SUCCESSION OF PLANT COMMUNITIES ON RECLAIMED IRON TAILINGS IN NORTHERN MICHIGAN[1]

Stephen G. Shetron[2], Chris Ovanic[2], and Gary Goodman[2]

Abstract: Vegetation trial blocks up to 2 ha in size were established on iron tailing between 1970 and 1972 to test the following: [1] procedures for large scale establishment of vegetation; [2] the potential of various grass, legume, shrub and tree species for vegetating tailing pond surfaces; [3] potential of the plantings to develop into self sustaining plant communities. Establishment procedures consisted of inventory of the tailing pond surface by three particle size classes: sand, stratified sand and slimes, or slimes, and sampling for fertility, physical, chemical, and biological properties. Grass and legume species adaptable to this region with soil requirements similar to the tailing were selected for testing. These are species used for hay and pasture. Shrub and tree species whose botanical range included this region with site requirements similar to tailing were selected for wind breaks, wildlife cover, and aesthetics. Within two to five years from seeding local tree species [Populus sp.] established themselves in those test blocks that had low percentages of ground cover. Blocks with increasing percentage of ground cover values contained less local volunteer tree species. Legume - grass blocks with 90 to 100% ground cover contained very few local tree species. After two decades those seeded blocks which had low ground cover percentages are now approaching 100% ground cover by local tree, forb and grass species. Along the perimeter of the tailing basin succession has commenced with native spruce [Pices sp.] and fir [Abies sp.] in the understory of volunteer Populus species. Those tree species used for wind breaks have attained heights of 15 to 20 meters and diameters up to 5 cms at breast height.

Additional Key Words: Reclamation, succession, tailing

Introduction

Early attempts to reclaim lands disturbed by mining companies with vegetation were confined to coal disturbed lands. Generally, tree seedlings were used to colonize these kinds of disturbed lands coated with mine wastes (Ashby 1984, Deitschaman & Lane 1952, Limstron 1960). With the advent of National Environmental Policy Act of 1969, awareness of mine company waste disturbed lands increased with passage of various kinds of environmental rules and regulations at the federal and state level, especially for coal strip mined lands. Two to three decades ago the primary pressure to reclaim hard rock mine disturbed sites was public opinion especially as it concerned aesthetics or air and water quality.

However, this has slowly changed since hard rock mining companies do have legislative pressures [air and water quality at the state and federal levels] or, actual state rules and regulations for reclamation of hard rock mine and mill disturbed lands (MDNR Geological survey 1978). Manuscript length limits delving into an expose for state by state rules and regulations for hard rock mine reclamation.. However, hard rock mining companies have intensified vegetative reclamation programs to improve mill wastes such as dumps, dikes around tailing ponds, and tailing pond surface in order to comply with regulations.

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This paper discusses the establishment of vegetative cover on the surface of tailing ponds at a point in time [late 60's] that lacked any significant reclamation experiences with seeding and fertilization equipment, species to plant, what kinds of physical, chemical or biological lab tests needed. The surface of a tailing pond is open, smooth, and unless covered will severely wind erode. For many of us at that time we had to rely on agronomic recommendations for testing, seeding rates, equipment, and sources of seeds. We were in essence doing **"SEAT - OF - THE - PANTS - RESEARCH!"** However, our main objectives then as now is similar to Cheniks' (1960, 1963) approach to vegetation reclamation which consisted of three objectives: (1) economical; (2) easily accomplished; and (3) effective or result in a self sustaining plant community.

This paper presents a look at a tailing basin vegetated over 2 decades ago. The question posed at that time; "Which of the various stages of natural succession should be implemented to vegetate a tailing pond surface ?" and, 'If left undisturbed will succession take place?', "Will it be self perpetuating."

Study Area

Late 50's and early 60' s saw the beginning of open pit mining of low grade iron ore and pelletizing on the Marquette Iron Range in Northern Michigan. When the initial vegetative studies began in 1968, pellet production was about 6 million metric tons per year for three mills. The initial study site was located in a 20 ha deactivated tailing pond used for emergency spills at a mill producing pellets from non-magnetic ore [Hematite]. Climate for the area is considered cool - humid with a mean annual temp of 8 C, precipitation averages 82 cms per year of which half can be in the form of snow. Because of the proximity of Lake Superior, < 35 km, the climate is highly variable with rapid swings in temperature and rainfall on a hourly basis.

A diked portion of 3 ha in size in the emergency spill basin was set aside for vegetation trials in 1968 on tailings from pelletizing non - magnetic ore. Because of a lack of published research concerning establishment of vegetation on these kinds of mill wastes the following procedures were adopted: (1) field layout for vegetation trials were to consist of randomized one-tenth acre blocks replicated three times; (2) each block sampled for physical, chemical [to include tests for fertilizer recommendations], and biological properties; (3) select vegetative species typical of two stages of primary succession (Oosting 1956, Young 1968); (4) select grass and legume species to include those that were heat, cold and drought tolerant used for pasture renovation and hay production in this region [Heath et al 1962, Smith 1962]. Legumes selected were alfalfa [Medicago sativa], clovers [Trifolim sp], grasses were brome [Bromus inermus] fescues, [Festuca sp.], orchard grass [Dactylis glomerata], reed canary [Phalaris arundinacea]. Seeding rates were double the Michigan Agricultural Experiment Station recommendations. Doubling the seeding rates were to compensate for loses due to wind erosion and wildlife especially song birds; (5) the same approach used with grass and legume was used with selection native tree and shrub species ; (6) because of wind erosion problems hay and sawdust mulches were included to control wind erosion. Results of the 1968 trials were reported by Shetron and Duffek [1970].

During 1970 a 35 ha tailing basin was deactivated at a pellet mill processing low grade Hematite. Because of public concerns over the tailing dust resulting from severe wind erosion from this basin, the vegetation trials were expanded to include this basin. The 35 ha basin became our outdoor lab. to test what was learned from the small scale 1968 through 1970 vegetation trials. Increase in acreage of the seedings should identify establishment problems the 1968 trials may not have addressed. The 35 ha basin was sampled by the three major particle size classes for the following tasks: [1] to map the basin by particle size distribution; [2] a guide to sample for fertility, physical, chemical and biological properties prior to seeding ; [3] seeding rates, mulching needs, and potential equipment limitations [wet slimes]. Those grass and legume species that had the best establishment and survival data for the 1968 trials were selected for further testing in the larger deactivated tailing basin.

Discussion

Establishing Vegetation

The initial vegetation trials of 1968 showed that grasses [brome, fescue,, orchard grasses, and reed canary, timothy] & legumes [alfalfa and clovers inoculated twice] species could be successfully established based on the following general procedures: (1) sampling for fertility especially nitrogen, phosphorus, potassium and pH; (2) sample according to a tailing pond particle sizes [sand, stratified, or slimes] of the upper one meter. A depth of one meter was selected to determine the presence or absence of slime bands in the coarse tailings. Slime bands will retain water essential for growth especially in coarse tailings with low moisture retention properties Table 1.

Table 1. Selected physical properties for the 1970 - 71 seeded tailing pond

Sample Location	Depth	Texture	Bulk Density gms/cc	% Pore Space	% Available Water by Wt.
Inlet	0 - 9 ins	Sand	1.84	30	2.5
Stratified	0 - 9 ins	Fine Sand &	1.65	38	5.5
		Silt Loam	1.55	42	19.3
Slimes (Decant)	0 - 9 ins	Silt Loam	1.50	44	30.3

(3) all seedings were with either a hydro -seeder [those portions of the pond inaccessible to equipment], drill or Brillion seeder and cultipacked to a depth of 2 cms or less in order insure sufficient moisture for germination. Seeding and cultipacking was an important first step before mulching. Because of the severity of the micro-climate of the tailing pond surface; e.g. temps of 45 C, they dried rapidly discouraging broadcast seedings or seedings in mulches. Seeding first and then mulching on coarse tailings was the best approach. Slimes and stratified tailing were seeded direct. Mulches were used only if portions were already severely wind or water eroded. However, irrigation systems such as central pivot will mitigate drought problems for establishment of seedings especially in coarse tailings during periods of low rainfall and high temperatures.

Sampling the basin for the various physical and fertility texts showed a vast difference in the particle size classes. Figure one is the particle size map outlining the three major size classes of the 35 ha tailing basin as a result of out sampling program.

The inlet end is composed of medium grading to fine sands as a result of decreasing effluent velocity. As the water stream moves across the basin it behaves similar to a breaded stream which resulted in a stratified middle portion composed of fine to very fine sands, silts, and some clays size particles. The slime end represent the decant pool composed of clay and silt size particles. Deactivation of the basin exposing the tailing pond surface would qualify it as a habitat for primary succession colonization [Bradshaw 1983) since no vegetation has grown on the tailing previous to establishing vegetation (Oosting 1956).

Actually, the particle size map in conjunction with the total plant available water data shows, that the basin ranges from very dry (inlet) or xeric sand tailings to very wet slimes, mesic to hydric, across the middle portion to the decant slime end. Based on these data the inlet portion of the basin was considered for contract mulching after seeding. Field run mature hay was applied at 4 metric tns/ha with an asphalt tack. After one day of strong gusty winds, 40 to 50 km/hr, a second application with twice the hay and asphalt was applied to replace those portions lost to wind erosion. No further wind problems were encountered. The stratified portion of the basin was seeded directly. However, mulching as a treatment was used with those blocks with similar seeding mixes and treatments in all three particle size regions in the basin. Both hay asphalt and wood fiber [Conwed] mulches were applied. The slime decant end presented seeding problems, especially the use of equipment, which had a tendency to become easily

Figure 1. Map of the surface one meter of the tailing basin showing the three particle size regions, texture, at the time of sampling and seeding in 1971.

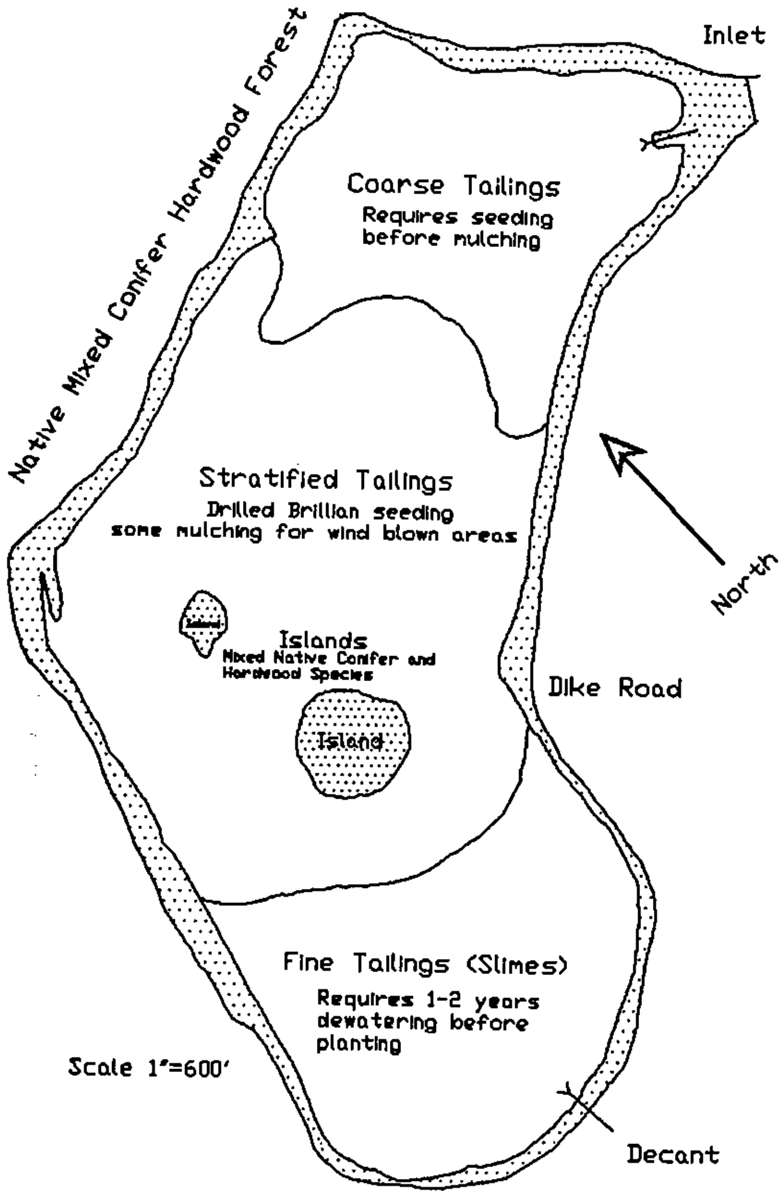
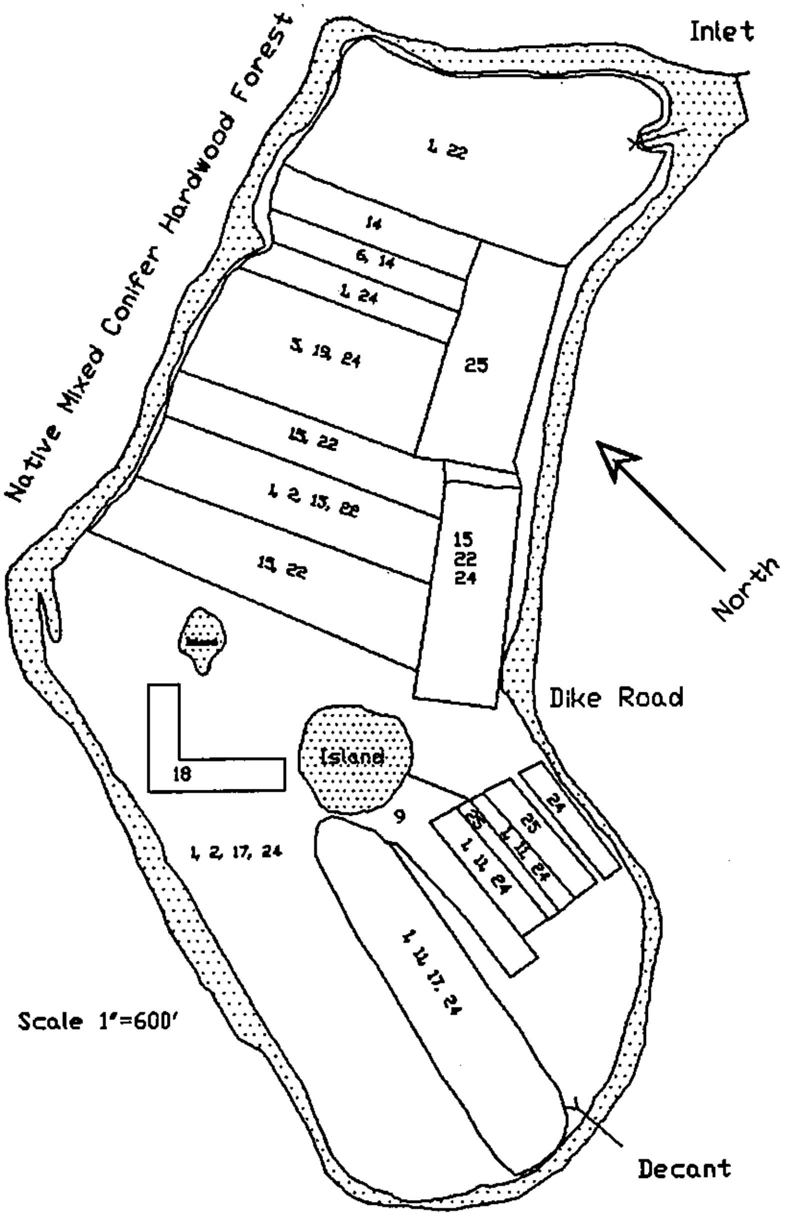


Figure 2. Map of tailing basin showing the seeding blocks established in 1971 and 1972.



Map Legend

Grass/weed Species	Map Key
Alfalfa	1
Alsike clover	2
Brome Grass	3
Cattail	4
Creeping Red Fescue	5
Drilled Seed	6
Fescue	7
Goldenrod	8
Handmulched - No Seed	9
Hawkweed	10
Japanese Millet	11
Knapweed	12
Moss	13
Mulch	14
Orchard Grass	15
Red Clover	16
Red Top	17
Reed Canary Grass	18
Rye Grass	19
Sedge Grass	20
Sweet Clover	21
Tall Fescue	22
Tansy	23
Timothy	24
Western Grass Species	25
Wheat Grass	26

Blow out of the seedings on the sand tailings required hydro-mulching, reseeding and fertilization. As previously mentioned this occurred at the inlet end and in scattered places in other blocks. Likewise, the wet slime tailing prevented seedings. The first year, 1971, saw only portions of the slimes seeded while the rest of the basin was successfully seeded. The entire basin, except for about 5 ha of slimes, was completely seeded during 1972. Jones (1972)) collected 1972 hay yield data for the stratified portion. Yields ranged from 2 metric tons per acre for grass blocks and over 3 metric tons per acre for the grass - legume blocks. Seed produced by the various introduced grass and legume species during 1972 was germinating in protected bare spots within the stabilized parts of each block. Jones also recorded the occurrence of migrating water fowl, fur bearing mammals, raptors and song birds Within one year half of the basin had progressed from a unvegetated barren tailing pond surface to pasture/hay field appearance. Visual observations the first and second year revealed that moss and lichens species had invaded the basin especially on the moister tailing textures, slimes and silts, seeded or not. Because the slimes were expansive, mired. Portions of the slime end were seeded where equipment could traverse without becoming mired in the wet slimes. Those slime areas that were not seeded were planted to willow (Salix sp.) cuttings collected locally. About eighteen thousand were planted between 1971 and 1972. Low areas with standing water were hand seeded with cattail heads collected from wetlands adjacent to the tailing basin.

The tailing pond represented an unknown medium for establishment of vegetation, especially its fertility, since it had not been subject to weathering and the factors of soil formation. Table 2 summarizes plant available nutrients within the basin before and one after seeding and fertilization. Before seeding data were used to formulate

Table 2. Summary of plant available nutrients before and after to seeding.

			Nutrients available kilograms per ha				
Location	Depth	pH	N	P	K	Ca	Mg
Before Seeding							
Sand (inlet)	0 - 3	7.6	0	4	37	560	76
Stratified	0 - 3	7.6	0	5	56	903	107
Slimes (decant)	0 - 3	8.1	0	8	69	1075	153
One year after seeding							
Sand (inlet)	0 -3	6.8	40	91	250	299	69
Stratified	0 -3	7.2	35	74	64	106	27
Slimes Limited seeding and fertilization due to equipment limitations							
Twenty two years after seeding							
Sand (inlet)	0 - 3	6.1	Tr	2	22	660	22
Stratified	0 - 3	5.9	Tr	2	40	240	60
Slimes (decant)	0 - 3	8.0	Tr	2	24	330	24
Effect of stratification on nutrient retention after one year.							
Sand above slime band		6.5	39	16	28	211	19
Slime band		7.6	51	8	58	272	29
Sand below slime band		7.0	41	5	30	149	14

a nitrogen, phosphorus, and potassium blend [15-10-20 @ 300 kg/ha] for fertilization at the time of seeding as well as top dressing [300 kg/ha/year] for two years. The species mix, legume and grass or just a grass specie, for seeding as well as location within the basin governed the amount of fertilizer to be applied. For example the inlet rooting zone is composed of coarse tailings which required fertilization with over a half metric ton spread over years. The procedure was necessary to prevent a salt build up in the tailing as a result of heavy fertilizer applications. This was to keep the osmotic potential of the plant available water supply low enough to prevent physiological drought of the seedlings. No fertilizer has been applied since 1975. All N, P, K increase the first year and decrease with time. Calcium stabilizes and Mg decreases. PH shows a decrease with time suggesting both a base leaching loss and plant uptake.

Table 3 lists the legume, grass, tree and shrub species selected for the kinds of tailing particle sizes as a rooting medium when considering the fertility and moisture relationships. Because of the fertility and water relations at the inlet end, six western grass species were selected for establishment trials. Of the legume and grass species, perennial ryegrass was new, and, all but the hybrid poplars were new tree or shrub species not tested in 1968.

Table 3. List of species for seeding test blocks, shrub and tree planting

Legumes and grasses (local)	Trees and shrubs
Vernal alfalfa (Mediicago sativa)	Northern white cedar (Thuja occidentalis)
Alsike clover (Trifolium hybridum)	European larch (Larix dedicua)
Reed Canary grass (Phalaris arundinacea)	Black locust (robina pseudoacacia)
Creeping red fescue (Festuca reubra)	Tulip poplar (Liriodendron tulipifera)
Alta tall fescue (Festuca arundinacea)	Choke cherry (Prunus virginiana)
Perennial rye grass (Lolium multiflorium)	Hybrid poplar - Michigan 88 (Populus sp.)
Orchard grass (Dactylis glomerata)	Hybrid poplar 4 varieties from Fry & Sons
Timothy (Phleum pratense)	Nursery, PA.
Western Grass sp. Adaptable to this Region	Hybrid poplar - 11 varieties from USFS
Tall wheat grass (Agroypron elongatum)	New Hampshire
Intermediate wheat grass (agropyron intermedium)	Local willow sp (Salix sp.)
Crested wheat grass (Agroypron cristatum)	Arnot bristly locust (Robina fertilis)
Western wheat grass (Agroypron smithii)	Silky dogwood (Cornus amomum)
Switch grass (Panicum virgatum)	Cardinal autumn olive (Elaeagnus umbellata)
Green needle (Stipa viridula)	European black alder (Alnus glutinosa)
	Silver buffalo berry (Shepherdia argentea)
	Laural willow (Salix sp.)
	Multiflora rose (rosa sp.)
	Siberian pea (Caragana arborescens)

Vegetation Analysis

Succession is the replacement of plant species by another, shade - intolerant by shade tolerant species capable of competitively suppressing the species that precede them, or, as a result of changes in the physical environment [Crow et al 1994, Oosting 1962]. Environmental factors influencing succession are: (1) physical change such as erosion [wind and water] or fire; (2) less optimal site conditions for existing species , thus more optimal for those that replace them; (3) removal of a segment by insect or disease. Because initial conditions change with time, patterns emerge between initial colonization and late plant communities. Colonization of a tailing pond surface with vegetation is an attempt to establish a cover that is comparable to local plant communities, or, to establish a community with patterns that will succeed towards the local plant communities. The initial stage is critical with regard to establishing a plant community that will be self sustaining. Four succession stages are generally considered: bare ground, herb, shrub, and tree stages. The herb, or more appropriately the grass stage for this study, was selected as the successional stage for this region that would result in a quick, inexpensive protective cover. Trees and shrubs were included but, were planted on natural glacial drift used to construct the dikes. [Table 3].

Figure Two outlines the various seeding blocks for the large scale test of those seeding mixes with the best performance with the 1968 trials. Two note worthy vegetation items are shown on the Figure. First are two islands, ovals, about the center of the basin with a mix of native species consisting of white spruce (Piece glauca), red maple (Acer rubra), white pine (Pinus strobus), balsam fir (Abies balsamea), balsam popular (Populus balsamifera), white birch (Betula papyrifera). Second is the woodland situated along the parameter of the basin composed of the same species as the islands. An exception was the stripping dump along the north end. The dike system cut across natural vegetation types varying from the above mentioned woodland, to wetlands covered with cattails, american larch (Larix laricina), black spruce (Picea mariana), balsam fir and lowland hardwood species., e.g. trembling aspen (Populus tremuloides).

cracks formed when dry. They were not present on barren wind swept coarse tailing, but did occur in sheltered bare patches in seeded areas protected from the winds. Also in the open protected bare spots, local weeds species such as hawkweed become established. Seed source was judged to be from one of two sources, wildlife or blown in from adjacent vegetated areas, or a combination of both. Slimes when dry cracked and were generally seeded to existing species seeded on the basin.

Western grass species seedings did not fair as well as the local domestic grass or legume/grass seeding mixtures. Tall wheat grass was the best performer of the six species tested. Again wind erosion removed seed and fertilizer limiting establishment. The excess moisture in the slime tailings curtailed growth, but better establishment of the western grass species was recorded (Jones 1972).

Tree and shrub species did well the two growing seasons. Survival rates varied from 95% for siberian pea, black locust and european alder, 80% for autumn olive, 65% for choke cherry and silky dogwood, to a low of 45% for the hybrid aspen planted in the basin at six locations ranging from sands to slimes. Best survival and growth was recorded on the slimes and stratified tailings. Winter dieback was recorded for siberian pea, black and bristly locust, and autumn olive. The basin may have acted as a cold air trap since the tailing surface was on the average 6 feet below the top of the dike. The slime portion because of its wetness was considered an ideal location for willow cuttings.

Figure 3 and Table 4 reflect the changes in the original seedings after 2 decades of complete stabilization with vegetation. Inventories were made during 1981 and 1994. Even though several grass blocks were mulched, percent ground cover was very poor the first year. Coverage and number of species was least in the dry sandy discharge portion, improved within the stratified portion and was the best in the more moist slime portion. Mulched blocks had higher ground cover percentages than unmulched blocks which often contained bare wind blown patches.

A drastic change in the composition of original seeding blocks across the basin has occured, Figure 3 . In addition to the original grass and legume species, 26 volunteer vascular species representing 14 families [1971 -72 seedings introduced 2 families, Legume and Poa] were recorded for both the 81 and 94 inventories. These species Compositae [16 species], Polygonaceae [2 species], Leguminosae [6 species], Poa [12 species], and one each for 10 other families. The diversity of families is attributed to several factors. First is the introduction of volunteer seeds from the hay asphalt mulch; since the contractor used mature field run hay; second is the nearness of woodlands; third the presence of wildlife using the basin.

Ground Cover - For the coarse tailing inlet end total tailing surface coverage was 68% with 12% for alfalfa and brome grass 28% accounting for 40%, mosses at 18% with local weeds species the remaining 10%. The 1993-94 data show an increase in cover to 95% with Alfalfa increasing to 20%, Broom decreased to 10%, orchard grass and fescue volunteered between 81 and 93 with 12% coverage, Hawkweed increased from .1% to 13% , Knapweed from 0 to 11.5% and moss declined to 11.5%. Other species not recorded in 1981 are Balm of Gilead, Black Locust with a combined coverage of 7.3%, Orchard grass and Equisitum. Although the combined coverage of Alfalfa and Broome grass decreased by about 11%, total coverage contributed by all species increased by 25% with volunteer species, especially Hawkweed and Knapweed from less than 1% to over 24%. Moss declined by 38% indicating replaced by other species such as Knapweed or Balm of gilead. The same number of introduced and volunteer species occur for both 1981 and 1994.

Eighteen species with a coverage of 78.6% were tallied in 1981 for the stratified portion of the basin. Alfalfa had 12.4%, grasses 19.2%, moss 19.5, Populus sp. 8.1% and litter 12.4%. The 1993-94 data show a coverage of 82.3 % and a richness of 27 species. Alfalfa coverage increased by 4%, grasses 4% increase, Hawkweed 10%, mosses 12% increase, tree species decreased by 7%, (10% for 1981 to 3% for 1994). The increase in species diversity consisted of those species typical of an old field in this region; for example strawberry, hawkweed, tansy, sheep sorrel, yarrow, dandelion, and plantain. Although tree percent cover decreased, size of the remaining trees increased to where individual tree canopy covered more surface area. Bare ground and moss coverage increased since most of these data were collected from the tree invaded blocks.

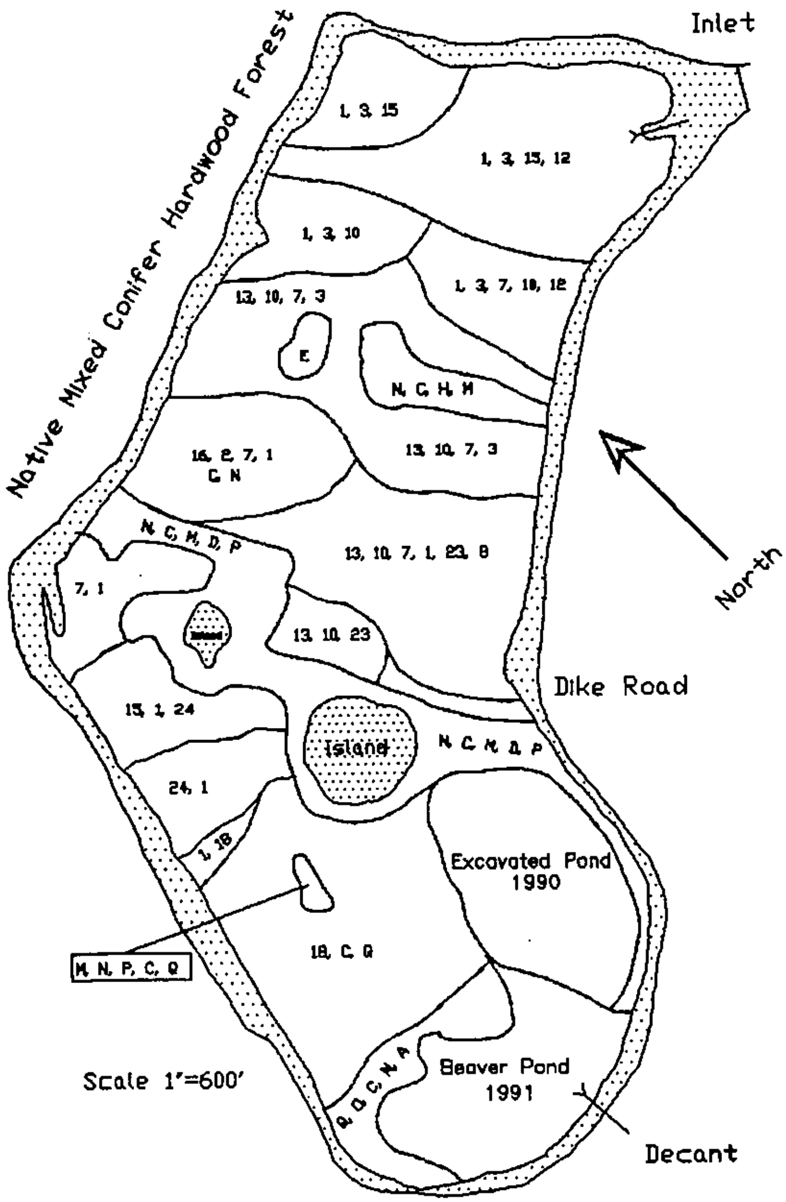
Table 4. Summary table of introduced and volunteer species as inventoried by particle size separation and percent cover.

		Coarse Tailings		Stratified Tailings		Fine Tailings (Slimes)	
		1981	1994	1981	1994	1981	1994
Introduced	Alfalfa, Vernal	12.2	20.4	12.4	16.1	7.3	4.4
	Alsike Clover			0.1	0.2	5.1	8.9
	Bluegrass *	1.9					
	Brome Grass *	28.5	9.6		0.2		3.6
	Fescue	7.5	5	4.1	7.3	1.3	2.2
	Grass sp		1.2	15.1	3	10.2	
	Orchard Grass		6.5		0.4	1.7	
	Red Clover *			0.6	0.5	4.8	7.8
	Reed Canary Grass				5.3		24.4
	Sweet Clover *			Trace		7.3	
	Timothy				3.5	2.1	2.8
Volunteer	Bladder Champion Weed	0.7					
	Broom Snakeweed						1.1
	Butter Cup					0.2	
	Cattail						1.7
	Daisy Fleabane	0.1				0.1	1.7
	Dandelion	0.1			0.2	0.7	
	Fireweed					1.7	
	Goldenrod			0.5	1.3	2.2	2.2
	Hawkweed	0.1	13.1	1.3	10.9	5.6	4.4
	Horseweed	0.2	0.4				
	Knapweed		11.5				
	Moss *	18.3	11.5	19.5	31.4	7.4	1.7
	Ox Eye Daisy			Trace		0.5	
	Pearly Everlasting			1.5	1	1.8	
	Plantain sp				1.5	Trace	
	Pyrola sp				0.2	3	
	Queen Anne's Lace				0.8	Trace	
	Sedge Grass						5.6
	Sheep Sorrel				1	0.4	
	Strawberry			Trace	1.8	0.4	1.1
	Tansy	0.2			1.4		2.2
	Thistle					0.1	
	Yarrow	Trace		0.4		4.8	
Introduced Trees	Black Locust		5.4		0.2		
	Cardinal Autumn Olive					0.1	
	Choke Cherry					Trace	
	European Black Alder					0.2	0.3
	Laurel Willow			1.6		0.8	
Volunteer Trees	Aspen			0.3	0.4		
	Balm of Gilead		1.9		1.9	0.3	3.3
	Cottonwood			8.1		2.3	
	Paper Birch			0.2		0.4	0.6
	Red Maple					Trace	1.1

* Introduced from contracted hay mulch used to control wind erosion

Richness of the slime end of the basin changed in the ten year period between 1981 and 1994. Two changes took place; first about 4 ha of slimes to a depth of 15 meters were removed to seal a landfill, and, it is now a lake; second beavers have established a dam at the decant outlet creating a pond flooding about 3 ha. Number of species tallied in 1981 was 34 with a coverage of 100%. For 1994 data number of species declined to 21 with a coverage of 88% which reflects the activity of the beaver and lake development. Comparing the coverage of those species that were not impacted by the beaver pond or tailing removal shows tree species increasing from 4% to 7% with the largest gain with Balm of Gilead. Reed canary grass, cattails, and sedge grass were not inventoried in 1981, but, were present during 1994 with a coverage over 30%, or one third of the 1994 cover percentage. Cottenwood, black and european alder were not tallied in 1994. This reflects the activity of the beaver with developing a pond and a vegetation shift to wetland species such as the invasion of plants such as cattails and sedges replacing willows.

Figure 3. Map of tailing basin showing vegetated areas two decades after initial 1971 & 1972 seedings.



Map Legend

Grass/weed Species	Key
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Cattail	4
Creeping Red Fescue	5
Drilled Seed	6
Fescue	7
Goldenrod	8
Handmulched - No Seed	9
Hawkweed	10
Japanese Millet	11
Knapweed	12
Moss	13
Mulch	14
Orchard Grass	15
Red Clover	16
Red Top	17
Reed Canary Grass	18
Rye Grass	19
Sedge Grass	20
Sweet Clover	21
Tall Fescue	22
Tansy	23
Timothy	24
Wester n Grass Species	25
Wheat Grass	26
Tree Species	**Key**
Alder	A
Autumn Olive	B
Balm of Gilead	C
Balsm Fir	D
Black Locust	E
Choke Cherry	F
Trembling Aspen	G
Jack Pine	H
Larch	I
Paper Birch	J

Red Maple	K
Spruce Sp.	L
White Pine	M
Willow Sp.	N

This suggests a shift from a mesic to hydric tailing environment allowing the invasion of species adaptable to a wetter rooting environment.

The layout of the transects shown in Figure 1 did not take into consideration of species migrating into the basin along the edges of the dike. Field notes as well as visual observation by these authors reveals that American Larch will invade the tailings especially slimes. Destructive sampling revealed saplings ages of 5 to 17 years and heights up 4 meters. Balm of Gilead, cottenwood, and white pine seedlings and saplings are common edge tree species 4 to 6 cms in diameter and 3 to 5 meters tall ranging in age from several years to two decades. Understory vegetation within these saplings consists mostly of bare ground with white spruce and balsam fir seedling and saplings up to six feet in height. and up to 17 years of age. In this setting the initial grass seeding created an environment for Populus specie invasion which now shows a succession to a spruce - fir forest typical of this region in Northern Michigan. Seed source for the invasion of the white spruce, balsam fir, and american larch is from the islands left in the basin, wildlife, local woodlands, and wet sites adjacent the tailing pond.

Summary

The present state of the vegetation on the tailing basin has fulfilled one of three vegetative reclamation requirements: **"DEVELOPMENT OF A SELF SUSTAINING PLANT COMMUNITY."** Vegetation data collected over the past two plus decades shows that once these kinds of mill wastes are stabilized they will be able to sustain a reasonable amount of cover controlling wind erosion, enhancing aesthetics and creating a place for wildlife; for example the creation of a flooded area by beaver. Two forms of succession has been observed in the basin ; [1] area seeded to introduced grass and legumes show an increase in native weed species especially in the more fertile and wetter slimes; [2] native tree species have invaded the more barren sites and show succession from the pioneer aspen species to spruces and white pine typical of Northern Michigan. Since the 1981 inventory, white spruce, balsam fir and american larch have invaded a number of places along the edge of the dikes, islands and adjacent to native woodlands and wetland sites. These sites external to the basin are contributors of local seeds for natural revegetation. The vegetation data collected over the past 2 decades show that tailing pond design and location should consider leaving islands of natural vegetation as a seed source for native revegetation. Also, every effort should be made to locate and design tailing basins to encompass as many local vegetation types for a diversity in seed sources.

Selection of plants to vegetate the tailing was biased by concepts of successional processes. granted some of the forbs selected were exotics, they were selected for two reasons: to match the fertility and climate of the pond area; rapid germination and establishment to prevent wind and water erosion. As discussed by Winterhalder [1993] study of the local successional patterns will serve as a guide for reclamation procedures with regard to establishment of vegetation and potential colonization by local plant species.

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