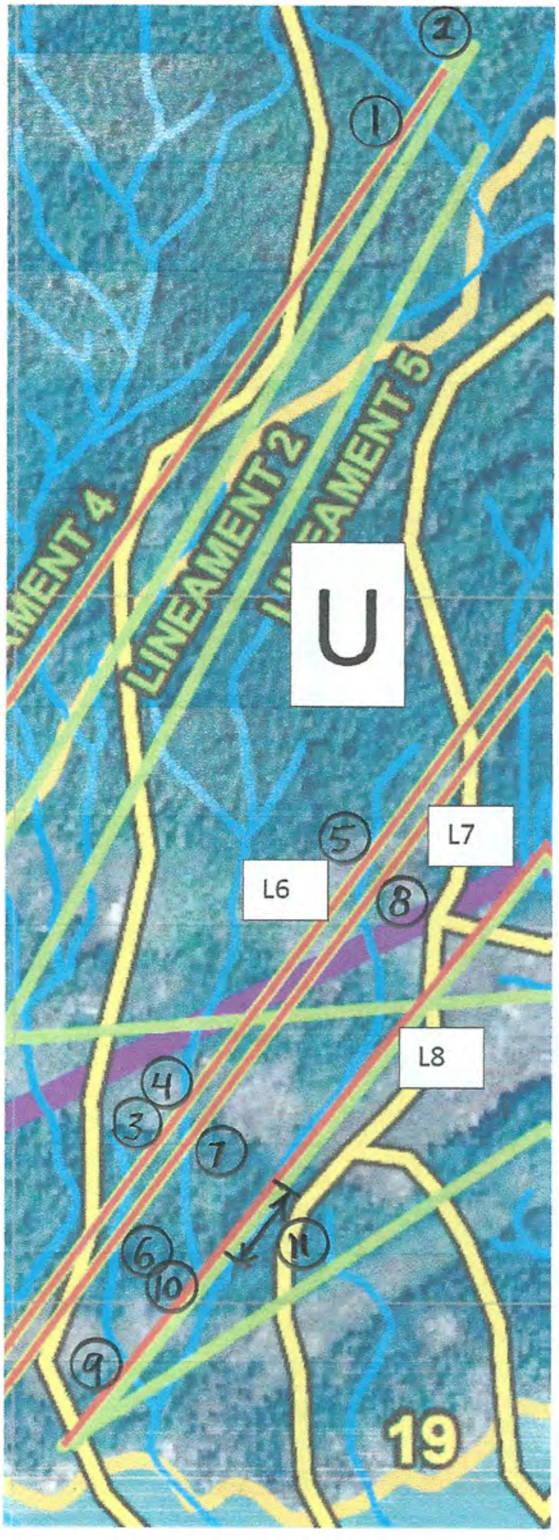


L12 crossing Q (16)

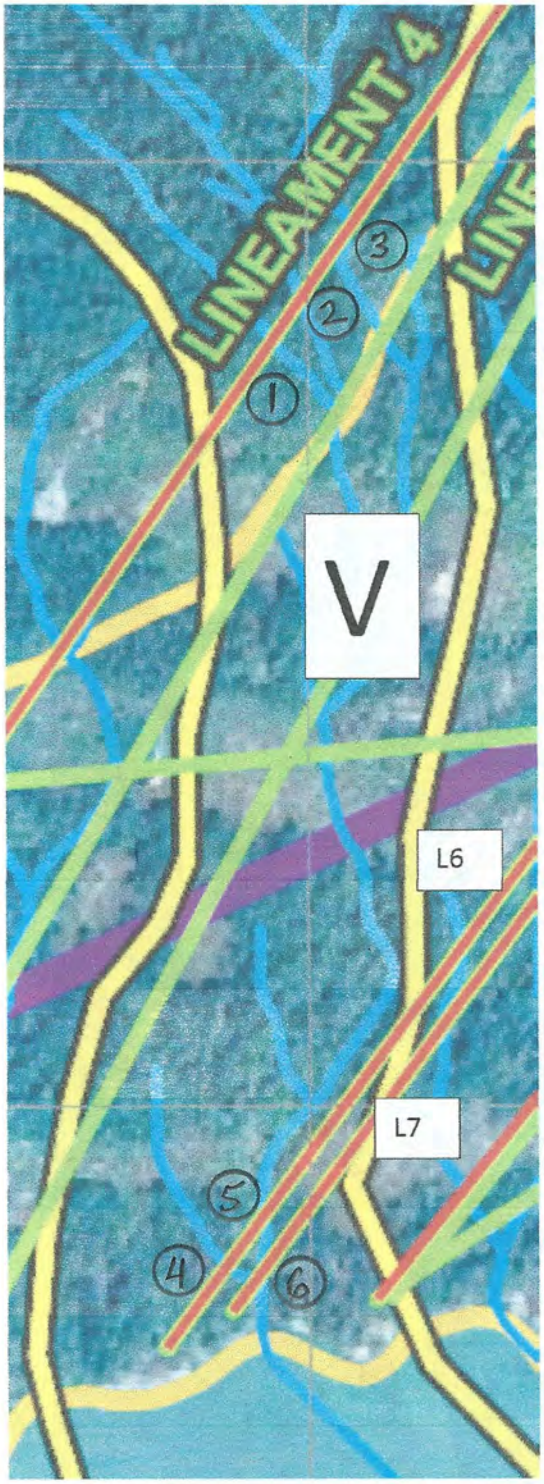


L6, 7, 8, 11 crossing R (17)

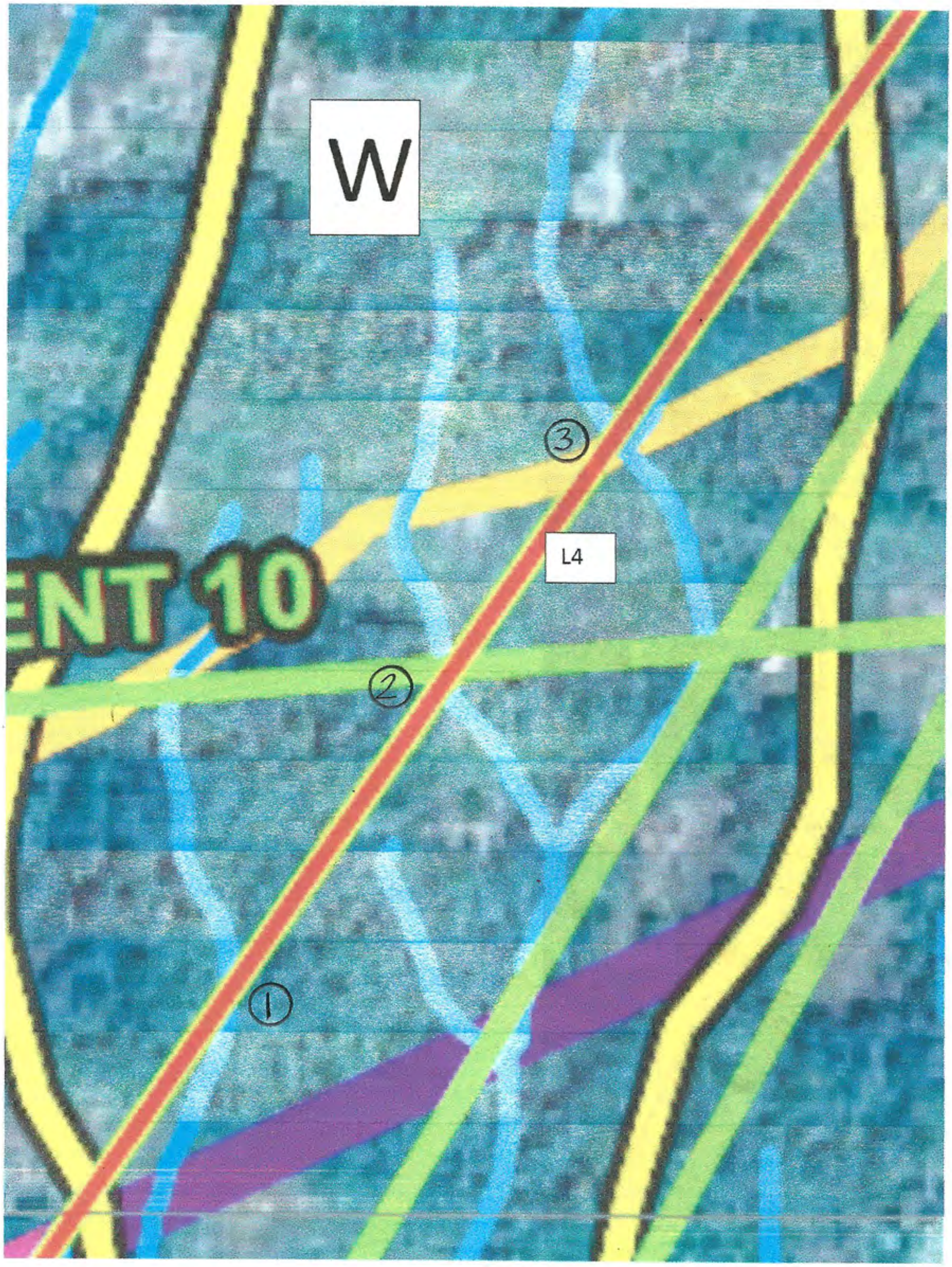
*****NOTE*** No intersections in S (18) or T (19) catchments with lineaments of concern.**



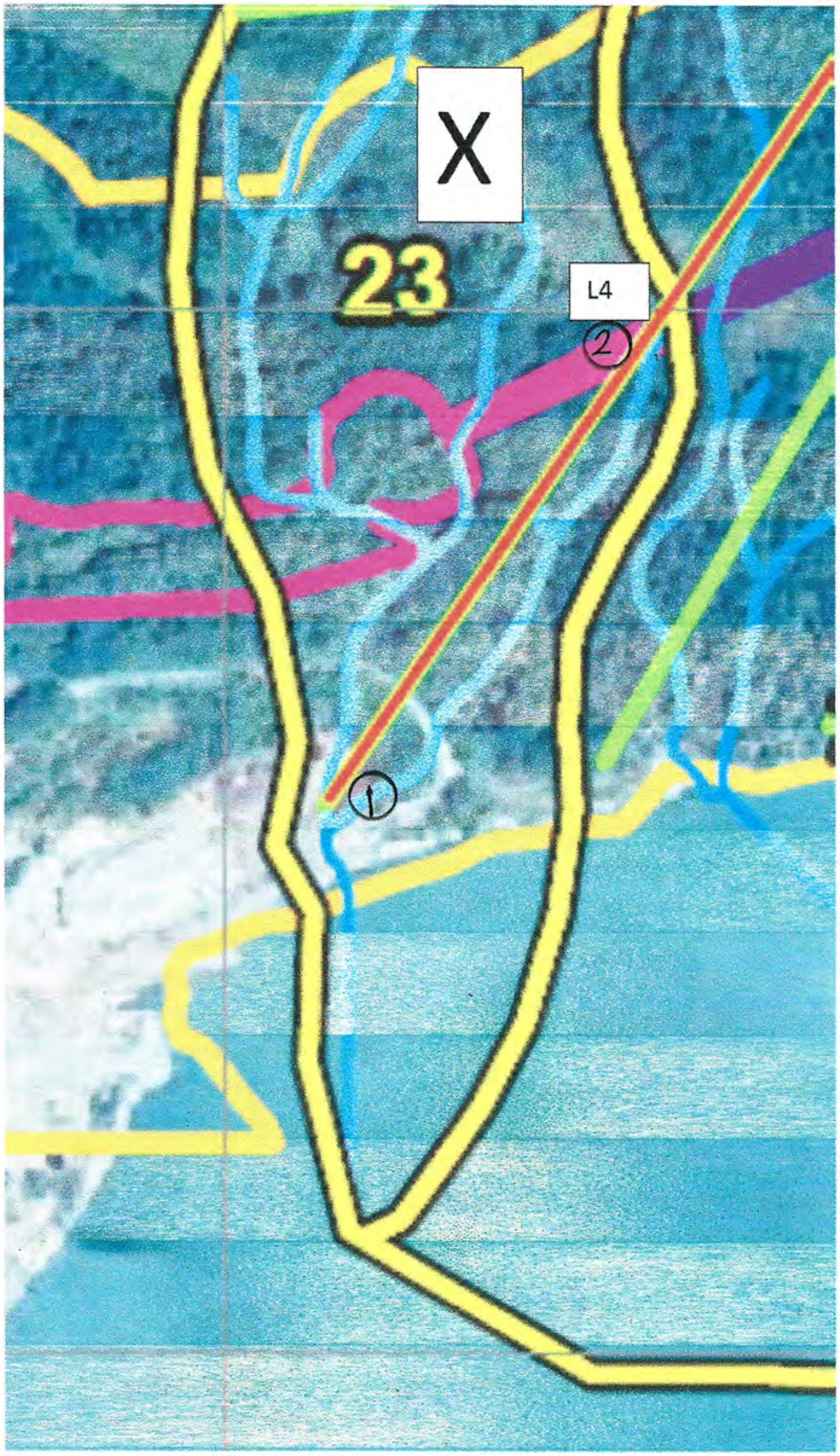
L4, 6, 7 and 8 crossing U (20).



L4, 6 and 7 crossing V (21)



L4 crossing W (22).



L4 crossing X (23).

APPENDIX C

FRACTURE ZONE/STREAM DEPLETION EVALUATION

EGP Tunnel Project - Fracture Zone/ Stream Depletion Evaluation

Notes:

Following team call on Feb 20, 2020, we agreed to the following starting assumptions for this analysis:

- Use *all* the drainage identified by Jacobs (no removal of stream channels). Drainage based on topography; not been ground-truthed.
- Assume average stream width of 2 m for all drainage channels
- Assume stream water entering fracture zone is proportional to lineament/stream intersection *width* divided by total lineament *length.*
- Assume all lineament/stream intersections are pertinent and of equal weight in depleting overall streamflow, in each catchment
- Sum the intersection depletions and divide by overall mean annual discharge (MAD) value for each catchment.
- Use calculated *ungrouted* fracture zone inflows to assess worst case depletion of streamflow.

Catch-ment ID	Lineament crossing stream(s)	Lineament Length	Intersection tracking #	Intersection angle x	Intersection width W' = 2m/ sin x	Q ungrouted (El Tani Method)	Q loss from stream at intersection	Catchment MAD	Q Loss as %MAD
		m		deg	m	L/min	L/min	L/min	%
A (1)	17	2125	1	50	2.6	1320	1.6	240	0.68
		2125	2	80	2.0	1320	1.3	240	0.53
Totals							2.9	240	**1.20**
B (2)	17	2125	1	40	3.1	1320	1.9	660	0.29
		2125	2	53	2.5	1320	1.6	660	0.24
		2125	3	30	4.0	1320	2.5	660	0.38
	19	950	4	7	16.4	300	5.2	660	0.79
		950	5	5	22.9	300	7.2	660	1.10
		950	6	40	3.1	300	1.0	660	0.15
Totals							19.4	660	**2.94**
C (3)	17	2125	1	62	2.3	1320	7.2	300	2.42
Totals							7.2	300	**2.42**
D (4)	17	2125	1	60	2.3	1320	1.4	240	0.60
		2125	2	62	2.3	1320	1.4	240	0.59
Totals							2.8	240	**1.18**
E (5)	17	2125	1	80	2.0	1320	1.3	1560	0.08
	18	740	2	30	4.0	660	3.6	1560	0.23
		740	3	12	9.6	660	8.6	1560	0.55
		740	4	34	3.6	660	3.2	1560	0.20
		740	5	25	4.7	660	4.2	1560	0.27
		740	6	30	4.0	660	3.6	1560	0.23
Totals							24.4	1560	**1.56**
F (6)	17	2125	1	78	2.0	1320	1.3	2580	0.05
Totals							1.3	2580	**0.05**
G (7)	17	2125	1	68	2.2	1320	1.3	180	0.74
Totals							1.3	180	**0.74**
H (8)	17	2125	1	65	2.2	1320	1.4	480	0.29
Totals							1.4	480	**0.29**
I (24)	*No intersections with lineaments of concern								
J (9)	*No intersections with lineaments of concern								
K (10)	13	1481	1	32	3.8	240	0.6	6600	0.01
		1481	2	64	2.2	240	0.4	6600	0.01
		1481	3	8	14.4	240	2.3	6600	0.04
		1481	4	85	2.0	240	0.3	6600	0.00
		1481	5	73	2.1	240	0.3	6600	0.01
	16B	756	6	1	114.6	66	10.0	6600	0.15
		756	7	4	28.7	66	2.5	6600	0.04
Totals							16.5	6600	**0.25**
L (11)	*No intersections with lineaments of concern								
M (12)	7	1577	1	30	4.0	186	0.5	3900	0.01
	8	1754	2	66	2.2	522	0.7	3900	0.02
		1754	3	90	2.0	522	0.6	3900	0.02

		1754	4	78	2.0	522	0.6	3900	0.02
		1754	5	68	2.2	522	0.6	3900	0.02
		1754	6	60	2.3	522	0.7	3900	0.02
		1754	7	88	2.0	522	0.6	3900	0.02
	11	1207	8	90	2.0	198	0.3	3900	0.01
		1207	9	80	2.0	198	0.3	3900	0.01
	12	1159	10	65	2.2	306	0.6	3900	0.01
		1159	11	67	2.2	306	0.6	3900	0.01
		1159	12	64	2.2	306	0.6	3900	0.02
		1159	13	56	2.4	306	0.6	3900	0.02
		1159	14	55	2.4	306	0.6	3900	0.02
	13	1481	15	50	2.6	240	0.4	3900	0.01
		1481	16	6	19.1	240	3.1	3900	0.08
Totals							11.5	3900	**0.29**
N (13)	7	1577	1	80	2.0	186	0.2	2040	0.01
		1577	2	88	2.0	186	0.2	2040	0.01
	8	1754	3	55	2.4	522	0.7	2040	0.04
		1754	4	81	2.0	522	0.6	2040	0.03
		1754	5	80	2.0	522	0.6	2040	0.03
		1754	6	87	2.0	522	0.6	2040	0.03
		1754	7	90	2.0	522	0.6	2040	0.03
	12	1159	8	63	2.2	306	0.6	2040	0.03
		1159	9	82	2.0	306	0.5	2040	0.03
		1159	10	76	2.1	306	0.5	2040	0.03
		1159	11	44	2.9	306	0.8	2040	0.04
	11	1207	12	46	2.8	198	0.5	2040	0.02
		1207	13	87	2.0	198	0.3	2040	0.02
		1207	14	65	2.2	198	0.4	2040	0.02
		1207	15	85	2.0	198	0.3	2040	0.02
		1207	16	70	2.1	198	0.3	2040	0.02
		1207	17	73	2.1	198	0.3	2040	0.02
	13	1481	18	67	2.2	240	0.4	2040	0.02
		1481	19	75	2.1	240	0.3	2040	0.02
		1481	20	20	5.8	240	0.9	2040	0.05
		1481	21	53	2.5	240	0.4	2040	0.02
Totals							10.2	2040	**0.50**
O (14)	13	1481	1	27	4.4	240	0.7	120	0.59
Totals							0.7	120	**0.59**
P (15)	11	1207	1	68	2.2	198	0.4	300	0.12
	12	1159	2	40	3.1	306	0.8	300	0.27
		1159	3	6	19.1	306	5.1	300	1.68
Totals							6.2	300	**2.08**
Q (16)	12	1159	1	67	2.2	306	0.6	60	0.96
Totals							0.6	60	**0.96**
R (17)	6	1320	1	55	2.4	402	0.7	720	0.10
		1320	2	4	28.7	402	8.7	720	1.21
	7	1577	3	38	3.2	186	0.4	720	0.05
		1577	4	25	4.7	186	0.6	720	0.08
		1577	5	47	2.7	186	0.3	720	0.04
	8	1754	6	70	2.1	522	0.6	720	0.09
		1754	7	45	2.8	522	0.8	720	0.12
		1754	8	29	4.1	522	1.2	720	0.17
	11	1207	9	57	2.4	198	0.4	720	0.05
		1207	10	21	5.6	198	0.9	720	0.13
Totals							14.7	720	**2.05**
S (18)	*No intersections with lineaments of concern								

T (19)	*No intersections with lineaments of concern								
U (20)	4	1336	1	72	2.1	570	0.9	1200	0.07
		1336	2	67	2.2	570	0.9	1200	0.08
	6	1320	3	37	3.3	402	1.0	1200	0.08
		1320	4	32	3.8	402	1.1	1200	0.10
		1320	5	17	6.8	402	2.1	1200	0.17
	7	1577	6	32	3.8	186	0.4	1200	0.04
		1577	7	38	3.2	186	0.4	1200	0.03
		1577	8	45	2.8	186	0.3	1200	0.03
	8	1754	9	70	2.1	522	0.6	1200	0.05
		1754	10	53	2.5	522	0.7	1200	0.06
		1754	11	5	22.9	522	6.8	1200	0.57
Totals							15.4	1200	**1.29**
V (21)	4	1336	1	75	2.1	570	0.9	6240	0.01
		1336	2	55	2.4	570	1.0	6240	0.02
		1336	3	30	4.0	570	1.7	6240	0.03
	6	1320	4	80	2.0	402	0.6	6240	0.01
		1320	5	35	3.5	402	1.1	6240	0.02
	7	1577	6	31	3.9	186	0.5	6240	0.01
Totals							5.8	6240	**0.09**
W (22)	4	1336	1	32	3.8	570	1.6	480	0.34
		1336	2	50	2.6	570	1.1	480	0.23
		1336	3	71	2.1	570	0.9	480	0.19
Totals							3.6	480	**0.76**
X (23)	4	1336	1	31	3.9	570	1.7	720	0.23
		1336	2	23	5.1	570	2.2	720	0.30
							3.8	720	**0.53**

Appendix D
Indigenous Engagement Documentation

16705 Fraser Highway
Surrey, B.C. V4N 0E8
www.fortisbc.com

June 25, 2020

Musqueam Indian Band
6735 Salish Drive
Vancouver, BC

Via email: craftis@musqueam.bc.ca

Dear Chris,

Re: Notification of Water Licence Permit Application for the Tunnel Component of the Eagle Mountain-Woodfibre Gas Pipeline Project

FortisBC Energy Inc. (FortisBC) submitted a Pipeline Permit application to the British Columbia Oil and Gas Commission (BC OGC) for the tunnel component of the Eagle Mountain – Woodfibre Gas Pipeline (EGP) Project (EGP Tunnel) on November 1, 2019 (AA# 100084403). During the review of the Pipeline Permit application, the BC OGC determined that a Water Licence under the Water Sustainability Act is required for the EGP Tunnel due to potential impacts to groundwater aquifers and surface streams.

FortisBC is writing to notify Musqueam Indian Band of the upcoming Water Licence application to the BC OGC for the EGP Tunnel. An overview of the EGP Tunnel, summary of the studies done to determine potential impacts to the surficial groundwater system, and mitigation measures are described herein.

EGP Tunnel Overview

FortisBC received an Environmental Assessment Certificate (EAC) for the EGP Project from the British Columbia Environmental Assessment Office on August 9, 2016. The EGP Project proposes the construction of approximately 47 kilometres (km) of Nominal Pipe Size 24 beginning north of the Coquitlam Watershed and ending at the Woodfibre Liquefied Natural Gas Ltd. on the northwestern shore of Howe Sound.

Geology and groundwater conditions for the EGP Tunnel can classified as:

1) Soft ground reach under the estuary (Soft Ground Tunnel)

2) Estuary-rock transition reach (Interface Zone)

3) Hard rock reach, which extends from the estuary-rock transition to the West Portal (Hard Rock Tunnel)

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The Water Licence Application will be specific to the Hard Rock Tunnel since no groundwater seepage or discharge is anticipated to occur for the Soft Ground Tunnel.

Potential Impacts

The results of a conceptual hydrogeological model conducted by Tetra Tech Canada Inc. indicate that fracture zones occurring in the granitic bedrock coincide with surficial lineaments along the Hard Rock Tunnel. Streams occur along or cross many of the lineaments and the surface water is likely hydraulically-connected with underlying saturated overburden and rock mass.

An Environmental Flow Needs (EFN) Assessment was conducted by Jacobs Consultancy Canada Inc. to determine if water inflow to the Hard Rock Tunnel from fracture zones could potentially deplete water from overlying streams and cause an EFN concern as defined in the Provincial EFN Policy. The study streams and catchment areas (watersheds) from the Study Area are shown in the figure attached to this letter.

The results of the EFN Assessment indicate that the calculated total streamflow depletion as a percentage of the mean annual discharge (MAD) was low, with an average depletion of 1.04 percent of MAD.

As these calculated depletions are <15 percent and the streams are non-fish bearing, the effects of Hard Rock Tunnel dewatering on streamflow in the Study Area would likely be considered as an EFN Risk Management Level 1 (lowest concern). Furthermore, since it is intended to grout the fracture zones found within the Hard Rock Tunnel, the potential streamflow depletion is anticipated to be significantly reduced.

Mitigation Measures

As part of the specifications included in the Request for Proposal, the Contractor is expected to adhere to the directions provided in the EAC Condition Management Plans (CMPs) and will provide an EGP Tunnel-specific Environmental Protection Plan (EPP) that shall meet or exceed the standards outlined in the CMPs. Preliminary mitigation measures to manage water quality and quantity during construction and operation of the EGP Tunnel have been included in performance specifications included in the Request for Proposal package for the EGP Tunnel. The main mitigation measure to reduce the quantity of produced water will be the implementation of a grouting program that will consist of drilling a series of advance boreholes and injecting cementitious grout at high pressure into the lineaments of concern.

A description of preliminary mitigation measures to manage the quantity and quality of water discharge from tunnel construction and operations is described below.

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Management of Water Quantity

In order to avoid flooding of the Hard Rock Tunnel works and to facilitate a functionally dry working area, grouting of fracture zones will be carried out during construction.

Continual monitoring of inflows and water quality will be conducted by taking flow measurements from observed seepage sources within the Hard Rock Tunnel. These measurements will help determine if additional grouting is required to impede groundwater inflows. Should a high groundwater inflow occur from a particular feature, the Contractor will grout the feature to prevent groundwater ingress. It is considered that by grouting the five to ten critical water-bearing features expected in the Hard Rock Tunnel, the actual inflow will be substantially reduced.

Management of Water Quality

The Contractor will prepare and submit a Water Treatment Plan for collecting, handling, treating, measuring, and disposing of groundwater and other waste water generated from construction activities. The Water Treatment Plan must include drawings and designs, treatment goals, and detailed process descriptions with a corresponding flowchart.

All treatment measures to be implemented must not exceed the applicable BC Approved Water Quality Guidelines for discharge of treated water to the environment. The Water Treatment Plan will include details on the means and methods of treatment, frequencies of monitoring water quality to check compliance with regulatory requirements prior to discharge, a water quality monitoring program, and contingency plans, amongst others.

Erosion and Sediment Control

Erosion and sediment control measures will be implemented by the Contractor during dewatering activities. The following general requirements have been added to the in the Groundwater Management Performance Specification included in the Contractor Request for Proposal for the EGP Tunnel.

- The Contractor must accomplish dewatering in a way that prevents the loss of fines from excavation sidewalls, will maintain stability of excavated slopes and bottom of excavations, and will result in construction operations being conducted in the dry to the extent required to complete the work.

- Keep all water entering excavations sufficiently controlled to develop a workable subgrade and control groundwater levels as specified to facilitate construction.

- Provide and construct all necessary intercepting ditches, barriers, sedimentation basins, holding ponds, or other acceptable means, as necessary, to prevent muddy water, eroded materials, and other undesirable constituents from being discharged.

- Mechanized equipment, except equipment associated with water handling and treatment, must not be operated in flowing surface water. The Contractor’s methods of dewatering, excavating, and

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stockpiling excavated materials (to the extent allowed) must include preventative measures to control silting and erosion.

- Water from excavations, drilling, grouting, or similar construction operations must not enter flowing or dry watercourses without the use of water treatment to achieve compliance with regulatory requirements.

- Dewatering system construction, operation, and monitoring must be performed in the presence of a FortisBC representative, who must be allowed unrestricted access.

- Observe and record the flow rate and time of the operation of each dewatering system used daily and in accordance with any additional requirements.

- Monitor and record groundwater levels surrounding all excavations to ensure groundwater levels are maintained in accordance with applicable regulatory requirements and seasonal fluctuations.

Closing

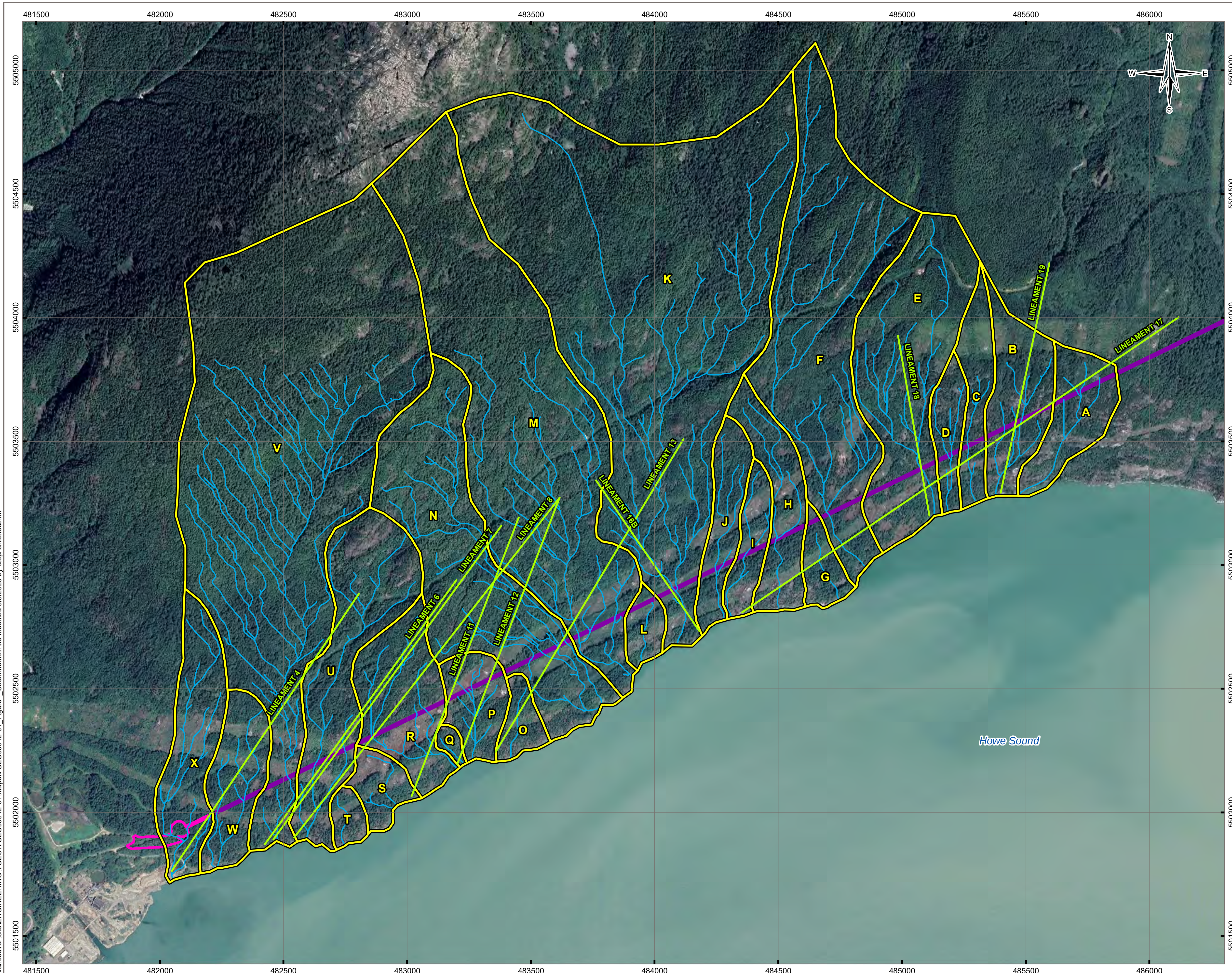
FortisBC recognizes that these proposed activities are located within the consultative area of Musqueam Indian Band and we endeavor to provide ongoing, open communication regarding these proposed works in advance of applying to the BC OGC. Please feel free to contact me regarding this or other aspects of the EGP Project.

Looking forward to working with you.

Respectfully,

Olivia Stanley
FortisBC

Attachments:
- Figure 1



LEGEND

- Study Stream (Jacobs 2020)
- Study Catchment (Jacobs 2020)
- Lineament of Concern (Wood 2019, MJA 2019)
- Tunnel Alignment (MJA 2019)
- Woodfibre Portal Area

NOTES
Base data source:
Imagery from Google (Aug 2019).

STATUS
ISSUED FOR REVIEW

EGP TUNNEL PROJECT

Tunnel Alignment with Stream Catchments and Lineaments of Concern

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	FORTIS BC

Scale: 1:15,000
200 100 0 200
Metres

TETRA TECH

FILE NO.
VGEO03612-01_Figure1_Catchments.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	YL	LR	0

DATE	PROJECT NO.
March 5, 2020	ENG.VGEO03612-01

Figure 1

Q:\Vancouver\GIS\ENGINEERING\VGEO\VGEO03612-01\Maps\VGEO03612-01_Figure1_Catchments.mxd modified 3/5/2020 by stephanie.leusink

16705 Fraser Highway
Surrey, B.C. V4N 0E8
www.fortisbc.com

June 25, 2020

Squamish Nation
320 Seymour Blvd.
North Vancouver, BC

Via email: denise_jensen@squamish.net

Dear Denise,

Re: Notification of Water Licence Permit Application for the Tunnel Component of the Eagle Mountain-Woodfibre Gas Pipeline Project

FortisBC Energy Inc. (FortisBC) submitted a Pipeline Permit application to the British Columbia Oil and Gas Commission (BC OGC) for the tunnel component of the Eagle Mountain – Woodfibre Gas Pipeline (EGP) Project (EGP Tunnel) on November 1, 2019 (AA# 100084403). During the review of the Pipeline Permit application, the BC OGC determined that a Water Licence under the Water Sustainability Act is required for the EGP Tunnel due to potential impacts to groundwater aquifers and surface streams.

FortisBC is writing to notify Squamish Nation of the upcoming Water Licence application to the BC OGC for the EGP Tunnel. An overview of the EGP Tunnel, summary of the studies done to determine potential impacts to the surficial groundwater system, and mitigation measures are described herein.

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3) Hard rock reach, which extends from the estuary-rock transition to the West Portal (Hard Rock Tunnel)

The Water Licence Application will be specific to the Hard Rock Tunnel since no groundwater seepage or discharge is anticipated to occur for the Soft Ground Tunnel.

Potential Impacts

The results of a conceptual hydrogeological model conducted by Tetra Tech Canada Inc. indicate that fracture zones occurring in the granitic bedrock coincide with surficial lineaments along the Hard Rock Tunnel. Streams occur along or cross many of the lineaments and the surface water is likely hydraulically-connected with underlying saturated overburden and rock mass.

An Environmental Flow Needs (EFN) Assessment was conducted by Jacobs Consultancy Canada Inc. to determine if water inflow to the Hard Rock Tunnel from fracture zones could potentially deplete water from overlying streams and cause an EFN concern as defined in the Provincial EFN Policy. The study streams and catchment areas (watersheds) from the Study Area are shown in the figure attached to this letter.

The results of the EFN Assessment indicate that the calculated total streamflow depletion as a percentage of the mean annual discharge (MAD) was low, with an average depletion of 1.04 percent of MAD.

As these calculated depletions are <15 percent and the streams are non-fish bearing, the effects of Hard Rock Tunnel dewatering on streamflow in the Study Area would likely be considered as an EFN Risk Management Level 1 (lowest concern). Furthermore, since it is intended to grout the fracture zones found within the Hard Rock Tunnel, the potential streamflow depletion is anticipated to be significantly reduced.

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As part of the specifications included in the Request for Proposal, the Contractor is expected to adhere to the directions provided in the EAC Condition Management Plans (CMPs) and will provide an EGP Tunnel-specific Environmental Protection Plan (EPP) that shall meet or exceed the standards outlined in the CMPs. Preliminary mitigation measures to manage water quality and quantity during construction and operation of the EGP Tunnel have been included in performance specifications included in the Request for Proposal package for the EGP Tunnel. The main mitigation measure to reduce the quantity of produced water will be the implementation of a grouting program that will consist of drilling a series of advance boreholes and injecting cementitious grout at high pressure into the lineaments of concern.

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Erosion and Sediment Control

Erosion and sediment control measures will be implemented by the Contractor during dewatering activities. The following general requirements have been added to the in the Groundwater Management Performance Specification included in the Contractor Request for Proposal for the EGP Tunnel.

- The Contractor must accomplish dewatering in a way that prevents the loss of fines from excavation sidewalls, will maintain stability of excavated slopes and bottom of excavations, and will result in construction operations being conducted in the dry to the extent required to complete the work.

- Keep all water entering excavations sufficiently controlled to develop a workable subgrade and control groundwater levels as specified to facilitate construction.

- Provide and construct all necessary intercepting ditches, barriers, sedimentation basins, holding ponds, or other acceptable means, as necessary, to prevent muddy water, eroded materials, and other undesirable constituents from being discharged.

- Mechanized equipment, except equipment associated with water handling and treatment, must not be operated in flowing surface water. The Contractor’s methods of dewatering, excavating, and

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stockpiling excavated materials (to the extent allowed) must include preventative measures to control silting and erosion.

• Water from excavations, drilling, grouting, or similar construction operations must not enter flowing or dry watercourses without the use of water treatment to achieve compliance with regulatory requirements.

• Dewatering system construction, operation, and monitoring must be performed in the presence of a FortisBC representative, who must be allowed unrestricted access.

• Observe and record the flow rate and time of the operation of each dewatering system used daily and in accordance with any additional requirements.

• Monitor and record groundwater levels surrounding all excavations to ensure groundwater levels are maintained in accordance with applicable regulatory requirements and seasonal fluctuations.

Closing

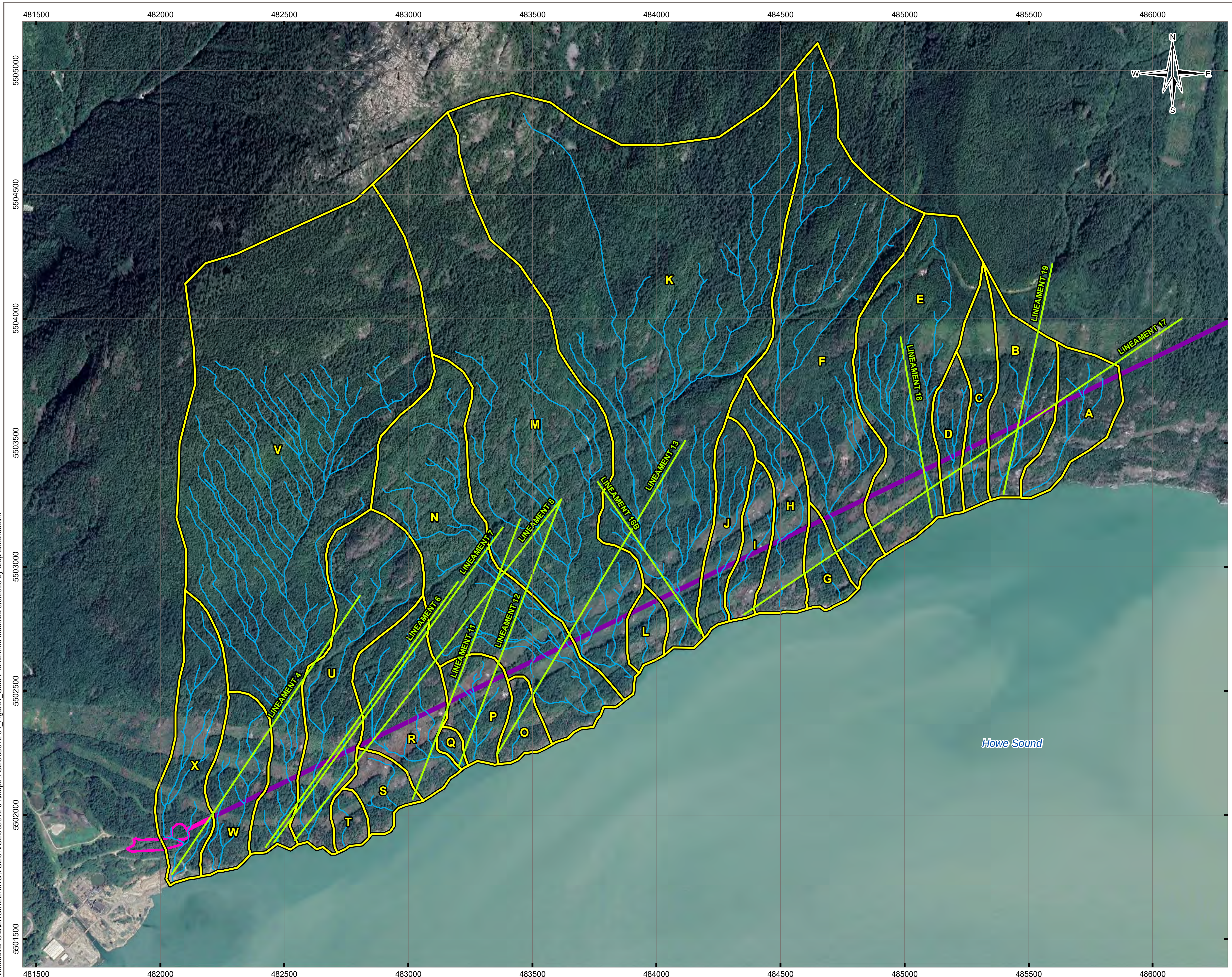
FortisBC recognizes that these proposed activities are located within the consultative area of Squamish Nation and we endeavor to provide ongoing, open communication regarding these proposed works in advance of applying to the BC OGC. Please feel free to contact me regarding this or other aspects of the EGP Project.

Looking forward to working with you.

Respectfully,

Amar Athwal
FortisBC

Attachments:
- Figure 1



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LEGEND

- Study Stream (Jacobs 2020)
- Study Catchment (Jacobs 2020)
- Lineament of Concern (Wood 2019, MJA 2019)
- Tunnel Alignment (MJA 2019)
- Woodfibre Portal Area

NOTES
Base data source:
Imagery from Google (Aug 2019).

STATUS
ISSUED FOR REVIEW

EGP TUNNEL PROJECT

Tunnel Alignment with Stream Catchments and Lineaments of Concern

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	FORTIS BC

Scale: 1:15,000
200 100 0 200
Metres

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TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	YL	LR	0

DATE	PROJECT NO.
March 5, 2020	ENG.VGEO03612-01

Figure 1

FORTIS BC

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June 25, 2020

Tsleil-Waututh Nation
3178 Alder Court
North Vancouver, BC

Via email: jsteele@twnation.ca

Dear Jessica,

Re: Notification of Water Licence Permit Application for the Tunnel Component of the Eagle Mountain-Woodfibre Gas Pipeline Project

FortisBC Energy Inc. (FortisBC) submitted a Pipeline Permit application to the British Columbia Oil and Gas Commission (BC OGC) for the tunnel component of the Eagle Mountain – Woodfibre Gas Pipeline (EGP) Project (EGP Tunnel) on November 1, 2019 (AA# 100084403). During the review of the Pipeline Permit application, the BC OGC determined that a Water Licence under the Water Sustainability Act is required for the EGP Tunnel due to potential impacts to groundwater aquifers and surface streams.

FortisBC is writing to notify Tsleil-Waututh Nation of the upcoming Water Licence application to the BC OGC for the EGP Tunnel. An overview of the EGP Tunnel, summary of the studies done to determine potential impacts to the surficial groundwater system, and mitigation measures are described herein.

EGP Tunnel Overview

FortisBC received an Environmental Assessment Certificate (EAC) for the EGP Project from the British Columbia Environmental Assessment Office on August 9, 2016. The EGP Project proposes the construction of approximately 47 kilometres (km) of Nominal Pipe Size 24 beginning north of the Coquitlam Watershed and ending at the Woodfibre Liquefied Natural Gas Ltd. on the northwestern shore of Howe Sound.

Geology and groundwater conditions for the EGP Tunnel can classified as:

1) Soft ground reach under the estuary (Soft Ground Tunnel)

2) Estuary-rock transition reach (Interface Zone)

3) Hard rock reach, which extends from the estuary-rock transition to the West Portal (Hard Rock Tunnel)

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The Water Licence Application will be specific to the Hard Rock Tunnel since no groundwater seepage or discharge is anticipated to occur for the Soft Ground Tunnel.

Potential Impacts

The results of a conceptual hydrogeological model conducted by Tetra Tech Canada Inc. indicate that fracture zones occurring in the granitic bedrock coincide with surficial lineaments along the Hard Rock Tunnel. Streams occur along or cross many of the lineaments and the surface water is likely hydraulically-connected with underlying saturated overburden and rock mass.

An Environmental Flow Needs (EFN) Assessment was conducted by Jacobs Consultancy Canada Inc. to determine if water inflow to the Hard Rock Tunnel from fracture zones could potentially deplete water from overlying streams and cause an EFN concern as defined in the Provincial EFN Policy. The study streams and catchment areas (watersheds) from the Study Area are shown in the figure attached to this letter.

The results of the EFN Assessment indicate that the calculated total streamflow depletion as a percentage of the mean annual discharge (MAD) was low, with an average depletion of 1.04 percent of MAD.

As these calculated depletions are <15 percent and the streams are non-fish bearing, the effects of Hard Rock Tunnel dewatering on streamflow in the Study Area would likely be considered as an EFN Risk Management Level 1 (lowest concern). Furthermore, since it is intended to grout the fracture zones found within the Hard Rock Tunnel, the potential streamflow depletion is anticipated to be significantly reduced.

Mitigation Measures

As part of the specifications included in the Request for Proposal, the Contractor is expected to adhere to the directions provided in the EAC Condition Management Plans (CMPs) and will provide an EGP Tunnel-specific Environmental Protection Plan (EPP) that shall meet or exceed the standards outlined in the CMPs. Preliminary mitigation measures to manage water quality and quantity during construction and operation of the EGP Tunnel have been included in performance specifications included in the Request for Proposal package for the EGP Tunnel. The main mitigation measure to reduce the quantity of produced water will be the implementation of a grouting program that will consist of drilling a series of advance boreholes and injecting cementitious grout at high pressure into the lineaments of concern.

A description of preliminary mitigation measures to manage the quantity and quality of water discharge from tunnel construction and operations is described below.

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Management of Water Quantity

In order to avoid flooding of the Hard Rock Tunnel works and to facilitate a functionally dry working area, grouting of fracture zones will be carried out during construction.

Continual monitoring of inflows and water quality will be conducted by taking flow measurements from observed seepage sources within the Hard Rock Tunnel. These measurements will help determine if additional grouting is required to impede groundwater inflows. Should a high groundwater inflow occur from a particular feature, the Contractor will grout the feature to prevent groundwater ingress. It is considered that by grouting the five to ten critical water-bearing features expected in the Hard Rock Tunnel, the actual inflow will be substantially reduced.

Management of Water Quality

The Contractor will prepare and submit a Water Treatment Plan for collecting, handling, treating, measuring, and disposing of groundwater and other waste water generated from construction activities. The Water Treatment Plan must include drawings and designs, treatment goals, and detailed process descriptions with a corresponding flowchart.

All treatment measures to be implemented must not exceed the applicable BC Approved Water Quality Guidelines for discharge of treated water to the environment. The Water Treatment Plan will include details on the means and methods of treatment, frequencies of monitoring water quality to check compliance with regulatory requirements prior to discharge, a water quality monitoring program, and contingency plans, amongst others.

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Looking forward to working with you.

Respectfully,

Olivia Stanley
FortisBC

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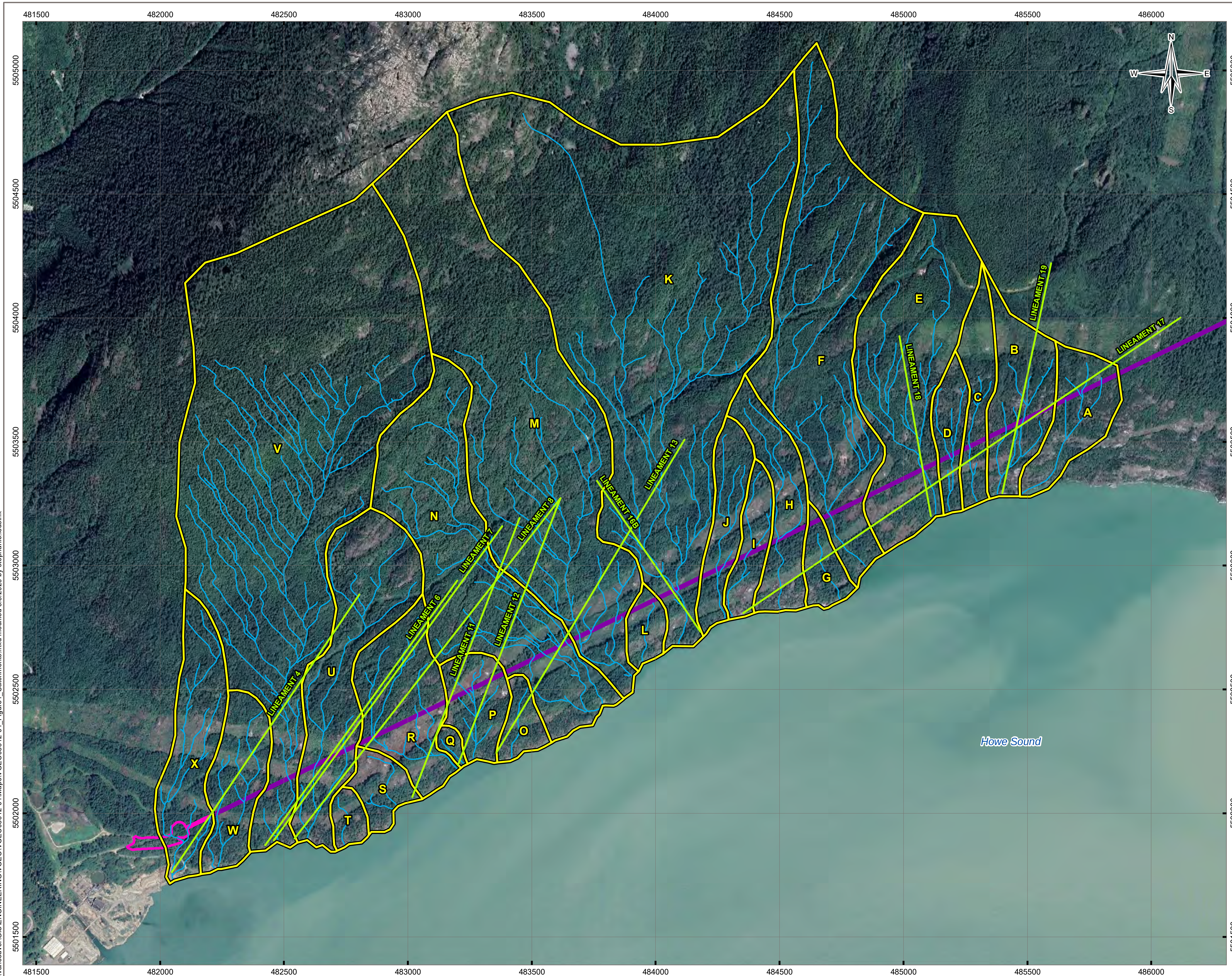

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OFFICE	DWN	CKD	APVD	REV
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Figure 1