CREATING WETLANDS FOR COMPENSATORY MITIGATION BY RECLAMATION OF IRON MINE TAILINGS BASINS AT THE REPUBLIC MINE IN MARQUETTE COUNTY, MICHIGAN[1]

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Abstract. Iron mining in Michigan's Upper Peninsula has unavoidably impacted regulated wetlands. State and federal laws require these wetland impacts be mitigated by the creation or restoration of compensatory wetlands. Integrating wetland creation with tailings basin reclamation provided the necessary wetland acreage for regulatory compliance. The properties of the tailings and the design of the basins provided not only a suitable medium and location for wetland creation, but also presented substantial challenges. The creation of new wetlands required manipulation of the water levels within the basins and careful wetland design. Michigan Department of Environmental Quality permits required creating emergent, scrub/shrub, and forested wetland communities on neutral tailings. Numerous planting and seeding techniques were used to establish the different plant communities. These techniques included dormant seeding, drill seeding, aerial seeding, and transplanting wetland vegetation. Cover crops of Japanese millet (*Echinochloa crusgalli*) and red-top grass (*Argrostis alba*) were used in conjunction with hay mulch minimize erosion and sequester wind blown seeds from the surrounding native areas. Forested wetlands were established by transplanting wetland tree species at specific tree densities to compensate for expected mortality. The established wetland communities were monitored annually for a period five years to document the successful development of vegetation, hydrology, and wildlife in accordance with reclamation success criteria.

Additional Key Words: replacement wetlands, mitigation, tailings reclamation, revegetation, restoration techniques.

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Introduction

Iron mining has been an integral part of the economy of Michigan's Upper Peninsula for more than a century. Although many mines have ceased mining operations, two large open-pit iron mines, Empire and Tilden Mine, continue to operate. Impacts to state and federal regulated wetlands have unavoidably occurred during the operations of these mines. These impacts, as mandated by the corresponding regulations, must be mitigated. The mitigation of wetland impacts required Empire and Tilden Mine to begin a large scale wetland mitigation project.

In 1997, Cliffs Mining Services Company (managing partner in the mines; now named Cliffs Michigan Mining Company, CMMC) began a search for land suitable for wetland mitigation sites. These sites would provide the acreage needed to mitigate the permitted and future wetlands impacts from mining operations. With the aid of Geographical Information Systems (GIS), over 809,000 hectares (2,000,000 acres) of land in the central Upper Peninsula were investigated as potential mitigation sites. The search turned up a total of eight possible locations suitable for wetland mitigation, including Republic Mine, which was owned by the Marquette Iron Mining Partnership and its managing partner, CMMC.

Mining activities at Republic Mine ceased in 1981 and the mine was officially closed in 1996. The Michigan Natural Resources and Environmental Protection Act, Public Act 451 of 1994, as amended, Part 631 (Reclamation of Mining Lands) requires a comprehensive closure plan to be filed with the Michigan Department of Environmental Quality (MDEQ). The submitted and accepted closure plan proposed an innovative reclamation approach for part of the tailings and reuse water basins. This closure plan would not only fulfill the wetland mitigation requirements for permitted activities, but would also prove environmentally advantageous by creating wetlands and enhancing upland and aquatic habitat in the adjoining ecosystem. Working closely with the MDEQ and the U.S. Environmental Protection Agency (EPA), CMMC realized the Republic Mine site offered a unique compensatory wetland mitigation opportunity, which has also served as a successful model of wetland mitigation banking within Michigan.

Project Site

The Republic Mine is located within the southwestern portion of Marquette County of Michigan's Upper Peninsula (Fig. 1). The mine is located within the Michigamme River Watershed, which is located in proximity to the Empire and Tilden wetland impacts. During mining activities at Republic Mine, approximately 1,620 hectares (4,000 acres) of the 2,830-hectare (7,000 acres) site were altered.

Of the disturbed 1,620 hectares (4,000 acres), the wetland mitigation project encompassed 930 hectares (2,300 acres). The creation/restoration of wetland communities was conducted on 249 hectares (615 acres), with the remaining 681 hectares (1,682 acres) set aside to serve as a buffer for the created/restored wetlands. Due to the project size, the wetland mitigation project was divided into two phases Phase I and Phase II (Fig. 2). A portion of these acreages were required by the Empire and Tilden mining permits for compensatory wetland mitigation, while the remaining acreage was placed in the State of Michigan wetland mitigation bank program, as authorized by the administrative rules for Wetland Mitigation Banking under Part 303 (Wetland Protection) of 1994 Public Act 451. Upon MDEQ preliminary approval of the proposed mitigation bank, the Republic Wetlands Preserve (RWP) was formed. The RWP is a separate legal entity comprised of the Empire and Tilden Mine's partners and CMMC.

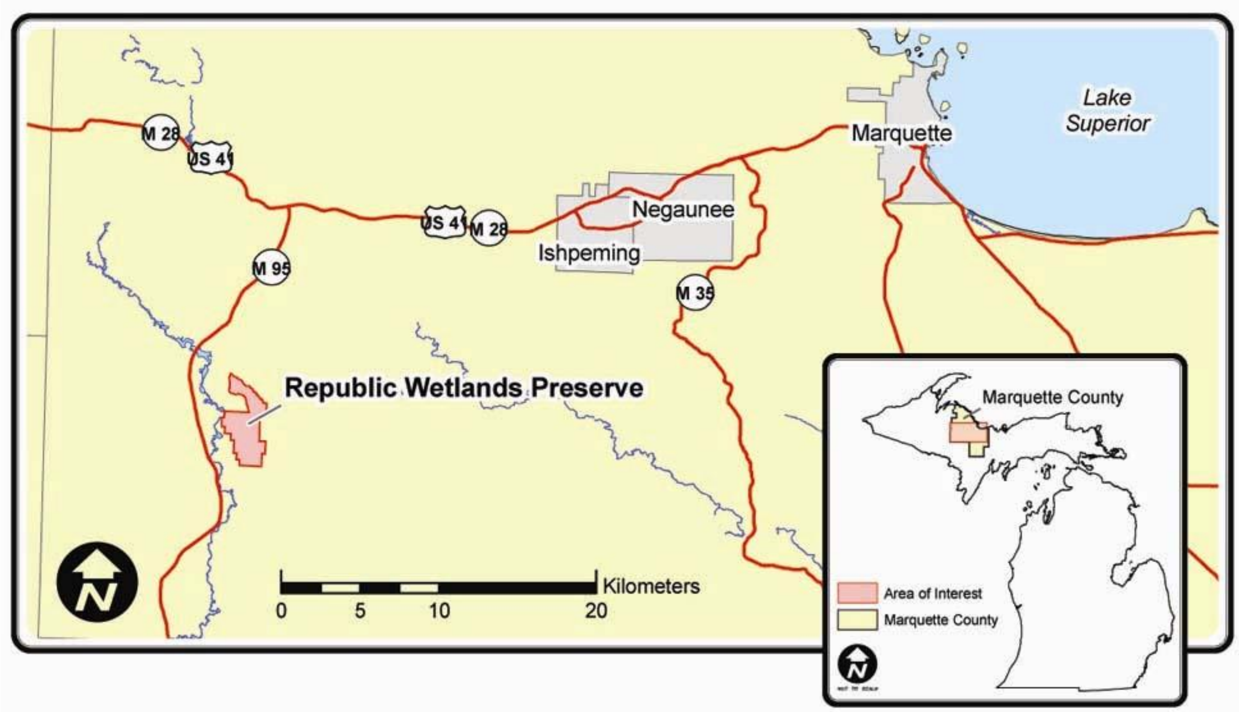

Figure 1. Republic Wetlands Preserve location within Michigan's Upper Peninsula.

The Empire and Tilden mining permits required the mitigation of emergent, scrub/shrub, and forested wetland communities. MDEQ wetland community impact permits typically specify in-kind compensatory wetland mitigation, based on the different functions and values the various types of wetland communities contribute to the ecosystem. In other words, created/restored wetland communities must replace the same type of wetland community as was impacted. MDEQ has determined replacement ratios specific to each type of wetland community, due to the difficulty and challenges associated with wetland mitigation. These ratios are specified in the administrative rules for Part 303 (Wetland Protection). The replacement ratio for forested wetlands is 2:1, which requires two hectares of forested wetland be created for every hectare of forested wetland impacted. All other wetland types are mitigated at a 1.5:1 replacement ratio. Wetland communities which have high function and values or rare wetland communities may receive higher replacement ratios.

Wetland Design Specifications

As part of the approval process for the RWP design, MDEQ specified certain measurable elements (performance criteria) that must be met in order for the compensatory wetland mitigation at the RWP to be certified and accepted (Table 1). The MDEQ performance criteria and guidelines were incorporated into the annual monitoring and used to track the development and function of the created/restored wetlands.

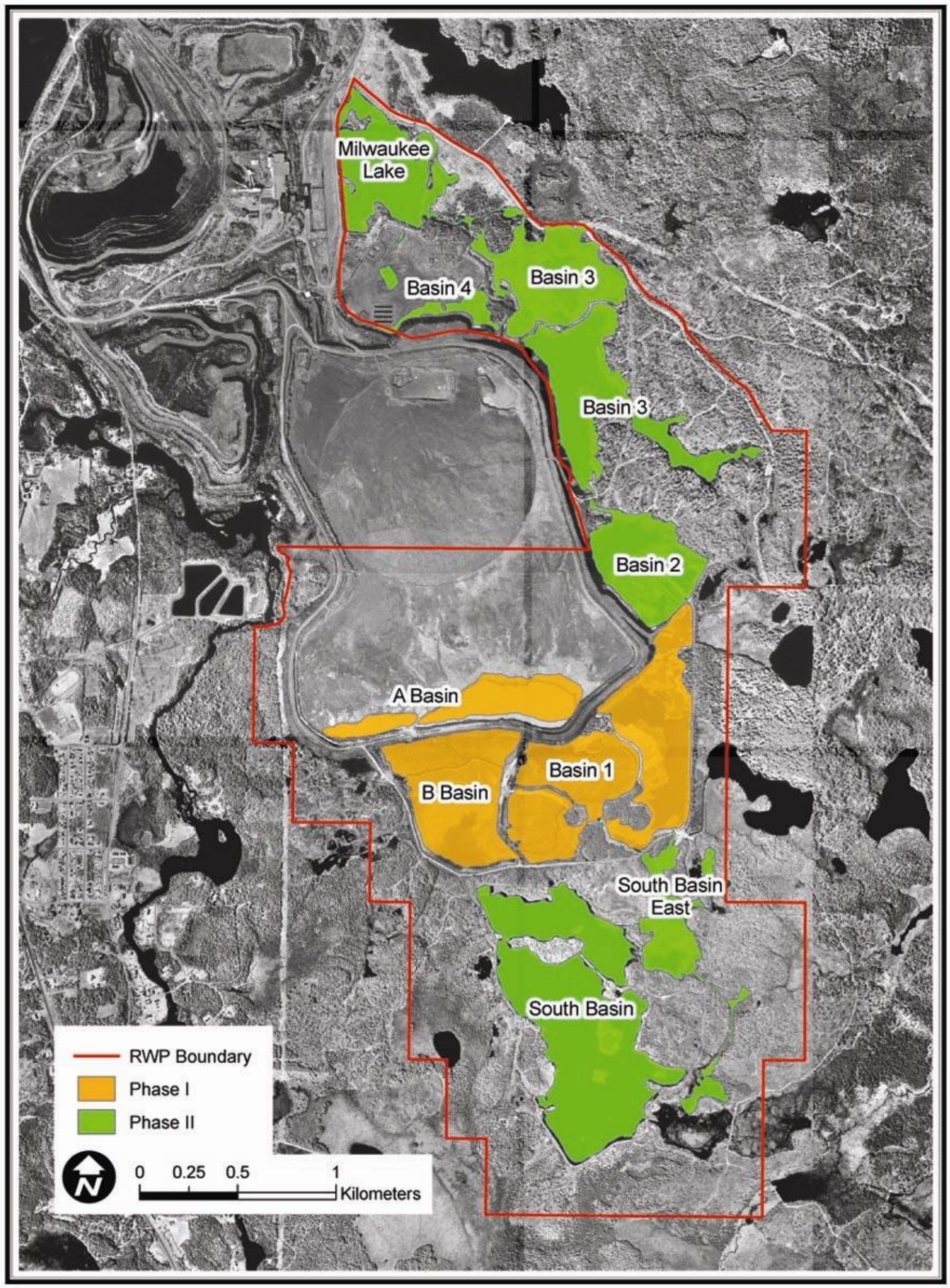

Figure 2. Republic Wetlands Preserve Site Map.

Prior to RWP wetland design, wetland delineations were conducted at the operating mines, to assess the required acreage needed for each mitigated wetland community. These delineations concluded the wetland communities surrounding Empire and Tilden Mines consisted largely of forested wetlands. The larger replacement ratio for forested wetlands (2:1) required the maximization of forested wetland mitigation acreage within the RWP. The need to create large amounts of forested wetland communities provided some of the major design challenges, due to the specific hydrologic requirements of forested wetlands**.**

Table 1. Performance Criteria for Republic Wetland Preserve.

Element	**Component**	**Characteristic (Units)**	**Quality/Criteria**
Vegetation	Forested Wetland	1. Woody stem density (stems per hectare)	741 (300 stems per acre)
		2. Density of herbaceous species (% aerial coverage)	80%
		3. Hydrophytic species (% dominance)	60%
	Scrub-shrub Wetland	4. Density of shrub species (% aerial coverage)	30%
		5. Density of herbaceous species (% aerial coverage)	80%
		6. Hydrophytic species (% dominance)	60%
	Emergent Wetland	7. Density of herbaceous species (% aerial coverage)	30%
		8. Hydrophytic species (% dominance)	60%
Hydrology	Inundation or Saturation	9. Saturation in the top 30.5 centimeters (12 inches) of the soil	12.5% of growing season
	Water Depth	10. ≤ 15% of total wetland mitigation area may be greater than 1.2 meters (4 feet) in depth	Up to 37 hectares (92 acres)
	Average Water Depth	11. Average annual water depth ≤ 45 centimeters (18 inches) inches	
Soils	Hydric conditions	12. Hydric soil morphology	Non-specific, as noted

Table 1 (continued). Performance Criteria for Republic Wetland Preserve.

Element	Component	Characteristic (Units)	Quality/Criteria
Wildlife	Waterfowl	13. Presence of target species (presence/absence)	Canada goose, mallard, hooded merganser
	Non-game Birds	14. Presence of target species (presence/absence)	Spotted sandpiper, great blue heron, swamp sparrow, yellow warbler, common yellowthroat
	Furbearers	15. Presence of target species (presence/absence)	Muskrat, long-tailed weasel, mink, raccoon
	Other Mammals	16. Presence of target species (presence/absence)	Striped skunk, deer mouse, meadow vole, white-tail deer
	Reptiles and Amphibians	17. Presence of target species (presence/absence)	Common garter snake, painted turtle, American toad, northern spring peeper, eastern gray treefrog, green frog
	Aquatic Invertebrates	18. Invertebrates (presence/absence)	Any
	Aquatic Wildlife	19. Fish (presence/absence)	Any

Methods

Tailings Basin Mitigation.

The tailings were comprised of processed and unweathered parent rock material ground to fine clay and silt size particles rather than soil. These tailings were generally slightly alkaline, typically ranging from a pH of 7.0 to 8.1. The tailings found within each basin were stratified both locally (within the individual basin) and within their location of the former mine operations recirculating water cycle. Close to the tailings discharge point the particles were coarse in texture, becoming finer in texture nearer the decant location (Ovanic 1996, Shetron et al. 1977). Progressing down gradient through the recirculating water cycle, the tailings were predominately silt and clay sized particles. The tailings were also stratified vertically, exhibiting thin bands of silt and clay sized particles separated by coarser material, possibly due to the differential settling rates or translocation of bases and clay particles as water passes through the tailings after de-watering (Ovanic 1996). The coarser tailings were excessively drained and created nutrient stress condition for plants, requiring mechanisms to retain moisture and nutrients. The thin layers of silt and clay particles tended to hold water within the tailings and were important for the retention of saturation to support plant growth. The fine particle tailings, or “slimes”, were the best soil for creating wetlands.

The physical properties of the tailings provided a suitable medium for wetland mitigation. However, the tailings also presented challenges to operating heavy equipment in the unconsolidated material. These challenges were overcome by careful wetland community design utilizing techniques for water level control, substrate management, and site tailored planting/seeding methods, which led to the successful conversion of the tailings basins into thriving wetlands communities.

Due to the substrate saturation within the tailings basins, the use of equipment with a low ground pressure signature was required, such as wide-tracked vehicles and tractors. Construction activities were often delayed until late summer when dryer conditions existed or into the winter when the tailings frozen. Mats or other auxiliary flotation devices were utilized to increase the surface area the equipment exhibited on the tailings. Vibrations from the heavy-equipment operation caused the thixotropic tailings to lose their structure and liquefy. Temporary excavations in areas inaccessible to equipment were conducted using explosive charges.

Water Level Control.

The tailings basins received most of their water balance from precipitation events. The basins generally were higher in the landscape than the neighboring undisturbed areas, so groundwater recharge was not a viable long-term source of water. Therefore, intensive water level management was conducted within the RWP to meet the wetland design criteria and the establishment of wetland hydrology. Conducting staged drawdowns to control the surface water and construction of berms and spillways are examples of methods employed to manage the tailings basins water levels.

By conducting staged drawdowns spaced at six months to one year, the water levels were sequentially lowered, exposing mud flats around the perimeters of the basins. The spacing of these drawdowns allowed time for wetland plant species to establish, which limited erosion and encouraged revegetation.

Low-profile berms were constructed within the basins to retain water within the soil profile (i.e., saturation). The berms were constructed during the winter months from tailings excavated from the up gradient side of the berm. This created a depression for water accumulation. To control flood events, spillways were placed in former runoff channels at designed elevations.

Passive-rock spillways were the preferred method to establish water level control structures at the basin outfall locations, due to their limited maintenance, unlike conventional stop-log control structures, and reduced liability. The passive-rock spillways were lined with geotextile fabric placed at the design grade, which was overlain with rock. This created a broad “seeping” spillway that discouraged beaver activity and provided adequate spillway capacity to pass flood events. This spillway design also functioned as a ford for vehicle passage.

Beavers frequently constructed dams throughout the RWP and would flood sensitive areas if left unchecked. Beaver dams were eliminated when they became problematic to forested wetland development.

Planting/Seeding Methods.

Given the substrate conditions and plant material, various planting and seeding techniques were tested for revegetation. In most cases, seed drills were found to be generally ineffective on the tailings basins at the RWP. The tailings were not easily penetrated with the seed shoe of the drills and the tailings did not close over the seed. Heavy equipment traffic in the revegetation areas was also a concern, because of the potential to damage the pioneer plant species critical to establishing plant cover. From these tests it was concluded that broadcast seeding application, dormant and aerial seeding, and manual planting were the best method for revegetation.

The limited accessibility of the tailings required either dormant or aerial seeding which was undertaken in the spring, fall, and early winter. The early winter season provided increased equipment access once the ground surfaces froze and before deep snow arrived. Species that were dormant seeded included Japanese millet (*Echinochloa crusgalli*), and red-top grass (*Argrostis giganttea*). Both of these species are defined as having positive wetland indicator status (Herman et al. 2001) and grow well in a variety of conditions. Hay mulch was also spread during the winter to retain surface moisture and provide shade coverage for the growing plants once spring arrived. Japanese millet was used extensively for aerial seeding operations, due to its large seed size and bulk density; lighter seeds such as cattails were not suitable for aerial seeding. Aerial seeding could only be used on areas with unobstructed flight paths and was applied during times of low wind speeds.

Bare-root emergent species, such as cattails (*Typha spp.*), rushes (*Juncus spp.*), and sedges (*Carex spp.*), were planted during the growing season on accessible mud flats. Labor intensive bare-root plantings were used only in localized areas. Some areas were dormant seeded at this time.

As mentioned above, Japanese millet was used extensively throughout the project and provided a cost-effective pioneer species that added organic matter to the soil surface. The millet stabilized the substrate, cooled surface temperatures, and decreased wind and water erosion. The surface organic matter sequestered wind and water-dispersed seeds from the native seed bank. As other species became established, the Japanese millet monocultures gradually diminished.

Between 1996 and 2002, over 50 hectares (130 acres) were planted with approximately 240,000 seedlings to create forested wetland communities. The tree species planted included; tamarack (*Larix laricina*), northern white cedar (*Thuja occidentalis*), balsam fir (*Abies balsamea*), green ash (*Fraxinus pennsylvanica*), red maple (*Acer rubrum*), and black spruce (*Picea mariana*). Communities of balsam poplar (*Populus balsamifera*) have voluntarily seeded in, and are the predominant species in some forested wetland communities within the RWP. The forested wetlands have been planted at a rate of 2,960 trees per hectare (1,200 trees per acre). The fast-growing, tamarack trees are tolerant of low nutrient conditions and annually exhibit the greatest growth.

Due to the low nutrients and low organic matter presented by mine tailings, planting containerized tree seedlings was preferred over planting bare root stock. The roots of the containerized seedlings are surrounded by soil medium and mycorrhizal innoculant, which appear to reduce transplant shock allowing it adapt to the tailings. Bare-root stock does not have these advantages needed for survival in the tailings substrate and mortality is typically much higher than containerized stock.

Wetland Community Monitoring

Vegetation. Wetland development has been quantitatively monitored following MDEQ permit requirements within Phase I and Phase II for a period of five years for each Phase using approved plant community, soil, and hydrology monitoring protocols (*Republic Wetlands Preserve Wetland Mitigation Monitoring Report*, 1999 through 2004). Plant community sampling typically involved the use of low-level aerial photography and randomly placed $1m^2$ quadrats for herbaceous vegetation and nested quadrats to sample woody vegetation.

Soils. Soil samples were frequently collected and analyzed by a qualified laboratory for nutrient content and organic matter development. In addition to organic matter content, the parameters analyzed included; nitrogen, phosphorus, pH, potassium, and soil electrical conductivity.

Hydrology. Wetland hydrology was evaluated using a combination of weather, stream flow, staff gage, and wetness coefficient data (Herman et al. 2001) derived from vegetation sampling.

Wetland Community Acreage. Using GIS, the created/restored wetland communities were mapped onto a project base map to confirm required acreage. The use of GIS also enabled the yearly inventory of wetland communities and acreage. The GIS products also helped to identify problematic areas requiring additional monitoring.

Results

The five year monitoring periods for both Phase I and Phase II, have been completed, respectively 2002 and 2004. Data used for discussion in this paper are derived from Phase II of the RWP project.

Forested Vegetation Development.

Woody stem density specified by the MDEQ performance criteria (Table 1). Stem density has ranged from 153 stems per hectare (61.9 stems per acre) to 20,802 stems per hectare (8,418.4 stems per acre), with an average stem density 3,965 stems per hectare (SD= 4,475) (1,604.5 stems per acre). Stem density varied considerably among sample plots within the communities. The woody stem density for the Phase II forested wetland communities ranged from a minimum of 2,224 stems per hectare (900 stems per acre) in 2000 to 5,132 stems per hectare (2,077 stems per acre) in 2004. Similarly the average stem density in Phase I and ranged from 2,587 stems per hectare (1,047 stems per acre) in 1999 to a maximum of 8,896 stems per hectare (3,660 stems per acre) in 1998.

Balsam poplar, tamarack, and red maples appeared to thrive in many locations. Browsing by whitetail deer (*Oedicelius virginiana*) appeared to limit the success of northern white cedar trees. An experimental deer exclosure for northern white cedars appeared to allow the successful development of these trees. The successful establishment of black spruce was limited to by what appeared to be fluctuating water levels at their planting location. Additional plantings of black spruce were not installed, so further analysis of the species success was not possible.

Scrub/shrub Vegetation Development.

The average aerial coverage of scrub/shrub vegetation ranged from 37 to 61 percent among Phase II sample plots. The average aerial coverage of scrub/shrub vegetation exceeded MDEQ performance criteria (Table 1).

Most scrub/shrub development was comprised of speckled alders (*Alnus rugosa*) and various species of willows (*Salix* sp.). These species occur naturally within the watershed surrounding the RWP and appeared to readily establish in scrub-shrub areas.

Herbaceous Vegetation Development.

Herbaceous wetland vegetation development has been dramatic at RWP, especially compared to the tailings basins prior to reclamation efforts (Fig. 3a and 3b). Herbaceous cover has exceeded the MDEQ performance criteria (Table 1) in all years of monitoring in all wetland vegetation community types Phase II (Fig. 4).

Figures 3a and 3b. Before (3a) and after (3b) photos of wetland community development.

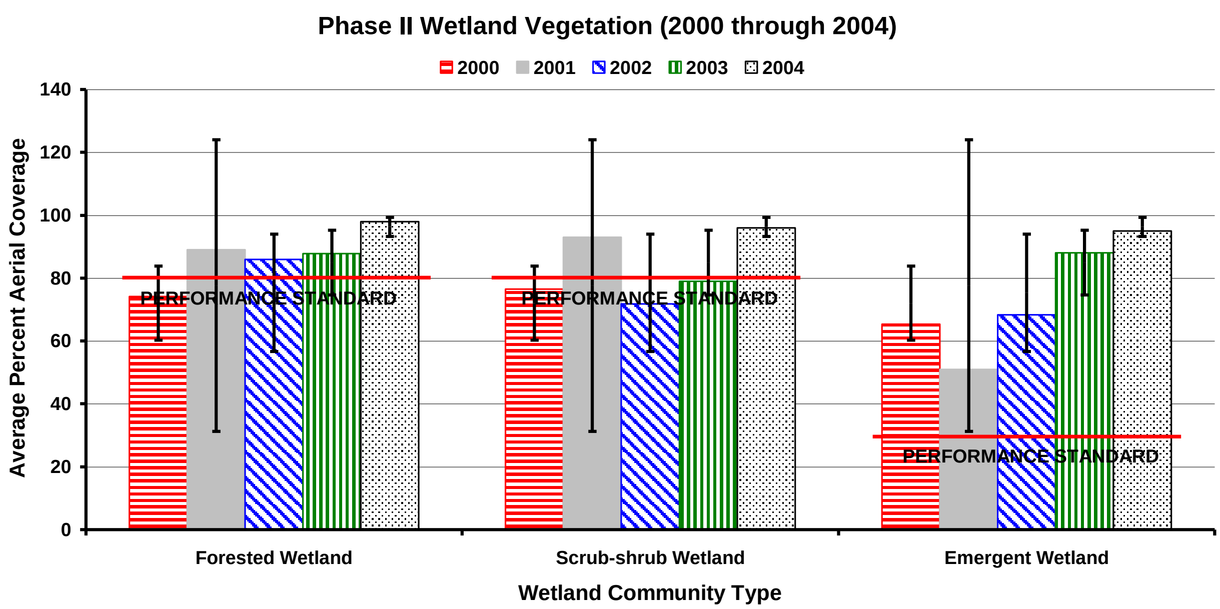

Figure 4. The average percent aerial coverage of wetland herbaceous vegetation within emergent, scrub-shrub, and forested wetlands of Phase II RWP. Note: Red line indicates performance standard by wetland type and error bars represent two standard deviations.

Wildlife Use.

Wildlife surveys, frog and toad, fish and macroinvertebrate, bird, and wildlife surveys, have been conducted on an annual basis to document the use of the wetland communities by wildlife. These surveys have been conducted as part of the MDEQ permitting process and have identified a total of 23 mammal species that have been observed on a continual basis; a total 122 bird species that have made use of the RWP throughout the five-year monitoring period; and frog and toad surveys have yielded a total of eight species. Fish surveys have identified 15 species, most of which were minnows (Cyprinidae), and 26 macroinvertebrate taxa were identified. Most of the macroinvertebrate taxa were consistent with organisms that are typically observed in ponded or low-flow aquatic environments.

As the new wetland communities became established at the RWP, wildlife use continued to increase. To date, five threatened or endangered species and one special concern wildlife species have been documented using the RWP.

- Peregrine falcons, a state and federal endangered species, were documented using the RWP on several occasions in 2000.
- Grey wolves, a Michigan endangered species have been known to use site on occasion. This observation has been supported by a Michigan Department of Natural Resources biologist who has confirmed the presence of wolves in the vicinity.
- Common loon, a Michigan threatened species on the decline, have used the open water habitats in the past, and have reared young in RWP since 2000.
- Osprey, a Michigan threatened species, have nested at RWP for the past three years, including 2004, and reared two young in 2000.
- Bald eagles, a state threatened species, have two nests within the RWP and attempted one nest in 2000, but the nest was a failure for unknown reasons. However, the bald eagles were sighted on numerous occasions in 2000 in the RWP.
- Moose tracks have been observed on dirt roads adjacent to the RWP, but moose have not been observed within the RWP to date. It is expected that moose, a special concern species in Michigan, frequent the remote buffer areas along the southern portion of the area.

Numerous other wildlife species have been identified using the RWP during various stages of their life cycle. These functions include migration/resting, feeding, nesting, rearing of young, or cover.

Mitigation and Banking Credit

With completion of the 2004 monitoring, the RWP consisted of 127 hectares (313 acres) of emergent, 44 hectares (108 acres) of scrub/shrub, and 95.5 hectares (236 acres) of forested wetland communities. The wetland banking rules provide for a partial credit for preserved wetlands and uplands in a mitigation bank. Mitigation credit for approximately 11 hectares (28 acres) of preserved wetlands and 26 hectares (65 acres) of preserved upland credit were proposed in the RWP mitigation bank. Thus, the total mitigation credit is 287 hectares (710 acres).

Allocation of Banking Credits

Approximately 146 hectares (360 acres) have been allocated within RWP for permitted projects at Empire and Tilden Mines, leaving approximately 129 hectares (318.5 acres) in the mitigation bank for future permits (Charles Wolverton, King & MacGregor Environmental, personal communication). The Republic Mine plant, pit, and rock stockpile areas are also being reclaimed, but are not part of the RWP.

Summary

In order to fulfill permit and bank agreement requirements, the RWP underwent yearly monitoring to assess whether the project is in compliance with the performance criteria. The five-year monitoring periods for Phase I and Phase II were completed in 2002 and 2004, respectively, with no additional monitoring that was required.

The establishment of the wetland habitats on the former tailings basins has been dramatic. The wetland plant communities are evolving as the indigenous native species become established. With the evolving communities, the character of the RWP is evolving, showcasing that previously mined land can be reclaimed not only with traditional methods, but with techniques designed to create high-quality diverse wildlife habitat to mitigate for impacts at other active mines.

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