Best Management Practices for Placer Mining in Yukon Wetlands

Recommendations and Guidelines

Summary Document

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For the
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November 10, 2015

1. Introduction

Placer mining has been a cornerstone of the Yukon's economy and modern culture since the great Klondike Gold Rush of 1898. Currently there are over 100 family based placer mines with combined gross revenues in excess of $70 million annually. All Yukon placer mines are privately financed operations. Placer mining is especially vital in the Yukon's small communities.

Most Yukon placer gold deposits occur under or beside streams which may be located in wetlands. Therefore, typical wetland avoidance strategies found in other kinds of mining activity are completely impractical for this industry. Yukon placer mining activities involve the stripping of surface vegetation, the thawing of overlying permafrost soils and gravels and the recovery of free gold from pay gravels lying above bedrock using sluiceboxes.

Sluicebox tailings are processed in settling ponds in old mine pits or low areas. Vegetation and overburden are removed and stockpiled on the side. Depending on the mining method, equipment and site limitations, the overburden is put in a previous mining pit (panel mining) or left on the sides of the pit, recontoured, stabilized and covered with topsoil to enhance re vegetation. These surface mining activities significantly alter or destroy wetlands until they have been reclaimed.

Wetlands are considered to be important ecosystems and most areas of the developed world have permanently altered or destroyed a large proportion of their wetlands through the construction of subdivisions, industrial parks, marinas, farms and a variety of other developments. However, the Yukon appears to have vast areas of intact wetlands and the proportion of areas impacted by industrial activity (principally human occupation, placer mining and oil/gas exploration) is very low.

Wetland reclamation is a new and evolving science with many unknowns especially in Canada's north where permafrost is a significant factor affecting drainage, plants and animals. Permafrost has not yet been addressed in other reclamation guides. Winter ice on standing water in the Yukon also often exceeds 2 meters in thickness. Yukon reclamation techniques need to consider various limitations such as the lack of previous experience and models, the complexity of wetlands, the difficulty to predict the success of reclamation and the limited financial resources of placer miners. Placer miners also have significant investments in their operations, and will need sufficient time to adjust their mining methods and equipment to match any new requirements.

Wetlands are lands that are saturated with water or covered in shallow water (section 2 & figures 2-6). The broad goal of wetland reclamation after placer activity is to re-establish the appropriate saturation and/or flooded conditions, soils and topography to allow the natural establishment of a self-sustaining mix of uplands and marsh or shallow water wetland habitat. Marsh and shallow water complexes are by far the most significant wetlands in terms of wildlife diversity (National Wetlands Working Group, 1988).

Reclaiming wetland areas into a variety of wetland and upland habitats is preferable. Most species require a mix of wetland and uplands which are often more productive. Some swamps, bogs and fens will form spontaneously with no intentional reclamation measures undertaken; however this is most likely over extremely long timeframes (figures 4-8, 14-17 & 19). Semi-designed wetlands involve minor topographic and reclamation features added during landform design and/or construction. Due to the limited finances of privately funded placer mines and their relatively small footprint, this report offers best management practices to aid in the development of semi-designed wetlands. The use of these BMP's should promote natural reclamation to productive uplands with marshes and shallow water wetlands.

Most of the literature regarding wetland construction relates to the exacting restoration of specific types of wetlands which have not been excavated to mineral soils and not to the general reclamation of heavily disturbed sites. There is very limited information regarding the restoration of northern wetlands, particularly those in permafrost areas. Most of the relevant research has come from the restoration of mega oil sands mining projects in Northern Alberta where complex peat land bogs and fens have been reclaimed to much simpler marshes and shallow water wetlands at a staggering cost of between $50,000 to $114,000 per hectare.

The re-establishment of wetlands will take in the order of 10 to 15 years. At that point, the system should be well covered with succession (pioneer) vegetation and be "free to evolve." Reclaimed wetlands should not require long-term maintenance and management. It is also possible that the habitat will not evolve exactly in the way it was expected. Adjustments may be required from time to time to the best management practices to ensure the success of the re-development of wetlands.

This summary report provides practical and affordable guidelines and recommendations for reclaiming placer mined wetlands in the Yukon. It is based on recent local field research by the authors and an extensive literature review of wetland reclamation from various industries. The restoration of the water saturation levels, shallow shoreline and hillside slopes and the regrowth of vegetation are the most important components for successful wetland reclamation. Other wildlife enhancements are included as well for upland areas because the wildlife in wetlands generally uses both types of habitats.

For further, more detailed information refer to the background document "Wetland Reclamation for Placer Mining" by Anne Chevreux and Randy Clarkson.

2. Types of Wetlands

Wetlands are lands where the ground area is saturated with water or covered in shallow water. Wetlands are recognized as very important ecosystems and are highly valued by traditional land users such as subsistence hunters, trappers and fishers, as well as food and plant gathering for medicinal purposes. Wetlands can generate very productive ecosystems and they provide many environmental services to humans such as carbon storage, flood reduction, water supply and purification. Their conservation is considered a high priority worldwide.

The five classes described by the Canadian Wetland Classification System (bogs, fens, marshes, swamps and shallow open water; National Wetlands Working Group, 1997; (figure 2) are distributed throughout the Yukon. Their exact location depends on local climate, landform, hydrology, fauna, vegetation, soil and the existence of permafrost. However, a systematic inventory of Yukon's wetlands has **not** yet been developed to clarify the location and types of wetlands in the Yukon.

Peat forming, wetlands such as bog and fens, that have more than 40 cm (16 inches) of an organic top layer (peat; figure 1) and are often associated with streams and lakes or are isolated at higher elevations. Their water level is stable. Peatlands often occur on the landscape as a combination of both bogs and fens.

a) Bogs are able to receive their water, nutriments and minerals only from precipitation. They are limited to areas where the precipitation exceeds evaporation and the water table is at or near the surface. The water is generally acidic and low in nutrients and located in hummocks and hollows. Bogs usually support a black spruce forest but may also be treeless. They are usually covered with *sphagnum* and feather mosses and with ericaceous shrubs (shrubs that thrive in acidic soils).

b) Fens have a high water table that is usually at or above the surface. The waters are mainly nutrient-rich and can be acidic or alkaline. They receive their water, nutriments and minerals from precipitation, surface runoff and groundwater. The vegetation consists of extensive leveled carpets and lawns mostly composed of sedges, grasses, reeds and brown mosses, with some shrub cover and sometimes trees.

Figure 1 - Peat

Anne Chevreux Photo

Mineral wetlands such as marshes, swamps or shallow open water areas do not have as much peat accumulation.

c) Swamps are wooded wetlands that are in ongoing contact with water in either mineral or shallow peat soils. The water table is usually at or near the surface and nutrient-rich. The waters stand or gently flow in pools and channels. If peat is present, it is mainly well decomposed. Their thin peat layer is primarily composed of decomposing wooded material (shrubs and trees) rather than the *Sphagnum* or sedge-dominated peat in fens and bogs. The vegetation is characterized by a dense cover of coniferous or deciduous trees, tall shrubs, herbs and some mosses. The canopy coverage is greater than 50%. Swamps are not well known habitat and the ability of reclaiming these systems is limited.

d) Marshes are a mineral or a peat-filled wetland dominated by reeds, rushes and sedges (herbaceous water plants) rather than mosses or trees. They are periodically inundated by standing or slowly moving water, and are neutral to alkaline. The surface water levels may fluctuate seasonally, with declining levels exposing drawdown zones of matted vegetation or mud flats. The waters are nutrient-rich. They receive their waters from ground and surface.

e) Shallow-water wetland ponds are distinguished from marshes by having at least 75% of the total surface area in open water during the summer but they have similar chemical characteristics. Water depth is an important characteristic: in deeper wetlands, nutrients are diluted and there is less sunlight for growth of plants. However deeper ponds are less likely to freeze to the bottom in winter and therefore can provide habitat for beavers, muskrats and other aquatic life. They are often embedded in fen/bog complexes or surrounded by marshes or upland forests. An absence of fish in most of these ponds increases the abundance of aquatic organisms to the benefit of waterfowl.

Figure 2 - Wetland Types

Bog

Fen

Marsh

Swamp

Shallow Open Water (with a black bear)

Anne Chevreux Photo

3. Reclamation versus Restoration

It is important to understand the difference between “reclamation” and “restoration”. The intent of “restoration” is that the habitat has to be identical to the natural conditions that existed prior to modification, whereas reclamation means the return of a site disturbed by mining or exploration to a condition where it will be able to re-establish a suitable productive environment but one that is not necessarily identical to the one disturbed. It is important to stress that the goal of wetland reclamation after placer activity is reclamation **not** restoration.

The broad goal of the wetland reclamation after placer activity is to re-establish the appropriate saturation and/or flooded conditions, soils and topography to allow the natural development of a self-sustaining wetland habitat. Most reclamation plans include a varied landscape, incorporating several ponds and lakes, wetlands, and interconnected drainage systems with vegetated uplands. Reclamation is also considered successful if native species grow in the reclaimed site. The reclaimed habitat should re-establish a suitable environment for culturally important species, such as moose and beaver for First Nations as well as other hunters and trappers.

4. Types of wetlands that can be reclaimed

In theory all five classes of wetlands can be reclaimed to a type of wetland that depends on the depth of the depression (area lower than the surrounding landscape, and usually less well drained; figure 3). However, the wetlands that are reclaimed usually result in marshes or shallow open water wetlands. These can be reclaimed with relatively minor changes to the post mining landscape. They often begin as open water wetlands. However, as wetland vegetation establishes, several wetlands become more marsh-like in form within five years. A general finding of the wetland reclamation experience is that robust wetland plant species will establish opportunistically (on their own) in marsh and shallow water systems constructed with overburden, fine tailings and process-affected water (figures 4-6, 14-17 & 19).

Peat forming wetlands (bogs and fens) are formed over hundreds of years and the restoration process is extremely complex, prohibitively costly and difficult to achieve. One method involves the flattening of the landscape, the construction of cross-valley dikes to flood the area, the placement of mulch or hay and fertilizer, and the harvesting and transplanting of nearby plants/mosses. The restoration of ground saturation is the main factor for peat land restoration success. Therefore most peat wetlands are reclaimed into marshes or shallow water wetlands.

Swamps are typically situated between a fen and a drier upland environment. There have been no attempts so far to reclaim swamps in the oil sands industry.

Figure 3 - Wetland types in the reclaimed landscape depending on depth of the depression (CEMA 2014)

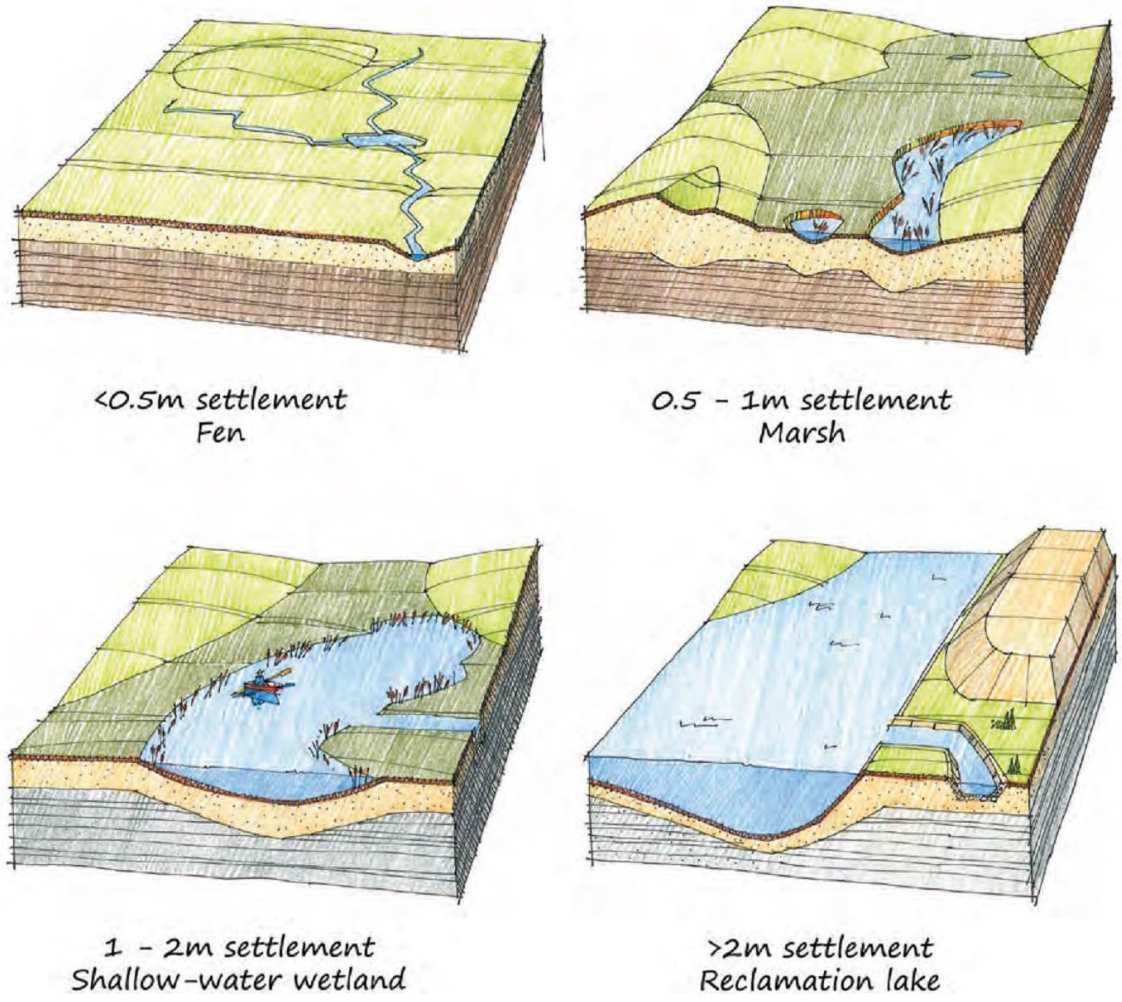


Figure 4 - Opportunistic Marsh and shallow open water from mined area in the Indian River Valley

This area was mined 25 years prior to photo with no intentional reclamation.

Photo By Anne Chevreux

Figure 5 - Aerial View of Opportunistic Wetlands in a Wide Low Gradient Valley

Note: This photo was taken 25 years after mining (natural restoration has occurred without any intentional land or wetland reclamation measures). The wide low gradient and high ground water table with abundant organics (black muck) have resulted in filled mine pits and settling ponds which have reclaimed naturally into shallow water and marsh wetlands. The various ponds are irregular in shape, of various sizes and interconnected. This area was mined before the implementation of mining land use regulations in 1996. Mining land use regulations now require a miner to place fine soils over disturbed areas. Photo by Stuart Schmidt.

Marshes

Marshes are often associated with open shallow wetlands. Marshes will appear in depressions and shallow slopes between 0.2 and 1 meter (8 inches to 3 feet) deep (figures 4 & 6). There should be shallow slopes on the shorelines to create marsh areas.

Figure 6 - Marsh area in a post-mined pond in Indian River Valley

Note: Marshes often develop on the shallow underwater shorelines of shallow water wetlands in previously open pits and settling ponds in previously mined areas. This photo was taken 20-25 years after mining with no intentional reclamation measures. Anne Chevreux Photo

End Pit Lakes

In general, placer mining activities create deep pits which fill with water if the ground water table is near surface. Some placer (panel) mining systems are able to move their processing plants frequently and use old pits for settling ponds and/or fill old pits with overburden. Other mining systems create large pits using trucks or conveyors to transport pay gravels to a more permanent processing area. It is generally very costly and impractical to fill large pits or the last pit of a panel mining system. The filling of pits could also be counterproductive where the filled level is above the ground water level and results in dry land forests instead of wetlands. Pits with water levels exceeding 2 meters would not usually freeze to the bottom in winter and would allow habitat for fish, beavers and muskrats.

The short term objectives of these end pit lakes are to manage the water flow, ensure an acceptable water quality, store processed pay gravels, provide a sustainable aquatic ecosystem and support other economic, ecological, and societal uses. The ultimate objective is to reach a self-sustaining aquatic ecosystem that serves as habitat for wildlife, particularly fish species.

5. Best Management Practices for Placer Mining in Yukon Wetlands

With placer mined wetlands it is important to recreate a complex of various wetlands and uplands which will support a wide diversity of wildlife species, especially threatened species during and after mining. It is also extremely difficult to develop and carry out detailed plans for placer mining due to the uncertainties inherent in placer mining. Placer miners need to be able to quickly adapt to changing pay gravel distributions, varying site conditions and economics. However, each placer mining system should work closely with these wetland reclamation best management practices to ensure successful and cost-effective wetland reclamation.

The exact location and types of wetlands created will be difficult to predict in advance of mining. This will often be dictated by the individual mining methods, available equipment, location of pay gravels, the local groundwater levels, soil types and vegetation. For example, mined out pits and old settling ponds already exist as low areas at most placer mines and therefore are the post mine landscape features which are most readily converted to wetlands. When previous pits are used as settling ponds, the fine sediments help to seal off the pits so that they retain water for wetlands. Top soils spread over shallow sloped pit walls will help to seal the pits and provide a growth medium for wetland plants (figures 9-11).

Sloped and contoured piles of overburden soils and/or coarse tailings should be covered with fine soils and used to separate wetlands from each other and allow greater diversity with upland vegetation and wildlife in the area. A wide range of topographic features should be incorporated into the reclamation landscape including small hills, small depressions and undulating topography. Shallow depressions can be excavated or left unfilled on flat areas or gentle slopes to create wetlands.

The depth of the water in the reclaimed wetland affects the type and amount of available vegetation for waterfowl. Shallow waters allow the sunlight to reach the bottom of the pond, thus allowing various plants and animals to develop there. Shallow water wetlands are less than 2 m deep and recommended for waterfowl habitat.

Water depths greater than 2 m (7 feet) or shallower depths with flowing water are recommended for open water habitat, to oxygenate the water, allow aerobic decomposition (with oxygen) and allow over-wintering by fish, muskrat and beaver. Shallow still water ponds less than 3 m in depth will often freeze to the bottom and result in anaerobic decomposition (deprived of oxygen) with large amounts of hydrogen sulphide that kill fish, muskrats and beavers.

Keeping wetlands wet is the most important control on wetland ecosystems and will often dictate whether you are successful at reclaiming wetlands. Water enters wetlands via stream flows, runoff, precipitation and up from the groundwater table. Wetlands lose water to other streams, into groundwater and through evapotranspiration (figure 7). The period of time during which a wetland is covered by water is unique for each wetland type and will determine the type of wetland created.

Mining usually thaws permafrost areas, often disrupts patterns of groundwater flow, and may change the surface water balance. Topography and drainage patterns can also be altered by mining and reclamation activities. However, the most reliably saturated or wetted ground will occur in low areas near or below the natural ground water table. Low areas will also be easier to fill with water. It is not advisable to (completely) backfill the mine pit if the natural ground water table is 2 m (or less) above the pit bottom. The sides of the pit wall should be sloped to very shallow angles (from 3:1 to 5:1, horizontal to vertical) by excavating the walls (figures 21 & 25) and/or pushing overburden in from the sides of the pit. Shallow shoreline slopes attract water birds, reduce turbidity and promote revegetation (figures 14-17 & 22).

If the wetland is situated in a higher area, it may be necessary to try to seal the bottom of the pond with fine soils and/or connect the wetland with the closest small stream to keep it saturated and/or under water (figures 12, 29-32). Fine tailings from settling ponds or fine overburden soils can be used to seal the bottoms of mine pits. Any connections with streams should be made at right angles to the direction of flow and the junctions should be armored with boulders or coarse cobbles to prevent erosion. Dam and dike construction activities by beavers may increase the depth of the ponds and help maintain water levels in perpetuity long after placer miners have left the area.

The overburden should be located not too far from the pit wall in a place where it can be easily pushed back over the mined area or into the pit. Overburden and fine soils will flow at very shallow angles when placed in water. Some gravel should be placed along some shoreline areas for shorebirds. Limited shoreline areas can have steeper stable banks for beavers and muskrats. Piles of logs and broken-up logs, smaller pieces of debris such as roots, twigs, and branches can be kept after the clearing activity and placed on the bottom and on the slopes of the pond. It is better to leave broken and dead trees standing in the reclaimed landscape (figures 35 & 36).

Progressive reclamation is recommended to allow the reclamation to start in areas that are no longer required for mining while mining is still continuing in other areas. The grading and re-contouring of tailing piles and steep excavated slopes should be completed while mining activity is taking place or at the end of each mining season unless these areas are required for mining in the near future. Upland slopes should be less than 2:1 (horizontal to vertical) or benched (table 1).

Topsoil, black muck and other organic materials and fine soils should be separated from overburden and conserved to be spread out later over disturbed areas. After spreading fine soils on the re-contoured slopes, the land surface may require roughening by running tracked vehicles up and down the slope, or by back blading with a toothed bucket horizontally along the slope, or by placing logs or woody debris on the slope (figures 9-11).

The following best management practices are suggested but they should be a living document that will be modified with the specific mining activity and continue to be updated as required. It is most important that the reclaimed wet lands are kept moist and/or covered in water for at least part of the

open water season. The end result of these BMP's should be the creation of a diversity of productive wildlife habitats with uplands and wetlands.

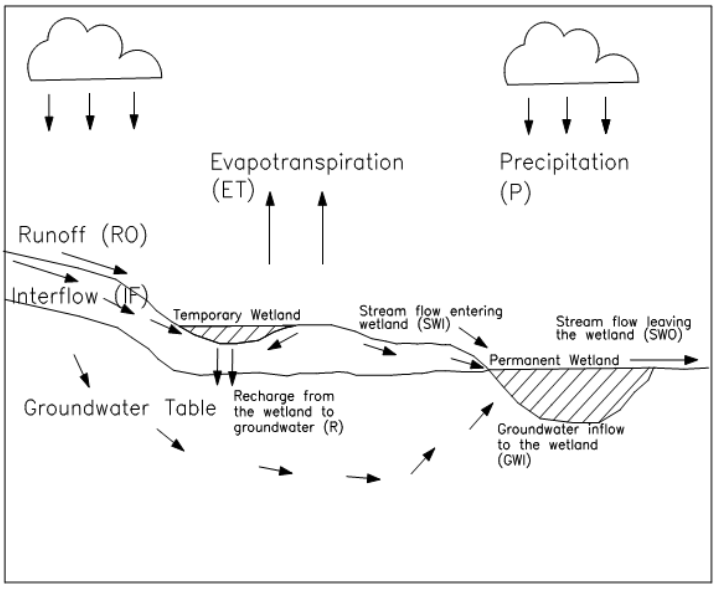
5.1 Avoid Disturbing Wetlands Where Practical

Avoid disturbing wetlands where practical so that you do not have to reclaim them. This is not possible when economic placer gravels are located directly under wetlands. However, try use upland or dry areas for the storage of overburden and other stripped material when working on the edge of a wetland complex. Try to avoid building roads, camps and other infrastructure on wetlands. This will often save money and time during construction and also save the wetlands. Protecting some of the remaining intact wetlands located over uneconomic pay gravel areas is very important as they will contribute to habitat diversity and will help to revegetate the constructed wetlands.

5.2 Keep Wetlands Wet

Keeping wetlands wet is the most important control on wetland ecosystems and will often dictate whether the reclamation achieves its objectives. Water enters wetlands via stream/river/lake flows, runoff, precipitation and up from the groundwater table. Wetlands lose water to other waterways, into groundwater and through evapotranspiration (figure 7). The period of time during which a wetland is covered by water is unique for each wetland type and will determine the type of wetland created.

Figure 7 - Schematic diagram of water input and output in a wetland
(Oil Sands Wetlands Working Group, 2000)



The most reliably saturated or wetted ground will occur in low areas near or below the natural ground water table. Low areas will also be easier to fill with water. It is not advisable to completely backfill the mining pit if the natural ground surface is well above the ground water table. It would be better to backfill the pit to level to near or up to 2 m below the actual ground water table.

If the wetland is situated in a higher area, it may be necessary to try to seal the bottom of the pond with fine soils and/or connect the wetland with the closest stream to keep it saturated and/or under water (figure 27). Fine tailings from settling ponds or fine overburden soils can be used to seal the bottoms of mine pits. Any connections with streams should be made at right angles to the direction of flow and the junctions should be armored with boulders or coarse cobbles to prevent erosion.

Where the ground water table is very low and/or if there is insufficient surface runoff or precipitation to keep water in the wetland, the pond may have to be dammed, drainage ditches blocked, and/or a crude spillway constructed. Water should fill up to a level at or slightly below the outlet or spillway elevation. Spillways are not preferred as they often require long term maintenance. However, dam and dike construction activities by beavers may increase the depth of the ponds and help maintain water levels in perpetuity long after placer miners have left the area (figure 32).

Mining usually thaws permafrost areas, often disrupts patterns of groundwater flow, and may change the surface water balance. Topography and drainage patterns can also be altered by mining and reclamation activities. Therefore some former wetland areas may not hold water and moisture in spite of the use of these best management practices. In these cases these areas should be reclaimed as dry lands.

Variations in the water depth or saturation level are normal. In fact, spring drawdown and re-flooding by 15-45 cm (6 to 18 inches) enhances waterfowl habitat and the germination of emergent plants.

5.3 Stockpile Organics and Fine Soils for Later Use

Stockpile trees, organics and fine soils in stable piles during stripping operations. Topsoil, black muck and other organic materials should be separated from overburden and conserved in windrows parallel to the slope or in another convenient place to be spread out later. Reclamation stockpiles should be left in stable piles and protected from erosion by keeping the pile slopes at low angles, covering them with trees and shrubs or ditching around the perimeter of the piles. They should be situated not too far from the mine pit if they are required for partial backfilling.

Mixing overburden with either topsoil or subsoil reduces greatly its growth enhancement. However, any fine soils will capture and retain moisture and thus improve the speed and success of revegetation. The topsoil should be redistributed as soon as practical to limit erosion, aeration and the composting of wetland plant seeds. About 30 to 100 cm (1 to 3 feet) of topsoil should be applied on mined areas where it is available.

5.4 Use Old Mine Pits and Low Areas for Settling Ponds

Figure 8 - Settling Pond Wetland in Mined Area

While mining, use old mine pits and/or low areas for settling ponds. Fine sediments from process water will help to seal the bottom of mine pits and low areas and make them more suitable for reclaimed wetland areas. Do not refill or cap old settling ponds with coarse rock unless there is a risk of erosion. Old settling ponds below or near the ground water table often reclaim rapidly into marsh and shallow water wetlands.

This photo was taken by Randy Clarkson 5 years after active mining with no intentional restoration measures.

5.5 Grade and Recontour Post Mined Areas

After mining, open pit walls and overburden piles should be graded to a maximum slope of 2:1 (horizontal to vertical) or less for uplands, shallower slopes for the wetted edges. A wide range of topographic features should be incorporated into the reclamation landscape, including small hills, small depressions and undulating topography (figures 5, 8 & 19). Shallow depressions can be excavated on flat areas or gentle slopes to construct wetlands. The grading and recontouring of tailing piles and steep excavated slopes should be completed by the end of each mining season unless these areas are required for mining in the future.

5.6 Bench Steep Slopes

Slope benching should be done where a shallow slope (2:1, horizontal to vertical) cannot be achieved. Benching provides many of the same benefits on a macro scale that are provided by surface roughening on a micro scale. Slope length and gradient are reduced and this prevents erosion by slowing down water runoff. Benching can also enhance infiltration because the slowed water will have time to percolate into the soil. Benches can be constructed to divert runoff into adjacent vegetated areas by constructing a slight gradient along the length of the bench. In most cases benches are constructed level (with no gradient) and are very effective at trapping sediment that has eroded from the slope above, with minimal risk of slope failure.

Table 1 - Recommended slope grades for soil types (Yukon Placer Secretariat, 2010)

Slope	Soil Characteristics	Ice Content	Recommended Procedure*
Side Slope	Fine, poorly-drained soil	Ice rich	Leave the cut face vertical with an overlapping mat of vegetation if possible.
		Ice present but less than 5%	Grade slope to less than 3:1. Leave overlapping mat of vegetation if possible.
		Ice not present	Grade slope to less than 3:1
	Coarse, well-drained soil	Ice not present	Grade slope to less than 2:1. Bench or terrace if slope is over 15 m high.
Pile	Coarse, well-drained soil	Ice not present	Grade slope to less than 2:1. Round off the top of the pile.
	Fine, poorly-drained soil	Ice not present	Grade slope to less than 3:1. Round off, reshape, re-contour top of pile.

Fine textured soils erode easily and require more attention than coarse soil. As water accelerates, it becomes more erosive. Without some sort of a break in the slope, surface erosion develops into rill erosion, followed by gully erosion and channel erosion.

- ✓ Terraces or benching allows the gradient of the slope between the terraces to be left steeper.
- ✓ Reducing water velocity over exposed soils reduces the potential for erosion by reducing the slope length or steepness.
- ✓ Increasing the roughness at the soil surface also reduces the potential for erosion. Controlling runoff on the placer mine with a good layout of ditches, drains, and diversions is the key. Prevention is easier and less expensive than corrective measures. Controlling sediment should be left as the last thing to do in the mine plan to limit sedimentation off site.

5.7 Roughen Disturbed Surfaces

If the disturbed surfaces are very smooth or compacted you should roughen them by running tracked vehicles up and down the slope, or by back blading with a toothed bucket horizontally along the slope, or by placing logs or woody debris on the slope. Ensure that the grooves are made horizontally across the slope to reduced runoff and erosion.

Polster (2013) proposes a technique called “rough and loose” that provides an effective way to control erosion and create conditions that promote the revegetation of the site. This technique encourages equipment operators to make rough and loose surfaces that provide ideal microsites for seeds to lodge in and for seedlings to grow. Moisture-loving species will establish in the bottoms of the holes while species that favor dry sites will be found on the tops of the mounds. This species diversity enhances ecosystem resilience. Do not use your neatest heavy equipment operator for reclamation!

Figure 9 - Roughening the Surface with a Bulldozer
(Source: Virginia Department of Forestry, 2003)

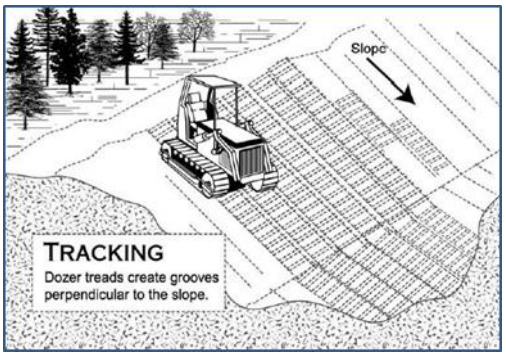


Figure 10 – Roughening with a Bulldozer

Figure 11 – Roughening a Shallow Slope

Note: Roughing creates microsites which allow more rapid natural revegetation to occur.
Jim Leary Photos

5.8 When to Backfill Mine Pits

If the depth of ground water is low and fills the bottom of the pit to a maximum of 2 m, the mine pit should not be backfilled but the sides should be sloped to allow habitat for waterfowl (figures 14-17). If ground water fills the pit to a depth of greater than 2 m the pit may be partly backfilled or reclaimed as an end pit lake (figure 13). If you plan to backfill mine pits, be sure to locate the overburden not too far from the pit in a place where you can easily push it back over the mined area or into the pit. When it is not practical to back fill a pit deeper than 2 m, or a pit where the groundwater fills the bottom to a maximum depth of 2 m, follow the recommendations for end pit lakes.

Figure 12 - Reclaimed Mine Pit to Wetland in Narrow Upper Drainage Area

This area was mined about 3-4 years earlier - Jim Leary Photo

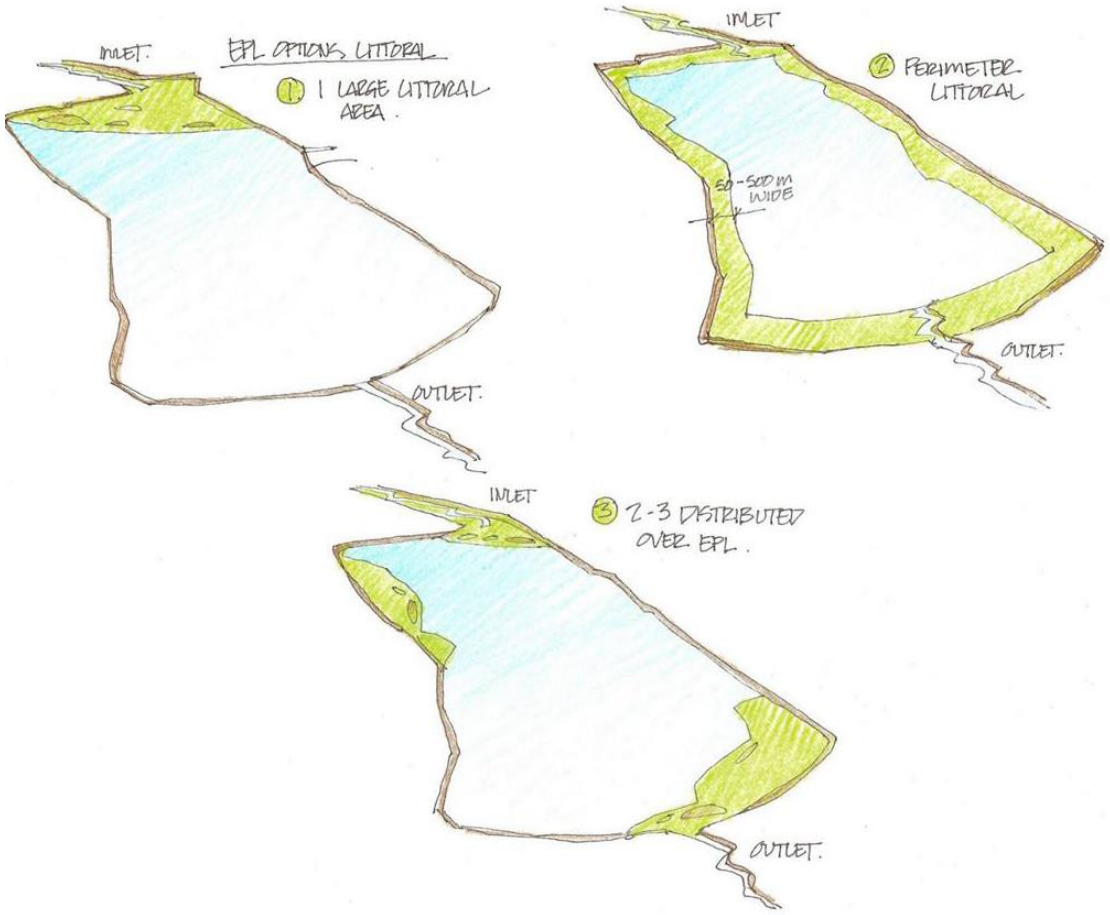
5.9 Create Deep or "End Pit Lakes"

If the mining method and equipment is not set up for infilling pits it can be very costly and may have some unintended environmental impacts, especially if out-of-pit material storage areas have already been reclaimed. Even in mining systems set up to backfill pits, the last pit is not backfilled as there is no material to fill it with. If ground water fills the pit to a depth of greater than 2 m the pit may be partly backfilled or reclaimed as an end pit lake. It is important to provide "littoral zones" (figures 13 & 21) around the edge of the deep water bodies. These zones are the shallow, nutrient-rich areas on the perimeter of lakes where plants can grow, and fish and waterfowl can find refuge and habitat.

The littoral zones should have shallow slopes to promote emergent vegetation (which roots underwater and grows to the surface). They should represent more than 10% of the surface area where practical. Littoral zones can be built by cutting back the final pit walls or pushing overburden over the edges of the pond to create gentle slopes that could become littoral zones (figures 13 & 26). This process should also be used to create irregular shorelines (figures 18-19 & 27). The bottom of the lake should be irregular as well (figure 20). Topsoil should be placed on the slopes to promote revegetation (figures 9 -11).

Lakes are relatively rare in the Klondike Plateau and other unglaciated areas of the Yukon and the reclaimed area lakes may be greatly appreciated by the public for recreational purposes.

Figure 13 - Littoral zones (CEMA, 2012)



5.10 Use Existing Post Mine Pits and Depressions to Construct Shallow Water and Marsh Wetlands

Use the existing depressions, mine pits and settling ponds where practical to construct low areas which will become shallow water and marsh wetlands. These excavations will often fill with water naturally through precipitation or ground water infiltration. The existing pits will reflect the mining configuration and the characteristics of the pay gravel deposit. However, these depressions can be modified to help create productive wetlands. There will be fewer modifications required if the end goal of wetland reclamation is part of the mining process.

Figures 14-17 - Waterfowl in Mine Pits and Settling Ponds

Shallow Water Wetlands in Reclaimed Pit

Canada Geese in Post Mined Pit- Randy Clarkson

Trumpeter Swans in Post Mine Pit – Rob Lake

Canada Geese Nursery in Settling Pond – Rob Lake

Note: These photos were taken from 1 year (lower right) to 20 years (upper left) after mining with no intentional restoration measures.

5.11 Size and shape the pond

Create ponds between 0.2 and 5 ha (0.5 to 12 acres) in area and with as complex shapes as practical in the existing depressions. Biodiversity can be increased by creating a complex wetland shape that maximizes the length of shoreline per unit of surface area (figures 18-19 & 27). This provides more habitats for more wetland species and minimizes bank erosion resulting from wave action. The rectangular shape of most placer mine pits can be made more irregular by pushing material in from the sides of the pit and/or excavating the walls of pit (figure 26). Caution should be exercised to ensure the bulldozer does not sink into the muck.

Figure 18 - Natural shallow open water and marsh wetland shapes in Alberta (CEMA, 2014)

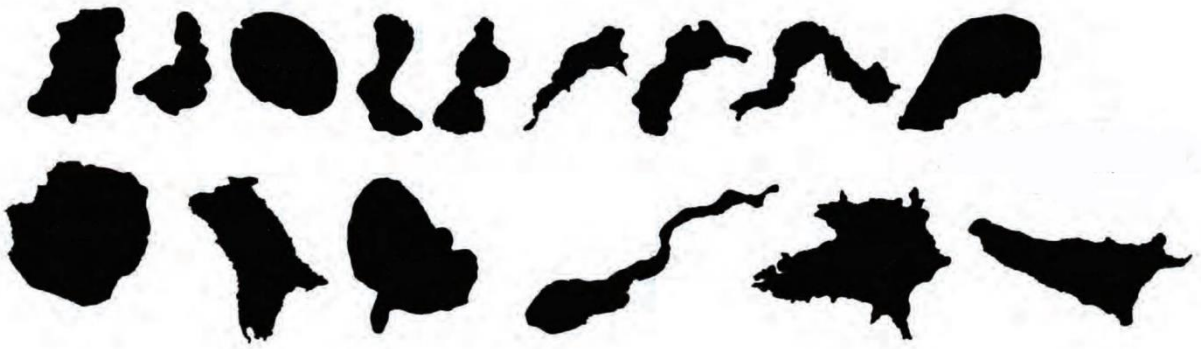


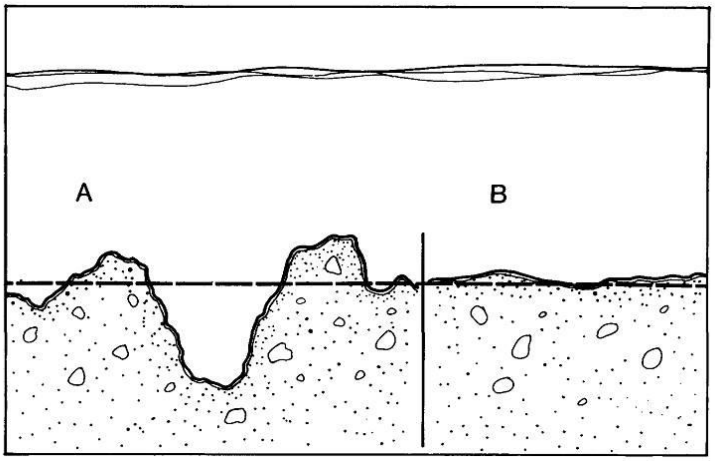
Figure 19 - Irregular Shaped Shallow Water Wetlands Formed in Old Mine Pits and Settling Ponds

Note: This is an “opportunistic” wetland formed without any intentional land or wetland reclamation measures. It has formed in a low gradient wide valley with high ground water levels. The light colored areas are coarse gravel and boulder tailings which were not covered with fine soils. This area was mined in 1985 - before the implementation of mining land use regulations in 1996. Mining land use regulations now require a miner to place fine soils over disturbed areas. Photo - Randy Clarkson

5.12 Construct Ponds with Irregular Bottoms

The construction of irregular bottoms on the ponds enhances habitat diversity for wildlife (figure 20).

Figure 20 - Irregular bottom for ponds (Michalski et al., 1987)



5.13 Slope the Pond Shorelines

Wetlands can be divided into different zones (figure 21). The littoral zone is the area filled with water. The vegetation can be submerged (under the water), floating or emergent (plants rising above the water surface). The slopes are submerged as well. The shoreline (riparian area) is the fringe of land at the edge the water. The upland area is situated higher than the water level and covered by natural vegetation.

Figure 21 - Pond zones (CEMA, 2012)

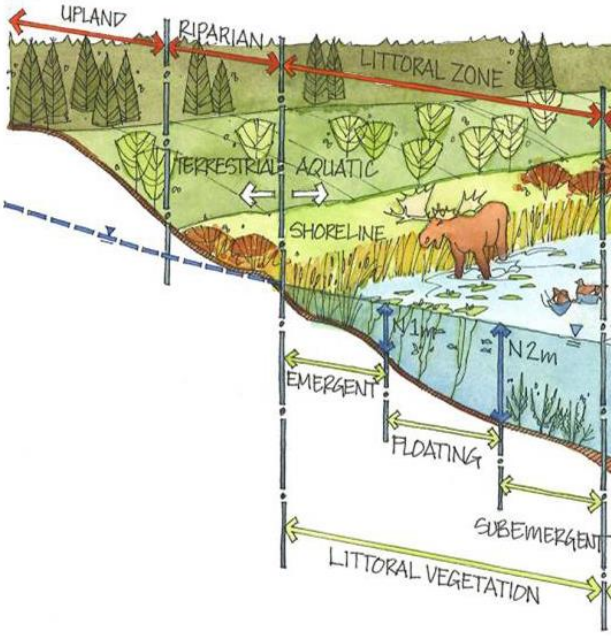


Figure 22 – Shorebirds on Post Mined Area

Hailey Riemer Photo

Submerged slopes are recommended for emergent (floating with roots under water). Breeding waterfowl require significant amounts of emergent vegetation. Most of the shoreline should be shallow for waterfowl for nesting and brood rearing habitat. However, limited areas of steep high banks should be constructed or left standing for winter denning by muskrat and for beaver lodge construction (maximum slope of 5:1 and less than 2 m high). Macrophytes (pondweed) and floating plants (yellow pond lily roots) are high-quality summer foods for moose.

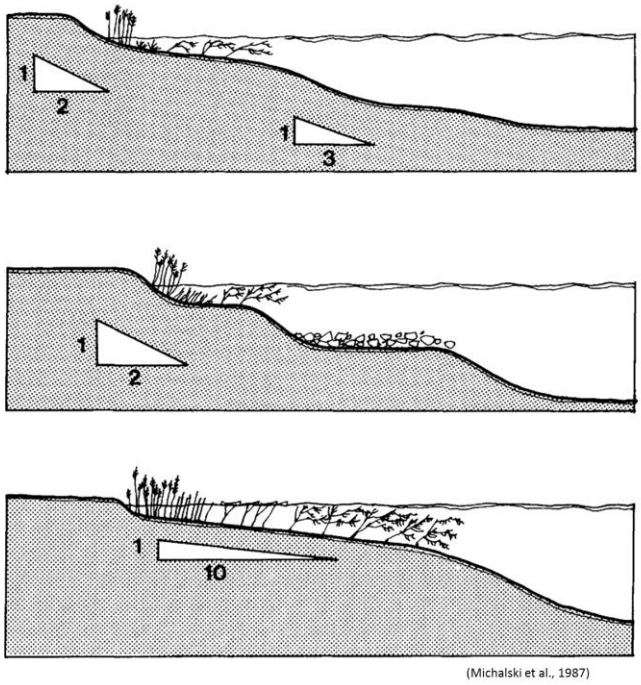
Figures 23 & 24 - Moose in Post Mined Settling Pond

Randy Clarkson Photo

Anne Chevreux Photo

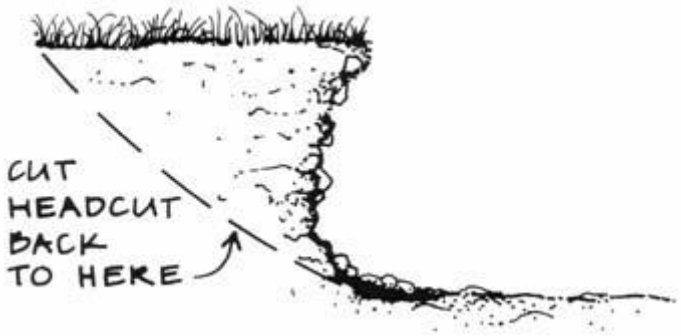
Note: – These photos were taken about 3 &10 years after mining with no intentional reclamation.

Figure 25 - Example of slope ratio (Michalski et al., 1987)



The outer edges of the ponds should have shallow slopes. Shallow slopes attract waterfowl, reduce turbidity and promote emergent vegetation. Shoreline banks should be sloped to a 3:1 (horizontal to vertical) ratio or less (figure 25). The ponds should be bordered by natural vegetation for duck nesting habitat. Overburden and fine soils will flow at very shallow angles when placed in water. Use caution when pushing with a bulldozer to prevent sinking into the muck.

Figure 26 - Slope ration 3:1 (Prunuske 1987)



5.14 Place Minor Amounts of Gravel on Some Areas of the Shorelines of Ponds

Where practical, place gravel on some minor areas of the shorelines (beaches) of ponds to be used by shore birds for habitat. Gravel piles should be located in other areas to provide various habitat functions including perch sites, shelter, concealment, escape cover, nest sites, and den sites. Mining tailing piles provide nesting habitat for the Common Nighthawk which is a threatened species (COSEWIC, 2007), due to steep population declines. Gravels can also be redistributed in ponds, along shorelines, and on pit floors, rather than discarded or buried under constructed landforms. A limited number of shallow gravel piles should be left in the reclaimed landscape for wildlife habitat.

5.15 Connect the Ponds

Connect the ponds with ditches and/or to the stream if there is not enough groundwater to fill the pond. Connections between wetlands facilitate the exchange and movement of aquatic animals and plants among reclaimed and unaffected wetlands. Check with the Department of Fisheries and Oceans before connecting wetlands to salmon bearing streams. Surround the wetlands with some shallow (overburden) uplands/ mounds covered by fine soils.

Figure 27 - Narrow Valley Wetland Ponds Connected Together

Note: The irregular shape of the post mined ponds - Jim Leary Photo

5.16 Separate the Ponds with Low Hills/Mounds

Shallow mounds/hills should separate the various depressions to allow for species of waterfowl which seek their own territory. These areas could have been overburden or tailings storage piles and should be covered with fine soils with the surface roughened to promote natural re-vegetation.

5.17 Revegetate Disturbed Areas if Required

Revegetation is a major element of wetland reclamation. Disturbed areas should be left in a state conducive to successful revegetation by plant species native to the area (natural revegetation). Seeding, fertilizing or "assisted" revegetation is generally not required where there is sufficient organics and/or black muck (loess layer overlying the gravels) that help natural revegetation. However, where fine soils are not available and natural regeneration is problematic, seeds and/or fertilizer can be applied. In these cases consult "The Yukon Revegetation Manual" (Matheus, & Omtzigt, 2013) or "Natural Vegetation and Sustainable Reclamation at Yukon Mine and Mineral Exploration Sites" (Whiters, 1999) for guidelines for revegetation in the Yukon. Use only seeds certified not to contain invasive species.

Where practical, leave patches of natural vegetation in or near the operating area, preferably along travel corridors or adjacent to streams and water bodies. These patches will provide food and cover for wildlife and provide seeds for the reclaimed area. This may be difficult to do in mine areas in permafrost due to the difficulty with thawing around patches of natural vegetation.

Figure 28 - Natural Revegetation at a Yukon Placer Mine

Note: This post mine area photo is one year after smoothing, contouring and covering with fine soils.
Randy Clarkson Photo

Figures 29 & 30 - Annual Progress in Natural Revegetation of a Post Mined Pit in an Upper Narrow Valley

Jim Leary Photos

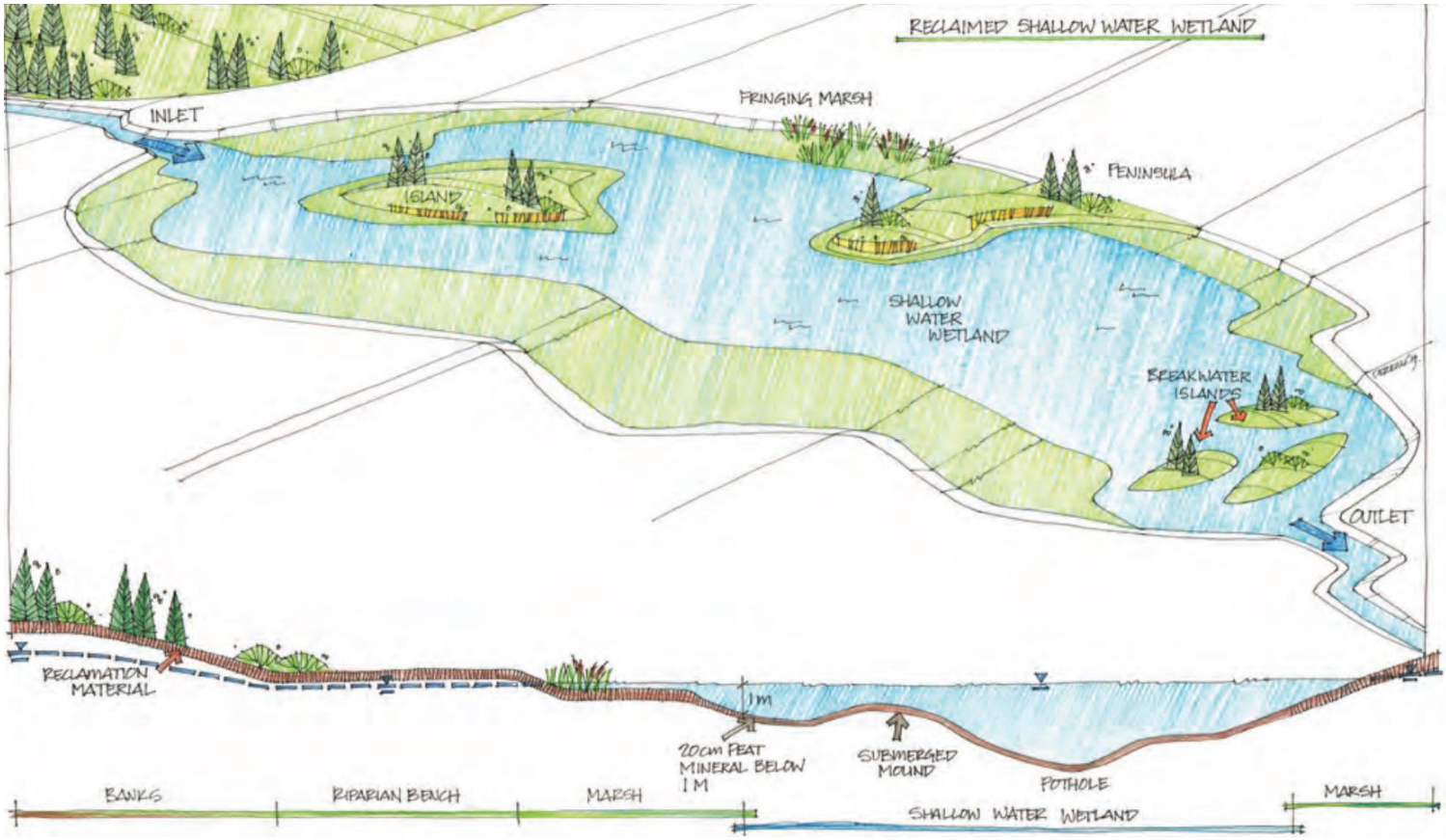
5.18 Spread Woody Debris

When practical and if available, place some logs and woody debris in the bottom and on the slopes of the pond. In natural ponds, trees and branches often fall into the water from the streamside area anyways. Coarse woody debris provides habitat for small aquatic insects, which are important prey items for wildlife species and important to wetland function. They are important habitat for fish which provides protection for spawning substrate (loose gravels), and an area with greater food availability.

5.19 Do not Add Fish and Aquatic Organisms

The presence of fish alters wetland dynamics. Predatory species of fish will eat the aquatic insects and vegetation necessary for waterfowl. Fish should not be actively added to reclaimed wetlands, however fish should be allowed to colonize these systems naturally, after the wetland system develops and can sustain natural colonization.

Figure 31 - Diagram of a reclaimed shallow water wetland (CEMA, 2014)



Note: This is an idealized sketch of a mine pit prepared for wetland reclamation. Shallow water (less than 2 m deep) wetlands need to have shallow irregular shores and irregular bottoms but can be of almost any shape or size or have a variety of shapes on the bottom of the pond.

5.20 Consider Making Habitat for Beavers and Muskrats

Beavers will inevitably invade the reclaimed landscape and they will have an impact on vegetation. Beaver control is not a long-term option at present, given the requirement for self-sustaining landscapes and the fact that beavers are an important part of boreal forest ecology and important to First Nation communities and to other trappers. Beavers must be anticipated and accommodated. They will build lodges and canals and they will dam creeks, outlets of wetlands and ponds (figure 32). Beavers will modify the reclaimed wetlands and create their own marshes and shallow water wetlands:

- ✓ Wetlands will be enlarged and water depths increased by damming (1 to 2 meters, 3 to 7 feet)
- ✓ Marshes and shallow-water wetlands can be expected to form in areas constructed as watercourses and fens

The presence of muskrats alters wetland dynamics as well. Muskrats can produce channels through marshes and affect the proportion of shallow water through grazing.

Figure 32 - Beaver dam in a post-mined pond

Anne Chevreux Photo

Figure 33 – Muskrat in post-mined pond

Rob Lake Photo

5.21 Consider Creating Other Upland Wildlife Enhancements

One of the objectives of wetland reclamation is to create a habitat that will support a great diversity of wildlife. Wildlife species usually do not use just one habitat type and uplands are often as important as wetlands.

Bank Swallows breed in a wide variety of natural and artificial sites with vertical banks. The Bank Swallow is listed as threatened by COSEWIC (2013). Sand-silt soils are preferred for excavating nest burrow. Banks cut from mining waste piles are sometimes used by Bank Swallows for nesting (figure34). Some mining cuts with steep faces that could be suitable for Bank Swallows should be left alone and the banks that host active Bank Swallow nesting sites should not be removed.

Figure 34 - Mining cut with Bank Swallow nests on Ruby Creek

Anne Chevreux Photo

Piles of logs and broken-up logs, smaller pieces of debris such as roots, twigs, and branches can be kept after the clearing activity. Properly constructed and located (hillsides, bottoms…), they afford nesting sites and cover for wildlife. They are important for small mammals, reptiles, amphibians and invertebrates as well. They also provide a source of nutriments, shade and moisture for revegetation, control erosion and enhance diversity.

Brush piles need very little maintenance and they will benefit wildlife for several years. They eventually decompose, however shelter is provided until the natural vegetation develops. A variety of logs should be kept intact as much as possible and placed flat on the ground.

Figure 35 - Bald Eagle on a dead tree

Photo – Rob Lake

Figure 36 - Snag (Eva Paulson)

Do not cut down snags and broken trees. Snags or dead standing trees provide a wide range of wildlife uses: cavity nesting, raptor perches and nesting, and food for insectivorous birds and mammals (figures 35 & 36). Natural dead standing trees should be left standing in the reclaimed landscape.

5.22 Monitor the Progress of Reclamation

The establishment of wetland will take in the order of 10 to 15 years. At that point, the system should be well covered with succession (pioneer) vegetation and be "free to evolve." Reclaimed wetlands should not require long-term maintenance and management. It is also possible that the habitat will not evolve in the way it was intended and a few former wetlands may have to be reclaimed as dry lands. Monitoring should be conducted to see if adjustments need to be made to these Best Management Practices from time to time. This monitoring information should be used to gauge restoration success and not to justify tearing up and re-reclaiming former wetland areas. Monitoring should be conducted by mines inspectors to ensure that erosion has been limited, revegetation of disturbed areas has occurred, and that the reclaimed wetlands are saturated and/or under water.

What needs to be monitored?

Table 3 shows the various reclaimed areas to monitor and the maintenance needed to guide the habitat in its early years on track toward the reclamation goal (re-establishment of one of the five wetland classes).

a) Revegetation

The growth rates and succession of vegetation species should be noted. For poorly vegetated areas it may be necessary to use seeds and/or fertilizer. The propagation of non-native or undesirable species should be monitored.

b) Ponds

The reclaimed wetlands should be saturated and/or under water. Erosion and the stability of the edges should be controlled.

c) Tailing piles and overburden

Erosion should be controlled.

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

Problem	Indicators	Adaptive Management Strategies
Water loss / drying	Exposed soil area Salts present	-Convert drier areas from wetland habitat to upland habitat -Change height of discharge structure (if present)
Water gain / flooding	Higher Water Level Aquatic Vegetation Diminishing	-Change height of discharge structure (if present) -Add more soils if available and not already reclaimed -Remove beavers by trapping and remove dam (if present) -Allow habitat for beavers and muskrats to develop
High rate of infilling with sediments	Increased Turbidity Reduced Aquatic Plant Growth	-Check for and correct any erosion Issues -Block off access to silty water -Change height of discharge structure (if present)
Shoreline erosion	Excess Sediments Around Edges Decreased Vegetation on Shoreline	-Install rip-rap or coarse aggregate on eroded area -Cover shoreline with timber and woody debris -Plant willow cuttings on shoreline
Lack of vegetation	Bare areas	-Check for loss of organic soils -Replace as necessary and reduce soil losses by erosion -Transplant willows or pods of vegetation
Low plant diversity	All the same	-Increase connections with other wetlands -Control invasive species (if present)
Low aquatic organism diversity	Less use by water birds - less clear	-Eliminate or reduce predatory fish population (go fishing!) -Create more shallows on edges of ponds

Acknowledgements

The authors would like to thank:

1) Schmidt Mining Corp. for initiating and funding Anne Chevreux's Indian River wetlands field study in 2014;
2) The Klondike Placer Miners' Association for continuing this work and funding the 2015 field study and this report preparation;
3) The Yukon Department of Energy, Mines & Resources and the Yukon Department of the Environment for additional funding towards this report;
4) The many people who contributed photos for this report including Rob Lake(Gimlex Mines), Jim Leary (Client Services and Inspection, Dawson), Hailey Reimer and Stuart Schmidt (Schmidt Mining Corp.); and
5) The many Indian River placer miners who offered first-hand knowledge and assistance to the field research program.

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