Wetland Reclamation for Placer Mining

Recommendations and Guidelines

Background Document

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1. Executive Summary and Recommendations

1.1 Summary

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 a combined gross revenue 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. Placer mining disturbs the ground due to the removal of overburden with heavy equipment, the diversion of streams and the construction of roads (section 4 & figure 1). Some placer mines are located on wetlands and the disturbance or destruction of these wetlands usually cannot be avoided.

Wetlands are lands that are saturated with water or covered in shallow water. Wetlands are recognized as very important ecosystems and are highly valued. The five classes described by the Canadian Wetland Classification System (bogs, fens, marshes, swamps and shallow open water) are distributed throughout the Yukon (section 5, table 1 & figures 2 & 3). 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 marsh or shallow water wetland habitat (section 7 & figure 4). 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 opportunistically (without active reclamation); however this is most likely over extremely long timeframes. Semi-designed wetlands involve minor topographic and reclamation features added during landform construction. Due to the limited finances of privately funded placer mines and their relatively small footprint, this report offers recommendations to develop semi-designed wetlands and encourage their natural reclamation to marshes and shallow water wetlands.

A lot of literature regarding wetland construction is available, but most of it 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 (section 9). 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 establishment of wetlands will take in the order of 10 to 15 years. At that point, the system should be well covered with succession 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.

One of the authors, Anne Chevreux (2014) completed the most relevant and recent local studies of birds and mammals in the wetlands in the Indian River valley near Dawson City, Yukon (section 7.5). The landscape had changed from flat peat forming wetlands in permafrost to shallow ponds and nearby mounds covered in pioneer species of deciduous trees which were not in permafrost. Chevreux found that mining activity had increased the number of ponds and water surface available for waterfowl populations. Her study indicated that post placer mined areas had developed without any deliberate restoration activities into a mosaic of different wetland and upland habitats with extensive species abundance and diversity that included several threatened species.

The Yukon has placer mining land use regulations and a guidebook for mitigation measures but currently has no legislation or guidance that directly addresses wetland conservation (section 8.1). British Columbia also has guidebooks but there currently is no policy for placer mined wetland reclamation. However B.C. is actively involved in protecting and rehabilitating wetlands and is developing a wetland mitigation and compensation strategy (section 8.2).

Officially about 1/3 of the State of Alaska is considered to be “wetlands” (section 8.3). Most placer miners in Alaska operate under a US Corps of Engineers newly revised General Permit which has less stringent regulations for miners who operate with less than 5 acres (2 ha) of “rolling” disturbance and less than 1500 feet (457 m) of stream diversions. The General Permit contains suggestions for the reclamation of mine sites and the creation of wetlands in depressions. The few larger Alaskan placer mines must apply for an individual permit with obligations to restore or create wetlands and/or fund improvements to wetlands in other areas.

The majority of surface mines in the US have been reclaimed as grasslands. American mining companies are now required to reclaim mined lands to equal the original productivity of the land and as a result of this, very few new surface mine impoundments have been created.

1.2 Placer Mine/ Wetland Reclamation Recommendations

Wetland restoration is new and evolving in the Yukon and placer miners should be offered a generous phase in period to adopt any new best management practices or new regulations. Any placer mine reclamation plan is constrained by the location of economic pay gravels and other uncertainties inherent in placer mining. A generalized plan with some best management practices can be developed, but it should be a living document that will be modified along with the mining activity. A wide range of topographic features should be incorporated into the reclamation landscape including small hills, small depressions and undulating topography (section 10). Shallow depressions can be excavated or left unfilled on flat areas or gentle slopes to create wetlands.

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 least by 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 (section 10.5 & table 2).

Where practical, patches of natural vegetation should be left in or near the operating area, preferably along travel corridors or adjacent to streams and water bodies. 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.

Keeping wetlands wet is the most important part of developing wetlands. Water enters wetlands via stream flows, runoff, precipitation and up from the groundwater table (section 11.1 & figure 7). Wetlands lose water to other waterways, into groundwater and through evapotranspiration. 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.

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 for 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 near to or up to 2 m below the actual ground water table. Then the sides of the pit wall should be sloped to very shallow angles (from 3:1 to 5:1) by excavating the walls (figure 12) and/or pushing overburden in from the sides of the pit. Shallow shoreline slopes attract water birds, reduce turbidity and promote revegetation.

If overburden is required for backfilling, it 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. Use caution when pushing with a bulldozer to prevent sinking into the muck. Small gravel piles should be placed along some shoreline areas for shorebirds. Some areas can have steeper stable banks for beavers and muskrats (figure 16).

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. 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. 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. 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 germination of emergent plants.

Shallow water wetlands are less than 2 meters 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. It is recommended to construct ponds between 0.2 and 5 ha in area with as complex shapes as practical, and with irregular bottoms on the ponds to enhance habitat diversity (figure 9). Wetlands should be interconnected to facilitate the exchange and movement of aquatic animals. Shallow mounds should separate the various wetland depressions to allow for species of water fowl which seek their own territory.

The infilling the mined-out pit with re-handled material may be preferred for reclaiming wetlands. However, if the mining method and equipment is not set up for infilling pits it can be very costly and could have some 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 often no material to fill it with.

When it is not practical to back fill a pit, it is important to provide “littoral zones” (section 12, figures 10, 11, 12, 13 & 17) for very deep (>4 m) water bodies. These zones are the shallow, nutrient-rich areas of 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. They should represent more than 10% of the surface area where practical. These shallow zones can be created 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. This process can also be used to create irregular shorelines (figure 8).

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 natural dead standing trees in the reclaimed landscape (section 11.8).

The establishment of wetlands will take in the order of 10 to 15 years. At that point, the system should be well covered with succession 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.

Monitoring should be conducted to ensure that erosion has been limited, revegetation of disturbed areas has occurred, and that the reclaimed wetlands are saturated and/or under water (section 14). Table 3, provides some potential problems and adaptive management solutions with constructed wetlands.

2. Abstract

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. 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 will need sufficient time (at least 2 years) to adjust their mining methods and equipment to match any new requirements.

This 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.

3. Objective

The objective of this report is to assist placer mining operators with advice regarding reclamation techniques in wetland areas so that the mined areas will be left in a state conducive to the natural re-establishment of wetland and supporting upland habitats. This should assist impact assessors and regulators and help to ensure consistency and fairness in their assessments and resulting permit conditions.

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4. Introduction - Placer Mining

Placer mining has been a cornerstone of the Yukon's economy and modern culture since the great Klondike Gold Rush of 1898. Placer mining is responsible for the accelerated early development of northwestern Canada. Much of the Yukon's transportation infrastructure can be attributed to early placer mining. The industry has been the Yukon's most reliable generator of economic wealth and has continued unabated through the great depression of the 1930's and recent economic recessions. In recent years, placer mines have often been the only operating mines in the Yukon.

Currently there are over 100 family based placer mines with a combined gross revenue in excess of $70 million annually. Spin off benefits to the local economy are in the order of 2.5 times that amount with local labor, purchases of fuel, equipment, parts, groceries and other supplies. Placer mining is especially vital in the Yukon's rural areas including Dawson, Mayo and Haines Junction. Most of the recent hard rock exploration "gold rush" (2010-2012 with total annual exploration at $150 to $300 million) to explore for lode gold mines was based on the presence of placer mining in those areas.

All Yukon placer mines are privately financed operations. Typical placer mines range from small family operations to those employing a dozen workers and several of the largest available sizes of heavy equipment. Placer mines are heavy equipment intensive resource industries. The next greatest concentration of large scale heavy equipment (D10-D11 size bulldozers) would be found several hundreds of kilometers southeast in the Alberta oil sands mega projects.

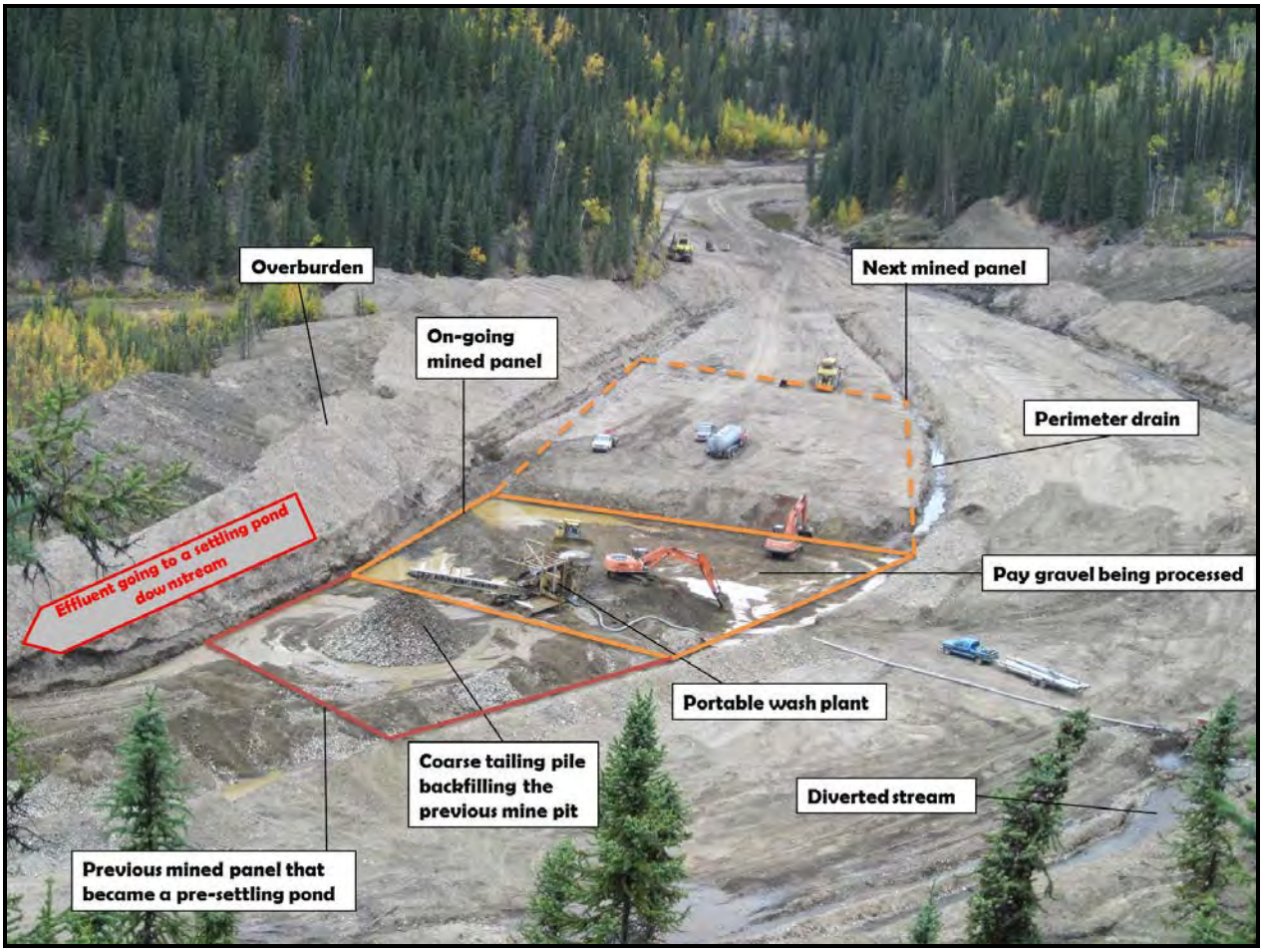
Placer mining disturbs the ground due to the removal of overburden with heavy equipment, the diversion of streams and the construction of roads. Some placer mines are located on wetlands and the disturbance or destruction of these wetlands usually cannot be avoided.

Several methods for placer mining exist depending on the shape of the valleys, the depth of overburden, and the operator's mining equipment. The extraction of the gold is usually done by stripping off the surface vegetation and soils, ripping or allowing permafrost soils and overburden to thaw, removing the overburden with bulldozers or excavators and trucks, and then processing the gold-bearing gravels in 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, figure 1) or left on the sides of the pit, recontoured, stabilized and covered with topsoil to enhance re vegetation.

The distribution of permafrost varies from less than 25% in southern Yukon to continuous in areas north of Dawson City. Most of the placer mining is located within 100 km of Dawson City and almost all of the placer mined areas and all wetland areas are underlain by permafrost. To mine permafrost areas, the overburden and the pay gravels must be thawed by stripping in layers, exposing to sunlight and by ditching around the area to dewater the melting permafrost. Wide areas must be

stripped at once to ensure that the soils are thawed quickly. Then, the thawed pay gravel is processed in a sluicebox that uses gravity and water for recovering the gold. Sluiceboxes use a large amount of water which is clarified with settling ponds before returning to the natural environment.

Figure 1 - Panel mining operation in a narrow floodplain (R. Clarkson)



Note: The stream has been diverted to the right side of the figure 1, overburden has been thawed, stripped and pushed to either side of the valley. Mining is progressing upstream with active mining and a sluicebox in the center of the photo, coarse tailings and fine sluicebox tailings deposited in a downstream previously mined pit to the lower left of the photo, and with stripping and thawing occurring upstream in preparation for mining in the upper center of the photo.

Yukon mining land use regulations presently require the overburden piles to be recontoured and covered in fine soils to enable natural revegetation. Water use regulations require the settling of sluicebox effluent (in this case in a downstream settling pond off the photo) and a stable stream diversion with reclaimed stream side areas and fish habitat features.

5. Introduction - 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 (Olewiler, 2004). 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 3) 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 2) 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 "complex peat lands," the complexity due to the occurrence of both bogs and fens.

a) Bogs are able to receive their water, nutriments and minerals only from precipitation and 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 2 - Peat

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 (Smith et al., 2007). 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.

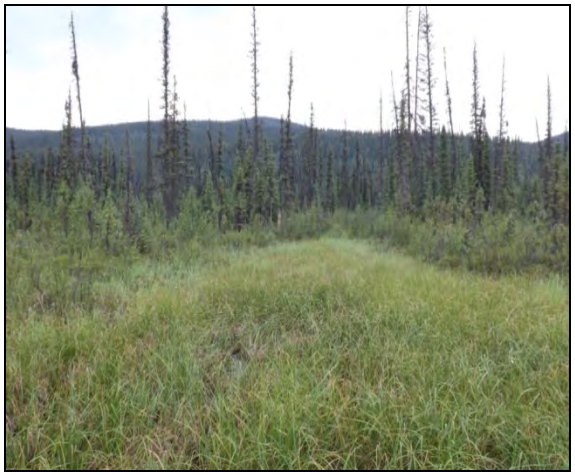
d) Marshes are a mineral or a peat-filled wetland dominated by reeds, rushes and sedges (herbaceous water plants) rather than mosses or trees. They are periodically inundated by standing or slowly moving water, and are neutral to alkaline. The surface water levels may fluctuate seasonally, with declining 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 resulting in lower phosphorus concentration and a reduced phytoplankton presence (Cobbaert et al., 2014). 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 (Bayley and Prather, 2003; Halsey et al., 1997). An absence of fish in most of these ponds increases the abundance of aquatic organisms to the benefit of water fowl (CEMA, 2014).

Figure 3 - Wetland types

Bog

Fen



Marsh

Swamp

Shallow open water

Table 1 - Summary of the general wetland type characteristics

Wetland Class	Form	Soil	Water		Plants/trees
Bog	Wooded (coniferous); shrubby; open	With > 40 cm of accumulated organics, generally micro relief with hummock and depressions	Acid and low in nutrients	The water table is generally 40 to 60 cm below the peat surface, water from precipitation, no major fluctuation in water level	Oligotrophic species of *Sphagnum*, feather mosses ericaceous shrubs, and lichens, black spruce
Fen	Wooded (coniferous); shrubby; open	With > 40 cm of accumulated organics	Acid or alkaline, nutrient-rich	Water table near the peat surface (approximately 0.2 m below peat surface), Dominated by runoff, precipitation and seepage, no major fluctuation in water level	Sedges, brown or *sphagnum* mosses, shrubs, and trees (Tamarack)
Marsh	Open	With <40 cm of accumulated organics	Neutral to basic pH, nutriment rich	0.2 to 1 m water depth, seasonal water level fluctuations, high amounts of water flow, and influenced by ground and surface waters, Commonly associated with shallow open water wetlands	Emergent forbs, rushes, reeds, sedges and grasses Submerged and floating aquatics
Swamp	Trees (≥ 10m high) Wooded (coniferous) Wooded (mixed wood) Wooded (deciduous) Shrubby (≥ 2m high). General canopy coverage ≥ 50%	With < 40 cm of accumulated organics mineral soils, but some peat present, (Hummocks)	Alkaline, nutrient-rich	water table is usually at or near the surface, strong seasonal water level fluctuations, gently flowing waters or stagnant	Deciduous or coniferous trees (Black spruce, Tamarack), shrubs, herbs
Shallow open water	Submersed and/or floating aquatic vegetation Unvegetated	With < 40 cm of accumulated organics	Alkaline, nutrient-rich	1-2 m water depth in persistent open water zone, at least 75% of total surface area in open water during the summer	Emergent vegetation, Submerged and floating vegetation or algae

The marsh and shallow water complexes are by far the most significant wetlands in term of wildlife diversity (National Wetlands Working Group, 1988).

6. 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. Reclamation is also considered successful if native species grow in the reclaimed site.

Alberta Environment (2008) defines wetland reclamation as the creation of wetlands on disturbed land where they did not formerly exist or where their previous form was entirely lost. Reclaimed wetlands could take decades, even centuries to become indistinguishable from natural ones.

It is important to stress that the goal of wetland reclamation after placer activity is not restoration. Most reclamation plans include a varied landscape, incorporating several ponds and lakes, wetlands, and interconnected drainage systems within a vegetated landscape (Westcott & Watson, 2007).

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 development of a self-sustaining wetland habitat with one of the five wetland classes’ characteristics. The reclaimed habitat should meet the criteria of natural wetland and re-establish a suitable environment for culturally important species, such as moose and beaver for Aboriginal peoples.

Moreover, reclaiming wetland complexes is more preferable than focusing on one wetland type. A mix of shallow-water wetlands, marshes, and fens, is more productive. Some swamps, bogs and fens will form opportunistically regardless of intent, however this is most likely over extremely long timeframes. Guidance for constructing shallow-water wetlands, marshes, and fens is well documented, although for fens there is more uncertainty about the details of the ecosystem that will evolve.

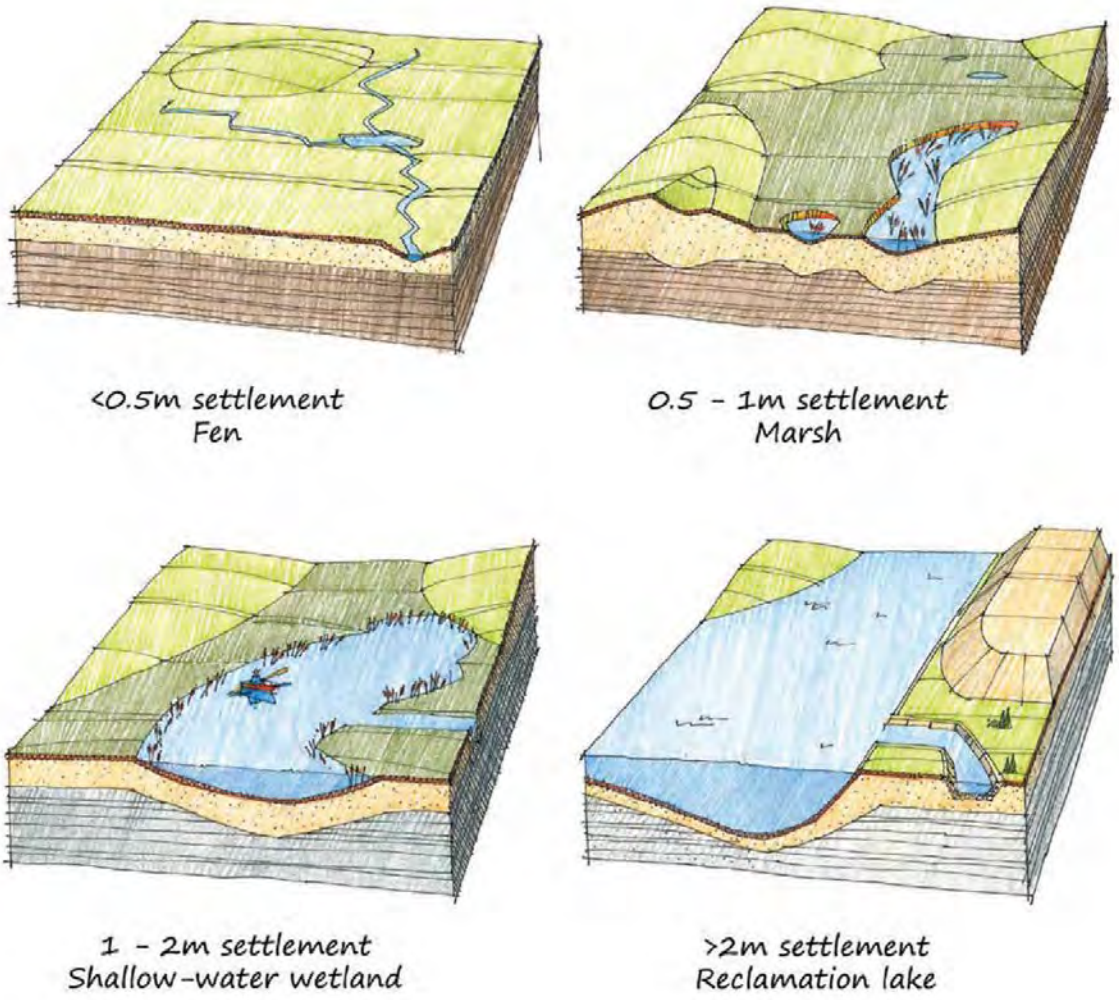
Semi- designed wetlands involve minor topographic and reclamation features added during landform construction largely or entirely in the field. The amount of design and field effort is less than with fully designed wetlands (CEMA, 2014). Opportunistic or spontaneous wetlands form in response to hydrological conditions in the landscape without any design or intervention to enhance reclamation (CEMA, 2014). Some of the best wetlands in reclaimed areas are opportunistic (Oil Sands Wetlands Working Group, 2000). They may form in reclaimed areas that have: active seepage discharge; low areas left behind by construction or reclamation; low areas formed by settlement of fills; and beaver dams. These wetlands are generally small and develop in marshes or fens.

Due to the limited finances of privately funded placer mines and their relatively small footprint, this report offers recommendations to develop semi- designed wetlands.

7. 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 4). However, the wetlands that are reclaimed usually result in marshes or shallow open water wetlands. Reclaimed areas with different types of wetlands are preferred. Wetland can either be designed, semi-designed or even develop spontaneously.

Figure 4 - Wetland types in the reclaimed landscape depending on the depth of the depression (CEMA, 2014)



7.1 Bogs & Fens

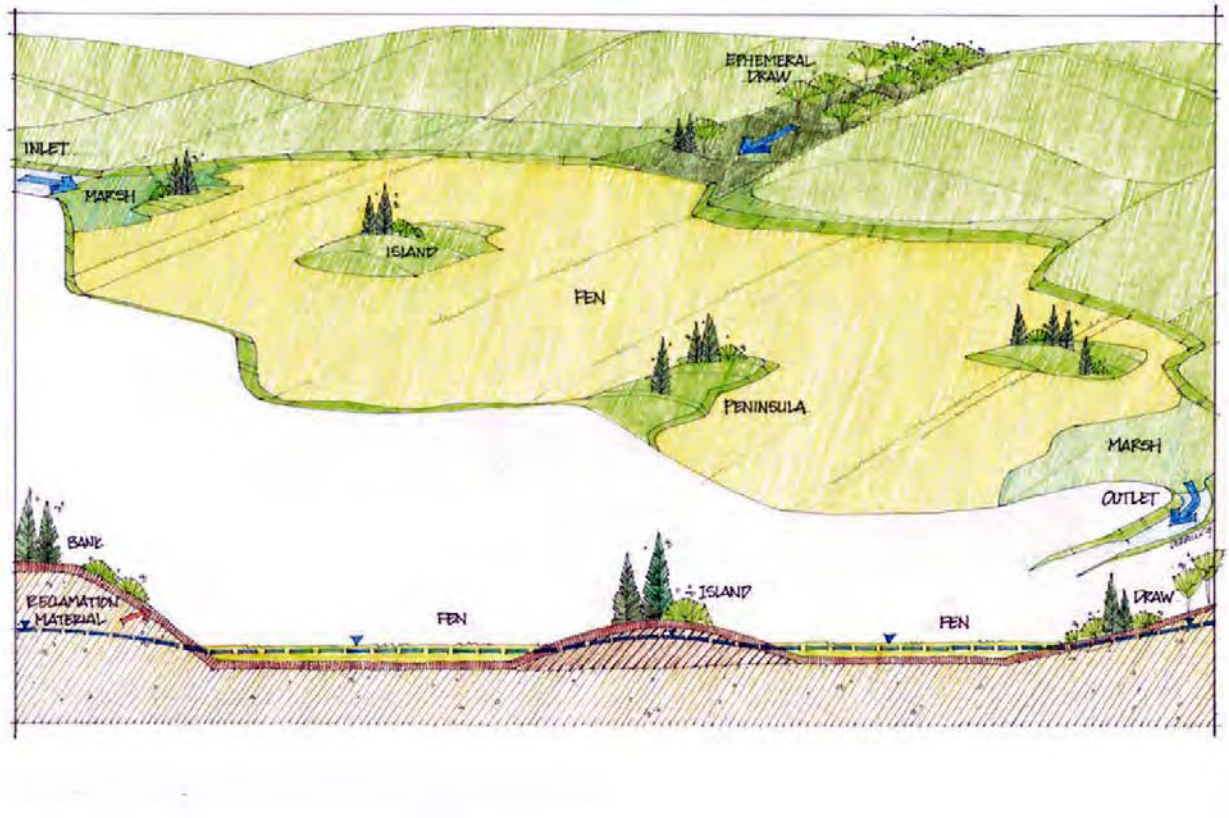
Peat forming wetlands are formed over hundreds of years and are usually extremely difficult to reclaim. In North America, peat-forming wetlands (bogs and fens) have been widely impacted mainly for horticultural purposes (as growing substrates) or disturbed by forestry and drilling for petroleum (Turetsky & St. Louis, 2006). The restoration of peat forming wetlands has been well studied in Eastern Canada, through the work of the Peatland Ecology Research Group (PERG) on sites harvested for horticultural supplies of peat. Generally peat forming wetlands impacted for horticultural purposes are easier to reclaim as long as the mineral soil has not been disturbed and a bottom layer of peat remains intact.

The relatively wet climate of eastern Canada and the undisturbed lower layers of peat make it easier to regain saturation and reclaim peat forming wetlands than in drier northern climates and where the mineral soil has been exposed (through mining and construction). Twenty eight harvested peatlands with residual peat across Canada and in Minnesota, USA were restored. The harvested fens revegetated remarkably fast (50%-70% vegetation cover) when there was a high water table and a thin layer of residual peat. However, *Carex* and *Sphagnum* moss, which are dominant in undisturbed fens did not recolonize the fens.

After mining and construction, both bogs and fens have been restored but the process is extremely complex and costly. It involves the flattening of the landscape, the construction of cross-valley dikes to flood the area, and/or the blocking of drainage ditches, the placement of mulch 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.

The spontaneous reclamation of fen is possible whereas bog reclamation would need plant transplantation (Graf, Rochefort & Poulin, 2008; figure 5). Some fens revegetate spontaneously over time except for those with *Sphagnum* and *Carex* dominant in undisturbed states. One major difference between fen and bog restoration is the presence of spontaneous vegetation on abandoned fens. Many wetland plants have established themselves on sites over time without active reintroduction. However, reintroducing vegetation increases vegetation cover and species richness.

Figure 5 - Diagram of a reclaimed fen (CEMA, 2014)



7.2 Swamps

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 but research is ongoing to have a better understanding of natural boreal swamps in order to propose reclamation techniques in the future. No other literature was found regarding the reclamation of swamps.

7.3 Marshes and shallow open water wetlands

Knowledge regarding the restoration of prairie potholes in Alberta and Saskatchewan is now well advanced. Many projects in these wetlands were focused on recovering waterfowl habitat and there is detailed data regarding the habitat requirements of ducks and geese, including the germination of seeds during drawdown in the critical near-shore emergent zone. The intensity of disturbance and the relative size of the projects could be comparable to placer mining.

Many small marshes and ponds have been constructed on reclaimed landscapes, and others have appeared during slope failures or due to dike seepage. They often begin as open water wetlands; however, as wetland vegetation establishes, several wetlands have 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 in marsh and shallow water systems constructed with overburden, peat, soft tailings and process-affected water (figure 6).

Figure 6 - Opportunistic Marsh and shallow open water in the Indian River Valley, May 2015

7.4 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 result 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. These deeper pits are common hydrologic features found in post-mining landscapes. They appear after oil sand, coal, precious metal, uranium, iron and lignite mining. They are often referred to as "End Pit lakes" (EPL).

CEMA (2012) produced a guidance document on creating EPL. They describe the difference between EPL from the different industries. Hard rock mine pit lakes in precious metal mine ore bodies tend to be very deep (20 to 380 m) with relatively small surface areas (0.01 to 1.9 km^2). Oil sands end pit lakes will tend to be shallow (6 to 55 m deep) with relatively large surface areas (0.6 to 13 km^2). EPLs may or may not contain tailings associated with mining and tailings operations. They are situated at the end of the mining operations. They are found at the lower elevation on the mine site. End pit lakes are features that have been proposed as well in the final reclaimed landscape after oil sand activities.

The objectives of these end pit lakes are to manage the water flow, ensure an acceptable water quality, store tailings, 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. It is widely understood that a healthy and sustainable aquatic ecosystem can be characterized by the successful colonization of species at upper trophic levels, such as large fish and waterfowl (CEMA, 2012).

7.5 Northern Wetland Research

In a 2003 report on placer stream restoration in the Yukon, the authors noted that: "mining excavations frequently replace pre-existing valley bottom channels with a diverse range of pits, pre-settling ponds, settling ponds and spoil piles. In some locations, riparian and wetland habitats suitable for wildlife, waterfowl and possibly fish are developing around these excavations" (M. Miles and Associates LTD., 2003).

One of the authors, Chevreux (2014) carried out a bird study on post- mined and unmined wetlands in the Indian River Valley which is located about 40 km southeast of Dawson City. The Indian River Valley is a wide low gradient valley with a high ground water table and abundant depths of organic soil (black muck). The mined areas were about 25 years old and had reclaimed spontaneously without the benefit of any attempts at reclamation. The mine pits filled with ground water and increased the surface area of open water from 4 to 20%. The landscape had changed from flat peat forming wetlands in permafrost to shallow ponds and nearby mounds covered in pioneer species of deciduous trees (balsam poplar, birch, willow and aspen) which were not in permafrost. Chevreux found that mining activity had increased the number of ponds and water surface available for waterfowl populations.

Chevreux focused her study on songbirds, waterfowl and raptors as indicators of ecosystem health. She found 52 species of birds in unmined and post-mined areas and half of the bird species were similar in both areas. The study showed that post-mined and adjacent natural wetlands hosted a comparable richness. Nevertheless, species abundance and diversity appeared to be more extensive in post-mined sites. Some species specialized in wetlands were found in post-mined areas. The post-mining landscape offered a mosaic of different habitats. This habitat heterogeneity increases species richness and diversity (Šálek, 2012).

Other recent studies have shown evidence that post-mined sites constitute refuges for a great variety of species even endangered (Brenner, 2007). The Indian River Valley breeding surveys showed the same number of species of conservation concern in unmined and post-mined areas. The Rusty Blackbird, a species whose population has seen a drastic decline over the last 40 years, was found on both areas with the same abundance. The post-mined areas were hosting several very threatened species such as the Common Nighthawk and the Bank Swallow. Horstman, Nawrot, and Woolf, (1998) mentioned that post-mining ponds possibly help to compensate for the loss of natural wetlands.

In May 2015, a brief field survey to determine the depth and water quality (Dissolved oxygen, conductivity, pH, temperature and turbidity) was carried out by Chevreux on 25 post-mined ponds on the Indian River Valley. The objective was to determine if these man-made water bodies evolved with the same characteristics of natural wetlands after 30 years. However, it is difficult to compare with natural wetlands of the Yukon, especially open shallow wetlands as there has not been any extensive study of these wetlands. All the literature on boreal shallow water wetlands comes from research led in Alberta.

Similar to natural shallow open water wetlands, the post-mined ponds had a neutral to basic pH (pH ranging from 6.78 to 8.4). Dissolved oxygen refers to the level of free oxygen present in the water. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality[1]. Dissolved oxygen in the post-mined ponds ranged from 7 to 14 ppm and averaged 9 ppm. The water temperature was relatively warm ranging from 15 to 25 °C and averaging 19 °C. The turbidity ranged from 1 to 18 NTU and averaged 3 NTU.

One major characteristic of shallow open water wetlands is the depth - less than 2 m. This depth allows the submergent vegetation and microscopic organisms to grow. The study showed that the depths of the ponds sampled ranged up to 4.9 m but averaged 1.2 m. Both submergent vegetation and emergent vegetation (cattails) were frequently observed. There were several beaver dams and lodges as well as muskrats and northern pike. Many ponds including the deepest ponds had been dammed by beavers. Cumulatively, about 82% of the total water area in all of the ponds was less than 2 m in depth.

In Alaskan restoration projects, the revegetation of the gravel sites was generally successful (McKendrick et al., 1992). Some plants such as graminoids and mosses (*Sphagnum* sp.) were reintroduced (Shirazi et al., 1998). The application of two to six feet (0.6-1.8 m) of overburden improved regeneration success by increasing moisture retention and aeration for seed establishment (McKendrick et al., 1992).

8. Reviews of Wetland / Reclamation Policies

No documentation has been found on specific wetland reclamation after placer mining. In general, placer mining activities create deep pits which fill with water if the ground water table is near the surface. In the Yukon, British Columbia and Alaska where the main placer activities occur, reclamation techniques concern mainly erosion control, regrading, recontouring, and spreading topsoil for natural revegetation and revegetation techniques. Guidance is given as well for seeding and transplanting.

[1] http://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/

8.1 Yukon Wetland / Reclamation Policy

There is currently no legislation or policy that directly addresses wetland conservation in the Yukon. The Yukon *Placer Mining Land Use Regulations* (PMLU) focuses on miners creating the conditions that will lead to successful revegetation by native plants. It requires the conservation of organics, smoothing and recontouring and spreading fine soils over disturbed areas to create a sustainable habitat that is revegetated and stable. It does not address wetland reclamation in particular. However, the Yukon government has been working on a policy for wetland conservation for several years.

The Handbook of reclamation techniques in the Yukon (Minister of Indian Affairs and Northern development, 1999) offers recommendations for controlling erosion and encouraging revegetation. Application of seed (native species) and fertilizer, or "assisted" revegetation, is required only in areas unsuited to natural revegetation. There are other recommendations concerning slope contouring to control erosion.

The Guidebook of Mitigation Measures for Placer Mining in the Yukon (Yukon Placer Secretariat, 2010), gives various recommendations for protecting and mitigating fish habitat. Some of the recommendations also apply to the reclamation of wetlands. For example, it describes two general strategies to control erosion: use the coarsest available materials (rock) to control the force of water; and, actively use plant growth in combination with machine work to control erosion. The first strategy may include the use of rock for: covering slopes that are difficult to re-vegetate; lining ditches that might easily erode; weighing the toe (bottom) of slopes to prevent slope failure; protecting outlet areas such as culverts and drainage ditches from scour.

The guidebook also addresses the unique requirements of mining on permafrost and the importance of careful reclamation: “The mining plan must account for management of permafrost soils. Rates of erosion and of re-vegetation are quite different among the mining districts depending on the amount of permafrost and climactic characteristics. The approach to erosion control and re-vegetation are different as well. For example, wet decomposing permafrost soil might respond well to natural re-vegetation methods in the Klondike, (but in the drier districts, a different approach might be needed (Kotler, 2003).

Hydrology in permafrost soil is quite different and an important factor to consider. “Water can only flow under, within, or above it in unfrozen zones. When the active layer (the top layer of soil that thaws each year) is frozen in winter and spring, sub-permafrost water is sometimes forced to the surface in the form of springs and forms aufeis (thick ice known locally as glaciers or overflow)” (Yukon Placer Secretariat, 2010).

8.2 A Review of British Columbia Wetland / Reclamation Policy

British Columbia's placer mining industry is very small compared to that of the Yukon with most of the gold production coming from the Atlin area where most of the placer mined streams are "deregulated" and have much more lenient discharge standards than the rest of the province. There currently is no policy for placer mined wetland reclamation in B.C. However, since 1969 placer miners in B.C. are legally required to reclaim disturbances caused by mining activities under the *Mines Act*, the *Health, Safety and Reclamation Code for Mines in British Columbia* (the Code), and under site specific permit conditions in their mines operating permit.

Placer miners are required to post a reclamation security bond with the Ministry of Forests, Lands and Natural Resource Operations prior to mechanized work at any site. The amount of this security is based on the operator's estimate of how much it would cost to clean up a mine site if it were to revert to the Crown. Securities are returned to proponents once they have completed the appropriate measures.

The Atlin Placer Mining Best Management Practices Guidebook was developed recently by B.C., the Taku River Tlingit First Nation and the Atlin Placer Miner's Association (2014). It has the following key reclamation components: re-establishment of natural drainage patterns; erosion control; de-compaction (where needed); re-contouring; replacement of growth medium (where available) and appropriate re-vegetation." Various recommendations are also provided for reclaiming settling ponds.

The province provides some best management practices through the document called "Wetland Ways". British Columbia is actively involved in protecting and rehabilitating wetlands and is developing a wetland mitigation and compensation strategy such as in Alberta, that supports no net loss (and where appropriate, net gain) of wetlands where wetland losses from development have resulted in impaired watershed hydrology (Cox & Cullington, 2009).

Reclamation research and information exchange has existed in British Columbia for more than three decades through the Technical and Research Committee on Reclamation. The members are from the Ministry of Energy and Mines, the Ministry of Environment, mining companies, the Mining Association of British Columbia, Association for Mineral Exploration in BC, Natural Resources Canada, the University of British Columbia and Thompson Rivers University (Ministry of Energy and Mines, 2013).

8.3 A Review of Alaskan Wetland Reclamation Policy

Prior to 1981 and the introduction of new water quality regulations (1982), litigation by the Sierra Club (1984 & 1986) and the enforcement of EPA regulations (1989) Alaskan placer gold production was much greater than in the Yukon. However by 2001, Alaskan placer gold production had dropped to 15% of 1981 levels and Alaskan placer employment had dropped to 8 % of previous levels (Clarkson, 2003). Recently there has been an upsurge in the Alaskan placer industry due to the popularity of TV reality shows (Gold Rush Alaska and Yukon Gold), an economic recession in the United States and the

less onerous General Permit from the Corps of Engineers for miners with less than five acres of "rolling" disturbance". Currently there are an estimated 297 operations producing over double the amount of placer gold produced by the Yukon industry (Athey, Freeman, Harbo & Lasley, 2014).

Officially, Alaska wetlands represent about 130 million acres (53 million hectares) or one third of the State[2] because all of the tundra is considered to be "wetlands". Since 1977, the Corps of Engineers is responsible for protecting wetlands as part of the water protection under the *Clean Water Act* (1972) of the United States[3]. The Corps of Engineers General Permit has authorized small mechanical placer mining operations on wetlands in Alaska since 1988[4]. The new (May 2015) general permit has tightened the maximum area of disturbance from 10 acres to 5 acres (2 ha) and the maximum length of stream diversions from 2000 to 1500 feet (457 m). However a "rolling footprint" is allowed as long as an operator is engaged in concurrent reclamation (GP-2014-55 General Permit). All existing general permits have been extended for one more year and most suction dredging and temporary mining roads (less than 3 year use) are exempt from the Corps' regulations.

The reclamation requirements from the new General Permit from the Corps of Engineers (May 2015)[5] include among others, backfilling mining pits, reshaping and regrading to conform to the adjacent landforms, using all materials for reclamation. The document provides some suggestions for mitigations including: incorporation of swales; application of topsoil on the depressions; and the creation of wetlands in depressions. It also suggests that wetland depressions be lined with at least 2 to 6 inches (1 -2.5 cm) of topsoil . That they be constructed at an elevation that intercepts the water table so that saturation is within 12 inches (0.3m) of the water table or have surface water for at least 14 days of the growing season. It also offers guidance to construct shallow ponds from settling ponds with less s than 3 feet (1 m) depth at the center.

In cases where a mine site does not fit into these general permit restrictions, they can apply for the Standard Individual Permit where environmental baseline studies and more stringent compensatory mitigations may apply. The few largest placer mines operating with greater than 5 acres of a "rolling footprint" of disturbance have the obligation to mitigate the destruction of the wetland by restoring, creating a new wetland or giving funding to a mitigation bank system. Within that mitigation plan, is a mandatory monitoring and maintenance schedule for any area that is part of wetland reclamation or mitigation. The monitoring and maintenance period generally extends to 10 years with performance standards applied to each year.

A reclamation bond is required for disturbance over 5 acres in size (U.S. Department of the Interior, Bureau of Land Management (BLM) Alaska, 2014). This requirement may be satisfied if the mining operator participates in Alaska Department of Natural Resources '(ADNR) Bond Pool program

[2] http://dec.alaska.gov/Water/wwdp/wetlands/index.htm
[3] http://www.poa.usace.army.mil/Missions/Regulatory.aspx
[4] http://www.poa.usace.army.mil/Portals/34/docs/regulatory/specialpns/General%20Permit%20%28GP%29%20POA-2014-55,%20Fact%20Sheet.pdf
[5] General Permit (GP) POA-2014-55

which requires a deposit of $150/acre. The reclamation bond is refunded when the reclamation has been approved.

Satisfactory reclamation emphasizes three major objectives (US Department of the Interior, 2013):

1. The productivity of the reclaimed land should at least equal that of the pre-mined surface. This does not necessarily mean that the site must be restored to an approximation of its original condition, or that surface uses after mining will be the same as those that existing before mining. As an example, an area used for marginal grazing prior to mining may be reclaimed to a useful and attractive recreational complex or perhaps a housing area.

2. Satisfactory reclamation should leave the mined area in a condition that will not contribute to environmental degradation, either in the form of air or water-borne materials or from chemical pollution.

3. The reclaimed area should be esthetically acceptable and safe for intended uses

In the manual from BLM (U.S. Department of the Interior Bureau of Land Management, 1992), the goal of reclamation of riparian/wetland sites is to minimize disturbance and to restore and preserve the beneficial functions of those wetlands. Several of these functions are: containing flood events and reducing erosion; filtering of sediments and pollutants carried with overland flow; storage of water; stabilization of stream banks through roots development; and maintenance of habitat with functional ecosystems. The report emphasizes minimizing the impacts to the wildlife and fisheries habitat.

Revegetation should provide a diversity of plants. Buffer zones of native vegetation are recommended to promote the re-establishment of native species. Other practices include: incorporating diverse landforms such as slopes, surface undulations, minor depressions, swales, rock or brush piles and convoluted drainage, direct topsoil replacement, shrub and trees transplant. The manual does not encourage pond creation unless it is planned and engineered for a specific purpose which is compatible with the reclamation goals. A paragraph is addressed specially for pit backfilling. Pit reclamation can result in complete backfilling, partial pit backfilling, high wall slope reduction or a combination of these.

9. Previous Experiences in Wetland Reclamation in Other Industries

A lot of literature regarding wetland construction is available, but most of it relates to restoration, not reclamation. There is extensive literature on wetland restoration which offers guidance for existing natural (or impacted by agriculture) watersheds or the construction of highly engineered water treatment wetlands. There is limited information available on wetland reclamation in a mining context or in northern climates. Most of the (sparse) mining reclamation wetland literature has focused on bioremediation of acidic-rock/heavy-metal drainage.

Placer miners in the Yukon face different challenges (wetlands on permafrost and peat-forming wetlands) that have not been addressed in other reclamation guidance. However, Alberta has been quite advanced in wetland reclamation research due to oil sand mining. Oil sand mining operates on a much larger scale than placer mining and it faces water contamination by chemicals and petroleum products which do not occur in placer mining. Oil sand companies are also very large publically-traded companies and spend about $50,000 (Foote, 2012) to $114,000 per ha (Grant, Dyer & Woynillowicz, 2008) to reclaim wetlands.

Extensive literature exists on reclamation after surface mining such as coal mining, bentonite, sand, gravel and quarry mining. They all offer recommendations for improving wildlife habitat, especially waterfowl. In general, the landforms that are created on the post-mining landscape are expected to differ from the original distribution of habitat types (Harris et al., 2006). For example, a shift from peat forming wetland-dominated systems to areas with increased amounts of upland, non-peat forming wetlands, and lakes is expected (Johnson and Miyanishi, 2008). These ecosystems will have different attributes in terms of hydrology, soil properties, etc. to those that existed previously (Richardson et al., 2010).

Many studies indicate that the ponds created after mining activities provide valuable fish and wildlife habitat, especially breeding and migrating waterfowl (Carrozino et al., 2011; Harabiš et al., 2013; Hortsman et al., 1998; Nawrot & Klimstra, 1989; Rumble, 1989; Uresk & Severson, 1988). These post-mined areas are important not only for waterfowl but other wildlife as well: moose, muskrat, beavers (Chevreux, 2014, Eaton et al., 2013), dragonflies (Harabiš et al., 2013), reptiles and amphibians (Brenner & Hofis 1990; Fowler et al. 1985). They are often considered as possible replacements for wetlands destroyed in other locations ("wetland banking"). For instance, in Wyoming wetland creation is a valuable management technique and many natural resource agencies use it to improve, create and mitigate wildlife habitat (McKinstry et al., 2001).

Complexes that involve different types of wetlands are preferred. Wetland reclamation can either be designed, semi-designed or occur without any intervention. Reclaiming wetland complexes is more preferable than focusing on one wetland type. A mix of shallow-water wetlands, marshes, and fens, is more productive. Some swamps, bogs and fens will form opportunistically regardless of intent, but most likely only over extremely long timeframes. Literature regarding the reclamation of swamps was not found by the authors.

9.1 Oil Sands Wetland Reclamation Experience

These past few years, many studies and reports document wetland reclamation and performance in oil sands in Alberta. Oil sands are surface mines which involve the removal of overburden and the creation of open pits. The Oil Sands Industry is mining mainly on peat-forming types of wetlands. Disturbances created by the oil sand mining activity lead to destruction of habitat, changes

to hydrology caused by drainage of water and compaction of soil, and contamination from hydrocarbon spills or mineral/clay soils used for construction (Graf, 2009).

In particular oil sands wetland reclamation generally involves the reconstruction of the entire watershed (CEMA, 2014) due to the large scale of mining. The construction of wetland ecosystems starts with the establishment of appropriate and sustainable water supply due to a water deficit which is characteristic of the drier oil sands region of northern Alberta. Oil sand companies are typically very large publically-traded companies and spend about $50,000 (Foote, 2012) to $114,000 per ha (Grant, Dyer & Woynillowicz, 2008) to reclaim the previous peat forming wetlands to simpler marsh and shallow open water wetlands.

Many wetlands have already been reclaimed on oil sand disturbed areas, but mostly to marshes or shallow open water wetlands. Peat forming wetlands are particularly difficult to reclaim. These wetland types must develop over long periods of time and may be difficult to initiate. Peat formation also requires the presence of a specific vertical structure and more specific chemical conditions. The restoration of saturated soils is the main factor in peatland restoration success. In some cases fens can revegetate spontaneously except for mosses such as *Sphagnum* and *Carex* dominant undisturbed fens.

Other types of wetlands, such as marshes or shallow open water wetlands are likely to be more common in the post-mining landscape than they were previously, as these types are relatively easy to create.

9.2 Coal Mining Reclamation Experience

There has been considerable research done regarding reclamation practices associated with coal mining in the eastern United States. Coal mining involves both underground and surface (strip) mining methods. In the 1990's, wildlife habitat became a common and acceptable post-mining land use and many papers deal with wildlife habitat enhancement recommendations. The use of wetlands in the reclamation process has also been widely studied (Brenner & Hofis, 1990; Buehler & Percy, 2012; Fowler, Hill & Fowler 1985) but most of these wetlands were reclaimed for water treatment. The majority of surface mines in the eastern United States have been reclaimed as grasslands.

Prior to the *Surface Mining Control and Reclamation Act* of 1977 (P.L. 95-97) miners were not required to back fill mining pits. Mining companies are now required to reclaim mined lands to equal the original productivity of the land and as a result of this, very few new surface mine impoundments have been created (Rumble, 1989). Rumble had in his paper that well designed impoundments should be an alternative for reclaiming areas where mining has destroyed existing wetlands. They represent opportunities for improving the quantity and quality of wildlife and fish habitats (McKee, 2007).

In their Handbook of methods to reclaim wildlife habitat on surface mines in Wyoming, Parrish and Anderson (1994) offer a wide variety of reclamation techniques after coal mining, including wetland

reclamation. Parkhurst (1994) studied waterfowl use of coal ponds formed by strip mining in eastern Oklahoma (25 ponds). The average depth of ponds was 5 meters.

9.3 Sand, Gravel and Quarry Mining Reclamation Experience

Numerous reports and guidelines are available about wetland reclamation following sand, gravel and quarry mining. All of the reports focus on pond reclamation and offer design recommendations to reclaim these as an ideal wildlife habitat. Michalski et al., 1987 offer reclamation techniques for creating ponds after quarry mining. Pit depth is variable but generally does not exceed 5 to 7 m (Green et al., 1991). Matter & Mannan (1988) offer design recommendations for creating or enhancing wetland habitat in flooded sand and gravel pits in or near riverine systems in the southwestern United States.

9.4 Bentonite Mining Reclamation Experience

McKinstry et al. (2001), studied wetlands created from bentonite mining. The ore is mined near the surface and the overburden is almost nonexistent. Pits were formed and filled with runoff or intercept groundwater. They are typically small (average 12 ha) and shallow (<3m) and look like prairie potholes in function and structure. The paper explains that non reclaimed ponds from mining activities developed the soil and vegetative characteristics of wetlands as defined by the US Army Corps of Engineers. They offer recommendations for designing the ponds.

10. Guidance for the Construction of Reclaimed Wetlands

10.1 General Reclamation

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. The layout of reclaimed wetlands is constrained by the mining activity and the uncertainties inherent in placer mining. The amount, location, and types of wetlands will be dictated by the mining methods, materials, the local hydrology and soil.

Best management practices can be developed but it must be a living document that will be modified along with the mining activity. It should identify general methods to reclaim areas and assure that wetlands are kept moist and/or covered in water. It should create a diversity of habitats with wetlands to increase the biodiversity (a great variety of living components). Protecting some of the remaining intact wetlands over uneconomic pay gravel areas is very important as they will contribute to habitat diversity and will help to revegetate the constructed wetlands.

10.2 Progressive reclamation

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. This progression creates patches with more mature reclamation at one end and early pioneer vegetation at the other end. It also shortens the time period required for achieving closure objectives and provides valuable experience on the effectiveness of reclamation measures on an ongoing basis. Progressive reclamation can also reduce the financial liability of the site and as equipment and employees are on site throughout the mining cycle, the cost of reclamation can be reduced considerably.

The grading and recontouring of tailing piles and steep excavated slopes should be completed while mining activity is taking place, preferably at the conclusion of each pit but at least by the end of each mining season provided these areas are not required for mining in the future. Slopes should be 2:1 (horizontal to vertical) or less. 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 on flat areas or gentle slopes.

10.3 Reclamation material

Reclamation stockpiles should be left in stable piles and protected from erosion caused by streams, snow melt and precipitation. They should be situated not too far from the mine pit if required for backfilling. Topsoil, black muck and other organic materials should be separated from overburden and conserved in windrows parallel to the slope in a convenient place to be spread out later. Topsoil with specific vegetation types should be segregated where practical. Mixing overburden with either topsoil or subsoil reduces greatly its value (Michalski et al., 1987). 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 possible 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.

10.4 Revegetation

Revegetation is a major element of wetland reclamation. Placer miners are required to leave the ground surface in a state conducive to successful revegetation by plant species native to the area (natural revegetation). Seeding, fertilizing or “assisted” revegetation is rare because of the presence of fertile organic (black muck) layer overlying the gravels that help natural revegetation and the risk of introducing invasive species. However, in case seeding or planting is necessary, “The Yukon Revegetation Manual” (Matheus, & Omtzigt, 2013) or “Natural Vegetation and Sustainable Reclamation at Yukon Mine and Mineral Exploration Sites” (Whiters, 1999) should be consulted as guidelines for revegetation in the Yukon.

Where practical, leave patches of natural vegetation in or near the operating area, preferably along travel corridors or adjacent to streams and water bodies (Parrish & Anderson, 1994). These patches will provide food and cover for wildlife and provide seeds for the reclaimed area. 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. 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!

10.5 Slope benching

Slope 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 2 - Recommended slop 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 (Yukon Placer Secretariat, 2010).

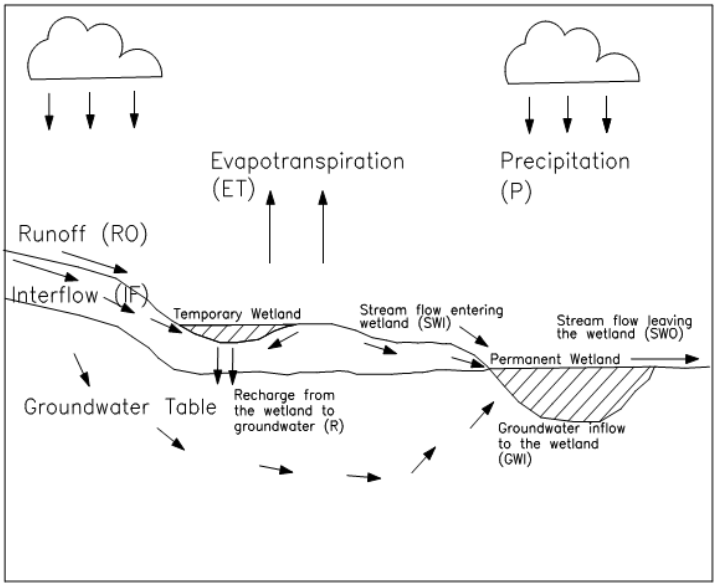
11. Constructing Shallow Water and Marshes Wetlands

Mining activities can result on the creation of excavations that often eventually will fill with water naturally through precipitation or ground water infiltration. Pond design is constrained by the mining configuration and the characteristics of the ore body deposit. However, there are several parameters which miners can use to meet the final reclamation objectives. The goal of this section is to recommend approaches that will help the operators to leave the habitat in a way that it will evolve in a self-sustaining marsh or shallow open water wetland.

11.1 Keeping Wetlands Wet

Keeping wetlands wet is the most important control on wetland ecosystems and will often dictate whether the reclamation achieves its objectives (CEMA, 2014). 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)



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 (CEMA, 2012). 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 may not be 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. 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.

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 (Taft et al., 2002; Kaminski et al. 2006) and germination of emergent plants (Alberta Environment, 2008).

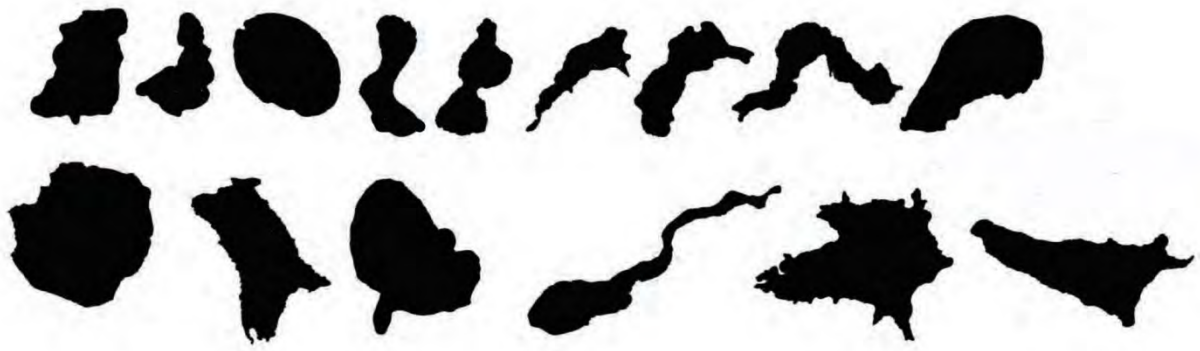
11.2 Backfilling Mine Pits

If the depth of ground water is low and fills the bottom of the pit to a maximum of 2 m, the mine pit may not require backfilling but the sides should be sloped to allow habitat for shore birds. The infilling the mined-out pit with re-handled material may be preferred for reclaiming wetlands. Locate the overburden not too far from the pit in a place where you can more easily push it back over the mined area or into the pit. If the mining method and equipment is not set up for infilling pits it can be very costly and could have some 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. When it is not practical to back fill a pit, follow the recommendations for ponds and deeper excavations (section 12).

11.3 Size and shape of the pond

Ponds between 0.2 and 5 ha in area and with as complex shapes as practical should be constructed. Biodiversity can be increased by creating a complex wetland shape that maximizes the length of shoreline per unit of surface area (figure 8). This provides more habitats for more wetland species and minimizes bank erosion resulting from wave action (Attum et al., 2008). The rectangular shape of most placer mine pits can be made more irregular by pushing material in from the sides of the pit. Where practical, pits should be filled progressively with mining and material pushed into them from the sides. Caution should be exercised to ensure the bulldozer does not sink into the muck.

Figure 8 - Natural shallow open water and marsh wetland shapes in Alberta (CEMA, 2014)



11.4 Connectivity

Connections between wetlands facilitate the exchange and movement of aquatic animals and plants among wetlands (Bancroft et al., 1994). Wetlands are also connected to the surrounding uplands (Attum et al., 2008). Shallow mounds should separate the various depressions to allow for species of water fowl which seek their own territory. These areas would be covered with fine soils to promote natural re-vegetation. The wetlands may be connected to the stream if there is not enough groundwater or precipitation to keep the pond filled.

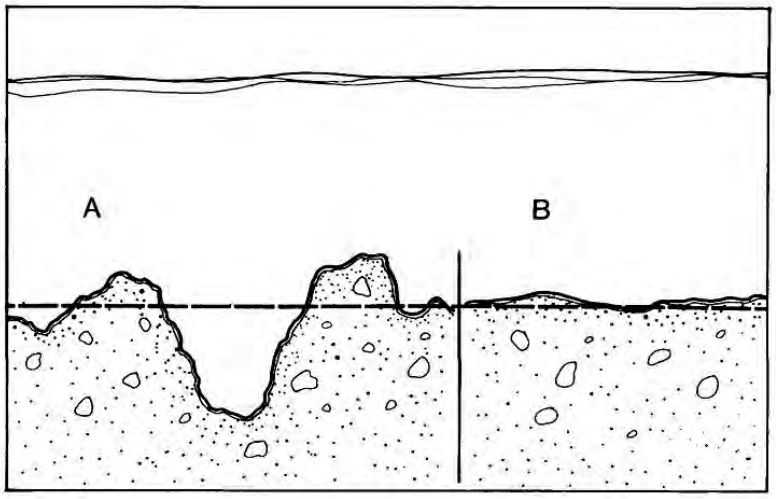
11.5 Depth

The depth of the water in the 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 (Ma et al., 2010; Michalski et al., 1987). Shallow water wetlands are less than 2 m deep and recommended for waterfowl habitat (in southern jurisdictions).

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.

The construction of irregular bottoms on the ponds enhances habitat diversity (figure 9).

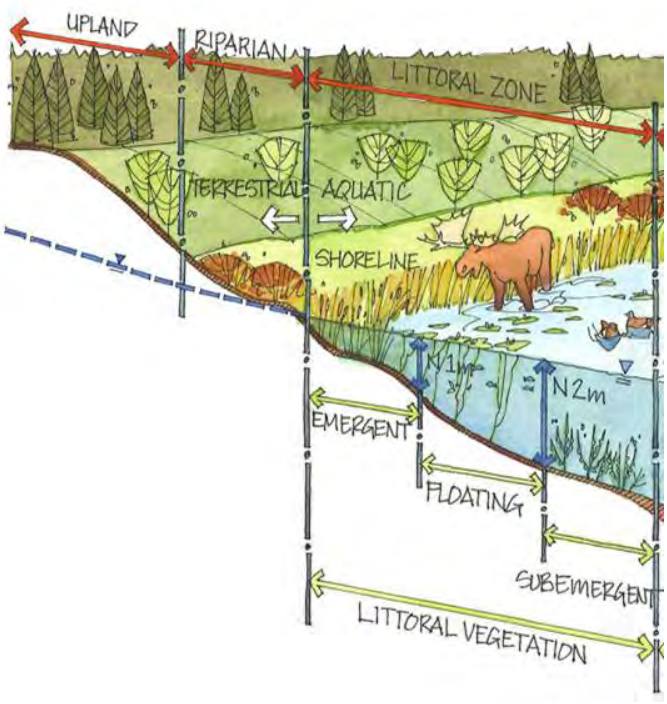
Figure 9 - Irregular bottom (Michalski et al., 1987)



11.6 Slopes

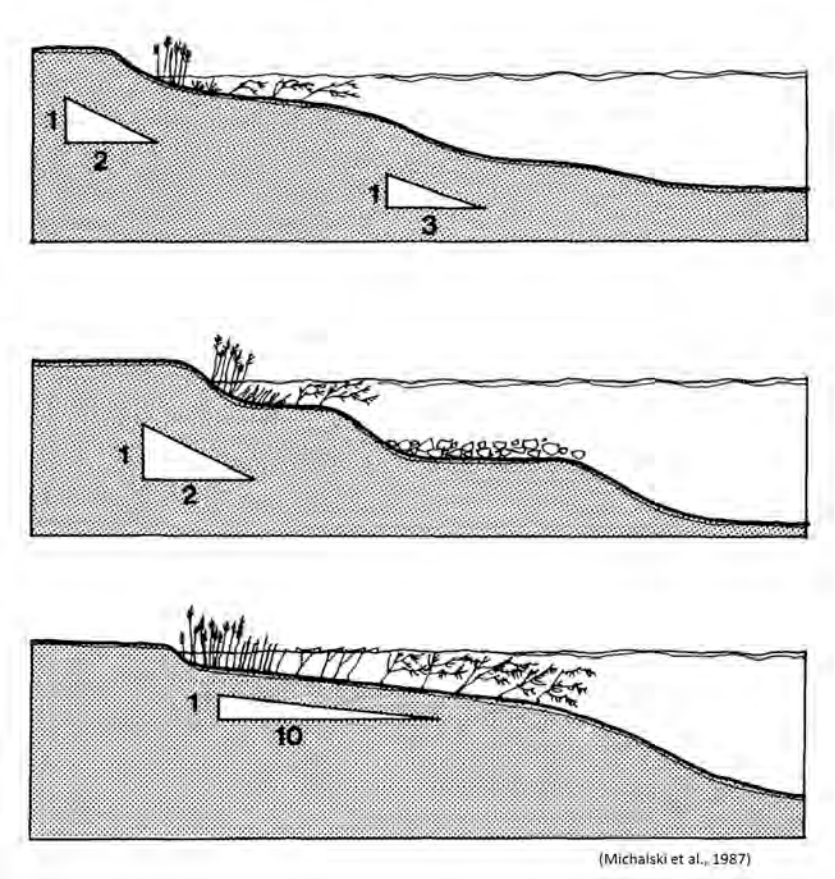
Wetlands can be divided into different zones (figure 10). The littoral zone is the area filled with water. The vegetation can be submerged (under the water), floating or emergent (plants rising above the water surface). The slopes are submerged as well. The shoreline (riparian area) is the fringe of land at the edge the water. The upland area is situated higher than the water level and covered by natural vegetation.

Figure 10 - Pond zones (CEMA, 2012)



Submerged slopes are recommended for emergent (above water) plants (Steiner & Freeman, 1989). Breeding waterfowl require significant amounts of emergent vegetation. Around 30-90 % of emergent vegetation cover is preferred by waterfowl for nesting and brood rearing habitat (Wiacek et al., 2002). 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, (Wiacek et al., 2002). Macrophytes (pondweed) and floating plants (yellow pond lily roots) are high-quality summer foods for moose (Garibaldi, 2006; Wiacek et al., 2002).

Figure 11 - Example of slope ratio (Michalski et al., 1987)



The outer edges of the ponds should have shallow slopes. Shallow slopes attract shorebirds, reduce turbidity and promote emergent vegetation (Erwin et al., 1994; Hoffman et al., 1994). Scalet and Modde (1984) recommended that shoreline banks be sloped to a 3:1 ratio and should not exceed 1:5 slope (figure 12). The ponds should be bordered by natural vegetation for duck nesting habitat. Place gravels along some shoreline areas for shorebirds. 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 12 - Slope ration 3:1 (Prunuske, 1987)

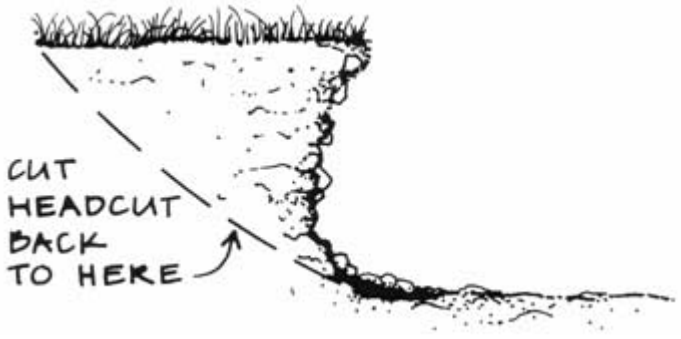
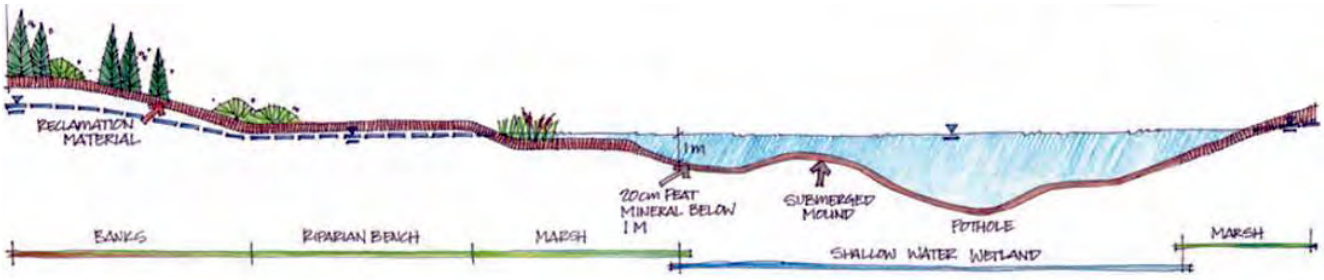


Figure 13 - Cross section of a shallow pond with marsh and riparian areas (CEMA, 2014)



Note: Figure 13 illustrates the ideal situation with a very gentle slope from the reclamation material to the bottom of the pond going progressively with stepping berms.

11.7 Marsh

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 (figure 15). There should be shallow slopes to create marsh areas. The mining cut should be backfilled until there is depression less than 1 meter (3 feet) deep.

Figure 14 - Marsh area in a post-mined pond in Indian River Valley in May 2015

11.8 Woody Debris

In natural ponds, trees and branches often fall into the water from the streamside area. Coarse woody debris provides habitat for small aquatic insects (Alsfeld et al., 2009), which are important prey items for wildlife species and important to wetland function. They are important habitat for fish which

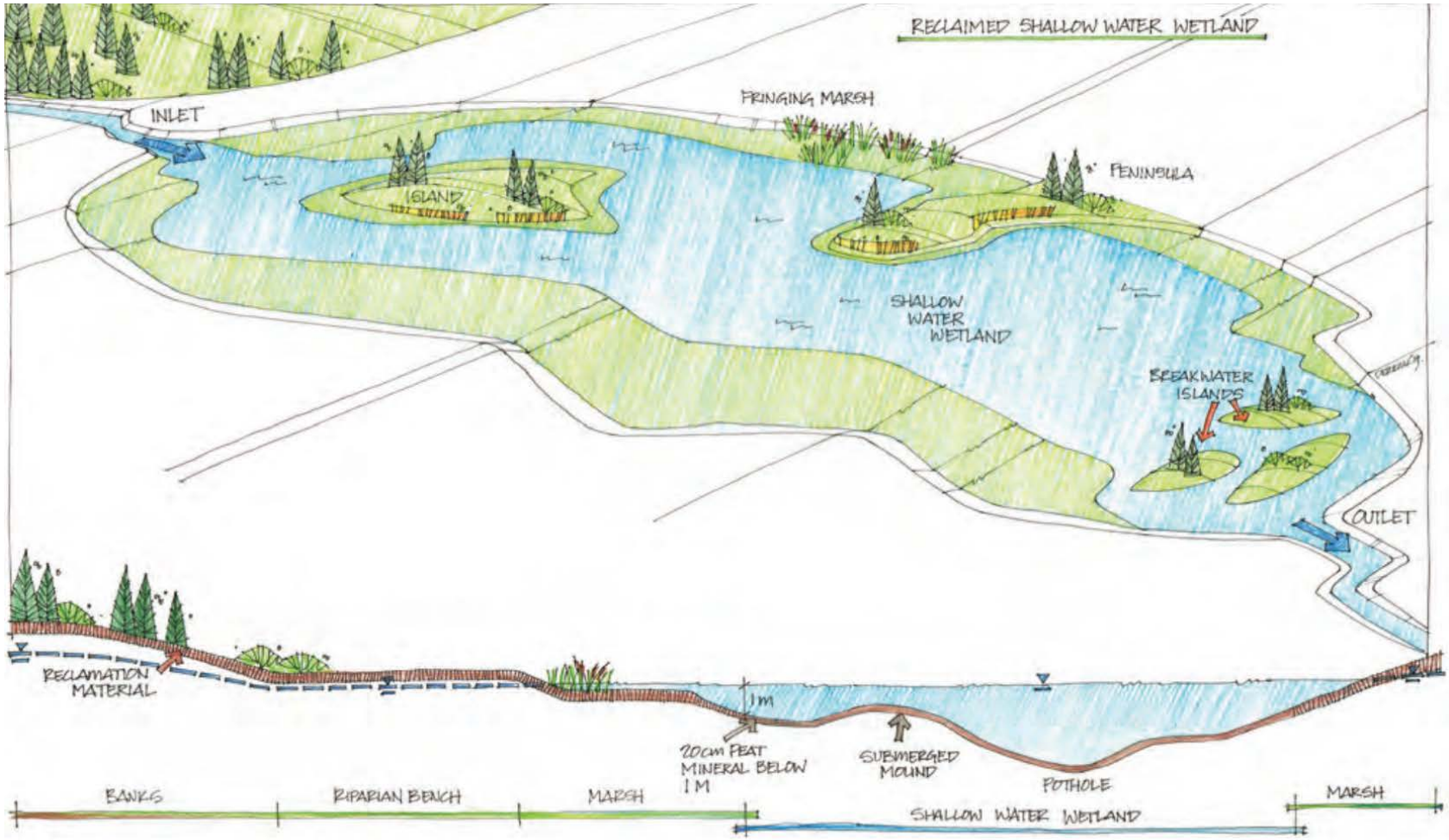
provides protection for spawning substrate (loose gravels), and an area with greater food availability. Place some logs and woody debris in the bottom and on the slopes of the pond.

11.9 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 (Gould, 2000). 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 (CEMA, 2014).

The introduction of natural wetland soil can be used to introduce aquatic organisms (Brady et al. 2002) but is preferable to do so when the submerged vegetation has already grown. Transplanting 6-7 cm (2-3 inches) of organic soil from natural marsh enriches the vegetation with native species (Brown and Bedford, 1997). For ensuring root penetration a 20 cm (8 inch) depth of organic soil is optimal at water depths less than 45 cm (18 inches, Brown & Bedford, 1997). However, it is important to ensure that you are not introducing any invasive species.

Figure 15 - Diagram of a reclaimed shallow water wetland (CEMA, 2014)



11.10 Beavers and Muskrats

Beavers (*Castor Canadensis*) 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. Beavers must be anticipated and accommodated. They will build lodges and canals and they will dam creeks, outlets of wetlands and ponds (Eaton et al., 2013; figure 17). 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 (*Ondatra zibethicus*) alters wetland dynamics as well. Muskrats can produce channels through marshes and affect the proportion of shallow water through grazing (Eaton et al., 2013).

Figure 16 - Beaver dam in a post-mined pond in Indian River Valley, May 2015

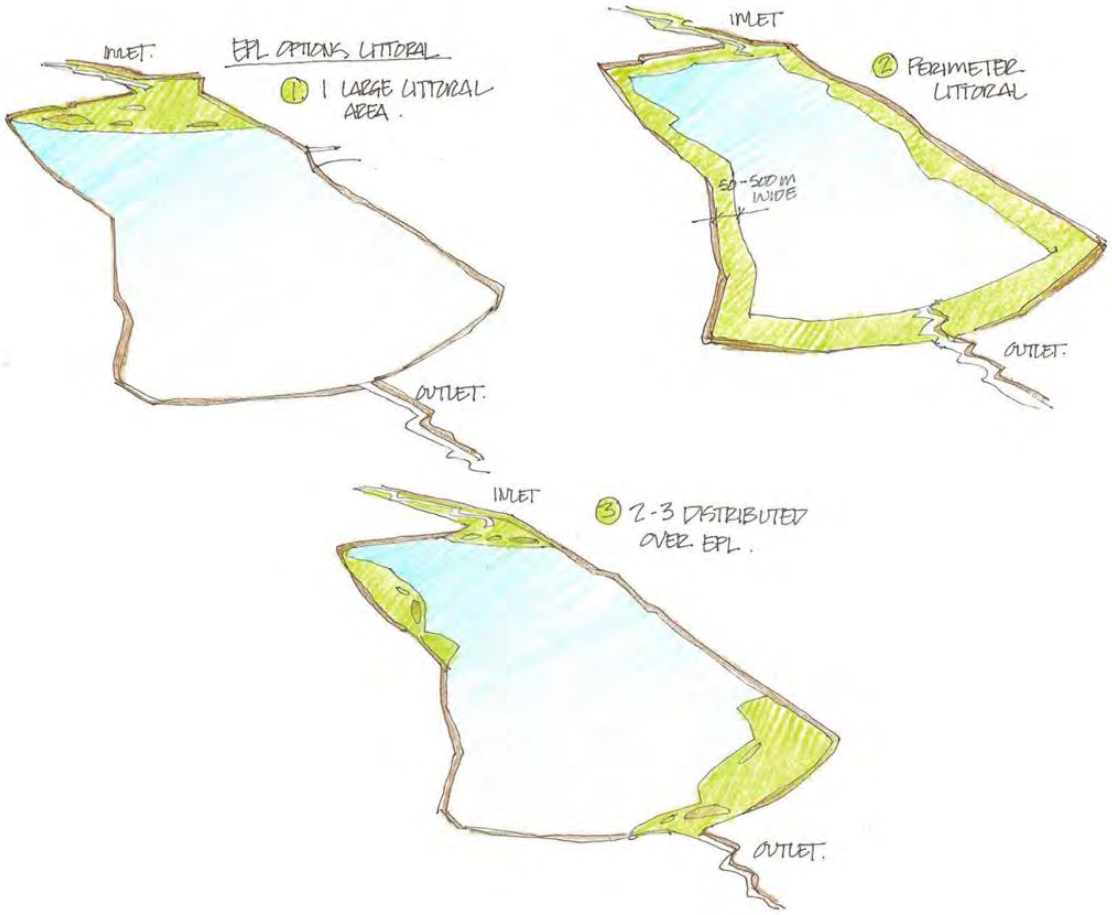
12. Deeper excavations

Placer miners mine pay gravels at different depths with various types of heavy equipment. The infilling of the mined-out pit with re-handled material may be preferred for reclaiming wetlands. It is preferable to locate the overburden not too far from the pit in a place it can easily be pushed back over the mined area or into the pit. If the mining method and equipment is not set up for infilling pits it can be very costly and could have some 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 nearby material to fill it with. For example, for a 100 x 100 m and 6 m deep excavation would cost approximately $250,000 to excavate and about the same price to back fill it (Peterson, 1993). An average operation would consist of six pits, therefore the reclamation costs would average of about $1,350,000 (not possible for privately financed placer miners). In comparison, contouring overburden and spreading topsoil would average about $25,000 for each pile.

In some cases, miners will create deeper excavations where there is a high ground water table and the ponds cannot be backfilled. In “End Pit Lake guidance document”, CEMA (2012) insists that it is important to provide “littoral zones” (figure 18) for very deep water bodies. These zones are the shallow, nutrient-rich areas of 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. 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. This process can also be used to create irregular shorelines. The shoreline of these deeper ponds should be irregular. The bottom of the lake should be irregular as well. Topsoil should be placed on the slopes to promote revegetation.

Figure 17 - Littoral zones (CEMA, 2012)



13. Other 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.

The Bank Swallow (*Riparia riparia*) breeds in a wide variety of natural and artificial sites with vertical banks. The Bank Swallow is listed as Threatened by COSEWIC (2013). Sand-silt substrates are preferred for excavating nest burrows (COSEWIC, 2013). Banks cut from mining waste piles are used by Bank Swallows for nesting (Chevreux, 2014; figure 19). 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 18 - Mining cut with Bank Swallow nests on Ruby Creek, May 2014

Gravel piles can 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 (*Chordeiles minor*) (COSEWIC, 2007). This species is listed as threatened by COSEWIC (2007), at risk by the CESCC and is included on schedule 1 of SARA, 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 (Michalski et al., 1987). Some shallow gravel piles should be left in the reclaimed landscape for wildlife habitat

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 (Benson, 2002). 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 (Pyper & Vinge, 2012).

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 (Pyper & Vinge, 2012).

Figure 19 - Bald Eagle on a dead tree (R. Lake)

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 (figure 21). Natural dead standing trees should be left standing in the reclaimed landscape (Eaton et al., 2014).

Figure 20 - Snag (Eva Paulson)

14. Monitoring

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 vegetation and be "free to evolve." Reclaimed wetlands should not require long-term maintenance and management (Oil Sands Wetlands Working Group, 2000). 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 the 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).

Revegetation

The growth rates and succession of vegetation species should be surveyed. 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.

Ponds

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

Tailing piles and overburden

Erosion should be controlled.

Table 3 - 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

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References

Alberta Environment (2008). Guideline for wetland establishment on reclaimed oil sands leases (2nd edition). Prepared by Harris, M.L. of Lorax Environmental for the Wetlands and Aquatics Subgroup of the Reclamation Working Group of the Cumulative Environmental Management Association, Fort McMurray, AB. December 2007. 330p. http://www.waterforlife.alberta.ca/documents/WetlandEstablishmentReclaimedOilSands-2007.pdf

Alsfeld, A.J., Bowman, J.L. & Deller-Jacobs, A. (2009). Effects of woody debris, microtopography, and organic matter amendments on the biotic community of constructed depressional wetlands. Biological Conservation 142: 247-255. http://landmark-se.com/images/links/alsfeld_biologicalconservation_effects-woody-debris-wetlands.pdf

Athey, J.E., Freeman, L.K., Harbo, L.A. & Lasley, P.S. (2014). Alaska's Mineral Industry 2013. Special Report 69. Report prepared for the Department of Natural Resources, Division of Geological & Geophysical Surveys (DGGS). http://pubs.dggsalaskagov.us/webpubs/dggs/sr/text/sr069.pdf

Attum, O., Lee, Y., Roe, J., & Kingsbury, B.A. (2008). Wetland complexes and upland-wetland linkages: landscape effects on the distribution of rare and common wetland reptiles. Journal of Zoology, 275, pp. 245-251. 10.1111/j.1469-7998.2008.00435.x

Bancroft, C.T., Strong, A.M., Sawicki, R.J., Hoffman, W., & Jewell, S.D. (1994). Relationships among wading bird foraging patterns, colony locations, and hydrology in the Everglades. In: S.M. Davis, J.C. Ogden, (Eds.), *Everglades: The ecosystem and its restoration*, (pp. 615-657), St. Lucie, FL: Delray Beach.

Bayley, S.E. & Prather, C.M. (2003). Do wetland wetlands exhibit alternative stable states? Submersed aquatic vegetation and chlorophyll in western boreal shallow lakes. *Limnology and Oceanography*, 48, pp. 2335-2345. http://hzmjcpx.aslo.net/lo/toc/vol_48/issue_6/2335.pdf

Benson, S. A. (2002). Reclaiming Wildlife Habitat at the Buckskin Mine. In AMSR (Ed.), *National Meeting of the American Society of Mining and Reclamation* (pp.241-258). Lexington, KY. Retrieved from http://www.asmr.us/Publications/Conference%20Proceedings/2002/0241%20Benson.pdf

Brady, V.J., Cardinale, B. J., Gathman, J.P., & Burton, T.M. (2002). Does facilitation of faunal recruitment benefit ecosystem restoration? An experimental study of invertebrate assemblages in wetland mesocosms. *Restoration Ecology*, 10, (4), pp. 617-626. http://snre.umich.edu/cardinale/wp-content/uploads/2012/04/brady_rest_ecol_2002.pdf

Brenner, F.J. (2007). Impact of the surface mining control and reclamation act on species of special concern in Pennsylvania. In R.I. Barnhisel (Ed.), *National Meeting of the American Society of Mining and Reclamation*. Lexington, KY: ASMR. Retrieved from: http://www.asmr.us/Publications/Conference%20Proceedings/2007/0079-Brenner-PA.pdf

Brenner, F. J., & Hofis, D. L. (1990). Wildlife use of mitigated wetlands on surface mine lands in western Pennsylvania. In J. Skousen, J. Sencindiver & D. Samuel (Eds.), *Proceedings of the 1990 Mining and Reclamation Conference and Exhibition (Vol.2)* (pp. 373-382). Morgantown, WV: West Virginia University. Retrieved from: http://wvmdtaskforce.com/proceedings/90/90BRE/90BRE.HTM

Brown, S. C. & Bedford, B. L. (1997). Restoration of wetland vegetation with transplanted wetland soil: an experimental study. *Wetlands*, 17, pp. 424-437. 10.1007/BF03161432.

Buehler, D. A. & Percy, K. (2012). Coal Mining and Wildlife in the Eastern United States: A Literature Review (Unpublished paper). University of Tennessee, TE. Retrieved from http://www.appalachianwildlife.com/Coal%20Mining%20and%20Wildlife%20in%20the%20Eastern%20United%20States-final%20draft.pdf

Carrozino, A.L., Stauffer, D.F., Haas, C.A. & Zipper, C.E. (2011). Enhancing wildlife habitat on reclaimed mine lands. VCE Publication 460-145. http://pubs.ext.vt.edu/460/460-145/460-145_pdf.pdf.

Clarkson, R. (2003). Black Friday History Presentation – Presented to Yukon Chamber of Commerce.

Chevreux, A. (2014). Bird Baseline Study, Indian River Valley. Unpublished report. Schmidt Mining Corp., Klondike Pacer Mining Association.

Cobbaert, D., Wong, A. & Bayley, S.E. (2014). Precipitation-induced alternative regime switches in shallow lakes of the Boreal Plains (Alberta, Canada). *Ecosystems*, 17, pp. 535-549. 10.1007/s10021-013-9741-5

COSEWIC (2013). Canadian Wildlife Species at Risk. Committee on the Status of Endangered Wildlife in Canada. http://www.cosewic.gc.ca/eng/sct0/rpt/rpt_csar_e.cfm

COSEWIC (2013). COSEWIC assessment and status report on the Bank Swallow *Riparia riparia* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. http://www.registrelep-sararegistry.gc.ca/virtual_sara/files/cosewic/sr_hirondelle_rivage_bank_swallow_1213_e.pdf

COSEWIC (2007). COSEWIC assessment and update status report on the common nighthawk, *Chordeiles minor,* in Canada*,* Committee on the Status of Endangered Wildlife in Canada, Ottawa. http://novascotia.ca/natr/wildlife/biodiversity/pdf/statusreports/sr_CommonNighthawk.pdf

Cox, R. K. & Cullington J. (2009), Wetland Ways: Interim Guidelines for Wetland Protection and Conservation in British Columbia. Wetland Stewardship partnership. http://www.env.gov.bc.ca/wld/documents/bmp/wetlandways2009/wetlandways_docintro.html

Cumulative Environmental Management Association (CEMA), (2014). Guidelines for wetland establishment on reclaimed oil sands leases. 3rd Edition. Cumulative Effects Management Association, Fort McMurray, Alberta. 494 pp. http://cemaonline.ca/index.php/administration/cat_view/2-communications/18-rwg-recommendations

Cumulative Environmental Management Association (CEMA), (2012). End Pit Lake guidance document. Cumulative Effects Management Association, Fort McMurray, Alberta. 436 pp. http://cemaonline.ca/index.php/administration/doc_download/174-end-pit-lake-guidance-document

Eaton, B.R., Fisher, J.T., McKenna, G.T., & Pollard, J. (2014). An Ecological Framework for Wildlife Habitat Design for Oil Sands Mine Reclamation (OSRIN Report No. TR-67). Edmonton, AB: Oil Sands Research and Information Network, University of Alberta, School of Energy and the Environment. Retrieved from http://hdl.handle.net/10402/era.40338

Eaton, B., Muhly, T., Fisher , J.T. & Chai, S-L. (2013). Potential Impacts of Beaver on Oil Sands Reclamation Success – an Analysis of Available Literature. Oil Sands Research and Information Network, University of Alberta, School of Energy and the Environment, Edmonton, Alberta. OSRIN Report No. TR-37. 65 pp. http://hdl.handle.net/10402/era.32764

Erwin, R.M., Hatfield, J.S., Howe, M.Q., & Klugman, S.S. (1994). Waterbird use of saltmarsh ponds created for open water marsh management. *Journal of Wildlife Management*, 58, 516-524. doi: 10.1016/0006-3207(96)83248-4

Foote, L. (2012). Threshold considerations and wetland reclamation in Alberta's mineable oil sands. *Ecology and Society*, 17, 1, p.35. http://dx.doi.org/10.5751/ES-04673-170135

Fowler, D. K., Hill, D. M. & Fowler, L. J. (1985). Colonization of coal surface mine sediment ponds in southern Appalachia by aquatic organisms and breeding amphibians. In R. P. Brooks, D. E. Samuel, & J. B. Hill *(Eds.), Proceedings, Wetlands and Water Management on Mined Lands*, (pp.261-85). University Park, Pa: University Park Pennsylvania State University

Garibaldi, A. (2006). Report on traditional environmental knowledge input into wildlife habitat reclamation recommendations. Prepared by Garibaldi Heritage and Environmental Consulting for CEMA Biodiversity and Wildlife Subgroup, Reclamation Working Group, Fort McMurray, AB. Aug 2006. http://library.cemaonline.ca/

Gould, R. (2000). The effects of oil sands mine tailings in a constructed pond on the benthic invertebrate community structure and diet of yellow perch (*Perca flavescens*). M.Sc. thesis. University of Waterloo, Department of Biology, Waterloo, ON.

Graf, M. D. (2009). Literature review on the restoration of Alberta's boreal wetlands affected by oil, gas, and in situ oil sands development. Prepared for Ducks Unlimited Canada, 59 pp.

http://www.biology.ualberta.ca/faculty/stan_boutin/ilm/uploads/footprint/Graf%20Wetland_Restoration_Review%20FINAL-Small%20File.pdf

Graf, M. D., Rochefort, L. & Poulin M. (2008). Spontaneous revegetation of cutwaway peatlands of North America, *Wetlands*, *28*, (1), pp. 28-39. 10.1672/06-136.1

Grant J., Dyer S. & Woynillowicz D. (2008). Fact or Fiction: Oil Sands Reclamation. The Pembina Institute. 85p. http://www.pembina.org/reports/Fact_or_Fiction-report.pdf

Green, J.E. &. Salter, R.E. (1987). Methods for reclamation of wildlife habitat in the Canadian prairie provinces. Prepared for Environment Canada and Alberta Recreation, Parks and Wildlife Foundation by the Delta Environmental Management Group Ltd. 114 pp.
http://www.landstewardship.org/resources/resource/201/

Green, J. E., Van Egmond, T. D., Wylie, C., Jones, I., Knapik, L. & Paterson, L. R.A. (1991). User Guide to Pit and Quarry Reclamation in Alberta. Technical report, For Alberta Environment, 158p.
http://hdl.handle.net/10402/era.22792

Guthery, F.S. & Stormer, F.A. (1984). Playa management. In: F.R. Henderson (Ed.), *Guidelines for increasing wildlife on farms and ranches* (pp. 177B-183B). Manhattan, KS: Great Plains Agriculture Council, Wildlife Resources Committee and Kansas State University.

Halsey, L.A., Vitt, D.H. & Zoltai, S.C. (1997). Climatic and physiographic controls on wetland type and distribution in Manitoba, Canada. *Wetlands,* 17, pp. 243-262.
http://nofc.cfs.nrcan.gc.ca/bookstore_pdfs/25906.pdf

Harabiš, F., Tichanek, F. & Tropek, R. (2013). Dragonflies of freshwater pools in lignite spoil heaps: Restoration management, habitat structure and conservation value. *Ecological Engineering*, 55, 51-61. doi:10.1016/j.ecoleng.2013.02.007

Harris, J.A., Hobbs, R.J., Higgs, E., & Aronson, J. (2006). Ecological restoration and global climate change. *Restoration Ecology*, 14, pp. 170-176. 10.1111/j.1526-100X.2006.00136.x

Hoffman, W., Bancroft, C.T., & Sawicki, R.J. (1994). Foraging habitat of wading birds in the Water Conservation Areas of the Everglades. In: S.M. Davis, J.C. Ogden (Eds), *Everglades: The ecosystem and its restoration* (pp. 585-614). St. Lucie, FL: Delray Beach.

Horstman, A. J., Nawrot, J. R. & Woolf, A. (1998). Mine-associated wetlands as avian habitat. *Wetlands*, *18*, 298-304. http://dx.doi.org/10.1007/BF03161665

Indian and Northern Affairs Canada (1999). Handbook of Reclamation Techniques in the Yukon. Yukon Placer Mining Land Use Regulations. Ottawa: Minister of Public Works and Government Services Canada

http://www.emr.gov.yk.ca/mining/pdf/handbook_placer_regulations.pdf

Johnson, E.A. & Miyanishi, K. (2008). Creating new landscape and ecosystems: the Alberta oil sands. *Annals of the New York Academy of Science*, 1134, pp. 120-145. http://www.bgs.ucalgary.ca/files/bgs/johnson_miyanishi_2008.pdf

Kaminski, M.R., Baldassarre, G.A. & Pearse, A.T. (2006). Waterbird responses to hydrological management of Wetlands Reserve Program habitats in New York. *Wildlife Society Bulletin*, 34, pp. 921 - 926.

Kotler, E. (2003). Characteristics of permafrost and ice-rich ground surrounding placer mining operations, Yukon Territory: guidelines for management practices. DFO, Management Sector, Whitehorse, Yukon, 25p. http://emrlibrary.gov.yk.ca/ebooks/characteristics_of_permafrost_and_ice_rich_ground.pdf

Ma, Z., Yinting, C. Bo, L. & Jiakuan, C. (2010). Managing Wetland Habitats for Waterbirds: An International Perspective. *Wetlands*, 30, 15-27. doi 10.1007/s13157-009-0001-6

Matheus, P.E., & Omtzigt, C.M. (2013). Yukon Revegetation Manual: Practical Approaches and Methods. Whitehorse, YT. http://www.yukoncollege.yk.ca//downloads/front_Chapter_1-17.pdf

Matter, W. J.& Mannan, W. (1988). Sand and Gravel Pits as Fish and Wildlife Habitat in the Southwest. University of Tucson, Arizona. 18p. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA322798

McKendrick, J.D., Scorup, P.C. , Fiscus, W.E. & Turner, G. (1992). Gravel vegetation experiments – Alaska North Slope. *Agroborealis*, 24, (1), pp. 25-32.

McKee, G. (2007). Wildlife mitigation techniques at surface coal mines in northeast Wyoming. In R.I. Barnhisel (Ed.), *National Meeting of the American Society of Mining and Reclamation*, Gillette, WY. Lexington, KY: ASMR. http://www.asmr.us/Publications/Conference%20Proceedings/2007/0425-McKee-WY.pdf

McKinstry, M.C., Richmond, T.A. & Anderson, S.H. (2001). Wetland enhancement and creation on reclaimed abandoned mine lands in northeast Wyoming. American Society for Surface Mining and Reclamation. 18:348-355. http://www.asmr.us/Publications/Conference%20Proceedings/2001%20Vol%202/McKinstry%20348-355.pdf

Michalski, M.F.P., Gregory, D. R. & Usher, A.J. (1987). Rehabilitation of Pits and Quarries for Fish and Wildlife; Ontario Min istry of Natural Resources, Land Management Branch, 59p.

M. Miles and Associates LTD. (2003). Restoration of Placer Mined Streams: Identification of strategies to expedite recovery. Prepared for Yukon River Panel. 42p. http://yukonriverpanel.com/salmon/wp-content/uploads/2011/02/cre-86-02-restoration-of-placer-mined-streams-identification-of-strategies-to-expedite-recovery.pdf

Minister of Indian Affairs and Northern development, (1999). Handbook of reclamation techniques in the Yukon, Yukon Placer Mining Land use regulations, 39p.
http://www.emr.gov.yk.ca/mining/pdf/handbook_placer_regulations.pdf

Ministry of Energy and Mines British Columbia, (2013). Annual report of the chief inspector of mines 2013. 34p.
http://www.empr.gov.bc.ca/Mining/HealthandSafety/CI/Documents/2013_CI_Rpt.pdf

Ministry of Energy, Mines and Petroleum Resources Mining and Minerals Division, 2008, Health, Safety and Reclamation Code for Mines in British Columbia, 356p.
http://www.empr.gov.bc.ca/mining/healthandsafety/documents/hsrc2008.pdf

Ministry of Forests, Lands and Natural Resource Operations, Ministry of Energy and Mines, Taku River Tinglit First Nation, Atlin Placer Miner's Association, (2014). Atlin Placer Mining Best Management Practices Guidebook, 64p.
http://www.elp.gov.bc.ca/wld/documents/bmp/Skeena/Atlin%20Placer%20Mining%20BMP%20Guidebook_FINAL%20June%2030%202014.pdf

National Wetlands Working Group, (1997). The Canadian Wetland Classification System, 2nd Edition. Warner, B.G. and C.D.A. Rubec (eds.), Wetlands Research Centre, University of Waterloo, Waterloo, ON, Canada. http://www.gret-perg.ulaval.ca/fileadmin/fichiers/fichiersGRET/pdf/Doc_generale/Wetlands.pdf

National Wetlands Working Group (NWWG), (1988). Wetlands of Canada. Ecological Land Classification Series, No. 24. Sustainable Development Branch, Environment Canada, Ottawa, Ontario, and Polyscience Publications Inc., Montreal, Quebec, 452 p.

Nawrot, J.R. & Klimstra, W.D. (1989). Wetland habitat development on mined lands. In J.D. Mayer, ed., *Animals in Primary Succession: The Role of Fauna in Reclaimed Lands*, (pp. 269-285). Cambridge University Press, New York, New York.

Nordin, K. & Latoski, D. (1989). Placer Mining Design Handbook. Yukon Territory. Water board. 50p.
http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=C68A59FC9C14BA9A92BDC4FC00F0149F?doi=10.1.1.121.6185&rep=rep1&type=pdf

Oil Sands Wetlands Working Group, (2000). Guideline for Wetland Establishment on Reclaimed Oil Sands Leases. Neil Chymko (Editor) Report # ESD/LM/00-1, Alberta Environment, Environmental Service. ISBN 0-7785-1042-5, Publication No. T/517.

Olewiler, N. (2004).The Value of Natural Capital in Settled Areas of Canada. Published by Ducks Unlimited Canada and the Nature Conservancy of Canada. 36 pp
http://www.cmnbc.ca/sites/default/files/natural%2520capital_0.pdf

Parkhurst, R. S. (1994). Suitability of Ponds Formed by Strip Mining in Eastern Oklahoma for Public Water Supply, Aquatic Life, Waterfowl Habitat, Livestock Watering, Irrigation, and Recreation. Oklahoma Geological survey. 191p. http://pubs.er.usgs.gov/publication/ofr94324

Parrish, T. L., & Anderson, S. H. (1994). Handbook of methods to reclaim wildlife habitat on surface mines in Wyoming. Laramie, WY: Wyoming Cooperative Fish and Wildlife Research Unit.

Peterson, J. (1993). Mining Methods that Maximize Reclamation Efficiency and Minimize Costs. In *Papers of the Second EPA Placer Mine Reclamation Workshop*. U.S. EPA publication # EPA 910-R-93-015.

Polster, D. F. (2013). Natural processes: An effective model for mine reclamation. In *Overcoming Northern challenges, Proceedings of the 2013 Northern Latitudes Mining Reclamation Workshop and 38th annual meeting of the Canadian Land Reclamation Association*, Whitehorse, YT.

Prunuske, Liza. (1987). Groundwork: a handbook for erosion control in northern coastal California. Point Reyes Station, CA: Marin County Resource Conservation District.
http://www.conservation.ca.gov/dlrp/RCD/Documents/Erosion%20Control/Groundwork_4-18.pdf

Pyper, M. & Vinge, T. (2012). A visual guide to handling woody materials for forested land reclamation. Oil Sands Research and Information Network, University of Alberta, School of Energy and the Environment, Edmonton, Alberta Report No. TR-31. 10 pp.

Richardson, P.J., Lundholm, J.T. & Larson, D.W. (2010). Natural analogues of degraded ecosystems enhance conservation and reconstruction in extreme environments. *Ecological Applications,* 20, pp. 728-740.

Rumble, M.A. (1989). *Surface Mine Impoundments as Wildlife and Fish Habitat* (General Technical report RM-183). Fort Collins, CO: Us Department of Agriculture Forest Service.
http://www.fs.fed.us/rm/pubs_rm/rm_gtr183.pdf

Šálek, M. (2012). Spontaneous succession on opencast mining sites: implications for bird biodiversity. *Journal of Applied Ecology*, 49, pp. 1417-1425. doi: 10.1111/j.1365-2664.2012.02215.x

Scalet, C.G., Modde T. (1984). In: F.R. Henderson (Ed.), *Guidelines for increasing wildlife on farms and* ranches (pp. 199B-212B). Manhattan, KS: Great Plains Agriculture Council, Wildlife Resource Committee, and Kansas State University.

Shirazi, M.A., Haggerty, P.K., Hendricks, C.W., & Reporter. M. (1998). The role of thermal regime in tundra plant community restoration. *Restoration Ecology*, 6, (1), pp. 111-117. 10.1046/j.1526-100x.1998.06115.x

Smith, K.B., Smith, C.E., Forest, S.F. & Richard, A.J. (2007). A Field Guide to the Wetlands of the Boreal Plains Ecozone of Canada. Ducks Unlimited Canada, Western Boreal Office: Edmonton, Alberta. 98 p. http://www.ducks.ca/assets/2012/09/fieldguide.pdf

Steiner, GR. & Freeman, RJ. (1989). Configuration and substrate design considerations for constructed wetlands wastewater treatment. In: Hammer DA (ed). *Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Proceedings from the First International Conference on Constructed Wetlands for Wastewater Treatment*. Lewis Publishers, Chelsea, MI.

Taft, O.W., Colwell, M.A., Isola, C.R. & Safran, R.J. (2002). Waterbird responses to experimental drawdown: implications for the multispecies management of wetland mosaics. *Journal of Applied Ecology,* 39, pp. 987-1001. http://safranlab.weebly.com/uploads/1/5/2/2/15220084/taft_et_al._2000_applied_ecol.pdf

Turetsky, M.R. & St. Louis, V.L. (2006). Disturbance in boreal peatlands. In R.K. Wieder and D.H. Vitt (eds)., pp. 359-372. *Boreal peatland ecosystems*. SpringerVerlag, Berlin, Germany.

Uresk, D.W. & Severson, K. (1988). Waterfowl and shorebird use of surface-mined and livestock water impoundments on the northern Great Plains. *Great Basin Naturalist*, 48, 353-357. http://www.fs.fed.us/rmrs/docs/pubs/forest-grasslands-archive/waterfowl_shorebird.pdf

U.S. Department of the Interior, Bureau of Land Management (BLM) Alaska, 2014, Mining Reclamation Bonding Guide, 39p. http://www.blm.gov/style/medialib/blm/ak/aktest/minerals/minerals_pdfs.Par.54824.File.dat/Reclamation%20Bonding%20Guide%20--Ver10.pdf

U.S. Department of the Interior Bureau of Land Management, (1992). Solid Minerals Reclamation Handbook (BLM Manual H-3042-1), 223p. http://www.ntc.blm.gov/krc/uploads/239/Solid%20Minerals%20Reclamation%20Handbook%20H-3042-1.pdf

Vinge, T. & Pyper. M. (2012). Managing woody materials on industrial sites: Meeting economic, ecological, and forest health goals through a collaborative approach. Department of Renewable Resources, University of Alberta, Edmonton, Alberta. 32 p.

https://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CCYQFjAB&url=https%3A%2F%2Fera.library.ualberta.ca%2Fpublic%2Fview%2Fitem%2Fuuid%3Af9ea0da0-b0b9-49fe-9a80-e92578836145%2FDS1%2FWoodyDebrisFinal-Issuu.pdf&ei=WodwVaSGO4TaoATMh4CQDw&usg=AFQjCNEbGdu5_Som2uyhVmxOpTrgQ0sWrw&bvm=bv.95039771,d.cGU&cad=rja

Westcott, F. & Watson, L. (2007). End Pit Lakes Technical Guidance Document. Clearwater Environmental Consultants for CEMA End Pit Lakes Subgroup, Project 2005-61. http://www.ceaa.gc.ca/050/documents_staticpost/cearref_37519/44851/t.pdf

Wiacek R., Nietfeld M. & Lazaruk H. (2002). A review and assessment of existing information for key wildlife and fish species in the regional sustainable development strategy study area. Volume 1: wildlife. Prepared for the Wildlife and Fish Working Group, CEMA. Westworth Associates Environmental Ltd, Edmonton, AB

Whiters, S.P., (Leberge Environmental Services), (1999). Natural Vegetation Succession and Sustainable Reclamation at Yukon Mine and Mineral Exploration Sites. For Mining Environment Research Group (MERG). 67p. http://www.geology.gov.yk.ca/pdf/MPERG_1999_2.pdf

Yukon Government, Environment Yukon, (1999). Yukon State of Environment. Chapter 5: Focus on ecosystems. 20p. http://www.env.gov.yk.ca/publications-maps/documents/introtoc.pdf

Yukon Placer Secretariat, (2010). Guidebook of Mitigation measures for Placer Mining in the Yukon, 132p.

http://www.yukonplacersecretariat.ca/pdf/Guidebook_Nov_1_2010.pdf

Websites

Glossary post-mining Alliance:
http://www.postmining.org/post-mining-regeneration-glossary.php

Yukon Placer Mining Act
http://www.gov.yk.ca/legislation/acts/plmi.pdf

Yukon Placer Mining land Use Regulations
http://www.yukonminingrecorder.ca/mining_acts.html

Mines Act, British Columbia, 1996
http://www.bclaws.ca/civix/document/id/complete/statreg/96293_01

Water Act, British Columbia, 1996

http://www.bclaws.ca/civix/document/id/complete/statreg/96483_01

Legislation:
-General Mining Act of 1872
-Clean Water Act of 1972, Section 404

-43 CFR Part 3800 - Mining Claims under the general mining laws, Subpart 3809 - Surface Management
http://www.blm.gov/pgdata/etc/medialib/blm/co/field_offices/uncompahgre_field/documents/placer_mining.Par.47128.File.dat/2013-0405%203809%20Regulations.pdf

-43 CFR 3809.420 - What performance standards apply to my notice or plan of operations?
https://www.law.cornell.edu/cfr/text/43/3809.420

-43 CFR 3809.401 - Where do I file my plan of operations and what information must I include with it?
https://www.law.cornell.edu/cfr/text/43/3809.401

-Alaska law AS 27.19
http://www.juneau.org/engineering/AJ_MINE/documents/AKBond_Require_Chapter27.pdf

U.S. department of the Interior, Bureau of Land Management, 2012, Alaska Placer Mining Claim Operations Guide, 4p.
http://www.blm.gov/style/medialib/blm/ak/aktest/minerals/minerals_pdfs.Par.14567.File.dat/miners_guide_12-09.pdf

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Alaska	US Army Corp of Engineers		Debby.J.McAtee@usace.army.mil
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