TAILING RECLAMATION = OASIS = CLOSURE

By

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Abstract: Landscapes are composed of soils, vegetation, microclimates, geomorphic surfaces, and hydrology that have evolved over time. What we view is a mosaic of different kinds of cover and surfaces linked with one another. Disturbances such as roads, urban sprawl, forest clear cuts, or mining are discrete patches that disrupt the appearance of natural landscape. Closure activities of a mine site signify the final stage of an ongoing operation that may require considering three options to return of the mine site to some semblance of the premine landscape. To implement closure requires knowledge of the plant growth medium and its ability to sustain vegetation. Planning is essential and implemented with sufficient lead-time to be workable and economically feasible to satisfy closure regulations. This paper discusses reclamation experiences basic to closure activities. Examples are drawn from three decades of study on iron tailings in Northern Michigan.

Additional Key Words: Ecosystem, soil quality, succession, vegetation, impacts.

Introduction

Closure, or decommissioning, of a mine represents the final stage of several stages for a mining operation at a particular site on the landscape. Several stages associated with the development of the mine site could be considered prior to closure. They are: a **pre mine stage**, development **active mine site stage**, which could include a mill, development of an ore deposit [open pit or underground to produce the ore for the mill], numerous waste deposits such as tailings or stripping waste rock dumps; **deactivation** stage where by the mine site is "mothballed" with limited reclamation, to await new technology or favorable economics to reopen and process ore; the **closure** stage which represents a time period in the life of the mine when various components of the mine site are reclaimed, and removal of buildings and equipment. Management will be required to monitor the performance of closure activities, and beyond, as they pertain to regulatory requirements.

With the above scenario are concerns. First is the implementation of planning for development of the mine site to lessen the impact on the local environment. Several elements need to be considered: **First** a site description of the area to be opened up for mining according to regulatory requirements; e.g. wetland permits, or to establish a premine ecosystem base; Secondly a fine tuned plan of the site; for example proposed buildings, roads, location of short as well as long term waste deposit sites, past and current permitting requirements; and **Thirdly** a plan outlining and stating clear rehabilitation objectives that meets with confidence reclamation procedures past, current and anticipated future permitting requirements.

Since mining is only a temporary impact on the landscape, but impacts can be long lasting, and that closure is imminent during the life of the mine, reclamation planning is essential throughout the life of the mine. From the outset we need to consider the following reclamation objectives: **whether the mine site impact will allow reclamation to be consistent with premine landscape ecosystems and its biodiversity, or to establish similar conditions so that with time ecological biodiversity will be similar to premine conditions; or to remodel the site that is substantially different to premine conditions but yet comparable to premine landscape ecosystems values.** [AIMC 1996]

This paper discusses three decades of reclamation activities on tailings at active mine sites that are, or will be, subject to closure at some point in time. Our objective is to present experiences learned over these past decades to develop

Paper presented at the 2001 National Meeting of American Society of surface Mining and Reclamation, Albuquerque, New Mexico, June 3-7, 2001. Pub. By ASSMR, 3134 Montavesta RD. Lexington KY 40502.

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Proceedings America Society of Mining and Reclamation, 2001 pp 479-491
DOI: 10.21000/JASMR01010479

https://doi.org/10.21000/JASMR01010479

reclamation scenarios relevant to closure activities. However, it is the obligation of the mine operator to be sure all closure permitting requirements are satisfied and issued prior to reclamation activities.

PreMining Environment

The landscape environment of a mine site can be divided into a number of individual components. For example, it can be partitioned into political, economic, geographic, broad macro ecosystem with numerous micro ecosystems, geomorphic surfaces, and hydrologic segments such as streams, rivers, and wetlands. Landscapes are assemblages of numerous natural processes and human activities that interact within the physical environment. The structure of the environment at all levels consists of landscapes composed of micro ecosystems that are often repeated on various scales of complexity; forests, urban and rural areas, roads, malls, individual homes and subdivisions. Within each are attributes that are similar such as soils, vegetation, climate, wildlife, geomorphic surface, and human patterns, vice versa, Figure 1.

WHAT WE VIEW ARE MOSIACS OF TOWNS, VEGETATION, HILLS, COMPOSED OF SOIL, PLANTS, CLIMATE, WILDLIFE, SURFACE SLOPE SYSTEMS WITH PROCESSES THAT ARE IN HARMONY. AT THIS STAGE IT IS ESSENTIAL TO ESTABLISH THE STATE & QUALITY OF ECOSYSTEMS FOR FUTURE RECLAMATION REQUIREMENTS

Figure 1. Composition of premine stage landscape

These attributes are familiar to us and may not be out of place when viewed in their normal settings. However, when disturbed by human activity such as development of an active mine, we often become alarmed due to a visual change. An impact has occurred distorting our concept of that particular view in time and space.

Landscape environments can be viewed as having spatial arrangements of vegetation and soils for example, composed of patches, edges, corridors, wetland soils vs upland well drained soils and their associated vegetation patterns. (Rosenbereg et al 1997, Forman and Gorden 1995). Patches are considered homogeneous areas that differ from there neighboring areas.; e.g. individual tree, open field, large forest or subdivision.

Patches can be considered as a collection micro ecosystems within a much broader macro ecosystem. When they border one another we have an edge which may contain components of each patch. Examples of natural corridors would be rivers, streams, snow and rock avalanche runs, or dry washes in desert area. Human activity however, constructs numerous corridors such as power lines, roads, industrial complexes etc. Land use changes will affect the above and below soil and water surfaces biodiversity linkages through interactions of increased disturbnce [natural and human], chemical inputs or sediment loads disrupting natural processes in balance [Adams and Hall 2000]

Each landscape segment has its own individualistic attributes that grade between other segments of the landscape. When undisturbed by human activity a natural landscape is a mosaic of soils, vegetation, hydrology, and climates. The landscape and all of its diverse attributes that we call ecosystems is in natural **harmony.** Development of the landscape by human activity adds and subtracts patches, corridors, and edges creating a shift in the natural mosaic pattern. Lost patches to active mine development could be wetlands, grasslands, forested slopes, streams and river channels containing endangered and or threatened plant and animal species. Planning to anticipate land use needs is a continual activity since it requires knowledge of what changes will take place to comply with regulation requirements, and vice versa. When left unattended the potential for expensive mitigation increases to comply with regulations requiring a return to the original landscape ecosystems. Mine constructed geomorphic surfaces, tailings and retention dikes; will not behave as natural surfaces subjected to thousands of years of geological weathering. Effective reclamation to stabilize these surfaces will be substantially different but should reflect original ecosystem values.

This Mine Site -A brief overview of the landscapes in this region of Northern Michigan, and implications to closure reclamation. Landscapes in this portion are the product of continental glaciation circa 11,500 YBP [years before present] and correlated to the Marquette advance. [Farrand and Drexler 1985]. The thickness of the glacial drift varies from exposed bedrock to several hundred feet thick. Landforms range from linear plains to steeply slopes hills with deranged surface drainage. Numerous streams, lakes and poorly drained wetland sites are interspersed through the area.

Landscapes in this region are 90 % forested on upland mineral with jack pine [Pinus banksiana] on acid, droughty sandy outwash to sugar maple [Acer saccharium], basswood [Tilia americana] and yellow birch [Betula alaganseis] on coarse to fine loamy more alkaline soils in old growth hardwood forests. Wetland sites vary from mosses [sphagnum spp] on organics, northern white cedar [Thuja spp] and spruce [Picea spp] on neutral to alkaline organic soils.

The local climate for this part of Michigan would be classified as follows: cool/temperate with mean annual soil temperate less than 8C, annual ppt of 81 cms of which 50 to 60 % is the form of snow, 110 to 130 frost free days, and mean evapotranspiration of 48 cms. We general experience a surplus of water regime. In this region equinox times are wet followed by drier periods in between.

However, our local forests represent a final stage of development with respect to soil, climate vegetation, and hydrological properties. The plant communities have succeeded by natural processes where by assemblages of plants have been replaced over time by other more tolerant species hardwoods, and soils, plants, wildlife [including man], climate are now ecosystems in harmony [climax].

ACTIVE MINE STAGE

This stage of opening up the landscape to develop an active mine represents opportunities for management to plan for eventual closure. This stage represents a human disturbance phase shown in Figure 2.

CREATES DISEQUILIBRIUM OF NATURAL PROCESSES, NATURAL HARMONY DISRUPTED; SOIL, VEGETATION, HYDROLOGY, AND EROSION ACCELERATED

Figure 2. Human Disturbance Impact on landscape.

The placement of roads, siting of buildings, placement of waste deposits disrupts the natural harmony of macro and micro ecosystems. Proper documentation of the premine sites as well as what has been accomplished to reclaim wastes can alleviate the burden of costly closure costs, especially if the mine is to operate over a period of several decades. Furthermore those involved with the original reclamation activities my have retired or the original reclamation activities my have retired or moved on to other jobs. The use of personnel computers along with numerous software programs [Rockware 2001] and storage devices exist to back – up and store data.

To begin the process of developing reclamation activities on tailings, the **quality** of these materials to support vegetation must be detailed if proper prescriptions for establishing vegetation are to be in place. **Quality** in the sense that these materials are not natural soils that existed prior to disturbance. Natural soils are open systems that have a unique biodiversity as a result of the following **genetic processes**: **gaius and losses** of plant wastes, dust, water, organic matter, energy; **transformations** [weathering] of minerals into other kinds of minerals or nutrients, decomposition of organic matter that have been **transferred,** plant uptake, and leached from the root zone. Furthermore climate, organisms including man, vegetation, parent materials, topography [well-drained vs wetland soils], over a period of time are factors of soil formation [Jenny 1941]. For this region of Michigan it has been circa 11,500 YBP since the glaciers receded. A mixture of glacial debris [sands, clays, silts and minerals in various mixtures] were left by the glaciers. They have been subjected to genetic processes and factors of soil formation resulting in a variety of patterns of soils and vegetation. Tailings by comparison are at time 0, lack organisms [vegetation, microorganisms], linear plains, lack physical/chemical/ microbiological properties essential for vegetation establishment and survival. **Tailings are not the same as natural soils**. Our task is to initiate the soil building processes, and at the same time, establish, maintain and develop a self sustaining plant cover to control wind and water erosion as well as blend the disturbed sites with the surrounding landscapes [Chernik 1960].

The following general methods are an overview to quantify the quality of tailing as a means to develop closure prescriptions for establishing vegetation. Data collected throughout the life of the waste sites will enhance recognition of future reclamation problems. Included with each of the subjects are illustrations developed for current closure activities on iron tailings in the Northern Michigan Marquette iron range.

Methodology

Particle Separates Survey of the Tailing - To identify the major particle size separates fractions such as sands, silts and clays, in the basin. Purpose to define sampling areas, recognize wind and water erosion areas, special management areas; e.g. mulching, wet areas, equipment limitations, droughty areas [irrigation]. Figures 3 shows three major particle size separates areas in a deactivated basin circa 1970. The basin was mapped for these separates based on research that indicated fertility and water problems to establish vegetation [Shetron and Duffek 1970, Shetron 1982]. The differences can be attributed effluent flow as follows: discharge end where coarser particles settle out as effluent flow decreases in velocity, central portion as a result of meandering flow across the basin gives rise to a mixture of coarse and fine materials; a discharge end which is usually ponded and composed of settled out fines and suspended colloidal materials clays or slimes

Sampling. A sampling scheme was established according to Figure 3. This approach allows us to begin developing management strategies to over come deficiencies such as lack of nutrients, low water retention [droughty conditions], and compaction by particle size region in the basin. We found that ten individual random samples within each separate area in addition to a separate composite of 10 random samples will give a good indication of chemical, physical, fertility, and mineralogical problems. If more samples were needed due a large variance of the separate individual ten samples, a statistical sampling scheme would be developed to increase sampling numbers.

To maintain consistency over the years samples were sent to the Michigan State University Crops and Soils Soil Test Lab. for analysis. All samples were analyzed according to research extraction procedures for macro, micro and trace elements. Physical, mineralogical, and microbiological properties were conducted at the Michigan Technological University School of Forestry and Wood Products Forest Soils Research Lab.

Laboratory Analysis and Implication to Management- All vegetation require from the growth medium the following: 16 mineral elements, [5 macro elements which are nitrogen, phosphorus, potassium, calcium, magnesium] and 11 micro nutrients such as zinc, iron, boron used in small amounts, but, if in excess for plant requirements they become toxic]; water retention sufficient to maintain vegetation, friable or not compacted, well structured, organic matter, and not to hot or cold for establishment, survival and long term growth. If imbalances occur, conditions may exist leading to plant death.

Physical, chemical, mineralogical, and micro-biological analysis should be performed to quantify limitations, or excesses, of nutrients, water retention, or any unusual properties such as pyrites that would weather creating acidic tailings [Nielson and Peterson 1972]. Table 1 shows the importance of sampling by the major particle size separate. Water retention is very low for the sands, 2.5% by weight or 3.3 cms in the upper 20 cms, whereas the slimes retain several times more water, 30.3 % by weight or 9.3 cms in the upper 20 cms. . Furthermore, density of sands at the discharge end would restrict root development; natural soil densities above 1.6 to 1.7 gms/cc will limit plant root development [Brady and Weil 1999] limiting vegetation establishment by restricting deep root penetration for water.

Table 2 summarizes the nutrient status of the major nutrients in the three separate portion of the basin. Similar to the physical data, Table 1, notes the differences by particle size separate in the basin. We were fortunate the tailings are alkaline, pH above 6.5, with no mineralogical suites for acidification, pyrites, as many tailings reported in the literature [Neilson and Peterson 1972].

Since the water retention properties are very low in the sandy discharge end, mulching or irrigation would be management options to aid with vegetation establishment. The stratified sand and slime portion of the basin have bulk densities and water retention properties within the range for satisfactory development of plant roots. Densities of the discharge sands are approaching plant restrictive values and would require some type of deep tillage to loosen the tailings. Total available water supplies are variable and low for the sands requiring the use of mulch, bio-solids or other materials such as paper sludge. Physical tailings data is similar to many forested soils adjacent the basin.

Because of the low water retention values and high pH we developed a two-year program for fertilizer application with two to three applications per year. This was to prevent salt stresses, [physiological drought whereby high salt contents, especially in sandy droughty soils, in matrix water draws water out of plant roots which will eventually desiccate the plant] by applying excess amounts of fertilizer salts. Based on nutrient requirements of the vegetation we averaged 2.5 M tons/ha each year for the two years. The blend consisted of ammonium nitrate, triple superphosphate, and muriate of potash with a ratio of 1.5 – 1 – 2 [15 – 10 –20]. This was a pure mixture with no carrier such as dolomitic limestone or sand. We used ammonium nitrate in

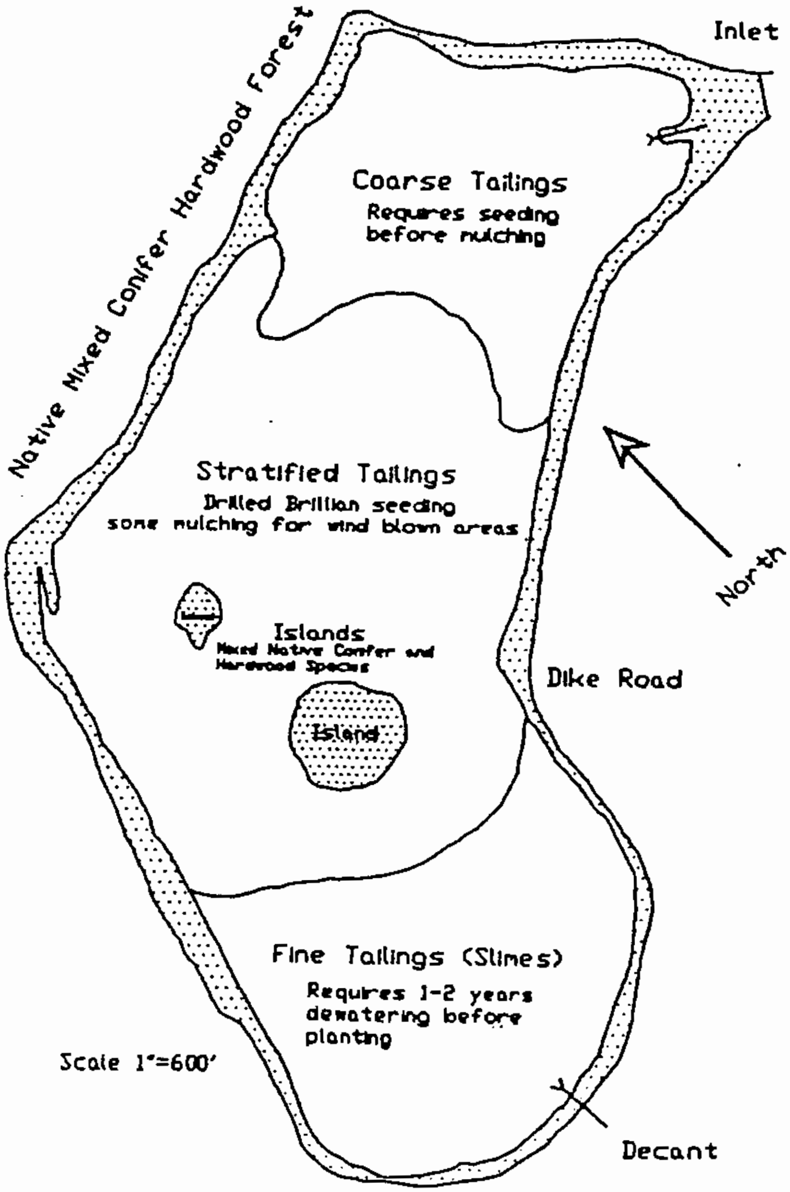

Figure 3. Schematic map of tailing basin outlining the three particle size regions at the time of deactivation and prior to sampling and seeding activities. Note general management considerations: mulching, drilled seedings, dewatering period [also wetland mitigation area] and vegetated islands as sources native volunteer species. [Modified from Shetron 1982]

Table 1 Selected physical tailings properties prior to 1970 – 1971 seeding.

Sample Location	Depth	Texture	Bulk Density	Pore Space	Available Water by Wt.
			gms/cc	%	%
Inlet	0 – 15 cm	Sand	1.84	30	2.5
Stratified	0 – 15 cms	Fine Sand &	1.65	38	5.5
		Silt Loam	1.55	42	19.3
Slimes (Decant)	0 – 15 cms	Silt Loam	1.50	44	30.3

Table 2 Summary of pH and macro nutrient data for three time periods and typical natural soils adjacent the basin.

Location	Depth	pH	N	P	K	Ca	Mg	% O. M.
	cms		------------------kg/ha					
Before Seeding 1971								
Sand (inlet)	0 - 7	7.6	0	8	64	1120	152	0
Stratified	0 - 7	7.6	0	10	112	1816	214	0
Slimes (decant)	0 - 7	8.1	0	16	138	2150	106	0
One year after seeding 1972								
Sand (inlet)	0 -7	6.8	80	182	500	600	140	0
Stratified	0 -7	7.2	70	148	128	1412	56	0
Slimes Limited seeding and fertilization due to equipment limitations								
Twenty two years after seeding								
Sand (inlet)	0 – 7	4.9 – 6.0	8	28	30	305	20	0 - 2
Slimes	0 – 7	5.7 – 6.3	82	30	320	3048	472	3 - 4
Natural soil [forested]	0 - 15	4.5	100	85	250	2-3Mt/ha	550	3 - 6

preference to urea for quick release nitrogen since urea is a slower nitrogen release often dependent on micro-organisms for decomposition and nitrogen release.

One property often overlooked with tailings are surface temps. Table 3 is a summary temperature data for several properties and conditions on the tailings. Even though they may be light colored, the lack of surface protection such as mulching will allow excessively high temperatures. The result would be excessive lose of moisture creating suitable wind erodible surfaces, as well as seedling desiccation. Color of tailings plays an important role with surface temperatures [Table 3]. Black tailings tend to have a hotter surface compared to lighter colored tan or grays surfaces. Mulched surface are cooler than bare, and, even micro surface such as a plow furrow has n vs s aspect surface temperature differences. Behavior of temperature in the tailings follows natural soil damping with depth with cooler temperature below the surface several cms

Plant Selection. Establishing vegetation on these kinds of wastes requires viewing them as new unweathered geomorphic surfaces. Selection of plants therefore will not be the same as adjacent which havc reached a steady state. A change in one factor will often lead to changes in others [disclimax]. Mine sites are disclimax [disturbed] sites that often require selecting species of earlier vegetative successional stages. With time the impacted areas will revert to the local natural successional trend which would eventually have a species mix similar to pre-disturbance. We selected the grass, legume, and shrub stage in order to have sufficient cover and variety of plants to protect the tailings surface from wind and water erosion. With time this successional stage should revert to forested species similar to adjacent landscapes.

Plants have different ranges in fertility needs and are dependent on the quality of the planting medium for survival and growth. The tailing data in Table 2 shows no nitrogen, organic matter, very low in phosphorous and appear to be sufficient for potassium, calcium and magnesium before seeding began in 1971. Prescriptions for amount of nutrients to apply would be developed for species to be planted in a particular stage of succession.

Figure 4 that follows is a generalized diagram to show species fertility relationships for selecting reclamation plants. Each of the three species groups, A, B, & C curves represent hypothetical growth and survival relationships based the plant growth medium chemical and physical properties. The properties of the tailings/selection of plants to seed or establish have to match. For example species group A tolerant of droughty sandy soils; e.g. discharge region Figure 3, would be selected for those sandy tailings in the discharge portion. Whereas, species tolerant of wetter more fertile fine textured soils, species group C for example, would be selected for the slimes portion of the basin. Whereas the stratified portion would be suitable for a wide variety of plants, species Group B. All grass and legume species selected for the 1970/71 seeded basin were C3 based on the local cool humid climate.

However, vegetated islands in the midst of the basin will serve as a source of native seeds to speed along establishing species common to premine slopes. When planning basins in rough and hilly areas leave vegetated slopes above the anticipated pool flood level. They represent excellent native seed sources.

Site Prep, Mulching, and Seeding. - Over the years a number of different kinds of mulches were utilized to prote4ct the surface from wind erosion, moisture lose and to keep the surface cool for seed germination.. Hydromuching at 2 - 4 M tons /hectare, field run hay, [harvested late in the season full of a variety of seeds] at 4-5 tons / hectare and asphalt tack hay mulch are the best. Asphalt tack is a good safety measure if the site to be seeded is exposed to a long fetch of wind activity. Sawdust, and wood chips were not as effective as the hay and hydromulch. due to a lack of uniformity with spreading thickness which limited germination. Several areas in long term vegetated tailings have been used as a source of hay for mulching and to supplement local dairy farmers hay needs during droughty years. For seed sources many seed suppliers have well illustrated seed catalogues showing range, adaptability, varieties, and special characteristics for grasses, shrubs and trees [Granite Seeds 1996]

Generally most of the seeding and site preparation procedures can be handled by local farmers. For example plowing and disking to break up compacted surfaces, seeding with grain and seed drills. Our best procedure for seeding is the use of grain and seed drills which will place the seeds and fertilizer below the surface protecting seeds from high surface temps, wind erosion, and below the dry surface dust mulch in moisture tailings. Also,

Table 3. The effect of tailing color, mulching, vegetative cover, and plow furrow aspect at the surface, 3 and 20 cm depths on tailing temperatures.

	Date and Time				
	6/19/79 Noon	6/28/79 Noon	7/05/79 Noon	7/12/79 Noon	7/12/79 2PM
	Degree C				
Air @ 12 cms	24	30	33	36	36
Bare tailing					
Surface	29	27	33	33	40
3 cms	24	23	33	33	36
20 cms	20	21	22	20	22
Vegetated Tailing					
Surface	22	24	32	32	36
3 cms	21	22	28	29	32
20 cms	18	20	21	24	30
Tailings color					
Bare red silts		43			
Bare gray/tan silts		38			
Bare black sands		45			
Old Plow Furrow Aspect Vegetated					
Slimes Red South		43			
Slimes Red North		27			
Mulched & Vegetated					
Surface					29
3 cms					24
20 cms					19

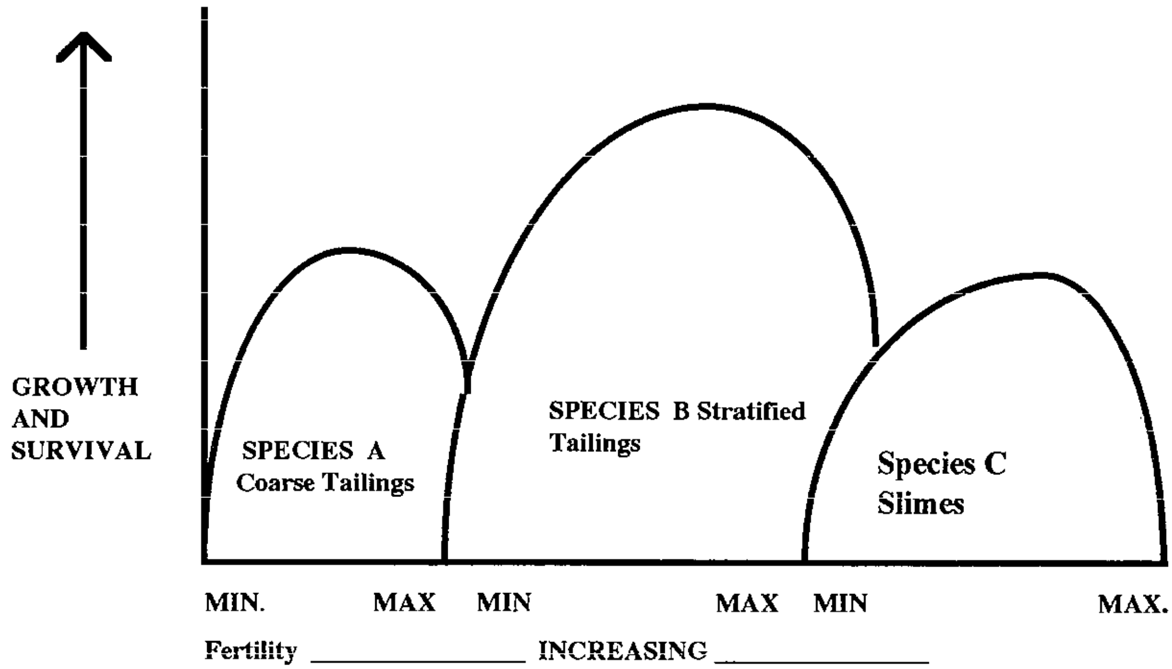

Figure 4. Hypothetical comparison of various species and fertility requirements as a guide to selecting species adaptable to variable tailing physical and chemical properties.

fertilizer and seed are below the surface in contact with moister material, germination and establishment is quicker. We found broadcast seeding and fertilizing with culitpacking applicable if it is during warm and rainy weather in contrast to cooler weather with colder surfaces especially below 10 C. We have had the best success, coverage, survival and growth with drill seeding. One of our continuing concerns with seeding is the activity of geese and their use of the basins during spring and fall migration. The mine site is on the Mississippi flyway and several thousand birds over fly the area twice a year.

In house studies for planting and planning closure scenarios. Over the past three decades of reclamation activities on tailings, a number of on going studies have been in place. The following list summarizes these activities.

A. Solid set circular irrigation system on coarse and stratified tailings with acreage's over 40 acres with long [half mile or more wind fetch]
B. Quantifying physical, chemical, mineralogical and microbiological characteristics of the tailings by particle size for each basin. Monitor plant/tailing fertility relationships with foliar/tailing sampling. This includes planted tailings 3 decades old as well as the various permitted waste products applied to add organic matter.
C. Using wet slime tailing ponds and make up water decant basins for developing wetland mitigation sites in order to expand existing tailings basins into undeveloped landscapes containing permit required wetland replacement.
D. Development of wind breaks [temporary as well as permanent] to control dust and wind erosion on the tailings,
E. Permanent monitoring sites for fertility, coverage, wildlife inventories. [biodiversity]
F. Use of bio-solids or paper mill sludge or other permitted waste products that would enhance the physical and chemical properties of tailing and dikes,
G. Study areas with poor seedling establishment: e.g. coarse textured tailings or compacted slimes.
H. Establishment of nurseries [hybrid aspen] for future windbreak plantings and beautification.
I. Testing survival and growth of various tree and shrub species for wildlife plantings.
J. Use of tailing as a cover on compacted dike roads that have been ripped. Tailings, if used properly, are excellent seedbed materials on
K. compacted, sandy, rocky dike roads and dike faces.
L. Develop and maintain grassland acreage for emergency hay mulching activities.
M. Evaluation of pre closure program to establish successional vegetation patterns to comply with closure objective: e.g. restore, similar conditions, or values.

Closure Stage

Closure represents the final stage of active land use for the mine site. Furthermore reclamation objectives implemented will dictate final results of attempting to vegetate tailings basins. Over the past 3 decades of study to vegetate several different kinds of tailings we have learned that to attempt to replace existing vegetation that was removed for the development of the mine site was impossible. The reason for this is that 90% vegetative cover for this part of Michigan is forest land composed of conifer and hardwoods ranging in age up to 250 + years [USDA 1960, Shetron 2000]. Reclamation of tailing basins in this part of Michigan will represent an "OASIS" in the midst of a desert [Bailey 1972]. Bailey's desert refers to forested landscapes, which do not have the diversity for sustaining a rich population of wildlife. Table 4 shows the results of four years of a breeding bird inventory, 1976 to 1979, on the 71 seeded tailings. Primary breeding species were Savannah Sparrow [Passerculus sandwichensis], Bobolink [Dolichonyx oryzivorus], and Vesper Sparrow [Pooecetes gramineus]. Because of the isolation of the tailings basin, Great Blue Heron [Ardes herodias] a shy bird, established tree top nest in parts of the deactivated decant pools. Nest populations expanded from 22 in 1976 to over 67 in 1979. Compared to other North American range land habitats the vegetated tailings were equal to prairie and grassland habitats indicating that these sites will be productive with time [Chilcote 1980].

Our initial efforts were aimed at a quick cover that is inexpensive, will provide adequate cover to control wind and water erosion, and will provide the essential environment leading to invasion native plant cover. Of the three options for closure reclamation mentioned in the introduction, establishing vegetative within the framework of natural succession, and allowing native plants to invade over time, will begin the successional trend returning the tailings basin to a similar state before disturbance. Table 5 compares introduced and volunteer species inventories one and two decades after the original 1971 seedlings. We used a variety seeding mixes with the following grass-legume mixes

Table 4. Comparisons of the breeding bird communities on the vegetated tailing basin with those inhabiting various North American rangeland habitats. [Chilcote 1980]

Type	Number Sites	Mean No. Species	Mean Density (IND/ha)	Biomass (gr/ha)	Single Species Dominance (%)	Dominance Index (%)
Tallgrass Prairie	11	4.1	3.3	164.9	48.3	74.6
Mixed-grass Prairie	6	4.7	2.4	99.5	48.5	76.3
Shortgrass Prairie	19	4.3	2.8	102.8	50.2	79.8
Palouse Prairie	4	3.0	2.1	68.3	52.0	86.0
Montane Grasslands	3	4.3	2.5	61.5	50.0	75.7
Tailings Basins						
West 1976	1	5.0	5.3	154.5	58.6	85.4
West 1977	1	4.0	4.8	106.5	72.3	95.0
East 1977	1	3.0	5.1	115.9	45.5	71.9

Table 5. Summary of introduced and volunteer species as inventoried by particle size separates as shown in Figure 3.

Species	% Cover Coarse Tailings		% Cover Stratified Tailings		% Cover Fine Tailings	
Species	1981	1994	1981	1994	1981	1994
Introduced	50	43	33	37	55	79
Volunteer	20	37	23	52	28	22
Trees	9	9	10	15	4	14

having the best germination, survival and coverage: alfalfa [Madicago sativa], brome [Bromus inermis] and fescue [Festuca rubra] for coarse and stratified tailings, medium red clover[Trifolium pratense] timothy [Phleum pratense], and alfalfa/fescue mix or reed canary grass [Phalaris arundinacea] for the slimes. Cattail [Typha latifola] heads collected in the spring and scattered along the edges of ponded waters in the slime decant end did very well adding to the plant diversity.

The 1981 inventory showed that for the coarse tailings a 70 % coverage of which 42% were introduced [original seeded species], 30% volunteer moss, forbs, and trees species, 1994 data showed an increase in coverage to 89% with introduced species declining to 43%, volunteer increased to 37% and tree species remained the same at 9%. Stratified tailings for 1981 had 60% coverage with 33% introduced and 23% volunteer, and 10% trees. 1994 showed 85% coverage with 37% introduced and 48 % volunteer, and trees increased to 15%. Slime coverage for 1981 was 55% introduced, 28% volunteer, and 14% trees. For 1994 coverage consisted 69% introduced and 22 % volunteer, and 9% volunteer trees [Shetron et al 1995]. These data show that after 2 + decades volunteer species have invaded the basin and show coverage increases over time especially with the coarser and stratified tailings. The increase in introduced species on the slime tailings suggests that introduced will out compete volunteers for growing space especially on tailings such as slimes with better moisture regimes.

Since the adjacent landscapes are forested two tree species were dominant volunteers. Balm of Gilead, Balsm Poplar [Populus balsimifera] occurred in all regions of the basin. Balm of Gilead is a pioneer species in this region and is common on landscapes after disturbances. Cottenwood [Populus tremuloides] coverage was confined to the moister stratified and slime tailings. Our best introduced tree species for wind breaks were hybrid poplars [Populus spp] and one volunteer willow [Salix sp.]. Willow cuttings were collected locally and planted in wet slime tailings for two purposes: first to remove stored moisture which limited equipment access for seeding, secondly to act as a wind break and avian nesting area.

It is appropriate to consider these sites as time zero with respect to the premine soil/plant relationships in place prior to establishing a mining operation. We believe that succession will take place and with time, one decade, native species will volunteer and begin to populate the area. Closure is an attempt to insert reclamation into the natural successional processes that over time will lead to the harmony of pre-disturbance [Bradshaw 1983, Ries 1993] coverage.

SUMMARY

Tailing basins, depending on the objectives selected to reclaim them, can be vegetated with a variety of plants. As we have shown in this brief overview of 3 decades of a vegetated tailings basin, Natural succession will occur returning the basin to ecosystem with values similar to natural landscapes. Closure reclamation should view tailings as a new geomorphic surface subject to the same forces as the natural landscape they replaced [Sawatsley and Cooper 1996]. They are exposed to erosion with the rates that far exceed landforms they resemble. Tailings are not natural soils and should be treated as a plant growth medium time 0 in development. Our role is to initiate and created those properties of quality that will support germination, establishment, and perpetual cover. Changes can be rapid in a matter of hours unless adequate vegetative protection is present. A general outline for reclamation, closure or not, should include:

A. Environmental analysis, inventory, of premine soil, climate, vegetation, and hydrology.
B. Active sampling, mapping, and continuous vegetation studies to create a data base for closure.
C. Implement best and most successful reclamation techniques for the kind of tailing subject to closure activities.
D. Be sure all required permits are on hand
E. Planning of basins to take advantage of local vegetation assemblages.

Acknowledgement

The senior author thanks the Cleveland Cliffs Iron Company/Cliffs Engineering Services for their many years of support and involvement with reclamation studies on tailings, dike slopes, and stripping dumps. Without this support and interest development of scenarios for closure of future deactivated tailings would not be possible.

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