Wetland Reclamation Guide for the Ruby Creek and Indian River East Block Placer Mine (2015-0150)

Government of Yukon

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Yukon Government

Disclaimer

The Wetland Reclamation Guide (“guide”) has been developed in consultation with Tr’ondëk Hwëch’in (“TH”) to provide assistance to Northern Exposure Ltd. (“proponent”) to prepare a wetland reclamation plan (“plan”) for its Ruby Creek and Indian River East Block Placer Mine Project (“project”).

The proponent is required develop a plan in accordance with Term 7 of Part B in the Class 4 Placer Land Use Operating Plan (YESAB Project Number 2015-0150). Term 7 states that:

> “The proponent shall submit a progressive reclamation plan that incorporates existing baseline data and which results in suitable terrain conditions that are conducive to the natural re-establishment, over time, of wetlands habitat in post-mined areas. The plan shall be based on the following considerations and guidance as set out by the Manager, Mining Lands, Mineral Resources Branch: guidelines on acceptable wetlands reclamation methods and expected reclamation performance; and appropriate and current baseline data, including the location and type of wetlands in the project area. The proponent shall provide the plan to Mineral Resources Branch, Manager, Mining Lands for his/her review and approval within 6 months of the effective date of the Water License. The approved plan must be implemented on future mined areas where wetlands have been identified.”

The requirement to develop a plan is also a result of a Memorandum of Understanding (“MOU”) agreed to by the Government of Yukon (“YG”) and TH. The MOU establishes a framework for consulting with TH on the development of this guide, as well as the review of the plan from the proponent. The objective set out in the MOU that have informed guide requirements in fulfillment of Term 7 are “The Parties agree that the guidelines shall address wetland reclamation methods and expected reclamation performance, and appropriate and current baseline data, including the location and type of wetlands in the project area” (Section 1(c)).

This guide is intended to assist Northern Exposures Ltd. in the planning and wetland reclamation of their mining land use site. Adopting the suggestions, approaches and options outlined herein are considered to be basic management practices and will not, in any way, constitute a defence in a court of law if an operator were to be investigated and subsequently prosecuted for a violation of the *Placer Mining Act* and *Placer Mining Land Use Regulation* or any other legislation.

1. Goal of the Wetland Reclamation Guide

The goal of the guide is to help the proponent in identifying wetland reclamation best practices that will re-establish wetland functions in post mine areas that are similar to the pre-existing wetland functions and self-sustaining. By ensuring that wetlands and their functions and values are identified as early as possible when planning the project, the proponent will be able to plan reclamation activities accordingly.

A good plan will identify reclamation practices specific to the project, the types of disturbances to be encountered by the project, best practices to minimize disturbances, and site management practices. The plan should demonstrate a good understanding of the project area, topography and geographic conditions (e.g. rivers / streams, upland, wetted areas, permafrost, etc.), and how these interact to achieve wetland habitat and how the wetlands develop and function naturally over time.

1.1 Goal of Wetland Reclamation

The goal of wetland reclamation is to preserve the wetland functions of an area by minimizing the disturbance footprint and by creating self-sustaining wetland conditions following disturbance, which are similar to pre-disturbance conditions and which perform similar functions.

2. The Wetland Reclamation Plan

The plan will describe how the proponent will undertake placer mining in and around wetlands and wetland reclamation activities in the disturbed areas. The reclamation proposed will create, as much as possible, conditions that mimic pre-existing conditions, which are self-sustaining and perform similar functions as the pre-existing systems and encourage the recolonizing and establishment of the native wetland vegetation species.

This section of the guide explains the information to be included in a plan in order to achieve the goal of the guide. Prior to submitting a wetland reclamation plan, the proponent is encouraged to collect information about the wetland before mining in and near a wetland. This information will assist the proponent to develop a reclamation plan that meets the goals of wetland reclamation and supports progressive wetland reclamation. Appendix B discusses how wetland reclamation can meet the goals of maintaining wetland function of the original wetlands.

2.1 Developing a Wetland Reclamation Plan – Key Considerations

Wetlands are diverse, productive and vital components of healthy ecosystems and landscapes providing numerous biotic and abiotic functions. As part of the reclamation plan, the proponent is encouraged to apply the following reclamation options in order of hierarchy outlined here:

2.1.1 Avoid Disturbing Wetlands

Protection and avoidance strategies should be considered first before undertaking mining activities, including the building roads, camps and other infrastructure in wetlands. Avoidance can contribute to savings in time and money during construction, and at the same time protect wetlands. In order to maintain wetland functions within a project area it may be necessary to leave some wetlands unmined.

2.1.2 Reclaim Wetland Habitat with Same Wetland Habitat (e.g. Bog to Bog)

When mining in wetlands cannot be avoided, the proponent should reclaim the original wetland with a suitable design that over-time, will replicate the original wetland type.

2.1.3 Reclaim Wetland Habitat with Different Habitat (e.g. Bog to Marsh)

While it is important that a wetland be reclaimed to the same class of wetland, this may not always be possible. A change in class of wetland (e.g., from a bog to marsh) may be an acceptable wetland reclamation strategy. In other words, when wetlands cannot be avoided or reclaimed with the same class, a new wetland class may be the final product.

The proponent should provide an analysis and decision making criteria for the reclamation option(s) selected, this could include consideration of costs, technical feasibility and uncertainty of success.

2.2 Before Preparing the Reclamation Plan

Before beginning mining and drafting a Placer Mining Wetland Reclamation Plan, it is important to recognise where the wetlands are and to understand the geologic conditions, soils, hydrology, permafrost, plant and wildlife diversity that impact the distribution and function of the wetlands existing in the project area.

Wetlands are complex ecosystems and the wetlands in the Indian River valley are a complex interaction between the terrain, bedrock, gravel terraces, depth of silty loess, peat, permafrost, surface and groundwater flow, the vegetation and the wildlife. There are 5 wetland classes, recognized by the National Wetlands Working group (1997), which are commonly found in valleys along Yukon's gold bearing streams bogs, fens, swamps, marshes and shallow open water. The functions, including habitat, provided by the different wetland classes varies significantly between the classes and is associated with the particular soils, hydrology and vegetation communities present at a site.

Appendix A of the guide provides additional information about the wetlands and their functions, specific to the Indian River Valley, which is useful for better understanding the wetlands and should be considered in development of a reclamation plan.

2.3 Preparing a Plan

It is recommended that you work with a qualified environmental professional to prepare a reclamation plan that includes the following:

- A goal of re-establishing wetland function similar to pre-existing conditions;
- Before mining, a clear description of the goods, services, and functions provided by the particular wetland must be undertaken. Choose an undisturbed reference site to compare reclaimed wetlands with;
- It is important to document the extent of different classes of wetlands, their soils, hydrology, vegetation, microorganisms and wildlife so that their contributions can be understood;
- A map showing placer claims, location of wetland areas and class of wetland, and where planned reclamation measures will be undertaken as well as areas where wetlands will not be disturbed;
- A set of proposed reclamation objectives (as outlined in Table 1) and the methods you plan to use to design and construct reclaimed wetland areas;
- An overall summary of how you intend to undertake and monitor progressive and post-mining wetland reclamation activities;
- If applicable, a description of any landscape characteristics that could potentially constrain achievement of wetland reclamation objectives (e.g., large or multiple pockets of permafrost, lack of accessible surface water, etc.); and
- If applicable, a summary of any protection/avoidance strategies that will be used for intact wetlands as well as adaptive management strategies that may be employed when problems are encountered.

2.4 Undertaking Progressive Reclamation

Progressive wetland reclamation can be crucial to successful re-establishment of wetland habitat. Progressive reclamation involves undertaking wetland reclamation as mining activity progresses so that efforts to restart wetland function occur within the same season. This allows reclamation to start immediately in areas that have been mined and are no longer required for mining.

Undertaking progressive reclamation allows additional time for methods and techniques to be successful (e.g., establishing pioneering and successional species), for monitoring and modification of the plan as needed and for cost-effective use of operator time and equipment. Progressive wetland reclamation can shorten the time period required for achieving your closure objectives and reduce financial liability of your site by avoiding additional reclamation costs. Progressive reclamation minimizes the length of storage time for organic and overburden materials increasing the viability of seeds and the speed of regeneration, and minimizing the chance for establishment of invasive species. Activities such as stockpiling materials, grading and re-contouring tailings piles and steep excavated slopes, sloping and adding topographic features such as swales, depressions, ponds and islands are all examples of activities that should be undertaken post-mining activity before you move to the next area to be mined. A list of reclamation objectives that can be employed are listed in Table 1.

2.5 Monitoring

Monitoring the success of reclamation techniques, with progressive reclamation, provides valuable experience on the effectiveness of reclamation measures on an ongoing basis. A plan to monitor the successes and shortcomings of wetland reclamation through the life of the project is an essential component of a wetland reclamation plan. The plan should be a living document that allows for modifications as you progress with your mining activity. Ongoing reclamation monitoring and maintenance during placer mining operations allows management of and the creation of functioning wetlands and keeps the area on track toward your final reclamation goal. Scheduled seasonal monitoring throughout the progressive wetland reclamation project allows one to make the necessary adjustments required that support the natural landscaping, re-vegetation, and use by wildlife species. Monitoring progressive wetland reclamation as mining proceeds is a good way of assessing the effectiveness of the reclamation practices being used.

The proponent should submit an annual report of monitoring and maintenance activities, which should include:

- Observing and documenting the growth rates and succession of natural vegetation species.
- Ensuring and documenting that reclaimed wetlands are saturated and/or under water (i.e., existence of ponds, marsh areas, etc.) and erosion and the stability of the edges of ponds is controlled.
- Ensuring and documenting that erosion of tailing piles and overburden is controlled and water releases are of acceptable quality.

3. Reclamation Objectives, Methods, and Approaches

Table 1 lists the methods, approaches and general performance indicators for achieving the recommended reclamation objectives of designing and constructing an area so that it may be reclaimed into a wetland.

Table 1: Objectives and methods for designing and constructing reclaimed wetlands.

Objective	Proposed Methods/Approach	General Performance Indicator
1. Wetland Reclamation Plan that results in self-sustaining wetlands and mimics existing conditions to the extent possible.	• Establishment of wetlands system similar to pre-existing wetlands and functions. • Show understanding of distribution of existing wetland classes and their functions. • Document existing conditions: soils, permafrost, hydrology, plant communities, insect productivity, use by birds, mammals, and amphibians • Identify comparison/reference site conditions • Specify areas to be avoided and ensure no ingress or operation within an appropriate buffer around them. • Plan mining, mine pits and tailings pond for easier reclamation. • Plan to re-contour surface to mimic original landscape as closely as possible. • Provide exact locations, footprint, access and approximate volumes of topsoil, peat and overburden that will be stored during mining. • Show how progressive reclamation will be accomplished.	• Plan which describes how to achieve a self-sustaining landscape complex of uplands, wetlands and water systems supporting natural vegetation and wildlife, similar to pre-existing conditions, confirmed and adapted through progressive reclamation and regular monitoring. • Plan to return local hydrologic inflows and outflows of surface water to near-original status.

Objective	**Proposed Methods/Approach**	**General Performance Indicator**
	• Take local hydrology such as inflow and outflow of surface water, sources of groundwater and timing of saturation and flooding into consideration to extent possible. • Plan to re-establish creek channel with slope and a floodplain similar to pre-disturbance. • Plan to monitor effectiveness of reclamation and adjust as required (adaptive management).	
2. Management of stockpiles.	• Limit erosion and facilitate progressive reclamation. • Retain native topsoil (organic rich mineral soil and vegetative cover) and stockpile in a secure manner. The first cut should be deep enough that the entire suckering root zone is taken in one pass, but should not be mixed with organic-poor subsoil. • Segregate organics from overburden and do not mix. Segregate topsoil into specific vegetation types where practical. • Situate piles close to mining areas for ease of backfilling. • Redistribute topsoil as soon as possible to limit erosion, aeration and the composting of wetland plant seeds.	• Reclamation materials are available and conveniently situated for future reclamation. • Maintenance of the value of various materials.
3. Restore surface elevations and slopes as close to original wetland as possible to maintain saturated	• Restoration of surface elevations and slopes as close to the original as possible.	• Surface elevations similar to undisturbed condition

Objective	Proposed Methods/Approach	General Performance Indicator
wetland conditions and encourage development of permafrost.	• Progressively fill and contour pits while mining. • Backfill mine pits/cuts to allow for saturated soils or shallow depressions. Backfilled pits/cuts should be close to original contours. • Put material back in reverse order of removal (In most cases this would consist of gravel, then silt, then organic topsoil). • Putting material back in reverse order with a thick silty loess layer overlain by retained organic material will assist with enabling cool conditions which foster permafrost development. • Design and construct low areas, swales or slight depressions at or below the natural ground water table. • Where the groundwater table is very low and/or if there is insufficient surface runoff or precipitation to keep water in the wetland, construct the pit to limit water loss. • If the wetland is situated in a higher area, seal the bottom of the wetland with fine soil (fine tailings from settling ponds or fine overburden can be used). • Where approvals or licences permit, the wetlands may be connected to the stream if there is not enough groundwater or precipitation to keep wet-areas wet.	• Various areas with saturated conditions with re-establishing wetland vegetation. • Normal fluctuations of water depth and saturation level. • A variety of wetland conditions with intervening uplands. • Frost persists late in spring or summer • Frost (measured with probe persists more than one year).

Objective	**Proposed Methods/Approach**	**General Performance Indicator**
	• If connecting the constructed wetland to a surface water source, construct so that intake streams are at right angles to the direction of flow and the junctions are armored with boulders or coarse cobbles to prevent erosion. • Keeping the area moist especially in the fall will help the soils to cool and increase the penetration of seasonal frost. • When creating marshes, construct level areas surrounding ponds close to the low water level. • Marshes may appear in shallow slopes and depressions with fluctuating water levels between 0 and 1 m deep. • Backfill the mining cut until there is a depression less than 1 m deep. • Swamps with woody shrub species will develop in areas subject to periodic flooding and fluctuating water levels.	
4. Re-vegetation of native plant species, including wetland plants and prevention of invasive species.	• Native wetland species suitable for wetland class. • Reference Yukon government's *Interpretive Bulletin 2013-01, Re-vegetation on Mineral Claims.* • Where available, leave areas of natural vegetation in or near the operating area, along travel corridors and riparian buffers around water bodies.	• Re-establishment of native wetland plant species to the area (natural re-vegetation). • Creation of marshes associated with open shallow wetlands. • Marshes, swamps and littoral zones

Objective	Proposed Methods/Approach	General Performance Indicator
	• Distribute saved and segregated organic topsoil from the different wetland classes in similar locations suitable for reestablishment. • Distribute occasional buckets full of undisturbed natural vegetation and underlying topsoil, if available, providing islands of native plants and seeds. • Leave ground surface rough and non-compacted to encourage natural re-seeding. • Make rough and loose surfaces with heavy equipment to control erosion and create conditions that promote natural re-seeding in areas of heavy use, such as roads and pads and to help water infiltration. • Reclaim areas as soon as possible after mining. • Prevent erosion and further disturbance to allow natural revegetation. • Re-vegetate areas if necessary as soon as possible. • Consider utilizing standing vegetation for planting stock from adjacent undisturbed areas. • Transplanting 6-7 cm of organic rich topsoil from natural marsh areas in previously mined areas can enrich the vegetation with native species. • A 20 cm depth of organic rich topsoil is optimal for ensuring root	help to increase infiltration and reduce excess run-off. • Wetland species are similar to those on natural wetlands in the region. • No invasive species present.

Objective	Proposed Methods/Approach	General Performance Indicator
	penetration at water depths less than 45 cm. - Where needed due to operational requirements, collect mature seeds of dominant species when ripe in year preceding planting or from nearby undisturbed areas in same year as reclamation. Collect bare root rhizomes and stems. Seed and plant in reclaimed area.	
5. Stable landforms: slopes, gradients, and saturated soils.	- Limit slope length and gradient. - Direct run-off to lower parts of reclaimed area to create wetlands. - Create a longer path for run-off so that it has more time to infiltrate and saturate soils. - Create floodplain areas above the usual level of creeks and ponds to minimize excess runoff. - Encourage revegetation of banks and floodplain. - If slopes are steep or erosion-prone, use biodegradable matting (hemp, jute, or coco fiber) to prevent gully formation. - Sufficient coarse material should be used for any retaining banks.	- Erosion is prevented by slowing water runoff. - Infiltration is enhanced due to slowed water flow allowing the water time to percolate the soil. - Excess runoff is minimized. - Excess run-off occasionally flows toward and is captured by adjacent intact vegetated areas. - No or limited slope failure.
6. Shallow water ponds that mimic pre-mine site.	- If pre-mined site includes shallow-open water wetlands, reclaimed ponds should be of similar size, shape and depths as pre-mining ponds.	- Creation of a functioning wetland complex. - Creation of a complex wetland

Objective	Proposed Methods/Approach	General Performance Indicator
	• Construct ponds between 0.2 and 5 ha in area and with as complex shapes as practical. • Construct ponds with irregular bottoms and water depths. Shallow water wetlands are typically less than 2 m deep. • Create irregular shaped ponds by pushing material in from the sides of the pits. • Create a variety of submerged slopes to promote establishment of aquatic and emergent plants. • Construct the outer edges of some ponds with shallow slopes to promote marsh and swamp vegetation and shorebirds. • Border ponds with stockpiled materials and topsoil to support natural re-vegetation and reduce turbidity. • Place gravels along some shoreline areas for shorebirds. • Create islands and/or peninsulas by pushing or dumping overburden and tailings from the shore, pushing or dumping frozen fill with snow and ice into mined out pits and/or placing loose organic material or coarse woody debris into the pond area. This may assist in allowing groundwater flow. • Create islands and/or peninsulas with irregular shapes and submerged gentle	shape that maximizes the length of shoreline per unit of surface area. • Minimized bank erosion caused by wave action or run-off. • Establishment of different functioning wetland zones promoting the re-establishment of diverse wetland habitats and species. • Mounds, islands and peninsulas in shallow water wetlands which improve the range and quality of nesting habitat for ducks, geese, swans and shorebirds. • Mounds and peninsulas are no more than 50 cm above or below above the ordinary high water mark.

Objective	Proposed Methods/Approach	General Performance Indicator
	sloped shorelines as far from the pond shoreline as possible. - Cover islands and/or peninsulas with stockpiled topsoil to promote natural re-vegetation. - In larger ponds, construct several smaller islands rather than one large one. - Construct shallow mounds to separate depressions allowing for waterfowl species to seek and establish their own territory.	
7. Wildlife habitat enhancement measures.	- Place some logs and woody debris in the bottom and on the slopes of the pond. - Retain some (limited) gravel piles on the landscape to provide various habitat functions, such as nesting habitat for the Common Nighthawk. - Retain some (limited) piles of logs and broken-up logs, and smaller pieces of debris such as roots, twigs and branches which will benefit certain wildlife. - Keep a variety of logs intact as much as possible and place them flat on the ground. - Retain snags or dead standing trees provide a wide range of wildlife uses. - Do not disturb or interfere with beavers and/or muskrats if they colonize the area.	- Coarse woody debris available as habitat for small aquatic insects important as prey for wildlife species and important to wetland function. - Numerous wildlife enhancements are present. - Where possible, site supports the same suite of wildlife that existed prior to mining. - Creation of a habitat that will support a great diversity of wildlife.
8. Successful wetland reclamation achieved	- Progressive reclamation.	- Monitoring report which documents

Objective	Proposed Methods/Approach	General Performance Indicator
through progressive reclamation and ongoing monitoring.	• Ongoing monitoring. • Annual report documenting successes and suggestions for modifications or improvements to reclamation techniques.	success of reclamation. • Learn from experience during progressive reclamation.

4. Monitoring and Reporting Reclaimed Wetland Progress

If problems occur during progressive reclamation, Table 2 on the following page offers some adaptive management strategies that can be employed to resolve them.

Table 2: Potential problems with constructed wetlands and adaptive management strategies

Problem	Indicators	Adaptive Management Strategies
Insufficient wetlands.	• The area of wetlands is much less than pre-existing condition.	• Create floodplain swamps, marshes. • Create conditions conducive to rebuilding soil permafrost. • Add stockpiled organic material. • Divert more water from stream channel to dips, swales and wetlands.
Wetlands are not performing functions similar to pre-disturbance functions.	• Water discharged contains sediment. • Flooding causes erosion. • There is no habitat supporting pre-disturbance species.	• Start reclamation earlier. • Stabilize slopes, borders of ponds. • Revegetate soils. • Slow water movement through the area. • Create floodplain swamps, marshes. • Stockpile and redistribute organic material, topsoil.
Water loss (drying).	• Exposed soil area. • Presence of salts.	• Convert drier areas from wetland habitat to upland habitat. • Increase the height of the discharge structure (if present) to prevent water discharge.
Water gain (flooding).	• Higher water level than desired. • Diminishing aquatic vegetation.	• Decrease the height of the discharge structure (if present) to allow for more water to discharge. • Add more stockpiled soils and organic materials into constructed ponds to reduce water depth.

High rate of pond infilling with sediments.	• Increased turbidity. • Reduced aquatic plant growth.	• Check for and correct any slope erosion issues. • Block off access to silty water. • Change height of discharge structure (if present).
Shoreline erosion.	• Excess sediments eroding around edges. • Decreased vegetation on shoreline.	• Cover eroding shoreline with gravel or timber and woody debris. • Plant willow cuttings on shoreline.
Lack of vegetation.	• Bare areas.	• Make soil surface rough and loose. • Check for loss of organic soils and replace organic soils as necessary with stockpiled topsoil. • Limit soil losses by erosion. • Plant willow cuttings. • Collect and plant wetland seeds, roots, rhizomes.
Low aquatic organism diversity in ponds.	• Expected waterfowl not present.	• Create more shallow littoral and marsh areas at the edges of ponds. • Encourage growth of aquatic plants, microorganisms.

5. Yukon Government and First Nations Collaboration

As part of routine inspections, Yukon government's Mining Inspectors will undertake routine monitoring and evaluation of wetland reclamation activities. The overarching principle of adaptive management (the process for continually improving best management practices and policies) is an essential part of inspections conducted by the Yukon government. This principle recognizes that there is a degree of uncertainty and lack of knowledge present with regards to reclaiming wetlands.

To assist with the degree of uncertainty and lack of knowledge, Yukon government encourages and welcomes First Nations involvement in the monitoring and inspections of wetlands reclamation with the Mining Inspectors. Yukon government aims to work collaboratively with

First Nations to make recommendations on adaptive management strategies for each site. The knowledge and experience gained from routine inspections of wetland reclamation practices with First Nations over time will result in higher success rates and provide more guidance.

Suggested Reading List:

Alberta Environment. 2008. *Guideline for wetland establishment on reclaimed oil sands leases* (2nd edition). Prepared by Harris of Lorax Environmental for the Wetlands and Aquatics Subgroup of the Reclamation Working Group of the Cumulative Environmental Management association, Fort McMurray, AB. Dec 2007. http://esrd.alberta.ca/water/programs-and-services/water-for-life/healthy-aquatic-ecosystems/documents/WetlandEstablishmentReclaimedOilSands-2007.pdf

Alberta Government 2013. Alberta transportation guide to reclaiming borrow excavations. http://www.transportation.alberta.ca/Content/docType245/Production/borrowguide.pdf

National Wetlands Working Group / Edited by B.G. Warner and C.D.A. Rubec, 1997. The Canadian Wetland Classification System Second Edition. http://www.env.gov.yk.ca/animals-habitat/documents/canadian_wetland_classification_system.pdf

Cox R.K. and Judith Cullington. 2009. Wetland Ways: Interim Guidelines for Wetland Protection and Conservation in British Columbia. Wetland Stewardship Partnership March 2009. http://www.env.gov.bc.ca/wld/documents/bmp/wetlandways2009/wetlandways_docintro.html

EPA. Principles of Wetland Restoration US Environmental Protection Agency. https://www.epa.gov/wetlands/principles-wetland-restoration

Kentula, Mary. Restoration, Creation, and Recovery of Wetlands, Wetland Restoration and Creation *in National Water Summary on Wetland Resources*, United States Geological Survey Water Supply Paper 2425; https://water.usgs.gov/nwsum/WSP2425/restoration.html

Laxton, S. and Coates, J., 2011. Geophysical and borehole investigations of permafrost conditions associated with compromised infrastructure in Dawson and Ross River, Yukon. In: Yukon Exploration and Geology 2010, K.E. MacFarlane, L.H. Weston and C. Relf (eds.), Yukon Geological Survey, p. 135-148.

Maurice, Maryse 2011. Reclamation and Restoration Plan Development. NAIT Boreal Research institute, Boreal Reclamation Program, Technical Note, March 2011. http://www.nait.ca/docs/Reclamation_Plan_Development_TN.pdf

MacKenzie, W.H. and J.R. Moran. 2004. Wetlands of British Columbia: a guide to identification. Res. Br., B.C. Min. For., Victoria, B.C. Land Manage. Handb. No. 52. https://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh52.pdf

SER. http://ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration

Smith, C.A.S., J.C. Meikle, CF Roots (editors) 2004. Ecoregions of the Yukon Biophysical properties of Yukon Landscapes. AAFC, PARC Technical Bulletin No.04-01. Summerland BC.

Yukon Geological Survey**.** http://permafrost.gov.yk.ca/permafrost101/

Zedler, Joy B. Progress in wetland restoration ecology. In TREE vol. 15, no. 10 October 2000. http://umanitoba.ca/institutes/natural_resources/pdf/Zedler_restoration.pdf

APPENDIX A

Wetlands in the Indian River and Their Functions

As scientists discover and explain the importance of wetlands to the environment and ultimately, to human health, it is important to recognize the functions that undisturbed wetlands provide and the factors that control their distribution. In order to restore wetland function after mining, it is important to know what classes of wetlands are present in a project area and what ecological functions they perform.

Wetlands are complex ecosystems and the abundant wetlands in the Indian River valley are a complex interaction between the terrain, bedrock, gravel terraces, depth of silty loess, peat, permafrost, surface and groundwater flow, the vegetation and the wildlife.

The following includes a discussion of some of the factors that impact the distribution of wetlands and how they function. The ecological functions that any part of the wetlands actually contributes to the whole watershed is unknown, undocumented and is just beginning to be researched.

Terrain, geologic conditions and permafrost

The main central part of the Indian River valley is a broad gently sloping valley constrained by steeper mostly quartzite and schist bedrock slopes along its northern side. To the south deep loess deposits blanket the weathered fluvial and glaciofluvial gravel terraces, topped by peat of variable thickness. West of Ophir Creek the river cuts down more steeply in a narrower valley through the metamorphosed sedimentary rocks changing the character of and the potential for wetlands. The meandering stream seems to be gradually migrating towards this north side of the valley leaving older meander scars marking the former channels and lots of broad areas of wetlands on the old silt covered terraces and along the river floodplain.

Permafrost is widespread and underlies most of the valleys including the wetlands. The permanently frozen soil restricts water inflow and often confines water flow to the active layer within the peat. Blocking groundwater flow within the active layer by compaction, construction of roadbeds, overburden piles can cause ponding or redirection of flow. Excess ice is present underlying most wetlands, causing subsidence and thermokarst when it thaws. The permafrost stores excess water and carbon. Flow and or ponding of water on the surface can lead to deepening of the permafrost table at that location, causing thermokarst if there is excess ground ice, or channelling of water flow, and changing hydrology (draining or flooding in other parts of the wetland.

There are 5 wetland classes commonly found in valleys along Yukon’s gold bearing streams as recognized by the National Wetlands Working group (1997). A description of the wetland classes follows.

Bogs

Bogs are peat landforms characterized by a surface raised above the surrounding terrain, receiving water from precipitation but virtually unaffected by any groundwater flow. The pH of the soil and soil water is low, usually less than pH 4.8. The surface of the bogs is usually fairly dry (usually providing much easier walking than other wetland classes).

Bogs are sparsely mapped in the study area. Typically, Yukon bog soils are frozen close to the surface, though the bogs investigated in September 2016 were generally found to be unfrozen to 60 to 100 cm. Many of the bogs investigated had wetter parts within them. Bogs in the Indian River valley are usually characterized by stunted black spruce vegetation, *Sphagnum fuscum* moss and, on the driest undisturbed sites, a high *Cladina* lichen cover. Other species such as Labrador tea, bog cranberry, cloudberry, low bush cranberry and crowberry are also typical. Lower pockets may consist of Sphagnum capillifolium, S. girgensohnii, brown mosses and various sedges.

Bogs are found in two different landscape positions in the Indian River valley. They are associated with deep peats on old river deposits, usually surrounded by fens. They are also found on steep, northerly facing slopes on the valley sides, where the cooler temperatures are associated with permafrost, slow decomposition of organic material and accumulation of peat under Sphagnum moss. The peat on these slopes is usually more than 30 cm thick but generally thinner than in the bogs on the valley floor.

Functions of bogs include storing water, organic material and carbon and providing habitat.

Fens

Fens are peatlands influenced by minerotrophic groundwater, rich in dissolved minerals, and therefore have a higher pH and are more productive than bogs. Slow groundwater and sometimes surface water flow are characteristic. The water table is usually at or just below the surface, and peat is composed of moderately decomposed sedge or brown moss peat. Fens can range from rich fens, dominated by herbaceous vegetation, to poor fens, with lower pH and nutrients and with many vegetation species in common with bogs.

Fens are very common in the Indian River valley. The depth of peat in fens within the study area varies from about 20 cm to more than 2 m. The pH is typically in the range of 5.5 to 7. The ground vegetation of fens is typically dominated by sedge and moss communities. In the Indian River valley, the most extensive fens are characterized by sedge tussocks, which may be of two different species: Tussock cottongrass (*Eriophorum vaginatum*) and muskeg sedge (*Carex lugens*). There tends to be a transition between the driest fens, which may have black, white and hybrid spruce trees (Bennett pers. com.); to shrub fens with shrub birch, leatherleaf (*Chamaedaphne calyculata*), willow (Salix spp.) and sedge tussocks; to wetter fens dominated by sedge tussocks and fewer shrubs. The wettest fens occur in channels with more water flow and are usually dominated by *Carex utriculata*. The deeper peat (difficult to assess where the soils are frozen) appears to be found on the old floodplain of the Indian River in old meander scars.

Functions of fens include stabilizing water flow, maintaining water flow during drought, flood control. storing organic material and carbon, filtering water, trapping sediment, and providing habitat.

Swamps

A swamp is a tall shrub or tree dominated wetland (usually >25% cover of woody species) that is influenced by minerotrophic groundwater. Swamps are characterized by well decomposed woody peat and can be either peatlands or non-peatlands. They typically have a fluctuating water table.

Swamps are one of the most common wetland classes in the Indian River valley. On the floodplain, there are willow and alder shrub swamps adjacent to the river that are frequently inundated by flood water. There are also coniferous treed swamps affected by a shallow water table and a shallow depth to permafrost. These may also be subject to flooding. The swamps are interspersed with white and black spruce riparian forest. The spruce trees in the swamps are usually slightly smaller and leaning ("drunken"), or with numerous dead branches, and the ground cover includes species indicating a shallow water table. Similar but narrower bands of coniferous treed floodplain forest and shrub swamps are also found along smaller tributary creeks.

Another type of swamp is found along the margins of the fens on the higher terraces where the black spruce coniferous swamps transition to adjacent uplands. These swamps generally have taller trees and a denser tree canopy than the fens, however growth is severely limited by excess water and underlying permafrost. These swamps are also slightly drier than fens, with more shrubs and lichen, but show a significant cover of sedge tussocks.

Functions of swamps include stabilizing water flow, flood control, maintaining water flow during drought, storing organic material and carbon, filtering water, trapping sediment, and providing habitat.

Marshes

A marsh is a minerotrophic wetland with a near-surface water table that fluctuates daily, seasonally, or annually. Water levels may vary from year to year. Marshes are characterized by herbaceous sedges, grasses, rushes and horsetails.

Marshes are not widespread in the study area but are common in recently abandoned meander channels of the Indian River. Grasses dominated by *Calamagrostis canadensis*, diverse sedges including *Carex utriculata*, *C. aquatilis*, and *Scirpus* sp., *Juncus* sp., and *Equisetum fluviatile* are typical dominant species in these marshes.

Functions of marshes include stabilizing water flow, flood control, maintaining water flow during drought, filtering water, trapping sediment, and providing habitat.

Shallow Water

Shallow water wetlands have standing or flowing water less than 2 m deep in mid-summer. Shallow water wetlands are transitional between seasonally wet (i.e. bog, fen, marsh or swamp) and permanent, deep water bodies. Water levels are seasonally stable, permanently flooded, or intermittently exposed during droughts, low flows or intertidal periods. Shallow waters are subject to aquatic processes typical of upper lake zones, such as nutrient and gaseous exchange, oxidation and decomposition.

Shallow waters are variously called ponds, pools, shallow lakes, oxbows, sloughs, reaches or channels. They may occupy portions of larger wetlands or bays and margins of deeper lakes. In the Indian River valley, these wetlands consist of few, small, shallow water ponds usually occupying abandoned river oxbows. In some parts, they may also be thermokarst ponds. They may be surrounded by fens, marshes, swamps and/or riparian forest. Aquatic submergents, such as pondweeds and bladderworts, and emergent, including cattails and rushes (*Juncaceae*), usually characterize the vegetation.

The shallow water wetland class excludes artificial water bodies (reservoirs, impoundments and dugouts), where water regimes have been manipulated. As such, *active* tailings ponds, with controlled inputs and outputs, are not wetlands. *Abandoned* tailings ponds less than 2 m deep and subject to natural aquatic processes typical of upper limnetic or infralittoral lake zones are shallow water wetlands.

Functions of shallow water wetlands include stabilizing water flows, trapping sediment and providing habitat.

Wetland Functions

The functions provided by the different wetlands vary significantly. The functions vary because of the different vegetation, soils and surficial materials, hydrology, permafrost characteristics, chemistry, soil microorganisms, and larger wildlife and the interactions between them. The general functions listed are based on observations and knowledge gleaned from reports on wetlands from other regions. However, little research has been undertaken to determine what specific functions the wetlands in this part of the Yukon perform and to what extent in the particular environment of the Indian River valley.

The functions of most wetlands will include stabilizing water flow; providing a source of water during drought; filtration of muddy floodwaters; slowing floodwaters and reducing downstream erosion and flooding and of course habitat;

The habitat provided by the different wetlands also varies significantly and is specific to the particular soils, hydrology and vegetation present at a site. Different birds, mammals, insects and soil microorganisms will use the different wetlands in different ways and may be specific to one class of wetland or may be associated with one particular plant species. They may provide food and cover for fish and wildlife; winter travel corridors for caribou, wolves, foxes, moose, and others; insect production in their warm shallow waters; fish spawning and rearing habitat for fingerlings; nest sites and feeding areas for water birds; and plant decomposition areas to add fish and insect food to rivers. Some species such as moose, caribou, foxes, and many birds can use both wetlands and upland habitats, however, many specialist species such as frogs, waterfowl, fish and aquatic insects, are completely dependent on wetlands for breeding habitat and survival.

Wetland Soil Ecology

Wetland soils are unique and not easily replaceable. Soils that stay wet for most of the year develop special conditions that eliminate all but specialized wetland plants. Saturated soils also have special chemical properties such as low oxygen, higher solubility of some chemicals, and slow decomposition. Where wetland plants grow on these soils, the soil surface gets sewn together with living root mats so the soils don't wash away as easily. Because the roots provide some oxygen into the soil around them, they change belowground conditions so insects and other plants can live there. Over decades to centuries the layers of leaf fall, roots, and dead stems create dense layers of plant-based organic matter that is fertile habitat for plants and animals.

Mineral Soils

Riverside gravel bars are important features for plants, insects and fish. Mineral soils range from gravelly to sandy to silty and regardless of grain size, ground up rocs are their primary ingredient. Because water cover reduces the exposure of wetland soils to air, organic matter (decomposed plants mostly) decay more slowly and accumulate instead of converting to nitrogen, oxygen and carbon dioxide gas and leaking into the atmosphere. This organic accumulation is much less than the peatland accumulations but still adds a rich dark organic component to mineral-based wetland soils. They are productive growing areas.

Peatlands

Two of the specialized wetland classes mentioned earlier, fens and bogs as well as some swamps, are wetlands that develop peat and grow on a base of peat. Peat is simply the partly decomposed stems, roots, and leaves shed by plants. However, the layers of peat act differently depending on depth of burial. At the surface, in the living peat soil, there are green living plants and roots as well as rough intact dead stems with the consistency of a kitchen sponge. There are large pore spaces in this surface layer and there is enough oxygen for insects to live here. Water can flow slowly through this zone. When droughts hit, these wetlands continue to slowly release large volumes of water that support river flows. The released water is dark colored like strong tea because it carries valuable dissolved carbon that ultimately benefits aquatic plants, the insects that eat the plants, the fish that eat the insects, then on to waterfowl, otters, birds of prey, and humans.

Peat at the surface of Yukon wetlands is often poorly decomposed Sphagnum peat which overlies slightly to moderately decomposed Sphagnum, woody and or sedge peat. Lower down in the peat layers, below the permanent water table, usually 10-30 cm below the surface, conditions are very different. This zone is cold, dark, with much slower water flow, essentially lacking oxygen, and therefore little decomposition, forming one of the world's largest carbon storage areas. plant layers may be more decomposed, sometimes looking like black muck.

Permafrost

"Permafrost is ground that remains frozen for longer than two consecutive years, and it may or may not contain significant amounts of ice. In southern Yukon, less than 25% of the land area is underlain by permafrost. In central Yukon, the distribution of permafrost is more extensive but still discontinuous, while north of Dawson, it is nearly continuous. Permafrost is generally thicker and colder as you move further north. It may be over 300 m thick and colder than -3° C in parts of the north slope, while in sporadic locations around Whitehorse it is only a few metres thick and is barely below 0° C. Permafrost distribution and ice content are influenced by a variety of local factors including topographic position, slope, aspect, vegetation cover, snow cover, and soil moisture and texture." (http://permafrost.gov.yk.ca/permafrost101/)

Permafrost underlies most of the Indian River landscape including wetlands. Temperature of the permafrost in the Dawson area ranges from -3 to -1 ^{o} C, and may be up to 60 meters thick (Yukon Ecoregions Working Group, 2004). Wetlands will develop and maintain permafrost when other drier environments do not. Permafrost restricts water inflow and often confines water flow to the active layer. Permafrost stores excess water and carbon. Wetlands are often ice rich containing excess ice. Excess ice is ice that is greater in volume than the volume of the pore space in the original soil resulting in a land surface that is raised relative to what it would be without the ice. Excess ice forms where there is an abundant water supply and this water freezes on contact with existing ice crystals in the soil. Excess ice can occur in the form of polygonal ice wedges, lenses or in layers, in peatlands and in mineral soil wetlands. Ice wedges in the loess can be up to 1 m wide and 4-5 m deep. Smaller ice wedges may be found in the peat. Tabular ice may be found in lower parts of the loess. (Yukon Ecoregions Working Group, 2004)

Peat

Peat is a good insulator during warm summer temperatures. The surface of the peat dries out especially in bogs and swamps which are dry at the surface, insulating the frozen soil below. Wet soils in the fall will lose heat more quickly, cooling and developing ice in the soil. Because of the latent energy required to convert water from ice to liquid water, once wetlands are frozen they can remain frozen for a long time.

Bogs in the Indian River valley have very limited water flow and are usually frozen close to the surface with a shallow active layer. Fens in the south are usually unfrozen. In the Dawson area, fens often have deeper active layers with groundwater flow on top of the permafrost table. Swamps in the region are also usually permanently frozen. Marshes are less likely to be frozen as they are usually very close to the river channel and the groundwater flow under the river.

Thermokarst

Natural disturbance such as forest fires can impact the permafrost by increasing the active layer depth and in parts of southern Yukon causing thawing of the permafrost where permafrost is very close to 0 ^{0}C (Burns 1998). Deeper active layers may result in melting of excess ground ice. Fires may increase the active layer in some parts more than others as patchy burns move through the landscape causing collection of water in depressions in the permafrost table causing further thaw.

In the southern Yukon, permafrost has been shown in several areas to be thawing from the surface, the depth to the permafrost is increasing beyond the depth of seasonal ground freezing following a forest fire. (Smith et al Burns et al.). In central Yukon, active layers are also likely increasing following the large fires which are characteristic of the region. As vegetation and moss layers re-establish the permafrost table will likely come back up.

Thawing of permafrost with excess ice causes subsidence and thermokarst when it thaws. Blocking groundwater flow within the active layer by soil compaction, construction of roadbeds, or depositing overburden can cause ponding or redirection of flow. Flow and or ponding of water on the surface can lead to deepening of the permafrost table at that location, causing further thermokarst if there is excess ground ice, or channelling of water flow, and changing the hydrology (draining or flooding) in other parts of the wetland.

Water Movement

The ways that water reaches wetlands are complex. We can see the rain and snow fall, but often water flows invisibly onto, into, through or under wetlands. Wetlands can receive water from precipitation, fog, subsurface flow, surface flow, flooding and or springs where subsurface water flows out at the surface, Water sources vary by site and by wetland type with bog wetlands receiving all of their water from precipitation. Fens occur where water flows through mineral soil as groundwater._This means that fens might stay wet and green even during drought because their water sources come from uphill out of springs and subsurface water.   Marshes and shallow water wetlands are wetted by precipitation, surface flows from the river, groundwater or all three. Swamps receive water from precipitation, subsurface flow and or flooding. Wetland classes often occur in complexes, merging into one another depending on water sources and soil types.

Riverside wetlands are usually fed by water that flows through the cobble and sand of the river channel. In fact, the undisturbed beds of almost all Yukon gold-bearing streams have a slow-moving current of water that moves *through* the sandy soils underneath the river's surface flows. Water can move from river channel to underground flow then back to river channel. Water flows under river bends and wells up into nearby oxbow wetlands. This underground river bulges to the surface to mix with the body of the river and in some places, part of the river flow soaks belowground to mix with the underground river flow. Sand is a very effective filter; water purification in rivers takes place when surface water moves through long stretches of underground sand, where the sand traps silt, nutrients, leaf and organic debris.

Wetland Plants

Like wetland soils and hydrology, the plants of wetlands are specialized too. Relatively few plant species survive permanently saturated soils; upland plants are drowned. When water fills the pore spaces in soil, the exchange of gasses is excluded, roots are smothered, leaves wilt and the plant dies. Wetland plants have special ways of carrying atmospheric gasses up and down their stems much like an internal air hose. Other wetland plant adaptations include seeds that require water (or wind) for transport. Underwater wetland plants are particularly good at absorbing the long light wavelengths that filter through water. Finally, the extensive roots that anchor these plants in soft soils also prevent erosion and uprooting during high water.

Wetland plants do not just *respond* to their environment however, they also *affect* it by stabilizing and trapping sediments. This function is particularly important in riparian wetlands because rushing water can keep sediments suspended for long distances. Dense aquatic plant stands create a network of slow or still water patches in the current by increasing the "surface roughness" of the channel. The vegetated sites allow suspended sediments to settle out and lodge, thereby clearing the water column. Like the sand-filtered groundwater flow, slowing the current is a second way wetlands filter flowing water and improve its quality for downstream users. A third way wetlands trap sediments, nutrients and pollutants is through attachment to surfaces. Slippery films of microscopic algae and other micro-organisms coat river rocks, plant stems and river bottoms. These films are called biofilms and they are usually less than 1 mm thick. They ooze a sticky protein-based material has a fly paper effect in capturing and incorporating fine particles in the water. Biofilms also develop on decomposing leaves, twigs and branches and capture particles flowing against them. Biofilms are the primary food source of whole groups of river insects called "scrapers" that act like windshield wipers or rock scrapers as they scrape and digest the biofilms.

APPENDIX B

Wetland Reclamation that Retains Wetland Function

Many Yukon riparian systems support elaborate and complex wetland fen and swamp systems along their banks and valley floors. These are important systems where plants, sediments and currents have worked together for thousands of years. Reclaiming wetlands to near their original conditions is vital but it can be a slow and expensive process.

Understanding Pre-mining Conditions

Equally important to knowing the quantity of minable gold in a system is understanding reclamation's ability to replace land conditions that closely mimic pre-mine conditions. Thus, before mining it is necessary to understand the hydrology, geology, morphology (land shape), biology, and how the wetlands respond to disturbances of flood, fire, grazing, and drought. Before mining, a clear description of the goods, services, and functions provided by the particular wetland must be undertaken.

The description of pre-mining conditions should include:

- description of the bedrock geology, surficial material, and chemistry, density/compaction and weathering status to allow reclamation to similar status and layering;
- soil conditions including depth to permafrost, water table, and depth of organic matter;
- water extent in rivers, streams and ponds mapped at high and low water to understand seasonal variability (if it as particularly wet or dry season, review of series of older aerial photos can help indicate more normal surface water conditions.);
- an inventory of the plant community, including submersed aquatic species, completed in mid-summer including a species list and notes on rare plants to help define the target for restoration; and
- wildlife diversity in the undisturbed area should be documented including insect productivity and use by birds, aquatic mammals, terrestrial mammals, and amphibians.

This data will help establish the reference conditions which are the target for reclamation.

The ecosite classification for the Boreal Low portion of the Klondike Plateau projected for completion in March 2018 (ELC, Environment Yukon) will assist with characterization of the reference conditions.

Reclaiming Peatlands

Many Yukon and Indian River wetlands are peatlands. Reclaiming peat fen and bog wetland to anything near their original conditions is a slow and expensive process that sometimes stalls at unproductive levels for long periods. Re-constructing flow-through groundwater supplies to wetlands has rarely been successful and this is one of the reasons reclamation specialists rarely attempt to construct fens. The interactions of soils and water are likely the two most complicated and intertwined reasons for wetland reclamation problems.

Colorado scientists attempted to reclaim short stretches of mountain fens similar to those in Yukon. Over a 15-year attempt, they had limited success. Two large oil companies in Alberta, Suncor and Syncrude, have attempted to create groundwater-dominated fens on mined tailings. The costs were large (estimated at over $1 million per ha) and at year 8, both have ended up a mix of marshes with intermixed uplands, trees, grasses and a few mosses. While the mossy spots are encouraging, the water flows, water and soil chemistry, lack of organic matter, and invasive weedy species remain overriding problems.

Attempts to rebuild bogs have been undertaken in Ireland and in Quebec with some limited success numerous years after and large costs.

Because of the difficulties in reclaiming peatlands it may be necessary to reclaim wetlands initially as swamps and marshes and shallow water instead of peatlands. In the permafrost environment of the Indian River valley, it is possible that conditions with sufficient moisture, and organic material on a reconstructed landscape similar to the pre-disturbance landscape that leads to permafrost re-establishment may develop fen wetland ecosystems over time.

Progressive Reclamation

Responsible environmental reclamation is the creation of a post-disturbance environment *different but very similar to* the pre-disturbance condition. This is crucial with wetland reclamation.

Progressive wetland reclamation means that wetland reclamation is undertaken as one progresses with mining. This allows reclamation to start in areas that are no longer required for mining. Undertaking progressive reclamation allows additional time for methods and techniques to be successful (e.g., establishing pioneering and successional species), for monitoring and modification of the plan as needed and for cost-effective use of operator time and equipment.

It difficult to determine the percentage of infringement on wetlands that can occur within a wetland complex and still maintain the function. This determination is particularly tricky when it comes to peatland, which cannot be restored by any known method. One way of guaranteeing enough wetland function remains in each river valley is “Progressive Reclamation” which is carried out such that wetland function in reclaimed areas is re-started within a reasonable time frame. Beginning the process of wetland reclamation in the block mined earlier in the year or the previous year would accomplish this.

Progressive wetland reclamation can shorten the time period required for achieving closure objectives and reduce financial liability of a site by avoiding additional reclamation costs (since equipment and employees are already on the site working along with the mining cycle).

Monitoring the success of reclamation techniques

Monitoring the success of reclamation techniques as mining progresses also provides for valuable experience on the effectiveness of reclamation measures on an ongoing basis.

Activities such as stockpiling materials, grading and re-contouring tailings piles and steep excavated slopes to the former surface form and elevation, sloping and adding topographic features such as swales, depressions, ponds and islands are all examples of activities that should be undertaken post-mining before moving to the next area to be mined. Recommended construction objectives are listed in Table 1.

Equally important to knowing the quantity of minable gold in a system is understanding reclamation's ability to replace land conditions that closely mimic pre-mine conditions. Thus, before mining it is necessary to understand the hydrology, geology, morphology (land shape), biology, and how they influence the distribution of wetlands and how the wetlands respond to disturbances of flood, fire, grazing, and drought. Before mining, a clear description of the goods, services, and functions provided by the particular wetland must be undertaken.

Comparison sites

The best way to create effective reclamation plans and to measure their success over time is comparison of the site to be mined to a similar healthy area that is undisturbed. These comparisons involve measurement of the exact mining site *before* operations starts as well as comparison to a nearby similar reference site that will remain undisturbed.

The reason comparison or reference sites are so important is because without clear descriptions of desirable post-mining conditions, it is impossible to know if reclamation was successful or not. Substantial disturbances and loss of wetland function occur in *every mining excavation*. These effects are obvious immediately following mining because even with ideal reclamation efforts, it will take time to return many of the benefits wetlands provide. In the worst-case scenario however, an inadequate reclamation plan will never get the wetland on the path of returning those benefits. Setting measurable goals against comparison wetlands is necessary.

Earthworks and Grading

Slopes. Final slopes should mimic natural sites and pre-mine condition. Undercut banks, abrupt cliffs and high walls, need to be safely decommissioned. The ecological function of cut banks is that the force of water redirected toward the opposite riverbank, a large swirl eddy is often created that is high quality fish habitat, and erosion causes dynamic shifts in river morphology when banks cave in.

Major land forms. Replace terraces or benches in their previous locations. Typically, in riverine systems there will be at least three elevation zones: (1) river bed during normal flows; (2) annual floodplain terraces that frequently experience flooding either as over-surface flows or as active sub-irrigated hyporheic flow. This is a very important filtration system for spring freshet conditions, and (3) extreme event flood plain where water levels reach into terrestrial borders causing major channel re-working and transport of cobble and even small boulders. Extreme flooding may occur infrequently at the decade or century frequency, yet, the changes they cause are large. Attempts to reclaim hydrologic regime of river usually failed in Alaska placer streams if the gradient was greater than 1%. Streams tended to become sandy bottomed and braided initially then down-cutting and undermining plantings and shore stabilization attempts of reclamation. Reclamation plans must accommodate each of these events without system collapse.

Surface stabilization. Plantings, decomposable geotextiles, or spray-on agglutinating agents are sometimes used to stabilize slopes. While these may help greatly in the early stages of reclamation, if sand and topsoil is used instead of heavier rock in bends or overflow channels, the water is likely to remove the erosion control efforts. If a reclaimed terrace is established yet destroyed by the first minor flood, it is clearly not a worthwhile investment. It is difficult to predict the direction of energy and landscape carving during major floods.

Channel erosion effects are three-fold; the channel is cut, the sand and cobble is deposited elsewhere in the stream, and the fines are released into the water column. Continual sediment delivery in streams is very bad for salmon and arctic grayling reproduction. Physical erosion control may require multiple attempts to stabilize the material.

Microtopography. Soil surfaces do not need to be smoothed; coarse surfaces may trap more precipitation, avoid gulley washing, and provide seed capture or safe sites for native vegetation. Topography should not, however, remain in a way that fosters large sediment loads or erosional gullying or channel capture.

Soil strata. Wetland soils occur in layers depending on saturation, sediment grain size, organic matter content and chemical conditions. In wetlands, the most biologically active zones occur at the surface, larger cobble is typical in the deeper zones and water permeability is usually greatest at the upper levels. Soil replacement sequences must mimic pre-mine conditions. From the bottom up, one example might include: cobble, subsoil, sand, mucks, peat, topsoil. Upstream disturbances that mobilize fine sediments can interact with the gaps between stones to create a sand-filled zone.

Soil Management

Wetland surface soils are very valuable and deserve special handling if their excavation is planned. Wetland soils usually contain dark organic matter, seeds, insects, plant fragments and abundant nutrients, all of which are difficult to replace, thus, they should be saved.

The soil volumes and storage locations require mapping for ease of replacement after mining. Large rocks, subsoil, sand, mucks and topsoils should be roughly sorted during excavation and stored separately. Each material should be backfilled in sequential order to provide similar drainage and plant-growing conditions during the reclamation period. Ideally, storage should be on previously excavated sites to minimize the total footprint of disturbance.

Wetland "morphology" refers to the shape, slope, and arrangement of land surface features. If the wetlands occurred on steep slopes, that is what needs to be replaced; if the wetland surfaces were benches or table-flat, that is the appropriate replacement shape. Deep pits, spoil piles and elevated placer tailings have no natural function after mining and need to be returned to the original wetland elevations and contours.

Many Yukon riparian systems support elaborate and complex wetland fen systems along their banks and valley floors. These are important systems where plants, sediments and currents have worked together for thousands of years. Fens characterized by groundwater subsurface flow are difficult to rebuild.

Water Movement and Controls

The amounts of open water, flow rates, soil compaction and quality of water produced at the end of mining should be approximately the same as pre-mine conditions. Some latitude is reasonable here to allow systems to sort themselves out and for wetland health to return after disturbance. It is important to measure the return to health along key areas of improvement.

Hydrologic control of surface water is not difficult if elevation, structure and containment are manageable. A well-understood regime must be in place however because best results generally do not come from chaotic or overly-stabilized management. Some knowledge on site of hydrologic regime prior to alteration is a good baseline on which to gauge irrigation management. If water berms, turn gates, coffer dams, channels, or stop log structures are needed to control flooding or wetting, they must be planned and will be removed when the maturing reclamation system no longer needs them.

Revegetation

Successful plant establishment and survival is a primary indicator that soils, aspect, slope, hydrology and disturbance patterns have been configured properly. It is possible to revegetate a reclamation site with plants that don't meet the system's needs; plants that will die in the first flood or drought; that may be quickly and permanently removed by fast-flowing water or beavers; and finally, plants that will only survive until the planting fertilizer supply in their root container is depleted. Plant cover of any sort is sometimes mistaken for successful colonization, however, a dense stand of cattails, a clean stand of non-local willows, or worse yet, weedy, invasive or exotic species can create many years of undesirable conditions.

Reclamation plantings group into three broad categories (1) natural colonizers; (2) hand or aerial seeded and (3) hand planted bare-root stock. Genetics of the planting stock matter. Seeds should be collected on and adjacent to the disturbance site in the year before seeding. Care is needed to collect seeds that are ripe and ready to fall. They should be stored in conditions similar to what they would experience in the field; damp frozen for damp soil plants; dry and cold for upland plants. Both should be kept in light-proof containers away from fluctuating temperatures and seed eaters. Local bare rooted plants are rarely available for purchase but may be collected in the region, ideally on site during excavation. They may be stored for a season “heeled in” to a trench covering their roots with loose damp soil until they are planted out the next spring or summer by qualified planters. Protection from browsers may require an electric fencing or mesh cages may be required to permit establishment.

Ponds in Reclamation

Fresh tailings from dredged and washed gravels contain enough suspended solids, particularly clays and silica dust that they resemble chocolate milk. Settlement ponds capture the heavier material and wetland or soil filtration can capture the remainder. If settlement pond bottoms rest on impermeable layers of settled clay or bedrock they may be re-filled, however, the buried layers of fine material produce a waterproof pond bottom and because water flows both over and through valley bottom soils clay barriers might change flow patterns.   Ponds in the post-mining environment should mimic natural landscape configuration. Few small shallow water ponds are typical of the Indian River valley. Deep ponds are rare or absent in river valleys with flowing water and moving sediments.

Large ponds will attract some key wildlife species such as waterfowl, furbearers and large browsers, yet, ponds do not provide the same system-wide benefits as the wetlands they replace. For example, carbon capture, soil stability in floods, water purification and water release in droughts are all typically lost. Furthermore, the first goal is not necessarily to produce moose, waterfowl or muskrat habitat to a degree greater than the original site.