# Technical Memorandum

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| Prepared by: | Charles Hunt | Job No.: | 53728_012_MO_RT_A_Overview ARD/PAG_For_OGC |
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### Revision Log

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## 1.0 Introduction

The FortisBC Energy Inc. (FortisBC) Eagle Mountain - Woodfibre Gas Pipeline Project (EGP Project) involves the construction of an approximately 9 km tunnel (EGP Tunnel) from the BC Rail Properties Ltd. (BC Rail) Site to the proposed Woodfibre Liquefied Natural Gas Ltd. (WLNG) production facility (WLNG Site) in Squamish, BC. The ultimate purpose of the EGP Tunnel is to enclose the NPS 24 (610 mm O.D.) natural gas pipeline system. In the Reference Design, the tunnel is approximately 8.7 km long, from the East Shaft, located in the BC Rail Site in Squamish, to the Woodfibre Portal, at the WLNG facility. Approximately 3.75 km of the tunnel alignment is in soft ground, with the remaining 5 km in bedrock (referred to as the Bedrock Tunnel).

The Bedrock Tunnel will be excavated through the igneous bedrock. Rock cover along the Reference Design Alignment varies from a minimum of approximately 20 metres west of the Interface Reach, to 450 m under Monmouth Ridge. The Reference Design contemplates a tunnel excavated by TBM with a nominal bore diameter of 4.2 m. The initial rock support varies from grouted spot rock bolts, to steel sets with lagging and shotcrete. Investigations and assessments have shown that Potentially Acid Generating (PAG) rock and rock which has the potential to leach metals (ML) may be present between Ch. 4+810 and 6+306 m (over a length of some 1,500 m).

This document summarizes the investigations, testing and management for Potentially Acid Generating (PAG) rock. With respect to the on site management of PAG rock the Contractor is required to prepare an ARD Construction Response Plan and an Acid Rock Construction and Metal Leachate Management Plan. The Acid Rock Construction and Metal Leachate management plan, will be prepared in consultation with

appropriate regulatory authorities, and furthermore follows Canadian guidelines and policies on best management practices to be incorporated into the ARD Construction Response plan.

## 2.0 Overview of Tunnel Excavation

The total quantity of rock from the 5,016 m long, 4.2 m diameter rock tunnel will be an excavated volume of approximately 90,000 cubic metres (bulked, in place the rock volume is 69,493 m3). As a portion of this total amount the quantity anticipated to be Potentially Acid Generating (PAG) rock is 26,944 m3 (bulked, in place the volume is 20,726 m3), leaving 63,000 m3 (bulked) Non Acid Generating (NAG) rock.

Testing of rock samples has been undertaken across the tunnel alignment from outcrops and from investigative boreholes. This sampling combined with geological mapping along the alignment suggests that some 2,463 m from the Woodfibre tunnel portal (entrance), a zone of PAG rock may be encountered, and continue for about 1,500 m. The testing from which this statement was made is outlined in Section 3.0, below.

## 3.0 Acid Rock Drainage and Metal Leaching 3-phased Testing:

Coverage of the ~5km Bedrock Tunnel alignment for ARD/ML was completed through sampling of both surface exposures and borehole cores during the three investigation periods in 2014, 2016 and 2019.

Preliminary ARD/ML characterization was completed by AMEC (currently operating as Wood) in 2014 (AMEC 2014). This study was based on assessment of regional and local geology to identify segments of the entire proposed pipeline route for sampling and testing. Testing of the samples near to the tunnel, revealed that the carbonate content, and therefore neutralising potential (NP) of most of the samples is very low. None of the samples contained visible sulphides, however all samples noted presence of iron staining or alteration. One sample from above the tunnel alignment (in Section D4 – refer to AMEC 2014) was reported as potentially acid generating (PAG) using a modified Sobek calculation. However, NPR classification, based on Carbonate NP, classifies remaining samples as uncertain acid generating potential (UC).

AMEC collected a number of rock samples from the drilling of the 560 m long sub-horizontal Geotechnical borehole BH2016-09H parallel to the proposed tunnel alignment commenced at the Coastal Portal (Wood, 2019). From the core, nine ARD/ML samples were collected for static test analysis. The results of the Acid Base Accounting (ABA) test showed that all but one of the samples submitted was classified as PAG based on a modified Sobek calculation. All samples contained very low neutralization potential, with values between 1.3 and 2.8 kg CaCO3/T, resulting in a PAG classification when trace quantities of sulphide and sulphur are present. The sampling undertaken from this borehole was selective, in that rock sampled was iron stained or contained visible sulphides and was not necessarily representative of all the rock within the borehole.

In May of 2019, McMillen Jacobs Associates (MJA) in collaboration with Tetra Tech (Tetra Tech 2019) collected samples of core from borehole BH2016-09H in equal 50 m intervals throughout the entire

length of the borehole. In June of 2019, the field inspection included a secondary review of the core at the site warehouse. All samples which were observed during the June site visit were found to be representative of the 3-5 m section adjacent to the sample depth. Additional areas of notable alteration within the core were also reviewed and described alongside descriptions of the core samples tested. Additional surface samples were collected from the site quarry and blasted rock which composes the foundation of BC Hydro transmission towers present along the tunnel alignment. Further to this, samples were collected from fresh and weathered outcrops along the proposed tunnel alignment. Twenty samples selected for analysis were submitted to ALS Minerals Laboratories in Vancouver, BC, for Acid Base Accounting (ABA) analysis and trace element analysis through inductively coupled plasma mass-spectrometry (ICP-MS). All samples were also included for shake flask extraction (SFE) analysis at ALS Environmental Laboratories in Burnaby, BC.

The results of these tests are reported in Tetra Tech 2019. The majority of the core samples tested in 2019 from BH2016-09H, particularly in the middle and deeper portions of the drill hole from 218 m – 449 m, are classified as PAG in accordance with MEND (Mine Environmental Neutral Drainage Program) guidelines, based on Modified Sobek and Carbonate neutralization potential ratio (NPR) values of less than one. Core samples from BH2016-09H from surface to 100 m depth are considered NAG with NPR values up to 25.6. In contrast, all of the surface samples, both from the site quarry and BC Hydro tower locations, are classified as NAG with respect to the Modified Sobek and Carbonate NPR values. Modified Sobek NPR values average around 9, with a range of 0.43 – 25.6. Carbonate NPR values average 1.7, with inorganic carbon at the detection limit (0.05% C) in all samples tested.

Based on the results of the analysis and geotechnical interpretation the tunnel has been subdivided into three domains; Western, Central and Headland, each of which comprise a portion of the proposed Bedrock Tunnel alignment. Based on geologic mapping and lab analysis completed to date, inclusive of the 2014, 2016 and 2019 investigation programs, bedrock within the Central Domain of the tunnel alignment is classified as PAG rock (with the potential to leach metals), and bedrock within the Western and Headland Domains are overall classified as NAG rock.

Subsequent to these reports and analyses, a management procedure for ARD rock and ML was prepared by MJA in collaboration with Tetra Tech in June of 2020 (MJA 2020).

## 3.1 Additional Humidity Cell Testing

On the basis that PAG rock would be excavated on site, additional testing using humidity cells was carried out under the guidance and direction of Tetra Tech (Tetra Tech 2020 & 2021a). Humidity cell tests are designed to model the geological processes of weathering at the laboratory scale. The humidity cells were established to predict primary reaction rates, including rates of elemental release, acid generation and acid neutralization. Samples are subjected to weekly cycles that alternate between the circulation of dry air and moist air over the samples to simulate precipitation cycles. The weekly leachates produced during the humidity cell procedure are analyzed for several parameters, including pH, conductivity, acidity, alkalinity, anions, and dissolved metals. These tests are performed to reduce the uncertainty in the results and evaluate the conclusions of static prediction tests. The data can be used as a preliminary assessment of onset time of acid rock drainage and metal leaching loading rates for

evaluating mitigation options. Testing was undertaken at ALS Environmental Laboratory in Burnaby, British Columbia.

The four humidity cells were selected to represent a range of expected compositions of bedrock material that may be excavated during tunnelling, as well as to provide good spatial representation along the length of the Bedrock Tunnel. Three humidity cells were established with material from a single depth interval, and one humidity cell is a composite sample from two discreet sample intervals. The composite sample was necessary due to the volume of left-over sample material at the lab and was chosen from two samples which reported similar composition in the preliminary static testing.

The following summarizes the results of the humidity cells to week 71:

- The pH in all four cells is below the BCAWQG acceptable range of 6.5-9. A value at or below pH 6 is considered acidic for the purpose of this reporting. All cells are considered acidic at this time. Cell 4 has remained at or slightly below pH 6 since Week 34. Cell 2 has generally stabilized just below pH 4 since Week 34. Cell 1 has remained around pH 3.6 since Week 61. Cell 3 has remained around pH 4 since Week 51.

- The change in pH can be correlated to the sulphate production and Carbonate NP depletion rates. As sulphides weather, reaction processes produce sulphates. The sulphide oxidation reaction also produces acidity.

- Leachable metal concentrations vary between the four cells and also over time during the course of leachate analysis to date. The metals concentrations vary based on initial whole rock elemental concentration, the susceptibility to leaching based on rock and mineral structure, and the leachate pH. Concentrations of some metals continue to increase at the current time, especially in Cell 1. This includes aluminum, calcium, chromium, copper, lead, magnesium, and silica. The aluminum, calcium, magnesium and silica increases may be related to the dissolution of carbonate and silicate minerals which provide buffering capacity.

- A number of elements saw an increase and spike associated with the drop in pH. The highest metal concentrations are often observed at the start of pH stabilization as noted above, at Week 34, 51, and 61 for the different cells.

## 3.2 Geochemical Modelling Report

The humidity cell analysis data was used as input to a geochemical model for the leachate chemistry from the tunnel wall rock exposures and waste rock excavated from the tunnel and stored on surface (Tetra Tech 2021b). The purpose of the geochemical model is to provide an estimation of onset time to acid generation and metal leaching from exposed tunnel waste rock as well as tunnel wall rock, as well as to evaluate predicted water quality generated from these areas. The geochemical model was developed using the computer code PHREEQCI Version 3.6.2-15100 (Parkhurst and Appelo, 2013), which was created by the U.S. Geological Survey and is an industry standard for predictive water quality modelling, and Microsoft Excel. The model uses historical temperature and precipitation for Woodfibre, site water

quality data was used (of which Woodfibre have an extensive record) and the actual gradation size of the TBM rock spoil (essentially a 3-inch minus).

The onset time for ARD in a field setting for waste rock placed in the Stockpile can be determined based on the leaching rate factor which is 0.5 based on the particle size of the expected Stockpile waste rock. The following estimates of ARD onset time for a stockpile are considered based on the modelling:

- Applying the scaling factors, Tetra Tech arrives at a range of about 20-70 weeks depending on the proportional mix in the pile. In other words the onset of acidic conditions in a stockpile open to the air and rainfall will not generate acidic conditions until a minimum of 20 weeks. Again, the low end of that range being a well flushed pile with dominantly Cell #2 waste rock, and the upper end of the range being a dominantly Cell #3/4 pile with representative fines as expected (50% less than 6mm) and some reduction in oxidation from winter placement and reduced flushing. A mix of all four cell types and a well-mixed pile (i.e. not all Cell #2 on top surface) would be in the 30 to 50 weeks range as an estimate.

The onset time for ARD in a field setting for bedrock exposed in the tunnel wall rocks can be determined based on the leaching rate factor of 0.1, based on the massive nature of the wall rock and minimal fracturing. The following estimates of ARD onset time for tunnel wall rock are considered based on the modelling:

- Unknown mix based on the four samples is in the range of 100 to 350 weeks. Assuming equal proportions from the four humidity cells. In other words, the walls of the tunnel excavated by a Hard Rock Tunnel Boring Machine (TBM) in Central domain will not generate acidic conditions until a minimum of 100 weeks.

Subsequent to these reports and analyses Tetra Tech prepared the report, Acid Rock Drainage and Metal Leaching Best Practices for Management and Mitigation (Tetra Tech, 2021c) specific to the laboratory results overviewed above. These best practices and procedures will be further developed during detailed design by a Qualified Person (specializing in ARD / ML evaluation and management) employed by the contractor-design team.

## 4.0 Overview of On-Site ARD Management Practices & Temporary Stockpiling

During the excavation of the tunnel the Contractor must undertake routine testing through a Qualified Person to assess the potential for PAG rock. This testing forms an integral part of the Condition Management Plans (CMPs developed by FEI), particularly the Construction Environmental Management Plan (CEMP) and ARD Management Plan. These latter two plans are being developed by the Contractor and will ensure that commitments and mitigation measures will be implemented during construction of the EGP Tunnel to avoid or reduce potential adverse effects on the environment specific to PAG rock. The Contractor is expected to adhere to the CMPs and will provide an EGP Tunnel Construction Environment Management Plan (CEMP) that shall meet or exceed the standards outlined in the CMPs and include an ARD/ML Management Plan/Construction Response Plan that will detail their approach to identification, excavation, storage and monitoring during tunnel construction.

Rigorous testing will be carried out (in accordance with the ARD Management Plan) on all rock excavated from the tunnel (both within the zone of rock that is considered to be PAG, as well as outside of this zone), to confirm our assumptions and previous test work. The previous testing has shown that the PAG rock starts to generate acidic water after a period of 20 to 70 weeks (in the presence of oxygen and depending on the particular mineralogy of the rock sample). This 20 to 70-week period could be further extended if water is prevented from draining through the PAG rock stockpile. It should be noted that PAG rock, if disposed of sub-aqueously, does not produce acid as the oxygen required for mineralogical degradation and reaction is not present. Sub-aqueous disposal therefore presents an acceptable alternative of permanently disposing of PAG rock rather than in a containment and/or at a permitted facility. Sub-aqueous disposal means placement of PAG rock beneath water, for example into the sea for land reclamation, placement beneath the groundwater table, or into the tunnel as backfill (the tunnel will be flooded upon completion).

There are three general alternatives that could potentially be used to permanently dispose of the PAG rock that have been considered: 1) disposal on site, 2) disposal in the tunnel, and 3) disposal off-site. These alternatives are discussed below:

1) On site disposal could be in the form of using the PAG rock as general fill below the water table for foundations of buildings and structures of the LNG facility. Unfortunately, the PAG rock will be excavated after planned foundation construction for the WLNG facility, based on the latest schedule from Woodfibre LNG. The other on site disposal option could encompass the construction of a permanent disposal cell at the WLNG quarry site.

2) The PAG rock could be temporarily stored at the Quarry Site until completion of the tunnel excavation, where all or a portion of the PAG rock could be used as backfill within the tunnel. The tunnel will be flooded after construction and as a result, this sub-aqueous disposal would be an acceptable alternative for permanent disposal.

3) MJA has investigated various uses for sub-aqueous backfill off-site. There are a number of projects around the Squamish waterfront (as well as within Howe Sound) that require fill to be placed underwater so as to help reclaim land or provide a foundation. Although several parties have expressed interest, it will be up to the awarded Contractor to determine..

On the balance it is therefore believed that the most environmentally sustainable solution to permanent disposal of the PAG rock is as backfill within the tunnel where the rock will be underwater in perpetuity.

With respect to the remainder of the non-PAG rock from the tunnel (63,000 $m^3$), testing has shown that the non-PAG rock is inert and is suitable for a variety of uses in construction, as engineered fill or as aggregate for concrete. Tests completed to date have included LA Abrasion and Alkali reactivity; both of which have confirmed the suitability.

## 4.1 Temporary stockpiling and containment of PAG rock

The PAG rock stored at the Temporary Stockpile at the Quarry Site will be contained in a geomembrane liner such that water ingress is minimized any leachate produced (water running through the stockpile) drains to a drawpoint. Water from this drawpoint will be stored and treated prior to discharge.

The use of a basal and side slope geo-membrane lining system that will contain and encapsulate the Temporary Stockpile for PAG rock at the quarry. The installation practices for geomembrane welding and quality control in terms of geophysical testing are able to detect very small tears or punctures in the geomembrane. The geophysics quality control testing essentially uses a closed circuit system to detect locations where electrical current passes through the geomembrane at a hole or puncture. This type or similar quality control practices will be used during the construction of the geomembrane lined containment for the Temporary Stockpile. Any tears or punctures found during quality control testing will be repaired.

Furthermore, in following best management practices the Temporary Stockpile will be covered routinely with geomembrane liners to prevent infiltration by surface water runoff and rainfall. The testing has showed that in the worst case 20 weeks are required for the onset of ARD conditions. In preventing water from percolating through the PAG rock the onset of ARD conditions can be impeded and delayed. Any water that does percolate through will be drawn off at a specific point and treated. Testing of the water at this draw point will determine if ARD conditions or metal leaching conditions have commenced.

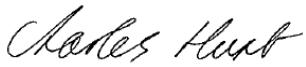
## 4.2 Control of water seepages in the tunnel

The tunnel will exhibit water seepages throughout its length of differing magnitudes. Most of these seepages will be minor drips, but some may inflow significantly (up to 100 litres per minute). FortisBC intends to sample water inflows into the tunnel throughout the excavation wherever sustained water inflows are greater than 10 litres per minute. At locations where these water samples show any deleterious qualities FortisBC intends to grout the rock to impede water from these seepages from entering the tunnel. In this manner, at the end of the tunnel construction the mixed water from all the inflows is anticipated to meet BC Approved Water Quality Guidelines at the discharge location. It should be noted that water samples from the creek at the Woodfibre Portal area have been routinely taken over the past few years to establish a baseline for water quality.

Baseline sampling of water along the tunnel alignment has been conducted on two occasions; August 2021 and November 2021. This baseline sampling found that localized ephemeral creeks had a pH lower than 6.0, and that some of these creeks drained the area above the Central Domain where PAG rock has been anticipated. Additional baseline sampling of creeks near to the Woodfibre Portal will be undertaken throughout the project.

Respectfully Submitted,

**MCMILLEN JACOBS ASSOCIATES**



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