Scope 3 – Reclamation Methodology Evaluation Research Program

Myra Falls Mine Reclamation Research Program

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Prepared for:

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The Reclamation Methodology Evaluation Research Program (RMERP) presented herein is part of a larger Reclamation Program to be provided to the British Columbia Ministry of Energy, Mines, and Petroleum Resources (EMPR). Reclamation research design, planning, implementation and monitoring are based on the approved closure and reclamation plan. The results of reclamation research are reported in the annual reclamation report, and re-evaluated and adjusted during the rolling five-year reclamation and closure report update.

Reclamation research for the mine site is based on the objectives of closure and reclamation in the mine permit approval, Park permit approval, stakeholder input and First Nation engagement. To support operational scale reclamation, a series of research trials and field-based knowledge gathering surveys are put in place to test and verify that specific reclamation prescriptions will work towards meeting end land use objectives prior to being applied at an operational scale.

The key reclamation research themes described in this RMERP are:

- Long-term Watercourse Reclamation Plan, including a Water Infrastructure Decommissioning and Reclamation Plan as well as associated studies, and an Aquatic Habitat Reclamation Plan. This plan addresses and describes the reclamation details of each watercourse at the mine site, and the methods proposed to determine the effectiveness of instream reclamation and habitat restoration.
- Terrestrial Reclamation Plan, including an Erosion and Sediment Assessment Program, Soil Compaction and Decompaction Plan, Revegetation Prescription Plan, research for old-growth attributes and a Soil Cover Plan. The focus of this theme is designing studies to assess, monitor and evaluate the reclamation efforts on soil, vegetation and wildlife at the mine site.
- Metal Uptake Monitoring Plan, addressing proposed study designs and methodologies to develop a monitoring program to evaluate metal uptake in exposed terrestrial and aquatic ecosystems. Additionally, a study is designed to assess and monitor the effects of metal uptake in aquatic organisms, as well as to identify what the potential constituents of concern (CoC), exposure risk and exposure pathways to wildlife are on site.

The RMERP outlines the proposed study design and methodology used in these plans to assess the effectiveness of proposed reclamation efforts and identifies additional research that may be required to test recommended future reclamation treatments and actions. The outcomes of the RMERP will inform the Reclamation Monitoring Program that will be presented under separate cover. Proposed research themes and implementation plans, responsibilities and timing identified by each discipline guide the discussions on how research activities are incorporated into Nyrstar's operations activities, and how Nyrstar can work towards an integrated reclamation research program.

Abbreviations

ABA	acid base accounting
BACI	before-after-control-impact
BC	British Columbia
CCME	Canadian Council of Ministers of the Environment
COPC	constituents of potential concern
Core Rack Area Borrow	CRAB
CPUE	catch-per-unit-effort
DO	dissolved oxygen
DOC	dissolved organic carbon
EEM	environmental effects monitoring
EMPR	Ministry of Energy, Mines, and Petroleum Resources
ha	hectare
IEG	Integral Ecology Group
km	Kilometre
MELP	Ministry of Environment, Lands and Parks
mm	millimetre

RISC	Resources Information Standards Committee
RMERP	Reclamation Methodology Evaluation Research Program
Robertson	Robertson Geoconsultants Inc
RRP	Reclamation Research Program
SIS	seepage interception system
Stantec	Stantec Consulting Ltd.
TDF	Tailings Disposal Facility
TSS	Total suspended solids
the mine site	Myra Falls Mine
TLU	traditional land use
Wood	Wood Environment & Infrastructure Solutions
WQG	Water quality guidelines

1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by Integral Ecology Group (IEG) to develop a Reclamation Methodology Evaluation Research Program (RMERP) for the Myra Falls Mine (the mine site). The site is in Strathcona-Westmin Provincial Park, approximately 90 kilometres (km) southwest of Campbell River, on central Vancouver Island, British Columbia (BC). The mine is a polymetallic zinc, copper, silver and gold mine operated by Nyrstar Myra Falls Ltd. (Nyrstar).

The Reclamation Methodology Evaluation Research Program (RMERP) (**Scope 3**) is part of a larger Reclamation Program to be submitted to the British Columbia Ministry of Energy, Mines, and Petroleum Resources (EMPR). The RMERP is one of the scopes of work that are contributing to the Reclamation Program as follows:

- **Scope 1:** Reclamation Research Program (RRP, Stantec 2019) that summarized reclamation research undertaken at the site and identified reclamation themes along with implementation plans to close knowledge gaps identified; the RRP provides the framework for following scopes.
- **Scope 2**: Site-wide End Land Use and Post-closure Ecosystem Development Plan to inform site-specific reclamation prescriptions.
- **Scope 3**: RMERP, presented herein, proposes study designs for the development of a five-year research program that evaluates reclamation methodologies recommended by current and future reclamation plans.
- **Scope 4**: Reclamation Monitoring Program to demonstrate that reclamation is meeting permit and internal requirements, using comparison to Quantifiable Performance Objectives and including trigger, action and response plans.

The results and recommendations of the research program have been informed by the assessments completed in Phase 1 of Nyrstar's reclamation studies, including Topsoil Management Plan (Wood 2018a), Pre-mining Habitat Assessment (Wood 2019a), and Habitat Loss Mitigation Plan (Wood, 2019b).

1.1 REGULATORY CONTEXT

Reclamation research design, planning, implementation and monitoring are based on the approved closure and reclamation plan. The results of reclamation research are reported in the annual reclamation report, and re-evaluated and adjusted during the rolling five-year reclamation and closure report update.

The objectives of closure and reclamation are based on *Mines Act* Permit M-26 and *Parks Act* Permit approvals, stakeholder input and First Nation engagement. To support operational scale reclamation, a series of research trials and field-based knowledge gathering surveys are proposed to test and verify that specific reclamation prescriptions will work towards meeting end land use objectives prior to being applied at an operational scale.

The following key regulations and permits have been considered in the development of the RRP and RMERP:

- Section 10 of the Health, Safety, and Reclamation Code for Mines
- *Mines Act* Permit M-26 administered by EMPR
- *Environmental Management Act* Effluent Permit PE-6858 administered by the BC Ministry of Environmental and Climate Change Strategy
- *Drinking Water Protection Act* and Drinking Water Protection Regulation Permit AMID-927USG administered by the Vancouver Island Health Authority
- *Fisheries Act* Metal and Diamond Mine Effluent Regulations administered by Environmental Canada
- Master Plan for Strathcona-Westmin Provincial Park (Ministry of Environment Lands and Parks, MELP)
- *Parks Act* Park Use Permits 102633 and 102201

1.2 INDIGENOUS CONTEXT

The site is located within the Strathcona-Westmin Provincial Park on Vancouver Island, BC. Four First Nations Groups occupy this region: Wei Wai Kum, We Wai Kai, K'ómoks, and Mowachaht/Muchalaht First Nations. A Pre-Mining Habitat Assessment (Wood 2019a) was completed to assess land capability for potential traditional use focused on the four First Nations Groups and their respective associated tribal regions (Kwakwaka'wakw, Kwakwaka'wakw, Coast Salish, Nuu-chah-nulth).

Understanding the end land use objectives for the post-mine landscape is key to meeting traditional land use (TLU) objectives. Some assessments have been completed to date which help guide site specific prescriptions. To support reclamation of the terrestrial habitats, six tree species, nine shrub species and seven herb species were identified in Wood's pre-mine habitat assessment report as potential TLU species, and the assessment focused on plant species for food and medicinal purposes (Wood 2019a). Traditional use plants are part of the consideration when developing reclamation prescriptions and at times are not always commercially available or their propagation is not well understood and forms the basis of some of the research that is completed. For the aquatic habitat that requires restoration often understanding how waterways were used prior to mining provides guidance on the prescriptions that need to be designed and tested.

The *Mines Act* Permit M-26 and the *Parks Act* Park Use Permits 102633 and 102201 have outlined requirements for engagement with First Nations as presented in Table 1.

Nyrstar is leading the engagement process with First Nations as part of their reclamation program. Inputs from First Nations provided through engagement activities will be incorporated into the RRP and RMERP.

Introduction

Table 1 Permit Requirements regarding Engagement of First Nations

Permit Name	Permit Section	Permit Condition
Mines Act Permit M-26	Section A: General	Unless otherwise requested, the Permittee shall provide to the Wei Wai Kum, We Wai Kai, K'ómoks, and Mowachaht/Muchalaht First Nations all material reports and plans relevant to this permit, including annual monitoring reports and material changes to the approved Reclamation and Closure Plan.
	Section E: Reclamation and Closure Program	The land surface shall be reclaimed with the intent of re-establishing average pre-mining capability to the following end land use objectives: wildlife habitat, particularly for Columbian black-tailed deer, Roosevelt Elk, black bears, wolves, cougars, American marten, red squirrel, deer mice, and bats, provincial park wilderness and recreational values, and opportunities for traditional use of the land by the Wei Wai Kum, We Wai Kai, K'ómoks, and Mowachaht/Muchalaht First Nations.
Parks Act Park Use Permit No. 102201 and 102633	Article 6: Covenants of the Permittee	The Permittee must: Once each calendar year, meet with the Minister, the area First Nations and the Strathcona-Westmin Park Public Advisory Committee, to discuss any management concerns that arose in the previous calendar year and to brief the Minister, the area First Nations and the Strathcona-Westmin Park Public Advisory Committee on the Permittee's planned activities under this Permit for the current calendar year.

1.3 RECLAMATION RESEARCH THEMES

The objectives of the RMERP are to propose study designs and research evaluation methods for the reclamation research themes identified in the Reclamation Research Program (Scope 1). The outcomes of the RMERP will also inform the Reclamation Monitoring Program (Scope 4). The reclamation research themes that will lead into the more detailed research program activities described in this RMERP are:

1. **Long-Term Watercourse Reclamation Plan** including a Water Infrastructure Decommissioning and Reclamation Plan, associated studies, and an Aquatic Habitat Reclamation Plan;
2. **Terrestrial Reclamation Plan** including an Erosion and Sediment Assessment Program, Soil Compaction and Decompaction Plan, Revegetation Prescription Plan, research for old-growth attributes and Soil Cover Plan; and
3. **Metal Uptake Monitoring Plan** including a Soils and Vegetation Baseline and Uptake Program, a Wildlife Exposure Risk Study, a Water Quality Sampling Program and a Metal Uptake in Aquatic Organisms Program.

The following sections provide details on the study designs of the reclamation research activities and identify additional research that may be required to test recommended future reclamation treatments/actions.

2.0 CURRENT RECLAMATION RESEARCH PROGRAM

Progressive reclamation during mining operations has been ongoing at Myra Falls for many years. Nyrstar's current reclamation research program includes the following initiatives:

- Geochemistry:
  - Closure cover design for Old tailings disposal facility (TDF), waste rock dumps, and the Lynx TDF
  - Test trials for proposed geomembrane cover designs
  - Passive water treatment for small, stable, source flows (e.g., adit outflows)
  - Tailings desulphurization trials to reduce potentially acid generating strength and to inform cover designs
  - Updated site-wide contaminant load balance model that simulates zinc loads in groundwater in the Myra Valley Aquifer and in Myra Creek flows and zinc loads to the water treatment system to support future operations and post-closure planning
  - Development of the Phase I Lynx Seepage Interception System (SIS) to reduce zinc loads in groundwater and Myra Creek
  - Design of a system of decants and spillways to manage mine-impacted water from the Old TDF
- Vegetation:
  - Moss/lichen trial for the Quarry area to determine success of natural vs. mine-affected areas
  - Groundcover transplanting block trials in the Quarry expansion area
- Hydrology and Aquatic Habitat
  - Long-Term Water Management Plan has been completed for water infrastructure required during water treatment
  - Stockpile Water Management Plan for the constructed stockpile
  - Arnica Diversion Ditch lining studies to limit groundwater infiltration into potential acid generating materials (at Lynx TDF and waste rock piles) with the goal for year-round flow and water quality improvements
  - Studying the use of the modified section of Arnica Creek as a location for off-channel habitat for flood refuge
  - Studying the use of Lynx Closure Spillway as a location for off-channel habitat for flood refuge
  - Modifications to Lower Lynx Diversion Ditch, close to confluence of Myra Creek, to support off-channel habitat and flood refuge
  - Creating new side-channels for aquatic habitats for Myra Creek by excavating the quarry to the south to match Myra Creek elevation (quarry rock is not potentially acid generating and will be used for construction and covers)
  - Myra Creek reclamation designs to increase width to probable maximum flood where possible, add coarse woody debris and gravel to the widened channel, and to allow opportunity for vegetation growth
  - Assessing for the effects from metal uptake using *in situ* hatchbox studies in Myra Creek.

3.0 PROPOSED RECLAMATION METHODOLOGY EVALUATION RESEARCH PROGRAM

The following section describes the proposed RMERPs based on the reclamation themes identified in Scope 1.

3.1 LONG-TERM WATERCOURSE RECLAMATION PLAN

Objectives: The objective of the Long-Term Watercourse Reclamation Plan is to develop a successful mitigation program to return watercourses to their pre-disturbance hydrology and geomorphology to support biodiversity (e.g., fish and fish habitat), recreation, and flood management with restoring lateral and/or longitudinal connectivity of water and sediment and minimizing non-contact water with mine impacted material.

Methods: A Long-Term Watercourse Reclamation Plan will be developed in a phased approach. The first phase identifies watercourse reclamation that can be achieved post closure during water treatment and the second phase is watercourse reclamation that can be achieved post closure after water treatment is not required. As timing of the completion of water treatment is unknown, this plan describes the first phase of the Long-Term Watercourse Reclamation Plan which includes hydrology and aquatics studies. These studies will provide an assessment of monitoring methods used to determine the effectiveness of watercourse reclamation and are further described below.

3.1.1 Water Infrastructure Decommissioning and Reclamation Plan

Objectives: A Water Infrastructure Decommissioning and Reclamation Plan will describe reclamation details of each watercourse. The *Mines Act* Permit M-26 describes the goal of watercourse reclamation to return watercourses to a stable, erosion-free, and self-sustaining state where possible. While noting that streambank instability and streambed erosion are part of the lifecycle of natural watercourses, this goal is generally interpreted as restoring the watercourse to a state that reflects its natural behavior, follows a pathway that is reflective of underlying topography, and has opportunity for lateral migration.
More specifically, the goal for watercourse reclamation is defined as returning watercourses to their pre-disturbance hydrology and geomorphology to support biodiversity (e.g., fish and fish habitat), recreation, and flood management with restoring lateral and/or longitudinal connectivity of water and sediment.

Site Selection: This plan will assess watercourses that are located within the permit boundary of the mine and will include, at minimum:

- Major diversion ditches: Arnica Diversion Ditch, Upper Lynx Diversion Ditch, and Lower Lynx Diversion Ditch
- Other minor diversion ditches
- Myra Creek
- Arnica Creek
- Cascade Creek
- Webster Creek
- Any other small tributaries that may have been modified during mining
- Adit outflow(s)

Methods: Additional hydrology data is needed to develop the Water Infrastructure Decommissioning and Reclamation Plan. Studies have been identified and are described in the following subsections.
Once these studies are complete, the Water Infrastructure Decommissioning and Reclamation Plan can be developed.

3.1.1.1 Performance Assessment of Diversion Ditches

Objectives: Non-contact surface water from the Arnica Creek and Cascade Creek watersheds is diverted around the mine material, specifically the waste rock piles, Lynx TDF, and the Old TDF (see Figure 1). These diversions, the Arnica Diversion Ditch, the Upper Lynx Diversion Ditch, and Lower Lynx Diversion Ditch will be assessed to confirm design requirements for long-term flow capacity and stability and to understand the context of how these ditches affect the flow and sediment transport in the watershed. Understanding what volume and amount of water is coming into the ditches from upstream is as critical as understanding how water moves through the ditches and into the downstream receiving waterbodies in order to design channels that can function in the long term with minimal intervention.

If necessary, options for upgrades to support long-term flow capacity and stability will be included.

Site Selection: Diversion ditches, including Arnica Diversion Ditch, the Upper Lynx Diversion Ditch, and Lower Lynx Diversion Ditch, as well as any minor ditches identified in this assessment.

Methods: This performance assessment will include desktop and field components and be completed by a qualified professional with appropriate qualifications in fluvial geomorphology and hydrology. A desktop review will be completed to identify all known diversion ditches, to review all available data, and to identify catchment areas for each diversion ditch. The desktop review will include an assessment of hydrology and geomorphology of natural drainages upstream and downstream of the diversion ditches. A site visit will be conducted to confirm and verify results of the desktop assessment. A geomorphic field assessment will be conducted for waterbodies upstream and downstream of the ditches. The field work will also include surveying any unmapped diversion ditches, mapping locations of surface water flows in and out of the site, and assessment of rip-rap performance. A fly-over will occur if required to document inaccessible areas. This performance assessment will also include collection of hydrometric data, and/or installation of a hydrometric station if deemed necessary, which will be combined with the Surface Water Flow Monitoring Study, as described in the following section. Once the desktop and field work are complete, identification of risk of overflow under current designs and a proposal of potential design upgrades will be completed.

Once this assessment is complete and any upgrades to current diversion ditches are completed, performance monitoring of the assessment ditches will occur. A water infrastructure capacity assessment has been completed by Wood in September 2019 which includes a summary of ditching design capacity to meet EMPR permit requirements (Wood 2018b). Performance monitoring of diversion ditches will be described in the Reclamation Monitoring Program (Scope 4).

311000 311200 311400 311600 311800 312000 312200 312400 312600 312800 313000 313200 313400 313600

5495400 5495200 5495000 5494800 5494600 5494400 5494200 5494000

Lynx 5L West Adit
Lynx 5L East Adit
Lynx 6L West Adit
Lynx 6L East Adit
Lynx 8L Adit
Lynx 10L West Adit
Lynx 10L East Adit
Phillip's Reach Adit
Myra 11L Adit
Myra 10L Adit
Myra 9L Adit

WRD 1
WRD 2
WRD 3
WRD 4
WRD 6

LYNX TDF
LYNX OFFICES
MILL
OLD TDF
QUARRY
SUPER POND
SURGE POND
ETA/ COOKHOUSE AREA
POLISHING PONDS
HW OFFICES AND HEADFRAME
DISCONNECTED NOD

INNER DRAIN
OLD OUTER DRAIN (DISCONNECTED)
OLD OUTER DRAIN
SHORT DRAIN
MEDIUM DRAIN
LONG DRAIN
TO CAMPBELL RIVER

UPPER LYNX DIVERSION DITCH, ULDD
LOWER LYNX DIVERSION DITCH, LLDD
CASCADE CREEK
ARNICA CREEK
MYRA CREEK
WEBSTER CREEK

S:\Files\Projects\212000 Nyrstar\212011 2017 Closure Planning Support\GIS_CAD\Maps\Report 7\Final Maps\Figure2-2_GeneralMineArrangement.mxd

General Mine Arrangement 2018, Nyrstar Myra Falls

Legend

Class B Park Boundary

Scale 1:7,000

0 50 100 200 300 400 500 Meters

NAD83 UTM Zone10N

Robertson GeoConsultants Inc.
Consulting Engineers and Scientists for the Mining Industry
www.robertsongeoconsultants.com

Client: nyrstar	**Figure: 1**
Project: 2018 Load Balance Update	Last Update: Nov 16, 2018
Report: RGC 212011/7	Drawn: L.R.
Original File: Figure2-2_GeneralMineArrangement.mxd	

3.1.1.2 Surface Water Flow Monitoring Study

Objectives: To inform reclamation channel design and flow modelling, flow data is required for future models and reclamation works.

Site Selection: Flow data will be collected by installing hydrometric stations on the mine site and conducting flow measurements. The existing hydrometric station (on Myra Creek) will be optimized for flow monitoring. Additional station locations will be installed on selected sites based on professional opinion of a qualified professional with appropriate qualifications in fluvial geomorphology and hydrology. At minimum, these stations are to be installed at lower Arnica Creek, Lower Lynx Diversion Ditch, and Webster Creek. A more detailed assessment of the total number of stations to be installed will be undertaken by a qualified professional prior to field work.

Methods: The hydrological data collected at the site is required to meet Resources Information Standards Committee (RISC 2018) standards. The existing network will be reviewed and evaluated based on the guidelines; recommendations for any adjustments to the current program will be provided. Hydrometric stations can consist of either a pressure transducer or other types of hydrometric monitoring instrumentation such as a weir or flume. Results of the hydrology study of Myra Creek completed by Wood (2019b) will be evaluated and incorporated into this study.

Once hydrometric stations are installed, monitoring will include routine field flow measurements to occur during operations and continue until closure and will coincide with water quality data collection. Monitoring details of the Surface Water Flow Monitoring Study will be described in the Reclamation Monitoring Program (Scope 4).

3.1.1.3 Myra Creek Geomorphology Assessment

Objectives: To inform channel reclamation design of Myra Creek, a geomorphologic assessment is necessary to determine a design template based on natural channel morphology in the watershed.

Site Selection: The assessment location will be Myra Creek upstream and downstream of the mine. The final locations of this survey will be determined onsite by a geomorphologist, incorporating the understanding of the long-term objectives of the channel and reaches in Myra Creek that appear to be in a state of quasi-equilibrium.

Methods: The assessment will include topographic surveys, channel morphology, surface and sub-surface sediment size distributions, areas of natural erosion and sedimentation processes as well as the natural stability of the channel can provide a natural template to inform channel reclamation design. Selected sites should reflect the stream geomorphology of Myra Creek that is unaffected by mining operations, to be used as reference sites. This assessment will be conducted and completed alongside the fish habitat utilization monitoring (see Section 3.1.2) as the stream morphology impacts the likelihood of fish presence.

3.1.1.4 Power Supply Options Analysis

Objectives: A Power Supply Options Analysis will provide an assessment of power supply sources (i.e., alternative, cost-effective supply solutions) for current and pre-closure water treatment to assess if one or more of the hydroelectric facilities (i.e., Thelwood and Tennant Creek hydroelectric dams) may be removed as part of progressive reclamation. This options analysis will inform the Long-Term Watercourse Reclamation Plan.

Site Selection: Existing hydroelectric facilities that exist under the mine's *Park Act* permits will be selected for this options analysis and include Thelwood and Tennant Creek facilities.

Methods: The Power Supply Options Analysis would include the following three main steps:

1. Identify the power supply options
   a. Review existing data and power supply needs
   b. Propose power supply options
2. Evaluate the power supply options based on availability, efficiency, reliability, risk and cost
3. Recommend a preferred option that is feasible and inline with reclamation objectives

3.1.2 Aquatic Habitat Reclamation Plan

Objectives: The objective of the Aquatic Habitat Reclamation Plan is to inform the development of the Long-Term Watercourse Reclamation Plan. Aquatic habitat reclamation is intended to have a positive effect on water quality and reduce suspended sediments over time, which can be achieved by:

Reclaiming riparian areas to act as a filter by decreasing overland runoff velocities, reducing erosion, and causing sediments to deposit in vegetated areas prior to entering a waterway. Riparian areas also offer shade and are a critical contributor of allochthonous material, such as leaves and branches.

Reclaiming stream habitat using a channel configuration suited to the hydrological regime and geomorphology of the watercourse to reflect natural bed substrates (e.g., sediment particle size and composition) and suspended sediment levels.

Surface water flow patterns on the Myra Falls Mine permit area have been modified to manage flows around the mine. Diversion channels have been built to capture and reroute tributaries and sections of Myra Creek and Arnica Creek have been straightened. The intent is to leave these watercourses in their current position but restore channel function and habitat potential. It is anticipated that, as the channel form is restored (i.e., channel units including riffle, run and pool sequences reflect the sinuosity, gradient and substrate of the natural channel), habitat features such as spawning gravels, pool habitat, cover, will return in a manner that reflects natural habitat in these watercourses (i.e., upstream and downstream of the permit area).

SCOPE 3 – RECLAMATION METHODOLOGY EVALUATION RESEARCH PROGRAM

Proposed Reclamation Methodology Evaluation Research Program

Conceptual stream channel restoration plans include:

- Widening Myra Creek and adding channel structure (e.g., coarse woody debris, artificial snags, boulders and gravel) to enhance and protect habitat
- Purposeful planting of soils and vegetation in the riprap outside the normal flood levels on the creek to enhance shading on the creek
- Enhance the Lynx closure spillway, Lower Lynx Diversion ditch, the Quarry, and Arnica Creek to create off-stream habitat

Stream Channel Restoration Plans have not been completed; therefore, aquatic habitat reclamation treatments have not yet been developed. These will be created over time as plans are available and geomorphic constraints for these water features are determined.

Proposed studies and monitoring methods to determine the effectiveness of instream reclamation and habitat restoration are as follows:

Geo-referenced Habitat Surveys: air photos provide an effective tool for georeferencing habitat maps and illustrating the nature of important habitat features. Annual mapping can be used to demonstrate how habitat evolves over time and responds to channel modifications and restoration.

Bed Sediment Monitoring: Streamflow dynamics and the supply of sediment from upstream sources affect how sediment is eroded and deposited. Channel modifications completed as a result of the mine or for reclamation purposes have the potential to affect the size of sediments and where the sediment is deposited and accumulated in the channel. The distribution and size of sediment is critical for the different life stages of fish species, such as cutthroat trout (*Oncorhynchus clarkii*) which is a target species that utilizes the area. A monitoring program will be developed to ensure that sediment within the reclaimed areas are suitable for the target fish species. The effectiveness of the reclamation efforts on bed sediments can be monitored annually and verified with a fish habitat utilization study further described below.

Fish Habitat Utilization Study: Cutthroat trout is the only fish species found in the watershed (Nautilus, 2017), and increasing numbers are expected in Myra Creek following stream channel and habitat restoration. Appropriate assessments (e.g., redd surveys, electrofishing, angling techniques, trapping) will include monitoring fish presence in Myra Creek and fish use of habitat features (e.g., suitable gravel beds for spawning; cover for rearing). To assess the effectiveness of stream channel and habitat restoration efforts, fish habitat use can be quantified by calculating and comparing the spatial and temporal (seasonal) relative abundance (catch-per-unit-effort; CPUE) of cutthroat trout across sites within the reclamation zone and upstream and downstream of the mine site (reference sites). Fish density (number of fish/m^2) can be estimated if sections of known size are netted off. Additionally, measurements of captured fish weight and size can be collected, as well as information on age-class spatial distribution.

Fish Habitat Sampling Site Selection: Sampling locations for fish presence will have to be selected during an onsite assessment. Reference sites to be sampled for fish presence and abundance can be identified through onsite surveys based on stream morphology and likelihood of fish presence. Alternatively, the same sampling locations can be used (within the reference and exposure areas) as throughout Cycles 1 and 2 of the environmental effects monitoring (EEM, Nautilus, 2017).

Multiple sample locations throughout the watershed will allow accounting for spatial variability and compare fish habitat utilization between sites that are subject to reclamation efforts as well as sites upstream and downstream of the mine site (reference sites). If capture methods prove to be ineffective, fishing techniques can be altered, or sample sites moved. By fishing for cutthroat trout pre- and during reclamation of the mine site, the changes due to reclamation efforts and channel design on the presence and age distribution of cutthroat trout in the area can be assessed (Before-After-Control-Impact [BACI] design). Sampling across different seasons allows us to assess annual abundance trends. Sampling intensity and frequency are to be determined and evaluated throughout the RMERP.

Considerable overlap exists between the aquatic and hydrology components of the evaluation program; therefore, these two components will have to be implemented concurrently to maximize efficiencies.

3.2 TERRESTRIAL RECLAMATION PLAN

The following sections present the different components and study designs for the Terrestrial Reclamation Plan.

3.2.1 Soil Erosion and Sediment Delivery Assessment Program

Erosion and Sediment delivery potential is high at the mine site given the annual rainfall amounts, as well as the intensity/duration/frequency of rainfall events. This is particularly true on areas of exposed mineral soil prior to re-establishment of vegetative cover. The following provides details on the proposal Soil Erosion Program.

Objectives: The objectives of the Soil Erosion Program are to:

- Provide information on erosion occurrence and extent on the slope gradients, slope lengths, material types and facilities on the mine site;
- Document incidents of rill and gully erosion on reclaimed areas of the mine site and causal factors of erosion

The Soil Erosion Program will focus on measuring rill erosion on different slope gradients and slope lengths and volumetric measures of soil loss due to gully erosion. The program will provide approximate estimates of rill and gully soil erosion loss and will provide insight into the causal factors of rill and gully erosion on the reclaimed landscape. The program will be conducted in conjunction with the revegetation prescription program and will provide information that can be used for mitigating soil erosion loss and future reclamation planning.

Site Selection: Sites selected for measuring erosion will be where Nyrstar staff and a Qualified Professional identify areas where rill and gully erosion has been observed. Rather than focusing on single sites, the approximately 30 ha area old TDF could provide an area for larger scale reclamation that can also include selected soil erosion monitoring sites.

Methods: The following rill and gully erosion sampling methods are recommended:

Rill Erosion: Rill Erosion will be initially be measured using Alutin transect method and perhaps later using a soil bridge (McCool et al, 1981) at established reference points. Information collected at sites will not only include volumetric measurements of soil loss but also the occurrence and extent of rill erosion by mine facility type (e.g. Waste Rock dump #6) slope gradient, slope length, soil texture, soil coarse fragment content and vegetative cover.

Gully Erosion: The gully erosion program objectives are to provide a reconnaissance estimate of gully erosion soil loss and to identify the cause and factors leading to gully erosion on the mine site. Soil loss from gullies identified on the mine site will be estimated from cross sectional and longitudinal transects that measure the soil evacuated from the gully. Additional information on the cause of gully erosion and activity state of the gully will also be collected.

3.2.2 Soil Compaction and Decompaction Program

Research on decompaction methodologies for reclamation areas at Myra Falls is a requirement under the *Mine's Act* Permit M-26. Successful revegetation of reclaimed sites requires non-compacted surface materials, which can be affected by mining operations (e.g. machinery operation, traffic and storage, Strahm et al., 2007).

Soil compaction results in a decrease in soil pore volume, which affects soil structure, soil aeration, soil water infiltration and soil drainage. These factors in turn affect soil erosion potential, plant root development, microbial activity, nutrient uptake and availability and ultimately the ability of reclamation sites to support plant communities. Soil compaction on a mine site is often the result of heavy machinery traffic or frequent use of lighter equipment. The susceptibility of soils to compaction depends on several factors including soil texture, organic matter content, and soil moisture conditions.

Wood (2018) recommended rough and loose placement (i.e., placing buckets of soil in a staggered pattern) along the banks of Myra Creek. The existing permit requires the placement of 300 mm of growth medium over 700 mm of compacted till on the Lynx TDF dam face. An alternative approach is to place non-acid generating waste rock over the compacted till followed by a non-compacted placement of woody debris and finer textured soil.

Objectives: The objectives of the soil compaction/decompaction program study are to:

- provide information on the range of soil bulk density on the reclaimed mine site
- provide information on soil bulk density, types of soil, methods of soil replacement and reclamation site preparation
- provide information on the effectiveness and decompaction treatments employed on the mine site

Site Selection: Initially, soil compaction study sites will be selected to represent the range of soil replacement and reclaimed site preparation on reclaimed facilities on the mine site. The location of soil compaction sites will be based on consultation with operational reclamation staff and an onsite Qualified Professional who will identify areas where different soil replacement/reclamation site preparation were employed.

If the soil compaction assessment indicates the need for soil decompaction treatments, then soil-decompaction treatments may be employed on these areas or in areas where soil compaction is observed during site preparation or revegetation efforts. The soil decompaction methods (e.g., single-shank excavator ripper, winged ripper blades, excavator mounding) will be decided in conjunction with Myra Falls operational staff and will partially depend on reclamation material type availability of equipment.

Methods: The method used to measure soil bulk density will depend on soil conditions and purpose. Portable nuclear moisture/density method may be used during the initial survey and to study decompaction treatments and their long-term effects. Water or sand replacement methods may be used during the initial survey of soil bulk density on areas of soil replacement and areas of site preparation. Any decompaction studies also need to measure plant growth and vigor on areas where soil decompaction was carried out and areas where decompaction was not carried out.

3.2.3 Revegetation Prescriptions Program

Mines Act Permit M-26 requires that land surfaces shall be reclaimed to end uses that enhance Park values including reintegration of disturbed land into the surrounding landscape, re-establishment of native forest, and reduction of erosion through the development of maintenance-free indigenous vegetation communities.

Investigations into the components of the revegetation plan (i.e., test planting, erosion potential, soil development and ecological trajectories) need to be undertaken as part of the Terrestrial Reclamation Plan (Section 3.2).

Establishment of a vegetation cover that will reduce erosion and then later develop into a self-sustaining and functionally diverse plant community that will support the desired end land use is crucial. It is envisioned that initial revegetation prescriptions will reflect successional processes through to the desired climax forested ecosystems, apart from areas such as Amalgamated Paste Area (APA) berm which will remain in early seral grass cover for geotechnical reasons. With succession, there should be an increase in the number of species utilizing the reclaimed landscape, eventually to a point where species diversity is similar to neighboring undisturbed ecosystems.

SCOPE 3 – RECLAMATION METHODOLOGY EVALUATION RESEARCH PROGRAM

Proposed Reclamation Methodology Evaluation Research Program

A variety of revegetation approaches and prescriptions may be employed on the reclaimed landscape. The objectives of the revegetation prescription program are to evaluate reclamation approaches and prescriptions presently utilized on site and to test and evaluate some alternative methods of revegetation. Seeding with native grasses (and potentially legumes) may be used in some areas to control erosion, limit invasive-plant establishment and build up soil organic matter. However, in order to begin native successional processes, native plant collection, propagation and establishment need to be included in the revegetation and accompanying research plan. The Nyrstar Myra Falls Interim Site-Wide Closure and Reclamation Plan (IEG, 2014) outlined a list of locally appropriate candidate vegetation species based on anticipated soil moisture. This plan recommends planting 2,000 to 5,000 red alder seedlings per hectare. Other strategies that may be utilized to assist in revegetation efforts could include natural vegetation establishment and ingress from seeds and propagules contained within the replaced cover-soil, direct seeding of grass and forb species, transplanting seedlings or “pads” of vegetation from undisturbed sites and planting of propagules (e.g., live staking).

Objectives: The objectives of the revegetation prescriptions program are to:

- Determine the viability of revegetation, by testing planting and seeding methods with native plant species, including culturally important species
- Evaluate the reclamation approaches and prescriptions to confirm that ecological trajectories are consistent with the land-use and capability targets
- Evaluate the success of revegetation, soil development and erosion control. This program should include specific sampling parameters and performance criteria.

Site Selection: The revegetation prescription sites will be identified with Nyrstar staff and a Qualified Professional. A potential site for larger scale reclamation that also allows for revegetation prescriptions is the 30 ha old TDF site. Seeding for erosion control and tree and shrub establishment, soil cover, seedling/vegetation transplants and live staking trial can be established in this area.

Methods: The following assessments and measurements are recommended to evaluate revegetation viability and effectiveness in establishing plant species composition that will lead to the establishment of desired ecosystems within a 5-year period:

- *Seeding for Erosion Control* – An evaluation of seeding of native grasses (and legumes if available) for erosion control will be carried out in conjunction with the erosion and sediment program. Seeding for erosion control can be carried out by hand seeding with a cyclone seeder, all-terrain vehicle (ATV) mounted cyclone seeder, hydro seeding, seeding with mulch and aerial seeding. Plant cover and vigor will be assessed along transects in areas with notable evidence of accelerated rill and gully erosion and in adjacent areas. Assessments will be carried out following emergence of plants and 4 to 5 months after seeding (assuming seeding occurs in the spring) and during the following growing season.

- *Seeding for Tree and Shrub Establishment* – An evaluation of direct seeding with grasses, forbs, shrubs and some tree species for both erosion control and to initiate the establishment of targeted species will be carried out post-treatment at 4 to 5 months (assuming seeding occurs in the spring), year 1, year 2, year 3 and year 5. Species composition and plant vigor and growth will also be assessed at designated long-term vegetation monitoring plots. Initially, vegetation monitoring plots will be established for each hectare of area that is seeded. Plot size will be determined based on seeding rates.
- *Natural Vegetation Establishment on Soil Covers* – An evaluation of the establishment of targeted species of forbs, shrubs and trees from the placement of soil from soil stockpiles and direct placement of soil from undisturbed to reclaimed areas will be undertaken within 4 to 5 months post-treatment (assuming it is the same growing season), and at year 1, year2, year 3, and year 5. Tree, shrub and forb species emergence, growth and vigor will be assessed on plots established on areas with soil cover placement. Plots will be established in areas with direct soil placement, soil placement from soil stockpiles and areas with no soil cover.
- *Seedling/vegetation transplants* – An evaluation of both seedling and/or vegetation pad transplanting (transplanting grass, forbs, seedlings, saplings and forest floor litter and humus from undisturbed areas to the reclaimed landscape will be undertaken 4 to 5 months after soil placement (assuming it is the same growing season) and at year 1, year 2, year 3, and years 5. Plots will be established on areas representative of the reclaimed facility and method of transplant (i.e., transplanted seedlings and transplanted vegetation pads).
- *Planted Seedlings and Propagules (e.g., live staking of willows or cottonwood and a possible trial with red alder)* – A post-treatment evaluation of seedling/propagule mortality, vigor, growth rate and ability to compete with surrounding vegetation will be assessed on designated plots at 6 months, year 1, year 2 years year 3, and year 5. It is envisioned that vegetation monitoring plots will be established on each hectare of the reclaimed landscape that is planted. Vegetation monitoring plots will also need to be located to ensure representation of the range of soil and site conditions in the areas that are being revegetated.

Successional trajectories will be monitored by documenting the changes in species composition and cover that occur in the ecosystem both within the first 5 years and in the longer term. The frequency of assessment and prescribed methods after year 5 will be recommended in the 5-year reclamation revegetation report.

Returning reclaimed soils with characteristics such as organic matter content, structure, nutrient cycling and microbial activity that are similar to neighboring undisturbed soils will take a long time. In addition, soils on the reclaimed landscape can be very heterogeneous so measuring development such as increases in soil organic matter, soil nitrogen content, changes in pH can be markedly different from soils in one area to the soils in an adjacent area. Soils will be described and sampled at the time of plot establishment for future reference; however, in the short term (e.g. first five years), it is recommended to look at general soil amelioration and monitor vegetation growth and vigor rather than expending effort on detailed soil sampling and analysis.

Sampling Intensity: The number of plots established to assess revegetation viability and success, control erosion and track ecological trajectories will depend on the characteristics of the revegetation prescriptions carried out on the mine site.

3.2.4 Wildlife Habitat Restoration Program

Nyrstar must re-establish suitable wildlife habitat for local wildlife species as per Section D, Part 2(a) of *Mines Act* Permit M-26. It is anticipated that soil and vegetation prescriptions will assist in the re-establishment of native vegetation communities that will support the life requisites (e.g., food, thermal and security cover) of a diversity of wildlife species, including the target species and species groups[1] listed under the M-26 Permit. The site will progress though successive structural stages over time, each of which is expected to support different wildlife communities (reference crosswalk table, Scope 2).

Detailed restoration prescriptions for wildlife have not yet been fully developed for the mine site. Restoration prescriptions will include the installation of habitat elements (i.e., rock piles, woody debris) to improve site conditions for wildlife species, and vegetation prescriptions that incorporate important vegetation species for wildlife habitat. The establishment of wildlife features associated with old-growth habitat is discussed in Section 3.2.5. The proposed Wildlife Habitat Restoration Program is further described below.

Objectives: The objectives of the Wildlife Habitat Restoration Program are to:

- Determine the viability of revegetation and habitat enhancement methodologies to restore ecosystems that support the life requisites of a diversity of native wildlife species
- Establishment and assessment of research trials to evaluate the effectiveness of wildlife reclamation approaches and prescriptions applied
- Evaluate whether wildlife habitat restoration prescriptions are resulting in trajectories that will support desired end-land use objectives. This program will include performance objectives that can be used to quantify restoration success for focal wildlife species

The following field surveys and research trials are recommended to evaluate the feasibility and effectiveness of wildlife habitat restoration methodologies:

Wildlife Use Surveys: An evaluation of current wildlife use at Myra Falls (disturbed and undisturbed areas) will be carried out prior to the initiation of reclamation activities and after reclamation activities occur as part of a BACI sampling design.

[1] Columbian black-tailed deer, Roosevelt elk, black bear, wolf, cougar, American marten, red squirrel, deer mouse, and bats

A preliminary wildlife field survey within the permit area will be carried out during the spring/summer to assess current wildlife use, habitat suitability, and location of wildlife features. The results of the survey will be used to:

- Document evidence of wildlife use, potential habitat for target species, wildlife accessibility, and connectivity to undisturbed habitat.
- Assess the likelihood of wildlife interaction with contaminants on site to inform the Metal Uptake Monitoring Plan (Section 3.3).
- Assess wildlife habitat restoration potential for target species based on landform and the post-closure land cover predictions described in Scope 2
- Identify priority areas for habitat restoration and wildlife monitoring
- Inform site-specific reclamation prescriptions to enhance wildlife habitat and connectivity

Subsequent wildlife use surveys will be carried out following revegetation prescriptions and the installation of habitat elements to monitor wildlife use of restored areas and evaluate restoration success. Monitoring of wildlife use over time may provide a useful measure of performance of habitat recovery. Details of the wildlife monitoring program are discussed in Scope 4.

Habitat Elements: Test plots will be carried out to evaluate methods for restoring habitat elements and wildlife features on site that are required to support native wildlife species. Test plots should consider, but not be limited to, installing the following habitat elements: bird nesting boxes, bat roosts, coarse woody debris, and boulder piles. The success of the test plots will be evaluated and monitored using specific sampling parameters and performance criteria (discussed in Scope 4).

Habitat Suitability Modelling: Habitat suitability modelling will be used to characterize current conditions and identify priority areas to restore for target wildlife species, and areas that may limit or restrict wildlife use. Results from the models can be used to guide the direction of reclamation activities.
Habitat suitability models will be linked with the post-closure ecosystem projections.

3.2.5 Research for Old-Growth Attributes Program

The structural and biological attributes of old-growth forests provide important ecosystem functions and unique habitat values for wildlife species. Nyrstar must implement methods to mitigate old-growth forest that is lost as a result of mining activities as per section E, Part 2 (b) of *Mines Act* Permit M-26.

Research on old-growth attributes is intended to test the viability of reclamation treatments for re-establishing habitat elements that are essential for the life requisites of old-growth wildlife species. Loss of old-growth forest affects species dependent on habitat elements such as large trees with dead tops, wildlife trees, and large coarse woody debris. These species include marbled murrelet, bats, small owls, American marten, red squirrel and others. Structural attributes of old-growth forests that provide habitat for old-growth wildlife species include:

- Standing dead trees (snags)
- Fallen logs, coarse woody debris in various stages of decay
- Thick forest floor layers
- Large diameter trees with large branches and fissured bark

- Trees with varying levels of decay (e.g. stem cavities, dead tops)
- Multi-layered canopies, canopy gaps, vegetation species diversity, variable stand density

Old-growth attributes are characterized by spatial and vertical heterogeneity. Some attributes can be created artificially through reclamation treatments (e.g. installing snags, coarse woody debris); others require time to develop (tree size, forest floor thickness). Due to the uncertainty surrounding methods for re-establishing old-growth forests on mine sites and the long timeframe involved, offsetting, as described by Wood (2019c) will also be required to meet *Mines Act* Permit M-26conditions.

Research for old-growth attributes in the Monitoring Methodology Evaluation program will focus on attributes that can be improved and evaluated on the mine site within a 5-year time period; however, restoring the functioning, composition and structure of old-growth forests will require long-term monitoring and adaptive management far beyond the 5-year period.

Objectives: The objectives of the research for old-growth attributes are:

- Determine the feasibility of restoration methods to re-establish old-growth attributes that can support the life requisites of old-growth wildlife species
- Evaluate restoration prescriptions to confirm that ecological trajectories support the end-land use and capability targets for old-growth ecosystems

Research Trials: Research trials to develop and evaluate techniques for restoring old-growth forest attributes will be an important component to determine whether the reclaimed landscape can support pre-mining habitat capability for wildlife species. Habitat enhancement restoration treatments proposed by Wood (2019c) to be evaluated using research trials include:

- Scattering woody debris on rough and loose microtopography to provide decomposing wood that will provide thermal and security cover for wildlife species and perching sites for birds
- Installing artificial snags to provide nesting and perching sites for birds
- Constructing small boulder piles to provide thermal and security cover for small animals

A potential site for conducting some of these trials may be the 30ha old TDF site.

Other restoration treatments to consider include managing forest stands to accelerate the old-growth characteristics. For example, some studies have begun to examine the effectiveness of managing harvested stands to restore old-growth features (O'Hara et al., 2010) e.g., thinning trees to create heterogeneity, underplanting to restore tree diversity, killing trees and inoculating them with fungi to create snags. Effectiveness of restoration treatments to improve old-growth attributes on mine sites is unknown. As many of the methods posed for re-establishing old-growth features on mine sites remain untested, the objective of the research trials is to find innovative ways to enhance functional values for old-growth wildlife species. Performance objectives to evaluate old-growth attributes that can be achieved in the short- and long-term, and how to monitor them will be discussed in the Reclamation Monitoring Program (Scope 4).

3.2.6 Soil Cover Plan

The Soil Cover Plan comprises an investigation into the characteristics of materials on site for reclamation suitability. Investigations into the components of the soil cover trials (i.e., erosion potential, decompaction, and vegetation development) are captured under the Terrestrial Reclamation Plan.

The characterization of growth medium and alternative materials on site is required to assist in the development of the site-wide material balance and inventory and to identify materials that are suitable for use in reclamation to achieve end land-use objectives. Gathering this information is important to advise how much material is available on site for use in reclamation and to inform adaptive management if shortfalls are encountered. The estimated volume of growth medium (topsoil and/or overburden) required for reclamation will be approximately 550,720 m^3 (IEG, 2019).

Objectives: The objectives of the material characterization assessment are to:

- Identify and map the locations of potential sources of growth medium and alternative materials on site
- Sample and analyze growth medium and alternative materials for physical and chemical and properties
- Determine suitability of growth medium and alternative material samples for use in reclamation
- Develop a material resource inventory of suitable materials available for use in reclamation, including available woody debris

Site Selection: site selection for sampling of growth medium and alternative materials will be completed by a Qualified Professional and will include:

- Growth medium (topsoil):
- Jim Mitchell Borrow Source area
- Additional areas identified onsite during site reconnaissance
- Alternative materials (till and waste rock):
  - Existing and new quarry areas
  - Core Rack Area Borrow (CRAB) / CRAB East
  - Lynx Office / Switchback
  - Phillips Reach

Methods: Soil sample sites will be assessed by a Qualified Professional. The depth of sampling will depend on whether the site is previously disturbed or not. The following specification can be used:

- Disturbed areas (e.g., Stockpiles, Borrow pits, Quarry areas, etc.): surface grab sample (0-30 cm depth), 1 sample per sampling site
- Undisturbed areas: full profile sampling (to C horizon or refusal layer, typically 1-2 m depth), 1 sample per soil horizon

Mapping of available materials (including coarse woody debris) will be completed through visual observation during the site reconnaissance.

Laboratory Analysis: A comprehensive analytical suite will be tested for all samples. This includes, but is not limited to:

- Soil texture and coarse material content
- Soil pH
- Cation exchange capacity
- Soil organic carbon
- Plant available nutrients
- Total element concentrations (Canadian Council of Ministry of Environment [CCME] standard)—for both coarse fraction and soil-sized fraction of materials
- Acid generating potential via static acid base accounting (ABA)—for waste rock samples only

Sample Intensity: The number of samples collected during the soil sampling program will be determined onsite by a Qualified Professional. The sample intensity will depend on the type, variability and volumes of materials encountered for sampling. A laboratory duplicate sample will be collected for every 10 primary samples collected (i.e., 10% of the total sampling number).

3.3 METAL UPTAKE MONITORING PLAN

Nyrstar must develop a monitoring program for evaluating metal uptake in exposed terrestrial and aquatic ecosystems, which specifies sampling requirements and performance criteria as per Section D, Part 12 (l) of *Mines Act* Permit M-26. The following sections describe the different components of the proposed Metal Update Monitoring Plan.

3.3.1 Soils and Vegetation Baseline and Uptake Program

Objectives: The objectives of the soil and vegetation baseline and uptake program are to:

- Collect baseline information on soil metal content on salvaged soil stockpiles and on the newly reclaimed landscape
- Establish a network of sites that will be used to monitor both soil and vegetation metal concentrations
- Evaluate metal uptake of vegetation on the reclaimed landscape

Metals of Concern: The CCME and the U.S. Environmental Protection Agency have identified certain metals as Constituents of Potential Concern (COPC) based on concerns of bioaccumulation of these metals can resulted in damage to terrestrial plants and wildlife and aquatic organisms. Theses metals include Aluminum (Al), Antimony (Sb), Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Mercury (Hg), Molybdenum (Mo), Nickle (Ni), Silver (Ag), Zinc (Zn), and Selenium (Se).

Soil analysis carried out by Wood (2018) on only one sample identified elevated levels Chromium (Cr), Copper (Cu) and Vanadium (V) that were below CCME benchmarks on only one collected soil sample.

Site Selection: Soil samples will be collected from existing stockpiles of salvaged soils and from soil/vegetation metal monitoring plots established on a cross section of mine features including the Old TDF, Old Tailings Facility Impoundment structure, Lynx Tailings Disposal facility, Waste Rock Dump #1 and Waste Rock Dump #6. Initially it is suggested that plots be established on the old TDF area that is available for reclamation.

Initially, five to ten soil samples will be collected from salvaged soil stockpiles. Two to three soil/vegetation plots will also be established on each facility when they are available for reclamation. Additional sampling of plots or soil stockpiles may be carried out or additional soil/vegetation metal monitoring plots may be established if there are elevated levels of metals or if metal levels within sampled sites in a specific facility are variable and further sampling is required to accurately characterize the site. The established plots will be used to collect and monitor soil and vegetation metal levels.

It should be noted that toxic effects from metals usually require persistent exposure to high concentrations. Plots will also be established off-site to characterize reference conditions, if areas comparable to the mine site can be located. It is expected that some of the soil (and vegetation) samples collected will be at levels higher that undisturbed soils collected off-site.

Methods: The following sampling methods and frequencies are recommended:

- *Soil Sampling:* The depth of soil sampling is contingent upon the drainage properties of soils, amount of precipitation, and migration ability of metal ions. Soil samples will be collected at 3 locations for each established plot. It is suggested that soil samples should be collected from the top surface mineral layer (0 to 10 cm) and where possible at 10-40 cm depth. Soils should be sampled when plots are established and then 5 years later.
- *Vegetation Sampling:* Vegetation samples for metal uptake will be collected when plots are established if sites are vegetated. On sites vegetated where early successional grasses (and legumes) are established the optimum timing for vegetation sampling is prior to seed head emergence for grasses, and prior to the bloom stage in legumes. As vegetative community succession progresses vegetation samples will be collected from seed heads, berries and shoots of plants eaten by wildlife species or those used as part of TLU. Vegetation samples will initially be collected yearly to determine the levels and trends in metal uptake. Vegetation metal sampling frequency will be assessed at in year 3 and 5 to determine if yearly monitoring is still required.

3.3.2 Wildlife Exposure Risk Study

The Wildlife Exposure Risk Study will investigate potential the constituents of potential concern (CoPC), exposure risk, and exposure pathways to wildlife on site. If CoPC are found to exceed specified performance criteria in terrestrial and/or aquatic systems, corrective mitigation actions will be implemented.

Objectives: The Wildlife Exposure Risk Study will provide information that will assist in evaluating:

- Wildlife exposure risk to CoPC at Myra Falls
- Requirements for wildlife health-related research and monitoring
- Risk to human health from consumption of wildlife exposed to CoPC

Site Selection: Sampling locations will include areas where wildlife is known or suspected to be exposed to CoPC in both terrestrial and aquatic systems. The location of sampling will be determined following the results from the soil, water and vegetation sampling and the preliminary site-wide wildlife use survey.

Potential exposure pathways for wildlife on site include:

- consumption of mine impacted water
- consumption of plants or soil associated with mine impacted water
- consumption of metals in soil

Methods: The following methods are proposed:

Sample Collection and Laboratory Analysis: Wildlife use of contaminated areas will be monitored. In areas where wildlife is exposed to contaminated water or terrestrial materials, the levels of metal exposure in mammals and birds will be determined by collecting biological samples. Biological samples may include collecting hair, feather, or eggshell samples that will be sent to laboratory for metal analysis.

Literature Review: A research study will be undertaken to investigate the exposure risk to CoC for wildlife species that are consumed by humans. A literature review will be used to understand the exposure risk for contaminants at Myra Falls and to inform monitoring recommendations for wildlife health if needed. The review will link the results of the soil, vegetation and water quality studies (Section 3.3.1, Section 3.3.3, Section 3.3.4) to regional wildlife health and potential human exposure pathways. The literature review will focus on wildlife species that are commonly used for subsistence hunting and harvesting by the Wei Wai Kum, We Wai Kai, K'ómoks, and Mowachaht/Muchalaht First Nations. Input from local First Nation groups should be incorporated to include traditional and local knowledge related to regional wildlife, and subsistence hunting specific to the project area. Results from these studies will inform whether mitigation actions or additional restoration treatments are required.

3.3.3 Water Quality Sampling Program

The Water Quality Sampling Program will be required to quantify metal concentrations in water and to monitor the effect of the reclamation efforts over time. The program will focus on metals including zinc, cadmium and copper and is further described below.

Objectives: The Water Quality Sampling Program will collect physical and chemical water quality data at sites affected by mining operations and at control sites to inform the Metal Uptake Monitoring Plan and to monitor the effectiveness of the reclamation efforts.

Zinc, cadmium and copper were identified as CoPCs associated with the Nyrstar Myra Falls mine operations. This was because each of these parameters consistently exceeded provincial water quality guidelines (WQGs) due to loads to the creek from impacted groundwater and treated effluent from the Polishing Ponds (RGC, 2018).

Various water quality scenarios are predicted to decrease zinc, cadmium and copper concentrations due to onsite groundwater management and implementation of mitigations (RGC, 2018). This includes the Phases 1 & 2 Lynx SIS to collect and treat contaminated groundwater that would otherwise enter the surface water environment including Myra Creek. Reclamation efforts will cover and vegetate most exposed area on the mine site and further reduce the availability of these constituents. These reclamation activities are also expected to reduce concentrations of other water quality parameters.

Water Quality Samples: To inform the water quality assessment, it is recommended that the following parameters are measured:

- *In situ* physical water quality parameters (*i.e.*, temperature, conductivity, pH and dissolved oxygen (DO)).
- Chemical parameters (*i.e.* metals, routine ions (including alkalinity and hardness), dissolved organic carbon (DOC) and total suspended solids (TSS). A lab analysis will be done to examine total and dissolved metals.

Water quality sampling should be conducted weekly or seasonally to capture variation related to different flow regimes (i.e. freshet vs. low flow periods). Measurements should be conducted in the reclamation area and at reference sites upstream and downstream of the mine site for comparison. Assessments of water quality parameters will allow evaluation of the effectiveness of the reclamation design.
Metal concentrations in the water will be measured against Environment Canada's Metal and Diamond Mining Effluent Regulations (2019) and limits described in Permit PE-06858.

Sampling Locations: Water quality sampling locations can incorporate the existing sample sites from previous monitoring years (Nautilus Environmental, 2017) into the Metal Uptake Monitoring Plan. It is recommended that, at a minimum, sample sites include:

- Exposure sites in drains collecting mine and ground water and discharge to Myra Creek in the vicinity of initial reclamation activities (e.g., Phase 1 Lynx SIS)
- Exposure sites in Myra Creek upstream and downstream of the drains, downstream of the mine, and in Buttle Lake
- Reference locations in Myra and Arnica Creek

3.3.4 Metals Uptake in Aquatic Organisms Program

Objectives: The objectives of this program are:

- Evaluate the metals uptake in cutthroat trout throughout the reclamation efforts
- Improve the understanding of the effects of metal uptake (i.e., measurement endpoints) on cutthroat trout including early life stage survival, normal development, larvae length and weight, and metal body burden.

In elevated concentrations, metals can be toxic to aquatic organisms. Even though some metals are considered micro-nutrients (e.g., zinc, copper) at low concentrations, they are considered harmful as concentrations increase. Exposed aquatic receptors may accumulate metals in their body tissue and present a risk to humans.

Site-wide reclamation activities are expected to decrease metal concentrations in the surface water and reduce exposure to aquatic organisms. Tissue metal concentrations in benthic macro-invertebrate communities and fish are subsequently expected to decrease. The evaluation program will assess the effectiveness of reclamation treatments by monitoring fish tissue metal burdens. Benthic macro-invertebrate communities are not recommended to be assessed and monitored in this program for reasons described below.

Methods: Nyrstar's current Environmental Effects Monitoring (EEM) program assesses the effects from metal uptake using *in situ* hatchbox studies in Myra Creek. These include tests for cutthroat trout early life stage survival, normal development (i.e., abnormalities), larvae length and weight, and metal body burden. *In situ* hatchbox studies is the recommended uptake study for Myra Creek Falls.

Myra Creek and its tributaries appear to be naturally oligotrophic (i.e., low productivity). Therefore, benthic macro-invertebrate densities are expected to be low and collecting enough invertebrate tissue to test for metal body burden may not be feasible. For example, small black fly larvae were the dominant benthic invertebrate in Myra Creek in 2016 (Nautilus Environmental, 2017) and densities were low. Therefore, it is not recommended to use benthic macro-invertebrates to assess the effect of metal uptake in aquatic organisms.

Cutthroat trout are the only resident fish species in Myra Creek and its tributaries (Nautilus Environmental, 2017). Because of this population's low density, destructive fish sampling to collect tissue samples is not considered feasible. Other options considered by Nyrstar were mesocosms and caged bivalves. However, due to site conditions and local hydrology, these options were also deemed infeasible (Nautilus Environmental, 2017). Due to these limitations, Stantec concurs that *in situ* hatch boxes are the most appropriate, and scientifically defensible option and, therefore, recommends using the *in situ* hatchbox studies for the program.

Site Selection: It is recommended that sites are selected based on Nyrstar's current EEM program to maximize the value of this component (i.e., longer data set):

- Reference sites:
  - MC-M1 – Upstream on Myra Creek, above Arnica Creek confluence
  - S11-A – Upstream on Myra Creek below Arnica Creek Confluence and immediately above activity area
- Exposure sites:
  - Eff-DS – on Myra Creek downstream of the effluent outfall adjacent the Tailing Impoundment area
  - TP-4 – On Myra Creek immediately above the Lynx Diversion Ditch
  - MC-M2 – On Myra Creek downstream of the mine activity area and upstream of Myra Falls

- Laboratory Control:
  - Control treatment in the laboratory using fish eggs sourced from the same batch as the exposure and reference fish eggs.

Tissue Collection and Laboratory Analysis: *In situ* hatchbox methods will reflect those used by, and described in, Nyrstar's Myra Falls Environment Canada's EEM Program (Nautilus Environmental, 2017; BCMWLAP 2003). Cutthroat trout eggs (eyed stage embryos) will be sourced and reared in hatchboxes within Myra Creek through to swim up stage (approximately 8 weeks) during the spring (mid- to late March through mid- to late May).

Water quality samples, and information on water depth and flow rate, will be collected from Myra Creek at each location where hatchboxes are deployed to inform the biological results. Additional water samples collected at the hatchbox locations will be sent for laboratory analysis including routine ions, nutrients, dissolved organic carbon, and total and dissolved metals.

4.0 INTEGRATED RECLAMATION RESEARCH PROGRAM

4.1 IMPLEMENTATION PLAN

A proposed implementation plan outlining the different reclamation research activities and how they apply to each discipline is presented in Table 2.

Table 2 Reclamation Methods and Evaluation Research Program Activities and Discipline Linkages

Reclamation Research Theme	Research Design Program Activities		Implementation Plan	Responsibility	Discipline Linkages						
					Hydrology	Water Quality	Aquatic Habitat	Soils	Vegetation	Wildlife	Traditional Land Use
Long-Term Watercourse Reclamation Plan	Water Infrastructure Decommissioning and Reclamation Plan	Performance Assessment of Diversion Ditches	Develop a Performance Assessment of Diversion Ditches that will include: • Identify catchment areas • Flow and sediment transport assessment of catchment area and ditches • Surveying and mapping • Fly-over • Rip-rap assessment • Hydrometric data collection • Risk of overflow under current designs • Propose potential design upgrades	Third-party consultant	X	X	X				
		Surface Water Flow Monitoring Study	Develop a Surface Flow Monitoring Plan that will include: • Installation of additional hydrometric stations • Flow measurements that coincide with water quality measurements and follow RISC (2018) Standards	Developed by a third-party consultant. Monitored by Nyrstar Personnel	X	X	X				
		Myra Creek Geomorphology Study	Develop a Myra Creek Geomorphology Study that will: • Select a reference site(s) to determine a natural template for Myra Creek with incorporating the understanding of the long-term objectives of the channel.	Third-party consultant	X		X				
		Power Supply Options Analysis	Develop a Power Supply Options Analysis that will: • Identify power supply options • Evaluate the power supply options • Recommend a preferred option	Third-party consultant	X		X				
	Aquatic Habitat Reclamation Plan	Fish Habitat Utilization	Develop a Fish Habitat Utilization Study that will: • Select sampling locations to assess and measure fish habitat utilization • Evaluate and recommend fishing techniques based on sampling locations and stream characteristics. • Monitor (seasonal/annual) fish presence and habitat utilization at selected sampling locations through capture, calculating relative abundance.	Third Party Consultant Monitoring to be done by a qualified professional	X	X	X			X	

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Table 2 Reclamation Methods and Evaluation Research Program Activities and Discipline Linkages

Reclamation Research Theme	Research Design Program Activities		Implementation Plan	Responsibility	Discipline Linkages						
					Hydrology	Water Quality	Aquatic Habitat	Soils	Vegetation	Wildlife	Traditional Land Use
		Geo-reference Habitat Surveys	Develop a Geo-reference Habitat Study that will: • Conduct aerial surveys identifying and monitoring important geographical and habitat features.						X		
		Bed Sediment Monitoring Survey	Develop a Bed Sediment Monitoring Study that will: • Conduct onsite surveys to locate sample sites to assess and evaluate instream channel modifications. • Monitor sample sites based on where substrate accumulates and the size of sediments (pebble counts and sediment particle size).		X	X	X				
Terrestrial Reclamation Plan	Soil Erosion and Sediment Delivery Assessment Program		• Determine erosion occurrence and extent on the slope gradients, slope lengths, material types and facilities on the mine site; • Document incidents of rill and gully erosion on reclaimed areas of the mine site, casual factors of erosion	Third-party consultant (planning) Nyrstar (planning and conducting) Monitoring to be done by a qualified professional			X	X	X		
	Soil Compaction/Decompaction Program		• Establishment of trial sites to measure and research bulk density on various soil replacement, reclamation site preparation and decompaction methodologies. • Evaluate the appropriateness of employed soil replacement and reclamation site preparation techniques. • Evaluate the effectiveness of decompaction techniques.	Nyrstar, Stantec and IEG Monitoring to be done by a qualified professional				X	X		
	Revegetation Prescriptions Program		• Determine the viability of revegetation, by testing planting and seeding methods with native plant species, including culturally important species. • Evaluate the reclamation approaches and prescriptions to confirm that ecological trajectories are consistent with the land use and capability targets. • Evaluate the success of revegetation, soil development and erosion control. This program should include specific sampling parameters and performance criteria.	Third-party consultant (planning) Nyrstar (conducting) from a Qualified Professional					x	x	x

Table 2 Reclamation Methods and Evaluation Research Program Activities and Discipline Linkages

Reclamation Research Theme	Research Design Program Activities	Implementation Plan	Responsibility	Discipline Linkages						
				Hydrology	Water Quality	Aquatic Habitat	Soils	Vegetation	Wildlife	Traditional Land Use
	Wildlife Habitat Restoration Program	• Determine the viability of habitat enhancement and revegetation methodologies to restore ecosystems that support the life requisites (e.g., food, thermal and security cover) of a diversity of native wildlife species. • Establishment and assessment of research trials to evaluate wildlife reclamation approaches and prescriptions applied • Evaluate whether wildlife habitat restoration prescriptions are resulting in trajectories that will support desired end-land use objectives. This program will include performance objectives that can be used to quantify restoration success for focal wildlife species.	Third Party Consultant. Monitoring to be done by a qualified professional				X	X	X	X
	Research for Old-Growth Forest Attributes Program Monitor Establishment of Old-Growth Features on Reclaimed landscape	• Determine the feasibility of restoration methods to re-establish old-growth attributes that can support the life requisites of old-growth wildlife species • Evaluate restoration prescriptions to confirm that ecological trajectories support the end-land use and capability targets for old-growth ecosystems	Third Party Consultant. Monitoring to be done by a qualified professional					x	x	x
	Soil Cover Plan Soil sampling program to determine the volumes and reclamation suitability of materials on site	• Growth Medium • Alternate reclamation materials • Coarse Wood Debris materials	Third Party Consultant. Monitoring to be done by a qualified professional				X	X		
Metal Uptake Monitoring Plan	Monitoring of Trace Metals in Soil and Vegetation	• Collect baseline information on soil metal content on salvaged soil stockpiles and on the newly reclaimed landscape. • Establish a network of sites on the reclaimed landscape as they become available that will be used to monitor both soil and vegetation metal concentrations. • Allow to an evaluation of metal uptake by vegetation on the reclaimed landscape.	Third Party Consultant. Monitoring to be done by a qualified professional				X	X	X	X

Table 2 Reclamation Methods and Evaluation Research Program Activities and Discipline Linkages

Reclamation Research Theme	Research Design Program Activities	Implementation Plan	Responsibility	Discipline Linkages						
				Hydrology	Water Quality	Aquatic Habitat	Soils	Vegetation	Wildlife	Traditional Land Use
	Wildlife Exposure Risk Study	• Assess and evaluate the wildlife exposure risk and exposure pathways to CoPC on site • Evaluate risk to human health from consumption of wildlife exposed to CoPC	Third Party Consultant. Monitoring to be done by a qualified professional				X	X	X	X
	Water Quality Sampling Program	• Conduct desktop review or onsite assessment to select sampling locations. • Assess and monitor spatial and temporal variation in metal concentration throughout the study area. • Evaluate water quality parameters and how these are affected by the reclamation project.	Monitoring to be done by a qualified professional		x	x				x
	Metal Uptake in Aquatic Organisms Program	• Water Chemistry • Aquatic Receptor Metal Uptake through an *in situ* hatchbox study. • Collect water quality samples at each hatchbox location.	Third Party Consultant. Monitoring to be done by a qualified professional		x	x			x	x

4.2 PROPOSED RESEARCH DESIGN AND EVALUATION SCHEDULE

A proposed implementation plan for the RMERP activities described under each discipline is presented in Table 3.

Table 3 Reclamation Methods and Evaluation Research Program Implementation Schedule

Reclamation Research Theme	Research Design Program Activities		Implementation	Year 1	Year 2	Year 3	Year 4	Year 5		Beyond Year 5
Long-Term Watercourse Reclamation Plan	Water Infrastructure Decommissioning plan	Performance Assessment of Diversion Ditches	Develop a Performance Assessment of Diversion Ditches that will include: • Identify catchment areas • Flow and sediment transport assessment of catchment area and ditches • Surveying and mapping • Fly-over • Rip-rap assessment • Hydrometric data collection • Risk of overflow under current designs • Propose potential design upgrades	Conduct a Performance Assessment of Diversion Ditches	Propose potential design upgrades	n/a	Develop the Water Infrastructure Decommissioning Plan with results of this assessment	Develop the Water Infrastructure Decommissioning Plan with results of this assessment		n/a
		Surface Water Flow Monitoring Study	Develop a Surface Flow Monitoring Plan that will include: • Installation of additional hydrometric stations • Flow measurements that coincide with water quality measurements and follow RISC (2018) Standards	Installation of hydrometric stations Flow measurements that coincide with water quality measurements	Flow measurements that coincide with water quality measurements	Flow measurements that coincide with water quality measurements	Flow measurements that coincide with water quality measurements Develop the Water Infrastructure Decommissioning Plan with results of this study	Flow measurements that coincide with water quality measurements Develop the Water Infrastructure Decommissioning Plan with results of this study	Flow measurements that coincide with water quality measurements	
		Myra Creek Geomorphology Study	Develop a Myra Creek Geomorphology Study that will: • Select a reference site(s) to determine a natural template for Myra Creek with incorporating the understanding of the long-term objectives of the channel	Conduct a Myra Creek Geomorphology Study	n/a	n/a	Develop the Water Infrastructure Decommissioning Plan with results of this study	Develop the Water Infrastructure Decommissioning Plan with results of this study	n/a	
		Power Supply Options Analysis	Develop a Power Supply Options Analysis that will: • Identify power supply options • Evaluate the power supply options • Recommend a preferred option	Conduct a Power Supply Options Analysis	n/a	n/a	Develop the Water Infrastructure Decommissioning Plan with results of this study	Develop the Water Infrastructure Decommissioning Plan with results of this study	n/a	
	Aquatic Habitat Reclamation Plan	Fish Habitat Utilization Survey	Develop a Fish Habitat Utilization Study that will: • Select sampling locations to capture fish • Evaluate and recommend fishing techniques based on sampling locations and stream characteristics. Monitor (seasonal/annual) fish presence and relative abundance at selected sampling locations through capture.	Select sampling locations & fishing techniques to use throughout survey area. Conduct seasonal fish sampling throughout the survey area and estimate relative abundance	Conduct seasonal fish sampling throughout the survey area and estimate relative abundance	Conduct seasonal fish sampling throughout the survey area and estimate relative abundance	Conduct seasonal fish sampling throughout the survey are and estimate relative abundance. Develop Aquatic Habitat Reclamation Plan and report on effectiveness of reclamation plan on fish habitat utilization.	Conduct seasonal fish sampling throughout the survey area and estimate relative abundance. Develop Aquatic Habitat Reclamation Plan and report on effectiveness of reclamation plan on fish habitat utilization.		Continue to monitor the survey area to gain understanding of trends in relative fish abundance

SCOPE 3 – RECLAMATION METHODOLOGY EVALUATION RESEARCH PROGRAM

Integrated Reclamation Research Program

Table 3 Reclamation Methods and Evaluation Research Program Implementation Schedule

Reclamation Research Theme	Research Design Program Activities		Implementation	Year 1	Year 2	Year 3	Year 4	Year 5		Beyond Year 5
		Geo-reference Habitat Surveys	Develop a Geo-reference Habitat Study that will: • Conduct aerial surveys identifying and monitoring important geographical and habitat features.	Conduct aerial surveys identifying key geographic and local habitat features	Conduct annual aerial survey assessing and monitoring the effect of the reclamation project on the key geographic and local habitat features identified in Year 1.	Conduct annual aerial survey assessing and monitoring the effect of the reclamation project on the key geographic and local habitat features identified in Year 1.	Conduct annual aerial survey assessing and monitoring the effect of the reclamation project on the key geographic and local habitat features identified in Year 1. Develop Aquatic Habitat Reclamation Plan with results of this study	Conduct annual aerial survey assessing and monitoring the effect of the reclamation project on the key geographic and local habitat features identified in Year 1. Develop Aquatic Habitat Reclamation Plan with results of this study	n/a	
		Bed Sediment Monitoring Survey	Develop a Bed Sediment Monitoring Study that will: • Conduct onsite surveys to locate sample sites to assess and evaluate instream channel modifications. • Monitor sample sites based on where substrate accumulates and the size of sediments to assess sediment suitability for target fish species.	Conduct survey to determine sampling site(s) Monitor sample site(s) and assess sediment suitability for target fish species	Monitor sample site(s) and evaluate sediment suitability for target fish species	Monitor sample site(s) and evaluate sediment suitability for target fish species	Monitor sample site(s) and evaluate sediment suitability for target fish species	Monitor sample site(s) and evaluate sediment suitability for target fish species Develop Aquatic Habitat Reclamation Plan with results of this study		
Terrestrial Reclamation Plan	Soil Erosion and Sediment Assessment Program		• Determine erosion occurrence and extent on the slope gradients, slope lengths, material types and facilities on the mine site; • Document incidents of rill and gully erosion on reclaimed areas of the mine site, casual factors of erosion	Survey the reclaimed areas for incidents of rill and gully erosion Measure Rill Erosion of Facilities on Reclaimed landscape Measure Gully erosion observed on the Reclaimed landscape Produce report summarizing results and provide recommendations on mitigations and path forward	Survey the reclaimed areas site for incidents of rill and gully erosion including site measured in year 1 Measure Rill Erosion of Facilities on Reclaimed landscape Measure Gully erosion observed on the Reclaimed landscape Produce yearly report summarizing results and provide recommendations on mitigations and path forward	Survey the site for incidents if rill and gully erosion including site measured in year 1 and 2 Measure Rill Erosion of Facilities on Reclaimed landscape Measure Gully erosion observed on the Reclaimed landscape Produce report summarizing results and provide recommendations on mitigations and path forward Provide yearly possible recommendations on possible establishment of permanent rill erosion sites	Survey the site for incidents if rill and gully erosion including site measured in year 1 to 3 Measure Rill Erosion of Facilities on Reclaimed landscape Measure Gully erosion observed on the Reclaimed landscape Produce yearly report summarizing results and provide recommendations on mitigations and path forward	Survey the site for incidents if rill and gully erosion including site measured in year 1 to 4 Measure Rill Erosion of Facilities on Reclaimed landscape Measure Gully erosion observed on the Reclaimed landscape Produce report summarizing results and provide recommendations on mitigations and path forward. Produce report summarizing results of 5-year program and provide recommendations on mitigations and path forward Provide possible recommendations on possible establishment of permanent rill erosion sites.		Continue to monitor and measure gully and rill erosion

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Integrated Reclamation Research Program

Table 3 Reclamation Methods and Evaluation Research Program Implementation Schedule

Reclamation Research Theme	Research Design Program Activities	Implementation	Year 1	Year 2	Year 3	Year 4	Year 5	Beyond Year 5
	Soil Compaction and Decompaction Program	Establishment of trial sites to measure and research bulk density on various soil replacement, reclamation site preparation and decompaction methodologies Evaluate the appropriateness of employed soil replacement and reclamation site preparation techniques Evaluate the effectiveness of decompaction techniques	Consult with Nyrstar areas and method of reclamation site preparation and possible areas of soil compaction Measure soil bulk densities a variety of reclaimed site preparation types. Produce yearly summary report on bulk densities, identify areas of possible soil compaction and recommend possible candidate areas for decompaction trials (if any).	Consult with Nyrstar areas being prepared for reclamation in year 2 and areas of possible compacted soils Consult with Nyrstar setting up operational decompaction trials on identified compaction areas Measure soil bulk density on decompaction trial areas (if any) Produce yearly summary report	Consult with Nyrstar areas being prepared for reclamation in year 3 and areas of possible compacted soils Measure soil bulk density on decompaction trial areas (if any) Measure plant growth and vigor on areas of decompaction trials verses non treated areas. Produce yearly summary report	Consult with Nyrstar areas being prepared for reclamation in year 4 and areas of possible compacted soils Measure soil bulk density on decompaction trial areas (if any) Measure plant growth and vigor on areas of decompaction trials verses non treated areas. Produce yearly summary report	Consult with Nyrstar areas being prepared for reclamation in year 5 and areas of possible compacted soils Measure soil bulk density on decompaction trial areas (if any) Measure plant growth and vigor on areas of decompaction trials verses non treated areas Produce report that summarizes results of 4 to 5-year decompaction trials, makes recommendations on future path forward for decompaction studies and makes recommendations on appropriate reclamation site preparation and decompaction mitigations.	Continue monitoring decompaction trials as outlined in recommendations made in the 5-year summary report
	Revegetation Prescription Program	• Determine the viability of revegetation, by testing planting and seeding methods with native plant species, including culturally important species • Evaluate the reclamation approaches and prescriptions to confirm that ecological trajectories are consistent with the land use and capability targets Evaluate the success of revegetation, soil development and erosion control. This program should include specific sampling parameters and performance criteria	Measure revegetation success on areas seeded for erosion control in year 1. Establish plots in areas where the following prescriptions have been carried out: Seeding for vegetation establishment, cover soil replacement (direct and from stockpiles), seedling vegetation transplants and seedling/propagule planting. Produce interim yearly report	Measure revegetation success on areas seeded for erosion control in year 1 and year 2. Measure plots established in year 1. Establish plots in areas where the following prescriptions have been carried out in year 2 (Seeding for vegetation establishment, cover soil replacement (direct and from stockpiles), seedling vegetation transplants and seedling/propagule planting). Measure plots established in year 1 and year 2. Produce interim yearly report	Measure revegetation success on areas seeded for erosion control in year 2 and year 3 Establish plots in areas where the following prescriptions have been carried out in year 3 (Seeding for vegetation establishment, cover soil replacement (direct and from stockpiles), seedling vegetation transplants and seedling/propagule planting) Measure plots established in year 1, year 2 and year 3. Produce interim yearly report	Measure revegetation success on areas seeded for erosion control in year 3 and year 4 Establish plots in areas where the following prescriptions have been carried out in year 4 (Seeding for vegetation establishment, cover soil replacement (direct and from stockpiles), seedling vegetation transplants and seedling/propagule planting) Measure plots established in year 2, year 3 and year 4. Produce interim yearly report	Measure revegetation success on areas seeded for erosion control in year 4 and year 5. Measure plots established in year 1, year 2, year 3 and year 4. Produce 5-year summary report	Continue revegetation monitoring program as recommended in the 5-year summary report

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Integrated Reclamation Research Program

Table 3 Reclamation Methods and Evaluation Research Program Implementation Schedule

Reclamation Research Theme	Research Design Program Activities	Implementation	Year 1	Year 2	Year 3	Year 4	Year 5	Beyond Year 5
	Wildlife Habitat Restoration Program	• Determine the viability of habitat enhancement and revegetation methodologies to restore ecosystems that support the life requisites (e.g. forage, shelter) of a diversity of native wildlife species • Establishment and assessment of research trials to evaluate wildlife reclamation approaches and prescriptions applied • Evaluate whether wildlife habitat restoration prescriptions are resulting in trajectories that will support desired end-land use objectives. This program will include performance objectives that can be used to quantify restoration success for focal wildlife species	Complete a site-wide preliminary wildlife use survey Complete TLU studies to identify culturally important wildlife species, habitat elements and metal uptake thresholds Provide feedback to restoration treatments based on wildlife use survey and TLU studies Establish plots in areas where habitat elements have been installed Complete habitat suitability modelling Produce report summarizing the results	Measure success of habitat elements installed in year 1. Re-evaluate and modify if necessary. Monitor wildlife use within revegetated plots established in year 1 and 2 Provide feedback to restoration treatments where applicable Produce report summarizing the results	Monitor wildlife use of habitat elements installed in year 1, measure success of habitat elements installed in year 2. Re-evaluate and modify if necessary. Monitor wildlife use within revegetated plots established in year 1, year 2 and year 3 Provide feedback to restoration treatments where applicable Produce report summarizing the results	Monitor wildlife use of habitat elements installed in year 1, year 2 and year 3 Monitor wildlife use within revegetated plots established in year 1, year 2, year 3 and year 4 Provide feedback to restoration treatments where applicable Produce report summarizing the results	Monitor wildlife use of habitat elements installed in year 1, year 2 and year 3 Monitor wildlife use within revegetated plots established in year 1, year 2 year 3, and year 4 Provide feedback to restoration treatments where applicable Produce report summarizing the results	Continue to monitor wildlife use of installed habitat elements and revegetated plots
	Research for Old-Growth Forest Attributes Program Monitor Establishment of Old-Growth Features on Reclaimed landscape	• Determine the viability of restoration methods to re-establish old-growth attributes that can support the life requisites of old-growth wildlife species • Evaluate restoration prescriptions to confirm that ecological trajectories support the end-land use and capability targets for old-growth ecosystems	Conduct onsite survey to determine location of old-growth attribute restoration prescriptions and reference sites Establish research trial plots Produce report summarizing the results	Evaluate success of restoration prescriptions in trial plots, modify if necessary Produce report summarizing the results	Monitor wildlife use of trial plots Provide feedback to restoration prescriptions when applicable Produce report summarizing the results	Monitor wildlife use of trial plots Provide feedback to restoration prescriptions when applicable Produce report summarizing the results	Monitor wildlife use of trial plots Evaluate success of restoration prescriptions in trial plots, modify if necessary Provide feedback to restoration prescriptions when applicable Produce report summarizing the results	Continue to monitor the wildlife use of trial plots
	Soil Cover Plan	Soil sampling program to determine the volumes and reclamation suitability of materials on site.	Complete field survey and reporting. Results to be detailed in the Nyrstar Myra Falls Annual Reclamation Report	n/a	n/a	n/a	n/a	n/a
Metal Uptake Monitoring Plan	Soil and Vegetation Metal Baseline and Uptake	• Collect baseline information on soil metal content on salvaged soil stockpiles and on the newly reclaimed landscape • Establish a network of sites that will be used to monitor both soil and vegetation metal concentrations and establish plots “off-site” as reference. • Evaluate metal uptake of vegetation on the reclaimed landscape	Establish sample mine site and “off-site” soil and vegetation metal monitoring plots Collect soil samples and analyze samples for CPOC metals collected at plot and salvaged soil stockpiles Collect and analyze Vegetation samples for CPOC metals at established plots	- Collect and analyze Vegetation samples for COC metals at established plots Establish and sample additional plots as if required Produce report summarizing results	- Collect and analyze Vegetation samples for COC metals at established plots Produce report summarizing results	- Collect and analyze Vegetation samples for COC metals at established plots Produce report summarizing results	Collect soil samples and analyze samples for COC metals collected at plot Collect and analyze Vegetation samples for COC metals at established plots Produce report summarizing results and make path forward including modifying the program and sampling frequency	Continue soil and vegetation metal monitoring program as outlined in the report recommendation made in the year 5 report.

Table 3 Reclamation Methods and Evaluation Research Program Implementation Schedule

Reclamation Research Theme	Research Design Program Activities	Implementation	Year 1	Year 2	Year 3	Year 4	Year 5		Beyond Year 5
			Produce report summarizing results and make path forward including the need to establish additional plots or modify the program		Make recommendations on any need to modify the vegetation metal uptake monitoring program				
	Wildlife Exposure Risk Study	• Assess and evaluate the wildlife exposure risk and exposure pathways to CoPC on site • Evaluate risk to human health from consumption of wildlife exposed to CoPC	Complete a site-wide preliminary wildlife use survey Establish wildlife monitoring plots in areas of potential exposure concern Produce report summarizing the results	Monitor wildlife use in areas of exposure concern Evaluate wildlife risk by linking water quality, soil, and vegetation metal analysis results Produce report summarizing the results	Monitor wildlife use in areas of exposure concern Collect and analyze biological samples (i.e. feathers, hair) where wildlife use in areas of exposure concern is confirmed Provide feedback to mitigation measures and restoration treatments when applicable Produce report summarizing the results	Monitor wildlife use in areas of exposure concern Conduct additional collection and analysis of biological samples if required Provide feedback to mitigation measures and restoration treatments when applicable Produce report summarizing the results	Monitor wildlife use in areas of exposure concern Conduct additional collection and analysis of biological samples if required Provide feedback to mitigation measures and restoration treatments when applicable Complete a research study to evaluate the potential human exposure risk to CoC through subsistence hunting and harvesting Produce report summarizing the results	Continue wildlife exposure risk monitoring program	
	Water Quality Sampling Program	• Desktop review or onsite assessment to identify locations to sample water quality for metal contamination during the reclamation program • Assess and evaluate spatial and temporal variation in metal concentration throughout the study area. • Monitor and evaluate water quality parameters and how these are affected by the reclamation project.	Conduct onsite assessments to identify sampling locations within the mine site and reference sites; same locations as placement of *in situ* hatchboxes (see *Metal Uptake in Aquatic Organisms*) Analyze metal concentration at sample locations	Analyze metal concentration and water quality parameters at sample locations Provide feedback to reclamation project or restoration design when applicable	Analyze metal concentration and water quality parameters at sample locations Provide feedback to reclamation project or restoration design when applicable	Analyze metal concentration and water quality parameters at sample locations Provide feedback to reclamation project or restoration design when applicable Develop Metal Uptake Monitoring Plan with the results from this study.	Analyze metal concentration and water quality parameters at sample locations Provide feedback to reclamation project or restoration design when applicable Develop Metal Uptake Monitoring Plan with the results from this study		

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Integrated Reclamation Research Program

Table 3 Reclamation Methods and Evaluation Research Program Implementation Schedule

Reclamation Research Theme	Research Design Program Activities	Implementation	Year 1	Year 2	Year 3	Year 4	Year 5	Beyond Year 5
	Metal Uptake in Aquatic Organisms Program	• Water Chemistry • Aquatic Receptor Metal Uptake through an *in situ* hatchbox study. • Collect water quality samples at each hatchbox location.	Conduct onsite surveys to determine site selection (exposure / reference). Place *in situ* hatchboxes in selected sites. Collect water quality samples at each hatchbox location. Bring batch of eggs sample to laboratory to be used as a control unit and to track development.	Evaluate effects of potential metal concentration in water (following Nyrstar's current EEM program). Collect water quality samples at each hatchbox location.	Evaluate effects of potential metal concentration in water (following Nyrstar's current EEM program). Collect water quality samples at each hatchbox location.	Evaluate effects of potential metal concentration in water (following Nyrstar's current EEM program). Collect water quality samples at each hatchbox location. Develop Metal Uptake in Aquatic Organisms Plan using the results from this study	Evaluate effects of potential metal concentration in water (following Nyrstar's current EEM program). Collect water quality samples at each hatchbox location. Develop Metal Uptake in Aquatic Organisms Plan using the results from this study	

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