The Use of N-Viro Soil and Municipal Solid Waste Compost to Establish Vegetation at Sand and Gravel Operations

First Year Progress Report

April 1997

Minnesota Department of Natural Resources
Division of Minerals

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Acknowledgments

As with most successful and innovative projects, this one required the enthusiastic input of numerous parties. Bob Bieraugel of the Shiely Co. was instrumental in making this project a reality, and his enthusiasm and receptiveness to new ideas was greatly appreciated. Serving as a consultant to N-Viro Minnesota, Inc., Kathy Draeger was also a key component of this undertaking, and the input of soil scientist Mike Jorgenson was also welcomed. Plant Manager Marc Duncan was notably receptive to having outsiders come in to his pit and poke around, and Shiely employee Dennis Kilmer was very helpful in fulfilling numerous requests in a timely manner. Bob Jacobson of the Minnesota Department of Transportation was responsible for supplying the seed drill and doing the drilling, and his assistance was greatly appreciated. Numerous DNR employees (including Steve Dewar, Deena Bahner, J.D. Lehr and Dave Antonson) had a hand in various portions of the project, for which we were most grateful, and special thanks go to Glenn Melchert and Kim Hennings, who were involved in construction of the lysimeter plots.

Executive Summary

In 1996, two organic amendments, N-Viro Soil (NVS; an exceptional quality sewage sludge product), and municipal solid waste (MSW) compost were used in an attempt to improve vegetation success on a nine acre south-facing slope at Shiely Co.'s Nelson Mine on Grey Cloud Island. Smaller plots were established to evaluate the impact these amendments would have on water quality and to investigate their use as a replacement for topsoil on a 50-acre washed sand stockpile.

Weather

Rainfall during the 1996 growing season (May 1 through September 30), was only 11.2 inches, which was 57% of the historical average for this time period.

Demonstration Slope

Four treatments and two seed mixes were applied to the slope, which had first been covered with local "topsoil". The treatments included: NVS (22.3 dry tons/acre), MSW compost (23 dry tons/acre), fertilizer, and a control. The top third of each plot was seeded with a cool season grass mix (MNDOT 50) and the bottom two thirds were planted with a native seed mix (MNDOT 20).

Addition of NVS and MSW compost to the south-facing demonstration slope increased both percent cover and biomass on the slopes, and decreased erosion. Average percent cover ranged from 61% on the NVS plot to 31% on the unfertilized topsoil control plot. There was little difference between the average percent cover values for the NVS and the MSW compost (61% vs. 56%), while the corresponding value for the topsoil with fertilizer plot was 44%. Biomass showed a similar trend, with the mean values of both the NVS and the MSW compost being about 44 dry g/m^2, followed by the topsoil+fertilizer plot at 21 dry g/m^2, and then by the topsoil control plot at about 13 dry g/m^2.

Almost all of the percent cover and biomass on the slope was provided by annual weeds, primarily lambs quarters (*Chenopodium album*) and ragweed (*Ambrosia sp.*). Some grass-like species were observed in the fall after the amount of rainfall increased, and a few isolated forb plants (partridge pea) were observed in the native species portions of the plots.

Vegetation success was also affected by inadequate mulch and by grazing by geese. Mulch was to be applied at 2 tons/acre, but due to contractor errors the net rate of mulch was estimated to be only 1.0 to 1.5 tons/acre. Geese grazed the slope heavily, and were likely responsible for the almost complete destruction of the oat cover crop.

More soil movement was observed in the plots without the organic amendments than was seen in the NVS and MSW compost plots, and one sizeable erosion channel developed on the topsoil+fertilizer plot.

Addition of the organic amendments to the slope increased the total reclamation cost by about 25-50% ($240-420 per acre). A major factor in the cost of the organic amendments was the transportation cost. For this project, the NVS processing site was much closer to the mine site than the municipal solid waste composting facility (20 miles vs. 50 miles), and as a result, the overall cost to use the NVS was $180 per acre less than the MSW compost.

Lysimeter Plots

Nine 2.5 m x 4 m plots were constructed to examine the effect of the organic amendments on water quality. NVS and MSW compost were added to topsoil at the same rates used on the demonstration slope, and pan lysimeters were installed in each plot to collect water as it moved downward through the plot. All plots were planted with the cool season grass mix. Due to the lack of rainfall no water was collected in the lysimeters.

There was little difference in percent cover between the plots. Percent cover ranged from 69% to 76%. Although average biomass on the MSW compost plots was almost twice the value for the fertilizer and NVS plots (31 dry g/m^2 vs 15.3 dry g/m^2), this difference is believed to be an artifact of the small number of biomass samples collected.

Washed Sand Plots

As part of their washing operations, Shiely produces a reject sand which is currently contained in a 50-acre stockpile. The material is coarse and low in both nutrients and organic matter. Eighteen 2.5 m x 4 m plots were established to examine the use of NVS and MSW compost (as replacements for topsoil) to reclaim this area. Six different treatments were investigated, with three plots per treatment:

- NVS applied at a rate of 60 wet tons/acre (31 dry tons/acre),
- NVS applied at a rate of 30 wet tons/acre (15.5 dry tons/acre),
- NVS applied at a rate of 15 wet tons/acre (7.8 dry tons/acre),
- MSW at 20 tons/acre,
- 4" of topsoil with fertilizer, and
- 2" of topsoil with no fertilizer.

All plots were seeded with the cool season grass mix. Percent cover and biomass were highest on the plots containing 30 wet tons of NVS per acre and decreased in the order:

NVS30 > topsoil+fertilizer > NVS60 > NVS15 > MSW > topsoil

In addition to the reclamation study, individual species trials were conducted on the washed sand plots by the University of Minnesota.

1. Introduction.

Sand and gravel mining plays an important role in the economy of Minnesota, especially in high population areas such as the Mpls-St. Paul metropolitan area. Construction sand and gravel is used in concrete aggregates, concrete products, asphalt, road base, fill, snow and ice control, and other miscellaneous uses, and sand and gravel consumption is so important to the economy that it is considered one of the most accurate measures of economic activity. In 1991, over 26 million tons of material was produced in Minnesota, with a value of over $61 million (Buttleman, 1992), and Bob Bieraugel of the Shiely Co. (a large producer of aggregates in the state) estimates that 45 million tons of aggregate are now produced annually in Minnesota, for an average of 10 tons per each person in the state.

In the past, many gravel pits were abandoned upon completion of mining and reclamation was dependent upon natural revegetation. Although vegetation did usually re-establish to some degree in these pits, steep pit walls (and slopes with no topsoil) were often left after the operation closed, and vegetation success was often limited. In Minnesota, sand and gravel mining is regulated by local units of government, usually counties. In the late 1960's and early 1970's, counties began to require that reclamation plans be submitted for these operations. In general these operations are required to remove and stockpile topsoil during pit development, and then to replace it at the end of operation and establish vegetation. Operators are also often required to slope pit walls and stockpiles so that they are 3:1 or flatter.

Topsoil was often not stockpiled at older operations, and at some mines the topsoil is limited or of poor quality. The objectives of this study were to 1) examine the feasibility of using amendments produced from waste materials to supplement or replace topsoil, and 2) to determine the effect of these materials on water quality. The two waste products that were chosen for this project were N-Viro Soil (NVS) and Municipal Solid Waste (MSW) compost. (Additional amendments were considered. A complete list of potential amendments and the rationale for the selection of NVS and MSW compost can be found in Appendix 1.)

NVS is a sewage sludge-derived biosolid that is produced by addition of alkaline materials to dewatered sludge. The addition of alkaline material produces an exothermic reaction that raises temperatures to above 140° F and also increases pH levels above 12. This temperature and pH increase is sufficient to destroy pathogenic organisms while permitting beneficial soil microbes to survive (Kovacik, 1988, Burnham et al., 1992). Odors are also reduced considerably during the N-Viro process, and heavy metals, PCB's and other potential contaminants are kept low by regularly monitoring the sewage and alkaline materials prior to mixing. Metals that are present in the NVS are reported to be largely unextractable from NVS-treated soils, due to the somewhat elevated soil pH levels usually caused by NVS amendment (Burnham, 1992, Logan, 1990). Table 1 summarizes the composition of the NVS used in this project, as well as applicable Class 1 standards. Details on the N-Viro production process are presented in Appendix 2.

Table 1. NVS quality summary and applicable standards. Units are ppm unless noted otherwise.

Parameter	Average values[A], mg/kg		Composite[B] sample	Kg/ha applied	EPA's 503 standards for "clean sludge"
	1995	1996			
Plant Available (Exchangeable) Values					
% Organic Matter	na	na	16.2	---	---
NO_3-N (lbs/acre)	na	na	16	---	---
P (Bray 1)	na	na	3	---	---
K	na	na	580	---	---
Zn	na	na	2.1	---	---
SO_4-S	na	na	30.0	---	---
pH (s.u.)	12.3	12.1	12.0	---	---
B	na	na	3.5	---	---
Fe	na	na	324	---	---
Mn	na	na	1.9	---	---
Cu	na	na	4.2	---	---
Na	na	na	236	---	---
S.C. (mmhos/cm)	na	na	3.0	---	---
Ca	na	na	16383	---	---
Mg	na	na	190	---	---
CEC	na	na	86	---	---
Total Values					
Cd	5.1	5.1	2.45	0.12	39
Cr	18	19	24.1	1.21	1200
Cu	170	210	171.8	8.58	1500
Pb	106	100	52.0	2.60	300
Ni	28	55	18.3	0.92	420
Zn	120	139	69.87	3.50	2800
Hg	0.41	0.32	0.055	0.002	17
As	12	8.3	4.60	0.22	41
Se	6.3	6.0	<0.181	---	36
B	153	249	na	---	---
Mo	7.1	8.1	na	---	18

A: These are the values reported by Met Council's Environmental Services Divisions for NVS.
B: This is the sample DNR collected from the pile of NVS delivered to the Lysimeter Plots.

na = not analyzed
--- = not applicable

MSW compost is made primarily from household waste. Any hazardous materials and large items that can't be composted (golf clubs, mattresses, etc.) are removed from the waste stream prior to entering the processing line. Recyclable items (corrugated paper, plastics, aluminum cans, etc.) are removed by hand as the waste enters the plant on a conveyor belt. The remaining waste is shredded and mixed with water in a rotating drum, and is then passed through powerful magnets to remove any remaining ferrous materials.

The resulting raw compost is then placed into a composting hangar, where it is formed into windrows. The temperature and moisture of the material in the windrows are carefully monitored, and every eight days the windrows are turned, mixed and fluffed, with additional moisture being added if necessary. After 40 days this material is brought to a refinement building, shredded, and screened (3/8" screen) to separate the fine compost from the reject material. A machine called a "destoner" is then used to remove glass, stones and other hard particles. The finished product is then placed into stockpiles where further maturation occurs.

Although these two products (NVS and MSW compost) have been used in agriculture (Halbach et al., 1994a, 1994b, Stark and Schumacher, 1987), their use for mineland reclamation applications has been limited. MSW compost has been used successfully in test plots and small scale demonstration areas to reclaim coarse taconite tailings (Norland and Veith, 1995, Melchert et al., 1994), but no large-scale demonstration project has been completed.

NVS and MSW compost (from the Buffalo, MN, composting facility) were selected for this project based on their apparent suitability for the application in question, their easy availability in the metro area, and their current under-use. Both of these products are derived from waste materials which, if "markets" are not expanded, will need to be incinerated and/or landfilled. NVS is produced at the Seneca Wastewater Treatment Facility about two days per week, and if markets for this material weren't present, the sludge produced during those two days would instead need to be incinerated and the ash landfilled. Increasing the markets for NVS could lead to even less sludge being burned and buried.

Although yard waste compost is now widely accepted as a valuable organic material (by gardeners, landscapers, etc.), the use of MSW compost is currently limited, due largely to negative perceptions of "garbage". MSW compost can increase the organic content, fertility and moisture holding capacity of soil, and appears to be suitable for a wide variety of applications. Table 2 presents analytical data for the MSW compost used in this project.

The use of both NVS and MSW compost are regulated by the United States Environmental Protection Agency (USEPA) and the Minnesota Pollution Control Agency (MPCA). NVS is considered by MPCA to be an "Exceptional Quality" sludge, as defined by USEPA's regulations (40 CFR, Part 503, listed in 58 Federal Register 9248, February 19, 1992). To meet this standard the sludge must satisfy three criteria.

Table 2. MSW compost quality summary and applicable standards. Units are ppm unless noted otherwise.

Parameter	Material used at Shiely		Kg\ha applied	Standards[3]	
	Lot 24[1]	Composite[2]		Class 1, ppm	Class 2, kg/ha
Plant Available (Exchangeable) Values					
% Organic Matter	na	20.5*	---	---	---
NO_3-N (lbs/acre)	na	18	---	---	---
P (Bray 1)	na	3	---	---	---
K	na	910	---	---	---
Zn	na	24.5	---	---	---
SO_4-S	na	14.0	---	---	---
pH	na	7.4	---	---	---
Ca	na	3500	---	---	---
Mg	na	360	---	---	---
B	na	9.9	---	---	---
Fe	na	70.8	---	---	---
Mn	na	73.6	---	---	---
Cu	na	4.1	---	---	---
Na	na	243	---	---	---
CEC	na	23.9	---	---	---
S.C. (mmhos/cm)	na	5.0	---	---	---
Total Concentrations					
% Total solids	na	68.7	---	---	---
% Total vol. solids	na	45.5	---	---	---
P	1400	2910	---	---	---
K	na	5210	---	---	---
Cd	7.6	14.7	0.76	39	39
Cr	58.7	76.0	---	---	---
Cu	348	3968**	205	1500	1500
Pb	317	508	26.2	300	300
Ni	64.6	429	22.1	420	420
Zn	1520	4445	230	2800	2800
Hg	5.21	4.00	0.20	5	5
As	<20	4.64	0.24	41	41
Mo	5.2	6.840	0.35	18	18
Se	<15	<0.303	<0.016	100	100
Total PCB's	na	3.5	0.18	6	6 ppm
Total % C	24 (TOC)	26.89	---	---	---
Total % N	1.15	1.32	---	---	---
S.C. (mmhos/cm)	8.1	8.73	---	---	---

** anomalous value, but no sample available for reanalysis
na = not analyzed --- = not applicable
* This value is anomalously low in relation to the corresponding value for total %C
Notes: Class 1 compost must not contain >3% inert materials (dry weight) that are ≥4 mm in diameter, and Class 1 standards are based on concentrations. Class 2 compost must not contain >4% inert materials (dry weight) that are ≥ 4 mm in diameter, and, except for Pb, Class 2 standards are based on cumulative loadings.
1: This was the specific lot from which the material for this study was taken; data provided by Wright County.
2: A composite sample collected by DNR from the material applied to the lysimeter plots.
3: PCA standards for municipal solid waste compost (adopted September 1996)

The three criteria are:

1. Levels of 9 heavy metals (As, Cd, Cu, Pb, Hg, Ni, Se, Zn) must be kept below certain levels.

2. Vector attraction reduction must be attained. This means that the characteristics of sludge that attracts organisms (flies, rodents, mosquitoes, etc.) capable of transporting infectious agents must be minimized.

3. The material must be pasteurized; that is, pathogen reduction must occur.

In order to attain the last criteria (pathogen reduction), several alternatives are available to the sludge producer. In the case of NVS, the alternative chosen is that the sludge must meet the following requirements:

1. A temperature of 52° C must be maintained for a 12-hour period,
2. A minimum pH of 12 must be maintained for a 72-hour period, and
3. Total solids must be at least 50%. This is needed for stability; it the material was allowed to be wetter than this, organic material would decompose faster, maybe even anaerobically, and pH might come down too quickly.

If the three criteria are satisfied, the MPCA (under their proposed rules, which are pending) and the USEPA consider the material to be as safe as any other commonly available soil amendment, and therefore the landowner can apply the material without a permit. NVS has always met these criteria since production was commenced at the Seneca Wastewater Treatment facility in Eagan (MPCA's Jorja DuFresne, personal communication), and is the only sludge produced in Minnesota that is classified as Exceptional Quality. If these criteria were not met at some point in the future, the material would be classified as a Class B sludge and its use would be much more regulated, with factors such as allowable vegetation type, setbacks, and soil/water quality monitoring becoming involved. In this case, production of NVS would be halted until the problem could be rectified.

Municipal solid waste compost is classified by the MPCA as either Class 1 or 2. In 1996 the MPCA revised the standards and regulations relating to this material (Wirth, personal communication), and these standards are presented in the September 6, 1996 issue of the State Register. Under these rules, Class 1 compost must meet specific contaminant standards and can be used without restriction (Table 2), but Class 2 material requires MPCA approval, and its use is regulated based on the loading of metals to the soil.

When the study began, the former rules were in effect; these rules were based on concentration for both Class 1 and Class 2 materials. Under these rules, and based on the data provided to the DNR by the Wright County Compost Facility, the MSW used in this study was Class 2 material (Table 2), due to its elevated zinc levels. (Analysis of the specific material delivered to the site indicated that parameters other than zinc were also above the Class 1 limits; see Table 2.)

More detail on the classification and use of MSW compost is given in Appendix 3. Class 1 material is currently being used successfully in landscape projects and other applications, but Class 2 material does not have a comparable market (Mehrenberg, personal communication). Class 2 compost was acceptable for this project, and if successful may encourage its use in other applications.

2. Demonstration plots

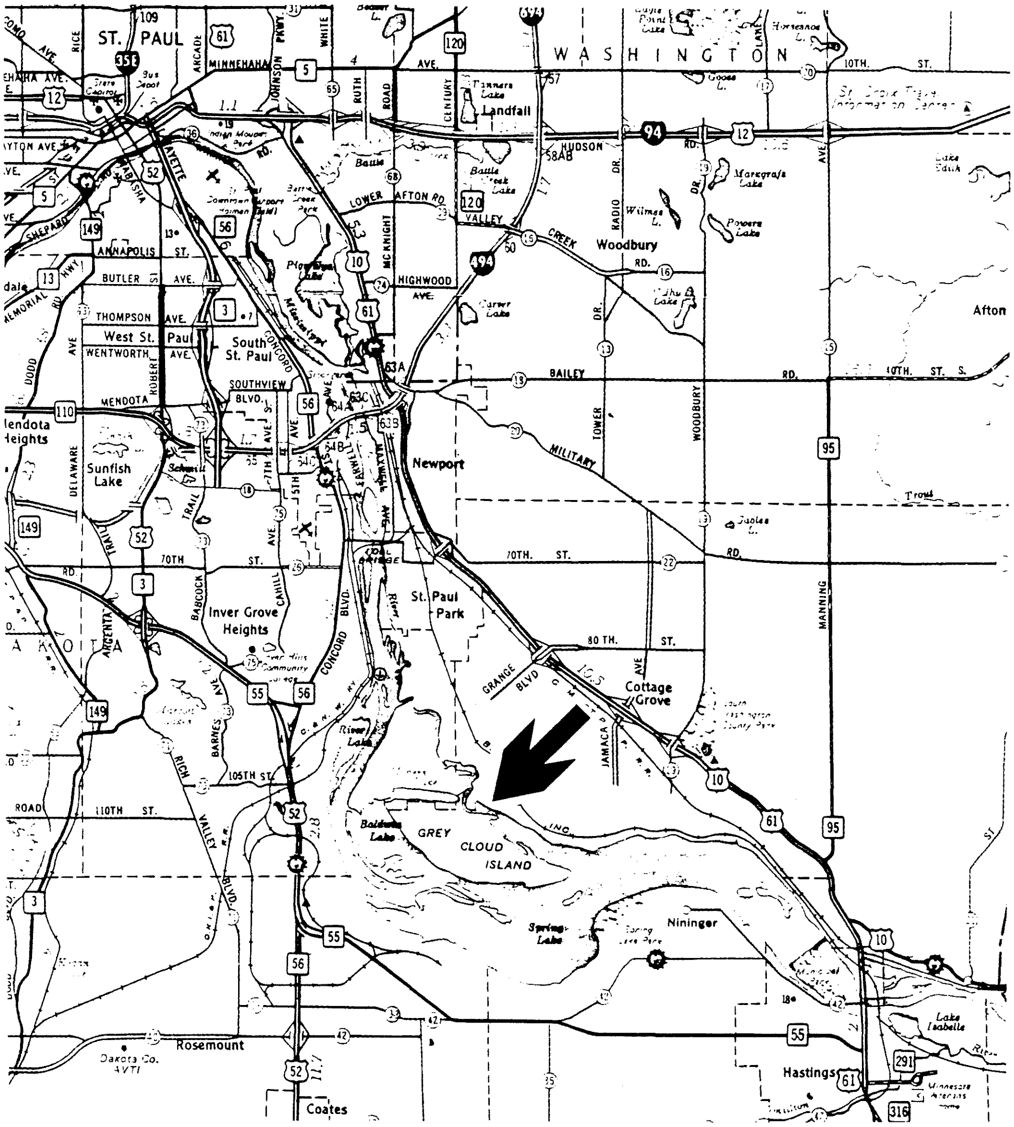
2.1 Site selection process.

The Division of Minerals was interested in conducting a cooperative gravel pit reclamation project in the Twin Cities metropolitan area which would entail the investigation of innovative reclamation techniques, and which would be easily accessible to other gravel pit operators so that the results of the project could be observed. Numerous potential project sites were considered and rejected due to factors such as limited access, insufficient size, and competing land-use plans, and in November 1995 a letter was sent to ARM (Aggregate Resource Minnesota; a sand and gravel mining trade group) which solicited interest by ARM members for such a project.

Two responses were received regarding this solicitation, and after consulting with those two companies on a suitable project and location, it was decided that a project would be undertaken at Shiely Co.'s Curley Nelson Mine, located on Grey Cloud Island, near Cottage Grove (Figure 1). (The Shiely Co. is owned by CAMAS America, Inc.)

At this large sand and gravel mine, which covers over 500 acres of Grey Cloud Island, a large floating dredge is used to extract sand and gravel from deposits at the east end of the pit. This material is passed through a crusher and then placed on a long conveyor belt that leads to a wash plant near the facility headquarters, where it is washed and separated into different classes of material. Very fine-grained sand called reject sand (which is unsuitable for most construction applications and therefore in little demand) is send via a slurry pipe to a large (50-acre) waste sand pile near the center of the mine. The other materials are either loaded onto large gravel trucks or onto barges in the adjacent Mississippi River for transport.

The focus of this project was a large, unreclaimed southern-facing sandy slope of about 9 acres, with an approximate slope of 4:1 (Figure 2). Despite three years of reclamation efforts, vegetation was sparse and large erosion gullies had formed down the length of the slope (Figure 3). This slope had been created when a steep pit wall was backfilled with reject sand from the mining operation. The slope was then covered with an approximate 1 ft. layer of a very sandy topsoil, which is also referred to as "black sand". Soil analyses revealed that the organic content



From downtown St. Paul, take Highway 61 south, go past 494, and then get off at the 70th St. exit. Take a right, follow the road to the next stop sign, then take a right (on Broadway). Go a few blocks to the next stop sign, then take a left. (You will then be on 3rd St, which turns into Grey Cloud Island Drive.) Take this road a couple miles till you come to a Y in the road, and take a left at the Y. Stay on this road for 2 or 3 more miles until you reach the pit. (You will pass over a small bridge just before reaching the pit.)

Figure 1. Location of Grey Cloud Island and Shiely Co.'s Nelson Mine.

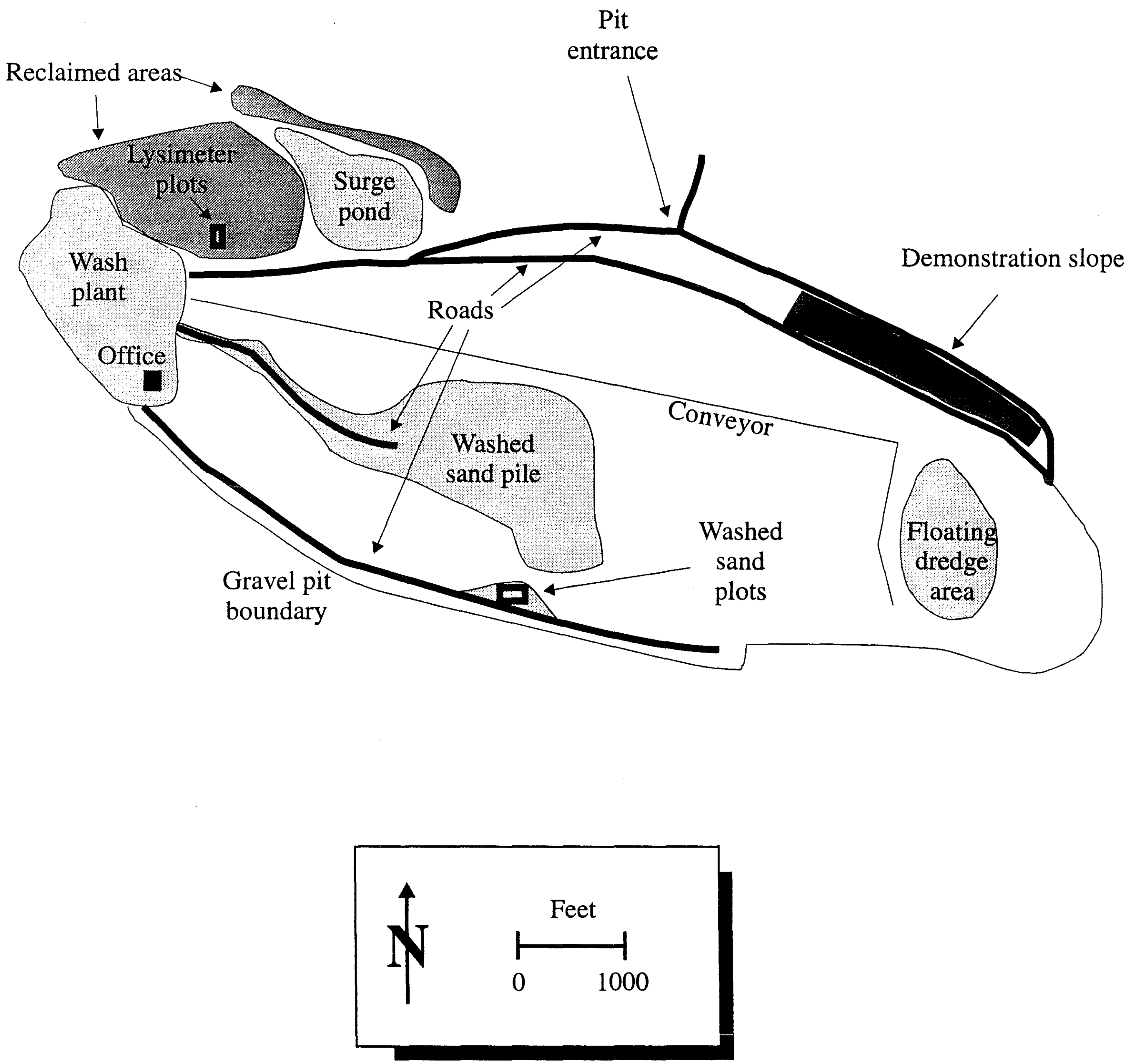


Figure 2. Site map of Shiely Co.s Nelson Mine with locations of the demonstration plots, the lysimeter plots and the washed sand plots.

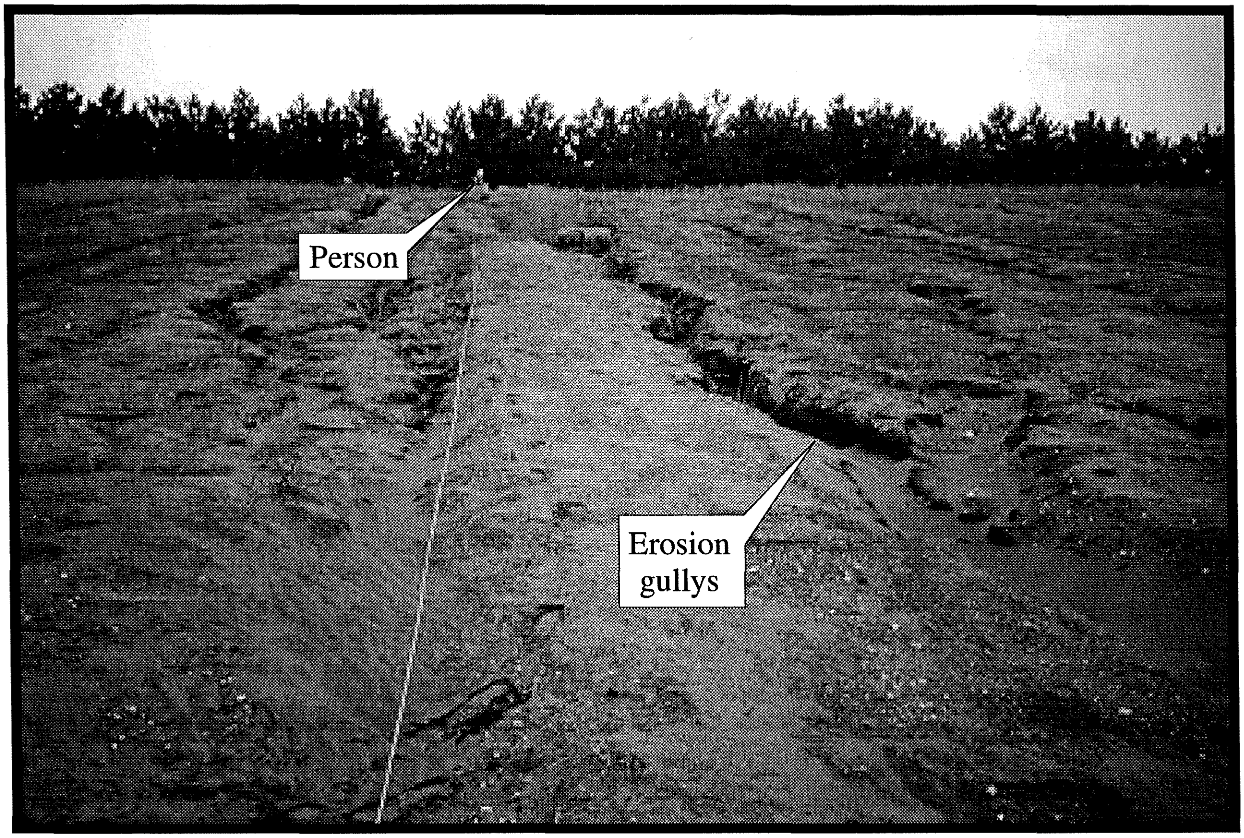


Figure 3. Original condition of the demonstration slope, as seen looking up the slope.

of the black sand was extremely low as were most nutrients, and in appearance this material resembles a colored sand (Table 3). Failure to establish vegetation on the slope was most likely due to the low fertility and low organic content of this material, and vegetative success should improve considerably if the organic and nutrient content of the slope surface could be increased, which may occur with NVS and MSW compost amendments.

Rather than construct a large number of small test plots, the slope was instead designated as a "demonstration project". The objective of this part of the study was to investigate the large-scale suitability of applying and using the two soil amendments in gravel pit reclamation, and was not intended to be a tightly controlled experiment. Since water quality impacts are often a matter of concern when biosolid materials such as NVS and MSW compost are used in these types of applications, additional smaller test plots were constructed on another site at the mine to monitor these potential impacts; these plots are referred to as the "lysimeter plots".

Table 3. Topsoil (a.k.a. black sand) quality summary. All values are ppm unless noted otherwise.

Parameter	Original DNR sample of slope collected Nov. 95	Samples collected from each demonstration plot after grading but prior to amendment spreading				Samples collected from the topsoil stockpile near the pit entrance			
		NVS plot	Topsoil +fert. plot	MSW plot	Control plot	First DNR sample[1]	Second DNR sample[2]	Grab sample A[3]	Grab sample B[3]
Plant Available (Exchangeable) Values									
Soil pH (s.u.)	7.5	6.9	7.0	6.9	7.0	6.5	7.3	6.2	6.3
NO_3-N (lbs/acre)	4	na	na	na	na	139	24	na	na
% Organic matter	0.8	1.1	1.2	1.1	1.3	1.7	1.5	1.3	1.5
P (Bray 1) (Olsen)	28 13	32 10	30 10	36 12	30 9	24 14	54 18	38 17	35 16
K	30	40	40	40	30	40	60	50	40
Ca	800	800	800	900	800	8000*	1900	700	700
Mg	160	140	150	150	130	140	160	120	130
Na	4	8	9	9	9	68	15	8	9
S (SO_4-S)	3	3	5	5	3	4.0	18.0	7	8
Zn	0.3	0.3	0.5	0.4	0.3	0.8	1.2	0.5	0.6
Cu	0.5	0.7	0.5	0.7	0.5	0.7	2.1	1.2	1.3
Mn	7.4	16.1	12.8	11.0	10.5	33.1	78.4	108.5	119.7
Salts (mmhos/cm)	0.1	0.1	0.1	0.1	0.1	0.2	1.2*	0.2	0.3
CEC	5.4	na	na	na	na	41.6	11	na	na
B	0.8	na	na	na	na	0.8	1.2	na	na
Fe	10.8	na	na	na	na	326.8	165	na	na
Total Values									
Cd	na	na	na	na	na	na	<0.883	na	na
Cr	na	na	na	na	na	na	5.54	na	na
Pb	na	na	na	na	na	na	<12	na	na
Ni	na	na	na	na	na	na	7.14	na	na
Hg	na	na	na	na	na	na	<0.018	na	na
As	na	na	na	na	na	na	0.949	na	na
Cu	na	na	na	na	na	na	1.525		
Zn	na	na	na	na	na	na	19.50		
Se	na	na	na	na	na	na	<0.259	na	na

na: not analyzed
*: These values are clearly anomalous, but reanalyses are not possible because the sample was discarded.
1 This sample was a composite of 10 grab samples that were collected from 6" to 10" below the surface of the topsoil stockpile (April 96).
2 This DNR sample is a composite of grab samples taken from the load of topsoil brought from the stockpile to the lysimeter plots (May 96).
3 These two samples were collected by Kathy Draeger and Mike Jorgenson, and were for "Stockpile A" and "Stockpile B", but these two stockpiles are just two parts of the same stockpile at the pit entrance.

The mine also contains a large (approximately 50 acre) washed sand pile that receives sand that is too fine for most industry uses, and which is instead just stockpiled at the mine. The washed sand is alkaline and infertile, with very low organic and nutrient contents (Table 4). Some areas of the pile that have been undisturbed for several years support virtually no vegetation, and additional test plots were constructed on this material. Figure 2 depicts the location of these plots, the lysimeter plots and the demonstration slope.

2.2 Demonstration slope design and preparation.

Many factors were considered in the layout of the demonstration slope. A summary of potential advantages and disadvantages of options that were considered is presented in Appendix 1. The final design called for the slope to be separated into four individual plots (Figure 4), with each of the four plots receiving a different amendment. Two different seed mixes were used across the entire slope. The top 1/3 of the entire slope was seeded with a standard seed mix used by the Minnesota Department of Transportation for road sides (MNDOT 50 mix), while the bottom 2/3 of the entire slope was seeded with a native prairie seed mix (MNDOT 20 mix; Table 5). Details on seed selection and planting methods are presented in Section 2.6 and Appendix 4. The plots were designed as follows:

<u>Plot 1</u> NVS, applied at a rate of 43 wet tons/acre (22.3 dry tons\acre; approximately equal to an application depth of 1/4"), with no fertilizer added.

<u>Plot 2</u> Existing "topsoil", with fertilizer (12-12-12 N-P-K) applied at a rate of 165 lb/acre on the upper 1/3 of the slope (i.e. the MNDOT 50 seed mix) and a rate of 83 lbs/acre on the bottom 2/3 of the slope (i.e. the MNDOT 20 seed mix).

<u>Plot 3</u> MSW compost, applied at a rate of 23 dry tons/acre (approximately equal to an application depth of ½"), with fertilizer added at ½ the rate used for Plot 2.

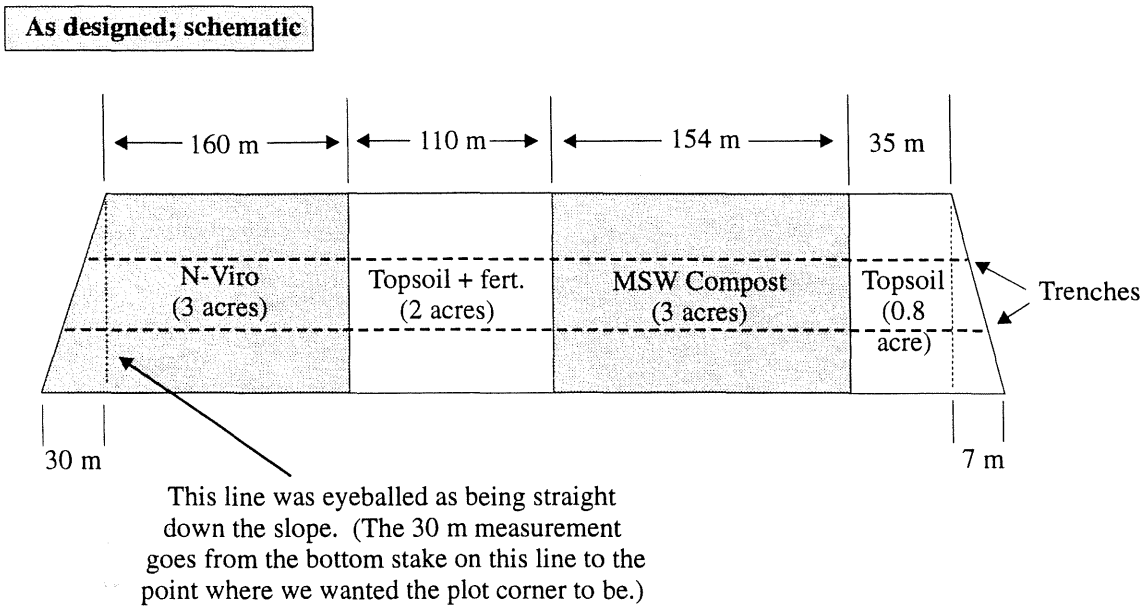
<u>Plot 4</u> This is the control plot, where neither amendment material nor fertilizer was added.

Prior to spreading the amendments, it was necessary to smooth out the surface of the slope and to fill in some of the large erosion gullies that were present on the slope. A front-end loader was used to load black sand from a stockpile located near the pit entrance into a bottom-opening dump truck, and then this material was deposited in long thin rows that ran up and down the slope. (These rows were placed approximately 50 feet apart across the entire slope.) A front-end loader equipped with a dozer blade pushed this material down the slope and filled in the erosion gullies, and then a bobcat was used to remove approximately 100 hay bales that were present on the slope from previous erosion-control efforts; these bales were pushed to the bottom of the slope and removed.

Table 4. Composition of material in the 50-acre washed sand pile. All values are ppm unless noted otherwise.

Parameter	DNR's November 1995 sample of the 50-acre pile	Draeger's 1996 sample of the smaller pile near the road (see Figure 2)
Plant Available (Exchangeable) Values		
% Organic Matter	0.1	0.2
NO_3-N (lbs/acre)	6.0	2.0
P (Bray 1)	5.0	6.0
K	20	70
Zn	0.2	0.5
SO_4-S	2.0	6.0
pH (s.u.)	8.9	7.6
B	0.8	0.2
Fe	10.8	6.5
Mn	3.6	2.2
Cu	0.3	0.3
Na	7.0	8.0
S.C. (mmhos/cm)	0.1	na
Ca	1400	1800
Mg	110	100
CEC	8.0	na
Total Values		
Cd	na	1.02
Cr	na	6.86
Cu	na	5.94
Pb	na	<13.9
Ni	na	7.61
Zn	na	14.29
Hg	na	<0.01
As	na	1.48
Se	na	0.268
B	na	na
Mo	na	0.301

na = not analyzed



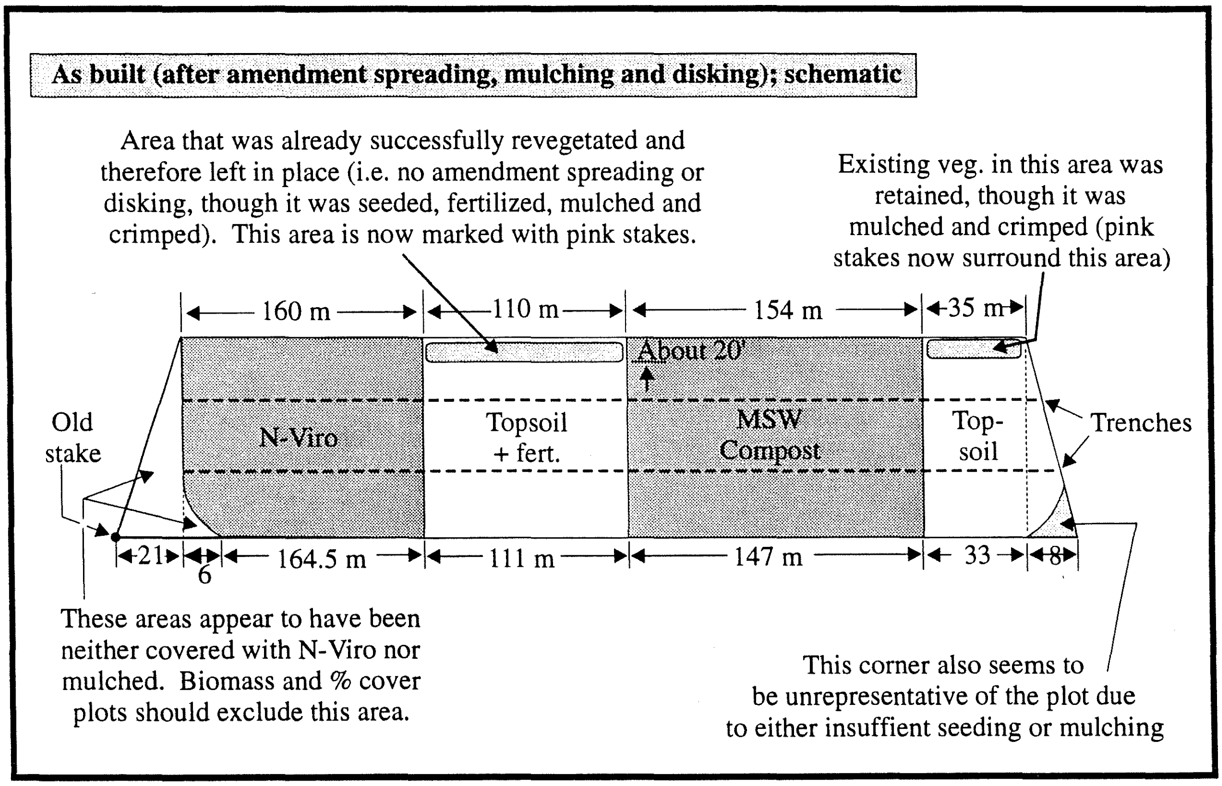


Figure 4. Design schematic of the four plots on the demonstration slope.

Table 5. Seed mixes specified for the demonstration plots. The actual mixes (purchased from Peterson Seed Co., Savage, MN) differed somewhat from these specs; specifics of the actual mixes will be presented in the final report.)

Species	Percent of Total	Total lbs. PLS*
Native Grass/Forb Prairie Mix (similar to MNDOT mixture 20A)		
Bluestem, big	5.0	12.0
Bluestem, little	10.0	24.0
Dropseed, sand	2.0	4.8
Grama, sideoats	6.0	14.4
Indian grass	3.0	7.2
Switch grass	3.0	7.2
*Forbs (SE Region Mix)	3.0	7.2
Wheat-grass, slender	2.0	4.8
<u>Cover crops:</u>		
Wild-rye, Canadian	3.0	7.2
Oats	33.0	79.2
Rye-grass, annual	11.0	26.4
Flax	19.0	45.6
		Total 240.0 lbs
Turf/Native Grass Mix (similar to MNDOT mixture 50A)		
Bluegrass, Canada	16.6	39.9
Bluestem, little	5.0	12.0
Bromegrass, smooth	16.6	39.9
Prairie clover, purple	1.0	2.4
Switch grass	6.7	16.0
Timothy	5.8	13.9
Wheat-grass, slender	6.7	16.0
<u>Cover crops:</u>		
Rye-grass, perennial	10.0	24.0
Rye-grass, annual	5.0	12.0
Oats	16.6	39.9
Flax	10.0	24.0
		Total 240.0 lbs.

* PLS stands for Pure Live Seed. A portion of all seed mixes is made up of dead and/or inviable seeds, so that 10 lbs of pure live seed mix may weigh over 10 lbs.

Note: Fine grass and forb seeds were separated from large and fluffy seeds. Forb mix consists of the following species (5% for each species, bulk weight 6 ounces each): Aster, heath; Aster, New England; Aster, sky-blue; Bergamot, wild; Black-eyed Susan; Blazingstar, meadow; Blazingstar, rough; Blazingstar, tall; Bushclover, round-headed; Coneflower, grey-headed; Milkvetch, Canada; Milkweed, butterfly; Onion, prairie; Ox-eye, common; Partridge pea; Prairie clover, purple; Prairie clover, white; Penstemon, showy; Tic-seed, stiff; and Vervain, blue. Acceptable substitutes were: Aster, smooth-blue; Aster, upland-white; Goldenrod, showy; Goldenrod, stiff; Spiderwort, Ohio; Vervain, hoary; and Tick-trefoil, showy.

Once this process was complete, the loader traversed the length of the slope, pushing and dragging the dozer blade as it went, until the entire slope was generally smooth. This slope preparation work occurred on Tuesday and Wednesday, May 7 and 8, 1996. Soil samples were collected from each plot prior to amendment spreading; analyses of these samples are presented in Table 3.

2.3 Amendment and fertilizer spreading.

The NVS and the MSW compost were hauled to the site in semitrailers which generally had a load capacity of around 20 tons. Details on mass and time of shipment are in Appendix 5. Spreading of the amendments started with the MSW compost, and commenced about 9:30 am on Thursday 5/9/96. Original plans had been to use bulldozers to push the amendments down the slope, but once at the site we realized that this plan was too optimistic since achieving the desired application rate would require that the dozers create a uniform ½" layer down a 250'-long slope. A 9-ton side-slinging MSW compost spreader, which was borrowed from the MSW facility in Buffalo, MN, was used to spread the amendments.

A front-end loader was used to load the compost from the pile at the top of the plot into the spreader. The spreader then drove down (via the topsoil control plot) to the bottom of the slope, and then drove across the plot, shutting off the outlet port as it reached the end of the plot. It then drove up the slope (via the topsoil+fertilizer plot) and back to the loader, where it was reloaded. The process was then repeated until the entire plot was covered.

The passes across the slope weren't completely parallel to the roads. Each pass tended to be higher in the center of the plot than at the ends, because the spreader tended to slip somewhat on the sandy substrate present on the slope. This curved path resulted in two triangle-shaped patches at the top of the slope that were bare (see Figure 4), and these two patches were filled in after the initial passes had been completed. Stakes (marked at ½" intervals) were used to determine the uniformity of MSW application. Additional material was applied until the required loading was achieved throughout the plot.

During operation, the MSW spreader threw compost from about 5' to about 15' away from the spreader. The thickness of the swath was not completely uniform, with thicker cover at the center (i.e. about 10' from the spreader), and lighter coverage at the edges of the swath. Therefore even "perfect" coverage would result in uneven amendment depth.

The application process was then repeated for the N-Viro soil plot, except that the addition rate of 43 wet tons/acre (22.3 dry tons/acre) was equivalent to a target depth of 1/4" instead of 1/2". The NVS was denser than the MSW compost, and the swath of material was not as wide as was observed with the MSW.

Fertilizer (12-12-12 NPK) was applied to the MSW plot and the topsoil+fertilizer plot. The fertilizer was applied at a rate of 165 lb/acre on the upper 1/3 of the topsoil plot (i.e. the

MNDOT 50 seed mix) and a rate of 83 lbs/acre on the bottom 2/3 of the two plots (i.e. the MNDOT 20 seed mix). The fertilizer was spread by a circular spreader pulled behind a small tractor, with the application rate being controlled by the speed of the tractor. Since the MSW has some fertilizer value (approximately 1-¼-¼ NPK; Table 2), the rate on this plot was 1/2 of that applied to the topsoil plot.

Fertilizer was not spread on the control or the NVS plot. NVS also has fertilizer value (Table 1) and the representatives of N-Viro Minnesota wanted to test the hypothesis that the NVS contained sufficient nutrient capacity to meet the needs of the vegetation.

2.4 Disking the amendments into the plots, and trench/berm construction

After the amendments and fertilizer were spread, all the plots were disked to incorporate the material into the soil. A 12'-wide disk attachment, with 6" disk spacing, was attached to the back of a tractor, and was dragged across the entire width of the slope. Two areas of existing vegetation on the topsoil plots were not disked. These areas were at the top of the slope and extended about 15-20' down the slope (Figure 4). Two shallow trenches (approximately 1 ft. deep) were then cut lengthwise into the slope to separate the slope into thirds, with the spoil material cast immediately down slope of the trench to form small berms. These trenches, which were created by dragging a plow behind a small tractor, were designed to break up water flow down the slope and thus help prevent the formation of large erosion gullies.

2.5 Seeding and mulching.

The top 1/3 (or approximately 74 to 92 ft.) of the slope was seeded with a MNDOT mix (50 mix; Table 3). Even though this mix may not necessarily be the optimal seed mix to use in such an application, it was selected based on its wide availability and use, and its relatively low cost. Since the purpose of this project is to identify innovative reclamation techniques that are both successful and cost-effective, it was felt that it would be appropriate to use the seed mix that would most often be used by other operators. The MNDOT 50 mix was broadcast at a rate of 60 lbs/acre.

The bottom 2/3 of the slope was planted with a native prairie seed mix (MNDOT 20, Table 3). Prairie species often do well on drier soils with low fertility and tend to produce a more diverse stand of native vegetation than the more widely used and less expensive 50 mix. The 50 mix, although generally effective in producing a high percent cover, tends to produce a lower diversity stand that includes non-native species such as brome grass. The 20 mix, which contained some seeds that were fluffier and lighter than those in the 50 mix (and therefore more difficult to broadcast) were planted with a seed drill (Truax Flex 88, with the till attachment raised up) at a rate of 30 lbs/acre. Typical costs for seeds and planting are summarized in Appendix 4.

After seeding was completed, the entire slope was mulched with straw. The desired mulch rate was two tons/acre across the entire slope. (For the entire 9 acre site, this amounted to 18 total tons.) The mulching contractor had planned to spread the mulch with a platform-mounted blower which shot the mulch out over the area. This blower was pulled by the truck that carried the hay bales. However, the truck could not maneuver on the sandy slope, so instead Shiely had to pull the truck and blower with a large front-end loader across the slope. The large loader produced depressions in the slope and caused some compaction as well. Weather conditions during the mulch application were not ideal, with rain and a southeast wind. The mulch application was not uniform and the contractor left the site before all the mulch was applied (bringing the remaining mulch with him). Based on visual observation, the effective mulch rate was on the order of 1.0 to 1.5 tons/acre (Dewar, personal communication). After the mulch was spread it was crimped in by a tractor that was pulling a crimper.

2.6 Monitoring program

After construction of the slope was completed, the site was generally visited on a weekly basis. During these site visits the demonstration slope was inspected to qualitatively observe the progress of the vegetation, to look for erosion gullies, and to chronicle the general status of the slope, sometimes with a camera or a video camera. Notes from these site visits are presented in Appendix 6.

Measurements of percent cover on the demonstration plots were made on August 6-8, 1996, using a systematic grid pattern. (The top 2/3rds of the N-Viro plot were done on August 6, the bottom 3rd of that plot and the entire control plot were done on August 7, and the MSW and topsoil+fertilizer plots were done on August 8. Details on sampling design, rationale, and field notes are presented in Appendix 7.)

On the demonstration slope, 24 percent cover estimates and 4 biomass samples were collected from each of the three sections of each plot (which were separated by the two trenches). Original plans had been to consider each plot to consist of two portions, the MNDOT 50 area and the MNDOT 20 area, but the middle 1/3rd of the slope seemed to have more vigorous vegetative growth than the bottom 1/3rd (even though both sections were planted with the 20 mix), and therefore those two sections were considered independently. (The two trenches were the dividers between the three sections.)

Three transects were laid out on each third of a plot so that it was divided into three equal areas. (A buffer area was excluded prior to calculation of these transects, with 5 meters excluded at the top, bottom and sides of the entire plot, and with 2 meters excluded on either side of the two trenches. The buffer area was designed to avoid edge effects and to exclude the top portion of the topsoil plots where original vegetation had not been removed prior to reclaiming the slope.) On each transect, 8 sites (called quadrats) were located so that the distances between the sites were equal. Percent cover was thus estimated for a total of 288 quadrats on the entire slope (i.e. 72 per plot). At each quadrat an 0.5 m^2 frame was placed on the ground, and then the vegetative cover was estimated by visually determining its "cover class", which correspond to a range of percent cover (Appendix 7). Several methods for determining percent cover are available; the method used in this study, while less quantitative than other available methods, has been found to be appropriate in mineland reclamation studies (Jordan and Dewar, 1988).

It should be noted that there are two basic methods for determining percent cover; random sampling and systematic sampling. The primary advantage of random sampling is that it allows rigorous statistical analysis of the data. With a systematic sampling system there is no way to calculate a standard error term or confidence limits, and so no mathematical statement of error can be made. On the other hand, it has been demonstrated in repeated field experiments that systematic sampling provides the same level of precision as random sampling (Raelson 1982), and the systematic method is undoubtedly more time-efficient than random sampling, in which the sampler must zig-zag across the plot in a random fashion.

On the lysimeter plots, the location of the quadrats were selected by constructing a series of string lines, but this approach was not feasible on the large demonstration area slope. Instead, the widths and lengths of the plots were paced off (excluding the buffer areas), and then the appropriate distances between quadrats (in paces) were calculated. Flags were then set up at the ends of the plots to show where the end of the transects should be, and the transects were put in place by walking in a straight line between the flags. Percent cover quadrats were then located at the predetermined intervals (i.e. the entire width of the plot except the buffer area, divided by nine).

In an effort to ensure that the location of the quadrats were unbiased and not affected by a subconscious tendency to place the frame in areas of either thick or thin vegetative growth, the exact placement of the measuring frames were determined by throwing a pencil over the left or right shoulder of the person who was pacing the transects. The upper-right-hand corner of the percent cover frame was placed at the tip of the pencil, with the long side of the frame being oriented so that it was roughly parallel to the length of the slope. In addition, when approaching a sampling point, an attempt was made to ignore the surrounding vegetation so as not to bias the throwing of the pencil.

Once the percent cover frame was placed, the percent cover within the frame was estimated by determining the appropriate 'cover class' for that area. There were 10 cover classes (Appendix 7), but the ranges of these classes were broader near the middle of the scale, and smaller near the ends of the scale. A two-person crew was used to make these estimates, and in most cases there was good agreement on the assignment of cover class. In those relatively few times when there was disagreement about cover class, the two crew members took turns making the final decision.

Four biomass samples were collected from each third of a plot, so that 12 samples were collected from each of the four plots. A random number table was used to determine which of the 24 percent cover quadrats (on each third of a plot) would also be biomass sites, and at each of these four sites, a smaller (0.1 m^2) frame was placed within the percent cover frame in the upper-right-hand corner. All above-ground biomass within this smaller frame was clipped off and placed into an appropriately labeled ziploc bag. The 48 samples thus collected were then sent to the MDNR-Minerals laboratory in Hibbing, MN, where they were dried in an oven for 24 hours at 80° C and then weighed. In future years, biomass and percent cover estimates will be made at the same approximate time of year (i.e. as near to August 6-8 as possible) so that meaningful growth comparisons can be made. General observations on plant growth and species prevalence were made throughout the field season. Video records were made on several occasions to document changes in the plots.

3. Lysimeter plots.

3.1 Site selection and plot design.

The lysimeter plots were created to allow determination of water quality impacts that may be associated with the use of NVS and MSW compost in gravel pit reclamation. Installing lysimeters in the large demonstration plots was considered but rejected due to two factors. Both of these problems had been observed with lysimeters constructed at a small-scale demonstration study conducted on a taconite tailings slope (Melchert et al., 1994).

- It would have been very difficult to construct the demonstration plot so that identical conditions could have been created on each demonstration plot. Any difference in water quality results could be an artifact of the plot layout and construction rather than an effect of the amendments themselves. For example, it was impossible to apply a completely uniform layer of the amendments, so that a lysimeter may have been installed in an area that had an unusually thick (or thin) application, thereby potentially either magnifying or underestimating potential impacts that would arise from the slope as a whole. Also, since slope length and grade varies, factors such as hydraulic conductivity, permeability, soil composition and erosion could also potentially be variable to the point of compromising results.

- If an erosion gully formed over the lysimeter, water quality data from that lysimeter may not be representative of the slope as a whole. On a flat area, where erosion forces are minimized, this potential problem is avoided.

Because of these concerns, 10 smaller lysimeter plots were constructed on a previously reclaimed flat area, located near the wash plant (Figure 2). These plots were built to simulate the reclamation efforts used on the demonstration slope. This site was selected because mining activities no longer occur in this area (so the plots can remain in place indefinitely without danger of getting in the way of pit operations). This site is also easily accessible, and the reclamation methods used on the demonstration slope could be replicated.

Each lysimeter plot measures 2.5 x 4 meters, and two parallel rows were constructed. Topsoil was added to all 10 plots, and then fertilizer, NVS and MSW compost were added to the plots in triplicate (i.e. three plots received fertilizer, three received compost, and three received NVS), with the order of the plots having been randomly assigned (Figure 5). The tenth plot (to which MSW compost was added) is used to check for water in the lysimeters (see Section 3.3) (with the assumption that if there is water in that plot then there is also likely water in the other nine plots), and it also serves as an observation plot to examine the effectiveness of MSW compost without fertilizer.

3.2 Construction.

The lysimeter plots were intended to model the reclamation of the demonstration slopes, but in a more convenient and flatter location. The demonstration slope was formed after mining operations in that portion of the pit had been terminated (as the active pit face migrated to the southeast), and was created by backfilling the steep pit wall with reject sand until a slope of roughly 4:1 slope was achieved. This sandy slope was then covered with a layer of the topsoil (a.k.a. black sand) that had been stripped and stockpiled prior to mining. A survey of the slope indicated that the thickness of this topsoil layer ranged between 4" and 12", with an average thickness of about 6" to 8".

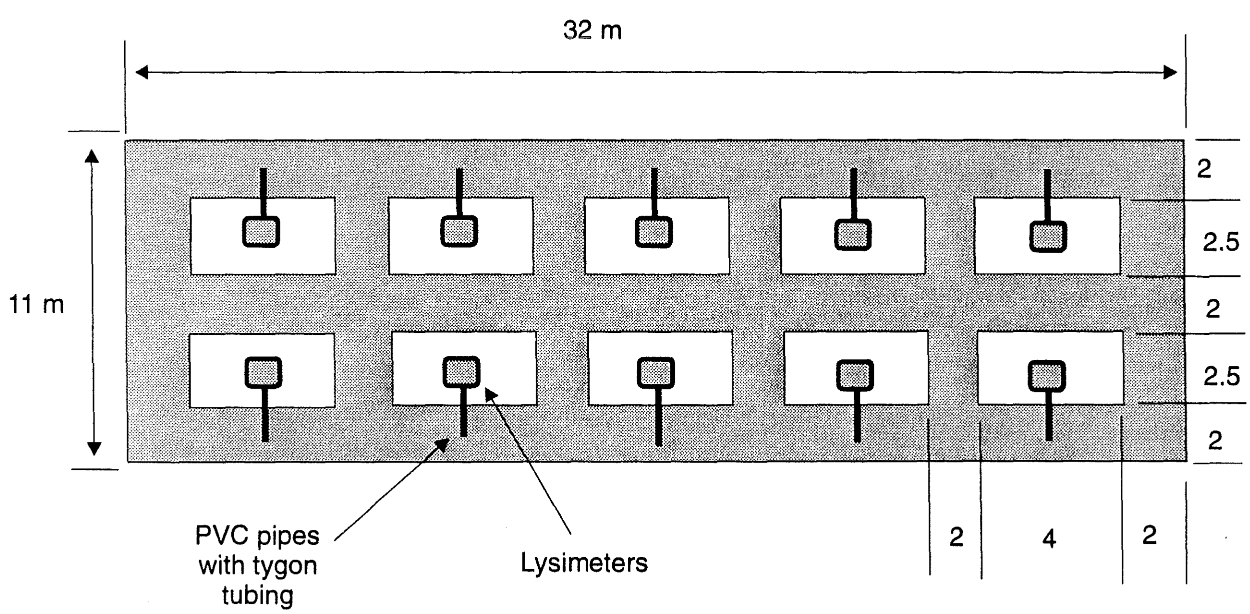


Figure 5. Design schematic of the lysimeter plots.

At the flat area intended for the lysimeter plots, similar conditions existed, with a layer of topsoil also present in this area, with this layer also averaging about 6" to 8" thick. The main difference between this area and the demonstration slope was that this area was flat (and thus experiences little erosion compared to the slope), which in turn allowed the vegetation in this area to do very well. In order to simulate the situation at the demonstration area, it was necessary to strip the plot area of its vegetation, since the small amount of vegetation on the slope was destroyed during slope preparation. On April 25 a front-end loader was used to strip off the topsoil/vegetation layer.

Once the plot area was stripped and smoothed, the lysimeters were installed in each of the 10 plots. The lysimeters were constructed from 2' x 3' plastic basins (1' deep) that were equipped with 18" sections of slotted well screen (Figures 6 and 7). (Additional details on lysimeter construction are presented in Appendix 8.) The lysimeters were set in the plots so that the lowest corner (where the plumbing is attached) was at a depth of 18" from the surface After the plots were allowed to settle for about two weeks, a 6" layer of topsoil (from the same stockpile used to fill in gullies on the demonstration slope prior to amendment spreading) was spread on top of the plots. Topsoil was then placed (by bobcat) in the areas between the plots and in a band about 5' wide around the perimeter of the plots. This additional topsoil was placed to prevent the plots from behaving hydraulically like isolated raised beds.

The amendments were then weighed and spread by hand on top of this topsoil layer in the appropriate plots. NVS was applied at a rate equivalent to 40 wet tons/acre (20.8 dry tons/acre), while the MSW compost was applied at 20 dry tons/acre. Fertilizer (12-12-12) was weighed and applied to the topsoil plot at a rate of 165 lbs/acre, and to the MSW plot at 83 lbs/acre. (No fertilizer was applied to the NVS plots.) The plots were then tilled with a rear-tine tiller to mix the amendment material and fertilizer into the topsoil layer. The tines were adjusted to avoid tilling into the underlying sand layer. All plots were seeded with the MNDOT 50 mix at a rate of 60 lbs/acre. The seeds were lightly raked and the plots were hand-mulched with the equivalent of 2 tons of straw per acre.

Erosion netting was then placed over each plot. (The mulch was crimped in on the demo slope, but this wasn't practical on the much smaller lysimeter plots, so the netting was used instead to keep the mulch from blowing away.) The netting is ultraviolet-sensitive, and will eventually break down. Additional details on the planting of the plots and a detailed timeline are given in Appendix 9.

3.3 Monitoring program.

A continuously-recording rain gage was set up in the center of the plots. Since this gage needs to be wound up about every 7-10 days, these plots were visited approximately once a week throughout the 1996 growing season. The precipitation data from this gage is discussed in Section 5.2.4, with additional detail presented in Appendix 10. Water samples were to be collected after major rainfall events, which were projected to occur every other week on

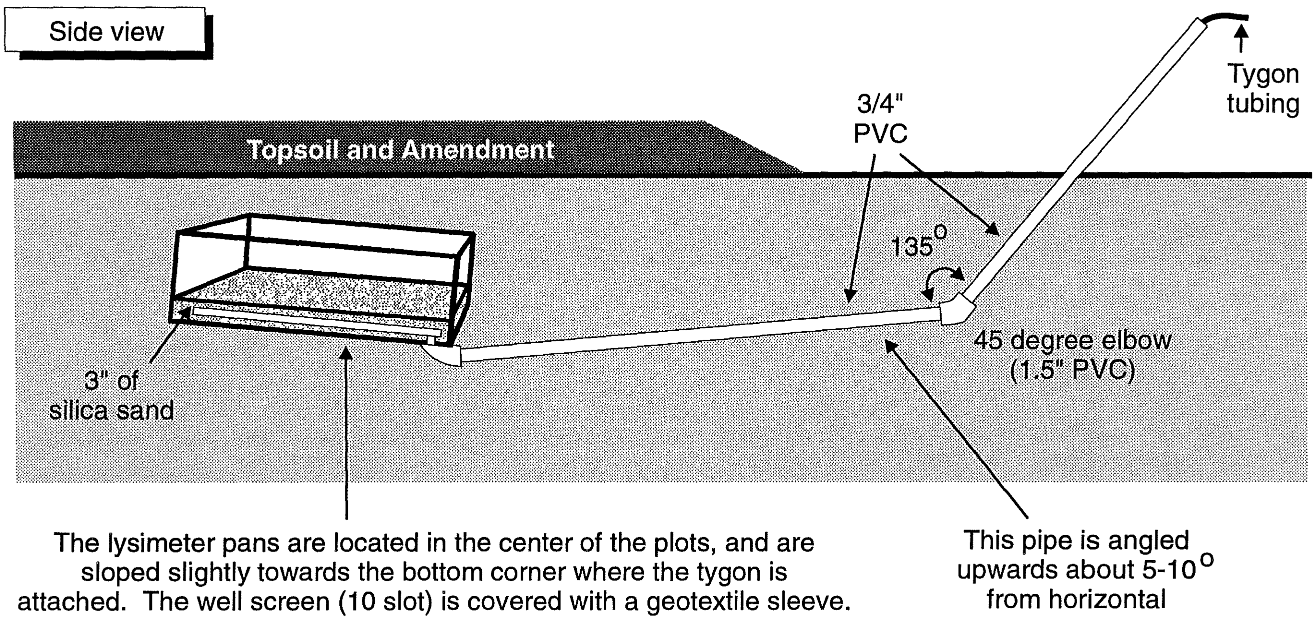


Figure 6. Design of the lysimeters.

Figure 7. Lysimeter installation.

average. However, rainfall from May through September was significantly below normal (11.2 inches, or about 57% of the 30-year average of approximately 19.8 inches), and as a result no water samples were collected.

A peristaltic pump will be used to collect samples during the 1997 field season. The pump will be initially hooked up to the Tygon tubing emerging from the lysimeter in the 10th plot (the extra plot), with the pump then turned on for a few minutes to determine if water is present in the lysimeter pan. If no water emerges after 2-3 minutes, the pan will be assumed to be dry, as are the other nine plots. If water does emerge, at each plot a small amount (equal to the volume in the Tygon tubing between the lysimeter and the pump) will be collected and then discarded; this is intended to avoid any contamination of the current sample from the previous sampling period. The remainder of the water will be collected until the flow stops, and then the total pumped volume will be measured. Samples will be collected in 2-liter HDPE jugs, labeled, and then brought to the laboratory to measure pH and specific conductance, and to prepare the samples for additional analyses. (Additional details on sample preparation and analysis is presented in Appendix 11.) The results of these analyses will then be entered into a computer data base, from which tables, graphs and statistical analyses will be produced.

4. Washed sand plots.

4.1 Site selection and plot design.

Original plans had been to construct the washed sand plots on top of the large pile adjacent to the haul road. This site was rejected primarily due to the concerns of the plant manager about safety issues related to the heavy traffic in the area associated with the mining operation. He also couldn't guarantee that the site would remain undisturbed for several years, a condition that was necessary because of the fact that it often takes native species several years to become established. A smaller and more remote site was found near the Mississippi River, about a third of a mile from the wash plant. This site contained the same waste material as the larger (and currently active) pile. The use of this site doesn't interfere with pit operations, and since the site is far away from current operations it should remain undisturbed for at least five years.

As shown in Figure 8, the design of the plots was for a matrix of 15 plots, each of which was 2.5 meters wide and 11 meters long. Five different amendments were applied to the plots, with triplicates of each amendment producing a total of 15 plots. The five amendments were:

a) NVS at a loading of 60 wet tons/acre (31.2 dry tons/acre)
b) NVS at a loading of 30 wet tons/acre (15.6 dry tons/acre)
c) NVS at a loading of 15 wet tons/acre (7.8 dry tons/acre)
d) MSW compost at a loading of 28 wet tons/acre (20 dry tons/acre, based on a density of 69% solids)
e) Topsoil

Each of the 15 plots was also divided to yield one sub-plot of 2.5 x 4 m, and another that was 2.5 x 7 m. The smaller portion received the MNDOT 50 plant mix, while the larger portion of each plot was used by the University of Minnesota to study plant germination and growth of individual species.

4.2 Construction.

After the plots were staked out and string lines were placed, topsoil was added to each of the three topsoil plots at an approximate depth of 2 inches. MSW compost and NVS were then applied to their respective plots with 5-gallon buckets, and then a tiller was used to work the NVS and MSW compost into the topsoil; the topsoil plots were not tilled; the topsoil was instead left as a top dressing. Once this was completed the seed mix (MNDOT 50 mix) was broadcast by hand onto the smaller portions of each plot, and the larger portions were hand planted with a variety of plant species as part of the University of Minnesota study. Mulch was then applied to each plot at an approximate rate of 2 tons/acre, and then covered with erosion netting.

After this original matrix of 15 plots was constructed, three additional plots (each 2.5 x 4 m) were then constructed (Figure 8). These were added to simulate the fertilizer plots on the demo slope and at the lysimeter plots, and were intended to represent the typical approach taken for reclamation (i.e. the "standard reclamation" approach). Topsoil was placed on these three plots at a depth of 4 inches (and was not tilled in), and then 12-12-12 fertilizer was broadcast onto the plots at a rate of 165 lbs/acre and raked in. These three plots were then mulched at an approximate rate of 2 tons/acre, and then erosion netting was placed on top of the mulch.

It should be noted that the washed sand plots are on top of a hilly area, and are very exposed to the wind. After the big windstorm in June (see Appendix 10) tore netting off of one of the NVS60 plots, almost half of the mulch on the plot was completely blown off by wind. This mulch was replaced with some leftover mulch that had been left at the site, and then the netting was put back in place. While it is recognized that this altered the original conditions of the plot somewhat, the alternative was deemed to be worse; to leave large mulch-free areas on the plot where vegetation establishment and growth would have been hindered irrespective of the amendment on which they had been planted.

4.3 Monitoring program.

Biomass and percent cover was measured on the washed sand plots on August 16, 1996, using the same method as described for the lysimeter plots. Similar measurements will be made in 1997 (and possibly beyond) to observe temporal changes in vegetative cover on these plots. The number of biomass samples per plot will be increased from one to either two or three, to get more accurate measurements.

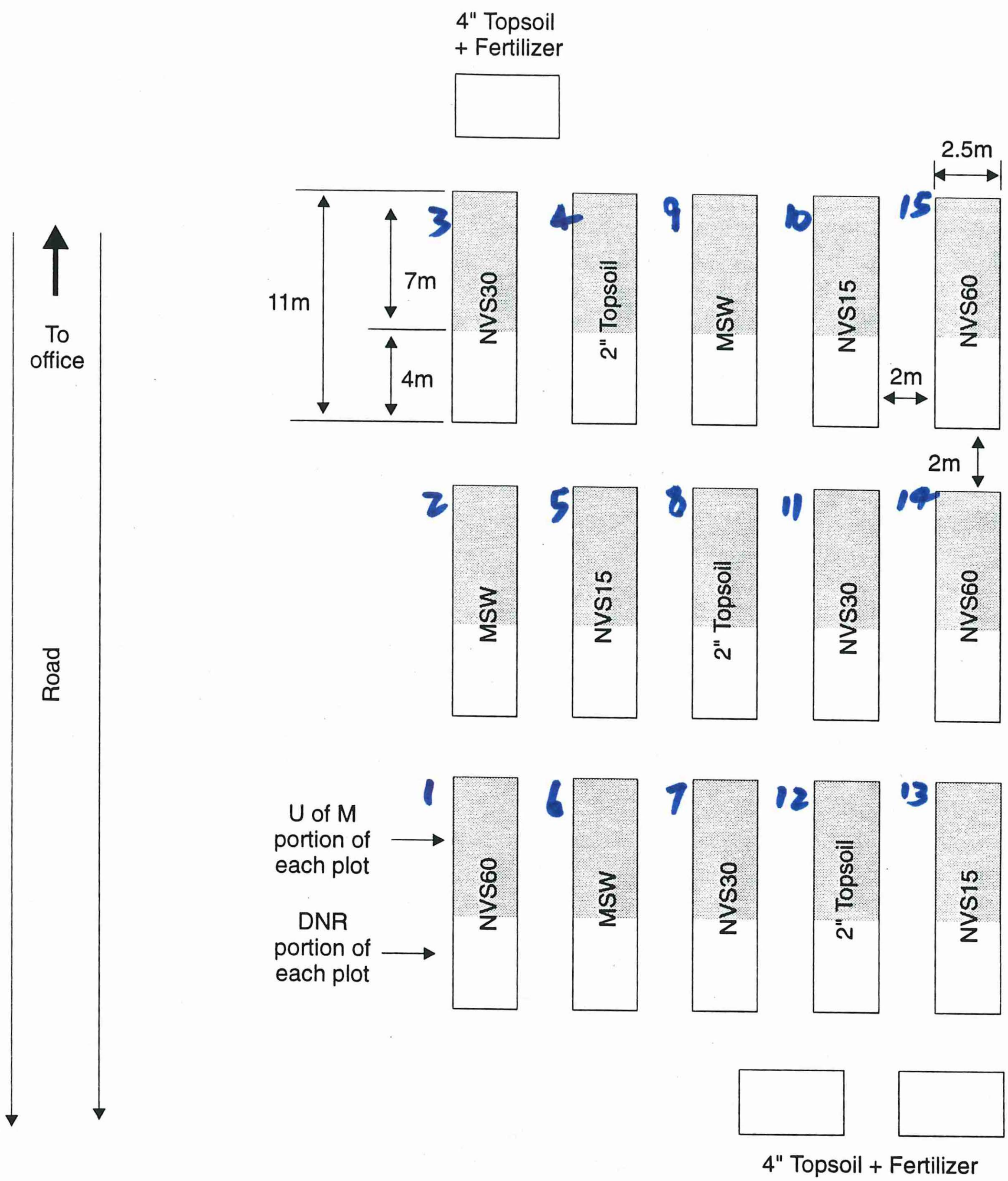


Figure 8. Design schematic of the washed sand plots.

Numbering for
* Soil samples
taken
5-21-97

(3 cores taken
per plot)

5. Results and discussion.

5.1 Demonstration slope

5.1.1 Biomass and percent cover.

There are two primary methods for determining percent cover; random sampling and systematic sampling. The main advantage of random sampling is that it is possible to rigorously calculate standard error terms or confidence limits, so that a mathematical statement of error can be made. On the other hand, it has been demonstrated in repeated field experiments that systematic sampling provides the same level of precision as random sampling (Raelson 1982), and the systematic method is undoubtedly more time efficient than random sampling, in which the sampler must zig-zag across the plot in a random fashion. Random sampling may have been reasonable on the relatively small lysimeter and washed sand plots, but on the much larger demonstration slope this was impractical; merely setting up the string lines would have taken several days of effort by a two-person crew. A systematic grid system was therefore used to measure both biomass and percent cover on the demonstration plots, lysimeter plots and washed sand plots.

As shown in Table 6 and Figure 9, percent cover and biomass on the MSW compost and the NVS demonstration plots were very similar, and both were considerably higher than the topsoil/fertilizer plot and the control plot. The mean biomass of the NVS plot was 22.5 g dry weight/0.5 m^2, and the comparable value for the MSW compost plot was 21.9. The topsoil/fertilizer plot had a value approximately half of those two values (10.3), and the control plot was the lowest at 6.6. (Percent cover results followed a similar pattern.) These values agree with visual observations of the plots; vegetative growth (primarily lambs quarters) on the NVS and MSW compost plots was noticeably denser than on the fertilizer plot, which in turn had more vegetation than the control plot (which had large areas of bare ground even in late summer).

5.1.2 Species prevalence

Demonstration plots A list of plants observed growing on the demonstration plots during the summer of 1996 is presented in Table 7, with latin names presented when known. (This should not be considered to be a comprehensive list; the list is a composite of "walking surveys" made on several separate trips, and other species may have gone unobserved.) By August of 1996, both the NVS and the MSW compost plots were covered with dense stands of lambs quarters, with some ragweed mixed in. A rough eyeball estimate would be that more than 50% of the vegetation on these two plots was lambs quarters, with another 10-20% being ragweed.

There was less biomass and percent cover but more species diversity on the two topsoil plots, especially on the one without fertilizer (i.e. the control plot). On the topsoil+fertilizer plot there were large patches of yellow nut grass (which was present on the other plots but not in the

Table 6. Summary of 1996 biomass and percent cover data.

Site	Treatment		Biomass (g/0.5 m^2)					Percent Cover					
		n	Min	Max	Mean	S.D.	n	Min	Max	Mean	Median	SD
Demo slope	NVS	Top	4	12.685	28.690	19.756	8.265	24	15.0	97.0	57.271	62.5	23.851
		Middle	4	9.215	35.309	19.699	11.058	24	37.5	85.0	54.896	62.5	16.656
		Bottom	4	4.789	65.916	28.063	28.008	24	37.5	99.5	70.688	73.75	19.239
		All	12	4.789	65.916	22.506	16.816	72	15.0	99.5	60.951	62.5	21.049
"	Fert.	Top	4	7.491	19.996	11.652	5.710	24	3.0	85.0	40.583	37.5	23.887
		Middle	4	1.821	10.612	5.511	3.700	24	15.0	85.0	43.750	37.5	14.670
		Bottom	4	1.010	32.042	13.840	13.740	24	15.0	85.0	49.167	62.5	18.660
		All	12	1.010	32.042	10.334	8.813	72	3.0	85.0	44.500	37.5	19.496
"	MSW	Top	4	1.946	20.302	10.609	7.678	24	15.0	97.0	56.438	62.5	19.873
		Middle	4	12.858	41.147	27.461	14.695	24	15.0	85.0	56.875	62.5	22.033
		Bottom	4	6.396	43.442	27.506	17.671	24	15.0	85.0	56.146	62.5	18.867
		All	12	1.946	43.442	21.859	15.138	72	15.0	97.0	56.486	62.5	20.015
"	Control	Top	4	3.298	6.823	5.141	1.464	24	15.0	85.0	49.167	62.5	18.660
		Middle	4	9.469	10.939	10.004	0.644	24	3.0	62.5	22.958	15.0	18.709
		Bottom	4	2.759	6.448	4.183	1.983	24	3.0	62.5	21.042	15.0	15.665
		All	12	2.759	10.939	6.648	2.965	72	3.0	85.0	31.056	37.5	21.740
Lysimeter plots	NVS		3	1.242	11.290	7.659	5.573	24	37.500	97.000	68.875	n/a	18.280
"	MSW		3	6.418	29.726	15.457	12.503	24	37.500	97.000	71.250	n/a	19.247
"	Fertilizer		3	6.513	9.284	7.802	1.395	24	37.500	97.000	76.042	n/a	17.884
Washed sand plots	NVS 60		3	0 (no sample)	7.15	3.575	n/a	24	3.000	85.000	28.208	n/a	19.906
"	NVS 30		3	12.95	36.15	24.55	n/a	24	15.000	62.500	45.104	n/a	16.656
"	NVS 15		3	1.11	11.18	6.145	n/a	24	15.000	62.500	22.604	n/a	13.032
"	MSW		3	4.43	7.69	6.06	n/a	24	3.000	37.500	11.438	n/a	8.069
"	Topsoil		3	3.84	5.52	4.68	n/a	24	0.500	15.000	4.688	n/a	4.784
"	Topsoil+Fert.		3	6.79	10.18	8.485	n/a	24	15.000	85.000	34.271	n/a	20.397

Note: The relatively small number of percent cover and biomass samples on the lysimeter plots and the washed sand plots produced results that should be considered to be less reliable than the results of the demonstration plots. For example, the location of a biomass plot on the lysimeter or washed sand plots may happen to fall on a bare patch of ground, so that the biomass value is anomalously low, but if the sample had instead been collected a few feet away it may have included a single large plant, which would have produced a much higher biomass value. On the demonstration plot, where many more sample were collected, the effects of such localized variations are minimized.

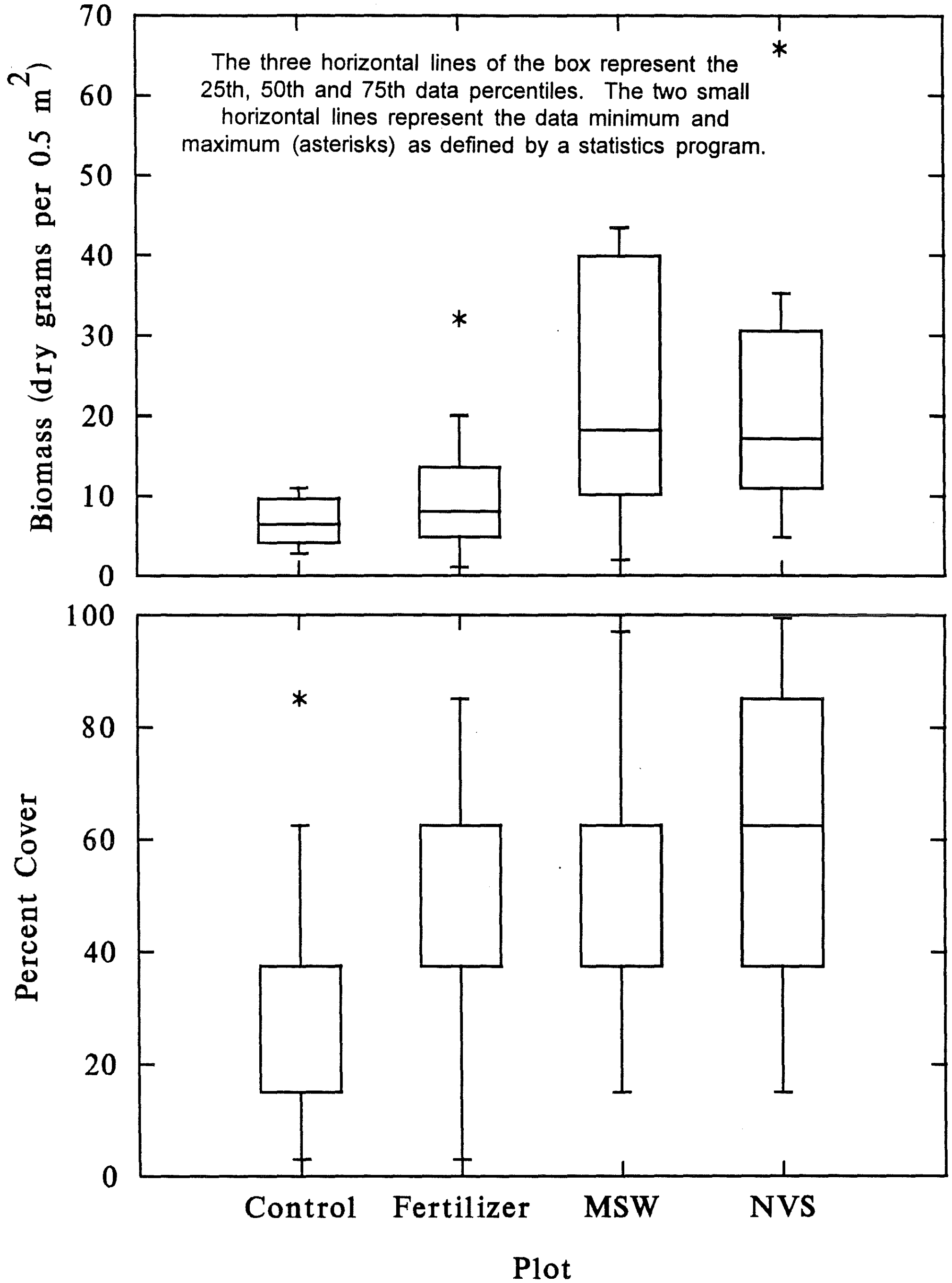


Figure 9. Box plot representatations of the 1996 percent cover and biomass data from the demonstration plots.

Table 7. List of plants observed on the demonstration plots (August 1996).

Common names	Latin names
Alfalfa (from an area at the top of the fertilizer plot that hadn't been disturbed during plot construction)	
Black-eyed Susan	Rudbeckia hirta
Carpet Weed	Mollugo verticillata
(not known)	Cassia Fascilula
Foxtails	Setaria sp.
Evening Primrose	Oenothera biennis
Hedge Bind Weed	Convolvulus sepium
Hoary Vervain	Verbena sp.
Lambs Quarters	Chenopodium album
Morning Glory	Ipomoea sp.
Mullein	Verbascum thapsus
Nightshade	Solanum sp.
Pennsylvania Smart Weed	Polygonum pensylvanicum
Pig Weed	Amaranthus sp.
Purslane	Portulaca oleraceal
Quack Grass	Agropyron repens
Rag Weed	Ambrosia sp.
Russian Thistle	Salsola Kali
Sandbur, Burgrass	Cenchrus pauciflorus
Sunflower	Helianthus ammus
Oats	(not known)
Winged Pig Weed	Cycloloma atriplicifolium
Wormwood	Artemisia annual
Yellow Cone Flower	(not known)
Yellow Nut Grass	Cyperus esculentus

large patches that were seen on the topsoil+fertilizer plot), and the lambs quarters, while still present, weren't as prevalent as they were on the NVS and MSW compost plots.

Lysimeter plots The same general species found on the demo plots during 1996 were also found on the lysimeter plots, but other species such as Foxtails and Perennial Rye were also observed. Lambs quarters and oats were the dominant species on all 10 plots.

5.1.3 Success/failure of cover crops.

Cover crops are relatively quick growing plant species that are intended to provide short-term soil stabilization until the primary crop has time to grow and mature. The cover crops used on the demonstration plots were oats, flax and annual rye (Table 3), which were part of both seed mixes used on these plots.

Unfortunately, the demonstration plots are adjacent to a large dewatering pond, which was home to a resident population of Canada Geese. The oats planted on the entire 9 acres of demo plots were virtually all grazed by the geese. There were essentially no oats on the bottom two thirds of the slope; it is thought that the geese pull the young oats entirely out of the ground (Kim Hennings, personal communication). (The oats that did grow were severely grazed by the geese.) There was also very little annual rye, and virtually no flax. The lysimeter plots and the washed sand plots also had virtually no flax, and the preliminary conclusion is that the flax was not an effective cover crop. The resident population of geese at that particular pond consistently numbered about 20 adults, with each pair of adults associated with 5 to 10 goslings, and yet this relatively modest population of geese had no problem stripping almost the entire slope completely free of the cover crops. It would seem prudent to identify cover crops that aren't as palatable to geese in similar future situations. (Broad leaf cover crops like buckwheat may be less susceptible to grazing by geese.) At the lysimeter plots and the washed sand plots, which aren't located close to any bodies of water, the cover crops were not grazed by the geese.

5.1.4 Erosion control.

Although the plan was to cover the entire slope with a uniform layer of straw, the result was considerably different, with some areas receiving very thick coverage (even large clumps), while adjacent areas were left virtually mulch-free. Unfortunately, this uneven mulch coverage proved to be a significant problem given the drought conditions that persisted throughout the summer; plants that sprouted in the bare areas could not survive the combined stresses of harsh sunlight and parched soils, with the result that little vegetation grew in these areas. Initial vegetation was observed only in the areas with adequate mulch coverage, or in the rows where the mulch had been crimped into the soil (Figure 10). Over time these bare patches may get filled in, but in the meantime a large rainfall event could cause these areas to erode.

Overall there was less erosion on the slope than occurred during previous revegetation attempts. Qualitative observations indicated less erosion occurred on the plots that received organic soil amendments. A significant erosion channel developed on the topsoil+fertilizer plot, and a few smaller channels were observed on both the MSW and the control plot. It was also observed that the top ditch on the control plot was almost completely filled in with material that had washed down the slope, while the adjacent MSW compost plot had very little material in the furrow. (Some material was also observed in the top ditch of the topsoil+fertilizer plot.) More observations on erosion patterns will be made in 1997.

Figure 10. Photograph of the crimped-in mulch on the demonstration plots.

5.1.5 Odors.

Odors are a problem that have plagued many previous attempts to use biosolids in applications such as gravel pit reclamation. In the past, horse manure and sewage sludge has been landspread (primarily on farm fields), sometimes with little apparent concern for neighbors or passersby, and many people still have unpleasant memories of those operations. Coupled with the fear that future biosolid applications will be similar in nature, with their accompanying depressing effect on quality of life (and possibly on property values as well), these impressions of biosolids will continue to have an inhibiting effect on decisions regarding these materials, until evidence to the contrary is provided. While even Class B sludge may have suitable uses (i.e. reclamation of extremely remote abandoned pits), most pits tend to be near high-population areas, so that a realistically usable product must be largely odor-free.

Both NVS and MSW compost have characteristic odors that may be considered somewhat unpleasant to an average observer. But project staff considered the odors tolerable even when standing next to the stockpiles for an extended period of time. Odors decreased after the generally mild after the material was disked into the stockpile, though they increased slightly after rain events. Odors continued to decrease until they were no longer noticeable in the fall.

5.2 Lysimeter plots.

5.2.1 1996 precipitation data.

A continuously-recording rain gage was set up on the lysimeter plots on May 14, 1996. Except for a period in June when the rain gage was blown over during a major wind storm, and another period in September when the gage malfunctioned, continuous rainfall data was collected through November 10 (Appendix 10). To fill in these two data gaps, data was obtained from a weather station in Rosemount, which is across the Mississippi River from the Nelson Mine. (Comparison of the data collected from the Shiely site and the corresponding values reported at Rosemount indicated that the precipitation patterns were quite similar, though there were a few days when significant differences were reported at the two sites.) Figure 11 presents total monthly rainfall at the Nelson Mine, as compared to historical (1961-90) and 1996 values reported by the Rosemount monitoring station.

On November 11, the gage was winterized to provide data on total snowfall throughout the winter. Antifreeze was added to the rain gage's collection pail; if the antifreeze had not been added, the snowfall would quickly fill up the pail so that some snow would go unrecorded.) A wind shield was also set up around the rain gage at that time, which was intended to provide a column of relatively stable air around the gage, so that accurate snowfall data could be collected.

Precipitation was very low during most of the 1996 field season. As is apparent from Figure 11, May-September 1996 precipitation was very low compared to historical averages, while October and November rainfall exceeded the historical averages. Total rainfall for the period of May 1 through September 30 (i.e. the growing season) was 11.2", which is about 57% of the 30-year average for this period of time (19.8") recorded at the nearby Rosemount weather station.

5.2.2 Water quality and quantity.

Due to the droughty conditions experienced at the Nelson Mine during the summer of 1996, no water samples were collected from the lysimeter plots. Samples will be collected in 1997 if they become available.

5.2.3 Biomass and percent cover.

With the exception of one anomalously high biomass value from a MSW compost plot (due to a single very large lambs quarter plant), the biomass observed on the NVS, MSW compost and

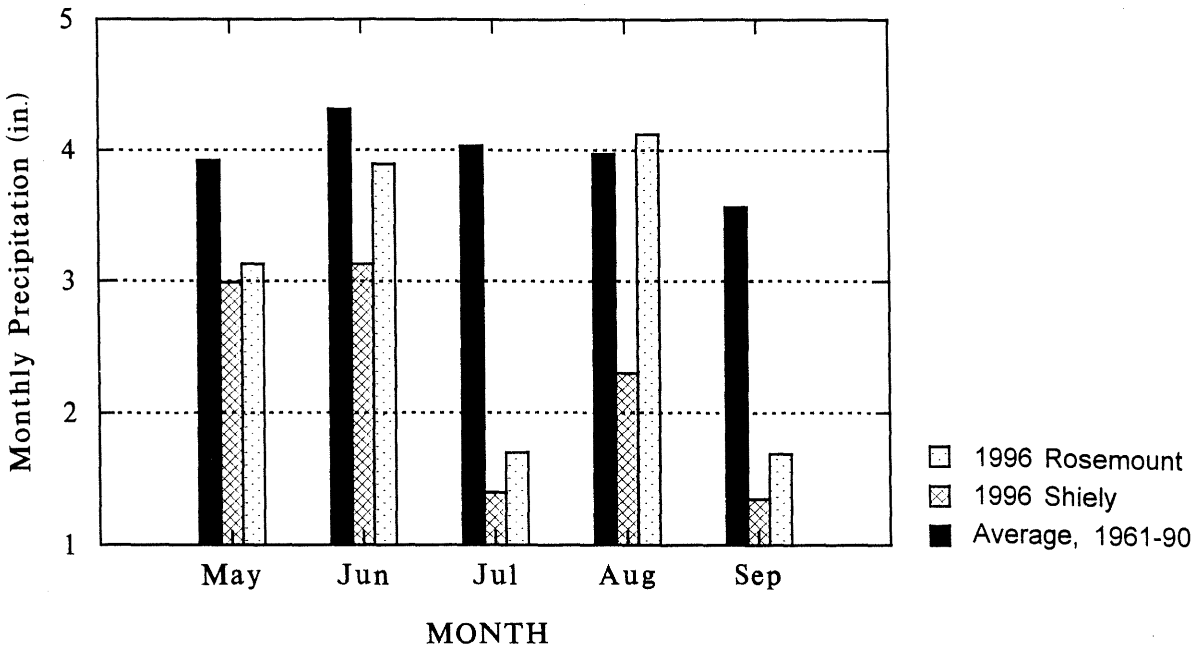


Figure 11. Bar chart of monthly 1996 precipitation recorded at Shiely Co.'s Nelson Mine, compared with both 1996 values and average historical (1961-90) values from the nearby Rosemount weather monitoring station. (2.07 of the 2.99 inches recorded for May fell prior to completion of the demonstration plots.)

the fertilizer plots were all similar. This is contrast to the demonstration plots, where the NVS and MSW compost plots had significantly higher biomass than the fertilizer plot. Percent cover was also very similar, with no significant difference observed between the three amendments. It should be noted that the relatively small number of percent cover and biomass samples on the lysimeter plots and the washed sand plots produced results that should be considered to be less reliable than the results of the demonstration plots. For example, the location of a biomass plot on the lysimeter or washed sand plots (as determined from a random number table) may happen to fall on a bare patch of ground so that the biomass value is anomalously low. If the sample had instead been collected a few feet away it may have included a single large plant, which would have produced a much higher biomass value. On the demonstration plot, where many more samples were collected, the effect of such localized variations are minimized. In 1997 additional samples will be collected from the lysimeter plots to minimize this problem.

5.3 Washed sand plots.

Again, the small number of biomass and percent cover plots makes interpretation of the data less accurate. The data show that the NVS60 plots had considerably less biomass than the NVS30 plots (Table 6). However, visually there did not appear to be much difference between these plots. This discrepancy was due in large part to the fact that one of the NVS60 biomass plots happened to fall on a bare patch, while a huge lambs quarter plant grew just a few feet away. Next year the number of biomass samples taken from each of the 18 plots will be increased to two or three instead of just one, in an effort to minimize this problem.

As shown in Table 6, percent cover and biomass were highest on NVS30 plots, and decreased in the order:

NVS30 > topsoil+fertilizer > NVS60 > NVS15 > MSW > topsoil.

It should also be noted that the harsh, droughty weather had a large impact on the vegetation on these plots, which also had to grow on a very sandy, wind-exposed site. If 1997 precipitation is closer to normal, the biomass and percent cover on these plots should improve considerably.

5.4 Cost estimates.

A major concern with the use of any soil amendment is the effect on the total cost of reclamation. Typically organic amendments produced from waste materials are free, but the cost of transportation is usually the single highest cost in determining the feasibility of an organic amendment for a reclamation project. Although NVS is produced in Eagan, the final curing and windrows are at the Pig's Eye facility near downtown St. Paul, which is only about 25 miles from the mine site. The closest MSW compost facility is in Wright county, about 50 miles from the site. As a result the shipping cost for the NVS was $60 per load as compared to $150 for the MSW compost. Shiely was able to arrange a back-haul for the compost with a trucking firm which was hauling material from the mine. Without the back haul, the cost would have been $200 per load.

The costs for applying the amendments on the demonstration plots were estimated based on the actual time it took to apply the amendments, and an estimated time and equipment charge of $75/hour. Application required a compost spreader and a front-end loader, and once the method was developed, it took about 45 minutes per acre, or about $120/acre to apply the amendments. (These costs are based on the use of Shiely personnel; costs from an outside contractor would likely be higher.) The total cost for the organic amendments ranged from $240/acre for the NVS to $420/acre for the MSW compost (Table xxx).

The single most expensive item was the mulch: $475/acre for material, application and crimping. This cost is based on the low bid, which resulted in a poor quality mulch application. The next lowest bid was over $500 per acre for just the mulch and application (Bieraguel, personal communication). Native seeds are almost twice as expensive as the cool season mix ($204/acre vs $120/acre), and, as a rule of thumb, a contractor will charge an amount equal to the cost of the seeds to plant them.

Initial estimates from contractors for this project to fertilize, seed, and mulch were $800/acre for the cool season mix, and from $1150-$1425/acre for the native seeds (Appendix 4). (The price range depends on the amount of forbs in the mixture.) Actual cost ranged from $770/acre for the cool season mix to $1040 for the native mix (Table 8).

Although the organic amendments raised the cost of reclamation by 25-50%, the additional cost is small in comparison with having to reclaim the area again. Prior to 1996, several attempts had been made to stabilize this area. In addition to the reclamation cost of $800/acre, a substantial amount of topsoil was required to repair the erosion gullies and to prepare the slope prior to planting. Slope preparation that occurred prior to this project was estimated to cost about $240/acre (Appendix 12).

6. Conclusions.

A) Addition of NVS and MSW compost to the south-facing demonstration slope increased percent cover and biomass and decreased erosion.

B) Addition of NVS and MSW compost to topsoil on the lysimeter plots did not have a measurable effect on percent cover or biomass during the first growing season.

C) First year data suggest that NVS may be a suitable replacement for topsoil on the washed sand material. Percent cover and biomass were higher on the 30 tons/acre (15.6 dry/tons/acre) plots than they were on the plots with 4" of topsoil and fertilizer.

D) NVS and MSW compost can be spread successfully on large-scale projects with a compost spreader. The spreader was capable applying a reasonably uniform layer of both materials on a 4:1 slope.

E) Inadequate mulch (and grazing by geese) appeared to affect the amount and type of vegetation on the demonstration slope.

F) In this project, the organic amendments added $240-420 per acre to the revegetation cost and increased the total reclamation cost by 25-50%. Although this is a considerable cost, it is less than 50% of what it would cost to reclaim the area again.

Table 8. Reclamation cost summary.

	Costs using native seed mix ($/acre)	Costs using cool season mix ($/acre)
Fertilizer		
Fertilizer (12/12/12)	12	25
Application	50	50
Incorporation	50	50
Total	112	125
Seeds		
Seed cost (A)	204	120
Planting	250 (B)	50
Total	454	170
Mulch		
Mulch application (C)	425	425
Crimping	50	50
Total	475	475
Total cost without amendments	1041	770
Organic amendments		
Material (D)	No charge for amendments	No charge for amendments
Transport (E)	120 - 300	120 - 300
Application	120	120
Total	240 - 420	240 - 420
Total cost with organic amendments	1280 - 1460	1010 - 1190

A: Seed cost doesn't include flax.

B: Estimate for contractor (from personal communication with Bob Jacobson of MNDOT and Bob Bieraugel of Shiely Co.)

C: Contractor; bid included mulch and application.

D: Currently there is no charge for NVS or Class II MSW compost.

E: Difference in transportation costs is due to the proximity of the respective facilities to Grey Cloud Island. MSW compost was delivered as a back haul; without backhaul, the price would increase to $400/acre.

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Appendix 1

Amendment Selection Rationale

Appendix 1

Amendment Selection Rationale

The primary goal of this project was to identify waste materials that could be successfully used as a soil amendment in gravel pit reclamation. N-Viro Soil (NVS) was identified early in the planning stage of this project as a promising candidate, but an additional material was desirable so that it could be investigated in comparison to NVS. Numerous amendment materials besides NVS and MSW compost were considered for use on the demonstration plots, including:

- Yard waste compost
- River dredge spoils
- Lake sediments
- Wastes from sugar beet processing (for possible use near the Red River in NW MN)
- Sewage sludge (possibly useful in rural areas, and is currently being used in mining areas)
- Agricultural wastes
- Decomposed sawdust
- Manure or composted manure

The criteria used to select the best candidate materials were:

1. The material should be likely to succeed at promoting vegetative growth without causing undesirable side effects such as nutrient burning of the vegetation,
2. The material should be inexpensive or free, and produced in large enough quantity that a suitable supply is usually obtainable,
4. It should be produced close enough to potential users that shipping costs wouldn't make use of the material prohibitive,
5. It should be unlikely to adversely impact the air, water and soils associated with the project (i.e. from pathogens, metals, excess nutrients, odors, etc.),
6. And it should be a material that is not commonly used in many applications. That is, if the material already has a significant "market" it would be less desirable than an alternative waste material that would otherwise remain unused.

Based on these criteria, NVS and MSW compost were selected as being most suitable for this project. The one other material that seemed suitable for this project was yard waste compost, but this was rejected because it is already commonly used in numerous applications such as landscaping and agriculture, and as such is less in need of "promotion" via a demonstration project. There were also other practical considerations, such as the fact that, though sewage sludge may produce vigorous vegetative growth, it also causes odors that are often unacceptable to neighbors of gravel pits.

The fact that NVS and MSW compost were deemed most suitable for this particular project should not be construed as indicating that the other materials may not have legitimate applications in gravel pit reclamation. For example, sugar beet waste may be a viable alternative for use in NW Minnesota, where the source of the waste is closer to the gravel pits. Use of this material in the Twin Cities would be less suitable because, even if the material proved to be an ideal soil amendment, shipping costs would likely prove prohibitive for most gravel pit operators. Similarly, agricultural wastes or composted manure may be good choices in rural areas where shipping costs wouldn't be a limiting factor and where there is less population density (and thus fewer neighbors who may object to such an application.)

Once NVS and MSW compost were selected for the project, the next issue to consider was how the demonstration plots should be designed. Several options were considered, as summarized in Table A1.1, with the final design calling for the amendments to be applied to four separate side-by-side plots. The primary reason that the plots were placed side-to-side instead of lengthwise was to ensure that any effect of a particular amendment wouldn't be compromised by a neighboring plot. For example, if the slope had been divided into four long strips with the strip at the top of the slope being the NVS plot, and if any of the lower strips had failed, it wouldn't have been possible to state with certainty that the failure of the lower plots was not caused by leachate flowing into that plot from the NVS plot. By keeping the orientation of the plots side-by-side, the chance of a plot being affected by the other plots was minimized.

The two seed mixes were spread across the entire slope, with the top third of the slope planted with the MNDOT 50 mix, and the bottom 2/rds of the slope planted with the native prairie (MNDOT 20) mix. (The boundary between the two seed mixes was the upper of the two horizontal trenches that were cut into the slope.) Like the amendments, several options were available for the orientation of the seed mixes, and Table A1.1 summarizes the advantages and disadvantages of each option.

Table A1.1. Advantages/disadvantages associated with three design proposals for the demonstration plots at Shiely Co.'s Nelson Mine on Grey Cloud Island.

	Advantages	Disadvantages
Option 1 (Vertical plots with horizontal vegetation strips)	(1) Success/failure of the amendments won't be compromised by effects of other amendments. (2) Application of the seed mixes would be easier/cheaper. (3) A berm could be constructed between the two seed mixes to break up flow down the slope.	(1) Success/failure of the prairie mix may be compromised by the presence of the MnDOT mix on the upper portion of the slope (i.e. the prairie mix may be successful for a 135' run, but not for the whole 275'). (2) A long slope w/o bench or windrows (except the one that could be placed between the seed mixes). (3) There may be some difference between the top and bottom of the slope (i.e. hydrologic conditions, etc.).
Option 2 (Vertical plots with vertical vegetation strips)	(1) Same as (1) above. (2) Success/failure of the prairie mix wouldn't be compromised by presence of MnDOT mix on upper slope.	(1) Harder/costlier to spread the seed mixes because of the shorter runs involved. However, the MnDOT and prairie mixes could be arranged in a fashion (shown in Figure 1) which would minimize this problem. (2) Very long continuous slope; no bench or windrows (though they could be designed in if deemed necessary). (3) This option would be unworkable if it were necessary to go up and down slope to spread the seeds; this would not reflect actual practices, which are generally side-to-side, and would unnecessarily encourage additional erosion.
Option 3 (Horizontal plots)	(1) Easier/cheaper to spread both the amendments and the seed mixes. (2) Would include up to 3 windrows or berms to break up flow down the slope.	(1) Potential compromising of effects caused by the various amendments (i.e. constituents of the NVIRO may leach into the MSW or topsoil plots, or the MSW may fail if used on the entire slope even though it succeeds on a short slope.)

Appendix 2

NVS Information

Appendix 2

NVS Information

N-Viro Soil (NVS) is a biosolid that is produced at the Seneca Wastewater Treatment Facility located in Eagan, MN. The N-Viro facility is operated by the Metropolitan Council's Environmental Services Division, and Steve Stark is the manager of the operation. MDNR personnel toured the Seneca facility on August 1, 1995 to learn about the process; the following are notes from that visit, along with some details and clarification provided by Steve Stark on 1/17/96. (At the time of the site visit the N-Viro facility was run by an entity called N-Viro Minnesota, Inc., but Met Council took over control of the facility in May 1996 and now runs the facility.)

In 1990, the Metropolitan Council began to use the N-Viro process to treat some of the sewage sludge in the metropolitan area. This process takes sludge from two suburban areas and mixes it with alkaline material to produce a soil amendment. The N-Viro facility is located in Eagan at the Senaca Waste Water Treatment Plant.

Primary and secondary sludges are fed into the facility, a polymer is added to help dewater the sludge, and then a belt press is used to remove some of the water. The sludge enters the plant at about 5% solid and as it leaves the filter press it is about 25% solid waste. After the water is removed, the sludge is mixed with alkaline waste products. The alkaline materials currently being used are lime kiln dust and fly ash, and they currently have three sources of the fly ash:

1. Two NSP facilities; the Riverside plant, and the Black Dog plant. Steve said to note that metals analyses of the fly ash often fluctuate widely because they switch often between the two plants, which produce different quality fly ash. NSP delivers the product for free.

2. An Archer Daniels Midland soybean facility in Mankato. They pay ADM $2/ton for the ash, and then ADM takes care of shipping costs.

3. From the N-Viro entity itself. Steve said that many of the current NVS facilities contract completely with N-Viro to supply the alkaline portion of their product, but that in MN they prefer to locate their own sources. (He also said that so far no one has paid Steve to take the ash off of their hands.)

On a solid basis, about 42% of the total non-sludge material added to the process last year came from NSP, about 25% from ADM, and about 33% from Cutler Magner (the lime kiln dust).

The alkaline solids are added for two purposes: (1) to raise the pH and the temperature of the sludge and (2) to absorb excess moisture from the sludge. Heat is generated as the calcium oxide hydrates to lime. This is an exothermic reaction which raises the temperature to around 140 °F. pH is raised to around 12, and the percent solids increases about 50 percent. The NVS now consists of roughly 3 parts alkaline material (i.e. kiln dust and fly ash) per each part sludge (on a dry weight basis). So for each pound of dry sludge, approximately three pounds of alkaline material are added. These materials are added in the plant and mixed in a mixer to blend the alkaline materials with the sludge, and then this mixture is placed in an insulated truck.

The truck is taken to the Pigs Eye Facility on Warner Road near downtown St. Paul. The truck is parked and temperature probes are inserted. The sludge must maintain a temperature of around 140 °F for 12 hours. Temperatures are monitored continuously to ensure that this requirement is met. The combination of high pH and elevated temperature for the 12 hour period reportedly kills all the pathogenic bacteria (E. Coli, Salmonella, etc.), viruses and parasitic eggs, while leaving some of the beneficial soil bacteria intact because they can survive higher temperatures than the pathogens. Steve wasn't certain if this was true (that some beneficial bacteria are able to survive the process), but said that even if the material was sterile, once it's incorporated into the soil it is quickly colonized by the "good" bacteria.

After 12 hours the material is unloaded from the truck (using a coordinated series of moving slats located in the floor of the trailer), and placed in a windrow where it remains for four days. During this time the material is turned with a windrow turner. During this period of time some ammonia is released from the pile. After the 4-day period the sludge is removed from the windrow and piled in a holding area at the Pigs Eye Facility. The pH of the material after the windrowing is still at 12, but decreases somewhat with time. Met Council is doing studies to look at the changes in this material over time, both with respect to the pH and with microbiological activity in the pile itself. As of our 8/1/96 site visit, one pile had been sitting at the site for 4 months and we could see a few plants starting to colonize the material.

The finished product is about 25% organic and has trace metals that are within EPA guidelines for exceptional quality sludge. Under Federal regulations, and recently revised regulations of the Minnesota Pollution Control Agency, when the sludge meets the specifications it can be used as a fertilizer without restriction. Thomas Kovacik (involved with the NVS facility in Toledo, Ohio) said that over half of the metals in the product arise from the alkaline material (which is largely cement kiln dust at the Ohio facility), and Steve said that that is probably true with the MN NVS as well, though some metals would obviously be higher and some would be lower.

For the past three years N-Viro MN has been applying the product primarily to agricultural fields where crops for animal feed have been grown. The estimated cost to treat the sludge and apply it to the fields is about $200 per ton of material. N-Viro MN has conducted a series of tests on the material. The most extensive was the University of Minnesota study on an agricultural field. At this site, about 80 tons of NVS per acre were applied for three consecutive years. According to N-Viro MN, there were no significant increases in metal levels in the soil or the vegetation. NVS at 80 tons per acre is the equivalent of about a 3/4" application. Prior to planting, the material is applied and then disked in at a depth of about 6".

N-Viro MN also conducted another study where they had planted a berm with a variety of application rates and species. NVS applications ranging from 10 tons up to 80 tons per acre were compared with a topsoil control plot. Last year (1995) was the first year of the study and the NVS performed very well. One of the advantages of NVS, according to N-Viro MN, is that it does not contain any weed species and, therefore, weed invasion on the NVS plots was much less than present on the top soil plot. NVS appears to be a promising soil amendment and may have use in gravel pit restoration, particularly in those areas where topsoil has not been stockpiled.

The other use of this material may be as a substrate for sulfate reduction, which can be used to treat acidic drainage. Previous attempts to use sewage sludge to support microbial activity have had limited success. This has been primarily due to the fact that the other sewage sludge had been a digested sludge so that much of the small organic material had been broken down. With the N-Viro process, since the sludge is not digested prior to mixing with the alkaline materials, it should be very reactive. In addition, the high pH may provide neutralization of acidic drainage.

Attached are analytical data tables for:

1. Coal ash from NSP (1996)
2. Coal ash from Archer Daniels Midland (ADM) in Mankato (1996)
3. Cutler-Magner Lime Kiln Dust (LKD; 1996)
4. Sludge from the Seneca Wastewater Treatment Facility (1995 and 1996)
5. NVS chemical data (1995 and 1996)
6. NVS biological data (1995 and 1996)

1996 NSP Coal Ash Analysis

Lab	Date	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	P (%)	K (%)	Se	S (%)	Zn	Heat Rise(C	pH	Lime Eq.
MCES	1/8/96	9.2	554	10.4	32	147	103	0.06	6.4	32	0.32	0.20	7.1	0.8	64	5.5		
MCES	1/8/96	11.0	540	7.0	20	169	85	0.97	8.9	68	0.30	0.19	10.8	1.5	55	2.0		
MCES	1/16/96	10.3	514	8.4	33	165	101	0.31	8.1	58	0.26	0.22	8.0	1.2	65	2.2		
MCES	1/22/96	11.9	559	10.0	34	197	114	0.98	11.6	82	0.28	0.24	11.5	1.6	71	3.0		
MCES	1/29/96	14.2	714	13.4	44	229	139	1.37	8.8	60	0.46	0.29	13.9	1.7	85	1.5	11.0	48.3
MCES	2/6/96	12.6	632	11.7	40	201	128	1.12	7.6	42	0.34	0.27	10.3	1.6	84	1.8	10.7	43.1
MCES	2/12/96	10.0	546	7.8	26	174	104	0.69	6.2	36	0.34	0.25	10.8	1.4	68	1.8	10.5	36.3
MCES	2/19/96	10.3	598	10.0	34	165	110	0.41	7.0	40	0.37	0.24	8.0	1.4	74	2.2	11.7	47.9
MCES	2/26/96	10.0	652	8.1	29	183	100	0.80	21.7	228	C	0.17	11.0	C	71	1.1	10.9	C
MCES	3/13/96	10.9	511	7.6	22	147	62	0.08	11.8	109	0.37	0.17	8.1	1.9	66	1.5	10.9	34.2
MCES	3/18/96	15.2	783	11.4	43	216	94	0.89	28.2	288	0.50	0.25	14.2	2.5	119	1.1	11.3	46.8
MCES	3/25/96	10.7	561	8.2	32	183	75	0.88	21.9	225	0.31	0.24	11.0	2.3	86	2.0	10.9	37.9
MCES	4/1/96	7.0	559	10.4	23	100	58	0.08	5.0	36	0.66	0.19	4.0	0.6	103	1.9	12.2	48.0
MCES	4/8/96	7.5	534	9.1	19	110	58	0.05	5.1	36	0.58	0.19	5.7	0.6	108	1.6	11.9	44.9
MCES	4/15/96	6.6	595	14.2	10	101	53	0.02	4.3	32	0.52	0.17	5.1	0.8	57	1.7	12.0	46.3
MCES	4/22/96	9.6	498	6.2	30	136	67	0.27	20.9	201	0.43	0.21	7.5	1.5	76	0.8	11.3	35.6
MCES	4/29/96	10.0	582	7.6	41	180	81	0.46	36.5	400	0.49	0.23	9.9	3.2	89	2.1	11.6	44.3
MCES	5/6/96	7.9	572	10.3	37	168	87	0.27	26.5	329	0.48	0.23	9.3	1.8	84	2.2	11.0	46.1
MCES	5/13/96	6.1	506	11.4	38	134	76	0.08	5.6	27	0.57	0.17	7.2	0.7	60	2.9	12.1	51.5
MCES	5/20/96	6.6	576	17.1	39	131	74	0.13	6.0	54	0.43	0.19	7.7	1.9	84	3.9	12.0	48.4
MCES	5/27/96	6.7	677	11.6	26	107	57	0.30	5.9	45	0.20	0.15	5.5	3.0	89	2.2	12.0	47.1
MCES	6/2/96	8.8	663	11.4	26	106	61	0.17	6.2	48	0.41	0.17	6.2	2.1	113	1.1	11.9	47.9
MCES	6/10/96	9.5	629	10.2	56	175	81	0.15	28.7	264	0.03	0.24	9.8	1.7	89	2.2	11.4	54.1
MCES	6/17/96	9.9	628	10.0	51	171	77	0.27	34.2	296	0.20	0.22	6.1	2.2	89	2.4	11.0	53.4
MCES	6/24/96	6.8	573	9.3	44	171	82	0.14	18.6	204	0.40	0.23	7.3	1.3	80	1.4	11.7	48.7
MCES	6/24/96	8.0	642	10.2	15	95	58	0.01	6.0	33	0.24	0.14	7.8	0.9	51	3.5	12.0	46.3
MCES	6/30/96	9.3	510	7.9	48	159	78	0.18	7.1	26	C	0.21	2.0	C	53	2.5	11.5	C
MCES	6/30/96	8.7	574	11.6	19	122	66	0.02	5.9	37	0.41	0.17	6.1	0.9	99	2.4	12.1	50.3
MCES	6/30/96	9.8	595	10.0	47	205	88	0.12	41.2	408	0.47	0.26	8.7	2.8	98	1.8	10.3	45.4

1996 NSP Coal Ash Analysis

Lab	Date	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	P (%)	K (%)	Se	S (%)	Zn	Heat Rise(C	pH	Lime Eq.
MCES	7/7/96	12.8	619	8.9	44	201	88	0.43	62.8	529	0.41	0.26	10.3	3.1	92	0.8	10.2	43.3
MCES	7/8/96	8.6	537	8.6	28	117	70	0.05	6.5	28	0.51	0.18	7.9	C	63	1.0	10.4	49.0
MCES	7/15/96	12.3	613	8.9	44	181	85	0.25	39.2	371	0.41	0.24	10.5	2.4	77	1.1	10.5	45.3
MCES	7/22/96	12.7	636	7.9	44	193	88	0.62	59.4	649	0.50	0.25	11.1	3.6	91	1.3	11.6	44.0
MCES	7/29/96	14.5	549	8.0	49	185	89	0.50	55.5	471	0.40	0.25	6.8	2.8	111	1.0	10.5	43.9
MCES	8/4/96	13.0	490	8.1	34	179	70	0.56	48.6	370	0.35	0.22	9.0	3.0	102	1.3	8.8	31.5
MCES	8/11/96	10.4	554	9.6	35	185	73	0.52	49.2	476	0.41	0.24	11.9	3.1	98	0.6	8.4	33.5
MCES	8/18/96	12.6	565	10.6	44	218	82	0.55	54.6	462	0.42	0.27	10.7	3.1	101	0.3	10.2	37.8
MCES	8/25/96	15.1	594	11.8	58	191	93	0.47	44.0	443	0.48	0.30	11.2	2.7	114	0.3	10.2	36.1
MCES	9/1/96	14.2	646	12.1	56	192	95	0.46	60.5	651	0.08	0.28	10.4	3.4	130	0.5	10.5	42.4
MCES	9/9/96	13.2	665	13.1	56	213	108	0.41	46.8	436	0.08	0.33	10.7	3.0	132	1.0	10.5	41.7
MCES	9/15/96	11.4	563	8.2	44	173	84	0.37	42.2	429	0.45	0.25	8.8	2.9	99	0.6	10.4	36.4
MCES	9/22/96	12.9	656	11.6	44	190	95	0.44	60.2	552	0.58	0.30	10.3	3.5	110	0.4	10.6	42.8
MCES	9/29/96	13.0	691	11.6	42	187	95	0.66	42.0	415	0.54	0.27	10.9	3.1	111	1.5	11.0	44.7
MCES	10/6/96	13.3	635	11.2	43	196	82	0.76	53.5	458	0.40	0.30	12.0		108	1.1	11.4	41.5
MCES	10/12/96	14.0	704	13.1	49	209	122	0.59	46.7	450	0.49	0.34	10.8		123	0.7	10.7	
MCES	10/20/96	14.0	700	11.4	46	210	109	0.31	46.0	444	0.46	0.31	12.2		112	0.4	10.9	
MCES	10/27/96	11.1	629	13.0	38	180	90	0.31	28.4	259	0.39	0.24	9.1	2.0	93	1.8	10.7	50.0
MCES	11/3/96	1.0	555	7.4	37	163	78	0.38	1.0	415	0.46	0.23	4.1	3.6	71	2.9	10.3	50.5
MCES	11/10/96		655	9.8	29	169	80	0.57	61.8	444	0.38	0.23		3.6	90	1.3	10.4	44.4
MCES	11/17/96		587	9.2	25	189	78	0.38	52.5	497	0.28	0.21		4.0	78	3.1	10.5	41.6
MCES	11/24/96	26.1	732	11.7	44	218	102	0.50	79.5	619	0.56	0.27	11.2	3.7	84	2.5	10.6	49.7
MCES	12/8/96		604	8.9	31	216	76	0.51	68.8	597	0.34	0.24		3.7	117	3.9	10.4	
MCES	12/15/96							0.61	66.8		0.33			3.4		2.0	11.3	41.6
MCES	12/22/96							0.59	64.4		0.27					1.1	10.1	40.7
MCES	12/30/96							0.54	47.0		0.34					2.6	10.3	
MCES	1/6/97															1.4	10.5	

	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	P (%)	K (%)	Se	S (%)	Zn	Heat Rise(C	pH	Lime Eq.
96 Average:	10.8	601	10.1	37	171	86	0.43	30.9	273	0.39	0.23	9.0	2.3	89.2	1.8	10.9	44.1

C = Cancelled test due to low sample volume

1996 ADM-Mankato Coal Ash Analysis

Lab	Date	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	P (%)	K (%)	Se	S (%)	Zn	Heat Rise(C)	pH	Lime Eq.
MCES	1/8/96	6.1	351	6.0	11	97	67	0.04	2.7	29	0.30	0.14	4.1	1.3	24	2.5		
MCES	1/16/96	4.7	249	4.0	11	78	52	0.11	2.0	24	0.22	0.12	3.0	1.4	27	3.2		
MCES	1/22/96	5.6	308	7.8	19	89	74	0.12	3.4	29	0.21	0.15	4.1	1.5	35	3.5		
MCES	1/29/96	4.2	226	7.3	12	62	54	0.04	2.3	21	0.20	0.10	2.8	1.3	20	3.4	10.8	29.4
MCES	2/6/96	4.4	252	7.5	15	72	63	0.06	2.8	23	0.19	0.11	2.5	1.3	24	3.4	10.8	30.1
MCES	2/12/96	5.4	298	5.9	9.2	89	60	0.08	3.0	29	0.27	0.14	3.9	1.5	34	3.5	10.7	33.5
MCES	2/19/96	4.8	290	6.1	307	88	56	0.09	3.6	141	0.26	0.14	2.0	1.5	28	3.7	11.7	30.2
MCES	2/26/96	5.2	306	4.3	10	92	57	< 0.20	3.4	38	0.24	0.13	4.5	1.5	30	4.9	10.8	30.4
MCES	3/13/96	4.8	354	6.5	11	95	46	< 0.20	3.1	29	0.28	0.14	2.0	1.5	46	3.8	10.8	30.8
MCES	3/18/96	4.5	247	4.4	10	75	31	0.10	2.5	20	0.22	0.11	2.0	1.3	36	3.7	11.0	26.3
MCES	3/25/96	4.4	295	6.0	12	95	42	0.18	2.6	27	0.27	0.14	3.5	1.4	71	3.8	11.3	27.5
MCES	4/1/96	4.7	300	5.7	8.8	85	36	0.15	2.8	27	0.20	0.12	3.4	1.4	51	2.8	11.8	27.8
MCES	4/8/96	6.0	330	5.0	10	102	39	0.10	3.9	30	0.28	0.12	4.3	1.5	50	4.0	11.6	31.9
MCES	4/15/96	5.3	325	4.8	10	91	41	0.10	4.0	30	0.24	0.11	4.1	1.5	48	2.2	11.0	31.1
MCES	4/22/96	5.1	314	4.8	10	88	40	0.08	3.2	30	0.25	0.10	2.0	1.5	38	1.1	12.0	31.8
MCES	4/29/96	5.1	312	4.3	10	93	39	0.08	3.1	28	0.24	0.10	2.8	1.4	38	2.6	11.8	28.2
MCES	5/6/96	5.0	304	7.1	10	85	45	< 0.04	2.4	25	0.24	0.10	3.4	1.4	38	3.1	11.8	29.7
MCES	5/13/96	5.8	258	6.4	14	85	45	0.06	4.1	23	0.24	0.14	4.4	1.4	44	3.2	11.7	28.1
MCES	5/20/96	5.6	290	7.1	16	87	46	0.07	3.8	27	0.25	0.14	3.9	1.4	46	3.0	11.8	26.9
MCES	5/27/96	5.4	306	5.3	13	84	41	0.06	4.0	25	0.28	0.13	3.0	1.4	49	1.3	11.3	31.3
MCES	6/2/96	6.1	361	6.3	18	86	46	0.08	3.5	28	0.22	0.11	4.2	1.4	50	2.9	11.5	32.0
MCES	6/10/96	5.7	343	6.2	16	82	42	0.07	3.1	28	0.13	0.10	2.5	1.4	38	1.3	11.3	37.5
MCES	6/17/96	6.1	345	5.7	16	83	36	0.14	3.5	28	0.18	0.10	4.8	1.6	35	1.5	11.6	40.5
MCES	6/30/96	6.2	319	5.2	10	79	39	0.18	2.6	54	0.21	0.10	3.8	1.6	27	2.1	11.1	32.5

test that measures exothermic rise
200gms dust with 800 ml water
measures peak temp rise

% $CaCO_3$
equivalent

acid titration test
to get equivalent
equivalence [illegible]

1996 ADM-Mankato Coal Ash Analysis

Lab	Date	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	P (%)	K (%)	Se	S (%)	Zn	Heat Rise(C)	pH	Lime Eq.
MCES	7/8/96	6.0	315	4.2	13	83	42	0.11	4.9	26	0.25	0.10	4.0	C	29	1.6	11.9	32.0
MCES	10/6/96	4.4	221	6.0	8.5	75	36	0.08	3.8	26	0.19	0.13	3.5		23	2.5	11.7	28.3
MCES	10/12/96	4.8	291	6.8	19	103	42	0.05	4.9	25	0.20	0.18	4.4		37	1.7	11.4	29.4
MCES	10/20/96	4.5	268	8.3	18	90	55	< 0.05	4.5	26	0.17	0.14	4.0		28	1.9	11.6	
MCES	10/27/96	4.8	304	8.2	12	99	48	0.07	4.3	25	0.23	0.15	3.3	1.9	36	1.5	12.1	35.1
MCES	11/3/96	5.1	267	4.3	14	84	50	0.08	4.2	28	0.64	0.14	3.6	C	31	1.4	11.4	C
MCES	11/17/96		328	7.5	10	83	52	0.09	4.8	31	0.33	0.14		1.7	37	1.7	11.0	35.8
MCES	11/24/96	8.2	271	5.9	10	71	42	0.09	4.3	23	0.34	0.11	3.9	C	33	3.5	11.6	C
MCES	11/30/96	9.1	294	6.6	11	80	48	0.07	3.7	24	0.35	0.13	4.2	C	32	1.5	11.5	31.6
MCES	12/8/96		293	5.6	11	85	51	0.11	3.5	28	0.34	0.15		1.7	37	2.7	10.7	
MCES	12/22/96							0.11	4.0		0.30					3.3	11.3	28.4
MCES	12/30/96							0.09	3.2		0.27					2.3	11.2	
MCES	1/6/97															2.3	11.6	

	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	P (%)	K (%)	Se	S (%)	Zn	Heat Rise(C)	pH	Lime Eq.
96 Average:	5.4	298	6.0	21	86	47	0.10	3.5	31	0.26	0.13	3.5	1.5	37	2.7	11.4	31.0
95 Average:	5.7	302	6.5	13	90	70	0.22	3.5	29	0.18	0.15	3.3	1.8	45	3.2		
94 Average:	12	357	7.3	26	109	64	0.27	9.5	38	0.29	0.15	5.1	1.6	55	3.0		
93 Average:	37	390	< 2.2	51	111	20	0.27	< 14	39	0.40	0.15	14.4	1.3	42	4.5		

C = Cancelled test due to low sample volume

1996 Cutler-Magner LKD Analysis

Lab	Date	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	P (%)	K (%)	Se	S (%)	Zn	Heat Rise(C)	pH	Lime Eq.
MCES	1/8/96	14	138	3.8	8.0	20	310	0.11	1.9	22	0.01	0.88	2.7	3.1	48	19.0		
MCES	1/16/95	12	106	2.9	17	9.2	97	< 0.04	1.0	20	0.02	0.83	2.0	2.6	48	16.8		
MCES	1/22/96	12	122	6.4	16	20	77	< 0.04	2.5	25	0.02	0.77	2.0	3.0	66	13.1		
MCES	1/29/96	12	137	6.4	14	20	46	< 0.04	1.4	24	0.03	0.69	1.0	3.2	59	13.0	12.2	103
MCES	2/6/96	12	131	8.0	16	22	103	< 0.04	1.1	26	0.04	0.79	1.0	3.2	71	15.0	12.0	102
MCES	2/12/96	13	126	4.3	6.4	19	81	< 0.04	1.5	20	0.04	0.72	1.9	3.1	50	13.8	11.8	106
MCES	2/19/96	10	120	3.5	6.9	18	175	< 0.20	0.9	19	0.04	0.94	1.9	2.8	51	16.2	12.0	107
MCES	2/26/96	10	145	2.0	11	21	418	< 0.20	2.5	22	0.04	0.76	1.9	2.9	51	14.2	12.2	101
MCES	3/13/96	9.0	96	2.1	10	17	42	0.01	1.0	17	0.04	0.77	4.2	2.5	42	15.8	12.0	104
MCES	3/18/96	7.9	90	1.8	13	19	34	0.06	1.0	17	0.04	0.70	4.7	2.6	41	15.3	12.0	102
MCES	3/25/96	12	131	3.7	13	19	36	< 0.03	1.0	21	0.03	0.82	3.6	2.8	65	14.5	12.3	100
MCES	4/1/96	10	110	2.3	14	20	31	0.09	1.7	20	0.03	0.94	4.7	2.8	43	16.7	12.2	102
MCES	4/8/96	10	122	1.6	12	38	34	0.09	2.1	22	0.03	0.79	3.2	2.9	47	16.1	11.8	99
MCES	4/15/96	11	123	1.6	12	20	119	0.06	1.8	21	0.04	0.75	3.1	2.7	53	9.0	12.4	96
MCES	4/22/96	14	152	3.0	10	26	59	< 0.02	2.0	21	0.03	0.61	2.8	3.3	74	5.4	12.2	93
MCES	4/29/96	13	155	2.8	10	20	42	< 0.01	1.6	21	0.04	0.75	2.3	2.4	59	7.9	12.0	95
MCES	5/6/96	13	134	5.2	10	19	45	< 0.01	1.9	20	0.05	0.72	2.1	3.2	54	13.3	12.0	95
MCES	5/13/96	14	141	4.9	10	17	116	< 0.02	2.3	18	0.03	0.90	2.3	2.9	48	12.2	12.1	103
MCES	5/20/96	13	128	0.1	0.1	17	418	< 0.01	2.0	18	0.03	0.76	1.8	2.8	60	14.1	12.2	101
MCES	5/27/96	12	158	4.4	15	28	333	< 0.01	3.7	23	0.02	0.83	2.7	3.3	600	7.1	12.2	97
MCES	6/2/96	9.5	124	7.0	33	50	836	< 0.01	5.9	27	0.03	2.80	12	5.1	399	9.3	12.5	88
MCES	6/10/96	11	128	3.0	15	20	108	< 0.01	2.5	20	0.04	0.67	4.8	2.9	103	11.9	12.1	98
MCES	6/17/96	11	119	2.8	13	17	142	0.02	2.1	17	0.03	0.73	2.6	2.9	53	12.0	12.1	105
MCES	6/24/96	11	128	2.4	10	17	477	< 0.02	1.5	17	0.01	0.47	2.6	2.7	95	11.1	12.2	100
MCES	6/30/96	10	142	2.3	10	15	341	< 0.01	1.4	16	0.02	0.63	2.0	2.6	58	8.8	12.0	102

by product of lime manufactures
— heat $CaCO_3$

fine ground $CaCO_3$
would have Lime eq

S could be from
limestone or from
fuel – [illegible]
[illegible]

1996 Cutler-Magner LKD Analysis

Lab	Date	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	P (%)	K (%)	Se	S (%)	Zn	Heat Rise(C)	pH	Lime Eq.
MCES	7/7/96	10	111	1.6	10	13	232	< 0.04	2.4	11	0.01	0.43	2.0	3.0	43	12.4	12.0	105
MCES	7/15/96	10	131	1.6	10	15	147	< 0.02	2.4	13	0.16	0.52	2.1	2.9	42	13.7	12.1	102
MCES	7/22/96	10	114	1.6	12	14	190	< 0.03	1.6	9	0.04	0.55	3.4	2.8	38	11.8	12.3	108
MCES	7/29/96	9.2	97	1.6	14	15	62	0.07	3.2	10	0.02	0.68	3.0	2.5	56	13.5	12.0	117
MCES	8/4/96	8.1	106	2.9	12	20	58	0.08	3.2	18	0.02	0.64	5.2	2.8	52	13.0	12.0	101
MCES	8/11/96	9.4	121	3.6	17	23	42	0.07	3.0	21	0.52	0.70	5.6	2.5	68	11.1	12.3	99
MCES	8/18/96	10	119	4.0	20	18	35	0.04	3.7	17	0.04	0.84	5.8	2.4	57	11.3	12.1	97
MCES	8/25/96	9.1	105	4.0	22	21	43	0.05	2.6	20	0.03	0.63	4.3	2.7	57	9.8	12.0	95
MCES	9/1/96	11	128	5.1	38	21	41	0.04	2.3	27	0.08	0.92	4.6	2.6	59	4.7	12.5	96
MCES	9/9/96	8.0	108	2.2	18	55	42	0.04	2.9	16	0.08	0.55	6.3	2.3	75	12.2	12.5	102
MCES	9/15/96	10	125	3.1	19	23	45	0.05	2.8	20	0.08	0.55	5.4	2.4	63	4.1	12.1	82
MCES	9/22/96	9.5	116	3.2	17	23	87	0.07	3.2	20	0.04	0.57	5.4	C	55	10.2	12.5	104
MCES	9/29/96	9.2	124	3.5	18	26	234	0.04	2.8	20	0.02	0.56	5.6	2.5	51	14.1	12.1	104
MCES	10/6/96	11	125	4.6	17	21	238	< 0.05	3.7	19	0.02	0.72	4.9		38	12.4	12.2	99
MCES	10/20/96	9.1	94	3.9	17	20	134	< 0.03	2.5	17	0.01	0.59	4.8		46	18.1	12.1	107
MCES	10/27/96	8.3	103	3.2	15	20	128	< 0.04	2.3	16	0.02	0.78	4.4	2.0	43	9.4	12.3	110
MCES	11/3/96	7.8	85	1.6	14	19	99	0.05	2.1	13	0.02	0.61	3.6	2.0	34	15.3	12.3	120
MCES	11/10/96		79	2.2	10	20	34	< 0.04	2.5	13	0.06	0.48			32	15.8	12.3	
MCES	11/17/96		96	2.7	10	22	40	0.06	2.8	16	0.08	0.60		2.5	50	13.2	12.1	102
MCES	11/24/96	7.1	82	2.8	10	19	72	0.05	2.7	14	0.04	0.53	5.3	C	42	12.9	12.1	C
MCES	11/30/96	7.8	84	3.4	10	19	38	0.05	2.3	17	0.05	0.56	4.5	2.1	41	16.1	12.3	107
MCES	12/8/96		63	1.6	9	19	21	0.05	1.7	20	0.03	0.36		1.8	78	14.1	12.1	
MCES	12/15/96							0.06	1.8		0.02			1.9			12.5	
MCES	12/22/96							< 0.03	1.9		0.02					8.3	12.1	90
MCES	12/30/96							< 0.03	1.9		0.01					11.0	12.3	
MCES	1/6/97															12.2	12.3	

	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	P (%)	K (%)	Se	S (%)	Zn	Heat Rise(C)	pH	Lime Eq.
96 Average:	10	118	3.2	14	21	140	0.05	2.3	19	0.05	0.73	3.7	2.7	74	12.4	12.2	101
95 Average:	16	126	4.1	12	18	365	0.13	1.8	20	0.03	0.76	2.3	3.1	61	10.0		
94 Average:	16	116	5.6	22	27	186	0.03	1.8	23	0.05	0.81	5.0	2.6	87	5.4		

C = analysis cancelled due to low sample volume

Seneca Sludge Analysis

DATE	TS	VS	%KJN	%NH3-N	%P	%K	%S	AS	B	CD	CR	CU	PB	HG	MO	NI	SE	ZN	PCB	pH
1/2/95	23.1	83.1	7.23	0.22	2.76	0.50	0.49	3.5	17	6.9	17	426	85	0.6	16	16	13.0	323	< 0.20	5.7
1/9/95	21.8	84.0	4.91	0.17	1.71	0.44		3.4	17	7.8	23	327	63	0.8	12	12	13.8	292	< 0.20	5.9
1/23/95	17.4	83.3	7.36	0.13	2.44	0.52		4.1	5.7	2.9	17	520	44	2.5	16	16	13.8	384	< 0.20	5.6
1/30/95	24.6	83.9	3.46	0.09	1.31	0.32		3.6	13	4.5	20	447	67	0.6	11	20	10.2	370	< 0.20	5.7
2/1/95	18.5	83.1	5.41	0.22	2.81	0.66	0.13	3.8	14	2.2	27	501	73	1.1	14	23	14.1	323	< 0.20	6.9
2/6/95	18.9	81.5	5.29	0.23	2.70	0.65		3.2	12	3.2	21	446	41	0.5	17	17	12.7	311	< 0.20	6.9
2/13/95	20.1	82.3	4.53	0.18	1.94	0.45		4.4	13	4.0	25	647	64	0.6	14	20	11.4	337	< 0.20	6.3
2/21/95	18.9	81.2	4.66	0.21	1.96	0.63		3.7	6.3	4.2	26	457	93	1.0	11	24	11.6	320	< 0.20	7.2
3/6/95	23.2	82.8	3.97	0.18	1.59	0.37	0.18	4.3	31	5.6	25	698	67	1.1	11	21	6.0	343	< 0.20	5.8
3/13/95	21.3	80.7	5.63	0.15	2.30	0.64		4.7	17	4.7	23	704	85	0.5	13	23	9.4	349	< 0.20	5.7
3/20/95	21.4	79.8	10.28	0.16	3.93	0.41		4.1	20	1.9	21	621	83	0.9	15	22	8.4	377	< 0.20	5.6
3/27/95	21.3	79.5	5.63	0.15	2.39	0.56		4.3	17	2.3	61	554	54	2.4	15	19	8.9	325	< 0.20	5.8
4/3/95	20.4	80.7	6.32	0.19	2.50	0.48	0.20	3.8	14	5.9	125	632	93	1.2	17	26	9.3	358	< 0.20	5.6
4/10/95	19.7	81.4	5.58	0.22	1.68	0.39		4.3	26	10	79	827	111	0.9	16	31	9.1	405	< 0.20	6.0
5/2/95	16.9	80.6	10.65	0.29	4.91	0.69	0.13	4.9	44	8.3	31	563	99	0.6	15	28	14.8	327	< 0.20	5.8
6/19/95	22.1	81.7	6.33	0.26	2.04	0.27	0.22	5.9	13	7.6	28	1344	82	0.8	21	24	8.1	511	< 0.20	6.1
7/11/95	20.0	79.9	6.50	0.37	2.10	0.32	0.21	4.3	35	5.0	58	1150	92	0.8	21	40	7.0	525	< 0.20	8.0
8/7/95	21.9	78.7	5.48	0.34	1.96	0.31	0.23	4.6	20	5.5	21	804	84	1.2	27	18	7.3	466	0.28	5.5
9/7/95	19.2	80.1	4.64	0.22	2.24	0.50	0.19	4.9	63	6.6	16	1604	80	1.1	32	18	10.4	526	0.23	5.6
10/18/95	18.7	79.0	5.13	0.26	2.46	0.63		3.7	19	6.6	25	578	91	1.3	21	25	11.8	361	< 0.20	5.5
11/6/95	22.0	80.5	6.37	0.27	2.37	0.32		4.5	30	6.0	42	928	342	4.8	18	38	7.3	445	< 0.20	5.9
12/6/95	18.8	80.8	5.85	0.30	2.45	0.59		3.9	22	3.2	18	617	118	2.3	14	19	10.6	353	< 0.20	5.6

	TS	VS	%KJN	%NH3-N	%P	%K	%S	AS	B	CD	CR	CU	PB	HG	MO	NI	SE	ZN	PCB	pH
1995 Average:	**20.5**	**81.3**	**5.96**	**0.22**	**2.39**	**0.48**	**0.22**	**4.2**	**21**	**5.2**	**34**	**700**	**91**	**1.3**	**17**	**23**	**10.4**	**379**	**< 0.20**	**6.0**
1994 Average:	19.6	81.7	5.72	0.30	2.11	0.44	0.21	3.9	37	5.9	27	501	79	1.1	18	20	11.7	399	0.22	5.9
1993 Average:	18.1	80.0	6.27	0.37	2.28	0.38	0.41	2.9	26	6.0	40	397	83	1.1	26	18	8.0	400	0.31	6.1
1992 Average:	19.9	81.3	5.59	0.28	2.15	0.44				6.1	27	560	79	1.2		20		421	0.29	

Seneca Sludge Analysis

DATE	TS	VS	%KJN	%NH3-N	%P	%K	%S	AS	B	CD	CR	CU	PB	HG	MO	NI	SE	ZN	PCB	pH
1/23/96	17.3	81.7	6.36	0.33	3.12	0.77		3.2	23	4.0	14	550	75	0.7	13	21	15.0	322	< 0.20	6.3
2/5/96	16.1	79.7	6.83	0.23	3.11	0.73		3.8	31	8.8	19	535	79	0.5	11	20	18.6	329	< 0.20	6.1
3/18/96	16.9	79.1	4.79	0.15	2.96	0.85		4.1	46	0.6	30	592	68	0.5	12	24	16.6	329	< 0.20	5.9
4/9/96	17.3	78.4	4.97	0.22	2.60	0.73		3.8	40	4.6	29	676	43	1.0	11	23	14.5	269	< 0.20	5.3
5/6/96	16.7	79.9	5.87	0.16	2.40	0.55		6.6	24	4.9	30	1060	454	1.1	15	24	15.6	344	< 0.20	6.0
6/22/96	18.6	80.0	5.05	0.17	3.44	0.59		9.1	< 2.7	4.3	27	962	71	0.5	19	45	18.3	472	0.23	5.6
8/5/96	$\boxed{18.0}$							8.3		4.1	17	878	45	0.7		27		434		
10/2/96	$\boxed{18.0}$							4.5		5.6	21	950	106	0.4		24		371		
10/3/96	18.0	80.7	6.67	0.22	2.28	0.48		5.1	34	5.1	22	1000	97	0.5	17	24	13.9	396	0.21	7.1
11/5/96	22.2	82.5	1.71	0.22	1.71	0.40		4.2	46	3.6	13	941	76	1.0	14	12	11.7	412	0.21	5.9
12/3/96	17.9	81.1	7.26	0.34	3.41	0.50		4.6	8.9	5.4	28	933	194	0.5	14	27	16.2	440	0.22	6.5

	TS	VS	%KJN	%NH3-N	%P	%K	%S	AS	B	CD	CR	CU	PB	HG	MO	NI	SE	ZN	PCB	pH
1996 Average:	**17.9**	**80.3**	**5.50**	**0.23**	**2.78**	**0.62**		**5.2**	**28**	**4.6**	**23**	**825**	**119**	**0.7**	**14**	**25**	**15.6**	**374**	**< 0.21**	**6.1**
1995 Average:	20.5	81.3	5.96	0.22	2.39	0.48	0.22	4.2	21	5.2	34	700	91	1.3	17	23	10.4	379	< 0.20	6.0
1994 Average:	19.6	81.7	5.72	0.30	2.11	0.44	0.21	3.9	37	5.9	27	501	79	1.1	18	20	11.7	399	0.22	5.9
1993 Average:	18.1	80.0	6.27	0.37	2.28	0.38	0.41	2.9	26	6.0	40	397	83	1.1	26	18	8.0	400	0.31	6.1
1992 Average:	19.9	81.3	5.59	0.28	2.15	0.44				6.1	27	560	79	1.2		20		421	0.29	

$\boxed{\quad\quad}$ = surrogate value is used here because lab did not analyze for total solids (TS) and TS is needed to calculate metal concentrations on a dry weight basis

1995 N-Viro oil Analysis

Date	T.S. (%)	ENP (%)	ENP (lb/T)	TVS (%)	TKN (%)	NH3-N (%)	Avail. N (lb/T)	P (%)	K (%)	S (%)	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn	PCB	pH	F.Coli MPN/g
1/3/95	52.9	54.0	571	22.0	1.17	0.04	4.9	0.85	0.67	2.0	10.2	110	4.9	14	134	54	0.23	5.7	20	6.8	123	< 0.2	12.1	<4 mpn/gram
1/9/95	54.3	50.0	543	22.1	0.95	0.05	4.1	0.57	0.85	1.9	10.5	142	5.7	17	115	64	0.29	4.8	25	7.0	99	< 0.2	12.3	<4 mpn/gram
1/15/95	55.8	49.0	547	24.5	0.79	0.02	3.3	0.38	0.81	1.8	7.9	137	5.0	13	132	101	0.13	5.2	24	4.8	100	< 0.2	12.4	<4 mpn/gram
1/23/95	54.9	51.0	560	22.7	0.90	0.06	4.0	0.39	0.61	1.7	7.7	6.6	3.5	11	123	100	0.26	3.8	17	5.5	98	< 0.2	12.3	<4 mpn/gram
1/30/95	55.0	53.0	583	25.3	0.67	0.04	2.9	0.30	0.77	1.6	8.7	134	4.4	13	122	90	0.87	4.0	25	6.4	109	< 0.2	12.3	<4 mpn/gram
2/6/95	50.6	51.0	516	28.5	0.83	0.03	3.5	0.45	0.85	1.6	11.5	153	4.3	13	152	102	0.40	6.3	27	6.3	117	< 0.2	12.3	<4 mpn/gram
2/13/95	50.9	47.9	488	29.0	1.28	0.05	5.4	0.98	0.94	2.3	11.6	172	4.9	17	168	177	0.33	5.9	33	6.5	122	< 0.2	12.1	<4 mpn/gram
2/21/95	52.3	60.8	636	28.0	0.52	0.03	2.2	0.29	0.90	1.7	14.7	183	5.4	15	144	131	0.36	7.8	37	6.5	118	< 0.2	12.4	<4 mpn/gram
2/27/95	49.3	54.5	537	28.2	0.61	0.02	2.6	0.41	0.78	1.7	12.8	163	5.9	19	137	111	0.24	7.5	29	6.9	115	< 0.2	12.1	<4 mpn/gram
3/6/95	51.7	48.0	496	29.2	1.01	0.04	4.2	0.66	0.84	1.5	11.6	152	4.6	17	169	94	0.23	6.4	32	6.2	112	< 0.2	12.1	<4 mpn/gram
3/13/95	54.8	44.0	482	27.8	1.09	0.02	4.5	0.55	0.92	1.6	13.3	153	5.3	19	166	91	0.57	6.6	32	8.0	103	< 0.2	12.1	<4 mpn/gram
3/20/95	50.8	43.0	437	30.2	1.20	0.05	5.1	0.65	0.69	1.6	11.8	139	3.9	11	195	82	0.96	6.9	27	5.5	120	< 0.2	12.3	<4 mpn/gram
3/27/95	46.1	44.0	406	35.2	1.08	0.05	4.7	0.54	1.00	2.2	13.9	169	4.3	20	172	128	0.26	8.7	31	7.8	140	< 0.2	12.1	<5 mpn/gram
4/3/95	51.1	44.0	450	30.7	1.68	0.03	6.9	0.80	0.90	1.7	11.4	179	5.1	27	169	90	0.59	6.8	34	8.6	129	< 0.2	12.3	<4 mpn/gram
4/10/95	56.0	44.0	493	21.1	1.61	0.03	6.6	0.73	0.84	2.6	15.7	250	7.1	36	142	73	0.30	8.7	31	7.5	136	< 0.2	12.4	<4 mpn/gram
4/17/95	60.4	51.0	616	23.3	1.06	0.06	4.6	0.48	0.88	2.9	16.2	217	5.6	27	145	89	0.26	7.8	35	6.8	147	< 0.2	12.3	<4 mpn/gram
4/24/95	60.5	52.0	629	18.1	0.64	0.03	2.8	0.30	0.92	2.8	16.2	195	6.6	25	138	114	0.26	6.1	32	7.4	130	< 0.2	12.4	<4 mpn/gram
5/1/95	50.8	44.0	447	33.7	1.50	0.05	6.3	0.81	0.91	1.9	15.4	150	7.1	26	197	129	0.33	6.9	33	8.7	124	< 0.2	12.6	<4 mpn/gram
6/5/95	58.0	45.0	522	26.8	0.90	0.01	3.6	0.48	0.77	1.6	11.0	129	4.5	23	160	66	0.22	7.4	28	5.9	99	< 0.2	12.3	<4 mpn/gram
6/30/95	57.5	48.0	552	27.4	0.92	0.04	3.9	0.37	0.62	2.3	12.3	156	3.7	22	166	79	0.37	8.0	22	4.9	123	< 0.2	12.5	<4 mpn/gram
7/28/95	56.1	48.0	539	30.8	1.07	0.02	4.4	0.46	0.64	1.8	12.8	178	5.3	19	241	116	0.45	12.1	38	5.5	134	< 0.2	11.9	<4 mpn/gram
9/1/95	55.7	46.0	512	36.4	0.93	0.03	3.9	0.47	0.53	1.9	11.1	55	4.3	12	228	120	0.43	9.9	25	5.2	150	< 0.2	12.2	<4 mpn/gram
10/2/95	54.2	52.0	564	28.8	0.76	0.07	3.4	0.37	0.74	1.5	8.9	123	4.4	15	247	109	0.22	8.1	25	5.2	124	< 0.2	12.4	<4 mpn/gram
10/30/95	52.5	52.0	546	30.2	0.67	0.02	2.8	0.36	0.66	2.1	17.1	119	4.1	17	202	88	0.21	7.6	22	4.4	114	< 0.2	12.5	4 mpn/gram
12/4/95	51.3	46.0	472	32.6	1.05	0.06	4.6	0.47	0.56	2.0	10.5	179	5.5	16	214	220	1.50	8.8	41	4.3	121	< 0.2	12.5	<4 mpn/gram
1/1/96	50.9	45.0	458	40.0	0.88	0.05	3.8	0.45	0.43	2.0	7.1	228	5.8	15	232	134	0.47	6.1	39	5.1	115	< 0.2	12.1	<4 mpn/gram
							503 "Clean Sludge" Limits:				**41**	**--**	**39**	**1200**	**1500**	**300**	**17**	**18**	**420**	**36**	**2800**			
1992 Average:	57.5	57.2	659	17.9	0.92	0.04	3.0	0.33	1.38	3.1	25	198	4.5	30	94	174	0.18	12	38	17	295	< 0.2	12.2	
1993 Average:	59.6	52.5	625	23.3	0.78	0.02	3.3	0.37	0.95	3.3	21	256	3.6	31	93	135	0.08	14	45	7.6	308	< 0.1	12.6	
1994 Average:	55.6	51.2	572	25.3	0.96	0.03	4.0	0.50	0.62	2.8	11	215	4.9	22	148	65	0.34	11	29	6.8	170	< 0.2	12.3	
1995 Average:	**53.6**	**48.7**	**523**	**28.2**	**0.99**	**0.04**	**4.2**	**0.52**	**0.77**	**1.9**	**12.0**	**153**	**5.1**	**18**	**170**	**106**	**0.41**	**7.1**	**29**	**6.3**	**120**	**< 0.2**	**12.3**	
St. Dev. (+/-):	3.4	4.3	59	5.0	0.29	0.02	1.2	0.19	0.15	0.4	2.8	49	1.0	6	39	35	0.30	1.8	6	1.2	14	*Error*	0.2	
%St. Dev. (+/-):	6	9	11	18	30	40	28	36	19	20	23	32	19	33	23	33	71	25	21	20	12	*Error*	1	

1996 N-Viro oil Analysis

mg/Kg

Date	T.S. (%)	ENP (%)	ENP (lb/T)	TVS (%)	TKN (%)	NH3-N (%)	Avail. N (lb/T)	P (%)	K (%)	S (%)
1/1/96	50.9	45.0	458	40.0	0.88	0.05	3.8	0.45	0.43	1.0
1/29/96	52.6	47.0	494	32.4	1.50	0.04	6.3	0.63	0.44	1.1
2/12/96	49.4	42.4	419	34.3	1.17	0.03	4.9	0.65	0.45	0.8
2/26/96	51.9	39.5	410	28.7	0.96	0.03	4.1	0.48	0.36	0.9
3/11/96	53.0	43.1	457	33.3	1.09	0.02	4.5	0.66	0.35	1.1
3/25/96	49.5	40.9	405	33.7	1.84	0.02	7.5	0.93	0.43	0.9
4/8/96	54.7	42.8	468	29.6	0.82	0.02	3.4	0.59	0.41	1.0
4/22/95	53.6	42.3	453	28.8	1.21	0.02	5.0	0.71	0.38	0.6
5/6/96	56.5	43.0	485	28.8	0.65	0.01	2.7	0.42	0.35	1.2
5/20/96	56.7	42.9	487	25.5	0.88	0.02	3.6	0.74	0.41	0.8
6/3/96	56.6	43.4	492	27.7	0.48	0.02	2.0	0.35	0.59	1.2
6/17/96	61.2	53.0	649	22.8	0.59	0.02	2.5	0.47	0.38	
6/30/96	64.0	51.0	653	18.0	0.16	0.02	0.7	0.14	0.27	
7/15/96	61.0	51.3	626	20.6	0.54	0.00	2.2	0.36	0.27	
7/29/96	63.4	53.6	680	19.3	0.32	0.01	1.3	0.39	0.32	
8/12/96	59.0	38.5		25.1						
1996 Average:	55.9	45.0	509	28.0	0.87	0.02	3.6	0.53	0.39	1.0
1995 Average:	53.6	48.7	523	28.2	0.99	0.04	4.2	0.52	0.77	1.9
1994 Average:	55.6	51.2	572	25.3	0.96	0.03	4.0	0.50	0.62	2.8
1993 Average:	59.6	52.5	625	23.3	0.78	0.02	3.3	0.37	0.95	3.3
1992 Average:	57.5	57.2	659	17.9	0.92	0.04	3.0	0.33	1.38	3.1

Date	As	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn	PCB	pH	F.Coli MPN/g
	41		39		1500	300	0.15	15	420	100	2800			
1/1/96	7.1	228	5.8	15	232	134	0.47	6.1	39	5.1	115	< 0.2	12.1	<4 mpn/gram
1/29/96	8.4	196	5.5	12	198	73	0.21	5.9	29	6.3	107	< 0.2	12.0	<4 mpn/gram
2/12/96	8.7	233	5.3	34	196	71	0.51	6.7	35	5.5	107	< 0.2	12.0	<5 mpn/gram
2/26/96	6.4	208	3.8	22	179	100	0.04	4.8	22	6.9	99	< 0.2	12.4	<4 mpn/gram
3/11/96	6.8	240	4.8	18	200	134	0.66	7.7	40	5.7	91	< 0.2	12.2	<4 mpn/gram
3/25/96	8.1	226	4.4	17	190	59	0.36	8.3	48	6.9	120	< 0.2	12.2	<5 mpn/gram
4/8/96	7.5	263	4.5	13	212	46	0.29	7.9	48	6.6	102	< 0.2	12.0	<4 mpn/gram
4/22/95	9.1	265	4.2	14	226	58	0.26	6.9	25	3.7	100	< 0.2	12.1	<4 mpn/gram
5/6/96	9.2	232	5.9	16	218	59	0.44	12	90	4.6	96	< 0.2	11.9	<4 mpn/gram
5/20/96	9.5	257	7.1	20	215	140	0.16	6.3	28	8.5	115	< 0.2	12.3	<4 mpn/gram
6/3/96	9.0	253	6.5	23	237	286	0.12	8.5	32	6.4	590	< 0.2	12.3	<4 mpn/gram
6/17/96	9.2	260	4.7	16	209	97	0.18	9.5	47	7.8	113	< 0.2	12.2	<4 mpn/gram
6/30/96	9.4	275	5.5	17	211	76	0.27	15	80	3.9	112		12.1	<4 mpn/gram
7/15/96		298	4.9	20	215	88	0.39		91		116		11.9	<4 mpn/gram
7/29/96		300	4.2	24	205	85	0.47		177		109		12.1	<4 mpn/gram
8/12/96													12.1	
503 "Clean Sludge" Limits:	**41**	**--**	**39**	**1200**	**1500**	**300**	**17**	**18**	**420**	**36**	**2800**			
1996 Average:	8.3	249	5.1	19	210	100	0.32	8.1	55	6.0	139	< 0.20	12.1	
1995 Average:	12	153	5.1	18	170	106	0.41	7.1	28	6.3	120	< 0.20	12.3	
1994 Average:	11	215	4.9	22	148	65	0.34	11	29	6.8	170	< 0.19	12.3	
1993 Average:	21	256	3.6	31	93	135	0.08	14	45	7.6	308	< 0.06	12.6	
1992 Average:	25	198	4.5	30	94	174	0.18	12	38	17	295	< 0.18	12.2	

ENP = Effective Neutralizing Power

1995 BioCheck Analyses of N-Viro Soil

Month	pH	%TS	%VS	TKN-N	NH3-N	P	K	Lime	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn
January	12.8	56.1	23.3	7.5	1.1	9.3	14.0	32.4	13.0	2.7	26	170	62	0.4	5.4	25	8.4	110
February	12.8	60.7	25.7					32.7										
March	12.6	52.4	28.8	19.1	1.0	10.7	17.8	27.1	6.0	2.8	22	190	42	0.5	5.6	20	12.0	82
April	12.8	61.3	20.1					31.8										
May	12.7	56.1	27.0	15.3	0.8	11.1	11.0	30.4	7.8	5.5	22	184	83	0.4	4.6	44	8.2	110
June	12.8	51.2	29.4					32.0										
July	12.7	54.2	31.3	12.6	0.8	13.3	12.6	24.3	5.0	6.0	25	233	68	0.5	7.9	68	12.0	135
August	12.5	59.0	32.2					28.4										
September	12.6	53.2	28.2	25.9	1.3	9.9	19.8	62.5	5.3	3.0	24	222	88	0.4	5.8	38	8.2	125
October	12.6	53.4	29.3					29.0										
November	12.5	51.0	33.0	28.6	2.9	15.1	8.1	49.0	8.4	3.9	21	208	231	0.5	7.6	76	9.8	138
December	12.5	54.6	28.5	11.6	2.1	11.1	7.3	28.7	7.0	4.3	38	218	88	0.5	5.1	95	4.0	104
'95 Average	**12.7**	**55.3**	**28.1**	**17.2**	**1.4**	**11.5**	**12.9**	**34.0**	**7.5**	**4.0**	**25**	**204**	**95**	**0.5**	**6.0**	**52**	**8.9**	**115**

1995 Month	Total Bacteria	Fecal Coli	Fecal Strep.	Salmonella	Viable Helminth	Non-viable Helminth	Enterovirus	Viable Protozoans	Protozoan Empty Shells
January	4.2E+5	< 1	4.0	< 1	< 1	1	< 1	< 1	
February	5.2E+5	< 1	450	< 1	< 1	< 1	< 1	< 1	
March	9.9E+4	< 1	270	< 3	< 1	< 1	< 1	< 1	38
April	3.6E+5	< 1	< 1	< 3	< 1	0.3	< 1		1.3
May	2.4E+4	< 1	< 1	< 3	< 1	< 1	< 1	0.7	
June	4.9E+5	< 1	< 1	< 3	< 1	< 1	< 1	< 1	
July	2.1E+6	< 1	1.2	< 3	< 1	< 1	< 1	< 1	
August	3.1E+6	< 1	21.7	< 3	< 1	1.2	< 1		3.2
September	1.3E+6	< 1	3.3	< 1	< 1	< 1	< 1		4.5
October	1.2E+5	< 1	50.9	< 3	< 1	< 1	< 1		2.8
November	1.2E+5	< 1	75.3	< 3	< 1	< 1	< 1		< 1
December	1.1E+4	< 1	1.2	< 3	< 1	3	< 1	4.5	
'95 Average:	**7.2E+5**	**< 1**	**98**	**< 3**	**< 1**	**1.4**	**< 1**	**2.6**	**10.0**

1996 BioCheck Analyses of N-Viro Soil

Month	pH	%TS	%VS	TKN-N	NH3-N	P	K	Lime	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn
January	12.7	49.8	30.3					32.2										
February	12.8	51.6	32.5	20.6	2.1	17.2	11.2	47.5	1.5	0.5	32	81	71	0.5	1.0	31	1.0	98
March	12.8	52.6	32.9					44.0										
April	12.7	55.4	30.1	20.1	1.8	13.1	7.1	48.5	6.5	1.0	32	253	30	0.5	7.0	65	5.2	99
May	12.6	57.5	24.6					56.5										
June	12.5	63.0	20.1	11.7	0.6	9.1	8.9	52.8	7.5	1.7	39	260	94	0.5	8.7	75	4.1	112

1996 Month	Total Bacteria	Fecal Coli	Fecal Strep.	Salmonella	Viable Helminth	Non-viable Helminth	Enterovirus	Viable Protozoans	Non-Viable Protozoans
January	1.2E+5	< 1	2.6	< 3	< 1	1	< 1		4.2
February	4.8E+6	< 1	744	< 3	< 1	1.6	< 1		13.2
March	6.8E+4	< 1	< 1	< 3	< 1	< 1	< 1		1.5
April	9.8E+4	< 1	3.0	< 3	< 1	< 1	< 1		< 1
May	1.0E+4	< 1	< 1	< 3	< 1	< 1	< 1		< 1
June	7.6E+4	< 1	< 1	< 3	< 1	< 1	< 1		< 1

Appendix 3

MSW Compost Information

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According to *Soil and crop research on municipal solid waste class 1 compost utilization in Minnesota*, a 1994 report from the Soil Science Department of the University of Minnesota that was funded by the Minnesota Office of Waste Management, there are currently 8 facilities in the state that produce municipal solid waste (MSW) compost. The MSW compost used in this project was produced at the Wright County Compost Facility, located in Buffalo, MN. Dave Mehrenberg is the facility manager. On April 18, 1996, Paul Eger and Jon Wagner of the MDNR toured the facility with Dave Mehrenberg. Attached is a document that summarizes the production process; the following notes are production details that aren't included in the attached document.

Approximately 60% of the input to the facility comes from the county, with the rest coming from the NSP facility in Elk River. The lot (#24) from which the material for the Shiely project will be taken is now 230 days old, and currently (as of 4/18/96) has a volume of about 1000 cubic yards. (The compost will become denser as it matures.)

After initial processing (see attached document for details), the compost is placed in windrows atop a floor that has aeration slots. (The aeration slots are approximately 3/4" by 5", with about 5" of separation between the slots on all sides.) Odors are absorbed by the water vapor that arises from the compost, and most goes straight up, so that odors aren't usually a problem for neighbors on adjacent properties. Occasionally, however, especially in the morning, the water vapor will travel horizontally for distances of up to a mile, and then drop straight down along, bringing the odors with it.

MSW is generally low in nitrogen, making it difficult to get a "hot burn" that is often obtained with composts that have higher nitrogen contents, and this problem is compounded by the fact that the primary substrates in MSW (wood and paper products) are high in carbon. Gardening books tend to recommend a C:N ratio of about 25:1 or 30:1, and the more nitrogen you add the hotter the compost will get. MSW compost has a much higher ratio, and "burns" much more slowly.

The pH of the compost is usually in the high 7's. They are required to analyze inerts (manmade materials such as plastics that won't compost), but do not report them on their analytical summary tables. Regulations related to compost state that total inerts cannot be more than a certain percentage (3% or 4%), but this doesn't include rocks. (Rocks are considered to be a natural substrate, and not an inert material as it applies to compost.)

After the windrow process is completed, the compost passes through a ballistic separator in which the compost flows through it but materials such as glass don't; instead they are fed to conveyors that lead up and out of the separator.

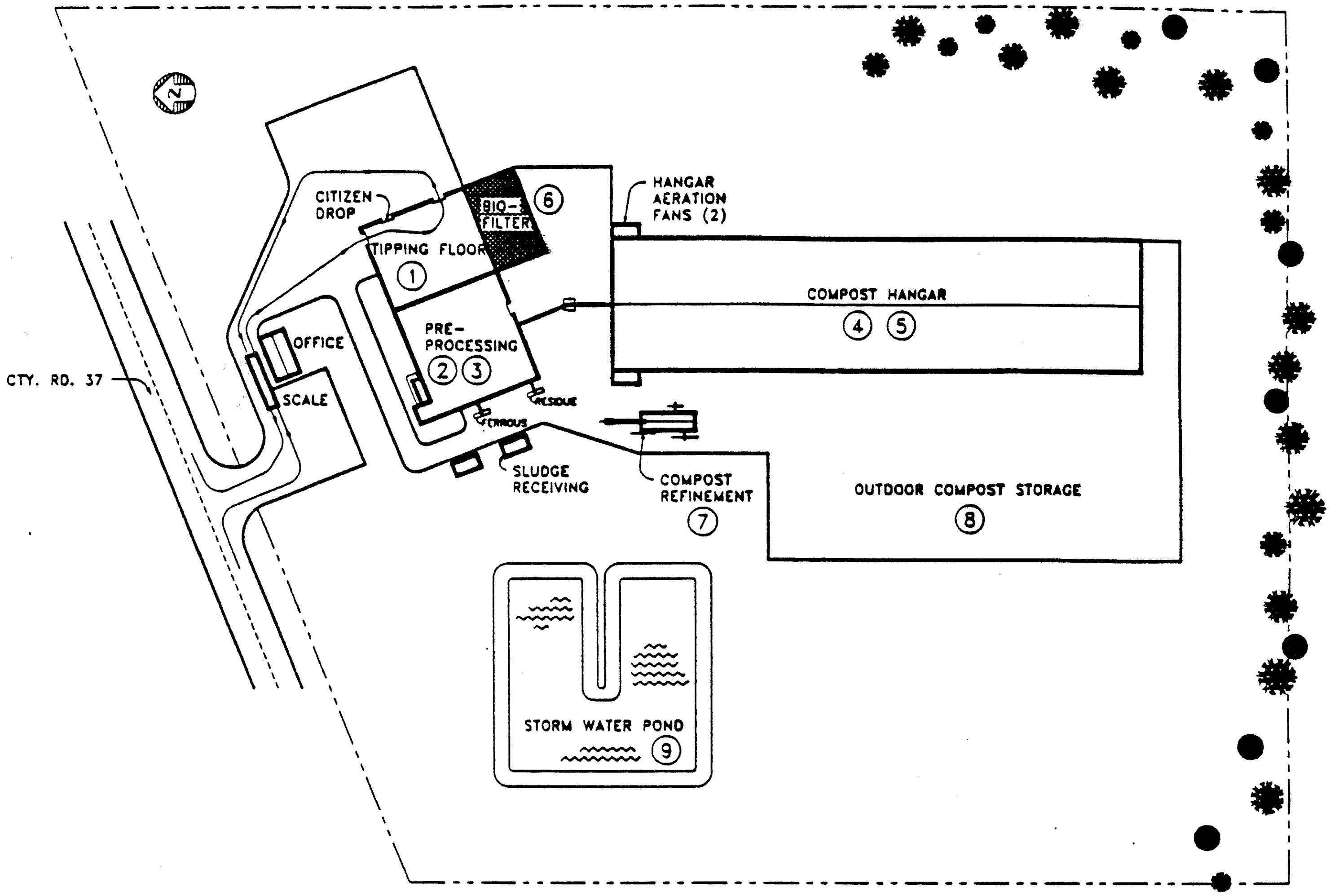
The bacteria that are essential to the composting process will rob nitrogen from the compost until the bacterial population crashes, at which time the nitrogen becomes available for vegetative uptake. Also, as the compost ages it develops a tackiness that allows crumb-like structures to form, which aids in soil aeration and soil permeability. The mature compost has some nutritive value; Dave estimated it as approximately 1/¼/¼ NPK.

Anaerobic conditions are undesirable because it is the anaerobe bacteria that produce foul odors. The windrows are protected by a canopy to prevent water to form in puddles between the windrows, because it can "wick in" on the bottom of the windrow and produce anaerobic conditions within the pile. No MSW compost is totally aerobic; it burns so hot in some pockets that air can't get to it. The bacterial populations are often facultative, which means they can operate under both aerobic and anaerobic conditions.

Most of the odors that arise from the windrows (and during other stages or processing) are captured and directed to a biofilter, which is a pile of wood chips (approximately 6' tall) in which bacteria live. Eventually the wood chips become exhausted, at which point it is very nitrogen-rich as a result of nitrogen fixation carried out by the bacteria, and the wood chips are replaced about every 3 to 4 years.

WRIGHT COUNTY, MINNESOTA

MIXED MUNICIPAL SOLID WASTE COMPOSTING FACILITY



OVERVIEW

The residents of Wright County, Minnesota are among the first in the nation to recognize the value of composting waste.

Their new facility located on a 27 acre site near Monticello opened its doors in March 1992. The $14 million plant is designed to process all of Wright County's commercial and residential solid waste; 165 tons per day.

Twenty eight full and part-time employees oversee the operation of the plant which recovers recyclable materials (corrugated paper, plastic, aluminum and steel), and converts about 40% of the waste into a useful and valuable material -- compost. Following recyclable recovery and composting, the amount of original waste landfilled is reduced by more than 50%.

PROCESSING

The process begins when the garbage haulers of Wright County dump their trucks on the tipping floor. This is the unsorted waste of businesses and residences - just as it was put into dumpsters and trash cans. Workers remove the large and unprocessible items, including mattresses, automobile batteries, golf clubs, etc. It is then transferred into the process building on conveyors where a series of machines prepare the waste for composting.

Rotating drums (or trommels) are used throughout the process to separate the waste stream by size. After the first drum separation, hand-sorting takes place. This is where recyclable materials, including corrugated paper, plastics, and aluminum are removed by workers. These will be baled and sold.

Following this material recovery step, the remaining waste is shredded, mixed with water in a special rotating drum and screened to separate compostable material. The material also passes under powerful magnets to remove valuable steel for recycling.

By the time the waste leaves the processing building as raw compost it is consistent in size and water content and is virtually free of non-compostable material.

The material now leaves the processing building for the composting hangar. Composting takes place in a covered hangar where temperature, moisture and air are carefully controlled. Piles 8 feet high by 550 feet long, called windrows, are created by a belt conveyor running down the center of the hangar.

Every eight days the piles are turned, mixed, fluffed, repositioned and necessary moisture added by a special windrow turning machine.

Each windrow will be turned and repositioned five times until it has moved to the outside edge of the hangar. From there it can be moved to the refinement building.

In the refinement building a shredder breaks up lumps and another screening drum separates the fine compost from the rejects, (which is anything over 3/8" in size). It is now that a destoner is used to remove glass, stones and other small, hard particles. The result of all these various processes is a mature, stable, high quality compost suitable for a variety of uses.

This facility has been designed to manage potential problems such as groundwater contamination, air quality (dust and odors) and noise. All run-off water is collected, contained and reused in the composting process.

The equipment operates within insulated buildings which reduces noise levels. Dust is controlled through an aspiration system indoors and sprinkling of the compost outdoors.

Odors, a major concern, are controlled by "capturing" them at the tipping floor, process building and compost hangar and passing them through a bio-filter. The bio-filter is a bed of bark chips which scrubs the air as it is forced through.

As you can see, this facility was designed to be a "good neighbor".

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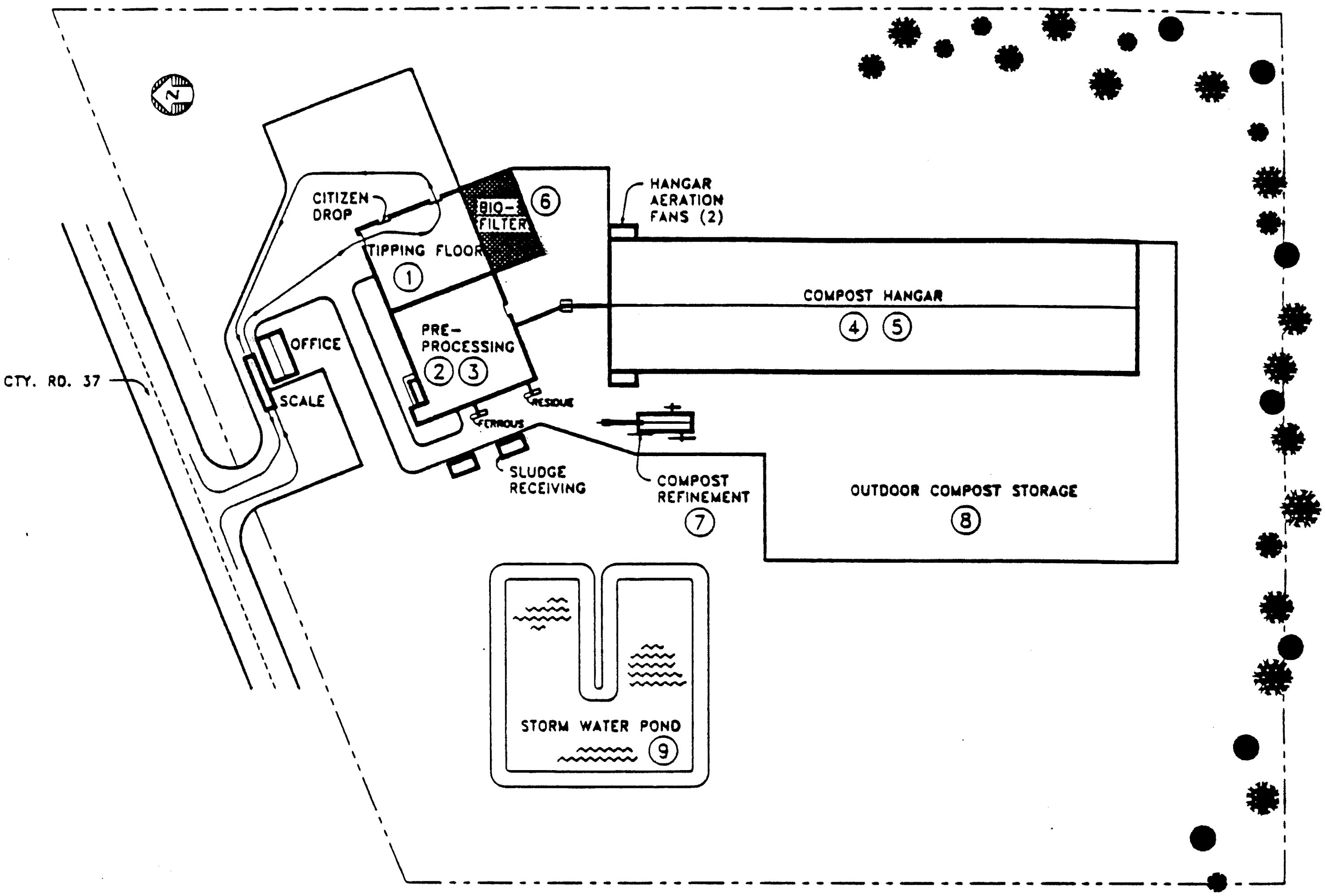
After the windrow process is completed, the compost passes through a ballistic separator in which the compost flows through it but materials such as glass don't; instead they are fed to conveyors that lead up and out of the separator.

The bacteria that are essential to the composting process will rob nitrogen from the compost until the bacterial population crashes, at which time the nitrogen becomes available for vegetative uptake. Also, as the compost ages it develops a tackiness that allows crumb-like structures to form, which aids in soil aeration and soil permeability. The mature compost has some nutritive value; Dave estimated it as approximately 1/¼/¼ NPK.

Anaerobic conditions are undesirable because it is the anaerobe bacteria that produce foul odors. The windrows are protected by a canopy to prevent water to form in puddles between the windrows, because it can "wick in" on the bottom of the windrow and produce anaerobic conditions within the pile. No MSW compost is totally aerobic; it burns so hot in some pockets that air can't get to it. The bacterial populations are often facultative, which means they can operate under both aerobic and anaerobic conditions.

Most of the odors that arise from the windrows (and during other stages or processing) are captured and directed to a biofilter, which is a pile of wood chips (approximately 6' tall) in which bacteria live. Eventually the wood chips become exhausted, at which point it is very nitrogen-rich as a result of nitrogen fixation carried out by the bacteria, and the wood chips are replaced about every 3 to 4 years.

WRIGHT COUNTY, MINNESOTA
MIXED MUNICIPAL SOLID WASTE COMPOSTING FACILITY



OVERVIEW

The residents of Wright County, Minnesota are among the first in the nation to recognize the value of composting waste.

Their new facility located on a 27 acre site near Monticello opened its doors in March 1992. The $14 million plant is designed to process all of Wright County's commercial and residential solid waste; 165 tons per day.

Twenty eight full and part-time employees oversee the operation of the plant which recovers recyclable materials (corrugated paper, plastic, aluminum and steel), and converts about 40% of the waste into a useful and valuable material -- compost. Following recyclable recovery and composting, the amount of original waste landfilled is reduced by more than 50%.

PROCESSING

The process begins when the garbage haulers of Wright County dump their trucks on the tipping floor. This is the unsorted waste of businesses and residences - just as it was put into dumpsters and trash cans. Workers remove the large and unprocessible items, including mattresses, automobile batteries, golf clubs, etc. It is then transferred into the process building on conveyors where a series of machines prepare the waste for composting.

Rotating drums (or trommels) are used throughout the process to separate the waste stream by size. After the first drum separation, hand-sorting takes place. This is where recyclable materials, including corrugated paper, plastics, and aluminum are removed by workers. These will be baled and sold.

Following this material recovery step, the remaining waste is shredded, mixed with water in a special rotating drum and screened to separate compostable material. The material also passes under powerful magnets to remove valuable steel for recycling.

By the time the waste leaves the processing building as raw compost it is consistent in size and water content and is virtually free of non-compostable material.

The material now leaves the processing building for the composting hangar. Composting takes place in a covered hangar where temperature, moisture and air are carefully controlled. Piles 8 feet high by 550 feet long, called windrows, are created by a belt conveyor running down the center of the hangar.

Every eight days the piles are turned, mixed, fluffed, repositioned and necessary moisture added by a special windrow turning machine.

Each windrow will be turned and repositioned five times until it has moved to the outside edge of the hangar. From there it can be moved to the refinement building.

In the refinement building a shredder breaks up lumps and another screening drum separates the fine compost from the rejects, (which is anything over 3/8" in size). It is now that a destoner is used to remove glass, stones and other small, hard particles. The result of all these various processes is a mature, stable, high quality compost suitable for a variety of uses.

This facility has been designed to manage potential problems such as groundwater contamination, air quality (dust and odors) and noise. All run-off water is collected, contained and reused in the composting process.

The equipment operates within insulated buildings which reduces noise levels. Dust is controlled through an aspiration system indoors and sprinkling of the compost outdoors.

Odors, a major concern, are controlled by "capturing" them at the tipping floor, process building and compost hangar and passing them through a bio-filter. The bio-filter is a bed of bark chips which scrubs the air as it is forced through.

As you can see, this facility was designed to be a "good neighbor".

Appendix 4

Seed Mix Information and Planting Methods

Appendix 4

Seed Mix Information and Planting Methods

All seeds for this project except the flax were purchased from Peterson Seed Co., P.O. Box 346, Savage, MN, 55378, phone 1-800-328-5898, fax (612) 445-1679. The flax, which was not available from Peterson Seed, was procured by Shiely employee Dennis Kilmer.

Two different seed mixes were used for this project; a native prairie seed mix, similar to MNDOT's 20A mix, and a standard cool-season mix, similar to MNDOT's 50A mix. And the native seed mix was actually a combination of two sub-mixes, which Peterson Seed calls their Prairie Mixes #1 and #2. The composition of these mixes are presented on an attached document that was obtained from the company, along with the percentage and pound of each seed that was included in each mix.

The two prairie mixes include something called the SE Regional Forbs Mix. Attached is a document that lists the composition of this forbs mix, as well as acceptable substitutes. A Peterson employee (Larry) said that the seeds in this forbs mix are present in roughly the same proportions, but that no documentation exists of the exact weights or percentages of the individual seeds in the lot that was used for this particular project. He also said that the goal is to make the mix using all seeds listed for the mix, but that if any are unavailable at the time the mix is prepared, substitutes are selected at random from the list of acceptable subsitutes. Unfortunately, the exact substitutes (if any) used in the mix for this particular project were also not documented.

Little evidence was found of the native prairie plants on the demonstration slope, but several parties have stated that this may be due in part to the fact that natives can sometimes take several years to become established. Attached is a memo from Kim Hennings of the Fish and Wildlife Division of the MDNR addressing this topic.

From: Kim Hennings
To: DNR-PO-4thfloor.PAEGER
Date: 7/15/96 4:21pm
Subject: Shiely Reclamation Project

According to Bob Djupstrom and Ellen Fuge of the SNA (Scientific and Natural Areas) Program, it is normal to see very little growth of prairie species until the second or third year after planting. So don't give up hope yet. They even wondered if the goose grazing may not be beneficial by keeping the vegetation cover down on the nurse crop and other weedy species that would otherwise shadeout germination of the prairie species. They said that it is normal to mow a new prairie planting once or twice during the first year to prevent overshading by the cover crop and other weeds.

The problem with the goose grazing may not be so much that they have eaten the prairie species, but that they have reduced the cover crop needed to stabilize the soil and prevent erosion.

They also said that you may want to consider substituting oats and timothy for the brome component in the mix. Oats does not have the leaf coverage and is not as invasive as brome and is an annual. You will have some reseeding for several years, but this should not be a problem. The only reason Bob questioned the use of timothy was that it is not a native species. This would not be a concern if you are using MDOT mixtures and are not that concerned with being a purist. They would not use timothy in a seed mixture to reestablish native prairie on an SNA because they do not want any nonnative species.

Our wetlands wildlife specialist suggested a fall planting to discourage goose depredation in spring. The idea would be that the cover crop, e.g. winter wheat, would provide a taller layer in spring and summer that may discourage goose grazing. There is more of a problem, however, with prairie seedings in fall than in spring. If goose grazing was a major problem, you may also consider interseeding winter wheat in fall to provide higher cover in spring and summer. Bob warned that this could interfere with the prairie seedlings by creating too much shade.

Based on all of this information, it seems that your problem is in establishing an adequate cover crop to stablize the soils while not shading out or out competing the prairie species. If goose depredation is impacting the cover crop to the point that you do not get adequate coverage, then you may need to address the goose grazing somehow with one of the ideas described above. On the other hand, how many other gravel pit restorations will likely have goose problems?

Bob and/or Ellen would be happy to discuss any of these issues with you if you give them a call. Bob's phone number is 297-2357 and Ellen's is 297-3288. Hopes this helps.

01/31/97 12:17 FAX 612 683 8108 SHIELY CO. 002/002

INVOICE

PETERSON SEED COMPANY, INC.

P.O. BOX 346 • SAVAGE, MN 55378

612/445-2606 WATS 800/328-5898 FAX 612/445-1679

DATE 5/29/96	PAGE 1
TICKET NO 037854	INVOICE NO 043259

JUN -3 1996

SOLD TO: SHIELY COMPANY
2915 WATERS RD
SUITE 105
EAGAN MN 55121

SHIP TO: SHIELY COMPANY
2915 WATERS RD
SUITE 105
EAGAN MN 55121

SHIP VIA	SHIP DATE	TERMS
Will Call	5/10/96	NET 30 6/28/96

SALESPERSON	CUST NO	CUST PO NUMBER
Minnesota	277000	

QUANTITY	DESCRIPTION	PRICE	AMOUNT
237.00	LB CUSTOM TURF MIX (Native Grass/Forb Mix #1)	6.957	1,649.00
72.00	LB CUSTOM TURF MIX (Native Grass/Forb Mix #2)	6.250	450.00
272.00	LB CUSTOM TURF MIX (Turf/Native Grass Mix #1)	1.985	540.00
	INVOICE SUBTOTAL		2,639.00
	INVOICE TOTAL		2,639.00

CODING	ENTERED	APPROVAL ACCT.	APPROVAL MNGR	APPROVAL OFFICE
DD			KB	

VENDOR #	INVOICE #	INV. DATE
66617	43259	0529

AMOUNT	DISC.	DUE DATE
2,639.00		0628

DESCRIPTION	BKG. DATE
Nelson Reclamation w/ DNR	0696

LOC.	GL #	AMOUNT	EQUIP. # / NOTE

ER COPY

SEED MIXES FOR CAMAS/SHIELY

NATIVE GRASS/FORB PRAIRIE MIX #1

SPECIES	%OF TOTAL	TOTAL LBS. PLS
BIG BLUESTEM	6	12
LITTLE BLUESTEM	12	24
SAND DROPSEED	2	5
SIDEOATS GRAMA	7	14
INDIANGRASS	4	7
OATS	41	79
ANNUAL RYEGRASS	14	26
SWITCHGRASS	4	7
SLENDER WHEATGRASS	2	5
CANADIAN WILDRYE	2	7
SE REGIONAL FORBS MIX	4	7
	100	194

NATIVE GRASS FORB PRAIRIE MIX #2

SPECIES	%OF TOTAL	TOTAL LBS. PLS
BIG BLUESTEM	5	3
LITTLE BLUESTEM	10	6
SAND DROPSEED	2	1
SIDEOATS GRAMA	6	4
INDIANGRASS	3	4
OATS	52	31
ANNUAL RYEGRASS	11	7
SWITCHGRASS	3	2
SLENDER WHEATGRASS	2	1
CANADIAN WILDRYE	3	2
SE REGIONAL FORBS MIX	3	2
	100	60

TURF/NATIVE GRASS MIX #1

SPECIES	%OF TOTAL	TOTAL LBS. PLS
CANADA BLUEGRASS	18	40
LITTLE BLUESTEM	6	12
SMOOTH BROME	18	40
PURPLE PRAIRIE CLOVER	1	2
PERENNIAL RYEGRASS	11	24
OATS	18	40
ANNUAL RYEGRASS	6	12
SWITCHGRASS	7	16
TIMOTHY	6	14
SLENDER WHEATGRASS	7	16
	100	216

MN DOT FORBS MIX LIST

SE FORB MIX ★

Heath Aster
New England Aster
Sky-blue Aster
Wild Bergamot
Black-eyed Susan
Meadow Blazingstar
Rough Blazingstar
Tall Blazingstar
Round Headed Bushclover
Grey-headed Coneflower
Canada Milkvetch
Butterfly Milkweed
Prairie Onion
Common Ox-eye
Partridge Pea
Purple Prairieclover
White Prairieclover
Showy Penstemon
Stiff Tic-seed
Blue Vervain

SW FORB MIX

Heath Aster
Sky-blue Aster
Wild Bergamot
Black-eyed Susan
Dotted Blazingstar
Rough Blazingstar
Tall Blazingstar
Columnar Coneflower
Grey-headed Coneflower
Purple Coneflower
Canada Milkvetch
Butterfly Milkweed
Prairie Onion
Common Ox-eye
Partridge Pea
Purple Prairieclover
White Prairieclover
Showy Penstemon
Stiff Tic-seed
Blue Vervain

NW FORBS MIX

Heath Aster
New England Aster
Sky-blue Aster
Upland-White Aster
Wild Bergamot
Black-eyed Susan
Dotted Blazingstar
Rough Blazingstar
Tall Blazingstar
Columnar Coneflower
Purple Coneflower
Stiff Goldenrod
Canada Milkvetch
Marsh Milkweed
Prairie Onion
Common Ox-eye
Purple Prairieclover
White Prairieclover
Showy Penstemon
Blue Vervain

NE FORB MIX

Heath Aster
Sky-blue Aster
Upland-white Aster
Wild Bergamot
Black-eyed Susan
Gray Goldenrod
Stiff Goldenrod
Giant Hyssop
Canada Milkvetch
Common Ox-eye
Blue Vervain
Hoary Vervain

WET FORB MIX

Canada Anemone
New England Aster
Wild Bergamot
Black-eyed Susan
Meadow Blazingstar
Tall Blazingstar
Boneset
Culver's Root
Blue Genetian
Bottle Gentian

(Wet Forb Mix cont'd)

Blue-flag Iris
Ironweed
Joe-pye Weed
Great-blue Lobelia
Meadowrue
Marsh Milkweed
Common Ox-eye
Purple Prairieclover
Serrated Sunflower
Showy Tick-trefoil
Blue Vervain
(contractor supplies 16 of above)

SUBSTITUTIONS

NE SUBSTITUTES

Smooth Blue-Aster
Fireweed
Missouri Goldenrod
Wild Lupine
Marsh Milkweed
Showy Penstemon

SE SUBSTITUTES ★

Smooth-blue Aster
Upland-white Aster
Showy Goldenrod
Stiff Goldenrod
Ohio Spiderwort
Hoary Vervain
Showy Tick-trefoil

SW SUBSTITUTES

Silky Aster
Smooth-blue Aster
Upland-white Aster
Round-headed Bushclover
Showy Goldenrod
Stiff Goldenrod
Hoary Vervain

NW SUBSTITUTES

Silky Aster
Smooth-Blue Aster
Round-headed Bushclover
Showy Goldenrod
Hoary Vervain
Showy Tick-trefoil

Appendix 5

Shipping Details (Including Weight Tickets)

Appendix 5

Shipping Details (Including Weight Tickets)

The MSW compost and the NVS were hauled to the site in semitrailers which had a load capacity of approximately 20 tons each (which includes tare weight). It should be noted that the hauling date was dependent upon the lifting of road restrictions. The road restrictions, which are imposed by individual counties and therefore differ between counties, are intended to avoid subjecting the roads to large stresses when ice may still be present in fissures in the roadbed. Such stresses could lead to severe deterioration if heavy trucks travelled across them. Because the date that road restrictions are lifted often isn't established until virtually the day that it occurs, timetables for hauling must remain flexible, particularly since different counties lift the restrictions on different days. (Thus, if it is necessary to haul the amendment through several counties, it can't occur until the latest restriction is lifted.)

The first load of MSW compost and NVS were delivered to the top of the demonstration slope on the morning of Monday, May 6, which was the first day that all pertinent road restrictions were lifted. The load of MSW was deposited at the top of the MSW plot, but the NVS load was also mistakenly placed at the top of the MSW plot. (It was later brought over to the top of the NVS plot with a front-end loader.) On the morning of May 8, the remainder of the MSW compost and NVS was hauled to the site and deposited at the tops of the respective plots.

9 loads of MSW compost were required to bring the required amount to the site (including the original load that was delivered on May 6). Eight of the nine loads had a net weight (i.e. total weight of the loaded truck minus the tare weight) of approximately 30,000 lbs, or approximately 15 tons. The other load (the last one) had only about 5 tons of compost. XXX loads of NVS were hauled (which also includes the load of May 6); the NVS was denser and was also applied in a thinner layer, so fewer loads were needed. Shipping was done by Miller Trucking, and the weight tickets for the two amendments are attached.

THIS SHIPPING ORDER must be legibly filled in, in Ink, in Indelible Pencil, or in Carbon, and retained by the Agent.

DESIGNATE WITH AN (X)
BY TRUCK ☐ **FREIGHT** ☐

RECEIVED, subject to the classification and lawfully filed tariffs in effect on the date of issue of this Shipping Order.

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned and destined as indicated below, which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Uniform Freight Classification in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment.
Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

From P.S.G. WRIGHT COUNTY COMPOST
At 505 N.E. County Road 37
Buffalo, MN 55313

DATE 5-6 1996
SHIPPER'S NO. 3031

CARRIER
CARRIER'S NO.
BY

CONSIGNEE AND DESTINATION
Shiely's Nelson Plant
St. Paul.

ROUTE
DELIVERING CARRIER Miller Trucking
CAR OR VEHICLE INITIALS & NO.

NO PACKAGES	HM	DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS	ERG #	WEIGHT (SUBJECT TO CORR.)	CLASS OR RATE	✓
		Class II compost		61,300		
				30,140		
				31,160		

Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement.
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.
Per
(Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."

Received $
to apply in prepayment of the charges on the property described hereon.

Agent or Cashier.
Per
(The signature here acknowledges only the amount prepaid).

Charges Advanced:
$

PLACARDS SUPPLIED YES NO
DRIVER'S SIGNATURE
EMERGENCY RESPONSE PHONE NO

SHIPPERS CERTIFICATION: This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.
SIGNATURE Greg Duske TITLE

* If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."
† **Shipper's imprints in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.**
Note — Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding

C.O.D. SHIPMENT
C.O.D. Amt
Collection Fee
Total Charges

THIS SHIPMENT IS CORRECTLY DESCRIBED.
CORRECT WEIGHT IS ______ LBS.

† The fibre boxes used for this shipment conform to the specifications set forth in the box makers certificate thereon, and all other requirements of the Consolidated Freight Classification.

Shipper
Per

P.S.G. WRIGHT COUNTY COMPOST
(320) 963-5797

Shipper, Per [signature]

Agent must detach and retain this Shipping Order and must sign the Original Bill of Lading.

Permanent post-office address of shipper

2

FORM 72003 REORDER FROM RAPIDFORMS, INC., THOROFARE, NJ 08086-9499

ORDER must be legibly filled in, in Ink, in Indelible Pencil, or in Carbon, and retained by the Agent.

DESIGNATE WITH AN (X)

BY TRUCK ☐ FREIGHT ☐

..., subject to the classification and lawfully filed tariffs in effect on the date of issue of this Shipping Order.

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned and destined as indicated below, which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Uniform Freight Classification in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment.
Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

From At: P.S.G. WRIGHT COUNTY COMPOST
505 N.E. County Road 37
Buffalo, MN 55313

DATE: 5-6 1996

SHIPPER'S NO.: 3032

CARRIER

CARRIER'S NO.:

BY:

CONSIGNEE AND DESTINATION: Shiely's Nelson Plant
St. Paul

ROUTE:

DELIVERING CARRIER: Miller Trucking

CAR OR VEHICLE INITIALS & NO.:

NO. PACKAGES	HM	DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS	ERG #	*WEIGHT (SUBJECT TO CORR.)	CLASS OR RATE	✔
		Class II Compost		60,680		
				30,040		
				30,640		

Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement.
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

Per

(Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."

Received $ ________ to apply in prepayment of the charges on the property described hereon.

Agent or Cashier.

Per

(The signature here acknowledges only the amount prepaid).

Charges Advanced:

$

PLACARDS SUPPLIED YES NO

DRIVER'S SIGNATURE

EMERGENCY RESPONSE PHONE NO

SHIPPERS CERTIFICATION: This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.

SIGNATURE Randy Wegler TITLE ________

* If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."
† **Shipper's imprints in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.**
Note — Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding ________

C.O.D. SHIPMENT

C.O.D. Amt ________

Collection Fee ________

Total Charges ________

THIS SHIPMENT IS CORRECTLY DESCRIBED.

CORRECT WEIGHT IS ________ LBS.

† The fibre boxes used for this shipment conform to the specifications set forth in the box makers certificate thereon, and all other requirements of the Consolidated Freight Classification.

Shipper

Per

P.S.G. WRIGHT COUNTY COMPOST
(320) 963-5797

Shipper, Per [signature]

Agent must detach and retain this Shipping Order and must sign the Original Bill of Lading.

Permanent post-office address of shipper

FORM 72003 REORDER FROM RAPIDFORMS, INC., THOROFARE, NJ 08086-9499

2

Carbon, and retained by the agent.

RECEIVED, subject t... classification and lawfully filed tariffs in effect on the date of issue of this Shipping Order.

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned and destined as i... below, which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Uniform Freight Classification in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment.
Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

From P.S.G. WRIGHT COUNTY COMPOST
505 N.E. County Road 37
At Buffalo, MN 55313

DATE 5/8 1996 — SHIPPER'S NO. 3033

CARRIER — CARRIER'S NO. 129791

BY Miller

CONSIGNEE AND DESTINATION: Shiely DNR Project

ROUTE — DELIVERING CARRIER Gres / 84

CAR OR VEHICLE INITIALS & NO.

NO. PACKAGES	*HM	DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS	ERG #	*WEIGHT (SUBJECT TO CORR.)	CLASS OR RATE	✓
		32 cu yds		Gross 63280		
		Class II compost		Tare 30500		
				Net 32780		

Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement.
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.
Per ______
(Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."

Received $ ______
to apply in prepayment of the charges on the property described hereon.

Agent or Cashier.

Per ______
(The signature here acknowledges only the amount prepaid).

Charges Advanced:
$ ______

PLACARDS SUPPLIED YES NO — DRIVER'S SIGNATURE — EMERGENCY RESPONSE PHONE NO

SHIPPERS CERTIFICATION: This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.

SIGNATURE [signature] TITLE Facility [illegible]

* If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."
† Shipper's imprints in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.
Note — Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding ______

C.O.D. SHIPMENT
C.O.D. Amt ______
Collection Fee ______
Total Charges ______

THIS SHIPMENT IS CORRECTLY DESCRIBED.
CORRECT WEIGHT IS ______ LBS.

† The fibre boxes used for this shipment conform to the specifications set forth in the box makers certificate thereon, and all other requirements of the Consolidated Freight Classification.

Shipper
Per ______

P.S.G. WRIGHT COUNTY COMPOST
(320) 963-5797

Shipper, Per Greg Durle

Agent must detach and retain this Shipping Order and must sign the Original Bill of Lading.

Permanent post-office address of shipper

FORM 72003 REORDER FROM RAPIDFORMS, INC., THOROFARE, NJ 08086-9499

2

THIS SHIPPING ORDER must be legibly filled in, in Ink, in Indelible Pencil, or in Carbon, and retained by the Agent.

DESIGNATE WITH AN (X)
BY TRUCK ☐ **FREIGHT** ☐

RECEIVED, subject to the classification and lawfully filed tariffs in effect on the date of issue of this Shipping Order.

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned and destined as indicated below, which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Uniform Freight Classification in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment.
Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

From / At: P.S.G. WRIGHT COUNTY COMPOST
505 N.E. County Road 37
Buffalo, MN 55313

DATE: 5/8 1996

SHIPPER'S NO. 3034

CARRIER

CARRIER'S NO. 125793

BY: Miller

CONSIGNEE AND DESTINATION: Shiely DNR Project

ROUTE

DELIVERING CARRIER: John / 747

CAR OR VEHICLE INITIALS & NO.

NO. PACKAGES	† HM	DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS	ERG #	*WEIGHT (SUBJECT TO CORR.)	CLASS OR RATE	✓
		28 cuyds		Gross 57920		
		Class II compost		Tare 29000		
				Net 28920		

Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement.
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.
Per ______________
(Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."

Received $ ______________
to apply in prepayment of the charges on the property described hereon.

Agent or Cashier.

Per ______________
(The signature here acknowledges only the amount prepaid).

Charges Advanced:

PLACARDS SUPPLIED YES NO

DRIVER'S SIGNATURE: John Bial

EMERGENCY RESPONSE PHONE NO

SHIPPERS CERTIFICATION: This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.

SIGNATURE: [illegible signature] TITLE: Facility Mgr

* If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."
† Shipper's imprints in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.
Note — Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding ______________

C.O.D. SHIPMENT
C.O.D. Amt ______________
Collection Fee ______________
Total Charges ______________

THIS SHIPMENT IS CORRECTLY DESCRIBED.
CORRECT WEIGHT IS ______________ LBS.

† The fibre boxes used for this shipment conform to the specifications set forth in the box makers certificate thereon, and all other requirements of the Consolidated Freight Classification.

Shipper
Per ______________

P.S.G. WRIGHT COUNTY COMPOST
(320) 963-5797

Shipper, Per ______________

Agent must detach and retain this Shipping Order and must sign the Original Bill of Lading.

Permanent post-office address of shipper

FORM 72003 REORDER FROM RAPIDFORMS, INC., THOROFARE, NJ 08086-9499

2

THIS SHIPPING ORDER must be legibly filled in, in Ink, in Indelible Pencil, or in Carbon, and retained by the Agent.

DESIGNATE WITH AN (X)
BY TRUCK ☐ **FREIGHT** ☐

RECEIVED, subject to the classification and lawfully filed tariffs in effect on the date of issue of this Shipping Order.

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned and destined as indicated below, which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Uniform Freight Classification in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment.
Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

From At: P.S.G. WRIGHT COUNTY COMPOST
505 N.E. County Road 37
Buffalo, MN 55313

DATE: 5/8 1996
SHIPPER'S NO.: 3035
CARRIER
CARRIER'S NO.:
BY: Miller

CONSIGNEE AND DESTINATION: Shiely DNR Project

ROUTE:
DELIVERING CARRIER: Randy/11
CAR OR VEHICLE INITIALS & NO.:

NO. PACKAGES	* HM	DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS	ERG #	*WEIGHT (SUBJECT TO CORR.)	CLASS OR RATE	✔
		Class II Compost		66180		
				31400		
				34,780		

Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement.
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.
Per ____________
(Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."

Received $ ____________
to apply in prepayment of the charges on the property described hereon.

Agent or Cashier.

Per ____________
(The signature here acknowledges only the amount prepaid).

Charges Advanced:
$ ____________

PLACARDS SUPPLIED YES NO

DRIVER'S SIGNATURE

EMERGENCY RESPONSE PHONE NO

SHIPPERS CERTIFICATION: This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.

SIGNATURE ____________ TITLE ____________

* If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."
† **Shipper's imprints in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.**
Note — Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding ____________

C.O.D. SHIPMENT
C.O.D. Amt ____________
Collection Fee ____________
Total Charges ____________

THIS SHIPMENT IS CORRECTLY DESCRIBED.
CORRECT WEIGHT IS ____________ LBS.

† The fibre boxes used for this shipment conform to the specifications set forth in the box makers certificate thereon, and all other requirements of the Consolidated Freight Classification.

Shipper
Per ____________

P.S.G. WRIGHT COUNTY COMPOST
(320) 963-5797

Shipper, Per ____________

Agent must detach and retain this Shipping Order and must sign the Original Bill of Lading.

Permanent post-office address of shipper

FORM 72003 REORDER FROM RAPIDFORMS, INC., THOROFARE, NJ 08086-9499

2

...INC., 301 GROVE ROAD, THOROFARE, ... 9499 CALL TOLL FREE ...

STRA... BILL OF LADING—SHORT FORM—ORIGINAL—NOT NEGOTIABLE

DESIGNATE WITH AN X: BY TRUCK [X] FREIGHT [ ]

RECEIVED, subject to the classifications and lawfully filed tariffs in effect on the date of issue of this Bill of Lading. the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned and destined as indicated below, which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Uniform Freight Classification in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment. **Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.**

From At: **P.S.G. WRIGHT COUNTY COMPOST**
505 N.E. County Road 37
Buffalo, MN 55313

DATE: 5/9 1996

SHIPPER'S NO.: 3036

CARRIER

CARRIER'S NO.:

BY: PSG/Wright County Cmpst

CONSIGNEE AND DESTINATION: Shiely-Nelson

ROUTE:

DELIVERING CARRIER: OK

CAR OR VEHICLE INITIALS & NO.:

NO. PACKAGES	† HM	DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS	ERG #	*WEIGHT (SUBJECT TO CORR.)	CLASS OR RATE	✓
		Class II Compost		39520		
				29400		
		came in compost spreader		10,120		

Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement: The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

Per ___ (Signature of Consignor)

If charges are to be prepaid, write or stamp here "To be Prepaid."

Received $ ___ to apply in prepayment of the charges on the property described hereon.

Agent or Cashier

Per ___ (The signature here acknowledges only the amount prepaid.)

Charges Advanced: $

PLACARDS SUPPLIED ☐ YES ☐ NO

DRIVER'S SIGNATURE

EMERGENCY RESPONSE PHONE NO.

SHIPPERS CERTIFICATION: This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.

SIGNATURE [signature] TITLE

* If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."
† Shipper's imprints in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.
Note — Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding ___

C.O.D. SHIPMENT
C.O.D. Amt.
Collection Fee
Total Charges

THIS SHIPMENT IS CORRECTLY DESCRIBED.
CORRECT WEIGHT IS ___ LBS.

† The fibre boxes used for this shipment conform to the specifications set forth in the box makers certificate thereon, and all other requirements of the Consolidated Freight Classification.

Per ___ Shipper

P.S.G. WRIGHT COUNTY COMPOST
(320) 963-5797

Shipper, Per ___ **Agent, Per** ___

Permanent post-office address of shipper

1

...ADING—SHORT FORM—ORIGINAL—NOT NEGOTIABLE

DESIGNATE WITH AN (X)
BY TRUCK ☐ **FREIGHT** ☐

...cations and lawfully filed tariffs in effect on the date of issue of this Bill of Lading.

...arent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned and destined as indicated below, which said carrier (the word carrier being understood throughout this contract ...tion in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as ...d property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of ...Bill of Lading set forth (1) in Uniform Freight Classification in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment. **...at he is familiar with all the terms and conditions of the said bill of lading, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed ...cepted for himself and his assigns.**

P.S.G. WRIGHT COUNTY COMPOST
505 N.E. County Road 37
Buffalo, MN 55313

DATE 5/9 1996

SHIPPER'S NO. 3037

CARRIER

CARRIER'S NO.

CONSIGNEE AND DESTINATION: Shelly-Nelson Plant

BY: Miller

ROUTE

DELIVERING CARRIER: Dave / 12

CAR OR VEHICLE INITIALS & NO. 7:15 am

NO. PACKAGES	HM	DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS	ERG #	*WEIGHT (SUBJECT TO CORR.)	CLASS OR RATE	✓
		Class II Compost		63540		
				32340		
				31,200		

Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement.
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

Per ______
(Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."

Received $ ______
to apply in prepayment of the charges on the property described hereon.

Agent or Cashier.

Per ______

(The signature here acknowledges only the amount prepaid).

Charges Advanced:

$ ______

PLACARDS SUPPLIED YES NO

...SIGNATURE Dave Thompson

EMERGENCY RESPONSE PHONE NO.

SHIPPERS CERTIFICATION: This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.

SIGNATURE ______ TITLE ______

* If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."
† Shipper's imprints in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.
Note — Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding ______

C.O.D. SHIPMENT
C.O.D. Amt ______
Collection Fee ______
Total Charges ______

THIS SHIPMENT IS CORRECTLY DESCRIBED.
CORRECT WEIGHT IS ______ LBS

† The fibre boxes used for this shipment conform to the specifications set forth in the box makers certificate thereon, and all other requirements of the Consolidated Freight Classification.

Shipper
Per ______

P.S.G. WRIGHT COUNTY COMPOST
(320) 963-5797

Shipper, Per ______ ______ **Agent, Per** ______

Permanent post-office address of shipper

FORM 72003 REORDER FROM RAPIDFORMS, INC., THOROFARE, NJ 08086-9499

1

SHORT FORM—ORIGINAL—NOT NEGOTIABLE

DESIGNATE WITH AN (X)

BY TRUCK ☐ **FREIGHT** ☐

and lawfully filed tariffs in effect on the date of issue of this Bill of Lading.

...ood order, except as noted (contents and condition of contents of packages unknown), marked, consigned and destined as indicated below, which said carrier (the word carrier being understood throughout this contract ...in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as ...property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of ...Bill of Lading set forth (1) in Uniform Freight Classification in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment. **...that he is familiar with all the terms and conditions of the said bill of lading, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed ...d accepted for himself and his assigns.**

At

P.S.G. WRIGHT COUNTY COMPOST
505 N.E. County Road 37
Buffalo, MN 55313

DATE 5/9 1996

SHIPPER'S NO. 3038

CARRIER

CARRIER'S NO.

BY Miller

CONSIGNEE AND DESTINATION: Shieley - Nelson Plant

ROUTE

DELIVERING CARRIER John/747

CAR OR VEHICLE INITIALS & NO.

NO. PACKAGES	HM	DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS	ERG #	*WEIGHT (SUBJECT TO CORR.)	CLASS OR RATE	✓
		Class II Compost		58340		
				28980		
				29,360		

Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement.
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

Per

(Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."

Received $ ______
to apply in prepayment of the charges on the property described hereon.

Agent or Cashier.

Per

(The signature here acknowledges only the amount prepaid).

Charges Advanced:

$

PLACARDS SUPPLIED YES NO

DRIVER'S SIGNATURE John Beisel

EMERGENCY RESPONSE PHONE NO

SHIPPERS CERTIFICATION: This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.

SIGNATURE [illegible] TITLE

* If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."
† **Shipper's imprints in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.**
Note — Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding ______

C.O.D. SHIPMENT
C.O.D. Amt ______
Collection Fee ______
Total Charges ______

THIS SHIPMENT IS CORRECTLY DESCRIBED.
CORRECT WEIGHT IS ______ LBS.

† The fibre boxes used for this shipment conform to the specifications set forth in the box makers certificate thereon, and all other requirements of the Consolidated Freight Classification.

Shipper

Per

P.S.G. WRIGHT COUNTY COMPOST
(320) 963-5797

Shipper, Per ______ ______ **Agent, Per** ______

Permanent post-office address of shipper

FORM 72003 REORDER FROM RAPIDFORMS, INC., THOROFARE, NJ 08086-9499

1

—SHORT FORM—ORIGINAL—NOT NEGOTIABLE

DESIGNATE WITH AN (X)
BY TRUCK ☐ **FREIGHT** ☐

...s and lawfully filed tariffs in effect on the date of issue of this Bill of Lading.

...nt good order, except as noted (contents and condition of contents of packages unknown), marked, consigned and destined as indicated below, which said carrier (the word carrier being understood throughout this contract ...tion in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as ...said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of ...straight Bill of Lading set forth (1) in Uniform Freight Classification in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment. **...ertifies that he is familiar with all the terms and conditions of the said bill of lading, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed ...pper and accepted for himself and his assigns.**

From At: **P.S.G. WRIGHT COUNTY COMPOST**
505 N.E. County Road 37
Buffalo, MN 55313

DATE: 5/9 1996

SHIPPER'S NO. 3040

CARRIER'S NO.

CARRIER

BY: Miller

CONSIGNEE AND DESTINATION: Shirley Nelson Plant

ROUTE

DELIVERING CARRIER: Greg / 84

CAR OR VEHICLE INITIALS & NO.

NO. PACKAGES	HM	DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS	ERG #	*WEIGHT (SUBJECT TO CORR.)	CLASS OR RATE	✓
		Class II Compost		62740		
				30500		
				32240		

Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement.
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

Per ____________________
(Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."

Received $ ____________________
to apply in prepayment of the charges on the property described hereon.

Agent or Cashier.

Per ____________________
(The signature here acknowledges only the amount prepaid).

Charges Advanced:
$ ____________________

PLACARDS SUPPLIED YES NO

DRIVER'S SIGNATURE: Greg Durke

EMERGENCY RESPONSE PHONE NO.

SHIPPERS CERTIFICATION: This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.

SIGNATURE ____________________ TITLE ____________________

* If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."
† **Shipper's imprints in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.**
Note — Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding ____________________

C.O.D. SHIPMENT
C.O.D. Amt ____________________
Collection Fee ____________________
Total Charges ____________________

THIS SHIPMENT IS CORRECTLY DESCRIBED.

CORRECT WEIGHT IS ____________________ LBS.

† The fibre boxes used for this shipment conform to the specifications set forth in the box makers certificate thereon, and all other requirements of the Consolidated Freight Classification.

Shipper

Per ____________________

P.S.G. WRIGHT COUNTY COMPOST
(320) 963-5797

Shipper, Per ____________________ ____________________ **Agent, Per** ____________________

Permanent post-office address of shipper

FORM 72003 REORDER FROM RAPIDFORMS, INC., THOROFARE, NJ 08086-9499

1

Shiely Project | MSW Wgt Tix | 8/15/96

Date	Shipping #	Net wgt compost (lbs)	Dry wgt (lbs)
5/6/96	3031	31,160	
5/6/96	3032	30,640	
5/8/96	3033	32,780	
5/8/96	3034	28,920	
5/8/96	3035	34,780	
5/9/96	3037	31,200	
5/9/96	3038	29,360	
5/9/96	3040	32,240	
5/9/96	3036	10,120	

wgt ~ 1000 lbs/yd

} these 2 were stockpiled separately on ~~east~~ end of road

} this came in compost spreader

some residue msw not applied, some went to lysimeter & waste sand
1 loader bucket (~3 yds) to each area, so ~6 yds removed

Total msw to ~~dance~~ area 199,300

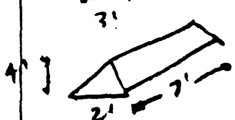
– removed to lysimeter, waste sand ~ 6,000

– residual

Total 199,300
to plots –6,000
residual –6,000

Net wgt compost spread = 187,3[illegible] lbs

Volume = ½ bhl = 10.5 ft³



½ bhl = 7 ft³

⅓ A_b h = 8 ft³

total residual ~ 6 yds = 6000 lbs

8/5/96

msw compost 31% moisture

$$\text{dry wgt} = \frac{.69 \times 187{,}300}{2000 \text{ lbs/ton}} \sim 65 \text{ tons}$$

$$\text{area of spread} \quad \frac{\left(\frac{154\,m + 146.5\,m}{2}\right) \times \left(\frac{78\,m + 73.5\,m}{2}\right) \times \left(3.28\ \text{ft}/m\right)^2}{43{,}560\ \text{ft}^2/\text{acre}} = 2.8\ \text{acre}$$

$$\text{application rate} \quad \sim \frac{65 \text{ tons dry}}{2.8 \text{ acre}} = 23 \text{ tons/acre}$$

Appendix 6

Notes From Site Visits

Appendix 6

Notes from site visits

May 20 site visit by Wagner

I drove out to the site on Monday 5/20/96 to check on damage from a major storm that went through the area in the early morning hours of Sunday 5/19/96. This storm destroyed dozens of garages in the area and damaged hundreds of houses, and according to an article in the 5/20/96 Star Tribune, had sustained straight-line winds of over 70 mph, with gusts that were clocked as high as 99 mph. However, the extreme speed of the storm as it swept through the area actually helped prevent a major rainfall event; the storm clouds simply didn't have enough time to drop a large amount of rain before they left the area. The Mpls/St. Paul airport rain meter received less than 0.5" of precipitation.

I saw many downed trees along the stretch of Grey Cloud Island Road just north of South Grey Cloud Island, including some very large pine trees (see slides). At the gravel pit itself, I saw no sign of major tree damage. Mark Duncan, the plant manager, joked that he heard one of the meteorologists on TV say that we usually don't get storms like this till late in the summer, but that he could have told them weeks ago that such an event would occur right after the slope was planted; Murphy's Law in action!

Demonstration plots

Mulch Some of the demonstration plots had sizeable bare spots where there was no mulch, but the initial mulching procedure was far from perfect, and it was unclear if these bare spots were due to the storm or to the initial placement problems. My feeling was that the winds may have blown away some of the mulch, but the procedure used to crimp in the mulch was sufficient to prevent most of it from being blown off the slope.

Geese Despite the chicken-wire fence that had been placed along the bottom and the sides of the demo plots, numerous geese were present on the demo plots when I arrived about 10:30 am. I counted 19 geese, with ten of these geese being pairs of birds that had chicks in tow. I spoke to Mark Duncan later, and he said that he was at the site on Sunday (5/19), and counted 20 geese, which were grazing near the MSW plot. (Some heavy equipment was operating near the far end of the pit on Monday, which probably scared the geese toward the NVS plot.) Hopefully this means that there is just a resident population of geese that are feeding on the seeds, and that they are not attracting additional geese from outside the pit.

Dennis said that he saw one of the geese families leave the NVS plot (after he and I met on the site this afternoon), and that they exited the plot by walking up the entire slope, and walking around the top of the fence. Smart critters! Placing a fence along the top of the plots may stop these families from entering the plots en masse, but since about half of the geese that both Mark and I observed were "single" (i.e. without apparent mates or chicks), such a fence would probably be relatively useless, since these "single" geese could simply fly over the fence. I will check with Dennis tomorrow to see if he planted the excess seed along the bottom row as a "sacrificial" seed belt, in hopes that the geese would eat these instead of the seeds up on the plots.

Vegetation Plant growth was commencing on all of the plots, though the plants were still very small. It appeared to me that the MnDOT mix was doing better than the prairie mix, with noticeable clumps of new grasses being noticeable in the MnDOT portion of the plots. Even the prairie portions were doing ok, however, with plant growth, although sparse, occurring throughout. The main species in the prairie portions was a small (<1/4") clover-like plant; could this be the flax cover? (Need to check with Steve Dewar.)

Erosion Much to my relief, I saw no evidence of large-scale erosion in the demo plots as a result of the storm, even on the areas where the heavy equipment used in mulching went up and down the slope. The two berms placed lengthwise on the slopes also seemed to be holding up well.

Potential for vandalism As I was walking back to my van after inspecting the demo plots, a white four-by-four (with dual wheels on the back) drove up to me on the top road. I thought it was [Plant Manager] Mark Duncan so I walked up to greet him, but instead it was one of the locals wondering whether it would be ok to do some four-wheeling on our demo slope! I told him that 1) he was on private property, 2) that he definitely would not be welcome on our slope, and that 3) I felt that Mark Duncan would likely not want him anywhere on the property, if for no other reason than insurance concerns. I told him to go talk to Mark, and I was careful not to just order him off the property, because I felt that this would unnecessarily anger him, and that he may then come back later and trash the slope just to spite me. It is clear that even one truck could destroy the work we've done on the demo slope in just a matter of minutes, and I didn't want to antagonize this guy any more than necessary.

I spoke to Mark a bit later, and, not surprisingly, the guy never came over to talk with Mark. Mark says that they get all kinds of trespassers on the property, including four-wheelers, trail bikes and ATV's, drunks who either get mistakenly lost on the property or who are looking for a thrill ride, and a whole variety of similarly confused and misguided individuals. He said that the four-wheelers will drive right over the perimeter fence at night, so that merely locking the pit entrance gate at night is by no means a guarantee against such vandalism. (They often drive over the fence near the top of the MSW plot.) About all we can do is hope that the vegetation gets established on the slope before the four-wheelers decide to trash it.

Lysimeter plots and Washed-Sand plots

Both the lysimeter plots and the plots on the washed-sand pile emerged relatively unscathed from the storm. At the lysimeter plots, some of the lathe stakes at the corners of the 10 plots were snapped off near the ground, but the stubs of the stakes remain in the ground, so restaking will be easy. All of the mulch netting was left intact, and I saw signs of vegetative growth in all 10 of the plots.

The rain gauge was hardest hit, as it was toppled over by the wind, with pieces spread out in the brome field surrounding the plots. The pail was found near the row of pine trees that are east of the plots, and the top cone-section was found about 100 feet north of the plots. The only part I couldn't find was the board that the gauge was sitting on, but this wasn't a major loss. I took the gauge back to the office to repair it, meaning that there will be no rain gauge data for 5/19 or 5/20; I hope to have it back operating by around 1:00 pm 5/21, and will contact Greg Spoden at the State Climatologist's office to get data for 5/19 and 5/20. (I'm almost sure that there was no rain on 5/20, but I will confirm this with Greg.) I will try to anchor the gauge down better to prevent it from toppling again, maybe by placing lathe stakes around it and connecting them with wire.

At the plots on the washed-sand pile I saw no major damage; all of the stakes and all of the mulch netting remain intact. The only apparent effect of the storm was that the stack of hay bales (to be used for mulch) was toppled, with bales scattered about the area (though not on top of any of the plots). I saw vegetative growth on the two topsoil plots at the south end of the plots, but didn't check the other plots.

July 5 site visit by Wagner and Eger

Paul Eger and I (Jon Wagner) inspected the demonstration slope on Friday, July 5; we were unable to inspect the lysimeter and washed sand plots because the front gate was locked for the holiday weekend. Paul used the camcorder to record details of our observations; this memo is intended to capture the main points of our visit.

I was struck by how much greener the demo slope was than the last time I visited (June 25), but closer inspection revealed the biggest change was a huge increase in unplanted species (i.e. invasive weeds). Ragweed and lambs quarters are seemingly everywhere, with some of these plants being over a foot tall. What was particularly striking was that I recall seeing little or no evidence of these species on June 25; all of the growth of these plants apparently occurred in the last ten days! In general, the control plot and the topsoil+fertilizer plot had fewer of these weeds growing. In fact, though the lathe stakes have largely been destroyed or removed since plot construction, the sides of the MSW plot and the east edge of the NVS plot were apparent just by the presence of the weeds (primarily lambs quarters). There seemed to be a distinct line separating these plots, with the MSW and NVS plots having much lusher, fuller growth of these weeds. My guess is that the weeds find something in the soil in the MSW and NVS plots more inviting than the soil in the other two plots.

In general, it looks like the resident geese population has succeeded in pretty well devastating the cover crop on the bottom 1/3rd of the entire slope (which is part of the native species seed belt). Virtually the only plants visible on this bottom strip were the weeds (mostly Lambs Quarters), and the few cover plants that did remain were clearly cropped off near the soil line. The middle strip (also the native seed mix) contains relatively more plants of the cover crop (oats, rye?), though the weeds were still very widespread and prevalent. The top strip (the MNDOT strip) generally had the fewest ragweed and lambs quarters plants, and the cover plants (oats; different than what was used in the native seed mix) were generally sparse, but not as sparse as on the bottom strip.

Paul and I agreed that it seemed that this difference in cover crop survival was due in large part to the proximity to the surge pond (and, thus, the geese). The geese simply grazed first on the lower third because it was more accessible, and only moved up higher on the slope as the cover crop became depleted on the lower slope. (It was clear, however, that they would also go high up the slope when it was worth their while; on the NVS plot, where on Monday, July 1, Paul had observed seeds forming on the oat cover crop, the seeds were now gone, presumably having been stripped clean by the geese in the last four days!) It is looking like two of the steps that seemed at first blush to be relatively incidental to the success of the revegetation effort (mulching and geese control) are instead of critical importance.

Other miscellaneous notes:

1. On areas where the NVS soil was thicker than the intended application rate (for example, at the staging area at the top of the plot), there is virtually no vegetation growth. Presumably this is because of the high pH associated with this material, though the possibility of nutrient-burn shouldn't be overlooked).

2. On the NVS plot, especially near the bottom, a plant called Carpet Weed was widespread. Though observed also on the other plots, it was much more prevalent on the NVS plot.

3. In the MNDOT strip we saw evidence of some of the grass species that had been planted, but these plants were sparse and stunted, no doubt due to the very dry conditions that have prevailed at the site so far this year.

4. The small erosion gullys noted previously in the topsoil+fertilizer plot had not grown appreciably, though this is not surprising since we have had little rain since they were first noted. However, the plant growth above these gullys has increased markedly lately (mostly Lambs Quarters), so that the gullys may not expand much next time we get a big rain.

5. At least from an aesthetic point of view the weed species are less desirable than the planted species, but from a slope-stabilization point of view they aren't looking so bad, particularly considering the alternative; vegetative growth insufficient to prevent the massive erosion gullys from forming again. It will be interesting to see if the native species will be able to become established given that they must now compete with the (unplanned) weed population, which will obviously claim a large portion of the available nutrients, and which will possibly shade out the emerging native plants.

6. On the topsoil+fertilizer plot, there are sizable areas that are covered almost entirely with dense stands of a sedge-like plant that has tentatively been identified as yellow nutgrass. This plant is much more pleasing aesthetically than the otherwise omnipresent lambs quarters, and it would be interesting to know why this plant seems to be doing better on this plot than on the neighboring MSW and NVS plots. Possibly lambs quarter and ragweed desire some nutrient(s) that is plentiful in the organic amendment plots, but which is deficient in the topsoil+fertilizer plot, and this allows the Nutgrass an

opportunity to invade without competition from those otherwise hyper-invasive weed species.

7. The cover crops seem particularly needy of moisture, and it remains possible that the slope may have done considerably better by this point in time (i.e. better cover crop production and less weed invasion) if we had had wetter weather. In the two trenches that stretch across the slope, the cover crop plants are noticeably thicker than on the rest of the slope, particularly in the top trench. On the MSW plot this is particularly striking, with the top trench essentially containing an elongated island of cover crop plants surrounded by a sea of lambs quarters. The trenches are presumably moister than surrounding areas, because this is where rain water coming down the slope largely ends up, but also because the mulch is less exposed to the wind and therefore less likely to blow away. Based on this evidence, it seems likely that the cover crop would have fared considerably better if the mulching had been better, with fewer bare spots and a more even application, and if the spring weather hadn't been so dry.

August 1 site visit by Bahner

The plastic rain gage had 0.4" and the continuous-recording gage had 0.6" of rain. The extra lysimeter plot was pumped; again no water. Despite the recent rains, there was no noticeable odor on the demo plots. The main erosion gully (MSW plot) is about 6" deep in spots.

Videotaped visits

Several 1996 site visits were chronicled by videotape. These videos will be spliced together and edited, and will be available for viewing by contacting Paul Eger or Jon Wagner at the DNR-Minerals (612-296-4807).

Appendix 7

Percent Cover and Biomass Analysis Methods and Notes

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Percent cover and biomass analysis methods and notes

In August 1996, percent cover measurements were conducted and biomass samples were collected from the demonstration plots, the lysimeter plots and the washed sand plots. As described in the report, each of the four demonstration plots received 72 percent cover measurements (24 on each third of the plot) for a total of 288 measurements, and 12 biomass samples were collected from each plot (4 on each third of a plot) for a total of 48 samples.

A systematic sampling scheme was used for both percent cover and biomass instead of a random sampling scheme. The primary benefit of a random scheme is that it makes rigorous statistical analysis calculations possible, but it is also a more time-consuming endeavor because of the fact that it requires the measurer to zig-zag randomly around the plots. However, numerous analyses have indicated that there is usually little difference between the results of random surveys and systematic surveys (Dewar and Jordan, 1988), and a systematic scheme is much more time efficient.

On the lysimeter and washed sand plots, percent cover was measured at eight sites within each plot, with one of the eight sites being randomly selected as also being the location of a biomass sample. Thus for the nine lysimeter plots there was a total of 72 percent cover estimates and 9 biomass samples, and for the 18 washed sand plots there was a total of 144 percent cover estimates and 18 biomass samples.

It should be understood that the results of the demo plots are generally more reliable than the lysimeter and washed sand plots, because there were so many more samples collected per plot. There were several instances at the lysimeter and washed sand plots where the randomly selected biomass sample happened to fall at a spot where there was either an abnormally high amount of vegetation or almost no vegetation, whereas if the sample had been collected from a site just a few feet away, the result would have been dramatically different. On the demo plots such anomalies would have a relatively small effect on the overall measurements, because there are so many other samples that the effect of the anomalous sample is diluted. For example, if one of the percent cover samples on the NVS demo plot was anomalous, it would represent only 1.4% of the total 72 measurements made for the plot, and would therefore have a minimal effect on the overall measurements for the plot. However, if one of the three biomass samples collected per treatment at the lysimeter or washed sand plots was anomalous, the effect would be much greater on the overall measurements because it would represent 33% of the total.

Percent cover was estimated by placing an 0.5 square meter metal frame at the designated spot (see report for details), and then determining which of eight cover classes was appropriate. This estimate indicates the total amount of ground that is covered by vegetation; that is, a low ground-hugging plant such as carpet weed is given as much emphasis as a taller, more massive plant such as lambs quarters. Generally there was agreement between the two members of the survey crew about which cover class was appropriate; in those few cases where there was disagreement, the members took turns making the final decision.

Biomass samples were collected by placing an 0.1 square meter frame in the upper right-hand corner of the selected percent cover measurement, then cutting off all above-ground vegetation within the frame from plants that also originated within the frame. (That is, the base of a plant had to be within the biomass frame for vegetation from that plant to be included in the sample; overhanging branches of plants that were growing outside the frame were excluded.) The samples were then placed in ziploc bags and immediately sent to the DNR-Minerals office in Hibbing, where they were dried for 24 hours at 80° C, and then weighed.

It should be noted that although the widths of the four demo plots differ, the same number of percent cover and biomass measurements were made on each plot, so that the smaller plots (i.e. the control and the topsoil+fertilizer plots) were characterized in more detail than the larger plots (i.e. the NVS and MSW compost plots). That is, there was more distance between the sample sites on the larger plots than on the smaller plots, so a smaller proportion of the larger plots was measured.

The eight cover classes used were:

1. 0% to 1%
2. 1% to 5%
3. 5% to 25%
4. 25% to 50%
5. 50% to 75%
6. 75% to 95%
7. 95% to 99%
8. 99% to 100%

The classes were broader near the middle than at the high and low ends, and, not surprisingly, many of the measurements fell within just a few of the larger classes. This was necessary from a practical standpoint, because if the larger classes had been split into smaller classes it would have been very difficult for the survey crew to agree on the appropriate class. For example, if instead 10 classes had been used, with each class covering 10% of the total range, it would have been very difficult to state with any certainty whether a particular sample fell (for example) within the 40-50% class or the 50-60% range. Larger ranges were thus necessary near the middle of the range, but more precision is practical at the ends of the range because it becomes easier to detect subtle differences in cover.

Attached to this appendix are the 1996 biomass and percent cover data from all sites (the demo plots, the lysimeter plots and the washed sand plots), as well as statistical analysis data for the demo plots.

Table A7.1. Percent cover data from the demonstration plots at Shiely's Nelson Mine (1996 data).

Area	Plot	Section	Transect	Plot#	Date	Biomass?	Percent Cover Class	Percent Cover Range	Percent Cover Ave.	Comments
Demo slope	MSW	Top	1	.	8 8 96	Yes	5	50-75%	62.5	
Demo slope	MSW	Top	1	.	8 8 96	Yes	6	75-95%	85.0	
Demo slope	MSW	Top	1	.	8 8 96	No	7	95-99%	97.0	
Demo slope	MSW	Top	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Top	1	.	8 8 96	No	6	75-95%	85.0	
Demo slope	MSW	Top	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Top	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Top	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Top	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Top	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Top	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Top	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Top	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Top	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Top	2	.	8 8 96	No	6	75-95%	85.0	
Demo slope	MSW	Top	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Top	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Top	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Top	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Top	3	.	8 8 96	Yes	4	25-50%	37.5	
Demo slope	MSW	Top	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Top	3	.	8 8 96	Yes	3	5-25%	15.0	
Demo slope	MSW	Top	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Top	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Middle	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Middle	1	.	8 8 96	Yes	6	75-95%	85.0	
Demo slope	MSW	Middle	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Middle	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Middle	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Middle	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Middle	1	.	8 8 96	No	3	5-25%	15.0	Excess mulch
Demo slope	MSW	Middle	1	.	8 8 96	No	6	75-95%	85.0	
Demo slope	MSW	Middle	2	.	8 8 96	No	3	5-25%	15.0	
Demo slope	MSW	Middle	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Middle	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Middle	2	.	8 8 96	Yes	5	50-75%	62.5	
Demo slope	MSW	Middle	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Middle	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Middle	2	.	8 8 96	No	6	75-95%	85.0	
Demo slope	MSW	Middle	2	.	8 8 96	Yes	4	25-50%	37.5	
Demo slope	MSW	Middle	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Middle	3	.	8 8 96	No	6	75-95%	85.0	
Demo slope	MSW	Middle	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Middle	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Middle	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Middle	3	.	8 8 96	No	6	75-95%	85.0	
Demo slope	MSW	Middle	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Middle	3	.	8 8 96	Yes	6	75-95%	85.0	
Demo slope	MSW	Bottom	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	1	.	8 8 96	No	6	75-95%	85.0	
Demo slope	MSW	Bottom	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	1	.	8 8 96	Yes	4	25-50%	37.5	
Demo slope	MSW	Bottom	1	.	8 8 96	Yes	5	50-75%	62.5	
Demo slope	MSW	Bottom	1	.	8 8 96	Yes	5	50-75%	62.5	
Demo slope	MSW	Bottom	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Bottom	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	2	.	8 8 96	No	3	5-25%	15.0	

Area	Plot	Section	Transect	Plot#	Date	Biomass?	Percent Cover			Comments
							Class	Range	Ave.	
Demo slope	MSW	Bottom	2	.	8 8 96	No	6	75-95%	85.0	
Demo slope	MSW	Bottom	2	.	8 8 96	No	6	75-95%	85.0	
Demo slope	MSW	Bottom	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Bottom	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	3	.	8 8 96	No	3	5-25%	15.0	
Demo slope	MSW	Bottom	3	.	8 8 96	Yes	5	50-75%	62.5	
Demo slope	MSW	Bottom	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	MSW	Bottom	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	MSW	Bottom	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Top	1	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Top	1	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Top	1	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Top	1	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Top	1	.	8 6 96	No	3	5-25%	15.0	
Demo slope	N-Viro	Top	1	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Top	1	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Top	1	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Top	2	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Top	2	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Top	2	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Top	2	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Top	2	.	8 6 96	Yes	7	95-99%	97.0	
Demo slope	N-Viro	Top	2	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Top	2	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Top	2	.	8 6 96	Yes	5	50-75%	62.5	
Demo slope	N-Viro	Top	3	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Top	3	.	8 6 96	Yes	4	25-50%	37.5	
Demo slope	N-Viro	Top	3	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Top	3	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Top	3	.	8 6 96	No	3	5-25%	15.0	
Demo slope	N-Viro	Top	3	.	8 6 96	Yes	5	50-75%	62.5	
Demo slope	N-Viro	Top	3	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Top	3	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Middle	1	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Middle	1	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Middle	1	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Middle	1	.	8 6 96	Yes	5	50-75%	62.5	
Demo slope	N-Viro	Middle	1	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Middle	1	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Middle	1	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Middle	1	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Middle	2	.	8 6 96	Yes	4	25-50%	37.5	
Demo slope	N-Viro	Middle	2	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Middle	2	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Middle	2	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Middle	2	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Middle	2	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Middle	2	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Middle	2	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Middle	3	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Middle	3	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Middle	3	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Middle	3	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Middle	3	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Middle	3	.	8 6 96	Yes	4	25-50%	37.5	
Demo slope	N-Viro	Middle	3	.	8 6 96	Yes	4	25-50%	37.5	
Demo slope	N-Viro	Middle	3	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Bottom	1	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Bottom	1	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Bottom	1	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Bottom	1	.	8 6 96	Yes	5	50-75%	62.5	

Area	Plot	Section	Transect	Plot#	Date	Biomass?	Percent Cover Class	Range	Ave.	Comments
Demo slope	N-Viro	Bottom	1	.	8 6 96	No	4	25-50%	37.5	
Demo slope	N-Viro	Bottom	1	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Bottom	1	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Bottom	1	.	8 6 96	Yes	6	75-95%	85.0	
Demo slope	N-Viro	Bottom	2	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Bottom	2	.	8 6 96	No	8	99-100	99.5	
Demo slope	N-Viro	Bottom	2	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Bottom	2	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Bottom	2	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Bottom	2	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Bottom	2	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Bottom	2	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Bottom	3	.	8 6 96	Yes	4	25-50%	37.5	
Demo slope	N-Viro	Bottom	3	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Bottom	3	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Bottom	3	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Bottom	3	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Bottom	3	.	8 6 96	No	6	75-95%	85.0	
Demo slope	N-Viro	Bottom	3	.	8 6 96	No	5	50-75%	62.5	
Demo slope	N-Viro	Bottom	3	.	8 6 96	Yes	7	95-99%	97.0	
Demo slope	Fertilizer	Top	1	.	8 8 96	No	3	5-25%	15.0	
Demo slope	Fertilizer	Top	1	.	8 8 96	No	3	5-25%	15.0	Mostly carpet weed
Demo slope	Fertilizer	Top	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Top	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Top	1	.	8 8 96	No	5	50-75%	62.5	Mostly carpet weed
Demo slope	Fertilizer	Top	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Top	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Top	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Top	2	.	8 8 96	No	2	1-5	3.0	
Demo slope	Fertilizer	Top	2	.	8 8 96	Yes	5	50-75%	62.5	Almost all nutgrass
Demo slope	Fertilizer	Top	2	.	8 8 96	No	6	75-95%	85.0	
Demo slope	Fertilizer	Top	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Top	2	.	8 8 96	No	2	1-5	3.0	
Demo slope	Fertilizer	Top	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Top	2	.	8 8 96	No	5	50-75%	62.5	Mostly carpet weed
Demo slope	Fertilizer	Top	2	.	8 8 96	Yes	4	25-50%	37.5	
Demo slope	Fertilizer	Top	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Top	3	.	8 8 96	No	6	75-95%	85.0	Almost all nutgrass
Demo slope	Fertilizer	Top	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Top	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Top	3	.	8 8 96	No	2	1-5	3.0	
Demo slope	Fertilizer	Top	3	.	8 8 96	Yes	4	25-50%	37.5	Mostly carpet weed
Demo slope	Fertilizer	Top	3	.	8 8 96	No	3	5-25%	15.0	
Demo slope	Fertilizer	Top	3	.	8 8 96	Yes	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	1	.	8 8 96	Yes	3	5-25%	15.0	Mostly nutgrass
Demo slope	Fertilizer	Middle	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	1	.	8 8 96	Yes	5	50-75%	62.5	
Demo slope	Fertilizer	Middle	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Middle	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Middle	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	2	.	8 8 96	Yes	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	2	.	8 8 96	No	6	75-95%	85.0	
Demo slope	Fertilizer	Middle	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Middle	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	3	.	8 8 96	No	4	25-50%	37.5	

Area	Plot	Section	Transect	Plot#	Date	Biomass?	Percent Cover Class	Range	Ave.	Comments
Demo slope	Fertilizer	Middle	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Middle	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Middle	3	.	8 8 96	Yes	4	25-50%	37.5	
Demo slope	Fertilizer	Bottom	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Bottom	1	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Bottom	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	1	.	8 8 96	Yes	4	25-50%	37.5	
Demo slope	Fertilizer	Bottom	1	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	1	.	8 8 96	Yes	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	1	.	8 8 96	No	3	5-25%	15.0	
Demo slope	Fertilizer	Bottom	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Bottom	2	.	8 8 96	Yes	3	5-25%	15.0	
Demo slope	Fertilizer	Bottom	2	.	8 8 96	No	5	50-75%	62.5	About half carpet weed
Demo slope	Fertilizer	Bottom	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Bottom	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	2	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Bottom	2	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Fertilizer	Bottom	3	.	8 8 96	Yes	3	5-25%	15.0	
Demo slope	Fertilizer	Bottom	3	.	8 8 96	No	6	75-95%	85.0	
Demo slope	Fertilizer	Bottom	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	3	.	8 8 96	No	5	50-75%	62.5	
Demo slope	Fertilizer	Bottom	3	.	8 8 96	No	4	25-50%	37.5	
Demo slope	Control	Top	1	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	1	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Top	1	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Top	1	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	1	.	8 7 96	Yes	4	25-50%	37.5	
Demo slope	Control	Top	1	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	1	.	8 7 96	Yes	5	50-75%	62.5	
Demo slope	Control	Top	1	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Top	2	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Top	2	.	8 7 96	Yes	3	5-25%	15.0	
Demo slope	Control	Top	2	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	2	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	2	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Top	2	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	2	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Top	2	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	3	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	3	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	3	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Top	3	.	8 7 96	Yes	3	5-25%	15.0	
Demo slope	Control	Top	3	.	8 7 96	No	6	75-95%	85.0	
Demo slope	Control	Top	3	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	3	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Top	3	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Middle	1	.	8 7 96	No	2	1-5	3.0	
Demo slope	Control	Middle	1	.	8 7 96	No	2	1-5	3.0	
Demo slope	Control	Middle	1	.	8 7 96	No	2	1-5	3.0	
Demo slope	Control	Middle	1	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Middle	1	.	8 7 96	No	2	1-5	3.0	
Demo slope	Control	Middle	1	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Middle	1	.	8 7 96	No	2	1-5	3.0	
Demo slope	Control	Middle	1	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Middle	2	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Middle	2	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Middle	2	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Middle	2	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Middle	2	.	8 7 96	Yes	4	25-50%	37.5	

Area	Plot	Section	Transect	Plot#	Date	Biomass?	Percent Cover Class	Percent Cover Range	Percent Cover Ave.	Comments
Demo slope	Control	Middle	2	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Middle	2	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Middle	2	.	8 7 96	Yes	3	5-25%	15.0	
Demo slope	Control	Middle	3	.	8 7 96	No	2	1-5	3.0	
Demo slope	Control	Middle	3	.	8 7 96	No	2	1-5	3.0	
Demo slope	Control	Middle	3	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Middle	3	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Middle	3	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Middle	3	.	8 7 96	Yes	5	50-75%	62.5	
Demo slope	Control	Middle	3	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Middle	3	.	8 7 96	Yes	4	25-50%	37.5	
Demo slope	Control	Bottom	1	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Bottom	1	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Bottom	1	.	8 7 96	Yes	2	1-5	3.0	
Demo slope	Control	Bottom	1	.	8 7 96	No	2	1-5	3.0	
Demo slope	Control	Bottom	1	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Bottom	1	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Bottom	1	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Bottom	1	.	8 7 96	Yes	4	25-50%	37.5	
Demo slope	Control	Bottom	2	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Bottom	2	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Bottom	2	.	8 7 96	No	2	1-5	3.0	
Demo slope	Control	Bottom	2	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Bottom	2	.	8 7 96	Yes	3	5-25%	15.0	
Demo slope	Control	Bottom	2	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Bottom	2	.	8 7 96	Yes	4	25-50%	37.5	
Demo slope	Control	Bottom	2	.	8 7 96	No	2	1-5	3.0	
Demo slope	Control	Bottom	3	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Bottom	3	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Bottom	3	.	8 7 96	No	5	50-75%	62.5	
Demo slope	Control	Bottom	3	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Bottom	3	.	8 7 96	No	4	25-50%	37.5	
Demo slope	Control	Bottom	3	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Bottom	3	.	8 7 96	No	3	5-25%	15.0	
Demo slope	Control	Bottom	3	.	8 7 96	No	2	1-5	3.0	

Table A7.2. Percent cover data from the lysimeter plots at Shiely's Nelson Mine (1996 data).

							Percent Cover			
Area	Plot	Section	Transect	Plot#	Date	Biomass?	Class	Range	Ave.	Comments
Lysimeter	Topsoil	na	na	6	8 7 96	No	6	75-95%	85.0	
Lysimeter	Topsoil	na	na	6	8 7 96	Yes	5	50-75%	62.5	
Lysimeter	Topsoil	na	na	6	8 7 96	No	7	95-99%	97.0	
Lysimeter	Topsoil	na	na	6	8 7 96	No	6	75-95%	85.0	
Lysimeter	Topsoil	na	na	6	8 7 96	No	6	75-95%	85.0	
Lysimeter	Topsoil	na	na	6	8 7 96	No	7	95-99%	97.0	
Lysimeter	Topsoil	na	na	6	8 7 96	No	7	95-99%	97.0	
Lysimeter	Topsoil	na	na	6	8 7 96	No	5	50-75%	62.5	
Lysimeter	Topsoil	na	na	1	8 7 96	No	5	50-75%	62.5	
Lysimeter	Topsoil	na	na	1	8 7 96	No	7	95-99%	97.0	
Lysimeter	Topsoil	na	na	1	8 7 96	No	6	75-95%	85.0	
Lysimeter	Topsoil	na	na	1	8 7 96	No	5	50-75%	62.5	
Lysimeter	Topsoil	na	na	1	8 7 96	No	6	75-95%	85.0	
Lysimeter	Topsoil	na	na	1	8 7 96	No	6	75-95%	85.0	
Lysimeter	Topsoil	na	na	1	8 7 96	No	6	75-95%	85.0	
Lysimeter	Topsoil	na	na	1	8 7 96	No	6	75-95%	85.0	
Lysimeter	Topsoil	na	na	4	8 7 96	No	4	25-50%	37.5	
Lysimeter	Topsoil	na	na	4	8 7 96	No	7	95-99%	97.0	
Lysimeter	Topsoil	na	na	4	8 7 96	No	5	50-75%	62.5	
Lysimeter	Topsoil	na	na	4	8 7 96	No	4	25-50%	37.5	
Lysimeter	Topsoil	na	na	4	8 7 96	No	5	50-75%	62.5	
Lysimeter	Topsoil	na	na	4	8 7 96	No	5	50-75%	62.5	
Lysimeter	Topsoil	na	na	4	8 7 96	No	6	75-95%	85.0	
Lysimeter	Topsoil	na	na	4	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	7	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	7	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	7	8 7 96	No	7	95-99%	97.0	
Lysimeter	MSW	na	na	7	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	7	8 7 96	No	4	25-50%	37.5	
Lysimeter	MSW	na	na	7	8 7 96	No	7	95-99%	97.0	
Lysimeter	MSW	na	na	7	8 7 96	No	6	75-95%	85.0	
Lysimeter	MSW	na	na	7	8 7 96	No	6	75-95%	85.0	
Lysimeter	MSW	na	na	2	8 7 96	No	4	25-50%	37.5	
Lysimeter	MSW	na	na	2	8 7 96	No	7	95-99%	97.0	
Lysimeter	MSW	na	na	2	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	2	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	2	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	2	8 7 96	No	7	95-99%	97.0	
Lysimeter	MSW	na	na	2	8 7 96	No	6	75-95%	85.0	
Lysimeter	MSW	na	na	2	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	8	8 7 96	No	4	25-50%	37.5	
Lysimeter	MSW	na	na	8	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	8	8 7 96	No	7	95-99%	97.0	
Lysimeter	MSW	na	na	8	8 7 96	No	6	75-95%	85.0	
Lysimeter	MSW	na	na	8	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	8	8 7 96	No	5	50-75%	62.5	
Lysimeter	MSW	na	na	8	8 7 96	No	6	75-95%	85.0	
Lysimeter	MSW	na	na	8	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	3	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	3	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	3	8 7 96	No	7	95-99%	97.0	
Lysimeter	NVS	na	na	3	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	3	8 7 96	No	4	25-50%	37.5	
Lysimeter	NVS	na	na	3	8 7 96	No	4	25-50%	37.5	
Lysimeter	NVS	na	na	3	8 7 96	No	7	95-99%	97.0	
Lysimeter	NVS	na	na	3	8 7 96	No	5	50-75%	62.5	1/4 was gopher mound
Lysimeter	NVS	na	na	5	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	5	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	5	8 7 96	No	7	95-99%	97.0	
Lysimeter	NVS	na	na	5	8 7 96	No	5	50-75%	62.5	

Area	Plot	Section	Transect	Plot#	Date	Biomass?	Percent Cover Class	Range	Ave.	Comments
Lysimeter	NVS	na	na	5	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	5	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	5	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	5	8 7 96	No	6	75-95%	85.0	
Lysimeter	NVS	na	na	9	8 7 96	No	4	25-50%	37.5	
Lysimeter	NVS	na	na	9	8 7 96	No	6	75-95%	85.0	
Lysimeter	NVS	na	na	9	8 7 96	No	7	95-99%	97.0	
Lysimeter	NVS	na	na	9	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	9	8 7 96	No	5	50-75%	62.5	
Lysimeter	NVS	na	na	9	8 7 96	No	6	75-95%	85.0	
Lysimeter	NVS	na	na	9	8 7 96	No	6	75-95%	85.0	
Lysimeter	NVS	na	na	9	8 7 96	No	5	50-75%	62.5	

Table A7.3. Percent cover data from the washed sand plots at Shiely's Nelson Mine (1996 data).

Area	Plot	Section	Transect	Plot#	Date	Biomass?	Percent Cover Class	Percent Cover Range	Percent Cover Ave.	Comments
Washed Sand	NVS60	na	na	1	8 16 96	No	6	75-95%	85.0	
Washed Sand	NVS60	na	na	1	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS60	na	na	1	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS60	na	na	1	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS60	na	na	1	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS60	na	na	1	8 16 96	Yes	4	25-50%	37.5	
Washed Sand	NVS60	na	na	1	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS60	na	na	1	8 16 96	No	5	50-75%	62.5	
Washed Sand	NVS60	na	na	14	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS60	na	na	14	8 16 96	Yes	4	25-50%	37.5	
Washed Sand	NVS60	na	na	14	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS60	na	na	14	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS60	na	na	14	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS60	na	na	14	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS60	na	na	14	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS60	na	na	14	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS60	na	na	15	8 16 96	No	2	1-5	3.0	
Washed Sand	NVS60	na	na	15	8 16 96	No	2	1-5	3.0	
Washed Sand	NVS60	na	na	15	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS60	na	na	15	8 16 96	No	2	1-5	3.0	
Washed Sand	NVS60	na	na	15	8 16 96	No	2	1-5	3.0	
Washed Sand	NVS60	na	na	15	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS60	na	na	15	8 16 96	Yes	3	5-25%	15.0	
Washed Sand	NVS60	na	na	15	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS30	na	na	3	8 16 96	No	5	50-75%	62.5	
Washed Sand	NVS30	na	na	3	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS30	na	na	3	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS30	na	na	3	8 16 96	No	5	50-75%	62.5	
Washed Sand	NVS30	na	na	3	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS30	na	na	3	8 16 96	No	5	50-75%	62.5	
Washed Sand	NVS30	na	na	3	8 16 96	Yes	4	25-50%	37.5	
Washed Sand	NVS30	na	na	3	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS30	na	na	7	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS30	na	na	7	8 16 96	Yes	4	25-50%	37.5	
Washed Sand	NVS30	na	na	7	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS30	na	na	7	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS30	na	na	7	8 16 96	No	5	50-75%	62.5	
Washed Sand	NVS30	na	na	7	8 16 96	No	5	50-75%	62.5	
Washed Sand	NVS30	na	na	7	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS30	na	na	7	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS30	na	na	11	8 16 96	No	5	50-75%	62.5	
Washed Sand	NVS30	na	na	11	8 16 96	Yes	5	50-75%	62.5	
Washed Sand	NVS30	na	na	11	8 16 96	No	5	50-75%	62.5	
Washed Sand	NVS30	na	na	11	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS30	na	na	11	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS30	na	na	11	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS30	na	na	11	8 16 96	No	5	50-75%	62.5	
Washed Sand	NVS30	na	na	11	8 16 96	No	5	50-75%	62.5	
Washed Sand	NVS15	na	na	5	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS15	na	na	5	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	5	8 16 96	Yes	3	5-25%	15.0	
Washed Sand	NVS15	na	na	5	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS15	na	na	5	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS15	na	na	5	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	5	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	5	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	12	8 16 96	Yes	3	5-25%	15.0	
Washed Sand	NVS15	na	na	12	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	12	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS15	na	na	12	8 16 96	No	5	50-75%	62.5	

Area	Plot	Section	Transect	Plot#	Date	Biomass?	Percent Cover Class	Percent Cover Range	Percent Cover Ave.	Comments
Washed Sand	NVS15	na	na	12	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	12	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	12	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS15	na	na	12	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	13	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	13	8 16 96	No	4	25-50%	37.5	
Washed Sand	NVS15	na	na	13	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	13	8 16 96	Yes	3	5-25%	15.0	
Washed Sand	NVS15	na	na	13	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	13	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	13	8 16 96	No	3	5-25%	15.0	
Washed Sand	NVS15	na	na	13	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	2	8 16 96	Yes	2	1-5	3.0	
Washed Sand	MSW	na	na	2	8 16 96	No	2	1-5	3.0	
Washed Sand	MSW	na	na	2	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	2	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	2	8 16 96	No	2	1-5	3.0	
Washed Sand	MSW	na	na	2	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	2	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	2	8 16 96	No	2	1-5	3.0	
Washed Sand	MSW	na	na	4	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	4	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	4	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	4	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	4	8 16 96	No	4	25-50%	37.5	
Washed Sand	MSW	na	na	4	8 16 96	No	2	1-5	3.0	
Washed Sand	MSW	na	na	4	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	4	8 16 96	Yes	3	5-25%	15.0	
Washed Sand	MSW	na	na	9	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	9	8 16 96	No	2	1-5	3.0	
Washed Sand	MSW	na	na	9	8 16 96	No	2	1-5	3.0	
Washed Sand	MSW	na	na	9	8 16 96	No	2	1-5	3.0	
Washed Sand	MSW	na	na	9	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	9	8 16 96	No	2	1-5	3.0	
Washed Sand	MSW	na	na	9	8 16 96	No	3	5-25%	15.0	
Washed Sand	MSW	na	na	9	8 16 96	Yes	3	5-25%	15.0	
Washed Sand	Fertilizer	na	na	16	8 16 96	No	5	50-75%	62.5	
Washed Sand	Fertilizer	na	na	16	8 16 96	No	4	25-50%	37.5	
Washed Sand	Fertilizer	na	na	16	8 16 96	No	5	50-75%	62.5	
Washed Sand	Fertilizer	na	na	16	8 16 96	No	4	25-50%	37.5	Almost all 1 LQ plant
Washed Sand	Fertilizer	na	na	16	8 16 96	No	4	25-50%	37.5	
Washed Sand	Fertilizer	na	na	16	8 16 96	No	4	25-50%	37.5	
Washed Sand	Fertilizer	na	na	16	8 16 96	No	3	5-25%	15.0	
Washed Sand	Fertilizer	na	na	16	8 16 96	No	6	75-95%	85.0	
Washed Sand	Fertilizer	na	na	17	8 16 96	No	3	5-25%	15.0	
Washed Sand	Fertilizer	na	na	17	8 16 96	No	3	5-25%	15.0	
Washed Sand	Fertilizer	na	na	17	8 16 96	No	4	25-50%	37.5	
Washed Sand	Fertilizer	na	na	17	8 16 96	No	4	25-50%	37.5	
Washed Sand	Fertilizer	na	na	17	8 16 96	No	3	5-25%	15.0	
Washed Sand	Fertilizer	na	na	17	8 16 96	No	5	50-75%	62.5	
Washed Sand	Fertilizer	na	na	17	8 16 96	No	3	5-25%	15.0	
Washed Sand	Fertilizer	na	na	17	8 16 96	No	5	50-75%	62.5	
Washed Sand	Fertilizer	na	na	18	8 16 96	No	4	25-50%	37.5	
Washed Sand	Fertilizer	na	na	18	8 16 96	No	3	5-25%	15.0	
Washed Sand	Fertilizer	na	na	18	8 16 96	No	3	5-25%	15.0	
Washed Sand	Fertilizer	na	na	18	8 16 96	No	4	25-50%	37.5	
Washed Sand	Fertilizer	na	na	18	8 16 96	No	4	25-50%	37.5	
Washed Sand	Fertilizer	na	na	18	8 16 96	No	3	5-25%	15.0	
Washed Sand	Fertilizer	na	na	18	8 16 96	No	3	5-25%	15.0	
Washed Sand	Fertilizer	na	na	18	8 16 96	No	3	5-25%	15.0	
Washed Sand	Topsoil	na	na	6	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	6	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	6	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	6	8 16 96	Yes	2	1-5	3.0	

Area	Plot	Section	Transect	Plot#	Date	Biomass?	Percent Cover Class	Range	Ave.	Comments
Washed Sand	Topsoil	na	na	6	8 16 96	No	3	5-25%	15.0	
Washed Sand	Topsoil	na	na	6	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	6	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	6	8 16 96	No	3	5-25%	15.0	
Washed Sand	Topsoil	na	na	8	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	8	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	8	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	8	8 16 96	No	3	5-25%	15.0	
Washed Sand	Topsoil	na	na	8	8 16 96	Yes	2	1-5	3.0	
Washed Sand	Topsoil	na	na	8	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	8	8 16 96	No	3	5-25%	15.0	
Washed Sand	Topsoil	na	na	8	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	10	8 16 96	No	1	0-1%	0.5	
Washed Sand	Topsoil	na	na	10	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	10	8 16 96	Yes	2	1-5	3.0	
Washed Sand	Topsoil	na	na	10	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	10	8 16 96	No	1	0-1%	0.5	
Washed Sand	Topsoil	na	na	10	8 16 96	No	1	0-1%	0.5	
Washed Sand	Topsoil	na	na	10	8 16 96	No	2	1-5	3.0	
Washed Sand	Topsoil	na	na	10	8 16 96	No	2	1-5	3.0	

Table A7.4. Biomass data (dry weights; g) from the demonstration plots, lysimeter plots and the washed sand plots at Shiely's Nelson Mine (collected August 6-8, 1996).

Demonstration Slope:

SAMPLE SITE	DRY WT. (g)
NVIRO TOP 22	28.690
NVIRO TOP 18	24.882
NVIRO TOP 13	12.768
NVIRO TOP 16	12.685
NVIRO MIDDLE 22	17.391
NVIRO MIDDLE 23	16.882
NVIRO MIDDLE 9	35.309
NVIRO MIDDLE 4	9.215
NVIRO BOTTOM 24	65.916
NVIRO BOTTOM 8	32.449
NVIRO BOTTOM 17	9.099
NVIRO BOTTOM 4	4.789
FERTILIZER TOP 16	19.996
FERTILIZER TOP 22	8.527
FERTILIZER TOP 24	10.593
FERTILIZER TOP 10	7.491
FERTILIZER MIDDLE 3	4.343
FERTILIZER MIDDLE 24	1.821
FERTILIZER MIDDLE 15	10.612
FERTILIZER MIDDLE 5	5.267
FERTILIZER BOTTOM 7	1.010
FERTILIZER BOTTOM 5	5.861
FERTILIZER BOTTOM 10	16.446
FERTILIZER BOTTOM 20	32.042
MSW TOP 1	12.009
MSW TOP 20	1.946
MSW TOP 22	8.179
MSW TOP 2	20.302
MSW MIDDLE 24	41.147
MSW MIDDLE 12	39.029
MSW MIDDLE 2	12.858
MSW MIDDLE 16	16.810
MSW BOTTOM 20	43.442
MSW BOTTOM 8	19.515
MSW BOTTOM 6	6.396
MSW BOTTOM 7	40.672
CONTROL TOP 13	6.823
CONTROL TOP 4	3.298
CONTROL TOP 19	4.912
CONTROL TOP 3	5.531
CONTROL MIDDLE 13	9.850
CONTROL MIDDLE 16	9.759
CONTROL MIDDLE 22	10.939
CONTROL MIDDLE 24	9.469
CONTROL BOTTOM 15	6.448
CONTROL BOTTOM 13	2.759
CONTROL BOTTOM 8	3.342

Table __. Biomass data (dry weights; g) from the demonstration plots, lysimeter plots and the washed sand plots at Shiely's Nelson Mine (collected August 6-8, 1996); continued.

Lysimeter Plots

SAMPLE SITE	DRY WT. (g)
MSW 8 LYS	10.228
MSW 2 LYS	6.418
MSW 7 LYS	29.726
TOPSOIL 1 LYS	7.610
TOPSOIL 6 LYS	9.284
TOPSOIL 4 LYS	6.513
NVS 5 LYS	11.290
NVS 3 LYS	1.242
NVS 9 LYS	10.444

Washed Sand Plots

SAMPLE SITE	DRY WT. (g)
TOPSOIL #6	3.84
TOPSOIL #10	5.52
TOPSOIL. #8	4.45
TOPSOIL+FERT. #16	10.18
TOPSOIL+FERT. #17	6.79
TOPSOIL+FERT. #18	7.43
NVS 15 #5	10.97
NVS 15 #12	11.18
NVS 15 #13	1.11
NVS 30 #3	15.72
NVS 30 #7	12.95
NVS 30 #11	36.15
NVS 60 #1	7.15
NVS 60 #15	3.03
NVS 60 #14	no sample
MSW #2	7.69
MSW #4	4.43
MSW #9	6.43

Table A7.5. Summary statistics of 1996 biomass data from the demonstration slope. The data are first presented for the entire plot, and then broken down into thirds of the slope.

Demonstration plots - all data

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = CONTROL

TOTAL OBSERVATIONS: 11

	WEIGHT
N OF CASES	11
MINIMUM	2.759
MAXIMUM	10.939
RANGE	8.180
MEAN	6.648
STANDARD DEV	2.965
MEDIAN	6.448

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = FERTILIZER

TOTAL OBSERVATIONS: 12

	WEIGHT
N OF CASES	12
MINIMUM	1.010
MAXIMUM	32.042
RANGE	31.032
MEAN	10.334
STANDARD DEV	8.813
MEDIAN	8.009

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = MSW

TOTAL OBSERVATIONS: 12

	WEIGHT
N OF CASES	12
MINIMUM	1.946
MAXIMUM	43.442
RANGE	41.496
MEAN	21.859
STANDARD DEV	15.138
MEDIAN	18.163

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = NVIRO

TOTAL OBSERVATIONS: 12

	WEIGHT
N OF CASES	12
MINIMUM	4.789
MAXIMUM	65.916
RANGE	61.127
MEAN	22.506
STANDARD DEV	16.816
MEDIAN	17.137

Demonstration plots , broken down into thirds of the slope

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = CONTROL
SECTION$ = BOTTOM

TOTAL OBSERVATIONS: 3

	WEIGHT
N OF CASES	3
MINIMUM	2.759
MAXIMUM	6.448
RANGE	3.689
MEAN	4.183
STANDARD DEV	1.983
MEDIAN	3.342

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = CONTROL
SECTION$ = MIDDLE

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	9.469
MAXIMUM	10.939
RANGE	1.470
MEAN	10.004
STANDARD DEV	0.644
MEDIAN	9.805

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = CONTROL
SECTION$ = TOP

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	3.298
MAXIMUM	6.823
RANGE	3.525
MEAN	5.141
STANDARD DEV	1.464
MEDIAN	5.222

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = FERTILIZER
SECTION$ = BOTTOM

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	1.010
MAXIMUM	32.042
RANGE	31.032
MEAN	13.840
STANDARD DEV	13.740
MEDIAN	11.154

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = FERTILIZER
SECTION$ = MIDDLE

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	1.821
MAXIMUM	10.612
RANGE	8.791
MEAN	5.511
STANDARD DEV	3.700
MEDIAN	4.805

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = FERTILIZER
SECTION$ = TOP

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	7.491
MAXIMUM	19.996
RANGE	12.505
MEAN	11.652
STANDARD DEV	5.710
MEDIAN	9.560

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = MSW
SECTION$ = BOTTOM

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	6.396
MAXIMUM	43.442
RANGE	37.046
MEAN	27.506
STANDARD DEV	17.671
MEDIAN	30.094

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = MSW
SECTION$ = MIDDLE

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	12.858
MAXIMUM	41.147
RANGE	28.289
MEAN	27.461
STANDARD DEV	14.695
MEDIAN	27.920

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = MSW
SECTION$ = TOP

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	1.946
MAXIMUM	20.302
RANGE	18.356
MEAN	10.609
STANDARD DEV	7.678
MEDIAN	10.094

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = NVIRO
SECTION$ = BOTTOM

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	4.789
MAXIMUM	65.916
RANGE	61.127
MEAN	28.063
STANDARD DEV	28.008
MEDIAN	20.774

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = NVIRO
SECTION$ = MIDDLE

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	9.215
MAXIMUM	35.309
RANGE	26.094
MEAN	19.699
STANDARD DEV	11.058
MEDIAN	17.137

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = NVIRO
SECTION$ = TOP

TOTAL OBSERVATIONS: 4

	WEIGHT
N OF CASES	4
MINIMUM	12.685
MAXIMUM	28.690
RANGE	16.005
MEAN	19.756
STANDARD DEV	8.265
MEDIAN	18.825

Lysimeter plots

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = MSW lysimeter plots

TOTAL OBSERVATIONS: 3

	WEIGHT
N OF CASES	3
MINIMUM	6.418
MAXIMUM	29.726
RANGE	23.308
MEAN	15.457
STANDARD DEV	12.503
MEDIAN	10.228

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = NVS lysimeter plots

TOTAL OBSERVATIONS: 3

	WEIGHT
N OF CASES	3
MINIMUM	1.242
MAXIMUM	11.290
RANGE	10.048
MEAN	7.659
STANDARD DEV	5.573
MEDIAN	10.444

THE FOLLOWING RESULTS ARE FOR:
PLOT$ = TOPSOIL lysimeter plots

TOTAL OBSERVATIONS: 3

	WEIGHT
N OF CASES	3
MINIMUM	6.513
MAXIMUM	9.284
RANGE	2.771
MEAN	7.802
STANDARD DEV	1.395
MEDIAN	7.610

Appendix 8

Lysimeter Plot Construction Details

Appendix 8

Lysimeter Plot Construction Details

Initial construction

On April 25, 1996, DNR employees Paul Eger, Jon Wagner and Glenn Melchert installed the pan lysimeters in the water quality plots. Air temperatures were around 60° F, and it was partly cloudy most of the day, but it was extremely windy.

The area to be stripped of existing topsoil and vegetation had been staked out on 4/18/96 by Eger and Wagner, with orange lathe stakes placed at the corners of the plot, and with pink lathe stakes placed at distances of 5 m from the corners, along the lines made by the four sides of the plot. (The pink stakes were placed so that the location of the orange corner stakes could be found in the event that the orange stake was destroyed or moved in the process of stripping.) The overall size of the plot was 32 m long by 11 m wide.

The initial stripping was done with a Caterpillar front-end loader (model 988B), and the goal was to strip the top 12" of material, since soil samples that we had collected earlier indicated that the topsoil ranged from 4 to 12 inches, with an average depth of between 6 and 8 inches. The operator (from Shiely) stripped the plot from side to side, dumping the topsoil and vegetation to the west of the plots. (This material was later hauled to a different location at the mine.) Actual stripping depth was closer to 18", with slightly deeper depths at the center of the plot area. Any clumps of vegetation or topsoil that were observed after the loader was finished were removed by hand. And although most of the subsoil was fine sand, small pockets of gravel and black sand were found. This area had been filled (reclaimed) previously, and it is likely that these pockets were related to the reclamation of the area.

The initial stripping left the middle of the plot noticeably lower than the sides, and noticable high/low spots were observed. However, after the intial stripping was done the loader was used to repeatedly backdrag the plot (with care being taken to ensure that none of the stripped topsoil/vegetation was returned to the plot), and by the time the loader was finished the plot was quite smooth, with most of the high and low spots evened out.

A Bobcat was then used to grade and smooth out the plot, and the end result was a reasonably flat, smooth plot. It appeared that the entire plot seems to dip somewhat from south to north, but this is a shallow slope, and shouldn't affect the performance of the plots. It should be noted, however, that the bobcat had noticeable difficulty negotiating the soft sand that was in the plot after stripping, leading to the conclusion that the bobcat would be largely unusable on the slope where the demonstration plots will be constructed, which will have both soft sand and a slope. (This turned out to be the case with the tractor hauling the mulcher, and a front-end loader was eventually used to pull the tractor and mulcher across the slope.)

Once the overall plot was ready, the center of each lysimeter site was located and staked; the center of each pan is located 3.25 m from the respective sides of the cleared area for the plots

(8.25 meters from the row of pink stakes that were used to set the lysimeters). The operator of the bobcat (Shiely employee Dennis Kilmer) has a digging apparatus that affixes to the bobcat, and this digger was then used to dig the holes for the lysimeters and also the trenches from the lysimeters to the side of the plots, which were required for placement of the PVC/Tygon tubing plumbing.

The bottom of the pans were set so that the low point of the pan (the corner where the plumbing is attached) was at a depth of 18" from the surface; the lysimeters were all sloped to this corner. The sand below the pan was then carefully smoothed out to ensure that the force of the sand above the lysimeter is evenly spread on the lysimeter so that the lysimeter doesn't break. A small hole was dug in the southeast corner of each lysimeter hole, so that the plumbing coming out of the bottom of the lysimeters could fit without having to receive the load of all the sand above the lysimeters.

The lysimeters essentially consist of a 2' x 3' pan (1' deep), with an 11-ft. length of 3/8" Tygon tubing affixed to bottom the southeast corner with plumbing fixtures and clamps. The spot where the tubing comes out of the pan is protected with a 90° 1.5" PVC elbow. The Tygon was then threaded through a length of 3/4" Schedule 40 PVC, and then the end of this PVC was cemented to the elbow. This pipe generally runs parallel to the soil surface, but with a small incline from the pan. A 45° elbow was then threaded over the Tygon, and was then cemented to the end of the PVC pipe so that the open end of the 45° elbow was facing up. The Tygon was then threaded through another length of 3/4" Schedule 40 PVC, which thus angled upwards at an approximate angle of 45° from the initial PVC pipe (which itself is angled upwards somewhat). Inside each pan (along the bottom of one of the long sides) was a length of well screen (some 10 slot, some 30 slot), with all of the wellscreen protected with a geotextile sock that was stitched on three sides.

Once the plumbing was in place and cemented, 100 lbs. of industrial-grade silica sand was placed into the lysimeter, at an average depth of 3". Fine sand (i.e. the subsoil from the area) was mixed with the top inch of the silica sand in an effort to ensure that no boundary layer would form between the silica sand and the material above it. Any open space around the outside of the pan was then filled in to prevent the pan from splitting apart from the force of sand being filled in from above. Once this was completed, the bobcat was used to fill in the lysimeter and trench areas, so that only the riser pipe remains visible. (The ends of both the Tygon and the PVC housing were taped to prevent foreign materials and rainwater from entering the pans.)

It should be noted that the lengths of PVC varied; in Plot A (the southeastern-most plot), the first piece of pipe was 4' long and the riser pipe is 6' long. After it was determined that too much of the riser pipe was left sticking out of the ground, it was decided that for Plot B (to the north of Plot A), the first pipe would be 5' long, as would the riser pipe. This also led to a riser pipe that was deemed to stick too far out, and so the remaining plots (C through J) have a straight pipe that is 5.5' long, and a riser pipe that is 4.5' long.

After all of the lysimeters were covered back up, the areas above the pans and the plumbing trenches were hand-tamped to pack down the relatively loose sand above the pans and plumbing.

The bobcat was then used to smooth out the area between the orange stakes (i.e. the 32 m x 11 m plot). The lysimeter plots were then left alone till May 3 to give the sand a chance to settle.

Plot layout

On May 3, 1996, Paul Eger and Jon Wagner set out lathe stakes to delineate the boundaries of the 10 lysimeter plots, and the following is a description of the methods used in this process. The overall plot size is 32 x 11 meters, which allows for a 2 m boundary around all sides of the 10 plots, which are each 2.5 x 4 meters in size.

The first step was to place stakes along the long sides of the overall plot. The first stake was placed at 2 meters (measuring from the southern end of the overall plot), with succeeding stakes placed at 6, 8, 12, 14, 18, 20, 24, 26 and 30 meters. Once these stakes were placed, we connected corresponding stakes on the two long sides with a tape measure pulled fairly taut, and then measured appropriate distances along this tape measure to locate the proper locations of the corner stakes. Measuring from the western long side, these stakes were placed at 2, 4.5, 6.5 and 9 meters, which allowed a 2 meter buffer on the outside of each of the two plots, and also between the two plots (see figure 1). Once this was completed, we moved up to the next pair of stakes along the long sides and repeated the process until we had stakes placed at all four corners of each of the 10 lysimeter plots.

This process was adequate for locating the approximate location and size of the 10 plots, but it was determined that we should ensure that each of the plots was indeed exactly 2.5 x 4 meters in size, and exactly rectangular instead of a parallelogram. To do this:

1. We decided that the northwest stake in each plot would be the basis of measurement.

2. Then we measured from that stake to the southwest stake, and adjusted the southwest stake if it wasn't exactly four meters from the northwest stake. Once the west side of the plot was thus established, we then used two tape measure to "rectangulate" the plot. To do this we anchored the end of one of the tape measures at the northwest corner, and then anchored the end of the other tape measure at the southwest corner. Since a rectangle that is 2.5 x 4 meters has a hypotenuse of about 4.9 meters, we then adjusted the two tape measures simultaneously until a point was located that was both 4.9 meters from the northwest corner (i.e. along the hypotenuse of the rectangle) and also 4 meters from the southwest corner. When this point was located a lathe stake was placed.

3. Once the northwest, southwest and southeast corners were thus located, the same process was used to locate the northeast corner, where the final stake was placed. This procedure was then repeated for the remaining 9 lysimeter plots.

This 'rectangulation' method was quite accurate, meaning that each of the 10 plots should be very close to exactly 2.5 x 4 meters, with right angles at each corner.

Spreading of the topsoil and the amendments

On Friday 5/10/96, Paul Eger, Jon Wagner and Kim Hennings (DNR, Division of Fish & Wildlife) spread topsoil (a.k.a. "black sand") and soil amendments on the lysimeter plots. The weather was partly cloudy, with temperatures of approximately 50° and no rain.

On Wednesday 5/8/96, a load of black sand (i.e. "topsoil") was trucked over to the lysimeter plots from the topsoil pile that is located adjacent to the pit entrance. (This same material was used to fill in the large erosion gullies present on the demonstration plots prior to grading of the plots.) On 5/10/96, Dennis Kilmer (from Shiely) used his bobcat to drop loads of this material onto the 10 individual lysimeter plots. He approached the plots from the outside, and generally placed about two bucketfuls on each side of the lysimeter pipe. Our goal was to place a 6" layer of black sand on the plots, and Dennis said that it took him a total of about 4.5 loads per plot to accomplish this. After the loads were dropped onto the plots, Dennis used the bobcat to backdrag the topsoil to get a fairly flat layer, and then garden rakes were used to even it out further and make it as close to level (and 6" deep) as possible.

Once all 10 plots were thus covered with topsoil, the buffer areas between the plots and around the outside of the plots were similarly filled in with topsoil by the bobcat. The 2.5 meter-long strips between the short ends of the plots were filled in first, and then the long (28 m) strip in the center was filled in. This procedure allowed Dennis to fill in all of the buffer areas without compacting it with his bobcat treads, which was desirable because the plots themselves weren't compacted by the bobcat, and the idea was to have one large area with similar hydrologic (i.e. soil compaction) properties, as opposed to 10 less-compacted "islands" within a larger compacted area.

The next step was to cover the plots with the amendments (N-Viro, MSW+fertilizer, and plain fertilizer). Each of these three amendments was placed in three separate plots, for a total of nine plots; the order of these plots was determined by a random draw. It was decided to cover the tenth plot with plain MSW (i.e. with no fertilizer), to compare against the MSW+fertilizer. This tenth plot won't be useful for quantitative observations because of its lack of replicates, but it will be interesting nonetheless to qualitatively observe any differences between this plot and the MSW+fertilizer plots.

Application rates of the MSW and N-Viro were calculated so as to be the same as the rates used on the large demonstration plots. A 5-gallon plastic pail was weighed empty, and then was weighed while filled with the amendments. Calculations (shown below) indicated that 6.6 pails of material was needed for each plot. This was surprising because the N-Viro is noticeably denser and heavier than the MSW, but its application rate is lower than MSW, and by coincidence the requirement for both materials turned out to be 6.6 pails per plot.

6.6 pails of each amendment was then hand-placed on the appropriate plots, and then fertilizer was placed onto the topsoil and the MSW plots (with the MSW plots receiving a half-rate application as compared to the topsoil plots). The topsoil plots each received fertilizer at a rate of 165 lbs/acre, and the MSW plots each received 85 lbs/acre of fertilizer (the same rates as used on the demonstration plots). The fertilizer used was also the same as used on the large demonstration plots, which was 12:12:12 NPK.

The final step then was to till in the amendments to ensure that they didn't remain as a distinct layer on top of the topsoil. An effort was made to use a garden tiller to accomplish this, but it was then discovered that the tiller was assembled incorrectly, with the tiller blades put on backwards so that efforts to till the materials instead resulted in sizeable trenches. It was then decided to mix in the amendments as well as possible with the garden rakes, and on Monday 5/13/96 a different tiller was brought in to do the tilling.

Appendix 9

1996 Timeline

Appendix 9

Chronology of events at Nelson Mine in May 1996:

Prior to April 25	Planning meetings with DNR, N-Viro MN, Shiely personnel.
April 25	Lysimeter plots: stripped about 18 total inches of topsoil (6-8") and subsoil (~12"), installed lysimeter pans (lowest corner of the bottom at 18" below grade), placed 3" of filter sand placed in bottom of lysimeter, mixed about 1" of fine sand (subsoil) with the top 1" of sand in the pan to minimize the transition in hydraulic conductivity between the subsoil and filter sand. Pans were then backfilled with bobcat, the area was manually tamped to compact, then a 6" layer of topsoil was dropped onto the plots with the bobcat, with care taken not to compact the plots. Topsoil was then placed in the buffer areas between the plots with the bobcat. Allowed to settle.
May 3:	Staked lysimeter plots. Measured the demo slope dimensions, and placed flagged stakes every 100 meters along top road. Painted stakes then placed to indicate plot dimensions.
May 7:	First loads of MSW and first load of N-Viro dropped off. This is first day road restrictions were off.
May 8:	Loader loaded "topsoil" from topsoil stockpile near pit entrance into a "uke", which then deposited the material in vertical rows atop the demonstration plots. This was done to fill in the large erosion rills present on the slope.
May 8:	Finished placing "topsoil" rows on the slope; horizontal grading completed.
May 9:	Spreading of MSW, N-Viro and fertilizer on appropriate slopes. Disking in of the amendments. Creation of the two long trench/berms.
May 10:	Subsoil sample collected from lysimeter plot area; a composite of 13 samples from the area between the plots, collected a depth of 0 to 9" below the surface. Placing/spreading of topsoil on lysimeter plots, followed by placement/spreading of amendments and fertilizer on appropriate plots. Material was weighed in 5 gallon buckets, and manually spread. Fertilizer weighed and spread manually also. Tilling in attempted, but tiller didn't work correctly so rakes were used to mix in the amendments as well as possible. Collected a composite sample of both MSW and N-Viro from respective stockpiles as the material was moved to the plots.

May 13	Demonstration area was seeded. On top 1/3 of the slope the seed was broadcast, while for lower 2/3 rd's, the native seed mix was drilled in with a Truax seed drill by MnDOT. All lysimeter plots were tilled with a rear tine roto-tiller, with the tines set to only till topsoil; disturbance of subsoil was minimal. Seeded lysimeters plots by hand, raked seeds lightly to cover. Seeded 15 plots in the waste sand plot matrix, then raked seeds lightly to cover. Rain.
May 14	Straw mulch applied to demo area. Specifications called for 2 tons/ acre, actual effective cover approximately 1 to 1.5 tons/acre. (Dennis Kilmer estimated that the contractor left with about 1/4 - 1/3 of the straw). The lower 2/3 rd's of slope had lowest coverage. Mulched lysimeter plots (1/4 bale of straw per plot), spread erosion net and staked. Constructed additional topsoil plots at washed sand site; sites were outside of U of M matrix, plots had 4"topsoil and fertilizer was raked into soil.
May 15:	Mulched and netted all washed sand plots except for the three topsoil+fertilize plots that were constructed after the original 15 plots. Seeded topsoil+fertilizer plots. Rain gauge installation. Rain.
May 17	Mulched and netted the three topsoil+fertilizer plots on washed sand pile.
May 18:	Netting of final two topsoil plots on the washed sand pile. Checked rain gauge; working ok. Interviewed candidates for student worker position (to work on Shiely project).
May 20:	Major storm with extremely strong winds came through early morning of Sunday.
May 21:	Inspection of storm damage and plot status. Located scattered pieces of rain gauge, brought back to DNR building. Spoke with 4-wheeler near demo plots who asked if it would be ok to drive on demo slope!
May 23:	Set up rain gauge 11am Tuesday. Inspected veg. growth on demo slopes and lysimeter plots.
May 29	Erosion net had blown off the northern-most plot in row 2, and had pushed the mulch into a pile, the mulch was redistributed and the netting restaked. Shot videotape of area.
July 5	Video taken of demonstration area.
July 10	Steve Dewar (Hibbing MDNR Minerals) inspected demo plots.
June 13- June 18	Rain gage malfunctioned. (Pen was lodged under rotating drum.)

July 16	Video taken of lysimeter and washed sand plots.
Aug 1	Inspected demo slope; no odors detected despite ~0.5" of rain in last week.
Aug 6-8	Percent cover estimates and biomass samples collected from demo plots.
Aug 7	Percent cover estimates and biomass samples collected from lysimeter plots.
Aug 16	Percent cover estimates and biomass samples collected from washed sand plots.
Aug 29-Sep 11	Rain gage malfunctioned. (A screw on the windup motor came loose.)
Oct 17	Inspected demo slope; noticed filling-in of ditches, but brought no camera.
Oct 26	Videotape made of demo plots, showing filling-in of ditches on control and fertilizer plots. Saw grass-like species coming up, particularly on top 1/3 of slope. No odors despite much recent rain. Placed pink flags at erosion channels on demo slope.
Nov 7	Winterized the gain gage. (Put up rain shield, added antifreeze, calibrated.)

(The lysimeter plots were also visited approximately once every 7-10 days throughout the season to wind up the rain gage, and the demo and washed sand plots were also frequently inspected during these trips.)

Appendix 10

Precipitation Data

Appendix 10

Precipitation Data

A continuously-recording rain gage was set up on the lysimeter plots on Wednesday 5/15/96, after the seeding and mulching of the plots was completed. Except for a few time periods when the gage malfunctioned, daily precipitation data was collected though November 6, at which time the gage was winterized by the addition of antifreeze and construction of a wind shield; this data is presented in Table A10.1. (It should be noted that though the rain gage wasn't set up till May 15, the amendments were spread on the lysimeter plots on Friday 5/10/96, and the plots received a considerable amount of rain on Monday and Tuesday (5/13 and 5/14). The times when the meter malfunctioned were:

1) <u>May 15-22.</u> A major wind storm (with winds that were reported to have approached 100 mph) blew through the area at about 1 am on Sunday, May 15 and knocked over the rain gage, scattering pieces of the gage around the surrouding area. The gage was repaired and set up again by 11 am Wednesday 5/22/96. Greg Spoden of the State Climatologist's Office (email address gspoden@Soils.Umn.EDU) was contacted and asked to estimate rainfall during this time period.

   Greg checked the Internet for estimates that are derived from radar observations. These data indicated that for the 24-hour period ending at 5 am Sunday 5/19/96, between 0.75" and 1.00" of rain fell on lower Grey Cloud Island (location of the rain gage). For the next 24-hour period (ending 5 am Monday 5/20/96), less than 0.10" of rain fell; Greg said, to be on the safe side, to round this off to 0.10". No rain was reported for the next 3 days.

   Greg also said that the State Climatologist's office has a rain gage set up at the Rosemount monitoring station, which is across the Mississippi River from Grey Cloud Island. These data are collected at 5 pm, and for the period of 5 pm Saturday 5/18/96 through 5 pm Sunday 5/19/96, 0.77" of rain fell; this estimate agrees well with the data derived from the radar estimates. No rain was reported at Rosemount for the next three days. (It should be noted, that for the time period of 5 pm Friday 5/17/96 through 5 pm Saturday 5/18/96, 0.15" of rain was collected at Rosemount, but this rain was not related to the big storm that blew through late Saturday night or early Sunday morning.)

   Though localized weather patterns can vary considerably from nearby areas, these data seemed to be reasonable (and were the best available), and were used to fill in the missing data. On Monday 6/3/96 a cheap plastic rain gage was set up at the lysimeter plots to serve as emergency backup in the event that the main rain gage gets knocked over again. (Wood stakes were also then driven into the ground in a circle around the base of the gage for support purposes, so hopefully this will be a one-time event.)

2. <u>June 13-18.</u> On Thursday, June 13 (at 11 am), a new chart was installed in the continuous-recording rain gage, and the ink needle was correctly placed on the chart. However, when the meter was then inspected on Tuesday, June 18 (about 11 am), it was

discovered that the needle had somehow become lodged beneath the rotating drum, so that no rain was recorded during the June 13-18 interval. Glenn Melchert (DNR-Minerals hydrologist; Hibbing) suggested that the needle may have become thus lodged when the bucket and cover piece were placed onto the top of the gage; he suggests that the **last** thing to do at the rain gage is to set the needle (i.e. after the bucket and cover are put back).

The cheap plastic rain gage set up at the site indicated that a total of 1.3" of rain fell during June 13-18. The corresponding Rosemount data totalled approximately 1.5", and was used to fill in the missing data.

3. August 29 - September 11. The rain gage motor was wound up at 11 am on August 29, and appeared to be in good operating order. However, when the gage was next checked it was discovered that the motor had malfunctioned, and no data was collected. The motor was removed and repaired (a small screw in the wind-up mechanism had come loose), and replaced on September 12. Again, Rosemount data was used to fill in the gap.

Table A10.1. 1996 precipitation data from the Shiely rain gage.

(Precipitation data from the Shiely rain gage are unavailable for three periods during the 1996 field season due to gage malfunctions, and prior to May 15. Data from the Rosemount weather station is therefore also presented so it can be used to fill in these gaps in the Shiely data.)

Date	Shiely[A] precip. (in.)	Rosemount[B] precip. (in.)	Combined[C] precip. (in.)	Combined[D] sum (in.)	Rosemount[E] sum (in.)
5 1 96	.	0.00	0.00	0.00	0.00
5 2 96	.	0.17	0.17	0.17	0.17
5 3 96	.	0.38	0.38	0.55	0.55
5 4 96	.	0.00	0.00	0.55	0.55
5 5 96	.	0.44	0.44	0.99	0.99
5 6 96	.	0.00	0.00	0.99	0.99
5 7 96	.	0.03	0.03	1.02	1.02
5 8 96	.	0.18	0.18	1.20	1.20
5 9 96	.	0.02	0.02	1.22	1.22
5 10 96	.	0.44	0.44	1.66	1.66
5 11 96	.	0.00	0.00	1.66	1.66
5 12 96	.	0.00	0.00	1.66	1.66
5 13 96	.	0.00	0.00	1.66	1.66
5 14 96	.	0.41	0.41	2.07	2.07
5 15 96	0.00	0.06	0.00	2.07	2.13
5 16 96	0.00	0.00	0.00	2.07	2.13
5 17 96	0.00	0.00	0.00	2.07	2.13
5 18 96	0.15	0.15	0.15	2.22	2.28
5 19 96	0.77	0.77	0.77	2.99	3.05
5 20 96	0.00	0.00	0.00	2.99	3.05
5 21 96	0.00	0.00	0.00	2.99	3.05
5 22 96	0.00	0.00	0.00	2.99	3.05
5 23 96	0.00	0.03	0.00	2.99	3.08
5 24 96	0.00	0.00	0.00	2.99	3.08
5 25 96	0.00	0.05	0.00	2.99	3.13
5 26 96	0.00	0.00	0.00	2.99	3.13
5 27 96	0.00	0.00	0.00	2.99	3.13
5 28 96	0.00	0.00	0.00	2.99	3.13
5 29 96	0.00	0.00	0.00	2.99	3.13
5 30 96	0.00	0.00	0.00	2.99	3.13
5 31 96	0.00	0.00	0.00	2.99	3.13
6 1 96	0.10	0.14	0.10	3.09	3.27
6 2 96	0.00	0.03	0.00	3.09	3.30
6 3 96	0.00	0.09	0.00	3.09	3.39
6 4 96	0.00	0.00	0.00	3.09	3.39
6 5 96	0.20	0.09	0.20	3.29	3.48
6 6 96	0.90	1.17	0.90	4.19	4.65
6 7 96	0.00	0.06	0.00	4.19	4.71
6 8 96	0.00	0.00	0.00	4.19	4.71
6 9 96	0.00	0.00	0.00	4.19	4.71
6 10 96	0.00	0.00	0.00	4.19	4.71
6 11 96	0.00	0.00	0.00	4.19	4.71
6 12 96	0.00	0.00	0.00	4.19	4.71
6 13 96	0.00	0.00	0.00	4.19	4.71
6 14 96	.	0.00	0.00	4.19	4.71
6 15 96	.	0.29	0.29	4.48	5.00
6 16 96	.	0.56	0.56	5.04	5.56
6 17 96	.	0.63	0.63	5.67	6.19
6 18 96	0.00	0.11	0.00	5.67	6.30
6 19 96	0.00	0.02	0.00	5.67	6.32
6 20 96	0.00	0.00	0.00	5.67	6.32
6 21 96	0.40	0.43	0.40	6.07	6.75
6 22 96	0.00	0.00	0.00	6.07	6.75
6 23 96	0.05	0.11	0.05	6.12	6.86

Date	Shiely[A] precip. (in.)	Rosemount[B] precip. (in.)	Combined[C] precip. (in.)	Combined[D] sum (in.)	Rosemount[E] sum (in.)
6 24 96	0.00	0.02	0.00	6.12	6.88
6 25 96	0.00	0.00	0.00	6.12	6.88
6 26 96	0.00	0.00	0.00	6.12	6.88
6 27 96	0.00	0.00	0.00	6.12	6.88
6 28 96	0.00	0.00	0.00	6.12	6.88
6 29 96	0.00	0.14	0.00	6.12	7.02
6 30 96	0.00	0.00	0.00	6.12	7.02
7 1 96	0.00	0.00	0.00	6.12	7.02
7 2 96	0.00	0.01	0.00	6.12	7.03
7 3 96	0.00	0.00	0.00	6.12	7.03
7 4 96	0.00	0.00	0.00	6.12	7.03
7 5 96	0.00	0.00	0.00	6.12	7.03
7 6 96	0.60	0.55	0.60	6.72	7.58
7 7 96	0.00	0.05	0.00	6.72	7.63
7 8 96	0.00	0.00	0.00	6.72	7.63
7 9 96	0.10	0.10	0.10	6.82	7.73
7 10 96	0.00	0.00	0.00	6.82	7.73
7 11 96	0.00	0.19	0.00	6.82	7.92
7 12 96	0.00	0.01	0.00	6.82	7.93
7 13 96	0.00	0.00	0.00	6.82	7.93
7 14 96	0.00	0.00	0.00	6.82	7.93
7 15 96	0.00	0.04	0.00	6.82	7.97
7 16 96	0.00	0.00	0.00	6.82	7.97
7 17 96	0.00	0.00	0.00	6.82	7.97
7 18 96	0.00	0.00	0.00	6.82	7.97
7 19 96	0.00	0.00	0.00	6.82	7.97
7 20 96	0.00	0.00	0.00	6.82	7.97
7 21 96	0.00	0.00	0.00	6.82	7.97
7 22 96	0.00	0.11	0.00	6.82	8.08
7 23 96	0.00	0.00	0.00	6.82	8.08
7 24 96	0.15	0.28	0.15	6.97	8.36
7 25 96	0.00	0.10	0.00	6.97	8.46
7 26 96	0.00	0.00	0.00	6.97	8.46
7 27 96	0.50	0.00	0.50	7.47	8.46
7 28 96	0.00	0.03	0.00	7.47	8.49
7 29 96	0.05	0.20	0.05	7.52	8.69
7 30 96	0.00	0.02	0.00	7.52	8.71
7 31 96	0.00	0.01	0.00	7.52	8.72
8 1 96	0.00	0.00	0.00	7.52	8.72
8 2 96	0.00	0.00	0.00	7.52	8.72
8 3 96	0.00	0.00	0.00	7.52	8.72
8 4 96	0.00	0.00	0.00	7.52	8.72
8 5 96	0.40	0.61	0.40	7.92	9.33
8 6 96	0.40	0.00	0.40	8.32	9.33
8 7 96	0.25	0.48	0.25	8.57	9.81
8 8 96	0.00	0.00	0.00	8.57	9.81
8 9 96	0.00	0.00	0.00	8.57	9.81
8 10 96	0.00	0.01	0.00	8.57	9.82
8 11 96	0.00	0.00	0.00	8.57	9.82
8 12 96	0.00	0.00	0.00	8.57	9.82
8 13 96	0.00	0.00	0.00	8.57	9.82
8 14 96	0.00	0.00	0.00	8.57	9.82
8 15 96	0.00	0.00	0.00	8.57	9.82
8 16 96	0.00	0.00	0.00	8.57	9.82
8 17 96	0.00	0.00	0.00	8.57	9.82
8 18 96	0.00	0.00	0.00	8.57	9.82
8 19 96	0.75	0.90	0.75	9.32	10.72
8 20 96	0.00	0.01	0.00	9.32	10.73
8 21 96	0.00	0.00	0.00	9.32	10.73
8 22 96	0.40	0.28	0.40	9.72	11.01
8 23 96	0.00	0.00	0.00	9.72	11.01
8 24 96	0.00	0.00	0.00	9.72	11.01
8 25 96	0.00	0.00	0.00	9.72	11.01
8 26 96	0.10	1.83	0.10	9.82	12.84
8 27 96	0.00	0.00	0.00	9.82	12.84
8 28 96	0.00	0.00	0.00	9.82	12.84
8 29 96	.	0.00	0.00	9.82	12.84

Date	Shiely[A] precip. (in.)	Rosemount[B] precip. (in.)	Combined[C] precip. (in.)	Combined[D] sum (in.)	Rosemount[E] sum (in.)
8 30 96	.	0.00	0.00	9.82	12.84
8 31 96	.	0.00	0.00	9.82	12.84
9 1 96	.	0.00	0.00	9.82	12.84
9 2 96	.	0.21	0.21	10.03	13.05
9 3 96	.	0.06	0.06	10.09	13.11
9 4 96	.	0.00	0.00	10.09	13.11
9 5 96	.	0.00	0.00	10.09	13.11
9 6 96	.	0.00	0.00	10.09	13.11
9 7 96	.	0.00	0.00	10.09	13.11
9 8 96	.	0.02	0.02	10.11	13.13
9 9 96	.	0.00	0.00	10.11	13.13
9 10 96	.	0.01	0.01	10.12	13.14
9 11 96	.	0.00	0.00	10.12	13.14
9 12 96	0.00	0.00	0.00	10.12	13.14
9 13 96	0.00	0.00	0.00	10.12	13.14
9 14 96	0.00	0.00	0.00	10.12	13.14
9 15 96	0.00	0.00	0.00	10.12	13.14
9 16 96	0.00	0.00	0.00	10.12	13.14
9 17 96	0.00	0.00	0.00	10.12	13.14
9 18 96	0.00	0.00	0.00	10.12	13.14
9 19 96	0.00	0.00	0.00	10.12	13.14
9 20 96	0.40	0.52	0.40	10.52	13.66
9 21 96	0.20	0.13	0.20	10.72	13.79
9 22 96	0.00	0.06	0.00	10.72	13.85
9 23 96	0.00	0.00	0.00	10.72	13.85
9 24 96	0.00	0.07	0.00	10.72	13.92
9 25 96	0.05	0.00	0.05	10.77	13.92
9 26 96	0.40	0.36	0.40	11.17	14.28
9 27 96	0.00	0.15	0.00	11.17	14.43
9 28 96	0.00	0.02	0.00	11.17	14.45
9 29 96	0.00	0.08	0.00	11.17	14.53
9 30 96	0.00	0.00	0.00	11.17	14.53
10 1 96	0.00	0.00	0.00	11.17	14.53
10 2 96	0.00	0.00	0.00	11.17	14.53
10 3 96	0.00	0.00	0.00	11.17	14.53
10 4 96	0.00	0.00	0.00	11.17	14.53
10 5 96	0.00	0.00	0.00	11.17	14.53
10 6 96	0.00	0.00	0.00	11.17	14.53
10 7 96	0.00	0.00	0.00	11.17	14.53
10 8 96	0.00	0.00	0.00	11.17	14.53
10 9 96	0.00	0.00	0.00	11.17	14.53
10 10 96	0.00	0.02	0.00	11.17	14.55
10 11 96	0.00	0.00	0.00	11.17	14.55
10 12 96	0.00	0.00	0.00	11.17	14.55
10 13 96	0.00	0.00	0.00	11.17	14.55
10 14 96	0.00	0.00	0.00	11.17	14.55
10 15 96	0.00	0.11	0.00	11.17	14.66
10 16 96	1.25	0.00	1.25	12.42	14.66
10 17 96	0.80	3.40	0.80	13.22	18.06
10 18 96	0.00	0.01	0.00	13.22	18.07
10 19 96	0.00	0.00	0.00	13.22	18.07
10 20 96	0.00	0.01	0.00	13.22	18.08
10 21 96	0.00	0.00	0.00	13.22	18.08
10 22 96	0.00	0.07	0.00	13.22	18.15
10 23 96	1.10	0.94	1.10	14.32	19.09
10 24 96	0.00	0.00	0.00	14.32	19.09
10 25 96	0.00	0.00	0.00	14.32	19.09
10 26 96	0.00	0.00	0.00	14.32	19.09
10 27 96	0.00	0.00	0.00	14.32	19.09
10 28 96	0.00	0.00	0.00	14.32	19.09
10 29 96	1.15	0.99	1.15	15.47	20.08
10 30 96	0.30	0.10	0.30	15.77	20.18
10 31 96	0.00	0.00	0.00	15.77	20.18
11 1 96	0.00	0.00	0.00	15.77	20.18
11 2 96	0.00	0.00	0.00	15.77	20.18
11 3 96	0.35	0.00	0.35	16.12	20.18
11 4 96	0.00	0.28	0.00	16.12	20.46

Date	Shiely[A] precip. (in.)	Rosemount[B] precip. (in.)	Combined[C] precip. (in.)	Combined[D] sum (in.)	Rosemount[E] sum (in.)
11 5 96	0.00	0.01	0.00	16.12	20.47
11 6 96	0.00	0.03	0.00	16.12	20.50

A: Data from the rain gage at the lysimeter plots.
B: Data from the Rosemount weather monitoring station.
C: Data from the lysimeter plots, with gaps filled in with Rosemount data.
D: The sum of the previous column (i.e. Shiely data, with gaps filled in with Rosemount data).
E: The sum of the Rosemount data.

Table A10.2. 1996 climate data from the Rosemount Agricultural Experimental Station. (This includes high and low air temperatures as well as precipitation.)

ROSEMOUNT_AGRI_EXP_STN (217107) 1961-1990 Normals from NCDC

Total Precipitation (inches)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1.06	0.94	2.13	2.87	3.92	4.31	4.03	3.97	3.56	2.56	1.84	1.23	32.42

STATION: ROSEMOUNT_AGRI_EXP_STN (Station ID: 217107)

Year	Mo	Dy	High (F)	Low (F)	Precipitation (in)	Snow Fall (in)	Snow Depth (in)
1996	01	01	32	27	0.04	0.3	8
1996	01	02	30	13	0.05	0.7	9
1996	01	03	13	-12	0.00	0.0	9
1996	01	04	20	2	0.00	0.0	9
1996	01	05	8	-14	0.00	0.0	9
1996	01	06	7	-24	0.00	0.0	9
1996	01	07	2	-22	0.00	0.0	9
1996	01	08	20	-6	0.00	0.0	9
1996	01	09	35	15	0.00	0.0	9
1996	01	10	29	5	0.06	0.5	9
1996	01	11	27	21	0.49	5.0	14
1996	01	12	40	16	0.00	0.0	13
1996	01	13	41	20	0.00	0.0	12
1996	01	14	31	11	0.00	0.0	12
1996	01	15	17	-3	0.00	0.0	12
1996	01	16	33	17	0.03	0.0	11
1996	01	17	32	19	0.09	0.0	11
1996	01	18	34	0	1.44	1.0	11
1996	01	19	1	-18	0.02	0.2	11
1996	01	20	3	-17	0.00	0.0	11
1996	01	21	26	-1	0.00	0.0	11
1996	01	22	25	6	0.00	0.0	11
1996	01	23	8	-6	0.00	0.0	11
1996	01	24	15	-3	0.00	0.0	11
1996	01	25	10	-10	0.15	1.5	12
1996	01	26	6	-9	0.01	0.1	12
1996	01	27	13	-4	0.12	0.4	12
1996	01	28	16	-12	0.11	0.9	13
1996	01	29	21	-9	0.16	1.8	14
1996	01	30	-7	-22	0.00	0.0	14
1996	01	31	1	-29	0.00	0.0	14
1996	02	01	-2	-29	0.00	0.0	14
1996	02	02	-15	-37	0.00	0.0	14
1996	02	03	-11	-30	0.00	0.0	13
1996	02	04	2	-27	0.00	0.0	13
1996	02	05	11	-9	0.00	0.0	13
1996	02	06	26	-8	0.00	0.0	13
1996	02	07	40	24	0.00	0.0	12
1996	02	08	44	31	0.00	0.0	10
1996	02	09	40	19	0.00	0.0	10
1996	02	10	41	31	0.07	0.5	10
1996	02	11	32	25	0.00	0.0	10
1996	02	12	27	15	0.00	0.0	10
1996	02	13	38	16	0.00	0.0	10
1996	02	14	35	23	T	0.0	10
1996	02	15	30	9	T	0.0	10
1996	02	16	20	-8	0.00	0.0	10
1996	02	17	25	14	0.00	0.0	10
1996	02	18	22	-2	0.01	0.1	10

Year	Mo	Dy	High (F)	Low (F)	Precip-itation (in)	Snow Fall (in)	Snow Depth (in)
1996	02	19	39	21	0.00	0.0	9
1996	02	20	39	30	0.00	0.0	8
1996	02	21	32	11	0.00	0.0	8
1996	02	22	34	23	0.03	0.0	7
1996	02	23	40	33	0.04	0.0	6
1996	02	24	47	27	0.00	0.0	5
1996	02	25	40	27	0.00	0.0	4
1996	02	26	34	20	0.00	0.0	4
1996	02	27	24	12	0.02	0.0	4
1996	02	28	13	2	0.01	0.1	4
1996	02	29	21	-8	0.00	0.0	4
1996	03	01	25	5	0.00	0.0	4
1996	03	02	20	-2	0.01	0.0	4
1996	03	03	23	-9	0.00	0.0	4
1996	03	04	25	7	0.05	0.9	5
1996	03	05	26	15	0.00	0.0	5
1996	03	06	20	6	0.07	0.8	6
1996	03	07	8	-7	0.00	0.0	6
1996	03	08	18	-8	0.00	0.0	6
1996	03	09	26	-3	0.00	0.0	6
1996	03	10	41	12	0.00	0.0	5
1996	03	11	45	33	0.00	0.0	4
1996	03	12	49	36	0.00	0.0	2
1996	03	13	57	33	0.00	0.0	0
1996	03	14	51	34	0.00	0.0	0
1996	03	15	46	30	0.00	0.0	0
1996	03	16	46	26	0.00	0.0	0
1996	03	17	44	27	0.00	0.0	0
1996	03	18	35	25	T	0.0	0
1996	03	19	37	22	0.03	0.3	0
1996	03	20	37	23	0.00	0.0	0
1996	03	21	39	13	0.00	0.0	0
1996	03	22	44	18	0.00	0.0	0
1996	03	23	42	23	0.00	0.0	0
1996	03	24	38	27	1.51	5.5	5
1996	03	25	27	10	0.51	5.0	10
1996	03	26	12	-12	0.00	0.0	10
1996	03	27	35	0	0.00	0.0	8
1996	03	28	41	19	0.00	0.0	6
1996	03	29	45	26	0.00	0.0	4
1996	03	30	44	34	0.00	0.0	2
1996	03	31	39	21	0.00	0.0	1
1996	04	01	40	23	0.00	0.0	0
1996	04	02	47	31	0.00	0.0	0
1996	04	03	46	31	M	0.0	0
1996	04	04	44	25	0.00	0.0	0
1996	04	05	42	22	0.00	0.0	0
1996	04	06	42	23	0.00	0.0	0
1996	04	07	40	22	0.00	0.0	0
1996	04	08	46	23	0.00	0.0	0
1996	04	09	53	24	0.00	0.0	0
1996	04	10	66	31	0.00	0.0	0
1996	04	11	69	43	0.00	0.0	0
1996	04	12	64	30	0.06	0.0	0
1996	04	13	37	24	0.00	0.0	0
1996	04	14	38	27	0.03	0.0	0
1996	04	15	52	30	0.16	1.5	0
1996	04	16	53	30	0.01	0.0	0
1996	04	17	68	31	0.00	0.0	0
1996	04	18	68	49	0.03	0.0	0
1996	04	19	71	39	0.09	0.0	0
1996	04	20	68	37	0.00	0.0	0
1996	04	21	60	29	0.13	0.0	0
1996	04	22	51	29	0.00	0.0	0
1996	04	23	60	26	0.00	0.0	0
1996	04	24	67	33	0.16	0.0	0
1996	04	25	66	50	0.05	0.0	0

Year	Mo	Dy	High (F)	Low (F)	Precip-itation (in)	Snow Fall (in)	Snow Depth (in)
1996	04	26	58	28	0.06	0.0	0
1996	04	27	52	27	0.00	0.0	0
1996	04	28	59	29	0.00	0.0	0
1996	04	29	53	44	0.00	0.0	0
1996	04	30	59	29	0.00	0.0	0
1996	05	01	59	30	0.00	0.0	0
1996	05	02	58	29	0.17	0.0	0
1996	05	03	57	36	0.38	0.0	0
1996	05	04	59	42	0.00	0.0	0
1996	05	05	55	39	0.44	0.0	0
1996	05	06	48	33	T	0.0	0
1996	05	07	61	40	0.03	0.0	0
1996	05	08	61	49	0.18	0.0	0
1996	05	09	56	47	0.02	0.0	0
1996	05	10	55	42	0.44	0.0	0
1996	05	11	55	35	0.00	0.0	0
1996	05	12	57	31	0.00	0.0	0
1996	05	13	61	32	0.00	0.0	0
1996	05	14	60	45	0.41	0.0	0
1996	05	15	60	45	0.06	0.0	0
1996	05	16	72	55	T	0.0	0
1996	05	17	81	59	T	0.0	0
1996	05	18	86	60	0.15	0.0	0
1996	05	19	82	59	0.77	0.0	0
1996	05	20	74	56	0.00	0.0	0
1996	05	21	74	49	0.00	0.0	0
1996	05	22	74	50	0.00	0.0	0
1996	05	23	71	52	0.03	0.0	0
1996	05	24	65	49	0.00	0.0	0
1996	05	25	64	47	0.05	0.0	0
1996	05	26	57	48	T	0.0	0
1996	05	27	59	48	0.00	0.0	0
1996	05	28	73	49	0.00	0.0	0
1996	05	29	73	47	0.00	0.0	0
1996	05	30	75	45	0.00	0.0	0
1996	05	31	73	48	0.00	0.0	0
1996	06	01	73	60	0.14	0.0	0
1996	06	02	71	50	0.03	0.0	0
1996	06	03	62	51	0.09	0.0	0
1996	06	04	63	44	0.00	0.0	0
1996	06	05	67	44	0.09	0.0	0
1996	06	06	70	51	1.17	0.0	0
1996	06	07	71	52	0.06	0.0	0
1996	06	08	76	46	0.00	0.0	0
1996	06	09	81	51	0.00	0.0	0
1996	06	10	79	54	0.00	0.0	0
1996	06	11	80	60	0.00	0.0	0
1996	06	12	89	61	0.00	0.0	0
1996	06	13	89	62	0.00	0.0	0
1996	06	14	84	57	0.00	0.0	0
1996	06	15	87	64	0.29	0.0	0
1996	06	16	72	66	0.56	0.0	0
1996	06	17	69	63	0.63	0.0	0
1996	06	18	64	59	0.11	0.0	0
1996	06	19	72	62	0.02	0.0	0
1996	06	20	78	62	0.00	0.0	0
1996	06	21	79	62	0.43	0.0	0
1996	06	22	73	54	0.00	0.0	0
1996	06	23	78	55	0.11	0.0	0
1996	06	24	78	55	0.02	0.0	0
1996	06	25	82	56	0.00	0.0	0
1996	06	26	84	67	0.00	0.0	0
1996	06	27	92	68	0.00	0.0	0
1996	06	28	95	73	0.00	0.0	0
1996	06	29	95	75	0.14	0.0	0
1996	06	30	84	67	0.00	0.0	0
1996	07	01	83	59	0.00	0.0	0

Year	Mo	Dy	High (F)	Low (F)	Precip-itation (in)	Snow Fall (in)	Snow Depth (in)
1996	07	02	82	62	0.01	0.0	0
1996	07	03	81	58	0.00	0.0	0
1996	07	04	83	59	0.00	0.0	0
1996	07	05	85	60	0.00	0.0	0
1996	07	06	84	66	0.55	0.0	0
1996	07	07	81	58	0.05	0.0	0
1996	07	08	79	59	0.00	0.0	0
1996	07	09	72	54	0.10	0.0	0
1996	07	10	77	49	0.00	0.0	0
1996	07	11	76	59	0.19	0.0	0
1996	07	12	76	60	0.01	0.0	0
1996	07	13	76	58	0.00	0.0	0
1996	07	14	76	55	0.00	0.0	0
1996	07	15	79	60	0.04	0.0	0
1996	07	16	88	58	0.00	0.0	0
1996	07	17	87	69	0.00	0.0	0
1996	07	18	89	72	0.00	0.0	0
1996	07	19	79	67	0.00	0.0	0
1996	07	20	75	57	0.00	0.0	0
1996	07	21	80	64	0.00	0.0	0
1996	07	22	80	61	0.11	0.0	0
1996	07	23	82	55	0.00	0.0	0
1996	07	24	81	58	0.28	0.0	0
1996	07	25	79	55	0.10	0.0	0
1996	07	26	80	54	0.00	0.0	0
1996	07	27	78	57	0.00	0.0	0
1996	07	28	77	63	0.03	0.0	0
1996	07	29	73	57	0.20	0.0	0
1996	07	30	77	51	0.02	0.0	0
1996	07	31	77	54	0.01	0.0	0
1996	08	01	82	53	0.00	0.0	0
1996	08	02	83	57	0.00	0.0	0
1996	08	03	83	60	0.00	0.0	0
1996	08	04	82	68	0.00	0.0	0
1996	08	05	82	69	0.61	0.0	0
1996	08	06	91	66	0.00	0.0	0
1996	08	07	90	64	0.48	0.0	0
1996	08	08	81	59	0.00	0.0	0
1996	08	09	80	53	0.00	0.0	0
1996	08	10	73	53	0.01	0.0	0
1996	08	11	80	60	0.00	0.0	0
1996	08	12	82	58	0.00	0.0	0
1996	08	13	85	62	0.00	0.0	0
1996	08	14	84	61	0.00	0.0	0
1996	08	15	80	57	0.00	0.0	0
1996	08	16	80	54	0.00	0.0	0
1996	08	17	82	55	0.00	0.0	0
1996	08	18	78	55	0.00	0.0	0
1996	08	19	76	67	0.90	0.0	0
1996	08	20	77	56	0.01	0.0	0
1996	08	21	86	60	0.00	0.0	0
1996	08	22	85	66	0.28	0.0	0
1996	08	23	80	53	0.00	0.0	0
1996	08	24	79	55	0.00	0.0	0
1996	08	25	87	58	0.00	0.0	0
1996	08	26	80	64	1.83	0.0	0
1996	08	27	73	51	0.00	0.0	0
1996	08	28	77	51	0.00	0.0	0
1996	08	29	79	54	0.00	0.0	0
1996	08	30	79	57	0.00	0.0	0
1996	08	31	80	57	0.00	0.0	0
1996	09	01	80	57	0.00	M	M
1996	09	02	82	65	0.21	M	M
1996	09	03	81	66	0.06	M	M
1996	09	04	84	64	0.00	M	M
1996	09	05	83	64	0.00	M	M
1996	09	06	82	61	0.00	M	M

Year	Mo	Dy	High (F)	Low (F)	Precip-itation (in)	Snow Fall (in)	Snow Depth (in)
1996	09	07	82	59	0.00	M	M
1996	09	08	69	62	0.02	M	M
1996	09	09	77	50	0.00	M	M
1996	09	10	83	50	0.01	M	M
1996	09	11	80	52	0.00	M	M
1996	09	12	64	48	0.00	M	M
1996	09	13	63	39	0.00	M	M
1996	09	14	70	36	0.00	M	M
1996	09	15	67	54	0.00	M	M
1996	09	16	66	53	0.00	M	M
1996	09	17	65	46	0.00	M	M
1996	09	18	72	44	0.00	M	M
1996	09	19	72	45	0.00	M	M
1996	09	20	67	53	0.52	M	M
1996	09	21	67	52	0.13	M	M
1996	09	22	70	47	0.06	M	M
1996	09	23	70	51	0.00	M	M
1996	09	24	68	42	0.07	M	M
1996	09	25	69	41	0.00	M	M
1996	09	26	66	47	0.36	M	M
1996	09	27	54	44	0.15	M	M
1996	09	28	67	45	0.02	M	M
1996	09	29	62	40	0.08	M	M
1996	09	30	68	47	0.00	M	M
1996	10	01	79	55	0.00	M	M
1996	10	02	73	43	0.00	M	M
1996	10	03	56	27	0.00	M	M
1996	10	04	61	36	0.00	M	M
1996	10	05	75	49	0.00	M	M
1996	10	06	69	55	0.00	M	M
1996	10	07	57	38	0.00	M	M
1996	10	08	58	28	0.00	M	M
1996	10	09	53	31	0.00	M	M
1996	10	10	57	29	0.02	M	M
1996	10	11	66	30	0.00	M	M
1996	10	12	78	43	0.00	M	M
1996	10	13	75	41	0.00	M	M
1996	10	14	70	49	0.00	M	M
1996	10	15	72	45	0.11	M	M
1996	10	16	76	40	0.00	M	M
1996	10	17	62	41	3.40	M	M
1996	10	18	52	35	0.01	M	M
1996	10	19	63	30	0.00	M	M
1996	10	20	60	43	0.01	M	M
1996	10	21	57	43	0.00	M	M
1996	10	22	50	35	0.07	M	M
1996	10	23	44	37	0.94	M	M
1996	10	24	44	35	0.00	M	M
1996	10	25	58	35	0.00	M	M
1996	10	26	65	53	0.00	M	M
1996	10	27	66	42	0.00	M	M
1996	10	28	66	27	0.00	M	M
1996	10	29	52	36	0.99	M	M
1996	10	30	55	23	0.10	M	M
1996	10	31	33	15	0.00	M	M
1996	11	01	32	16	0.00	M	M
1996	11	02	35	15	0.00	M	M
1996	11	03	57	22	0.00	M	M
1996	11	04	48	34	0.28	M	M
1996	11	05	45	39	0.01	M	M
1996	11	06	46	38	0.03	M	M
1996	11	07	49	29	0.00	M	M
1996	11	08	40	31	0.00	M	M
1996	11	09	34	24	0.00	M	M
1996	11	10	34	22	0.00	M	M

M = missing, e = estimated, T = trace

Appendix 11

Water Quality Samples; Collection and Analysis Techniques

Appendix 11

Water quality samples; collection and analysis techniques

No water samples were collected from the lysimeters during 1996 because of the extremely dry conditions; rain from May through September was only 56% of the 30-year average. The "extra" lysimeter plot was checked on a roughly weekly basis for the presence of water in the lysimeter pan, but no water was detected, even after a couple of precipitation events that totalled more than an inch of rain each. The peristaltic pump was also occasionally attached to the other lysimeters, in case there was something wrong with the lysimeter plumbing in the "extra" plot, but no water was detected in the other lysimeters either. It seems probable that the 18" of material on top of the lysimeter pans acted as a "sponge" that soaked up all available water before it could report to the lysimeter pan, despite the fact that most of this material is sand.

Hopefully, 1997 precipitation will be sufficient to allow collection of water samples, but even if samples are collected, the volume available for samples may be limited. Original plans were to analyze any samples collected for a large suite of parameters, but this plan may well have to be modified if only limited sample volume is available. If this is the case, that there is insufficient sample volume to permit the complete suite of desired paramaters to be analyzed, the parameters will need to be prioritized in order of importance, with some of the "less important" parameters being omitted for certain samples because of insufficient sample volume. The parameters can be broken down into four groups (listed below in descending order of importance), with each of these groups requiring a certain minimum sample volume:

- **Major anions; SO_4 and Cl.** This group requires a minimum of 100 mL.

- **Major cations + trace metals + Flame RCRA metals.** Parameters included in this group are the major cations Ca, Mg, Na and K, the trace metals Cu, Ni, Co and Zn, and the RCRA flame metals Cd, Cr, Pb, Ag, Ba. (RCRA metals are those that are required by the federal Resource Conservation and Recovery Act. "Flame" metals are analyzed with the atomic absorption method, but on a setting that produces results in the ppm range. which is less precise than the "furnace" setting, which can detect concentrations in the ppb range. 100 mL minimum volume.

- **Cold Vapor RCRA metals.** These include Hg, As and Se. Again, the atomic adsorption method is used, but in "furnace" mode, which produces more precise results than does the flame mode (i.e. ppb range in furnace mode, compared to ppm range for the flame mode.) 100 mL minimum volume.

- **Nutrients.** These include TKN (Total Kjeldahl Nitrogen), NO_2-NO_3 (nitrite-nitrate), NH_4 (ammonia) and TP (total phosphorous). These four require a total of at least 525 mL, but 250 of this is for TKN, which is therefore the first to go when sample volume becomes a problem.

Because the plots are small and in close proximity with each other, it is assumed that each plot receives roughly the same volume of precipitation, and that whatever volume is found to be in plot #10 will also be present in the other nine plots. Thus, if one liter of water was pumped from the extra plot, it will be assumed that about one liter is also present in the other plots, which would be more than enough to allow all parameters to be analyzed. (In this case, where more than enough sample volume is available to allow analysis of all parameters, a small amount of flow from the other plots could be allowed to discarded at the beginning of each pumping session, so that any contaminants present on the inside surfaces of the Tygon tubing could be rinsed away so that they don't compromise the results of the new samples.) However, if only a few ounces of water was pumped from #10, this tygon-rinsing step may have to be considered a luxury that can't be accommodated given the very limited sample volume that is likely to be present in the other plots.

The samples will be analyzed in the field for pH and specific conductance in the field, and then brought back to the St. Paul DNR Central Office, where they will be frozen and prepared for shipment to the Hibbing DNR-Minerals office, where the samples will be filtered, acidified and prepared for analysis. The samples will be analyzed by the Department of Agriculture (pursuant to a pre-existing arrangement between DNR-Minerals and the Dept. of Ag), with the results of the analyses being returned in approximately three weeks from the time that they are received.

Appendix 12

Cost Estimates

Table A12.1. Reclamation costs for fertilizing, planting and mulching.

	Native Seed $/acre	Cool Season Mixture $/acre
Fertilizer	12	25
Fertilizer application	50	50
Incorporate fertilizer	50	50
Seeds	204[1]	120[1]
Planting	250[2]	50
Mulch &[3] application	425	425
Crimping mulch	50	50
Total	1041	770

[1] Seed cost doesn't include flax
[2] Estimates for contractor (Bob Jacobson, Bob Bieraguel, personal communications)
[3] Contractor

Table 2. Cost of organic soil amendments.

Organic amendments	NVS $/acre	MSW $/acre
Transport	120/acre	300/acre[1]
Application	120/acre	120/acre

[1] Cost based on back haul, without backhaul would be $400/acre
MSW 15 tons wet/truck, 10.5 tons dry
Nviro 20 tons wet/truck, 11 tons dry

Application Costs - Based on field notes, it took 3 hours to apply the MSW compost. This was the first amendment applied and it took some adjustment to finalize procedure. The Nviro application took only 1 ½ hours (22 dry tons/acre to 3 acres). For cost calculations, assume 3/4 hours per acre. Need compost speader and loader; use $75/hour for each machine.

Note: Unless noted work was done or organized by Shiely personnel, contractor costs are likely to be higher.

Table 3. Itemized costs for Shiely reclamation.

Seeds	Unit Cost	Lbs/Acre	Cost/Acre	Acres	Total Cost
Native Mix	6.79/lb	30	203.70	6	1222
MNDOT50	1.99/lb	60	119.40	3	358
Fertilizer[1]					
MnDot 50	.15[1]	165	25	3	75
Native Mix	.15	83	12.50	6	75
Application[2]					
Fertilize			50		
Disc			50		
Plant Native Seeds			250[3]	6	1500
Plant MNDOT 50			50	3	150
Mulch, material & application			425/acre	9	3825
Crimp Mulch			50	9	450

[1] Price quote from Midwest Feed, South St. Paul, $6 for 50lbs of 10-10-10, estimate ~ 15¢/lb for 12-12-12.

[2] Estimate was 6 hours to seed and fertilize, fertilized 5 acres, 3 MSW, 2 topsoil, broadcast seeded 3 acres, top 1/3 of all plots, 8 acres ~ 3/4 hr each x $65/hr @ $50/acre, assume 45 minute/acre to crimp and to incorporate.

[3] MNDOT planted the native seed mix, so there was no direct cost to the project. This is an estimated price for a contractor to seed the area.

Break down of in-kind services, detailed estimate of construction costs.
(Original costs assumed an outside contractor would be hired to do all aspects of the work)
Actual costs are based on Shiely personnel

Construction, demonstration area

Site Preparation	Original Estimate 12 Acres	Actual Cost 9 Acres
Estimate by the hour, $100/hr, estimate 2-3 days, spreading soil amendments	$2500 - 3500	32 hours @ $70/hr = $ 2200
$500/acre x 7 acres	$3500	$120/acre x 6 acres = $720
Seeding, fertilizer, mulching $800/acre x 3	$2400	$800/acre x 3 = $2400
Seeding, mulching $750/acre x 1	$750	Included in other table entries
Prairie seed mixture $1150-1425/acre x 7.5 acre	$8625-10687	$1050/acre x 6 = $6600
Shipment of soil amendments		
M.S.W.	$3,000	$150/load x 8 = $1200 (1 load = 15 tons wet)
	To be payed by Nviro	$60/load x 6 = $360 (1 load = 20 tons wet)
Total	$20,800-23,800	$13,200

Appendix 13

Literature Review

Appendix 13

Literature Review

Note: The following notes have not yet been organized into any recognizably orderly fashion. The final report will include a completed literature review appendix.

April 1, 1997

Notes from articles on the use of biosolids with particular emphasis on MSW compost and NVIRO soil.

1.

1991-1993 N-Viro Soil
Demonstration Project
Final Report to:
Metropolitan Waste Control Commission
by
T. Halbach, S. White and C. Rosen

Minnesota Extension Service
Department of Soil Science
University of Minnesota

3 year study, 2 sites one in Dakota, one in Scott Co
compare NViro vs anhydrous NH_3
other factors in the plots were the same: ie, pest control, tillage etc

Analysis
- Corn Grain yield
- Soil chemical Analyses
- plant tissue
- Soil moisture analysis
  - 3', 6' deep suction lysimeter

Timeline 1991-93

Dakota County, irrigated site

1991

Soil samples collected April 9-14
NVIRO applied May 11, 33 dry tons/acre
corn planted May 12
anhydrous ammonia applied to control plot 6/12
soil moisture samples, collected weekly 8/8 thru 10/22
1 set (2 @ 3', 2 @ 6') in NViro plot, 1 set in control

September 24-27 corn grain yield
October 23-26 post harvest soil samples collected

<u>1992</u>

2/18 - NViro applied, 34 dry tons/acre
5/4 - corn planted
6/9 - anhydrous NH_3 is applied
7/2-9/23 soil moisture samples collected
11/11-11/12 corn grain yield measurement
11/18 soil samples collected
12/92 NViro applied, 58 dry tons/acre

<u>1993</u>

4/29 soil samples collected
5/6-9 corn planted
6/29 anhydrous - NH_3 applied
7/1-9/29 soil moisture samples collected
10/7 corn grain yield measurements
11/4 soil samples

Total NViro applied over 3 year period = 125 dry tons per acre

Results, generalizations

one of the problems is that there was some statistically difference in soil chemistry between the 2 plots
no difference in yield

soil -0-6" pH NViro > pH control
(pH of NViro plot increased from ~ 6.9-8)
plant nutrients K increased substantially from ~ 200 to ~ 600
Soluble salts increased substantially from 0.3 to ~2

Soil 6-12" pH did not seem to change
K and soluble salts increased.
But not as much as in upper 6")

No consistent increase in organic matter.

Metals in soil

General, total metals as determined by ICP and microwave digest
differences appear in top 6" of soil

Ca largest increase from ~ 5000 to >20,000
Cu gradual increase ~ 30 to ~ 70
Cr gradual increase ~ to 50 ~ 70
Pb gradual increase ~ 40 to ~ 70

(the last soil sample collected in 1993 seems strange, concentrations return to baseline - doesn't make sense)

Ni-no change
Zn gradual increase ~ 70 to ~ 100

difference don't show up in 6-12" layer

corn -

some increases in whole plant tissue
both 92&93-B, Cd, K, Zn
92 only - Cu
tissue
in grain
92,93 K, B
92 Cu, Zn

differences for metals in plant
are small but statistically significant

Water
Seems strange that have no pre-application data, and that wait so long to collect samples, particularly if irrigated site, should be continual down flow of moisture although report states that in 1991 not sufficient moisture to collect many samples

NVIRO plot had elevated levels of Ca, K, Mg, S, B

Al
Cr elevated in NViro plots but reported levels appear too high
Cu since ICP detection limits are high, the reported
Ni value are suspect, e.g.
Pb Pb .2-.3-mg/l

no pH or sc data

Dakota soils
Wadena loam - deep well drained soils moderately permeable in upper part, rapidly permeable in lower part.

Scott County

dark colored well drained soils, Dakota Loam, Dakota Sandy Loam waukegan silt loam

as result of an uneven application of manure, sites was moved so 1991 not same site as 92-93

Timeline

1992

3/31 preapplication soil samples
4/17 33.75 dry Tons per acre NViro applied
4/17-19 NViro incorporated
4/20 Anhydrous N applied to control
5/27-9/23 soil moisture samples
1 set of lysimeters (3',6') in each plot
(2 Nviro, 2 control plots)
11/17 post harvest soil samples collected
11/18 38.38 dry tons per acre NViro applied

1993

4/22 soil samples collected
4/29 anhydrous N applied to control
6/30-9/30 soil moisture samples collected
6/28??? whole plant samples collected
11/4 soil samples collected

Total NViro added = 72 dry tons per acre

Results

yield - no statistically significant difference

soil chemistry

Ca, Mg, P increased in top 6"

Cu, Pb also increased (although levels are a range of natural levels)
Ca much higher levels than Dakota site
soil sulfate, soluble salts, pH increased in 0-6", NVIRO

Water

1992 - Nviro generally higher nitrate (although not statistically significant)
Nviro high in K (Ns)
Not much difference in Ca, Mg, S (sees strange)
Ni seems unusally high (ns)
Cu Slightly higher (ns)
No apparent diffence in Pb, Cd, Cr
1993

NViro higher in NO_3 (Dakota County)
NViro higher in NO_3 although most doesn't test as significant
Ca, Mg, S elevated, generally statistically significant
K elevated
Cu, Ni appears elevated

So in summary NViro increases pH, total dissolved solids, and sulfur (presumed present as sulfate)
Some elevations in metals, not consistent between sites, Questionable data due to limitations of equipment
date is inconclusive, since some parameters, particularly Pb exceeded standards.

Summary

NViro was added on an annual basis to 2 agricultural sites in the metropolitan area. 125 dry ton per acre over a three year period was added to a farm in Dakota County, and 72 dry ton per acre over two years were applied to a farm field in Scott Co. Soil concentrations increased in the top 6" at both sites for pH, Ca, Mg, P, soluble salts and sulfate. Concentrations of Cu, Cr, Pb, and Zn, increased at the Dakota county site, while Cu and Pb increased at the Scott county site. Some increases in No change was observed in deeper soil layers. Samples collected from suction lysimeters at depths of 3 and 6 feet were analyzed for nutrients and for major cations and metals by ICP. Detection limits for most trace metals were above water quality limits and the results of the samples appear to be problematic. Elevated concentrations of nickel, lead, chromium and copper were measured at both sites, but none of the differences tested statistically significant, either due to insufficient sample numbers or high variability in the results. Concentrations of some of the metals appeared to be analytical errors and not real concentrations.

2. Soil and Crop Research on Municipal Solid Waste Class I Compost Utilization in Minnesota

Soil Science Department
University of Minnesota
Thomas R. Halbach, Assistant State Specialist, Waste Management & Water Quality
Dr. C.J. Rosen, Associate Professor Department of Soil Science
Dr. J.F. Moncrief, Associate Professor, Department of Soil Science
Martha Mamo, Graduate Research Assistant, Department of Soil Science
Sherry Schmidt, Former Graduate Research Assistant, Department of Soil Science
Susan Thomas, Former Graduate Research Assistant, Report Writer, Department of Soil Science

MSW Study
Greenhouse Study
    tested 8 composts
    80 dry tons/acre to Hubbard loamy sand soil
    field corn
    (This result seems somewhat strange)
results - highest yields - fertilizer *(NPK) only (2-10x higher)
    compost increased pH, soluble salts, trace metals
        and nutrients in soil
    *(soils fertilized with N only had yields similar to soil & MSW only)
earthworm bioassay, Minnesota Z - test
    4 composts stable
    1 toxic
    1 unstable
Small Plot Studies
    compost application 0,20,40,80 dry tons/acre
    Urea added 0, 220, 440, lbs/acre (didn't add NPK)
    field corn grown
    suction lysimeters installed at 90/180 cm to
        Monitor nitrate
    variable results, but got better or equivalent yield with 0 compost and N fertilizer
        tissue samples - only analyzed for N
Variability high, not only between compost facilities but
    even within some facility
Compost Quality
    Immature - cause phytotoxicity - possibly due to
            Intermediate organic compounds
    C/N ratio desirable is 13:1 to 20:1, within this
        range tie-up of N minimal
        Soluble salts - can be limiting factor in application
Sludge - EPA limits based on pathways for potential transfer
    to individuals
    - generally higher then class I limits

Table 1. Metal specifications for Class I compost suggested by the Minnesota Pollution Control Agency (MPCA, 1989) and maximum pollutant concentrations in clean sewage sludge suggested by the U.S. Environmental Protection Agency (U.S. EPA, 1993). All concentrations are expressed on a dry-weight basis.

Pollutant	MPCA	U.S. EPA
	mg/kg	
Arsenic	ND[z]	41
Cadmium	10	39
Chromium	1000	1200
Copper	500	1500
Lead	500	300
Mercury	5	17
Molybdenum	ND	18
Nickel	100	420
Selenium	ND	36
Zinc	1000	2800

[z]ND = not defined.

Less then ½ of 1% of household waste contains hazardous materials (MPCA, 1993)

MSW - usually needs supplemental N to obtain yields equivalent to fertilized control
- greatest benefit is as soil conditioner thru increased organic matter, improves physical - properties by increasing total soil porosity & increasing aggregate stability.
- in general poor source of NPK, average 1,1/4,1/4 and high rates needed to provide nutrients not recommended due to concerns re-soluble salts and trace metals.

__3.__ Department of Soil Science, University of Minnesota. 1987a The utilization of solid waste compost, co-composts, and shredded refuse on agricultural lands--literature review. (S. Stark and N. Schumacher). Report to the Legislative Commission on Minnesota Resources and the Metropolitan Council of the Twin Cities Area (pursuant to 1985 laws, First Spl Session, Chapter 13, Section 31). 45 p.

Substantial composting in Europe, eg. Netherlands (17%), Sweden (24%) of refuse composted
US, limited - in US idea is that composting must be profitable instead of being like public service (eg waste water treatment)

One study showed decrease in PAH content during composting, Recommends using benzo (a) pyrene as general indicator for PAH

Martens, R. 1982. Concentrations and microbial mineralization of four to six ring polycyclic aromatic hydrocarbons in composted municipal waste. Chemosphere 11:761-770.

report summarizes effect of compost on a number of agricultural crops
beneficial effects of MSW on soil, primarily soil conditioner, not fertilizer

1. Reduces bulk density
2. Increases aggregation
3. Reduces runoff and erosion

Reference: Banse, H.J. 1961. Beeinflussung der physiakalishen bodeneigenschaften durch kompostgaben. Internationale Arbeitsgemeinschaft frullforschung Informationblatt 1:30-34. Zurich, Switerzerland as referenced in Tietjen, C. And S.A. Hart. 1969. Compost for agricultural land? Jour Sanit. Eng. Div., Proc. Am. Soc. Civil Eng. 95 (SA2) :269-287.

4. Increase moisture retention

<u>MSW in mining</u>

Hortenstine, C.C., and D.F. Rothwell. 1972. Use of municipal compost in reclamation of phosphate-mining sand tailings. J. Environ. Qual. 1:415-417.

__4.__ Department of Soil Science, University of Minnesota. 1987b. Characteristics of solid waste composts and co-composts affecting their use as soil amendments--literature review. (S. Stark and N. Schumacher). Report to the Legislative Commission on Minnesota Resources and the Metropolitan Council of the Twin Cities Area (pursuant to 1985 laws, First Spl Session, Chapter 13, Section 31). 34 p.

Chaney - factors that control metal toxicity to plants

Chaney, R.L. 1973. Crop and food chain effects of toxic elements in sludges and effluents. __In__ Recycling Municipal Sludges and Effluents on Land. Nat. Assoc. Of State Univ. And Land Grant colleges, Washington, D.C.

1. Amount and combination of metals present in soil
2. Soil pH, critical, as pH increases, availability and toxicity of metals decreases, at high pH, metals convert to insoluble form.
3. Amount of organic matter higher organic content decreases metal availability.
4. Phosphate, higher phosphate generally decreases metal availability
5. Cation Exchange Capacity (CEC)
   As CEC increases, metal availability decreases

impact of soil salinity, as measured by electrical conductivity if < 2 mmhos/cm effects negligible.

Chemical Properties of Municipal Solid Waste Composts

variability between and within compost facilities
moisture content varies 20-50%
ash content ~50% (dry weight basis)
pH neutral to slightly alkaline
organic C ~ 30% (dry weight basis)
N,P higher than soils but availability low
10-15% total N available 1st year, no residual effect
up to 15% P, available in year 1, and 2
K lower than soils but high comparable to inorganic fertilizer

De Haan, S. 1981. Results of municipal waste compost research over more than fifty years at the Institute for Soil Fertility at Haren Groningen, the Netherlands. Neth. J. Agric. Sci. 29:49-61

to convert organic C to organic matter, multiply organic C by 1.7-2.0
So MSW contains 50-60% organic matter
humic and non humic fractions
metals
concentrations higher in fine fraction
chemical extraction - not totally specific, some overlap between steps
water extraction - metals most active form, highly available
only small amount in this form
thought that metals which are in water, soluble, exchangeable (KNO_3) or organically bound (DTPA) are plant available
more metals in compost are organically bound than exchangeable

one author (Petruzzelli) found that these 3 steps generally removed $<10\%$ of the metals

difficult to correlate bioavailability to extraction results,

could use bioavailability of metals in sludges as guide for compost

extensive work on compost in Europe.

5. VEGETATION RESPONSE TO ORGANIC SOIL AMENDMENTS ON COARSE TACONITE TAILING. (Paper presented at the 1992 Nat'l Meeting of the American Society for Surface Mining and Reclamation, Duluth, MN, June 14-18, 1992.

Michael R. Norland, David L. Veith, and Steve W. Dewar[2]

2 year results, USX, Eveleth

Tends to lump data if not significantly by different, (statistical test) so difficult to compare individual treatments

for MSW - significant increase in% cover with ½ fertilizer (200 lbs/acre) no significant difference between 200 and 400 lbs/acre

standard reclamation		% cover 34.6
	MSW	50-65

appears to be increase in % cover with increased organic addition at Eveleth, biggest difference is between 0 and 20 tons/acre small difference between 20-40, larger between 40-80

6. STANDING CROP BIOMASS AND COVER ON AMENDED COARSE TACONITE IRON ORE TAILING. (Paper presented at the 1993 National Meeting of the American Society for Surface Mining and Reclamation, Spokane, Washington, May 16-19, 1993) Michael R. Norland, David L. Veith, and Steven W. Dewar [2]

3 year results, Eveleth
standard reclamation 42.1, cover, not statistically differ from ½ rate fertilizer

½ rate fertilizer (200 lbs/acre) significantly increased % cover for lower rates of organic amendment addition; smaller and not significant increase at highest rate.

Standard reclamation	42.1	Essentially no difference
0 fertilizer, 20 tons/acre organic amendment	47.1	Large difference
20 tons/acre + 200 lbs acre fertilizer	65.1	
20 tons/acre +400	68.4	

As addition rate of organic increases, results improve dramatically above standard reclamation

			200 lbs	400 lbs
eg	standard reclamation	42.1%		
	20 tons, 0 fertilizer	47.1	65.1	68.4
	40 tons, 0 fertilizer	56.3	71.7	78.6
	80 tons, 0 fertilizer	75.0	81.0	83.6

(these results lump all organic amendments together, in general there doesn't seem to be much difference between types of organic amendments)

7. REVEGETATION OF COARSE TACONITE IRON ORE TAILING USING MUNICIPAL SOLID WASTE COMPOST

Michael R. Norland, David L. Veith*

Eveleth, 4 year results, need standard reclamation results and MSW with 0 fertilizer and ½ rate

need results from 1995
implication is that on coarse material like Eveleth May need to go to higher application rate of amendment or fertilizer make list composted yard waste (90%), MSW with additional Diapers (84%), and reed/sedge peat (90%), were within 10 points of standard when 200 lbs/acre fertilizer was added.

Additional fertilizer, in general, did not increase biomass significantly
although the highest % cover was measured on the plots with the highest rate of organic addition and fertilizer
% of cover was greater than or equal to 97% with fertilizer
87-97% with no fertilizer.

it does not appear to be cost effective to add excess organic material & fertilizer.

8. RESULTS OF MUNICIPAL WASTE COMPOST* RESEARCH OVER MORE THAN FIFTY YEARS AT THE INSTITUTE FOR SOIL FERTILITY AT HAREN/GRONINGEN, THE NETHERLANDS. (The words municipal, town and domestic, and waste and refuse are used as synonyms in this paper. Municipal waste compost is abbreviated to MWC, occasionally)
S.de Haan

research on MSW compost started in 1920's

when article was written 90% compost being applied to "amenity" area
(Parks, waysides etc - not crop production)
until 1950 most of compost applied to cut over peat and heath soils reclamation
since about 1600 large areas of peat areas which had been cut for heat, were reclaimed with refuse from city of Groningen

change toward end of 19th century, with inorganic fertilizers and indoor plumbing
manure high in N, P, K than MSW compost and lower in metals
reference some German work on PAH

change in waste stream over time, less organic residue, more paper and plastic

9. MSW COMPOSTS: IMPACTS OF SEPARATION ON TRACE METAL CONTAMINATION.

Tom Richard, Cornell University, Peter Woodbury, Boyce Thompson Institute, Vincent Breslin, S.U.N.Y. Stony Brook, Steven Crawford, DPRA

Source of metals
- batteries
- consumer electronics
- ceramics and some glass
- plastics (Cd used in pigments, plasticizers, stabilizers)
- light bulbs

levels in paper & inks have declined
- Zn 146 ppm in mixed recovered paper
- (When composted concentration can increase by 20-95%) (since volume and mass of organic materiel decreases)

study was done in NJ to look at metal concentration in waste stream
large study in ~ 1992 in Vancouver, need data, check with Office of Waste Management, Environment Canada

Some of European facilities didn't separate until end, most newer plants, separate, at least some material, at the front

lead: wine bottle caps, solder, shot pellets, fishing wgts ~estimated
- estimated 30 grams/resident/year
- other sources, lead paint particles

Fillmore County, was first full scale us facility processing residential source separated organic materials, 50% of waste stream to compost
- 15-20% to recycling

separation before composting produces lower metal levels in compost, then composting everything and separating at the end.

Best results if take only organic material. Lowest levels of metals (this explains why yard waste compost has lower metal value)

10. TWENTY YEARS OF LAND APPLICATION RESEARCH
Biocycle, September 1990, p 54-59

Rufus L. Chaney Part I
research has shown can define a "no observed adverse effect level" (NOAEL) quality sludge, "clean sludge"

adsorption of metals and organics, pure chemicals are toxic at lower levels than metals in sludge.

Organic-N in sludge less likely to cause ground water pollution than inorganic fertilizer.

Developed 12 fundamental pathway's for risk assessment
limiting one generally is direct ingestion of sludge by livestock or children

can minimize exposure by incorporating into soil prior to planting

"Soil-Plant" Barrier-
    some metals, eg, Pb; are so insoluble or bound to soil
        not transferred into edible portion of plant
    some metals, eg Zn ,Ni, Co, are phytoxic, before they
        accumulate to level that would affect livestock
        some metals, eg, Cd, Se there is no soil-plant barrier
problem with greenhouse studies
    metal salts - linear response, plant uptake vs soil metal
    sludge, plant levels reach plateau
in plot studies, roots confined to zone with high levels where in field
roots can grow deep
nature of water uptake also differs from field, produces higher metal uptake.

<u>11.</u> HEAVY METALS IN THE ENVIRONMENT

Liviana Leita* and Maria De Nobili
Water-Soluble Fractions of Heavy Metals during Composting of Municipal Solid Waste

Metals concentrations increase during composting, due to loss in organic matter organics tend to stabilize metals, amount of metals that were water extractable did not increase.