# Meliadine Tailings Storage Facility Thermal Modelling

February 14, 2022


AGNICO EAGLE

okane

Integrated Mine Closure and Relinquishment Solutions

# Meliadine Tailings Storage Facility Thermal Modelling

*948-029-002 Rev5*

February 2022

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| Rev. # | Rev. Date | Author | Reviewer | PM Sign-off |
|---|---|---|---|---|
| 0 | March 2, 2021 | LT | JS | GA |
| 1 | May 3, 2021 | LT | JS | GA |
| 2 | August 5, 2021 | LT | JS | LT |
| 3 | September 29, 2021 | LT | JS | LT |
| 4 | October 22, 2021 | LT | JS | LT |
| 5 | February 14, 2022 | KH | LT | LT |

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# EXECUTIVE SUMMARY

Agnico Eagle Mines Limited (Agnico Eagle) operates the Meliadine Gold Mine, located approximately 25 km north of Rankin Inlet, and 80 km southwest of the hamlet of Chesterfield Inlet in the Kivalliq Region of Nunavut. The project was approved to proceed subject to Terms and Conditions of the Project Certificate No. 006. The project is composed of six known gold deposits: Tiriganiaq, F Zone, Wesmeg, Wesmeg North, Wolf, and Discovery, with approval to mine all deposits using open pit methods and to mine Tiriganiaq with open pit and underground methods. Approved facilities include ore stockpiles, waste storage facilities, a tailings storage facility, and other various infrastructure.

Agnico Eagle is proposing to expand the Mine (referred to as the Meliadine Extension) through additional underground mining and open pit mining. The Meliadine Extension Project is proceeding in a phased approach until 2043. The Meliadine Extension Project has adopted a mine plan for the permitting process which assumes higher gold prices than those used in project economics assessments. This Meliadine Extension mine plan allows for the maximum possible footprints of mining domains (open pits, waste rock storage facilities, tailings storage facilities, etc.) to be permitted, affording Agnico Eagle greater operational flexibility.

Okane Consultants Inc. (Okane) was retained by Agnico Eagle to complete a thermal assessment, which also includes evaluation of seepage conditions, of the Meliadine Extension tailings storage facility (TSF), and approved cover system. The approved cover system configuration includes a minimum of 3.7 m of non-acid generating and metal leaching (NAG/NML) waste rock placed at surface on the slopes of the TSF and 2.5 m of NAG/NML waste rock overlying 0.5 m of overburden material on the plateau of the TSF. The objectives of the detailed thermal and seepage modelling are to:

- provide long-term hydrologic inputs for the site-wide water and load balances;
- provide long-term thermal inputs including expected depths of interaction and pore space temperatures for runoff, interflow, and basal seepage for the site-wide water and load balances; and
- if necessary provide a basis for closure design of the TSF which is defendable to internal project stakeholders and regulators by addressing material risk to the project related to the TSF.

The site-wide water and load balance will then assess the impact of TSF on site-wide water quality. Representative concentration pathway (RCP) 4.5 was modelled to be consistent with permitted conditions for the existing Meliadine project. RCP4.5 represents a 'medium RCP' scenario with stabilization of radiative forcing around 2100. RCP4.5 has been selected as the base case condition for evaluation of the Meliadine Extension Project. RCP4.5 predicts an average annual temperature of approximately -4.6°C over the last 30 years of the climate change database (2090-2120).

**Hydrologic Inputs to Site-Wide Water Balance**

The largest flow path emanating from the TSF is expected to be interflow. Interflow is defined as near surface lateral flow of surface infiltration. As time progresses, interflow is expected to account for 20-25% of total precipitation occurring on the TSF. This is equivalent to the expected surface infiltration, which indicates that a negligible volume of surface infiltration will percolate beyond the active layer and be available to report as basal seepage in the underlying foundation material. While the interflow will mostly be contained within the cover system layers, up to 5-10% of total precipitation (up to half of total interflow) will come in contact with tailings material. Other inputs to the site-wide water balance include runoff, which is expected to be low (<5% of total precipitation).

Waste rock has a high surface infiltration capacity and low runoff potential due to its coarse-textured nature and low fines content. Both the overburden layer and tailings provide a stark textural contrast to the coarser waste rock material. This textural discontinuity coupled with frozen conditions produce a preference for lateral flow of surface infiltration (as interflow) rather than deeper vertical flow into the TSF.

Modelling results indicate that as water infiltrates into the surficial materials, net percolation flows vertically through the TSF during operations, closure, and early post-closure after which time most surface infiltration is diverted as interflow. Surface infiltration that results in net percolation eventually freezes back at depth. The base layer of the TSF remains consistently frozen from the time of placement. As a result, basal seepage from the landform is negligible under both climate scenarios. During construction and freeze back, water can percolate into the TSF beyond the active layer and cover system, resulting in increased storage and consequently lower interflow. As time progresses, a quasi-steady state is reached within the tailings due to high saturation, reducing percolation and promoting interflow. It takes approximately 20 years for the TSF to reach the quasi-steady state.

**Thermal and Oxygen Inputs to Site-Wide Load Balance**

The depth of interaction of interflow within the cover system will be equivalent to the thickness of the cover system, which varies across the landform. At the base of the cover system, temperatures will reach up to 4°C on the plateau under both climate change conditions. On the slopes, the base of the cover system will reach a maximum temperature of approximately 0°C (marginally frozen) under RCP4.5 conditions.

The depth of interaction of interflow coming in contact with tailings material is defined by the maximum depth of thaw below surface. In late post-closure, the maximum depths of thaw (>-1.3°C) is 35 m under RCP4.5.

The high degree of saturation maintained in the tailings limits resupply of oxygen and in turn reduces the potential development of ML/ARD products. Based on the thermal modelling, suboxic conditions (defined as less than 0.2 vol. % $O_2$) develop rapidly in the tailings profile due to the consumption of oxygen through sulphide oxidation. Thus, a small volume of tailings near surface will maintain both marginally frozen, or unfrozen temperatures, and oxic conditions.

**Summary of Expected Cover System Performance**

The expected performance of the cover system in limiting impacts to site water quality cannot be directly assessed from the thermal modelling alone. The thawed and partially thaws layer below the cover system provides the potential for interflow to occur year-round, but the near-freezing temperatures and suboxic conditions will substantially limit oxidation reactions, and therefore limit the potential solute load emanating from the tailings. Whether the reduction in load due to low temperatures and suboxic conditions is sufficient in achieving site water quality must be confirmed within an integrated site wide water and load balance. However, given the assumption that load from the majority tailings is minimal, the permitted closure cover system design is expected to be sufficient and does not need to be re-evaluated at this time (pending results of the site-wide load balance).

To summarize, key modelling results related to potential water quality impacts from the TSF indicate that:

- near-freezing temperatures in tailings will limit oxidation reactions;
- suboxic conditions in tailings will substantially limit oxidation reactions;
- long term preference for interflow within the cover system rather than net percolation will limit solute load transport; and
- while some solute load will occur, less than 10% of total precipitation is expected to be considered contact water.

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# 1 INTRODUCTION

Agnico Eagle Mines Limited (Agnico Eagle) operates the Meliadine Gold Mine, located approximately 25 km north of Rankin Inlet, and 80 km southwest of the hamlet of Chesterfield Inlet in the Kivalliq Region of Nunavut. The project was approved to proceed subject to Terms and Conditions of the Project Certificate No. 006. The project is composed of six known gold deposits: Tiriganiaq, F Zone, Wesmeg, Wesmeg North, and Discovery, with approval to mine all deposits using open pit methods and to mine Tiriganiaq with open pit and underground methods. Approved facilities include ore stockpiles, waste storage facilities, a tailings storage facility, and other various infrastructure.

Agnico Eagle is proposing to expand the Mine (referred to as the Meliadine Extension Project) through additional underground mining and open pit mining. The Meliadine Extension Project is proceeding in a phased approach until 2044. Okane Consultants Inc. (Okane) was retained by Agnico Eagle to complete a thermal and seepage assessment of the Meliadine Extension mine plan tailings storage facility (TSF) and approved cover system at the Meliadine Extension Project in closure conditions under two different climate scenarios.

Thermal modelling will support the reclamation design of the Meliadine TSF to ensure that in closure and post-closure the facility is physically and chemically stable. Development of coupled seepage and thermal modelling of the TSF and approved cover system under the base case climate scenario and associated landform water balance will improve confidence that the existing closure cover system will meet performance expectations or provide a basis for a revised closure and post-closure concept for the TSF if necessary.

The following report summarizes the thermal and seepage modelling program and includes key findings and recommendations for closure concepts to be considered for the TSF.

## 1.1 Project Objectives and Scope

Thermal and seepage modelling of the TSF was conducted to evaluate the effectiveness of the cover system design for closure to confirm that it is aligned with the closure objectives of physical and chemical stability. The specific objectives of this modelling were to predict:

- Long-term projected thermal conditions under two climate change scenarios;
- Long-term hydrologic inputs (runoff, interflow, and basal seepage) for the site-wide water and load balance model; and
- Depth of interaction and pore space temperatures for runoff, interflow, and basal seepage

Based on the modelling results and water balance, Okane is to provide a revised closure and post-closure concept for the TSF and cover system if required.

## 1.2 Report Organization

For convenient reference, this report has been subdivided into the following sections:

- Section 2 – Provides a summary of the site background and a conceptual model of performance of the TSF at Meliadine;
- Section 3 – Presents the model assumptions and inputs used for the numerical modelling simulations completed;
- Section 4 – Summarizes the results of numerical models and provides a discussion on the potential implications of results on site-wide water quality;
- Section 5 – Re-iterates major conclusions from the modelling program in relation to the modelling objectives; and
- Section 6 – Suggests recommendations for next steps based on the modelling results presented.

# 2 BACKGROUND

The Meliadine Project is comprised of six known gold deposits and development is proceeding in a phased approach (known as the Approved Project under the Water License Amendment, and the Meliadine Extension Project), until 2044 The phased approach allows for development to occur within capital constraints and during concurrent exploration. The Meliadine Extension Project will be composed of open pits and underground workings, waste rock storage facilities, TSF expansion, water management facilities, and construction of a haul road between Tiriganiaq and Discovery.

Tailings leaving the mill at Meliadine are dewatered by a pressure filtration system. The filtered tailings are loaded from the Tailings Dewatering Building on haul trucks and transported to the paste plant to be used underground as backfill or to the dry-stack TSF. At the TSF tailings are end-dumped, spread, and compacted immediately after placement. Currently, the TSF is entering its third year of operation.

## 2.1 Conceptual Model

A conceptual model describes key processes, or mechanisms, and their site-specific respective controls, which are expected to influence performance of the dry stack TSF and TSF cover system. It is presented at a conceptual level, using a hierarchy of climate, geology and materials, and topography, leading to an understanding of the patterns of water movement on a specific landscape (INAP, 2017). Figure 2.1 schematically describes the cover system design framework.

A closure cover system has been approved for the Meliadine TSF (Figure 2.2) with the following stated objectives:

- Ensure surface runoff and seepage water quality is safe for humans and wildlife (SNC Lavalin, 2019); and
- Controls dust (SNC Lavalin, 2019).

Contact water from tailings are expected to have elevated total dissolved solids (TDS), ammonia ($NH_3$), and arsenic (As) signatures compared to discharge criteria (Lorax, 2021). Contact water is expected to be collected and managed prior to discharge from site. To limit the amount of water quality management of surface runoff and seepage water required to meet discharge water quality objectives, interaction between the tailings, and/or oxygen, and/or incident precipitation must be limited to the extent necessary to remain protective of water quality. The approved cover system design (Figure 2.2) must meet these objectives through thermal, oxygen, or hydraulic control mechanisms (or some combination of the above). The following sections illustrate conceptually the expected model of hydraulic and oxygen ingress performance and associated thermal control mechanisms for the approved cover system and TSF landform through the lens of the conceptual design framework (Figure 2.1).

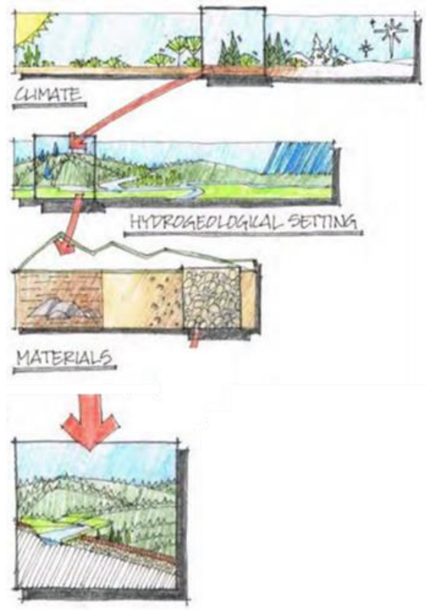


**Figure 2.1: Conceptual cover system design framework with three filters for climate, hydrogeology, and materials.**

Adapted from INAP, 2017.

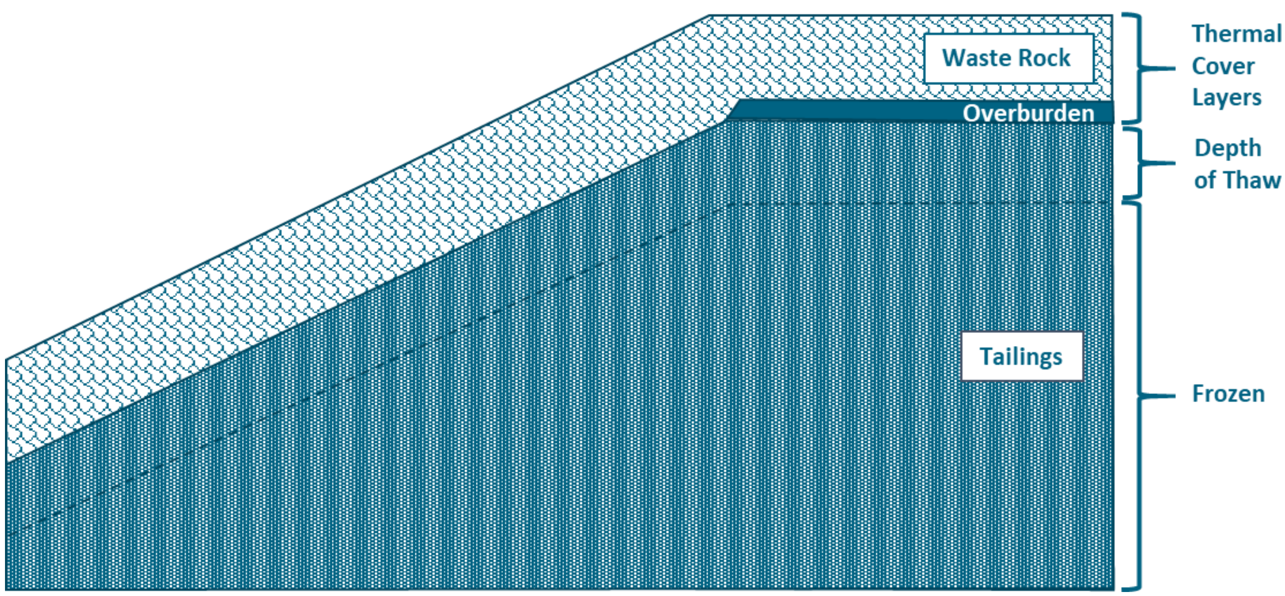


**Figure 2.2: Conceptual sketch of approved TSF cover system.**

### *2.1.1 Conceptual Model of Surface Water Balance*

The Meliadine site falls near the intersection of the ET (polar tundra) and Dfc (subarctic climate) classification of the Köppen-Geiger climate classification system where:

- E – 'polar' where average temperature of the warmest month is < 10°C;

- T – ‘tundra’ where the average temperature of the warmest month is < 10°C, but > 0°C;
- D – ‘continental’ where average temperature of the coolest month is < -3°C, and average temperature of warmest month > 10°C;
- f – ‘without a dry season’ where precipitation is relatively evenly distributed throughout the year; and
- c – ‘cold summer’ where one to three months average temperature reach < 22°C but > 10°C.

Annual precipitation is approximately 426 mm (ECCC, 2020), distributed relatively evenly as snowfall and rainfall. Climate data suggest that the site has a relatively balanced annual surface water budget, or slight water deficit, where the ratio of potential evapotranspiration (PET), sublimation, and snow redistribution is approximately equal to total annual precipitation. There is expected to be a water deficit throughout the summer as potential evaporation (PE) exceeds rainfall in June through August, and a water surplus in September, as PE decreases. Climate data suggest that net percolation, the water that moves from a cover system into a TSF when a cover system is in place, or simply just surface infiltration when there is no cover system placed yet, is likely to occur in the fall period, when PE is low and the cover system is fully thawed, and potentially during spring freshet.

Historic annual average air temperatures at Meliadine (approximately -10°C) indicate that permafrost aggradation into the tailings mass is expected and has been observed. Given historic climate conditions, the tailings are expected to freeze-back over time, and an active layer near-surface will develop seasonally. Frozen conditions within the tailings will limit the hydraulic conductivity of the tailings.

NAG/NML waste rock is placed at surface on both the slope and plateau of the TSF cover system (Agnico Eagle, 2018). Waste rock has a high surface infiltration capacity and low runoff potential due to its coarse-textured nature and low fines content. On the plateau and slope of the TSF, the overburden layer and/or tailings both provide a stark textural contrast to the coarse waste rock material. By comparison, the finer-textured overburden and tailings have a much lower saturated hydraulic conductivity than the overlying waste rock. This textural discontinuity is likely to produce a preference for lateral flow within the waste rock layer, particularly under high intensity infiltration conditions (rapid freshet, or storm events), rather than net percolation deeper beyond the cover system. The propensity for lateral flow is enhanced during unidirectional thaw from the surface as frozen conditions reduce the hydraulic conductivity, and the presence of ice lenses will further act as a barrier to net percolation.

The approved cover system, however, will not limit net percolation under more distributed infiltration conditions. The dry stack tailings are placed at approximately 80% degree of saturation and are expected to maintain a high degree of saturation under drained conditions regardless of temperature, due to the high fine fraction of the material. This discontinuity in hydraulic conductivity will allow for a high degree of saturation to be maintained within the overburden layer and tailings over time. On average, the approved cover system is not expected to limit infiltration, but the textural discontinuity and active layer development will promote lateral flow off the landform (Figure 2.3). The diversion of infiltration as lateral flow is expected to limit basal seepage to near negligible levels.

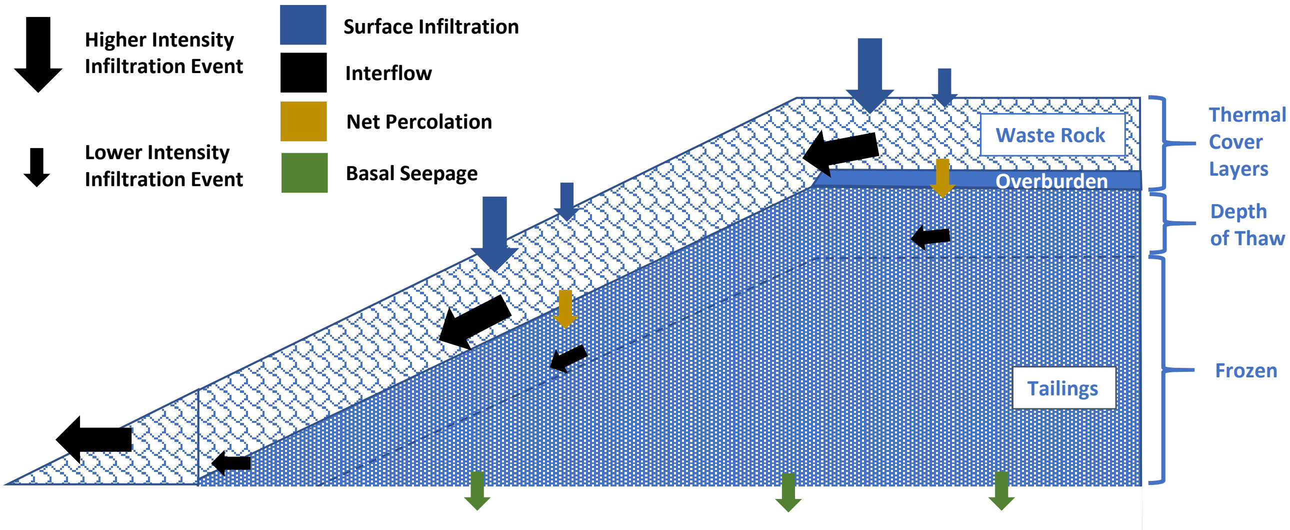


**Figure 2.3: Conceptual sketch of expected surface and landform water balance.**

### *2.1.2 Conceptual Model for Oxygen Ingress*

Oxygen availability throughout the TSF is expected to be limited as the tailings have a low air permeability due to the high degree of saturation at which they are placed. The conceptual surface water balance discussed above is expected to lead the tailings to maintain a high degree of saturation. Tailings are placed at field capacity (approximately 80% degree of saturation). At high degrees of saturation (approximately 85% saturation) oxygen ingress is limited to diffusion only (regardless of temperature); at this point, acid rock drainage (ARD) becomes self-limiting. The presence of ice zones at the boundary of the active layer are expected to also contribute to reducing air permeability.

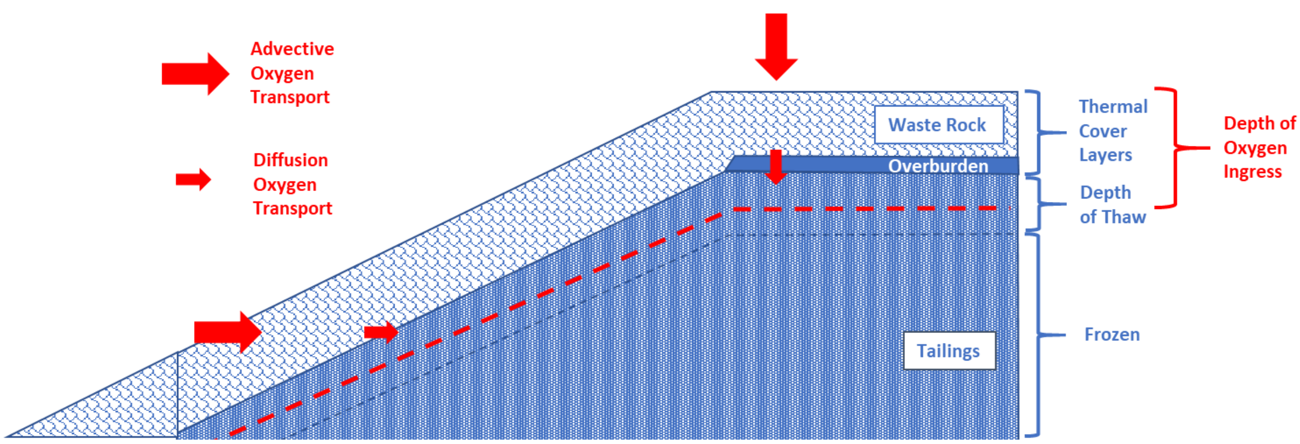


**Figure 2.4: Conceptual sketch of expected oxygen ingress.**

## 2.2 Description of Numerical Modelling Program

GeoStudio Version 11 was used to conduct the modelling for this project. This version of GeoStudio is functionally equivalent to Version 10, with some minor upgrades and bug fixes. Version 10 included a substantial upgrade to previous software versions, as it accounts for advective air flow as well as mineral oxidation within the TSF and associated heat generation via an add-in module developed for the software. Four components of the GeoStudio suite of programs will be used in combination for this project: SEEP/W; TEMP/W; AIR/W, and CTRAN/W (with the gas consumption and exothermic reactions add-in incorporated into the CTRAN analysis).

SEEP/W is a 1D/2D finite element model that can be used to model the saturated and unsaturated movement of moisture and pore-water pressure distribution within porous materials such as soil and rock. The latest version of SEEP/W incorporates a module that allows for soil-plant-atmosphere (SPA) modelling that was previously included in a separate software package (VADOSE/W). This module calculates pressure head (suction) and temperature profiles in the material profile in response to climatic forcing (such as evaporation) and lower boundary conditions (such as a water table). A key feature of the module is the ability of the model to determine actual evaporation and transpiration based on potential evaporation and predicted suction, as opposed to the user being required to input these surface flux boundary conditions. The actual evapotranspiration rate is generally well below the potential rate during prolonged dry periods because the suction in the material profile increases as the surface desiccates. In addition, the module is a fully coupled (through the vapour pressure term) heat and mass transfer model that is capable of simulating water vapour movement.

The SPA model of SEEP/W is also capable of evaluating the impact of frozen conditions on moisture storage and transport for a given soil or rock material. The change of phase from liquid to solid (i.e. water to ice) is accounted for using the apparent specific heat capacity approach, standard in thermal modelling. A heat source or sink is added at each time step based on the amount of heat released when a set volume of water changes to ice. When the ground becomes frozen, the permeability must be reduced. In the physics of freezing, there is a phenomenon whereby even in a saturated material, a "suction" develops at the ice-water interface much like that at the air-water interface in an unsaturated soil. If the temperature below freezing is known, then the suction can be computed using the Clausius Clapeyron phase equilibrium equation (Black and Tice, 1989). The SPA module does not account for this suction at the microscopic level in the mass transfer equation but does use the actual temperature to compute what the suction should be so that the program can look up a reduced permeability from the material's hydraulic conductivity function (suction versus hydraulic conductivity). SEEP/W simulations can be completed with or without this functionality.

TEMP/W is a 1D/2D finite element model that can be used to model thermal changes in porous systems due to various changes in the environment, internal changes in temperature, or any other influencing condition that may result in a change of temperature in the subsurface. Typically, in a TEMP/W simulation, it is assumed that moisture content remains the same. However, when water movement occurs in a system, substantial heat transfer can occur as a result of this movement of water. As such, by coupling the TEMP/W simulation with a SEEP/W simulation, a more accurate temperature condition in the subsurface can be estimated.

AIR/W is a 2D finite element model that is executed within the SEEP/W model, which can be used to model air pressure and flow within a system in response to changes in pressure conditions at the boundary, or changes in water pressure. When coupled with TEMP/W, it can also calculate changes in air flow and pressure as a result of changes in air temperature.

CTRAN/W, with the addition of the gas consumption and exothermic reactions add-in, couples the gas, heat, water, and air transfer processes to simulate the exothermic oxidation process. The add-in models the oxidation process as an irreversible first order reaction. The rate of reaction is dependent on, and controlled by, the availability of oxygen, as well as temperature. The add-in allows oxygen to be consumed and heat to be produced within the TSF due to sulphide oxidation.

# 3 MODEL INPUTS

Model inputs for Meliadine TSF thermal model can be divided into five types:

1) Climate / Upper Boundary Conditions;
2) Geometry;
3) Materials;
4) Initial Conditions; and
5) Boundary Conditions.

The following sections describe the inputs used.

## 3.1 Climate

TEMP/W requires daily surface temperature data whereas SEEP/W and AIR/W require daily values of maximum and minimum air temperature; maximum and minimum relative humidity (RH); average wind speed; daily net radiation; and precipitation (amount and duration). Historical values for all these parameters, except net radiation, are available from Environment and Climate Change Canada (ECCC) for Rankin Inlet (Station ID: 2303405 and 2303401) (ECCC, 2020), approximately 25 km south of the Meliadine site. Solar radiation for Rankin Inlet is estimated by Environment and Climate Change Canada in the Canadian Weather Energy and Engineering Datasets (CWEEDS) using the MAC3 model (ECCC, 2016). This data was used to estimate net radiation on a daily basis. ECCC has hourly records for Rankin Inlet from 1981 to present, of which the period January 1981 to January 2020 was used to create a 39-year database for the Meliadine WRSFs project. ECCC also provides precipitation data that have been adjusted for gauge undercatch and evaporation due to wind effect, which was incorporated into the Meliadine climate database (ECCC, 2017). The adjusted precipitation data is available until 2013, after which the methodology was reproduced by Tetra Tech (2021) and applied to subsequent years. After comparing the climate data measured at Meliadine from October 2014 to December 2019 to measurements taken at Rankin Inlet for the same time period, it was concluded that the Rankin Inlet data did not need to be adjusted to represent the Meliadine site. Any missing data in the Rankin Inlet climate record were filled with average measurements for a given day.

Table 3.1 provides a summary of the average monthly conditions in the 39-year historical database developed for the Meliadine project.

**Table 3.1: Summary of average climate parameters for the 39-year (1981-2020) Meliadine historical climate database with adjusted precipitation (Tetra Tech, 2021).**

| Month | Temperature (°C) | | Relative Humidity (%) | | Wind (m/s) | Net Radiation[1] (MJ/m²/day) | Precipitation | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum | | | (mm) | (days) |
| January | -26.7 | -33.9 | 75.3 | 68.4 | 6.7 | -1.8 | 17 | 27 |
| February | -26.4 | -33.7 | 81.8 | 71.2 | 6.6 | -1.0 | 17 | 25 |
| March | -20.7 | -29.2 | 86.8 | 74.3 | 6.5 | 0.1 | 22 | 27 |
| April | -11.4 | -20.4 | 94.2 | 74.9 | 6.3 | 2.5 | 29 | 22 |
| May | -2.3 | -8.9 | 93.3 | 65.7 | 6.2 | 5.0 | 30 | 21 |
| June | 8.1 | 0.6 | 94.2 | 69.4 | 5.6 | 7.2 | 32 | 15 |
| July | 15.1 | 6.3 | 93.5 | 67.0 | 5.4 | 8.0 | 46 | 16 |
| August | 13.2 | 6.3 | 94.1 | 81.1 | 5.9 | 5.5 | 59 | 18 |
| September | 6.4 | 1.4 | 85.0 | 77.7 | 6.6 | 2.3 | 53 | 21 |
| October | -1.8 | -7.2 | 79.8 | 72.8 | 7.3 | -0.1 | 57 | 27 |
| November | -13.0 | -20.8 | 75.2 | 69.8 | 6.9 | -2.0 | 39 | 27 |
| December | -21.7 | -29.2 | 71.8 | 66.4 | 6.6 | -2.2 | 25 | 28 |
| Annual | -6.7 | -14.0 | 83.0 | 71.3 | 6.4 | 1.9 | 426 | 272 |

[1] Net radiation for a level location (e.g. the plateau of the WRSF)

A "synthetic average" climate year was defined by averaging the daily climate conditions from the 39-year climate database (e.g. averaging the maximum temperature on January 1st for all 39 years). However, precipitation was not applied considering solely the daily average amount, but also the average number of precipitation events per month. Hence, precipitation was applied for the average number of rainfall days per month and on days with the highest chance of rainfall. The daily rainfall amounts for days with lower chances of rainfall were added to the next high-chance event in the month so that the synthetic average climate year had the average amount of rainfall.

### *3.1.1 Climate Change*

The 39-year historical database presented above was adapted to account for climate change predictions over the next 100 years. This process is explained in the remainder of this section.

As part of the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5), the IPCC adopted new representative concentration pathways (RCPs) to replace the previous emission scenarios of the Special Report on Emission Scenarios (SRES) (IPCC, 2013). The four adopted RCPs differ from the SRES in that they represent greenhouse gas concentration trajectories, not emissions trajectories. The four scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) are named after the radiative target forcing level for 2100, which are based on the forcing of greenhouse gases and other agents and are relative to pre-industrial levels (van Vuuren et al., 2011). RCP2.6 represents a very low RCP with a peak of radiative forcing at around 3.1 W/m$^2$ mid-century, followed by a decline to 2.6 W/m$^2$ by 2100. RCP4.5 represents a medium RCP with stabilization of radiative forcing around 2100. RCP6.0 represents a medium-high RCP with stabilization of radiative forcing shortly after 2100, while RCP8.5 represents a high RCP with increasing emissions that do no stabilize until after 2200. Climate at the Meliadine site is expected to remain within the subarctic (Dfc) climate category, described above, under the A1FI (former SRES emission scenarios) climate change scenario, which is similar to RCP8.5 (Rubel and Kottek, 2010). A 100-year climate change database for this project was developed using daily data under RCP4.5. Figure 3.1 provides the concentration of all forcing agents (in parts per million (ppm) of $CO_2$-equivalence) for the four RCP scenarios.

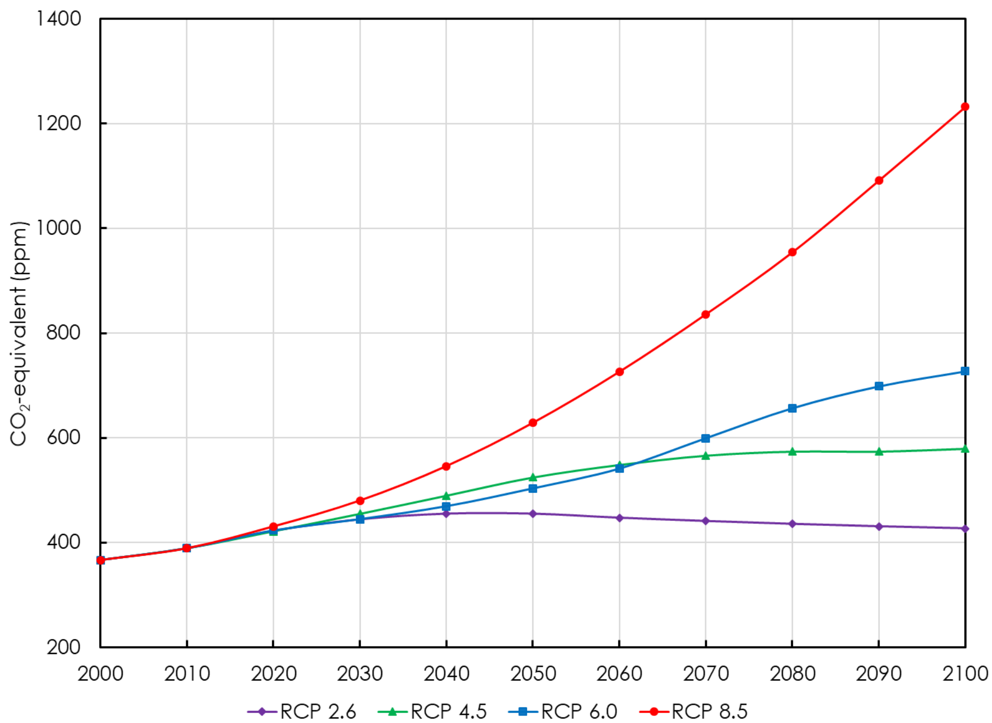


**Figure 3.1: All forcing agents' atmospheric $CO_2$-equivalent concentrations according to the four RCP scenarios.**

The climate change database for Meliadine was developed following the recommendations outlined on the Canadian Climate Data and Scenarios (CCDS) website, which is wholly supported by ECCC (CCDS, 2018). The website recommends the use of statistical downscaling to "downscale" a global circulation model's (GCM's) predictions to a specific location based on historical observations. Statistical downscaling is a two-step process consisting of: i) development of statistical relationships between local climate variables (e.g., surface air temperature and precipitation) and large-scale predictors (e.g., pressure fields), and ii) application of such relationships to the output of GCM experiments to simulate local climate characteristics in the future. The Pacific Climate Impact Consortium (PCIC) at the University of Victoria provides statistically downscaled daily temperature and precipitation under the RCP2.6, RCP4.5 and RCP8.5 scenarios for all of Canada at a resolution of approximately 10 km (PCIC, 2018). For this project, the second-generation Canadian Earth System Model (CanESM2), developed by the Canadian Centre for Climate Modelling and Analysis (CCCma), was used as the predictor GCM to downscale and make climate change databases representative of Meliadine. Temperature and precipitation were derived from the PCIC output, while the other climate variables required for SEEP/W and TEMP/W (i.e. relative humidity and net radiation) were downscaled using the Statistical Downscaling Model (SDSM) (Wilby et al., 2002; 2013; 2014), with the exception of wind speed due to the lack of climate change predictors.

Statistical downscaling is limited by the availability of large-scale predictors. Current CCCma CanESM2 model runs are limited temporally to 2100. In order to predict beyond 2100, the radiative forcing trend was applied to the temperature. RCP4.5 is expected to stabilize shortly after 2100 (Meinshausen et al., 2011).

Figure 3.2 and Figure 3.3 show the annual temperature and precipitation, respectively, estimated for the RCP4.5 100-year climate database developed for Meliadine. Temperatures are anticipated to rise at about the same rate (approximately 0.06°C/year) for RCP4.5 until approximately 2070, after which RCP4.5 estimates a reduction in the temperature increase rate. RCP4.5 predicts an average annual temperature of approximately -4.6°C over the last 30 years of the climate change database (2090-2120). The scenario predicts an increase in precipitation with time. An increase of approximately 13 mm over 100 years or 0.013 mm/year is predicted for RCP4.5. RCP4.5 was selected as the scenario for the base case simulations.

Previous projections of climate change at Meliadine were completed in support of the Final Environmental Impact Statement (FEIS) (Golder, 2014a). For the 2071-2100 time period FEIS climate change projections were much cooler and drier than the projected values developed for this assessment. The FEIS climate projections were based on emission scenarios of the SRES reported by the IPCC (discussed above) which have since been updated. The previous projections also relied on historic climate records from Baker Lake, as opposed to Rankin Inlet. A comparison of the post-closure climate change projections is provided in Table 3.2.

**Table 3.2: Comparison of FEIS climate projections to current climate projections for 2071-2100.**

| Climate Parameter | FEIS Projection[1] | RCP4.5 |
|---|---|---|
| Annual Precipitation (mm) | 300.0 to 320.0 | 455.7 |
| Mean Annual Air Temperature (°C) | -6.7 to -6.2 | -5.2 |

Golder, 2014a

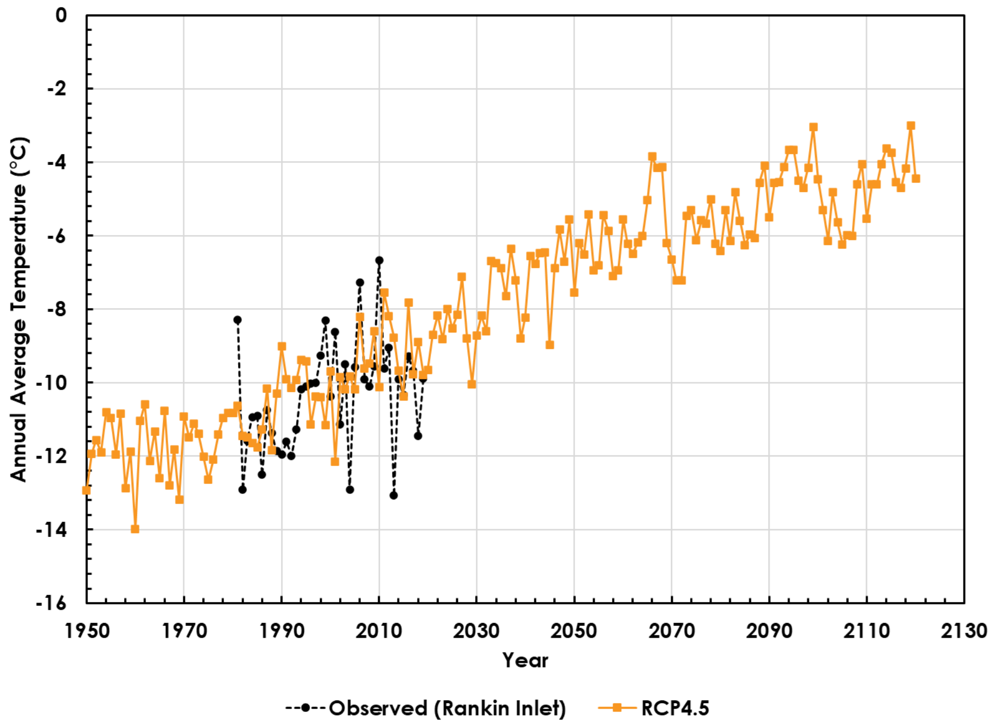


**Figure 3.2: Annual average temperature estimated for the RCP4.5 climate change scenario. Observed temperature at Rankin Inlet is also shown.**

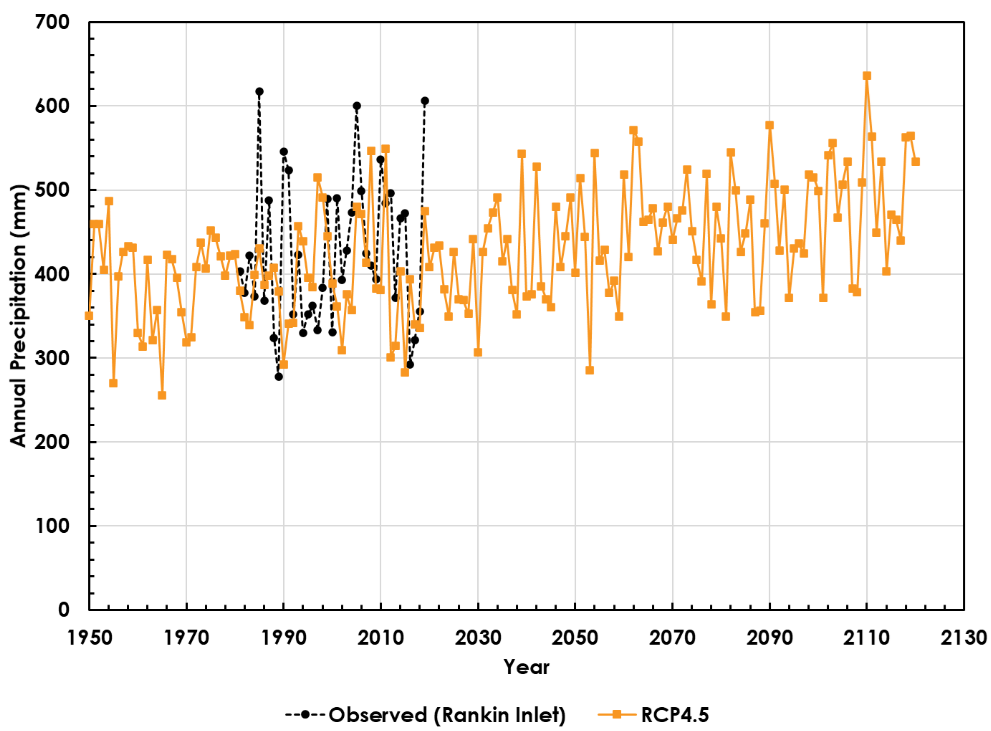


**Figure 3.3: Annual precipitation estimated for the RCP4.5 climate change scenario. Observed precipitation at Rankin Inlet is also shown.**

To account for creation of micro-climates on TSF embankments, calibrations to the base 100-year climate database were done to the net radiation and wind speed parameters. Net radiation was adjusted for north facing and south facing according to the method proposed by Swift (1976) and Weeks and Wilson (2006). Wind direction and speed were also adjusted for the modelled cross sections by creating a specific wind speed data set for NW and SW directions according to the wind roses shown in Figure 3.4 prepared from hourly wind speed and direction data from Rankin Inlet between January 1981 and January 2020. Figure 3.5 shows the wind roses for wind speed and direction from Meliadine Site between September 2014 and December 2019. The effects of surrounding landforms (such as the WRSFs) were assumed not to affect wind speed and direction. As the WRSFs and TSF are expected to be the dominant landform in the adjacent landscape, this is a reasonable assumption.

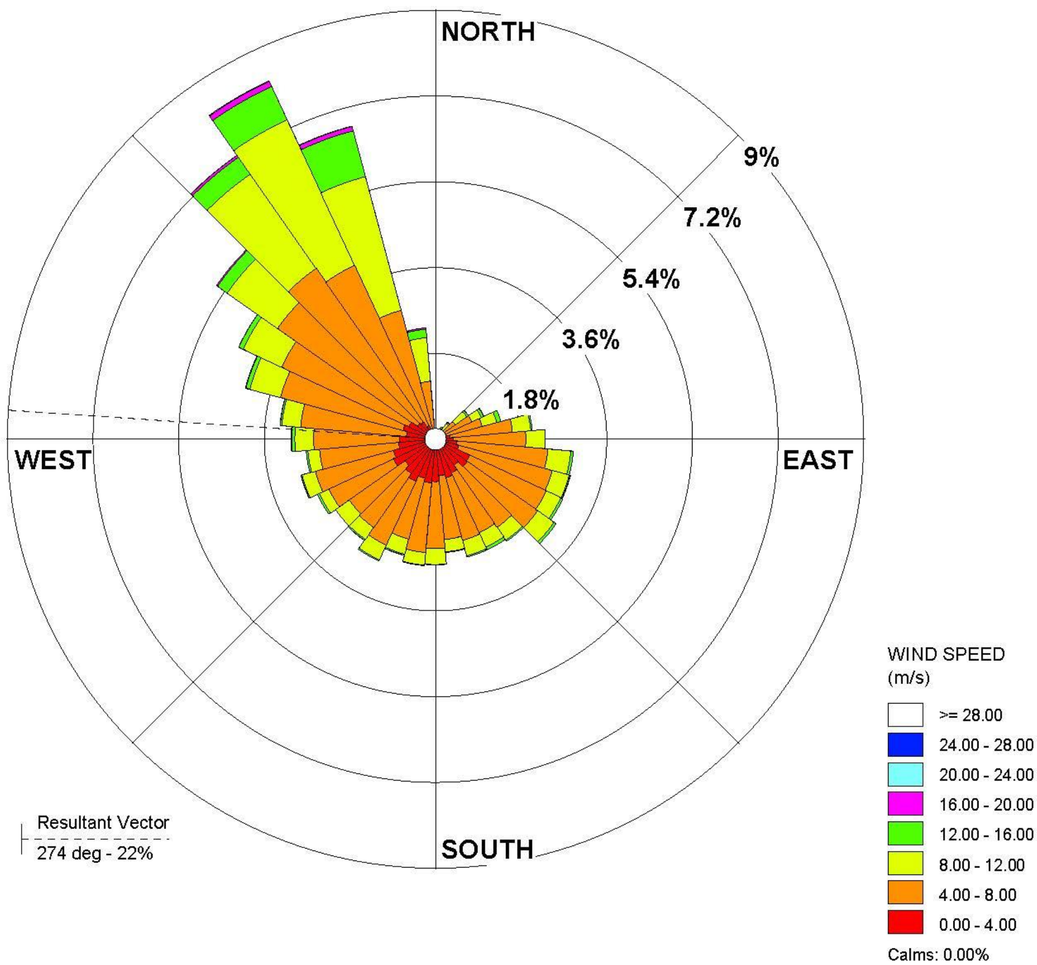


**Figure 3.4: Wind rose for Rankin Inlet climate station.**

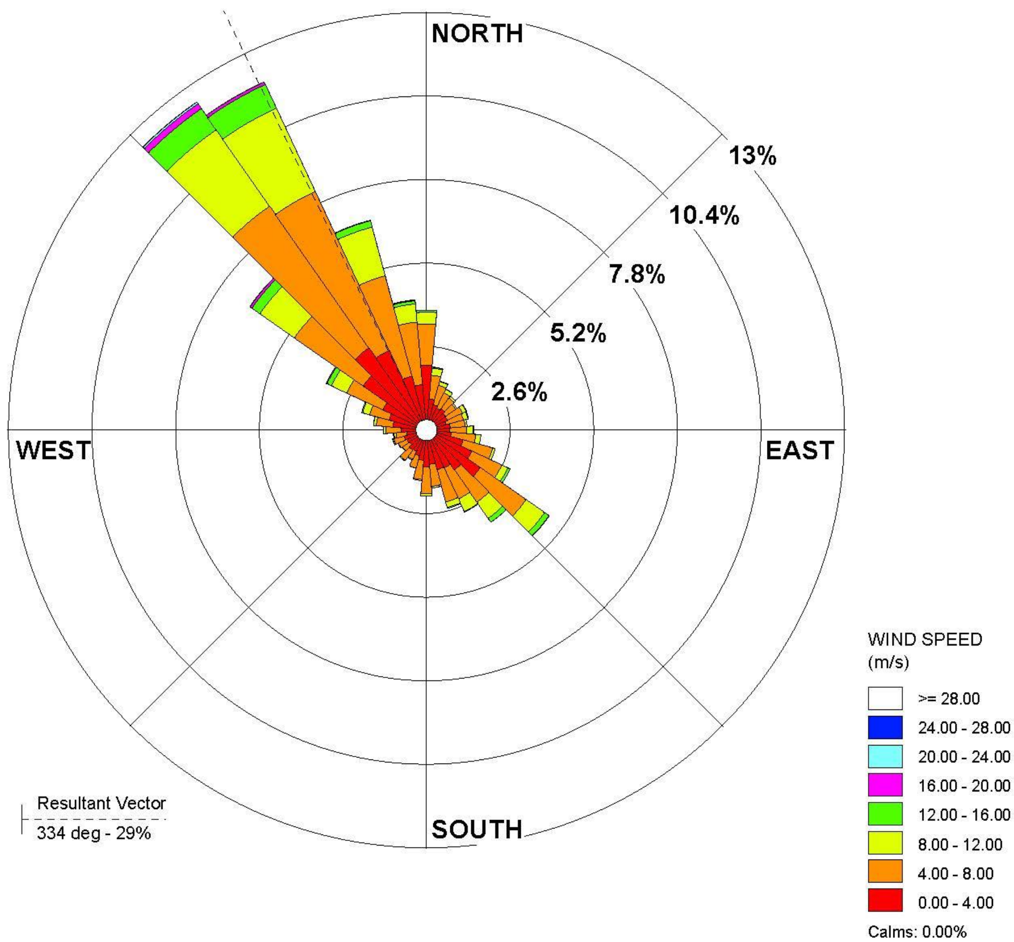


**Figure 3.5: Wind rose for Meliadine site climate station.**

### *3.1.2 Site Conditions*

During operations, snow cover is left in place on the TSF and only removed prior to placement of tailings / waste rock over original ground, prior to placement of a lift of tailings / waste rock over existing tailings / waste rock, and prior to spring freshet (Agnico Eagle, 2020a). In closure and post closure, snow removal will not occur.

Tailings deposition occurs year-round but not during short periods of intense rainfall; the area will be given time to drain and dry before placement recommences (Agnico Eagle, 2020a). Placement will also not occur during extreme winter storm events or during caribou red alerts.

## 3.2 Geometry

To capture the operational conditions within the TSF, cross sections were built up over time. The build-up was created using the permitted construction schedule provided in Appendix B. The plan details 0.3 m lifts of tailings, which are compacted immediately following placement. One-dimensional (1D) analysis was conducted during the operational period to obtain initial conditions for the closure / post-closure period.

Two-dimensional (2D) analyses were conducted for the closure / post-closure period. The geometry was developed using available CAD files as well as design parameters outlined in the TSF Detailed Deposition Plan (Agnico Eagle, 2020a), summarized in Table 3.3 and Figure 3.6, and the quarterly depositions plan drawings in Appendix B Agnico Eagle Tailings Storage Facility (TSF) Detailed Deposition Plan.

**Table 3.3: Key design parameters for the TSF.**

| Design Parameter | Value |
|---|---|
| Permitted Tailings Elevation[1] | 107 masl |
| Meliadine Extension Mine Plan Tailings Elevation[2] | 120 masl |
| Reference Ground Elevation | 65 masl |
| Permitted Mine Plan TSF Tonnage[1] | 14.9 Mt |
| Meliadine Extension Mine Plan TSF Tonnages[2] | 47.8 Mt |
| Side slope for lower placed tailings (below elevation 80.2 m) | 4H:1V |
| Side slope for upper placed tailings (above elevation 80.2 m) | 3H:1V |
| Slope of final tailings surface at crest | 4% |
| NAG/NML Waste Rock Cover System Thickness on Slopes | 3.7 m to 4.2 m |
| NAG/NML Waste Rock Cover System Thickness on Plateau | 2.5 m |
| NAG/NML Overburden Cover System Thickness on Plateau | 0.5 m |

1 – Agnico Eagle, 2021a
2 – Agnico Eagle, 2021b

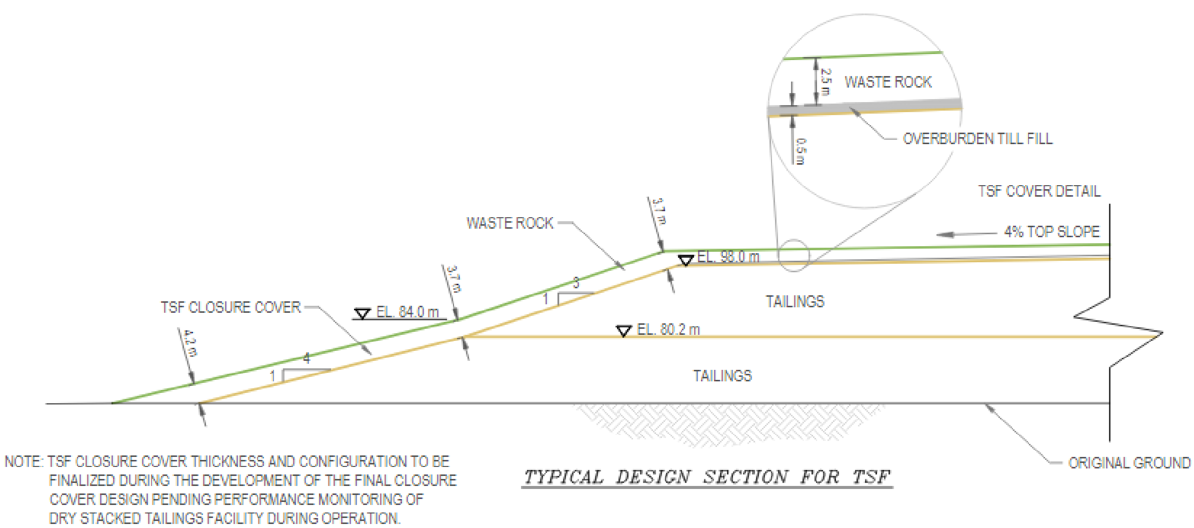


**Figure 3.6: Typical design section for TSF.**
(Agnico Eagle, 2020a)

Tailings were sloped at 4H:1V up to an elevation of 80.2 m, after which the side slopes were increased to 3H:1V, as shown in Figure 3.7. Original ground was assumed to be foundational overburden overlaying bedrock.

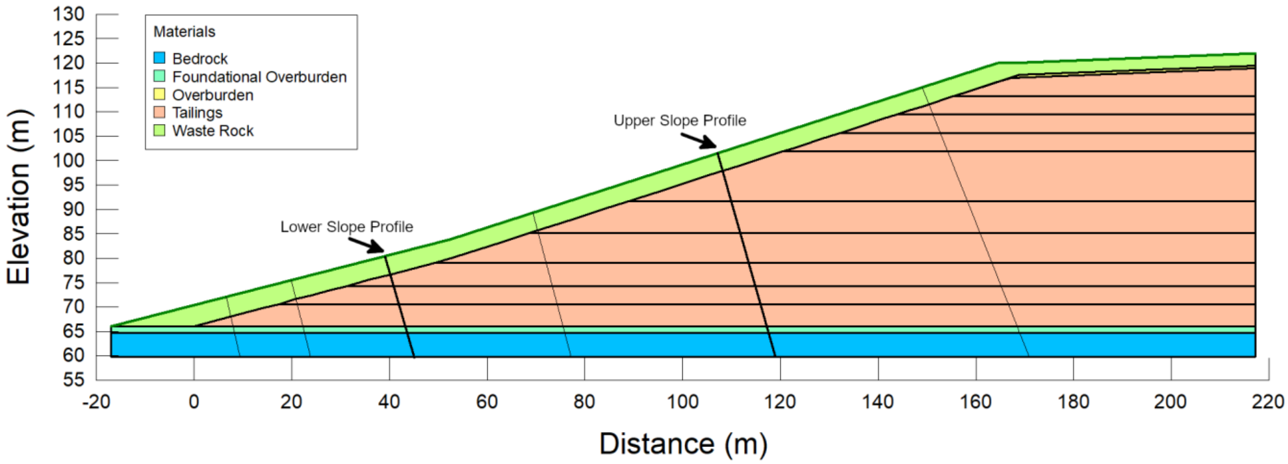


**Figure 3.7: 2D cross section developed for long-term Meliadine Extension modelling.**

## 3.3 Materials

Tailings properties were developed for the thermal modelling program based on available material testing and drill sampling. Tailings are characterized as a sandy silt, with a composition of 17% sand, 81% silt, and 2% clay (Figure 3.8). Based on the particle size distribution, the material is expected to demonstrate low plasticity and low compressibility (Agnico Eagle, 2020a).

Tailings are expected to leave the mill at a solids content of 85% (by weight) and water content of 17.6% (by mass). The maximum dry density of tailings is 1800 kg/m$^3$ at 14.9% (by mass) moisture content based on the Standard Proctor test. As tailings are placed wetter than optimum, the target dry density of 92% of maximum is assumed (Agnico Eagle, 2020a). The tailings are to be compacted to 1650 kg/m$^3$ before the next lift is placed. Based on laboratory testing, compaction to a dry density of 1700 kg/m$^3$ results in a saturated hydraulic conductivity of 2.91 x 10$^{-7}$ m/s (Agnico Eagle, 2020a).

Previous laboratory testing (Tetra Tech, 2014) has indicated that unfrozen tailings have a porosity of 0.388, air entry value of 20 kPa, and residual suction of 900 kPa. The soil water characteristic curve (SWCC) used in modelling was based on these results.

Waste rock, overburden till, and in situ overburden properties were previously developed for the Meliadine WRSF thermal modelling program based on available material testing and drill sampling (Okane, 2021).

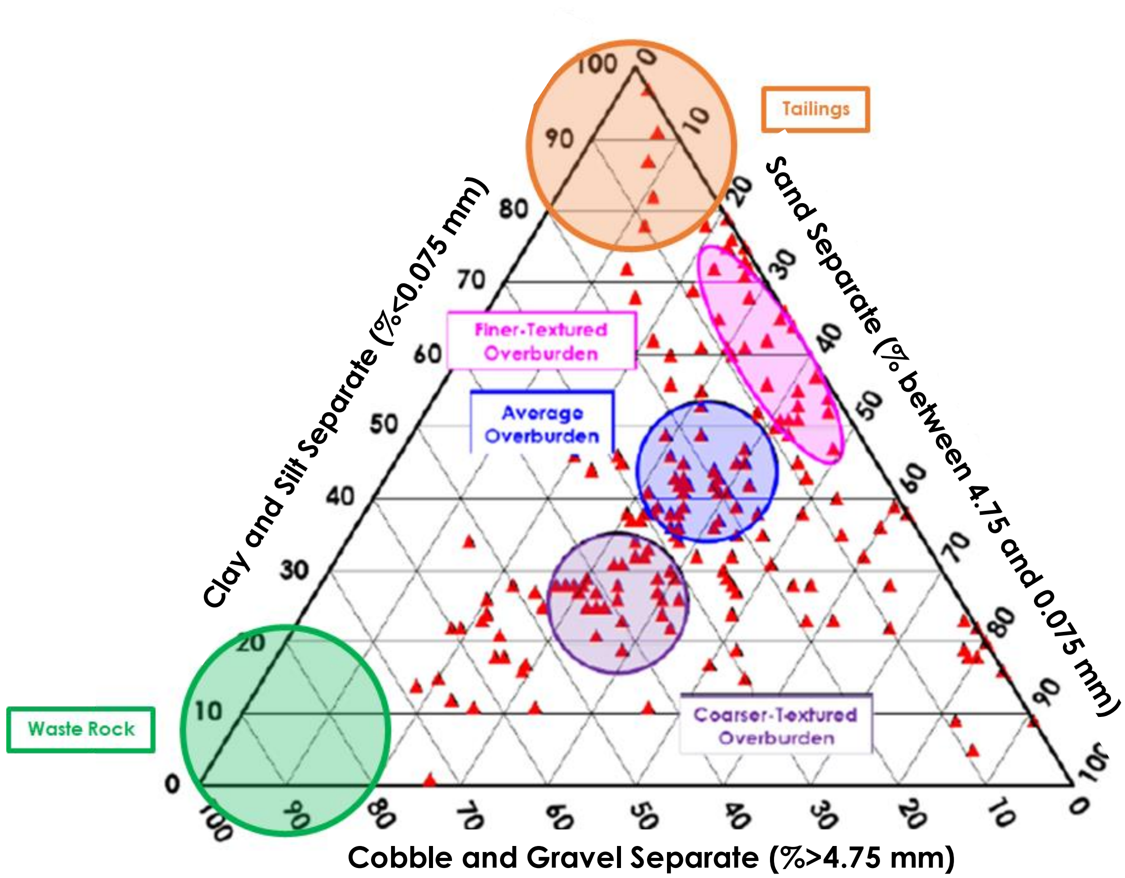


**Figure 3.8: Textural triangle for Meliadine overburden samples.**

The material properties or functions developed for each material based on available geochemical and geotechnical testing (eg. particle size distributions) are as follows:

- water retention curves (WRC – suction versus volumetric water content);
- hydraulic conductivity function (k-function – suction versus hydraulic conductivity);
- air conductivity function;
- thermal conductivity function (volumetric water content versus thermal conductivity);
- volumetric specific heat function (volumetric water content versus volumetric specific heat capacity);
- unfrozen water content function (unfrozen water content versus temperature); and
- geochemical reactivity.

Refer to Appendix A for a detailed description of material properties used in modelling.

## 3.4 Boundary Conditions

### *3.4.1 Hydraulic Boundary Conditions*

The lower boundary was simulated as a unit hydraulic gradient. This boundary conditions assumes that at the lower boundary, the suction (and as a result, water content and hydraulic conductivity) are constant with depth. For this situation, the total head equals the gravitational head, which results in a unit hydraulic gradient. In other words, a unit hydraulic gradient represents a location in the material profile where water movement is controlled mainly by gravity.

### *3.4.2 Air and Gas Boundary Conditions*

A barometric air pressure condition referenced to site elevation (75 masl at Meliadine) adjusted for daily air temperature was applied to the exterior of the cross sections. A constant oxygen concentration representing atmospheric conditions (280 g/m$^3$) was also applied to the exterior of the cross sections.

### *3.4.3 Temperature Boundary Conditions*

A depth of zero amplitude condition of -6°C was assumed to exist at the base of the bedrock in the model geometry (approximately 15 mbgl) (Golder, 2014b). To simulate exothermic reactions from the oxidation of tailings, the Gas Consumption and Exothermic Reaction boundary condition was applied to the tailings material in the TSF. This boundary condition couples the oxygen consumption due to mineral oxidation to heat generated by the associated exothermic reactions. Optimal oxidation rates were calculated from the Advanced Customizable Leach Columns (ACLCs) experiments as 1.2 x 10$^{-8}$kg $O_2$/t/second for the tailings material. These rates represent the oxidation rate at 10°C. The add-in adjusts the reaction rate at each timestep and node based on the current temperature and oxygen concentration. Daily minimum and maximum temperature boundaries were also applied to the exterior of the 2D cross sections as described in Section 3.1.

Salinity must be considered as it impacts the thermal behaviour of materials, particularly the freezing point depression. Estimated freezing point depression for the tailings material (Table 3.4) was applied to all model materials as GeoStudio Version 11 is limited to including freezing point depression value for the entire model domain. The NAG/NML overburden was assumed to have negligible salinity, however updated sampling (Lorax, 2021) indicates that the overburden possesses salinity of a maximum of 5.4 ppt and thus the freezing point depression used in the model remains conservative for the TSF materials. In addition, the potential for flushing of salinity over times, reducing salinity and reducing the effect on freezing point depression is not included in modelling, further increasing the potential for conservatism in modelling.

**Table 3.4: Assumed freezing point depression due to salinity of materials used in modelling.**

| Material | Assumed Salinity | Estimated Freezing Point Depression |
|---|---|---|
| NAG/NML Waste Rock | 20 ppt[5] | -1.3 °C |
| NAG/NML Overburden | 5.4 ppt[6] | -0.3 °C |
| Tailings | 20 ppt[1] | -1.3 °C |
| Groundwater | 55-57 ppt[2,3,4] | -3.3 °C |

1 – Agnico Eagle, 2020b
2 – TetraTech, 2014
3 – Golder, 2014b
4 – Agnico Eagle, 2017
5 – Okane, 2020
6 – Lorax, 2021

### *3.4.4 Temporal Boundary Conditions*

Results of modelling have been separated temporally into three distinct phases: operations, closure and post-closure. Deposition in the TSF is expected to continue until 2043 in the Meliadine Extension mine plan. However, the cross section chosen (Figure 3.7) is assumed to be located in the southeast of the TSF where deposition will cease earlier as the footprint of the Meliadine Extension TSF expands to the northwest. Deposition in the idealized cross section selected was assumed to cease in 2029.

The closure period is defined as the active decommissioning period of approximately three years following completion of operations (2044-2047). Post-closure follows the active closure period and has been modelled through to 2120.

## 3.5 Initial Conditions

Initial conditions for hydraulic, gas, and temperature conditions are required for modelling. The assumed initial conditions are summarized below. The initial conditions discussed below were applied to the 1D model, while the results of the 1D model at the end of the operational period were applied to the 2D model as initial conditions.

### *3.5.1 Hydraulic Conditions*

The waste rock and overburden material were assumed to be placed at an initial volumetric water content of approximately 0.05 and 0.2, respectively. Actual tailings placement to date has occurred at an average moisture content of 16.9% (by mass) (Agnico Eagle, 2020c), which corresponds to a volumetric water content of 0.29. Table 3.5 summarizes the initial hydraulic conditions for all materials used in the models.

**Table 3.5: Initial volumetric water content used in numerical modelling simulations.**

| Material | Initial Volumetric Water Content |
|---|---|
| Tailings | 0.29 |
| Waste Rock | 0.05 |
| Overburden Till | 0.2 |
| Foundational Overburden | 0.15 |
| Bedrock | 0.05 |

### *3.5.2 Gas Conditions*

The initial concentration of oxygen in the pore space of all the material at placement was assumed to be consistent with atmospheric conditions (280 g/m$^3$). Initial air pressure in the TSF was set to atmospheric levels (0 kPa).

### *3.5.3 Temperature Conditions*

The initial thermal conditions were determined through the calibration described in Section 4.1.

# 4 MODEL RESULTS

Modelling of the TSF was completed in three major steps: calibration, operational 1D modelling, and 2D long-term modelling.

## 4.1 Calibration

One-dimensional models were developed to calibrate the thermal properties of the tailings to site conditions using data collected from thermistor strings installed in the TSF. Two strings, GTC-02 and GTC-03, were used for the calibration (Figure 4.1). GTC-02 was selected as it provided the longest and most continual data record and GTC-03 was selected due to its location. GTC-03 is in the centre of the TSF, therefore less susceptible to edge effects, if present.

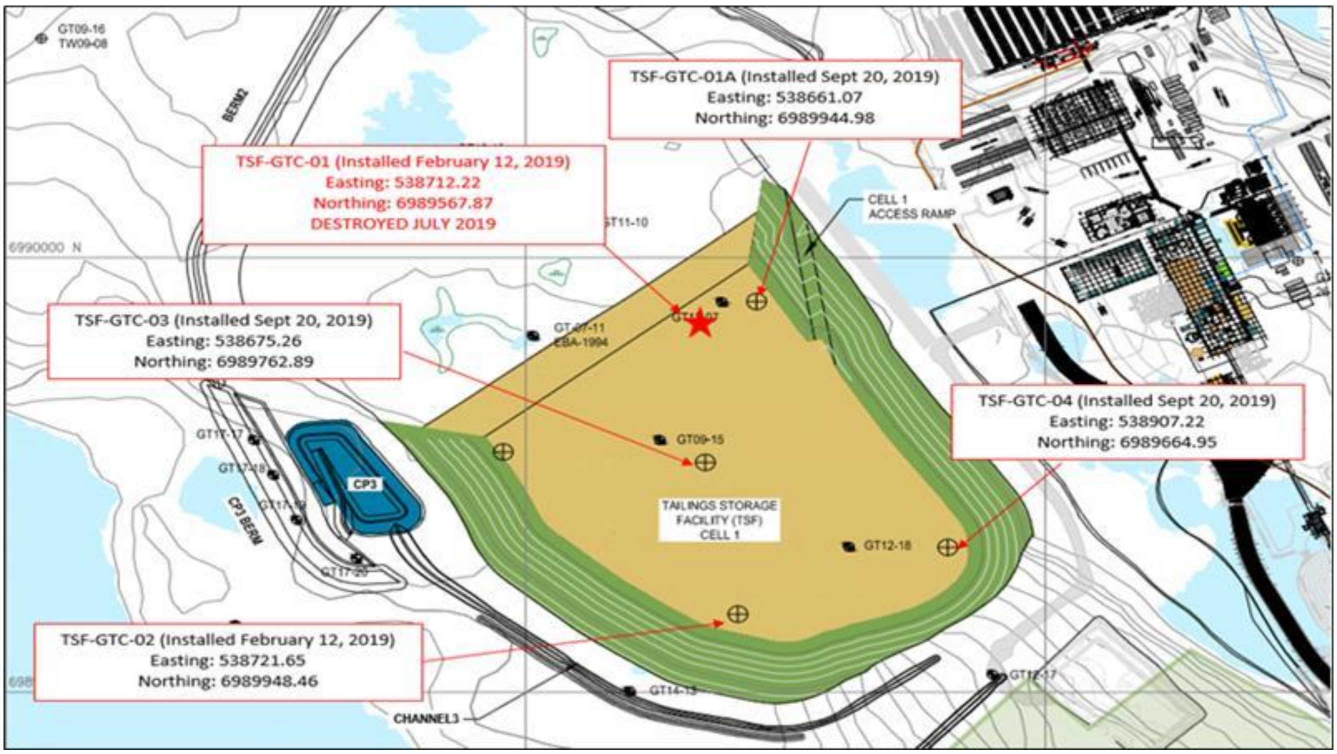


**Figure 4.1: 1D calibration locations.**

The primary thermal properties adjusted in the calibration were activation temperatures (the initial assumed temperature of material at placement), thermal conductivity function (the ability of a material to conduct heat), and volumetric heat capacity functions (the amount of heat that must be added to cause an increase of one degree).

Previous modelling completed by Tetra Tech (2018) indicated that the placement / activation temperature of the tailings was variable due to seasonal changes in air temperature (Table 4.1). Based on Okane's calibration, the placement temperatures found to be relatively consistent throughout the year, and thus the activation temperature of tailings were adjusted accordingly.

**Table 4.1: Initial tailings temperature conditions.**

| Time Period | Updated Initial Tailings Temperature (°C) | Initial Tailings Temperature (°C) (TT, 2014) |
|---|---|---|
| December to April | 15 °C | 15 °C |
| May to June | 15 °C | 20 °C |
| July to September | 15 °C | 25 °C |
| October to November | 15 °C | 20 °C |

The thermal conductivity of tailings material was increased (Figure 4.2) as a result of 1D calibrations, while the volumetric heat capacity of tailings was decreased (Figure 4.3).

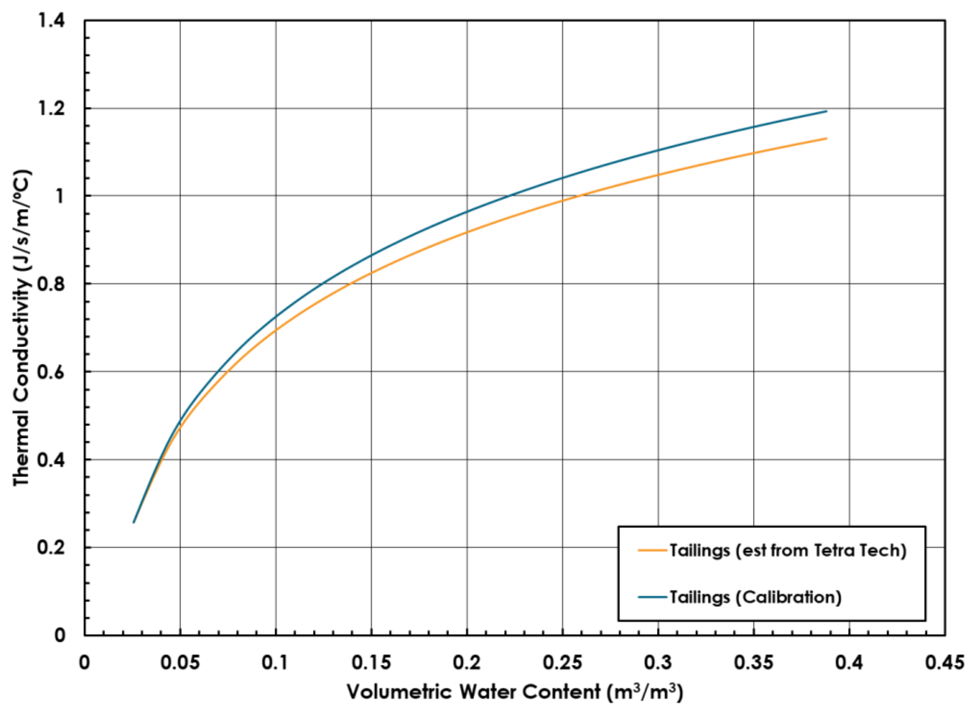


**Figure 4.2: Comparison of original and calibrated thermal conductivity functions for tailings.**

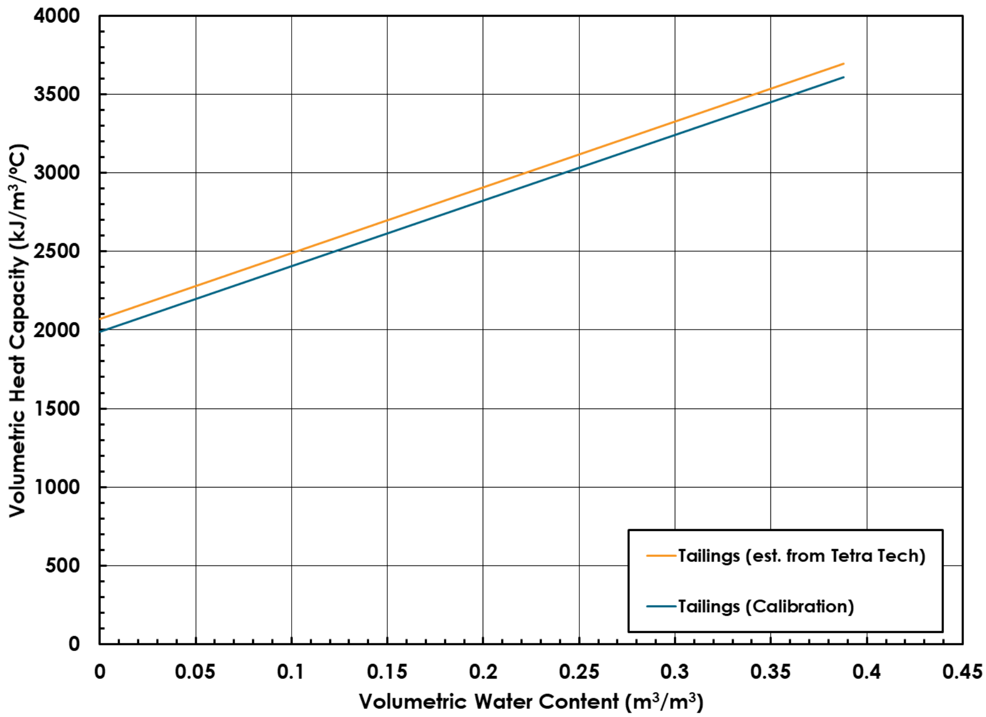


**Figure 4.3: Comparison of original and calibrated volumetric heat capacity functions.**

The results of the 1D calibration to thermistor data show a good match between the modelled temperatures and the measured temperatures (Figure 4.4).

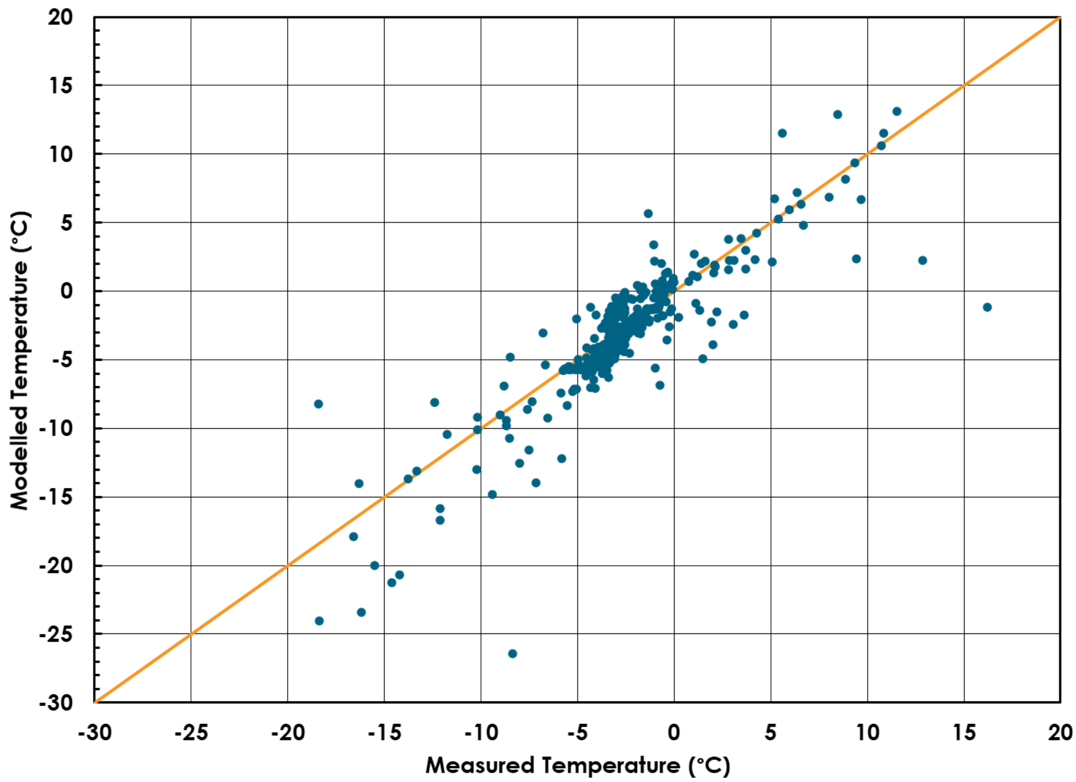


**Figure 4.4: 1D calibrations results for GTC-02 and GTC-03.**

## 4.2 1D Models

The thermal modelling of the one-dimensional (1D) sections was completed with the objectives of establishing initial conditions and simplified boundary conditions at closure / post-closure for the two-dimensional (2D) long-term models. 1D and 2D models were run for the base case climate scenario (RCP4.5) for 100-years (to 2120).

### *4.2.1 Active Layer*

The temperature and active layer depth during the operations period is heavily influenced by the season of tailings placement. For this assessment, the active layer is defined as the 0°C isotherm nearest to surface. By the end of the operations period and following cover placement in 2029, the majority of tailings are within the 0 to -2°C range and remain in a frozen to marginally frozen state. The active layer remains within the cover system under both climate scenarios in the closure period (Image a) of each figure). The closure period is defined as the active decommissioning period of approximately three years following completion of operations.

Beyond the active layer, a marginally frozen (0 and -1.3°C) talik remains at approximately 100 masl during the closure period under RCP4.5 (Figure 4.5). Tailings lifts placed in spring or summer can create marginally frozen taliks that persist for years after placement.

During the post-closure period, under RCP4.5, the marginally frozen talik is contained within the upper 19 m of the profile (including the cover system) and stays relatively consistent. The post-closure period is defined as the time following active decommissioning. In this case, the later post-closure period (2105 to 2120 is shown). Active layer depth from 1D models in the operations and post-closure phases for both climate scenarios modelled in summarize in Table 4.2.

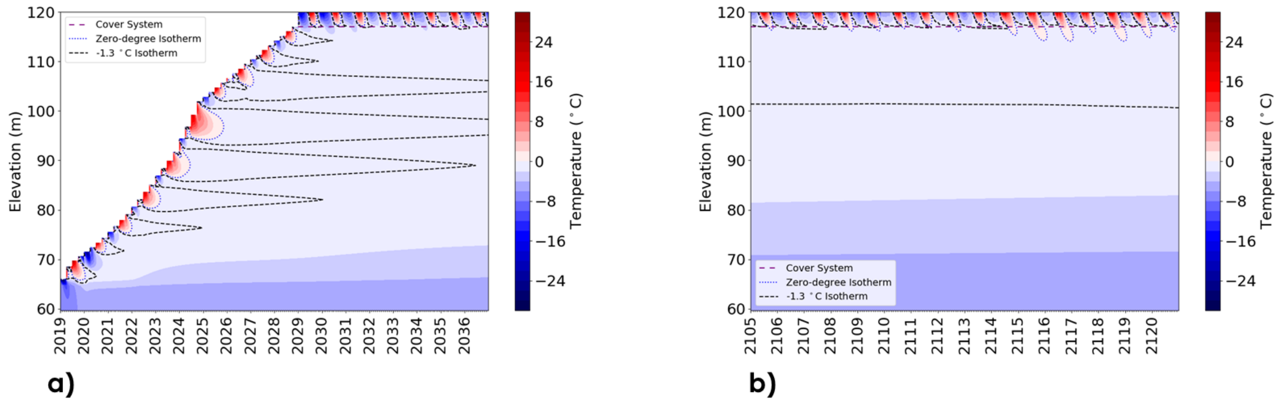


**Figure 4.5: Annual temperature profile on the plateau for the Meliadine Extension mine plan geometry during the a) operations period; b) post-closure period under RCP4.5 climate conditions.**

**Table 4.2: Summary of expected active layer depth from simplified 1D modelling.**

| **Project Phase** | **Estimated Maximum Active Layer Depth[1] (m)** |
|---|---|
| | **RCP4.5** |
| Post Cover Placement Cell 1 (2029-2043)[2] | < 3.0 |
| End of Simulation Period (2105-2120)[3] | < 6.0 |

1 – Active layer depth is defined by the annual 0°C isotherm nearest to surface.
2 – Remaining cells of TSF are still in operation during this time.
3 – Considered Late Post-Closure

### *4.2.2 Landform Water Balance*

A landform water balance was completed to develop simplified boundary conditions for 2D thermal modelling of the TSF. A summary of the 1D water balance for the plateau (uncovered) and slope (covered) during the operational period (2019-2028) is provided in Table 4.3 under RCP4.5, while a summary of the 100 year (2019-2120) long-term water balance is provided in Table 4.4. Runoff is assumed to interact with surficial waste rock to a depth of 30 cm, and where tailings are exposed on the plateau at a slope angle of less than 4%, to a depth of 1 cm or less (Sharpley, 1985; Zhang and Zhang, 2009).

During the operational period, the removal of snow from the tailings surface before placement of the next lift of tailings reduces the water available to infiltrate and prevents the water balance from closing. Before placement of the cover system, the surface infiltration is equivalent to the net percolation into the tailings.

**Table 4.3: Summary of average operational water balance (2019-2028) for the plateau and slope at Meliadine under RCP4.5 for the TSF.**

| Water Balance Parameter | RCP4.5 | |
|---|---|---|
| | Plateau | Slope |
| Total Precipitation (PPT) (mm) | 415 mm | 415 mm |
| Rainfall (% of Total PPT) | 50-55% | 50-55% |
| Snow (% of Total PPT) | 45-50% | 45-50% |
| Actual Evaporation (% of Total PPT) | 40-45% | 40-45% |
| Runoff (% of Total PPT) | 1-5% | 1-5% |
| Surface Infiltration[1] (% of Total PPT) | 10-15% | 10-15% |
| Sublimation (% of Total PPT) | 30-35% | 30-35% |

1- During the operational period, net percolation is equivalent to surface infiltration.

**Table 4.4: Summary of average 100 year (2019-2120) long-term water balance for the plateau and slope at Meliadine under RCP4.5 for the TSF.**

| Water Balance Parameter | RCP4.5 | |
|---|---|---|
| | Plateau | Slope |
| Total Precipitation (PPT) (mm) | 439 mm | 439 mm |
| Rainfall (% of Total PPT) | 55-60% | 55-60% |
| Snow (% of Total PPT) | 40-45% | 40-45% |
| Actual Evaporation (% of Total PPT) | 40-45% | 40-45% |
| Runoff (% of Total PPT) | <1-5% | 1-5% |
| Surface Infiltration (% of Total PPT) | 15-20% | 15-20% |
| Net Percolation[1] (% of Total PPT) | 10-15% | 10-15% |
| Sublimation (% of Total PPT) | 30-35% | 30-35% |

1 – Net percolation occurs until the upper tailings saturate in 30 to 40 years following cover placement.

## 4.3 2D Models

Following completion of the 1D models, modelling of the long-term Meliadine Extension mine plan two-dimensional cross section of the TSF was completed to evaluate long-term effectiveness of the cover system to ensure that surface runoff and seepage water quality objectives are met, and to develop long-term landform water balance for the TSF. A 91-year period (2029-2120) was modelled under RCP4.5. The following sections summarize the results of the long-term 2D modelling.

#### *4.3.1 Active Thermal Layer Depth*

The long-term thermal modelling results show the average conditions over the last 30 years of the modelled period (2090-2120). Similar to the 1D modelling, the freezing point depression is assumed to be -1.3°C, but the zero-degree isotherm has also been included in the figures to illustrate the range of conservatism possible due to flushing, as well as the extent of marginally frozen tailings.

In permafrost environments, thaw of the active layer occurs as a unidirectional process from the surface. During the summer months, when air temperatures are the warmest, the active layer absorbs and transfers heat from the atmosphere downwards toward the thawing front. This transfer of heat occurs predominantly through conduction, but infiltrating water can contribute to the heat transfer via forced convection.

Freezing in autumn occurs first as a unidirectional process from the bottom of the active layer at the freezing front. As the ambient air temperature declines, the temperature gradient driving conduction also declines, resulting in freezing upwards from the permafrost. Once the air temperature becomes negative, a freezing front develops at the surface and progresses into the active layer, creating bidirectional freezing. The cold air temperatures rapidly cool the surficial material, allowing the upper freezing front to quickly progress downward, while the lower freezing front moves slowly upwards. The thawed portion between the two freezing fronts is at or near 0°C, creating isothermal or zero-curtain conditions, where water and ice can coexist in equilibrium. Unfrozen pore water migrates both upwards and downwards toward the freezing fronts until all pore water is frozen and the zero-curtain closes. High saturation of the tailings limits air convection, as such conduction becomes the dominant method of thermal energy transfer in the system.

A summary of the depth of thaw expected under each climate scenario along the plateau of the TSF is summarized in Table 4.5.

Under RCP4.5 climate conditions, the majority of tailings remain under marginally frozen to frozen conditions (Figure 4.6a). A talik develops below the cover system with a “thin” band of temperatures in the 0 to 2°C range. The remainder of the talik is marginally frozen with annual temperatures between -1.3 to 0°C.

Slopes exhibit cooler temperatures as the seasonal active layer is confined to the cover system (Figure 4.7). The location of the slope profiles shown are provided in Figure 3.7. The upper slope shows the formation of a marginally frozen talik with a depth of approximately 18 m.

**Table 4.5: Summary of post-closure period depth of thaw along the plateau.**

| Climate Change Scenario | Maximum Average Depth of Thaw Below Surface (m) | | Freezing Front Depth (m) |
|---|---|---|---|
| | Marginally Frozen (0°C to -1.3°C) | Unfrozen (>0°C) | |
| RCP4.5 | 35 | 10 | 2.5 |

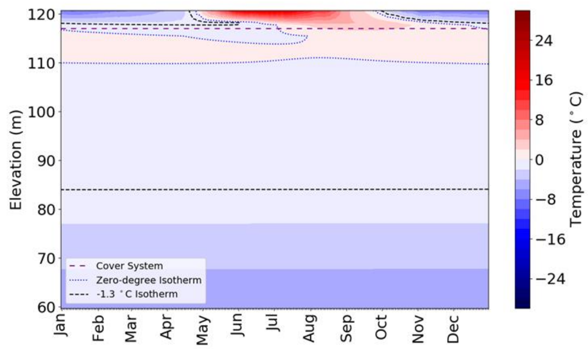


**Figure 4.6: Annual average near surface temperature along the plateau of the Meliadine Extension mine plan geometry for RCP4.5 climate conditions during the last 30 years of the post-closure period (2090-2120).**

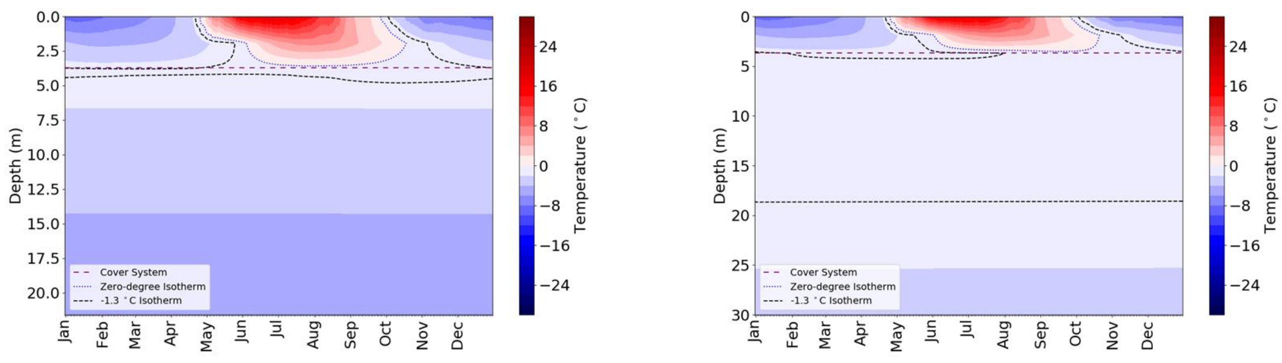


**Figure 4.7: Annual average near surface temperature along the slope of the Meliadine Extension mine plan geometry and the a) lower slope, b) upper slope profile under RCP4.5 climate conditions during the post-closure period (2090-2120).**

### *4.3.2 Oxygen Ingress Depth*

The high degree of saturation maintained in the tailings limits resupply of oxygen through convection, to the point where resupply of oxygen to the system is dominated by diffusion. Oxygen resupply to the TSF dictates the production of ML/ARD products; suboxic conditions reduce the development of ML/ARD products. Based on the thermal modelling, suboxic conditions develop rapidly in the tailings profile due to the consumption of oxygen through sulphide oxidation (Figure 4.8).

The resulting oxygen concentration profile of the TSF cross section under RCP4.5 in 2110 is shown in Figure 4.9. The suboxic condition, indicated by the dark blue dashed isoline, is defined as 0.2 vol. % $O_2$. At this oxygen concentration, oxidation rates decrease by an order of magnitude compared to the oxidation rate at atmospheric $O_2$ concentrations. Zones of higher oxygen concentration are present on the slopes; however, suboxic conditions exist almost to the base of cover system for most of the slope. The depth to the 0.2 vol. % $O_2$ isoline is deeper on the plateau than the slope, but the concentration gradient within the tailings is greater on the slope than the plateau.

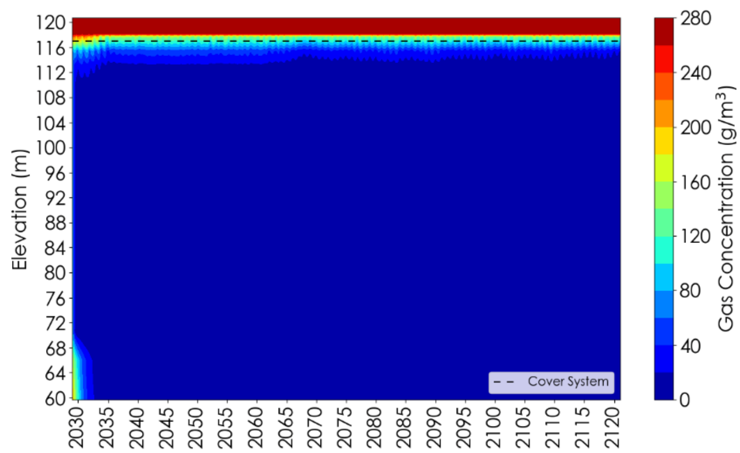


**Figure 4.8: Annual gas concentration along the plateau of the Meliadine Extension mine plan geometry for RCP4.5 climate conditions during the closure and post-closure period.**

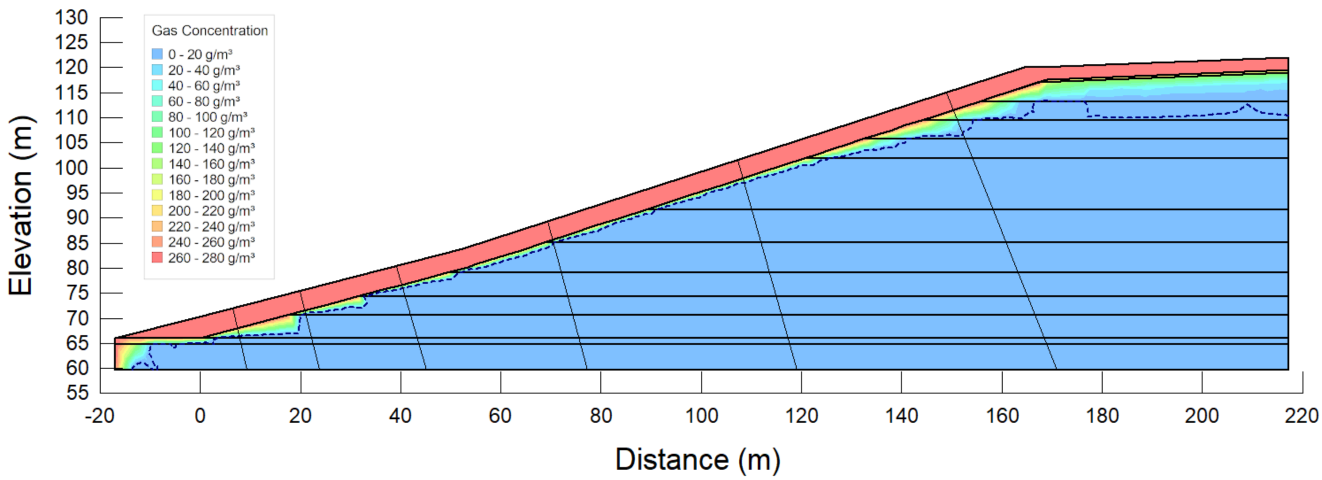


**Figure 4.9: Sketch of the gas concentration within the Meliadine Extension mine plan TSF geometry under RCP4.5 during summer 2110 showing the 0.2 vol. % $O_2$ isoline (dark blue dashed line).**

### *4.3.3 Landform Water Balance*

The landform water balance includes estimates of runoff, interflow, and basal seepage rates from the 2D section. A summary of the 91-year (2029 to 2120) surface water balance for the TSF is provided in Table 4.6.

**Table 4.6: Summary of average water balance for the long-term models.**

| Water Balance Parameter | RCP4.5 |
|---|---|
| Total Precipitation (PPT) (mm) | 439 mm |
| Rainfall (% of Total PPT) | 55-60% |
| Snow (% of Total PPT) | 40-45% |
| Actual Evaporation (% of Total PPT) | 40-45% |
| Runoff (% of Total PPT) | 1-5% |
| Surface Infiltration[1] (% of Total PPT) | 15-20% |
| Net Percolation[1] (% of Total PPT) | 1-5% |
| Sublimation (% of Total PPT) | 30-35% |

1 – Surface infiltration is partitioned into net percolation, defined as water that percolates into the tailings from the cover system and does not leave, and interflow (Table 4.7).

#### 4.3.3.1 Basal Seepage

Basal seepage is defined as seepage through the TSF that infiltrates within the footprint of the TSF into underlying materials. The high infiltration capacity of the waste rock material results in a propensity for incident precipitation to result in surface infiltration, rather than runoff (Table 4.6). As water infiltrates into the surficial materials, net percolation flows vertically through the TSF during operations and early post-closure after which time most surface infiltration is diverted as interflow. Surface infiltration which results in net percolation eventually freezes back at depth. The base layer of the TSF remains consistently frozen from the time of placement. As a result, basal seepage from the landform is negligible under all climate scenarios.

#### 4.3.3.2 Interflow

Interflow occurs as lateral flow within the active layer on the plateaus and slopes and within the unfrozen talik below the cover system. During construction and freeze back, water can percolate into the TSF beyond the active layer and cover system, resulting in increased storage and consequently lower interflow. As time progresses, a quasi-steady state is reached within the tailings due to high saturation, reducing percolation and promoting interflow. It takes approximately 20 years for the TSF to reach the quasi-steady state. Table 4.7 shows the progression of interflow with time as a percent of total precipitation and the contribution of interflow from the tailings and cover system. The monthly distribution of interflow and the relative monthly contribution from the tailings and cover system are shown in Table 4.7 and Table 4.8 for RCP4.5 respectively.

**Table 4.7: Interflow for the TSF as a percent of total precipitation.**

| | RCP4.5 | |
|---|---|---|
| | **2030-2050** | **2050-2120** |
| Total Interflow (% of Total Precipitation) | 10-15% | 20-25% |
| Interflow from Cover System (% of Total Precipitation) | 10-15% | 15-20% |
| Interflow from Tailings (% of Total Precipitation) | <1-2% | <5-7% |

**Table 4.8: Interflow distribution by month and source for RCP4.5.**

| Month | Percent of Total Interflow by Month | | Percent of Monthly Interflow Occurring from Cover System | | Percent of Monthly Interflow Occurring from Tailings | |
|---|---|---|---|---|---|---|
| | 2030-2050 | 2050-2120 | 2030-2050 | 2050-2120 | 2030-2050 | 2050-2120 |
| January | 0% | 0% | 0% | 0% | 0% | 0% |
| February | 0% | 0% | 0% | 0% | 0% | 0% |
| March | 0% | 0% | 0% | 0% | 0% | 0% |
| April | 0% | <1% | 0% | <1-5% | 0% | 95-100% |
| May | <1% | 5% | 15-20% | 40-45% | 80-85% | 55-60% |
| June | 7% | 15% | 70-75% | 65-70% | 25-30% | 30-35% |
| July | 16% | 37% | 80-85% | 85-90% | 15-20% | 10-15% |
| August | 50% | 26% | 95-100% | 85-90% | <1-5% | 10-15% |
| September | 20% | 12% | 90-95% | 70-75% | 5-10% | 25-30% |
| October | 6% | 4% | 60-65% | 5-10% | 35-40% | 90-95% |
| November | 0% | 0% | 0% | 0% | 0% | 0% |
| December | 0% | 0% | 0% | 0% | 0% | 0% |

Figure 4.10 illustrates the unfrozen water content and water flow in the month with greatest interflow (August). In this figure, water flow vectors show flow occurring in the cover system.

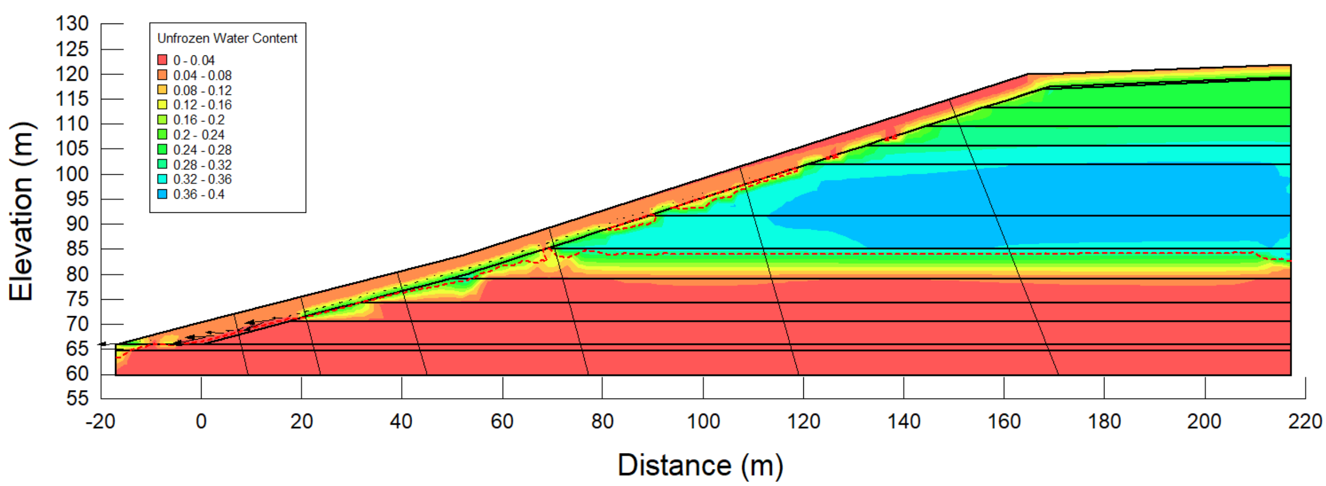


**Figure 4.10: Sketch of the hydrologic regime in summer 2110 of the Meliadine Extension mine plan TSF geometry under RCP4.5 with water flow vectors (black) and -1.3°C isotherm (red dashed line) shown.**

# 5 CONCLUSIONS

The thermal modelling of the Meliadine Extension Meliadine TSF presented herein is intended to:

- provide long-term hydrologic inputs for the site-wide water and load balances;
- provide long-term thermal inputs including expected depths of interaction and pore space temperatures for runoff, interflow, and basal seepage for the site-wide water and load balances; and
- if necessary provide a basis for closure design of the TSF which is defendable to internal project stakeholders and regulators by addressing material risk to the project related to the TSF.

The largest flow path emanating from the TSF is expected to be interflow. Interflow is defined as near surface lateral flow of surface infiltration. As time progresses, interflow is expected to account for 20-25% of total precipitation occurring on the TSF. This is equivalent to the expected surface infiltration, which indicates that a negligible volume of surface infiltration will percolate beyond the active layer and be available to report as basal seepage in the underlying foundation material. While the interflow will mostly be contained within the cover system layers, up to 5-10% of total precipitation (up to half of total interflow) will come in contact with tailings material. Other inputs to the site-wide water balance include runoff, which is expected to be low (<5% of total precipitation).

The expected near surface temperatures for the cover system interflow and tailings contact interflow are required to estimate loading rates within the site-wide load balance model. At the base of the cover system, temperatures will reach up to 4°C on the plateau under both climate change conditions. On the slopes, the base of the cover system will reach a maximum temperature of approximately 0°C (marginally frozen) under RCP4.5 conditions in late post-closure (2090-2120).

The average temperature, and depth of interaction of interflow in contact with the tailings is defined by the maximum depth of thaw below surface. In late post-closure, the maximum depths of thaw (>-1.3°C) are 35 m under RCP4.5.

The expected performance of the cover system in limiting impacts to site water quality cannot be directly assessed from the thermal modelling alone. The partially thawed layer below the cover system provides the potential for interflow to occur year-round, but the near-freezing temperatures and suboxic conditions will substantially limit oxidation reactions, and therefore limit the solute load emanating from the tailings. Whether the reduction in load due to low temperatures and suboxic conditions is sufficient in achieving site water quality must be confirmed within an integrated site wide water and load balance. However, given the assumption that load from the majority tailings is minimal, the permitted closure cover system design is expected to be sufficient and does not need to be re-evaluated at this time (pending results of the site-wide load balance).

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# Appendix A

# Material Properties

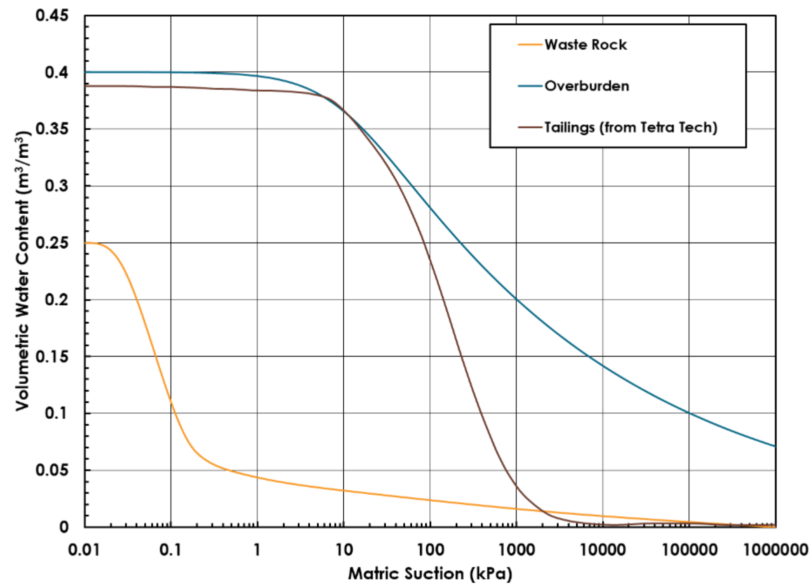


**Figure A.1: Water retention curves estimated for the tailings, overburden, and waste rock materials.**

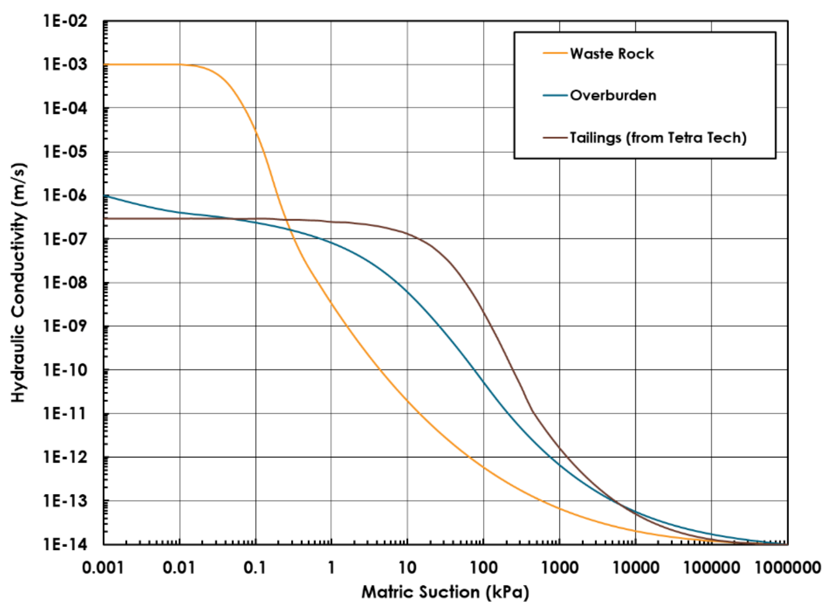


**Figure A.2: Hydraulic conductivity functions estimated for the tailings, overburden, and waste rock materials.**

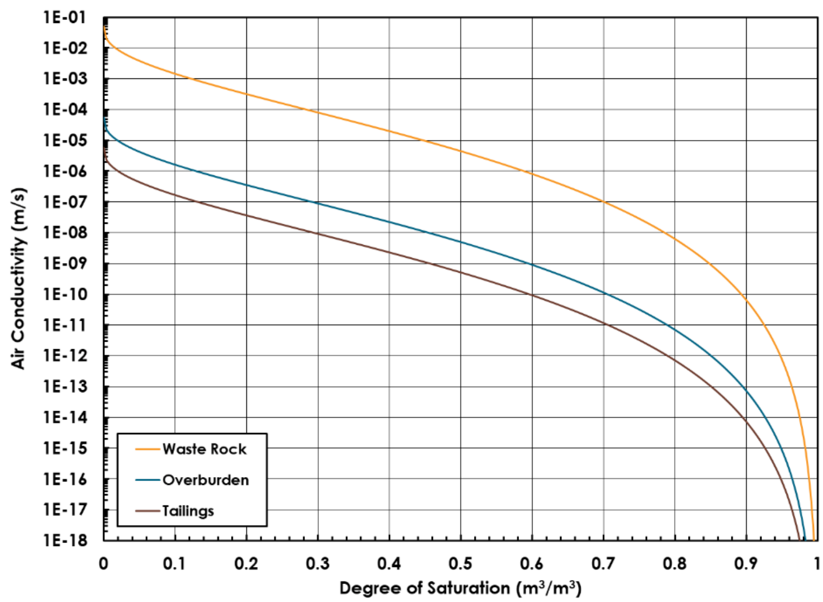


**Figure A.3: Air conductivity functions estimated for the tailings, overburden, and waste rock materials.**

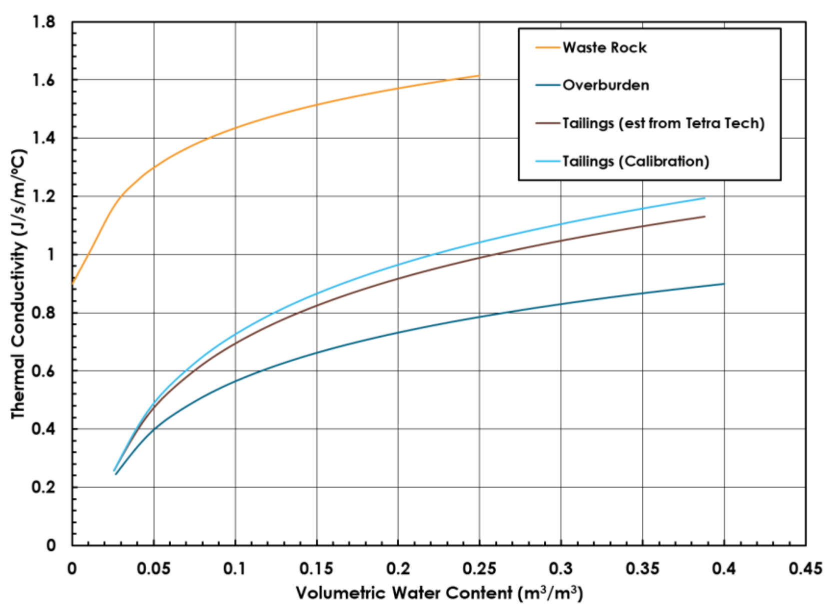


**Figure A.4: Thermal conductivity functions estimated for the tailings, overburden, and waste rock materials.**

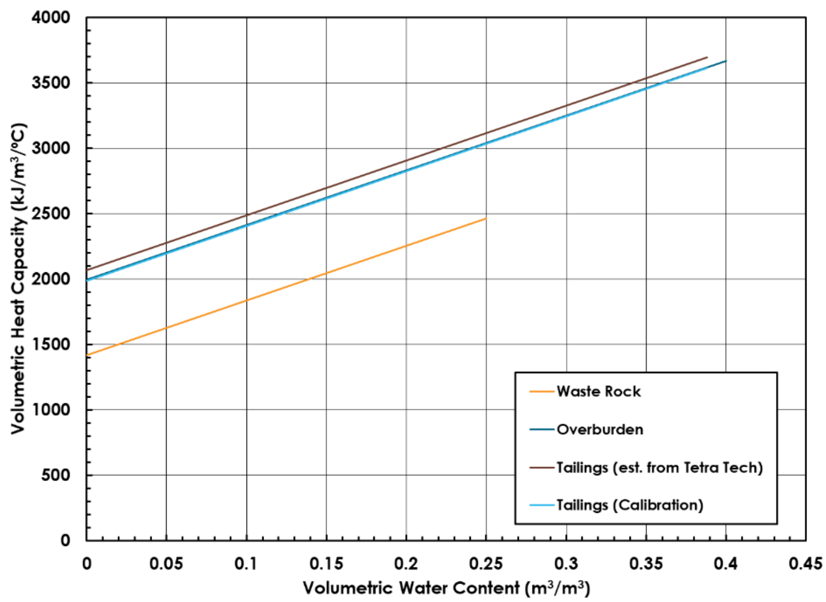


**Figure A.5: Volumetric heat capacity functions estimated for the tailings, overburden, and waste rock materials.**

# Appendix B

## Agnico Eagle Tailings Storage Facility (TSF) Detailed Deposition Plan

# Tailings Storage Facility (TSF)
# Detailed Deposition Plan
## 6515-583-163-REP-002

Prepared by:

Agnico Eagle Mines Limited – Meliadine Division

May 2020

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## APPENDICES

# DOCUMENT CONTROL

| Version | Date | Section | Page | Revision |
|---|---|---|---|---|
| 1 | January 25, 2019 | | | Final |
| 2 | April 30 2020 | 1.0 | 1 | Updated to operational tense; latest MWMP |
| | | 2.2 | 2 | Updated quantities (V11_3) |
| | | 2.3.2 | 4 | Updated geochemical discussion to include recent PAG/uncertain results |
| | | 3.2 | 7 | Snow removal in non-active areas |
| | | 3.3.2 | 8 | Added summary of 2019 placement learnings and actual placed volumes |
| | | 3.4.1 | 9 | Incorporated 2019 learnings into objectives of 2020 plan |
| | | 4.3 | 10 | Updated to reflect 2019 learnings |
| | | 4.3.2 | 11 | Updated sludge disposal |
| | | 4.3.3 | 12 | Added additional waste materials |
| | | 4.4 | 12 | Updated to include extreme blizzard conditions/whiteout |
| | | 5.0 | 13 | Section updated |
| | | 6.0 | 14 | Temporary water control measures added |
| | | 7.0 | 14 | Section updated and Table 11 added |
| | | 9.0 | 16 | Section updated |

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# 1.0 INTRODUCTION

Tailings generated from mill production at the Meliadine Mine are dewatered by pressure filtration to a solids content of approximately 85% by weight. The filtered tailings have the consistency of damp, sandy silt and are loaded from the Tailings Dewatering Building (TDB) onto haul trucks to be transported to either the paste plant for use underground as backfill or for placement and storage in the TSF in a process conventionally referred to as “dry stacking”. Production of filtered ore tailings started Q1 of 2019 as part of the commissioning process for the mill.

Recent documents discussing the TSF previously prepared by Agnico Eagle and submitted to the Nunavut Water Board (NWB) under Type “A” Water License (No. 2AM-MEL-1631), include:

- The Mine Waste Management Plan (MWMP) for the mine in April 2020. This plan provides the latest quantities and general operational procedures for the TSF; and
- The Tailings Storage Facility (TSF) Design Report and Drawings submitted November 2018. The report summarizes the design basis and design criteria for the TSF based on updated quantities from the 2018 MWMP and included issued for construction (IFC) drawings. The design report and drawings were approved by the NWB for implementation December 3, 2018.

The following Deposition Plan provides a brief summary of the key information from the above documents, as well as presents further details on the construction, operation, and monitoring requirements of the TSF facility. This is intended to be a “living document” for internal operational usage only and will be updated as required as planning, conditions and operational parameters change.

# 2.0 SUMMARY OF DESIGN BASIS AND CRITERIA

## 2.1 Location

The TSF is located on the high ground to the west of the Process Plant and east of Lake B7. Figure 1 shows the current footprint of the TSF in relation to other site infrastructure, including the TSF water management facilities and haulage roads. Haulage distance from the mill to the TSF ranges from 400 m to 800 m, while a minimum distance of approximately 200 m from the edge of the tailings to Lake B7 is respected.

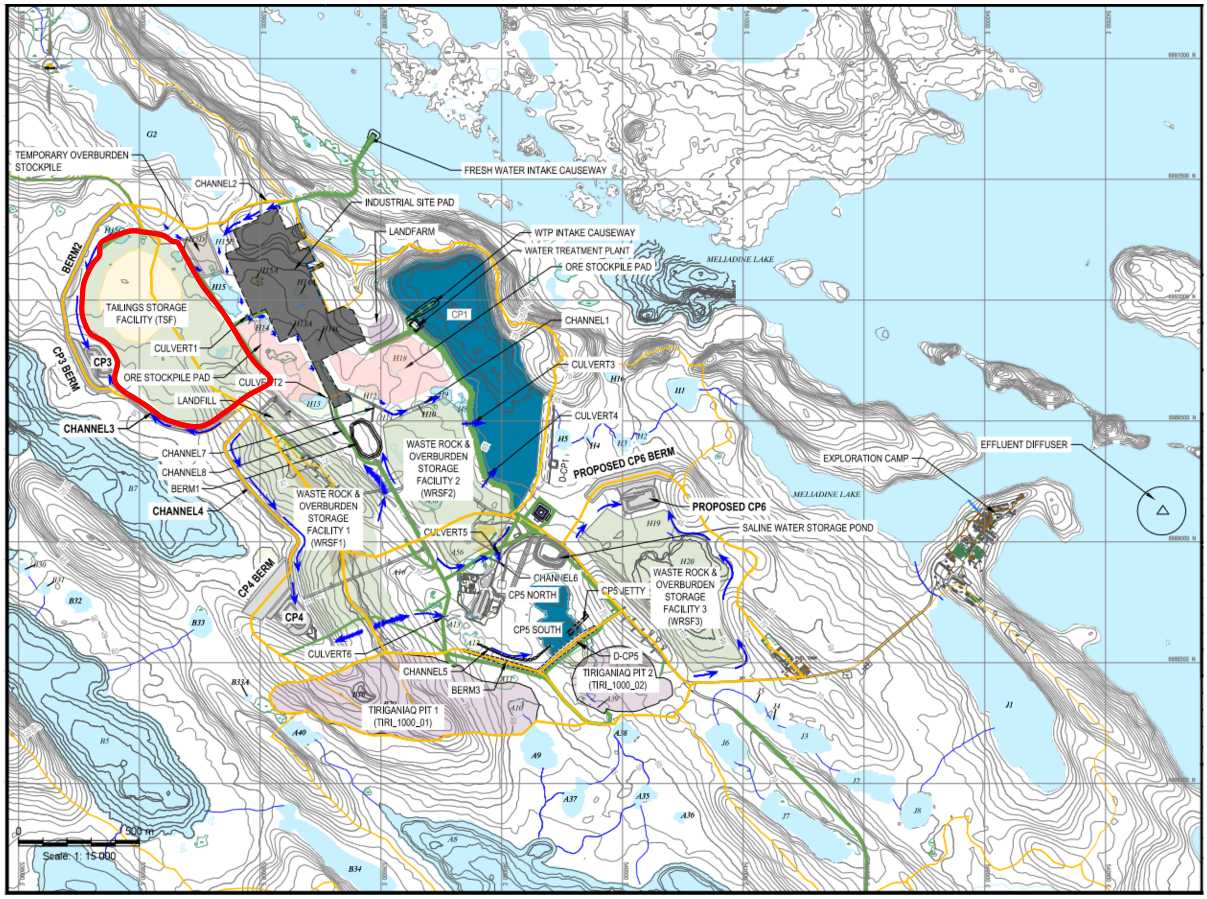


**Figure 1: Meliadine General Arrangement**

## 2.2 Tailings Production Schedule and Expected Quantities

The expected tailings quantities over the life-of-mine of eight (8) years (as defined in current Water License) are anticipated to be approximately 15.4 Mt. A proportion of tailings are slated for use as underground backfill (29% or 4.5 Mt), with the remainder (71% or 10.9 Mt) to be stored in the TSF.

Table 1 summarizes the production schedule, quantities and distribution of the tailings by year during the mine life based on the V11_3 mine plan adopted for the eight year LOM. Table 2 summarizes the quarterly production schedule, quantities, and distribution of the tailings for Year-1 (2019) to Year 1 (2020).

**Table 1: Schedule, Quantities, and Distribution of Tailings by Year (V11_3)**

| Year | Mine Year | Tailings Solids from Mill (t) | Tailings Solids to be Used as Underground Backfill (t) | Tailings Solids to be Placed in Dry Stacked TSF (t) |
|---|---|---|---|---|
| 2019 | Yr -1 | 976,706 | 394,680 | 582,026 |
| 2020 | Yr 1 | 1,519,200 | 634,163 | 885,037 |
| 2021 | Yr 2 | 1,709,655 | 657,048 | 1,052,607 |
| 2022 | Yr 3 | 1,775,614 | 778,607 | 997,007 |
| 2023 | Yr 4 | 1,770,250 | 280,999 | 1,489,251 |
| 2024 | Yr 5 | 2,013,000 | 302,926 | 1,710,074 |
| 2025 | Yr 6 | 2,190,000 | 500,187 | 1,689,813 |
| 2026 | Yr 7 | 2,190,000 | 521,941 | 1,668,059 |
| 2027 | Yr 8 | 1,255,251 | 408,999 | 846,252 |
| **Total (t)** | | **15,399,676** | **4,479,550** | **10,920,127** |

**Table 2: Quarterly Schedule, Quantities, and Distribution of Tailings 2019 to 2020 (V9A_8yrs)**

| Year | Mine Year | Mine Quarter | Tailing Solids from Mill (t) | Tailing Solids to be Used as Underground Backfill (t) | Tailing Solids to be Placed in Dry Stack TSF (t) |
|---|---|---|---|---|---|
| 2019 | Year-1* | Q1 | 102,459 | 0 | 102,459 |
| | | Q2 | 242,750 | 89,198 | 153,552 |
| | | Q3 | 297,331 | 144,223 | 153,108 |
| | | Q4 | 320,004 | 147,097 | 172,907 |
| 2020 | Year 1 | Q1 | 340,994 | 147,582 | 193,412 |
| | | Q2 | 319,525 | 67,114 | 252,411 |
| | | Q3 | 345,000 | 126,338 | 218,662 |
| | | Q4 | 323,480 | 102,928 | 220,552 |

** Includes approximately 60,000 t of tailings produced during mill commissioning in Q1 (2019)*

## 2.3 Tailings Properties and Characteristics

### 2.3.1 Geotechnical Properties

- The filtered tailings to the TSF are expected to leave the mill at a solids content of approximately 85% (by weight) and a water content of 17.6% (by mass).
- The maximum dry density is 1,800 kg/m$^3$ at an optimum moisture content of 14.9% (Standard Proctor). As the tailings will leave the mill at an expected moisture content approximately 2.7% wetter than optimum, a target dry density (compaction) of 92% of the maximum dry density was adopted for design.
- The tailings sample comprised approximately 17% sand, 81% silt, and 2% clay-sized particles. The material is of low plasticity and low compressibility;

- For tailings samples with a dry density of 1,700 kg/m$^3$, the inferred angle of friction is 33.5° and the apparent cohesion is 9.9 kPa. The saturated hydraulic conductivity for these samples is 2.91 x $10^{-07}$ m/sec.

### 2.3.2 Geochemical Characteristics

Results of the geochemical analysis conducted to date indicate that most of the tailings produced and placed in the TSF so far are either potentially acid generating (PAG) or fall into an “uncertain” category, while metal leaching (ML) has been observed to be an issue. Despite the PAG classification, the TSF is not considered to pose an ARD risk due to the placement methodology used, the assumption of freeze-back within the facility and the placement of progressive cover material.

Sampling and testing for ARD/ML potential will be on-going throughout the operational life of the facility and is discussed further in the *Mine Waste Management Plan* (Agnico Eagle, 2020).

## 2.4 Design Concept and Parameters

Filtered tailings will be managed using a two-cell placement system and incorporating a progressive closure cover as placement advances. Table 3 presents the key parameters adopted for the TSF design (Agnico Eagle 2018c).

**Table 3: Key Design Parameters for the TSF**

| Design Parameter | Value |
|---|---|
| Minimum target dry density of compacted tailings | 1,650 kg/m$^3$ (92%) |
| Average height of filtered tailings over original ground surface | 33 m |
| Side slope for lower placed tailings (below elevation 80.2 m) | 4H:1V |
| Side slope for upper placed tailings (above elevation 80.2 m) | 3H:1V |
| Slope of each lift of tailings surface at crest | 1% |
| Slope of final tailings surface at crest | 4% |
| Final top tailings surface area (Cell 1) | 46,359 m$^2$ |
| Final bottom tailings surface area (Cell 1) | 179,741 m$^2$ |
| Final top tailings surface area (Cell 2) | 84,655 m$^2$ |
| Final bottom tailings surface area (Cell 2) | 149,632 m$^2$ |

## 2.5 Progressive and Final Closure Cover

The TSF closure cover has the operational design objectives of controlling erosion and dust generation from the stack, in addition to enhancing the freeze-back capabilities of the facility. To reduce final closure costs and minimize erosion, cover material on the side slopes will be placed progressively with the filtered tailings. The placement of the cover material at the same time as the tailings are placed is a legal requirement under Agnico Eagle’s water license (Water License No. 2AM-MEL1631 Part J).

Based on the thermal analysis conducted by Tetra Tech (December, 2018), a preliminary closure cover design has been adopted:

- A minimum thicknesses of 4.5 m waste rock cover over the lower toe of the final tailings side slopes and a minimum thicknesses of 4.0 m waste rock cover over the upper side slopes; and

- A minimum thicknesses of 2.5 m waste rock cover over 0.5 m thick select overburden till fill over the top surface of final tailings. The top closure cover material will be placed when each cell reaches its operational capacity and sloped 4% to discourage ponding and surface infiltration.

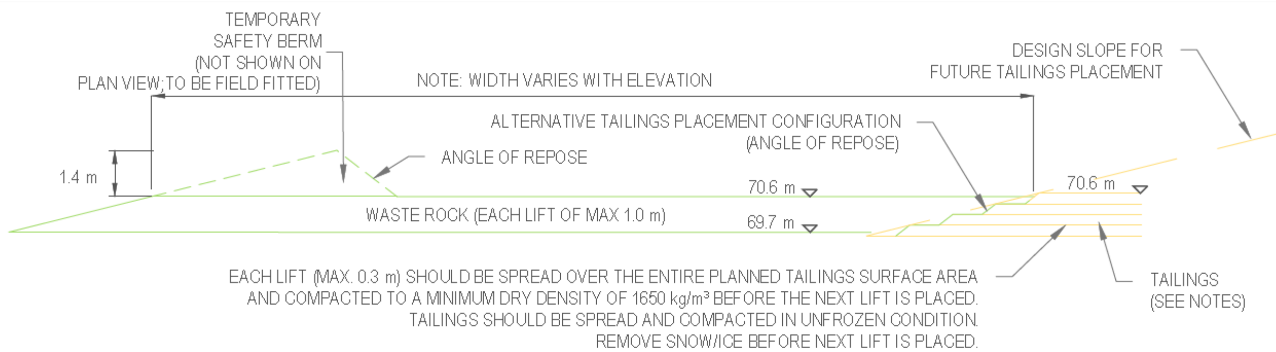


**Figure 2: Typical Waste Rock Cover with Safety Berm and Tailings Detail**

The waste rock cover will consist of 600 mm minus NPAG waste rock, of varying gradation placed in controlled lifts of maximum 1.0 m in height prior to compaction with a 10-ton vibratory roller.

Select overburden till will be placed and compacted over the top surface of the tailings to reduce surface infiltration.

Expected volumes of closure cover material distributed by year based on V9A_8yrs are provided in Table 4.

**Table 4: Summary of Cover Material Quantities during Mine Operations (V9A_8yrs)**

| Year | Mine Year | Volume of Waste Rock Placed on Side Slopes ($m^3$) | Volume of Waste Rock Placed on Final Top Surface ($m^3$) | Total Volume of Waste Rock Placed as Closure Cover ($m^3$) | Total Volume of Overburden Placed on Top Surface ($m^3$) |
|---|---|---|---|---|---|
| 2019 | -1 | 39,760 | | 39,760 | |
| 2020 | 1 | 97,036 | | 97,036 | |
| 2021 | 2 | 89,103 | | 89,103 | |
| 2022 | 3 | 110,124 | | 110,124 | |
| 2023 | 4 | 139,379 | | 139,379 | |
| 2024 | 5 | 117,037 | 123,942 | 240,979 | 22,940 |
| 2025 | 6 | 154,474 | | 154,474 | |
| 2026 | 7 | 127,840 | | 127,840 | |
| 2027 | 8 | 46,250 | | 46,250 | |
| 2028 | 9 | -- | 230,180 | 230,180 | 42,610 |
| **Total** | | **921,003** | **354,122** | **1,275,125** | **65,550** |

An adaptive closure strategy has been adopted for the Project, meaning that the preliminary closure cover design adopted for the TSF at this stage will be further evaluated and updated based on the TSF performance monitoring, water quality monitoring and evaluation, and the overall mine closure plan. The final closure cover design for the TSF will be developed before mine closure.

# 3.0 TAILINGS DEPOSITION STRATEGY

## 3.1 Objectives and Considerations

The overall tailings deposition plan reflects a number of considerations, including measures to promote freeze-back of the tailings and the underlying original ground, maintain long and short term stability, facilitate water management and minimize the overall footprint, as well as limit dust generation, control surface erosion, and reduce final closure costs.

This section summarizes the overall (multi-year) deposition strategy, in addition to providing quarterly information for the first two full years of tailings placement (2019 and 2020). All volumes presented are based on V9A_8yrs.

## 3.2 Overall Deposition Plan (Multi Year)

The yearly schedule of deposition per cell, as well as average height of tailings placed in each cell is summarized in Table 5. Drawings 6515-583-163-FIG-002 to 008 in Appendix A illustrate the yearly planned development of the TSF during mine operations and closure.

**Table 5: Tailings Placement Schedule and Estimated Tailings Heights (V9A_8yrs)**

| Year | Mine Year | Tailing Solids to be Placed in Dry Stack TSF (t) | | Estimated Average Height of Tailings Placed in Center Area of Each Cell (m) | | Planned Tailings Placement Period | |
|---|---|---|---|---|---|---|---|
| | | Cell 1 | Cell 2 | Cell 1 | Cell 2 | Cell 1 | Cell 2 |
| 2019 | Yr-1 | 582,026 | | 1.6 | | Jan to Dec | |
| 2020 | Yr 1 | 885,037 | | 5.3 | | Jan to Dec | |
| 2021 | Yr 2 | 1,052,607 | | 10.3 | | Jan to Dec | |
| 2022 | Yr 3 | 997,007 | | 16.1 | | Jan to Dec | |
| 2023 | Yr 4 | 868,728 | 620,522 | 22.7 | 2.6 | Jan to Jul | Aug to Dec |
| 2024 | Yr 5 | 717,635 | 992,439 | 33.0 | 6.9 | Jan to May | Jun to Dec |
| 2025 | Yr 6 | | 1,689,813 | | 15.2 | | Jan to Dec |
| 2026 | Yr 7 | | 1,668,059 | | 24.7 | | Jan to Dec |
| 2027 | Yr 8 | | 846,252 | | 33.0 | | Jan to Aug |
| **Total** | | **5,103,041** | **5,817,086** | | | | |

To promote freeze-back and permafrost development in the tailings and underlying ground surface, the following placement strategies shall be applied:

- **Seasonality considerations**: The initial lift of tailings over original ground will be placed during winter conditions whenever feasible.
- **Restricted yearly tailings thickness**: The maximum thickness of tailings placed during the initial year is limited to 2.6 m in the center area of each cell (up to 4.9 m in the area close to the cell

perimeter where the original ground elevation is lower than the center area), while the total yearly thickness placed in a cell for subsequent years shall be no greater than 10.3 m.

- **Thin lift placement over a large tailings surface area**: The tailings shall be placed and compacted in a lift of no greater than 0.3 m. Each lift of the tailings will be placed over the entire top surface of the planned area in each cell before next lift is placed such that localized placement of thick tailings is avoided. This will promote freeze-back of the tailings placed in winters and limit the overall thickness of the tailings placed in summers.

The tailings placement method of compacted thin lifts will also reduce the potential for wind erosion and dust generation from the surface. However, dust generation is anticipated to be a challenge during tailings placement in active zones, particularly during the winter months due to freeze drying of the surface. Additional measures to limit dust and control surface erosion are discussed in Section 6.0.

Snow cover on non-active areas has been observed to reduce the dust generated from freeze drying of the tailings surface. In general therefore, snow will be left in place on the TSF and will only be removed in advance of placement or prior to freshet.

Alternate zones for deposition, particularly during periods when weather conditions make placement more complex (i.e. heavy rainfall) or if the tailings are produced at less than optimum condition, will be identified by Engineering. Adverse operating conditions is discussed further in Section 4.4.

## 3.3 2019

### 3.3.1 Deposition Plan

The quarterly tailings deposition plan for 2019 is shown on Drawings 6515-583-163-FIG-009 to 012 in Appendix B. The tailings to the TSF in 2019 will be placed only within Cell 1; Cell 2 will not be used. The plan incorporates the following key tasks and considerations:

- A starter waste rock “berm” is initially placed along the outside perimeter (TSF haul road) to contain the initial lifts of the tailings. This berm will form the foundation of the closure cover;
- The tailings shall be placed and compacted in thin horizontal lifts (maximum thickness of 0.3 m) over the entire planned surface area to avoid localized thick tailings placement;
- Additional lifts of waste rock (with a maximum lift thickness of 1 m) shall be placed on the starter “berm” as the tailings surface is brought up; and
- Safety berms shall be placed on each lift of the waste rock once these lifts are above 3.0 m from original ground (as per Mine Act regulations). The safety berm may also help to reduce dust generation from the tailings surface.

Table 6 summarizes the quarterly tailings deposition plan in 2019.

**Table 6: Quarterly Tailings Deposition Plan in 2019 (V9A_8yrs)**

| Quarter in Year -1 | Tailing Solids to be Placed in Dry Stack TSF (t) | Estimated Volume of Compacted Tailings ($m^3$) | Approximate Top Elevation of Tailings in Cell 1 (masl) | Planned Tailings Deposition Area |
|---|---|---|---|---|
| Q1 | 102,459 | 62,096 | 70.2 | East portion of Cell 1 in CP1 Catchment Area |
| Q2 | 153,552 | 93,062 | 68.5 | West portion of Cell 1 in CP3 Catchment Area |
| Q3 | 153,108 | 92,793 | 69.7 | West portion of Cell 1 in CP3 Catchment Area |
| Q4 | 172,907 | 104,792 | 70.6 | Most of Cell 1, except for the high ground in the southeast end |

### 3.3.2 Actual Deposition

Placement during 2019 generally followed the deposition plan described in Section 3.3.1, with the following observations made:

- Cell 1 was divided into six (6) sub-cells for ease of management;

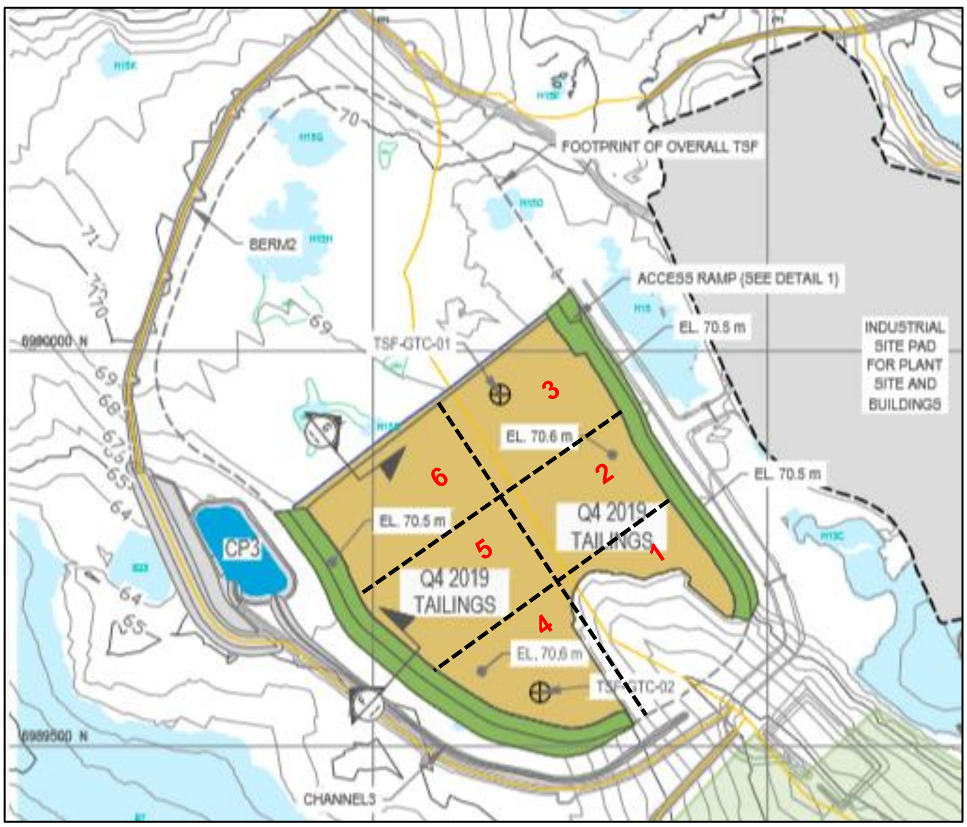


**Figure 3: TSF Cell1 Sub-Cell Arrangement**

- Water management during the 2019 freshet was challenging and left large areas of the TSF unsuitable for tailings placement due to saturated conditions. Historic rainfall levels throughout the year further hampered tailings placement in these areas. Affected areas of Cell 1 included all areas abutting against the esker (western portions of sub-cells 1 and 2; eastern portions of sub-cells 4 and 5) and all of sub-cell 6.

- In addition to decreased available surface area on which to place tailings, mill production was higher than anticipated and issues commissioning paste usage underground led to greater volumes of tailings being produced needing storage.
- Accordingly, as a greater volume of tailings was placed in a smaller area, the volumes of waste rock placed as cover material were also larger than predicted in 2019.
- The actual volumes of waste material placed per quarter compared to the expected quantities is provided in Table 7.

**Table 7: Comparison of Expected and Actual Volumes Placed in 2019**

| Quarter in 2019 (Year -1) | Volume of Placed Tailings ($m^3$) | | Volume of Placed Waste Rock ($m^3$) | |
|---|---|---|---|---|
| | Expected | As-Built | Expected | As-Built |
| Q1 | 62,096 | 85,143 | 7,229 | 22,541 |
| Q2 | 93,062 | 129,555 | 10,844 | 27,977 |
| Q3 | 92,793 | 146,323 | 10,844 | 16,238 |
| Q4 | 104,792 | 146,517 | 10,844 | 8,326 |
| **Total** | **290,710** | **507,538** | **39,760** | **75,082** |

## 3.4 2020

### 3.4.1 Deposition Plan

The quarterly tailings deposition plans for 2020 are shown on Drawings 6515-583-163-FIG-013 to 016 in Appendix C. As in 2019, the tailings to the TSF in 2020 will only be placed within Cell 1. The plan for 2020 deposition also considers the lessons learned during 2019 and applies the following tasks and considerations:

- **Freshet preparation**. Top priority during the early winter months of 2020 should be placement of a sufficiently thick tailings cover on the esker and sub-cell 6 in order to prevent water infiltration and enable placement during the warmer months. Any remaining "low spots" will be filled prior to freshet to avoid areas of pooling.
- **Even coverage**. Following freshet preparation, deposition will occur around Cell1 to bring all sub-cells up in an orderly, even progression.
- **Sloping**. Each lift of tailings will be sloped 1% from the centerline towards the berms to encourage run-off and minimize surface erosion.
- **Progressive cover placement**. The waste rock berms are to be lifted after every three (3) lifts of tailings. The progressive placement of waste rock is critical during summer months to protect the tailings from water erosion and during the winter months for dust control. Waste rock should be placed even with the height of the tailings and thoroughly compacted as this interface area has been shown to be very prone to degradation.

Table 8 provides the expected volumes of waste material to be placed in 2020. These volumes however, are based on milling rate of about 3,000t/day and are expected to be higher.

**Table 8: Quarterly Tailings Deposition Plan in 2020 (V9A_8yrs)**

| Quarter in 2020 (Year 1) | Estimated Volume of Tailings ($m^3$) | Estimated Volume of Waste Rock ($m^3$) |
|---|---|---|
| Q1 | 117,219 | 25,655 |
| Q2 | 152,976 | 25,655 |
| Q3 | 132,522 | 25,655 |
| Q4 | 133,668 | 25,655 |
| **Total** | **536,385** | **102,620** |

# 4.0 CONSTRUCTION METHODS AND PROCEDURES

A procedure summarizing the following sections is provided for reference in Appendix D.

## 4.1 Pre-construction

Limited pre-construction activities are required at the TSF prior to tailings placement as the tailings are placed directly over original ground. In general, pre-construction activities of each cell consist of:

- **Survey**, including a topographical survey of the original ground surface and staking the limits of waste rock cover, tailings, and lift heights.
- **Excess snow and/or ice removal** from the ground surface before the waste rock tailings over the original ground is placed. Some pumping of localized water accumulations may be required prior to placement in summer/fall.
- **Waste rock placement.** For areas where initial tailings placement is expected during summer/fall seasons, waste rock cover material may need to be placed prior to tailings placement and serve as a temporary access to the cell.

## 4.2 Equipment for TSF Construction

Agnico Eagle shall use equipment available on site for all aspects of TSF construction. Table 9 lists typical equipment that may be employed for TSF construction.

**Table 9: Typical Construction Equipment**

| Equipment | Use |
|---|---|
| CAT 988 loader | Load tailings from stockpile at the TDB into haul trucks |
| CAT D6 bulldozer | Spread tailings/waste rock |

| | |
|---|---|
| Volvo A40 G haul truck | Haul tailings/waste rock from stockpile to the TSF |
| CAT CS356 10-ton vibratory drum roller | Compacting the placed tailings/waste rock to achieve the design dry density |
| CAT 330 Excavator | Build safety berm, shape side slopes and remove snow |

## 4.3 Operational Construction

The general construction sequence of the TSF during operations shall be as follows:

- Filtered tailings are loaded from the TDB with a CAT 988 loader onto Volvo 40-ton haul trucks.
- Once at the TSF, haul trucks end dump the tailings in the specified area (within the survey stakes). Typically haul trucks back up to the dozer and exit on the same path within the placement area to minimize traffic on already placed and compacted tailings.
- Tailings must be spread and compacted immediately after being dumped at the TSF, before freezing occurs during winter periods in order to achieve the desired compaction. This will serve to seal the surface and reduce wind erosion;
- The tailings are spread over a large area into a thin lift of a maximum height of 0.3 m with a CAT D6 bulldozer. Each lift of the tailings is placed over the entire surface of the staked area in each cell before the next lift is placed such that localized placement of thicker tailings over a small area is avoided;
- Each lift of tailings are compacted with a CAT CS356 10-ton vibratory drum roller to a minimum dry density of 1,650 kg/m$^3$ before the next lift is placed. In situ density testing has indicated that the desired compaction can be achieved with three (3) full passes (forward and backward is one pass) at heavy vibrate, followed by one (1) static roll to seal the surface;
- Every lift of tailings material should be “stepped in”, forming a staircase-like structure around the outside perimeter to establish the required design side slope. Based on the 4H:1V slope, the step-in distance for each lift is 1.2 m. A step-in should be placed around the entire lift so that a good tie-in with future lifts can be achieved;
- Waste rock must be placed and compacted around the side slopes as progressive cover material after every three (3) lifts of tailings;
- A temporary safety berm shall be placed over the outside crest area of each lift of the waste rock cover or berm once waste rock heights achieve a 3.0 m height above original ground as per Mine Act requirements.
- The temporary safety berms should be incorporated into the next lift of cover material to ensure adequate compaction occurs throughout (ie. the safety berm material should be spread throughout the next lift of waste rock and compacted as part of the lift instead of leaving it un-compacted at the slope.

The placement of thin lifts of rock material can be used to allow circulation of haul trucks to the deposition point during summer placement if required. These intermittent layers will be covered by tailings when surfaces become trafficable.

As discussed further in Section 7.0, throughout the life of the mine ground temperature cables (GTCs) will be installed within the footprint of the TSF to monitor the temperatures of the underlying permafrost and the tailings. These cables will be progressively raised in height as the tailings stack increases. Truck routing therefore needs to account for the position of the GTCs to minimize the potential for damaging the cables and operators shall exercise extreme caution when pushing tailings up to and around the cable stands.

### 4.3.1 Filter Cloth Disposal

Used filter cloth from the filter presses will be regularly disposed of within the TSF. It is understood that each filter cloth measures approximately 3.0 m x 3.0 m and that each filter cloth will be changed at a rate of 1 cloth/2,000 cycles. Based on predicted consumption, an average of 14 filter cloths/day will require disposal.

The worn material will be rolled or folded into a bundle, brought to the TSF, unrolled flat and covered with tailings as part of the lift in progress. No additional handling or special placement procedures will be required as part of the disposal process.

### 4.3.2 Sludge Disposal

Waste from the STP was disposed of within the TSF during 2019 in a specialized decantation pond constructed in Cell 2. However, due to numerous concerns, including thermal issues, health and safety and interference with design specifications, placement of all STP waste (cake and sludge) will be moved to the active WRSFs. Decommissioning of the decantation pond will occur in 2020 and consist of covering the pond with waste rock. Tailings placement will continue around and over the decantation pond in later years.

### 4.3.3 Placement of Additional Waste Material

No additional waste materials other than tailings, waste rock and used filter cloths will be placed within the TSF.

## 4.4 Adverse Operating Conditions

Potentially adverse conditions must be accounted for in the operation of the TSF. These conditions, along with mitigative measures of dealing with them, are provided in Table 10.

**Table 10: Adverse Operating Conditions and Mitigative Measures**

| Adverse Condition | Mitigation |
|---|---|
| **High Moisture Tailings** | - Notify Tailings Mgmt Team (Mill, Engineering) of any unusual tailings conditions (ie. very wet and/or difficult to handle tailings)<br>- Sampling for moisture content should be obtained prior to placement in TSF<br>- Tailings with slightly higher than expected moisture contents will be placed in less critical areas (ie. near the centre of the stack) in a location designated by Engineering. The boundary of these areas should be surveyed for additional performance monitoring.<br>- Depending on ambient weather conditions, overly wet tailings may require draining prior to compaction at the discretion of the Geotechnical Engineer |
| **High Rainfall** | - Proper grade control and compaction during construction should seal the placed tailings and prevent water pooling<br>- Temporary diversion channels and/or berms may be required to divert water from the tailings stack<br>- Tailings deposition should not occur during short periods of intense rainfall; the area should be given time to drain and dry before placement commences |
| **Blizzard Conditions** | - The TDB contains approximately three (3) days of storage capacity in case of extreme whiteout/blizzard conditions. Capacity can be increased by piling tailings higher with an excavator.<br>- If weather forecasts indicate impending extreme weather events, every effort should be made to empty the TDB in advance to shore up as much storage as possible to avoid a mill shutdown.<br>- However, stockpiling in the TDB must be avoided if at all possible and only used in extreme situations. Stockpiling in the TDB increases the likelihood of freezing the tailings prior to placement – this increases the likelihood of not achieving compaction specifications and generates dust during placement. |
| **Snow Accumulation** | Snow removal from the TSF will occur at three (3) stages:<br>- Prior to placement of tailings/waste rock over original ground<br>- Prior to placement of a lift of tailings/waste rock over already placed tailings/waste rock<br>- Impact of snow accumulations on tailings freeze back will be monitored in non-active areas and snow removal may be required. |

## 4.5 Quality Control

A quality control plan and monitoring program will be developed and included as part of the OMS plan for the TSF. This plan will include, amongst other aspects:

- Documentation of actual tailings placement (load counts), snow management procedures and as-built geometries of both the tailings and the closure cover; and
- Verification of design assumptions, including ground temperatures, moisture content, placement temperatures of the filtered tailings, pore water salinity, and target dry density (compaction).

# 5.0 DUST AND EROSION CONTROL

As mentioned in Section 3.2, dust generation is expected to be a challenge in active areas of tailings placement. Specific measures to limit dust and control surface erosion include:

- Placement of progressive closure cover on the slopes and addition of the safety berm to form a barrier around the tailings placement area;
- The closure cover over the top tailings surface of Cell 1 will be placed when Cell 1 reaches capacity;
- Consideration of prevailing north-northeast wind direction by development of the southern portion of Cell 1 first and progression northward;
- During summer months, dust might be controlled by spraying water, although approval from the Geotechnical Engineer is required before attempting this measure;
- During winter months, snow cover should remain on inactive areas. The impact of this snow cover on underlying temperatures will continue to be monitored;
- Each lift of the tailings shall be compacted to form a firm and smooth surface. The top surface of the tailings shall be flat or have a gentle slope, which reduces the risk of surface erosion during rainfall events; and
- All equipment (heavy and vehicle) must avoid trafficking on non-active areas of placed and compacted tailings in order to reduce dust emissions.

The temporary slope on the northwest side of Cell 1, which separates Cell 1 and Cell 2, has a high potential of surface erosion under extreme rainfall events and dust generation under strong winds, even though it has a gentle slope of 4H:1V. Engineering measures, such as placing a thin lift of granular soil, may be required to control the potential surface erosion and dust generation. The final selection of a cost-effective control measure can be made based on field observations and performance monitoring during the early stage of operation.

# 6.0 WATER MANAGEMENT

The water management system of the TSF consists of a berm, three culverts, two channels, and two collection ponds designed to collect any seepage and runoff from the TSF, as well as divert water away from the storage facility itself. Two catchment systems manage runoff from the TSF, with the management strategy for each watershed summarized as follows:

1. CP1 Catchment (East side of watershed limit): Seepage and runoff from the placed filtered tailings within the CP1 catchment area will stream through Culverts 1, 18, and (future) 19 to Channel1 and Culvert 3 for final collection in Water Collection Pond CP1.
2. CP3 Catchment (West side of watershed limit): Seepage and runoff will be collected in Water Collection Pond CP3 either directly or via Channel3. Water collected in CP3 will be pumped to partially-drained natural pond H13 where it will flow through Channel 1 and Culvert 3 into CP1. Berm 2 serves to divert natural surface runoff away from the TSF.

CP3 is designed to store runoff from the first three days of the annual spring freshet, until the CP3 pumping station and piping is ready to operate. The collected water in CP3 will be completely pumped out within seven days (Tetra Tech 2018).

Minimal water will be stored in CP3 after the spring freshet water is pumped out, so that the runoff from an extreme rainfall event can be temporarily stored in CP3. No water will be discharged from CP3 directly to the environment during the operation phase of Meliadine Mine. The design minimum operating water pumping rate for the CP3 pumping system is 9,400 $m^3$/day (Tetra Tech 2018).

All water management infrastructure shall remain in place until mine closure activities are completed and monitoring results demonstrate that the contact water quality from the TSF meets the discharge criteria. Further details on water management for the TSF are provided in the Water Management Plan (Agnico Eagle 2020b).

Temporary water management structures, including ditches and deflection berms, may be required during freshet and summer seasons to divert water around the stack. The position of these measures must be made in consultation with the Geotechnical Engineer.

# 7.0 MONITORING AND INSPECTION

The monitoring and inspection program for the TSF consists of design verification testing (on and off site), geochemical testing, as-built surveying, visual inspections, dust collection and snow sampling and thermal monitoring.

A total of eight (8) ground temperature cables (GTCs) are currently planned for installation throughout the TSF area, installed to a minimum depth of 10 m below the original ground to verify the thermal conditions and assumptions. Four (4) of these GTCs have been installed in 2019 and additional vertical and horizontal ground temperature cables will be installed at a later date. Although thermistor readings were anticipated to be analysed once a month during the first year of a cell operation and then on a quarterly basis, monthly readings will continue during 2020.

Other instrumentation or monitoring programs can be added, when required, based on the performance monitoring of the TSF. Further details regarding the monitoring and inspection plan for the TSF can be located in the 2020 MWMP (Agnico Eagle 2020a) and a detailed monitoring and inspection program will be finalized during development of the OMS manual.

Table 11 summarizes the monitoring and inspection program for 2020.

**Table 11: Tailings Storage Facility Monitoring and Inspection Activities**

| Monitoring Component | | Monitoring Frequency | Reporting |
|---|---|---|---|
| Verification Monitoring | Tailings production rate and solid content | Continuous | Monitoring data will be used by Agnico Eagle internally, and will be reported to the Regulators upon request |
| | Design verification of placed tailings (moisture content, density, particle size) | Quarterly/Bi-annually | |
| | Routine visual geotechnical inspections of TSF | Weekly | |
| | Elevation and geometry survey | Annually | |
| | Water quality monitoring of CP3 | Monthly over the open water season or when water is present | |
| General Monitoring | Quantities of tailings placed into facilities | Monthly | Monitoring data will be reported to the Regulators in annual water licence report or annual inspection report |
| | Thermal and freeze-back monitoring | Monthly until 2021 and quarterly thereafter | |
| | Dust monitoring related to TSF | Daily during operation phase | |
| | Geochemical monitoring | Bi-monthly | |
| | Geotechnical inspection by qualified Geotechnical Engineer | Annually or more frequent at the request of an Inspector | |

# 8.0 DOCUMENTATION AND REPORTING

Routine reporting of surveillance and monitoring results is essential to provide time to make adjustments to existing systems or to initiate Emergency Response Plans. It is imperative that the observation of any unusual occurrence should be reported immediately to the Geotechnical Engineer/Environment for technical assessment. Unusual occurrences include but are not limited to the following:

- Excess wet/soft conditions over a relatively large area of the TSF;
- Any seismic event;
- Settlement, cracks, or slumping of the placed tailings or waste rock cover;
- Failure of any of the slopes;
- Abnormal seepage from any of the slopes or toes;
- High turbidity of runoff or seepage flow from the TSF; and
- Damage to any component of the TSF.

All reports are to be maintained by the Geotechnical Engineer and filed in a suitable format and location for easy access by authorized mine personnel, and for review by government agencies. Annual performance reviews will be copied to the regulatory agencies.

The requirements of other departments or governmental agencies may dictate certain items that require inspection, monitoring, or reporting. As with the monitoring and inspection program, details regarding documentation and reporting will be finalized during development of the OMS manual.

# 9.0 ADAPTIVE AND CHANGE MANAGEMENT

The Meliadine TSF is classified as a “high risk structure” under the AEM Corporate Governance structure, along with the waste rock storage facilities (WRSFs) and water management infrastructures. As such, any changes to the design or deposition that have the potential to impact the stability or thermal performance of the structure is subject to approval by the Responsible Person and Engineer of Record for the site. A full discussion of the roles of various individuals in the construction, operation and maintenance of the TSF, in addition to the responsibilities and tasks of these individuals, will be located in the OMS manual for the facility.

This deposition plan is based on some assumed and expected design parameters for the tailings and site conditions. These assumptions and parameters will continue to be verified during mine operation in 2020. This deposition plan will continue to be updated as required to reflect the actual parameters and site conditions and operating experience gained.

The preliminary closure cover design adopted for the TSF at this stage shall be further evaluated and updated based on the TSF performance monitoring, water quality monitoring and evaluation, and the final mine closure plan. The final closure cover design shall be developed before the mine closure.

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# APPENDIX A – OVERALL DEPOSITION PLAN DRAWINGS

| | |
|---|---|
| 6515-583-163-FIG-001 | General Arrangement |
| 6515-583-163-FIG-002 | Year 2 |
| 6515-583-163-FIG-003 | Year 3 |
| 6515-583-163-FIG-004 | Closure |
| 6515-583-163-FIG-005 | Typical Design Section of TSF and Sections B-B and C-C through Cells 1 and 2 |
| 6515-583-163-FIG-006 | Section A-A TSF during Operation Years -1 to 2 |
| 6515-583-163-FIG-007 | Section A-A TSF during Operation Years 3 to 5 |
| 6515-583-163-FIG-008 | Section A-A TSF during Operation Years 6 to 8 |

NO. DESSIN
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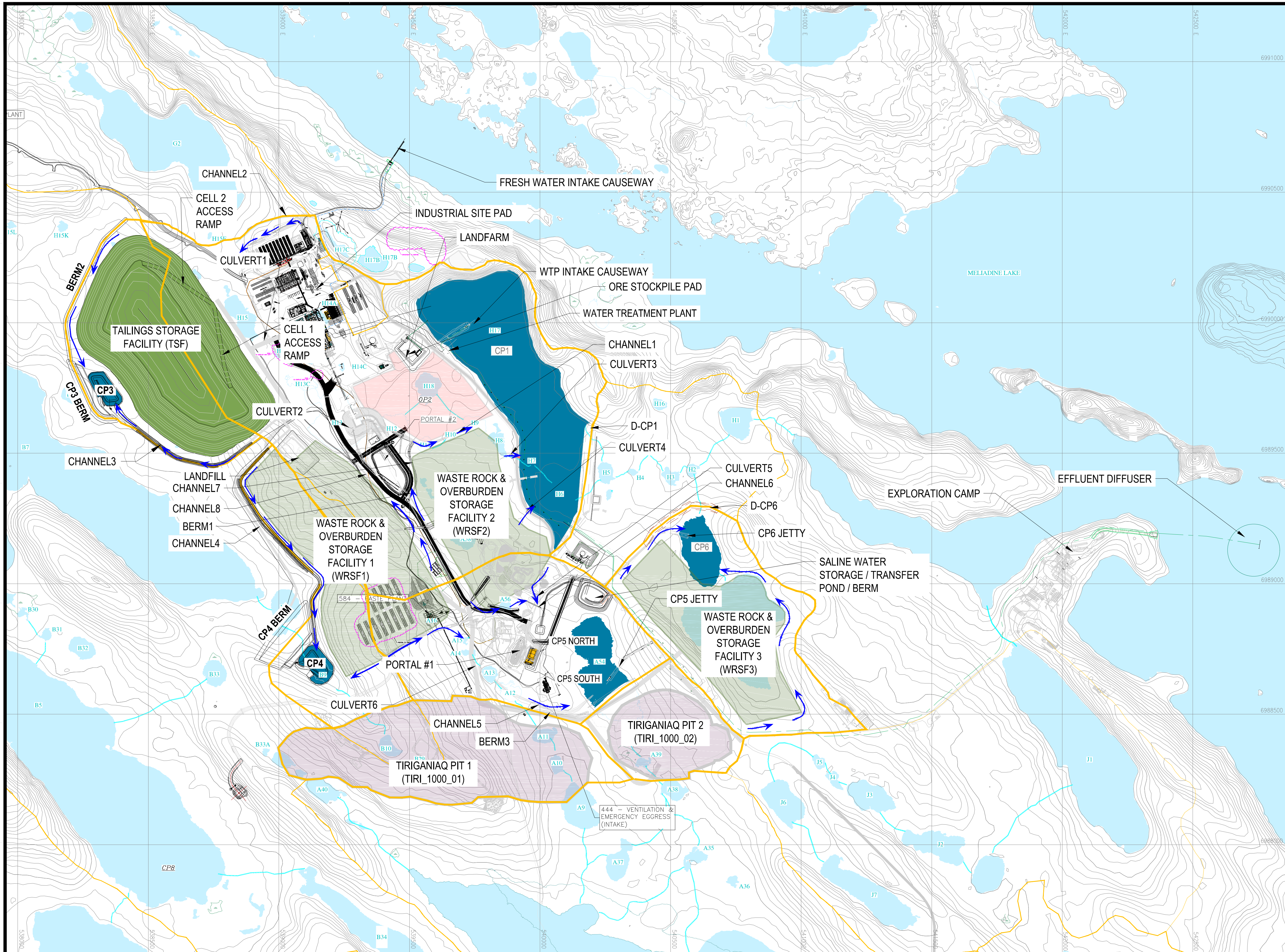
FORMAT ANSI B-11x17




LEGEND

- CATCHMENT BOUNDARY
- WATERBODY
- WATER COLLECTION POND
- OPEN PIT
- WASTE ROCK
- ORE
- CONTACT WATER FLOW DIRECTION

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date Nov. 14, 2018
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

REGISTERED PROFESSIONAL ENGINEER
G. ZHANG
LICENSEE
NOV. 14, 2018
NWT/NU

AGNICO EAGLE

TETRA TECH

POUR CONSTRUCTION
FOR CONSTRUCTION
DATE: 11/14/2018



| TITRE / TITLE | # DWG |
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| A | ISSUED FOR REVIEW | 2018-11-05 | |

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| DESSINE PAR DRAWN BY | EL/EP | DATE | 2018-11-14 |
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| APPROUVÉ PAR APPROVED BY | | | |
| No. PROJET PROJECT NO. | | | |
| DATE | | | |

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY DESIGN

GENERAL ARRANGEMENT

ÉCHELLE/ SCALE
FICHIER FILE .DWG

| No. DESSIN/ DRAWING NO. | REVISION | FEUILLE/SHT |
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| 6515-583-163-001 | 0 | 1 / 8 |

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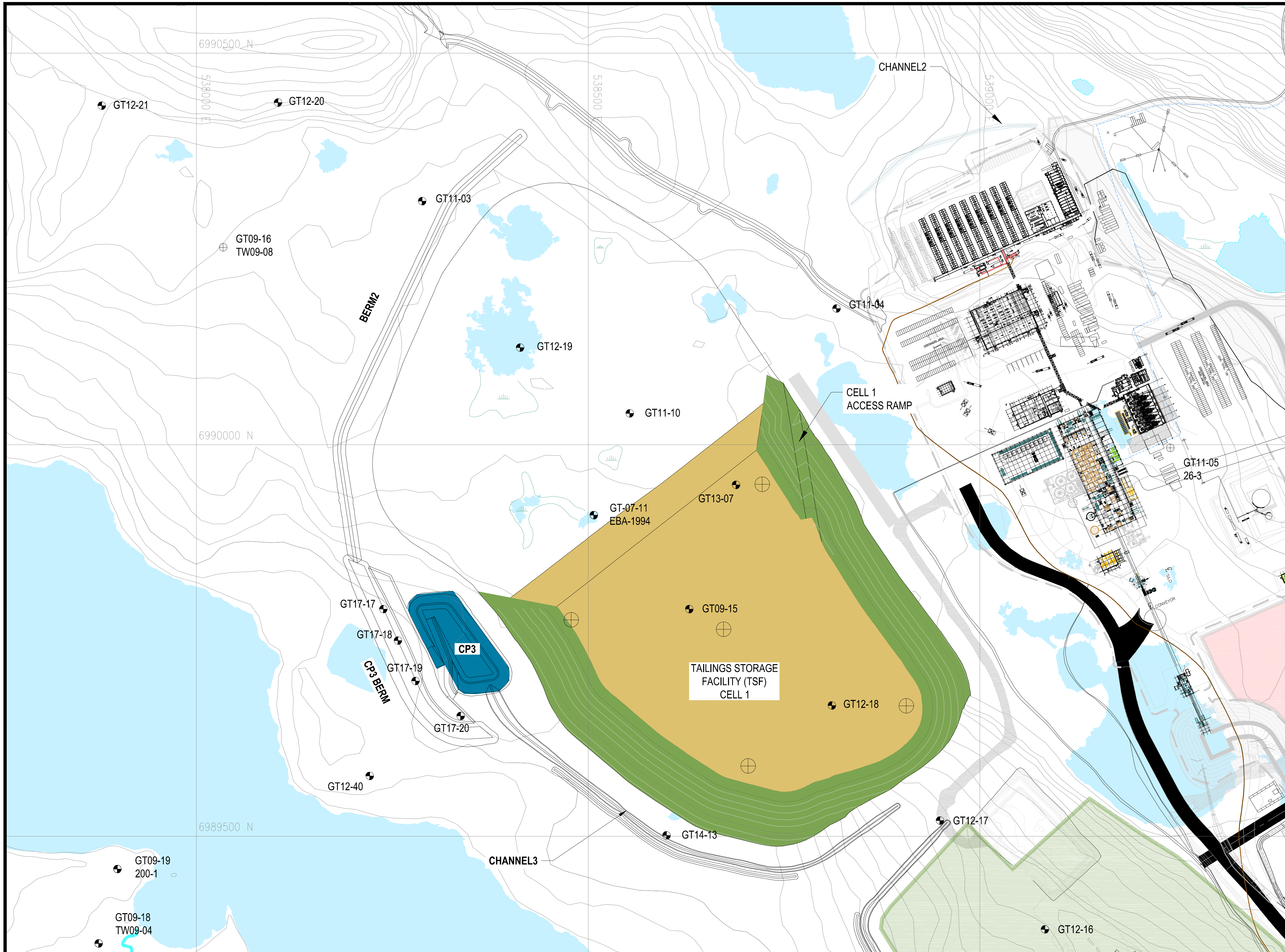
NO. DESSIN
DRAWING NO.

FORMAT ANSI B-11x17




LEGEND

- WASTE ROCK
- ORE
- TAILINGS
- WATER COLLECTION POND
- BOREHOLE
- PROPOSED GROUND TEMPERATURE CABLE LOCATION

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date Nov. 14, 2018
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

REGISTERED PROFESSIONAL ENGINEER
G. ZHANG
LICENSEE
NOV. 14, 2018
NWT/NU

AGNICO EAGLE

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FOR CONSTRUCTION
DATE: 11/14/2018



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| APPROUVÉ PAR / APPROVED BY | | | |
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| DATE | | | |

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY DESIGN

YEAR 2

ÉCHELLE/ SCALE
FICHIER FILE .DWG

| No. DESSIN/ DRAWING NO. | REVISION | FEUILLE/SHT |
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| 6515-583-163-002 | 0 | 2 / 8 |

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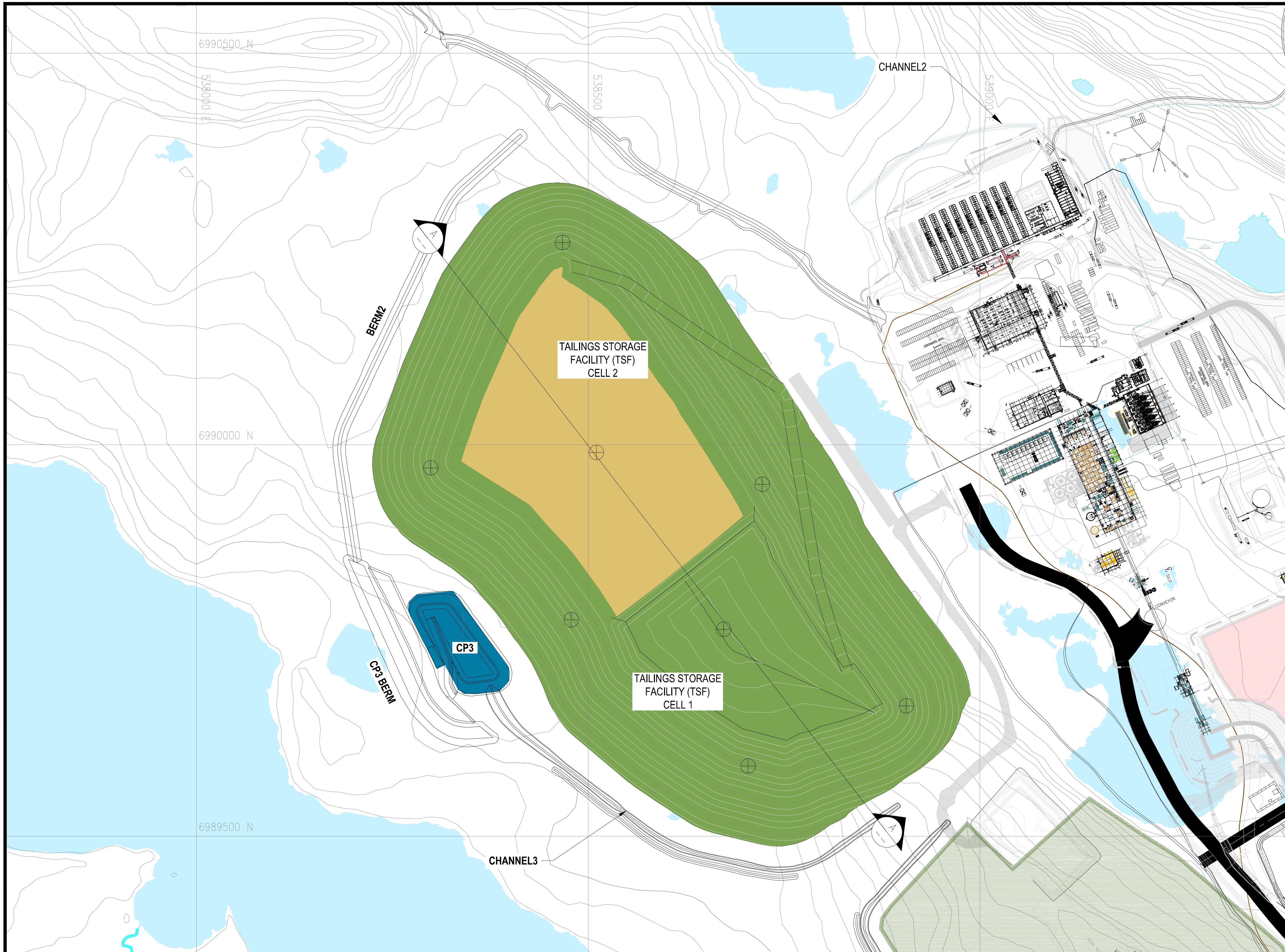
DRAWING NO.

FORMAT ANSI B–11x17




LEGEND

WASTE ROCK

ORE

TAILINGS

WATER COLLECTION POND

PROPOSED GROUND TEMPERATURE CABLE LOCATION

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date Nov. 14, 2018
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

PROFESSIONAL ENGINEER
G. ZHANG
LICENSEE
NWT/NU

AGNICO EAGLE

TETRA TECH

POUR CONSTRUCTION
FOR CONSTRUCTION
DATE : 11/14/2018



| TITRE / TITLE | # DWG |
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| A | ISSUED FOR REVIEW | 2018–11–05 | |

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| DESSINÉ PAR DRAWN BY | EL/EP | DATE | 2018–11–14 |
| VÉRIFIÉ PAR CHECKED BY | GZ/WTH | | 2018–11–14 |
| APPROUVÉ PAR APPROVED BY | | | |
| No. PROJET PROJECT NO. | | | |
| DATE | | | |

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY DESIGN

YEAR 7

ÉCHELLE/ SCALE
FICHIER FILE .DWG

No. DESSIN/ DRAWING NO. 6515–583–163–003
REVISION 0
FEUILLE/SHT 3 / 8

AE–CART–ANSI B

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NO. DESSIN
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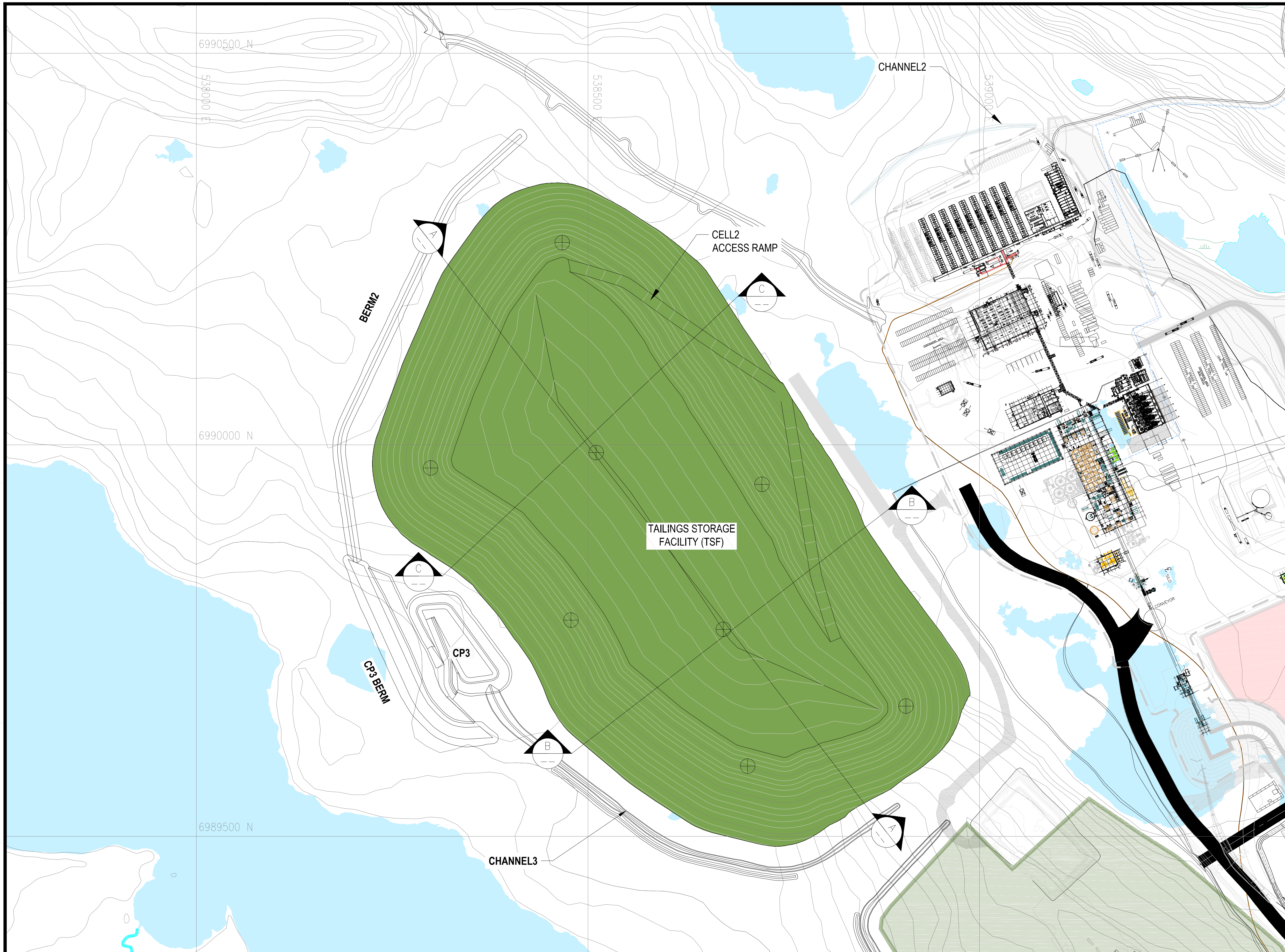
FORMAT ANSI B-11x17




## LEGEND

- WASTE ROCK
- ORE
- TAILINGS
- PROPOSED GROUND TEMPERATURE CABLE LOCATION

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date Nov. 14, 2018
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

PROFESSIONAL ENGINEER
G. ZHANG
LICENSEE
NOV. 14, 2018
NWT/NU

AGNICO EAGLE

TETRA TECH

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FOR CONSTRUCTION
AGNICO EAGLE
DATE : 11/14/2018



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| A | ISSUED FOR REVIEW | 2018-11-05 | |

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| VÉRIFIÉ PAR CHECKED BY | GZ/WTH | 2018-11-14 |
| APPROUVÉ PAR APPROVED BY | | |
| No. PROJET PROJECT NO. | | |
| DATE | | |

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY DESIGN

CLOSURE

| ÉCHELLE/ SCALE | FICHIER FILE | .DWG |
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| No. DESSIN/ DRAWING NO. | REVISION | FEUILLE/SHT |
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| 6515-583-163-004 | 0 | 4 / 8 |

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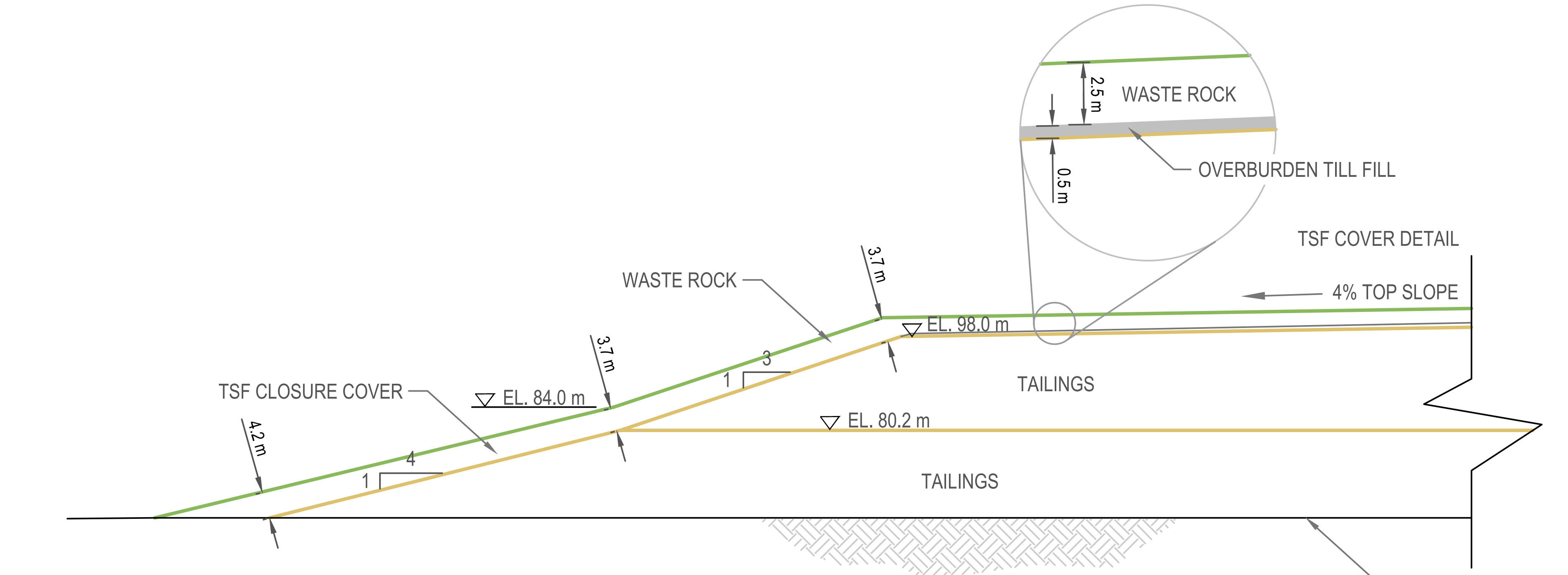
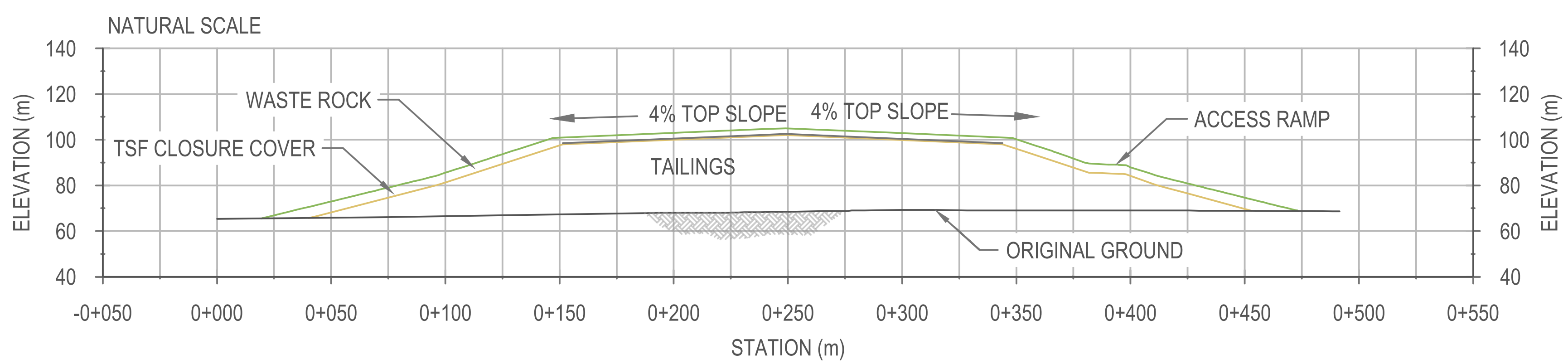
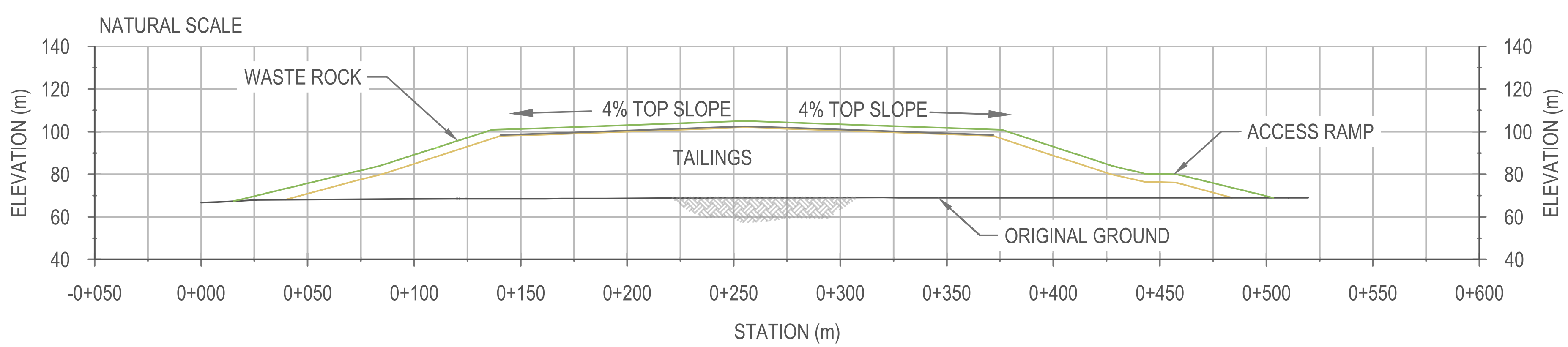



NOTE: TSF CLOSURE COVER THICKNESS AND CONFIGURATION TO BE FINALIZED DURING THE DEVELOPMENT OF THE FINAL CLOSURE COVER DESIGN PENDING PERFORMANCE MONITORING OF DRY STACKED TAILINGS FACILITY DURING OPERATION.

*TYPICAL DESIGN SECTION FOR TSF*




*SECTION B–B THROUGH CELL 1*




*SECTION C–C THROUGH CELL 2*

NOTES:

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TETRA TECH CANADA INC.
Signature
Date Nov. 14, 2018
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

G. ZHANG
LICENSEE
NWT/NU

AGNICO EAGLE

TETRA TECH

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FOR CONSTRUCTION
DATE : 11/14/2018

| TITRE / TITLE | # DWG |
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| DATE | | | |

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY DESIGN

TYPICAL DESIGN SECTION OF TSF AND SECTIONS B–B AND C–C THROUGH CELLS 1 AND 2

| ÉCHELLE/ SCALE | FICHIER FILE .DWG |
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| No. DESSIN/ DRAWING NO. | REVISION | FEUILLE/SHT |
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DRAWING NO.

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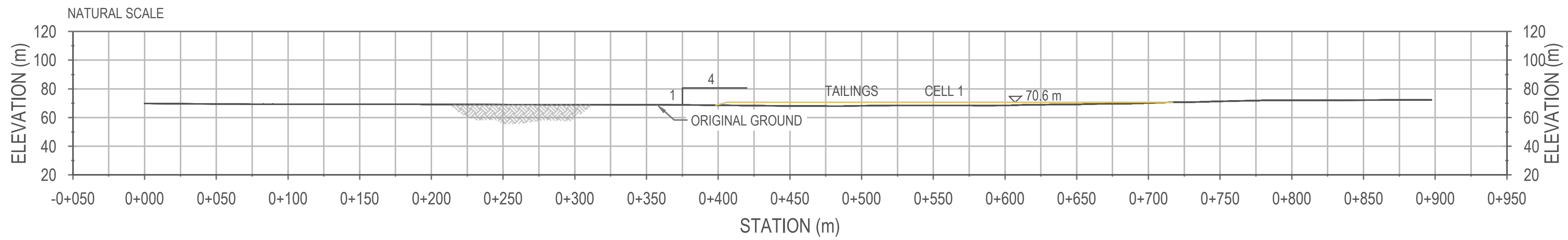
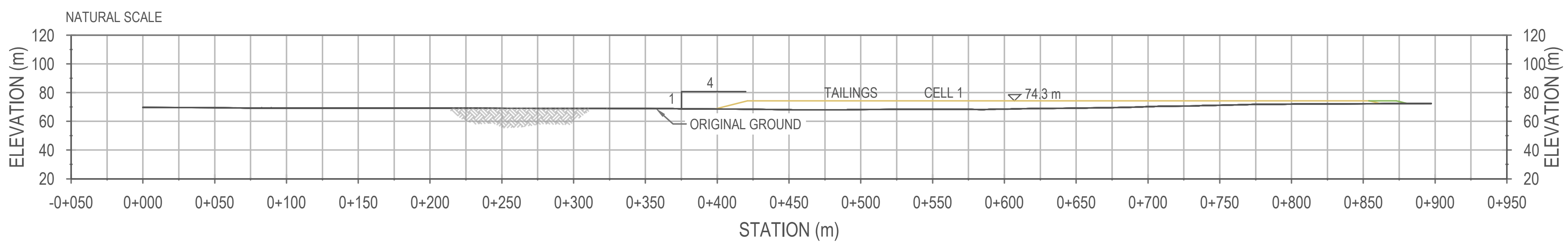
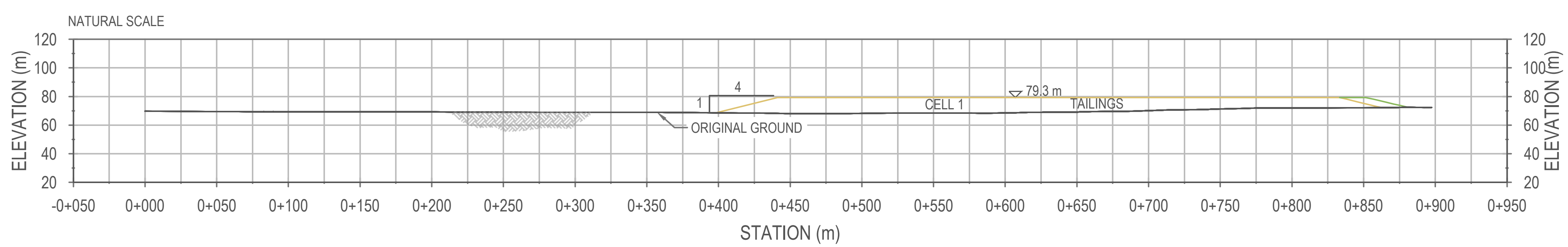



*SECTION A–A TSF DURING OPERATION (YEAR –1 SHOWN)*




*SECTION A–A TSF DURING OPERATION (YEAR 1 SHOWN)*




NOTE: TSF CLOSURE COVER THICKNESS AND CONFIGURATION TO BE FINALIZED DURING THE DEVELOPMENT OF THE FINAL CLOSURE COVER DESIGN PENDING PERFORMANCE MONITORING OF DRY STACKED TAILINGS FACILITY DURING OPERATION.

*SECTION A–A TSF DURING OPERATION (YEAR 2 SHOWN)*

NOTES:

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date Nov. 14, 2018
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

REGISTERED PROFESSIONAL ENGINEER
G. ZHANG
LICENSEE
Nov. 14, 2018
NWT/NU

AGNICO EAGLE

TETRA TECH

POUR CONSTRUCTION
FOR CONSTRUCTION
DATE : 11/14/2018

| TITRE / TITLE | # DWG |
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DESSINS EN RÉFÉRENCE/REFERENCE DRAWINGS

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| No. PROJET / PROJECT NO. | | |
| DATE | | |

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY DESIGN

SECTION A–A TSF DURING OPERATION
YEARS –1 to 2

ÉCHELLE/ SCALE
FICHIER FILE .DWG

No. DESSIN/ DRAWING NO. 6515–583–163–006
REVISION 0
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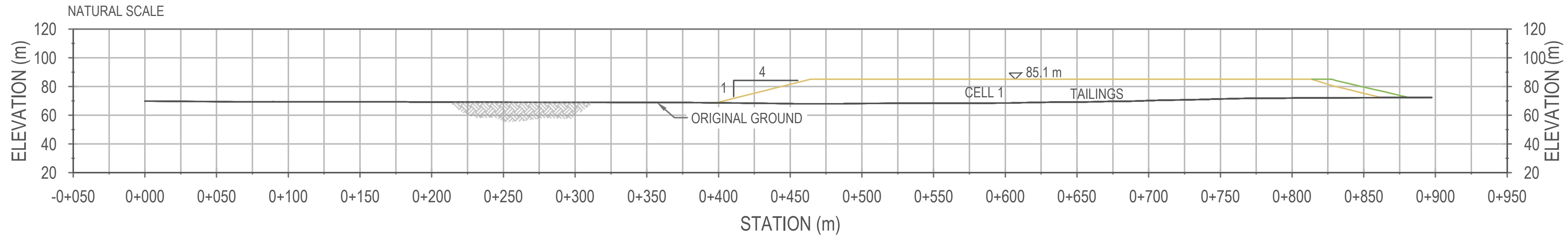
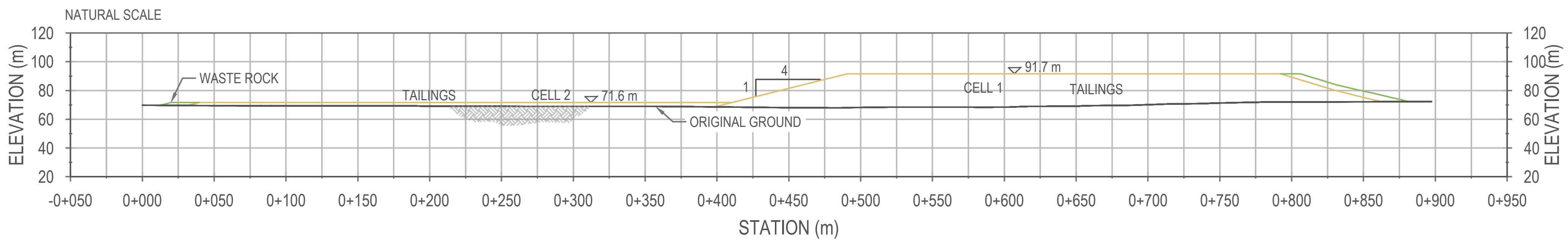
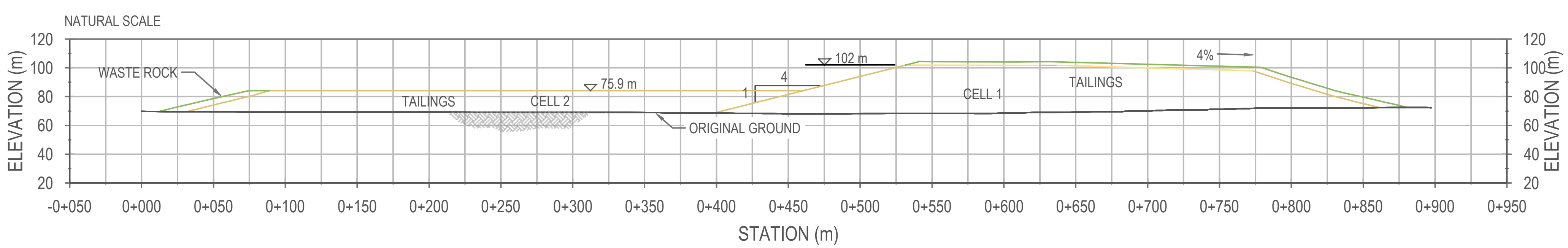



*SECTION A–A TSF DURING OPERATION (YEAR 3 SHOWN)*




*SECTION A–A TSF DURING OPERATION (YEAR 4 SHOWN)*




NOTE: TSF CLOSURE COVER THICKNESS AND CONFIGURATION TO BE FINALIZED DURING THE DEVELOPMENT OF THE FINAL CLOSURE COVER DESIGN PENDING PERFORMANCE MONITORING OF DRY STACKED TAILINGS FACILITY DURING OPERATION.

*SECTION A–A TSF DURING OPERATION (YEAR 5 SHOWN)*

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date Nov. 14, 2018
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

REGISTERED PROFESSIONAL ENGINEER
G. ZHANG
LICENSEE
Nov. 14, 2018
NWT/NU

AGNICO EAGLE

TETRA TECH

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FOR CONSTRUCTION
DATE : 11/14/2018

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| DATE | | | |

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY DESIGN

SECTION A–A TSF DURING OPERATION
YEARS 3 to 5

ÉCHELLE/SCALE
FICHIER/FILE .DWG

No. DESSIN/DRAWING NO. 6515-583-163-007
REVISION 0
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AE-CART-ANSI B

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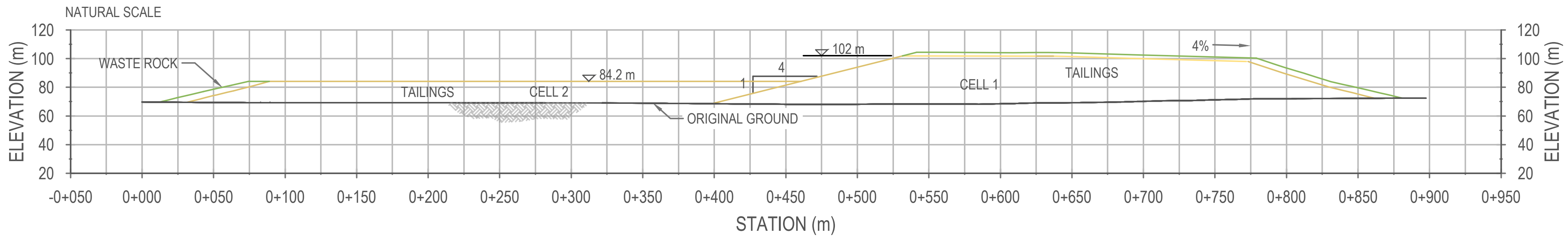
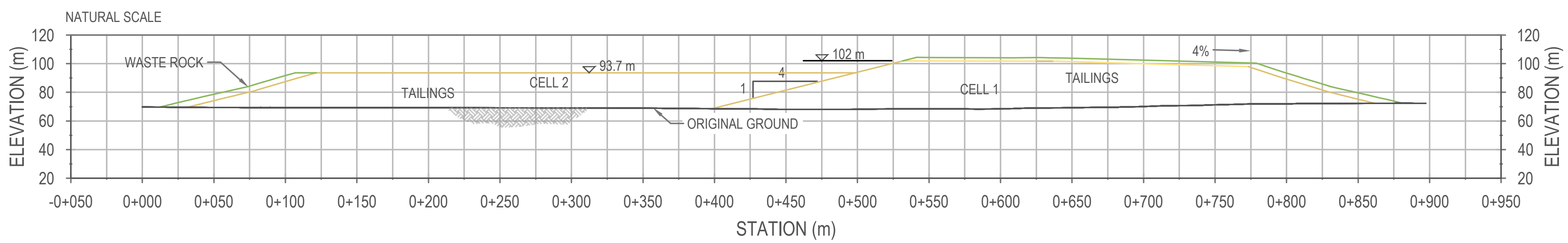
DRAWING NO.

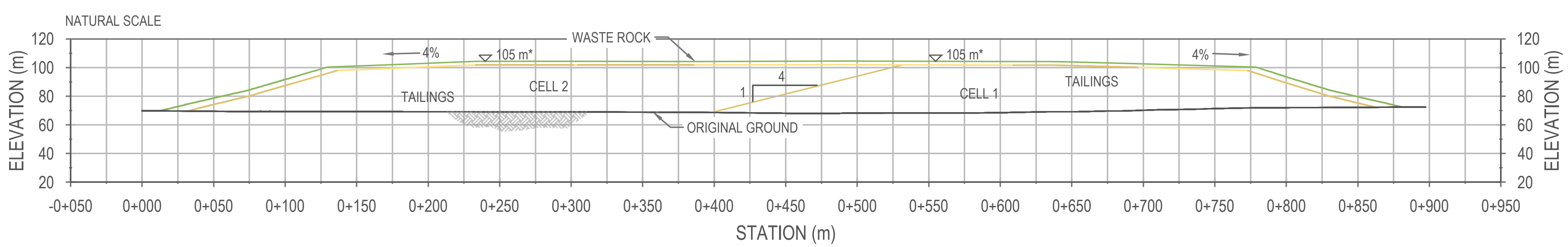
FORMAT ANSI B-11x17




*SECTION A–A TSF DURING OPERATION (YEAR 6 SHOWN)*




*SECTION A–A TSF DURING OPERATION (YEAR 7 SHOWN)*




NOTE: * TSF CLOSURE COVER THICKNESS AND CONFIGURATION TO BE FINALIZED DURING THE DEVELOPMENT OF THE FINAL CLOSURE COVER DESIGN PENDING PERFORMANCE MONITORING OF DRY STACKED TAILINGS FACILITY DURING OPERATION.

*SECTION A–A TSF DURING CLOSURE (YEAR 8 SHOWN)*

NOTES:

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date Nov. 14, 2018
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

G. ZHANG
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NWT/NU

AGNICO EAGLE

TETRA TECH

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FOR CONSTRUCTION
DATE: 11/14/2018

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| A | ISSUED FOR REVIEW | 2018–11–05 | |

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DATE

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY DESIGN

SECTION A–A TSF DURING OPERATION
YEARS 6 to 8

ÉCHELLE/SCALE
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No. DESSIN/DRAWING NO. 6515–583–163–008
REVISION 0
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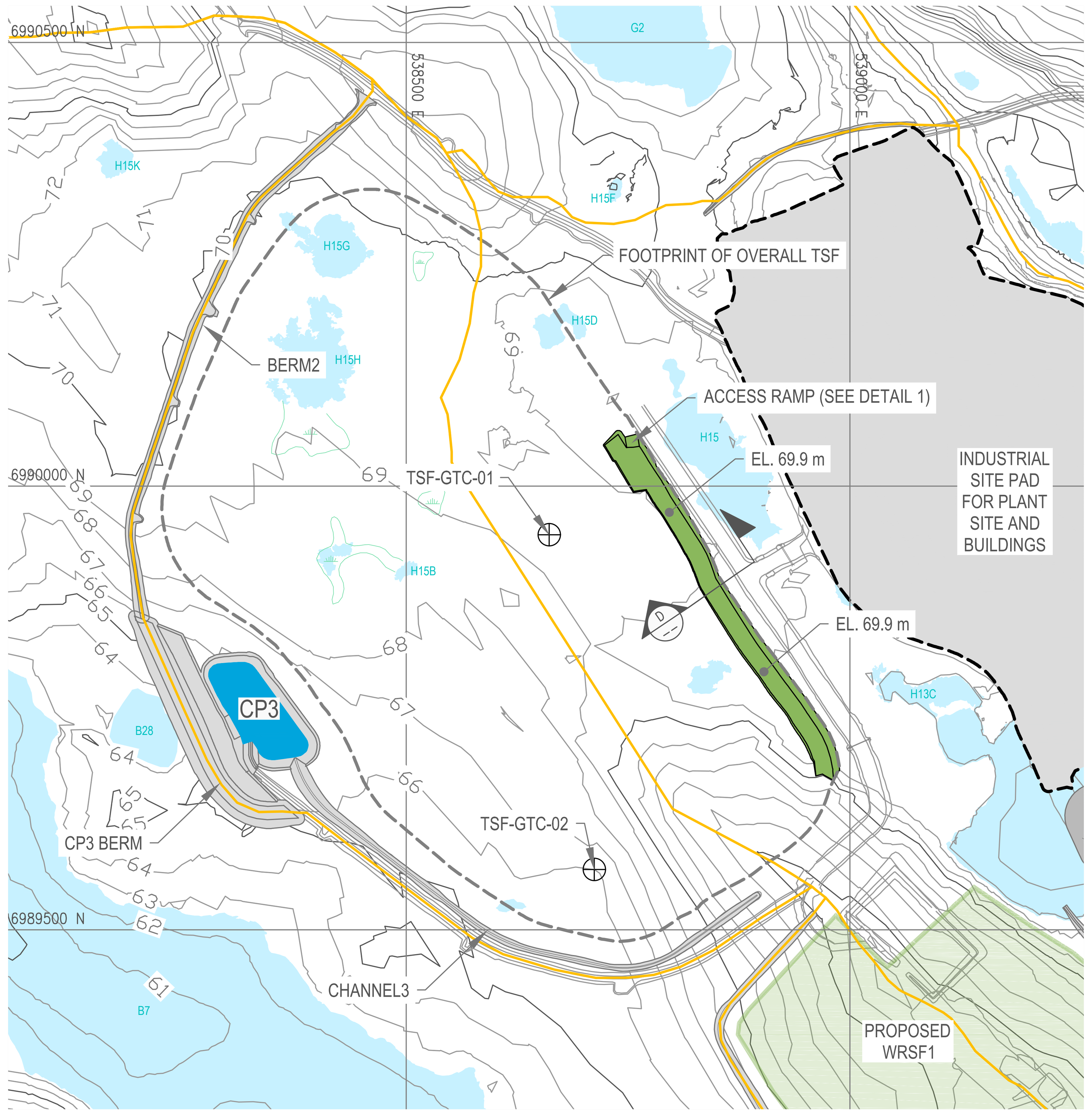
# APPENDIX B – QUARTERLY DEPOSITION PLAN DRAWINGS (2019, 2020)

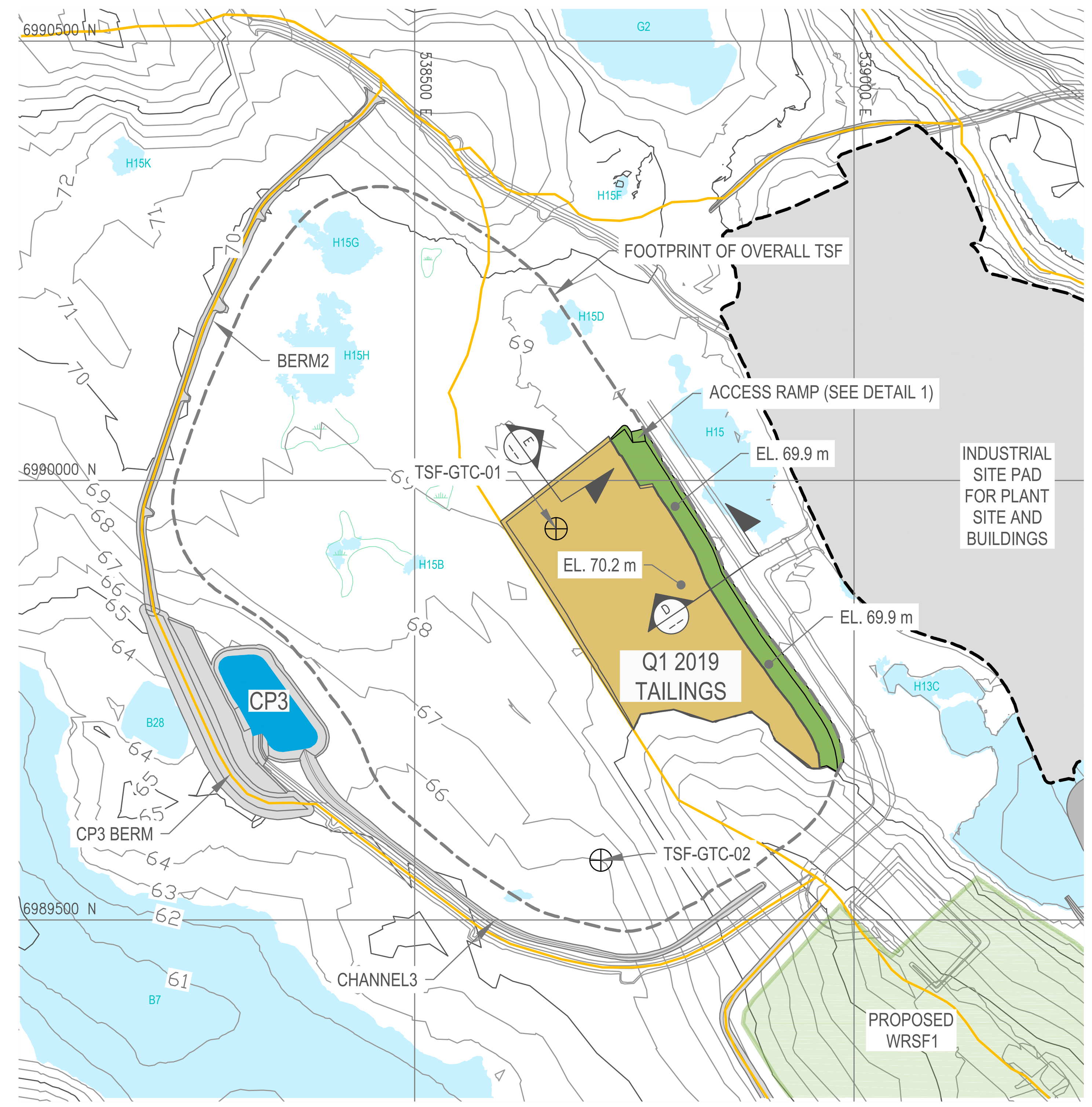
NO. DESSIN
DRAWING NO.

FORMAT ARCHD



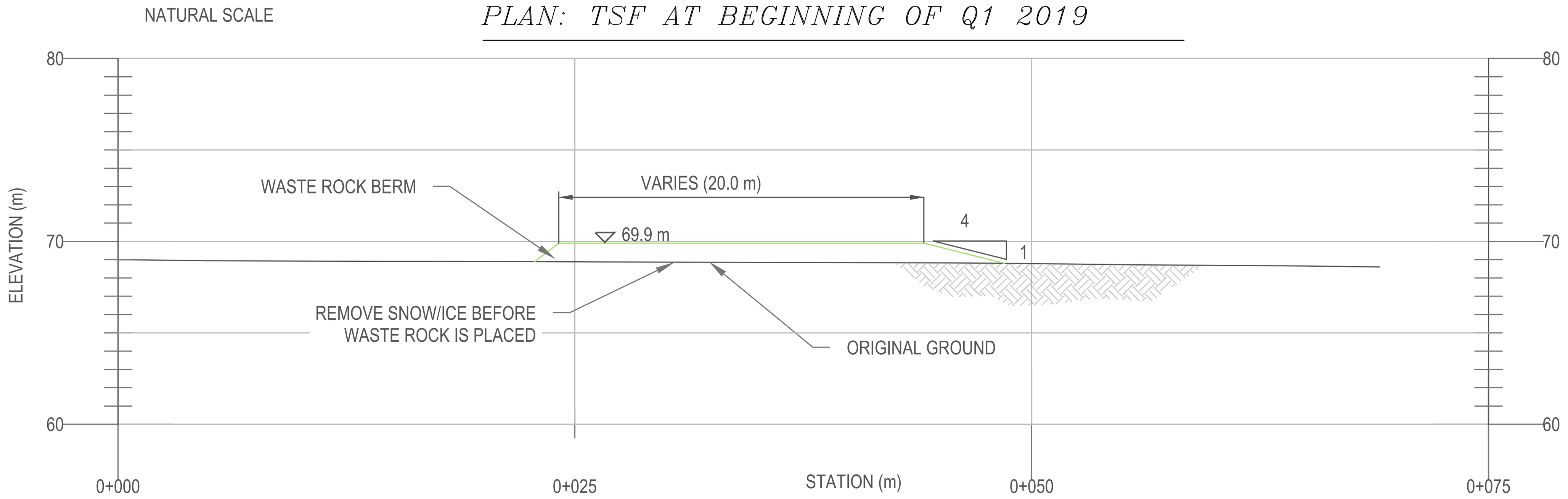

NATURAL SCALE

PLAN: TSF AT BEGINNING OF Q1 2019

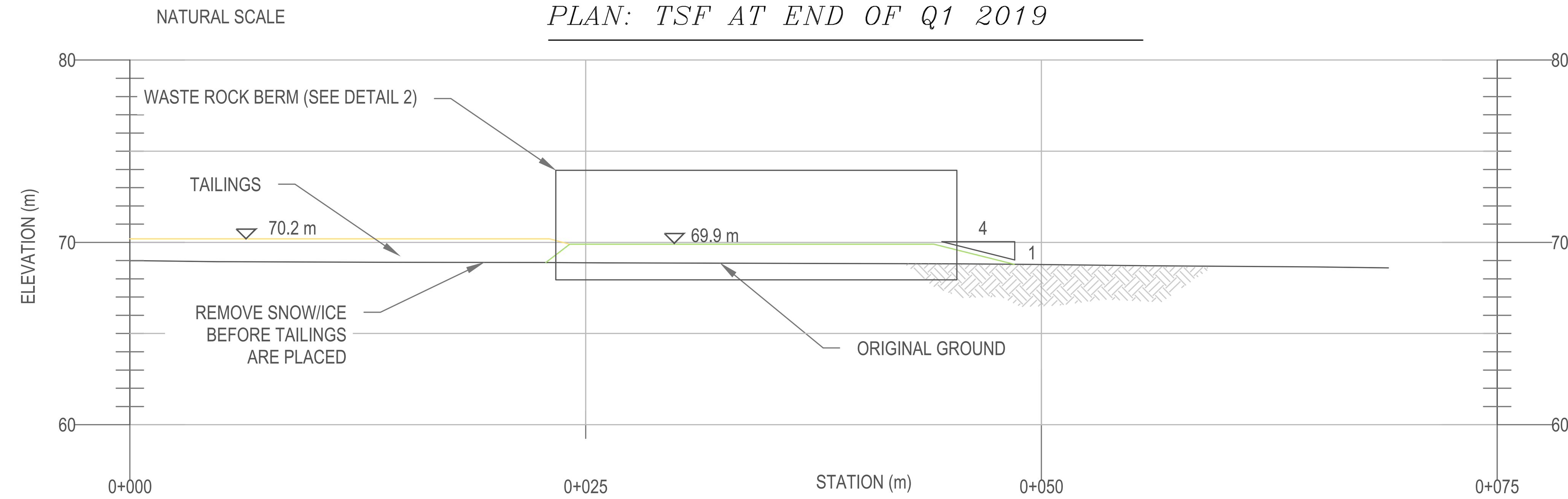



NATURAL SCALE

PLAN: TSF AT END OF Q1 2019

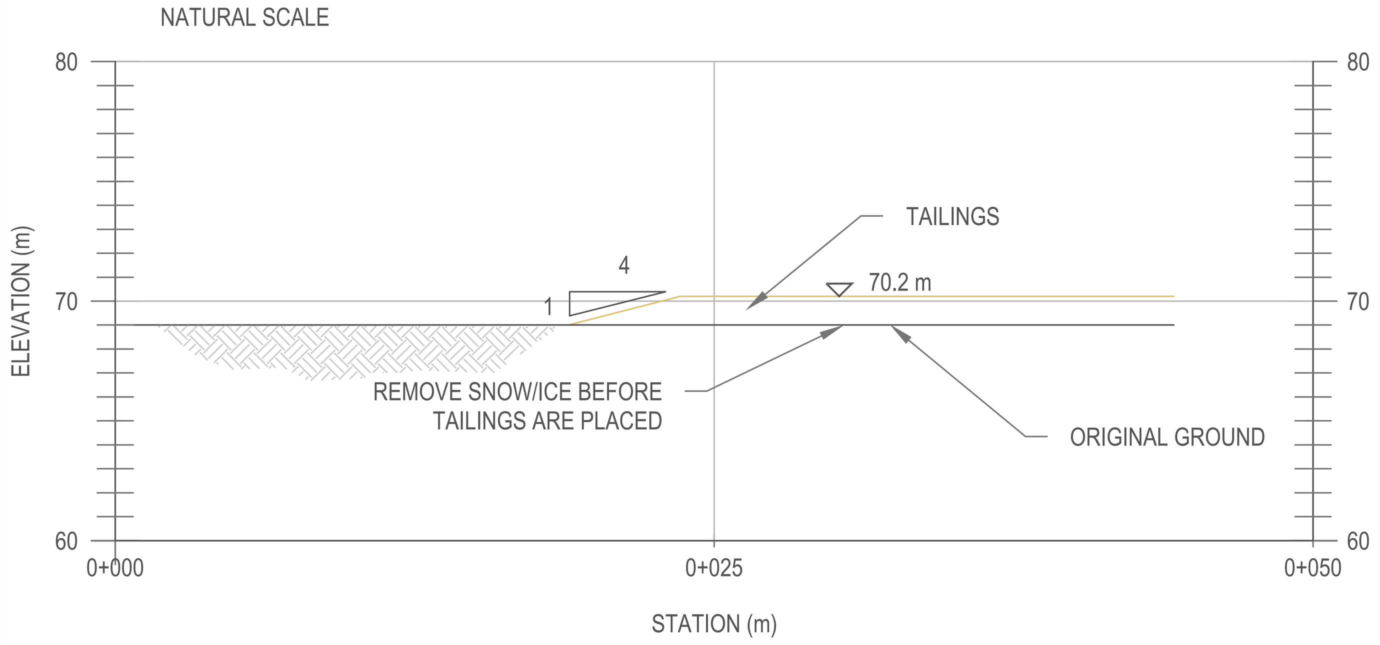



SECTION D: TSF AT BEGINNING OF Q1 2019

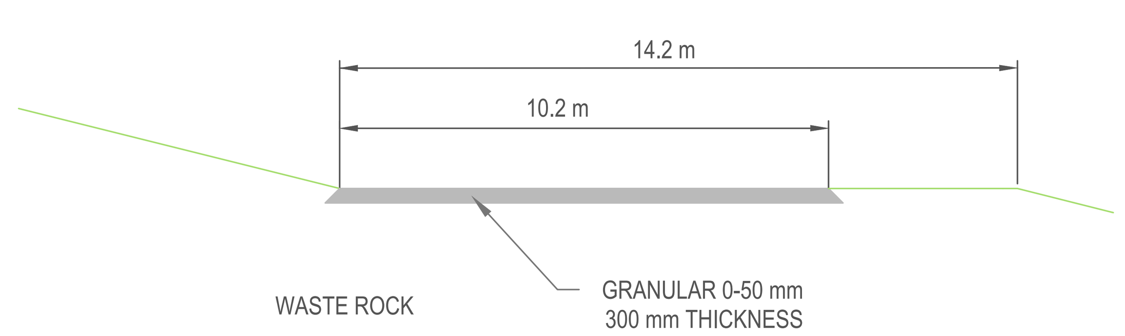



SECTION D: TSF AT END OF Q1 2019

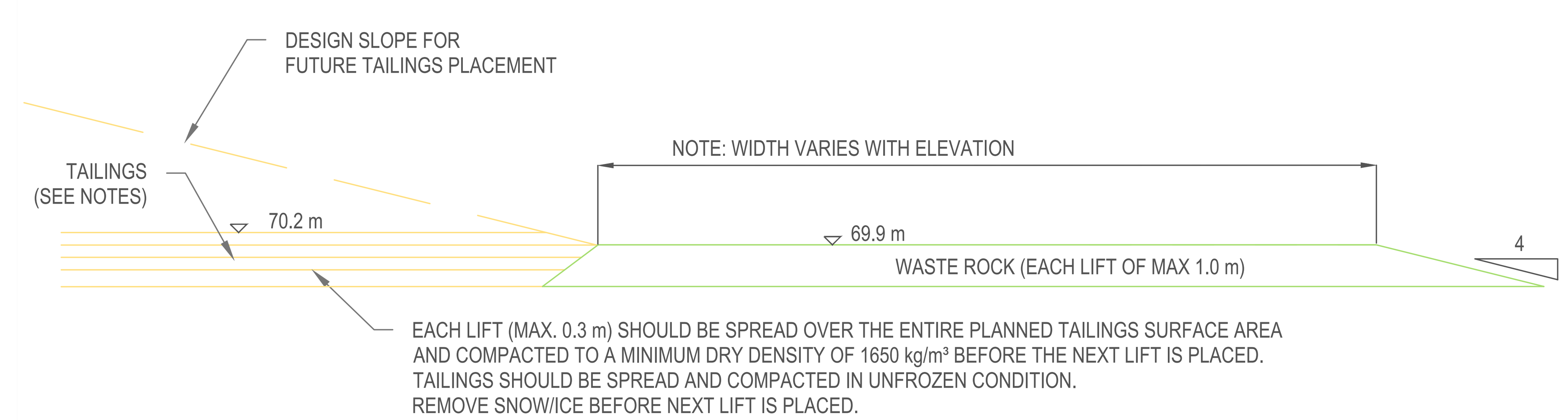
NATURAL SCALE




SECTION E: TSF AT END OF Q1 2019

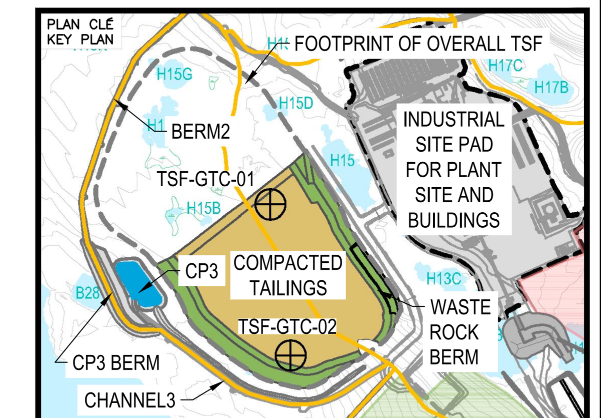



DETAIL 1: ACCESS RAMP




DETAIL 2: WASTE ROCK BERM WITH SAFETY BERM AND TAILINGS

PLAN CLÉ
KEY PLAN




TETRA TECH

NOTES GÉNÉRALES / GENERAL NOTES

- WASTE ROCK BERM
- TAILINGS
- GROUND TEMPERATURE CABLE
- CATCHMENT BOUNDARY

NOTES
1. REFER TO THE TAILINGS STORAGE FACILITY DETAILED DEPOSITION PLAN FOR OPERATION AND CONSTRUCTION REQUIREMENTS AND DETAILS.
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DESSINS EN RÉFÉRENCE / REFERENCE DRAWINGS

| TITRE / TITLE | # DWG |
|---|---|

AGNICO EAGLE

| REV. | DATE | DESCRIPTION | PAR/BY | APP. | CLIENT |
|---|---|---|---|---|---|
| 0 | 2019-01-29 | ISSUED FOR CONSTRUCTION | GZ | WTH | |
| B | 2019-01-27 | ISSUED FOR REVIEW | GZ | NG | |
| A | 2018-12-07 | 90% REVIEW | EP | GZ/WTH | |

REVISIONS

PERMIT TO PRACTICE TETRA TECH CANADA INC.
Signature
Date January 29, 2019
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

G. ZHANG LICENSEE NWT/NU

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY TAILINGS DEPOSITION PLAN FOR Q1 2019

| | | |
|---|---|---|
| DESSINÉ PAR / DRAWN BY | EP / EL | 2019-01-29 |
| VÉRIFIÉ PAR / CHECKED BY | GZ | 2019-01-29 |
| APPROUVÉ PAR / APPROVED BY | WTH | 2019-01-29 |
| ÉCHELLE / SCALE | | DATE |

NO. DESSIN / DRAWING NO. 6515-583-163-FIG-009

NO. PROJET / PROJECT NO. | REVISION 0 | FEUILLE / SHT 9 / 24

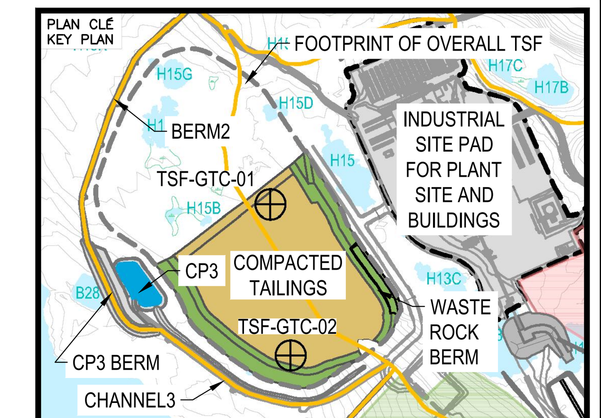
AE-CART-ARCH D

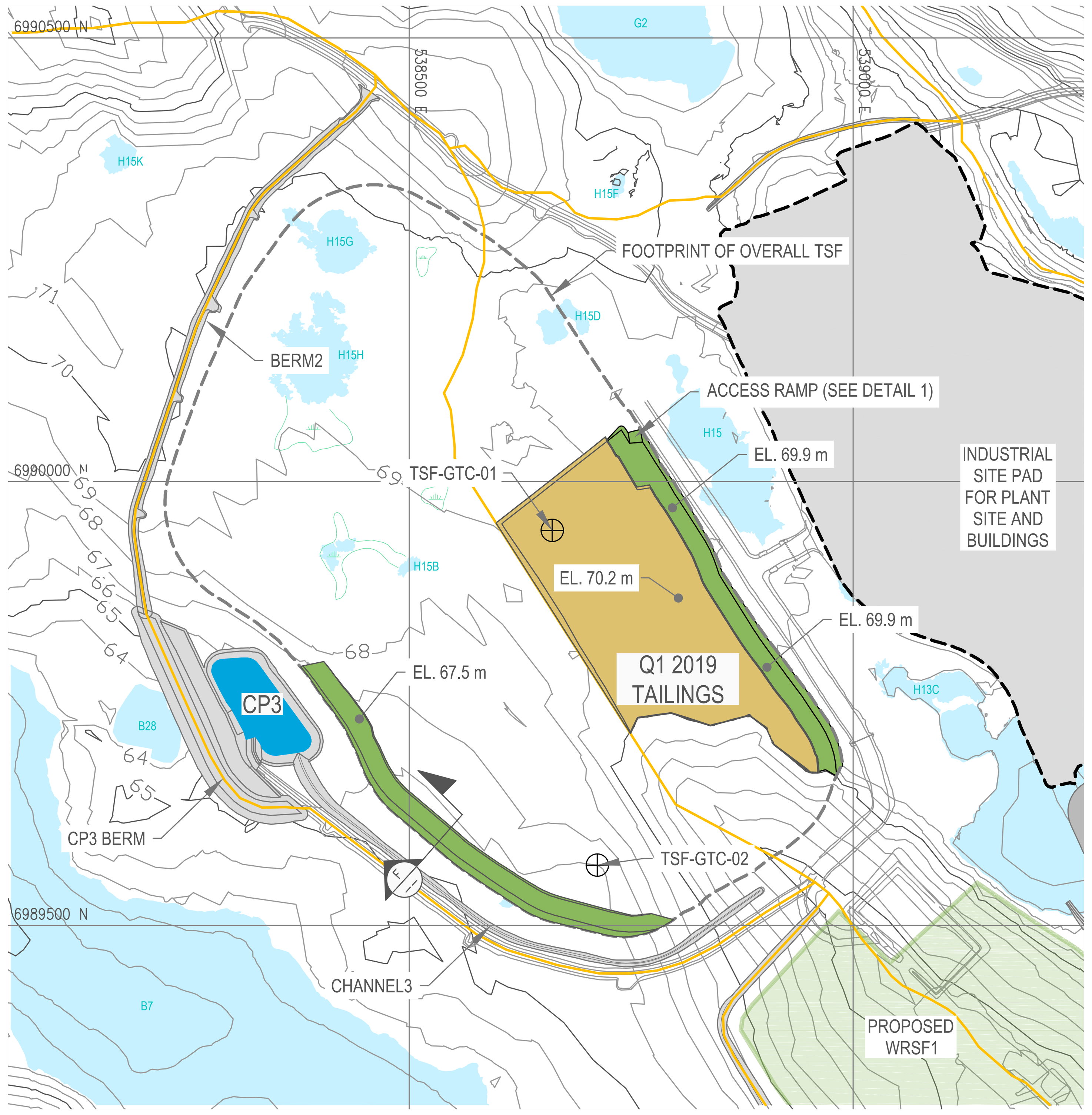
G:\Edmonton\Engineering\E141\Projects_MELIADINE\ENG.EARC03147-01 (Detailed Tailings Deposition Plan)\Figure 9-12 (Jan23_2019).dwg-2013-02-19 12:48:32

FILE NO. .DWG

NO. DESSIN
DRAWING NO.

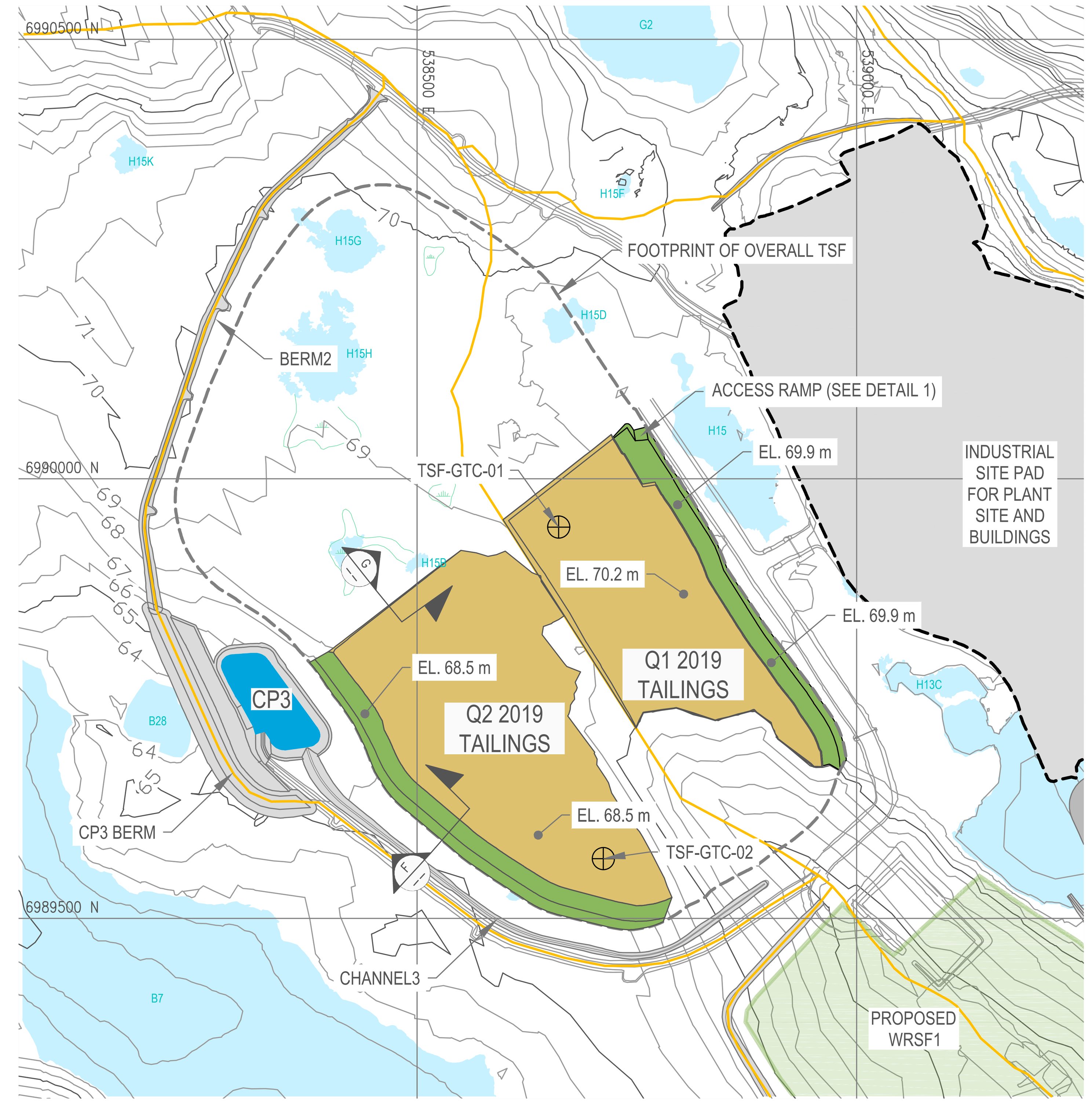
FORMAT ARCHD



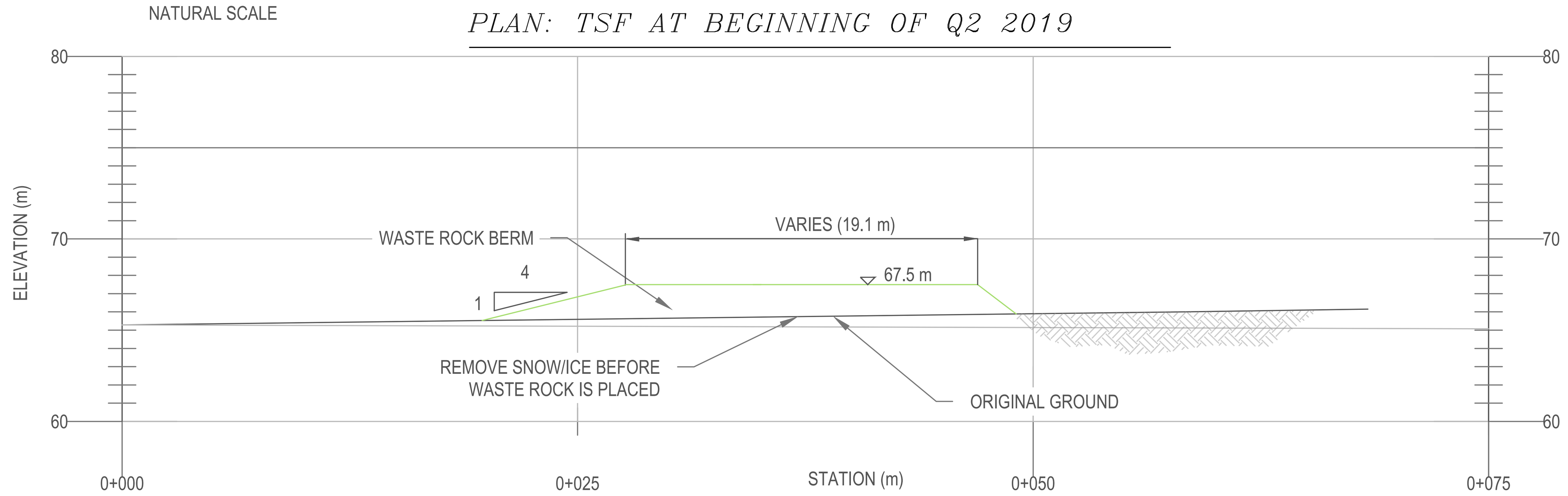

NATURAL SCALE

PLAN: TSF AT BEGINNING OF Q2 2019

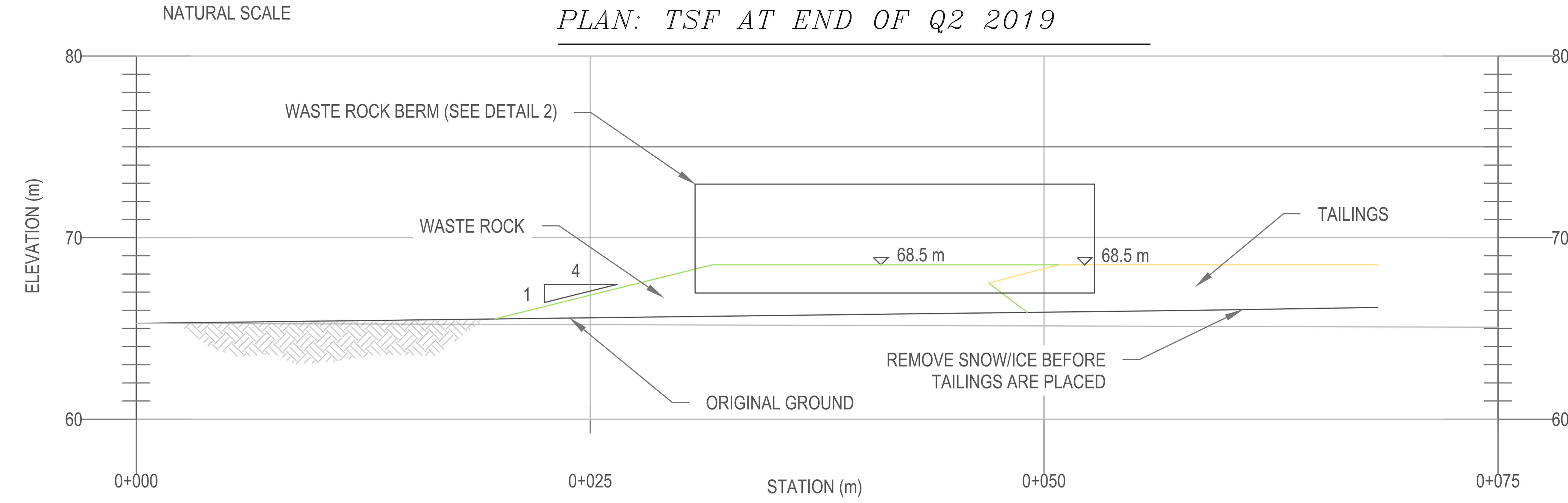



NATURAL SCALE

PLAN: TSF AT END OF Q2 2019

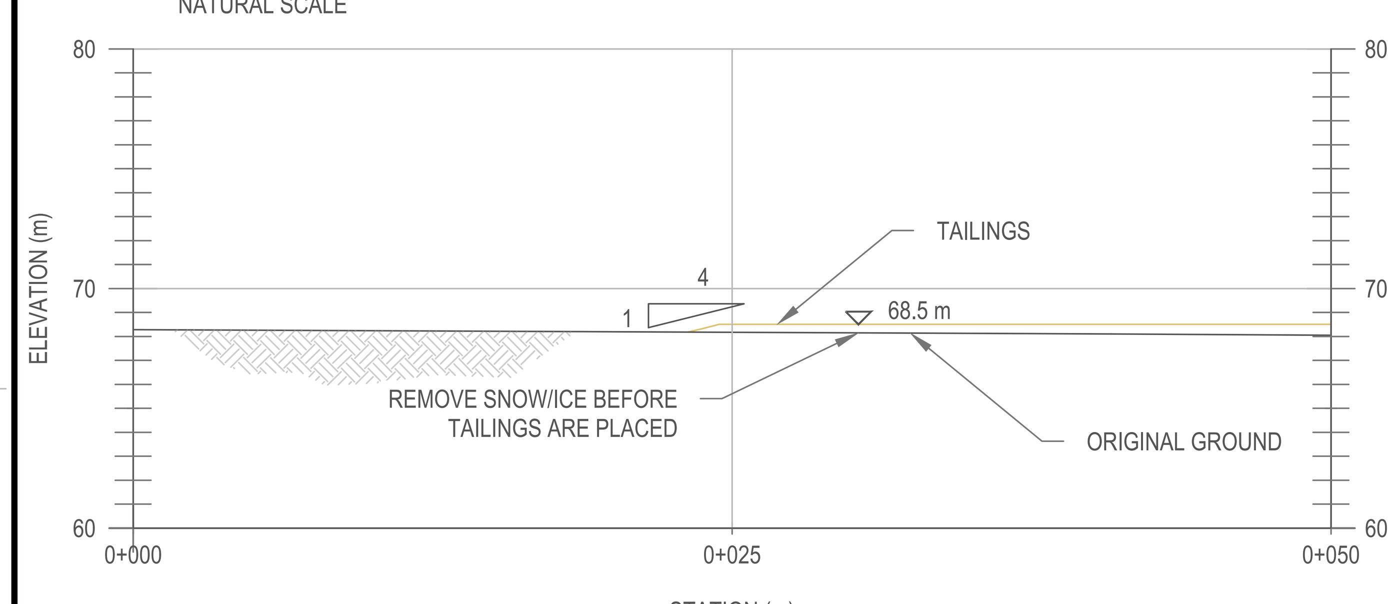



SECTION F: TSF AT BEGINNING OF Q2 2019

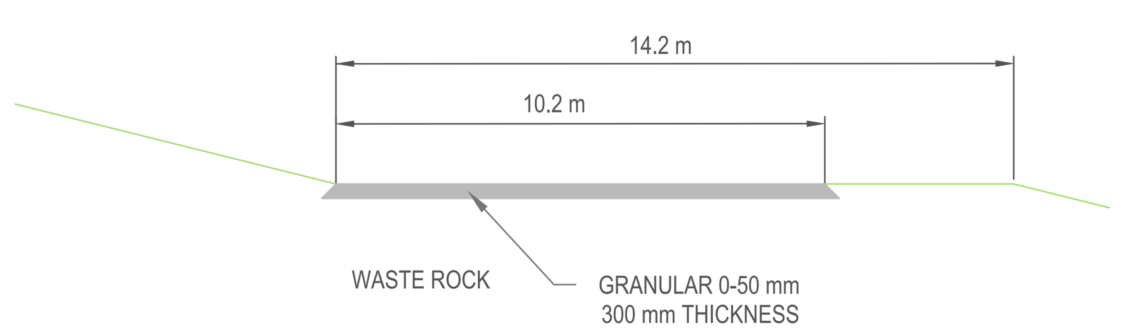



SECTION F: TSF AT END OF Q2 2019

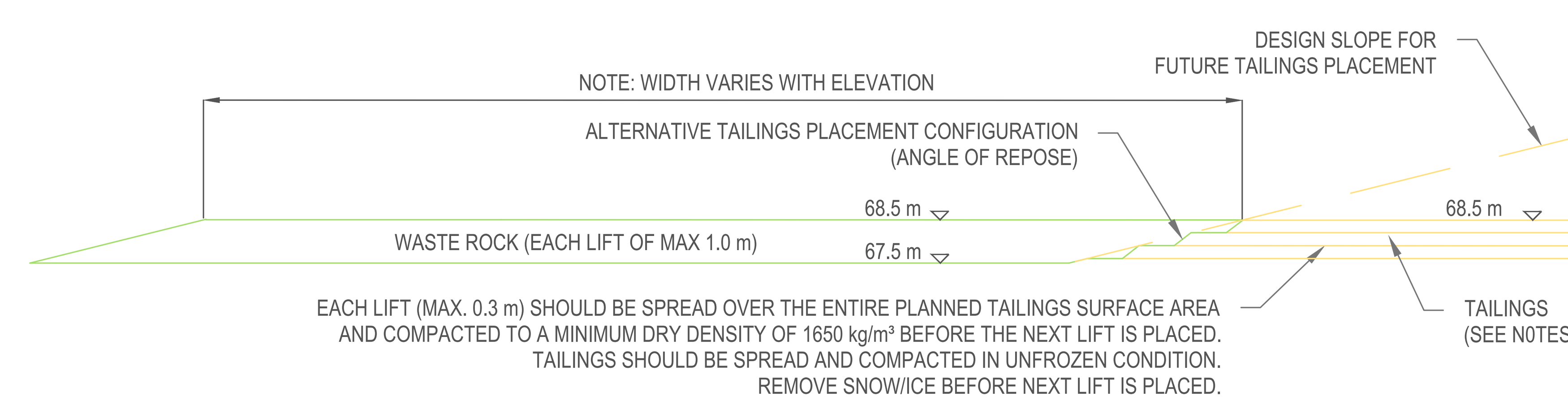
NATURAL SCALE




SECTION G: TSF AT END OF Q2 2019




DETAIL 1: ACCESS RAMP




DETAIL 2: WASTE ROCK BERM WITH SAFETY BERM AND TAILINGS

TETRA TECH

NOTES GÉNÉRALES / GENERAL NOTES

- WASTE ROCK BERM
- TAILINGS
- GROUND TEMPERATURE CABLE
- CATCHMENT BOUNDARY

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DESSINS EN RÉFÉRENCE / REFERENCE DRAWINGS

| TITRE / TITLE | # DWG |
|---|---|

AGNICO EAGLE

| REV. | DATE | DESCRIPTION | PAR/BY | APP. | CLIENT |
|---|---|---|---|---|---|
| 0 | 2019-01-29 | ISSUED FOR CONSTRUCTION | GZ | WTH | |
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| A | 2018-12-07 | 90% REVIEW | EP | GZ/WTH | |

REVISIONS

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date January 29, 2019
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

G. ZHANG
LICENSEE
NWT/NU

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY TAILINGS DEPOSITION PLAN FOR Q2 2019

| | | | |
|---|---|---|---|
| DESSINÉ PAR / DRAWN BY | EP / EL | DATE | 2019-01-29 |
| VERIFIÉ PAR / CHECKED BY | GZ | | 2019-01-29 |
| APPROUVÉ PAR / APPROVED BY | WTH | | 2019-01-29 |
| ÉCHELLE / SCALE | | DATE | |

NO. DESSIN / DRAWING NO. 6515-583-163-FIG-010

NO. PROJET / PROJECT NO. | REVISION 0 | FEUILLE / SHT 10 / 24

AE-CART-ARCH D

G:\Edmonton\Engineering\E141\Projects_MELIADINE\ENG.EARC03147-01 (Detailed Tailings Deposition Plan)\Figure 9-12 (Jan23_2019).dwg-2019-02-19 12:48:32

FILE NO. .DWG

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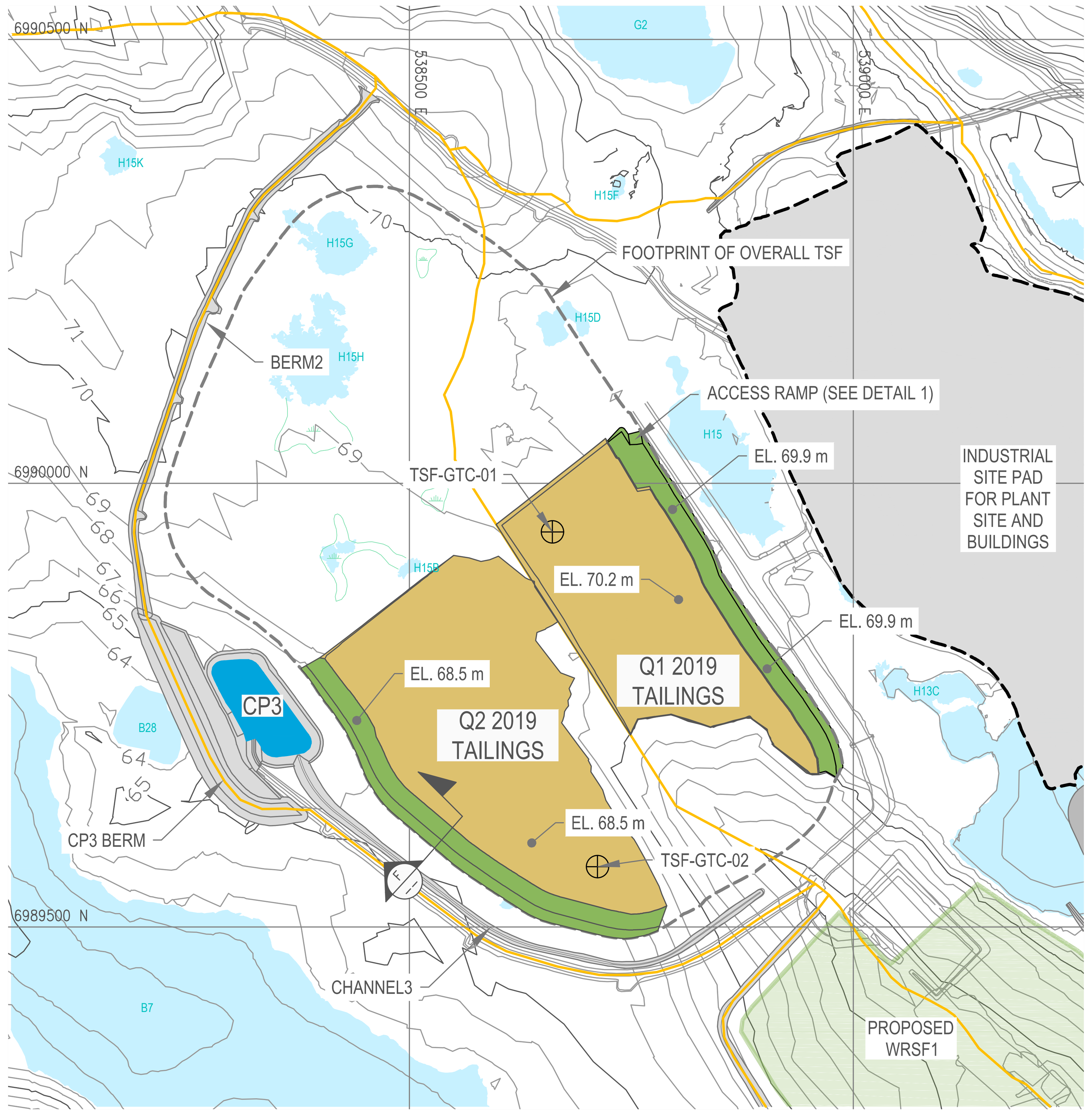
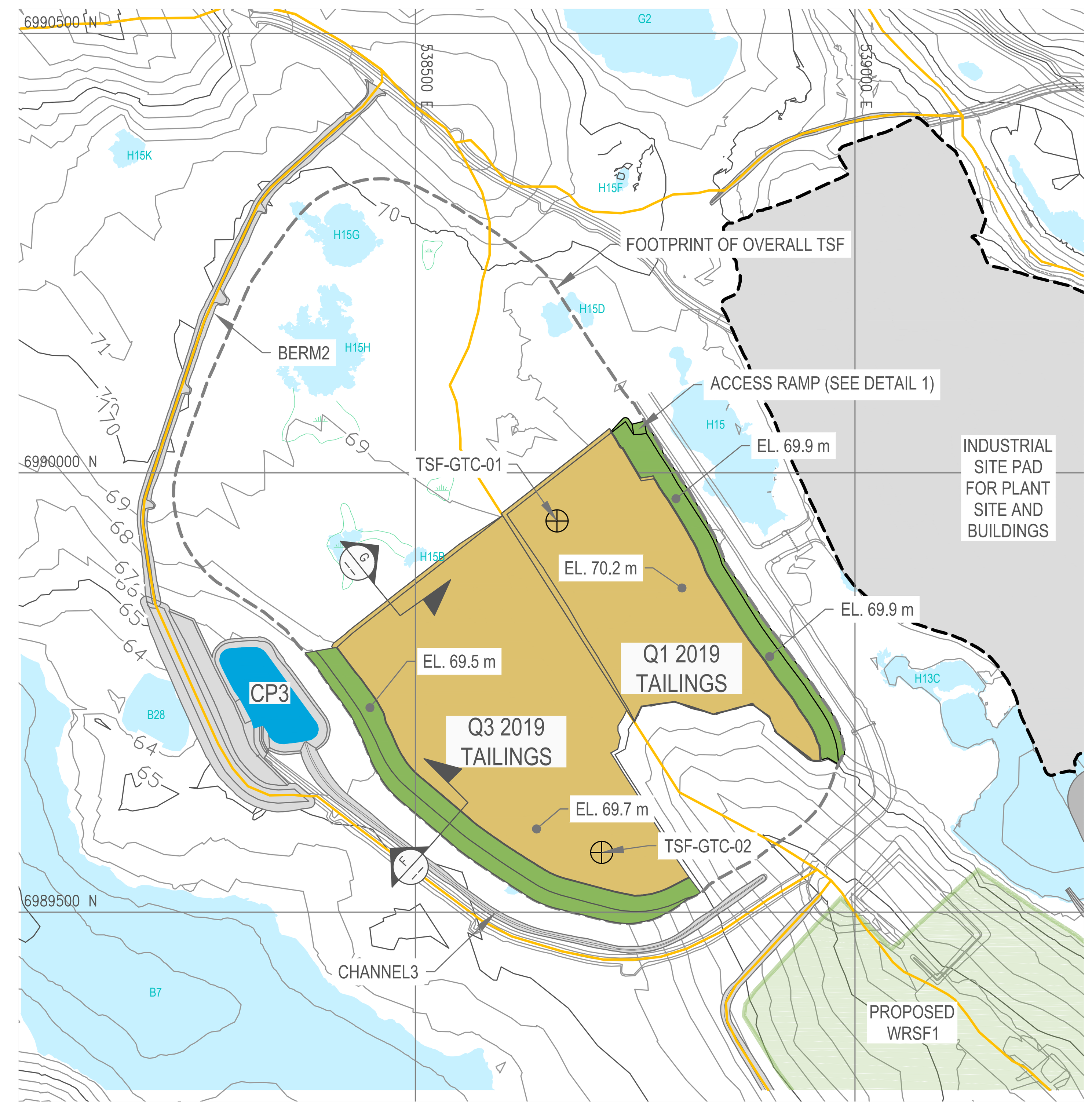
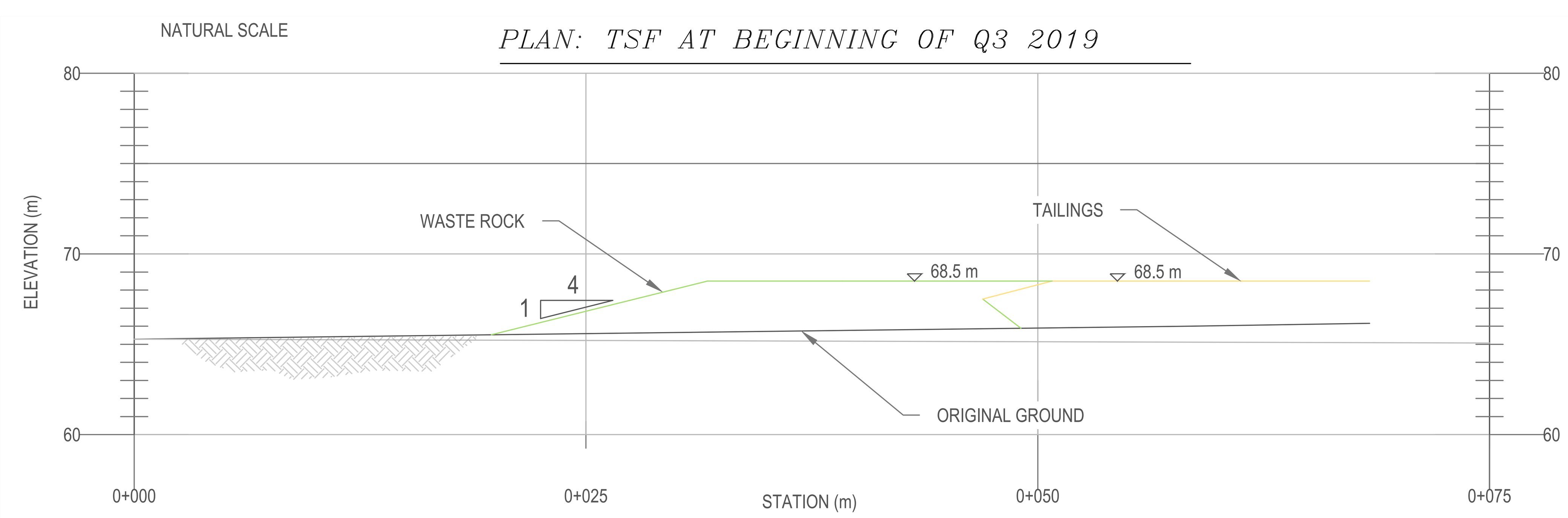
DRAWING NO.



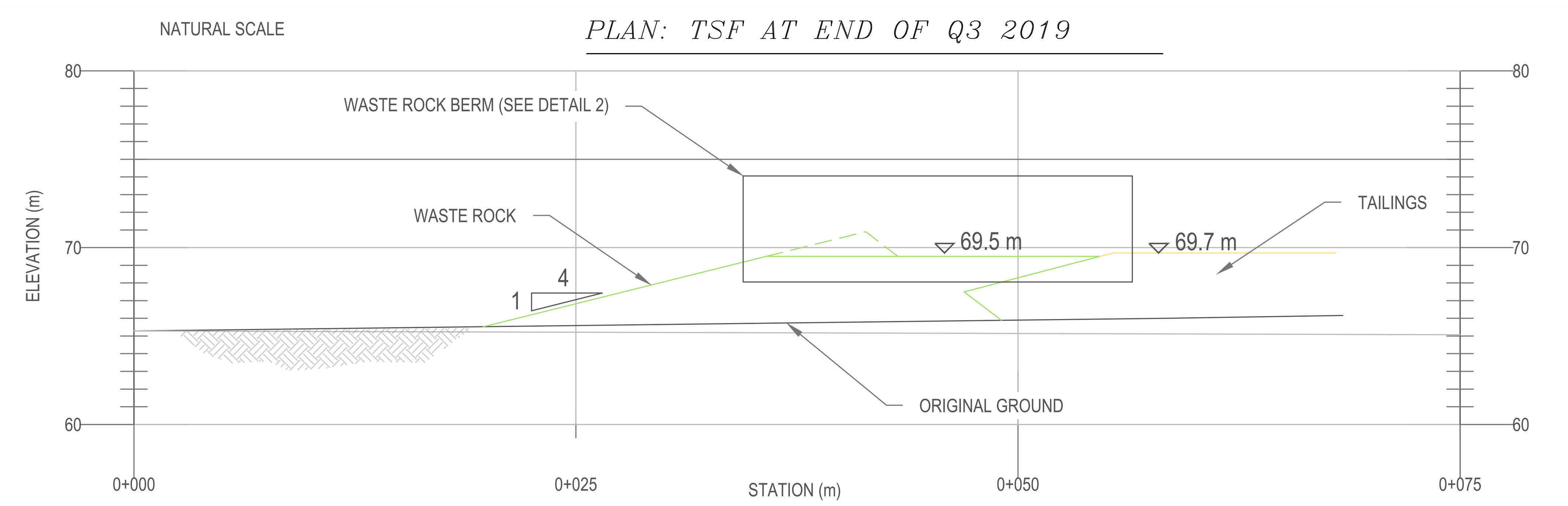

*PLAN: TSF AT BEGINNING OF Q3 2019*



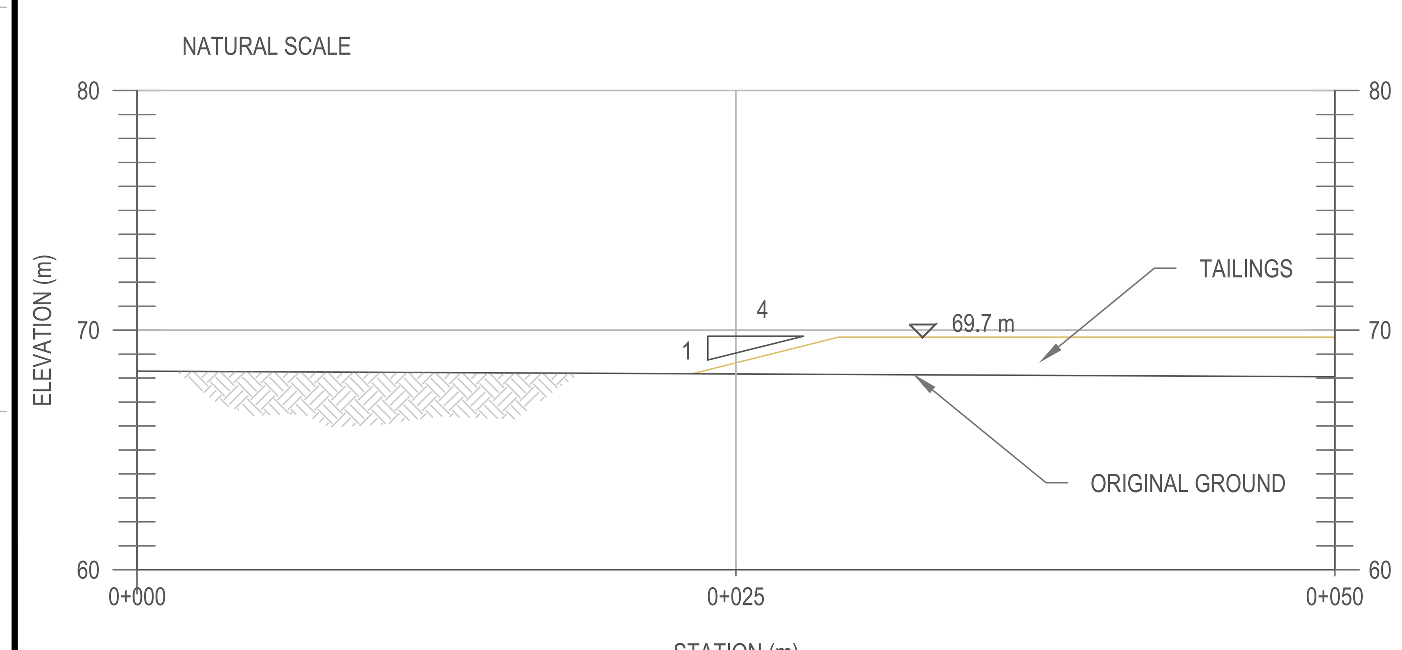

*PLAN: TSF AT END OF Q3 2019*



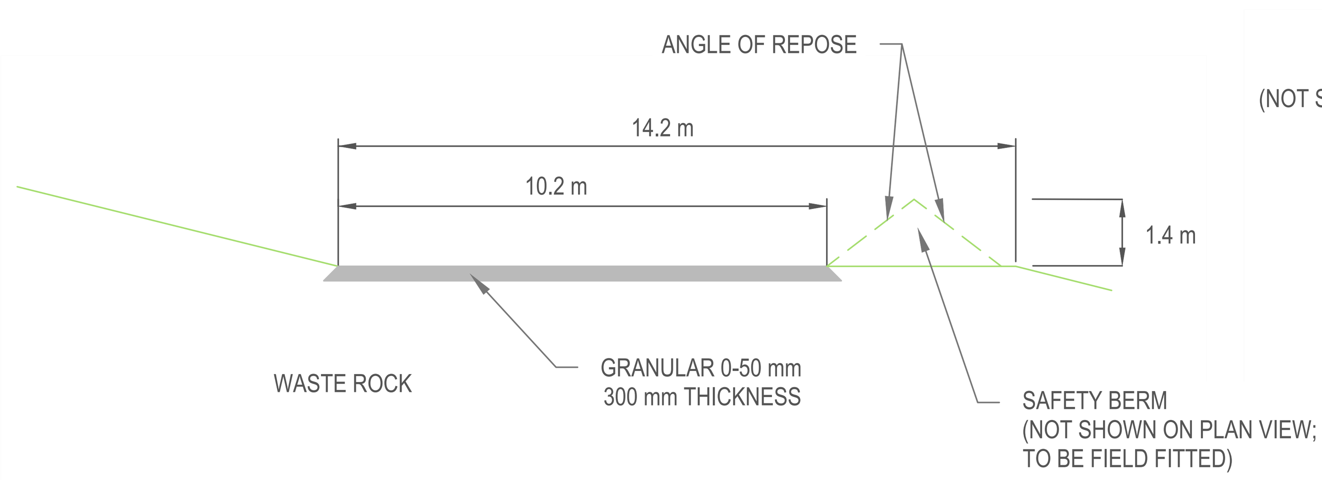

*SECTION F: TSF AT BEGINNING OF Q3 2019*



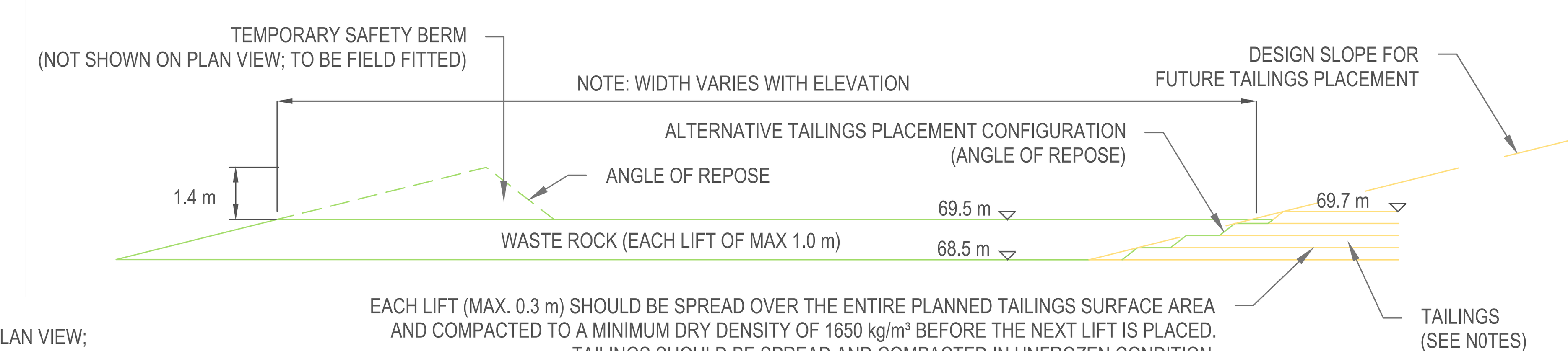

*SECTION F: TSF AT END OF Q3 2019*




*SECTION G: TSF AT END OF Q3 2019*



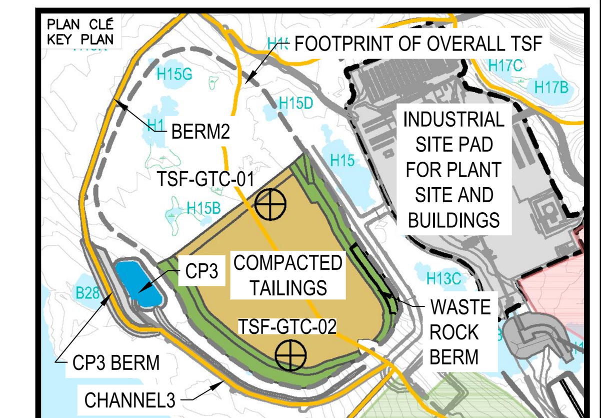

*DETAIL 1: ACCESS RAMP*




EACH LIFT (MAX. 0.3 m) SHOULD BE SPREAD OVER THE ENTIRE PLANNED TAILINGS SURFACE AREA AND COMPACTED TO A MINIMUM DRY DENSITY OF 1650 kg/m³ BEFORE THE NEXT LIFT IS PLACED. TAILINGS SHOULD BE SPREAD AND COMPACTED IN UNFROZEN CONDITION. REMOVE SNOW/ICE BEFORE NEXT LIFT IS PLACED.

*DETAIL 2: WASTE ROCK BERM WITH SAFETY BERM AND TAILINGS*

PLAN CLÉ
KEY PLAN




TETRA TECH

NOTES GÉNÉRALES / GENERAL NOTES

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DESSINS EN RÉFÉRENCE / REFERENCE DRAWINGS

| TITRE / TITLE | # DWG |
|---|---|

AGNICO EAGLE

| REV. | DATE | DESCRIPTION | PAR/BY | APP. | CLIENT |
|---|---|---|---|---|---|
| 0 | 2019-01-29 | ISSUED FOR CONSTRUCTION | GZ | WTH | |
| B | 2019-01-27 | ISSUED FOR REVIEW | GZ | NG | |
| A | 2018-12-07 | 90% REVIEW | EP | GZ/WTH | |

REVISIONS

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date January 29, 2019
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

G. ZHANG
LICENSEE
NWT/NU

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY TAILINGS DEPOSITION PLAN FOR Q3 2019

| | | |
|---|---|---|
| DESSINÉ PAR / DRAWN BY | EP / EL | 2019-01-29 |
| VÉRIFIÉ PAR / CHECKED BY | GZ | 2019-01-29 |
| APPROUVÉ PAR / APPROVED BY | WTH | 2019-01-29 |
| ÉCHELLE / SCALE | | DATE |

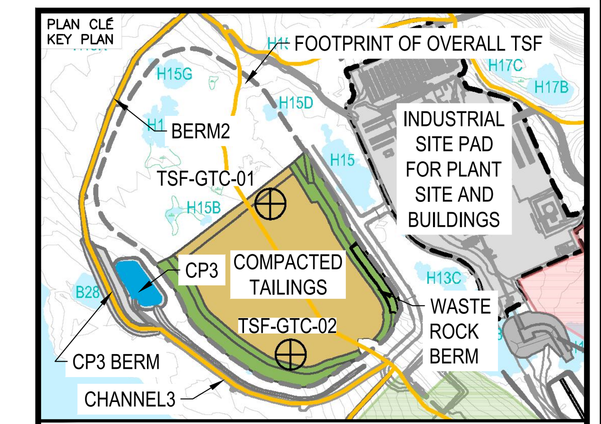
NO. DESSIN / DRAWING NO. 6515-583-163-FIG-011

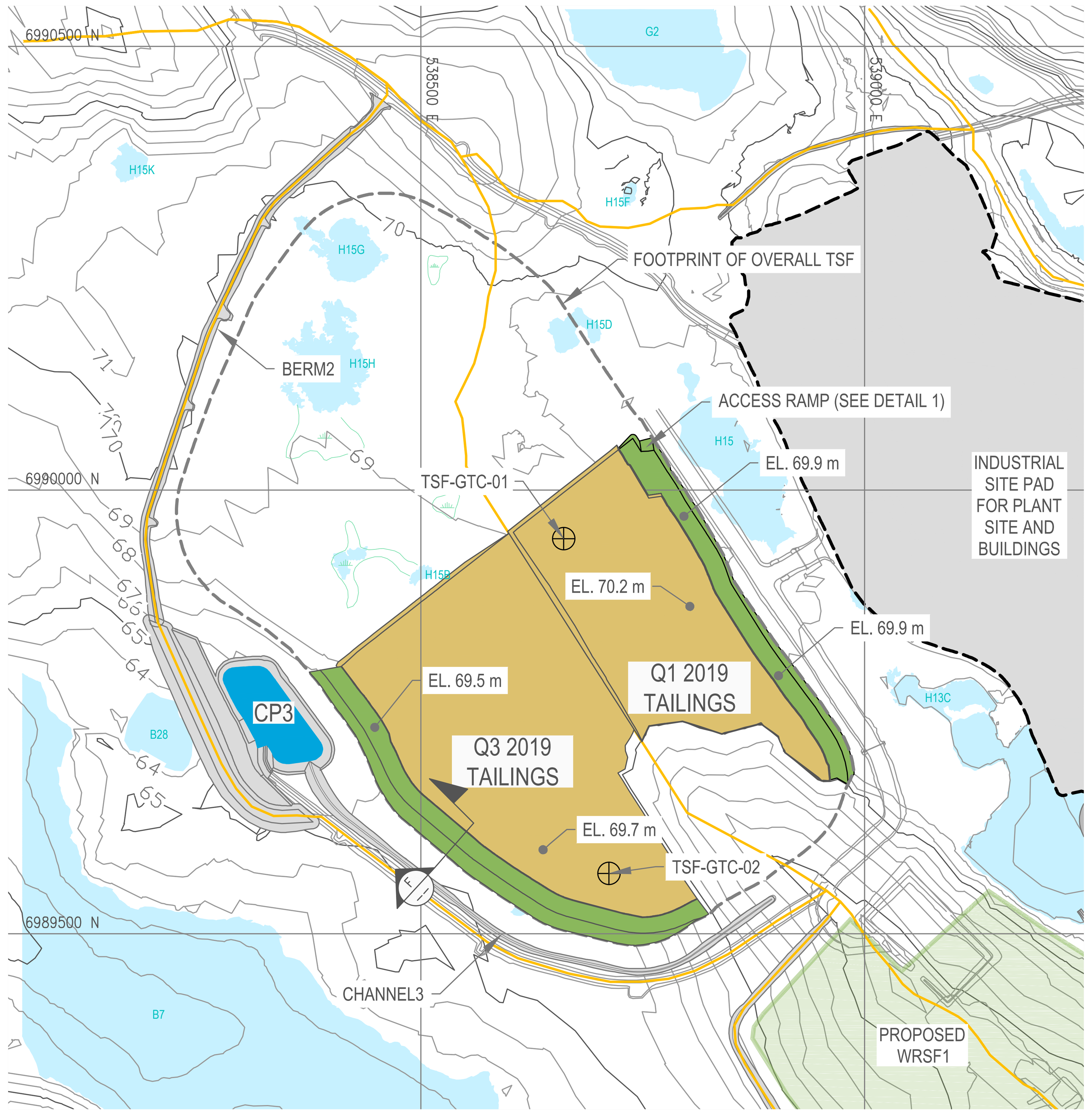
NO. PROJET / PROJECT NO. | REVISION 0 | FEUILLE / SHT 11 / 24

FORMAT ARCHD

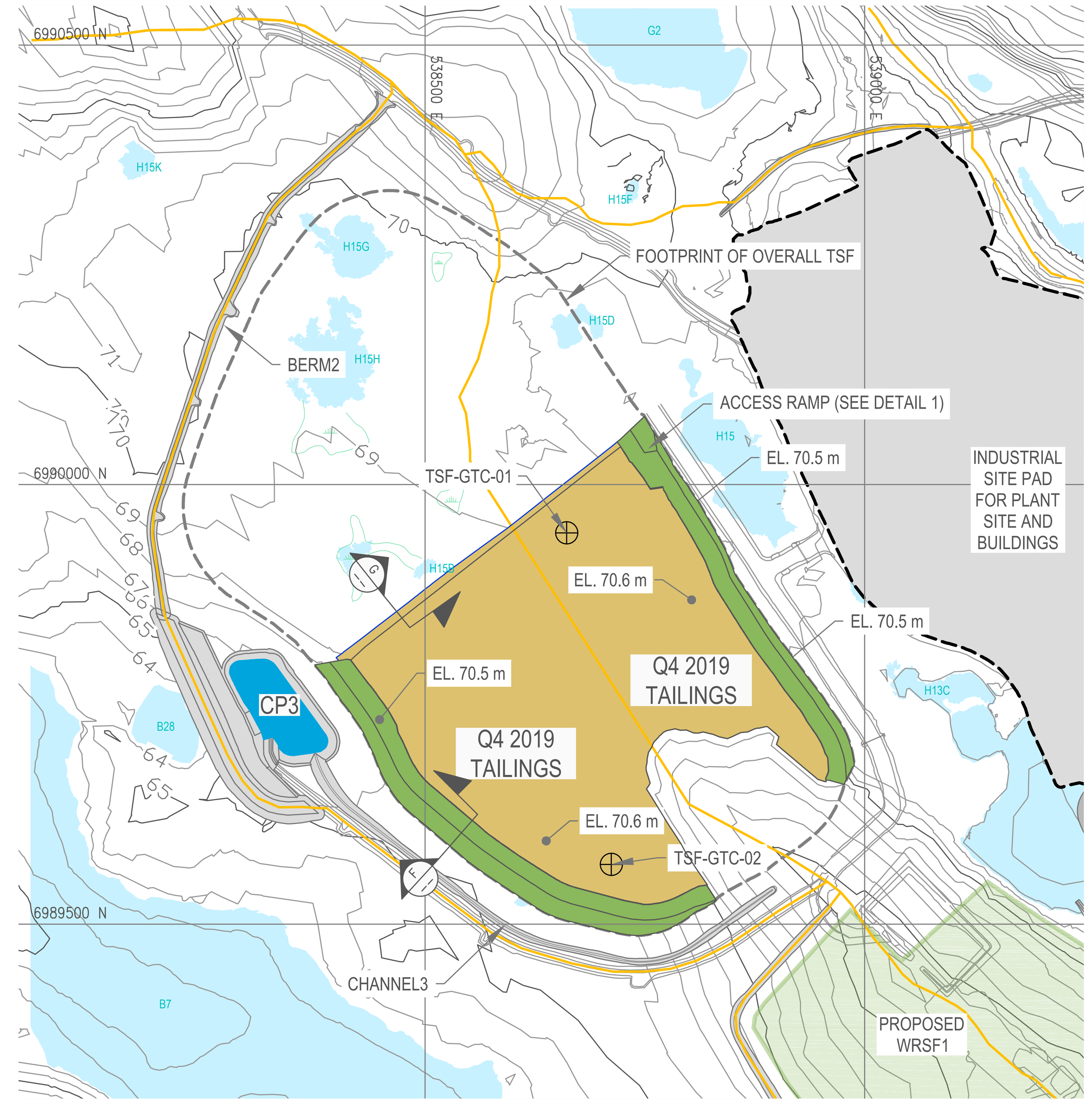
AE-CART-ARCH D

FILE NO. .DWG

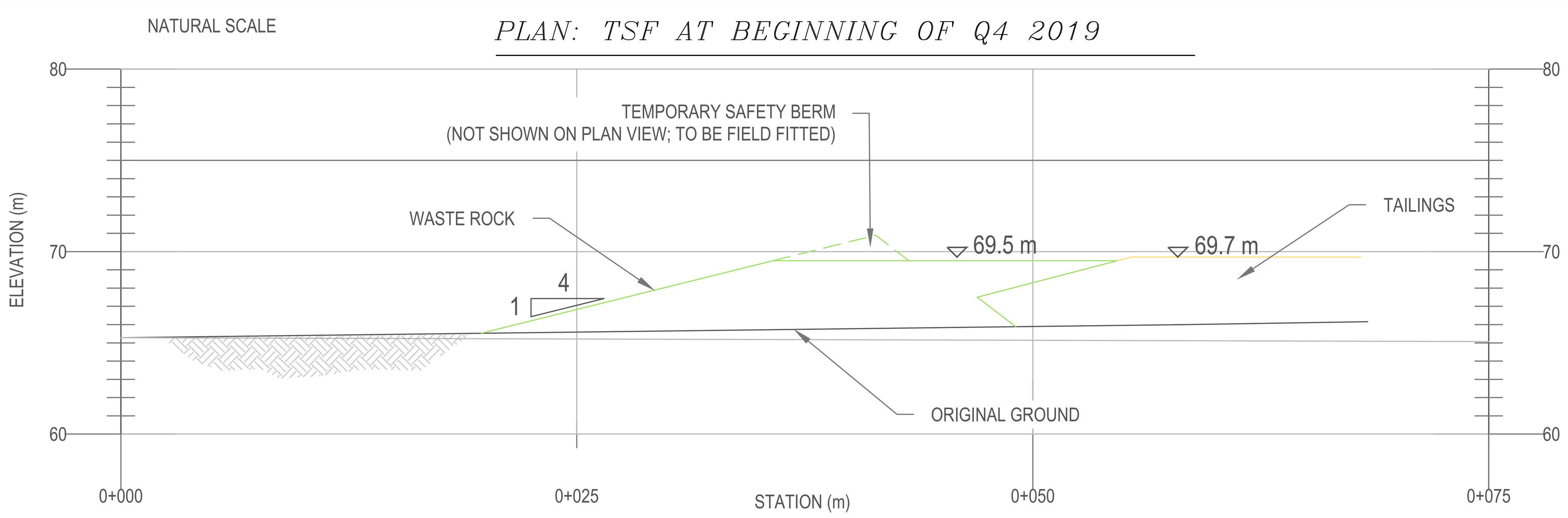


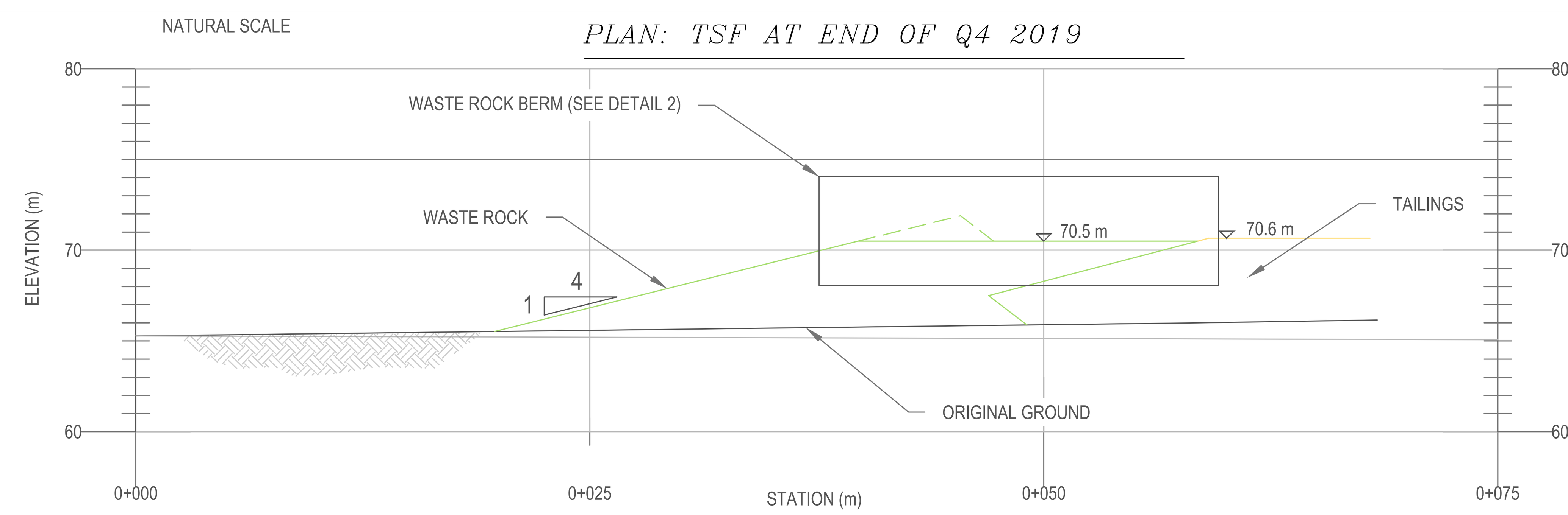

PLAN: TSF AT BEGINNING OF Q4 2019



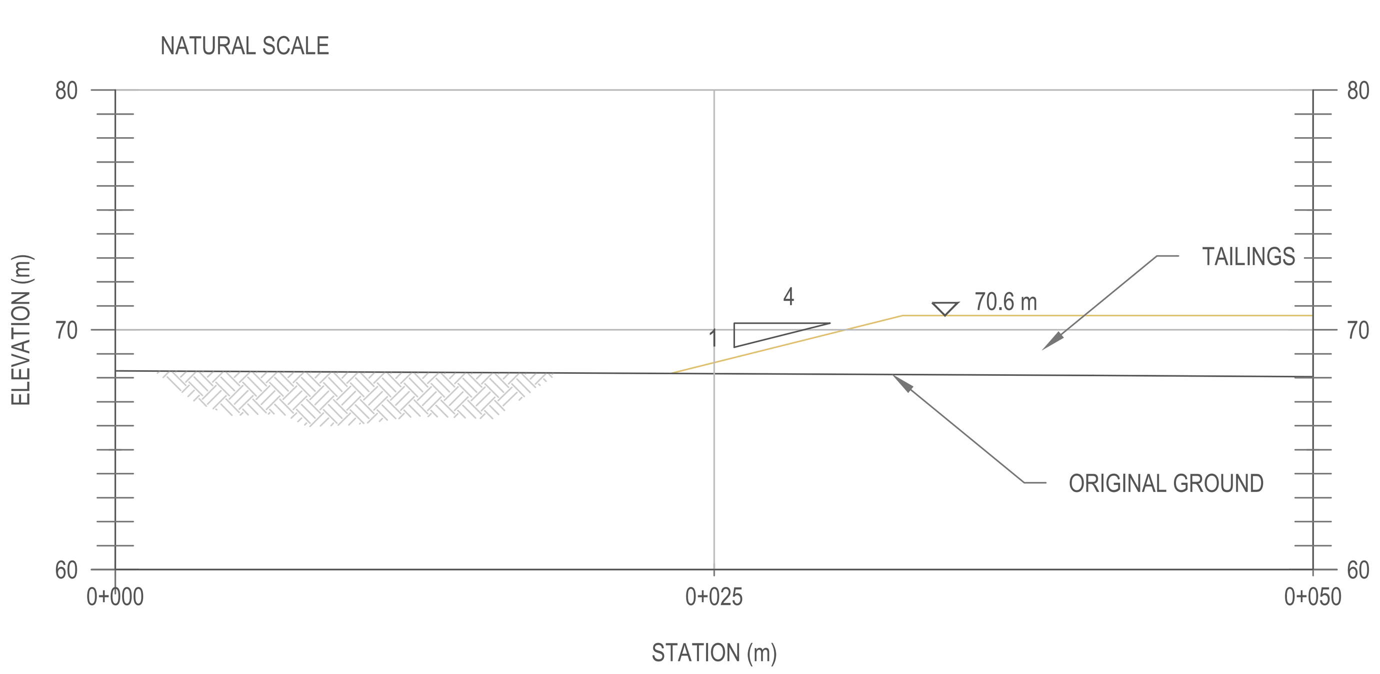

PLAN: TSF AT END OF Q4 2019



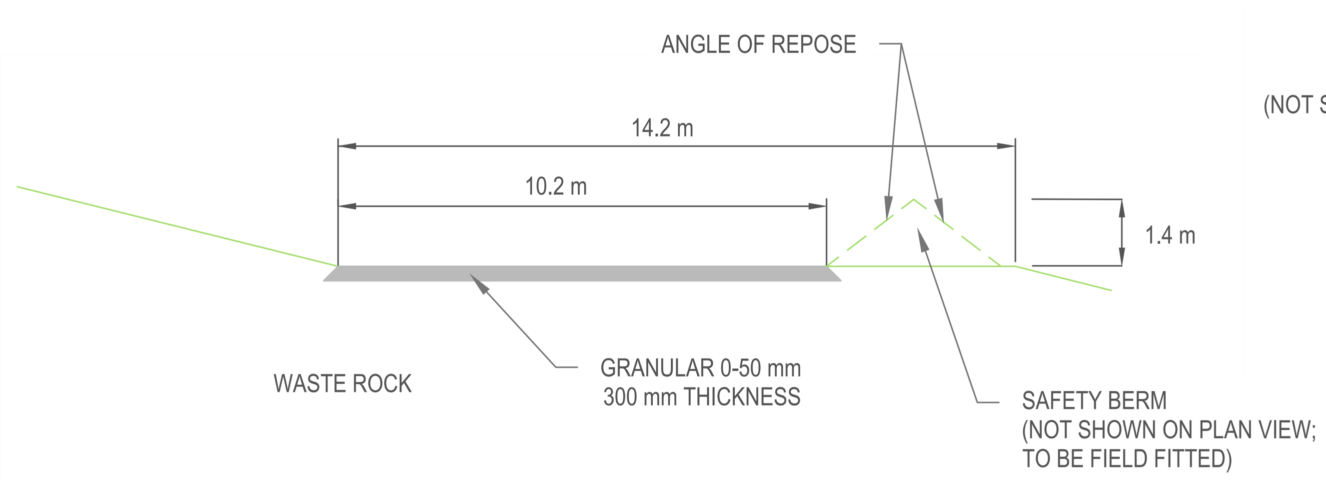

SECTION F: TSF AT BEGINNING OF Q4 2019



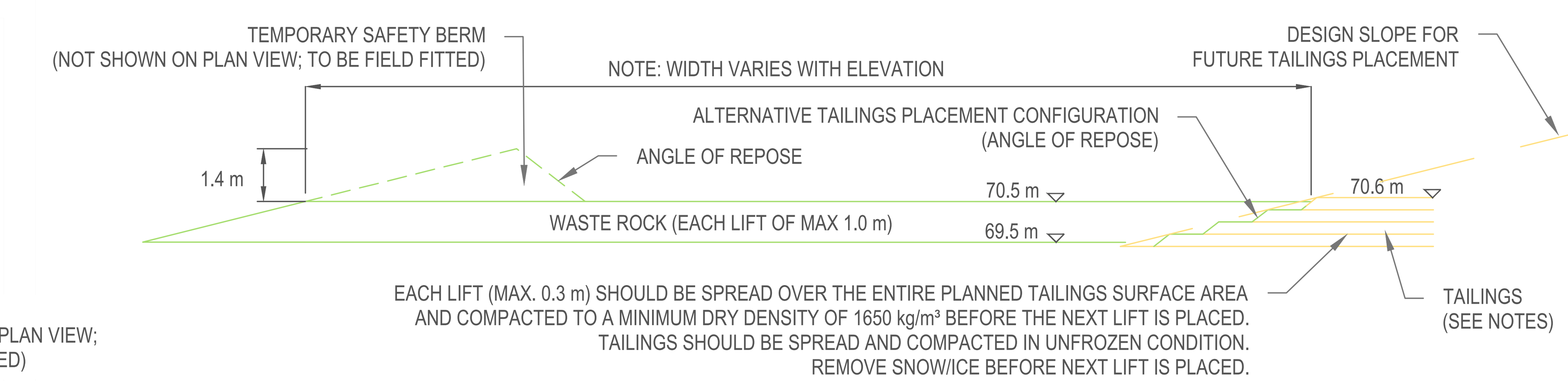

SECTION F: TSF AT END OF Q4 2019




SECTION G: TSF AT END OF Q4 2019




DETAIL 1: ACCESS RAMP




DETAIL 2: WASTE ROCK BERM WITH SAFETY BERM AND TAILINGS

TETRA TECH

NOTES GÉNÉRALES / GENERAL NOTES

- WASTE ROCK BERM
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DESSINS EN RÉFÉRENCE / REFERENCE DRAWINGS

| TITRE / TITLE | # DWG |
|---|---|

AGNICO EAGLE

| REV. | DATE | DESCRIPTION | PAR/BY | APP. | CLIENT |
|---|---|---|---|---|---|
| 0 | 2019-01-29 | ISSUED FOR CONSTRUCTION | GZ | WTH | |
| B | 2019-01-27 | ISSUED FOR REVIEW | GZ | NG | |
| A | 2018-12-07 | 90% REVIEW | EP | GZ/WTH | |

REVISIONS

REGISTERED PROFESSIONAL ENGINEER G. ZHANG LICENSEE NWT/NU Jan. 29 2019

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date January 29, 2019
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY
TAILINGS DEPOSITION PLAN FOR
Q4 2019

| | | | |
|---|---|---|---|
| DESSINÉ PAR DRAWN BY | EP / EL | DATE | 2019-01-29 |
| VÉRIFIÉ PAR CHECKED BY | GZ | | 2019-01-29 |
| APPROUVÉ PAR APPROVED BY | WTH | | 2019-01-29 |
| ÉCHELLE SCALE | | DATE | |

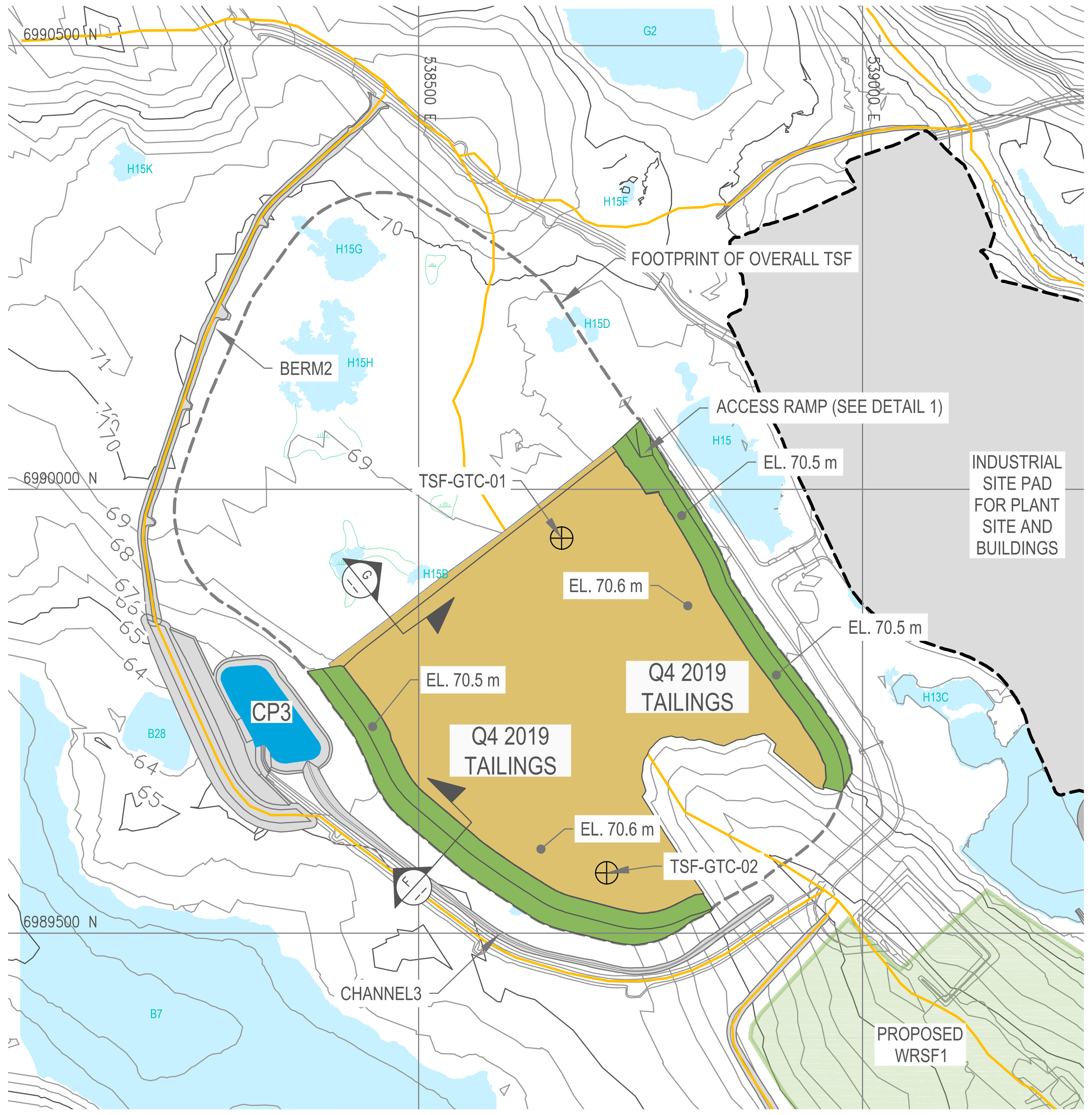
NO. DESSIN DRAWING NO. 6515-583-163-FIG-012

NO. PROJET PROJECT NO. | REVISION 0 | FEUILLE / SHT 12 / 24

FORMAT ARCHD

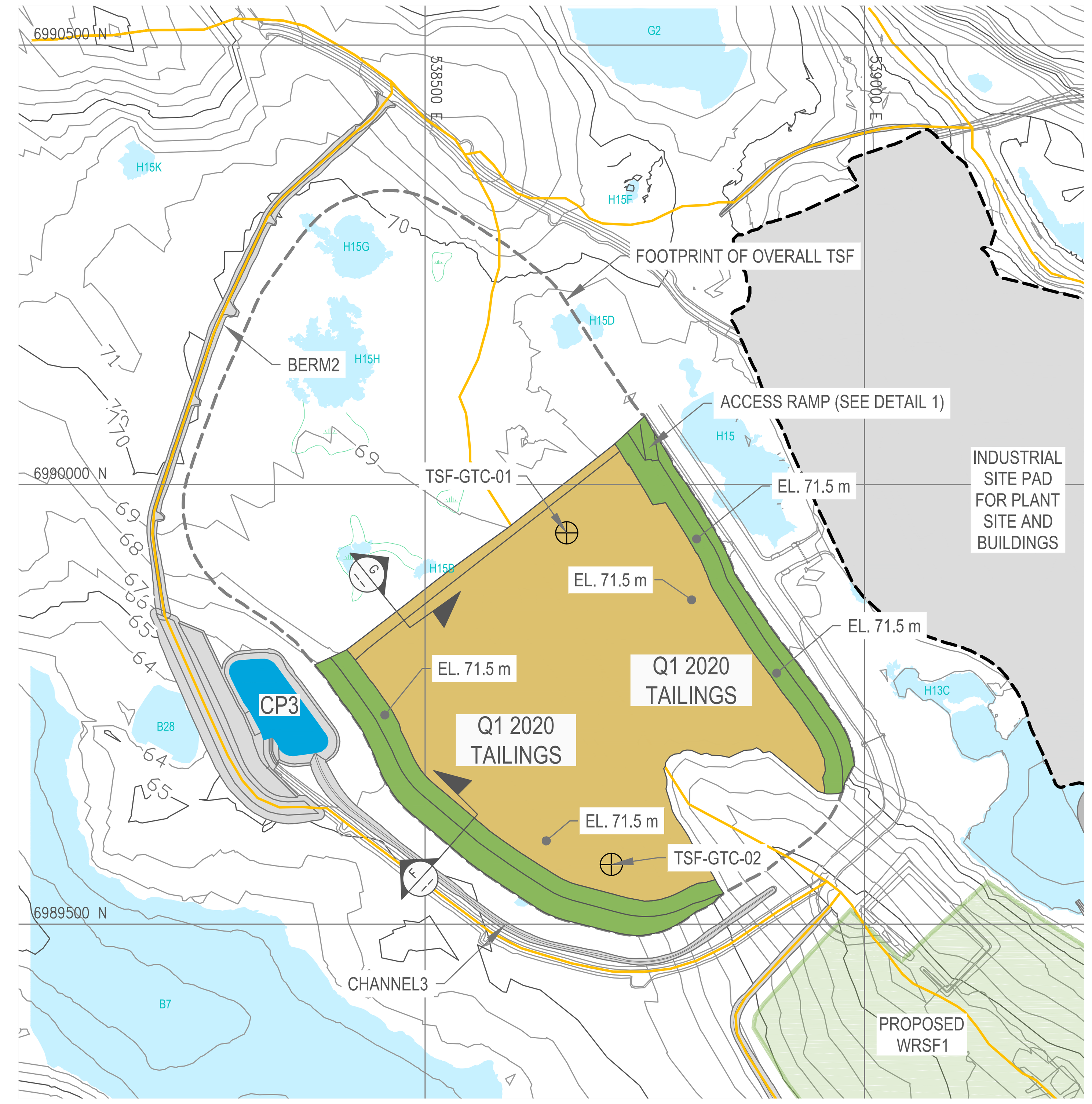
NO. DESSIN
DRAWING NO.

FORMAT ARCHD



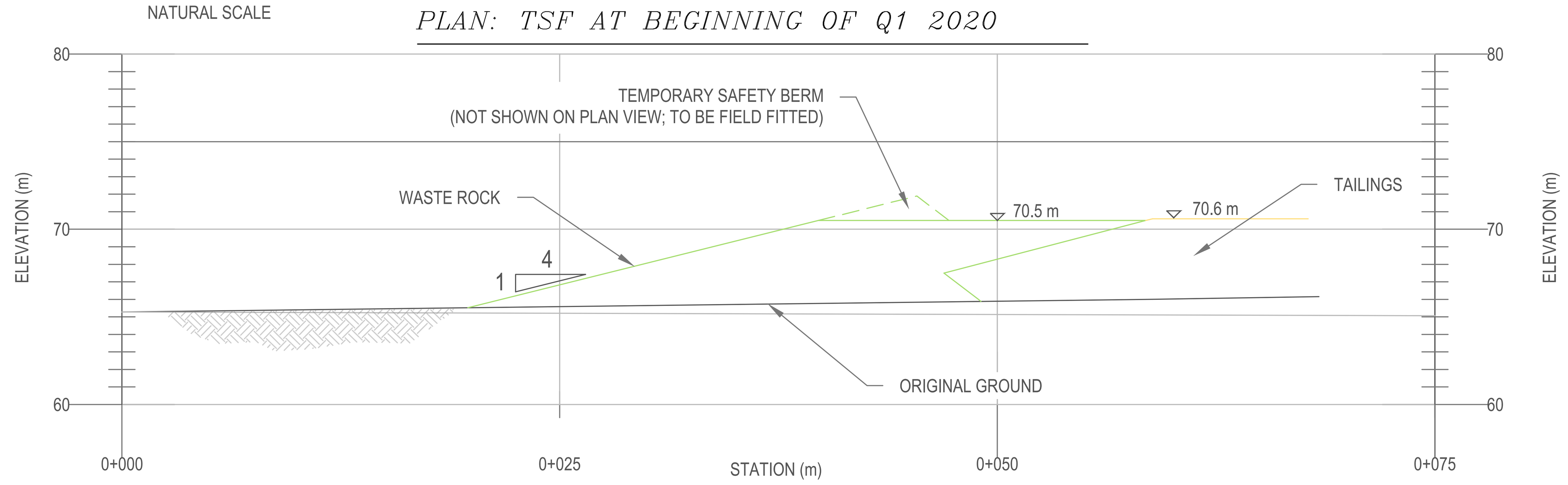

NATURAL SCALE

*PLAN: TSF AT BEGINNING OF Q1 2020*

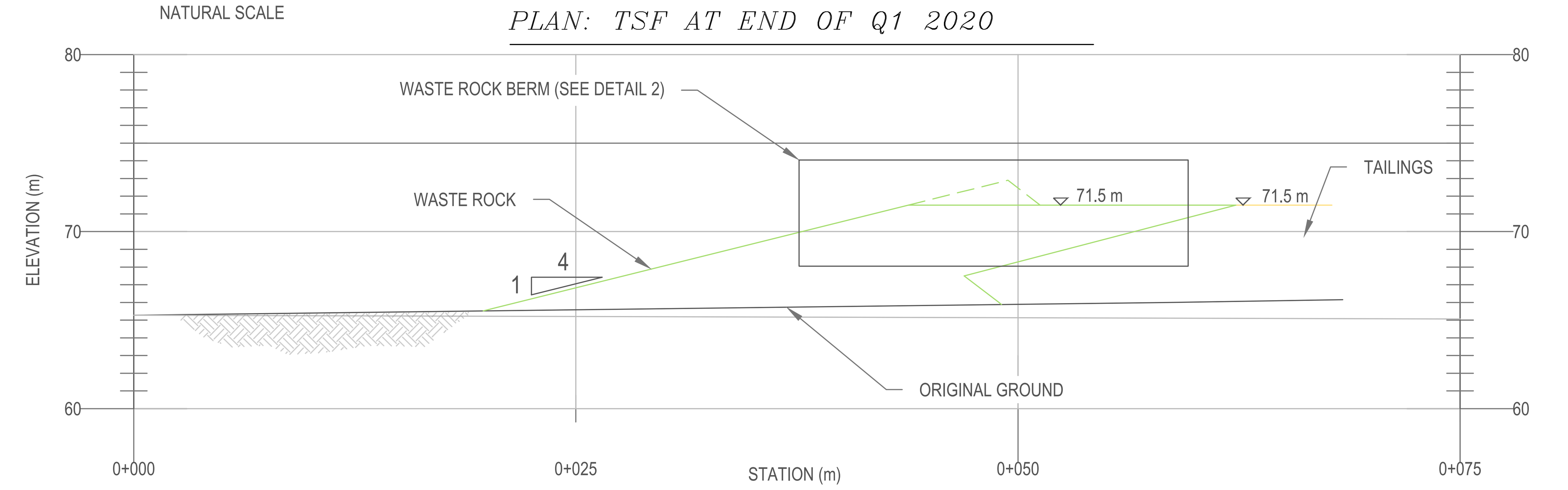



NATURAL SCALE

*PLAN: TSF AT END OF Q1 2020*

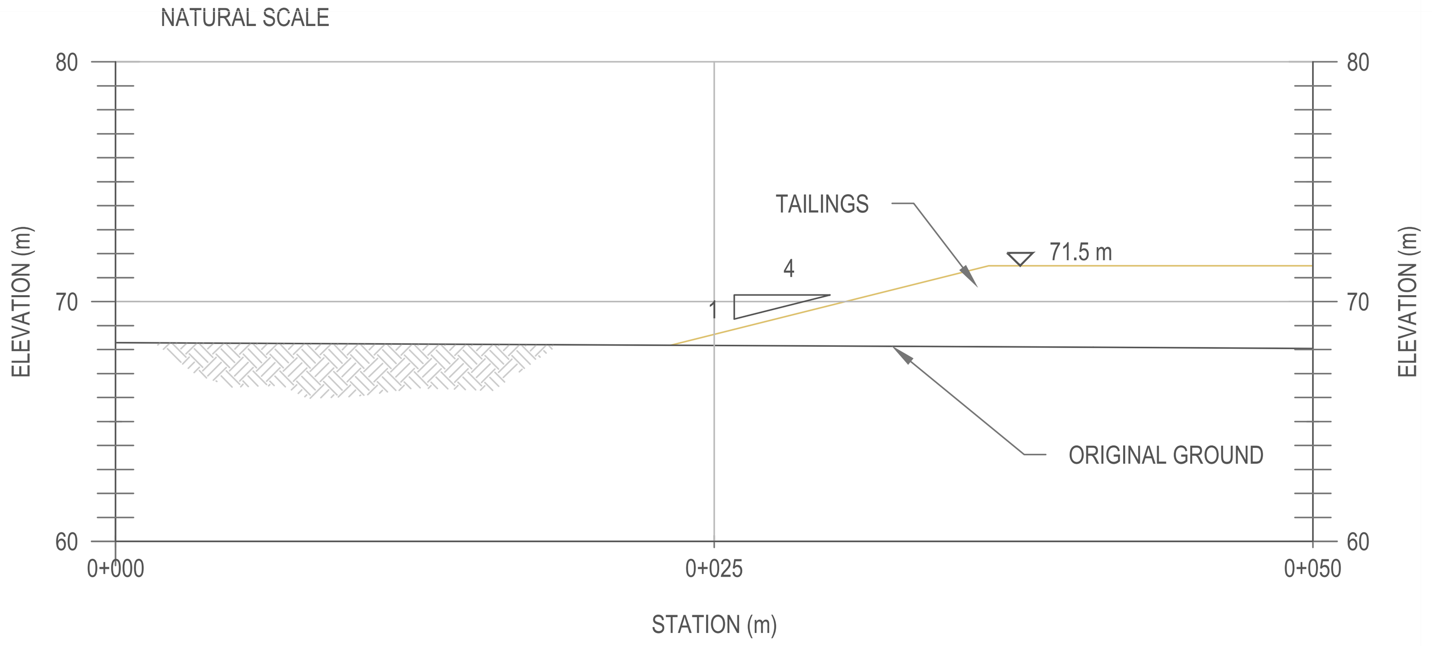



*SECTION F: TSF AT BEGINNING OF Q1 2020*

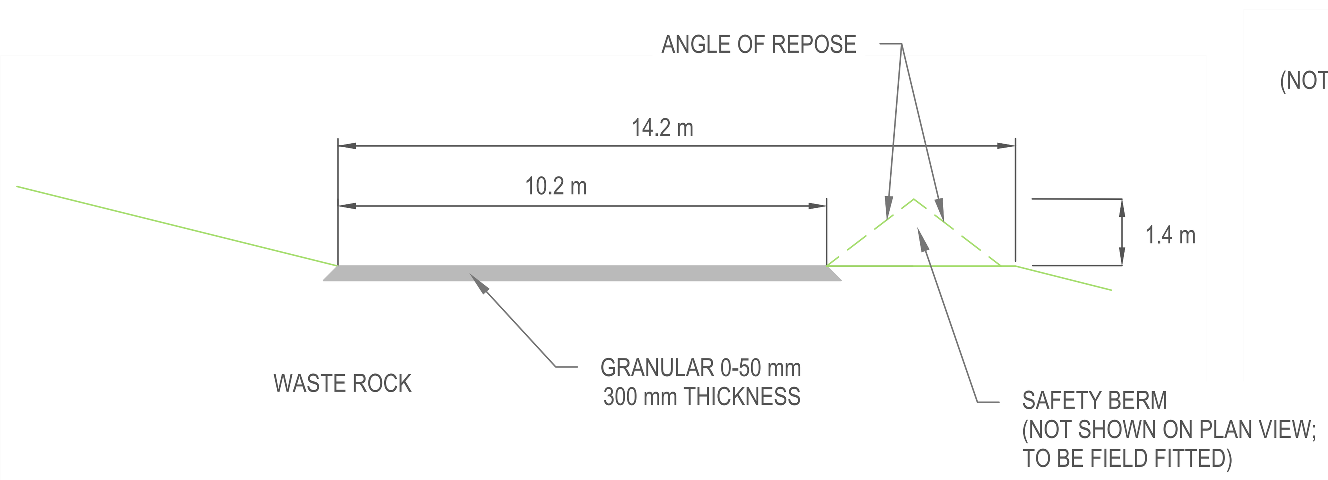



*SECTION F: TSF AT END OF Q1 2020*

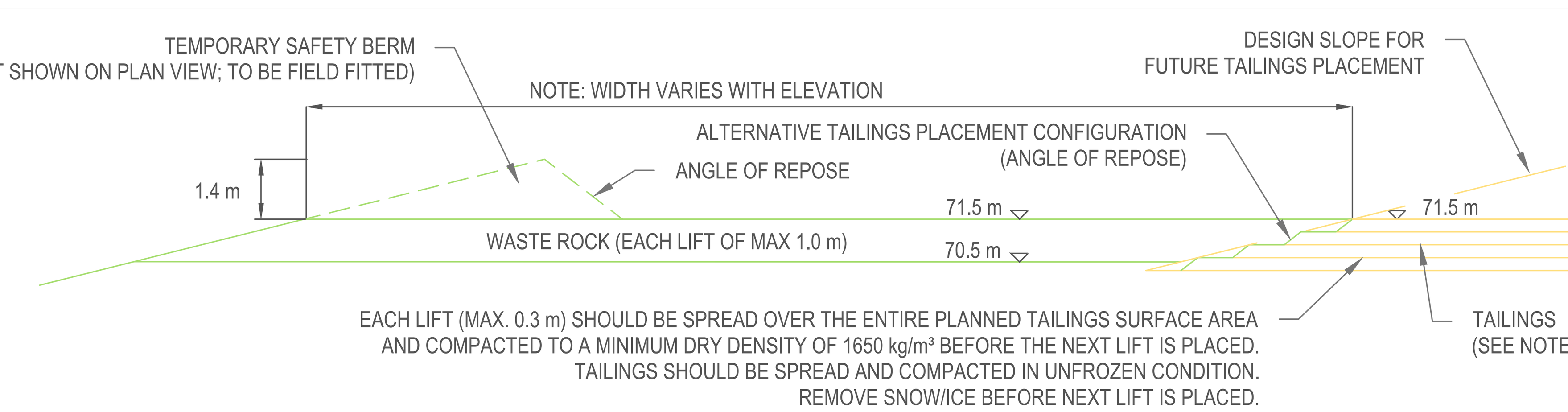
NATURAL SCALE




*SECTION G: TSF AT END OF Q1 2020*

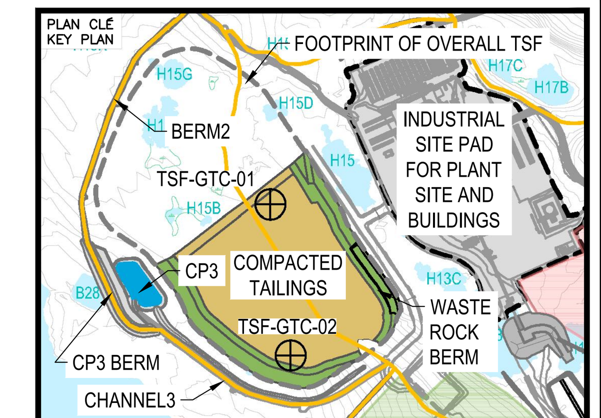



*DETAIL 1: ACCESS RAMP*




*DETAIL 2: WASTE ROCK BERM WITH SAFETY BERM AND TAILINGS*

PLAN CLÉ
KEY PLAN




TETRA TECH

NOTES GÉNÉRALES / GENERAL NOTES

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DESSINS EN RÉFÉRENCE / REFERENCE DRAWINGS

| TITRE / TITLE | # DWG |
|---|---|

AGNICO EAGLE

| REV. | DATE | DESCRIPTION | PAR/BY | APP. | CLIENT |
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REVISIONS

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date January 29, 2019
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

G. ZHANG
LICENSEE
NWT/NU

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY TAILINGS DEPOSITION PLAN FOR Q1 2020

| | | | |
|---|---|---|---|
| DESSINÉ PAR / DRAWN BY | EP / EL | DATE | 2019-01-29 |
| VÉRIFIÉ PAR / CHECKED BY | GZ | | 2019-01-29 |
| APPROUVÉ PAR / APPROVED BY | WTH | | 2019-01-29 |
| ÉCHELLE / SCALE | | DATE | |

NO. DESSIN / DRAWING NO. 6515-583-163-FIG-013

NO. PROJET / PROJECT NO. | REVISION 0 | FEUILLE / SHT 13 / 24

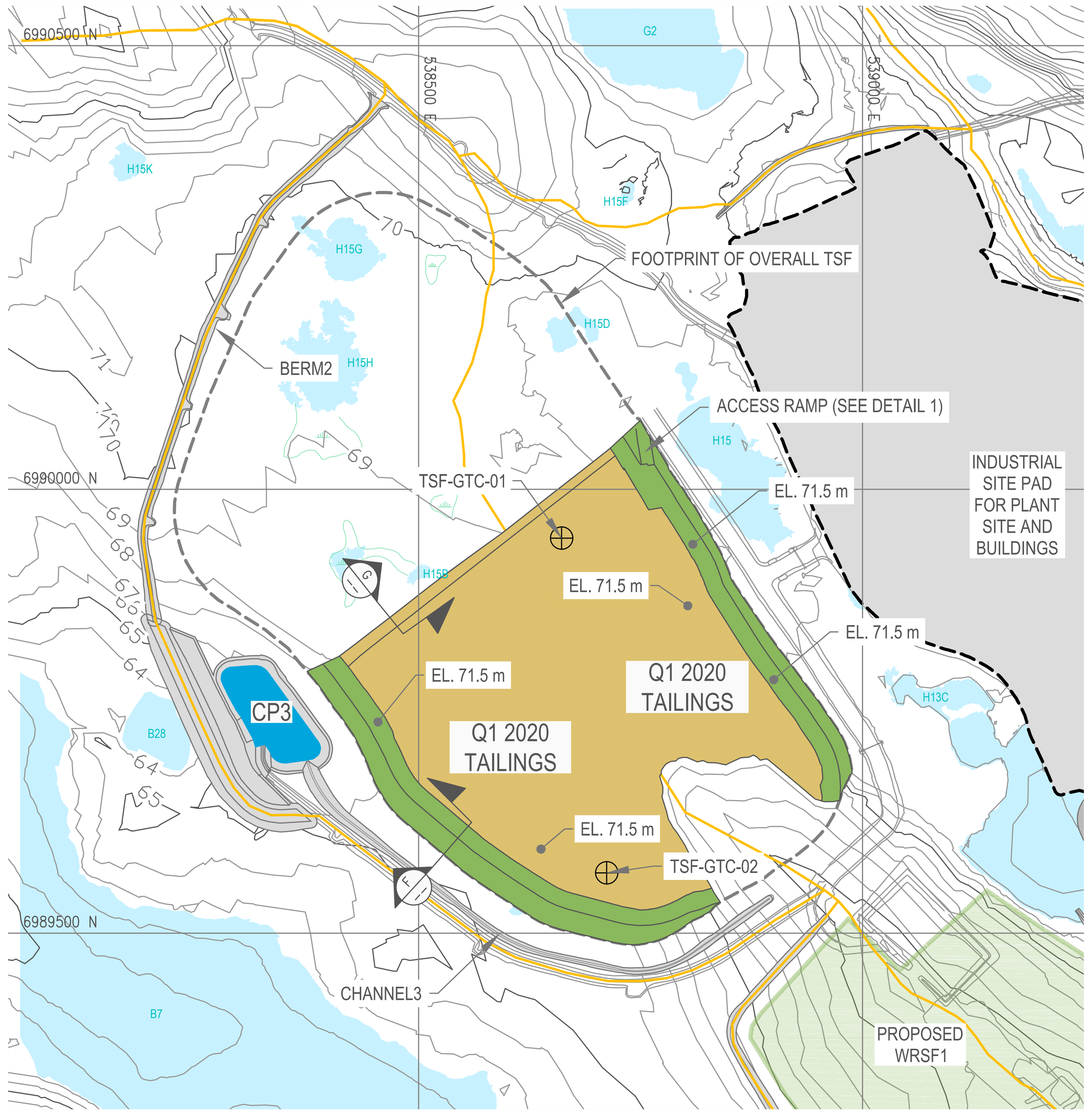
AE-CART-ARCH D

G:\Edmonton\Engineering\E141\Projects_MELIADINE\ENG.EARC03147-01 (Detailed Tailings Deposition Plan)\Figure 13-16 (Jan23_2019).dwg-2013-02-19 12:48:32

FILE NO. .DWG

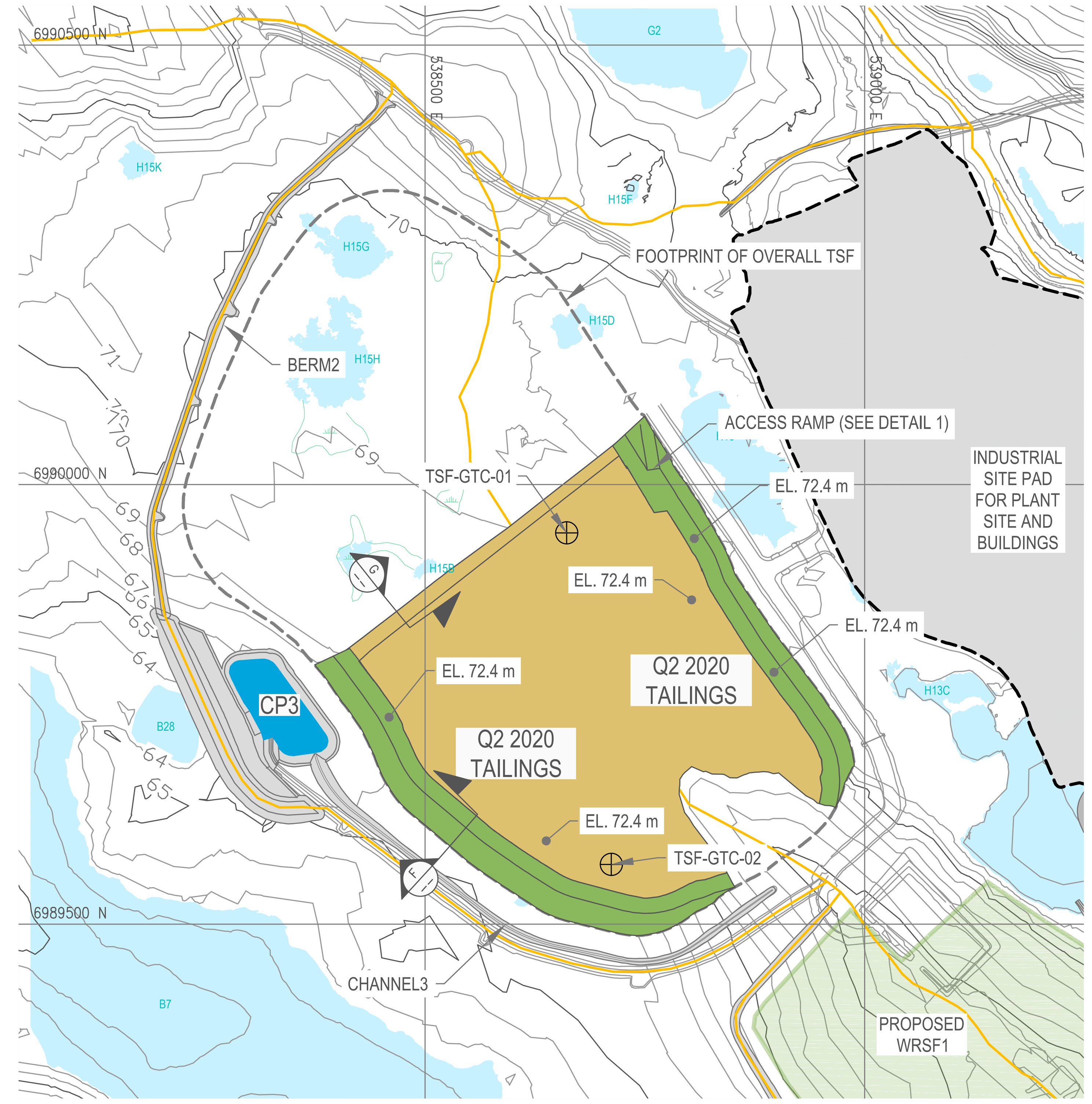
NO. DESSIN
DRAWING NO.

FORMAT ARCHD



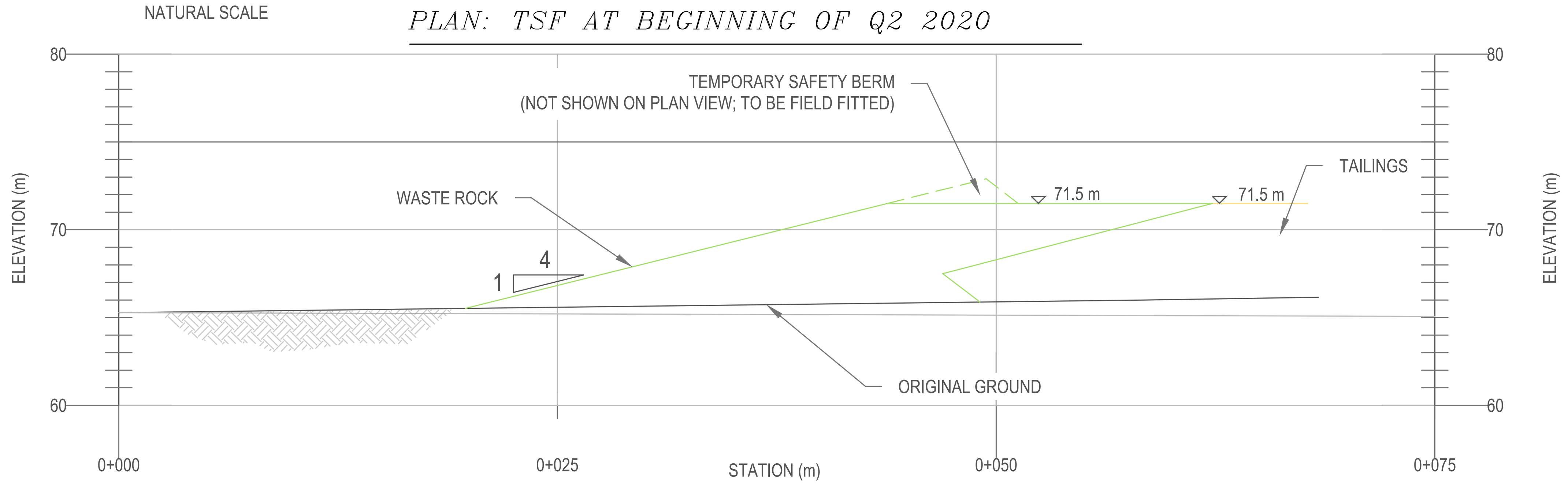

NATURAL SCALE

*PLAN: TSF AT BEGINNING OF Q2 2020*

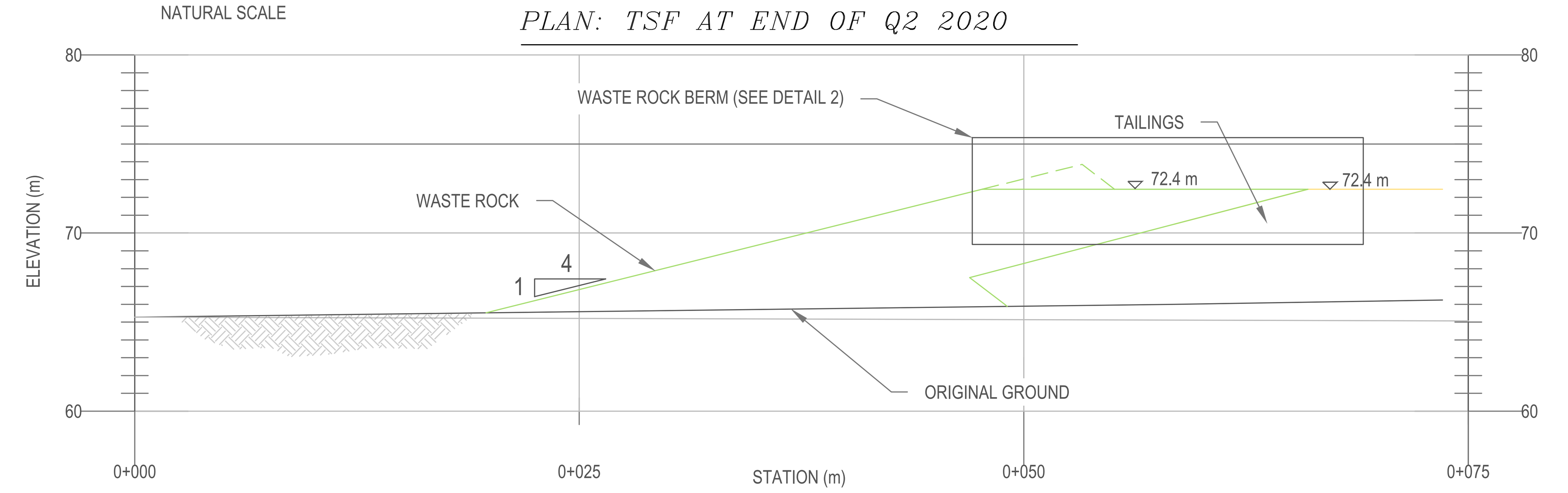



NATURAL SCALE

*PLAN: TSF AT END OF Q2 2020*

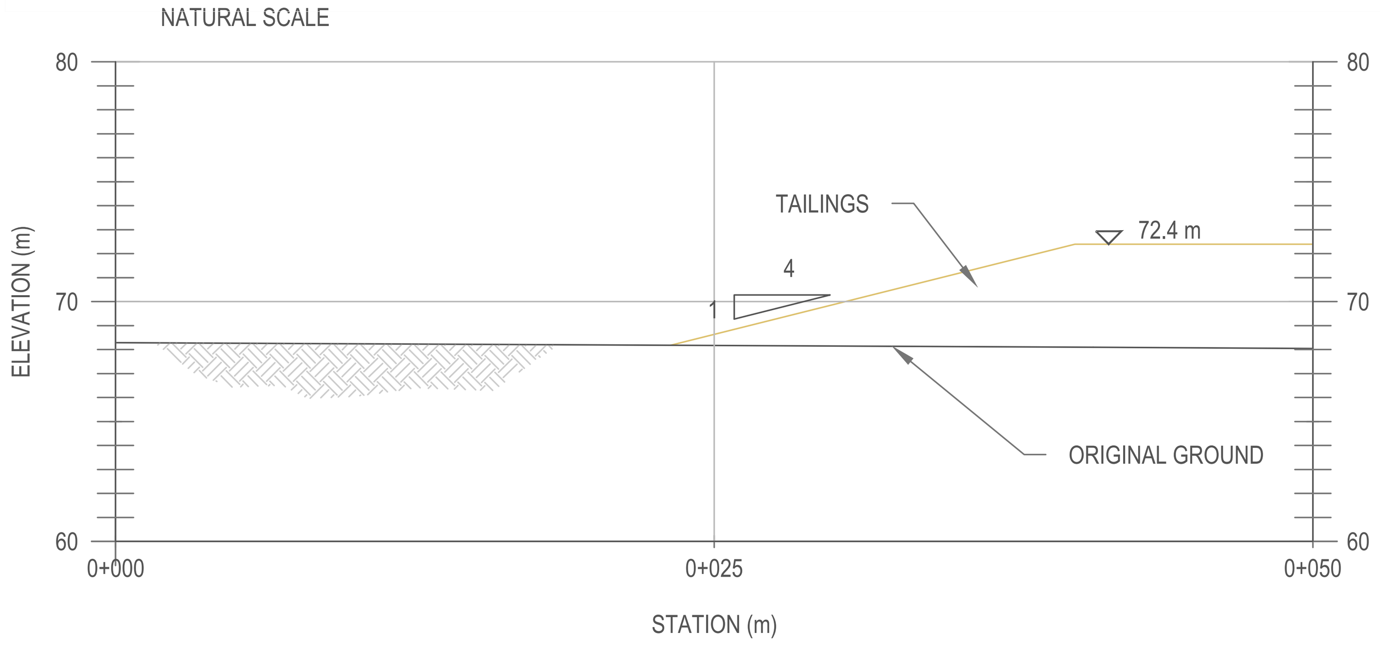



*SECTION F: TSF AT BEGINNING OF Q2 2020*

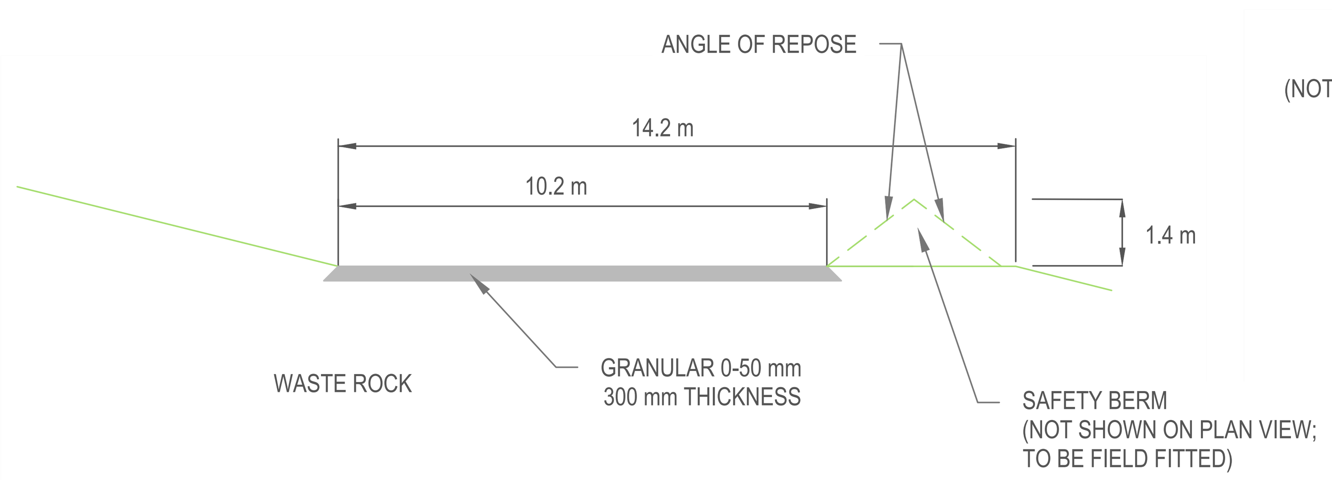



*SECTION F: TSF AT END OF Q2 2020*

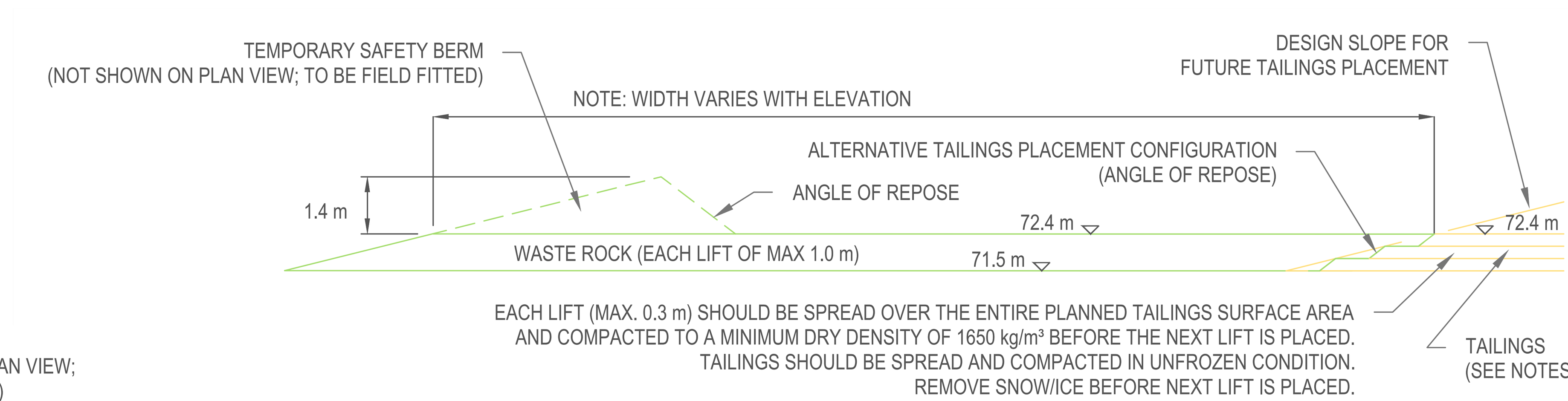
NATURAL SCALE




*SECTION G: TSF AT END OF Q2 2020*

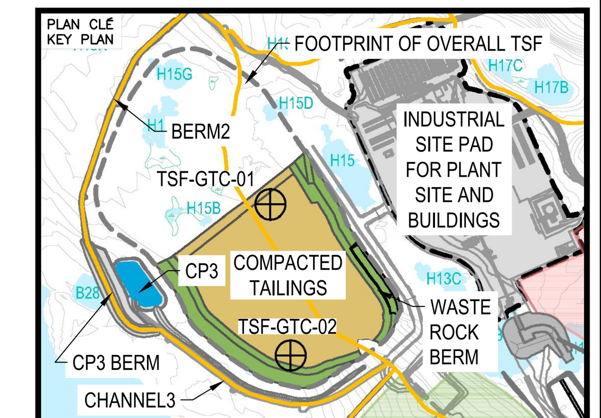



*DETAIL 1: ACCESS RAMP*




*DETAIL 2: WASTE ROCK BERM WITH SAFETY BERM AND TAILINGS*

PLAN CLÉ
KEY PLAN

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NOTES GÉNÉRALES / GENERAL NOTES

- WASTE ROCK BERM
- TAILINGS
- GROUND TEMPERATURE CABLE
- CATCHMENT BOUNDARY

NOTES

1. REFER TO THE TAILINGS STORAGE FACILITY DETAILED DEPOSITION PLAN FOR OPERATION AND CONSTRUCTION REQUIREMENTS AND DETAILS.
2. THE ENTIRE BOTTOM LIFT OVER THE PLANNED AREA (OR DESIGNED SUB-CELL IF APPLICABLE) SHOULD BE COMPLETED BEFORE THE NEXT LIFT IS PLACED SUCH THAT LOCALIZED PLACEMENT OF THICKER TAILINGS OVER A SMALL AREA IS AVOIDED.
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DESSINS EN RÉFÉRENCE / REFERENCE DRAWINGS

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| A | 2018-12-07 | 90% REVIEW | EP | GZ/WTH | |

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TAILINGS DEPOSITION PLAN FOR
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| ÉCHELLE / SCALE | | |

NO. DESSIN / DRAWING NO. 6515-583-163-FIG-014

NO. PROJET / PROJECT NO. | REVISION 0 | FEUILLE / SHT 14 / 24

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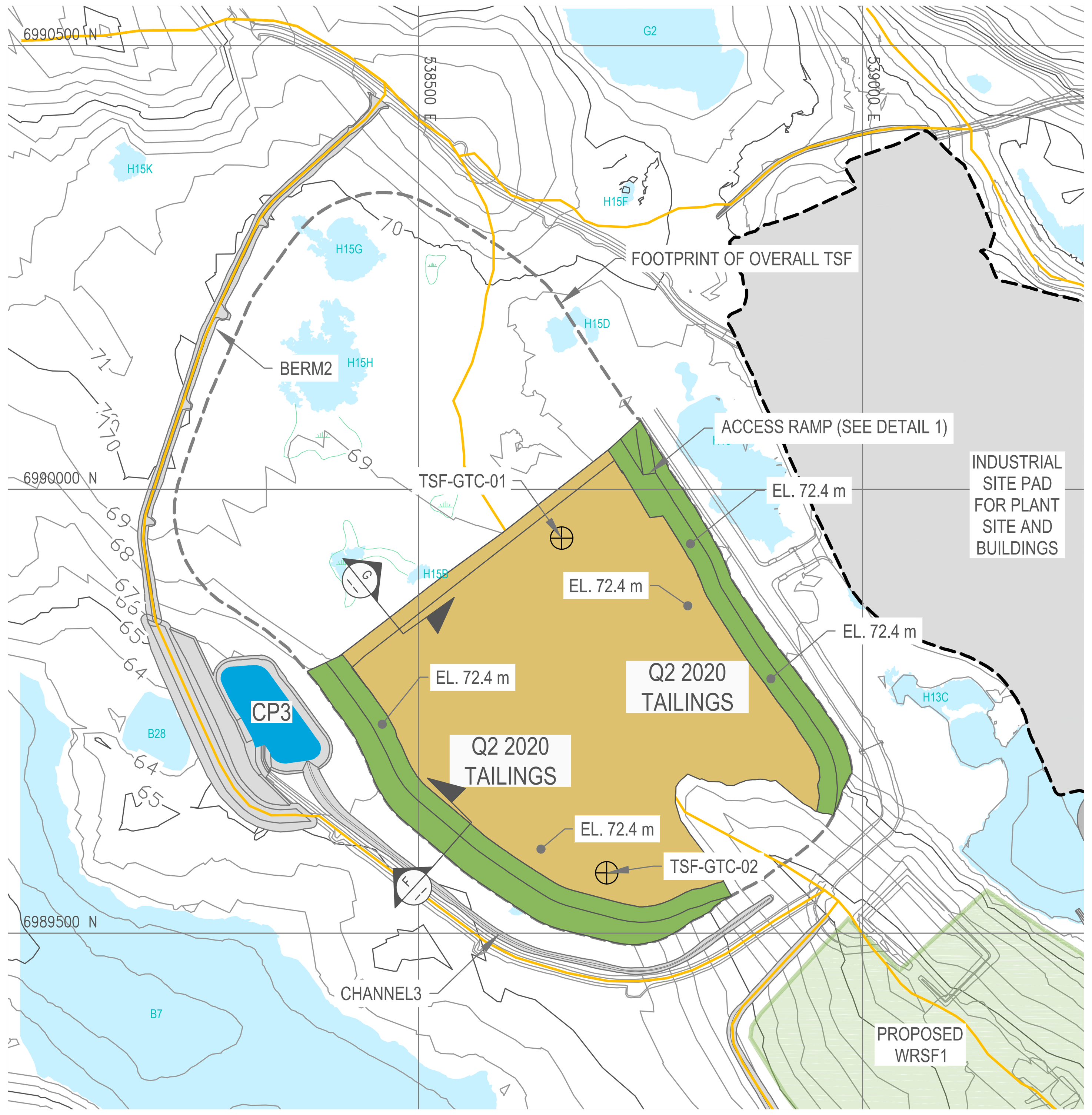
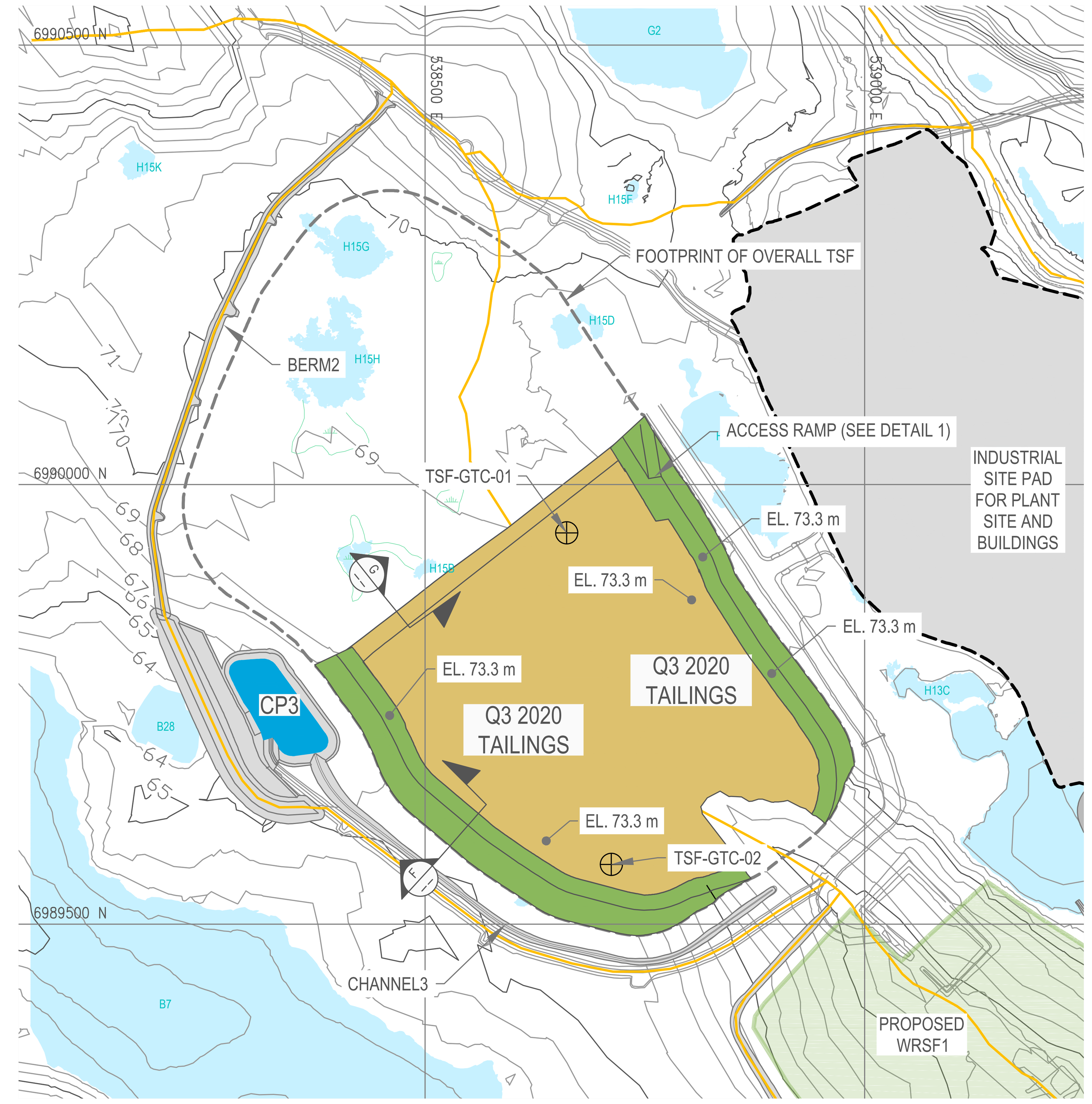
G:\Edmonton\Engineering\E141\Projects_MELIADINE\ENG.EARC03147-01 (Detailed Tailings Deposition Plan)\Figure 13-16 (Jan23_2019).dwg-2013-02-19 12:48:32

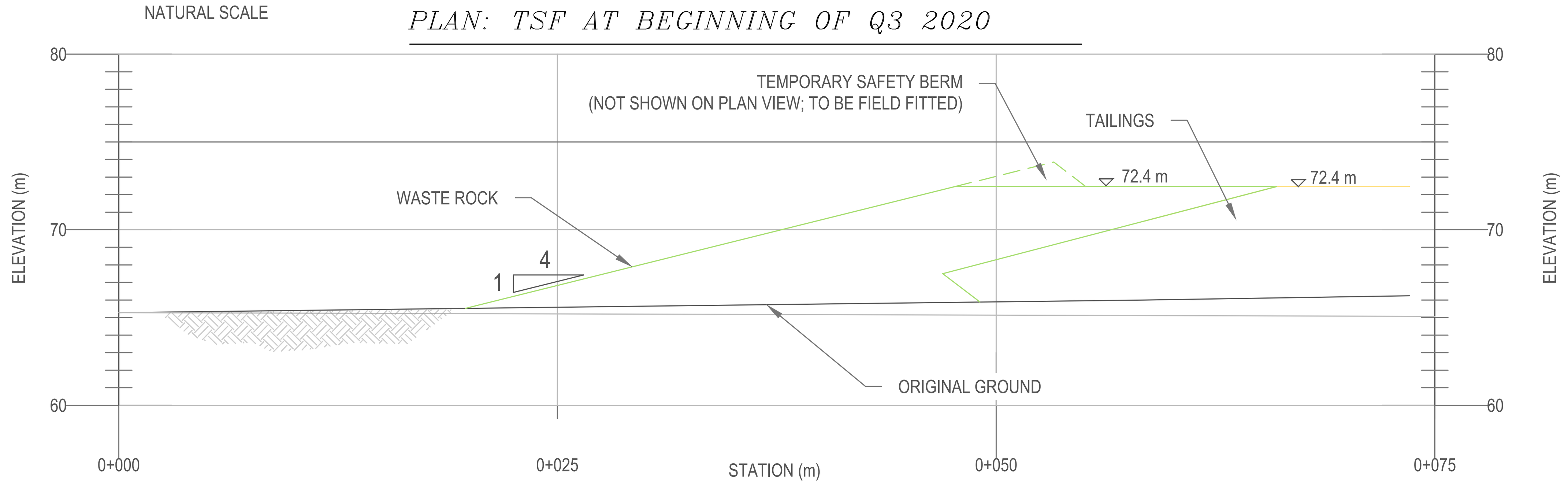
FILE NO. .DWG



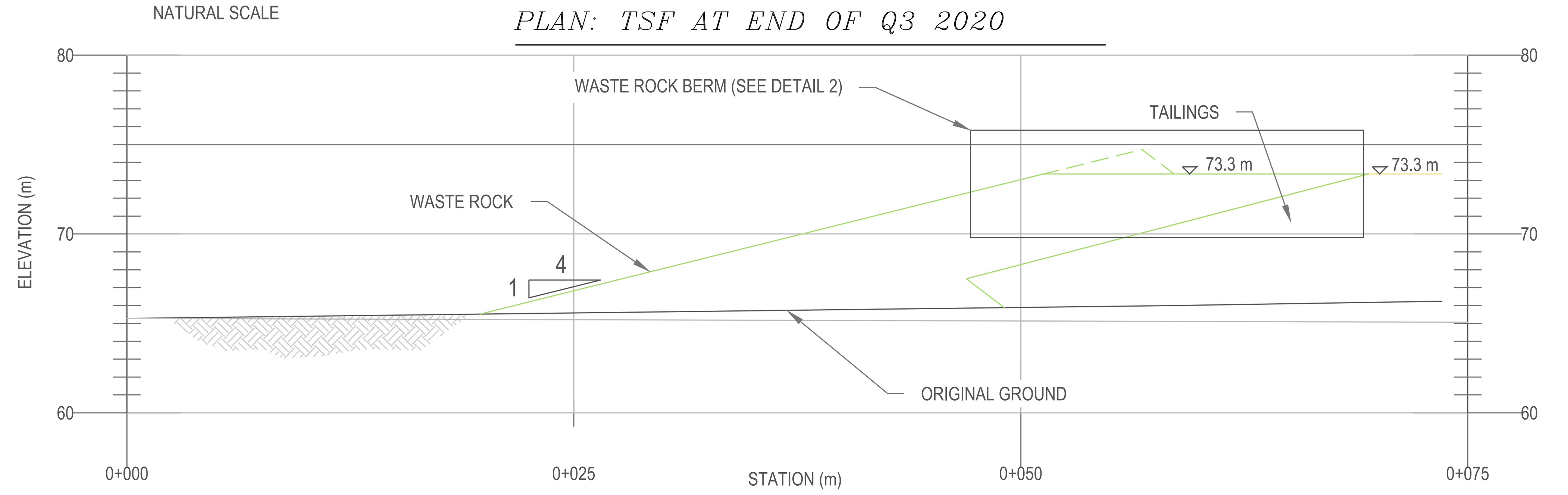

## PLAN: TSF AT BEGINNING OF Q3 2020



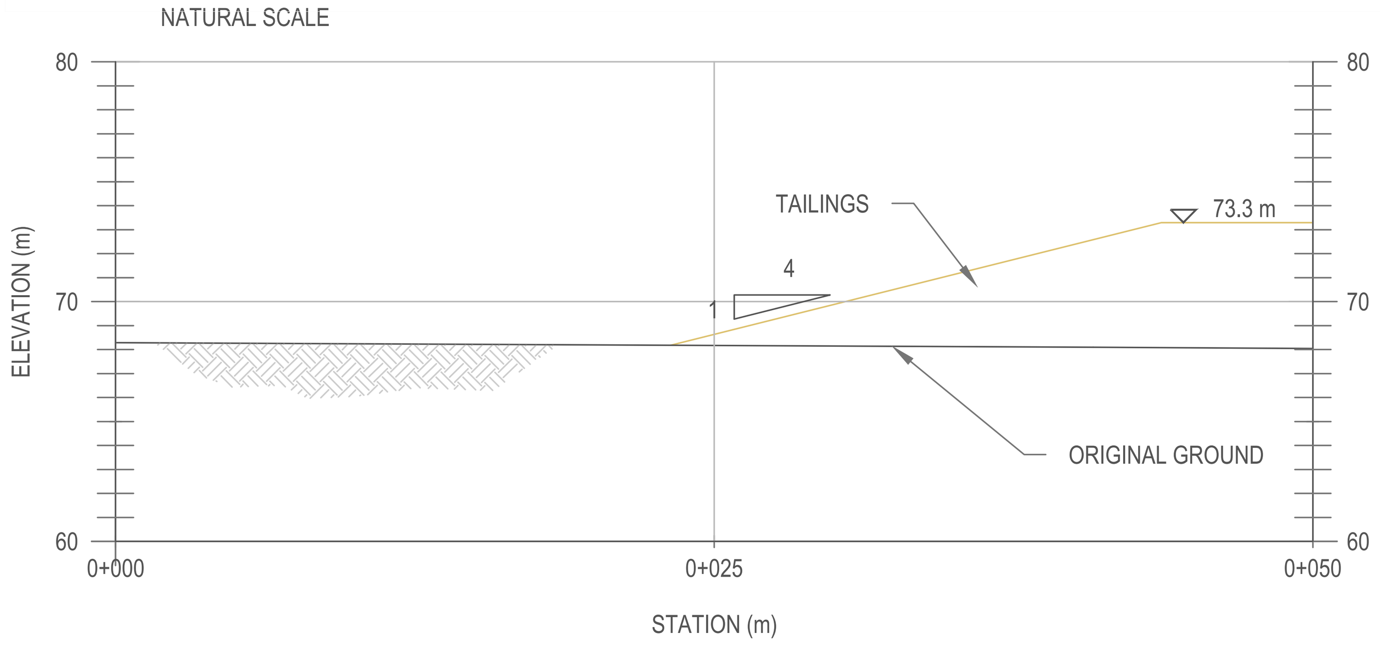

## PLAN: TSF AT END OF Q3 2020



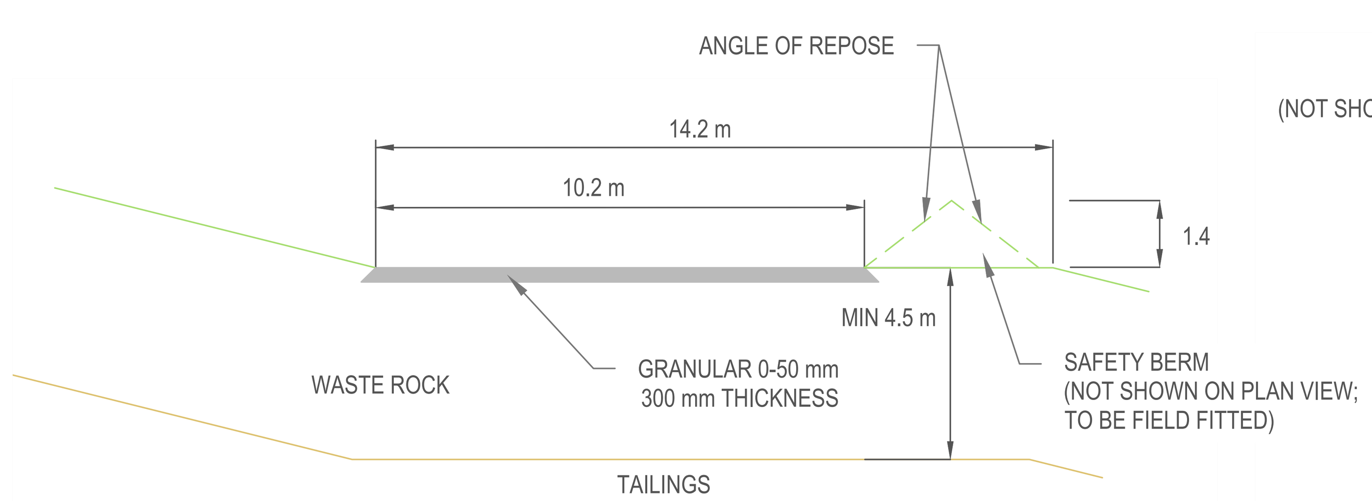

## SECTION F: TSF AT BEGINNING OF Q3 2020



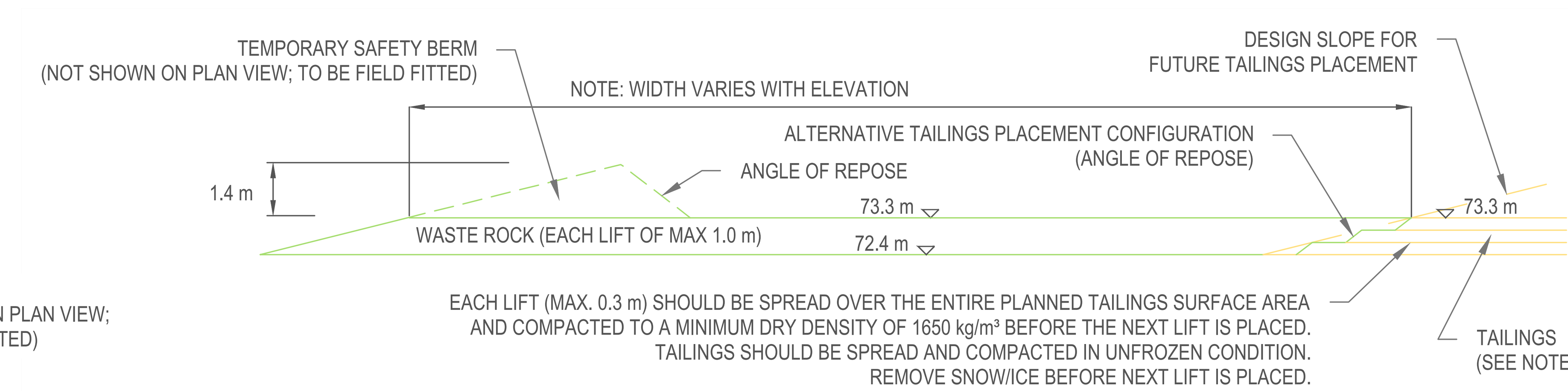

## SECTION F: TSF AT END OF Q3 2020




## SECTION G: TSF AT END OF Q3 2020

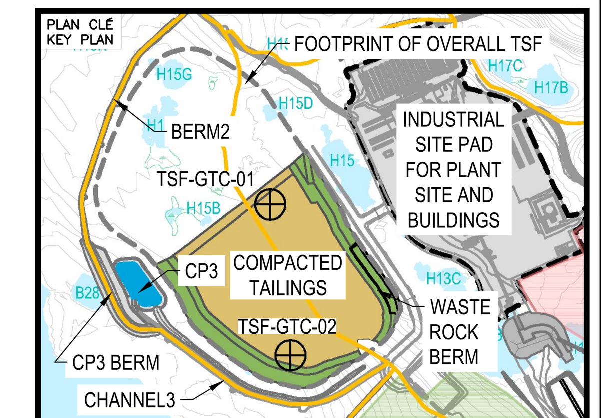



## DETAIL 1: ACCESS RAMP




## DETAIL 2: WASTE ROCK BERM WITH SAFETY BERM AND TAILINGS

PLAN CLÉ / KEY PLAN

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NOTES GÉNÉRALES / GENERAL NOTES

- WASTE ROCK BERM
- TAILINGS
- GROUND TEMPERATURE CABLE
- CATCHMENT BOUNDARY

NOTES

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DESSINS EN RÉFÉRENCE / REFERENCE DRAWINGS

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MELIADINE TAILINGS STORAGE FACILITY TAILINGS DEPOSITION PLAN FOR Q3 2020

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| APPROUVÉ PAR / APPROVED BY | WTH | | 2019-01-29 |
| ÉCHELLE / SCALE | | DATE | |

NO. DESSIN / DRAWING NO. 6515-583-163-FIG-015

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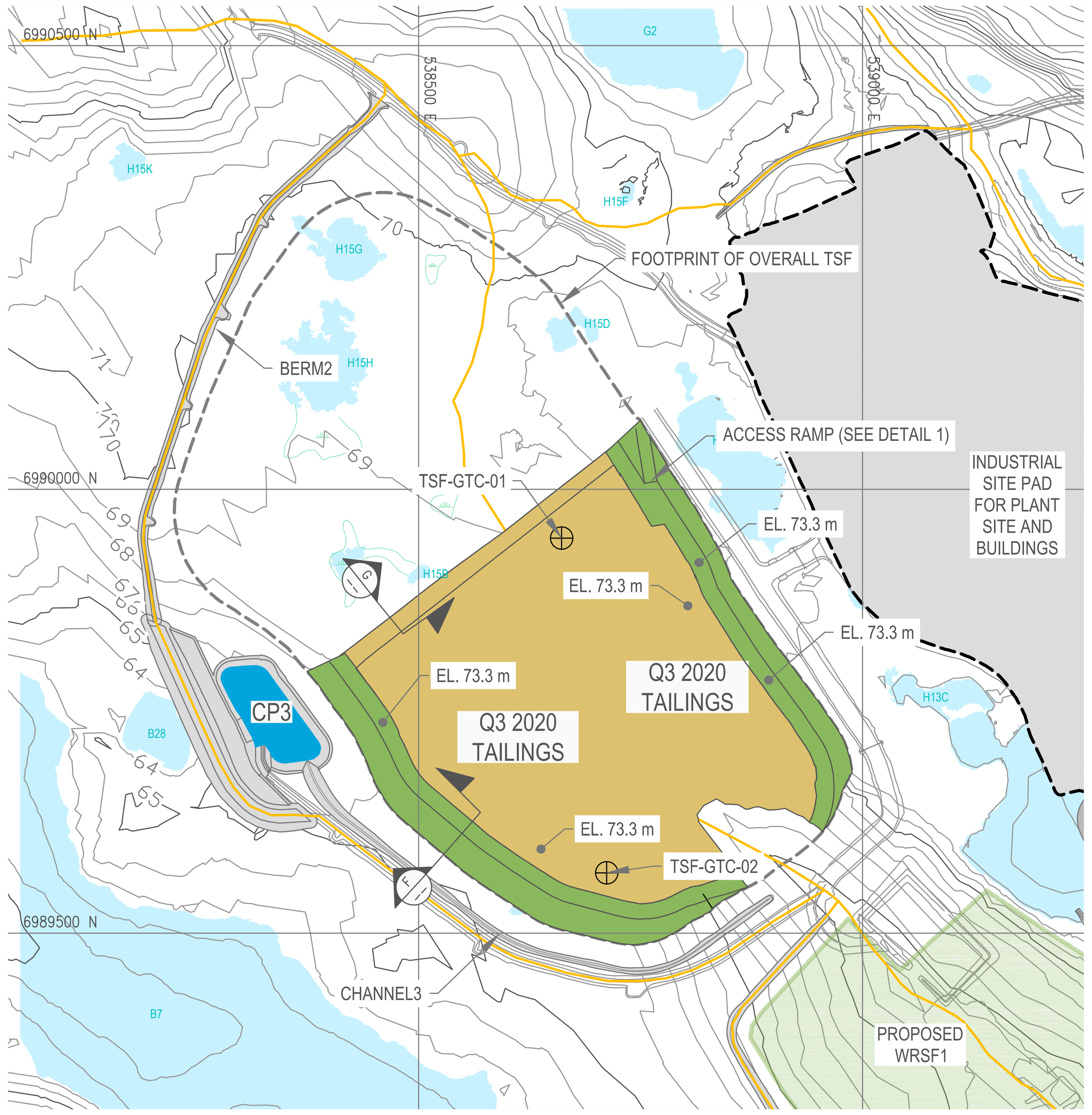
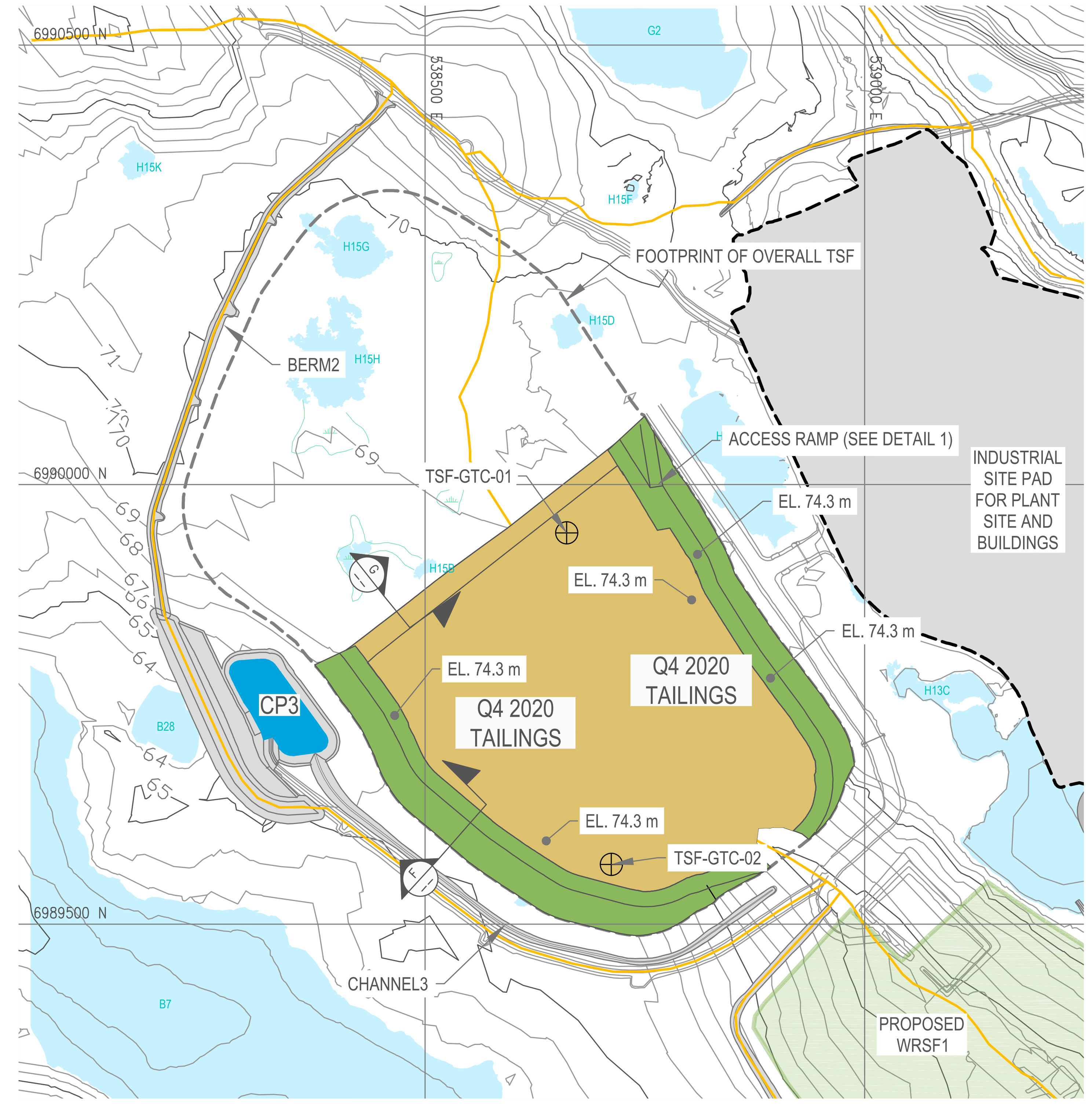
FILE NO. .DWG

NO. DESSIN
DRAWING NO.



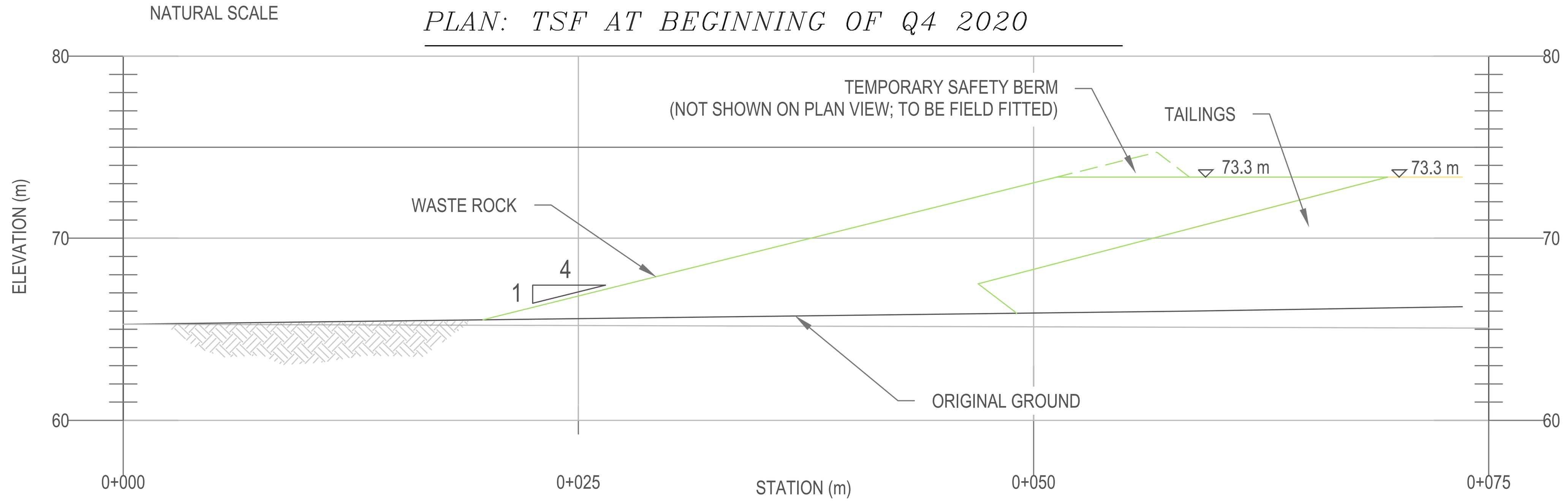

NATURAL SCALE

PLAN: TSF AT BEGINNING OF Q4 2020

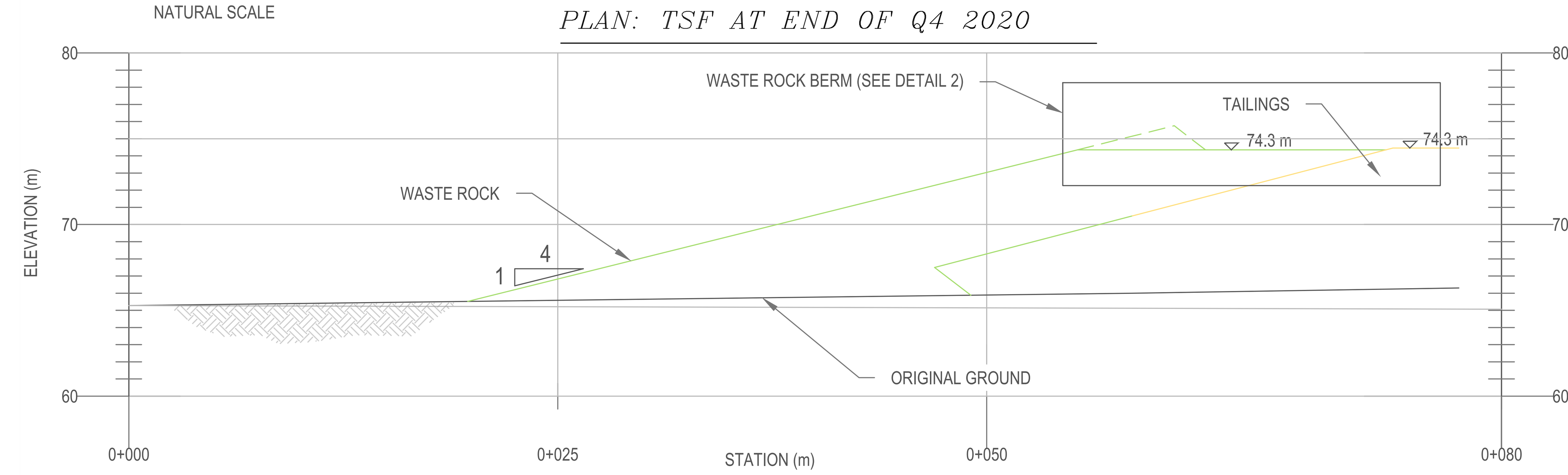



NATURAL SCALE

PLAN: TSF AT END OF Q4 2020

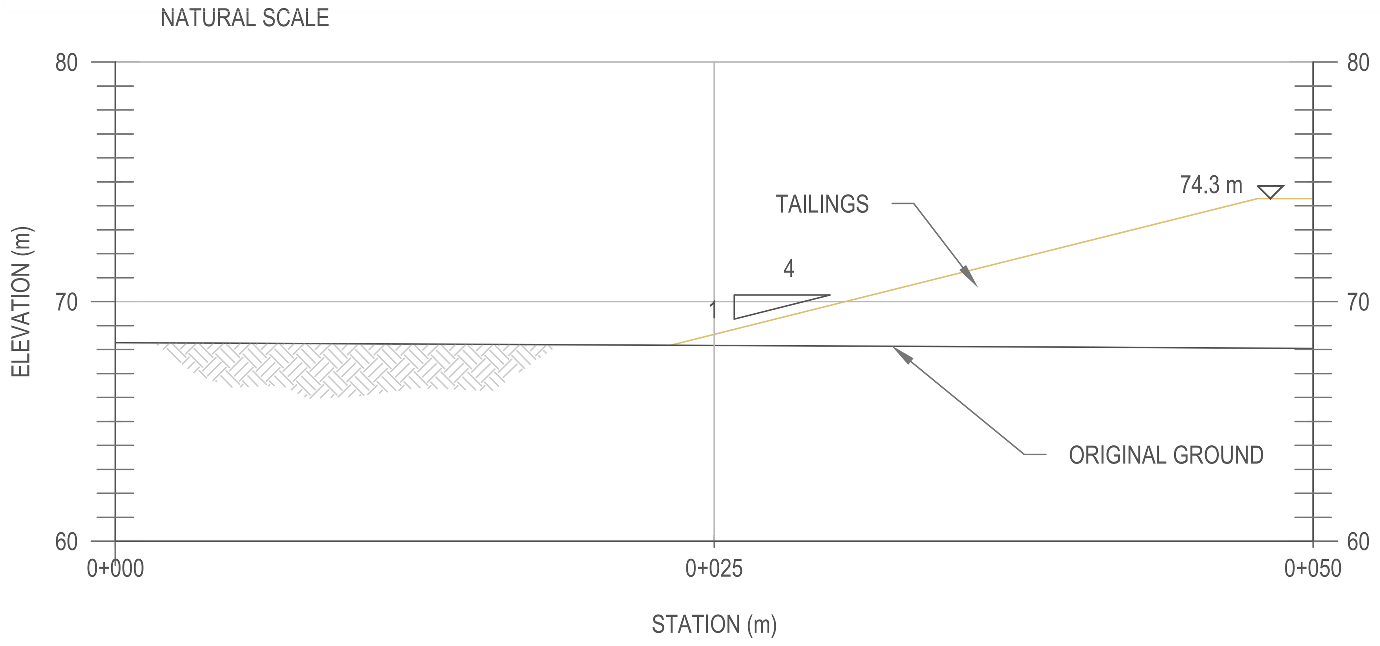



SECTION F: TSF AT BEGINNING OF Q4 2020

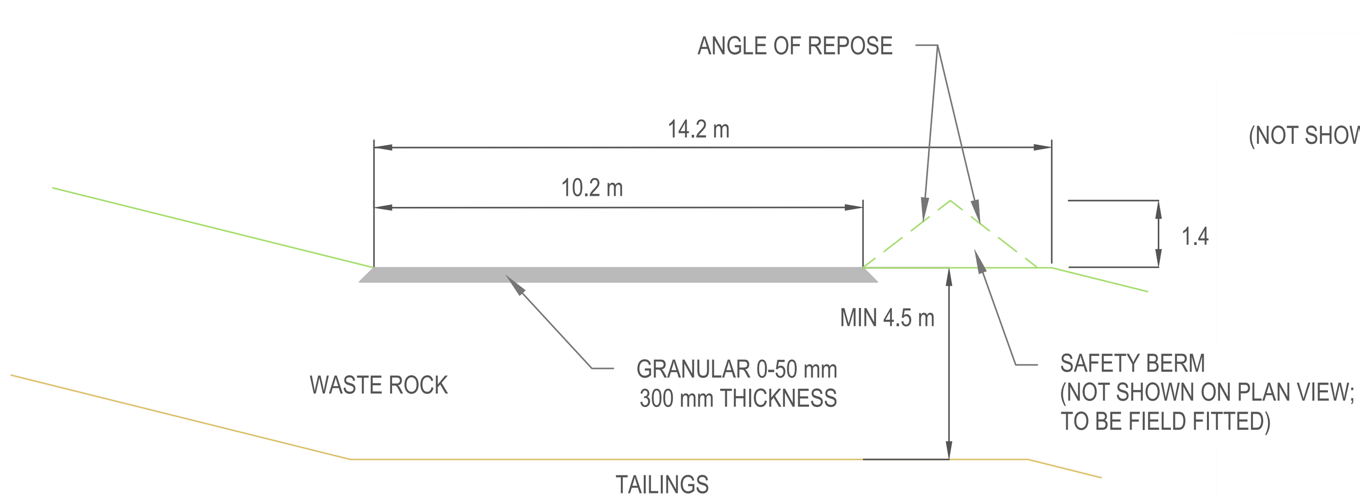



SECTION F: TSF AT END OF Q4 2020

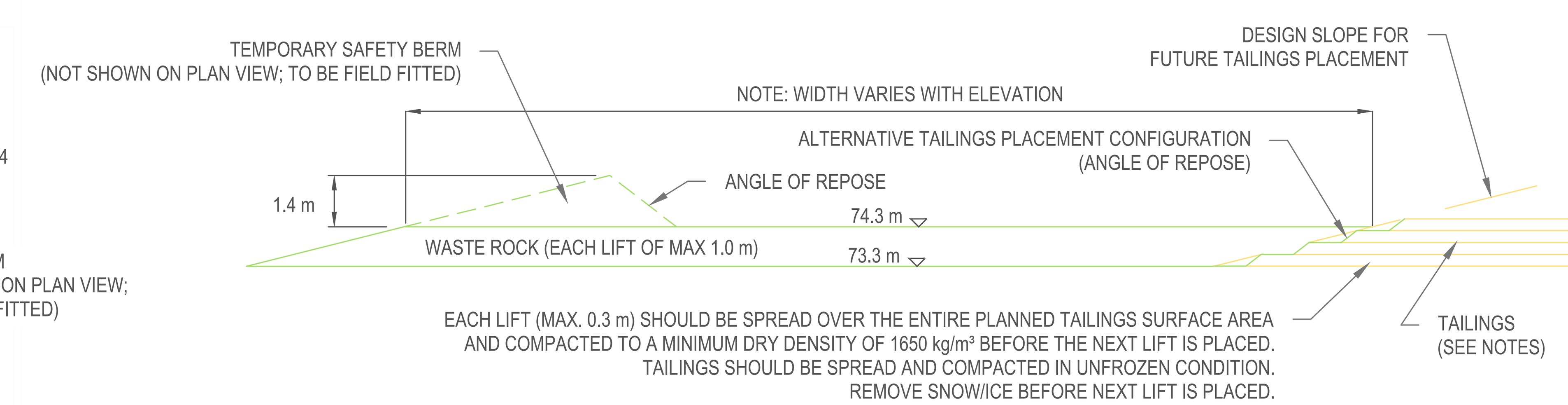
NATURAL SCALE




SECTION G: TSF AT END OF Q4 2020

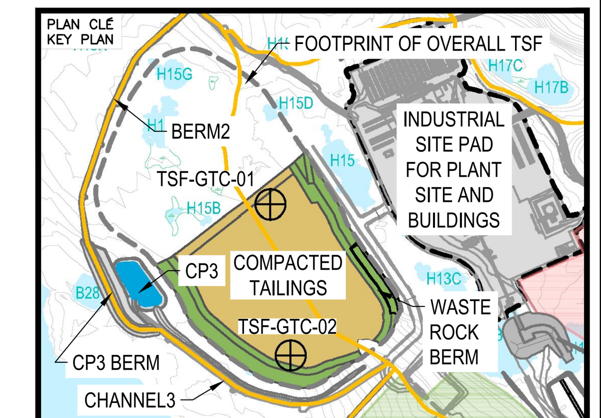



DETAIL 1: ACCESS RAMP




DETAIL 2: WASTE ROCK BERM WITH SAFETY BERM AND TAILINGS

PLAN CLÉ
KEY PLAN




TETRA TECH

NOTES GÉNÉRALES / GENERAL NOTES

- WASTE ROCK BERM
- TAILINGS
- GROUND TEMPERATURE CABLE
- CATCHMENT BOUNDARY

NOTES

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| A | 2018-12-07 | 90% REVIEW | EP | GZ/WTH | |

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Signature
Date January 29, 2019
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

G. ZHANG
LICENSEE
NWT/NU

TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY
TAILINGS DEPOSITION PLAN FOR
Q4 2020

| | | | |
|---|---|---|---|
| DESSINÉ PAR / DRAWN BY | EP / EL | DATE | 2019-01-29 |
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| APPROUVÉ PAR / APPROVED BY | WTH | | 2019-01-29 |
| ÉCHELLE / SCALE | | DATE | |

NO. DESSIN / DRAWING NO. 6515-583-163-FIG-016

NO. PROJET / PROJECT NO. | REVISION 0 | FEUILLE / SHT 16 / 24

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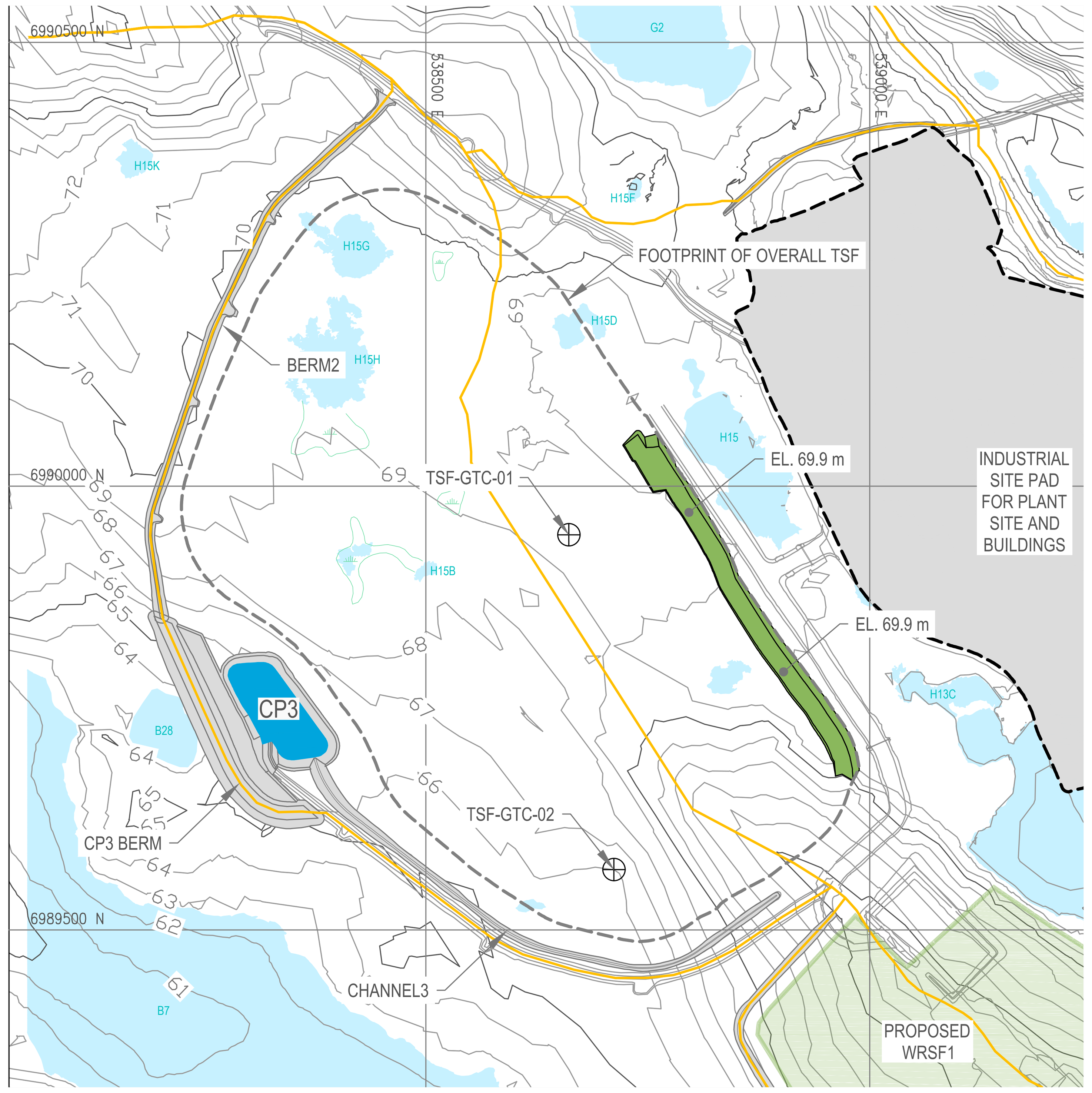
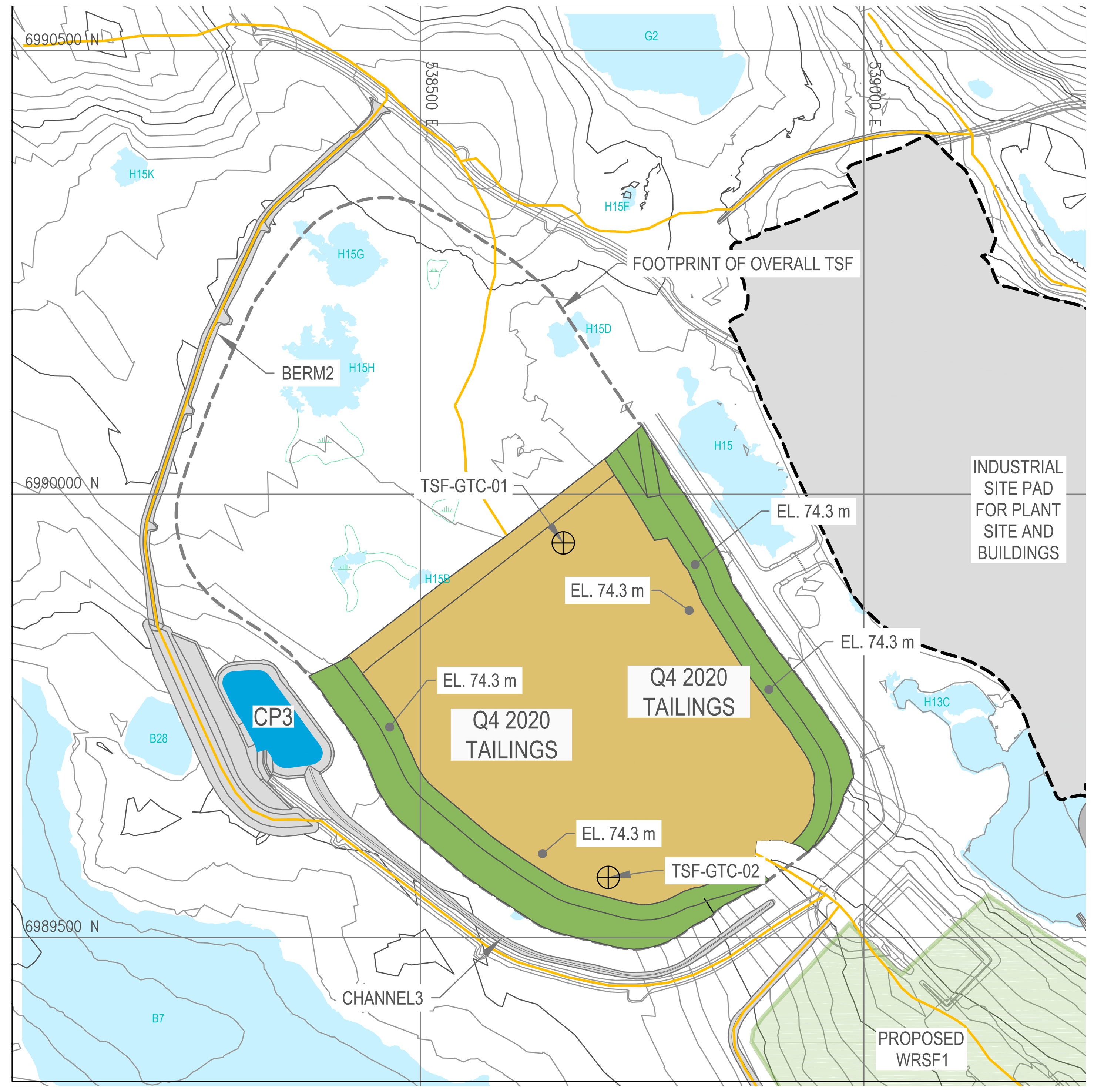
G:\Edmonton\Engineering\E141\Projects_MELIADINE\ENG.EARC03147-01 (Detailed Tailings Deposition Plan)\Figure 13-16 (Jan23_2019).dwg-2013-02-19 12:48:32
FILE NO. .DWG

NO. DESSIN
DRAWING NO.




PLAN: TSF AT BEGINNING OF Q1 2019

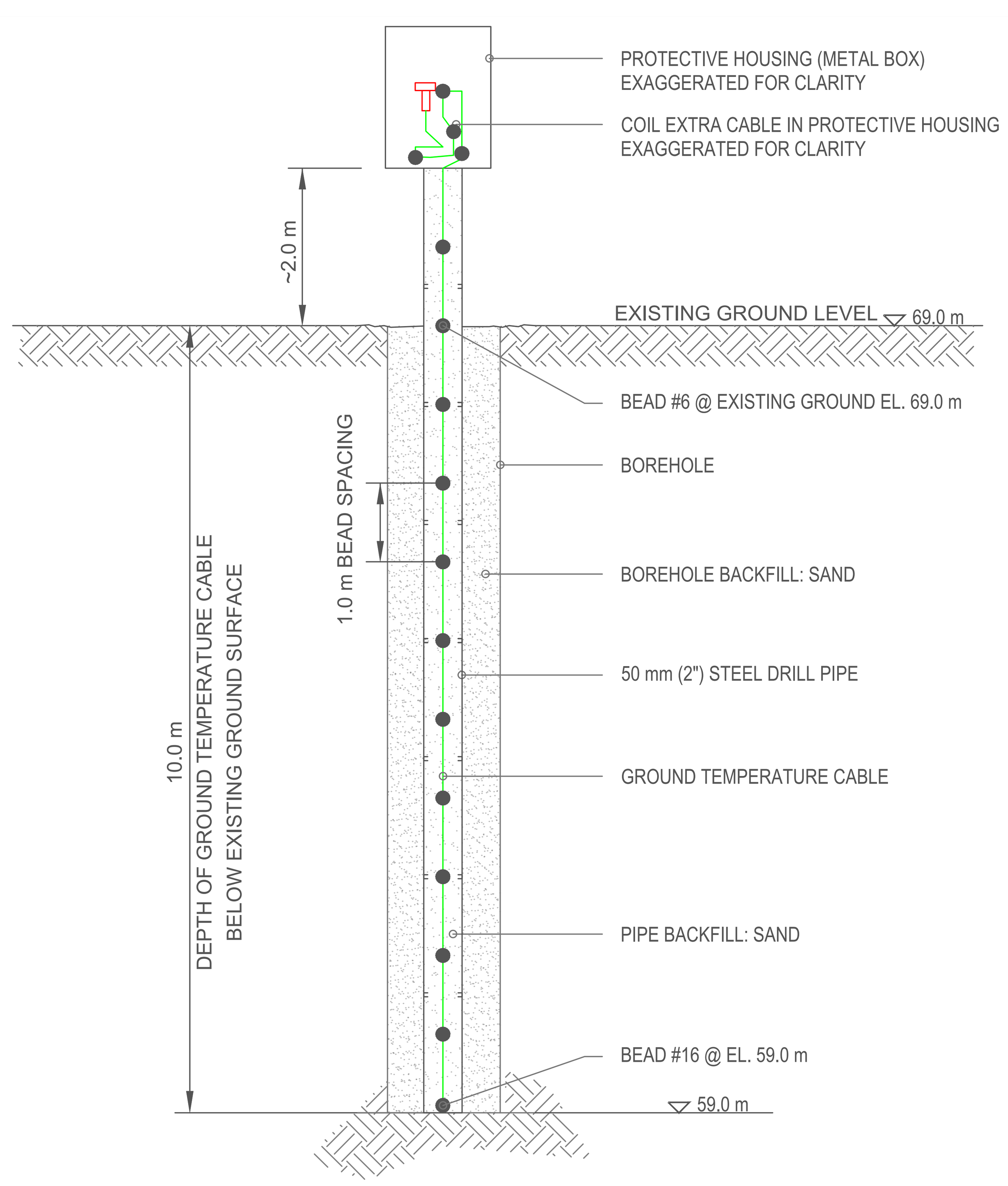



PLAN: TSF AT END OF Q4 2020

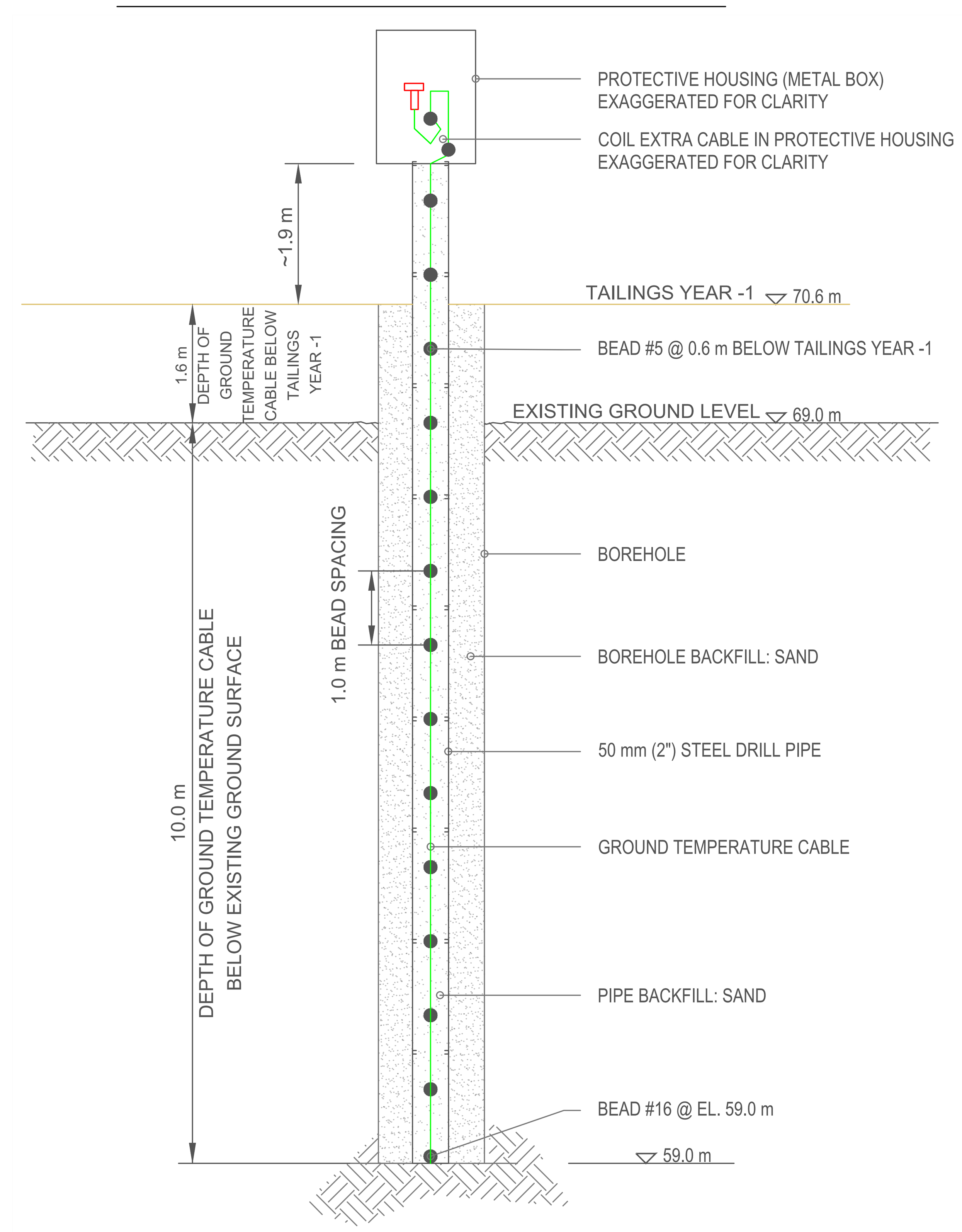
| TSF GROUND TEMPERATURE CABLE INSTALLATION | | | |
|---|---|---|---|
| GTC # | EASTING | NORTHING | ORIGINAL GROUND ELEVATION (m) |
| TSF-GTC-01 | 538661.0 | 6989945.1 | 69.0 |
| TSF-GTC-02 | 538711.9 | 6989567.9 | 66.0 |

NOTES:

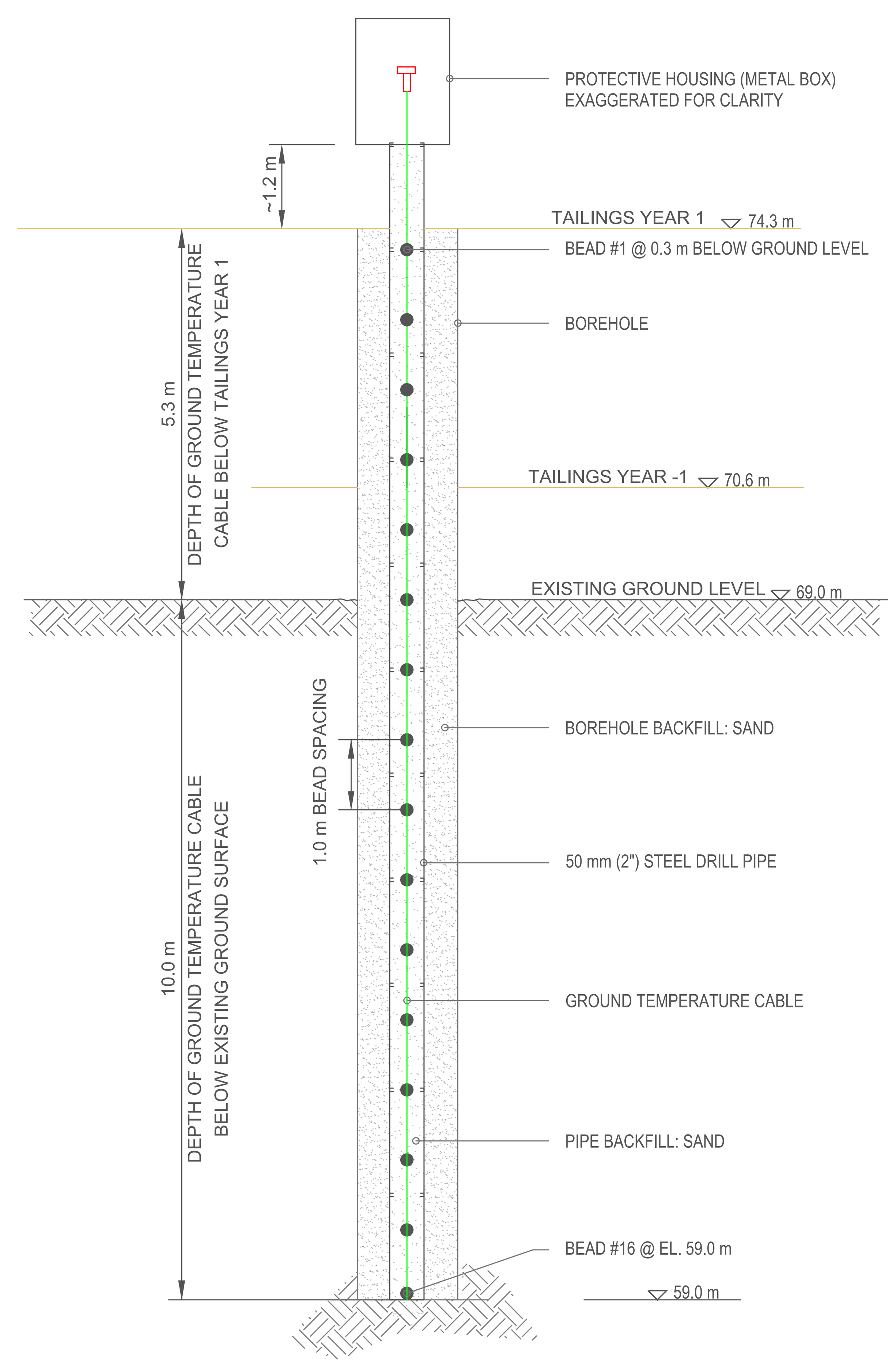
- TOTAL GROUND TEMPERATURE CABLE LENGTH IS 17 m (16 BEADS SPACED 1 m APART AND 2 m LEAD LENGTH).
- DETAIL FIGURES ARE HORIZONTALLY EXAGGERATED FOR CLARITY, VERTICAL BEAD SPACING AND TAILINGS/EXISTING GROUND ELEVATIONS ARE TO SCALE (BEAD SIZE IS EXAGGERATED FOR CLARITY).
- ADD 50 mm (2") STEEL DRILL PIPE, AS REQUIRED, WITH THE ADDITION OF TAILINGS TO THE TSF.
- THREAD THE GROUND TEMPERATURE CABLE THROUGH THE BOTTOM OF THE DRILL PIPE AS MORE PIPE ARE ADDED. RAISE THE PROTECTIVE HOUSING AS MORE DRILL PIPE ARE ADDED.
- DETAILS FOR TSF-GTC-02 SHOWN ON FIGURE 18




TSF-GTC-01 INSTALLATION Q1 2019

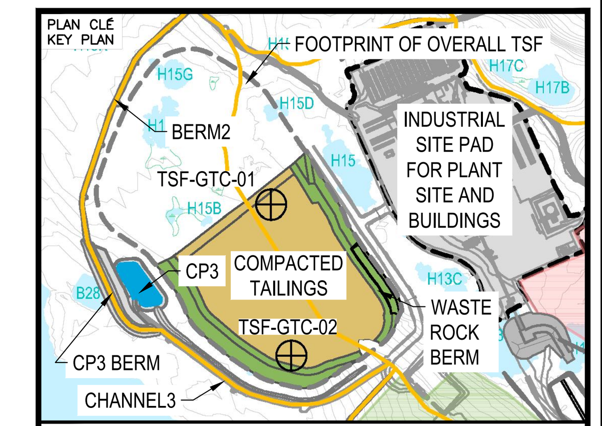



TSF-GTC-01 INSTALLATION Q4 2019




TSF-GTC-01 INSTALLATION Q4 2020

PLAN CLÉ
KEY PLAN




TETRA TECH

NOTES GÉNÉRALES / GENERAL NOTES

- WASTE ROCK BERM
- TAILINGS
- GROUND TEMPERATURE CABLE
- CATCHMENT BOUNDARY

DESSINS EN RÉFÉRENCE / REFERENCE DRAWINGS

| TITRE / TITLE | # DWG |
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TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY
TSF DURING OPERATION
GROUND TEMPERATURE CABLE INSTALLATION
LOCATION PLAN AND DETAIL FOR TSF-GTC-01

| | | DATE |
|---|---|---|
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| VÉRIFIÉ PAR / CHECKED BY | GZ | 2019-01-29 |
| APPROUVÉ PAR / APPROVED BY | WTH | 2019-01-29 |
| ÉCHELLE / SCALE | | |

NO. DESSIN / DRAWING NO. 6515-583-163-FIG-017

NO. PROJET / PROJECT NO. | REVISION 0 | FEUILLE / SHT 17 / 24

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FILE NO. .DWG

NO. DESSIN
DRAWING NO.

NOTES:
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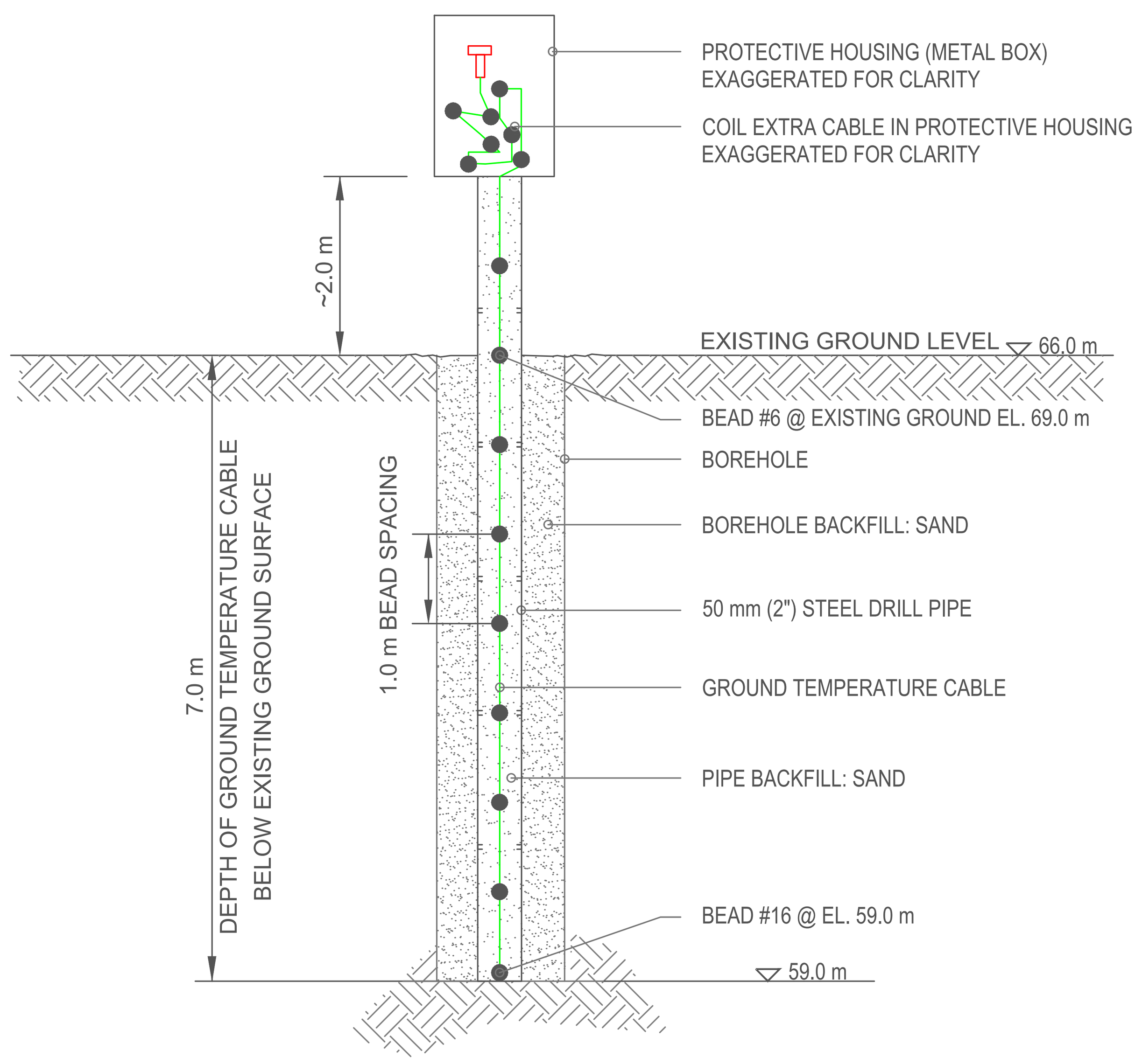
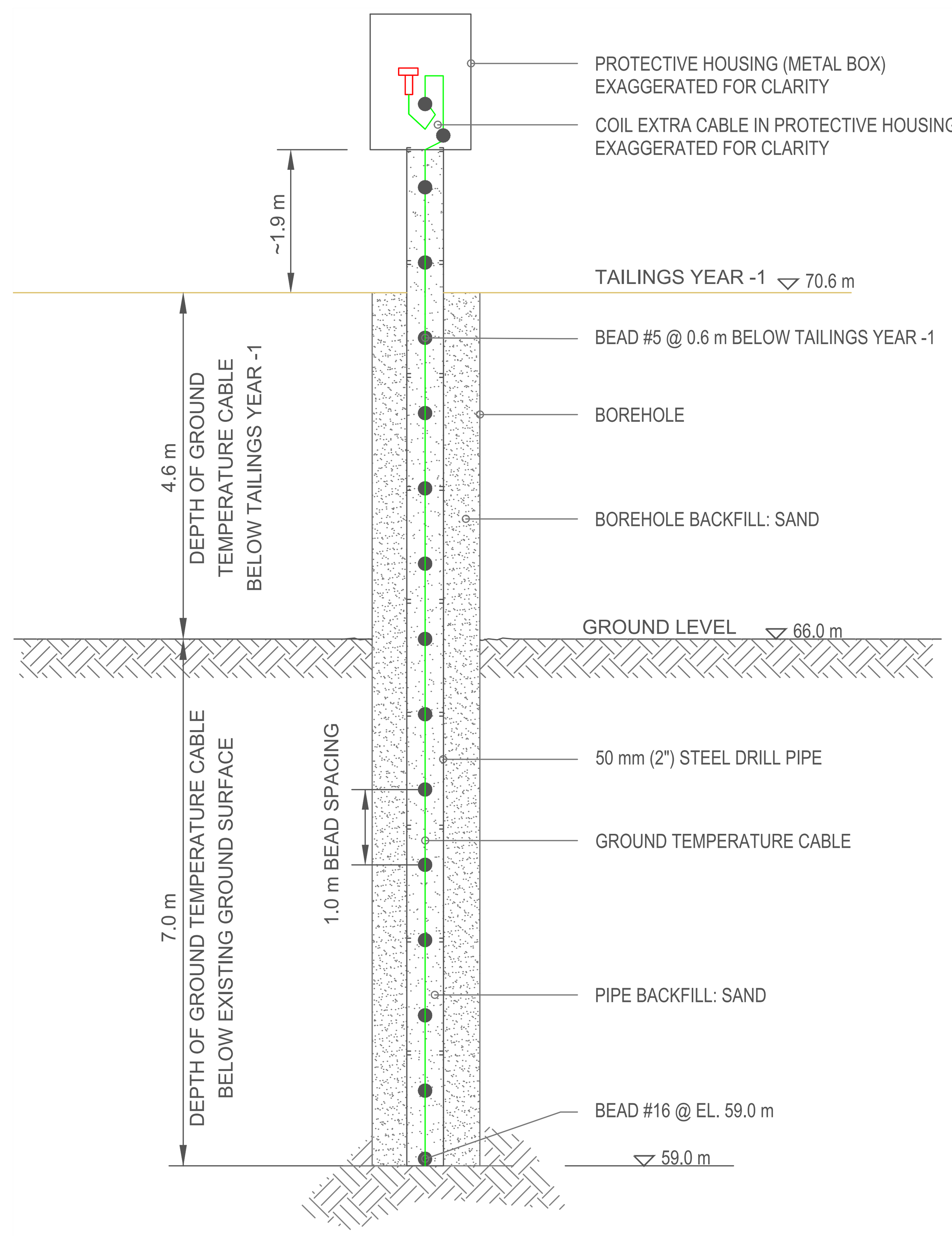
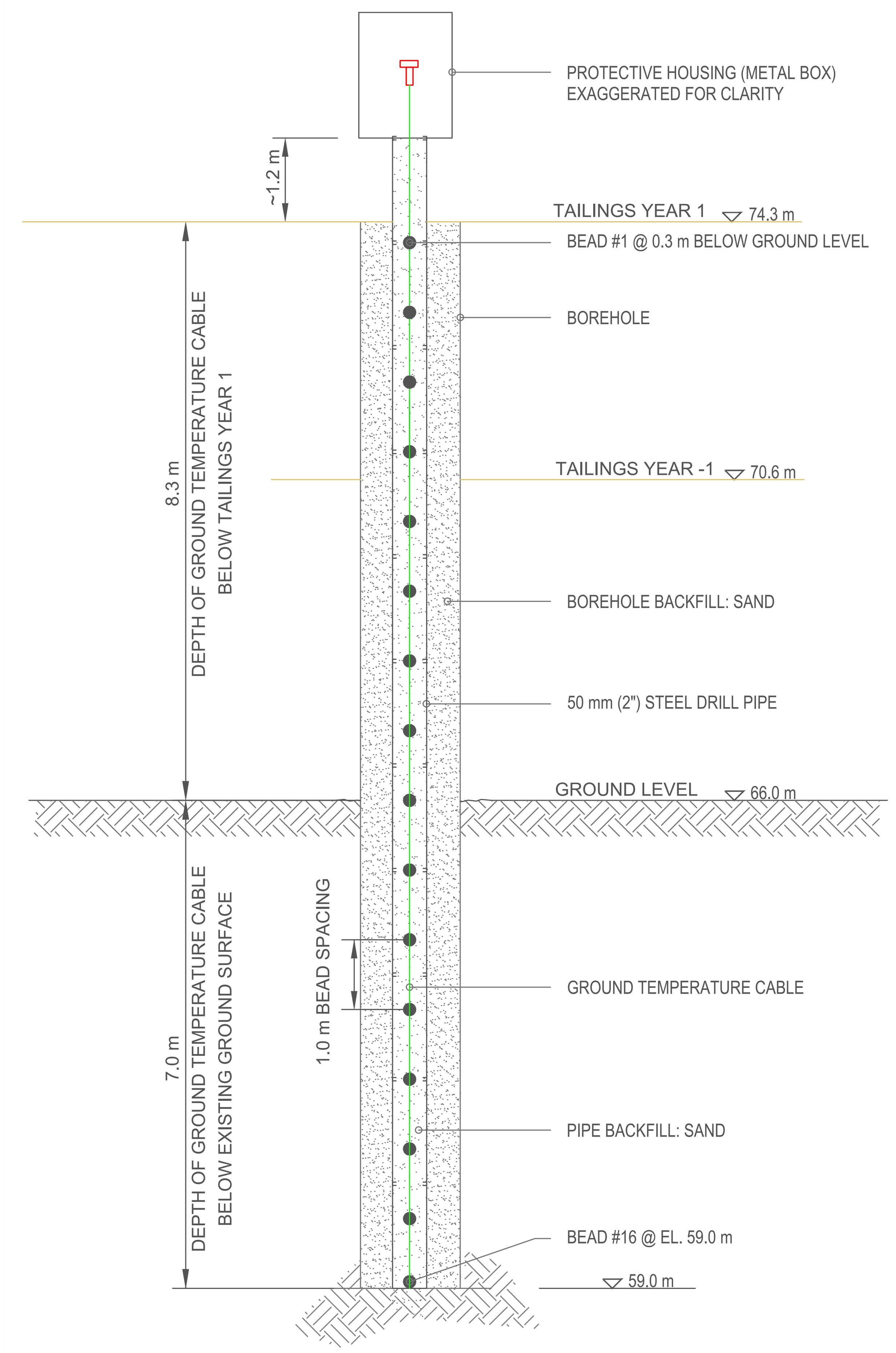
- LOCATION PLAN FOR TSF-GTC-02 SHOWN ON FIGURE 17




*TSF–GTC–02 INSTALLATION Q1 2019*



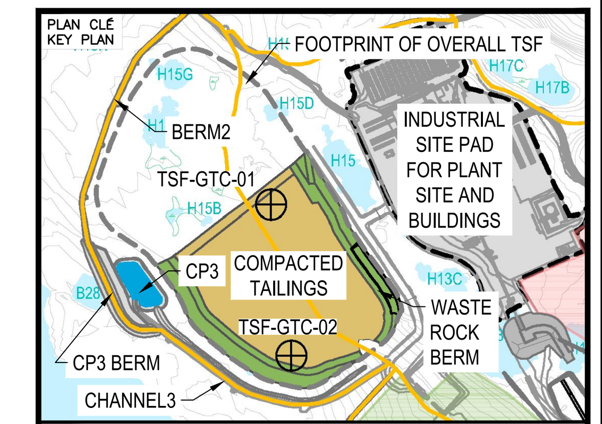

*TSF–GTC–02 INSTALLATION Q4 2019*




*TSF–GTC–02 INSTALLATION Q4 2020*

FORMAT ARCHD

PLAN CLÉ
KEY PLAN




TETRA TECH

NOTES GÉNÉRALES / GENERAL NOTES

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TITRE / TITLE
MELIADINE TAILINGS STORAGE FACILITY
TSF DURING OPERATION
GROUND TEMPERATURE CABLE INSTALLATION
DETAIL FOR TSF–GTC–02

| | | DATE |
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| DESSINÉ PAR / DRAWN BY | EP / EL | 2019–01–29 |
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| APPROUVÉ PAR / APPROVED BY | WTH | 2019–01–29 |
| ÉCHELLE / SCALE | | DATE |

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Q:\Edmonton\Engineering\E141\Projects_MELIADINE\ENG.EARC03147–01 (Detailed Tailings Deposition Plan)\Figure 17–18 Instrumentation (Jan23_2019).dwg–2013–02–19 12:48:32

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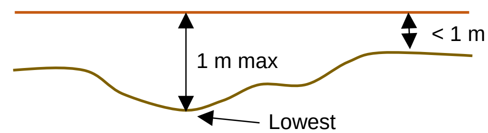
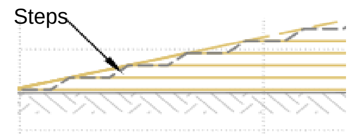
# APPENDIX C – TSF OPERATIONAL PROCEDURE

| TSF PRE-CONSTRUCTION PROCEDURE | | | |
|---|---|---|---|
| **Task Required** | **Department** | **Expected Timeline** | **Comments/Details** |
| Instrumentation<br>- Install GTCs | Engineering | 2019<br>On-going | First 4 cables installed<br>Additional cables to be installed prior to Cell2 placement |
| Snow removal (winter conditions) | E&I | Prior to material placement on original ground | Excess snow/ice must be removed prior to placement of tailings/waste rock on the tundra<br>Care must be taken to not remove tundra |
| Survey<br>- Topographical survey of OG<br>- Stake **<u>toes</u>** of WR cover berm<br>- Mark first lift (correction) height<br>- Stake limits of tailing placement<br>- Mark first lift height to designated elevation | Engineering | Prior to material placement on original ground | Waste rock to be placed in maximum lift heights of 1.0 m<br>First lift will be correction (variable heights)<br>Subsequent lifts will be to set elevation<br><br><u>Correction Lift Example:</u><br><br>Each lift of tailings will be to a designated elevation |
| **TSF OPERATIONAL PROCEDURE** | | | |
| Load/Haul/Place WR Cover Berm<br>- Remove excess snow from ground within WR cover berm footprint<br>- Load/Haul waste rock from Portal 2 to TSF<br>- Dump waste rock within survey stakes<br>- Spread waste rock with D6 to just outside the survey stakes to marked lift height<br>- Compact each lift with 10 ton vibratory compactor before placing the next lift<br>- Slope to design H:V with CAT 330 excavator after placement/compaction of 2 lifts | E&I | Prior to initial tailings placement within a cell | Compaction of each lift to occur to the satisfaction of the Geotechnical Engineer<br>Compaction should consist of:<br>- Minimum 3 passes (forward + backward = 1 pass) with 10 ton<br>- 10 ton should be moving at turtle speed<br>- The entire surface area of the lift needs to be compacted<br>Survey to stake toes of each lift and mark lift heights (design elevation) |
| Tailings Placement<br>- Remove excess snow from tailings footprint prior to placement on original ground<br>- Load/Haul tailings from TDB (also known as 'Church') to TSF<br>- Dump tailings within survey stakes | E&I | As shown on Deposition Drawings | Compaction of each lift to occur to the design specification:<br>- Three (3) passes (forward +backward = 1 pass) with 10 ton on high vibrate<br>- One (1) pass with NO vibration (static roll) to smooth surface ** no static roll needed if additional lifts to be placed in that area |

| | | | |
|---|---|---|---|
| - Spread tailings within designated area with D6 to lift # marked on stakes<br>- Compact each lift with 10 ton vibratory compactor<br>- Remove snow from placed tailings prior to placement of next lift<br>- Haul contact snow to designated snow dump location<br>- Place/Compact right against waste rock berm (where applicable)<br>- When not placing tailings against waste rock, each lift should be "stepped" in a staircase-like structure to ensure good contact when abutting areas are placed | | | immediately.<br><br>(Winter placement) Immediately after dumping of Tailings at TSF, the material must be spread and compacted before freezing in order to achieve desired compaction and prevent dust emissions.<br>Once compacted. avoid trafficking on these areas to minimize dust generation<br> |
| Load/Haul/Place Waste Rock Cover<br>- Remove excess snow from top of initial waste rock berm and temporary safety berm<br>- Pull and spread material from temporary safety berm throughout next lift<br>- Load/Haul waste rock from Portal 2 to TSF<br>- Dump waste rock within survey stakes<br>- Place waste rock on tailings "staircase" and spread just outside survey stakes to specified lift height<br>- Compact with 10 ton vibratory compactor<br>- Slope sides to design H:V with CAT 330<br>- Re-establish temporary safety berm on new lift | E&I | On-going after tailings placement commences | Additional waste rock cover material must be placed after every 3 lifts of tailings (0.9 m) has been placed |
| Operational Survey<br>- Stake limits of each tailings lift<br>- Mark heights (design elevation) of each tailings lift<br>- Spot check tailings grade in field<br>- Stake toes of each waste rock lift<br>- Mark lift height of each waste rock lift<br>- Spot check waste rock grade in field<br>- Spot check waste rock slope in field | Engineering | On-going during placement | |
| Quantity Reporting<br>- Expected tailings production<br>- Truck counts/Load sheets<br>- As-built survey of waste rock and tailings | <br>Mill<br>E&I<br>Engineering | <br>Weekly<br>Daily<br>Monthly | <br>Provide to Engineering, E&I<br>Provide to Engineering weekly<br>Verify against expected production/load counts |

| | | | |
|---|---|---|---|
| Quality Control | | | |
| - Moisture content, temperature of tailings leaving filter presses | Mill | Daily | Provide to Engineering weekly |
| - Moisture content, temperature of tailings being placed | Engineering | Weekly | |
| - Particle size analysis of tailings | Mill | Daily | Provide to Engineering weekly |
| - Dry density of compacted tailings | Engineering | Weekly | Field verification by Geotechnical Engineer until field trial with nuclear densometer<br>Quarterly verification after field trial |
| Inspection and Monitoring | | | |
| - Regular visual inspections during open water season | Engineering/ Environment | Weekly | Maintain records of all inspections |
| - Third-party visual inspection | Engineering | Annual | Required under Part I, items 14 and 15 of Water License-2AM-MEL1631 |
| - Regular thermistor readings | Environment | Monthly during first year then quarterly | Provide to Engineering for analysis and record keeping |

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# Thermal Modelling of Meliadine WRSFs

**February 14, 2022**

AGNICO EAGLE

okane

Integrated Mine Waste Management and Closure Services

Specialists in Geochemistry and Unsaturated Zone Hydrology

# Thermal Modelling of Meliadine WRSFs

*948-021-005 Rev5*

February 2022

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| Rev. # | Rev. Date | Author | Reviewer | PM Sign-off |
|---|---|---|---|---|
| 0 | November 4, 2020 | JS | MOK | GA |
| 1 | March 18, 2021 | LT | JS | GA |
| 2 | April 28, 2021 | LT | JS | GA |
| 3 | August 5, 2021 | LT | JS | LT |
| 4 | October 22, 2021 | LT | JS | LT |
| 5 | February 14, 2022 | KH | LT | LT |

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# EXECUTIVE SUMMARY

The Meliadine Project is comprised of six known gold deposits and development is proceeding in a phased approach (known as the Approved Project under the Water License Amendment, and the Meliadine Extension Project), until 2043. The phased approach allows for development to occur within capital constraints and during concurrent exploration. The Meliadine Extension Project will be composed of 12 additional open pits and underground workings, waste rock storage facilities, tailings storage facilities expansion, water management facilities, and construction of a haul road between Tiriganiaq and Discovery.

O'Kane Consultants Inc. (Okane) was retained by Agnico Eagle Mines Limited (Agnico Eagle) to complete a thermal assessment, which also includes evaluation of seepage conditions, of the waste rock storage facilities (WRSFs) at the Meliadine Extension Project. The objectives of the detailed thermal and seepage modelling are to:

- address very high-risk failure modes identified in a failure modes and effects analysis for the Meliadine WRSFs (Okane, 2020);
    - Quality control of potentially acid generating and metal leaching (PAG/ML) waste rock placement is insufficient, leading to increased geochemical loading from WRSFs;
- provide long-term hydrologic and thermal inputs for the site-wide water and load balances for assessing the impact of WRSFs on site-wide water quality; and
- support a basis for closure design of the WRSFs, which is defendable to internal project stakeholders and regulators.

A generic idealized WRSF cross section was selected, and sensitivity completed on this cross section to capture the variability of waste rock encountered on site. The Generic WRSF is representative of the majority of Meliadine WRSFs in terms of general configuration and expected waste rock/overburden distribution; the Meliadine WRSFs will have a substantial volume of overburden at the core of the WRSFs. Overburden at Meliadine is expected to be non-potential acid generating and non-metal leaching (NPAG/NML).

A climate change scenario was modelled, representative concentration pathway (RCP) 4.5, consistent with permitted conditions for the existing Meliadine project. RCP4.5 represents a 'medium RCP' scenario with stabilization of radiative forcing around 2100. RCP4.5 has been selected as the base case condition for the Meliadine Extension project, consistent with current permitted conditions. RCP4.5 predicts an average annual temperature of approximately -4.6°C over the last 30 years of the climate change database (2090-2120).

The Meliadine WRSFs are expected to have high surface infiltration capacity as a result of the physical nature of the waste rock (i.e. the coarser-textured nature). This high infiltration capacity is expected to lead to formation of ground ice at the boundary of the active layer over time. As this ice layer is established, infiltration will gradually be diverted laterally along the ice layer within the active zone, resulting in interflow reporting at the toe of the WRSFs. Interflow occurs as unsaturated flow, and thus has a long transit time for water infiltrating near the top of the WRSFs. This transit time is in the order of decades, so WRSFs will take decades to reach a pseudo steady-state hydrologic condition where most net surface infiltration reports as interflow.

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# 1 INTRODUCTION

Agnico Eagle Mines Limited (Agnico Eagle) operates the Meliadine Gold Mine, located approximately 25 km north of Rankin Inlet, and 80 km southwest of the hamlet of Chesterfield Inlet in the Kivalliq Region of Nunavut. The Project was approved to proceed subject to Terms and Conditions of the Project Certificate No. 006. The Project is composed of six known gold deposits: Tiriganiaq, F Zone, Pump, Wesmeg, Wesmeg North, and Discovery, with approval to mine all deposits using open pit methods, and to mine Tiriganiaq with open pit and underground methods. Approved facilities include ore stockpiles, waste rock storage facilities, a tailings storage facility, and other various infrastructure.

Agnico Eagle is proposing to expand the Mine (referred to as the Meliadine Extension Project) through additional underground mining and open pit mining. The Meliadine Extension Project is proceeding in a phased approach until 2043. The phased approach allows for development to occur within capital constraints and during concurrent exploration. The Meliadine Extension Project will be composed of 12 additional open pits and underground workings, waste rock storage facilities, tailings storage facilities expansion, water management facilities, and construction of a haul road between Tiriganiaq and Discovery. O'Kane Consultants Inc. (Okane) was retained by Agnico Eagle to complete a thermal assessment of the waste rock storage facilities (WRSFs) to support development of the Meliadine Extension Project for regulatory approval.

Thermal modelling will assist in developing the expected seasonal active layer through operations and post-closure and determine if permafrost conditions within the WRSFs are sustainable under climate change conditions. As part of this objective, a landform water balance was also completed for the operational, closure and post closure phases, including estimates of runoff, interflow, and basal seepage rates. Results of this thermal and seepage modeling work will be used to meet requirements of the impact statement guidelines, and to inform other work such as a detailed site water quality and load balance model for operations through post-closure.

Assessment of long-term thermal stability waste rock storage, ore storage, and tailings storage was a requirement of the initial environmental impact statement and will be a requirement for any future amendments to the environmental impact statement and the Project Certificate.

## 1.1 Project Objectives and Scope

The objective of the detailed thermal and seepage modelling is to provide long-term hydrologic and thermal inputs for the site-wide water and load balances, as well as a basis for closure design of the WRSFs that it is defendable to internal project stakeholders and regulators, and in line with findings from the FMEA (Okane, 2020). The specific very high failure modes that are addressed, or are in part addressed through the thermal and seepage modelling (Okane, 2020) are as follows:

- *Quality control of potentially acid generating and metal leaching (PAG/ML) waste rock placement is insufficient, leading to increased geochemical loading from WRSFs*. In this context, quality control refers to either the inadvertent placement, or greater than expected volume of PAG/ML waste rock in areas where the waste management plans indicate that only NAG/NML waste rock should be used, or the lack of a clear waste rock management guideline identifying where PAG/ML waste rock storage is acceptable. Greater load from WRSFs than anticipated could result in delays in achieving post-closure status. Long-term, this could lead to off-site effects as the system moves to passive discharge.

Based on this objective, the specific deliverables for the modelling program are:

1) Estimates of runoff, interflow, and basal seepage from WRSFs and overburden piles under climate change conditions scenarios agreed upon by Agnico Eagle.

2) Estimated depths of interaction and pore space temperatures for runoff, interflow, and basal seepage from the WRSFs and overburden piles under climate change conditions scenarios agreed upon by Agnico Eagle.

## 1.2 Report Organization

For convenient reference, this report has been subdivided into the following sections:

- Section 2 – Provides a summary of the site background and a conceptual model of performance of the proposed WRSFs and overburden piles at Meliadine;

- Section 3 – Presents the model assumptions and inputs used for the numerical modelling simulations completed;

- Section 4 – Summarizes the results of numerical models and provides a discussion on the potential implications of results on site-wide water quality; and

- Section 5 – Suggests recommendations for next steps based on the modelling results presented.

# 2 BACKGROUND

The Meliadine Extension Project includes 12 additional open pits and underground workings, WRSFs, TSF expansion, water management facilities, and construction of a haul road between Tiriganiaq and Discovery (Figure 2.1 and Figure 2.2).

Waste rock and overburden will be trucked to WRSFs throughout mine operations. Currently, Phase 1 has begun with development of the Tiriganiaq Underground deposit and construction of WRSF1 and WRSF3. At both facilities, overburden will be encapsulated by waste rock. It is assumed that similar construction methodology will form the base case for the Meliadine Extension Project WRSFs.

## 2.1 Conceptual Model

A conceptual model describes key processes, or mechanisms, and their site-specific respective controls, which are expected to influence performance of the proposed WRSFs. It is presented at a conceptual level, using a hierarchy of climate, geology and materials, and topography, leading to an understanding of the patterns of water movement on a specific landscape (INAP, 2017).

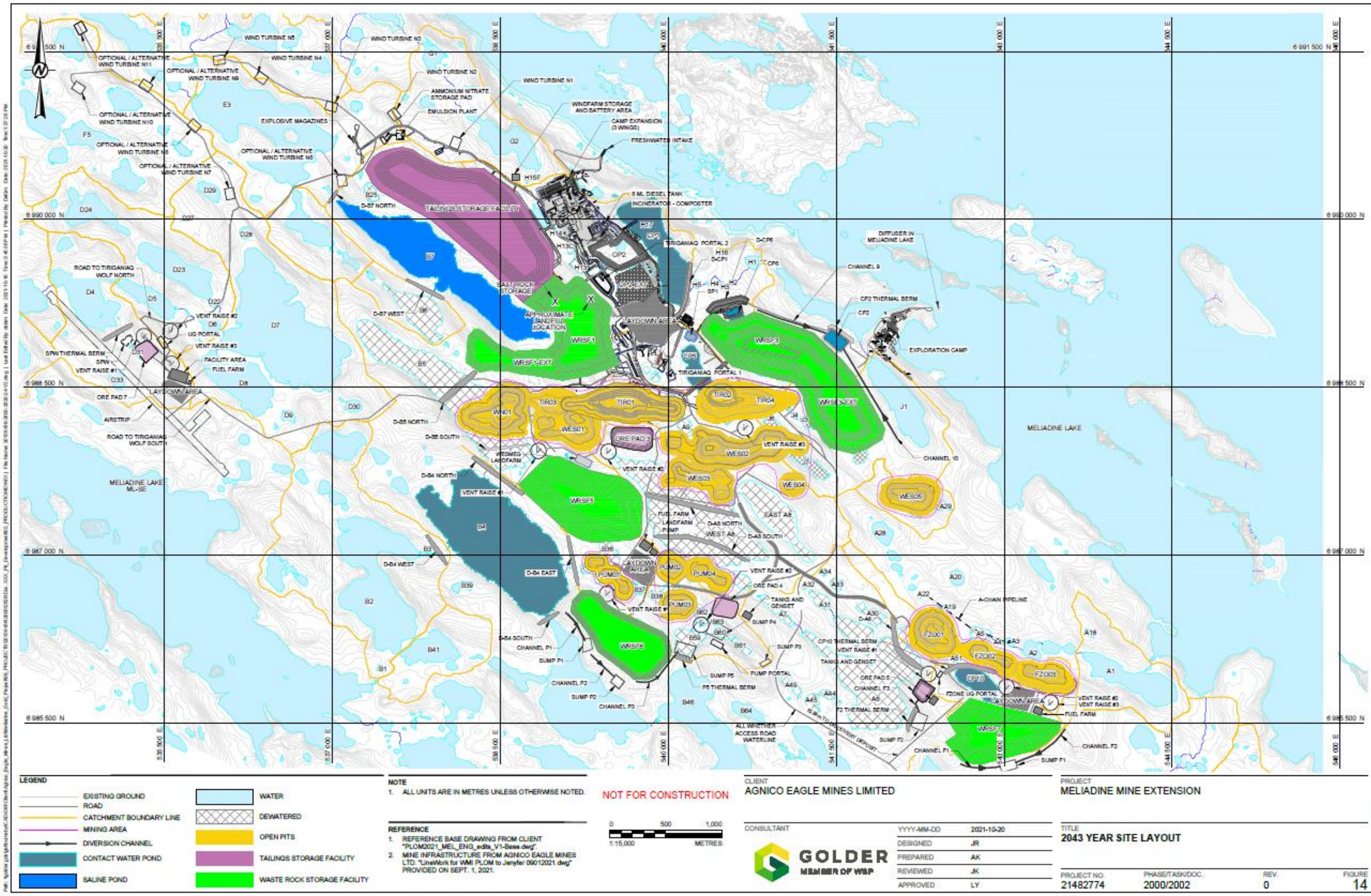


**Figure 2.1 : Meliadine Extension Project site layout.**

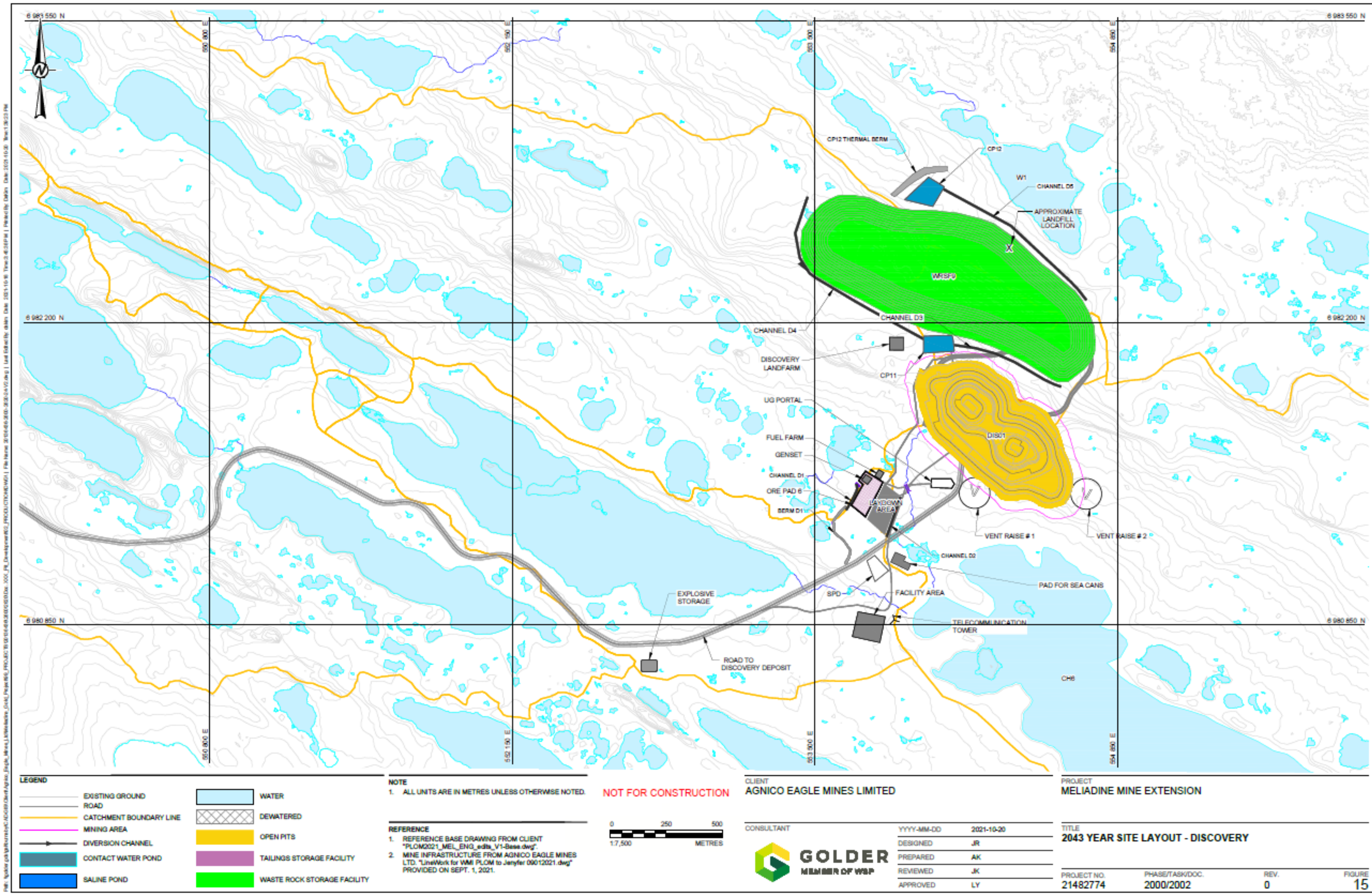


**Figure 2.2: Meliadine Discovery site layout.**

#### *2.1.1 Conceptual Model of Surface Water Balance*

The Meliadine site falls near the intersection of the ET (polar tundra) and Dfc (subarctic climate) classification of the Köppen-Geiger climate classification system where:

- E – 'polar' where average temperature of the warmest month is < 10°C;
- T – 'tundra' where the average temperature of the warmest month is < 10°C, but > 0°C;
- D – 'continental' where average temperature of the coolest month is < -3°C, and average temperature of warmest month > 10°C;
- f – 'without a dry season' where precipitation is relatively evenly distributed throughout the year; and
- c – 'cold summer' where one to three months average temperature reach < 22°C but > 10°C.

Annual precipitation is approximately 430 mm, distributed relatively evenly as snowfall and rainfall. Climate data suggest that the site has a relatively balanced annual surface water budget, or slight water deficit, where the ratio of potential evapotranspiration (PET), sublimation, and snow redistribution is approximately equal to total annual precipitation. There is expected to be a water deficit throughout the summer as potential evaporation (PE) exceeds rainfall in June through August, and a water surplus in September, as PE decreases. Climate data suggest that net percolation, the water that moves from a cover system into a WRSF when a cover system is in place, or simply just surface infiltration when there is no cover system placed, is likely to occur in the fall period when PE is low, and potentially during spring freshet.

Waste rock is expected to have very low available water holding capacity (AWHC) (<3 mm). The available water holding capacity refers to the volume of water held within a granular material that may be available for evapotranspiration. Given high evaporative conditions in July through August, this available water holding volume may be 'recycled' several times, as the volume of water held in the waste rock increases following a rainfall event, then is evapotranspired in the following period when it is no longer raining (or evaporates if/when there is little to no vegetation present). Climate data indicates there are typically 50-60 days where precipitation occurs between July to August. Based on the assumption that evapotranspiration is limited to non-rainfall days and is limited to the surficial metre of material, the maximum probable volume of water lost to evapotranspiration is approximately between 55 mm to 165 mm. This depth of evapotranspiration represents roughly 15%-40% of total annual precipitation.

The coarser-textured nature of the waste rock, which results in low available water holding capacity, also results in high surface infiltration capacity (though influenced by non-frozen conditions), and thus low surface water runoff potential. In short, the potential for saturated overland flow is very low. As noted, frozen conditions in the waste rock during spring freshet will both decrease the permeability of the waste rock and reduce viscosity of the water as it approaches its freezing point, leading to the potential for a small volume of runoff to occur in the freshet period.

The last parameter influencing surface infiltration is the portion of snowfall that is sublimated or redistributed. Conditions for sublimation and redistribution are high at Meliadine, particularly at the WRSFs, where windspeed is high and WRSFs are the predominant feature within the landscape. The potential for redistribution is expected to result in a net loss of snow on the WRSF (without accounting for sublimation). Previous estimates (Golder, 2014b) indicated that sublimation may account for up to 50% of the total winter precipitation, or 25% of total annual precipitation. This proportion may be even higher for the wind blown WRSFs at Meliadine.

Given the above drivers of the surface water balance, surface infiltration into the WRSF is expected to be 'high', between approximately 30% to 50% of total annual precipitation (130 mm to 215 mm). Given the low AWHC of the waste rock, the time for wet up of the landform is expected to be relatively short, as the *in-situ* water content of the waste rock is likely similar to its drained field capacity. However, the permafrost conditions which exist within the WRSF will allow for additional water to be stored in the waste rock beyond its field capacity. Fully saturated ice zones are expected to form along the boundary of the seasonal active layer, creating a low permeability ice zone. The active layer in the Meliadine area is generally between 1.0 m to 3.0 m (Golder, 2014b); however, the active layer is expected to be deeper in the WRSF as the thermal conductivity of waste rock is higher, and the volumetric heat capacity is lower than surrounding surficial overburden. The formation of a low permeability ice zone is anticipated to occur in the order of decades.

High salinity porewater (approximately 57 ppt) in waste rock emanating from underground workings will delay freeze back of the WRSFs, but more importantly is expected to increase the depth of the active layer if high salinity material is placed near surface.

The presence of a lower permeability ice zone coupled with the lower permeability of *in situ* surficial overburden and waste overburden or waste rock is expected to reduce basal seepage to negligible levels.

Once the lower permeability ice zone has formed, the WRSF will largely reach a pseudo steady-state condition where, from a hydraulic performance perspective, surface infiltration will report as toe seepage (or interflow along the lower permeability ice zone) from the WRSF (Figure 2.3). This, however, should not be interpreted as a 'plug flow' condition, where a drop of water infiltrating on the plateau of the WRSF reports as interflow in the same time frame as a drop of water infiltrating near the toe of the WRSF. The 'age' of interflow observed will increase over time as areas further away from the toe begin to report, finally reaching a pseudo 'steady-state' condition from a geochemical perspective. This process is also expected to occur in the order of decades. Lastly, interflow water quality is expected to evolve over the life of mine as buffering capacity of PAG/ML waste rock may be exceeded, and available reactive minerals are slowly exhausted.

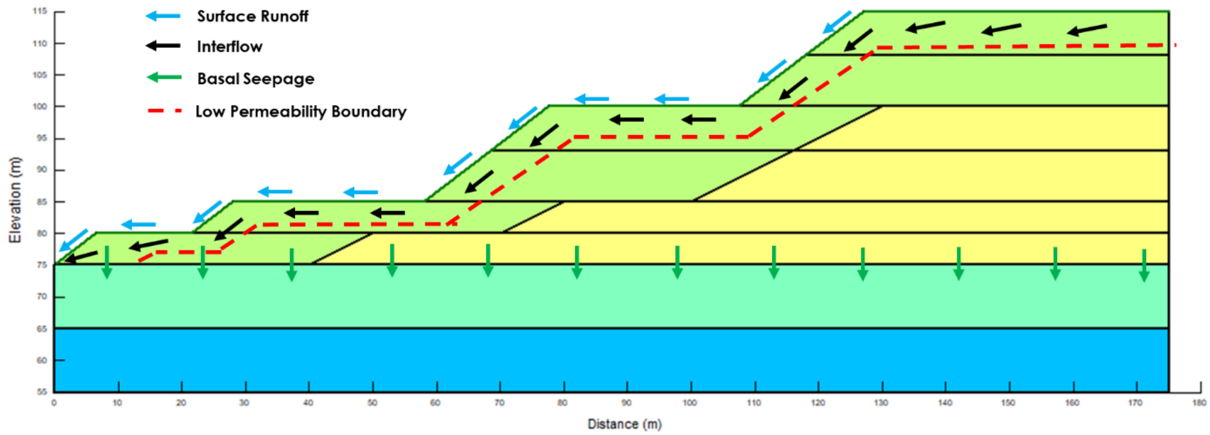


**Figure 2.3: Conceptual sketch of landform water balance at Meliadine WRSFs.**

Climate change in the region is expected to result in a warmer and wetter climate. The anticipated rise in average annual temperature is likely to increase the thickness of the active layer, potentially thawing a portion of the lower permeability ice layer already in place or increasing its depth within the WRSF. The increase in temperature is likely also to increase evaporative conditions; however, this is expected to be similar in proportion to the increase in precipitation resulting in a similar proportion reporting as net percolation (and surface infiltration).

### *2.1.2 Conceptual Model for Oxygen Ingress*

Oxygen availability throughout the WRSFs is not expected to be limited in the short term as the waste rock has very high air permeability (coarser-textured material of relatively low water content when placed). Air permeability can be estimated based on the intrinsic permeability derived from the estimated hydraulic conductivity for a given material, which can be measured in laboratory, or estimated based on material texture (Fredlund et al., 2012). The waste overburden, however, has much lower air permeability. Its presence within the core of the Meliadine WRSFs is expected to limit formation of large-scale convective airflow cells, which are known to encourage freezing of coarser-textured WRSFs in cold climates (Pham et. al, 2013). While co-disposal may limit convective cooling, it is not expected to inhibit freeze-back given the current climate at Meliadine. The lower air permeability of the waste overburden, however, is not expected to limit oxygen availability, as the overburden is assumed to have low reactivity (i.e. the consumption of oxygen due to oxidation reactions in the waste overburden is likely lower than the air permeability).

The presence of ice zones at the boundary of the active layer are expected to reduce air permeability. This may delay freeze back of the WRSFs.

## 2.2 Description of Numerical Modelling Program

GeoStudio Version 10 was used to conduct the modelling for this project, the same software and version that was used in the Whale Tail and IVR WRSFs thermal modelling. This version of GeoStudio is a substantial upgrade to previous software versions, as it accounts for advective air flow as well as mineral oxidation within the WRSF and associated heat generation via an add-in module developed for the software. Four components of the GeoStudio suite of programs were used in combination for this project: SEEP/W; TEMP/W; AIR/W, and CTRAN/W (with the gas consumption and exothermic reactions add-in incorporated into the CTRAN analysis).

SEEP/W is a 1D/2D finite element model that can be used to model the saturated and unsaturated movement of moisture and pore-water pressure distribution within porous materials such as soil and rock. The latest version of SEEP/W incorporates a module that allows for soil-plant-atmosphere (SPA) modelling that was previously included in a separate software package (VADOSE/W). This module calculates pressure head (suction) and temperature profiles in the material profile in response to climatic forcing (such as evaporation) and lower boundary conditions (such as a water table). A key feature of the module is the ability of the model to determine actual evaporation and transpiration based on potential evaporation and predicted suction, as opposed to the user being required to input these surface flux boundary conditions. The actual evapotranspiration rate is generally well below the potential rate during prolonged dry periods because the suction in the material profile increases as the surface desiccates. In addition, the module is a fully coupled (through the vapour pressure term) heat and mass transfer model that is capable of simulating water vapour movement.

The SPA model of SEEP/W is also capable of evaluating the impact of frozen conditions on moisture storage and transport for a given soil or rock material. The change of phase from liquid to solid (i.e. water to ice) is accounted for using the apparent specific heat capacity approach, standard in thermal modelling. A heat source or sink is added at each time step based on the amount of heat released when a set volume of water changes to ice. When the ground becomes frozen, the permeability must be reduced. In the physics of freezing, there is a phenomenon whereby even in a saturated material, a "suction" develops at the ice-water interface much like that at the air-water interface in an unsaturated soil. If the temperature below freezing is known, then the suction can be computed using the Clausius

Clapeyron phase equilibrium equation (Black and Tice, 1989). The SPA module does not account for this suction at the microscopic level in the mass transfer equation, but does use the actual temperature to compute what the suction should be so that the program can look up a reduced permeability from the material's hydraulic conductivity function (suction versus hydraulic conductivity). SEEP/W simulations can be completed with or without this functionality.

TEMP/W is a 1D/2D finite element model that can be used to model thermal changes in porous systems due to various changes in the environment, internal changes in temperature, or any other influencing condition that may result in a change of temperature in the subsurface. Typically, in a TEMP/W simulation, it is assumed that moisture content remains the same. However, when water movement occurs in a system, substantial heat transfer can occur as a result of this movement of water. As such, by coupling the TEMP/W simulation with a SEEP/W simulation, a more accurate temperature condition in the subsurface can be estimated. The freezing point depression caused by increased salinity can be considered in TEMP/W through the phase change temperature and the unfrozen water content function. Adjusting the unfrozen water content function has the advantage of being material specific, but without adjusting the phase change temperature, the latent heat is still applied at 0°C rather than the freezing point depression. Adjusting the phase change temperature affects the entire model domain, which may not be ideal for situations where not all porewater is saline.

AIR/W is a 2D finite element model that is executed within the SEEP/W model, which can be used to model air pressure and flow within a system in response to changes in pressure conditions at the boundary, or changes in water pressure. When coupled with TEMP/W, it can also calculate changes in air flow and pressure as a result of changes in air temperature.

CTRAN/W, with the addition of the gas consumption and exothermic reactions add-in, couples the gas, heat, water, and air transfer processes to simulate the exothermic oxidation process. The add-in models the oxidation process as an irreversible first order reaction. The rate of reaction is dependent on, and controlled by, the availability of oxygen, as well as temperature. The add-in allows oxygen to be consumed and heat to be produced within the WRSF due to sulphide oxidation. The current version of the add-in does not take into account mineral depletion with time, and thus assumes there is a constant supply of sulphide to oxidize, resulting in a conservative estimate of the heat added to the domain as a result of the exothermic oxidation process.

# 3 MODEL INPUTS

Model inputs for Meliadine WRSFs can be divided into five types:

1) Climate / Upper Boundary Conditions;

2) Materials;

3) Geometry;

4) Lower and Edge Boundary Conditions; and

5) Initial Conditions.

The following sections describe the inputs used.

## 3.1 Climate

TEMP/W requires daily surface temperature data whereas SEEP/W and AIR/W require daily values of: maximum and minimum air temperature; maximum and minimum relative humidity (RH); average wind speed; daily net radiation; and precipitation (amount and duration). Historical values for all these parameters, except net radiation, are available from Environment and Climate Change Canada (ECCC) for Rankin Inlet (Station ID: 2303405 and 2303401) (ECCC, 2020), approximately 25 km south of the Meliadine site. Solar radiation for Rankin Inlet is estimated by Environment and Climate Change Canada in the Canadian Weather Energy and Engineering Datasets (CWEEDS) using the MAC3 model (ECCC, 2016). This data was used to estimate net radiation on a daily basis. ECCC has hourly records for Rankin Inlet from 1981 to present, of which the period January 1981 to January 2020 was used to create a 39-year database for the Meliadine WRSFs project. ECCC also provides precipitation data that have been adjusted for gauge undercatch and evaporation due to wind effect, which was incorporated into the Meliadine climate database (ECCC, 2017). The adjusted precipitation data is available until 2013, after which the methodology was reproduced by Tetra Tech (2021) and applied to subsequent years. After comparing the climate data measured at Meliadine from October 2014 to December 2019 to measurements taken at Rankin Inlet for the same time period, it was concluded that the Rankin Inlet data did not need to be adjusted to represent the Meliadine site. Any missing data in the Rankin Inlet climate record were filled with average measurements for a given day.

Table 3.1 provides a summary of the average monthly conditions in the 39-year historical database developed for the Meliadine project.

**Table 3.1: Summary of average climate parameters for the 39-year Meliadine historical climate database with Tetra Tech (2021) adjusted precipitation.**

| Month | Temperature (°C) | | Relative Humidity (%) | | Wind (m/s) | Net Radiation[1] (MJ/m²/day) | Precipitation | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum | | | (mm) | (days) |
| January | -26.7 | -33.9 | 75.3 | 68.4 | 6.7 | -1.8 | 17 | 27 |
| February | -26.4 | -33.7 | 81.8 | 71.2 | 6.6 | -1.0 | 17 | 25 |
| March | -20.7 | -29.2 | 86.8 | 74.3 | 6.5 | 0.1 | 22 | 27 |
| April | -11.4 | -20.4 | 94.2 | 74.9 | 6.3 | 2.5 | 29 | 22 |
| May | -2.3 | -8.9 | 93.3 | 65.7 | 6.2 | 5.0 | 30 | 21 |
| June | 8.1 | 0.6 | 94.2 | 69.4 | 5.6 | 7.2 | 32 | 15 |
| July | 15.1 | 6.3 | 93.5 | 67.0 | 5.4 | 8.0 | 46 | 16 |
| August | 13.2 | 6.3 | 94.1 | 81.1 | 5.9 | 5.5 | 59 | 18 |
| September | 6.4 | 1.4 | 85.0 | 77.7 | 6.6 | 2.3 | 53 | 21 |
| October | -1.8 | -7.2 | 79.8 | 72.8 | 7.3 | -0.1 | 57 | 27 |
| November | -13.0 | -20.8 | 75.2 | 69.8 | 6.9 | -2.0 | 39 | 27 |
| December | -21.7 | -29.2 | 71.8 | 66.4 | 6.6 | -2.2 | 25 | 28 |
| Annual | -6.7 | -14.0 | 83.0 | 71.3 | 6.4 | 1.9 | 426 | 272 |

[1] Net radiation for a level location (e.g. the plateau of the WRSF)

A "synthetic average" climate year was defined by averaging the daily climate conditions from the 39-year climate database (e.g. averaging the maximum temperature on January 1st for all 39 years). However, precipitation was not applied considering solely the daily average amount, but also the average number of precipitation events per month. Hence, precipitation was applied for the average number of rainfall days per month and on days with the highest chance of rainfall. The daily rainfall amounts for days with lower chances of rainfall were added to the next high-chance event in the month so that the synthetic average climate year had the average amount of rainfall.

### *3.1.1 Climate Change*

The 39-year historical database presented above was adapted to account for climate change predictions over the next 100 years. This process is explained in the remainder of this section.

As part of the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5), the IPCC adopted new representative concentration pathways (RCPs) to replace the previous emission scenarios of the Special Report on Emission Scenarios (SRES) (IPCC, 2013). The four adopted RCPs differ from the SRES in that they represent greenhouse gas concentration trajectories, not emissions trajectories. The four scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) are named after the radiative target forcing level for 2100, which are based on the forcing of greenhouse gases and other agents and are relative to pre-industrial levels (van Vuuren et al., 2011). RCP2.6 represents a very low RCP with a peak of radiative forcing at around 3.1 W/m$^2$ mid-century, followed by a decline to 2.6 W/m$^2$ by 2100. RCP4.5 represents a medium RCP with stabilization of radiative forcing around 2100. RCP6.0 represents a medium-high RCP with stabilization of radiative forcing shortly after 2100, while RCP8.5 represents a high RCP with increasing emissions that do no stabilize until after 2200. Climate at the Meliadine site is expected to remain within the subarctic (Dfc) climate category, described above, under the A1FI (former SRES emission scenarios) climate change scenario, which is similar to RCP8.5 (Rubel and Kottek, 2010). A 100-year climate change database for this project was developed using daily data under RCP4.5, RCP6.0 and RCP8.5. Figure 3.1 provides the concentration of all forcing agents (in parts per million (ppm) of $CO_2$-equivalence) for the four RCP scenarios.

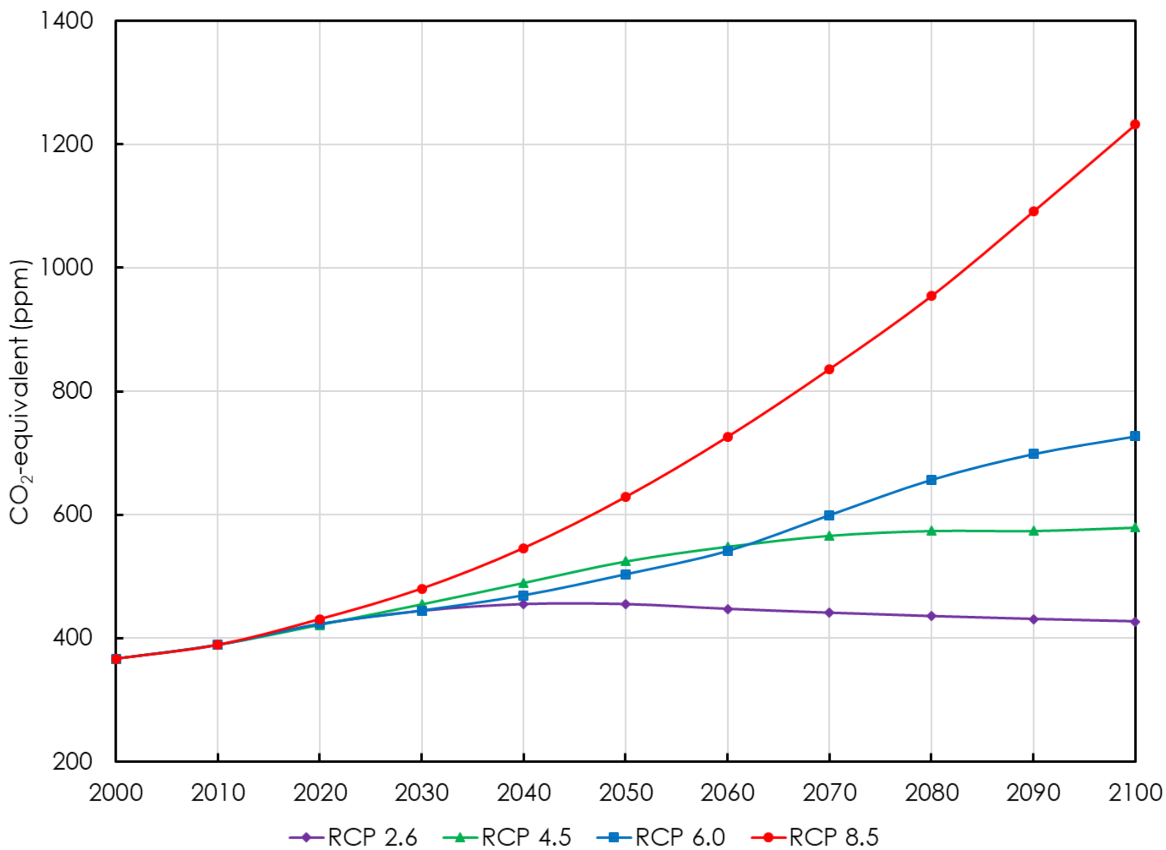


**Figure 3.1: All forcing agents' atmospheric $CO_2$-equivalent concentrations according to the four RCP scenarios.**

The climate change database for Meliadine was developed following the recommendations outlined on the Canadian Climate Data and Scenarios (CCDS) website, which is wholly supported by ECCC (CCDS, 2018). The website recommends the use of statistical downscaling to "downscale" a general circulation model's (GCM's) predictions to a specific location based on historical observations. Statistical downscaling is a two-step process consisting of: i) development of statistical relationships between local climate variables (e.g., surface air temperature and precipitation) and large-scale predictors (e.g., pressure fields), and ii) application of such relationships to the output of GCM experiments to simulate local climate characteristics in the future. The Pacific Climate Impact Consortium (PCIC) at the University of Victoria provides statistically downscaled daily temperature and precipitation under the RCP2.6, RCP4.5 and RCP8.5 scenarios for all of Canada at a resolution of approximately 10 km (PCIC, 2018). For this project, the second-generation Canadian Earth System Model (CanESM2), developed by the Canadian Centre for Climate Modelling and Analysis (CCCma), was used as the predictor GCM to downscale and make climate change databases representative of Meliadine. Temperature and precipitation were derived from the PCIC output, while the other climate variables required for SEEP/W and TEMP/W (i.e. relative humidity and net radiation) were downscaled using the Statistical Downscaling Model (SDSM) (Wilby et al., 2002; 2013; 2014), with the exception of wind speed due to the lack of climate change predictors.

Statistical downscaling is limited by the availability of large-scale predictors. Current CCCma CanESM2 model runs are limited temporally to 2100. In order to predict beyond 2100, the radiative forcing trend was applied to the temperature. RCP4.5 and RCP6.0 are expected to stabilize shortly after 2100, while RCP8.5 is expected to continue along the same trend until after 2200 (Meinshausen et al., 2011).

The CCCma does not provide GCM output for RCP6.0. In order to develop annual averages for RCP6.0, a weighted average function of RCP4.5 and RCP8.5 was developed based on the predicted climate change trends in Northern Canada using the Community Climate System Model, version 4 (CCSM4) (Peacock, 2012). Figure 3.2 and Figure 3.3 show the annual temperature and precipitation, respectively, estimated for the RCP4.5 and RCP6.0 100-year climate databases developed for Meliadine. Temperatures are anticipated to rise at about the same rate (approximately 0.06°C/year) for RCP4.5 and RCP6.0 until approximately 2070, after which RCP4.5 estimates a reduction in the temperature increase rate. RCP4.5 predicts an average annual temperature of approximately -4.6°C over the last 30 years of the climate change database (2090-2120), while RCP6.0 predicts an average annual temperature of -3.2°C over the same time period. Both scenarios predict an increase in precipitation with time. An increase of approximately 13 mm over 100 years or 0.013 mm/year is predicted for RCP4.5, while an increase of approximately 18 mm over 100 years or 0.018 mm/year is predicted to RCP6.0. RCP4.5 was selected as the scenario for the base case simulations which means that the model sensitivities described in Table 4.1 all use RCP4.5 as a common climate input for comparison purposes.

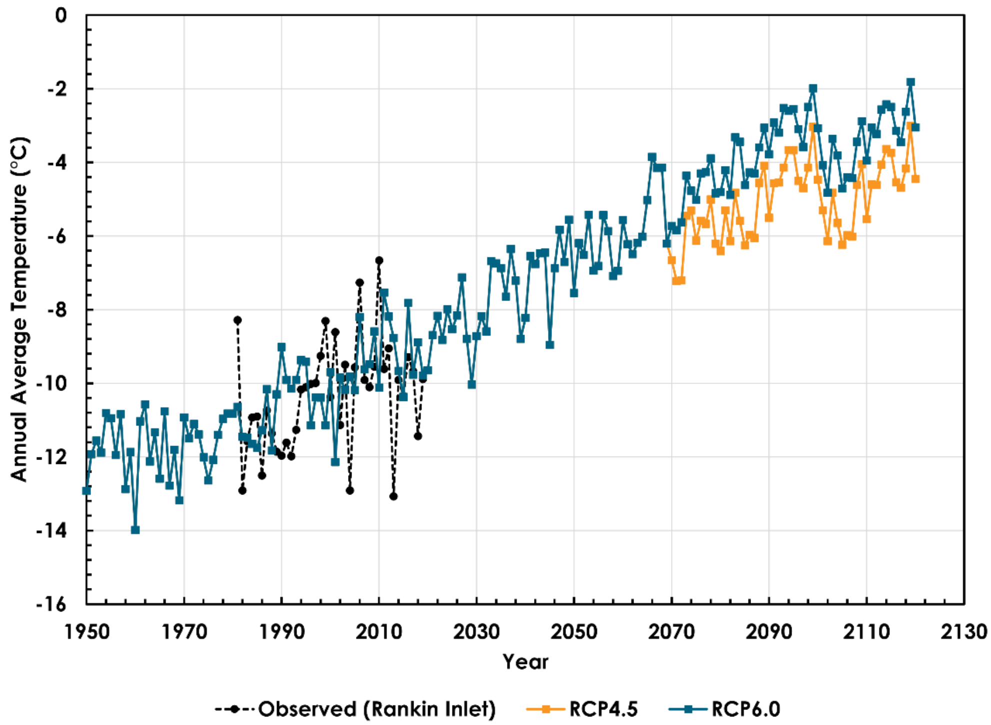


**Figure 3.2: Annual average temperature estimated for the RCP4.5 and RCP6.0 climate change scenarios. Observed temperature at Rankin Inlet is also shown.**

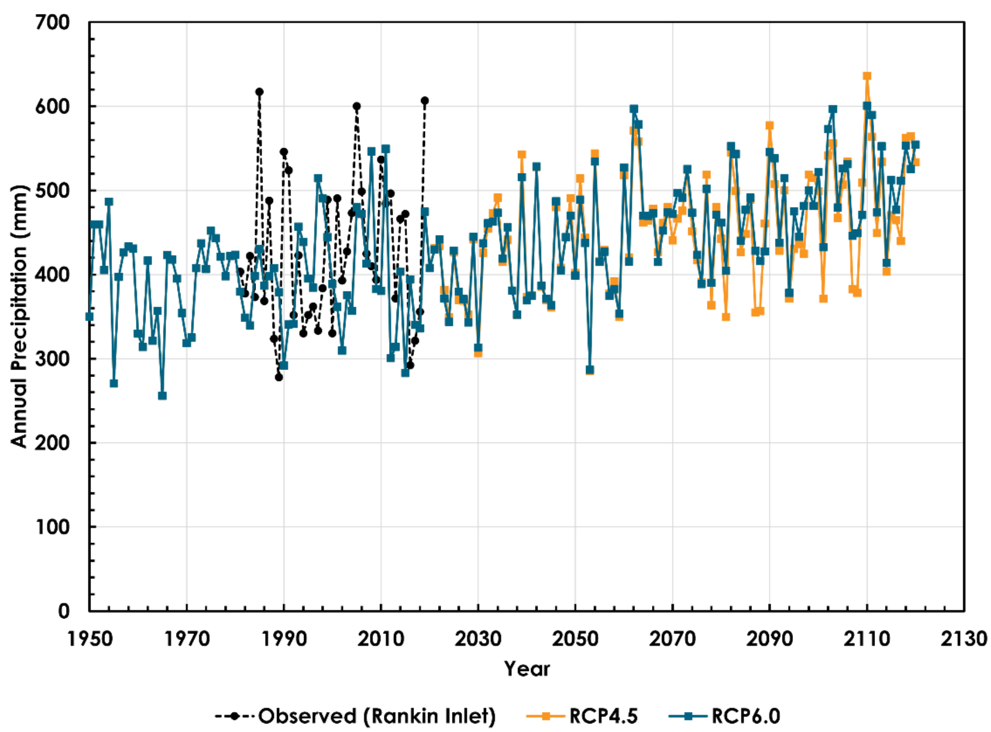


**Figure 3.3: Annual precipitation estimated for the RCP4.5 and RCP6.0 climate change scenarios. Observed precipitation at Rankin Inlet is also shown.**

To account for creation of micro-climates on WRSF embankments, calibrations to the base 100-year climate database were done to the net radiation and wind speed parameters. Net radiation was adjusted for north facing and south facing according to the method proposed by Swift (1976) and Weeks and Wilson (2006). Wind direction and speed were also adjusted for the modelled cross sections by creating a specific wind speed data set for NW and SW directions according to the wind roses shown in Figure 3.4 prepared from hourly wind speed and direction data from Rankin Inlet between January 1981 and January 2020. Figure 3.5 shows the wind roses for wind speed and direction from Meliadine Site between September 2014 and December 2019. The effects of surrounding landforms (such as the WRSFs) were assumed not to affect wind speed and direction. As the WRSFs are expected to be the dominant landform in the adjacent landscape, this is a reasonable assumption.

The impact of wind on the thermal regime (forced convection/advection) is likely limited to the edges of the WRSF in the predominant wind direction (NW), as the permeabilities of the materials are not sufficient to allow high enough air velocities within the centre of the WRSF to drive advection (Pham et al., 2015).

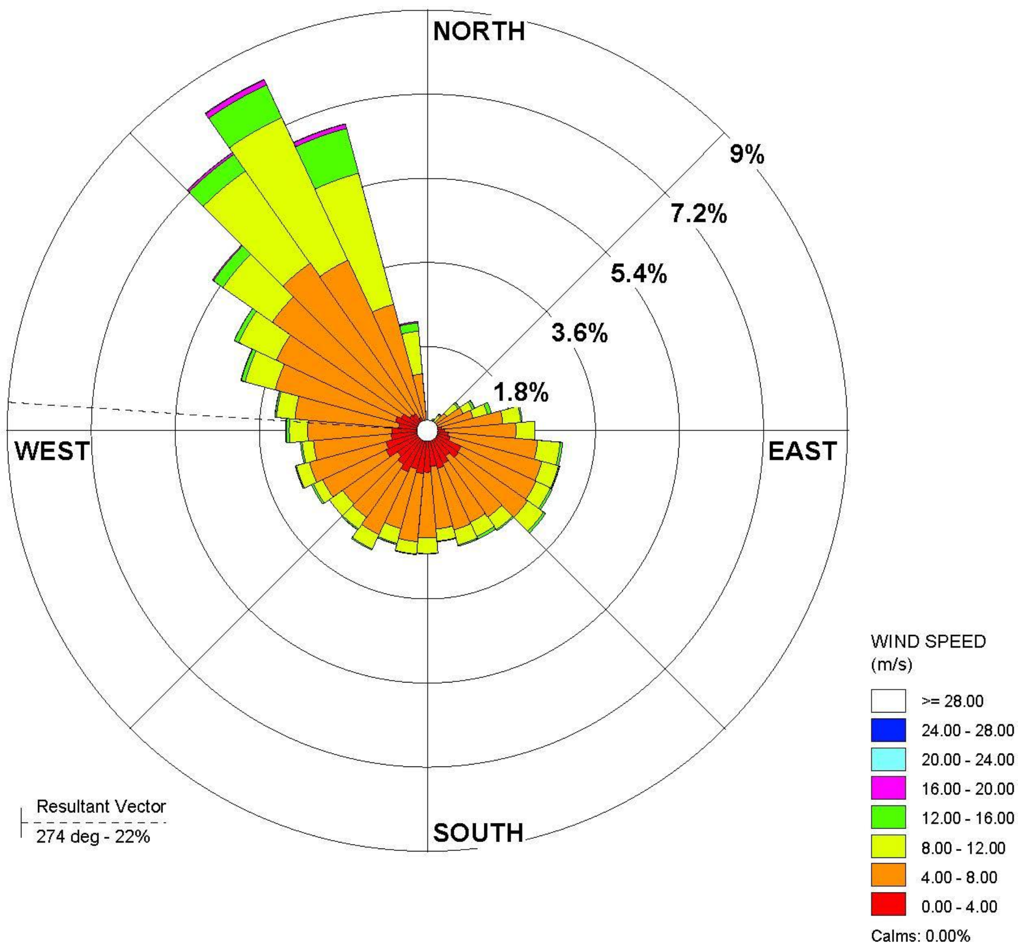


**Figure 3.4: Wind rose for Rankin Inlet climate station.**

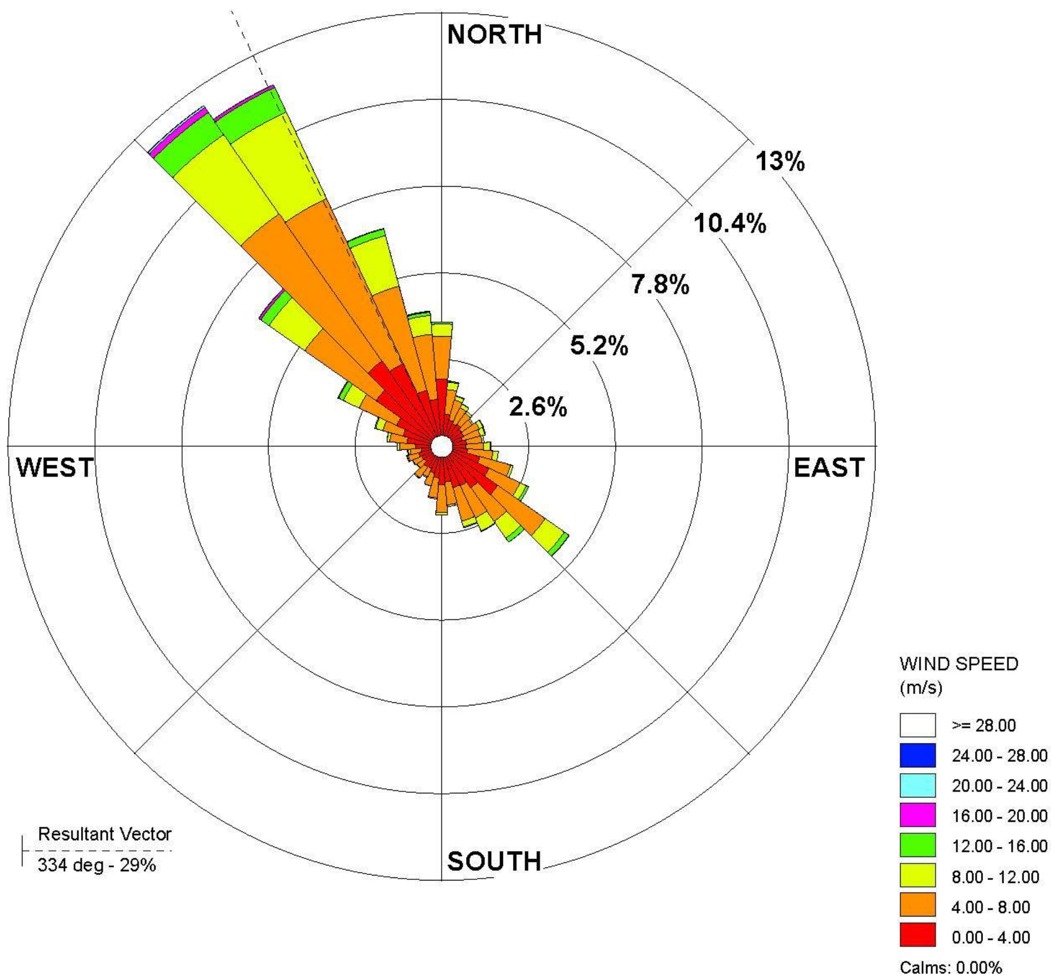


**Figure 3.5: Wind rose for Meliadine site climate station.**

## 3.2 Materials

Waste rock, waste overburden, and in situ overburden materials were all included in the modelling program. Waste rock material properties were assumed to be consistent with material observed at other Agnico Eagle sites in Nunavut. Specifically, material testing completed at the Portage WRSF located at the Meadowbank mine was used to approximate the texture, and therefore properties of the waste rock at Meliadine as very limited in situ sampling has been completed on run of mine waste rock at Meliadine. Okane (2021) compared a single run of mine waste rock sample from Meliadine to the samples collected at Meadowbank and found the single composite sample of Meliadine waste rock falls nearly within the range of waste rock texture sampled from the Portage WRSF and thus, is expected to be reasonably estimated by the material properties used in numerical modelling programs completed to date.

Waste overburden and in situ overburden properties were based on available drill sampling previously completed at Meliadine (Golder, 2012a; Golder, 2012b). All samples tested showed particle sizes no larger than 76.2 mm. Overburden can be generalized into finer-textured, coarser-textured, and average material types (Figure 3.6). A detailed description of the effects of range of thermal and hydraulic properties expected due to the range in texture is provided in 6Appendix A. The expected range of thermal and hydraulic properties were used to estimate the range of potential performance in sensitivity analyses described in Table 4.1.

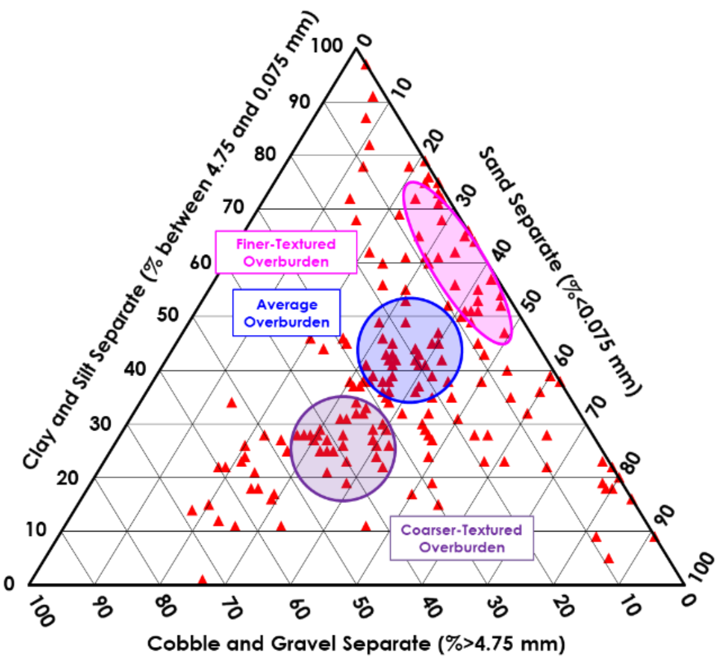


**Figure 3.6: Texture triangle for Meliadine overburden samples.**

Golder 2012a, 2012b.

The material properties or functions developed for each material based on available geochemical and geotechnical testing (eg. particle size distributions) are as follows:

- water retention curves (WRC – suction versus volumetric water content);
- hydraulic conductivity function (k-function – suction versus hydraulic conductivity);
- air conductivity function;
- thermal conductivity function (volumetric water content versus thermal conductivity);
- volumetric specific heat function (volumetric water content versus volumetric specific heat capacity);

- unfrozen water content function (unfrozen water content versus temperature); and
- geochemical reactivity.

As there exists some uncertainty in material properties due to natural heterogeneity in materials and limited laboratory data to inform on hydraulic and thermal properties (particularly for the waste rock materials), a range in material properties was investigated during sensitivity modelling (Table 4.1) in order to quantify the effect of any changes from the initial material inputs. Refer to Appendix A for a detailed description of material properties used in modelling.

## 3.3 Geometry

An idealized cross section (Figure 3.7) was selected for long term modelling. Typical geometry for the idealized cross-section is provided in Table 3.2. This was 'built-up' over time in 2D to simulate conditions at placement (Appendix B). Sensitivity analyses (Table 4.1) were performed on the idealized cross section (Figure 3.7). Previous thermal modelling work at Whale Tail showed the slope aspect had limited effect on the depth of thaw but that freeze-back would take longer along the southern aspects than the northern aspects. A southern exposure is expected to show conservative freeze-back through the WRSF due to increased solar radiation and less convective cooling from the leeward slope.

**Table 3.2: Typical cross-section geometry.**

| Parameter | Idealized Cross Section |
|---|---|
| Initial Bench Height | 5 m |
| Maximum Bench Height | 15 m |
| Setback | 30 m |
| Interbench Slope (Waste Rock) | 1.3H:1V |
| Interbench Slope (Overburden) | 2H:1V |
| Overall Slope (Ultimate toe to ultimate crest) | 3.25H:1V |

Timing of material placement (overburden) is expected to have a large impact on freeze-back time. It was assumed that the first lift of overburden is to be placed only in winter to maintain frozen conditions within the WRSF foundation materials.

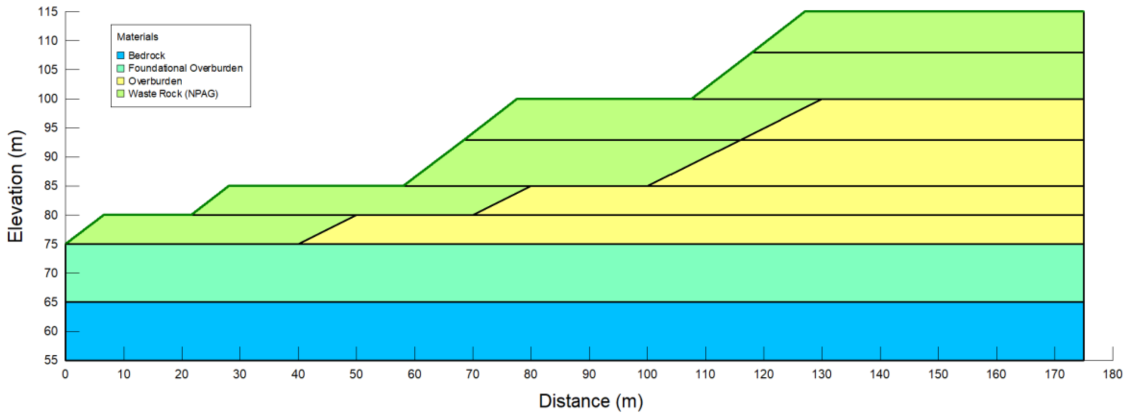


**Figure 3.7: Idealized southwest facing cross-section of Meliadine Generic WRSFs (adapted from Tetra Tech, 2019a).**

## 3.4 Boundary Conditions

### *3.4.1 Hydraulic Boundary Conditions*

The lower boundary was simulated as a unit hydraulic gradient. This boundary conditions assumes that at the lower boundary, the suction (and as a result, water content and hydraulic conductivity) are constant with depth. For this situation, the total head equals the gravitational head, which results in a unit hydraulic gradient. In other words, a unit hydraulic gradient represents a location in the material profile where water movement is controlled mainly by gravity.

### *3.4.2 Air and Gas Boundary Conditions*

A barometric air pressure condition referenced to site elevation (75 masl) and adjusted for daily air temperature was applied to the exterior of the cross sections. A constant oxygen concentration representing atmospheric conditions (280 g/m$^3$) was also applied to the exterior of the cross sections.

### *3.4.3 Temperature Boundary Conditions*

A depth of zero amplitude condition of -5°C was assumed to exist at the base of the bedrock in the model geometry (approximately 20 mbgl) (Tetra Tech, 2019c). Daily minimum and maximum temperature boundaries were applied to the exterior of the 2D cross section as described in Section 3.1.

Where underground waste rock is encountered in WRSFs, there is the potential that the high salinity in the pore water will result in reduced freezing of both the existing pore water, and freshwater infiltration from precipitation. Underground waste rock was assumed to contain pore water with 57 g/L salinity (Tetra Tech, 2019b). Mixing of the saline groundwater with fresh water was assumed to occur in proportion to the percent of underground waste rock in the WRSF. As a conservative end point, approximately 35% of waste rock will come from underground sources, resulting in a mixed water salinity of 20 g/L and a freezing point depression of -1.3°C for the saline waste rock sensitivity.

## 3.5 Initial Conditions

Initial conditions for hydraulic, gas, and temperature conditions are required for modelling. The assumed initial conditions are summarized below (Table 3.3).

**Table 3.3: Initial conditions used in numerical modelling simulations.**

| Parameter | Material | Value | Note |
|---|---|---|---|
| Temperature | Waste Rock | 3°C | Placed in summer |
| Temperature | Waste Rock / Overburden | -5°C | Placed in winter |
| Oxygen | Waste Rock / Overburden | 280 g/m$^3$ | Atmospheric |
| Air Pressure | Waste Rock / Overburden | 0 kPa | Atmospheric |
| Volumetric Water Content | Waste Rock | 0.05 | |
| Volumetric Water Content | Overburden | 0.2 | |

### *3.5.1 Hydraulic Conditions*

The waste rock and overburden material were assumed to be placed at an initial volumetric water content of approximately 0.05 and 0.2, respectively.

### *3.5.2 Gas Conditions*

The initial concentration of oxygen in the pore space of both the waste rock and overburden material at placement was assumed to be consistent with atmospheric conditions (280 g/m$^3$). Initial air pressure in the WRSFs was set to atmospheric levels (0 kPa).

### *3.5.3 Temperature Conditions*

The initial thermal conditions were dependent on the time of year of material placement. Where waste rock was assumed to be placed between May and October inclusive, the temperature at placement was assumed to be 3°C. Average air temperature during this same period is approximately 2.8°C. Where waste rock or overburden was placed between November and April inclusive, the waste rock temperature was assumed to be -5°C, the upper limit of permafrost temperature. Permafrost temperatures at depths of zero amplitude are in the range of -5.0°C to -7.5°C (Tetra Tech, 2019c). All overburden was assumed to be placed during the winter months.

# 4 MODEL RESULTS

Modelling of the WRSFs was completed in two major steps: short term sensitivity modelling and long-term climate modelling. Short term sensitivity modelling was completed to assess the range of expected performance under conditions where uncertainty exists. Short-term sensitivity was completed using the base case climate RCP4.5 described above and the idealized cross section (Figure 3.7). For example, the texture of overburden was found to be quite variable, so the 'end points' of overburden texture were modelled to understand overburden texture's impact on performance.

Following completion of sensitivity modelling on the idealized cross section, long term climate modelling was completed using the RCP4.5 climate database described previously. The range of long-term climate scenarios were included in long term modelling to generate the range of expected thermal and hydraulic performance of WRSFs in closure and post-closure. Long term climate modelling was competed for the idealized cross-section (Figure 3.7).

## 4.1 Short-Term Sensitivity Results

Sensitivity modelling was completed on the idealized cross section under RCP4.5 conditions over a 30-year period (2020-2050), including construction of the WRSF. Table 4.1 outlines the list of modelled sensitivity scenarios. The effect of finer or coarser textured materials is defined within the material properties used in modelling. Material properties for the range of textures described is provided in Appendix A. The following sections summarize the results of the 2D sensitivity modelling.

**Table 4.1: Sensitivity scenarios for Meliadine WRSF thermal modelling.**

| Sensitivity Scenario | Parameter Examined | Note |
|---|---|---|
| 1 | Base Case | - |
| 2 | Finer-textured overburden | See Appendix A for finer-textured overburden material properties |
| 3 | Coarser-textured overburden | See Appendix A for coarser-textured overburden material properties |
| 4 | Finer-textured waste rock | See Appendix A for finer-textured waste rock material properties |
| 5 | High salinity waste rock | Salinity of 20 ppt was assumed, resulting in a freezing point depression of -1.3°C |
| 6 | Generic overburden pile | Short-term pile consisting of only overburden material |
| 7 | Snow depth decrease | Snow depth was decreased by 33% |

#### 4.1.1 *Short-Term Sensitivity Active Thermal Layer Depth*

The thermal modelling of the idealized WRSF cross section indicated an active layer typically less than 6 m in most sensitivities. The following figures (Figure 4.2 to Figure 4.8) illustrate annual average near-surface thermal conditions at several locations along the slope (Figure 4.1) between 2030-2050, once construction of the WRSF is complete.

In permafrost environments, thaw of the active layer occurs as a unidirectional process from the surface. During the summer months, when air temperatures are the warmest, the active layer absorbs and transfers heat from the atmosphere downwards toward the thawing front. This transfer of heat occurs predominantly through conduction but infiltrating water can contribute to the heat transfer via convection.

Freezing in autumn occurs first as a unidirectional process from the bottom of the active layer at the freezing front. As the ambient air temperature declines, the temperature gradient driving conduction also declines, resulting in freezing upwards from the permafrost. Once the air temperature becomes negative, a freezing front develops at the surface and progresses into the active layer, creating bidirectional freezing. The cold air temperatures rapidly cool the surficial material, allowing the upper freezing front to quickly progress downward, while the lower freezing front moves slowly upwards. The thawed portion between the two freezing fronts is at or near 0°C, creating isothermal or zero-curtain conditions, where water and ice can coexist in equilibrium. Unfrozen pore water migrates both upwards and downwards toward the freezing fronts until all pore water is frozen and the zero-curtain closes.

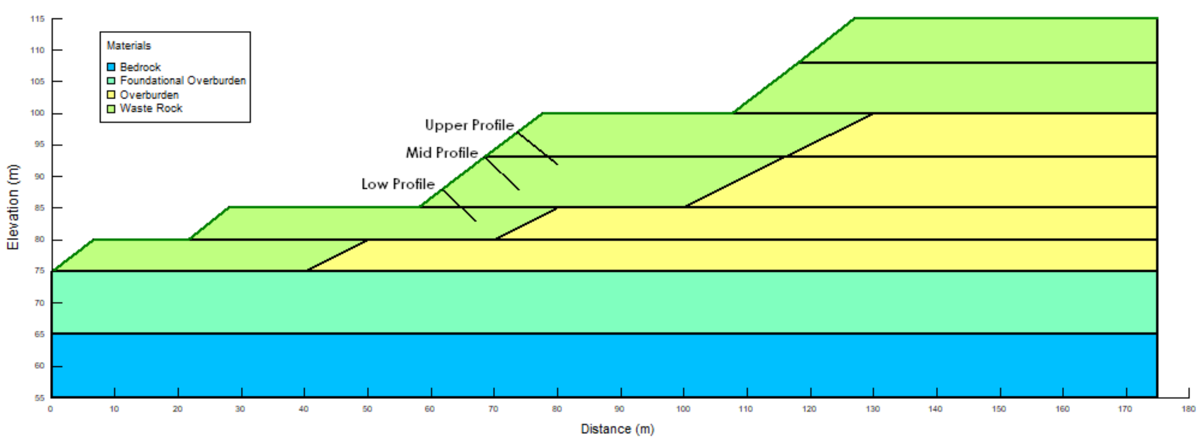


**Figure 4.1: Section view of typical thermal locations rendered below.**

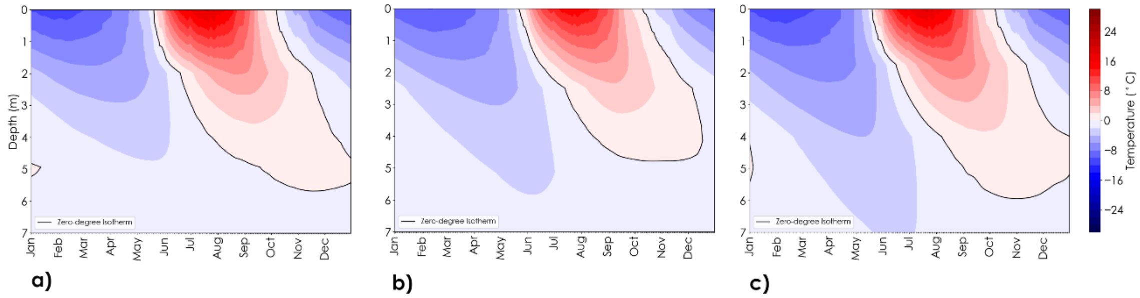


**Figure 4.2: Annual average near surface temperature along the slope of the base case sensitivity at the a) low profile, b) mid profile and c) upper profile under RCP4.5 climate conditions.**

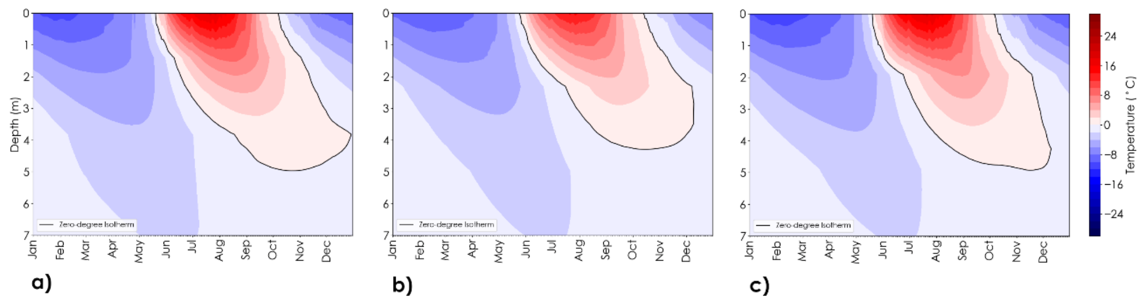


**Figure 4.3: Annual average near surface temperature along the slope of the coarser overburden sensitivity at the a) low profile, b) mid profile and c) upper profile under RCP4.5 climate conditions.**

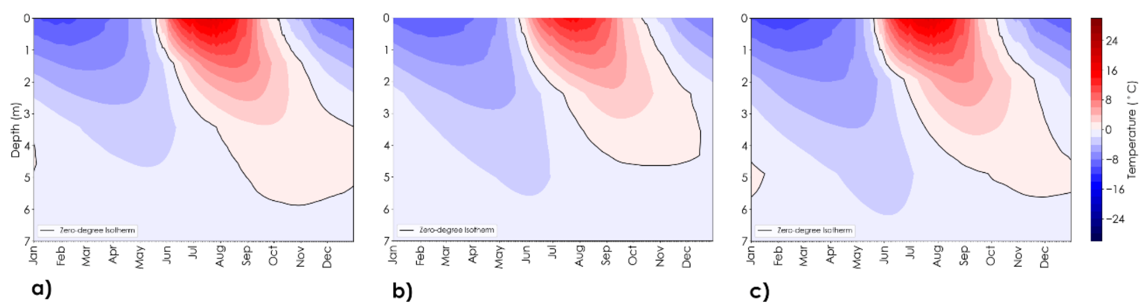


**Figure 4.4: Annual average near surface temperature along the slope of the finer overburden sensitivity at the a) low profile, b) mid profile and c) upper profile under RCP4.5 climate conditions.**

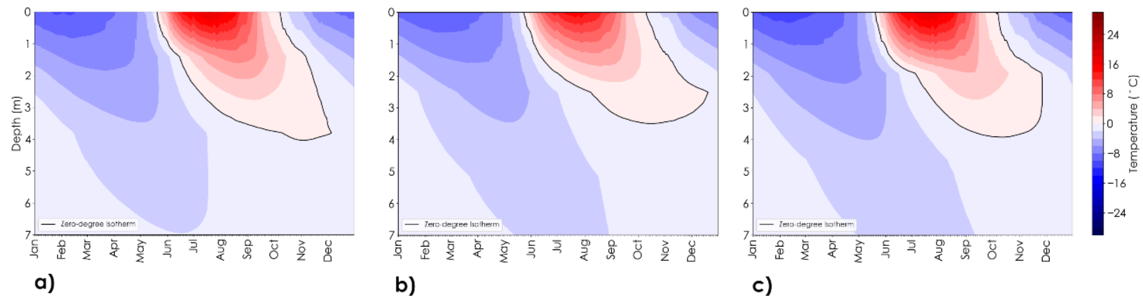

**Figure 4.5: Annual average near surface temperature along the slope of the finer waste rock sensitivity at the a) low profile, b) mid profile and c) upper profile under RCP4.5 climate conditions**

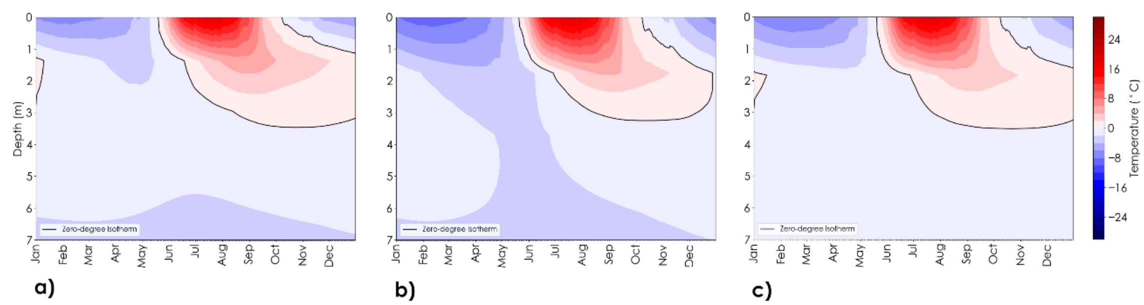

**Figure 4.6: Annual average near surface temperature along the slope of the overburden only sensitivity at the a) low profile, b) mid profile and c) upper profile under RCP4.5 climate conditions.**

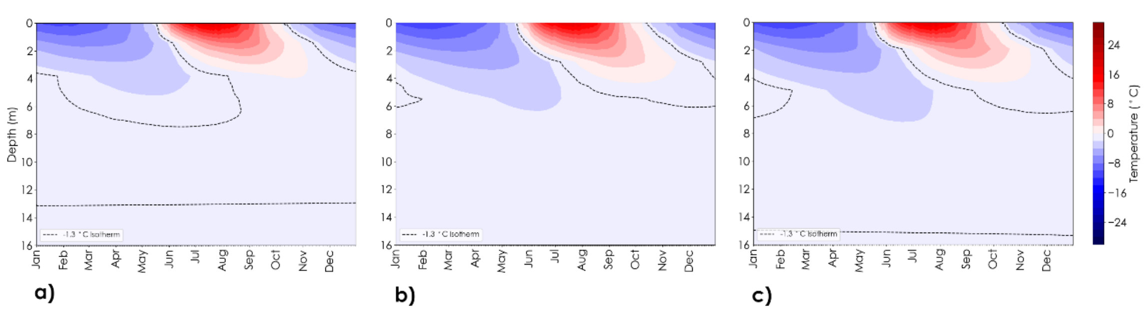

**Figure 4.7: Annual average near surface temperature along the slope of the saline waste rock sensitivity at the a) low profile, b) mid profile and c) upper profile under RCP4.5 climate conditions.**

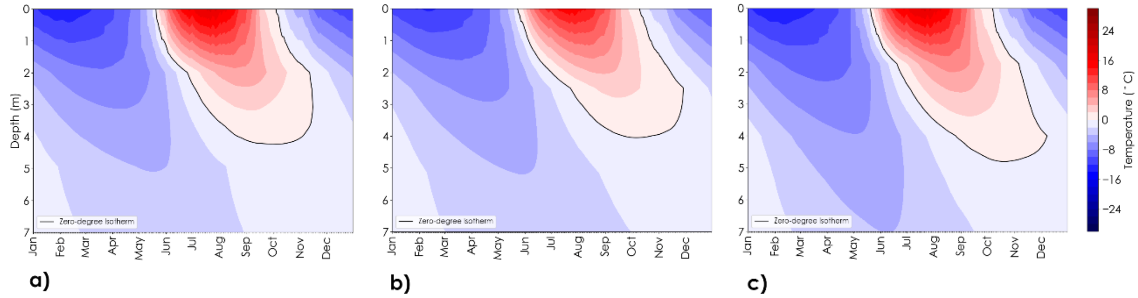


**Figure 4.8: Annual average near surface temperature along the slope of the decreased snow depth sensitivity at the a) low profile, b) mid profile and c) upper profile under RCP4.5 climate conditions.**

The primary mechanism responsible for thaw, conduction, is typically constrained within the upper 4 m before colder air temperatures decrease the thermal gradient. Freezing from the surface progresses rapidly, while freezing from the bottom is a slower process. Zero-curtain conditions are created, slowing the upper freezing front, until all pore water is frozen.

The presence of finer material near surface reduces the active layer depth, as observed in both the finer waste rock (Figure 4.5) and generic overburden pile (Figure 4.6) sensitivities. Finer material has a lower thermal conductivity, air conductivity and hydraulic conductivity, limiting the conduction and convection that can occur and influence the thaw depth. A finer fraction in the near surface could be obtained via different blasting methods or the inclusion of overburden material.

Saline groundwater from underground waste rock has the potential to increase the active layer depth due to the depression of the freezing point because of the high salinity (Figure 4.7). While the freezing point depression does not necessarily influence the ground temperatures, it lowers the temperature at which pore water will freeze, resulting in a greater thaw depth. Mixing saline water with fresh water will dilute the saline water and reduce the freezing point depression. To reduce the active layer depth, it is important to remove waste rock from underground workings which bears saline groundwater from the near surface.

A 33 % decrease in the snow depth, achieved through an increase in snow density, decreases the active layer thaw depth (Figure 4.8). Snow acts as an insulator during the winter, slowing the release of stored heat and keeping ground temperatures warmer than without snow. The reduction in snow depth decreases the insulation effect, allowing the ground to release more stored energy, allowing for colder temperatures to permeate deeper into the ground. A greater snow depth would increase the insulation effect and trap more heat within the near surface, resulting in deeper thawing.

### 4.1.2 Short-Term Sensitivity Landform Water Balance

A landform water balance was completed to aid in the thermal modelling of sensitivities. This includes estimates of runoff, interflow and basal seepage rates. A summary of the surface water balance for the generic WRSF plateau is provided in Table 4.2. Table 4.3 provides the surface water balance results for the slopes.

**Table 4.2: Summary of average water balance for the sensitivity scenarios for the plateau of the Generic WRSF under RCP4.5 between 2020-2050.**

| Water Balance Parameters | Base Case<br>Coarser-Textured Overburden<br>Finer-Textured Overburden<br>Saline Waste Rock<br>Decreased Snow Depth | Finer-Textured Waste Rock | Overburden Only |
|---|---|---|---|
| Total Precipitation (PPT) (mm) | 415 mm | 415 mm | 415 mm |
| Rainfall (% of PPT) | 50-55% | 50-55% | 50-55% |
| Snow (% of PPT) | 45-50% | 45-50% | 45-50% |
| Actual Evaporation (% of PPT) | 45-50% | 45-50% | 35-50% |
| Runoff (% of PPT) | <1% | <5% | 10-15% |
| Surface Infiltration (% of PPT) | 10-15% | 5-10% | <5% |
| Sublimation (% of PPT) | 30-35% | 30-35% | 30-35% |

**Table 4.3: Summary of average water balance for the sensitivity scenarios for the slopes of the Generic WRSF under RCP4.5 between 2020-2050.**

| Water Balance Parameters | Base Case<br>Coarser-Textured Overburden<br>Finer-Textured Overburden<br>Saline Waste Rock<br>Decreased Snow Depth | Finer-Textured Waste Rock | Overburden Only |
|---|---|---|---|
| Total Precipitation (PPT) (mm) | 415 mm | 415 mm | 415 mm |
| Rainfall (% of PPT) | 50-55% | 50-55% | 50-55% |
| Snow (% of PPT) | 45-50% | 45-50% | 45-50% |
| Actual Evaporation (% of PPT) | 45-50% | 45-50% | 35-50% |
| Runoff (% of PPT) | <1-5% | 5-10% | 15-20% |
| Surface Infiltration (% of PPT) | 5-10% | <5% | <5% |
| Sublimation (% of PPT) | 30-35% | 30-35% | 30-35% |

#### 4.1.2.1 Basal Seepage

The high infiltration capacity of the waste rock material result in a preference for precipitation to result in surface infiltration, rather than runoff (Table 4.3 and Table 4.4). The overburden material has a lower infiltration capacity than the waste rock, resulting in greater runoff, but lower surface infiltration. As water infiltrates into the surficial materials, net percolation flows vertically through the WRSF, eventually freezing back at depth. The base layer of the WRSF is consistently frozen from the time of placement. As a result, basal seepage from the landform is negligible under all sensitivity scenarios.

#### 4.1.2.2 Interflow

Interflow occurs as lateral flow within the active layer. Ice-rich zones that develop at the boundary of the active layer over time limit deeper infiltration into the WRSF. Surface infiltration that cannot infiltrate deeper is diverted laterally as interflow. Table 4.4 summarizes the interflow as a percent of total precipitation for each sensitivity scenario. A finer-textured overburden core results in more interflow than the base case, as the finer material had less infiltration capacity. The lower infiltration capacity of the finer-textured overburden core results in more diversion of water as interflow. A finer waste rock material resulted in less interflow than the base case, as less water infiltrates from the surface to begin with. A pile with only overburden material has very little infiltration, resulting in little to no interflow.

**Table 4.4: Interflow as a percent of total precipitation for the sensitivity models.**

| Sensitivity Scenario | Interflow (% of Total Precipitation) |
|---|---|
| Base Case | 5-10% |
| Coarser-Textured Overburden | 5-10% |
| Finer-Textured Overburden | 5-10% |
| Finer-Textured Waste Rock | <1-5% |
| Overburden Only | <1% |
| Saline Waste Rock | 5-10% |
| Decreased Snow Depth | 5-10% |

## 4.2 Long Term Climate Modelling Results

Following completion of the sensitivity models, long-term 2D modelling (Figure 3.7) was completed to develop long-term thermal active layer depths, estimates of pore air temperature within the active layer, and a landform water balance. A 100-year period (2020-2120) was modelled under RCP4.5, including construction of the WRSF, using six-hour timesteps saved daily. The following sections summarize the results of the long-term 2D modelling.

### *4.2.1 Active Thermal Layer Depth*

The long-term thermal modelling predicts a deepening of the active layer with time. The average active layer depth over the last 30 years of modelling (2090-2120) indicates an active layer of approximately 6 m in the base case sensitivity (2020 to 2050). The following figures (Figure 4.9) illustrate annual average near-surface thermal conditions at several locations along the slope (Figure 4.1) between 2090-2120 under RCP4.5.

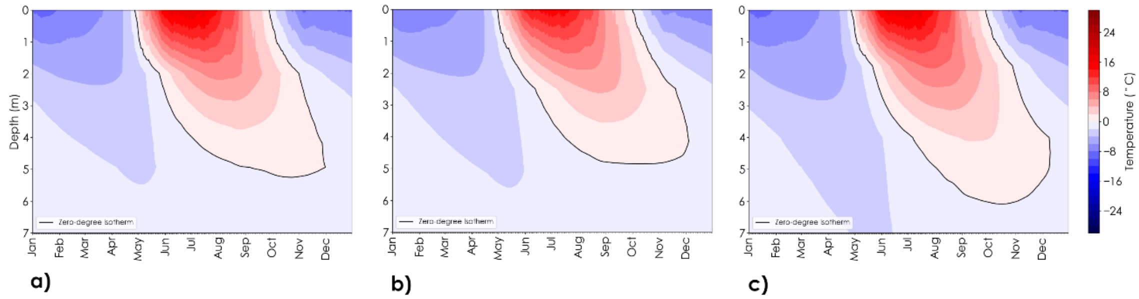


**Figure 4.9: Annual long term near surface temperature along the slope of the idealized cross section at the a) low profile, b) mid profile and c) upper profile under RCP4.5 climate conditions.**

The same thaw mechanisms that were observed in the sensitivity models were also observed in the long-term models. Conduction remains the primary driver of near-surface thaw. The progression of the thaw front continues until the thermal gradient driving conduction decreases due to the decrease in air temperature. The active layer reaches its maximum depth at this stage, after which the downward thawing front becomes an upward freezing front.

### *4.2.2 Active Layer Pore Temperature*

Pore air temperature is required to estimate reaction rates and loading rates from the WRSFs. As temperatures are expected to stabilize under both climate change scenarios modelled, an asymptotic regression was used to estimate typical pore air temperatures over time based on the modelling results. Detailed pore air temperature results by month and depth are summarized in Appendix C.

### *4.2.3 Landform Water Balance*

A landform water balance was completed to aid in the thermal modelling. This work includes estimates of runoff, interflow and basal seepage rates. A summary of the 100-year surface water balance for the WRSF plateau and slope is provided in Table 4.5 for the long-term models under RCP4.5.

**Table 4.5: Summary of average water balance for the plateau and slope of the long-term models under RCP4.5 conditions.**

| Water Balance Parameters | RCP4.5 | |
|---|---|---|
| | Plateau | Slope |
| Total Precipitation (mm) | 439 mm | 439 mm |
| Rainfall (% of Total Precipitation) | 55-60% | 55-60% |
| Snow (% of Total Precipitation) | 40-45% | 40-45% |
| Actual Evaporation (% of Total Precipitation) | 40-45% | 40-45% |
| Runoff (% of Total Precipitation) | <1-5% | 1-5% |
| Surface Infiltration (% of Total Precipitation) | 15-20% | 15-20% |
| Sublimation (% of Total Precipitation) | 30-35% | 30-35% |

Runoff is assumed to interact with surficial materials to a depth of 30 cm (Sharpely, 1985; Zhang, 2009). Table 4.6 summarizes the runoff distribution by month for the WRSF.

**Table 4.6: Runoff distribution by month under RCP4.5.**

| Month | RCP4.5 | |
|---|---|---|
| | Plateau | Slope |
| January | 0% | 0% |
| February | 0% | 0% |
| March | 0% | 0% |
| April | 23% | 23% |
| May | 75% | 76% |
| June | 1% | 1% |
| July | <1% | <1% |
| August | 0% | 0% |
| September | 0% | 0% |
| October | 0% | 0% |
| November | <1% | 0% |
| December | 0% | 0% |

#### 4.2.3.1 Basal Seepage

The high infiltration capacity of the waste rock material results in a propensity for incident precipitation to become surface infiltration, rather than runoff (Table 4.5). As water infiltrates into the surficial materials, net percolation flows vertically through the WRSF, eventually freezing back at depth. The base layer of the WRSF is consistently frozen from the time of placement. As a result, basal seepage from the landform is negligible in all long-term models.

#### 4.2.3.2 Interflow

Interflow occurs as lateral flow within the active layer on the plateaus and slopes. During construction and freeze back, water can percolate into the WRSF beyond the active layer, resulting in increased storage and consequently lower interflow. As time progresses, a zone of high saturation, ice-rich frozen waste rock develops below the active layer and prevents further percolation, resulting in the lateral diversion of infiltrating water and greater interflow.

Table 4.7 shows the progression of interflow with time as a percent of total precipitation for the Generic WRSF. The monthly distribution of interflow is shown in Table 4.9 for the Generic WRSF.

**Table 4.7: Interflow for the Generic WRSF cross section as a percent of total precipitation.**

| | RCP4.5 | |
|---|---|---|
| | **0-50 Years** | **50-100 Years** |
| Interflow (% of Total Precipitation) | 10-15% | 15-20% |

**Table 4.8: Interflow distribution by month for the idealized WRSF cross section as a percent of total interflow (2020-2120).**

| **Month** | **Percent of Interflow Occurring by Month (RCP4.5)** | |
|---|---|---|
| | **0-50 Years** | **50-100 Years** |
| January | 0% | 0% |
| February | 0% | 0% |
| March | 0% | 0% |
| April | 0% | 2% |
| May | 2% | 8% |
| June | 5% | 9% |
| July | 12% | 17% |
| August | 32% | 28% |
| September | 35% | 26% |
| October | 13% | 9% |
| November | 1% | 1% |
| December | 0% | 0% |

# 5 CONCLUSIONS

The thermal modelling of the proposed Meliadine WRSFs presented herein is intended to provide long-term hydrologic and thermal inputs for the site-wide water and load balances, as well as a basis for closure design of the WRSFs which is defendable to internal project stakeholders and regulators by addressing material risk to the project related to the WRSFs. Potential failure modes deemed to be of higher risk identified for the WRSF relate to the potential for geochemical loading from the WRSF resulting in poor water quality, and uncertainty surrounding the effect of climate change on geochemical loading from the WRSFs. Long term thermal models were completed for long term climate models RCP4.5 to assess the potential effects of climate change on geochemical loading.

The major component of the surface water balance, which has the potential to result in geochemical loading from the WRSF, is surface infiltration, and thus also net percolation, that results in interflow. Runoff and basal seepage are expected to be nearly negligible. In the idealized cross section modelling, representative of most WRSFs at the Meliadine site where most of the waste rock is expected to be NPAG/NML, this potential loading pathway is limited to the NPAG/NML materials.

For the short-term overburden sensitivity scenarios (Short-Term Scenario 6), runoff is expected to be more substantial (15% to 20% of total annual precipitation) compared to surface infiltration resulting in interflow (<1% of total annual precipitation). The lower thermal conductivity of overburden compared to waste rock results in an active layer of approximately 4 m.

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# Appendix A

# Material Properties

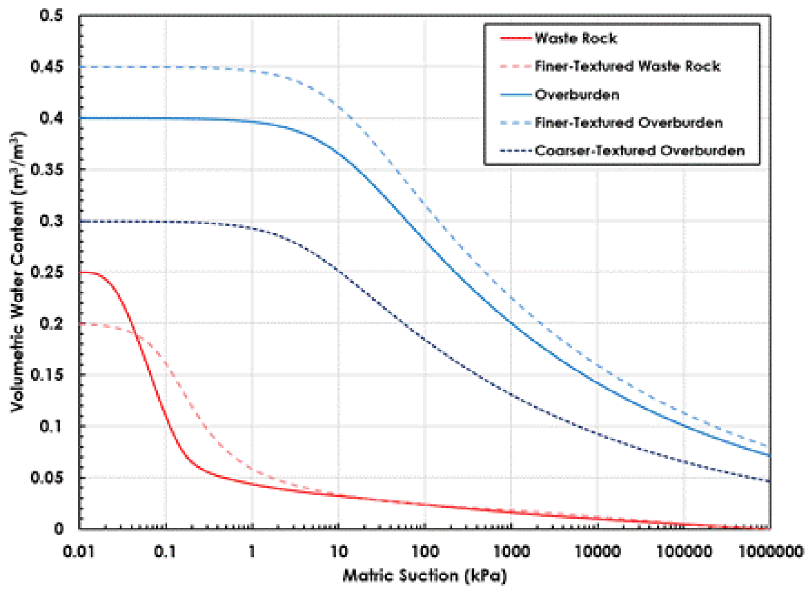


**Figure A.1: Water retention curves estimated for the overburden and waste rock materials.**

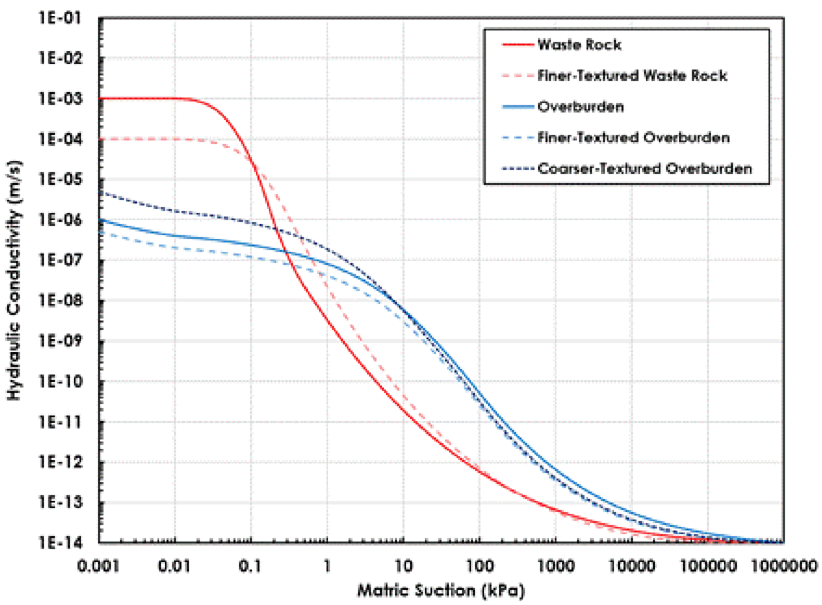


**Figure A.2: Hydraulic conductivity functions estimated for the overburden and waste rock materials.**

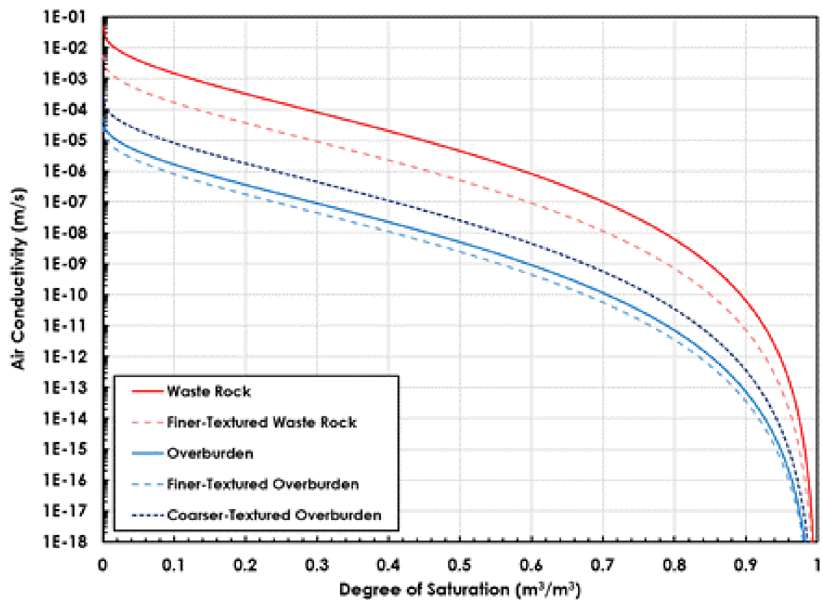


**Figure A.3: Air conductivity functions estimated for the overburden and waste rock materials.**

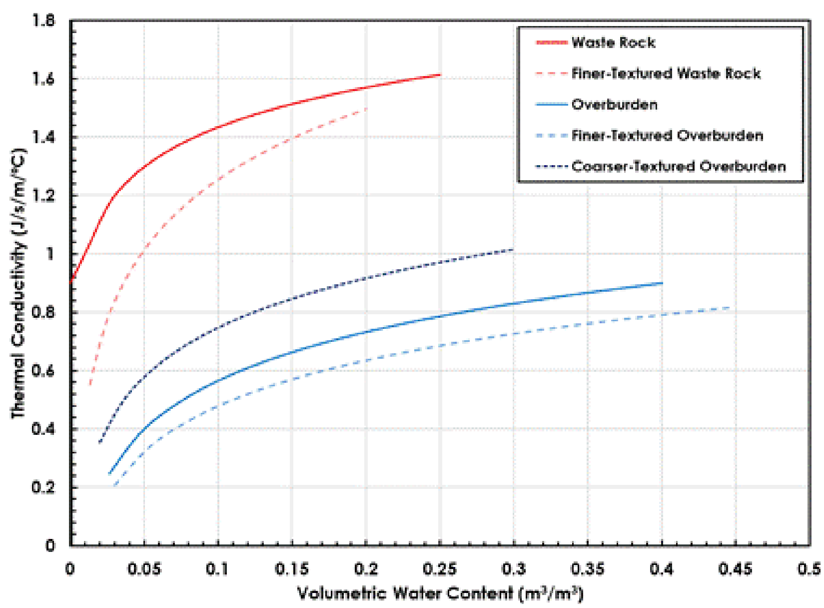


**Figure A.4: Thermal conductivity functions estimated for the overburden and waste rock materials.**

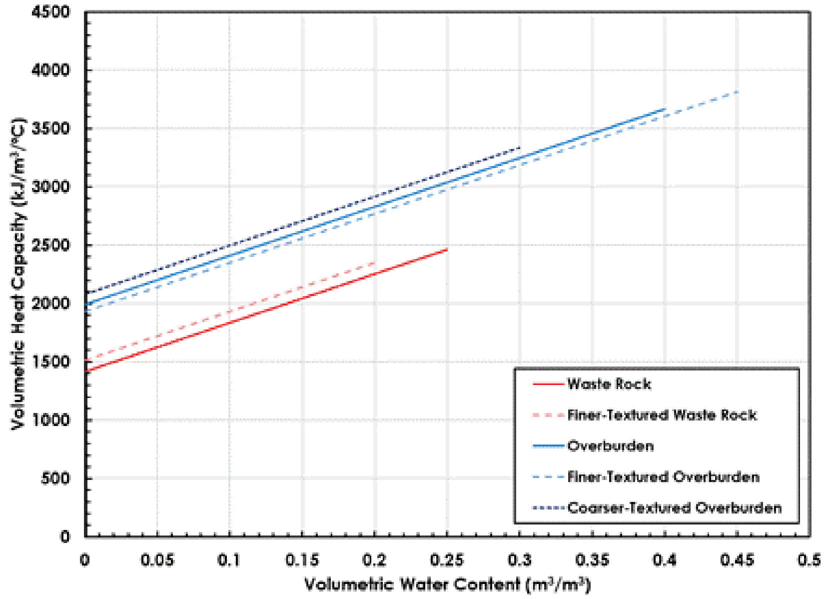


**Figure A.5: Volumetric heat capacity functions estimated for the overburden and waste rock materials.**

# Appendix B

# Model Geometry Evolution

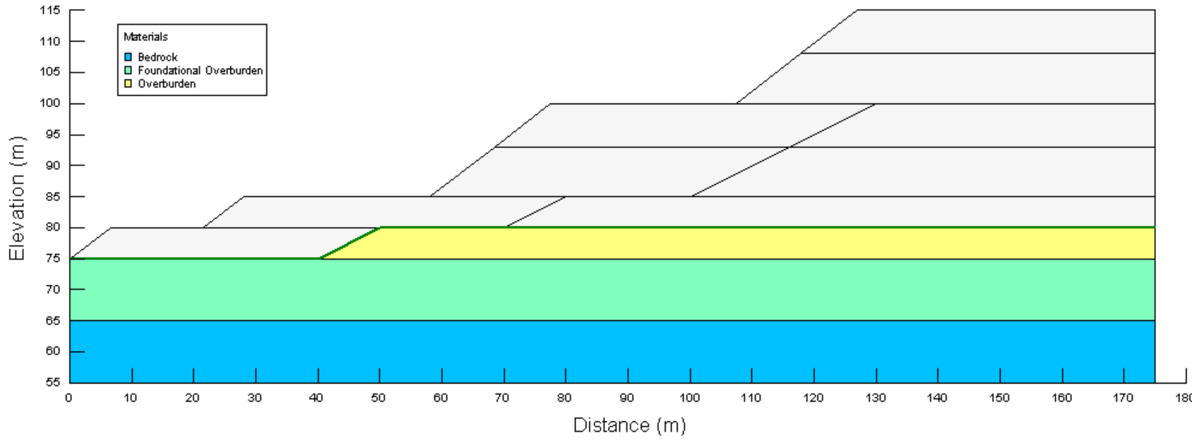


**Figure B.1: Generic base case WRSF construction – Winter 2020.**

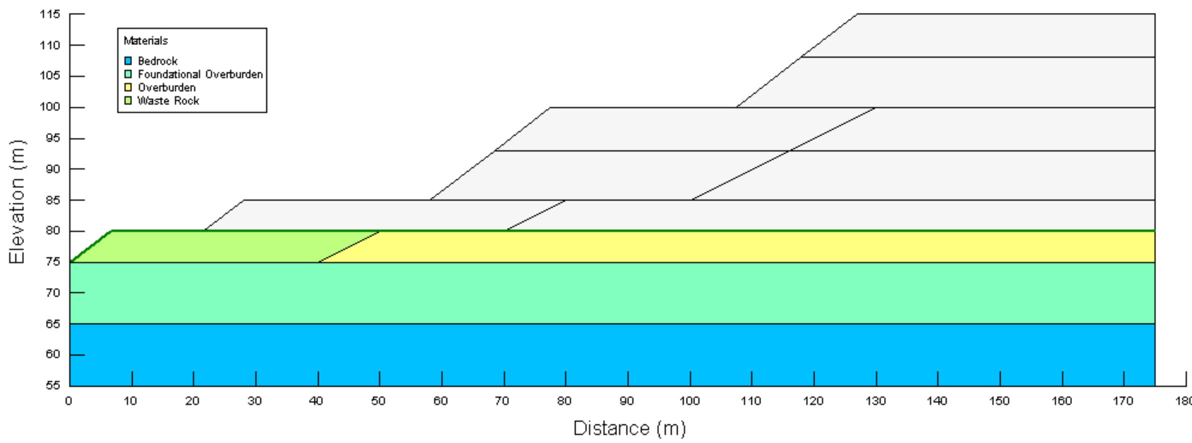


**Figure B.2: Generic base case WRSF construction – Summer 2020.**

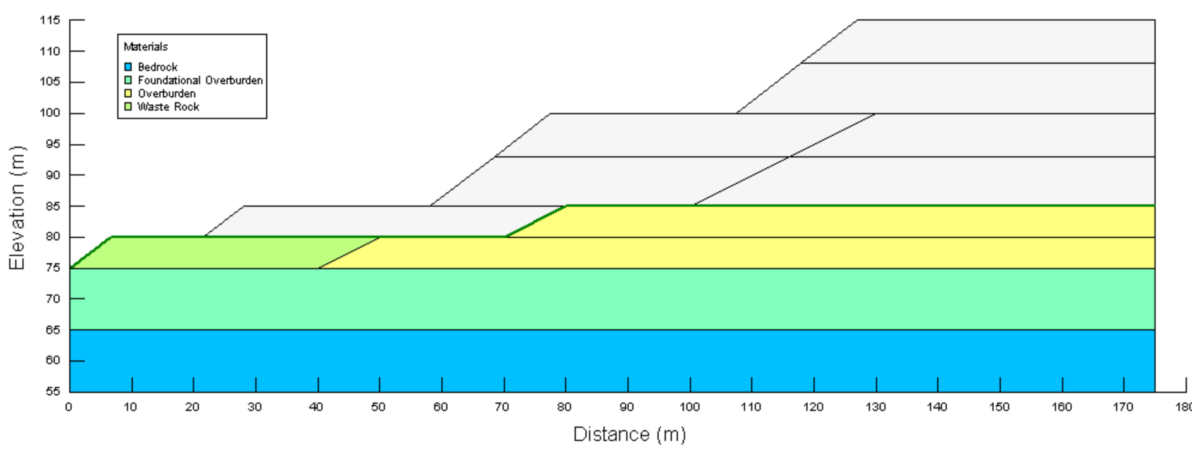


**Figure B.3: Generic base case WRSF construction – Winter 2021.**

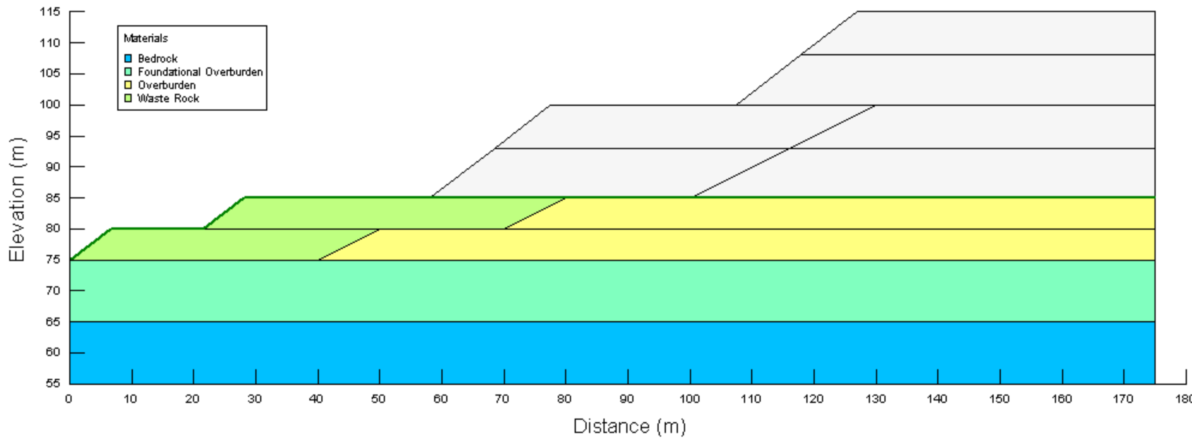


**Figure B.4: Generic base case WRSF construction – Summer 2021.**

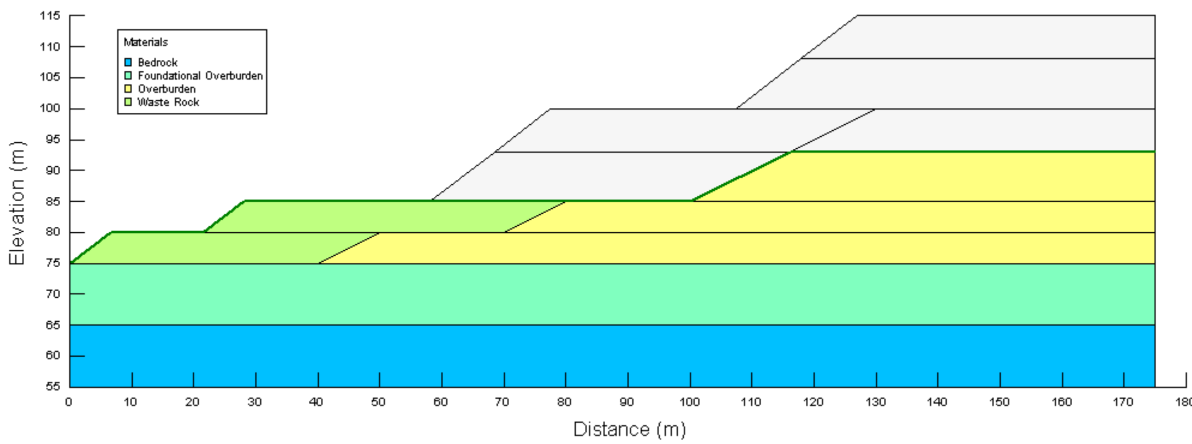


**Figure B.5: Generic base case WRSF construction – Winter 2022.**

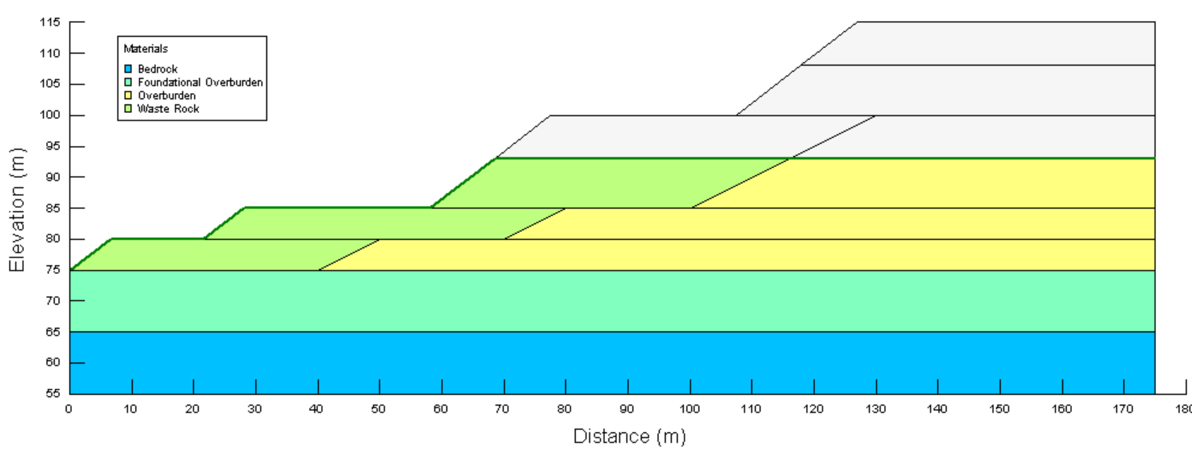


**Figure B.6: Generic base case WRSF construction – Summer 2022.**

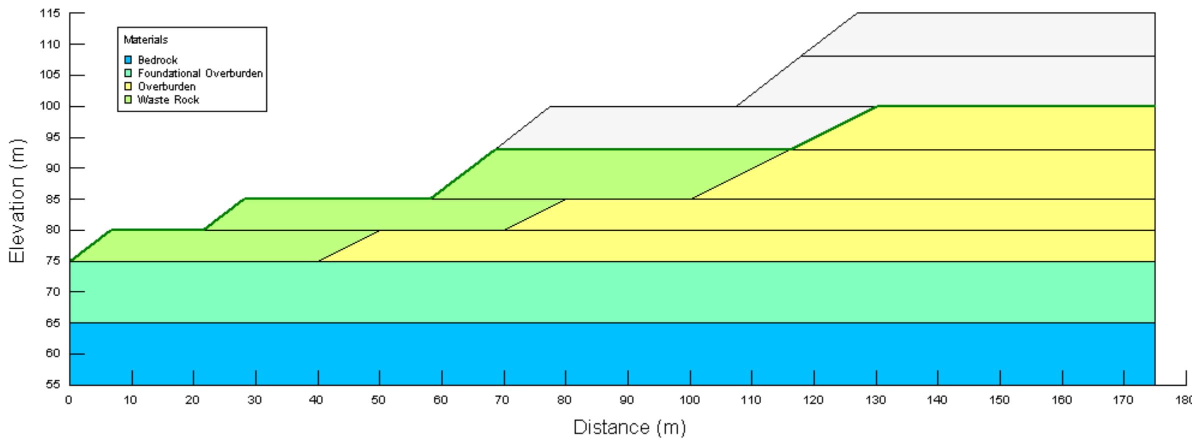


**Figure B.7: Generic base case WRSF construction – Winter 2029.**

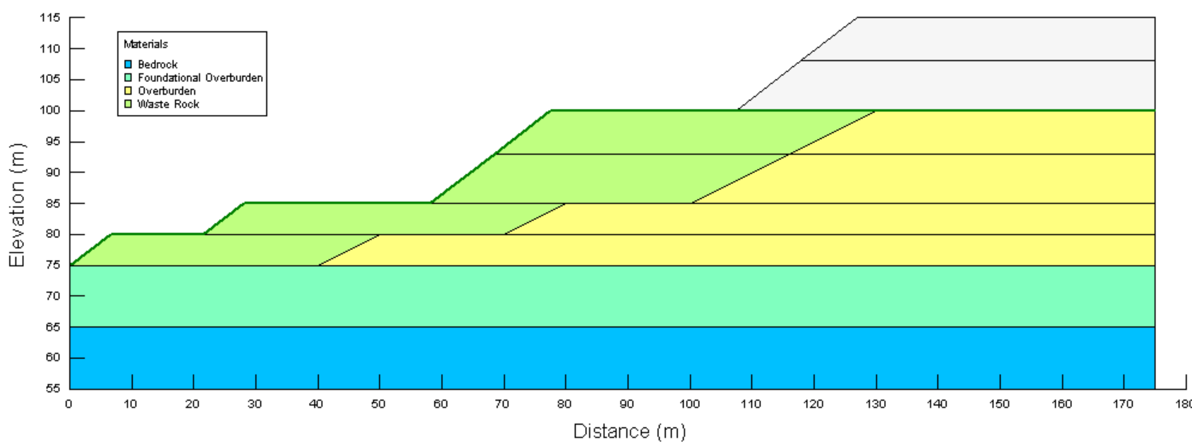


**Figure B.8: Generic base case WRSF construction – Summer 2029.**

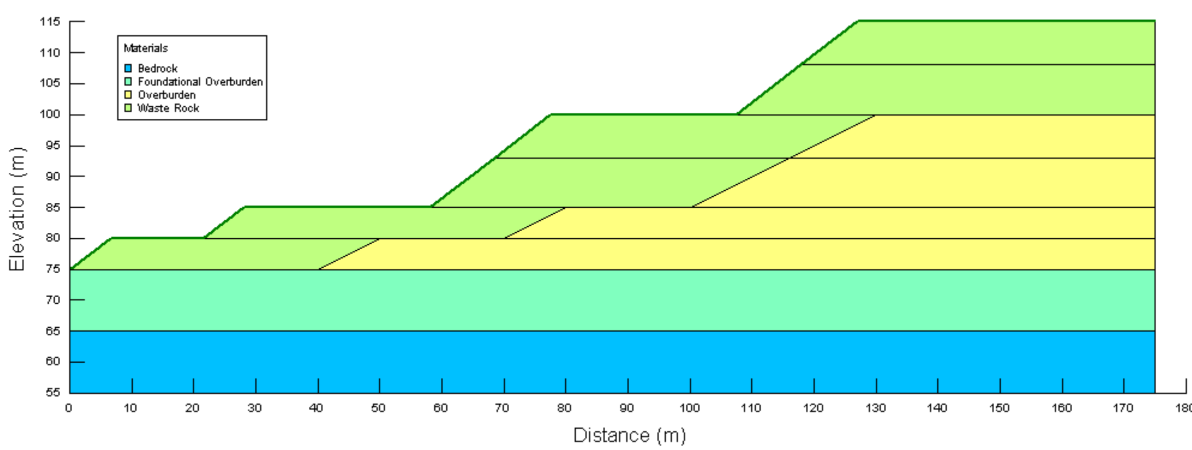


**Figure B.9: Generic base case WRSF construction – 2033.**

# Appendix C

## Active Layer Pore Space Temperature

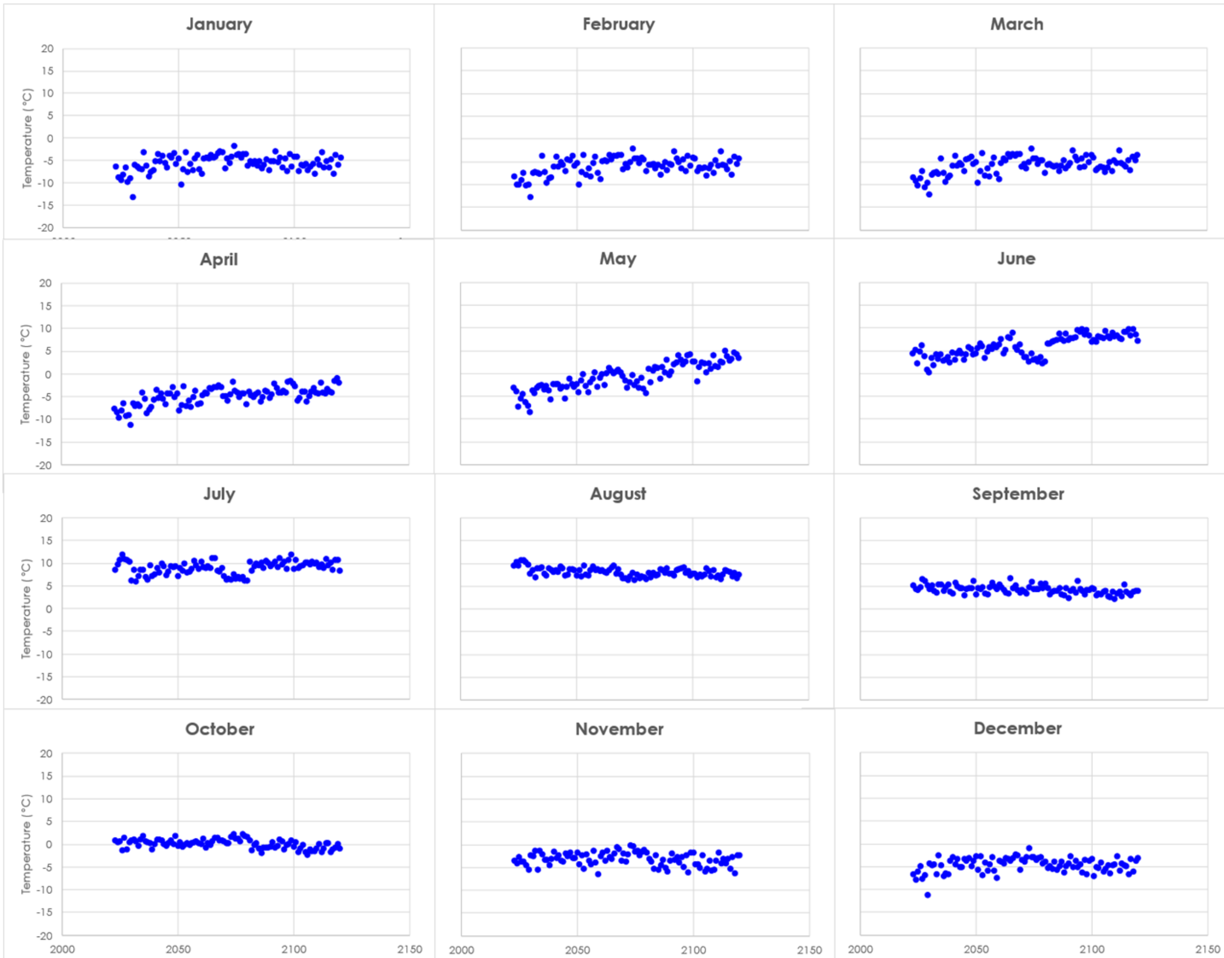


**Figure C.1: Average pore space temperature for the generic base case under RCP4.5 conditions from 0 m to 2 m depth.**

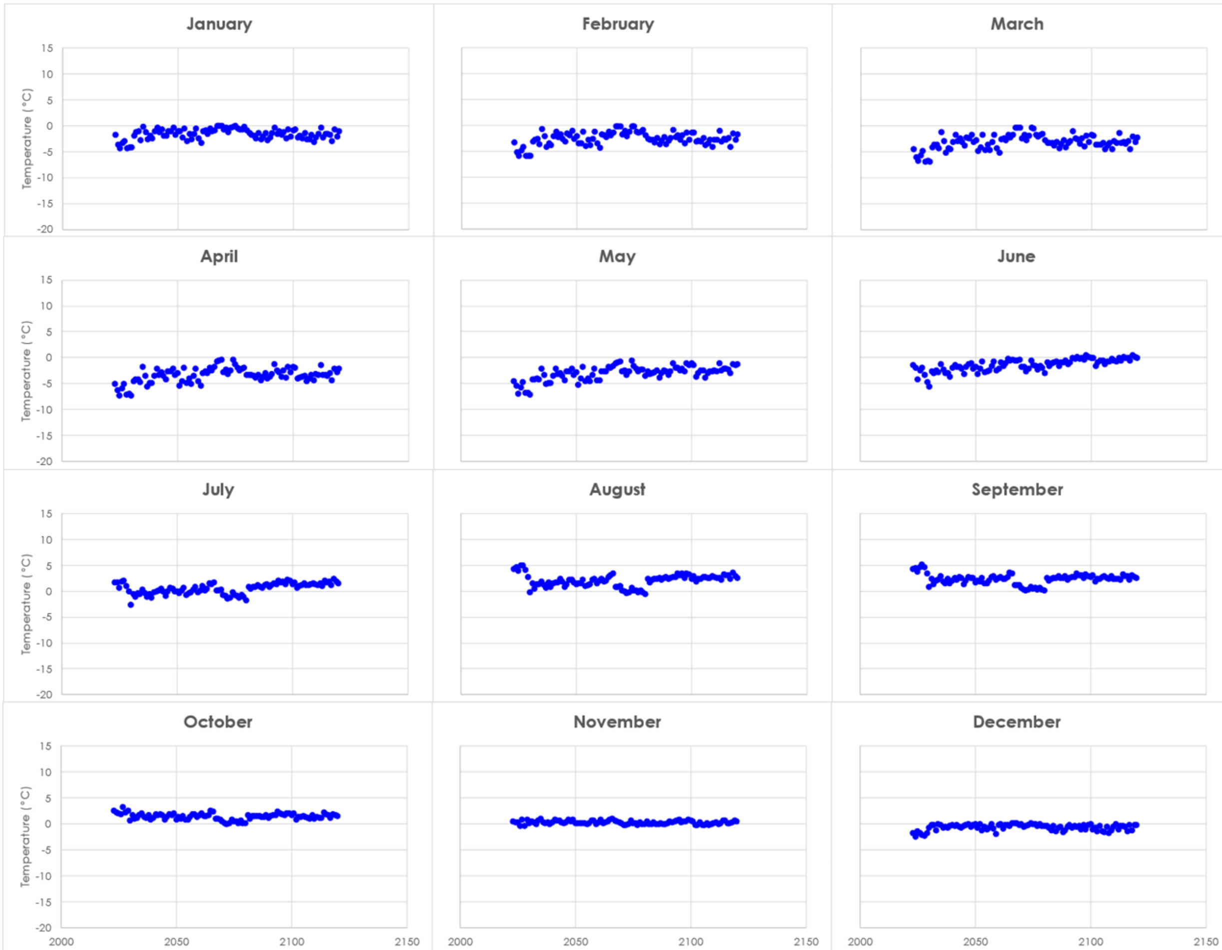


**Figure C.2: Average pore space temperature for the generic base case under RCP4.5 conditions from 2 m to 4 m depth.**

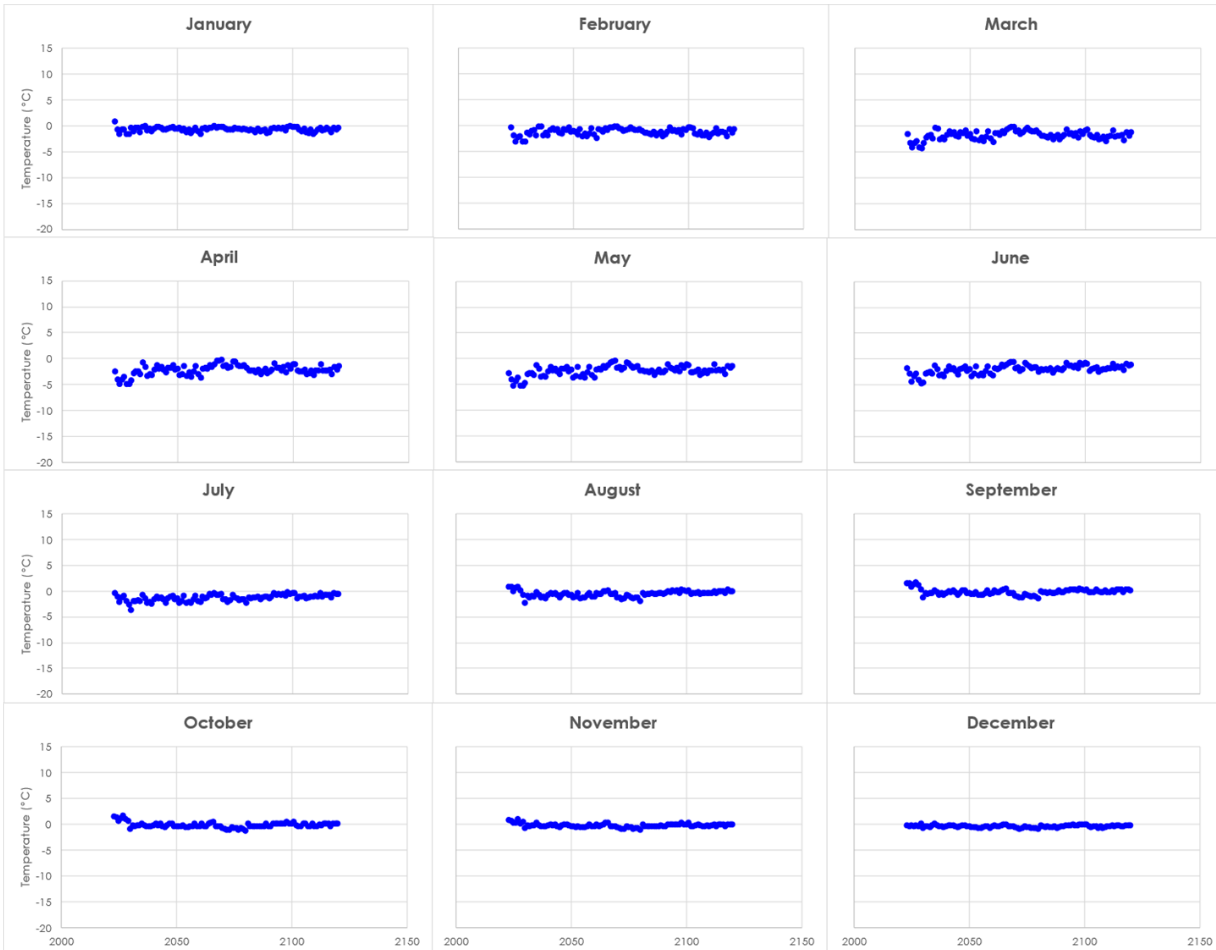


**Figure C.3: Average pore space temperature for the generic base case under RCP4.5 conditions from 4 m to 6 m depth.**

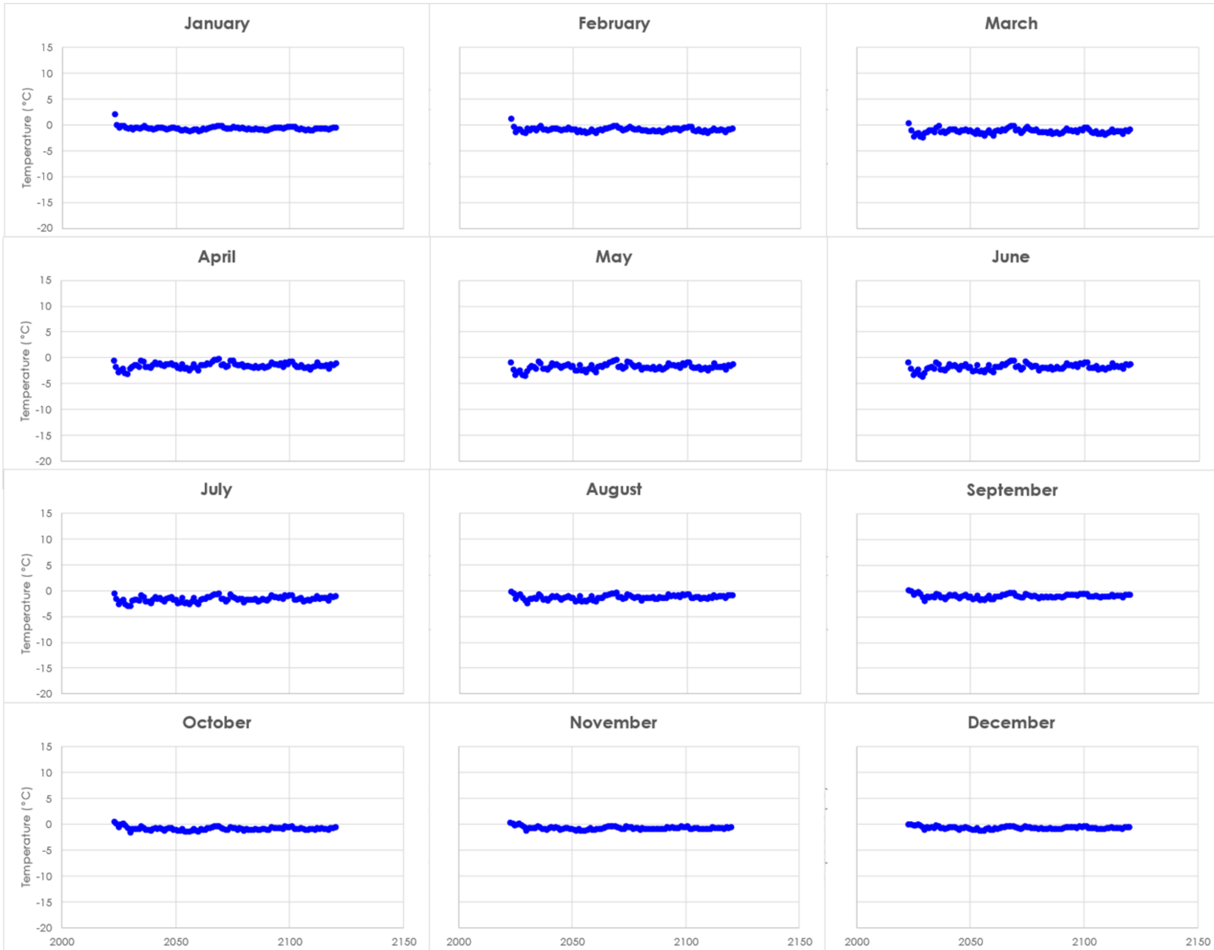


**Figure C.4: Average pore space temperature for the generic base case under RCP4.5 conditions from 6 m to 8 m depth.**

**Table C.1: Summary of average pore space temperatures for the Generic WRSF cross section under RCP4.5 conditions.**

| Depth | Parameter | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0m to 2m | A | -12.2 | -5.26 | 3.59 | 46.1 | 127 | 101 | 62 | 6.68 | -39.4 | -106 | 4.33 | -4.36 |
| | B | -49.2 | 4.18E+83 | 82.8 | 188 | 526 | 372 | 135 | -1.20 | -102 | -174 | 0.02 | 2.79E+44 |
| | C | 0.0009 | 0.09 | 0.001 | 0.0006 | 0.0007 | 0.0007 | 0.0005 | 0.00001 | 0.0004 | 0.0002 | -0.003 | 0.1 |
| 2m to 4m | A | -20.2 | -19.7 | 0.50 | -3.08 | 28.8 | 44.7 | 79.8 | 54.4 | 36.2 | -1.16 | -1.03 | 1.86 |
| | B | -63.2 | -57.4 | 0.0399 | 1.85E+48 | 90.1 | 166 | 181 | 158 | 93.7 | -0.0231 | -6.39 | 0.0179 |
| | C | 0.0006 | 0.0006 | -0.002 | 0.1 | 0.0005 | 0.0006 | 0.0004 | 0.0005 | 0.0005 | -0.002 | 0.0008 | -0.002 |
| 4m to 6m | A | -1.70 | -30.9 | 0.343 | -2.05 | 3.44 | 15.2 | 15.9 | 24.3 | 34.9 | 22.6 | -0.229 | -0.357 |
| | B | -3.86 | -37.9 | 0.0223 | 1.77E+28 | 16.7 | 63.2 | 95.9 | 76.6 | 64.1 | 44.0 | 6.05E+35 | 2.79E+44 |
| | C | 0.0006 | 0.0001 | -0.002 | 0.1 | 0.0005 | 0.0006 | 0.0008 | 0.0005 | 0.0003 | 0.0003 | 0.1 | 0.1 |
| 6m to 8m | A | 2.97 | 0.06 | -1.47 | -0.86 | -1.77 | 2.02 | 6.35 | 5.27 | 5.64 | 0.134 | -0.729 | -0.687 |
| | B | 8.72 | 2.33 | -0.75 | 1.31 | 1.74E+50 | 61.3 | 47.9 | 56.0 | 34.8 | 4097 | 6.05E+35 | 2.79E+44 |
| | C | 0.0004 | 0.0004 | 0.0006 | 0.0003 | 0.3 | 0.001 | 0.0009 | 0.001 | 0.0008 | 0.004 | 0.1 | 0.1 |

Temperature = $A - Be^{-C*YEAR}$

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