Chapter 2
Reclamation Policy and Scientific Context

> *Economy, which in things inanimate is but money-making, when exercised over men becomes policy.*
> –Plutarch, Lives, Crassus, 75 C.E.

2.1 Reclamation Guidelines and Definitions

A central purpose of regulatory guidelines and definitions is to provide clarity to managers and the public. Alberta reclamation policy and definitions lack clarity. Without clarity based in science, there can be no effective environmental management and no means to measure progress towards a goal. Government documents on reclamation tend to be vague and, at times, border on inchoate. Attempting to summarize the relevant reclamation guidelines and definitions is akin to describing a plume of smoke. Rather than paraphrase statements of indefinite meaning, I have provided verbatim text followed by interpretations. I ask the reader's forbearance as I attempt to find a path through the rhetorical quagmire of reclamation in the bitumen sands region.

Reclamation is defined by Alberta Environment (2011) as "the return of land and environmental values to a mining site after resources have been extracted. The process commonly includes recontouring or reshaping land to a natural appearance, replacing topsoil and planting native grasses, trees and ground covers." RSC (2010) observed that confusion as to the meaning of reclamation in Alberta has been exacerbated by use of non-standardized reclamation terms. Restoration has been defined by the Alberta Government (Powter 2002) as "the process of restoring site conditions as they were before the land disturbance." Restoration has not been widely adopted as a goal by industry and Alberta regulatory bodies (RSC 2010).

Successful reclamation requires well-defined target ecosystems for the variety of physical sites that exist within a region. Towards that end, in 1998 the Oil Sands Vegetation Reclamation Committee suggested some target forest ecosite types for uplands in the region (RSC 2010); no suggestions were provided for wetlands. Although well-defined ecosystem targets are an ecological necessity, they are not required by current reclamation policy. In the absence of empirically-based target vegetation assemblages, soils, and chemical and physical regimes, government and industry can not assess the environmental quality of industrial wetlands. Rather than set a goal of reclamation to empirically-defined ecosystems, government has set a goal of reclamation to an "equivalent land capability" defined as the ability to "support various

K. P. Timoney, *Impaired Wetlands in a Damaged Landscape*,
SpringerBriefs in Environmental Science, DOI 10.1007/978-3-319-10235-1_2

land uses after reclamation that are similar but not necessarily identical to those that existed before mining" (Alberta Environment 2008a). "Equivalent land capability" lacks both ecological precision and defined benchmarks for measuring success and is sufficiently vague to refer to virtually any condition other than abiotic terrain.

Much has been written about reclamation of Alberta's bitumen sands region, but much of that writing has taken the form of information intended for a lay audience, hoped-for outcomes, and attempts to define reclamation targets. Alberta Environment, the government agency responsible for landscape reclamation, has stated that "there is the potential for [creation of] healthy, dynamic and valuable ecosystems on closure landscapes [after bitumen mining]" (Alberta Environment 2008a). Despite a lack of evidence for successful wetland reclamation, government has produced a guideline document for wetland establishment after bitumen mining (Alberta Environment 2008a). However, much of the government's reclamation advice is based upon desired outcomes rather than on empirical evidence. For example, guidelines state that marshes can be used to increase hydraulic retention time of naphthenic acids in end-pit lakes (water bodies constructed in mined-out pits), yet 17 years after regulatory approval of the use of end-pit lakes as repositories for mine tailings and industrial process water, no end-pit lakes have been successfully reclaimed (RSC 2010).

The Alberta Government (2012) has provided an overview of reclamation in the region: "Reclamation... describes the activities undertaken to return the land to equivalent capability following mining... Revegetation is undertaken shortly after reclamation material placement. Prior to native tree and shrub planting, the first stage of revegetation often consists of seeding an annual cover crop such as barley or oats to minimize erosion, add organic matter to the soil, and provide moisture retention and protection for the seedlings... The operator monitors lands that have been reclaimed. Operators can apply for a reclamation certificate once they are satisfied that the reclaimed land will meet the pre-determined reclamation certification criteria for that landform. Reclaimed lands are not returned to the Crown until certification criteria have been met and a reclamation certificate has been issued... Reclaimed lands also include lands that are considered temporary reclamation, where further disturbance or reclamation will occur... Across the mineable oil sands region, a total of 3537 ha (terrestrial) and 1150 ha (aquatic and wetlands) had met the definition of permanent reclamation as of the end of December 2011, meaning that soils were placed and revegetation had occurred as per approved plans... In the last 5 years, almost 1300 ha have been categorized as permanently reclaimed, and will be considered for certification after a period of monitoring, and once the reclamation criteria have been met for those landscapes... The large land area categorized as reclaimed from over 35 years ago is mainly related to the work done by Syncrude in developing the wetlands and stream channels for the Beaver River diversion, completed in the mid-1970s. Although categorized as permanently reclaimed, this area may be disturbed again if mining activities are undertaken in this area."

The critical points made by Alberta Government (2012) are that reclamation is based on "equivalent land capability" (not restoration to pre-disturbance conditions); that certification means that the applicant has met the definition of permanent reclamation: "meaning that soils were placed and revegetation had occurred as per approved plans"; that "Operators can apply for a reclamation certificate once they are satisfied that the reclaimed land will meet the pre-determined reclamation certification criteria"; that "almost 1300 hectares have been categorized as permanently reclaimed, and will be considered for certification after a period of monitoring"; that reclaimed lands are not returned to the Crown until certification criteria have been met; and that monitoring of reclaimed areas must be conducted. There is much that is misleading in the foregoing reclamation statements made by government: (1) That there are pre-determined reclamation certification criteria for wetlands (there are none). (2) That government possesses vegetation monitoring data (it does not). (3) The aforementioned hectarages of lands that purportedly met the definition of permanent reclamation should not be confused with certified reclaimed lands. RSC (2010) observed that 6687 ha of land in the region were "considered to be reclaimed by industry", but as of this writing (July 2014), only 104 ha have been certified as reclaimed. Reclamation policy is discussed in Chap. 9.

Much of the research on post-bitumen mining reclamation has focussed on uplands and a disproportionate amount of attention has been focussed on woody plant species (RSC 2010). Although upland reclamation has been recognized as less intractable than wetland reclamation, establishment of upland plant communities that are characteristic of the pre-disturbance landscape may prove challenging because of factors such as increased soil salinity (Purdy et al. 2005) and atypical soil chemistry regimes (Rowland et al. 2009). Purdy et al. (2005) noted that high concentrations of some ions adversely affect plant growth and development in the region. In addition, changes to regional climate, hydrologic, and fire regimes (Timoney 2013), ongoing deposition of nitrogen and contaminants (Curtis et al. 2010; Kelly et al. 2010; Whitfield et al. 2010; Kurek et al. 2013), and unpredictable and novel successional trajectories (Johnson and Miyanishi 2008; Rowland et al. 2009) make reclamation of both wetland and upland communities an uncertain prospect. Despite decades of land disturbance and discussion, there remains disagreement over what constitutes acceptable post-disturbance communities from regulatory, industrial, public, and cultural perspectives (RSC 2010). Rooney and Bayley (2011a) have observed that the Alberta Government has accepted the large-scale conversion of peatlands to other land cover types because bitumen mining companies are not required to restore the landscape to its pre-disturbance vegetation cover. Furthermore, a significant additional number of wetlands may be lost through conversion of wetlands to post-disturbance uplands (RSC 2010).

Government and industry have maintained that reclamation in the bitumen sands region will be accomplished, but the veracity of that statement depends on the definition of reclamation. If the Alberta Government's minimalist reclamation definition is used (soils have been placed and revegetation has occurred), then virtually any site can be reclaimed with the exception of sites where extreme chemical and physical conditions preclude the establishment of autotrophic organisms (e.g., high-level radioactive waste). Would such a site meet the government criterion of "equivalent land capability"? Perhaps it would given that equivalent land capability means that a site can "support various land uses after reclamation that are similar but not necessarily identical to those that existed before mining". What is a "similar" land use and how would that definition be applied in a regulatory environment? Is a wetland site that has been mined and filled with overburden then planted to exotic, pollution-tolerant grasses equivalent to the larch fen that formerly occupied the site? The bar for reclamation has been set so low that it is not a hurdle but rather a line in the shifting sand.

If, however, reclamation certification is adjudicated based on the establishment of vegetation and animal assemblages that approximate natural reference conditions on sites that do not pose long-term risks to the biota, then reclamation after bitumen mining may not be feasible. Indeed, the Royal Society of Canada (RSC 2010) noted that bitumen developers might not apply for mining approval if they were required to restore peatlands and other wetlands because the feasibility of wetland reclamation is questioned. Whether reclaimed "equivalent" ecosystems will be ecologically functional and healthy remains an open question. Based on analyses of the data that form the body of this work, the industrial wetlands created or influenced by bitumen exploitation will be impaired relative to reference wetlands and therefore will not constitute "equivalent" ecosystems.

2.2 A Primer on Mineral Wetlands

Almost everyone is familiar with mineral wetlands; they occur in one form or another at the transition zone between uplands and open water in most parts of the world. They are found in ponds and shallow lakes, bordering water bodies, in shallow depressions, and in the deltas that form as rivers enter lakes and marine environments. They are the marshes and shallow aquatic communities of urban parks and stormwater ponds, the cypress swamps of the southeastern United States, the Everglades of Florida, the kettle hole marshes and sloughs of the prairies so important as waterfowl habitat, the salt marshes of coastal estuaries, and the northern marshes and willow swamps so important to moose, muskrat, and beaver.

The most salient characteristic of mineral wetlands is that, although they are highly productive, they accumulate little or no peat because the production of organic matter is in near equilibrium with the decomposition of organic matter. The mineral wetland communities that are the focus of this study are found in the Great Plains Prairie Biome and in the southern fringe of the Boreal Biome. These communities range from fresh to saline and from nutrient-poor to nutrient-rich. From the drier to the wetter end of the hydrologic gradient, these broad community groups (referred to as "classes" in this study) occupy a continuum and typically take the form of (a) carrs (willow thickets, savannahs, swamps); (b) dry meadows; (c) wet meadows and marshes; (d) emergent marshes; and (e) shallow aquatic vegetation (National Wetlands Working Group 1988; Fairbarns 1990; Timoney 2013).

Willow thickets are woody wetlands with a high cover ($> 50\,\%$) of *Salix*. Willow savannahs are woody mosaic wetlands with 10–50 % cover of *Salix* in a matrix of grasses and/or sedges such as *Calamagrostis canadensis* and *Carex atherodes*. Dominant *Salix* in these communities are most often *S. discolor, S. bebbiana, S. planifolia, S. petiolaris,* and *S. exigua*. Periodic standing water is common in carrs.

Whether a community is a dry meadow, wet meadow, marsh, or emergent marsh depends upon antecedent and present water conditions which can vary widely over time. Dry meadows are grass or sedge-dominated communities typically lacking standing water although they are sometimes seasonally inundated. These communities are “dry” relative to some other wetland types, but they are true wetlands given their landscape positions and typical wetland soils. Their dryness is more physiological than hydrological in that these meadows often occupy terrain of high salinity. Characteristic taxa include *Puccinellia nuttalliana, Calamagrostis, Elymus trachycaulus,* and *Hordeum jubatum.*

Wet meadows and marshes are inundated periodically or continuously with standing or slowly moving water. Vegetation cover can be nearly continuous and dominated by a variety of grasses and sedges. Water levels vary seasonally and over longer time scales but are typically near the rooting zones of the plants; sites may flood up to a maximum depth of about 30 cm standing water. Typical dominants are *Calamagrostis canadensis, Carex atherodes, C. aquatilis, C. utriculata,* and *Scolochloa festucacea,* and in saline areas and mudflats, *Spartina, Scirpus, Salicornia rubra, Triglochin, Spergularia salina, Chenopodium, Rumex maritimus,* and *Distichlis stricta*.

Emergent marshes typically take the form of vegetation patches in a matrix of open water. These marshes are usually found in water depths of 20–60 cm and are dominated by plants whose tops extend above water such as *Typha latifolia, Schoenoplectus tabernaemontani, Phragmites australis, Sparganium, Acorus*, *Alisma,* and *Sagittaria*.

In water too deep or persistent for emergent plants, shallow aquatic vegetation is typical. These communities assume a variety of forms including floating cyanobacterial (blue green algal) mats, floating and submersed *Lemna*, *Nuphar lutea*, suspended diatoms, and submersed *Utricularia vulgaris, Ceratophyllum demersum*, *Myriophyllum,* and a variety of *Potamogeton* species.

As with any categorization of natural biodiversity, the foregoing vegetation classes are a simplification. In reality, mineral wetland vegetation classes occupy a continuum in space that is dynamic in time and driven by variations in environmental conditions (Fig. 2.1). For example, an emergent marsh may undergo a transition to shallow aquatic vegetation if deep water persists over three to several years. Conversely, an emergent marsh may undergo a transition to a marsh or a wet meadow following a drawdown. Willow carrs and dry meadows may undergo transitions to wet meadow, marsh, or shallow aquatic vegetation depending on the timing and persistence of flooding. Sediment accumulation may act to desiccate a surface and drive changes towards woody dominance while intense herbivory by muskrats may convert an emergent marsh to shallow aquatic vegetation. Similarly, erosion, wave action, storms, avulsions, human-induced changes such as clearcutting, stripping of vegetation, dewatering, dumping of spoil, tailings, or fill, ditching, and channel modification can all act to drive changes in vegetation.

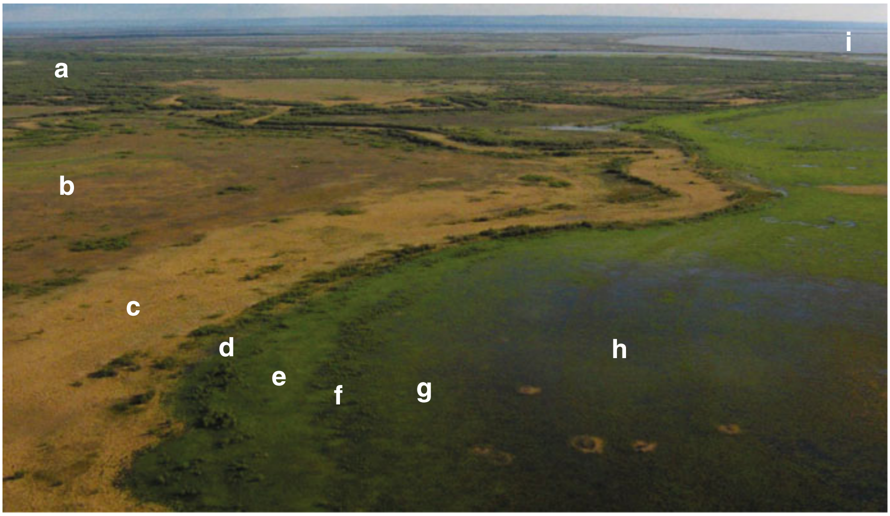

Fig. 2.1 An illustration of mineral wetland vegetation diversity. All communities in this image are mineral wetlands. (**a**) carr (mature willow thicket), (**b**) mixed marsh, (**c**) bluejoint reedgrass wet meadow and dry meadow, (**d**) carr (flooded willow savannah on levee), (**e**) marsh, (**f**) flooded young willow savannah, (**g**) marsh, (**h**) emergent marsh, (**i**) shallow aquatic vegetation. The levee at (**d**) is preventing floodwaters from reaching the vegetation at (**a**), (**b**), and (**c**). (Hilda Lake, Peace-Athabasca Delta, 2 June 2014)

2.3 A Survey of Recent Studies Relevant to Mineral Wetlands

This section summarizes findings of some recent studies that have examined chemical and biological attributes of industrial wetlands affected by bitumen exploitation. It is intended as a brief survey; additional studies are discussed as they relate to the results reported in later chapters. The survey demonstrates that exposure to industrial process water and tailings negatively affects vegetation species and community diversity, seed bank species diversity, seed germination, microbial functions and rhizosphere microbial species composition, rates of primary production and decomposition, carbon assimilation, invertebrate and zoobenthic species richness, and overall biological integrity.

Bitumen industrial process water and tailings influence wetland function. Salt and/or sulfate derived from bitumen industrial process water inhibit production and methanogenesis in cyanobacteria (Daly 2007). Microbial functions differed between the industrial wetlands and natural wetlands of similar age; amending industrial wetlands with topsoil did not affect cyanobacterial production or stimulate decomposition (Daly 2007). Tolerance of bitumen process water effluent by *Typha latifolia* has been demonstrated by Bendell-Young et al. (2000), who found that high photosynthetic rates in stressed plants did not translate into increased growth. The growth, physiology, and morphology of *Carex aquatilis* were compared in directly-affected, indirectly-affected, and natural marsh wetlands in the bitumen mining region of northeastern Alberta by Mollard et al. (2012). *Carex aquatilis* was tolerant of the pollution conditions in bitumen-affected wetlands, but its leaves and culms were shorter and accumulated more sodium than in natural wetlands. In the most-affected marshes, although the sedge survived and maintained similar net photosynthesis and transpiration rates to those in natural wetlands, *Carex aquatilis* was limited in its ability to assimilate carbon and therefore in its capacity to accumulate wetland organic matter. Significantly higher levels of salinity, electrical conductivity, sodium, and chloride, and lower oxidative reduction potentials were found in industrial than in natural wetlands.

The treatment of industrial wastewater was examined over a 3-year period in constructed *Typha latifolia* and *Schoenoplectus tabernaemontani* marsh trenches on the Suncor lease by Bishay (1998). She found that 32–99 % of the ammonia and 19–76 % of the hydrocarbons were removed from the wastewater through sediment retention and nitrification/denitrification for ammonia and through sediment retention and microbial mineralization for hydrocarbons. Under light loadings of wastewater (~ 1.6 cm/day), removal rates and macrophyte production and decomposition were not affected during the 3-year period. Under higher loadings of wastewater (4.9 cm/day), removal rates and macrophyte production and decomposition decreased. The author suggested that treatment wetlands may have had lower species diversity than natural reference wetlands. She concluded that longer-term and larger-scale studies would be required to assess the viability and sustainability of constructed wetlands.

Persistent toxicity of naphthenic acids and tailings has presented long-standing concerns. Phytotoxicity of naphthenic acid mixtures was investigated in *Typha latifolia, Phragmites australis,* and *Scirpus acutus* by Armstrong (2008). The microbial community of the rhizosphere changed with naphthenic acid exposure through an increase in potentially pathogenic bacteria and a decrease in bacteria thought beneficial to plant growth. Naphthenic acid toxicity was associated with death of plant root epidermis cells and changes in the chemistry of root pith parenchyma cells. The use of petroleum coke as a reclamation amendment to cap and isolate toxic fine tailings was investigated by Baker (2007). Addition of coke did not significantly increase concentrations of trace metals in sediment pore water or in the biota. Growth of macrophytes was not prevented by the addition of coke. Significantly, coke plots contained fewer stress-intolerant invertebrates than did reference plots. Richness of zoobenthic invertebrate taxa in reclaimed bitumen wetlands has been correlated with water pH, naphthenic acid concentration, conductivity, salinity, abundance of detritus, and sediment oxidation-reduction potential (Leonhardt 2003). Zoobenthic taxa richness was significantly lower in young tailings-affected wetlands than in reclaimed wetlands of similar ages (Leonhardt 2003).

Composite tailings inhibit seed germination from seed banks and lower the species diversity of vegetation and seed banks in reclaimed wetlands relative to natural wetlands. Crowe et al. (2002) observed that seed germination was inhibited in a composite tailings wetland, that plant diversity was lower there than in natural wetlands, and that *Typha latifolia* and *Trifolium hybridum* were tolerant of bitumen industrial process water. The negative effects of industrial effluents on seed germination may have accounted for the paucity of species that successfully colonized bitumen impacted wetlands. Marlowe (2011) examined the distribution of *Carex* species on reclaimed and natural sites on the Suncor lease. She observed a low positive association between the *Carex* taxa of natural and reclaimed sites and a reduction in *Carex* species richness with time on reclaimed sites. Reclaimed sites on sandy tailings were found to have lower *Carex* species richness and cover than did reclaimed sites on overburden. With regard to reclaimed mineral wetlands and the 11 *Carex* taxa reported in this study, data from Marlowe (2011) indicated that peak species richness (9–11 taxa) was observed within 10 years of wetland establishment, which fell to 6–7 taxa in the 11–20 year and > 20 year age-classes.

Reductions in plant species and plant community diversity have been observed in industrial wetlands relative to natural reference wetlands. Crowe (1999) studied 42 plant taxa at nine sites on or near the Syncrude lease. The wetlands on the Syncrude lease displayed a gradient of physical and chemical disturbance characterized by atypical plant taxa assemblages and a high proportion of exotic plant species. Trites and Bayley (2009) observed reduced plant species diversity and plant community diversity in reclaimed wetlands and suggested that insufficient time for dispersal may account for the absence of some communities and species such as *Carex atherodes*. Raab (2010) concluded that reclaimed wet meadows differ from natural reference wetlands in their above-ground biomass and characteristic vegetation and have lower concentrations of nutrients in the sediment. Rooney and Bayley (2011a) demonstrated that reclaimed wetlands do not support normal submersed aquatic vegetation assemblages. They cautioned that extensive loss of wetland habitat is being allowed to occur despite scarce evidence of successful reclamation.

Rooney and Bayley (2011b) noted that tailings-contaminated wetlands may suffer from hydrocarbon and salt-related toxicity and found that both tailings-contaminated and tailings-free reclaimed wetlands have lower biological integrity than do natural reference wetlands. They concluded that peatlands lost to bitumen mining will not be restored and that more than 29,500 ha of peatlands will be converted to upland forests and end-pit lakes. Rooney and Bayley (2011a, b) observed that the health of most reclamation wetlands in the region was below the standard set by reference wetlands. They stated that isolation from tailings and process-affected water will be insufficient to ensure adequate biological integrity and that other sources of stress are acting to impair the floating and submersed vegetation in shallow aquatic wetlands.

Rooney and Bayley (2011b) developed an index of biological integrity for shallow aquatic wetlands in the bitumen sands region that incorporated the species richness of floating vegetation, the percent of total richness contributed by *Potamogeton* species, and the relative abundance of *Ceratophyllum demersum*, floating-leaved species, and alkali-tolerant species. They concluded that industrial (both OSPA and OSREF) wetlands had significantly lower biological integrity than did reference wetlands.

Springer

http://www.springer.com/978-3-319-10234-4

Impaired Wetlands in a Damaged Landscape
The Legacy of Bitumen Exploitation in Canada
Timoney, K.P.

2015, XI, 218 p. 70 illus., 54 illus. in color., Softcover
ISBN: 978-3-319-10234-4