

RECLAMATION OF WASTE ROCK STOCKPILES AT CLEVELAND-CLIFFS MICHIGAN OPERATIONS¹

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Abstract: Cleveland-Cliffs Michigan Operations (CCMO) produces 13.0 million long tons of high quality iron ore pellets annually for consumption in the blast furnaces of both domestic and foreign steel producers. Annual total material movement is approximately 80 million long tons, of which half is waste rock. Since the inception of mining in 1962, over 1.3 billion long tons of waste rock have been placed in waste rock stockpiles. Geographically the mining area is rolling to rugged topography. Landforms are the product of repeated continental glaciation and vary from till and outwash plains to steeply sloped hills with dendritic surface drainage patterns. Sandy glacial drift is the parent material for soils in the area, the thickness of which varies from bedrock to several hundred feet thick in localized areas. The local climate is classified as cool to temperate with 110 to 130 frost-free days and the area generally experiences a surplus water regime with an annual precipitation of 35 inches, of which half is in the form of snow. Current and developing reclamation practices for waste rock stockpiles will be reviewed. These include the use of paper mill residuals, municipal biosolids and a developing program with composted municipal solid waste. In addition to the pulp and paper mills, waste water treatment plant and county landfill, other entities involved include the county soil conservation district, a forestry services contractor, an explosives contractor, and a well drilling contractor.

Additional Key Words: municipal biosolids, paper mill residuals, composted municipal solid waste, ammonium nitrate, trees and shrubs.

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Background

Cleveland-Cliffs Michigan Operations (CCMO) is an iron mining, concentrating and pelletizing facility owned and managed by the Cleveland-Cliffs Iron Company. CCMO is located near Palmer, Michigan on the Marquette Iron Range in Michigan's Upper Peninsula. Current mining and processing operations consist of four active open pits and two processing facilities. Michigan is the second largest producer of iron ore in the United States and CCMO is the leading mineral producer in the state.

The early 1950's saw technological advances that allowed the open pit mining and processing of low-grade iron ore in northern Michigan. The orebodies are hard, banded, sedimentary deposits of magnetite and hematite containing fine particles of iron that require complex processing to transform it into marble-sized iron ore pellets for consumption in the blast furnaces of both domestic and foreign integrated steel producers. Mine development began in the early 1960's with construction of the initial plant and production of the first pellets in late 1963. Annual production is 13.0 million long tons of high quality iron ore pellets. Through 2006 total pellet production has exceeded 500 million long tons.

The mine operates under State of Michigan Metallic Mineral Mining Permits No.1 and No. 2 under provisions of Part 631, Reclamation of Mining Lands, of the Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended. The Michigan Department of Environmental Quality (MDEQ), The Office of Geologic Survey administers Michigan's mining reclamation programs. CCMO is the only active iron mines in Michigan.

Mining Methods and Reclamation

Mining is a shovel/loader and truck operation. The ore body varies in thickness from 1,500' to 3,000' and dips steeply at 30 to 40 degrees, resulting in deep pits that are currently 800' to 1200' deep. Glacial drift materials cap the mining areas, varying from rock outcrops to several hundred feet thick in isolated areas, and are used to sheath the surfaces and outside slopes of waste rock stockpiles. With deep pits, the volume of waste rock mined exceeds the supply of overburden required for final stockpile reclamation. To avoid unnecessarily disturbing additional lands to obtain soil for reclamation purposes, CCMO works with the Michigan Department of Environmental Quality, to continuously evaluate innovative reclamation methods. Waste rock stockpiles are the primary landforms reclaimed at the current stage of mine life. Approximately half of all the material moved is waste rock. Since inception of mining in 1962, over 1.3 billion long tons of waste rock have been placed in stockpiles.

Geographic and Climatic Setting

Geographically the mining area is characterized as rolling to rugged topography. Mining is located in highland areas, which are old mountain remnants and are among the highest points in Michigan. Elevations range from 1,300' to 1,900' in elevation, whereas most surface land in Michigan lies between 600' and 1,000', with nearby Lake Superior having a mean elevation of 602'.

Climatologically the area is classified as cool to temperate with an average annual temperature of 40 F degrees, a high relative humidity, and a low percentage of possible sunshine.

The July average temperature is 65 F degrees. The close proximity of Lake Superior, 10-15 miles, makes the climate highly variable with rapid swings in temperature and precipitation. Annual precipitation is 35 inches of water equivalent of which 50-60% is in the form of snow. The area generally experiences a surplus of water regime. There are 110 to 130 frost-free days, although patchy frost is possible throughout the summer. Winters can be severe with heavy snowfall and the summers hot with unpredictable droughty periods (NWS, 2005).

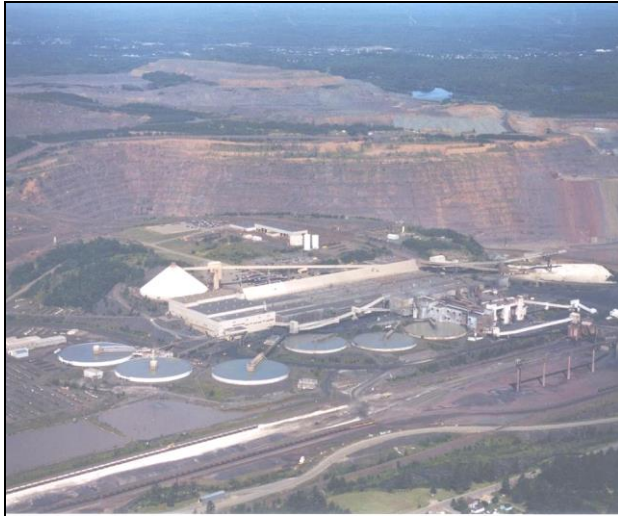


Figure 1 Michigan Operations East Facility



Figure 2 Michigan Operations West Facility

Soils and Vegetation

Soils in the region are the result of continental glaciation with the final retreat occurring 9,500 years ago. Since the retreat a variety of glacial materials blanket the landscape. The northern latitude and the cooling effects of Lake Superior result in a mean annual soil temperature of less than 36 degrees Fahrenheit. The mean evapotranspiration rate is approximately 19 inches (Shetron and Ovanic, 1995). Overall, climatic conditions are conducive to vegetation with timing of planting for seed germination critical. Most planting is done between May 15th and June 15th to take advantage of good spring moisture conditions created by snowmelt. Hot, dry summer months and cold, harsh winters limit the time frames when vegetation can be planted, germinate, and grow to establish the effective soil covers that are needed for grasses, shrubs and tree seedlings to meet final reclamation requirements.

Vegetation assemblages are primarily climax hardwood and conifer stands composed of sugar maple (*Acer saccharum*); hemlock (*Tsuga Canadensis*); red maple (*Acer rubra*); red oak (*Quercus rubra*); yellow and white birch (*Betula* species); trembling aspen (*Populus tremuloides*), big tooth aspen (*Populus grandidentata*), and balm of gilead (*Populus* species); red pine (*Pinus resinosa*), jack pine (*Pinus banksiana*), and white pine (*Pinus strobus*) and balsam fir (*Abies balsamea*) on well drained upland soils. Poorly drained lowland soils generally support northern white cedar (*Thuja occidentalis*) and spruce (*Picea* species) (Sommers, 1978).

Waste Rock Stockpile Characteristics

Forty-plus years of mining activity have resulted in rock stockpile site conditions that vary widely in characteristics. Site-specific application plans must be developed for each stockpile. Early stockpiles, dating to the 1960's, had minimal terraces with few restrictions on lift heights. Michigan reclamation law now mandates stockpile lifts no higher than 50 feet with 50 feet wide terraces.

Geomorphically the rock stockpiles resemble western mesas with talus slopes that have been exposed to the local climate for only a few years. Analyses of the waste iron formation contained in the stockpiles have shown that there is nothing detrimental to plant growth. Water quality monitoring has demonstrated that water quality is not degraded when stormwater percolates through the stockpiles and discharges into nearby surface waters.

The natural dark color of the stockpiles creates extreme surface temperatures during the growing season. The stockpiles become heat islands having the same effect created by buildings and paved streets in urban environments. Surface temperatures vary widely between day and night (Shetron, 1982). Temperature profiles on the stockpiles fluctuate with barren rocks having the highest variation and successfully vegetated areas having the lowest. Vegetated soil cover reduces surface temperatures during the growing season. By early fall, surface temperatures moderate and remain close to ambient temperatures (Ovanic, 1996).

With a 50 percent post blasting swell factor and a 36-degree natural angle of repose the stockpiles are loosely consolidated with poor moisture retention (Bohnet, 1996). They are devoid of organic carbon and lack plant essential nutrients. The few poorly naturally vegetated areas are characterized by low species and low structural diversity. Sparse pioneer aspens and birches are the predominant vegetation. Their limited growth and pale chlorotic color demonstrate a severe nutrient deficiency. In essence, the rock stockpiles are well-drained and nutrient poor. They are not naturally functioning systems and are not in equilibrium with the surrounding environment. With low water retention capabilities, adverse surface temperatures, a lack of organic matter, microbial populations, and the soil nutrients required for successful vegetation, the stockpiles do not provide a medium that supports and sustains vegetation.

Municipal Biosolids

Background

Marquette, Michigan is the largest city in northern Michigan and located fifteen miles from CCMO. The Marquette Area Wastewater Treatment Facility (MAWTF) provides wastewater treatment for the nearly 30,000 permanent residents of the City of Marquette, Marquette Township, and Chocolay Township, with a service area of 15 square miles. Constructed in 1980, the facility uses Rotating Biological Contactors as its secondary treatment process for an average of 3.1 million gallons of wastewater per day. Nearly all of the facility's wastewater is domestic, with less than 0.1% from industrial sources. The facility uses anaerobic digesters to produce nearly 2 million gallons of biosolids containing an average 6% solids content, and over 500 dry tons of solids annually.

Prior to 1994 biosolids produced at the facility were used exclusively in agricultural applications. By the fall of 1993, none of the approved application sites were available for a variety of reasons. Some sites no longer met the soil requirements. Increasing public opposition

based on misperceptions and a lack of understanding made agricultural application increasingly difficult. Finally, although Marquette County is over 1,200,000 acres in size, it is 90 percent forested, populated by only 45,000 residents, and is Michigan’s largest county with very little land actively farmed to produce a crop.

Attempts to apply biosolids in silviculture applications proved unsuccessful. The county, who is a major landowner, was unwilling to restrict land use for a six-week period as required following the application of Class B biosolids. Other major landowners were unwilling to restrict public access to their property as it may have jeopardized their “Commercial Forest Reserve” (CFR) status and subsequent tax breaks. Discussions were initiated between MAWTF and CCMO. Both parties recognized that municipal biosolids could supply the organic matter and the pool of nutrients to support plant growth as well as the energy source for microbes. An agreement between MAWTF and CCMO was reached that allowed for the application of biosolids on mine reclamation sites.

Regulatory Requirements

The biosolids produced at MAWTF meet USEPA (United States Environmental Protection Agency) and MDEQ “Class B” pollutant ceiling concentrations, Class B requirements for pathogens, and vector attraction reduction requirements. The USEPA Part 503 Biosolids Regulations that govern general treatment requirements, pollutant limits, management practices, operational standards, requirements for frequency of monitoring, record keeping, and reporting are strictly followed.



Figure 3 Applying Biosolids



Figure 4 Final Stockpile Slope

Program Description

Loose overburden materials from mining areas are hauled to stockpile final slopes and dumped three loads deep along the crest. A dozer then pushes this material down the slope. These applications continue until approximately two-thirds of the slope is covered. The overburden is allowed to go through two annual freeze thaw cycles prior to hydro-seeding, fertilizing and mulching. On stockpiles with smaller fifty-foot lifts, one winter is sufficient for settling.

All reclamation work is done by contract to CCMO specifications with the contractor providing all equipment, seed, fertilizer and mulch necessary to complete the job. Mulching rates have been three tons of hay per acre. Seed mixes are standardized using WDOT

(Wisconsin Department of Transportation) and MDOT (Michigan Department of Transportation) mixes. These mixes are comprised primarily of cool season grasses such as Kentucky bluegrass, perennial rye, hard fescue, tall fescue and creeping red fescue perform the best. Once vegetation is established biosolids applications begin.

The rate of biosolids application is based on agronomic rates and past experience for successful vegetative growth. Applications are made twice a year in the spring and late summer. The high moisture content (92%) from the biosolids benefits vegetation. Monthly surface water quality monitoring is conducted at all locations where runoff and or infiltration from stockpiles with biosolids applications occur and is submitted in an annual report to MDEQ. Twenty-two parameters are monitored; pH, temperature, dissolved oxygen, conductivity, hardness, nitrates, TKN, P, NH₄, As, Ba, Cd, Cr, Cu, Pb, Hg, Se, Ag, Zn, SO₄, total Mn and total Fe. Should a significant rainfall event (>0.5") occur within a few days of the biosolids application, surface water samples are collected and documented.

Biosolids application rate for new vegetation is 2 - 5 tons or 60 to 150 lbs. N per acre. For established vegetation there is a need for additional annual applications for maintenance of soil condition and continued growth. Established vegetation is defined as that which has been developed for 2 to 3 years. The target application on these sites to maintain rich growth is 2-3 tons or 60 to 90 lbs. N per acre. If applications are discontinued, vegetation is self-sustaining, but shows signs of stress and is more vulnerable in drought conditions.

Program Summary

Analysis shows that there is a decrease with depth of all metals listed in the Federal 503 standards. Soil analysis at 6"+ depths and analysis of surface water indicates no migration of nutrients in the areas fertilized with biosolids. Application of biosolids to new vegetation enhances growth, provides moisture, and increases moisture retention capabilities of the soils. Established vegetation becomes self-sustaining and does not require additional applications, but further applications will enhance growth.

Paper Mill Residuals

Background

With rising landfill costs, increased regulations and greater expenses associated with permitting new landfills, northern Michigan's two largest pulp and paper mills began a concerted effort to find beneficial alternatives for disposal of paper mill residuals. In addition to landfilling, one mill investigated silviculture applications and the other established a farm management plan for agricultural application of residuals. Climatic conditions, soil types and a short growing season in northern Michigan are not conducive to farming, resulting in limitations to large-scale agricultural land application programs. A typical agricultural land application program consisted of 50 farms of 20 acres each during a short growing season. For the remainder of the year residuals had to be disposed of by landfilling or incineration. For these reasons and others, landfilling, agricultural and silvicultural applications were not entirely satisfactory and the pulp and paper mills continued to investigate other alternatives.

Simultaneously, faced with a limited supply of soil for mine reclamation and increased regulatory requirements, CCMO began to investigate alternative growth mediums for final reclamation. Mining adequate quantities of overburden to sheath stockpiles would unnecessarily disturb additional lands and was not permitted by the MDEQ. It became evident that an

alternative growth medium was required that had substantial quantities of organic matter for successful long-term plant growth. Economic availability of large quantities of peat moss, composts and farm manures were not available or necessarily desirable. After considerable investigation, paper mill residuals became the most likely candidate for creation of an alternative growth medium. In effect, an artificial growth medium capable of sustaining plant growth could be created.

Regulatory Requirements

In 2003, recognizing that paper mill residuals are quality economic by-products for mine reclamation that provide large quantities of nutrients and organic matter, CCMO and northern Michigan's two largest pulp and paper mills, initiated discussions with the MDEQ. In Michigan, industrial applications (as opposed to agricultural applications) of paper mill residuals may be obtained by submitting a Self-Declaration Plan in general accordance with Part 115, Solid Waste Management, of the Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended. Specifically, Part 115, Rule 117 states, "A person may petition the director to designate a solid waste as an inert material appropriate for a specific type of reuse instead of virgin material." Both mills submitted Self-Declaration Plans for long-term application of residuals to rock stockpiles. After extensive reviews, MDEQ granted residuals from both paper mill's an "inertness designation for rock stockpiles" and accepted a CCMO Site Management Plan to use the residuals to develop a process to vegetate barren rock stockpile benches and slopes meeting final reclamation requirements. Additional long-term agreements with the paper mills completed the framework for this multi-year program that began in 2003.

Program Description

Site preparation is minimal. Large mining dozers, loaders and graders are used for initial preparation of application sites. The rate of application is based on agronomic rates and site specific experience for successful vegetative growth. In addition to nutrients, the high moisture content of the residuals (50%) benefits vegetation. Applications increase the organics and water retention capabilities of the soils helping to maintain growth. Plant tissue sampling, Sufficiency Range System and DRIS Index (Diagnosis Recommendation Integrated System), with residual analyses are used a diagnostic tool to determine the lack or excess of plant nutrients that may impact the plants establishment and productivity.

Residual application rates for stockpile surfaces are generally 12" in depth or approximately 200 dry tons per acre. On stockpile slopes the rate of application varies from 100 to 400 dry tons, where the physical size of the slope material dictates the application rate. All residuals applications are done by contract to CCMO specifications with the contractor providing the equipment to complete the job. Residual applications on level stockpile surfaces and slopes are made primarily with a small loader. Residuals crust over when spread requiring mechanical tillage or scarification to break up the crusted surface prior to planting. A small dozer pulled disk harrow has proved the most effective.

By coupling paper mill residuals analytical data with plant tissue analyses a nutritional profile of the residual-plant system is developed that is studied to monitor performance of nutrient cycling. One of the management objectives of this reclamation program is to develop an input/output balance resulting in a residual-plant nutrient equilibrium that sustains vegetation. A primary objective of data collection is to develop recommendations to manage and establish vegetation on rock stockpiles. The residuals have a CEC four times that of the local sandy glacial till indicating a greater ability to provide nutrients for plant use.



Figure 5 Before: Residuals Application



Figure 6 After: Final Vegetation

Table 1 General Characteristics of the waste rock and paper sludge.

General Physical & Chemical Properties	Waste Rock	Paper Sludge
Texture	Highly Fragmented	Smooth
Compaction	33% Voids	Well Compacted
Drainage	Well Drained	High Water Retention
Organic Matter	None	50 % Organics
Soil Content	None	50 % Clay & Calcium
PH	7.5-8.5	7.5
Nitrogen	None	1.50 %
Phosphorus	None	0.75 %
Potassium	None	0.10 %
Toxicity to Vegetation	None	None
Color	Dark Gray, Black	Light Gray, White
Reflectivity	Low	High

Hydroseeding is the preferred method of application on both slopes and level surfaces. Seed and fertilizer are applied together. Mulching rates have been three tons of hay per acre. Seed mixes are standardized using WDOT (Wisconsin Department of Transportation) and MDOT (Michigan Department of Transportation) mixes. The mixes comprised primarily of cool season grasses such as Kentucky bluegrass, perennial rye, hard fescue, tall fescue and creeping red fescue perform the best. Maintenance of seeded sites is done as required until the site stabilizes and the vegetative community becomes self-sustaining.

Refertilization to supplement the initial base application is done as needed to improve vigor and density. After 3-5 years the plantings on residuals reduce their reliance on commercial fertilizers. Fertilization recommendations are determined by annual plant tissue and residual fertility analyses.

Monthly surface water quality monitoring is conducted at all locations where runoff and or infiltration from stockpiles with residuals applications occur and made available to MDEQ.

Baseline data is collected for 8-12 months before residual applications. Each sample is tested for the twenty-two parameters: PH, temperature, dissolved oxygen, conductivity, hardness, nitrate, total Kjeldahl N, P, NH₄, As, Ba, CD, Cr, Cu, Pb, Hg, Se, Ag, Zn, SO₄, total Mn and total Fe.

Program Summary

The organic nitrogen and carbon decrease with mineralization of the cellulose-rich organic matter. Approximately 25 percent of the total N content of the residuals becomes available over a growing season. Generally, within three to four years the nutrients in the paper sludge are consumed. With nutrient recycling, established vegetation becomes self-sustaining and does not require additional applications of fertilizer, but further applications will enhance growth.

This reclamation program is in its fourth growing season. Numerous field trials, studies, data collection and monitoring have been conducted. Interpretation of data collected over time guides decisions with respect to residual application rates, reclamation plant species selection, planting patterns, usage of fertilizers, and other reclamation aspects. Individual residual and plant species characteristics, seasonal variability, insects and disease and variability of the rock stockpile surfaces can make it difficult for absolute interpretations. The program over four years has gone from a research program to one with standardized methodology.

Marquette County Conservation District

The Marquette County Conservation District (MCCD) was established in 1955. In Michigan, a Conservation District is a local entity of state government that operates under the Conservation District Law, Act 297, P.A. 1937. MCCD is managed by a five-member board of directors who are elected for 4-year terms by county residents at the district's annual meeting. The local district's mission is "to provide for the conservation and restoration of resources in Marquette County through forestry and wildlife practices, watershed management, soil erosion control and education". These services are available to landowners and residents of Marquette County.

Every spring, the Conservation District has an annual tree and shrub sale. As a non-profit organization the tree and shrub sale is the Conservation District's biggest fundraiser. Funds from the tree sale helps the Conservation District support public service programs that are offered to Marquette County residents at no cost, cost-shared or for a small fee. These programs include forest and wildlife management, native plants, soil and sedimentation control, presentations, tours and workshops, and conservation education providing information and presentations to schools, youth organizations, and the general public. The sale includes conifers for reforestation; trees and shrubs for wildlife, berry bushes, fruit trees, native wildflowers and conservation merchandise.

A primary goal of CCMO's reclamation programs is to establish wildlife habitat. This goal is met in three ways; initial planting of annual grains such as barley and oats; long-term plantings of perennial grasses and legumes such as clovers, fescues, ryegrass and wildlife habitat shrubs and trees. The small trees and shrubs provide breeding and nesting sites along with shelter and thermal cover for wildlife. The vast aerial extents of the stockpiles, which cover thousands of acres, require hundreds of thousands of plantings.

It was logical that CCMO and the Conservation District combine synergies and so an informal partnership developed. Currently CCMO supports the annual tree sale by purchasing wildlife shrubs for reclamation sites. The Conservation District's annual tree sales before

receiving support from Michigan Operations were approximately 25,000 trees, shrubs and other plants. With the involvement of Michigan Operations, annual sales have doubled and tripled. Michigan Operations has made annual purchases of 20,000 to 80,000 trees and shrubs, creating good will and keeping reclamation dollars in the local community, where it is used in the various Conservation District programs to educate and help residents. CCMO has purchased approximately 30 species of shrubs, small trees and warm season grass species from the Conservation District. As part of this cooperative arrangement, the Conservation District forester and native plants specialist visit reclamation sites annually reviewing program successes and offering suggestions for future plantings.

A sampling of Conservation District plantings include Chokecherry, (*Prunus virginiana*); Black Chokecherry, (*Aronia melanocarpa*); Roselow Crabapple, (*Malus sargentii*); Highbush Cranberry, (*Viburnum trilobum*); Wild Black Currant, (*Ribes americanum*); Red Osier Dogwood, (*Cornus stolonifera*); American Elderberry, (*Sambucus canadensis*); Red Berried Elderberry, (*Sambucus pubens*); Common Hackberry, (*Celtis occidentalis*); American Hazelnut, (*Corylus americana*); Washington Hawthorne, (*Crataegus* sp.); American Mountain Ash, (*Sorbus americana*); Nannyberry, (*Viburnum lentago*); Ninebark, (*Physocarpus opulifolius*); Sand Cherry, (*Prunus pumila*), Serviceberry, (*Amelanchier arborea*); Snowberry, (*Gaultheria hispidula*); Speckled Alder, (*Alnus rugosa*); Staghorn Sumac, (*Rhus typhina*); American Wild Plum, (*Prunus*); and Witch Hazel, (*Hamamelis virginiana*).

Forestry Contractor - Hybrid Aspen Nurseries

Michigan Operations annually plants between 50,000 and 100,000 trees for reforestation of mine reclamation sites. The trees are both coniferous and deciduous. Cost, quality and adaptability to reclamation sites are regularly reviewed. As part of this annual analysis, in 2002 hybrid aspens were investigated. Hybrid aspens because of their rapid growth rate quickly establish protection against wind and water erosion. They do not tolerate shade, making them ideal for planting in the vast open areas of rock stockpile benches and slopes.

Hybrid aspens were first planted in limited numbers in 2002 on the surfaces and slopes of several stockpiles. These were bare rootstock obtained from the Michigan Department of Natural Resources (MDNR) Wyman State Nursery. They did well and that success encouraged further test plantings of hybrid aspen cuttings. In 2003 Michigan Operations partnered with a local forester and the Michigan State University (MSU) East Lansing Research Station to plant four test plots of hybrid aspens from MSU stock on waste rock stockpiles. Each of the four plots contained a clone of a different manmade cross (hybrid) between members of the genus *Populus* (Aspen, Cottonwood, Poplar) of which there are approximately thirty native species. The success of this initial hybrid aspen planting program resulted in a plan to create additional on-site nurseries as the primary source of these trees for future reclamation work.

Encouraged by the results using MDNR and MSU stock, CCMO established additional hybrid aspen nurseries from stock used in mine reclamation at the nearby Humboldt Mine. The Humboldt Mine represented the first modern development of low-grade taconite ores in Michigan. The mine opened in 1954 and closed in 1970. Mine reclamation at Humboldt began in the 1970's under the direction of the Michigan Technological University School of Forestry and Environmental Science Department. Hybrid aspens were planted as part of final mine reclamation. Most of these trees have not only survived, they have thrived. Cuttings, or clones,

from these trees replicate the superior disease resistance and hardiness of the parent in Michigan's northern climate. Working with the forester, CCMO began harvesting cuttings from these trees in the winter of 2003. Over two winters CCMO harvested approximately 20,000 hybrid aspens from Humboldt cuttings for establishment of the nurseries and planting on mine reclamation sites. Aspens planted in these nurseries from various sources are rapidly becoming an excellent source of cuttings for future mine reclamation. CCMO has found that even late July plantings develop adequate roots. One hybrid species had 100% mortality, emphasizing the importance of using test plots and selecting the proper hybrid species. Managing the nurseries provides a continuous supply of hybrid aspens from cuttings for use in future mine reclamation.



Figure 7 Humboldt Hybrid Aspen Windbreak



Figure 8 Hybrid Aspen in Nursery

CCMO continues to work closely with this forestry contractor who has a local greenhouse and grows seedlings from locally harvested seed. CCMO and the forester study reference communities on mine sites to determine what species have the highest survivability. Seedlings from these species are then grown in the greenhouse for Michigan Operations reclamation sites. Numerous innovative and cost-effective ideas have resulted from this partnership.

Explosive's Supplier – Ammonium Nitrate

CCMO worked with the mine's explosives supplier to develop a program using ammonium nitrate (34-0-0) as a cost-effective fertilizer on reclamation sites. Prior to implementation, the program was carefully reviewed. Of the three major plant nutrients N, P, and K, N is the nutrient most required by plants.

Nitrogen fertilizer supplies have become increasingly tight and their cost has soared. Blasting 70 – 80 million long tons of rock annually requires large amounts of NH_4NO_3 . CCMO's explosive supplier buys NH_4NO_3 in bulk quantities by the rail car at a cost that is considerably less than other commercially available fertilizers. While not a balanced fertilizer, the lower cost of NH_4NO_3 from the mine's explosive supplier has allowed CCMO to expand the use of fertilizers on mine reclamation sites.

The fertilizer is bagged in 50-pound bags for ease in handling and delivered on-site. Use of this fertilizer is particularly effective on sites that are inaccessible or where a four-wheeler with a broadcaster would damage small seedlings. CCMO uses six hand broadcasters to spread the NH_4NO_3 using contracted workers.

Well Drilling Contractor - Pumping Technology

Preparation of rock stockpile sites for paper mill residuals can consume considerable dozer hours. To minimize dozer hours and spread residuals more uniformly CCMO is currently working with the largest well drilling company in northern Michigan to develop a pilot plant utilizing pumping technology to repulp paper mill residuals and spray them on steep stockpile slopes resulting in more complete coverage and deeper penetration of the rock surface, providing for deeper root penetration while creating a wicking effect for capillarity to bring moisture to the slope surface. This pilot plant will be tested in early 2007 utilizing a large oil field pump.

Additional Paper Mill Projects

CCMO continues to work with other three additional paper mills. Also, CCMO is working with one existing supplier of residuals to determine the practicality of using paper mill wood ash, another paper mill waste, as an amendment to the residuals on reclamation sites.

County Landfill – Composted Municipal Solid Waste

Michigan Operations and the county landfill are investigating the use of composted municipal solid waste (CMSW) as a growth medium for vegetation of rock stockpiles. The mix found in the CMSW compost has been found to be a highly effective soil amendment. The material has been used extensively in the southern states since the mid-nineties and its performance has made it a favorite for large volume contractors. The diversified nutrient mix found in the product is highly effective in producing quality growth. With MDEQ approval a test plot will be developed in 2007.

Summary

Cleveland-Cliffs Michigan Operations has formed numerous reclamation programs that promote cost-effectiveness, innovation and excellence of mine land reclamation. Many of these programs benefit local communities, businesses and agencies. This is part of Cleveland-Cliffs Michigan Operations proven commitment to maintain the high quality of northern Michigan's environment. For over forty years Michigan Operations has produced high quality iron ore pellets that have become fine steel products for families, businesses, agriculture, transportation and national defense.

Literature Cited

- Bohnet, E.L. and L. Kunze. 1990. p. 485-494. Waste disposal – Planning and Environmental Protection Aspects. Surface Mining. Society for Mining, Metallurgy, and Exploration, Inc.
- National Weather Service. Marquette, Michigan Office. 2005.
- Ovanic, C. E. 1996. p. 12-41 Summary of 25 Years of Reclamation Research on Cleveland Cliffs Mine Wastes. Michigan Technological University Forestry Department.

Shetron, S.G. and C.E. Ovanic. 1995. Succession of Plant Communities on Reclaimed Iron Tailings in Northern Michigan. Proceedings 1995 American Society for Surface Mining and Reclamation Conference.
<https://doi.org/10.21000/JASMR95010708>

Shetron, S.G. 1982. Cleveland-Cliffs Mine Waste Reclamation Guide, Marquette Iron Range Properties.

Sommers, L.M. 1978. Atlas of Michigan. p. 14-39. Department of Geography, Michigan State University Press.