

RESTORING AN ECOLOGICAL AND HYDROLOGICAL SYSTEM AT AN OPEN PIT COPPER MINE IN NORTHERN WISCONSIN¹

by

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Abstract: Kennecott Minerals' Flambeau Mine is in the process of reclaiming their open pit copper mine under the jurisdiction of Wisconsin's environmentally strict metallic mining laws. It is alleged that Wisconsin's modern mining laws are prohibitive, but the Flambeau Mine provides a case study demonstrating viable mining and reclamation within the constraints of rigorously protective regulatory requirements. Flambeau chose to backfill the open pit mine and reclaim the surface using state-of-the-science ecological restoration methods. The mine site is adjacent to the Flambeau River, one of Wisconsin's premier whitewater canoeing rivers. The company brought the surface of the former pit to its approximate original contour, rebuilt pre-existing intermittent stream channels, and developed a series of biofilters and wetlands to enhance runoff quality. Ten native plant community types were installed, ranging from aquatic emergent wetlands to northern dry woodlands and open mesic grasslands. The plant communities have been monitored for two growing seasons thus far. A trail system has been completed that opens the site to the public for recreational pursuits such as hiking, cross-country skiing, and bird watching. Bald Eagles and black bears are frequent visitors to the site. Visual inspection and statistical analysis of surface water samples present evidence that the site is approaching stabilization and that the hydrologic system is functioning as designed. The ecological sampling results for the first two years after revegetation indicate the reclaimed mine site is on the desired trajectory for plant community development, diversity, cover, plant frequency, and productivity.

Additional Key Words: mine reclamation, biofilters, native plant communities.

Introduction

The Flambeau Mining Company (Flambeau), a subsidiary of Kennecott Minerals Company, owns and operated an open pit copper mine (1993 through 1997) just south of Ladysmith, Wisconsin. In 1997 Flambeau both completed mining operations and initiated the final reclamation process. The 181-acre mine site, bounded on the west by the Flambeau River, on the east by State Highway 27, and to the north by the City of Ladysmith, is surrounded by Flambeau-owned properties comprising approximately 2700 acres that serve to buffer the site. However, there are private properties within 100 feet of the perimeter of the mine site (Hunt and Apfelbaum, 1998; Murphy and Dachel, 1996).

Unique features within and surrounding this project were:

- Flambeau River was located 140 feet from the west edge of the pit
- Intermittent streams required relocation and reestablishment
- Wetlands required mitigation
- State highway was within 1000 feet of facilities
- Private landowners were within 100 feet of the perimeter of the mine site
- Center of the City of Ladysmith was located 1.6 miles north of the mine site
- Relatively shallow groundwater table was within 20 feet of the surface

Local Site Analysis

The Flambeau project site is located in northwestern Wisconsin approximately 150 miles northeast of Minneapolis-St. Paul and 220

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miles northwest of the state capital at Madison. Immediately north of the project site is the city of Ladysmith, a picturesque rural retail community with a population of more than 4,000. Ladysmith, the Rusk County seat, lies at the junction of multiple highway and railroad systems. The surrounding area is characterized by low, gently rolling ridges (May and Dinkowitz, 1996).

The climate is temperate continental characterized by moderately warm summers and long, cold winters. Summer weather is generally mild; winter temperatures range from 0° F to 25° F and occasionally fall below -30° F. Temperature extremes range from a recorded high of 108° F to a low of -40° F. The wind directions are primarily from the south and west in the summer and north in the winter. The average annual precipitation is 31 inches. Annual snowfall averages 43 inches, typically covering the ground from late November to the beginning of April (May and Dinkowitz, 1996; WDNR, 1990).

The entire region has been glaciated and most of the landforms in central Rusk County are of glacial or water-worked origin. Adjacent to the Flambeau River are low, flat, poorly sorted, water-worked sediments with recent alluvium at the surface. A dissected terrace runs along the Flambeau River. The mine pit was partly cut into an area of pitted glacial sediments containing cobbles and large boulders. The upland area is underlain by a layer of loamy till 30 to 40 feet thick (WDNR, 1990).

The soils close to the river are well drained to excessively well-drained and formed in loamy deposits overlying sand and gravel outwash. Slopes range from gently sloping to moderately steep. Nearly level to gently sloping upland soils are somewhat poorly drained to poorly drained. Poorly drained organic soils, formed in topographic depressions under marsh vegetation, commonly adjoin upland soils (WDNR, 1990).

Groundwater in the area is of good quality, but has total dissolved solids concentrations in excess of 300 ppm. Several wells exceed the U.S Public Health Service secondary drinking water standards iron and manganese concentrations. The source of these high concentrations is believed to be the aquifer materials and is thus a natural occurrence. The

depth to groundwater in the area is less than 20 feet; the regional topography is relatively flat, with less than 100 feet of total relief between the recharge zone and the discharge zone; average precipitation results in groundwater recharge (of approximately 5 inches per year) sufficient to create a mounded watertable condition; and the glacial till is the uppermost aquifer. The low permeability till enhances the mounding effect caused by precipitation recharge. Groundwater movement in the region flows from recharge (i.e., upland areas) to discharge zones (i.e., flowing rivers, streams, springs or wetlands). Groundwater at the site flows west toward the Flambeau River (WDNR, 1990).

Flambeau has regularly monitored groundwater since the 1970s for elevations and quality. In addition to numerous wells placed up gradient and down gradient of the mine pit location, two monitoring well nests have been established on the east and west ends inside the backfilled pit area. The groundwater monitoring well system is sampled routinely for elevations and water quality parameters including copper, manganese, pH, conductivity, hardness, sulfate iron, alkalinity, total dissolved solids, color, odor, and turbidity (Murphy and Dachel, 1996).

The Flambeau River, with a drainage area of approximately 1,840 square miles, flows southwesterly entering the Chippewa River above Lake Holcombe in the southern part of Rusk County. The mine site is located approximately 15 miles above the confluence of the Flambeau River with the Chippewa River. The Flambeau River, a meandering, low-gradient (3 feet/mile) stream, supports a diverse, high quality macroinvertebrate community with a composition indicative of relatively clean, fast flowing, unpolluted water conditions. The common occurrence of mayflies and stoneflies indicates clean water conditions. The river supports an abundant, healthy, and diverse fish community. The Flambeau River in Rusk County is used for power generation, disposal of treated municipal and paper mill wastewater, recreation (e.g., fishing, boating, and canoeing), and wild and domestic animal use. The river is not used for domestic water supplies or for commercial navigation (WDNR, 1990).

The Flambeau River monitoring program began as part of the environmental studies supporting the initial mine permitting process. Upstream and downstream (within the

Waste Water Treatment Plant effluent mixing zone) samples were monitored quarterly with no significant differences between the sample sites. Flambeau River sediment was also sampled for heavy metals on an annual basis. Walleye and crayfish were sampled annually with no significant differences in the metal content of tissues sampled downstream of the mine compared to upstream of the mine (Murphy and Dachel, 1996).

Surface water sampling conducted by Flambeau and the WDNR indicated the Flambeau River has safe, well-oxygenated water with a near-neutral pH. No undue demand on oxygen was determined to exist at any time of the year. The highest levels of pH, dissolved oxygen, and total suspended solids were recorded in samples taken during the late summer. Ranges for these parameters were: pH (6.2 to 8.0) dissolved oxygen (6.0 to 12.0 mg/l); total suspended solids (about 1 to 15 mg/l). Trace concentrations of copper and zinc are not uncommon in surface waters of the area (WDNR, 1990).

The river bottom is generally made up of gravel, cobbles, and boulders with some minor areas of sand and silt. In the vicinity of the mine site, the bottom types are estimated to be 50% gravel, 35% sand, 10% cobble and boulders, and 5% muck based on habitat characterization in the field. There is very little fine-grained sediment in the Flambeau River due to the scouring action of the river. Sediment samples indicated the sediment was within normal ranges for all parameters sampled, except for mercury levels which are elevated. The mercury concentrations may be normal for the Flambeau River or may be due to past discharges from the upstream paper mill (WDNR, 1990).

Wetlands within one mile of the perimeter fence of the mine site were fitted with staff gauges and visually inspected monthly. Mitigation water was added to one wetland on an as-needed basis. Prior to site construction, wetland delineation had identified 8.3 acres of low to medium quality wetlands that would require replacement as a result of the mine. Hydric soils from the mine site wetlands were segregated and kept hydrated during the course of mining. Flambeau constructed an aquascape (designed wetland) on the mining site as replacement for one acre of lost wetlands, and to provide an area for research on construction and

vegetation establishment for future wetland replacements (Murphy and Dachel, 1996).

Eleven wetlands within the one-mile radius have been classified into six ecological types: northern wet forest; northern sedge meadow; northern wet-mesic forest; alder thicket; northern mesic forest; and bog. The largest wetland, covering 58 acres, is a perched water wetland with a combination of bog, alder thicket, and northern wet forest plant communities. The largest undisturbed wetlands on the project site prior to mining were northern wet-mesic forest wetlands 5.4 acres and 2.5 acres in size. All other wetlands on site prior to mining had been previously disturbed by human activity. Two wetlands immediately off the mining site northwest of the open pit are supported by groundwater, but are not groundwater discharge wetlands themselves. Both wetlands are located at the western edge of the till, at the foot of a sharp drop in slope. The land surface drops too quickly for the water table surface to conform and, as a result, a seep discharge occurs along the eastern edge of the wetlands. The sediments underlying the wetlands are of low permeability so the seepage on the eastern side of the wetlands is sufficient to maintain perched water wetland conditions (WDNR, 1990).

The natural communities in the surrounding area include alder thickets, northern mesic forest, northern sedge meadow, northern wet forest, northern wet-mesic forest, and open bog. Coniferous plantings are scattered about the area. The predominant species are white spruce, red pine, jack pine, and white cedar. Most of the conifer plantations stands range from 15 to 20 years in age. Upland forest is the largest natural ecological community found in the area. Dominant species present are sugar maple, red maple, basswood, white birch, quaking aspen, and large-toothed aspen. Lowland forest, classified as a northern wet-mesic forest community is present near the west end of the pit area. Major canopy trees include balsam, fir, white cedar, black ash, and hemlock.

Disturbance plant communities at the project site prior to mining, apart from active agricultural lands, included upland and lowland forests, coniferous plantings, old field, and wetlands. The disturbance agents in the area included logging, farming, drainage, sand and gravel mining, and road construction. The disturbance communities, left idle for several

years, were composed of early successional trees, shrubs, herbaceous plants, and nonnative grasses. Some of the common plants include quaking aspen, large toothed aspen, white birch, staghorn sumac, choke cherry, cattails, and numerous forbs and grasses.

Wildlife species (mammals, amphibians and reptiles) observed at the project site are similar to those of the surrounding region because of similar land uses and forest habitats. Game species observed at the site include waterfowl, upland game and white-tailed deer. Surveys conducted in the mine site area in 1972-73 and 1987-88 identified 84 and 75 bird species, respectively. The birds found in the study area were categorized into groups: summer breeding resident, year-round resident, and migrant. Sixty-four percent of the birds utilizing the study area were summer residents, 30% were permanent residents, 5% were migrants, and 1% were winter residents. Game species using the site include wood duck, mallards, American golden eye, and bufflehead. In addition, ruffed grouse and American woodcock are upland game birds commonly observed in the area. All of these birds, except the ruffed grouse, are migratory. The largest population of non-game bird species are found in the northern hardwoods/aspen-old field habitat, a diverse intermix of open areas, shrubby areas, early successional tree species, mature tree species, and pine plantations. This habitat provides a favorable mix of roosting, nesting, and feeding areas for many non-game species. There is one active bald eagle nest located about 1.0 mile downstream from the project area. An inactive nest site is located approximately 1.7 miles downstream from the site. Bald eagles are routinely observed hunting along the Flambeau River and over the mine site (WDNR, 1990).

Common species of fish in the Flambeau River include white sucker, yellow perch, and creek chub. The most common species observed by the DNR while boomshocking in 1972 were black bullhead, walleyed pike, yellow perch, red horse, northern pike, and white sucker. Three fish species - lake sturgeon, redbreast dace, and river herring - which inhabit the Flambeau River are considered rare in parts of their range. Heavy metal analyses performed on fillets and livers of selected fish collected from the study area during the fall of 1987 and spring and summer of 1988 included mercury, nickel, copper, lead, selenium, chromium, cadmium, arsenic, silver, zinc, and

uranium. The results indicate the metal concentrations in fish tissues are within acceptable ranges. The major groups of insects identified in benthic studies of the Flambeau river, were Chironomids, Ephemeropterans, and Tricopotersns. The change in abundance of specific species in the 1987-1988 surveys in comparison with the earlier studies is indicative of good water quality and an improvement in water quality since the 1970's (WDNR, 1990).

Discovery

Kennecott geologists began the modern era of base metal exploration and mining in Wisconsin in the early 1950s. Exploration for massive sulfide deposits in Wisconsin was driven by the observation that base metal deposits were present north of Lake Superior, but none were known south of the lake. It was assumed that the reason for this was the presence of extensive glacial cover south of the lake. Hence, exploration in Wisconsin focused on techniques that would lead to the discovery of blind deposits beneath the glacial cover. Exploration became competitive and was relatively unencumbered following Kennecott's announcement of the Flambeau deposit. When Exxon announced the discovery of the huge Crandon Deposit in 1976, citizens of the state became alarmed about a renewed potential mining boom, especially when the State Geologist projected 20 new mines in the state over the next 20 years. At least 13 volcanogenic massive sulfide deposits have since been discovered within the 1.86 to 1.88 billion year old greenstone rocks of northern Wisconsin. Since Exxon's discovery, exploration has been difficult due to regulation, permitting, and taxation, and made even less palatable by a sustained period of very low base metal prices. In 1993 Kennecott finally brought the Flambeau Deposit into production and in 1998, Rio Algom bought the Crandon Deposit from Exxon in an attempt to bring it on stream (Babcock, 1996; May and Dinkowitz, 1996; and Milborne, 1977).

Kennecott discovered the Flambeau deposit in November 1968, just prior to the National Environmental Policy Act (NEPA) in 1969, when their first diamond drillhole intersected 47.7 feet averaging 9.25 % copper and 0.049 opt gold. Airborne geophysical surveys delineated the Flambeau deposit in 1967 and 1968. At the same time industrial segments of the economy such as mining, steel, and auto

manufacturing were restructuring to compete in an emerging world economy. Kennecott, in spite of a deteriorating copper market and rising environmental concerns by citizens, bid unsuccessfully to secure mining permits. The mining permit hearing was canceled after Rusk County turned down the Company's zoning request (May and Dinkowitz, 1996).

Permitting

Kennecott, a survivor of a restructured base metal mining industry re-emerged in 1986 to reopen the Flambeau project and enter into discussions with local city, township, and county officials and citizens. The project plans changed such that Kennecott planned to mine only the enriched mineralization as direct shipping ore, thus eliminating on-site milling and disposal of tailings as originally proposed in the 1970s. In addition, the smaller open pit was to be backfilled and not flooded as proposed in the earlier version pit design (May and Dinkowitz, 1996).

The second mining permit application was submitted in 1989 to mine 1.8 million tons averaging 10.92 % copper and 0.088 opt gold. Once public concerns had been identified, a Local Agreement that alleviated concerns was signed and permit hearings proceeded under a more cooperative and constructive spirit. Hearings were held in 1990 and permits and approvals to commence construction were issued in January 1991. Flambeau Mining Company, a wholly owned subsidiary of Kennecott Minerals, commenced construction in July 1991 only to be stopped by an injunction. The injunction was based on the Endangered Species Act for two species, the purple warty-backed clam and an unusual dragonfly. Subsequent studies showed no impact to the species in question. Construction resumed in 1992 and ore production began in May 1993. Twenty-four plus years had elapsed from the discovery to production, though active project time was 16 years. Kennecott's bold and progressive approach (up-front planning, public dialogue, and the company's environmental commitment) created a base metal mining enterprise that was successful economically, environmentally, socially, and politically (May and Dinkowitz, 1996).

The Flambeau Mine is the only metallic mineral mine to obtain permits and operate under

Wisconsin's modern mining laws. A minimum of 4 or more years are required to complete the permitting process for operating a metallic mining operation in the State of Wisconsin. Flambeau received 11 permits as a result of satisfactorily complying with the requirements for baseline monitoring, facility design, government agency review, public comment, and a contested case hearing:

- Mine permit
- Wisconsin pollutant discharge elimination system permit (WPDES)
- Air pollution control permit
- Groundwater withdrawal permit
- One-time disposal facility permit
- Water regulatory permits (5 individual permits)
- Wastewater treatment facility approval

Numerous management plans, study reports and modeling results, later incorporated by reference into Flambeau's permits, were submitted to the Wisconsin Department of Natural Resources (WDNR). Waste rock characterization, one of the primary environmental concerns, included geochemical tests for determining acid production and neutralization potential. Type I, or low sulfur wastes (<1%) were stockpiled without a liner, whereas the Type II or high sulfur waste materials (>1%) were stockpiled over a high density polyethylene liner (HDPE) and leachate collection system. The wastewater treatment plant (WWTP) was designed on the basis of waste characterization. All Type II contact water, pit water etc. was treated in the WWTP while the Type I water was pumped to infiltration ponds. Waste rock characterization helped plan the methodology and sequencing for backfilling the open pit. Apart from the sulfur containing materials placed at the bottom, the sequence followed the original stratigraphy with till and topsoil at the surface. Airborne particulates generated by the mining and reclamation operations were suppressed by the use of WWTP effluent and monitored by high volume air samplers. Meteorological information, obtained at a station south of the mine site, continuously collected data on precipitation, temperature, and wind speed and direction that was submitted to the WDNR along with air monitoring data. The groundwater drawdown model extended 2750 feet from the edge of the mine pit. There were

no significant impacts on local wells. In fact, property owners are convinced that the palatability of their water supply improved (Murphy and Dachel, 1996).

Reclamation

In accordance with Flambeau's approved reclamation plan the open pit was backfilled and the ground surface was returned to the approximate original contour with minor approved adjustments to the grading and revegetation plans. During 1997, the open pit was substantially backfilled. Previous to backfilling, 30,000 tons of high quality limestone were co-mingled with sulfur bearing waste rock to provide neutralization of oxidation products as the groundwater table reestablished. In the summer of 1998 the subgrade relocation, topsoil placement, wetland construction, and revegetation were substantially completed in two phases. The majority of the site (~150 acres) is reclaimed as non-consumptive passive recreational land and wildlife habitat to include with trails, signage, and observation areas. The final land use for about 32 acres in the southeast portion of the site is an industrial outlot (AES, 1997; 1998; Murphy 1998).

On July 30, 1998, Flambeau received approval from the WDNR for a modification of Flambeau's Mining Permit and Reclamation Plan to: 1) delineate the 32-acre industrial outlot, 2) relocate an 8.5 acre wetland from near the Flambeau River to the area where the experimental aquascape was located and incorporate same, 3) retain an outfall as a permanent southern watershed drainage channel, and 4) adjust the onsite micro-watersheds and drainageways.

The revised grading plan reestablished drainage patterns on the site to move surface water off-site via the three intermittent stream channels. The northernmost channel was adjusted to drain the relocated 8.5-acre wetland complex located in the northeast portion of the site into natural perched wetlands adjacent to the site. The middle channel was reconfigured to run along side the north and south boundaries of the backfilled pit and drains the preponderance of the site into a 1.7-acre biofilter prior to discharge into the Flambeau River through an outfall used during mine operations. The southern channel drains runoff

from the industrial outlot through a small biofilter.

Surface water management in the upgradient areas is effectuated through the use of grassed swales, which carry water to biofilters or restored wetlands prior to flowing off site. The 8.5-acre wetland complex receives water from east of the site during runoff events and from snowmelt. Thus far, the wetland has retained open water throughout the growing season into winter. The grading plan provides topographic diversity with final elevations ranging from 1152 feet above mean sea level (msl) near the trailhead parking on the east side of the site to 1100 feet above msl near the discharge channel into the Flambeau River on the west side of the site. The broad swales and intermittent stream channels were designed at a maximum slope of 2%. Swales have gentle in-slopes of about 6:1 with 10-foot bottom widths. The bottoms are graded 2 to 4 feet below the top of the in-slope providing broad water courses. The majority of the stream channels, especially the bends, are reinforced with 6 to 10 inch glacial cobbles and soil bioengineering plantings of woody trees and shrubs, installed using the live stake methodology. The surface water management plan is designed for 100-year storm events (AES, 1997; 1998).

The mine site was brought to final grade in late August 1998. Topsoil, stockpiled on site, was relocated in sequence with till placement, grading, and ripping. Topsoil was placed by scrapers in a single pass to a minimum depth of 4 inches, shaped with a low pressure dozer, disced, and tested to meet bulk density requirements which were less than 1.75 g/cm³ (<110pcf). Hydric soils, stockpiled in a saturated condition, were relocated to biofilters and wetland reconstruction areas using scrapers and articulating haul trucks. The majority of the hydric soil went to the 8.5-acre wetland complex. Most of the wetland and biofilter areas, apart from where groundwater seeps were encountered, were prepared by excavating subgrade and placing compacted till material in the basin followed by 12 inches of topsoil, and then at least 8 inches of hydric soil. Inlet and outlets were constructed with cobble and were underlain with geotextile.

Meanwhile, other surface reclamation activities such as erosion control and revegetation were progressing on schedule and in

accordance with the terms of Flambeau's Mining Permit and approved Reclamation Plan as issued by the WDNR (Hunt and Apfelbaum, 1998; Murphy, 1998).

Revegetation

Following the preparation of the seedbed, ten planting zones corresponding to upland grassland, woodland, and wetland native plant community moisture gradients were delineated and staked out. The zones were seeded with cover crop, native grasses, and wildflowers in one operation using a Truax drill pulled behind a conventional farm tractor. The woodland zones, wet areas, and complexly shaped areas were hand broadcast. Clean straw mulch was applied at about one ton per acre and crimped where appropriate. Live plugs were hand-planted throughout the upland grassland, and woodland zones. Live plugs included penn sedge (*Carex pennsylvanicum*), wild geranium (*Geranium maculatum*), strawberry (*Fragaria virginiana*), columbine (*Aquilegia canadensis*), and woodland sunflower (*Helianthus strumosus*) among others. Aquatic/emergent wetland species rootstock was hand installed in groupings that mimicked natural distribution and for aesthetically pleasing patterns (Murphy, 1998; 1999).

In 1991 selected woody seedlings and saplings from the mine site were transplanted to a temporary nursery for the purpose of reforestation of the site once mining had ceased. Flambeau planted additional nursery stock tree seedlings into the nursery during 1993 and 1995. These plantings provided information on species hardiness, cultural methods, and availability of materials at the time of final reclamation, which was of extreme importance. Trees from the on-site nursery were transplanted throughout the woodland sites using a skid steer-mounted tree spade except for a dozen larger trees that were moved with a 55-inch truck-mounted spade. Trees were placed a minimum of 12 feet apart and located in ecologically correct positions on the landscape based on moisture, aspect, and soil conditions. Trees were watered, mulched, and staked if needed. Tree and shrub seedlings were hand planted and staked. Tree guards were placed on deciduous woody seedlings for protection from predation and desiccation. The woodland zones were irrigated with an overhead sprinkler irrigation system. Water was withdrawn from the Flambeau River to irrigate

and reflood the wetland and biofilter areas (Murphy and Dachel, 1996; Murphy, 1998; 1999).

Ecological Monitoring

An important requirement in the terms of Flambeau's Mining Permit and approved Reclamation Plan is ecological monitoring. Section 5.11.4.8 of the original approved Reclamation Plan contained in Flambeau's Mine Permit Application (MPA) addressed the monitoring requirements and performance standards for implementation on the reclaimed mine site (Appendix 1).

Typifying or representative areas from the ten major planting zones, as described in Flambeau's report entitled *Surface Reclamation Implementation Plan for the Flambeau Mine*, were quantitatively and qualitatively sampled. Appendix 2 presents the quantitative ecological methods that were selected to comply with the monitoring requirements and performance standards in Appendix 1.

Methods

Fifty-meter linear transects were installed on-site using the randomly chosen intersection points of a geo-referenced grid as the end points of the linear monitoring transects. Transect direction was established with randomly generated compass bearings. Starting from each randomly chosen grid point, a 50-meter measuring tape was pulled taut along the randomly chosen compass bearing. The transect end points were GPS surveyed and permanently marked with ground flush steel rebar rod of 24 inch length by 0.5 inch diameter. Sample quadrats are placed at 5-meter increments along each transect. At 5-meter increments along the measuring tape, a circular meter square quadrat is centered over the tape and the herbaceous plant percent cover (a measure of the vertical projection of photosynthetic leaf area) is measured in each quadrat.

The recorded data at each quadrat includes:

- Percent cover by species including all woody plants of less than 0.5-meter height
- Percent cover by substrate type (fine litter, 1 hour combustible fuels), coarse litter (>1 hour combustible

fuels), rock, bare soil, and bryophytes (mosses, lichens, liverworts, etc.)

The following information and results is derived from the data collected from each quadrat:

- Frequency of occurrence (percent of the total number of sample quadrats in which each species occurs)
- Richness (number of plant species)
- Erosion control effectiveness (average \pm Standard Deviation for percent bare soil and percent total plant and substrate cover per quadrat)
- Absolute and relative cover
- Frequency of occurrence
- Importance value (IV): the summation of relative cover and frequency of occurrence for a given species
- IV, percent cover, and frequency of occurrence data is calculated for each plant species for each transect, community type, and overall mine performance level

A variation of this method is used to measure wetland and biofilter vegetation. The plant species encountered in each quadrat along a wetland or biofilter transect are measured by:

- Percent cover by species within a quadrat
- Frequency of occurrence (percent of the total number of sample quadrats in which each species occurs in wetlands and biofilters)
- Estimated number of stems for each plant species encountered in a quadrat (density)

Plant species richness and diversity in each community type was sampled using the Timed Meander Search (TMS) technique. The TMS technique involves slowly walking through each plant community type and listing new plant species while blocking the search into increments of time. The TMS sampling technique covers representative areas of the site regardless of whether regular or random transects exist at a given location. The TMS method results in time-equated plant species lists. The data contribute to the development of total plant species lists and help quantify diversity for each plant community.

The data contribute not only to the species lists and diversity measurements, but statistics can be used to help characterize community development and compare different areas within the same community type (Hunt and Apfelbaum, 1998).

Woody vegetation equal to or greater than 0.5-meter height was sampled along the identical 50-meter linear study transects laid out for percent cover as described above. Parallel belts, two meters wide and nested within the 50-meter transects, were laid out on both sides of a study transect. The woody plants ≥ 0.5 -meter encountered within each 4 meter wide x 50-meter linear belt transect were measured for:

- Percent canopy intercept (vertical projection of photosynthetic leaf area over measured lineal distance of transect tape)
- Survivorship (measured as alive or dead canopy intercept)
- Diameter and if appropriate, Diameter at Breast Height [DBH- 4.5 feet above ground]
- Number of stems for each woody plant species

Herbaceous plant biomass is measured in at least 25 randomly selected meter square quadrats in the grassland community. At five-meter increments and offset one meter along selected permanent transects, a circular meter square quadrat is randomly placed on the ground and all vegetation in the quadrat is included in the sample for biomass using the following method:

- Vegetation is clipped with hand clippers to within 1-inch of the ground surface
- Clipped materials is placed in pre-labeled (transect #, quadrat #, and date) sealable "grocery style" paper bags and sealed
- Samples are air dried until consistent weight is measured
- Air-dried weight is the recorded biomass measurement

Along with the permanent transects used to measure vegetation (e.g. annual use of identical quadrat and belt transect locations), a number of different randomized transects are installed each year. An appropriate number of the additional random transects are determined statistically. These random transects are sampled in the same way as the permanent transects. Data are

summarized, analyzed and compared statistically with the analysis from the permanent transects. The statistical comparison evaluates whether the paired samples are from significantly similar populations, and if so, confirms the assumption of random sampling, which strengthens statistical robustness (Hunt and Apfelbaum, 1998).

The Mine Permit and approved Reclamation Plan require characterization and analysis (evaluation) of the wildlife habitat created as a result of the mine reclamation implementation. The wildlife habitat evaluation procedure documents and characterizes the following:

- vegetation diversity
- vegetation community structure
- vegetation function in terms of productivity
- potential for use by approved animal species

Above and beyond the required wildlife habitat evaluation procedure, Flambeau documents and characterizes bird and butterfly use of the habitats created through surface reclamation activities. Herbaceous plant cover, frequency of occurrence, importance value, richness, biomass, and woody plant structural measurements are used to generate habitat structural, functional, and spatial measurements that are used as input into the wildlife habitat evaluation procedure. Time trend and spatial trends in wildlife use, using species from avian and invertebrate taxonomic groups, is developed from annual and cumulative data. During 2000, Flambeau will identify the appropriate species to be used in the evaluation. The wildlife habitat evaluation procedure will further characterize and document the development of habitat and correlated responses of the key wildlife groups proposed to be included in this analysis. This process will result in the development of a general model for the evaluation of surface reclamation habitat(s) and the key wildlife groups that use the habitat(s). Observed use of the surface reclamation habitat(s) by Federal or Wisconsin sensitive, rare, threatened, or endangered species will be noted. Confirmed identifications of special status species and descriptions of the level of interaction between species and the surface reclamation habitat(s) will be documented. Other more generalized and casual observations of wildlife by Flambeau staff will also be documented. These observations will help characterize the development of the trophic

structure occupying the habitat created at the reclaimed site (Hunt and Apfelbaum, 1998).

Above and beyond the required wildlife habitat evaluation procedure, Flambeau documents and characterizes bird use of the habitats created through surface reclamation activities. Therefore, breeding birds are sampled as a measure of wildlife habitat quality. Richness (number of species of birds), breeding bird density (number of breeding pairs by species) and spatial and habitat-use affinities (mapped locations of bird use relative to habitat types) are the avian variables measured. Sampling is conducted once during the period late May through late June during the breeding season. Sampling points are spatially correlated or may coincide with transect end points and habitat types. A modification of the Reynolds et al. (Ibid.) method, similar to the Goff's proposal for surveying plants, was used. Identification and nomenclature for birds follows Robbins and the American Ornithological Union. Avian breeding status on the site follows the criteria adopted by the Illinois Department of Conservation (IDOC) for the Breeding Bird Atlas Project (Hunt and Apfelbaum, 1998).

Above and beyond the required wildlife habitat evaluation procedure, Flambeau documents and characterizes butterfly use of the habitats created through surface reclamation activities. Butterflies were chosen as another key animal group for the wildlife habitat evaluation procedure because invertebrates play an indicator role in the ecological health of grassland ecosystems. Butterflies are surveyed using standard walking survey procedures along the identical linear vegetation transects. All locations and species of butterflies are mapped and enumerated. Species, numbers of observations of species (frequency), and habitat affinity as determined by mapping locations of use are the key variables measured, analyzed and summarized for this group. Any unknown butterflies are sampled for laboratory identification. The taxonomic authorities for Butterflies are Opler and Krizek and Scott (Hunt and Apfelbaum, 1998).

Results

Flambeau's goal is to achieve or exceed the reclamation performance standards required under the permit and has targeted its Notice of Completion (NOC) submittal for the fourth quarter of the year 2000. Pursuant to the permit, ecological monitoring would continue for a

minimum of 4 years beyond the submittal of the NOC. At that time, Flambeau intends to request the Certificate of Completion (COC) from the WDNR.

First year sampling results showed that agronomic grasses, used as cover crop, dominated the site as expected. The mine site, exclusive of the industrial outlot, averaged 59 percent vegetative cover. The upland grassland zone, the dominant zone on the site, averaged 74 percent vegetative cover. Native grasses and forbs were widely dispersed throughout the site. Forty-seven native plant species were observed on the mine site. Second year sampling results showed that the reclaimed site averaged 89 percent vegetative cover and native plant species accounted for nearly 50 percent of the total cover. A total of 250 plant species were found on site and approximately 70 percent are native species (Murphy, 1998; 1999).

Woody vegetation sampled both by the belted transect method described herein and a total population census revealed 1) greater than 80 percent survival using both methods and 2) the belted transect method only marginally adequately represented all species planted. The belted transect encountered 65 percent of the woody species planted (15/23) (Murphy, 1999).

Wetland and biofilter vegetation has vigorously propagated. The original planted stems and rootstock are no longer discernible. The mean cover was about 96 percent. The number of plant species varied from about 8 to more than 31. The ratio was 60:40 grass/sedge to forb. The 1999 sampling results indicate the reclaimed mine site is tracking on the desired trajectory for plant community development, diversity, cover, plant frequency, and productivity (Murphy, 1999).

The water management plan for the site is working as planned. During periods of snowmelt and rainfall, surface water flowed into and through the wetlands and biofilters via the reconstructed swale system. By visual inspection, it was evident by water clarity that the site was approaching stabilization and that the hydrologic system was functioning as designed. Flambeau River water quality samples collected upstream and down from the reclaimed site in March and April during runoff events confirmed there was no significant difference (Murphy, 1999).

In the spring of 1999 bird studies were conducted on site. Fifty-five bird species were reported as breeding either on site in the reclaimed habitat or in immediately proximal habitat. Twenty-three species were identified exclusive to the reclaimed habitat. Eleven species were identified as passerine. Woodlands and wetlands had the highest bird richness ratings, but the site is already important for several grassland birds including horned larks and savanna sparrows. Butterfly surveys were conducted spring and fall 1999. A total of 12 butterfly species were recorded as using the reclaimed habitat. They consisted of migrants, residents, and native and nonnative species. Migrating species accounted for the majority of observed butterflies (Murphy, 1999). Flambeau conducted its first prescribed burn of the area in mid-April, 2000 (personal communication with Jana Murphy, Flambeau Environmental Manager).

Literature Cited

- Applied Ecological Services, Inc. (AES). November 1997. Supplement to the surface reclamation plan for the Flambeau Mine, Flambeau Mining Company, Ladysmith, Wisconsin. Prepared for Flambeau Mining Company. 25 p.
- Applied Ecological Services, Inc. (AES). March 1998. Surface reclamation plan for the Flambeau Mine. Prepared for Flambeau Mining Company. 10 p. with Appendices.
- Babcock, R. C. 1996. History of exploration for volcanogenic massive sulfides in Wisconsin: A commemorative volume: Institute on Lake Superior Geology Proceedings, 42nd Annual Meeting, Cable, WI v. 42, part 2, p. 1-16.
- Hunt, T.C., and Steven I. Apfelbaum. December 1998. Surface reclamation ecological monitoring program: Flambeau Mine, Ladysmith, Wisconsin (AES#98-450). Applied Ecological Services, Inc., prepared for Flambeau Mining Company. 17 p.
- May, E. R., and S. R. Dinkowitz. 1996. An overview of the Flambeau supergene enriched massive sulfide deposit geology and mineralogy, Rusk County, Wisconsin: A commemorative volume: Institute on Lake Superior Geology Proceedings, 42nd Annual Meeting, Cable, WI v. 42, part 2, p. 67-94.
- Milbourne, R.H. 1977. Wisconsin mining impact study: prepared by the Wisconsin Department of Revenue for the Upper Great Lakes Regional Commission. 147 p.
- Murphy, J. E., and R. T. Dachel. 1996. Case study of environmental requirements for the permitting, operation, and reclamation of a metallic mineral mine in Wisconsin-Flambeau Mine: A commemorative volume: Institute on Lake Superior Geology Proceedings, 42nd Annual Meeting, Cable, WI v. 42, part 2, p. 95-106.
- Murphy, J. E. 1998. Annual reclamation report: Flambeau Mining Company, N4100 Hwy 27, Ladysmith, Wisconsin, p. 15, Attachments A-J.
- Murphy, J. E. 1999. Annual reclamation report: Flambeau Mining Company, N4100 Hwy 27, Ladysmith, Wisconsin, p. 10, Attachments 1-7.
- Wisconsin Department of Natural Resources (WDNR). 1990. Final environmental impact statement Flambeau Mining Co.-Copper Mine Ladysmith, Wisconsin. Hunt, T. C. (Contributing author), 184 p.

Appendix 1.

Monitoring requirements and performance standards for implementation on the reclaimed mine site. Clarifications and additional details are *italicized* in the following summary of the requirements and standards contained in the MPA:

- ✓ Frequency and duration of monitoring
 - *Minimum of annual vegetative monitoring beginning prior to submittal of the Notice of Completion (NOC) and ending at Certificate of Completion (COC)*
- ✓ Measurements
 - Percent cover
 - 70 percent cover averaged over the site at 90 percent statistical confidence
 - As total cover (vertical projection of plant parts) by species
 - Annual measurement over entire site at no less than 160 randomly placed one square meter quadrats
 - Measurements occur during mid-August to early September
 - Measurements correlated with aerial color infrared photography
 - Sample design shall accommodate all community types and moisture gradients *evaluated*
 - Number of sample units per community type based on mean/variance tests (may be fewer than 160 quadrats)
 - Biomass
 - Total above ground herbaceous biomass determined twice, once for the NOC and once for the COC
 - Diversity
 - Harvest data shall come from no less than 25 randomly placed one square meter quadrats
 - At COC no less than 80 percent of biomass at NOC at 90 percent statistical confidence
 - Frequency and timing of controlled burns will not interfere with measurements
 - *Grassland community type only*
 - Frequency of occurrence by species *for terrestrial and aquatic vegetation*
 - Similarity of standing crop to original mixture shall consist of no less than 80 percent of the initially planted species at 90 percent statistical confidence
 - Minimum of 15 planted species per community type, except wetlands which shall have a minimum of 12 planted species
 - *Performance standard does not apply to that area of the site designated as the industrial outlot so long as that area, or any portion of it remains designated as the industrial outlot*
 - *Measurement determined using quadrats along transects and timed-meander searches*
 - Survivorship of woody plant stock
 - Determination by representative population sample
 - At the NOC and again at the COC no less than 80 percent of the

- initially planted species must survive in a similar proportion to the initial planting
 - Evidence of vigor and health
- *Wetland and biofilters* vegetation
 - Frequency of occurrence by species for aquatic vegetation
 - Species similarity of standing crop to initial planting will be no less than 80 percent at 90 percent statistical confidence
 - Density (*stem counts, or estimated stem counts depending on the species*) by species of standing crop will be no less than 80 percent at 90 percent statistical confidence to the initial planting
 - Minimum of 12 planted species
 - *Density and percent cover determined using quadrats along transects and timed-meander searches (described below)*
- Wildlife habitat
 - Habitat evaluation procedure (HEP) conducted on reclaimed wetland and terrestrial communities, *except the industrial outlot*
 - Evaluation procedure initiates two years after reclamation begins (Year 2000) and conducted once per year for three years thereafter
 - *Performance criteria are not quantitative, however representative areas of each community type will be evaluated for animal use and re-colonization,*

with a focus on

butterflies and birds

- *HEP will be considered a qualitative measure of trophic activity and faunal re-establishment on the site relative to the goal of habitat restoration*
- *By first quarter 2000, appropriate species for HEP will be selected*

Appendix 2.

The quantitative ecological methods selected to comply with the monitoring requirements and performance standards.

- ✓ Percent cover
 - Line transects and nested 1 square meter sample quadrats
 - Permanent transects comparison with annually randomized transects
 - Aerial color and infrared photography correlated with site
- ✓ Biomass
 - Total above ground biomass
 - Line transects and nested 1 square meter sample quadrats
- ✓ Diversity
 - Line transects and nested 1 square meter sample quadrats
 - Comparison between permanent and annually randomized transects
 - Timed meander search
 - Nested belt transects-cover intercept and diameter breast height
- ✓ Survivorship of woody plant stock
 - Nested belt transects-cover intercept and diameter breast height
 - Aerial color and infrared photography correlated with woodland units
- ✓ Wetland vegetation evaluation
 - Timed meander search
 - Line transects and nested 1 square meter sample quadrats
 - Aerial color and infrared photography correlated with wetland units
- ✓ Wildlife habitat evaluation procedure
 - Total above ground biomass
 - Line transects and nested 1 square meter sample quadrats
 - Comparison between permanent transects and annually randomized transects
 - Timed meander search
 - Nested belt transects-cover intercept and diameter breast height
 - Point-plot avian census technique
 - Butterfly transects
 - Derived measures
 - Frequency of occurrence
 - Importance value
 - Richness
 - Habitat rating