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

Final Report

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Minnesota Department of Natural Resources
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Acknowledgments

This collaborative effort between private industry and state government was a success due to the involvement of many people. Bob Bieraugel of Aggregate Industries (formerly Shiely Co.) was instrumental in getting this project off the ground, as was the open-mindedness he and the company had about using biosolids and municipal solid waste compost to help reclaim gravel pits, and the potential benefits of planting native species to reclaim gravel pits. Kathy Draeger, serving as a consultant to N-Viro Minnesota, was also an important component of the project. We would like to thank the Minnesota Department of Transportation for planting the native seed mix on the slope, and Bob Jacobson for his help in identifying the many species growing on the demonstration slope, as well as his insight into appropriate plant species to use for mineland reclamation. Numerous Shiely personnel (including Plant Manager Marc Duncan and Dennis Kilmer) assisted in the construction of the plots, and the DNR's Kim Hennings, Glenn Melchert and Dave Antonson, Deena Bahner and Nadine Light also provided welcome assistance.

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 and minimize erosion on a nine acre south-facing slope at Shiely Co.'s Nelson Mine on Grey Cloud Island. Two previous attempts using a standard seed mixture had failed, and erosion channels were present on much of the slope. 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 waste sand stockpile.

Demonstration slope

Four treatments and two seed mixes were applied to the slope, which had been covered with approximately 12" of local topsoil, which was low in nutrients and organic content. The treatments included: NVS (23.9 dry tons/acre), MSW (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 was planted with a native seed mix (MNDOT 20).

Addition of NVS and MSW to the south-facing demonstration slope increased both percent cover and biomass, and decreased erosion on the demonstration plots. In the first year (1996), average percent cover on both the NVS and MSW plots was about 60%, while the corresponding value for the fertilized and control plots were about 45% and 30%, respectively. By the third year, 1998, the overall average percent cover on the MSW plot was 89.1% and would meet the DNR mineland reclamation requirement of 90% vegetative growth after 3 years. (The standard provides 5 years for west and south facing slopes) . Overall average percent cover on the other plots ranged from 68.3 % on the control plot to 74.5% on the NVS plot. Despite lower percent cover, the slopes all appeared stable.

In the first year, almost all of the percent cover and biomass on the slope was provided by annual weeds, primarily lambsquarter (*Chenopodium album*) and ragweed (*Ambrosia sp.)* The only cover crop to germinate on the slope appeared to be oats, but this was entirely grazed by geese. By the third year, native species, particularly switch grass and little blue stem, dominated the portion of the plots planted with the MNDOT 50 mix and were also major components of the sections of the plots that had been seeded with the MNDOT 20 mixture. Indian grass, wild rye, and side oats gramma were also observed in the native portions of the plots and isolated plants of big blue stem, slender wheat grass, and sand drop seed were also present. The most common forbs were grey headed coneflower, black-eyed Susan and purple prairie clover, but butterfly weed, hoary vervain, showy penstemon and goldenrod were also observed. The NVS plots had a much higher percentage of weed species, primarily horseweed. In spots the horseweed appeared to account for roughly half of the total cover on the NVS plot.

Addition of 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. Despite the added cost, it would be less expensive to use the amendments and develop a good vegetative cover, than to reclaim the site several times. Costs could have been reduced if the NVS had been shipped to the site during the winter or late summer, when the Metropolitan Council would have paid for the transportation to the site.

Lysimeter plots

Nine 2.5 m x 4 m plots were installed to examine the effect of the organic amendments on water quality. NVS and MSW 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 (MNDOT 50). Due to the lack of rainfall no water was collected in the lysimeters during the first year of the study (1996).

Suction lysimeters were installed during the second year (1997) to allow collection of soil moisture, and heavy rains in July provided sufficient water in both the pan and suction lysimeters. Only minor differences in water quality were observed between plots and all parameters met water quality standards.

Waste sand plots

Shiely produces a washed reject sand which is currently contained in a 50-acre stockpile. This material is primarily coarse and medium sand, which is low in nutrients and organic matter. Eighteen 2.5 m x 4 m plots were established to examine the use of NVS and MSW as replacements for topsoil to reclaim this area. The plots consisted of: 60, 30 and 15 wet tons of NVS /acre (31.2, 15.6, and 7.8 dry tons/acre), 20 dry tons of MSW /acre, and 2" and 4" of topsoil. All plots were seeded with the cool season grass mix (MNDOT 50). Fertilizer was added only to the plots with 4" of topsoil.

By the end of the third year, while the NVS 60, NVS 30, MSW and 4" of topsoil with fertilizer plots all had an average percent cover of 85%, only the NVS 60 plot had an overall cover that approached the 90% reclamation standard. Cover was lowest on the NVS 15 and the 2" topsoil plots, and ranged from 70% to 62.5%, respectively.

The cost to move and apply topsoil for this project was estimated by Shiely to be $3.50/yd. Applying 4" of local topsoil, which is usually the minimum required by county reclamation plans, would cost about $1860 per acre. Using about 30 dry tons/acre of organic amendments in place of topsoil would not only produce better vegetation, but would also reduce the reclamation cost by about $1200 to $1500 /acre.

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. Statewide, the annual demand is over 50 million tons per year (an increase of about 50% since the early 1980's), which translates to about 10.5 tons of aggregate consumed per person per year (Aggregate Resources Task Force, 2000).

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 compost (MSW). (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.)

2. Background

2.1 N-Viro Soil

NVS is a biosolid 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 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 Exceptional Quality standards. Details on the N-Viro production process are presented in Appendix 2, as are annual breakdowns of NVS quality from 1992-2000, the years when NVS was produced at the Seneca plant.

The NVS used in this study was obtained from the Seneca Waste Water Treatment Plant (WWTP) in Eagan, MN, which began producing NVS in 1992. The NVS was comprised of 1 part sludge, 1 part kiln dust, and 2 parts coal fly ash (on a dry weight basis). The fly ash primarily came from two Northern States Power (NSP) plants - the Black Dog plant and the Riverside plant. Fly ash from the Archer Daniels Midland (ADM) plant in Mankato, MN, was also used at times in the NVS process. The lime kiln dust they used came from the Cutler Magner plant in Duluth, MN.

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

Parameter	Average values [A], mg/kg		Material applied at Shiely [B]	Metal [D] loading rate (kg/ha)	EPA's 503 standards for Exceptional Quality sludge
	1995	1996			
Plant Available (Exchangeable) Values					
% Organic Matter	na	na	16.2	---	---
NO_3-N (lbs/acre)	na	na	16	---	---
P (Bray 1) [C]	na	na	3	---	---
P (Olsen) [C]	na	na	88	---	---
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. (μS)	na	na	3.0	---	---
Ca	na	na	16,380	---	---
Mg	na	na	190	---	---
CEC	na	na	86	---	---
Total Values					
Cd	5.1	5.1	2.4	0.1	39
Cr	18	19	24	1.2	1200
Cu	170	210	172	8.6	1500
Pb	106	100	52	2.6	300
Ni	28	55	18.3	0.9	420
Zn	120	139	69	3.5	2800
Hg	0.41	0.32	0.06	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: As reported by Met Council's Env. Services Division. 1995 values based on 25 values, 1996 values based on 17 values.
B : This was a composite sample DNR collected from the pile of NVS delivered to the lysimeter plots.
C: Bray P is the most appropriate measure for soils with pH < 7.3, while Olsen P is most appropriate for soils with pH > 7.3.
D: The metal loading rate is based on the application of 23.9 dry tons/acre to the demonstration slope.
na = not analyzed --- = not applicable

However, production of NVS at Seneca was discontinued in January, 2001. The NVS facility had been constructed to manage the sludge produced at and transferred to the Seneca plant while their incinerators were down for repairs and upgrades. Once the incinerators were back on line, there was no further need for the NVS facility.

Additionally, the sludge used to create NVS at Seneca was actually comprised of sludge from two separate sources - from Seneca, and from the Blue Lake Wastewater WWTP (Shakopee, MN). But Shakopee stopped transferring its sludge to Seneca soon after Seneca's incinerators were back in full operation, and the overall effect of the restored incinerator capacity and the reduced volume of sludge resulted in the shutting down of Seneca's NVS facility.

The sludge from Shakopee is now being used to create heat-dried pellets. Unlike NVS, which involved a "pasteurization" process which doesn't kill many beneficial microorganisms, the heat drying process used to make the pellets is a sterilization process which kills all microorganisms in the sludge. The pellets meet the requirements for Exceptional Quality Sludge, and Met Council will deliver them for free to users in the seven county metropolitan area.

All sludge processed at Seneca is now incinerated and landfilled, and the only anticipated reason the NVS facility would be started up again would be if there were major problems with Seneca's incinerators or the heat driers at Blue Lake. However, the Metro WWTP (on Childs Road in St. Paul) is planning to build a new NVS facility, and its operation will likely begin in 2004. This plant is expected to produce as much or more NVS as the Seneca plant.

2.2 Municipal solid waste compost

MSW compost is made primarily from household waste. The material used in this study was produced at the Wright County facility in Buffalo, MN. 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 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.

The Wright County MSW compost facility is now closed, but as of September 2001 there were three producers of MSW compost in operation in Minnesota, as well as at least seven other operations that produce material that is a combination of MSW compost and other materials such as composted food waste (Appendix 3).

2.3 Amendment selection rationale

NVS and MSW compost were selected for this project based on their apparent suitability for the application in question, their easy availability in the metro area, and their under-use. (Details of selection rationale are

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

Total Concentrations:

Parameter	Material used at Shiely		Appli-cation rate (kg/ha)	Standards	
	Lot 24	Comp-osite		Class 1, ppm	Class 2, kg/ha
% 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	---	---	---

Plant Available (Exchangeable) Concentrations:

Parameter	Material used at Shiely		Appli-cation rate (kg/ha)	Standards	
	Lot 24	Comp-osite		Class 1, ppm	Class 2, kg/ha
% 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	---	---	---

* This value is anomalously low in relation to the corresponding value for total %C
** anomalous value, but no sample available for reanalysis   na = not analyzed   --- = not applicable

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)

presented in Appendix 1). Both of these products were derived from waste materials which are otherwise incinerated and/or landfilled. 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). In 1997, a large-scale demonstration project was conducted at EVTAC Mining Co., where MSW compost was used to reclaim coarse taconite tailings (Eger et al., 2001).

Since the completion of this project, however, the NVS process has been discontinued at the Seneca plant, and the Buffalo compost plant has been closed. However, as of July 2001 there are still three producers of MSW compost in Minnesota (in Baudette, Thief River Falls, and Truman), and there are at least seven other operations that produce composted materials made from combinations of MSW and other materials such as food wastes and poultry bedding waste (Appendix 3).

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.

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 (Minnesota Rules, Chapter 7041) 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 always met these criteria since production commenced at the Seneca Wastewater Treatment facility in Eagan, and was the only sludge produced in Minnesota classified as Exceptional Quality. (The heat dried pellets now produced at Seneca are also considered Exceptional Quality.) Biosolids that do not satisfy these stringent requirements are classified as Class B sludge, and use of this material is much more regulated than Exceptional Quality sludge. Additional requirements include type of vegetation, setbacks, and soil/water quality monitoring.

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 (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 new rules were not in effect; and the old 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.

- **Methods**

3.1 Experimental design

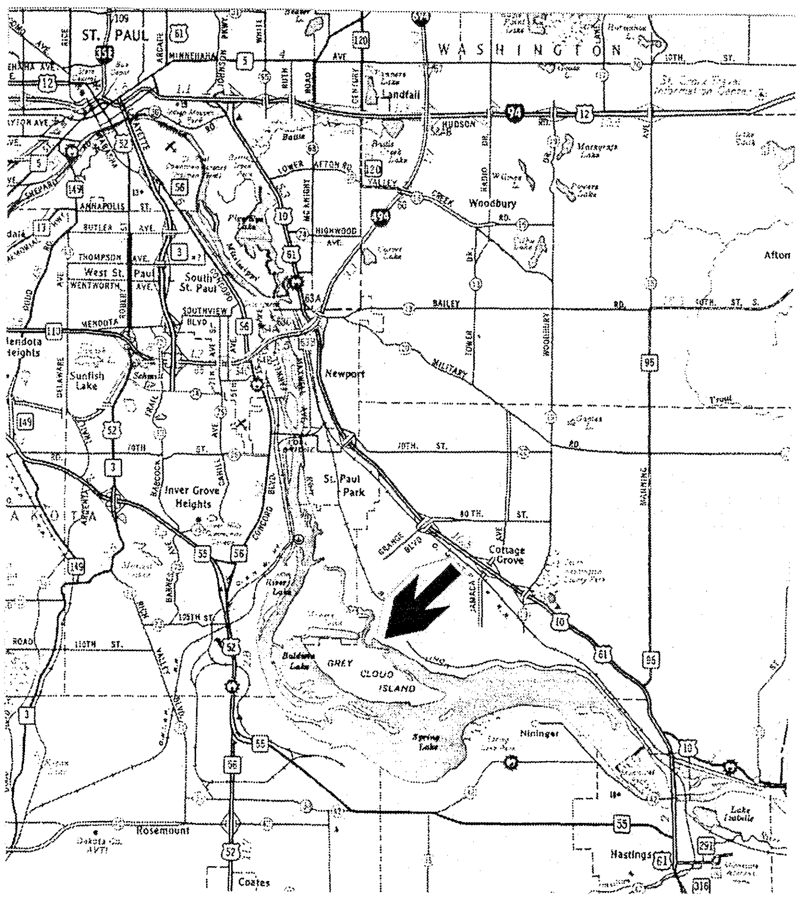
The Division of Minerals was interested in conducting a cooperative gravel pit reclamation project in the Twin Cities metropolitan area which would entail the investigation of innovative reclamation techniques. The site needed to be easily accessible to other gravel pit operators, so that the results 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. 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 currently owned by Aggregate Resources, 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.

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

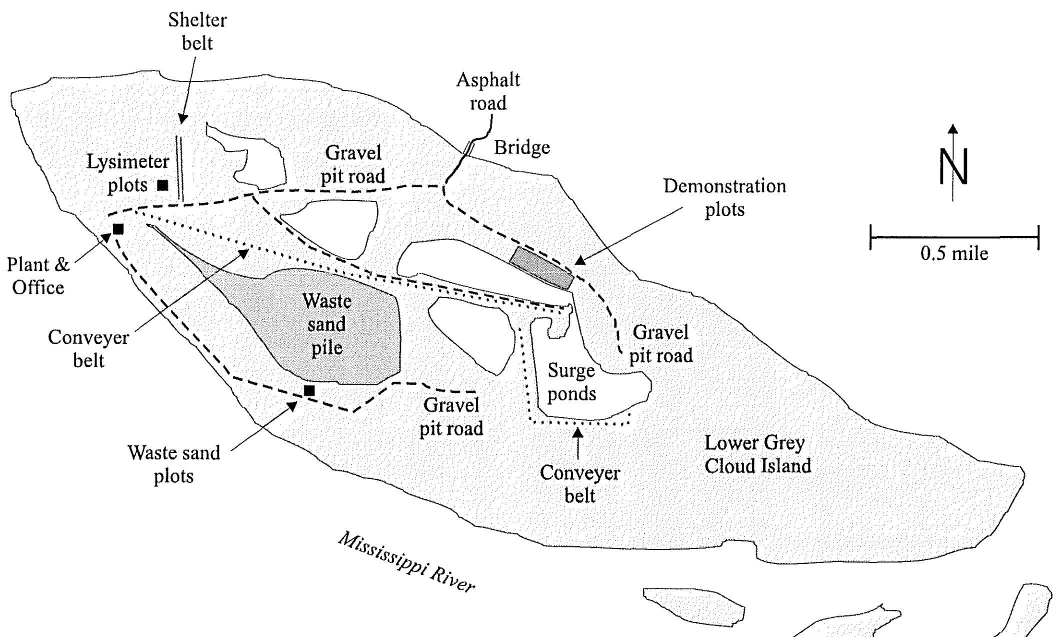
From downtown St. Paul, take Highway 61 south, go past 494, and then get off at the 70th St. exit. Take a right, follow the road to the next stop sign, then take a right (on Broadway). Go a few blocks to the next stop sign, then take a left. (You will then be on 3rd St, which turns into Grey Cloud Island 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.)



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 of the "topsoil" 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.

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

Figure 2. Site map of Shiely Co.'s Nelson Mine.



Note: This is an active mining area, and the location and contours of the surge ponds, waste sand pile and gravel pit roads are subject to change.

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

Table 3. Topsoil ("black sand" [4]) 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	78	108	120
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	327	165	na	na
Total Values									
Cd	na	na	na	na	na	na	<0.88	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	<0.02	na	na
As	na	na	na	na	na	na	0.95	na	na
Cu	na	na	na	na	na	na	1.52		
Zn	na	na	na	na	na	na	19.50		
Se	na	na	na	na	na	na	<0.26	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.

4 Due to the poor quality of the topsoil, Shiely personnel often called it black sand.

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 organic amendments derived from waste products (i.e. NVS and MSW compost) are applied, 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".

The mine also contains a large (approximately 50 acre) waste sand pile that receives sand that is too fine for most industry uses, and which is instead just stockpiled at the mine. The waste sand is alkaline and infertile, with very low organic and nutrient contents (Table 4). Most areas of the pile that had 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.

3.2 Demonstration plots

3.2.1 Design and slope 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 46 wet tons/acre (23.9 dry tons/acre; approximately equal to an application depth of 1/4"), with no fertilizer added. This application rate was based on the amount of available nitrogen (Appendix 13).

<u>Plot 2</u> Existing "topsoil", with fertilizer (12-12-12 N-P-K) applied at a rate of 330 lb/acre on the upper 1/3 of the slope (i.e. the MNDOT 50 seed mix) and a rate of 165 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 ton/acre (approximately equal to an application depth of ½"), with fertilizer added at ½ the rate used for Plot 2 (i.e. 165 lbs/acre were added to the MNDOT 50 part of this plot, and 83 lbs/acre to the MNDOT 20 part). (The target rate was 20 dry tons/acre, which was based on previous DNR research.)

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

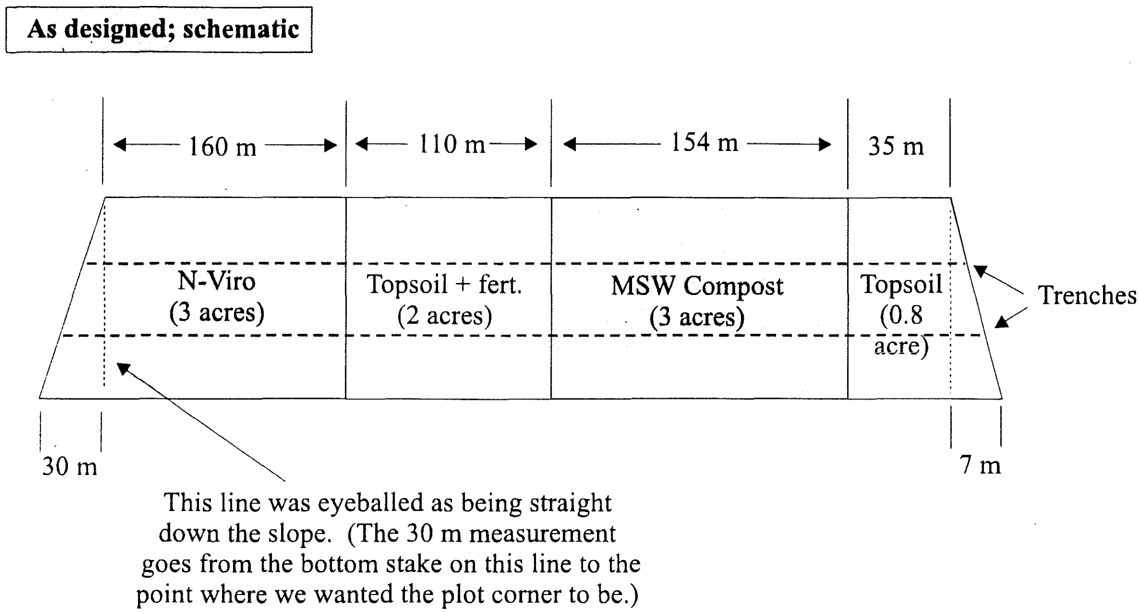
Prior to spreading the amendments, it was necessary to smooth out the surface of the slope and to fill in some of the large erosion gullies that were present on the slope. A front-end loader was used to load black sand from a stockpile located near the pit entrance into a bottom-opening dump truck, and 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

Table 4. Composition of material in the 50-acre waste 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



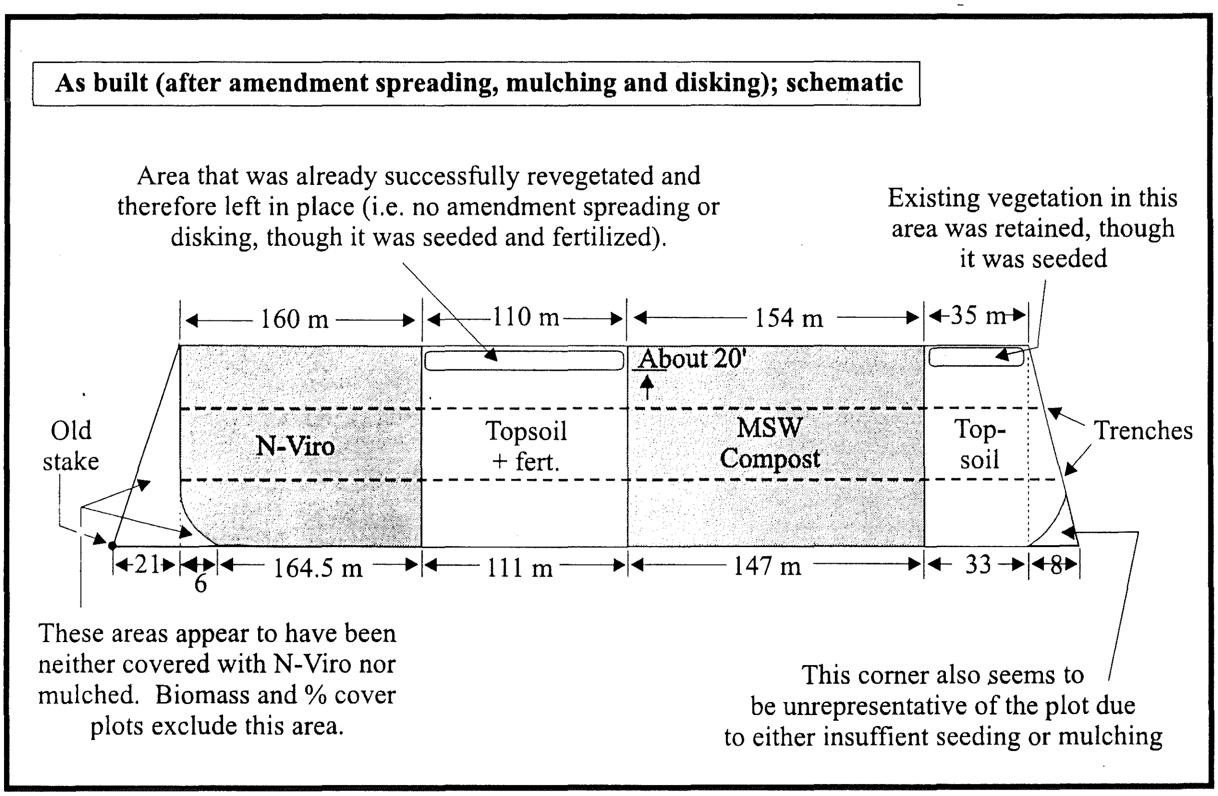


Figure 4. Design schematic of the four plots on the demonstration slope.

Table 5. Seed mixes specified for the demonstration plots (purchased from Peterson Seed Co., Savage, MN).

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
Cover crops:		
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
Cover crops:		
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 unviable seeds, so that 10 lbs of pure live seed mix may weigh over 10 lbs.

Note: The forb mix specifications included 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. If these were not available, the following species were defined as acceptable substitutes: Aster, smooth-blue; Aster, upland-white; Goldenrod, showy; Goldenrod, stiff; Spiderwort, Ohio; Vervain, hoary; and Tick-trefoil, showy. The exact composition of the forb mix applied at Shiely is not known.

from previous erosion-control efforts; these bales were pushed to the bottom of the slope and removed. 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. Soil samples were collected from each plot prior to amendment spreading; analyses of these samples are presented in Table 3.

3.2.2 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. The amendments were spread 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 drove down to the bottom of the slope, then spread material across the plot, shutting off the outlet port as it reached the end of the plot. It then drove up the slope 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 ½". 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 ½ 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.

3.2.3 Disking in of amendments, 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.

3.2.4 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.

3.2.5 Vegetation 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 8/6/96-8/8/96, 8/7/97-8/11/97, and 9/1/98-9/8/98, using a systematic grid pattern. An initial set of 1998 measurements were collected in late July, but these values didn't appear to agree with visual observations of the plots in August, so a second set of measurements were made. The second set is considered to be the most accurate of the two, but both sets of data are presented in Appendix 7. The percent cover measured in this study was the total vegetative cover, including litter. (Some studies use live percent cover). On the demonstration slope, significant amounts of litter did not appear until the 3rd year.

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 (Figure 4).

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, the standard error term, the confidence limits, and the mathematical statements of error are less statistically reliable than those made using a random system. 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.

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 in 1996 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 1997 and 1998 this system was modified, with the observers simply ignoring the surrounding vegetation as they approached the sample location, then dropping the frame randomly.

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 (Mueller-Combois and Ellenbert, 1974), but the ranges of these classes were broader near the middle of the scale, and smaller near the ends of the scale (Appendix 7). 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. 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.

3.2.6 Filling of erosion gullies

Some erosion gullies appeared near the toe of the slope following a 5" precipitation event on 7/17/97, and it appeared that a couple of these gullies threatened to migrate up the slope. Most of these emerging gullies were small (about 1-2' wide at the bottom), but a few were fairly large (5-10' wide at the bottom, and 10-15' long). The DNR conducted a GPS survey of these gullies, and Figure 5 depicts the approximate locations of the gullies, along with locations of the GPS way-station locations of each observed gully. Later in 1997 the company decided to fill these areas, to prevent them from enlarging.

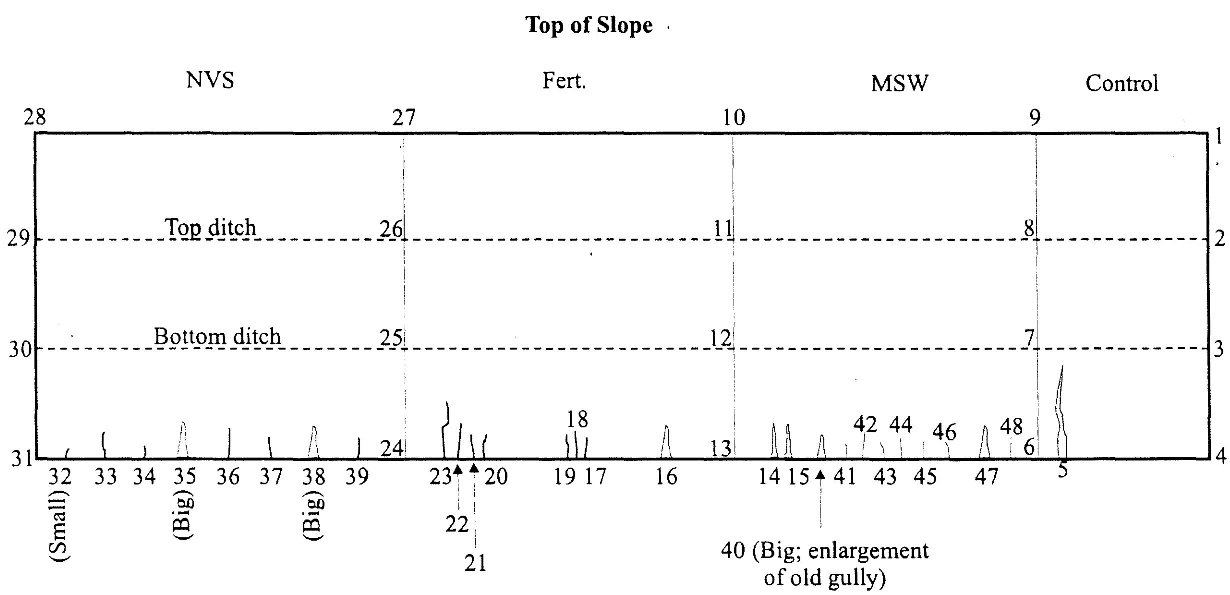


Figure 5. Location of erosion gullies observed 7/21/97, with GPS way-station locations.

3.2.7 Controlled burn, 4/28/00

A controlled burn of the demonstration slope was conducted on 4/28/2000. The purpose of the burn was to remove litter and woody species, and to release nutrients. Most of the planted species develop extensive root systems during their first few years of growth, which permits then to survive even after a burn, which often occurs naturally due to lightning strikes. The burn was postponed on two occasions due to windy conditions and low relative humidities. The only thing separating the top of the demonstration slope and a shelter belt (primarily conifers) was a narrow gravel road, and there was a fear that any wind blowing toward the shelter belt could ignite it.

The burn started at the (upper) northwest corner of the slope, and generally proceeded down the slope and to the east. A crew of five workers conducted the burn, with two workers igniting the slope through the use of hand-held flame drippers, while the remainder of the crew was equipped with ATV-mounted water tanks, and were prepared to react to any flames threatening to spread to the shelter belt. The burn took approximately two hours to complete, at which time most of the slope had been burned. Closer inspection of the burned prairie plants revealed, however, that the plants were only burned down to about an inch or so from the soil line, and within a couple weeks those plants were coming back strong. Appendix 14 contains a series of photos showing the burn and regrowth of the area.

3.3 Lysimeter plots

The lysimeter plots were created to measure any 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). This site was selected because mining activities no longer occur in this area (so the plots could 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.

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

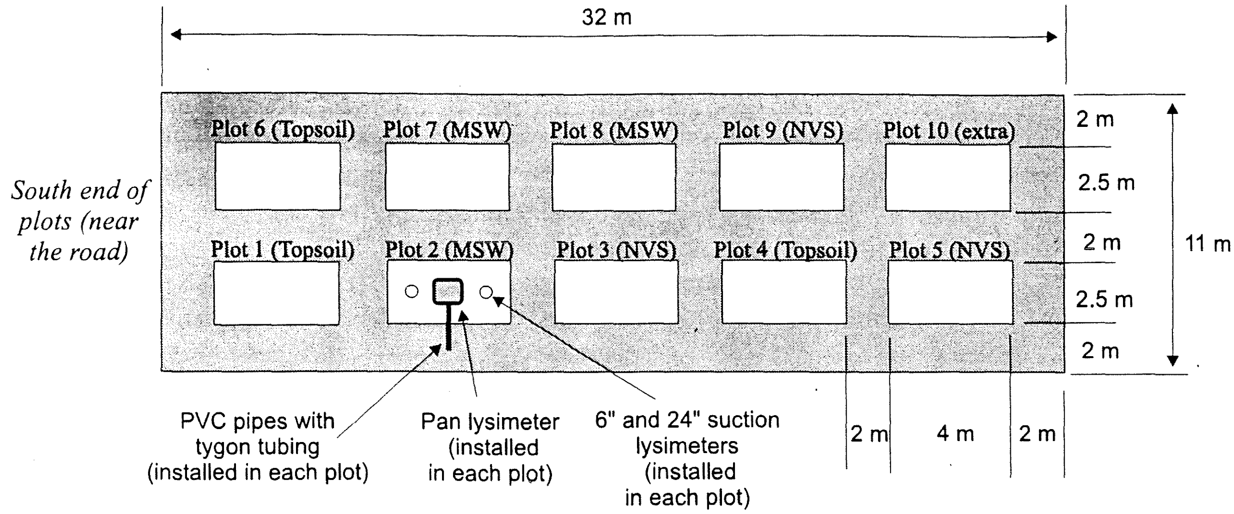


Figure 6. Design schematic of the lysimeter plots.

sand until a slope of roughly 4:1 slope was achieved. This sandy slope was then covered with a layer of the topsoil 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".

Similar conditions existed at the flat area intended for the lysimeter plots, with a layer of topsoil (averaging 6" to 8" thick) also present in this area. The main difference between this area and the demonstration slope was that this area was flat (and thus experienced little erosion compared to the slope), which in turn allowed the vegetation in this area to do very well in comparison to the vegetation on the demonstration slope.

3.3.1 Construction

Each lysimeter plot measured 2.5 x 4 meters, and two parallel rows were constructed. 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 4/25/96 a front end loader was used to strip off the topsoil/vegetation layer; the plots were built on top of the subsoil.

Once the plot area was stripped and smoothed, the lysimeters were installed in each of the 10 plots. The pan lysimeters were constructed from 2' x 3' plastic basins (1' deep) that were equipped with 18" sections of slotted well screen (Figures 7 and 8). (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 was 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. A bobcat was used to drop the topsoil on the plot, but the final spreading was done by hand. 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.

Each amendment was applied in triplicate, with the order of the plots having been randomly assigned (Figure 6). The final spreading of the amendments was done by hand (with rakes), and the bobcat did not drive on the plots.

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 330 lbs/acre, and to the MSW plot at 165 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.

(The tenth plot, to which MSW compost was added, was used to check for water in the lysimeters (see Section 3.3), with the assumption that if there was water in that plot then there would also likely be water in the other nine plots. It also served as an observation plot to examine the effectiveness of MSW compost without fertilizer.)

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 are presented in Appendix 7.

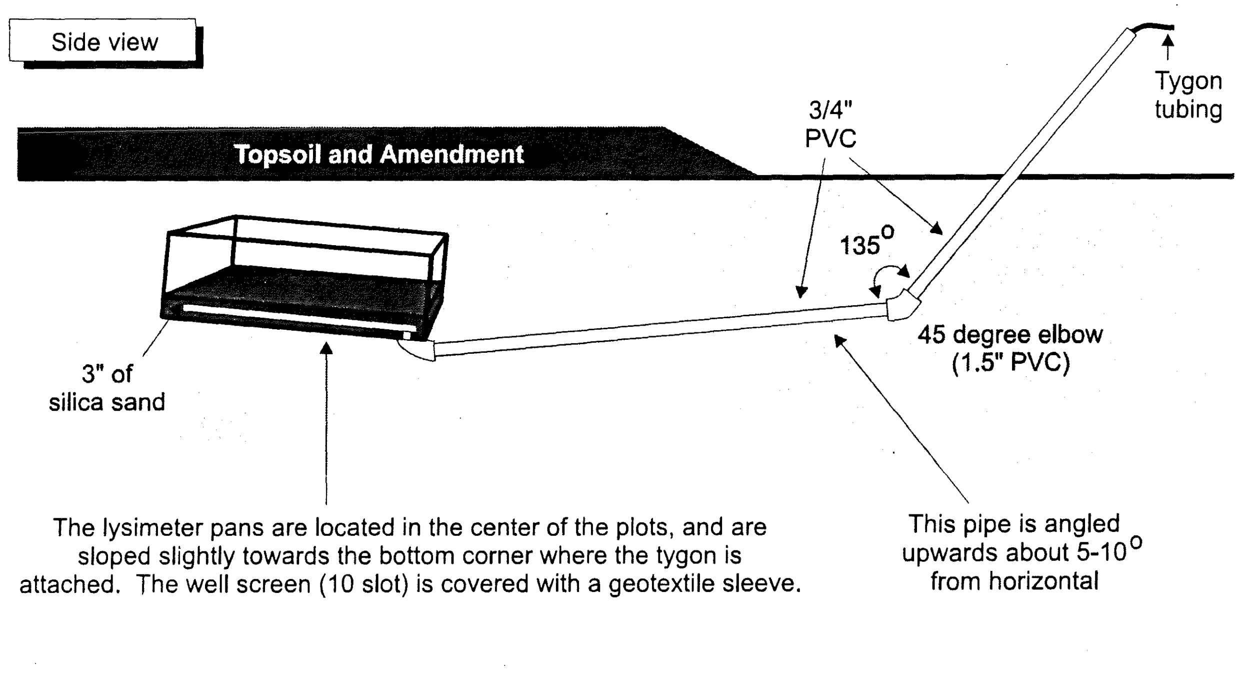


Figure 7. Design of the pan lysimeters.

Figure 8. Installation of the lysimeters.

3.3.2 Suction lysimeters

On June 16, 1997, suction lysimeters (Figure 9) were installed in each of the nine active lysimeter plots, due to a lack of water in the pan lysimeters. Possible explanations for the lack of water were that 1) water that passed through the amendment layer on each plot was soaked up by the dry soil between the amendment layer and the lysimeters (which were buried 1' below the amendment layer), or that 2) water that did reach the lysimeters was wicked back up into the soil layer above them before personnel arrived to pump out the lysimeters. A vacuum was applied to the suction lysimeters, which enabled them to draw moisture in from surrounding areas, and retain any captured moisture.

Two lysimeters were installed on each of the nine plots. One of each pair was set at a depth of about 9" deep, which means that, after subtracting the 6" depth of the "topsoil", the ceramic cup of the lysimeters (which are about 3" tall) are just below the interface between the topsoil and the sandy substrate that is underneath the topsoil. These shorter lysimeters were placed on the east end of each lysimeter plot (the end nearest the road, and were located about 4' from the end of the plot and about 4' from each side.

The other lysimeter on each plot was set at a depth of about 24" from the top of the topsoil, meaning that the bottom of the ceramic cups were set at about 18" from the topsoil/sand interface. These lysimeters were placed on the side of the lysimeter plots farthest away from the road, and the pan lysimeters were located between the two suction lysimeters. (The pan lysimeters were located about 4' from the end west of each plot and from each side.) The details of the installation are presented in Appendix 8.

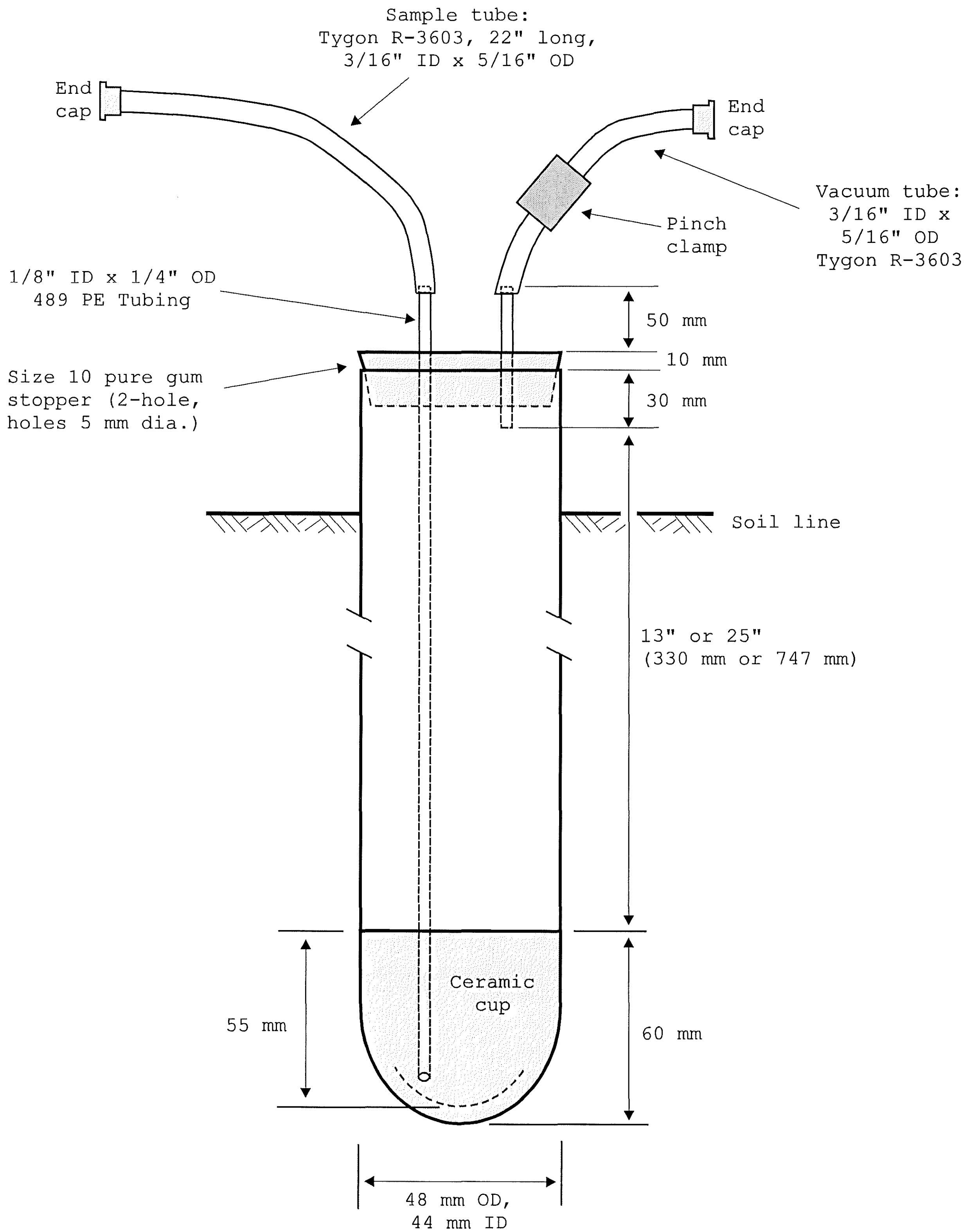


Figure 9. Design schematic of a suction lysimeter.

After each lysimeter had been installed, a cover that consisted of a piece of 2" PVC with an end cap on the top end was placed over each lysimeter, to protect the plastic tubing and stopper assembly from weather damage.

3.3.3 Precipitation monitoring

A continuously-recording rain gage (Universal Recording Rain Gage; Belfort Instrument Co., Baltimore, Maryland) 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 in 1996 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 substantial differences were reported at the two sites.)

On 11/11/96 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 the rainfall recorded by the gage accurately reflected precipitation at the site.

The rain gage was also used in 1997 to collect precipitation data, but again there were gaps in the data set which were filled in with data from Rosemount. These data are presented in Appendix 10.

3.3.4 Water quality sampling

Water samples were expected to be collected after major rainfall events, which were projected to occur every other week on average. However, rainfall from May through September, 1996 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 in 1996.

A peristaltic pump was used to collect water samples on two dates during the 1997 field season. On 7/6/97 samples were collected from some of the suction lysimeters (the other suction lysimeters were dry, as were all of the pans), and on 7/21/97 samples were collected from all lysimeters except the pan lysimeter in plot 6, which was dry (probably because of a plumbing leak).

The pump was hooked up to the Tygon tubing emerging from the lysimeters, and the water from the lysimeters was then pumped out. During the pumping of the pan lysimeters, specific conductance and pH were monitored during the first couple liters of flow (about every 0.5 to 1.0 L), to ensure that water quality had stabilized, and then water quality samples were collected in labeled 2-liter HDPE jugs. The pump was cleaned with deionized distilled water (DDW) after each lysimeter was pumped, and the specific conductance meter was also rinsed with DDW after each use.

On plots 1 and 3, the remaining water in each pan lysimeter was then collected in a 5-gallon pail until the flow stopped, and then the total pumped volume was measured by measuring water depth in the bucket. (And because specific conductance of the drainage from plot 3 had decreased near the end of its pumping, a second sample was collected.) However, there was not enough time to pump out the remaining water from the other seven pan lysimeters on that day (7/21/97), and by the time DNR personnel returned to the site to complete pumping of the other seven plots, they were all dry, presumably because the water had wicked back up into the soil above the pan.

The water quality samples were then sent to the DNR laboratory in Hibbing, MN, where they were analyzed for alkalinity and prepared for additional analyses (Ag, As, Ba, Ca, Cd, Cl, Co, Cr, Cu, Hg, K, Mg, Na, Ni, Pb, Se, SO_4, Zn, Total N, NH3-N, NO_3-NO_2, and Total P) at the Minnesota Department of Agriculture's laboratory in St. Paul, MN. Additional details on sample preparation and analysis is presented in Appendix 11.

3.3.5 Vegetation monitoring program

Biomass and percent cover measurements were conducted in August of 1996, 1997 and 1998. The exact date in August differed slightly (due to personnel conflicts, weather, etc.), but the goal was to collect measurements that reflected mature vegetation each year. It should be noted that there were much fewer percent cover and biomass measurements made on the lysimeter plots than there were on the demonstration plots, due to the smaller size of the lysimeter plots. This increases the odds that a measurement may be non-representative of the lysimeter plot as a whole - a biomass measurement may have been located where a single large plant would provide lots of cover and biomass, though a completely different result may have been obtained if the measurement had been made just a few feet away, where the plot may have been barren. On the much larger demonstration plots, where many more percent cover and biomass measurements were made, this effect was minimized.

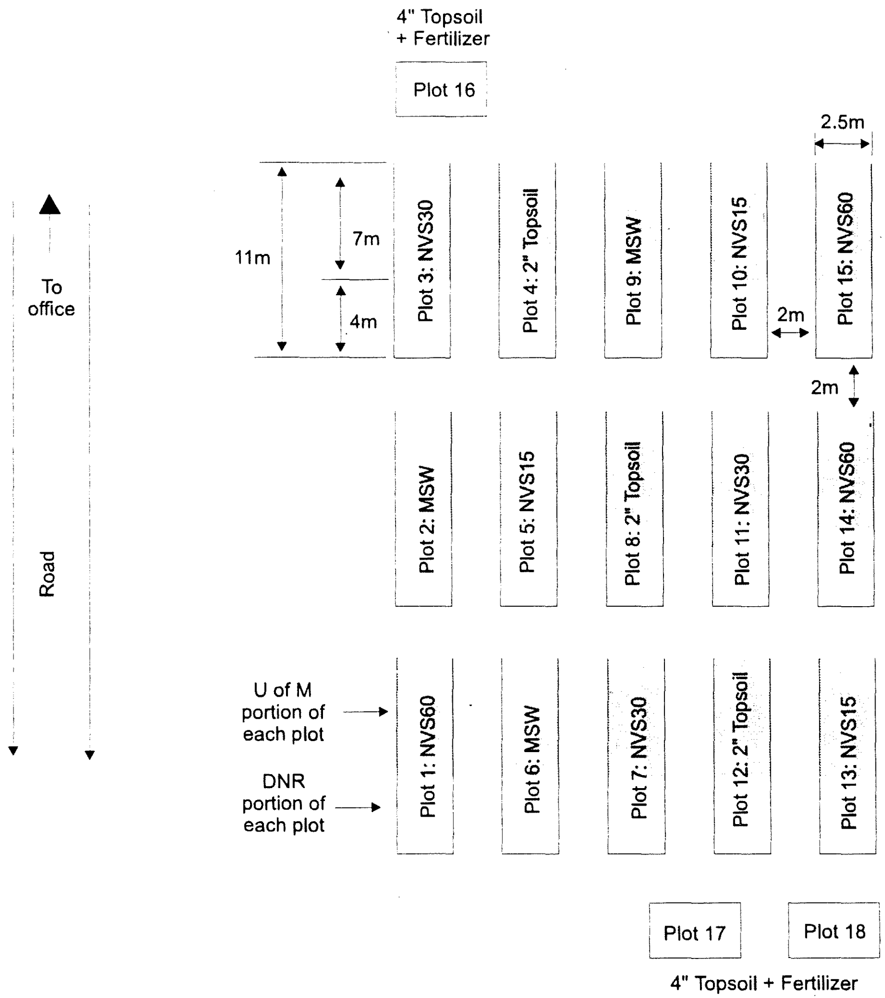
In 1996 and 1997, percent cover was measured (using a 0.5 m^2 frame) at eight sites within each of the 2.5 m x 4 m plots, with the sites being equidistant from each other and from the outside of the plot. In 1996, one of the eight percent cover sites were randomly selected to also have biomass sampled, using an 0.1 m^2 frame. In 1997 and 1998, however, two biomass samples were collected from each plot, to minimize the chance of getting anomalous results.

In 1998, percent cover and biomass data were originally collected on 7/23/98, but these data were lower than in 1996 and 1997, and also seemed to disagree with visual observations made on 8/14/98, when the vegetation appeared to be considerably lusher than indicated by the data. Additional measurements of percent cover were therefore taken again on 8/25/98. These consisted of two observers making estimates of the overall cover within each plot, with the average of the two values being reported for each plot. The three values from the triplicate plots representing each treatment were then averaged to arrive at a final average value for biomass and percent cover.

3.4 Waste sand plots

Original plans had been to construct the waste 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 didn't interfere with pit operations, and since the site is far away from current operations it was expected to remain undisturbed for at least five years.

Figure 10. Design schematic of the waste sand plots.



As shown in Figure 10, the original design of the plots was for a matrix of 15 plots, each 2.5 meters wide and 11 meters long. (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.)

Five different amendments were applied to the 15 plots, with triplicates of each amendment producing a total of 15 plots. The five amendments were:

- NVS at a loading of 60 wet tons/acre (31.2 dry tons/acre)
- NVS at a loading of 30 wet tons/acre (15.6 dry tons/acre)
- NVS at a loading of 15 wet tons/acre (7.8 dry tons/acre)
- MSW compost at a loading of 28 wet tons/acre (20 dry tons/acre, based on a density of 69% solids)
- 2" topsoil

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 waste sand; 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. None of these 15 plots received inorganic fertilizer.

After this original matrix of 15 plots was constructed, the three additional plots (each 2.5 x 4 m) were constructed (Figure 11). 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 330 lbs/acre and raked in.. These three plots were seeded (MNDOT50), mulched at an approximate rate of 2 tons/acre, and then erosion netting was placed on top of the mulch.

The waste sand plots were on top of a hilly area, and very exposed to the wind. Some time between 5/20/96 and 5/29/96, wind dislodged the netting on one of the NVS 60 plots (plot # 14), and blew almost half of the mulch off its original position on the plot. This mulch was redistributed, and then the netting was put back in place. This altered the original conditions of the plot somewhat, but the alternative was deemed to be worse; to leave large mulch-free areas on the plot, which would have hindered vegetative growth irrespective of the amendment of the plot.

Biomass and percent cover was measured on the waste sand plots in August of 1996, 1997 and 1998, using the same general method as described for the lysimeter plots. One biomass sample was collected per plot in 1996, but this was increased to two per plot in 1997 and 1998, to minimize the chance that the measurement would be made in a location that was atypical. Biomass and percent cover measurements were also made on 7/24/98, but these data didn't seem to correspond with visual observations of the plots, so percent cover measurements were made again on 9/9/98. Two observers estimated the overall cover on each plot (using the standard cover classes), then the two values were averaged. The values for each of the three triplicate plots were then averaged to arrive at an overall average value for each amendment. These later measurements were in good agreement with visual observations, suggesting that the July measurements occurred before the vegetation on the plots reached their maturity for the season.

4. Results

4.1 Precipitation

1996 Precipitation was very low during most of the 1996 growing season. Total rainfall for the period of May 1 through September 30 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. As shown in Figure 11, May-September 1996 precipitation was below historical averages, while October and November rainfall exceeded the historical (30-year) averages.

Although an attempt to winterize the rain gage was made, operational problems and a loss of access to the site made the winter data unreliable. Precipitation from the Rosemount site was used for the missing time period. The total precipitation for November 1996 through March 1997 was 10.6", or about 165% of the 30-year average (6.4").

1997 Problems were also encountered with the rain gage in 1997. Precipitation data for 1997 is a combination of data from the project site and data from Rosemount. Precipitation during the growing season (May through September) was well above normal due to the large rains in July. Total estimated rain at the site during July was about 13", or three times the normal amount. Over 5" of the total fell on July 17 (Appendix 10). Total annual precipitation was 33.0 inches, or 107% of the 30-year average (30.75", which is the arithmetic mean of 1961-1990 data, according to the "climate normals" section of the state climatologist's web site; http\\climate.umn.edu).

1998 Precipitation in 1998 was above normal for both May and June, and the 25.6" that fell from May through September was 130% of the 30-year average. Total annual precipitation (measured at Rosemount) was 39.6", which was 129% of the 30-year average.

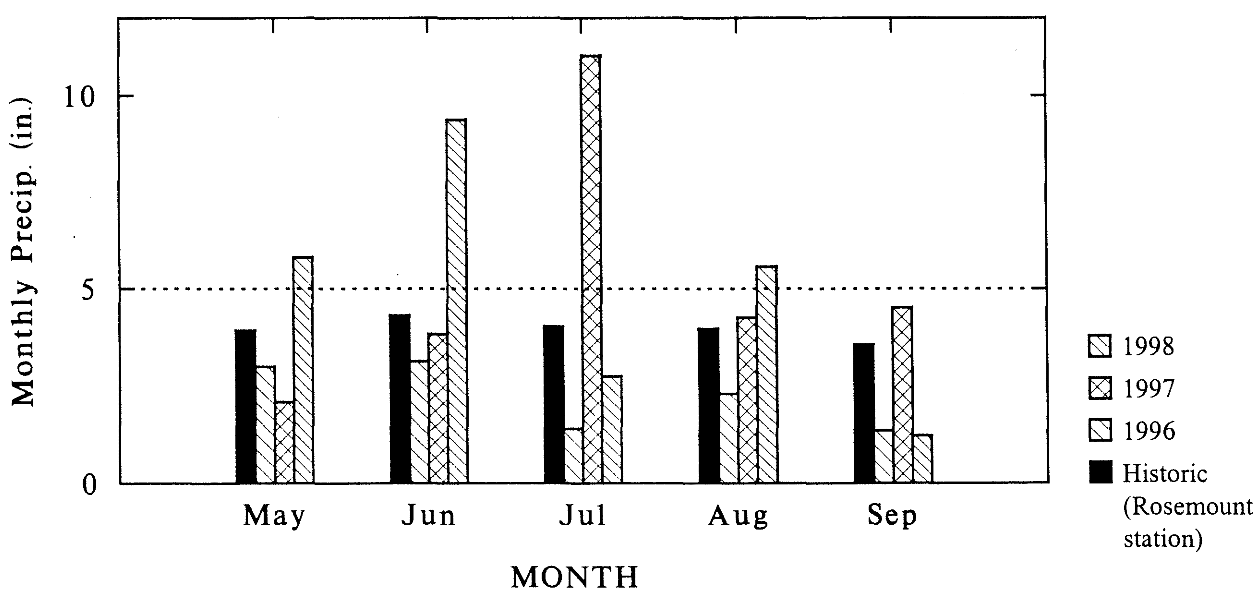


Figure 11. Bar chart of monthly precipitation (May-September, 1996-1998) and historical values.

4.2 Demonstration slope

Percent cover

In general, percent cover was highest on the plots with organic amendments (Table 6). In the first growing season, percent cover was highest on the NVS plot. The average cover for the entire plot was 61% or almost twice that of the control plot (31%). In 1997, percent cover on all plots decreased or remain unchanged (Table 6). In 1998, cover increased on all plots by about 30%, but only the MSW plot had enough cover to essentially meet the DNR mineland reclamation standard of 90% cover after three growing seasons. (The standard provides 5 years for west and south facing slopes; Minnesota Dept. Natural Resources, 1980). However, despite lower percent cover on the other plots, all the plots appeared stable.

Percent cover varied within the plot and between seed mixes. The lowest average cover (21-23%) was measured on the bottom two-thirds of the control plot in 1996 (native seed mixture). By 1998, the cover in this plot, ranged from 64-71% and was essentially equal on all sections of the plot.

The average 1996 percent cover on the native seed portions of the other plots were the same or higher than the portion planted with the standard MNDOT 50 mixture. By 1998, the average cover values varied with each plot by about 10-15%, with the highest values measured in the middle of the plot (Appendix 7).

Biomass

For the first two years, biomass on the plots with organic amendments was more than twice that on the unamended plots. Biomass averaged 41.8 dry g/m^2 for the NVS and MSW plots, and 17.4 and 19.4 for the fertilizer and control plots respectively (Table 6). In 1998, biomass increased in all plots, and although the values were still higher on the amended plots, biomass on the fertilizer plot increased by more than a factor of 2, from 17.4 to 40.4 dry g/m^2. The MSW plot had the highest biomass, 67 dry g/m^2, more than twice the control value of 29.8 dry g/m^2 (Figure 12).

Table 6. Summary of average annual percent cover and biomass on the demonstration plots.

Treatment	Year	Average biomass (dry g / m^2)	Average percent cover
NVS	1996 1997 1998	45.0 38.6 50.4	61.0 47.4 74.5
Fertilizer	1996 1997 1998	20.6 14.2 40.4	44.5 40.6 70.9
MSW	1996 1997 1998	43.8 40.0 67.0	56.5 51.6 89.1
Control	1996 1997 1998	13.2 25.6 29.8	31.1 31.6 68.3

Note: Percent cover estimates were ranges; the midpoint of each range was used in calculation of average percent cover.

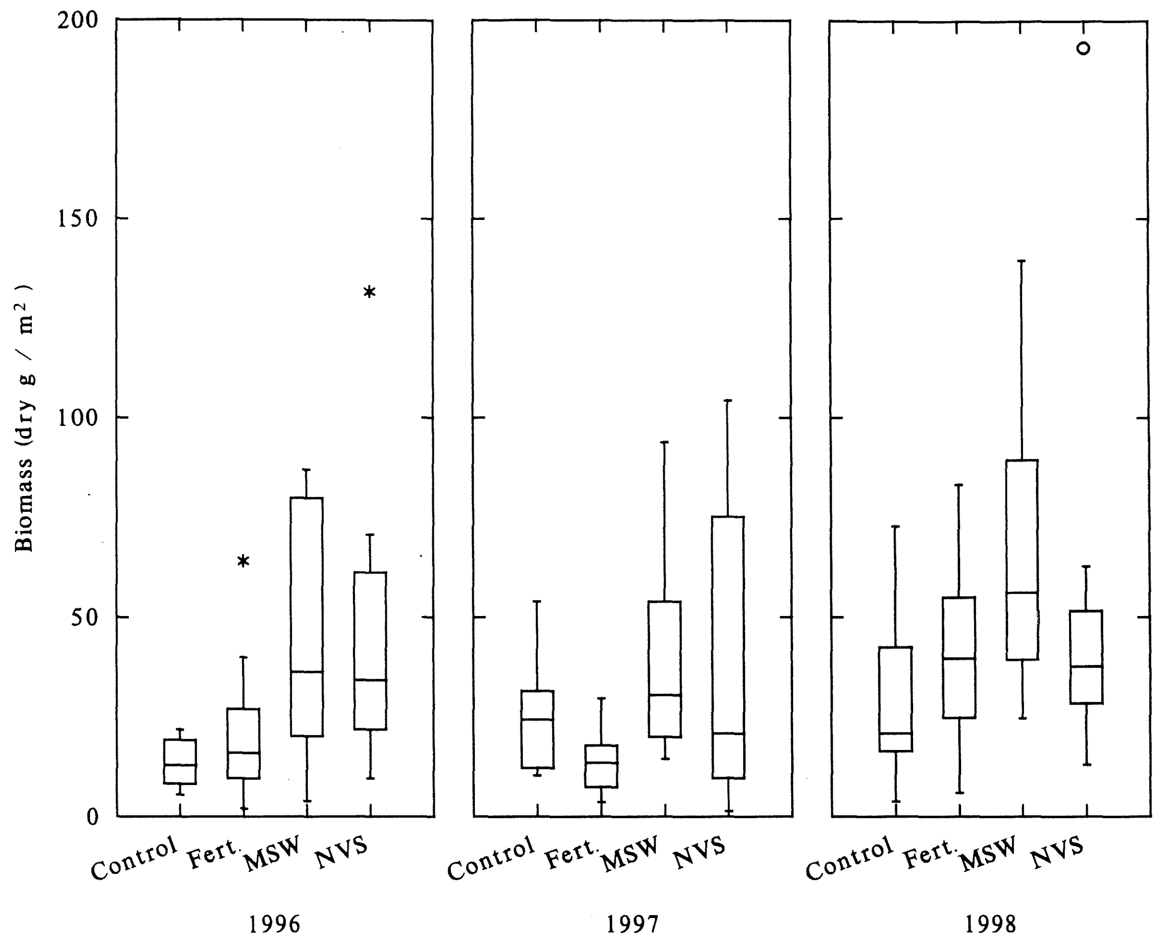


Figure 12. Biomass on the demonstration plots, 1996-1998. (The boxes depict maximum, minimum, median, and 25th and 75th percentiles of the data. Circles and asterisks indicate outliers as calculated by Systat 8.0, a statistical graphing software package.)

Species prevalence

1996 First year growth in all plots was dominated by annual weeds, primarily lambsquarter (*Chenopodium album)*, with some ragweed (*Ambrosia sp.*) About half of the vegetation on the NVS and MSW plots was lambsquarter, with another 10-20% being ragweed. Of the three primary cover crops (oats, flax, rye), only oats appeared to germinate, but the entire stand was grazed by geese. No flax or rye were observed in any of the plots.

There appeared to be more species diversity on the fertilizer and control plots, but most of the observed species were also annual weeds. On the topsoil+fertilizer plot there were large patches of yellow nut grass (*Cyuperus esculentus*, which was present on the other plots but not in the large amounts observed on the fertilizer plot), and both of these plots also contained substantial amounts of other annual weeds such as carpetweed (*Mollugo verticillata*) and pig weed (*Portulaca oleraceal*). A few isolated plants of partridge pea; *(Cassia fasciculata*) a forb included in the native seed mix was also observed in these plots.

None of the planted grasses were observed on any of the plots and with the exception of the few isolated plants of partridge pea, none of the planted forbs were observed.

1997 Annual weeds continued to dominate the plots, especially on the NVS and MSW plots, but ragweed appeared to increase and large amounts of horseweed (*Erigeron canadensis,* also called Marestail) were observed. The large patches of yellow nut grass were still present on the fertilizer plot. By late in the season some of the planted species (primarily grasses such as little blue stem and switch grass) were becoming established, particularly on the MSW plot. Some bluegrass was also noticeable in the area with the cool season mix (i.e. on the top third of the plots), particularly on the MSW and control plots.

1998 With the exception of the NVS plot (where there was still a large amount of horseweed), almost all of the weeds had been replaced by planted species. Warm weather grasses dominated the entire plot area including the upper portion where the MNDOT 50 mix had been planted. The most common grasses were switch grass and little blue stem, but Indian grass, wild rye, and side oats gramma were also observed in the native portions of the plots and, isolated plants of big blue stem, slender wheat grass, and sand drop seed were also present. The most common forbs were the grey headed coneflower, Black-eyed Susan and purple prairie clover, but ox eye, butterfly weed, hoary vervain, showy pentstemmon and goldenrod were also observed. The NVS plots had a much higher percentage of weed species, primarily horseweed. In some areas of the plot, the horseweed appeared to account for roughly half of the total cover on the plot.

Although 34% of the MNDOT 50 mix was brome grass and bluegrass, very little brome grass was present and no bluegrass was observed.

A list of plants observed growing on the demonstration plots in 1996-1998 is presented in Table 7, with Latin names presented when known. (This should not be considered a comprehensive list; the list is a composite of walking surveys made on several separate trips, and other species may have gone unobserved.)

Erosion

Although no quantitative measurements of erosion were made, qualitative observations of erosion were made during the initial part of the study. 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.

The two ditches cut into the slope (across the entire width of the slope), which were intended to break up water flow down the slope, became filled in at different rates on the different plots. By the end of 1996, 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, as did the NVS plot. Erosion had also partly filled in the top ditch of the fertilizer plot.

Rainfall in July 1997 was about 13 inches or about 3 times the normal amount. This included a 5.05 inch rainfall on July 17. After these rains, all the ditches on all four plots were essentially filled and erosion gullies at the toe of the slope were created or enlarged. Most of these emerging gullies were small (about 1-2' wide at the bottom), but a few were fairly large (5-10' wide at the bottom, and 10-15' long). The location of each gully was recorded with a GPS unit (Figure 5). There were gullies observed at the toe of all the plots, with the largest on the control plot. Vegetation was present on the up-slope side of these gullies but the company decided to fill the gullies (in August 1997) to prevent further erosion.

Table 7. List of plants observed on the demonstration plots, 1996-1998.

1996	1997	1998 (from survey by Bob Jacobson, MNDOT)
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.*) Lambsquarter (*Chenopodium album*) Morning Glory (*Ipomoea sp.*) Mullein (*Verbascum thapsus*) Nightshade (*Solanum sp.*) Pennsylvania Smart Weed (*Polygonum pennsylvanicum*) 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 Winged Pig Weed (*Cycloloma atriplicifolium*) Wormwood (*Artemisia annual*) Yellow Cone Flower (*not known*) Yellow Nut Grass (*Cyperus esculentus*)	No comprehensive surveys were done in 1997 for the demo plots. Annual weeds (mostly ragweed with some lambsquarter) still dominated, and late in the season horseweed (Erigeron canadensis) started to become more plentiful, especially on the NVS plot. Wild vetch and wild pea were also seen for the first time.	Big Bluestem (*Andropogon gerardii*) Black Eyed Susan, Cone Flower (*Rudbeckia hirta*) Bristly Foxtail, Bur bristelegrass (*Setaria verticillata*) Brome Butterfly Weed (*Asclepias tuberosa*) Carpetweed (*Mollugo verticillata*) Common Mullen (*Verbascum thapsus*) Evening Primrose (*Oenothera biennis*) Giant Foxtail (*Setaria faberii*) Hedge Bindweed (*Convolvulus sepium*) Hoary Vervain (*Verbena stricta*) Horse Balm (*Collinsonia canadensis*) Horseweed, Marestail (*Erigeron canadensis*) Kentucky Blue Grass (*Poa pratensis*) Lambsquarter (*Chenopodium album*) Little Bluestem (*Schizachyrium scoparium*) Ox Eye (*Helipsis helianthoides*) Pennsylvania Smartweed (*Polygonum pennsylvanicum*) Perennial Ragweed, Western Ragweed (*Ambrosia psilostachya*) Purple Prairie Clover (*Petalostemum purpureum*) Purslane, Pusley (*Portulaca oleracea*) Rough Pigweed, Redroot (*Amaranthus retroflexus*) Sandbur, Burgrass (*Cenchrus pauciflorus*) Showy Penstemmon (*Penstemon grandiflorus*) Side Oats Grama (*Bouteloua curtipendula*) Slender Wheat Grass (*Panicum virgatum*) Switch Grass *(Panicum virgatum)* Wild Rye (*Elymus canadensis*) Wild Vetch, Wild Pea (*Vicia angustifolia*) Winged Pigweed (*Cycloloma atriplicifolium*) Wineleaf Cinquefoil (*Potentilla tridentata*) Wormwood (*Artemisia annua*)

Notes: Alfalfa was observed in 1996 at the top of the fertilizer plot. This was from an area that hadn't been disturbed during plot construction. The species presented here are those observed during periodic walks through the plots, and should not be construed to be a comprehensive list.

4.3 Lysimeter plots

Percent cover

In 1996, percent cover was similar for all treatments, ranging from an average of 68.9 for the NVS plots to 76.0 for the fertilizer plots (Table 8). Percent cover decreased by 26% on the fertilizer plot in 1997, and although cover increased in 1998, it was still less than the first year cover and less than the cover on the amended plots. Three year cover was highest on the NVS plot (85%) and would have satisfied the mineland reclamation 3 year cover standard of 90%. Although the percent cover on two of the MSW plots was equivalent to the cover on the NVS plots, one plot had slightly less cover. As a result, the overall average was only 77.5% (Appendix 7).

Biomass

With the exception of the first year biomass on the NVS plot, biomass on the amended plots exceeded the biomass on the fertilizer plot. At the end of the third growing season, the biomass ranged from 36.4 g/m^2 in the NVS plots to 21.0 g/m^2 in the fertilizer plots (Table 8).

Species prevalence

1996 The predominant species in all plots were the cover crop of oats and the annual weed lambsquarter. Some of the rye cover crop was also observed, but no flax plants were observed.

1997 Some of the perennial grasses that were planted had begun to grow. Little blue stem, switch grass and brome grass were observed in all plots. The fertilizer plot appeared to have more brome than the amended plots.

1998 Little blue stem and switch grass were the dominant species in both the MSW and the fertilizer plots but brome was also observed. Brome was the dominant grass in the NVS plot, and the native species tended to occur primarily around the edge of the plots.

Table 8. Summary of average annual percent cover and biomass on the lysimeter plots.

Treatment	Year	Average biomass (dry g / m^2)	Average percent cover
NVS	1996	15.4	68.9
	1997	49.6	71.7
	1998	36.4	85.0
MSW	1996	31.0	71.2
	1997	37.0	60.0
	1998	28.6	77.5
Topsoil + Fertilizer	1996	15.9	76.0
	1997	19.0	49.9
	1998	21.0	62.5

4.4 Water samples

Water yield

Precipitation was below normal during the 1996 growing season, and no water was present in the pan lysimeters. The only time measurable water in the lysimeters occurred was after the 5.05" rain on July 17th. When samples were collected on July 21, about 10 gallons of water were removed from two of the lysimeters (Table 9). The total volume of the lysimeter, assuming that the porosity is 0.33, is about 15 gallons. Converting the volume of water removed to inches of water input yields about 2.7 inches, or about 54% of the input water was recovered in the lysimeter.

There was not enough time on July 21 to pump the remaining lysimeter. When the remaining pans were pumped on July 23, no water could be recovered. The water had disappeared from the pan lysimeters, likely because it soaked back up into the surrounding soil via capillary action. As a result, the total volume for these pans could only be estimated to be in excess of the 0.5 liters removed the day of sampling (Table 9).

Water Quality

Due to the very dry conditions experienced at the Nelson Mine during the spring and summer of 1996, and the inherent problems with the pan lysimeters, no water samples were collected from the lysimeter plots in 1996. In 1997, limited data was collected from the suction lysimeters on July 7th, but the only complete sample set was collected on July 21. With such a limited sample set collected over a year after application, it is impossible to draw any definitive conclusions.

In general, the amended plots contained slightly higher concentrations of the major cations and anions than the fertilizer plots. Average specific conductance ranged from 200 μS in the fertilizer plots to 410 μs in the NVS plots. The samples from the NVS plots contained more calcium, magnesium, and sulfate than the other two treatments, while sodium was highest in the samples from the MSW plots (Table 10).

Table 9. Pumping volumes from pan lysimeters on 7/20/97, plus stabilized pH and S.C. values.

Plot	Treatment	Final value (i.e. after drainage quality had stabilized)		Volume (gal)
1	Topsoil	290	7.39	~9.5
4	Topsoil	210	7.54	0.5
6	Topsoil	no water	no water	0.0
3A	NVS	900	7.20	0.5
3B	NVS	700	7.49	~10.0
5	NVS	290	7.39	0.5
9	NVS	290	7.58	0.5
2	MSW	310	7.32	0.5
7	MSW	295	7.50	0.5
8	MSW	390	7.57	0.5

Note The S.C. of drainage from plot 3 had slowly declined as it was being collected in the 5-gal pail, so a second water quality sample was collected near the end of pumping. The data shown above for 3B are those observed near the end of pumping, and the total volume pumped from plot 3 was approximately 10.5 gallons.

Table 10. Average water quality of drainage from the MSW, NVS and fertilizer lysimeter plots.

	Detection limit	MN Drinking Water. Std.	U.S. EPA Drinking Water Std.	Average value (ppm)		
				MSW	NVS	Fertilizer
pH	---	---	---	7.95	8.00	7.96
S.C. (μS)	---	---	---	260	410	200
Alk. (ppm)	---	---	---	140	160	105
Ag (ppb)	1.0 ppb	---	100 [A]	0.5	0.5	0.6
As (ppb)	1.0 ppb	50	50	0.7	1.1	0.9
Ba (ppb)	---	2000	2000	19.2	30.1	19.4
Ca (ppm)	---	---	---	30.6	50.0	36.9
Cd (ppb)	1.0 ppb	5.0	5.0	0.5	0.5	0.5
Cl (ppm)	0.5 ppm	---	---	0.3	0.3	0.3
Co (ppb)	1.0 ppb	---	---	0.9	3.9	1.6
Cr (ppb)	1.0 ppb	100	100	0.9	0.8	0.6
Cu (ppb)	---	---	1300 [B]	10.8	6.2	3.6
Hg (ppb)	0.5 ppb	2.0	2.0	0.25	0.25	0.25
K (ppm)	---	---	---	2.1	2.5	2.6
Mg (ppm)	---	---	---	9.9	17.1	10.0
Na (ppm)	---	---	---	12.2	6.6	3.1
Ni (ppm)	0.1 ppm	100	---	0.05	0.05	0.05
Pb (ppb)	1.0 ppb	---	15 [B]	0.5	0.5	0.5
Se (ppb)	1.0 ppb	50	50	0.6	0.5	0.5
SO4 (ppm)	---	500	250 [A]	9.3	44.7	19.5
Zn (ppm)	0.05 ppm	---	5.0 [A]	0.02	0.02	0.02
Total N (ppm)	---	---	---	1.80	0.85	0.61
NH_4-N (ppm)	---	---	---	0.08	0.05	0.06
NO_3 (ppm)	0.4 ppm	45 [C]	45 [C]	4.6	3.7	1.4
Total P	---	---	---	0.06	0.05	0.05

Notes Detection limits are presented only for those parameters with values less than the DL. Values that were less than the DL were converted to half of the DL. Thus a value of <1.0 ppb was changed to 0.5 ppb. Underlined values indicate that all values were less than the detection limit. The values presented are based on all samples, both suction and pan lysimeters.

A These are secondary standards, which are non-enforceable guideline that reflect aesthetic or cosmetic effects (taste, color, etc.).

B These are the "action levels" for copper and lead; if more than 10% of tap water samples exceed the action level, water systems must take additional treatment steps.

C This is based on an N-as-NO_3 value of 10.0 ppm.

All the samples collected from all the plots met drinking water standards. The concentrations of all the trace metals were low; copper in the MSW plots had the highest measured values (11 μg/L). Detection limits were not sensitive enough to accurately detect nickel or zinc in any of the samples.

Nitrate concentrations were higher in the amended plots, and in the samples from all the suction lysimeters than in those from the pans. The highest nitrate concentrations were measured in the shallow suction lysimeters on July 7th. The concentrations ranged from 2 mg/L in a fertilizer plot to 21 mg/L in a MSW plot (Appendix 11). Concentrations decreased after the 5 inch rainstorm on July 17.

The nitrate values in the pan samples were less than the detection limit of 0.40 mg/L, while concentrations in the suction lysimeters ranged from 0.41 in a fertilizer plot to 1.08 mg/L in a MSW plot (Appendix 11). The average nitrate concentrations in the plots with NVS and MSW were about three times higher than those in the fertilizer plot and ranged from 4.6 mg/L in the MSW plot to 1.4 mg/L in the fertilizer plot (Table 10).

4.5 Waste sand plots

Percent Cover

In 1996 percent cover was low on all plots, ranging from 4.7% on the topsoil plot to 45.1% on the NVS 30 plot (Table 11). Percent cover generally increased over time and by the end of the third year, the NVS 60, the NVS 30, the MSW and the top soil and fertilizer plots had an average percent cover of 85%. Although the average cover on these four treatments was identical, vegetation appeared to decrease in the order of NVS 60 > NVS 30 ≈ MSW > top soil + fertilizer. The cover class method used to estimate percent cover employs large ranges in percent cover. All of the plots had cover in the range of 75-95%, but the cover in the NVS 60 plots was closer to the upper end of the range, while cover on the top soil and fertilizer plot was at the bottom of the range (Appendix 7). Cover on the NVS 15 and the 2" topsoil plots without fertilizer was less, and ranged from 62.5% to 70%.

Biomass

Biomass was extremely variable in these plots. Biomass ranged from 10.2 g/m^2 on the NVS 60 plot in 1996 to 87.8 g/m^2 on the same plots in 1997. Biomass decreased to 38.6 g/m^2 in 1998. Biomass fluctuated on the other plots as well but no general trends could be observed (Table 11).

4.6 Costs

Costs to reclaim the demonstration slope ranged from $770/acre for the control with the MNDOT 50 seed mix to $1460/acre for the MSW with the native seed mix (MNDOT 20; Table 12). Native seeds were about 50% more expensive than the standard seed mix and seeding costs were estimated to be significantly more expensive ($250/acre vs $50/acre; Table 12). (The MNDOT 50 mix can be broadcast, while a seed drill is recommended for the native (MNDOT 20) seed mix.)

The major cost of using the organic amendments was the transportation cost which was a function of the distance from the source of the amendment to the mine. Transportation costs added $120-$300 per acre to the overall cost while application was estimated to add an additional $120 per acre. The most expensive item was the mulching, which contributed $475/acre to the overall cost.

Table 11. Summary of average annual percent cover and biomass on the waste sand plots.

Treatment	Year	Average biomass (dry g / m^2)	Average percent cover
NVS60	1996 1997 1998	10.2 87.8 38.6	28.2 74.6 85.0
NVS30	1996 1997 1998	43.2 26.6 16.3	45.1 57.9 85.0
NVS15	1996 1997 1998	15.5 43.4 18.3	22.6 39.0 70.0
MSW	1996 1997 1998	12.4 23.7 41.9	11.4 39.0 85.0
4" Topsoil + Fertilizer	1996 1997 1998	16.3 17.6 28.2	34.3 34.5 85.0
2" Topsoil	1996 1997 1998	9.2 14.2 22.6	4.7 23.1 62.5

5. Discussion

Demonstration Slope

Two previous attempts had been made to stabilize this area and both had been unsuccessful. Although there were no detailed records of the reclamation approach, a standard seed mix, which contained brome and alfalfa, was most likely applied. These species were present at the start of this project in a small strip about 10' wide at the top of the control and fertilizer plots.

The use of organic amendments and seed mixes which contained native species was successful in reclaiming and stabilizing this area, despite below normal precipitation during the first growing season, inadequate mulch, and a completely grazed cover crop. The plots with the organic amendments had less erosion, particularly during the first year, and the plot with the MSW compost had the highest percent cover and biomass.

Although this was the first attempt to use MSW in a gravel mine in Minnesota, MSW compost has been one of the most successful amendments in reclaiming coarse taconite tailings in northern Minnesota (Eger et al., 1999, 2001). Coarse taconite tailings are a coarse and medium sand waste generated during the processing of iron ore. They contain essentially no organic matter, very few nutrients and have very little water holding capacity. The addition of 20 dry tons/ acre of MSW compost provides sufficient moisture holding capacity to allow vegetation to become established, and has provided sufficient cover to meet the mineland reclamation of 90% cover after three growing seasons (Eger et al., 1999, 2001).

Table 12. Reclamation cost summary (1996 dollars).

	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.) For this project, planting was done by MNDOT.

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 back haul, the price would increase to $400/acre.

The NVS plot was not as successful as the MSW plot, and after three years the percent cover was substantially less than the MSW plot, and only about 5% greater than the plot with fertilizer. Although all plots were dominated by annual weeds in the first year, the weeds appeared to persist longer on the NVS plot. The NVS contained16.2% organic matter and about 0.9% nitrogen (TKN), but has a pH of 12. The high pH results from the addition of alkaline materials to the sludge, during the production of the NVS. The high pH helps to kill any pathogens and the alkaline nature of the final product makes it suitable as a liming agent. The pH of the topsoil on the demonstration slope was approximately 7.5 (Table 3), and no lime was needed. As the pH of the soil increases, the availability of phosphorus and certain micro nutrients such as copper and zinc decreases. Amendments with a lower pH (like the MSW) might be more suitable for these types of soils.

After three years, the dominant species on all sections of all the plots were native warm season grasses, primarily switch grass and little blue stem. In the mid to late 1980s, the specifications for the standard MNDOT mix 50 began to change. Native species, switch grass, little blue stem and slender wheat grass were added, and these grasses, due to their extensive root systems, do well in dry conditions. Although cool season grasses, including brome and blue grass, comprised 34% of the seed mix, these species were never widespread on the slope and had virtually disappeared by the end of the third growing season.

The portions of the plots that had been planted with the native seed mix (MNDOT 20) had a higher diversity than the upper portions of the slope (MNDOT 50), since more grass and forb species had been included in the initial seed mix. These species were successful in stabilizing even the control plot, where no amendment or fertilizer had been added, and in spreading into the area adjacent to the control plot.

The little blue stem in the MNDOT 50 mix had a distinct blue green color in contrast to the same plant in the 20 mix. It is believed that the blue green variety is a western species and not a native Minnesota variety (Jacobson, Djupstrom, personal communication). Although it appears to be successful, it was observed to produce seed somewhat later than the Minnesota variety. In future projects Minnesota varieties should be used to ensure successful long term survival.

In 1999, the demonstration slope was included in the South Washington County Garden Tour, as an example of successful reclamation and prairie planting, and in April of 2000 the entire slope was burned (Appendix 14). Although native species successfully stabilized this slope, periodic maintenance such as burning will be required to maintain the health of the prairie in this area. Without burning, woody species can invade and out-compete the natives. Additionally, burning returns nutrients to the soil, to ensure a continuing nutrient source for the native species.

<u>Lysimeter plots</u>

After three years, percent cover on both the NVS and MSW lysimeter plots exceeded the cover on the unamended plots. Since these plots were small and flat, growing conditions were expected to be better than on the south facing demonstration slope. Percent cover on the NVS plots exceeded that on the slope, but cover on both the MSW and topsoil plots was less.

When the location for the lysimeter plots was initially chosen, there was no signs of gophers. However, after the plots were constructed, gopher mounds were observed in the undisturbed area adjacent to the plots. Despite several attempts to poison the colony, the gopher colony expanded, and by 1998 there were mounds in the lysimeter plots (see photos in Appendix 15). Although the mound areas were not included in the cover estimates, the presence of the gophers has probably affected the overall vegetation in these plots.

In addition, the native species on the lysimeters plots did not appear as large as those on the demonstration slope. The lack of dominance and smaller size of the native species may have contributed to the lower overall cover measured in these plots.

Given the limited water quality data and the lack of any data in the first year of application, it is difficult to draw any definitive conclusions on the impact of these amendments on water quality from this study. However, previous studies with MSW have shown that the application of 20 dry tons/acre of MSW did not cause water quality problems (Melchert et al., 1994, Eger et al., 2001).

Data on the impact of NVS is very limited, with the only data from a study conducted in an agricultural area by Halbach et al in 1991-93. Some elevated metal concentrations were reported in Halbach's study. However, based on the reported pH of the water samples in that study, the elevated concentrations appeared to be related to high detection limits, and did not appear to be accurate reflections of the actual metal concentrations. In the Shiely study, the pH of the water samples exceeded 7, and no elevated metals were observed. Even though samples were not collected until the year after application, the low metal content of the NVS and the elevated pH of the drainage should prevent measurable metal migration from the site.

Waste sand

As little as 30 wet tons of NVS per acre were as successful in establishing vegetation on the waste sand as the standard approach of covering with 4" of topsoil and fertilizer. The addition of 60 wet tons per acre of NVS produced about 90% cover after three years.

While the cover on the MSW plot was comparable to that produced on the 4" of topsoil and fertilizer, it was lower than typically observed in other mineland reclamation studies. In these previous studies, fertilizer has always been added, since MSW by itself is only a low-grade fertilizer. Since one of the study participants wanted to compare the treatments without any added fertilizer, and since a majority of each plot was set aside to examine native species success, no fertilizer was applied to the original 15 plots. If fertilizer had been added, percent cover and biomass on the MSW plots would probably have been higher.

Costs

A major concern with the use of any soil amendment is the effect on the total cost of reclamation. Organic amendments produced from waste materials are typically free, and the cost of transportation is usually the single highest cost in determining the feasibility of using an organic amendment for a reclamation project.

Shipping costs for the NVS used in this project were about $5 per dry ton, though the Metropolitan Council was generally willing to ship the material for free to agricultural users in the seven county metropolitan area. The closest MSW compost facility (at the time this project commenced) was in Wright county, about 50 miles from the site. As a result, the shipping cost for the MSW compost was about $13 per dry ton. Shiely was able to arrange a back-haul for the MSW compost with a trucking firm which was hauling material from the mine. Without the back haul, the cost would have been about 33% higher.

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 12).

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 were 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 to fertilize, seed, and mulch the demonstration slope were $800/acre for the cool season mix, and $1,150-$1,425/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 12).

Although the organic amendments raised the cost of reclamation by 25-50%, the additional cost is small in comparison to 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).

To reclaim the waste sand area, a minimum of 4" of topsoil cover would typically be required by a county reclamation plan. Based on Shiely's estimate of $3.50 /yd to move and apply topsoil for this project, topsoil cover for the waste sand area would cost about $1860 per acre. To apply 30 dry tons of organic material (approximate addition rate for the NVS 60 plots) would cost about $360 for NVS and about $560 for MSW. Based on the data collected from this study, this approach would not only produce better vegetation but would also reduce the reclamation cost by about $1200 to $1500 /acre.

Future Use of Organic Amendments

Although the application of MSW compost from the Wright County Composting facility and of NVS from the Seneca plant in Eagan was successful in the reclamation of all the plots at the Nelson Mine, neither of these products are currently available. Similar municipal compost facilities are currently located in Baudette, Thief River Falls and Truman, MN, and facilities that use only a select organic portion of the municipal waste stream, or which produce materials that are mixtures of MSW compost and other organic materials (such as food wastes) are located in at least seven other Minnesota cities (Appendix 3).

Although NVS is no longer produced in Minnesota, there are about 40 plants located throughout the United States (according to an internet site associated with NVS International Corp.; http://www.wateronline.com). Also, construction of a new NVS facility is scheduled to commence at the Pig's eye treatment plant (on Child's Road in St. Paul) near the end of 2001. This facility will (on average) process about 10% of the sludge at the facility, which will produce about 25 dry tons per day. (This will be equivalent to the maximum production achieved at the Seneca plant.)

The NVS used in this project cost about $5 per dry ton to ship to the site, but the Metropolitan Council was generally willing to transport the NVS for free to agricultural users in the seven county metropolitan area. It is likely that after the new plant is built in St. Paul, the material will continue to be delivered at no cost within the seven county metropolitan area.

While the NVS application was successful, the liming potential and high pH (12) of the product was not needed for the alkaline soils at the Nelson Mine. Currently, the Blue Lake wastewater plant (Shakopee, MN) is producing about 25 dry tons per day of a heat dried pellet. These pellets meet the Exceptional Quality sludge requirements and have a pH of about 6.0, which would be more suitable for the reclamation of alkaline soils. They also have a high organic matter content (about 80%, as compared to about 60% for digested biosolid materials). The pellets are available for free, as is shipping of the pellets within the seven county metropolitan area for agricultural users.

Biosolids are generally in high demand in the spring and fall for agricultural uses, and the Metropolitan Council may not be willing to ship them for free during these times for use in reclamation activities. But there is less of a demand for the pellets in the summer growing season and in the winter, and the Metropolitan Council may be willing to ship them for free during these periods. Since the material is considered to be Exceptional Quality, stockpiling of the material for future use would be acceptable. A user wanting to use the pellets in gravel pit reclamation could therefore obtain the material during the summer or winter, and then spread the pellets at a later date.

Although these pellets have not been used for mineland reclamation in Minnesota, other biosolids have been successfully used in iron mine reclamation in Minnesota (Eger et al., 2001) and in gravel reclamation in other parts of the United States (Schmidt et al., 2001).

6. Conclusions

1. Addition of NVS, MSW compost, and fertilizer to the south-facing demonstration plots increased percent cover and biomass, and decreased erosion. The MSW plot was particularly successful, with close to 100% cover.

2. The vegetative success on the MSW plot was most likely due to the incorporation of organic matter and nutrients into the sandy topsoil of the demonstration slope. However, even the control plot had much better vegetation than the slope did prior to this project, indicating that selection of the proper seed mix is also an important factor in attaining successful plant growth on these sandy soils.

3. After three years the NVS plot had more annual weeds than the other plots.

4. NVS and MSW compost can be spread successfully on large-scale projects with a compost spreader. Bulldozers were ineffective in applying the amendments to the loose, sandy slope, because they were unable to attain the very thin, uniform layer that was required, and because they tended to slide downhill. But the spreader was able to apply a reasonably uniform, 1/4" to ½" layer of both materials on a 4:1 slope.

5. The two horizontal trenches cut into the demonstration slope were effective at reducing the amount of fine material that washed down the slope. Better vegetative cover on the MSW and NVS plots reduced the amount of material that accumulated in the trench. The trenches were completely filled in after above normal precipitation in July 1997, but they helped to reduce erosion on the slope until the plants had enough time to become established.

6. The water quality of samples collected from the lysimeter plots indicate that neither MSW nor NVS pose water quality risks when used in this type of application. The nitrate levels of the samples from the plots with MSW and NVS were higher than the fertilizer plots, but still well below the applicable water quality standard.

7. Both MSW and NVS may be suitable replacements for topsoil on the waste sand material. Percent cover and biomass were highest on the plots with 60 tons of NVS /acre (31.2 dry tons/acre). Cover on the NVS 30 (15.6 dry tons/acre) and the MSW plot (20 dry ton/acre) were comparable to the cover on the plots with 4" of topsoil plus fertilizer.

8. Inadequate mulch and grazing by of the oat cover crop by geese may have affected the amount and type of vegetation initially on the demonstration slope. Oats, perennial rye and flax were used as cover crops on the demonstration plots, but only the oats appeared to germinate and grow. However, since grazing by the geese decimated the oats, a different cover crop may be appropriate when the reclamation site is located near a water body that attracts waterfowl.

9. The little bluestem plants on the top 1/3rd of each plot, which came from outside Minnesota, appeared to develop seeds slower than the Minnesota variety. Minnesota genotypes should be specified in future applications

10. 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.

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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 2/3 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 NVS 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

Tables:

N-Viro Soil (NVS) is a biosolid that was produced at the Seneca Wastewater Treatment Facility (located in Eagan, MN) until January, 2001. The N-Viro facility was operated by the Metropolitan Council's Environmental Services Division, and Steve Stark was 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 ran the facility until it closed in January, 2001.) The data focuses on 1995 and 1996 because that was when the NVS used in this project was created.

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.

Table A2.1. Annual summaries of NVS chemical data (1992-2000).

Note: The values shown are yearly means, and all units are on a dry weight basis.

	T.S. (%)	ENP (%)	ENP (lb/T)	TVS (%)	TKN (%)	NH3-N (%)	Avail. N (lb/T)	P (%)	K (%)	S (%)	As (mg/kg)	B (mg/kg)	Cd (mg/kg)
2000 Average:	60.9	47.5	577	21.1	0.84	0.03	3.51	0.55	0.33	1.25	12.6	253	2.4
1999 Average:	57.1	49.6	565	23.9	0.82	0.02	3.38	0.52	0.36	1.27	11.4	239	1.9
1998 Average:	58.8	40.3	497	24.0	0.92	0.02	3.80	0.51	0.32	1.35	9.2	219	2.0
1997 Average:	58.0	41.0	475	27.1	0.88	0.02	3.55	0.61	0.34	1.25	8.0	236	5.0
1996 Average:	55.6	43.2	483	28.4	0.91	0.02	3.75	0.53	0.39	1.20	9.2	263	5.8
1995 Average:	53.6	48.7	523	28.2	0.99	0.04	4.20	0.52	0.77	1.94	12.0	153	5.1
1994 Average:	55.6	51.2	572	25.3	0.96	0.03	4.00	0.50	0.62	2.80	11.0	215	4.9
1993 Average:	59.6	52.5	625	23.3	0.78	0.02	3.25	0.37	0.95	3.31	20.5	256	3.6
1992 Average:	57.5	57.2	659	17.9	0.92	0.04	3.05	0.33	1.38	3.13	25.1	198	4.5

	Cu (mg/kg)	Pb (mg/kg)	Hg (mg/kg)	Mo (mg/kg)	Ni (mg/kg)	Se (mg/kg)	Zn (mg/kg)	PCB (mg/kg)	pH
2000 Average:	125	41	0.38	19	98	10.2	150	< 0.20	11.7
1999 Average:	129	50	0.45	17	91	9.8	143	< 0.20	11.9
1998 Average:	192	65	0.43	16	91	6.4	134	< 0.20	12.0
1997 Average:	173	78	0.36	15	80	6.7	114	< 0.20	12.2
1996 Average:	219	94	0.31	12	80	7.0	140	< 0.20	12.1
1995 Average:	170	106	0.41	7.1	28	6.3	120	< 0.20	12.3
1994 Average:	148	65	0.34	11	29	6.8	170	< 0.19	12.3
1993 Average:	93	135	0.08	14	45	7.6	308	< 0.06	12.6
1992 Average:	94	174	0.18	12	38	17.4	295	< 0.18	12.2

Table A2.2. 1995 NVS analyses.

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	

Table A2.3. 1996 NVS analyses.

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
1/1/96	50.9	45.0	458	40.0	0.88	0.05	3.8	0.45	0.43	1.0	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	52.6	47.0	494	32.4	1.50	0.04	6.3	0.63	0.44	1.1	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	49.4	42.4	419	34.3	1.17	0.03	4.9	0.65	0.45	0.8	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	51.9	39.5	410	28.7	0.96	0.03	4.1	0.48	0.36	0.9	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	53.0	43.1	457	33.3	1.09	0.02	4.5	0.66	0.35	1.1	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	49.5	40.9	405	33.7	1.84	0.02	7.5	0.93	0.43	0.9	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	54.7	42.8	468	29.6	0.82	0.02	3.4	0.59	0.41	1.0	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	53.6	42.3	453	28.8	1.21	0.02	5.0	0.71	0.38	0.6	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	56.5	43.0	485	28.8	0.65	0.01	2.7	0.42	0.35	1.2	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	56.7	42.9	487	25.5	0.88	0.02	3.6	0.74	0.41	0.8	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	56.6	43.4	492	27.7	0.48	0.02	2.0	0.35	0.59	1.2	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	61.2	53.0	649	22.8	0.59	0.02	2.5	0.47	0.38		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	64.0	51.0	653	18.0	0.16	0.02	0.7	0.14	0.27		9.4	275	5.5	17	211	76	0.27	15	80	3.9	112		12.1	<4 mpn/gram
7/15/96	61.0	51.3	626	20.6	0.54	0.00	2.2	0.36	0.27			298	4.9	20	215	88	0.39		91		116		11.9	<4 mpn/gram
7/29/96	63.4	53.6	680	19.3	0.32	0.01	1.3	0.39	0.32			300	4.2	24	205	85	0.47		177		109		12.1	<4 mpn/gram
8/12/96	59.0	38.5		25.1																			12.1	
503 "Clean Sludge" Limits:											41	--	39	1200	1500	300	17	18	420	36	2800			
1996 Average:	55.9	45.0	509	28.0	0.87	0.02	3.6	0.53	0.39	1.0	8.3	249	5.1	19	210	100	0.32	8.1	55	6.0	139	< 0.20	12.1	
1995 Average:	53.6	48.7	523	28.2	0.99	0.04	4.2	0.52	0.77	1.9	12	153	5.1	18	170	106	0.41	7.1	28	6.3	120	< 0.20	12.3	
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	< 0.19	12.3	
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	< 0.06	12.6	
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	< 0.18	12.2	

Table A2.4. 1995 bio-check analyses of NVS.

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**

Table A2.5. 1996 bio-check analyses of NVS.

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

Table A2.6. 1996 NSP coal ash analyses (page 1 of 2).

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

Table A2.6. 1996 NSP coal ash analyses (page 2 of 2).

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

Table A2.7. 1996 ADM-Mankato coal ash analyses (page 1 of 2).

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	4.6	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

Table A2.7. 1996 ADM-Mankato coal ash analyses (page 2 of 2).

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

Table A2.8. 1996 Cutler-Magner lime kiln dust (LKD) analyses (page 1 of 2).

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

Table A2.8. 1996 Cutler-Magner lime kiln dust (LKD) analyses (page 2 of 2).

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	<).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

Table A2.9. 1995 Seneca sludge analyses.

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	

Table A2.10. 1996 Seneca sludge analyses.

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	18.0							8.3		4.1	17	878	45	0.7		27		434		
10/2/96	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	

[ ] = 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

Appendix 3

MSW Compost Information

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 were 8 facilities in the state that produced municipal solid waste (MSW) compost when this project commenced. The MSW compost used in this project was produced at the Wright County Compost Facility, located in Buffalo, MN. Dave Mehrenberg was the facility manager, and on April 18, 1996, Paul Eger and Jon Wagner of the MDNR toured the facility with Dave. Attached is a document that summarizes the production process, as well as a list of compost facilities currently in operation around the state. 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.)

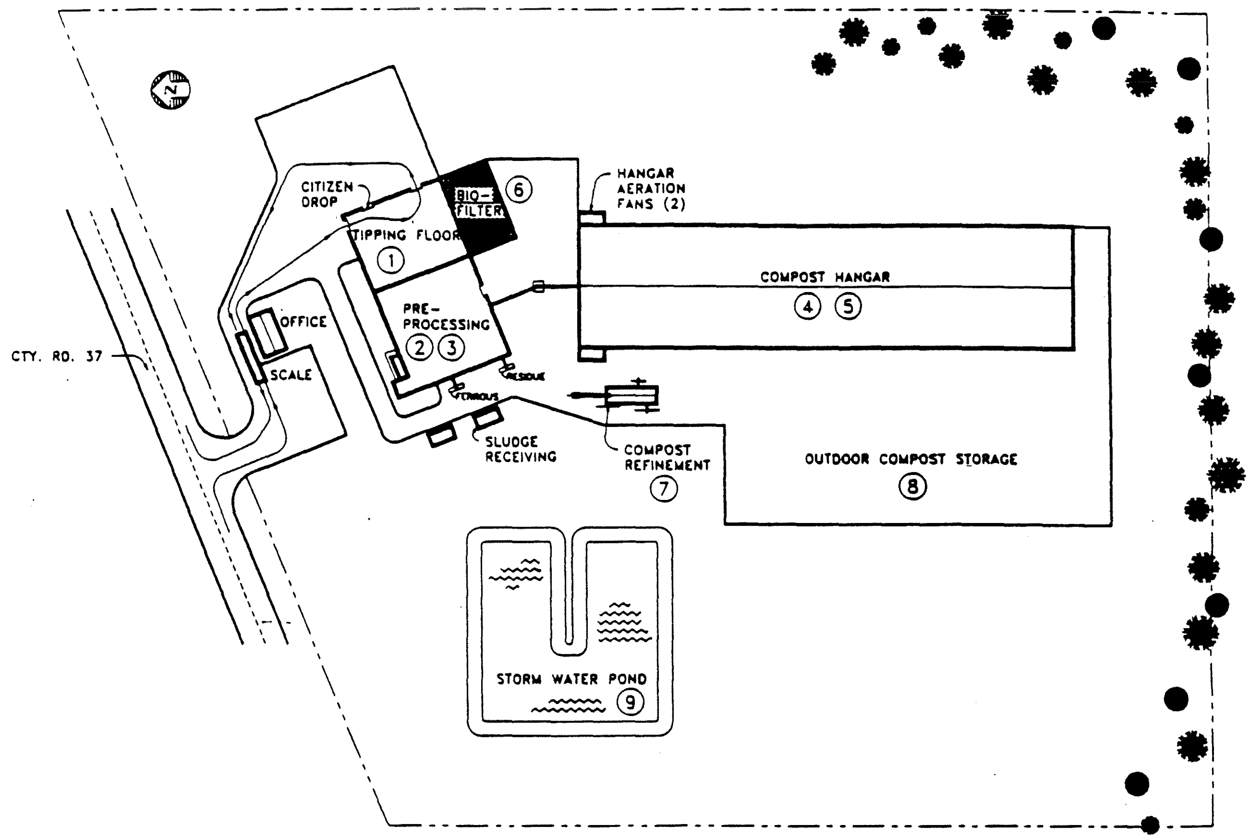
After the windrow process is completed, the compost passes through a ballistic separator in which the compost flows through it but materials such as glass don't; instead they are fed to conveyors that lead up and out of the separator.

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".

Table A3.1. Permitted MSW compost facilities as of July, 2001.

Three of these operations (Baudette, Thief River Falls, Truman) produce only MSW compost; the others combine MSW compost with other materials (i.e. composted food waste).

Facility Name	Contact Person Name and Address	Telephone No.	County	Region
SW-305 Resource Recovery **Elk River RDF Processing Fac 10700 - 165th Avenue NW Elk River, MN 55330**	Joe Weinhold NRG Resource Recovery 1221 Nicollet Mall, Suite 700 Mpls, MN 55403-2445	612/373-5431	Sherburne	Brainerd
SW-322 Compost and Transfer (former SW-244 **Fillmore County Res. Recovery Ctr Highway 16 East Preston, MN 55965**	John Martin Fillmore County Courthouse Highway 52 East, Box 655 Preston, MN 55965	507/765-2430	Fillmore	Rochester
SW-342 Compost **Lake of the Woods Cty Res. Recovery Fac. Potoma Township Baudette, MN 56623**	Gary Lockner Lake of the Woods County County Courthouse PO Box 808 Baudette, MN 56623	218/634-1945	Lake of the Woods	Detroit Lakes
SW-509 Compost Petro Soils **Lakehead Environmental Services Compost Facility 2916 Hill Avenue PO Box 698 Superior, WI 54880**	Brian Maki, General Manager 2916 Hill Avenue PO Box 698 Superior, WI 54880	715/392-5181	St. Louis	Duluth
SW-557 Compost **Mississippi Topsoils Compost Facility 14138 State Hwy 23 PO Box 444 Cold Spring, MN 56320**	Brad Matuska 14138 State Hwy 23 PO Box 444 Cold Spring, MN 56320	320-685-7676	Stearn	Brainerd
SW-285 Resource Recovery **Pennington County Densified Refuse Derived Fuel Facility SWIS/PENNCO Thief River Falls, MN 56701**	Richard Nordhagen 1355 Highway 32 South Thief River Falls, MN 56701	218/681-3710	Pennington	Detroit Lakes
SW-357 Compost **Prairieland Resource Recovery/Composting Facility 801 East 5th Street Truman, MN 56088**	Mark Baumann Prairieland Compost Facility 801 East 5th Street Truman, MN 56088	507/776-3288	Martin	Rochester
SW-286 Resource Recovery **Ramsey/Washington Resource Recovery Facility 3000 Maxwell Avenue Newport, MN 55055**	Joe Weinhold NRG Energy, Inc. 1221 Nicollet Mall, Suite 700 Minneapolis, MN 55403-2445	612/373-5431	Washington	Metro
SW-479 Compost **SMC Source Separated Composting, 700 Summit Avenue Mankato, MN 56000**	Mike Guillemette SMC 1905 Third Avenue PO Box 3069 Mankato, MN 56002-3069	507-388-3122	Blue Earth	Rochester
SW-375 Compost **Swift County SW Compost/Recycling Fac Highway 3 Benson, MN 56215**	Scott Collins Swift County County Courthouse 301 4th Street North Benson, MN 56215	320/843-2356	Swift	Marshall

Appendix 4

Seed Mix Information

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.

Attached is a document from Kim Hennings (MDNR, Division of Fish and Wildlife) addressing the goose predation which decimated the cover crop of oats on the demonstration plots.

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. Hope this helps.

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

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

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

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

JUN -3 1996

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.	MGR.	OFFICE
DD				

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

Appendix 5

Shipping Details and MSW application rate calculations

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. The NVS was denser and was also applied in a thinner layer, so fewer loads were needed. Shipping of the NVS was done by Miller Trucking.

Table A5.1. Net weight of MSW compost delivered to the demo slope.

Date	Weight ticket #	Net weight of compost (lbs)	Comments
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	3036	10,120	This load came in the compost spreader
5/9/96	3037	31,200	---
5/9/96	3038	29,360	This load was stockpiled on east end of road
5/9/96	3040	32,240	This load was stockpiled on east end of road

Some residual MSW was not applied. Some went to the lysimeter and waste sand plots (1 loader bucket, about 3 yards, was delivered to each site, so about 6 yard was removed.)

Total MSW = 199,300 lbs
Sent to lys and w.s. plots = 6,000 lbs
Residual = 6,000 lbs
So net weight of compost spread on demo slope = 187,300 lbs

MSW compost is about 31% moisture.

Dry weight = (0.69 x 187,300) / (2000 lbs/ton) = approximately 65 tons

Area of spread = $(((154 \text{ m} + 146.5 \text{ m}) / 2) \times ((78 \text{ m} + 73.5 \text{ m}) / 2) \times (3.28 \text{ ft/m})^2) / 43{,}560 \text{ ft}^2\text{/acre}$

= 2.8 acre

Application rate = 65 dry tons / 2.8 acre = 23 tons/acre

Note: The actual weight tickets are presented in the 1997 progress report for this project.

Appendix 6

Notes from site visits

1. 5/20/96 field notes by Wagner
2. 7/5/96 field notes by Wagner/Eger
3. 7/10/96 field notes by Steve Dewar
4. 8/1/96 field notes by Deena Bahner
5. 7/13/98 field notes by Eger (with Bob Jacobson)
6. 8/25/98 field notes by Eger
7. 8/14/00 visit to demonstration plots by Eger, Wagner, Bob Djupstrom and Kim Hennings

<u>5/20/96 field notes by Wagner</u>

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.

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.

7/5/96 field notes by Wagner/Eger

Paul Eger and I (Jon Wagner) inspected the demonstration slope on Friday, July 5, 1996; 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.

The demo slope much greener 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. annual weeds). Ragweed and lambsquarters 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 lambsquarters), 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, carpetweed 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.

<u>7/10/96 field notes by Steve Dewar</u>

On Tuesday July 10 I visited the Scheily research and demo sites. At the demo slope I noted geese grazing on the planted cover crop plants. Geese have apparently grazed all the oats and probably the rye as well down to stubble. Because our cover crop is now just stubble, weeds have become the primary cover. Lambsquarters, carpetweed, and yellow nutsedge have been tentatively identified as the primary weeds invading the site. Cover is estimated at 50-70% with some slight differences between treatments. The NViro plot appears to be the most vigorous. There was very little erosion evident due to the cover of weeds, cover crop stubble and mulch. Mulch appeared to be thin, not meeting the 2 ton/acre specification. This site is very weedy. Although it is not unusual for a first year planting to be somewhat weedy. I believe there sre some permanent grasses that were seeded that will become establishedand will outcompete the weeds with time.

At the lysimeter site the vegetation is well established and there was little difference between treatments.

At the waste sand research plots our topsoil+fertilizer plots were well established and doing the best as expected. The NVS 30 ton plots with the MnDOT 50 mix were doing well also. The U of M seed plots did not germinate except for 3 or 4 species on the topsoiled treatment plots only.

<u>8/1/96 field notes by Deena Bahner</u>

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.

<u>7/13/98 field notes by Eger (with Bob Jacobson)</u>

general observations of demo slope:

nviro plot more weeds, horse weed, mare's tail

Bob said that they have seen this on other projects too, not sure why, could be high pH

best cover is MSW

also plants are larger than on unfertilized and fertilized plots

most of cover on all plots are from planted species

nut grass, rag weed and lambs quarters are essentially gone

major weed is the mare's tail, inspots there is a fair amount of ground cherry

upper 1/3 is dominated by natives, primarily switch grass and little blue stem

fair amount of prairie clover

almost no brome, blue grass or timothy

natives are all bunch grasses

roots can spread about twice the size of the plant

even in native prairies don't get 100% ground cover

Bob thought that 60-80% was more typical

black eye Susan

are biennial, reseed (small furry leaves) need open ground to reseed

cool season natives, wild rye and slender wheat grass

warm season blue stem switch grass Indian grass, sand drop seed, side oats gramma

he expects that on this site due to aspect and site conditions that warm season will dominate

helpful factors,

switch looks like quack grass

Indian, reddish brown, bronze, yellow flower, comes out of sheath

side oats, seeds hang to side

little blue stem

plants on top 1/3 are bluish green

bottom 2/3 are more green, but seed stalks are reddish purplish and seed heads are whitish and appear fluffy, 1-2 ' tall

big blue stem, 3-5' has seed head that looks like turkey foot

slender wheat grass -skinny seed head

forbs

prairie purple clover
Penstemon
black eyed Susan
goldenrod
butterfly weed
ox eye daisy
    yellow flower with yellow center
vervain
bush clover
sunflower
primrose
sage

maybe best to group into bunch grasses, forbs and weeds

other weeds observed
ground cherry
ragweed
horse weed

others
milk weed
Mullen
sweet clover
vetch
2 types of mint

this time may be best to do survey is many of grasses are seeding, makes id easier

fire is not necessary, it does help and keeps out woody species returns nutrients to soil
looking at other alternatives to fire to help sustain quality of prairie

very little non native grasses in any of the plots, should contrast this to lysimeters

DOT using regreen a special cover crop a cross between slender wheat and x, lasts 3 years

Bob felt that for this site, the broadcast seeds may do better his fear with drill on bottom 2/3 was that since soil was light seeds may have been drilled too deep

problem weeds for prairies are anything that grows thick, dense and low, e.g. trefoil, vetch, red clover spotted knap weed, brome

he thought that bottom 2/3 species will spread to the upper slope

natives can compete better than exotic and weeds, for nutrients and water, due to extensive root systems

<u>8/25/98 field notes by Eger</u>

lysimeter plots:

qualitative observations

overall view of plots

in the original measurements of the plots for this season, some of the percent cover values seemed too low, the plots were reevaluated using a general overview of the plot, this is less precise, because it involves walking around the entire plot and giving an overall impression of the percent cover and the cover acceptability

in quantitative measures used hoops and only considered live vegetation, or standing dry, not litter
in qualitative tends to be more overall impression

check with Steve on reference for this technique, did he ever write this up?

Percent cover:

NVS>MSW>fertilizer, the difference between the NVS and the MSW was slight , but both were denser than the fertilizer

gophers have moved into many of the plots, despite repeated attempts to control their spread with poison

general observations

fertilizer:

the plants are smaller and have less seed production than the other treatments
the predominant species are the warm season natives, switch grass and blue stem, these are clumps and as a result there is less cover

MSW:

predominant species are switch and blue stem, but there is also some brome, plants are tall, in general, good cover

NVS:

there is a distinct difference in species in this treatment vs the others, brome appears to be the predominant grass and there is also what appears to be slender wheat grass, there seems to be less warm season grasses, and what does occur is around the edge of the plot, or slightly outside the plot

in some of the plots alfalfa or sweet clover has begun to grow, and the buffer area has begun to fill in

do we want to maintain these plots, if so should we reestablish the buffer zone we could till or roundup

conclusions:

all treatments were successful in establishing cover, but organic amendments improved overall cover and growth of plants warm season species did better in the fertilizer plots and in the MSW plots, while the cool season species did better in the NVS

if desire native species, cover and growth the MSW did best after 3 years (will the natives push out the brome over time? In the MSW plot)

differences between the lysimeter and demo slopes

check application rates of NVS
check fertilizers rates , I think lysimeter plots were fertilized but slope was not

only a few isolated wild rye plants at lysimeters where there is significant numbers on the demo slope

<u>8/14/98 field notes by Eger/Wagner</u>

took series of photos at demo plots

NVS:

overall slope has decent cover (should try and make a qualitative estimate similar to what has been done at lysimeter plots)

the striking observation for these plots is the large amount of mare's weed present in the plot, particularly in the bottom 2/3 of the plot. Took a photo at the boundary between the top and middle third and can see the higher percentage of mare's weed in the middle third of the sloe

in spots this weed provide 50-75% of the overall cover

in the top 1/3 there are native grasses

bottom third

more than 50% of cover is mare weed

fertilizer pot

plants in top 1/3 are not as tall as in NVS plot
much less mare weed

cover is less in middle third, primarily due to lack of mare weed
more mare weed in bottom third, and less overall cover in bottom third

MSW

top third
plants are taller, dense, particularly switch grass, much more cover and biomass than fertilizer plot, essentially no mare weed

middle third more diverse than top third

bottom third has some mare weed, overall cover is not as good as middle third

control

shorter vegetation and less dense

overall

all plots have developed reasonable vegetation, with best being on top and middle portions of slope

best growth is in the MSW top and middle third, with the middle third being more diverse and most aesthetically pleasing

NVS although cover is good , there is much more weed species than other plots

reasons for success

several other attempt to stabilize this slope have failed
in previous attempts no fertilizer was applied but our control plot despite lower cover and biomass did ok

some possible explanations include

heavy rainfall immediately after planting
different seed mix
this seems to be the most logical explanation for our success and previous failures, vegetation on the top third of the control plot is dominated by warm season grasses, which can do well on this south sandy slope

need to get info on what was done before

fertilizer helps, organic amendment particularly MSW increase cover and biomass of desirable species faster than NVS, additional data will be taken at 5 years to determine long tern effect

<u>8/14/00 visit to demonstration plots by Eger, Wagner, Djupstrom and Hennings</u>

Visited site with Bob Djupstrom (MDNR's SNA Planning Supervisor) and Kim Hennings of the MDNR.

Top slope on all plots dominated by switch grass; bob suggested decreasing amount of switch in mix.

Walked bottom 1/3 - plots looked better than ever, ragweed had come into bare spots, noticed on NVS and saw horseweed and yellow nut grass, which hadn't seeen much since the early part of the study.

Saw large areas of partridge pea, again hadn't seen since year one.

Much better diversity on lower slopes than had thought, some native species that were not in the mix had invaded; a native spurge, flowering spurge, small white flowers, sage, milkweed, sweet everlasting , switch grass, also called tickle grass, saw a plant of sand grass? Sand reed grass?

Cotton weed

Also saw bush clover which had not seen before. This was in the mix, fair amount of an aster which was not in flower yet, but some were in mix, one tic seed plant, 2 type of sunflower, white milkweed.

Lots of side oats gramma. The blue green bluestem on the top part of the slope is a western genus (Bob Jacobson thought it was from North Dakota, Bob Djupstrom thoutht maybe Nebraska. The Minnesota variety had already produced seed, while the western variety had not started yet, his concern was that we did not have enough grwoing season to have this plant produce seed, and so it would not spread and eventually die out.

Canadaian goldenrod will invade empty areas.

There seemed to be little visual difference between the first three plots. The control had noticeably less cover and grass, Bob J thought there might be more forbs, but not clear to me. The first thought of the other three, (me, jon and kim) was that this plot was not as good.

One of the advantages of the organic mateial is to hold moisture, so will get better germination. This will benefit natives also.

Recommends not using brome or blue grass in mix, didn't take and not as much wildlife value

Need to get rid of woody species on slope and cottonwoods at water, otherwise will spread. Burning won't kill woody species, just burn the tops.

West strain of bluestem on bottom could be due to seed that has been washed down the slope.

In future, specify Minnesota seeds, less switch.

When they do restoration work they just harvest the seeds in the area and reapply, so don't have a specific seed mix.

Appendix 7

Percent cover and biomass analysis methods and notes

In **1996,** percent cover measurements were conducted and biomass samples were collected from the demonstration plots, the lysimeter plots and the washed sand plots. 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.

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 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.

Also, 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 selected for the middle of the range, but more precision was practical at the ends of the range because it becomes easier to detect subtle differences in cover.

In **1997**, the same sampling scheme was used in 1997 (except that two biomass samples instead of one were collected from each lysimeter and washed sand plot).

In **1998** the original measurements seemed to be too low in comparison with visual observations (possibly because these measurements were made relatively early, in late July), so new percent cover measurements were made. On the demonstration plots, the same method was used as in 1996-97. But the results presented for the lysimeter and washed sand plots are based on visual estimates by two observers of total cover on each plot, with the values presented being the average of these two values for each plot. Thus the washed sand and lysimeter data for 1998 are presented in tables separate from the 1996-1997 data.

Table A7.1. Summary of 1996 biomass and percent cover data.

Site	Treatment	Biomass (dry 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	na	18.280
"	MSW	3	6.418	29.726	15.457	12.503	24	37.500	97.000	71.250	na	19.247
"	Fertilizer	3	6.513	9.284	7.802	1.395	24	37.500	97.000	76.042	na	17.884
Washed sand plots	NVS 60	3	0 (no sample)	7.15	3.575	n/a	24	3.000	85.000	28.208	na	19.906
"	NVS 30	3	12.95	36.15	24.55	n/a	24	15.000	62.500	45.104	na	16.656
"	NVS 15	3	1.11	11.18	6.145	n/a	24	15.000	62.500	22.604	na	13.032
"	MSW	3	4.43	7.69	6.06	n/a	24	3.000	37.500	11.438	na	8.069
"	Topsoil	3	3.84	5.52	4.68	n/a	24	0.500	15.000	4.688	na	4.784
"	Topsoil+Fert.	3	6.79	10.18	8.485	n/a	24	15.000	85.000	34.271	na	20.397

na = not analyzed

Table A7.2. Summary of 1997 biomass and percent cover data.

Site	Treatment		Biomass (dry g/0.5 m^2)					Percent Cover					
			n	Min	Max	Mean	S.D.	n	Min	Max	Mean	Median	SD
Demo slope	NVS	Top	4	7.4	48.1	23.1	19.0	24	37.5	85.0	52.9	62.5	15.7
		Middle	4	4.5	52.2	29.0	24.4	24	37.5	97.0	55.6	37.5	22.2
		Bottom	4	0.7	12.7	5.8	5.0	42	3.0	62.5	33.8	37.5	18.7
		All	12	0.7	52.2	19.3	19.3	72	3.0	97.0	47.4	37.5	21.2
"	Fert.	Top	4	2.7	9.2	6.7	3.0	24	15.0	62.5	44.8	37.5	11.6
		Middle	4	1.8	12.6	6.7	4.9	24	37.5	85.0	41.0	37.5	18.9
		Bottom	4	3.8	14.9	7.9	4.9	24	15.0	62.5	35.9	37.5	13.7
		All	12	1.8	14.9	7.1	4.0	72	15.0	85.0	40.6	37.5	15.3
"	MSW	Top	4	9.5	10.9	10.1	0.6	24	15.0	62.5	44.2	37.5	17.7
		Middle	4	7.2	38.2	22.1	12.7	24	37.5	85.0	59.8	62.5	18.5
		Bottom	4	10.3	46.9	27.6	15.3	24	15.0	85.0	50.9	50.0	19.9
		All	12	7.2	46.9	20.0	12.9	72	15.0	85.0	51.6	62.5	19.5
"	Control	Top	4	5.2	24.1	13.9	7.8	24	15.0	62.5	29.3	37.5	15.0
		Middle	4	5.4	27.0	14.1	9.3	24	15.0	62.5	40.0	37.5	15.6
		Bottom	4	5.8	17.2	10.3	5.3	24	3.0	62.5	25.5	15.0	16.4
		All	12	5.2	27.0	12.8	7.2	72	3.0	62.5	31.6	37.5	16.7
Lysimeter plots	NVS		6	11.6	40.6	24.8	10.7	24	37.5	97.0	71.7	62.5	16.3
"	MSW		6	9.4	29.8	18.5	8.2	24	37.5	85.0	60.0	62.5	15.6
"	Fertilizer		6	3.3	21.0	9.5	6.2	24	15.0	85.0	49.9	37.5	19.9
Washed sand plots	NVS 60		6	20.8	65.3	43.9	14.9	24	15.0	97.0	74.6	85.0	22.2
"	NVS 30		6	5.9	23.4	13.3	6.7	24	15.0	85.0	57.9	62.5	21.7
"	NVS 15		6	9.7	36.1	21.7	10.2	24	15.0	85.0	39.0	37.5	17.7
"	MSW		6	7.1	16.2	11.9	3.8	24	15.0	62.5	39.0	37.5	14.9
"	Topsoil		6	4.1	11.0	7.1	2.4	24	3.0	62.5	23.1	15.0	15.6
"	Topsoil+Fert.		6	5.4	12.0	8.8	2.9	24	3.0	62.5	34.5	37.5	15.3

Table A7.3. Summary of 1998 biomass and percent cover data.

Site	Treatment	Biomass (dry g/0.5 m²) (These samples were collected 7/20/98 - 7/24/98)					Percent Cover (The demo slope measurements were made 9/1/98, the lysimeter measurements were made 8/25/98, and the washed sand measurements were made 9/9/98)					
		n	Min	Max	Mean	S.D.	n	Min	Max	Mean	Median	SD
Demo slope	NVS Top	4	10.43	96.63	37.05	40.38	24	37.5	85.0	66.9	62.5	15.4
	Middle	4	6.53	23.28	16.64	7.42	24	37.5	99.5	81.9	85.0	14.5
	Bottom	4	14.61	31.33	21.74	7.61	24	37.5	99.5	74.8	85.0	17.8
	All	12	6.53	96.63	25.15	23.61	72	37.5	99.5	74.5	85.0	16.9
"	Fert. Top	4	12.32	32.32	20.51	11.26	24	37.5	85.0	72.7	73.8	13.5
	Middle	4	2.99	30.00	15.05	12.47	24	37.5	97.0	75.4	85.0	17.9
	Bottom	4	16.81	41.55	25.01	9.82	24	15.0	85.0	64.7	62.5	21.2
	All	12	2.99	41.55	20.19	11.02	72	15.0	97.0	70.9	85.0	18.1
"	MSW Top	4	12.38	33.52	25.16	9.93	24	62.5	97.0	83.6	85.0	7.0
	Middle	4	18.54	69.72	44.38	21.20	24	62.5	99.5	94.2	97.0	8.4
	Bottom	4	12.84	66.84	31.03	24.30	24	62.5	99.5	89.4	91.0	10.4
	All	12	12.38	69.72	33.52	19.52	72	62.5	99.5	89.1	85.0	9.6
"	Control Top	4	9.91	36.33	22.18	10.84	24	37.5	85.0	70.0	62.5	16.4
	Middle	4	8.83	16.78	11.60	3.58	24	37.5	97.0	70.7	62.5	17.7
	Bottom	4	1.92	31.22	10.90	13.78	24	15.0	97.0	64.4	62.5	23.2
	All	12	1.92	36.33	14.90	10.79	72	15.0	97.0	68.3	62.5	19.3
Lysimeter plots	NVS	6	7.30	21.50	18.18	5.41	3	85.0	85.0	85.0	85.0	---
"	MSW	6	9.39	21.93	14.34	4.77	3	85.0	85.0	85.0	85.0	---
"	Fertilizer	6	5.97	13.73	10.52	2.95	3	62.5	62.5	62.5	62.5	---
Washed sand plots	NVS 60	6	6.05	41.81	19.32	12.99	3	90.0	95.0	92.5	90.0	---
"	NVS 30	6	3.75	11.71	8.15	2.93	3	75.0	80.0	77.5	75.0	---
"	NVS 15	6	5.98	12.30	9.16	2.48	3	65.0	75.0	70.0	70.0	---
"	MSW	6	9.72	34.22	20.94	9.26	3	70.0	75.0	72.5	75.0	---
"	Topsoil	6	6.41	15.38	11.28	3.37	3	60.0	70.0	63.3	60.0	---
"	Topsoil+Fert.	6	2.60	37.50	14.09	12.13	3	75.0	75.0	75.0	75.0	---

Note: Percent cover estimates were made by selecting one of eight cover classes. Since these cover classes are ranges, which doesn't permit calculation of summary statistics, the midpoint of each range was selected to represent that cover class. Thus, an estimate of 25-50% cover was converted to 37.5%, the midpoint of that cover class. Two sets of percent cover measurements were made in 1998. The first set (made July 20-24) seemed too low when compared with visual observations of entire plots, so new measurements were made in early September. The percent cover data shown above for the demo plots are from this second set of data, but the biomass data were from samples collected during the July sampling. And while the same measurement system was used on the demo plots both times, the values presented for the lysimeter and washed sand plots are based on visual estimates of each plot by Eger/Wagner (thus no values for standard deviation are presented). As a result, the range of the values is much smaller than in previous years, since no measurements were made on quadrats within the plots.

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Demo slope	Control	Bottom	8 7 96	.	1	5-25%	15.0	.
Demo slope	Control	Bottom	8 7 96	.	1	1-5%	3.0	.
Demo slope	Control	Bottom	8 7 96	.	1	5-25%	15.0	.
Demo slope	Control	Bottom	8 7 96	.	1	5-25%	15.0	.
Demo slope	Control	Bottom	8 7 96	.	1	25-50%	37.5	.
Demo slope	Control	Bottom	8 7 96	.	1	5-25%	15.0	.
Demo slope	Control	Bottom	8 7 96	.	1	1-5%	3.0	.
Demo slope	Control	Bottom	8 7 96	.	2	1-5%	3.0	.
Demo slope	Control	Bottom	8 7 96	.	2	25-50%	37.5	.
Demo slope	Control	Bottom	8 7 96	.	2	1-5%	3.0	.
Demo slope	Control	Bottom	8 7 96	.	2	5-25%	15.0	.
Demo slope	Control	Bottom	8 7 96	.	2	5-25%	15.0	.
Demo slope	Control	Bottom	8 7 96	.	2	25-50%	37.5	.
Demo slope	Control	Bottom	8 7 96	.	2	5-25%	15.0	2.759
Demo slope	Control	Bottom	8 7 96	.	2	25-50%	37.5	3.342
Demo slope	Control	Bottom	8 7 96	.	3	50-75%	62.5	.
Demo slope	Control	Bottom	8 7 96	.	3	25-50%	37.5	6.448
Demo slope	Control	Bottom	8 7 96	.	3	5-25%	15.0	.
Demo slope	Control	Bottom	8 7 96	.	3	25-50%	37.5	.
Demo slope	Control	Bottom	8 7 96	.	3	5-25%	15.0	.
Demo slope	Control	Bottom	8 7 96	.	3	25-50%	37.5	.
Demo slope	Control	Bottom	8 7 96	.	3	1-5%	3.0	.
Demo slope	Control	Bottom	8 7 96	.	3	5-25%	15.0	.
Demo slope	Control	Bottom	8 7 96	.	3	5-25%	15.0	.
Demo slope	Control	Bottom	8 11 97	.	1	25-50%	37.5	6.400
Demo slope	Control	Bottom	8 11 97	.	1	5-25%	15.0	.
Demo slope	Control	Bottom	8 11 97	.	1	5-25%	15.0	.
Demo slope	Control	Bottom	8 11 97	.	1	5-25%	15.0	.
Demo slope	Control	Bottom	8 11 97	.	1	5-25%	15.0	.
Demo slope	Control	Bottom	8 11 97	.	1	5-25%	15.0	.
Demo slope	Control	Bottom	8 11 97	.	1	25-50%	37.5	.
Demo slope	Control	Bottom	8 11 97	.	1	5-25%	15.0	.
Demo slope	Control	Bottom	8 11 97	.	2	50-75%	62.5	.
Demo slope	Control	Bottom	8 11 97	.	2	1-5%	3.0	.
Demo slope	Control	Bottom	8 11 97	.	2	5-25%	15.0	.
Demo slope	Control	Bottom	8 11 97	.	2	25-50%	37.5	.
Demo slope	Control	Bottom	8 11 97	.	2	5-25%	15.0	.
Demo slope	Control	Bottom	8 11 97	.	2	1-5%	3.0	.
Demo slope	Control	Bottom	8 11 97	.	2	5-25%	15.0	.
Demo slope	Control	Bottom	8 11 97	.	2	5-25%	15.0	5.820
Demo slope	Control	Bottom	8 11 97	.	3	5-25%	15.0	11.850
Demo slope	Control	Bottom	8 11 97	.	3	25-50%	37.5	.
Demo slope	Control	Bottom	8 11 97	.	3	25-50%	37.5	.
Demo slope	Control	Bottom	8 11 97	.	3	25-50%	37.5	.
Demo slope	Control	Bottom	8 11 97	.	3	25-50%	37.5	.
Demo slope	Control	Bottom	8 11 97	.	3	25-50%	37.5	.
Demo slope	Control	Bottom	8 11 97	.	3	50-75%	62.5	17.160
Demo slope	Control	Bottom	8 11 97	.	3	5-25%	15.0	.
Demo slope	Control	Bottom	9 1 98	.	3	50-75%	62.5	31.220
Demo slope	Control	Bottom	9 1 98	.	3	95-99%	97.0	.
Demo slope	Control	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	Control	Bottom	9 1 98	.	3	5-25%	15.0	.
Demo slope	Control	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	Control	Bottom	9 1 98	.	1	78-95%	85.0	.
Demo slope	Control	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	Control	Bottom	9 1 98	.	2	25-50%	37.5	7.640
Demo slope	Control	Bottom	9 1 98	.	2	5-25%	15.0	.
Demo slope	Control	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	Control	Bottom	9 1 98	.	2	25-50%	37.5	2.820

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m^2)
Demo slope	Control	Bottom	9 1 98	.	2	95-99%	97.0	.
Demo slope	Control	Bottom	9 1 98	.	1	25-50%	37.5	.
Demo slope	Control	Bottom	9 1 98	.	2	78-95%	85.0	.
Demo slope	Control	Bottom	9 1 98	.	3	95-99%	97.0	.
Demo slope	Control	Bottom	9 1 98	.	2	50-75%	62.5	.
Demo slope	Control	Bottom	9 1 98	.	2	78-95%	85.0	.
Demo slope	Control	Bottom	9 1 98	.	2	78-95%	85.0	.
Demo slope	Control	Bottom	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Bottom	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Bottom	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Bottom	9 1 98	.	1	78-95%	85.0	.
Demo slope	Control	Bottom	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Bottom	9 1 98	.	1	50-75%	62.5	1.920
Demo slope	Control	Middle	8 7 96	.	1	25-50%	37.5	.
Demo slope	Control	Middle	8 7 96	.	2	5-25%	15.0	.
Demo slope	Control	Middle	8 7 96	.	3	25-50%	37.5	.
Demo slope	Control	Middle	8 7 96	.	3	25-50%	37.5	.
Demo slope	Control	Middle	8 7 96	.	3	1-5%	3.0	.
Demo slope	Control	Middle	8 7 96	.	2	25-50%	37.5	.
Demo slope	Control	Middle	8 7 96	.	2	5-25%	15.0	.
Demo slope	Control	Middle	8 7 96	.	2	25-50%	37.5	.
Demo slope	Control	Middle	8 7 96	.	2	5-25%	15.0	.
Demo slope	Control	Middle	8 7 96	.	2	25-50%	37.5	9.469
Demo slope	Control	Middle	8 7 96	.	2	50-75%	62.5	10.939
Demo slope	Control	Middle	8 7 96	.	1	25-50%	37.5	9.850
Demo slope	Control	Middle	8 7 96	.	1	5-25%	15.0	9.759
Demo slope	Control	Middle	8 7 96	.	1	1-5%	3.0	.
Demo slope	Control	Middle	8 7 96	.	1	1-5%	3.0	.
Demo slope	Control	Middle	8 7 96	.	1	25-50%	37.5	.
Demo slope	Control	Middle	8 7 96	.	1	5-25%	15.0	.
Demo slope	Control	Middle	8 7 96	.	1	1-5%	3.0	.
Demo slope	Control	Middle	8 7 96	.	1	1-5%	3.0	.
Demo slope	Control	Middle	8 7 96	.	3	1-5%	3.0	.
Demo slope	Control	Middle	8 7 96	.	3	5-25%	15.0	.
Demo slope	Control	Middle	8 7 96	.	3	50-75%	62.5	.
Demo slope	Control	Middle	8 7 96	.	1	1-5%	3.0	.
Demo slope	Control	Middle	8 7 96	.	2	5-25%	15.0	.
Demo slope	Control	Middle	8 11 97	.	3	25-50%	37.5	.
Demo slope	Control	Middle	8 11 97	.	3	50-75%	62.5	.
Demo slope	Control	Middle	8 11 97	.	3	5-25%	15.0	.
Demo slope	Control	Middle	8 11 97	.	3	5-25%	15.0	.
Demo slope	Control	Middle	8 11 97	.	3	25-50%	37.5	.
Demo slope	Control	Middle	8 11 97	.	3	25-50%	37.5	.
Demo slope	Control	Middle	8 11 97	.	3	25-50%	37.5	14.400
Demo slope	Control	Middle	8 11 97	.	3	25-50%	37.5	.
Demo slope	Control	Middle	8 11 97	.	2	5-25%	15.0	.
Demo slope	Control	Middle	8 11 97	.	2	25-50%	37.5	5.370
Demo slope	Control	Middle	8 11 97	.	2	25-50%	37.5	26.980
Demo slope	Control	Middle	8 11 97	.	2	25-50%	37.5	.
Demo slope	Control	Middle	8 11 97	.	2	50-75%	62.5	.
Demo slope	Control	Middle	8 11 97	.	2	25-50%	37.5	.
Demo slope	Control	Middle	8 11 97	.	2	25-50%	37.5	.
Demo slope	Control	Middle	8 11 97	.	1	50-75%	62.5	.
Demo slope	Control	Middle	8 11 97	.	1	25-50%	37.5	.
Demo slope	Control	Middle	8 11 97	.	1	25-50%	37.5	.
Demo slope	Control	Middle	8 11 97	.	1	50-75%	62.5	.
Demo slope	Control	Middle	8 11 97	.	1	5-25%	15.0	.
Demo slope	Control	Middle	8 11 97	.	1	50-75%	62.5	.
Demo slope	Control	Middle	8 11 97	.	1	25-50%	37.5	.
Demo slope	Control	Middle	8 11 97	.	1	25-50%	37.5	9.770

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m^2)
Demo slope	Control	Middle	8 11 97	.	2	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	Control	Middle	9 1 98	.	3	95-99%	97.0	.
Demo slope	Control	Middle	9 1 98	.	3	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	3	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	Control	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	Control	Middle	9 1 98	.	3	95-99%	97.0	.
Demo slope	Control	Middle	9 1 98	.	2	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	2	78-95%	85.0	.
Demo slope	Control	Middle	9 1 98	.	2	78-95%	85.0	9.780
Demo slope	Control	Middle	9 1 98	.	2	25-50%	37.5	8.830
Demo slope	Control	Middle	9 1 98	.	2	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	2	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	2	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	2	25-50%	37.5	.
Demo slope	Control	Middle	9 1 98	.	1	78-95%	85.0	16.780
Demo slope	Control	Middle	9 1 98	.	1	78-95%	85.0	11.010
Demo slope	Control	Middle	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	1	78-95%	85.0	.
Demo slope	Control	Middle	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Middle	9 1 98	.	1	25-50%	37.5	.
Demo slope	Control	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	Control	Top	8 7 96	.	3	75-95%	85.0	.
Demo slope	Control	Top	8 7 96	.	3	50-75%	62.5	.
Demo slope	Control	Top	8 7 96	.	3	50-75%	62.5	.
Demo slope	Control	Top	8 7 96	.	3	25-50%	37.5	.
Demo slope	Control	Top	8 7 96	.	3	50-75%	62.5	.
Demo slope	Control	Top	8 7 96	.	3	5-25%	15.0	4.912
Demo slope	Control	Top	8 7 96	.	3	25-50%	37.5	.
Demo slope	Control	Top	8 7 96	.	2	25-50%	37.5	.
Demo slope	Control	Top	8 7 96	.	2	50-75%	62.5	.
Demo slope	Control	Top	8 7 96	.	2	25-50%	37.5	.
Demo slope	Control	Top	8 7 96	.	2	50-75%	62.5	.
Demo slope	Control	Top	8 7 96	.	2	50-75%	62.5	.
Demo slope	Control	Top	8 7 96	.	2	25-50%	37.5	.
Demo slope	Control	Top	8 7 96	.	2	50-75%	62.5	.
Demo slope	Control	Top	8 7 96	.	2	25-50%	37.5	6.823
Demo slope	Control	Top	8 7 96	.	1	50-75%	62.5	3.298
Demo slope	Control	Top	8 7 96	.	1	25-50%	37.5	5.531
Demo slope	Control	Top	8 7 96	.	1	25-50%	37.5	.
Demo slope	Control	Top	8 7 96	.	1	50-75%	62.5	.
Demo slope	Control	Top	8 7 96	.	1	25-50%	37.5	.
Demo slope	Control	Top	8 7 96	.	1	5-25%	15.0	.
Demo slope	Control	Top	8 7 96	.	1	50-75%	62.5	.
Demo slope	Control	Top	8 7 96	.	3	50-75%	62.5	.
Demo slope	Control	Top	8 7 96	.	1	50-75%	62.5	.
Demo slope	Control	Top	8 8 97	.	3	5-25%	15.0	.
Demo slope	Control	Top	8 8 97	.	3	5-25%	15.0	12.580
Demo slope	Control	Top	8 8 97	.	3	25-50%	37.5	.
Demo slope	Control	Top	8 8 97	.	3	5-25%	15.0	.
Demo slope	Control	Top	8 8 97	.	3	25-50%	37.5	.
Demo slope	Control	Top	8 8 97	.	3	5-25%	15.0	.
Demo slope	Control	Top	8 8 97	.	3	25-50%	37.5	.
Demo slope	Control	Top	8 8 97	.	3	5-25%	15.0	.
Demo slope	Control	Top	8 8 97	.	2	25-50%	37.5	13.840

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m^2)
Demo slope	Control	Top	8 8 97	.	2	5-25%	15.0	.
Demo slope	Control	Top	8 8 97	.	2	5-25%	15.0	.
Demo slope	Control	Top	8 8 97	.	2	25-50%	37.5	.
Demo slope	Control	Top	8 8 97	.	2	50-75%	62.5	.
Demo slope	Control	Top	8 8 97	.	2	5-25%	15.0	.
Demo slope	Control	Top	8 8 97	.	2	25-50%	37.5	.
Demo slope	Control	Top	8 8 97	.	2	25-50%	37.5	.
Demo slope	Control	Top	8 8 97	.	1	5-25%	15.0	.
Demo slope	Control	Top	8 8 97	.	1	50-75%	62.5	.
Demo slope	Control	Top	8 8 97	.	1	25-50%	37.5	.
Demo slope	Control	Top	8 8 97	.	1	25-50%	37.5	.
Demo slope	Control	Top	8 8 97	.	1	25-50%	37.5	.
Demo slope	Control	Top	8 8 97	.	1	5-25%	15.0	5.170
Demo slope	Control	Top	8 8 97	.	1	5-25%	15.0	24.070
Demo slope	Control	Top	8 8 97	.	1	25-50%	37.5	.
Demo slope	Control	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	Control	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	Control	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	Control	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	Control	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	Control	Top	9 1 98	.	3	25-50%	37.5	.
Demo slope	Control	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	Control	Top	9 1 98	.	2	25-50%	37.5	.
Demo slope	Control	Top	9 1 98	.	2	50-75%	62.5	36.330
Demo slope	Control	Top	9 1 98	.	2	50-75%	62.5	21.370
Demo slope	Control	Top	9 1 98	.	2	25-50%	37.5	.
Demo slope	Control	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	Control	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	Control	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	Control	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	Control	Top	9 1 98	.	1	78-95%	85.0	21.130
Demo slope	Control	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	Control	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	Control	Top	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	Control	Top	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Top	9 1 98	.	3	78-95%	85.0	9.910
Demo slope	Control	Top	9 1 98	.	1	50-75%	62.5	.
Demo slope	Control	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	Fertilizer	Bottom	8 8 96	.	3	75-95%	85.0	.
Demo slope	Fertilizer	Bottom	8 8 96	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	3	5-25%	15.0	32.042
Demo slope	Fertilizer	Bottom	8 8 96	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	2	5-25%	15.0	16.446
Demo slope	Fertilizer	Bottom	8 8 96	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	1	25-50%	37.5	5.861
Demo slope	Fertilizer	Bottom	8 8 96	.	1	50-75%	62.5	1.010
Demo slope	Fertilizer	Bottom	8 8 96	.	1	5-25%	15.0	.
Demo slope	Fertilizer	Bottom	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	1	50-75%	62.5	.

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Demo slope	Fertilizer	Bottom	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 8 96	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	3	25-50%	37.5	14.860
Demo slope	Fertilizer	Bottom	8 7 97	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	3	5-25%	15.0	.
Demo slope	Fertilizer	Bottom	8 7 97	.	3	5-25%	15.0	.
Demo slope	Fertilizer	Bottom	8 7 97	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	3	5-25%	15.0	.
Demo slope	Fertilizer	Bottom	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	1	5-25%	15.0	.
Demo slope	Fertilizer	Bottom	8 7 97	.	2	25-50%	37.5	3.790
Demo slope	Fertilizer	Bottom	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	2	5-25%	15.0	.
Demo slope	Fertilizer	Bottom	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	1	50-75%	62.5	5.600
Demo slope	Fertilizer	Bottom	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	8 7 97	.	3	25-50%	37.5	7.380
Demo slope	Fertilizer	Bottom	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	9 1 98	.	3	78-95%	85.0	.
Demo slope	Fertilizer	Bottom	9 1 98	.	3	50-75%	62.5	16.810
Demo slope	Fertilizer	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	9 1 98	.	3	78-95%	85.0	.
Demo slope	Fertilizer	Bottom	9 1 98	.	3	5-25%	15.0	.
Demo slope	Fertilizer	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	9 1 98	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	9 1 98	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	9 1 98	.	2	78-95%	85.0	19.270
Demo slope	Fertilizer	Bottom	9 1 98	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	9 1 98	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	9 1 98	.	2	78-95%	85.0	.
Demo slope	Fertilizer	Bottom	9 1 98	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Bottom	9 1 98	.	2	78-95%	85.0	.
Demo slope	Fertilizer	Bottom	9 1 98	.	1	25-50%	37.5	22.400
Demo slope	Fertilizer	Bottom	9 1 98	.	1	50-75%	62.5	41.550
Demo slope	Fertilizer	Bottom	9 1 98	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Bottom	9 1 98	.	1	78-95%	85.0	.
Demo slope	Fertilizer	Bottom	9 1 98	.	1	78-95%	85.0	.
Demo slope	Fertilizer	Bottom	9 1 98	.	1	78-95%	85.0	.
Demo slope	Fertilizer	Bottom	9 1 98	.	1	78-95%	85.0	.
Demo slope	Fertilizer	Bottom	9 1 98	.	1	78-95%	85.0	.
Demo slope	Fertilizer	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	1	50-75%	62.5	5.267

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Demo slope	Fertilizer	Middle	8 8 96	.	1	5-25%	15.0	4.343
Demo slope	Fertilizer	Middle	8 8 96	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	2	75-95%	85.0	.
Demo slope	Fertilizer	Middle	8 8 96	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	2	25-50%	37.5	10.612
Demo slope	Fertilizer	Middle	8 8 96	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	3	25-50%	37.5	1.821
Demo slope	Fertilizer	Middle	8 8 96	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 8 96	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	1	5-25%	15.0	8.690
Demo slope	Fertilizer	Middle	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	2	5-25%	15.0	.
Demo slope	Fertilizer	Middle	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	2	25-50%	37.5	3.660
Demo slope	Fertilizer	Middle	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	3	75-95%	85.0	.
Demo slope	Fertilizer	Middle	8 7 97	.	3	25-50%	37.5	12.610
Demo slope	Fertilizer	Middle	8 7 97	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Middle	8 7 97	.	3	5-25%	15.0	.
Demo slope	Fertilizer	Middle	8 7 97	.	3	5-25%	15.0	1.830
Demo slope	Fertilizer	Middle	8 7 97	.	1	5-25%	15.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	3	78-95%	85.0	2.990
Demo slope	Fertilizer	Middle	9 1 98	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Middle	9 1 98	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Middle	9 1 98	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Middle	9 1 98	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Middle	9 1 98	.	1	78-95%	85.0	20.420
Demo slope	Fertilizer	Middle	9 1 98	.	1	78-95%	85.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	1	78-95%	85.0	30.000
Demo slope	Fertilizer	Middle	9 1 98	.	2	78-95%	85.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	2	95-99%	97.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Middle	9 1 98	.	2	78-95%	85.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	2	78-95%	85.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	2	78-95%	85.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	2	78-95%	85.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	2	78-95%	85.0	6.780

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m^2)
Demo slope	Fertilizer	Middle	9 1 98	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Middle	9 1 98	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	Fertilizer	Middle	9 1 98	.	1	95-99%	97.0	.
Demo slope	Fertilizer	Top	8 8 96	.	1	5-25%	15.0	.
Demo slope	Fertilizer	Top	8 8 96	.	1	5-25%	15.0	.
Demo slope	Fertilizer	Top	8 8 96	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 8 96	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 8 96	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 8 96	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 8 96	.	2	50-75%	62.5	7.491
Demo slope	Fertilizer	Top	8 8 96	.	2	1-5%	3.0	.
Demo slope	Fertilizer	Top	8 8 96	.	2	75-95%	85.0	.
Demo slope	Fertilizer	Top	8 8 96	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 8 96	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 8 96	.	2	1-5%	3.0	.
Demo slope	Fertilizer	Top	8 8 96	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 8 96	.	2	25-50%	37.5	19.996
Demo slope	Fertilizer	Top	8 8 96	.	3	25-50%	37.5	8.527
Demo slope	Fertilizer	Top	8 8 96	.	3	1-5%	3.0	.
Demo slope	Fertilizer	Top	8 8 96	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 8 96	.	3	75-95%	85.0	.
Demo slope	Fertilizer	Top	8 8 96	.	3	5-25%	15.0	.
Demo slope	Fertilizer	Top	8 8 96	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 8 96	.	3	25-50%	37.5	10.593
Demo slope	Fertilizer	Top	8 8 96	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 7 97	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 7 97	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	3	25-50%	37.5	8.590
Demo slope	Fertilizer	Top	8 7 97	.	3	50-75%	62.5	9.220
Demo slope	Fertilizer	Top	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 7 97	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 7 97	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Top	8 7 97	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	2	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	3	25-50%	37.5	.
Demo slope	Fertilizer	Top	8 7 97	.	3	25-50%	37.5	2.670
Demo slope	Fertilizer	Top	8 7 97	.	1	25-50%	37.5	6.200
Demo slope	Fertilizer	Top	9 1 98	.	1	25-50%	37.5	.
Demo slope	Fertilizer	Top	9 1 98	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Top	9 1 98	.	1	50-75%	62.5	.
Demo slope	Fertilizer	Top	9 1 98	.	1	50-75%	62.5	.

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m^2)
Demo slope	Fertilizer	Top	9 1 98	.	1	78-95%	85.0	32.320
Demo slope	Fertilizer	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	Fertilizer	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	Fertilizer	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	Fertilizer	Top	9 1 98	.	2	50-75%	62.5	12.530
Demo slope	Fertilizer	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	Fertilizer	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	Fertilizer	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	Fertilizer	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	Fertilizer	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	Fertilizer	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	Fertilizer	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	Fertilizer	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	Fertilizer	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	Fertilizer	Top	9 1 98	.	3	50-75%	62.5	24.880
Demo slope	Fertilizer	Top	9 1 98	.	3	78-95%	85.0	12.320
Demo slope	MSW	Bottom	8 8 96	.	1	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	1	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	2	75-95%	85.0	.
Demo slope	MSW	Bottom	8 8 96	.	2	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	3	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	3	5-25%	15.0	.
Demo slope	MSW	Bottom	8 8 96	.	3	25-50%	37.5	.
Demo slope	MSW	Bottom	8 8 96	.	3	25-50%	37.5	.
Demo slope	MSW	Bottom	8 8 96	.	3	25-50%	37.5	.
Demo slope	MSW	Bottom	8 8 96	.	3	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	3	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	3	50-75%	62.5	43.442
Demo slope	MSW	Bottom	8 8 96	.	1	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	2	75-95%	85.0	.
Demo slope	MSW	Bottom	8 8 96	.	2	5-25%	15.0	.
Demo slope	MSW	Bottom	8 8 96	.	2	25-50%	37.5	.
Demo slope	MSW	Bottom	8 8 96	.	2	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	2	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	2	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	1	50-75%	62.5	19.515
Demo slope	MSW	Bottom	8 8 96	.	1	25-50%	37.5	6.396
Demo slope	MSW	Bottom	8 8 96	.	1	50-75%	62.5	40.672
Demo slope	MSW	Bottom	8 8 96	.	1	50-75%	62.5	.
Demo slope	MSW	Bottom	8 8 96	.	1	75-95%	85.0	.
Demo slope	MSW	Bottom	8 11 97	.	1	50-75%	62.5	.
Demo slope	MSW	Bottom	8 11 97	.	1	25-50%	37.5	.
Demo slope	MSW	Bottom	8 11 97	.	1	25-50%	37.5	.
Demo slope	MSW	Bottom	8 11 97	.	1	25-50%	37.5	.
Demo slope	MSW	Bottom	8 11 97	.	1	50-75%	62.5	46.880
Demo slope	MSW	Bottom	8 11 97	.	1	50-75%	62.5	10.270
Demo slope	MSW	Bottom	8 11 97	.	1	75-95%	85.0	30.500
Demo slope	MSW	Bottom	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Bottom	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Bottom	8 11 97	.	2	5-25%	15.0	.
Demo slope	MSW	Bottom	8 11 97	.	2	25-50%	37.5	22.750
Demo slope	MSW	Bottom	8 11 97	.	2	25-50%	37.5	.
Demo slope	MSW	Bottom	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Bottom	8 11 97	.	1	25-50%	37.5	.
Demo slope	MSW	Bottom	8 11 97	.	2	25-50%	37.5	.

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m^2)
Demo slope	MSW	Bottom	8 11 97	.	3	25-50%	37.5	.
Demo slope	MSW	Bottom	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Bottom	8 11 97	.	3	50-75%	62.5	.
Demo slope	MSW	Bottom	8 11 97	.	3	50-75%	62.5	.
Demo slope	MSW	Bottom	8 11 97	.	3	25-50%	37.5	.
Demo slope	MSW	Bottom	8 11 97	.	3	25-50%	37.5	.
Demo slope	MSW	Bottom	8 11 97	.	3	75-95%	85.0	.
Demo slope	MSW	Bottom	8 11 97	.	3	50-75%	62.5	.
Demo slope	MSW	Bottom	8 11 97	.	3	5-25%	15.0	.
Demo slope	MSW	Bottom	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Bottom	9 1 98	.	2	78-95%	85.0	.
Demo slope	MSW	Bottom	9 1 98	.	1	95-99%	97.0	.
Demo slope	MSW	Bottom	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Bottom	9 1 98	.	2	99-100%	99.5	.
Demo slope	MSW	Bottom	9 1 98	.	2	78-95%	85.0	.
Demo slope	MSW	Bottom	9 1 98	.	2	99-100%	99.5	.
Demo slope	MSW	Bottom	9 1 98	.	2	78-95%	85.0	.
Demo slope	MSW	Bottom	9 1 98	.	2	78-95%	85.0	.
Demo slope	MSW	Bottom	9 1 98	.	1	50-75%	62.5	23.560
Demo slope	MSW	Bottom	9 1 98	.	1	95-99%	97.0	.
Demo slope	MSW	Bottom	9 1 98	.	2	78-95%	85.0	12.840
Demo slope	MSW	Bottom	9 1 98	.	2	95-99%	97.0	.
Demo slope	MSW	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	MSW	Bottom	9 1 98	.	3	95-99%	97.0	.
Demo slope	MSW	Bottom	9 1 98	.	3	78-95%	85.0	.
Demo slope	MSW	Bottom	9 1 98	.	3	99-100%	99.5	.
Demo slope	MSW	Bottom	9 1 98	.	3	95-99%	97.0	.
Demo slope	MSW	Bottom	9 1 98	.	3	95-99%	97.0	.
Demo slope	MSW	Bottom	9 1 98	.	3	95-99%	97.0	.
Demo slope	MSW	Bottom	9 1 98	.	1	95-99%	97.0	66.840
Demo slope	MSW	Bottom	9 1 98	.	1	95-99%	97.0	.
Demo slope	MSW	Bottom	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Bottom	9 1 98	.	3	78-95%	85.0	20.870
Demo slope	MSW	Middle	8 8 96	.	1	50-75%	62.5	.
Demo slope	MSW	Middle	8 8 96	.	1	25-50%	37.5	.
Demo slope	MSW	Middle	8 8 96	.	1	25-50%	37.5	.
Demo slope	MSW	Middle	8 8 96	.	1	5-25%	15.0	.
Demo slope	MSW	Middle	8 8 96	.	1	75-95%	85.0	.
Demo slope	MSW	Middle	8 8 96	.	1	50-75%	62.5	.
Demo slope	MSW	Middle	8 8 96	.	1	75-95%	85.0	12.858
Demo slope	MSW	Middle	8 8 96	.	2	25-50%	37.5	.
Demo slope	MSW	Middle	8 8 96	.	2	50-75%	62.5	.
Demo slope	MSW	Middle	8 8 96	.	2	25-50%	37.5	.
Demo slope	MSW	Middle	8 8 96	.	2	50-75%	62.5	.
Demo slope	MSW	Middle	8 8 96	.	2	50-75%	62.5	39.029
Demo slope	MSW	Middle	8 8 96	.	2	25-50%	37.5	16.810
Demo slope	MSW	Middle	8 8 96	.	3	50-75%	62.5	.
Demo slope	MSW	Middle	8 8 96	.	3	50-75%	62.5	.
Demo slope	MSW	Middle	8 8 96	.	3	75-95%	85.0	.
Demo slope	MSW	Middle	8 8 96	.	3	75-95%	85.0	.
Demo slope	MSW	Middle	8 8 96	.	3	50-75%	62.5	.
Demo slope	MSW	Middle	8 8 96	.	3	25-50%	37.5	.
Demo slope	MSW	Middle	8 8 96	.	3	75-95%	85.0	41.147
Demo slope	MSW	Middle	8 8 96	.	3	25-50%	37.5	.
Demo slope	MSW	Middle	8 8 96	.	2	5-25%	15.0	.
Demo slope	MSW	Middle	8 8 96	.	2	75-95%	85.0	.
Demo slope	MSW	Middle	8 8 96	.	1	50-75%	62.5	.

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Demo slope	MSW	Middle	8 11 97	.	3	25-50%	37.5	7.240
Demo slope	MSW	Middle	8 11 97	.	3	50-75%	62.5	.
Demo slope	MSW	Middle	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Middle	8 11 97	.	1	25-50%	37.5	.
Demo slope	MSW	Middle	8 11 97	.	1	75-95%	85.0	.
Demo slope	MSW	Middle	8 11 97	.	3	75-95%	85.0	.
Demo slope	MSW	Middle	8 11 97	.	3	75-95%	85.0	.
Demo slope	MSW	Middle	8 11 97	.	3	25-50%	37.5	38.160
Demo slope	MSW	Middle	8 11 97	.	2	75-95%	85.0	19.650
Demo slope	MSW	Middle	8 11 97	.	2	50-75%	62.5	23.360
Demo slope	MSW	Middle	8 11 97	.	3	25-50%	37.5	.
Demo slope	MSW	Middle	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Middle	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Middle	8 11 97	.	2	25-50%	37.5	.
Demo slope	MSW	Middle	8 11 97	.	2	25-50%	37.5	.
Demo slope	MSW	Middle	8 11 97	.	2	75-95%	85.0	.
Demo slope	MSW	Middle	8 11 97	.	1	50-75%	62.5	.
Demo slope	MSW	Middle	8 11 97	.	1	50-75%	62.5	.
Demo slope	MSW	Middle	8 11 97	.	1	50-75%	62.5	.
Demo slope	MSW	Middle	8 11 97	.	1	50-75%	62.5	.
Demo slope	MSW	Middle	8 11 97	.	1	25-50%	37.5	.
Demo slope	MSW	Middle	8 11 97	.	1	50-75%	62.5	.
Demo slope	MSW	Middle	8 11 97	.	3	75-95%	85.0	.
Demo slope	MSW	Middle	8 11 97	.	3	25-50%	37.5	.
Demo slope	MSW	Middle	9 1 98	.	1	95-99%	97.0	.
Demo slope	MSW	Middle	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Middle	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Middle	9 1 98	.	1	99-100%	99.5	.
Demo slope	MSW	Middle	9 1 98	.	1	95-99%	97.0	69.720
Demo slope	MSW	Middle	9 1 98	.	1	95-99%	97.0	40.240
Demo slope	MSW	Middle	9 1 98	.	2	95-99%	97.0	.
Demo slope	MSW	Middle	9 1 98	.	2	95-99%	97.0	.
Demo slope	MSW	Middle	9 1 98	.	2	99-100%	99.5	.
Demo slope	MSW	Middle	9 1 98	.	2	95-99%	97.0	.
Demo slope	MSW	Middle	9 1 98	.	2	50-75%	62.5	.
Demo slope	MSW	Middle	9 1 98	.	2	99-100%	99.5	.
Demo slope	MSW	Middle	9 1 98	.	2	95-99%	97.0	.
Demo slope	MSW	Middle	9 1 98	.	2	95-99%	97.0	.
Demo slope	MSW	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	MSW	Middle	9 1 98	.	3	95-99%	97.0	.
Demo slope	MSW	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	MSW	Middle	9 1 98	.	3	99-100%	99.5	18.540
Demo slope	MSW	Middle	9 1 98	.	1	99-100%	99.5	.
Demo slope	MSW	Middle	9 1 98	.	3	95-99%	97.0	49.000
Demo slope	MSW	Middle	9 1 98	.	3	95-99%	97.0	.
Demo slope	MSW	Middle	9 1 98	.	3	99-100%	99.5	.
Demo slope	MSW	Middle	9 1 98	.	3	95-99%	97.0	.
Demo slope	MSW	Middle	9 1 98	.	1	95-99%	97.0	.
Demo slope	MSW	Top	8 8 96	.	3	25-50%	37.5	1.946
Demo slope	MSW	Top	8 8 96	.	3	50-75%	62.5	.
Demo slope	MSW	Top	8 8 96	.	3	25-50%	37.5	.
Demo slope	MSW	Top	8 8 96	.	3	50-75%	62.5	.
Demo slope	MSW	Top	8 8 96	.	3	25-50%	37.5	.
Demo slope	MSW	Top	8 8 96	.	3	25-50%	37.5	.
Demo slope	MSW	Top	8 8 96	.	3	5-25%	15.0	8.179
Demo slope	MSW	Top	8 8 96	.	2	50-75%	62.5	.
Demo slope	MSW	Top	8 8 96	.	2	50-75%	62.5	.
Demo slope	MSW	Top	8 8 96	.	2	50-75%	62.5	.
Demo slope	MSW	Top	8 8 96	.	2	50-75%	62.5	.

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Demo slope	MSW	Top	8 8 96	.	2	50-75%	62.5	.
Demo slope	MSW	Top	8 8 96	.	2	25-50%	37.5	.
Demo slope	MSW	Top	8 8 96	.	2	75-95%	85.0	.
Demo slope	MSW	Top	8 8 96	.	2	25-50%	37.5	.
Demo slope	MSW	Top	8 8 96	.	1	75-95%	85.0	20.302
Demo slope	MSW	Top	8 8 96	.	1	50-75%	62.5	12.009
Demo slope	MSW	Top	8 8 96	.	1	95-99%	97.0	.
Demo slope	MSW	Top	8 8 96	.	1	75-95%	85.0	.
Demo slope	MSW	Top	8 8 96	.	1	50-75%	62.5	.
Demo slope	MSW	Top	8 8 96	.	1	50-75%	62.5	.
Demo slope	MSW	Top	8 8 96	.	1	25-50%	37.5	.
Demo slope	MSW	Top	8 8 96	.	1	50-75%	62.5	.
Demo slope	MSW	Top	8 8 96	.	3	25-50%	37.5	.
Demo slope	MSW	Top	8 11 97	.	2	5-25%	15.0	.
Demo slope	MSW	Top	8 11 97	.	1	25-50%	37.5	10.920
Demo slope	MSW	Top	8 11 97	.	1	50-75%	62.5	.
Demo slope	MSW	Top	8 11 97	.	1	25-50%	37.5	.
Demo slope	MSW	Top	8 11 97	.	1	50-75%	62.5	.
Demo slope	MSW	Top	8 11 97	.	1	50-75%	62.5	.
Demo slope	MSW	Top	8 11 97	.	1	50-75%	62.5	.
Demo slope	MSW	Top	8 11 97	.	1	5-25%	15.0	.
Demo slope	MSW	Top	8 11 97	.	1	25-50%	37.5	.
Demo slope	MSW	Top	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Top	8 11 97	.	2	5-25%	15.0	.
Demo slope	MSW	Top	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Top	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Top	8 11 97	.	3	25-50%	37.5	10.000
Demo slope	MSW	Top	8 11 97	.	2	50-75%	62.5	.
Demo slope	MSW	Top	8 11 97	.	2	5-25%	15.0	9.540
Demo slope	MSW	Top	8 11 97	.	2	25-50%	37.5	10.080
Demo slope	MSW	Top	8 11 97	.	3	50-75%	62.5	.
Demo slope	MSW	Top	8 11 97	.	3	25-50%	37.5	.
Demo slope	MSW	Top	8 11 97	.	3	25-50%	37.5	.
Demo slope	MSW	Top	8 11 97	.	3	50-75%	62.5	.
Demo slope	MSW	Top	8 11 97	.	3	25-50%	37.5	.
Demo slope	MSW	Top	8 11 97	.	3	25-50%	37.5	.
Demo slope	MSW	Top	8 11 97	.	3	25-50%	37.5	.
Demo slope	MSW	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	2	78-95%	85.0	22.230
Demo slope	MSW	Top	9 1 98	.	3	78-95%	85.0	32.520
Demo slope	MSW	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	MSW	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	MSW	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	3	78-95%	85.0	12.380
Demo slope	MSW	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	2	78-95%	85.0	33.520
Demo slope	MSW	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	2	95-99%	97.0	.
Demo slope	MSW	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	1	78-95%	85.0	.

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m^2)
Demo slope	MSW	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	MSW	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	NVS	Bottom	8 6 96	.	3	75-95%	85.0	.
Demo slope	NVS	Bottom	8 6 96	.	3	50-75%	62.5	.
Demo slope	NVS	Bottom	8 6 96	.	3	50-75%	62.5	.
Demo slope	NVS	Bottom	8 6 96	.	3	95-99%	97.0	65.916
Demo slope	NVS	Bottom	8 6 96	.	3	50-75%	62.5	.
Demo slope	NVS	Bottom	8 6 96	.	3	25-50%	37.5	9.099
Demo slope	NVS	Bottom	8 6 96	.	2	99-100%	99.5	.
Demo slope	NVS	Bottom	8 6 96	.	2	50-75%	62.5	.
Demo slope	NVS	Bottom	8 6 96	.	2	75-95%	85.0	.
Demo slope	NVS	Bottom	8 6 96	.	2	75-95%	85.0	.
Demo slope	NVS	Bottom	8 6 96	.	2	50-75%	62.5	.
Demo slope	NVS	Bottom	8 6 96	.	2	75-95%	85.0	.
Demo slope	NVS	Bottom	8 6 96	.	2	75-95%	85.0	.
Demo slope	NVS	Bottom	8 6 96	.	2	75-95%	85.0	.
Demo slope	NVS	Bottom	8 6 96	.	1	50-75%	62.5	4.789
Demo slope	NVS	Bottom	8 6 96	.	1	25-50%	37.5	.
Demo slope	NVS	Bottom	8 6 96	.	1	75-95%	85.0	.
Demo slope	NVS	Bottom	8 6 96	.	1	50-75%	62.5	.
Demo slope	NVS	Bottom	8 6 96	.	1	75-95%	85.0	.
Demo slope	NVS	Bottom	8 6 96	.	1	25-50%	37.5	.
Demo slope	NVS	Bottom	8 6 96	.	1	25-50%	37.5	.
Demo slope	NVS	Bottom	8 6 96	.	3	50-75%	62.5	.
Demo slope	NVS	Bottom	8 6 96	.	3	75-95%	85.0	.
Demo slope	NVS	Bottom	8 6 96	.	1	75-95%	85.0	32.449
Demo slope	NVS	Bottom	8 8 97	.	3	5-25%	15.0	.
Demo slope	NVS	Bottom	8 8 97	.	3	50-75%	62.5	.
Demo slope	NVS	Bottom	8 8 97	.	3	1-5%	3.0	5.200
Demo slope	NVS	Bottom	8 8 97	.	3	50-75%	62.5	.
Demo slope	NVS	Bottom	8 8 97	.	2	5-25%	15.0	.
Demo slope	NVS	Bottom	8 8 97	.	2	25-50%	37.5	.
Demo slope	NVS	Bottom	8 8 97	.	2	5-25%	15.0	12.720
Demo slope	NVS	Bottom	8 8 97	.	2	25-50%	37.5	4.490
Demo slope	NVS	Bottom	8 8 97	.	2	5-25%	15.0	.
Demo slope	NVS	Bottom	8 8 97	.	2	25-50%	37.5	.
Demo slope	NVS	Bottom	8 8 97	.	2	5-25%	15.0	.
Demo slope	NVS	Bottom	8 8 97	.	2	50-75%	62.5	.
Demo slope	NVS	Bottom	8 8 97	.	2	5-25%	15.0	.
Demo slope	NVS	Bottom	8 8 97	.	1	25-50%	37.5	0.710
Demo slope	NVS	Bottom	8 8 97	.	1	25-50%	37.5	.
Demo slope	NVS	Bottom	8 8 97	.	3	50-75%	62.5	.
Demo slope	NVS	Bottom	8 8 97	.	3	25-50%	37.5	.
Demo slope	NVS	Bottom	8 8 97	.	1	5-25%	15.0	.
Demo slope	NVS	Bottom	8 8 97	.	1	25-50%	37.5	.
Demo slope	NVS	Bottom	8 8 97	.	1	50-75%	62.5	.
Demo slope	NVS	Bottom	8 8 97	.	1	5-25%	15.0	.
Demo slope	NVS	Bottom	8 8 97	.	3	25-50%	37.5	.
Demo slope	NVS	Bottom	8 8 97	.	1	25-50%	37.5	.
Demo slope	NVS	Bottom	8 8 97	.	3	25-50%	37.5	.
Demo slope	NVS	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	NVS	Bottom	9 1 98	.	3	25-50%	37.5	.
Demo slope	NVS	Bottom	9 1 98	.	3	78-95%	85.0	.
Demo slope	NVS	Bottom	9 1 98	.	3	99-100%	99.5	.
Demo slope	NVS	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	NVS	Bottom	9 1 98	.	3	50-75%	62.5	.
Demo slope	NVS	Bottom	9 1 98	.	3	25-50%	37.5	.
Demo slope	NVS	Bottom	9 1 98	.	2	99-100%	99.5	.

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date			Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Demo slope	NVS	Bottom	9	1	98	.	2	50-75%	62.5	.
Demo slope	NVS	Bottom	9	1	98	.	2	78-95%	85.0	.
Demo slope	NVS	Bottom	9	1	98	.	2	95-99%	97.0	.
Demo slope	NVS	Bottom	9	1	98	.	2	78-95%	85.0	.
Demo slope	NVS	Bottom	9	1	98	.	2	78-95%	85.0	.
Demo slope	NVS	Bottom	9	1	98	.	2	95-99%	97.0	.
Demo slope	NVS	Bottom	9	1	98	.	2	50-75%	62.5	31.330
Demo slope	NVS	Bottom	9	1	98	.	1	78-95%	85.0	.
Demo slope	NVS	Bottom	9	1	98	.	1	78-95%	85.0	.
Demo slope	NVS	Bottom	9	1	98	.	1	50-75%	62.5	.
Demo slope	NVS	Bottom	9	1	98	.	1	78-95%	85.0	14.610
Demo slope	NVS	Bottom	9	1	98	.	1	50-75%	62.5	16.770
Demo slope	NVS	Bottom	9	1	98	.	1	78-95%	85.0	.
Demo slope	NVS	Bottom	9	1	98	.	1	50-75%	62.5	.
Demo slope	NVS	Bottom	9	1	98	.	1	78-95%	85.0	.
Demo slope	NVS	Bottom	9	1	98	.	3	50-75%	62.5	24.260
Demo slope	NVS	Middle	8	6	96	.	3	25-50%	37.5	.
Demo slope	NVS	Middle	8	6	96	.	3	50-75%	62.5	.
Demo slope	NVS	Middle	8	6	96	.	3	25-50%	37.5	.
Demo slope	NVS	Middle	8	6	96	.	3	75-95%	85.0	.
Demo slope	NVS	Middle	8	6	96	.	1	50-75%	62.5	.
Demo slope	NVS	Middle	8	6	96	.	1	25-50%	37.5	.
Demo slope	NVS	Middle	8	6	96	.	1	50-75%	62.5	.
Demo slope	NVS	Middle	8	6	96	.	1	25-50%	37.5	.
Demo slope	NVS	Middle	8	6	96	.	1	25-50%	37.5	.
Demo slope	NVS	Middle	8	6	96	.	1	75-95%	85.0	.
Demo slope	NVS	Middle	8	6	96	.	1	50-75%	62.5	.
Demo slope	NVS	Middle	8	6	96	.	1	50-75%	62.5	9.215
Demo slope	NVS	Middle	8	6	96	.	2	25-50%	37.5	35.309
Demo slope	NVS	Middle	8	6	96	.	2	50-75%	62.5	.
Demo slope	NVS	Middle	8	6	96	.	2	25-50%	37.5	.
Demo slope	NVS	Middle	8	6	96	.	2	50-75%	62.5	.
Demo slope	NVS	Middle	8	6	96	.	2	25-50%	37.5	.
Demo slope	NVS	Middle	8	6	96	.	2	50-75%	62.5	.
Demo slope	NVS	Middle	8	6	96	.	2	50-75%	62.5	.
Demo slope	NVS	Middle	8	6	96	.	2	75-95%	85.0	.
Demo slope	NVS	Middle	8	6	96	.	3	25-50%	37.5	16.882
Demo slope	NVS	Middle	8	6	96	.	3	25-50%	37.5	17.391
Demo slope	NVS	Middle	8	6	96	.	3	50-75%	62.5	.
Demo slope	NVS	Middle	8	6	96	.	3	50-75%	62.5	.
Demo slope	NVS	Middle	8	8	97	.	2	25-50%	37.5	52.180
Demo slope	NVS	Middle	8	8	97	.	2	75-95%	85.0	.
Demo slope	NVS	Middle	8	8	97	.	2	25-50%	37.5	.
Demo slope	NVS	Middle	8	8	97	.	2	25-50%	37.5	4.500
Demo slope	NVS	Middle	8	8	97	.	1	25-50%	37.5	11.690
Demo slope	NVS	Middle	8	8	97	.	1	25-50%	37.5	.
Demo slope	NVS	Middle	8	8	97	.	1	50-75%	62.5	.
Demo slope	NVS	Middle	8	8	97	.	1	50-75%	62.5	.
Demo slope	NVS	Middle	8	8	97	.	1	75-95%	85.0	.
Demo slope	NVS	Middle	8	8	97	.	1	25-50%	37.5	.
Demo slope	NVS	Middle	8	8	97	.	1	75-95%	85.0	.
Demo slope	NVS	Middle	8	8	97	.	2	25-50%	37.5	.
Demo slope	NVS	Middle	8	8	97	.	2	25-50%	37.5	.
Demo slope	NVS	Middle	8	8	97	.	2	25-50%	37.5	.
Demo slope	NVS	Middle	8	8	97	.	3	25-50%	37.5	.
Demo slope	NVS	Middle	8	8	97	.	1	95-99%	97.0	47.520
Demo slope	NVS	Middle	8	8	97	.	2	25-50%	37.5	.
Demo slope	NVS	Middle	8	8	97	.	3	50-75%	62.5	.
Demo slope	NVS	Middle	8	8	97	.	3	50-75%	62.5	.

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m^2)
Demo slope	NVS	Middle	8 8 97	.	3	25-50%	37.5	.
Demo slope	NVS	Middle	8 8 97	.	3	50-75%	62.5	.
Demo slope	NVS	Middle	8 8 97	.	3	25-50%	37.5	.
Demo slope	NVS	Middle	8 8 97	.	3	95-99%	97.0	.
Demo slope	NVS	Middle	8 8 97	.	3	75-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	1	95-99%	97.0	.
Demo slope	NVS	Middle	9 1 98	.	1	78-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	1	78-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	2	78-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	2	95-99%	97.0	.
Demo slope	NVS	Middle	9 1 98	.	2	78-95%	85.0	20.910
Demo slope	NVS	Middle	9 1 98	.	2	78-95%	85.0	6.530
Demo slope	NVS	Middle	9 1 98	.	2	50-75%	62.5	.
Demo slope	NVS	Middle	9 1 98	.	2	78-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	2	78-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	2	78-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	3	95-99%	97.0	.
Demo slope	NVS	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	3	95-99%	97.0	.
Demo slope	NVS	Middle	9 1 98	.	3	99-100%	99.5	.
Demo slope	NVS	Middle	9 1 98	.	3	78-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	3	50-75%	62.5	.
Demo slope	NVS	Middle	9 1 98	.	3	50-75%	62.5	23.280
Demo slope	NVS	Middle	9 1 98	.	3	78-95%	85.0	15.860
Demo slope	NVS	Middle	9 1 98	.	1	78-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	1	50-75%	62.5	.
Demo slope	NVS	Middle	9 1 98	.	1	78-95%	85.0	.
Demo slope	NVS	Middle	9 1 98	.	1	25-50%	37.5	.
Demo slope	NVS	Middle	9 1 98	.	1	78-95%	85.0	.
Demo slope	NVS	Top	8 6 96	.	3	5-25%	15.0	.
Demo slope	NVS	Top	8 6 96	.	1	75-95%	85.0	.
Demo slope	NVS	Top	8 6 96	.	1	5-25%	15.0	.
Demo slope	NVS	Top	8 6 96	.	2	75-95%	85.0	.
Demo slope	NVS	Top	8 6 96	.	2	50-75%	62.5	.
Demo slope	NVS	Top	8 6 96	.	2	50-75%	62.5	.
Demo slope	NVS	Top	8 6 96	.	3	75-95%	85.0	.
Demo slope	NVS	Top	8 6 96	.	3	50-75%	62.5	28.690
Demo slope	NVS	Top	8 6 96	.	1	50-75%	62.5	.
Demo slope	NVS	Top	8 6 96	.	3	25-50%	37.5	.
Demo slope	NVS	Top	8 6 96	.	3	75-95%	85.0	.
Demo slope	NVS	Top	8 6 96	.	3	25-50%	37.5	.
Demo slope	NVS	Top	8 6 96	.	3	50-75%	62.5	.
Demo slope	NVS	Top	8 6 96	.	3	25-50%	37.5	24.882
Demo slope	NVS	Top	8 6 96	.	2	50-75%	62.5	12.685
Demo slope	NVS	Top	8 6 96	.	1	25-50%	37.5	.
Demo slope	NVS	Top	8 6 96	.	2	95-99%	97.0	12.768
Demo slope	NVS	Top	8 6 96	.	1	25-50%	37.5	.
Demo slope	NVS	Top	8 6 96	.	2	75-95%	85.0	.
Demo slope	NVS	Top	8 6 96	.	2	75-95%	85.0	.
Demo slope	NVS	Top	8 6 96	.	2	25-50%	37.5	.
Demo slope	NVS	Top	8 6 96	.	1	50-75%	62.5	.
Demo slope	NVS	Top	8 6 96	.	1	25-50%	37.5	.
Demo slope	NVS	Top	8 6 96	.	1	25-50%	37.5	.
Demo slope	NVS	Top	8 8 97	.	1	50-75%	62.5	.
Demo slope	NVS	Top	8 8 97	.	1	75-95%	85.0	48.120
Demo slope	NVS	Top	8 8 97	.	1	50-75%	62.5	.
Demo slope	NVS	Top	8 8 97	.	1	50-75%	62.5	.
Demo slope	NVS	Top	8 8 97	.	1	50-75%	62.5	.

Table A7.4. Percent cover and biomass data from the demonstration plots, 1996-1998.

Location	Plot	Section	Date	Row	Site	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Demo slope	NVS	Top	8 8 97	.	1	50-75%	62.5	.
Demo slope	NVS	Top	8 8 97	.	2	25-50%	37.5	.
Demo slope	NVS	Top	8 8 97	.	2	25-50%	37.5	.
Demo slope	NVS	Top	8 8 97	.	2	25-50%	37.5	.
Demo slope	NVS	Top	8 8 97	.	2	50-75%	62.5	.
Demo slope	NVS	Top	8 8 97	.	2	25-50%	37.5	.
Demo slope	NVS	Top	8 8 97	.	2	75-95%	85.0	27.550
Demo slope	NVS	Top	8 8 97	.	2	25-50%	37.5	9.250
Demo slope	NVS	Top	8 8 97	.	3	25-50%	37.5	.
Demo slope	NVS	Top	8 8 97	.	3	25-50%	37.5	.
Demo slope	NVS	Top	8 8 97	.	3	25-50%	37.5	.
Demo slope	NVS	Top	8 8 97	.	3	25-50%	37.5	.
Demo slope	NVS	Top	8 8 97	.	3	50-75%	62.5	.
Demo slope	NVS	Top	8 8 97	.	3	50-75%	62.5	.
Demo slope	NVS	Top	8 8 97	.	3	50-75%	62.5	.
Demo slope	NVS	Top	8 8 97	.	3	25-50%	37.5	7.420
Demo slope	NVS	Top	8 8 97	.	2	50-75%	62.5	.
Demo slope	NVS	Top	8 8 97	.	2	25-50%	37.5	.
Demo slope	NVS	Top	8 8 97	.	1	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	1	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	1	78-95%	85.0	96.630
Demo slope	NVS	Top	9 1 98	.	1	25-50%	37.5	13.890
Demo slope	NVS	Top	9 1 98	.	1	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	NVS	Top	9 1 98	.	1	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	NVS	Top	9 1 98	.	1	78-95%	85.0	.
Demo slope	NVS	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	NVS	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	2	78-95%	85.0	.
Demo slope	NVS	Top	9 1 98	.	2	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	3	78-95%	85.0	10.430
Demo slope	NVS	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	3	78-95%	85.0	.
Demo slope	NVS	Top	9 1 98	.	3	25-50%	37.5	27.260
Demo slope	NVS	Top	9 1 98	.	3	50-75%	62.5	.
Demo slope	NVS	Top	9 1 98	.	3	25-50%	37.5	.
Demo slope	NVS	Top	9 1 98	.	3	50-75%	62.5	.

Table A7.5. Percent cover and biomass data from the lysimeter plots, 1996-1997.

Location	Plot	Date	Plot	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m^2)
Lysimeter	MSW	8 7 96	2.	50-75%	62.5	.
Lysimeter	MSW	8 7 96	2.	95-99%	97.0	.
Lysimeter	MSW	8 7 96	2.	75-95%	85.0	.
Lysimeter	MSW	8 7 96	2.	25-50%	37.5	.
Lysimeter	MSW	8 7 96	2.	50-75%	62.5	.
Lysimeter	MSW	8 7 96	2.	95-99%	97.0	.
Lysimeter	MSW	8 7 96	2.	50-75%	62.5	.
Lysimeter	MSW	8 9 96	2.	50-75%	62.5	6.418
Lysimeter	MSW	8 7 96	7.	95-99%	97.0	.
Lysimeter	MSW	8 7 96	7.	75-95%	85.0	.
Lysimeter	MSW	8 7 96	7.	50-75%	62.5	.
Lysimeter	MSW	8 7 96	7.	25-50%	37.5	.
Lysimeter	MSW	8 7 96	7.	50-75%	62.5	.
Lysimeter	MSW	8 7 96	7.	50-75%	62.5	.
Lysimeter	MSW	8 7 96	7.	95-99%	97.0	.
Lysimeter	MSW	8 9 96	7.	75-95%	85.0	29.726
Lysimeter	MSW	8 7 96	8.	75-95%	85.0	10.228
Lysimeter	MSW	8 7 96	8.	25-50%	37.5	.
Lysimeter	MSW	8 7 96	8.	50-75%	62.5	.
Lysimeter	MSW	8 7 96	8.	50-75%	62.5	.
Lysimeter	MSW	8 7 96	8.	50-75%	62.5	.
Lysimeter	MSW	8 7 96	8.	75-95%	85.0	.
Lysimeter	MSW	8 7 96	8.	50-75%	62.5	.
Lysimeter	MSW	8 7 96	8.	95-99%	97.0	.
Lysimeter	MSW	8 22 97	2.	50-75%	62.5	.
Lysimeter	MSW	8 22 97	2.	50-75%	62.5	.
Lysimeter	MSW	8 22 97	2.	25-50%	37.5	.
Lysimeter	MSW	8 22 97	2.	75-95%	85.0	.
Lysimeter	MSW	8 22 97	2.	75-95%	85.0	23.260
Lysimeter	MSW	8 22 97	2.	25-50%	37.5	.
Lysimeter	MSW	8 22 97	2.	50-75%	62.5	9.360
Lysimeter	MSW	8 22 97	2.	25-50%	37.5	.
Lysimeter	MSW	8 22 97	7.	50-75%	62.5	10.430
Lysimeter	MSW	8 22 97	7.	50-75%	62.5	.
Lysimeter	MSW	8 22 97	7.	50-75%	62.5	.
Lysimeter	MSW	8 22 97	7.	50-75%	62.5	.
Lysimeter	MSW	8 22 97	7.	25-50%	37.5	.
Lysimeter	MSW	8 22 97	7.	75-95%	85.0	.
Lysimeter	MSW	8 22 97	7.	50-75%	62.5	.
Lysimeter	MSW	8 22 97	7.	75-95%	85.0	29.760
Lysimeter	MSW	8 22 97	8.	25-50%	37.5	.
Lysimeter	MSW	8 22 97	8.	50-75%	62.5	.
Lysimeter	MSW	8 22 97	8.	50-75%	62.5	.
Lysimeter	MSW	8 22 97	8.	50-75%	62.5	.
Lysimeter	MSW	8 22 97	8.	50-75%	62.5	.
Lysimeter	MSW	8 22 97	8.	25-50%	37.5	.
Lysimeter	MSW	8 22 97	8.	50-75%	62.5	14.560
Lysimeter	MSW	8 22 97	8.	50-75%	62.5	23.580
Lysimeter	NVS	8 7 96	3.	25-50%	37.5	.
Lysimeter	NVS	8 7 96	3.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	3.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	3.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	3.	95-99%	97.0	.
Lysimeter	NVS	8 7 96	3.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	3.	95-99%	97.0	.
Lysimeter	NVS	8 7 96	5.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	5.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	5.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	5.	75-95%	85.0	.

Table A7.5. Percent cover and biomass data from the lysimeter plots, 1996-1997.

Location	Plot	Date	Plot	Ave. Cover class	Cover (%)	Biomass (dry g/0.5 m²)
Lysimeter	NVS	8 7 96	5.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	5.	95-99%	97.0	.
Lysimeter	NVS	8 7 96	5.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	9.	75-95%	85.0	.
Lysimeter	NVS	8 7 96	9.	75-95%	85.0	.
Lysimeter	NVS	8 7 96	9.	95-99%	97.0	.
Lysimeter	NVS	8 7 96	9.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	9.	25-50%	37.5	.
Lysimeter	NVS	8 7 96	9.	50-75%	62.5	.
Lysimeter	NVS	8 7 96	9.	75-95%	85.0	.
Lysimeter	NVS	8 9 96	3.	25-50%	37.5	1.242
Lysimeter	NVS	8 9 96	5.	50-75%	62.5	11.290
Lysimeter	NVS	8 9 96	9.	50-75%	62.5	10.444
Lysimeter	NVS	8 22 97	3.	75-95%	85.0	.
Lysimeter	NVS	8 22 97	3.	50-75%	62.5	.
Lysimeter	NVS	8 22 97	3.	50-75%	62.5	.
Lysimeter	NVS	8 22 97	3.	75-95%	85.0	.
Lysimeter	NVS	8 22 97	3.	50-75%	62.5	.
Lysimeter	NVS	8 22 97	3.	50-75%	62.5	40.590
Lysimeter	NVS	8 22 97	3.	75-95%	85.0	.
Lysimeter	NVS	8 22 97	3.	95-99%	97.0	16.920
Lysimeter	NVS	8 22 97	5.	25-50%	37.5	33.030
Lysimeter	NVS	8 22 97	5.	50-75%	62.5	.
Lysimeter	NVS	8 22 97	5.	25-50%	37.5	.
Lysimeter	NVS	8 22 97	5.	50-75%	62.5	.
Lysimeter	NVS	8 22 97	5.	50-75%	62.5	.
Lysimeter	NVS	8 22 97	5.	75-95%	85.0	.
Lysimeter	NVS	8 22 97	5.	75-95%	85.0	.
Lysimeter	NVS	8 22 97	5.	75-95%	85.0	25.840
Lysimeter	NVS	8 22 97	9.	50-75%	62.5	.
Lysimeter	NVS	8 22 97	9.	95-99%	97.0	.
Lysimeter	NVS	8 22 97	9.	50-75%	62.5	.
Lysimeter	NVS	8 22 97	9.	75-95%	85.0	.
Lysimeter	NVS	8 22 97	9.	50-75%	62.5	.
Lysimeter	NVS	8 22 97	9.	50-75%	62.5	11.570
Lysimeter	NVS	8 22 97	9.	75-95%	85.0	21.010
Lysimeter	NVS	8 22 97	9.	75-95%	85.0	.
Lysimeter	Topsoil	8 7 96	1.	75-95%	85.0	.
Lysimeter	Topsoil	8 7 96	1.	50-75%	62.5	.
Lysimeter	Topsoil	8 7 96	1.	50-75%	62.5	.
Lysimeter	Topsoil	8 7 96	1.	95-99%	97.0	.
Lysimeter	Topsoil	8 7 96	1.	75-95%	85.0	.
Lysimeter	Topsoil	8 7 96	1.	75-95%	85.0	.
Lysimeter	Topsoil	8 7 96	1.	75-95%	85.0	.
Lysimeter	Topsoil	8 7 96	4.	25-50%	37.5	.
Lysimeter	Topsoil	8 7 96	4.	25-50%	37.5	.
Lysimeter	Topsoil	8 7 96	4.	75-95%	85.0	.
Lysimeter	Topsoil	8 7 96	4.	50-75%	62.5	.
Lysimeter	Topsoil	8 7 96	4.	50-75%	62.5	.
Lysimeter	Topsoil	8 7 96	4.	50-75%	62.5	.
Lysimeter	Topsoil	8 7 96	4.	95-99%	97.0	.
Lysimeter	Topsoil	8 7 96	6.	75-95%	85.0	.
Lysimeter	Topsoil	8 7 96	6.	75-95%	85.0	.
Lysimeter	Topsoil	8 7 96	6.	95-99%	97.0	.
Lysimeter	Topsoil	8 7 96	6.	95-99%	97.0	.
Lysimeter	Topsoil	8 7 96	6.	50-75%	62.5	.
Lysimeter	Topsoil	8 7 96	6.	95-99%	97.0	.
Lysimeter	Topsoil	8 7 96	6.	75-95%	85.0	.

Table A7.5. Percent cover and biomass data from the lysimeter plots, 1996-1997.

Location	Plot	Date	Plot	Ave. Cover class	Cover (%)	Biomass (dry g/0.5 m²)
Lysimeter	Topsoil	8 9 96	1.	75-95%	85.0	7.610
Lysimeter	Topsoil	8 9 96	4.	50-75%	62.5	6.513
Lysimeter	Topsoil	8 9 96	6.	50-75%	62.5	9.284
Lysimeter	Topsoil	8 22 97	1.	50-75%	62.5	.
Lysimeter	Topsoil	8 22 97	1.	75-95%	85.0	.
Lysimeter	Topsoil	8 22 97	1.	50-75%	62.5	21.030
Lysimeter	Topsoil	8 22 97	1.	75-95%	85.0	.
Lysimeter	Topsoil	8 22 97	1.	50-75%	62.5	.
Lysimeter	Topsoil	8 22 97	1.	75-95%	85.0	.
Lysimeter	Topsoil	8 22 97	1.		.	5.380
Lysimeter	Topsoil	8 22 97	1.	50-75%	62.5	.
Lysimeter	Topsoil	8 22 97	4.	25-50%	37.5	9.150
Lysimeter	Topsoil	8 22 97	4.	5-25%	15.0	.
Lysimeter	Topsoil	8 22 97	4.	25-50%	37.5	.
Lysimeter	Topsoil	8 22 97	4.		.	7.390
Lysimeter	Topsoil	8 22 97	4.	25-50%	37.5	.
Lysimeter	Topsoil	8 22 97	4.	5-25%	15.0	.
Lysimeter	Topsoil	8 22 97	4.	50-75%	62.5	.
Lysimeter	Topsoil	8 22 97	4.	25-50%	37.5	.
Lysimeter	Topsoil	8 22 97	6.	25-50%	37.5	.
Lysimeter	Topsoil	8 22 97	6.	25-50%	37.5	.
Lysimeter	Topsoil	8 22 97	6.	50-75%	62.5	.
Lysimeter	Topsoil	8 22 97	6.	25-50%	37.5	.
Lysimeter	Topsoil	8 22 97	6.	25-50%	37.5	.
Lysimeter	Topsoil	8 22 97	6.	25-50%	37.5	10.670
Lysimeter	Topsoil	8 22 97	6.	25-50%	37.5	3.280
Lysimeter	Topsoil	8 22 97	6.	50-75%	62.5	.

Table A7.6. Percent cover and biomass data from the washed sand plots, 1996-1997.

Location	Plot	Date	Plot	Ave. Cover class	Cover (%)	Biomass (dry g/0.5 m²)
Washed sand	MSW	9 5 98	9.	25-50%	37.5	.
Washed sand	MSW	8 9 96	2.	1-5%	3.0	7.690
Washed sand	MSW	8 9 96	4.	5-25%	15.0	4.430
Washed sand	MSW	8 9 96	9.	5-25%	15.0	6.430
Washed sand	MSW	8 16 96	2.	1-5%	3.0	.
Washed sand	MSW	8 16 96	2.	5-25%	15.0	.
Washed sand	MSW	8 16 96	2.	5-25%	15.0	.
Washed sand	MSW	8 16 96	2.	5-25%	15.0	.
Washed sand	MSW	8 16 96	2.	1-5%	3.0	.
Washed sand	MSW	8 16 96	2.	1-5%	3.0	.
Washed sand	MSW	8 16 96	2.	5-25%	15.0	.
Washed sand	MSW	8 16 96	4.	5-25%	15.0	.
Washed sand	MSW	8 16 96	4.	5-25%	15.0	.
Washed sand	MSW	8 16 96	4.	5-25%	15.0	.
Washed sand	MSW	8 16 96	4.	1-5%	3.0	.
Washed sand	MSW	8 16 96	4.	5-25%	15.0	.
Washed sand	MSW	8 16 96	4.	5-25%	15.0	.
Washed sand	MSW	8 16 96	4.	25-50%	37.5	.
Washed sand	MSW	8 16 96	9.	1-5%	3.0	.
Washed sand	MSW	8 16 96	9.	1-5%	3.0	.
Washed sand	MSW	8 16 96	9.	1-5%	3.0	.
Washed sand	MSW	8 16 96	9.	5-25%	15.0	.
Washed sand	MSW	8 16 96	9.	1-5%	3.0	.
Washed sand	MSW	8 16 96	9.	5-25%	15.0	.
Washed sand	MSW	8 16 96	9.	5-25%	15.0	.
Washed sand	MSW	8 25 97	2.	25-50%	37.5	.
Washed sand	MSW	8 25 97	2.	5-25%	15.0	.
Washed sand	MSW	8 25 97	2.	50-75%	62.5	.
Washed sand	MSW	8 25 97	2.	25-50%	37.5	.
Washed sand	MSW	8 25 97	2.	25-50%	37.5	.
Washed sand	MSW	8 25 97	2.	25-50%	37.5	7.480
Washed sand	MSW	8 25 97	2.	50-75%	62.5	.
Washed sand	MSW	8 25 97	2.	25-50%	37.5	12.540
Washed sand	MSW	8 25 97	6.	50-75%	62.5	.
Washed sand	MSW	8 25 97	6.	25-50%	37.5	16.160
Washed sand	MSW	8 25 97	6.	5-25%	15.0	.
Washed sand	MSW	8 25 97	6.	25-50%	37.5	.
Washed sand	MSW	8 25 97	6.	25-50%	37.5	.
Washed sand	MSW	8 25 97	6.	50-75%	62.5	.
Washed sand	MSW	8 25 97	6.	50-75%	62.5	.
Washed sand	MSW	8 25 97	6.	25-50%	37.5	7.140
Washed sand	MSW	8 25 97	9.	5-25%	15.0	.
Washed sand	MSW	8 25 97	9.	25-50%	37.5	.
Washed sand	MSW	8 25 97	9.	25-50%	37.5	15.340
Washed sand	MSW	8 25 97	9.	25-50%	37.5	.
Washed sand	MSW	8 25 97	9.	25-50%	37.5	.
Washed sand	MSW	8 25 97	9.	25-50%	37.5	.
Washed sand	MSW	8 25 97	9.	5-25%	15.0	12.420
Washed sand	MSW	8 25 97	9.	25-50%	37.5	.
Washed sand	NVS15	8 9 96	5.	5-25%	15.0	10.970
Washed sand	NVS15	8 9 96	12.	5-25%	15.0	11.180
Washed sand	NVS15	8 9 96	13.	5-25%	15.0	1.110
Washed sand	NVS15	8 16 96	5.	25-50%	37.5	.
Washed sand	NVS15	8 16 96	5.	25-50%	37.5	.
Washed sand	NVS15	8 16 96	5.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	5.	25-50%	37.5	.
Washed sand	NVS15	8 16 96	5.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	5.	5-25%	15.0	.

Table A7.6. Percent cover and biomass data from the washed sand plots, 1996-1997.

Location	Plot	Date	Plot	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Washed sand	NVS15	8 16 96	5.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	12.	25-50%	37.5	.
Washed sand	NVS15	8 16 96	12.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	12.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	12.	25-50%	37.5	.
Washed sand	NVS15	8 16 96	12.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	12.	50-75%	62.5	.
Washed sand	NVS15	8 16 96	12.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	13.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	13.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	13.	25-50%	37.5	.
Washed sand	NVS15	8 16 96	13.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	13.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	13.	5-25%	15.0	.
Washed sand	NVS15	8 16 96	13.	5-25%	15.0	.
Washed sand	NVS15	8 25 97	5.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	5.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	5.	50-75%	62.5	.
Washed sand	NVS15	8 25 97	5.	5-25%	15.0	22.960
Washed sand	NVS15	8 25 97	5.	5-25%	15.0	23.930
Washed sand	NVS15	8 25 97	5.	5-25%	15.0	.
Washed sand	NVS15	8 25 97	5.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	5.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	10.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	10.	50-75%	62.5	.
Washed sand	NVS15	8 25 97	10.	50-75%	62.5	10.030
Washed sand	NVS15	8 25 97	10.	75-95%	85.0	36.100
Washed sand	NVS15	8 25 97	10.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	10.	5-25%	15.0	.
Washed sand	NVS15	8 25 97	10.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	10.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	13.	25-50%	37.5	9.690
Washed sand	NVS15	8 25 97	13.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	13.	50-75%	62.5	.
Washed sand	NVS15	8 25 97	13.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	13.	5-25%	15.0	.
Washed sand	NVS15	8 25 97	13.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	13.	25-50%	37.5	.
Washed sand	NVS15	8 25 97	13.	25-50%	37.5	27.300
Washed sand	NVS30	8 9 96	3.	25-50%	37.5	15.720
Washed sand	NVS30	8 9 96	7.	25-50%	37.5	12.950
Washed sand	NVS30	8 9 96	11.	50-75%	62.5	36.150
Washed sand	NVS30	8 16 96	3.	25-50%	37.5	.
Washed sand	NVS30	8 16 96	3.	50-75%	62.5	.
Washed sand	NVS30	8 16 96	3.	25-50%	37.5	.
Washed sand	NVS30	8 16 96	3.	50-75%	62.5	.
Washed sand	NVS30	8 16 96	3.	25-50%	37.5	.
Washed sand	NVS30	8 16 96	3.	25-50%	37.5	.
Washed sand	NVS30	8 16 96	3.	50-75%	62.5	.
Washed sand	NVS30	8 16 96	7.	25-50%	37.5	.
Washed sand	NVS30	8 16 96	7.	5-25%	15.0	.
Washed sand	NVS30	8 16 96	7.	50-75%	62.5	.
Washed sand	NVS30	8 16 96	7.	5-25%	15.0	.
Washed sand	NVS30	8 16 96	7.	25-50%	37.5	.
Washed sand	NVS30	8 16 96	7.	50-75%	62.5	.
Washed sand	NVS30	8 16 96	7.	25-50%	37.5	.
Washed sand	NVS30	8 16 96	11.	50-75%	62.5	.
Washed sand	NVS30	8 16 96	11.	50-75%	62.5	.

Table A7.6. Percent cover and biomass data from the washed sand plots, 1996-1997.

Location	Plot	Date	Plot	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Washed sand	NVS30	8 16 96	11.	50-75%	62.5	.
Washed sand	NVS30	8 16 96	11.	5-25%	15.0	.
Washed sand	NVS30	8 16 96	11.	50-75%	62.5	.
Washed sand	NVS30	8 16 96	11.	25-50%	37.5	.
Washed sand	NVS30	8 16 96	11.	25-50%	37.5	.
Washed sand	NVS30	8 25 97	3.	25-50%	37.5	10.040
Washed sand	NVS30	8 25 97	3.	50-75%	62.5	5.910
Washed sand	NVS30	8 25 97	3.	50-75%	62.5	.
Washed sand	NVS30	8 25 97	3.	5-25%	15.0	.
Washed sand	NVS30	8 25 97	3.	5-25%	15.0	.
Washed sand	NVS30	8 25 97	3.	25-50%	37.5	.
Washed sand	NVS30	8 25 97	3.	25-50%	37.5	.
Washed sand	NVS30	8 25 97	3.	50-75%	62.5	.
Washed sand	NVS30	8 25 97	7.	75-95%	85.0	13.450
Washed sand	NVS30	8 25 97	7.	50-75%	62.5	8.150
Washed sand	NVS30	8 25 97	7.	50-75%	62.5	.
Washed sand	NVS30	8 25 97	7.	50-75%	62.5	.
Washed sand	NVS30	8 25 97	7.	75-95%	85.0	.
Washed sand	NVS30	8 25 97	7.	75-95%	85.0	.
Washed sand	NVS30	8 25 97	7.	25-50%	37.5	.
Washed sand	NVS30	8 25 97	7.	50-75%	62.5	.
Washed sand	NVS30	8 25 97	11.	25-50%	37.5	.
Washed sand	NVS30	8 25 97	11.	75-95%	85.0	.
Washed sand	NVS30	8 25 97	11.	50-75%	62.5	.
Washed sand	NVS30	8 25 97	11.	75-95%	85.0	18.970
Washed sand	NVS30	8 25 97	11.	50-75%	62.5	23.370
Washed sand	NVS30	8 25 97	11.	25-50%	37.5	.
Washed sand	NVS30	8 25 97	11.	50-75%	62.5	.
Washed sand	NVS30	8 25 97	11.	75-95%	85.0	.
Washed sand	NVS60	8 9 96	1.	25-50%	37.5	7.150
Washed sand	NVS60	8 9 96	14.	25-50%	37.5	3.030
Washed sand	NVS60	8 9 96	15.	5-25%	15.0	.
Washed sand	NVS60	8 16 96	1.	25-50%	37.5	.
Washed sand	NVS60	8 16 96	1.	75-95%	85.0	.
Washed sand	NVS60	8 16 96	1.	50-75%	62.5	.
Washed sand	NVS60	8 16 96	1.	25-50%	37.5	.
Washed sand	NVS60	8 16 96	1.	25-50%	37.5	.
Washed sand	NVS60	8 16 96	1.	5-25%	15.0	.
Washed sand	NVS60	8 16 96	1.	25-50%	37.5	.
Washed sand	NVS60	8 16 96	14.	25-50%	37.5	.
Washed sand	NVS60	8 16 96	14.	25-50%	37.5	.
Washed sand	NVS60	8 16 96	14.	25-50%	37.5	.
Washed sand	NVS60	8 16 96	14.	25-50%	37.5	.
Washed sand	NVS60	8 16 96	14.	5-25%	15.0	.
Washed sand	NVS60	8 16 96	14.	25-50%	37.5	.
Washed sand	NVS60	8 16 96	14.	5-25%	15.0	.
Washed sand	NVS60	8 16 96	15.	1-5%	3.0	.
Washed sand	NVS60	8 16 96	15.	1-5%	3.0	.
Washed sand	NVS60	8 16 96	15.	1-5%	3.0	.
Washed sand	NVS60	8 16 96	15.	5-25%	15.0	.
Washed sand	NVS60	8 16 96	15.	5-25%	15.0	.
Washed sand	NVS60	8 16 96	15.	5-25%	15.0	.
Washed sand	NVS60	8 16 96	15.	1-5%	3.0	.
Washed sand	NVS60	8 25 97	1.	50-75%	62.5	20.810
Washed sand	NVS60	8 25 97	1.	95-99%	97.0	.
Washed sand	NVS60	8 25 97	1.	95-99%	97.0	.
Washed sand	NVS60	8 25 97	1.	50-75%	62.5	.

Table A7.6. Percent cover and biomass data from the washed sand plots, 1996-1997.

Location	Plot	Date	Plot	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Washed sand	NVS60	8 25 97	1.	5-25%	15.0	.
Washed sand	NVS60	8 25 97	1.	75-95%	85.0	37.790
Washed sand	NVS60	8 25 97	1.	50-75%	62.5	.
Washed sand	NVS60	8 25 97	1.	5-25%	15.0	.
Washed sand	NVS60	8 25 97	14.	95-99%	97.0	.
Washed sand	NVS60	8 25 97	14.	50-75%	62.5	.
Washed sand	NVS60	8 25 97	14.	75-95%	85.0	.
Washed sand	NVS60	8 25 97	14.	75-95%	85.0	48.520
Washed sand	NVS60	8 25 97	14.	75-95%	85.0	.
Washed sand	NVS60	8 25 97	14.	95-99%	97.0	.
Washed sand	NVS60	8 25 97	14.	50-75%	62.5	40.110
Washed sand	NVS60	8 25 97	14.	75-95%	85.0	.
Washed sand	NVS60	8 25 97	15.	75-95%	85.0	50.960
Washed sand	NVS60	8 25 97	15.	75-95%	85.0	.
Washed sand	NVS60	8 25 97	15.	50-75%	62.5	.
Washed sand	NVS60	8 25 97	15.	75-95%	85.0	65.310
Washed sand	NVS60	8 25 97	15.	75-95%	85.0	.
Washed sand	NVS60	8 25 97	15.	75-95%	85.0	.
Washed sand	NVS60	8 25 97	15.	75-95%	85.0	.
Washed sand	NVS60	8 25 97	15.	50-75%	62.5	.
Washed sand	Topsoil	8 9 96	2.		.	5.520
Washed sand	Topsoil	8 9 96	2.		.	4.450
Washed sand	Topsoil	8 9 96	2.		.	3.840
Washed sand	Topsoil	8 16 96	6.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	6.	5-25%	15.0	.
Washed sand	Topsoil	8 16 96	6.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	6.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	6.	5-25%	15.0	.
Washed sand	Topsoil	8 16 96	6.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	6.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	8.	5-25%	15.0	.
Washed sand	Topsoil	8 16 96	8.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	8.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	8.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	8.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	8.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	8.	5-25%	15.0	.
Washed sand	Topsoil	8 16 96	10.	0-1%	0.5	.
Washed sand	Topsoil	8 16 96	10.	0-1%	0.5	.
Washed sand	Topsoil	8 16 96	10.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	10.	0-1%	0.5	.
Washed sand	Topsoil	8 16 96	10.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	10.	1-5%	3.0	.
Washed sand	Topsoil	8 16 96	10.	1-5%	3.0	.
Washed sand	Topsoil	8 25 97	4.	25-50%	37.5	.
Washed sand	Topsoil	8 25 97	4.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	4.	5-25%	15.0	10.940
Washed sand	Topsoil	8 25 97	4.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	4.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	4.	5-25%	15.0	5.550
Washed sand	Topsoil	8 25 97	4.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	4.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	8.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	8.	25-50%	37.5	.
Washed sand	Topsoil	8 25 97	8.	25-50%	37.5	.
Washed sand	Topsoil	8 25 97	8.	25-50%	37.5	.
Washed sand	Topsoil	8 25 97	8.	25-50%	37.5	4.120
Washed sand	Topsoil	8 25 97	8.	5-25%	15.0	.

Table A7.6. Percent cover and biomass data from the washed sand plots, 1996-1997.

Location	Plot	Date	Plot	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Washed sand	Topsoil	8 25 97	8.	50-75%	62.5	6.030
Washed sand	Topsoil	8 25 97	8.	50-75%	62.5	.
Washed sand	Topsoil	8 25 97	12.	5-25%	15.0	8.160
Washed sand	Topsoil	8 25 97	12.	5-25%	15.0	7.950
Washed sand	Topsoil	8 25 97	12.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	12.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	12.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	12.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	12.	5-25%	15.0	.
Washed sand	Topsoil	8 25 97	12.	1-5%	3.0	.
Washed sand	Top+Fert.	8 9 96	16.	5-25%	15.0	10.180
Washed sand	Top+Fert.	8 9 96	17.	5-25%	15.0	6.790
Washed sand	Top+Fert.	8 9 96	18.	25-50%	37.5	7.430
Washed sand	Top+Fert.	8 16 96	16.	25-50%	37.5	.
Washed sand	Top+Fert.	8 16 96	16.	75-95%	85.0	.
Washed sand	Top+Fert.	8 16 96	16.	25-50%	37.5	.
Washed sand	Top+Fert.	8 16 96	16.	50-75%	62.5	.
Washed sand	Top+Fert.	8 16 96	16.	25-50%	37.5	.
Washed sand	Top+Fert.	8 16 96	16.	50-75%	62.5	.
Washed sand	Top+Fert.	8 16 96	16.	25-50%	37.5	.
Washed sand	Top+Fert.	8 16 96	17.	5-25%	15.0	.
Washed sand	Top+Fert.	8 16 96	17.	25-50%	37.5	.
Washed sand	Top+Fert.	8 16 96	17.	5-25%	15.0	.
Washed sand	Top+Fert.	8 16 96	17.	5-25%	15.0	.
Washed sand	Top+Fert.	8 16 96	17.	50-75%	62.5	.
Washed sand	Top+Fert.	8 16 96	17.	25-50%	37.5	.
Washed sand	Top+Fert.	8 16 96	17.	50-75%	62.5	.
Washed sand	Top+Fert.	8 16 96	18.	5-25%	15.0	.
Washed sand	Top+Fert.	8 16 96	18.	25-50%	37.5	.
Washed sand	Top+Fert.	8 16 96	18.	5-25%	15.0	.
Washed sand	Top+Fert.	8 16 96	18.	5-25%	15.0	.
Washed sand	Top+Fert.	8 16 96	18.	25-50%	37.5	.
Washed sand	Top+Fert.	8 16 96	18.	5-25%	15.0	.
Washed sand	Top+Fert.	8 16 96	18.	5-25%	15.0	.
Washed sand	Top+Fert.	8 25 97	16.	50-75%	62.5	.
Washed sand	Top+Fert.	8 25 97	16.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	16.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	16.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	16.	1-5%	3.0	11.800
Washed sand	Top+Fert.	8 25 97	16.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	16.	25-50%	37.5	5.380
Washed sand	Top+Fert.	8 25 97	16.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	17.	5-25%	15.0	10.460
Washed sand	Top+Fert.	8 25 97	17.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	17.	50-75%	62.5	.
Washed sand	Top+Fert.	8 25 97	17.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	17.	5-25%	15.0	.
Washed sand	Top+Fert.	8 25 97	17.	50-75%	62.5	.
Washed sand	Top+Fert.	8 25 97	17.	25-50%	37.5	6.880
Washed sand	Top+Fert.	8 25 97	17.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	18.	5-25%	15.0	.
Washed sand	Top+Fert.	8 25 97	18.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	18.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	18.	5-25%	15.0	11.950
Washed sand	Top+Fert.	8 25 97	18.	25-50%	37.5	.
Washed sand	Top+Fert.	8 25 97	18.	5-25%	15.0	.
Washed sand	Top+Fert.	8 25 97	18.	25-50%	37.5	6.320
Washed sand	Top+Fert.	8 25 97	18.	25-50%	37.5	.

Table A7.7. Percent cover data from the lysimeter and washed sand plots, 1998.

Note: Two sets of data were collected from the lysimeter and washed sand plots. The first set, collected 7/23/98 (lysimeter plots) and 7/24/98 (washed sand plots) were collected in same fashion as 1996-97 data, and are presented first in this table. These data seemed to be low in comparison with visual estimates, so a second set of estimates were made on 8/25/98 (lysimeter plots) and 9/16/98 (washed sand plots). These were visual observations of the overall cover on each plot. The results presented (which follow the initial set of samples in this table) are the averages of overall assessments of each plot made by two observers (Eger and Wagner).

First set of data:

Location	Plot	Date	Plot	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Lysimeter	MSW	7 23 98	2.	50-75%	62.5	.
Lysimeter	MSW	7 23 98	2.	25-50%	37.5	.
Lysimeter	MSW	7 23 98	2.	25-50%	37.5	.
Lysimeter	MSW	7 23 98	2.	25-50%	37.5	.
Lysimeter	MSW	7 23 98	2.	25-50%	37.5	.
Lysimeter	MSW	7 23 98	2.	50-75%	62.5	21.930
Lysimeter	MSW	7 23 98	2.	50-75%	62.5	15.610
Lysimeter	MSW	7 23 98	2.	25-50%	37.5	.
Lysimeter	MSW	7 23 98	7.	25-50%	37.5	10.570
Lysimeter	MSW	7 23 98	7.	50-75%	62.5	.
Lysimeter	MSW	7 23 98	7.	50-75%	62.5	.
Lysimeter	MSW	7 23 98	7.	25-50%	37.5	11.450
Lysimeter	MSW	7 23 98	7.	50-75%	62.5	.
Lysimeter	MSW	7 23 98	7.	25-50%	37.5	.
Lysimeter	MSW	7 23 98	7.	50-75%	62.5	.
Lysimeter	MSW	7 23 98	7.	50-75%	62.5	.
Lysimeter	MSW	7 23 98	8.	25-50%	37.5	.
Lysimeter	MSW	7 23 98	8.	50-75%	62.5	.
Lysimeter	MSW	7 23 98	8.	25-50%	37.5	.
Lysimeter	MSW	7 23 98	8.	25-50%	37.5	.
Lysimeter	MSW	7 23 98	8.	25-50%	37.5	.
Lysimeter	MSW	7 23 98	8.	50-75%	62.5	.
Lysimeter	MSW	7 23 98	8.	25-50%	37.5	17.090
Lysimeter	MSW	7 23 98	8.	50-75%	62.5	9.390
Lysimeter	NVS	7 23 98	3.	25-50%	37.5	.
Lysimeter	NVS	7 23 98	3.	25-50%	37.5	.
Lysimeter	NVS	7 23 98	3.	25-50%	37.5	.
Lysimeter	NVS	7 23 98	3.	50-75%	62.5	.
Lysimeter	NVS	7 23 98	3.	50-75%	62.5	.
Lysimeter	NVS	7 23 98	3.	50-75%	62.5	19.220
Lysimeter	NVS	7 23 98	3.	5-25%	15.0	7.300
Lysimeter	NVS	7 23 98	3.	25-50%	37.5	.
Lysimeter	NVS	7 23 98	5.	25-50%	37.5	.
Lysimeter	NVS	7 23 98	5.	25-50%	37.5	.
Lysimeter	NVS	7 23 98	5.	25-50%	37.5	.
Lysimeter	NVS	7 23 98	5.	50-75%	62.5	.
Lysimeter	NVS	7 23 98	5.	25-50%	37.5	.
Lysimeter	NVS	7 23 98	5.	50-75%	62.5	.
Lysimeter	NVS	7 23 98	5.	50-75%	62.5	19.690
Lysimeter	NVS	7 23 98	5.	50-75%	62.5	21.350
Lysimeter	NVS	7 23 98	9.	50-75%	62.5	21.500
Lysimeter	NVS	7 23 98	9.	50-75%	62.5	20.040
Lysimeter	NVS	7 23 98	9.	50-75%	62.5	.
Lysimeter	NVS	7 23 98	9.	50-75%	62.5	.
Lysimeter	NVS	7 23 98	9.	78-95%	85.0	.

Table A7.7. Percent cover data from the lysimeter and washed sand plots, 1998.

Location	Plot	Date	Plot	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Lysimeter	NVS	7 23 98	9.	25-50%	37.5	.
Lysimeter	NVS	7 23 98	9.	78-95%	85.0	.
Lysimeter	NVS	7 23 98	9.	78-95%	85.0	.
Lysimeter	Topsoil	7 23 98	1.	5-25%	15.0	12.390
Lysimeter	Topsoil	7 23 98	1.	5-25%	15.0	.
Lysimeter	Topsoil	7 23 98	1.	25-50%	37.5	8.280
Lysimeter	Topsoil	7 23 98	1.	25-50%	37.5	.
Lysimeter	Topsoil	7 23 98	1.	25-50%	37.5	.
Lysimeter	Topsoil	7 23 98	1.	5-25%	15.0	.
Lysimeter	Topsoil	7 23 98	1.	25-50%	37.5	.
Lysimeter	Topsoil	7 23 98	1.	50-75%	62.5	.
Lysimeter	Topsoil	7 23 98	4.	25-50%	37.5	5.970
Lysimeter	Topsoil	7 23 98	4.	5-25%	15.0	12.500
Lysimeter	Topsoil	7 23 98	4.	25-50%	37.5	.
Lysimeter	Topsoil	7 23 98	4.	25-50%	37.5	.
Lysimeter	Topsoil	7 23 98	4.	5-25%	15.0	.
Lysimeter	Topsoil	7 23 98	4.	5-25%	15.0	.
Lysimeter	Topsoil	7 23 98	4.	5-25%	15.0	.
Lysimeter	Topsoil	7 23 98	4.	5-25%	15.0	.
Lysimeter	Topsoil	7 23 98	6.	25-50%	37.5	13.730
Lysimeter	Topsoil	7 23 98	6.	25-50%	37.5	10.280
Lysimeter	Topsoil	7 23 98	6.	5-25%	15.0	.
Lysimeter	Topsoil	7 23 98	6.	25-50%	37.5	.
Lysimeter	Topsoil	7 23 98	6.	5-25%	15.0	.
Lysimeter	Topsoil	7 23 98	6.	25-50%	37.5	.
Lysimeter	Topsoil	7 23 98	6.	5-25%	15.0	.
Lysimeter	Topsoil	7 23 98	6.	25-50%	37.5	.
Washed sand	MSW	7 24 98	2.	50-75%	62.5	13.860
Washed sand	MSW	7 24 98	2.	50-75%	62.5	.
Washed sand	MSW	7 24 98	2.	25-50%	37.5	.
Washed sand	MSW	7 24 98	2.	25-50%	37.5	.
Washed sand	MSW	7 24 98	2.	25-50%	37.5	.
Washed sand	MSW	7 24 98	2.	25-50%	37.5	.
Washed sand	MSW	7 24 98	2.	25-50%	37.5	.
Washed sand	MSW	7 24 98	2.	25-50%	37.5	16.300
Washed sand	MSW	7 24 98	6.	50-75%	62.5	.
Washed sand	MSW	7 24 98	6.	78-95%	85.0	.
Washed sand	MSW	7 24 98	6.	95-99%	97.0	.
Washed sand	MSW	7 24 98	6.	25-50%	37.5	.
Washed sand	MSW	7 24 98	6.	50-75%	62.5	27.730
Washed sand	MSW	7 24 98	6.	25-50%	37.5	.
Washed sand	MSW	7 24 98	6.	50-75%	62.5	23.810
Washed sand	MSW	7 24 98	6.	50-75%	62.5	.
Washed sand	MSW	7 24 98	9.	25-50%	37.5	.
Washed sand	MSW	7 24 98	9.	5-25%	15.0	.
Washed sand	MSW	7 24 98	9.	25-50%	37.5	34.220
Washed sand	MSW	7 24 98	9.	25-50%	37.5	9.720
Washed sand	MSW	7 24 98	9.	50-75%	62.5	.
Washed sand	MSW	7 24 98	9.	25-50%	37.5	.
Washed sand	MSW	7 24 98	9.	50-75%	62.5	.
Washed sand	NVS15	7 24 98	5.	25-50%	37.5	.
Washed sand	NVS15	7 24 98	5.	25-50%	37.5	.
Washed sand	NVS15	7 24 98	5.	5-25%	15.0	.
Washed sand	NVS15	7 24 98	5.	25-50%	37.5	.
Washed sand	NVS15	7 24 98	5.	25-50%	37.5	12.300
Washed sand	NVS15	7 24 98	5.	5-25%	15.0	.

Table A7.7. Percent cover data from the lysimeter and washed sand plots, 1998.

Location	Plot	Date	Plot	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Washed sand	NVS15	7 24 98	5.	5-25%	15.0	6.380
Washed sand	NVS15	7 24 98	5.	1-5%	3.0	.
Washed sand	NVS15	7 24 98	10.	5-25%	15.0	.
Washed sand	NVS15	7 24 98	10.	25-50%	37.5	.
Washed sand	NVS15	7 24 98	10.	25-50%	37.5	.
Washed sand	NVS15	7 24 98	10.	5-25%	15.0	9.690
Washed sand	NVS15	7 24 98	10.	1-5%	3.0	.
Washed sand	NVS15	7 24 98	10.	5-25%	15.0	.
Washed sand	NVS15	7 24 98	10.	50-75%	62.5	.
Washed sand	NVS15	7 24 98	10.	25-50%	37.5	10.360
Washed sand	NVS15	7 24 98	13.	5-25%	15.0	.
Washed sand	NVS15	7 24 98	13.	5-25%	15.0	.
Washed sand	NVS15	7 24 98	13.	1-5%	3.0	.
Washed sand	NVS15	7 24 98	13.	25-50%	37.5	.
Washed sand	NVS15	7 24 98	13.	5-25%	15.0	.
Washed sand	NVS15	7 24 98	13.	5-25%	15.0	5.980
Washed sand	NVS15	7 24 98	13.	5-25%	15.0	10.260
Washed sand	NVS15	7 24 98	13.	5-25%	15.0	.
Washed sand	NVS30	7 24 98	3.	5-25%	15.0	.
Washed sand	NVS30	7 24 98	3.	25-50%	37.5	10.390
Washed sand	NVS30	7 24 98	3.	5-25%	15.0	5.840
Washed sand	NVS30	7 24 98	3.	25-50%	37.5	.
Washed sand	NVS30	7 24 98	3.	50-75%	62.5	.
Washed sand	NVS30	7 24 98	3.	25-50%	37.5	.
Washed sand	NVS30	7 24 98	3.	5-25%	15.0	.
Washed sand	NVS30	7 24 98	3.	5-25%	15.0	.
Washed sand	NVS30	7 24 98	7.	25-50%	37.5	8.740
Washed sand	NVS30	7 24 98	7.	25-50%	37.5	.
Washed sand	NVS30	7 24 98	7.	50-75%	62.5	.
Washed sand	NVS30	7 24 98	7.	25-50%	37.5	.
Washed sand	NVS30	7 24 98	7.	25-50%	37.5	.
Washed sand	NVS30	7 24 98	7.	50-75%	62.5	.
Washed sand	NVS30	7 24 98	7.	5-25%	15.0	.
Washed sand	NVS30	7 24 98	7.	25-50%	37.5	11.710
Washed sand	NVS30	7 24 98	11.	5-25%	15.0	.
Washed sand	NVS30	7 24 98	11.	50-75%	62.5	.
Washed sand	NVS30	7 24 98	11.	5-25%	15.0	.
Washed sand	NVS30	7 24 98	11.	5-25%	15.0	8.460
Washed sand	NVS30	7 24 98	11.	25-50%	37.5	3.750
Washed sand	NVS30	7 24 98	11.	25-50%	37.5	.
Washed sand	NVS30	7 24 98	11.	25-50%	37.5	.
Washed sand	NVS30	7 24 98	11.	25-50%	37.5	.
Washed sand	NVS60	7 24 98	1.	50-75%	62.5	.
Washed sand	NVS60	7 24 98	1.	25-50%	37.5	.
Washed sand	NVS60	7 24 98	1.	78-95%	85.0	.
Washed sand	NVS60	7 24 98	1.	25-50%	37.5	.
Washed sand	NVS60	7 24 98	1.	25-50%	37.5	.
Washed sand	NVS60	7 24 98	1.	25-50%	37.5	.
Washed sand	NVS60	7 24 98	1.	50-75%	62.5	19.900
Washed sand	NVS60	7 24 98	1.	25-50%	37.5	23.710
Washed sand	NVS60	7 24 98	14.	50-75%	62.5	.
Washed sand	NVS60	7 24 98	14.	78-95%	85.0	.
Washed sand	NVS60	7 24 98	14.	50-75%	62.5	.
Washed sand	NVS60	7 24 98	14.	50-75%	62.5	6.050
Washed sand	NVS60	7 24 98	14.	50-75%	62.5	.
Washed sand	NVS60	7 24 98	14.	50-75%	62.5	.
Washed sand	NVS60	7 24 98	14.	50-75%	62.5	.
Washed sand	NVS60	7 24 98	14.	25-50%	37.5	16.780

Table A7.7. Percent cover data from the lysimeter and washed sand plots, 1998.

Location	Plot	Date	Plot	Cover class	Ave. Cover (%)	Biomass (dry g/0.5 m²)
Washed sand	NVS60	7 24 98	15.	5-25%	15.0	.
Washed sand	NVS60	7 24 98	15.	25-50%	37.5	.
Washed sand	NVS60	7 24 98	15.	25-50%	37.5	.
Washed sand	NVS60	7 24 98	15.	25-50%	37.5	.
Washed sand	NVS60	7 24 98	15.	50-75%	62.5	.
Washed sand	NVS60	7 24 98	15.	50-75%	62.5	.
Washed sand	NVS60	7 24 98	15.	5-25%	15.0	7.650
Washed sand	NVS60	7 24 98	15.	78-95%	85.0	41.810
Washed sand	Topsoil	7 24 98	4.	25-50%	37.5	.
Washed sand	Topsoil	7 24 98	4.	25-50%	37.5	12.490
Washed sand	Topsoil	7 24 98	4.	25-50%	37.5	.
Washed sand	Topsoil	7 24 98	4.	5-25%	15.0	.
Washed sand	Topsoil	7 24 98	4.	25-50%	37.5	.
Washed sand	Topsoil	7 24 98	4.	5-25%	15.0	6.410
Washed sand	Topsoil	7 24 98	4.	1-5%	3.0	.
Washed sand	Topsoil	7 24 98	4.	5-25%	15.0	.
Washed sand	Topsoil	7 24 98	8.	25-50%	37.5	8.990
Washed sand	Topsoil	7 24 98	8.	25-50%	37.5	10.390
Washed sand	Topsoil	7 24 98	8.	25-50%	37.5	.
Washed sand	Topsoil	7 24 98	8.	5-25%	15.0	.
Washed sand	Topsoil	7 24 98	8.	50-75%	62.5	.
Washed sand	Topsoil	7 24 98	8.	5-25%	15.0	.
Washed sand	Topsoil	7 24 98	8.	25-50%	37.5	.
Washed sand	Topsoil	7 24 98	8.	25-50%	37.5	.
Washed sand	Topsoil	7 24 98	12.	5-25%	15.0	.
Washed sand	Topsoil	7 24 98	12.	5-25%	15.0	.
Washed sand	Topsoil	7 24 98	12.	25-50%	37.5	15.380
Washed sand	Topsoil	7 24 98	12.	25-50%	37.5	.
Washed sand	Topsoil	7 24 98	12.	25-50%	37.5	.
Washed sand	Topsoil	7 24 98	12.	1-5%	3.0	.
Washed sand	Topsoil	7 24 98	12.	25-50%	37.5	.
Washed sand	Topsoil	7 24 98	12.	25-50%	37.5	14.040
Washed sand	Top+Fert.	7 24 98	16.	5-25%	15.0	.
Washed sand	Top+Fert.	7 24 98	16.	1-5%	3.0	.
Washed sand	Top+Fert.	7 24 98	16.	1-5%	3.0	.
Washed sand	Top+Fert.	7 24 98	16.	25-50%	37.5	.
Washed sand	Top+Fert.	7 24 98	16.	5-25%	15.0	.
Washed sand	Top+Fert.	7 24 98	16.	5-25%	15.0	.
Washed sand	Top+Fert.	7 24 98	16.	1-5%	3.0	2.600
Washed sand	Top+Fert.	7 24 98	16.	25-50%	37.5	14.170
Washed sand	Top+Fert.	7 24 98	17.	25-50%	37.5	.
Washed sand	Top+Fert.	7 24 98	17.	25-50%	37.5	.
Washed sand	Top+Fert.	7 24 98	17.	5-25%	15.0	.
Washed sand	Top+Fert.	7 24 98	17.	25-50%	37.5	.
Washed sand	Top+Fert.	7 24 98	17.	25-50%	37.5	.
Washed sand	Top+Fert.	7 24 98	17.	25-50%	37.5	9.230
Washed sand	Top+Fert.	7 24 98	17.	25-50%	37.5	37.500
Washed sand	Top+Fert.	7 24 98	17.	25-50%	37.5	.
Washed sand	Top+Fert.	7 24 98	18.	50-75%	62.5	.
Washed sand	Top+Fert.	7 24 98	18.	5-25%	15.0	.
Washed sand	Top+Fert.	7 24 98	18.	5-25%	15.0	.
Washed sand	Top+Fert.	7 24 98	18.	25-50%	37.5	.
Washed sand	Top+Fert.	7 24 98	18.	78-95%	85.0	.
Washed sand	Top+Fert.	7 24 98	18.	25-50%	37.5	.
Washed sand	Top+Fert.	7 24 98	18.	25-50%	37.5	8.750
Washed sand	Top+Fert.	7 24 98	18.	25-50%	37.5	12.270

Table A7.7. Percent cover data from the lysimeter and washed sand plots, 1998.

Second set of data:

Lysimeter plots

Amendment	Plot #	Eger estimate	Wagner estimate	Average estimate	Overall estimate
MSW	2	75 - 95%	85	85	80
	7	75 - 95%	85	85	
	6	50 - 75%	75	69	
NVS	3	75 - 95%	80	82	85
	5	75 - 95%	85	85	
	9	75 - 95%	90	88	
Topsoil + fertilizer	1	50 - 75%	60	61	63
	4	50 - 75%	65	64	
	6	50 - 75%	65	64	

Note: Eger used cover classes for his estimates, Wagner used a single number. To arrive at the average values, the midpoint of the cover class was used to represent Eger's estimate.

Table A7.7. Percent cover data from the lysimeter and washed sand plots, 1998.

Washed sand plots

Amendment	Plot #	Eger estimate	Wagner estimate	Average estimate	Overall average
NVS60	1	75 - 95%	90%	88	89
	14	75 - 95%	90%	88	
	15	75 - 95%	95%	90	
NVS30	3	75 - 95%	75%	80	81
	7	75 - 95%	75%	80	
	11	75 - 95%	80%	82	
NVS15	5	50 - 75%	70%	66	70
	10	75 - 95%	75%	80	
	13	50 - 75%	65%	64	
MSW	2	75 - 95%	75%	80	79
	6	75 - 95%	70%	78	
	9	75 - 95%	75%	80	
2" Topsoil	4	50 - 75%	60%	61	63
	8	50 - 75%	70%	66	
	12	50 - 75%	60%	61	
4" Topsoil + fertilizer	16	75 - 95%	75%	80	80
	17	75 - 95%	75%	80	
	18	75 - 95%	75%	80	

Note: Eger used cover classes for his estimates, Wagner used a single number. To arrive at the average values, the midpoint of the cover class was used to represent Eger's estimate.

Table A7.8. Number of percent cover measurements on each demo plot that were either less than 5% or greater than 75%.

Plot	Location	Year	Number of plots with percent cover of:	
			<5%	>75%
Control	Top	1996 1997 1998	0 0 0	1 0 11
	Middle	1996 1997 1998	7 0 0	0 0 11
	Bottom	1996 1997 1998	5 2 0	0 0 8
Fertilizer	Top	1996 1997 1998	3 0 0	2 0 12
	Middle	1996 1997 1998	0 0 0	1 1 16
	Bottom	1996 1997 1998	0 0 0	1 0 10
MSW	Top	1996 1997 1998	0 0 0	4 0 27
	Middle	1996 1997 1998	0 0 0	6 6 23
	Bottom	1996 1997 1998	0 0 0	0 2 22
NVS	Top	1996 1997 1998	0 0 0	7 2 8
	Middle	1996 1997 1998	0 0 0	3 6 19
	Bottom	1996 1997 1998	0 1 0	12 0 13

Table A7.9. Percent cover vs. biomass comparisons.

Plot	Section	Year	% Cover	Biomass (dry g / m^2)
Control	Middle	1996	15.0	19.6
			37.5	19.0
			37.5	19.6
			62.5	21.8
Control	Middle	1997	37.5	10.8
			37.5	19.6
			37.5	28.8
			37.5	54.0

While biomass gererally increases as percent cover increases, biomass measurements tend t be highly variable. While percent cover is in dependent of the plant species, biomass values are affected by both the type and size of the plant that is collected. For example, the percent cover created by a large Russian Thistle may be the same as that produced by carpet weed, but the biomass contained in the thistle is much larger.

When all the data from the demonstration slope was plotted, there was a general increase in biomass as percent cover increased, but the r^2 for the regression was only 0.239 (Figure A7.1), indicating that the biomass was not directly correlated with percent cover.

Biomass can vary widely for plots of similar cover, and plots with widely varying percent cover can have essentially the same biomass. On the control plot, for example, the biomass in 1997 was well correlated with percent cover, but in 1996 there was little correlation between biomass and percent cover (Table A7.9). Similarly, a biomass value of 0.7 grams was measured on a NVS plot in 1997 that had a percent cover of 37.5%, while a fertilzer plot in 1996 had 62.5% cover but only 1.0 grams of biomass.

In 1996, only 1 biomass plot was measured on the lysimeter and washed sand plots. Although the number of plots was increased to two in 1997 and 1998, the variability was still high. A better measure of biomass on plots this small would be to mow the entire plot at the end of the third growing season (when reclamation requirements generally need to be met), because the permanent vegetation should be well established and will quickly grow back.

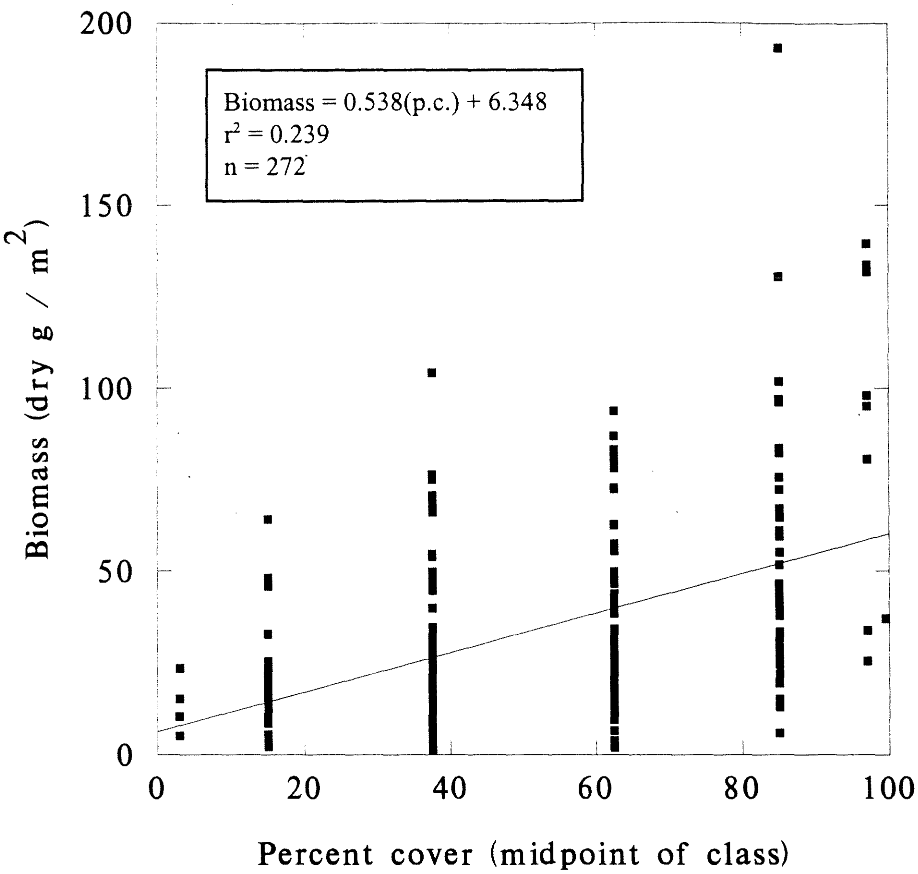


Figure A7.1. Biomass vs. percent cover (using 1996-98 data from all demonstration plots).

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.

<u>Spreading of the topsoil and the amendments</u>

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

Photographic history of the demonstration plots

Figure A9.1. Original condition of the demonstration slope, as seen from across the surge pond.

Figure A9.2. Original condition of the demonstration slope, looking west.

Figure A9.3. Original condition of the demonstration slope, looking up the slope.

Figure A9.4. Filling in erosion gullies and spreading topsoil prior to amendment spreading.

Figure A9.5. Loading MSW compost into the compost spreader. Note the pile of MSW compost in the foreground, and the steam rising from the load being placed into the spreader.

Figure A9.6. Spreading MSW compost on the demonstration plot with a compost spreader, which was also used to spread the NVS on its demonstration plot.

Figure A9.7. Seeding the upper third of the plot with the MNDOT 50A seed mix.

Figure A9.8. Mulching the demonstration slope with a platform-mounted blower. The truck with the hay bales was unable to maneuver on the sandy slope, so the front-end loader was brought in to pull the truck and blower. This produced depressions in the slope, as well as compaction.

Figure A9.9. One of the two trenches that run across the width of the demonstration slope, as seen after mulching was completed.

Figure A9.10. Crimped-in mulch, as seen two weeks after mulching was completed. Note the lack of mulch in the lower left hand corner, typical of the open areas that remained after mulching.

Figure A9.11. Demonstration slope on 7/1/96. With the cover crop (primarily oats) having been almost totally grazed by geese, the plants seen in this photo are mostly ragweed and lambsquarter.

Figure A9.12. Demonstration slope on 8/13/96 (dominated by ragweed and lambsquarter).

Figure A9.13. The demonstration slope on 7/17/97 (looking into MSW plot from the control plot). Annual weeds were still prevalent (though horseweed was the primary weed instead of ragweed and lambsquarter), but some of the planted species started to appear (black eyed susans are visible in this picture).

Figure A9.14. By 1998 the once-prevalent ragweed and lambsquarter had mostly disappeared. However, the NVS plot contained a large amount of mare's weed, which hadn't been observed on the demonstration slope until that year. This photo (taken 7/13/98) shows mare's weed on the NVS plot.

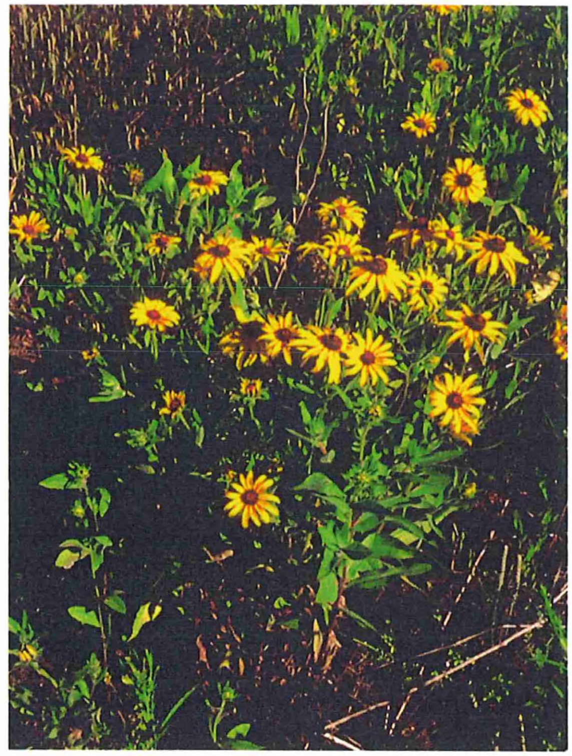
Figure A9.15. This photo (taken 8/14/98) was taken from the edge of the fertilizer plot, looking into the NVS plot. Note the predominance of mare's weed, except in the ditch that runs horizontally across the plot, which contained other plants, primarily goldenrod (the dark green plants in the background).

Figure A9.16. This photo (taken 8/14/98 at the toe of the fertilizer plot) shows the largest of the erosion gullies that started to form following the 5" rain of 7/16/97. The top of the gully was staked in July 1997, and the stakes were still at the top of the gully in July 1998, indicating that the gully was not getting larger.

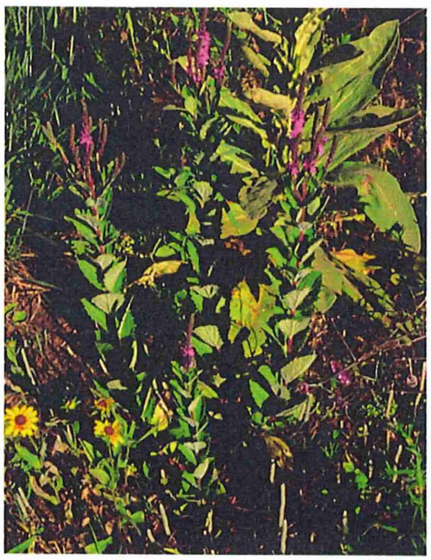
Figure A9.17. Photo of the MSW plot on 8/14/98. Note the almost complete lack of annual weeds, and the dense vegetative cover, which approached 100%.

Figure A9.18. Photo of the MSW plot in July 1999.

Butterfly weed *(Asclepias tuberosa)*



Black eyed susan *(Rudbeckia hirta)*



Hoary vervain (Verbena stricta)

White prairie clover
(Petalostenum candidum)

Purple prairie clover
(Petalostenum purpureum)

Figure A9.19. Some of the plant species observed on the demonstration slope in 2000.

Clockwise from top left: View along the upper ditch (in August), showing different vegetation in the ditch and in the surrounding areas; the same ditch as seen in April; the MSW plot in August; looking up the fertilizer plot at the erosion gully that had been filled in 1998.

Figure A9.20. Photographs of the demonstration slope in 2000.

Appendix 10

Precipitation Data

1996 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 11/6/96, 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 in 1996 when the meter malfunctioned were:

1) May 15-22 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 1996 data. On 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 primary gage for support purposes, so hopefully this will be a one-time event.)

2. June 13-18. 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, and 1996 rain data is presented in Table A10.1.

1997 Numerous problems were encountered with collection of 1997 precipitation data. The gage was first set out in April, but when the gage was next checked it was discovered that gears in the wind-up motor weren't operating correctly. A new motor was sent down from Hibbing, and the new motor was then installed. However, the next time the gage was checked it was discovered that a gear was missing from the drive shaft of the new motor, so that the circulating drum didn't move. A gear from another motor was then installed, but when the gage was next checked it was discovered that the motor was winding too quickly, so that it wasn't possible to determine on which days precipitation fell (though the total amount of rainfall during that time period was recorded).

A brand new motor (battery operated) was then installed, and ran correctly. However, on 7/17/97 the gage was checked and a new sheet of paper was installed, and though it started working correctly, about a day later the ink pen inexplicably stopped dispensing ink, so that no data was collected between 7/18/97 and 8/4/97. Gaps in the data were again filled in with Rosemount data, and data for 1997 is presented in Table A10.2.

1998-2001 The rain gages were removed after the 1997 growing season. Monthly data data from Rosemount are presented in Tables A10.3.

Table A10.1. 1996 daily precipitation data for the growing season (May 1 - September 30).

Note Gaps in data collected from the Shiely rain gage were filled in with data from the Rosemount Ag. Expt Station (latitude 44.78169, longitude 93.03160).

Date	Shiely[A] precip. (in.)	Rosemount[B] precip. (in.)	Combined[C] precip. (in.)	Combined[D] sum (in.)	Rosemount[E] sum (in.)	Notes
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	2.22	2.28	(High winds toppled
5 19 96	.	0.77	0.77	2.99	3.05	the rain gage)
5 20 96	.	0.00	0.00	2.99	3.05	
5 21 96	.	0.00	0.00	2.99	3.05	
5 22 96	.	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	Checked lysimeters
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	Checked lysimeters
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	Checked lysimeters
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	Checked lysimeters
6 19 96	0.00	0.02	0.00	5.67	6.32	

Table A10.1. 1996 daily precipitation data for the growing season (May 1 - September 30).

Date	Shiely[A] precip. (in.)	Rosemount[B] precip. (in.)	Combined[C] precip. (in.)	Combined[D] sum (in.)	Rosemount[E] sum (in.)	Notes
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	
6 24 96	0.00	0.02	0.00	6.12	6.88	Checked lysimeters
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	Checked lysimeters
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	

Table A10.1. 1996 daily precipitation data for the growing season (May 1 - September 30).

Date	Shiely[A] precip. (in.)	Rosemount[B] precip. (in.)	Combined[C] precip. (in.)	Combined[D] sum (in.)	Rosemount[E] sum (in.)	Notes
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	Chart malfunctioned
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	

Note: The footnotes for this table are presented at end of Table 10.2 (same footnotes for both tables).

Table A10.2. 1997 daily precipitation data for the growing season (May 1 - September 30).

Date	Shiely[A] precip. (in.)	Rosemount[B] precip. (in.)	Comb.[C] precip. (in.)	Comb.[D] sum (in.)	Rosemount[E] sum (in.)	Notes
5 1 97	.	0.00	0.00	0.00	0.000	
5 2 97	.	0.00	0.00	0.00	0.000	
5 3 97	.	0.23	0.23	0.23	0.230	
5 4 97	.	0.00	0.00	0.23	0.230	
5 5 97	.	0.06	0.06	0.29	0.290	
5 6 97	.	0.00	0.00	0.29	0.290	
5 7 97	.	0.00	0.00	0.29	0.290	
5 8 97	.	0.41	0.41	0.70	0.700	
5 9 97	.	0.07	0.07	0.77	0.770	
5 10 97	.	0.00	0.00	0.77	0.770	
5 11 97	.	0.00	0.00	0.77	0.770	
5 12 97	.	0.00	0.00	0.77	0.770	
5 13 97	.	0.00	0.00	0.77	0.770	
5 14 97	.	0.15	0.15	0.92	0.920	
5 15 97	.	0.02	0.02	0.94	0.940	
5 16 97	.	0.00	0.00	0.94	0.940	
5 17 97	.	0.00	0.00	0.94	0.940	
5 18 97	.	0.00	0.00	0.94	0.940	
5 19 97	.	0.30	0.30	1.24	1.240	
5 20 97	.	0.00	0.00	1.24	1.240	
5 21 97	.	0.00	0.00	1.24	1.240	
5 22 97	.	0.00	0.00	1.24	1.240	
5 23 97	.	0.00	0.00	1.24	1.240	
5 24 97	.	0.00	0.00	1.24	1.240	
5 25 97	.	0.00	0.00	1.24	1.240	
5 26 97	.	0.00	0.00	1.24	1.240	
5 27 97	.	0.64	0.64	1.88	1.880	
5 28 97	.	0.00	0.00	1.88	1.880	
5 29 97	.	0.08	0.08	1.96	1.960	
5 30 97	.	0.12	0.12	2.08	2.080	
5 31 97	.	0.00	0.00	2.08	2.080	
6 1 97	.	0.00	0.00	2.08	2.080	
6 2 97	.	0.00	0.00	2.08	2.080	
6 3 97	.	0.00	0.00	2.08	2.080	
6 4 97	.	0.00	0.00	2.08	2.080	
6 5 97	.	0.08	0.08	2.16	2.160	
6 6 97	.	0.08	0.08	2.24	2.240	
6 7 97	.	0.00	0.00	2.24	2.240	
6 8 97	.	0.00	0.00	2.24	2.240	
6 9 97	.	0.59	0.59	2.83	2.830	
6 10 97	.	0.00	0.00	2.83	2.830	
6 11 97	.	0.00	0.00	2.83	2.830	
6 12 97	.	0.17	0.17	3.00	3.000	
6 13 97	.	0.00	0.00	3.00	3.000	
6 14 97	.	0.00	0.00	3.00	3.000	
6 15 97	.	0.00	0.00	3.00	3.000	
6 16 97	.	0.36	0.36	3.36	3.360	
6 17 97	.	0.00	0.00	3.36	3.360	
6 18 97	.	0.00	0.00	3.36	3.360	
6 19 97	.	0.00	0.00	3.36	3.360	
6 20 97	.	0.17	0.17	3.53	3.530	
6 21 97	.	0.00	0.00	3.53	3.530	
6 22 97	.	0.00	0.00	3.53	3.530	
6 23 97	.	0.06	0.06	3.59	3.590	

Table A10.2. 1997 daily precipitation data for the growing season (May 1 - September 30).

Date	Shiely[A] precip. (in.)	Rosemount[B] precip. (in.)	Comb.[C] precip. (in.)	Comb.[D] sum (in.)	Rosemount[E] sum (in.)	Notes
6 24 97	.	0.00	0.00	3.59	3.590	
6 25 97	.	0.60	0.60	4.19	4.190	
6 26 97	0.00	0.00	0.00	4.19	4.190	
6 27 97	0.00	0.00	0.00	4.19	4.190	
6 28 97	1.50	0.00	1.50	5.69	4.190	
6 29 97	0.45	0.00	0.45	6.14	4.190	
6 30 97	0.00	1.72	0.00	6.14	5.910	Applied vacuum
7 1 97	1.60	0.00	1.60	7.74	5.910	
7 2 97	0.40	1.44	0.40	8.14	7.350	
7 3 97	0.00	0.00	0.00	8.14	7.350	
7 4 97	0.05	0.14	0.05	8.19	7.490	
7 5 97	0.00	0.02	0.00	8.19	7.510	
7 6 97	0.00	0.21	0.00	8.19	7.720	
7 7 97	0.35	0.17	0.35	8.54	7.890	Samples taken
7 8 97	0.00	0.32	0.00	8.54	8.210	
7 9 97	0.00	0.00	0.00	8.54	8.210	
7 10 97	0.00	0.00	0.00	8.54	8.210	
7 11 97	0.00	0.12	0.00	8.54	8.330	
7 12 97	0.15	0.20	0.15	8.69	8.530	
7 13 97	0.35	0.17	0.35	9.04	8.700	
7 14 97	0.00	0.50	0.00	9.04	9.200	
7 15 97	0.00	0.00	0.00	9.04	9.200	
7 16 97	0.00	0.00	0.00	9.04	9.200	
7 17 97	5.05	2.28	5.05	14.09	11.480	
7 18 97	0.00	0.01	0.00	14.09	11.490	
7 19 97	.	0.62	0.62	14.71	12.110	
7 20 97	.	0.17	0.17	14.88	12.280	
7 21 97	.	0.27	0.27	15.15	12.550	Samples taken
7 22 97	.	2.65	2.65	17.80	15.200	
7 23 97	.	0.18	0.18	17.98	15.380	Tried to pump; pans now dry
7 24 97	.	0.01	0.01	17.99	15.390	
7 25 97	.	1.39	1.39	19.38	16.780	
7 26 97	.	0.00	0.00	19.38	16.780	
7 27 97	.	0.16	0.16	19.54	16.940	
7 28 97	.	0.00	0.00	19.54	16.940	
7 29 97	.	0.00	0.00	19.54	16.940	
7 30 97	.	0.00	0.00	19.54	16.940	
7 31 97	.	0.00	0.00	19.54	16.940	
8 1 97	.	0.25	0.25	19.79	17.190	
8 2 97	.	0.00	0.00	19.79	17.190	
8 3 97	.	0.00	0.00	19.79	17.190	
8 4 97	.	0.06	0.06	19.85	17.250	
8 5 97	0.20	0.00	0.20	20.05	17.250	
8 6 97	0.00	0.34	0.00	20.05	17.590	
8 7 97	0.00	0.00	0.00	20.05	17.590	
8 8 97	0.00	0.00	0.00	20.05	17.590	
8 9 97	0.00	0.00	0.00	20.05	17.590	
8 10 97	0.00	0.00	0.00	20.05	17.590	
8 11 97	0.00	0.00	0.00	20.05	17.590	
8 12 97	0.00	0.00	0.00	20.05	17.590	
8 13 97	0.00	0.18	0.00	20.05	17.770	
8 14 97	0.15	0.00	0.15	20.20	17.770	
8 15 97	0.10	0.20	0.10	20.30	17.970	
8 16 97	0.00	0.00	0.00	20.30	17.970	

Table A10.2. 1997 daily precipitation data for the growing season (May 1 - September 30).

Date	Shiely[A] precip. (in.)	Rosemount[B] precip. (in.)	Comb.[C] precip. (in.)	Comb.[D] sum (in.)	Rosemount[E] sum (in.)	Notes
8 17 97	0.00	0.00	0.00	20.30	17.970	
8 18 97	0.00	0.59	0.00	20.30	18.560	
8 19 97	2.25	0.15	2.25	22.55	18.710	
8 20 97	0.00	2.29	0.00	22.55	21.000	
8 21 97	0.00	0.00	0.00	22.55	21.000	
8 22 97	0.00	0.00	0.00	22.55	21.000	
8 23 97	0.00	0.19	0.00	22.55	21.190	
8 24 97	0.00	0.00	0.00	22.55	21.190	
8 25 97	0.00	0.00	0.00	22.55	21.190	
8 26 97	0.00	0.00	0.00	22.55	21.190	
8 27 97	0.00	0.00	0.00	22.55	21.190	
8 28 97	0.00	0.00	0.00	22.55	21.190	
8 29 97	0.00	0.00	0.00	22.55	21.190	
8 30 97	1.15	0.00	1.15	23.70	21.190	
8 31 97	0.00	0.00	0.00	23.70	21.190	
9 1 97	0.30	0.00	0.30	24.00	21.190	
9 2 97	0.00	1.30	0.00	24.00	22.490	
9 3 97	0.00	0.00	0.00	24.00	22.490	
9 4 97	0.00	0.00	0.00	24.00	22.490	
9 5 97	0.00	0.00	0.00	24.00	22.490	
9 6 97	0.00	0.00	0.00	24.00	22.490	
9 7 97	0.00	0.00	0.00	24.00	22.490	
9 8 97	0.40	0.00	0.40	24.40	22.490	
9 9 97	0.00	1.20	0.00	24.40	23.690	
9 10 97	0.00	0.00	0.00	24.40	23.690	
9 11 97	0.00	0.00	0.00	24.40	23.690	
9 12 97	0.00	0.00	0.00	24.40	23.690	
9 13 97	0.00	0.00	0.00	24.40	23.690	
9 14 97	0.00	0.00	0.00	24.40	23.690	
9 15 97	0.00	0.00	0.00	24.40	23.690	
9 16 97	1.60	0.00	1.60	26.00	23.690	
9 17 97	0.00	1.73	0.00	26.00	25.420	
9 18 97	0.00	0.00	0.00	26.00	25.420	
9 19 97	0.00	0.00	0.00	26.00	25.420	
9 20 97	0.00	0.00	0.00	26.00	25.420	
9 21 97	0.00	0.00	0.00	26.00	25.420	
9 22 97	0.00	0.00	0.00	26.00	25.420	
9 23 97	0.00	0.00	0.00	26.00	25.420	
9 24 97	0.00	0.00	0.00	26.00	25.420	
9 25 97	0.00	0.00	0.00	26.00	25.420	
9 26 97	0.00	0.00	0.00	26.00	25.420	
9 27 97	0.20	0.00	0.20	26.20	25.420	
9 28 97	0.00	0.00	0.00	26.20	25.420	
9 29 97	0.00	0.28	0.00	26.20	25.700	
9 30 97	0.00	0.00	0.00	26.20	25.700	

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 A10.4. Monthly precipitation at Rosemount (1996 - 2000).

Year	Month	Precip. (inches)
1996	Jan	2.77
1996	Feb	.18
1996	Mar	2.18
1996	Apr	.62
1996	May	3.00
1996	Jun	3.64
1996	Jul	1.80
1996	Aug	5.24
1996	Sep	1.76
1996	Oct	5.83
1996	Nov	5.10
1996	Dec	2.11
1997	Jan	1.76
1997	Feb	.20
1997	Mar	1.47
1997	Apr	.87
1997	May	2.08
1997	Jun	3.83
1997	Jul	11.03
1997	Aug	4.25
1997	Sep	4.51
1997	Oct	2.63
1997	Nov	.98
1997	Dec	.27
1998	Jan	2.05
1998	Feb	.70
1998	Mar	3.88
1998	Apr	2.16
1998	May	5.81
1998	Jun	9.38
1998	Jul	2.75
1998	Aug	5.57
1998	Sep	1.22
1998	Oct	2.86
1998	Nov	1.65
1998	Dec	.50

Year	Month	Precip. (inches)
1999	Jan	2.05
1999	Feb	.60
1999	Mar	1.64
1999	Apr	5.30
1999	May	5.41
1999	Jun	4.60
1999	Jul	7.65
1999	Aug	4.51
1999	Sep	2.15
1999	Oct	.97
1999	Nov	1.17
1999	Dec	.54
2000	Jan	1.44
2000	Feb	1.14
2000	Mar	1.24
2000	Apr	1.69
2000	May	5.13
2000	Jun	4.56
2000	Jul	8.81
2000	Aug	3.13
2000	Sep	.56
2000	Oct	1.24
2000	Nov	4.06
2000	Dec	1.61

Appendix 11

Water quality data

No water samples were collected from the lysimeters during 1996 because of the very 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.

Samples were collected on two date in 1997 (July 7 and 21). There was insufficient sample volume to permit the complete suite of desired paramaters to be analyzed for all samples, so the parameters were prioritized in order of importance. The parameters were 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.

The samples were 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 were frozen and prepared for shipment to the Hibbing DNR-Minerals office, where the samples will be filtered, acidified and prepared for analysis at the Dept. of Agriculture.

Table A11.1. Water quality data (page 2 of 4).

Amend-ment	Lysimeter type	Plot	Date	Sample	S.C. (µS)	pH (s.u.)	Alk. (ppm)	As (ppb)	Ag (ppb)	Ba (ppb)	Ca (ppm)	Cd (ppb)	Co (ppb)	Cr (ppb)	Cu (ppb)	Hg (ppb)	K (ppm)	Mg (ppm)
NVS *	pan	3	7 21 97	10918	900	7.26	215.0	-1.0	-1.0	20.0	124.8	-1.0	16.0	1.0	8.0	-0.5	4.6	41.7
NVS *	pan	3	7 21 97	10919	650	7.57	225.0	-1.0	-1.0	50.0	88.7	-1.0	6.0	-1.0	7.0	-0.5	7.9	29.9
NVS	pan	5	7 21 97	10921	295	7.45	138.0	-1.0	-1.0	35.0	34.6	-1.0	5.0	-1.0	4.0	-0.5	2.4	13.8
NVS	pan	9	7 21 97	10924	290	7.70	138.0	-1.0	1.0	27.0	36.3	-1.0	2.0	1.0	4.0	-0.5	0.7	13.9
NVS	suction24	3	7 7 97	10886	500	7.81	.	.	.	.	.	.	.	.	.	-0.5	.	.
NVS	suction24	3	7 21 97	10903	415	8.29	190.0	-1.0	3.0	43.0	56.5	-1.0	2.0	-1.0	8.0	-0.5	1.5	18.8
NVS	suction24	5	7 21 97	10907	335	8.29	162.0	-1.0	.	13.0	15.1	-1.0	2.0	1.0	6.0	-0.5	0.0	14.0
NVS	suction24	9	7 7 97	10896	420	7.84	.	.	.	.	.	.	.	.	.	-0.5	.	.
NVS	suction24	9	7 21 97	10915	215	8.21	108.0	-1.0	-1.0	7.0	20.4	-1.0	1.0	1.0	5.0	-0.5	1.5	10.5
NVS	suction6	3	7 7 97	10885	260	7.77	.	.	.	.	.	.	.	.	.	-0.5	.	.
NVS	suction6	3	7 21 97	10902	330	8.42	.	-1.0	1.0	20.0	48.4	-1.0	2.0	-1.0	8.0	-0.5	10.3	11.7
NVS	suction6	5	7 7 97	10888	370	7.94	.	.	.	.	.	.	.	.	.	-0.5	.	.
NVS	suction6	5	7 21 97	10906	405	8.57	.	-1.0	.	37.0	67.3	-1.0	2.0	1.0	8.0	-0.5	1.4	18.3
NVS	suction6	9	7 7 97	10895	600	7.95	.	.	.	.	.	.	.	.	.	-0.5	.	.
NVS	suction6	9	7 21 97	10914	362	8.51	.	-1.0	.	82.0	52.0	-1.0	8.0	-1.0	7.0	-0.5	2.0	14.8

Table A11.1. Water quality data (page 1 of 4).

Amend-ment	Lysimeter type	Plot	Date	Sample	S.C. (μS)	pH (s.u.)	Alk. (ppm)	As (ppb)	Ag (ppb)	Ba (ppb)	Ca (ppm)	Cd (ppb)	Co (ppb)	Cr (ppb)	Cu (ppb)	Hg (ppb)	K (ppm)	Mg (ppm)
Fert.	pan	1	7 21 97	10916	295	7.45	160.0	-1.0	-1.0	23.0	40.7	-1.0	-1.0	-1.0	6.0	-0.5	2.7	13.3
Fert.	pan	4	7 21 97	10920	210	7.62	102.0	-1.0	-1.0	22.0	29.0	-1.0	-1.0	1.0	2.0	-0.5	0.9	9.8
Fert.	suction24	1	7 7 97	10883	218	7.68	.	.	.	.	.	.	.	.	.	-0.5	.	.
Fert.	suction24	1	7 21 97	10899	165	8.16	100.0	-1.0	2.0	14.0	39.4	-1.0	-1.0	1.0	3.0	-0.5	1.1	0.5
Fert.	suction24	4	7 21 97	10905	128	8.08	62.0	-1.0	.	3.0	12.7	-1.0	-1.0	-1.0	2.0	-0.5	0.9	5.8
Fert.	suction24	6	7 7 97	10891	282	7.88	.	.	.	.	.	.	.	.	.	-0.5	.	.
Fert.	suction24	6	7 7 97	10889	850	7.93	.	.	.	.	.	.	.	.	.	-0.5	.	.
Fert.	suction24	6	7 21 97	10909	195	8.27	100.0	-1.0	.	8.0	25.9	-1.0	-1.0	-1.0	3.0	-0.5	2.4	9.2
Fert.	suction6	1	7 7 97	10882	212	7.81	.	.	.	.	.	.	.	.	.	-0.5	.	.
Fert.	suction6	1	7 21 97	10898	228	8.32	.	1.0	.	18.0	39.3	-1.0	-1.0	-1.0	2.0	1.6	1.1	1.0
Fert.	suction6	4	7 7 97	10887	150	7.85	.	.	.	.	.	.	.	.	.	-0.5	.	.
Fert.	suction6	4	7 21 97	10904	200	8.28	.	-1.0	.	18.0	27.3	-1.0	-1.0	-1.0	2.0	-0.5	2.4	8.8
Fert.	suction6	6	7 7 97	10890	115	7.69	.	.	.	.	.	.	.	.	.	-0.5	.	.
Fert.	suction6	6	7 21 97	10908	170	8.35	.	-1.0	.	6.0	23.1	-1.0	-1.0	1.0	3.0	-0.5	2.5	7.5
MSW	pan	2	7 21 97	10917	310	7.42	150.0	-1.0	-1.0	52.0	30.8	-1.0	2.0	1.0	11.0	-0.5	3.2	10.3
MSW	pan	7	7 21 97	10922	295	7.54	175.0	-1.0	-1.0	27.0	33.7	-1.0	1.0	-1.0	5.0	-0.5	1.3	10.3
MSW	pan	8	7 21 97	10923	385	7.68	180.0	-1.0	-1.0	38.0	43.9	-1.0	1.0	1.0	14.0	-0.5	1.8	14.9
MSW	suction24	2	7 21 97	10901	220	8.11	118.0	-1.0	1.0	18.0	29.8	-1.0	1.0	1.0	9.0	-0.5	1.3	8.8
MSW	suction24	7	7 7 97	10893	348	8.02	.	.	.	.	.	.	.	.	.	-0.5	.	.
MSW	suction24	7	7 21 97	10911	250	8.02	110.0	-1.0	-1.0	8.0	30.5	-1.0	-1.0	1.0	10.0	-0.5	1.9	10.1
MSW	suction24	8	7 21 97	10913	248	8.18	118.0	-1.0	1.0	7.0	26.1	-1.0	-1.0	1.0	14.0	-0.5	2.6	8.9
MSW	suction6	2	7 7 97	10884	115	.	.	.	.	.	.	.	.	.	.	-0.5	.	.
MSW	suction6	2	7 21 97	10900	210	8.35	.	-1.0	.	.	31.1	-1.0	-1.0	1.0	5.0	-0.5	0.5	8.6
MSW	suction6	7	7 7 97	10892	372	7.81	.	.	.	.	.	.	.	.	.	-0.5	.	.
MSW	suction6	7	7 21 97	10910	160	8.16	.	-1.0	.	8.0	19.0	-1.0	1.0	1.0	18.0	-0.5	3.0	6.6
MSW	suction6	8	7 7 97	10894	203	7.68	.	.	.	.	.	.	.	.	.	-0.5	.	.
MSW	suction6	8	7 21 97	10912	270	8.37	.	-1.0	.	15.0	30.1	-1.0	1.0	1.0	11.0	-0.5	3.0	10.8

Table A11.1. Water quality data (page 3 of 4).

Amend-ment	Lysimeter type	Plot	Date	Sample	Na (ppm)	Ni (ppm)	Pb (ppb)	Se (ppb)	Zn (ppm)	Cl (ppb)	SO_4 (ppb)	TKN (ppb)	NH_4N (ppm)	NO_3 (ppm) Orig.	NO_3 (ppm) Reruns	TP (ppm)
Fert.	pan	1	7 21 97	10916	1.3	-0.1	-1.0	-1.0	-0.05	-0.5	3.9	0.71	0.04	-0.40	.	0.08
Fert.	pan	4	7 21 97	10920	0.8	-0.1	-1.0	-1.0	-0.05	-0.5	2.2	0.44	0.03	-0.40	.	0.06
Fert.	suction24	1	7 7 97	10883	.	.	.	.	.	.	.	.	0.06	2.21	2.26	.
Fert.	suction24	1	7 21 97	10899	1.1	-0.1	-1.0	-1.0	-0.05	-0.5	1.2	0.88	0.05	0.41	.	.
Fert.	suction24	4	7 21 97	10905	0.7	-0.1	-1.0	.	-0.05	-0.5	0.8	0.58	0.13	0.43	.	.
Fert.	suction24	6	7 7 97	10891	.	.	.	.	.	.	.	.	.	.	.	.
Fert.	suction24	6	7 7 97	10889	.	.	.	.	.	.	.	.	.	.	.	.
Fert.	suction24	6	7 21 97	10909	1.2	-0.1	-1.0	.	-0.05	-0.5	1.1	0.91	0.08	1.54	.	.
Fert.	suction6	1	7 7 97	10882	.	.	.	.	.	.	.	.	.	2.00	2.59	.
Fert.	suction6	1	7 21 97	10898	1.1	-0.1	-1.0	.	-0.05	-0.5	1.0	.	0.05	0.69	.	.
Fert.	suction6	4	7 7 97	10887	.	.	.	.	.	.	.	.	.	4.44	.	.
Fert.	suction6	4	7 21 97	10904	1.2	-0.1	-1.0	.	-0.05	-0.5	0.8	.	0.03	0.49	.	.
Fert.	suction6	6	7 7 97	10890	..	.	.	.	.	.	.	.	.	3.00	3.64	.
Fert.	suction6	6	7 21 97	10908	1.0	-0.1	-1.0	.	-0.05	-0.5	0.8	.	.	0.80	.	.
MSW	pan	2	7 21 97	10917	21.8	-0.1	-1.0	-1.0	-0.05	-0.5	9.1	1.60	0.05	-0.40	.	0.08
MSW	pan	7	7 21 97	10922	14.2	-0.1	-1.0	-1.0	-0.05	0.8	3.0	0.71	0.02	-0.40	.	0.02
MSW	pan	8	7 21 97	10923	20.7	-0.1	-1.0	-1.0	-0.05	-0.5	18.7	.	.	.	.	.
MSW	suction24	2	7 21 97	10901	12.1	-0.1	-1.0	-1.0	-0.05	-0.5	5.9	1.20	0.10	1.09	.	.
MSW	suction24	7	7 7 97	10893	.	.	.	.	.	.	.	.	.	17.10	.	.
MSW	suction24	7	7 21 97	10911	8.4	-0.1	-1.0	-1.0	-0.05	-0.5	20.4	3.70	0.18	0.64	.	.
MSW	suction24	8	7 21 97	10913	13.2	-0.1	-1.0	1.0	-0.05	-0.5	6.5	1.80	0.06	1.07	.	.
MSW	suction6	2	7 7 97	10884	.	.	.	.	.	.	.	.	.	.	.	.
MSW	suction6	2	7 21 97	10900	1.0	-0.1	-1.0	.	<u>0.18</u>	-0.5	4.0	.	0.07	0.69	.	.
MSW	suction6	7	7 7 97	10892	.	.	.	.	.	.	.	.	.	21.00	.	0.08
MSW	suction6	7	7 21 97	10910	5.5	-0.1	-1.0	.	-0.05	-0.5	8.9	.	0.07	1.08	.	
MSW	suction6	8	7 7 97	10894	.	.	.	.	.	.	.	.	.	5.34	6.39	.
MSW	suction6	8	7 21 97	10912	12.6	-0.1	-1.0	.	-0.05	-0.5	7.0	.	0.06	0.89	.	.

Table A11.1. Water quality data (page 4 of 4).

Amend-ment	Lysimeter type	Plot	Date	Sample	Na (ppm)	Ni (ppm)	Pb (ppb)	Se (ppb)	Zn (ppm)	Cl (ppb)	SO_4 (ppb)	TKN (ppb)	NH_4N (ppm)	NO_3 (ppm) Orig.	NO_3 (ppm) Reruns	TP (ppm)
NVS *	pan	3	7 21 97	10918	24.0	-0.1	-1.0	-1.0	-0.05	0.5	312.0	1.26	0.03	-0.40	.	0.04
NVS *	pan	3	7 21 97	10919	15.1	-0.1	-1.0	-1.0	-0.05	0.5	151.0	0.06	0.06	-0.40	.	0.05
NVS	pan	5	7 21 97	10921	5.4	-0.1	-1.0	-1.0	-0.05	-0.5	14.8	0.53	0.02	-0.40	.	0.02
NVS	pan	9	7 21 97	10924	4.1	-0.1	-1.0	-1.0	-0.05	-0.5	7.2	.	.	.	.	.
NVS	suction24	3	7 7 97	10886	.	.	.	.	.	.	.	.	0.13	15.90	15.70	.
NVS	suction24	3	7 21 97	10903	5.6	-0.1	-1.0	-1.0	-0.05	-0.5	25.2	.	0.04	0.55	.	.
NVS	suction24	5	7 21 97	10907	6.7	-0.1	-1.0	.	-0.05	-0.5	16.0	0.75	0.05	0.55	.	.
NVS	suction24	9	7 7 97	10896	.	.	.	.	.	.	.	.	.	.	.	.
NVS	suction24	9	7 21 97	10915	4.5	-0.1	-1.0	-1.0	-0.05	-0.5	4.2	0.72	0.04	.	.	.
NVS	suction6	3	7 7 97	10885	.	.	.	.	.	.	.	.	0.06	4.09	4.17	.
NVS	suction6	3	7 21 97	10902	5.3	-0.1	-1.0	-1.0	-0.05	-0.5	5.2	1.10	0.05	0.42	.	.
NVS	suction6	5	7 7 97	10888	.	.	.	.	.	.	.	.	.	7.04	7.06	.
NVS	suction6	5	7 21 97	10906	3.0	-0.1	-1.0	.	-0.05	-0.5	9.8	.	.	0.51	.	.
NVS	suction6	9	7 7 97	10895	.	.	.	.	.	.	.	.	.	14.70	14.50	.
NVS	suction6	9	7 21 97	10914	5.1	-0.1	-1.0	.	-0.05	-0.5	20.2	.	0.04	0.91	.	.

* Two samples were collected from the pan lysimeter in plot 3 on 7/20/97. Plot 3 was one of the two plots that were completely pumped out (approx. 10 gal), and specific conductance declined (from ~ 900 to 800 μS) near the end of pumping. A second sample was therefore collected near the end of pumping from this pan lysimeter. Only about 2 L were pumped from the other six plots, however, so the initial sample from plot 3 is probably most appropriate when comparing between plots, especially since the decrease from 900 to 800 μS occurred near the end of pumping.

Two anomalous values are underlined; no samples exist for re-analyses.

No pan sample was obtained on 7/21/97 from plot 6 (fertilizer), presumably due to a plumbing leak.

-: Less than detection limit
.: Not analyzed

pan = pan lysimeter
suction24 = 24" deep suction lysimeter
suction6 = 6" deep suction lysimeter

Table A11.2. Summary statistics of water quality data, broken down by amendment type. (Anomalous data have been omitted from these statistics.)

THE FOLLOWING RESULTS ARE FOR:
TYPE$ = Fertilizer

TOTAL OBSERVATIONS: 14

	SC	PH	ALK	AG	AS
N OF CASES	13	14	5	8	3
MINIMUM	115.000	7.450	62.000	0.500	0.500
MAXIMUM	295.000	8.350	160.000	1.000	2.000
RANGE	180.000	0.900	98.000	0.500	1.500
MEAN	197.538	7.955	104.800	0.563	1.000
STANDARD DEV	53.293	0.291	35.117	0.177	0.866
MEDIAN	200.000	7.905	100.000	0.500	0.500

	BA	CA	CD	CO	CR
N OF CASES	8	8	8	8	8
MINIMUM	3.000	12.700	0.500	0.500	0.500
MAXIMUM	23.000	40.700	0.500	0.500	1.000
RANGE	20.000	28.000	0.000	0.000	0.500
MEAN	14.000	29.675	0.500	0.500	0.688
STANDARD DEV	7.540	9.714	0.000	0.000	0.259
MEDIAN	16.000	28.150	0.500	0.500	0.500

	CU	HG	K	MG	NA
N OF CASES	8	13	8	8	8
MINIMUM	2.000	0.250	0.900	0.500	0.700
MAXIMUM	6.000	0.250	2.700	13.300	1.300
RANGE	4.000	0.000	1.800	12.800	0.600
MEAN	2.875	0.250	1.750	6.988	1.050
STANDARD DEV	1.356	0.000	0.811	4.400	0.207
MEDIAN	2.500	0.250	1.750	8.150	1.100

	NI	PB	SE	ZN	CL
N OF CASES	8	8	3	8	8
MINIMUM	0.050	0.500	0.500	0.025	0.250
MAXIMUM	0.050	0.500	0.500	0.025	0.250
RANGE	0.000	0.000	0.000	0.000	0.000
MEAN	0.050	0.500	0.500	0.025	0.250
STANDARD DEV	0.000	0.000	0.000	0.000	0.000
MEDIAN	0.050	0.500	0.500	0.025	0.250

	SO4	TKN	NH4N	NO3	TP
N OF CASES	8	5	8	12	2
MINIMUM	0.800	0.440	0.030	0.200	0.060
MAXIMUM	3.900	0.910	0.130	4.440	0.080
RANGE	3.100	0.470	0.100	4.240	0.020
MEAN	1.475	0.704	0.059	1.368	0.070
STANDARD DEV	1.083	0.199	0.033	1.325	0.014
MEDIAN	1.050	0.710	0.050	0.745	0.070

Table A11.2. Summary statistics of water quality data, broken down by amendment type. (Anomalous data have been omitted from these statistics.)

```
THE FOLLOWING RESULTS ARE FOR:
            TYPE$     = MSW
TOTAL OBSERVATIONS:     13
```

	SC	PH	ALK	AG	AS
N OF CASES	13	12	6	9	6
MINIMUM	115.000	7.420	110.000	0.500	0.500
MAXIMUM	385.000	8.370	180.000	0.500	1.000
RANGE	270.000	0.950	70.000	0.000	0.500
MEAN	260.462	7.945	141.833	0.500	0.667
STANDARD DEV	80.805	0.314	30.896	0.000	0.258
MEDIAN	250.000	8.020	134.000	0.500	0.500

	BA	CA	CD	CO	CR
N OF CASES	8	9	9	9	9
MINIMUM	7.000	19.000	0.500	0.500	0.500
MAXIMUM	52.000	43.900	0.500	2.000	1.000
RANGE	45.000	24.900	0.000	1.500	0.500
MEAN	21.625	30.556	0.500	0.944	0.944
STANDARD DEV	16.309	6.543	0.000	0.464	0.167
MEDIAN	16.500	30.500	0.500	1.000	1.000

	CU	HG	K	MG	NA
N OF CASES	9	13	9	9	9
MINIMUM	5.000	0.250	0.500	6.600	1.000
MAXIMUM	18.000	0.250	3.200	14.900	21.800
RANGE	13.000	0.000	2.700	8.300	20.800
MEAN	10.778	0.250	2.067	9.922	12.167
STANDARD DEV	4.236	0.000	0.938	2.263	6.655
MEDIAN	11.000	0.250	1.900	10.100	12.600

	NI	PB	SE	ZN	CL
N OF CASES	9	9	6	8	9
MINIMUM	0.050	0.500	0.500	0.025	0.250
MAXIMUM	0.050	0.500	1.000	0.025	0.800
RANGE	0.000	0.000	0.500	0.000	0.550
MEAN	0.050	0.500	0.583	0.025	0.311
STANDARD DEV	0.000	0.000	0.204	0.000	0.183
MEDIAN	0.050	0.500	0.500	0.025	0.250

	SO4	TKN	NH4N	NO3	TP
N OF CASES	9	5	8	11	2
MINIMUM	3.000	0.710	0.020	0.200	0.020
MAXIMUM	20.400	3.700	0.180	21.000	0.080
RANGE	17.400	2.990	0.160	20.800	0.060
MEAN	9.278	1.802	0.076	4.482	0.050
STANDARD DEV	6.167	1.140	0.047	7.391	0.042
MEDIAN	7.000	1.600	0.065	1.070	0.050

Table A11.2. Summary statistics of water quality data, broken down by amendment type. (Anomalous data have been omitted from these statistics.)

```
THE FOLLOWING RESULTS ARE FOR:
             TYPE$    = NVS
TOTAL OBSERVATIONS:     15
```

	SC	PH	ALK	AG	AS
N OF CASES	14	14	6	9	6
MINIMUM	215.000	7.260	108.000	0.500	0.500
MAXIMUM	900.000	8.570	215.000	0.500	3.000
RANGE	685.000	1.310	107.000	0.000	2.500
MEAN	406.929	8.001	158.500	0.500	1.083
STANDARD DEV	172.849	0.396	38.955	0.000	0.970
MEDIAN	366.000	7.945	150.000	0.500	0.750

	BA	CA	CD	CO	CR
N OF CASES	9	9	9	9	9
MINIMUM	7.000	15.100	0.500	1.000	0.500
MAXIMUM	82.000	124.800	0.500	16.000	1.000
RANGE	75.000	109.700	0.000	15.000	0.500
MEAN	31.556	50.600	0.500	4.444	0.778
STANDARD DEV	22.227	32.517	0.000	4.851	0.264
MEDIAN	27.000	48.400	0.500	2.000	1.000

	CU	HG	K	MG	NA
N OF CASES	9	14	9	9	9
MINIMUM	4.000	0.250	0.700	10.500	3.000
MAXIMUM	8.000	0.250	10.300	41.700	24.000
RANGE	4.000	0.000	9.600	31.200	21.000
MEAN	6.444	0.250	3.589	17.500	7.078
STANDARD DEV	1.740	0.000	3.362	9.466	6.430
MEDIAN	7.000	0.250	2.000	14.000	5.300

	NI	PB	SE	ZN	CL
N OF CASES	9	9	6	9	9
MINIMUM	0.050	0.500	0.500	0.025	0.250
MAXIMUM	0.050	0.500	0.500	0.025	0.500
RANGE	0.000	0.000	0.000	0.000	0.250
MEAN	0.050	0.500	0.500	0.025	0.278
STANDARD DEV	0.000	0.000	0.000	0.000	0.083
MEDIAN	0.050	0.500	0.500	0.025	0.250

	SO4	TKN	NH4N	NO3	TP
N OF CASES	9	5	9	11	2
MINIMUM	4.200	0.530	0.020	0.200	0.020
MAXIMUM	312.000	1.260	0.130	15.900	0.040
RANGE	307.800	0.730	0.110	15.700	0.020
MEAN	46.067	0.872	0.051	4.097	0.030
STANDARD DEV	99.972	0.299	0.032	5.937	0.014
MEDIAN	14.800	0.750	0.040	0.550	0.030

Table A11.3. Summary statistics of water quality data, broken down by amendment type and excluding 7/7/97 data. (Anomalous data have been omitted from these statistics.)

THE FOLLOWING RESULTS ARE FOR:
TYPE$ = Fertilizer
TOTAL OBSERVATIONS: 8

	SC	PH	ALK	AG	AS
N OF CASES	8	8	5	8	3
MINIMUM	128.000	7.450	62.000	0.500	0.500
MAXIMUM	295.000	8.350	160.000	1.000	2.000
RANGE	167.000	0.900	98.000	0.500	1.500
MEAN	198.875	8.066	104.800	0.563	1.000
STANDARD DEV	49.617	0.342	35.117	0.177	0.866
MEDIAN	197.500	8.215	100.000	0.500	0.500

	BA	CA	CD	CO	CR
N OF CASES	8	8	8	8	8
MINIMUM	3.000	12.700	0.500	0.500	0.500
MAXIMUM	23.000	40.700	0.500	0.500	1.000
RANGE	20.000	28.000	0.000	0.000	0.500
MEAN	14.000	29.675	0.500	0.500	0.688
STANDARD DEV	7.540	9.714	0.000	0.000	0.259
MEDIAN	16.000	28.150	0.500	0.500	0.500

	CU	HG	K	MG	NA
N OF CASES	8	7	8	8	8
MINIMUM	2.000	0.250	0.900	0.500	0.700
MAXIMUM	6.000	0.250	2.700	13.300	1.300
RANGE	4.000	0.000	1.800	12.800	0.600
MEAN	2.875	0.250	1.750	6.988	1.050
STANDARD DEV	1.356	0.000	0.811	4.400	0.207
MEDIAN	2.500	0.250	1.750	8.150	1.100

	NI	PB	SE	ZN	CL
N OF CASES	8	8	3	8	8
MINIMUM	0.050	0.500	0.500	0.025	0.250
MAXIMUM	0.050	0.500	0.500	0.025	0.250
RANGE	0.000	0.000	0.000	0.000	0.000
MEAN	0.050	0.500	0.500	0.025	0.250
STANDARD DEV	0.000	0.000	0.000	0.000	0.000
MEDIAN	0.050	0.500	0.500	0.025	0.250

	SO4	TKN	NH4N	NO3	TP
N OF CASES	8	5	7	8	2
MINIMUM	0.800	0.440	0.030	0.200	0.060
MAXIMUM	3.900	0.910	0.130	1.540	0.080
RANGE	3.100	0.470	0.100	1.340	0.020
MEAN	1.475	0.704	0.059	0.595	0.070
STANDARD DEV	1.083	0.199	0.036	0.436	0.014
MEDIAN	1.050	0.710	0.050	0.460	0.070

Table A11.3. Summary statistics of water quality data, broken down by amendment type and excluding 7/7/97 data. (Anomalous data have been omitted from these statistics.)

THE FOLLOWING RESULTS ARE FOR:
TYPE$ = MSW
TOTAL OBSERVATIONS: 9

	SC	PH	ALK	AG	AS
N OF CASES	9	9	6	9	6
MINIMUM	160.000	7.420	110.000	0.500	0.500
MAXIMUM	385.000	8.370	180.000	0.500	1.000
RANGE	225.000	0.950	70.000	0.000	0.500
MEAN	260.889	7.981	141.833	0.500	0.667
STANDARD DEV	64.987	0.349	30.896	0.000	0.258
MEDIAN	250.000	8.110	134.000	0.500	0.500

	BA	CA	CD	CO	CR
N OF CASES	8	9	9	9	9
MINIMUM	7.000	19.000	0.500	0.500	0.500
MAXIMUM	52.000	43.900	0.500	2.000	1.000
RANGE	45.000	24.900	0.000	1.500	0.500
MEAN	21.625	30.556	0.500	0.944	0.944
STANDARD DEV	16.309	6.543	0.000	0.464	0.167
MEDIAN	16.500	30.500	0.500	1.000	1.000

	CU	HG	K	MG	NA
N OF CASES	9	9	9	9	9
MINIMUM	5.000	0.250	0.500	6.600	1.000
MAXIMUM	18.000	0.250	3.200	14.900	21.800
RANGE	13.000	0.000	2.700	8.300	20.800
MEAN	10.778	0.250	2.067	9.922	12.167
STANDARD DEV	4.236	0.000	0.938	2.263	6.655
MEDIAN	11.000	0.250	1.900	10.100	12.600

	NI	PB	SE	ZN	CL
N OF CASES	9	9	6	8	9
MINIMUM	0.050	0.500	0.500	0.025	0.250
MAXIMUM	0.050	0.500	1.000	0.025	0.800
RANGE	0.000	0.000	0.500	0.000	0.550
MEAN	0.050	0.500	0.583	0.025	0.311
STANDARD DEV	0.000	0.000	0.204	0.000	0.183
MEDIAN	0.050	0.500	0.500	0.025	0.250

	SO4	TKN	NH4N	NO3	TP
N OF CASES	9	5	8	8	2
MINIMUM	3.000	0.710	0.020	0.200	0.020
MAXIMUM	20.400	3.700	0.180	1.090	0.080
RANGE	17.400	2.990	0.160	0.890	0.060
MEAN	9.278	1.802	0.076	0.733	0.050
STANDARD DEV	6.167	1.140	0.047	0.371	0.042
MEDIAN	7.000	1.600	0.065	0.790	0.050

Table A11.3. Summary statistics of water quality data, broken down by amendment type and excluding 7/7/97 data. (Anomalous data have been omitted from these statistics.)

THE FOLLOWING RESULTS ARE FOR:
TYPE$ = NVS
TOTAL OBSERVATIONS: 10

	SC	PH	ALK	AG	AS
N OF CASES	9	9	6	9	6
MINIMUM	215.000	7.260	108.000	0.500	0.500
MAXIMUM	900.000	8.570	215.000	0.500	3.000
RANGE	685.000	1.310	107.000	0.000	2.500
MEAN	394.111	8.078	158.500	0.500	1.083
STANDARD DEV	199.329	0.482	38.955	0.000	0.970
MEDIAN	335.000	8.290	150.000	0.500	0.750

	BA	CA	CD	CO	CR
N OF CASES	9	9	9	9	9
MINIMUM	7.000	15.100	0.500	1.000	0.500
MAXIMUM	82.000	124.800	0.500	16.000	1.000
RANGE	75.000	109.700	0.000	15.000	0.500
MEAN	31.556	50.600	0.500	4.444	0.778
STANDARD DEV	22.227	32.517	0.000	4.851	0.264
MEDIAN	27.000	48.400	0.500	2.000	1.000

	CU	HG	K	MG	NA
N OF CASES	9	9	9	9	9
MINIMUM	4.000	0.250	0.700	10.500	3.000
MAXIMUM	8.000	0.250	10.300	41.700	24.000
RANGE	4.000	0.000	9.600	31.200	21.000
MEAN	6.444	0.250	3.589	17.500	7.078
STANDARD DEV	1.740	0.000	3.362	9.466	6.430
MEDIAN	7.000	0.250	2.000	14.000	5.300

	NI	PB	SE	ZN	CL
N OF CASES	9	9	6	9	9
MINIMUM	0.050	0.500	0.500	0.025	0.250
MAXIMUM	0.050	0.500	0.500	0.025	0.500
RANGE	0.000	0.000	0.000	0.000	0.250
MEAN	0.050	0.500	0.500	0.025	0.278
STANDARD DEV	0.000	0.000	0.000	0.000	0.083
MEDIAN	0.050	0.500	0.500	0.025	0.250

	SO4	TKN	NH4N	NO3	TP
N OF CASES	9	5	7	7	2
MINIMUM	4.200	0.530	0.020	0.200	0.020
MAXIMUM	312.000	1.260	0.050	0.910	0.040
RANGE	307.800	0.730	0.030	0.710	0.020
MEAN	46.067	0.872	0.039	0.477	0.030
STANDARD DEV	99.972	0.299	0.011	0.244	0.014
MEDIAN	14.800	0.750	0.040	0.510	0.030

Table A11.4. Water quality from the fertilizer lysimeter plots, broken down by lysimeter type.

	Detection limit	Minnesota Drinking Water. Std.	U.S. EPA Drinking Water Std.	Average value (by lysimeter type and overall)			
				Pan	6" suction	24" suction	All
S.C. (μS)	---	---	---	250	180	200	200
pH (s.u.)	---	---	---	7.5	8.0	8.0	8.0
Alkalinity (ppm)	---	---	---	130	---	90	105
Ag (ppb)	1.0 ppb	---	100 *	0.5	0.7	0.5	0.6
As (ppb)	1.0 ppb	50	50	0.5	---	2.0	1.0
Ba (ppb)	---	2000	2000	22.5	14.0	8:3	14
Ca	---	---	---	34.8	29.9	26.0	30
Cd (ppb)	1.0 ppb	5.0	5.0	0.5	0.5	0.5	0.5
Cl	0.50 ppb	---	---	0.25	0.25	0.25	0.25
Co (ppb)	1.0 ppb	---	---	0.5	0.5	0.5	0.5
Cr (ppb)	1.0 ppb	100	100	0.8	0.7	0.7	0.7
Cu (ppb)	---	---	1300 **	4.0	2.3	2.7	2.9
Hg (ppb)	0.5 ppb	2.0	2.0	0.25	0.25	0.25	0.25
K (ppm)	---	---	---	1.8	2.0	1.5	1.8
Mg (ppm)	---	---	---	12	5.8	5.2	7.0
Na (ppm)	---	---	---	1.0	1.1	1.0	1.0
Ni (ppm)	0.10 ppm	100	---	0.05	0.05	0.05	0.05
Pb (ppb)	1.0 ppb	---	15 **	0.5	0.5	0.50	0.5
Se (ppb)	1.0 ppb	50	50	0.5	---	0.50	0.5
SO_4 (ppm)	---	500	250 *	3.0	0.9	1.0	1.5
Zn (ppm)	0.05 ppm	---	5.0 *	0.025	0.025	0.025	0.025
Total P (ppm)	---	---	---	0.07	---	---	0.07
TKN (ppm)	---	---	---	0.43	---	0.79	0.70
NH_4-N (ppm)	---	---	---	0.04	0.04	0.08	0.06
NO_3	0.4 ppm	45 ***	45 ***	0.2	1.9	1.2	1.4

Note: see footnotes on page A11.16

Table A11.5. Water quality from the MSW lysimeter plots, broken down by lysimeter type.

	Detection limit	Minnesota Drinking Water. Std.	U.S. EPA Drinking Water Std.	Average value (by lysimeter type and overall)			
				Pan	6" suction	24" suction	All
S.C. (μS)	---	---	---	330	220	270	260
pH (s.u.)	---	---	---	7.5	8.1	8.1	7.9
Alkalinity (ppm)	---	---	---	170	---	115	140
Ag (ppb)	1.0 ppb	---	100 *	0.5	0.5	0.5	0.5
As (ppb)	1.0 ppb	50	50	0.5	---	0.8	0.7
Ba (ppb)	---	2000	2000	39.0	11.5	11.0	22
Ca	---	---	---	36	27	29	31
Cd (ppb)	1.0 ppb	5.0	5.0	0.5	0.5	0.5	0.5
Cl	0.50 ppb	---	---	0.4	0.25	0.25	0.31
Co (ppb)	1.0 ppb	---	---	1.3	0.8	0.7	0.9
Cr (ppb)	1.0 ppb	100	100	0.8	1.0	1.0	0.9
Cu (ppb)	---	---	1300 **	10	11	11	11
Hg (ppb)	0.5 ppb	2.0	2.0	0.25	0.25	0.25	0.25
K (ppm)	---	---	---	2.1	2.2	1.9	2.1
Mg (ppm)	---	---	---	11.8	8.7	9.3	9.9
Na (ppm)	---	---	---	18.9	6.4	11.2	12.2
Ni (ppm)	0.10 ppm	100	---	0.05	0.05	0.05	0.05
Pb (ppb)	1.0 ppb	---	15 **	0.5	0.5	0.5	0.50
Se (ppb)	1.0 ppb	50	50	0.5	---	0.7	0.58
SO_4 (ppm)	---	500	250 *	10.3	6.6	10.9	9.3
Zn (ppm)	0.05 ppm	---	5.0 *	0.025	0.025	0.025	0.025
Total P (ppm)	---	---	---	0.05	0.08	---	0.05
TKN (ppm)	---	---	---	1.16	---	2.23	1.80
NH_4-N (ppm)	---	---	---	0.04	0.07	0.11	0.08
NO_3	0.4 ppm	45 ***	45 ***	0.2	5.8	5.0	4.5

Note: see footnotes on page A11.16

Table A11.6. Water quality from the NVS lysimeter plots, broken down by lysimeter type.

	Detection limit	Minnesota Drinking Water. Std.	U.S. EPA Drinking Water Std.	Average value (by lysimeter type and overall)			
				Pan	6" suction	24" suction	All
S.C. (μS)	---	---	---	500	390	380	390
pH (s.u.)	---	---	---	7.5	8.2	8.1	8.1
Alkalinity (ppm)	---	---	---	165	---	155	160
Ag (ppb)	1.0 ppb	---	100 *	0.5	0.5	0.5	0.5
As (ppb)	1.0 ppb	50	50	0.7	1.0	1.8	1.1
Ba (ppb)	---	2000	2000	27.3	46.3	21.0	32
Ca	---	---	---	65	56	31	51
Cd (ppb)	1.0 ppb	5.0	5.0	0.5	0.50	0.5	0.50
Cl	0.50 ppb	---	---	0.33	0.25	0.25	0.28
Co (ppb)	1.0 ppb	---	---	7.7	4.0	1.7	4.4
Cr (ppb)	1.0 ppb	100	100	0.8	0.7	0.8	0.8
Cu (ppb)	---	---	1300 **	5.3	7.7	6.3	6.4
Hg (ppb)	0.5 ppb	2.0	2.0	0.25	0.25	0.25	0.25
K (ppm)	---	---	---	3.9	4.6	1.5	3.6
Mg (ppm)	---	---	---	23.1	14.9	14.4	17.5
Na (ppm)	---	---	---	11.2	4.5	5.6	7.1
Ni (ppm)	0.10 ppm	100	---	0.05	0.05	0.05	0.05
Pb (ppb)	1.0 ppb	---	15 **	0.5	0.5	0.5	0.50
Se (ppb)	1.0 ppb	50	50	0.5	0.5	0.5	0.5
SO_4 (ppm)	---	500	250 *	110	12	15	46
Zn (ppm)	0.05 ppm	---	5.0 *	0.025	0.025	0.025	0.025
Total P (ppm)	---	---	---	0.03	---	---	0.05
TKN (ppm)	---	---	---	0.87	1.10	0.74	0.87
NH_4-N (ppm)	---	---	---	0.03	0.05	0.06	0.05
NO_3	0.4 ppm	45 ***	45 ***	0.20	4.61	5.67	4.1

Note: see footnotes on page A11.16

Footnotes for Tables A11.4 - A11.6

* These are secondary standards, which are non-enforceable guideline that reflect aesthetic or cosmetic effects (taste, color, etc.)

** These are the "action levels" for copper and lead; if more than 10% of tap water samples exceed the action level, water systems must take additional treatment steps.

*** This is based on an N-as-NO_3 standard of 10.0 ppm.

Pat Kirby (MN Dept. Ag.; personal communication, Wagner, 8/15/01) said the column called N in the Dept. Ag. lab sheets refers to Total Kjeldahl Nitrogen (TKN), which includes ammonia nitrogen. Therefore total nitrogen would be TKN + nitrate-nitrite. Also, the nitrate value is measured nitrate, not N-as-nitrate All available data was used for each lysimeter type..

Detection limits are presented only for those parameters with values less than the DL. Values that were less than the DL were converted to half of the limit. Thus a value of <1.0 ppb was changed to 0.5 ppb. Underlined values indicate that all values were less than the detection limit. All available data (from both 7/7/97 and 7/21/97) were used for these tables.

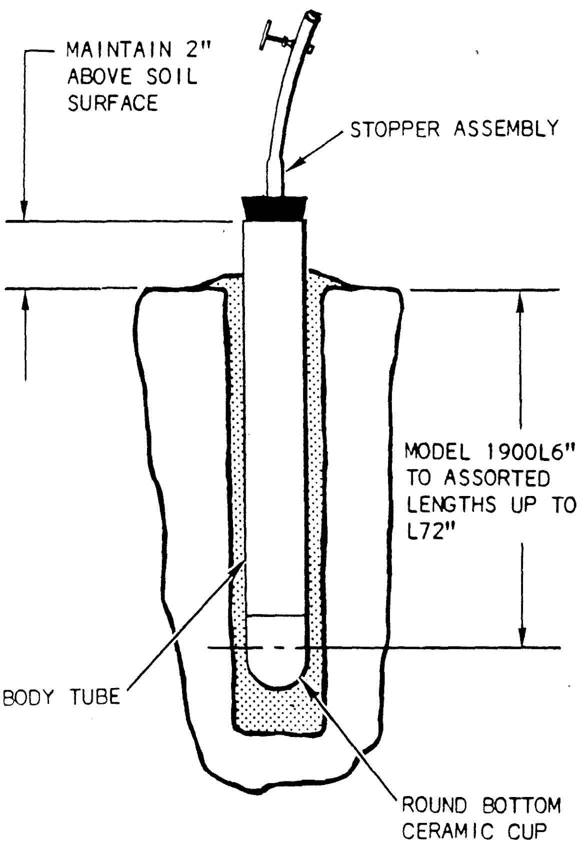
-: no analysis was made

The EPA and MDH standards are current as of August, 2001 (see www.epa.gov/safewater/mcl.html and www.health.state.mn.us.

Table A11.7. Suction lysimeter installation and sampling procedures (from Soil Moisture Equipment Co.)

Model 1900

SOIL WATER SAMPLER



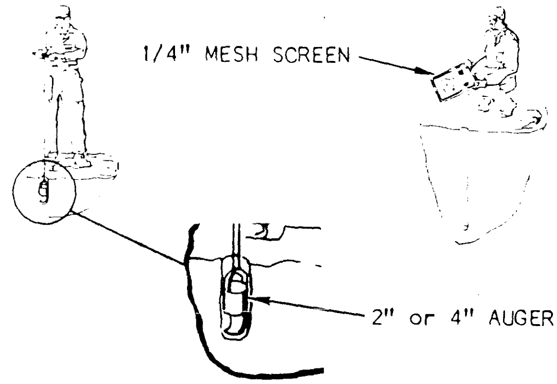
SITE LOCATION

The Model 1900 Soil Water Sampler can be installed in any location. The sampler can be installed in well drained soil or in areas where the water table is above the sampling depth. The surface area directly above the sampler should not be covered in any manner that would interfere with the normal percolation of soil moisture down to the depth of the sampler.

The samplers are normally installed vertically in the soil. However, they can be installed at an angle if this is necessary to reach some otherwise inaccessible point.

The samplers are available in various stock lengths for installation at depths up to 6 ft. Extra length samplers can be provided on special order, if this is necessary. However, for depths greater than 6 ft. it is normally less expensive to use the Model 1920 Pressure-Vacuum Soil Water Sampler.

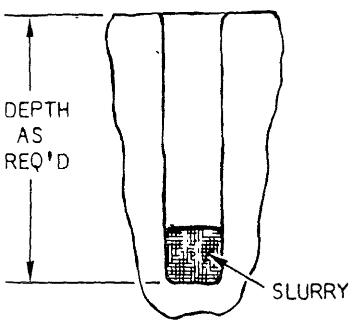
The Model 1900 Soil Water Sampler has been designed so that the body tube of the sampler projects 2" above the soil surface when the sampler is installed to the proper depth, as shown in the figure to the left.



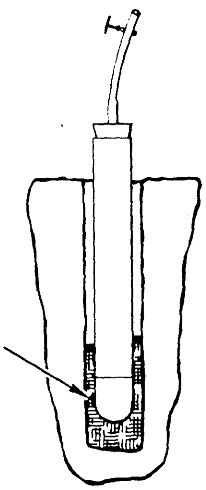
CORING THE HOLE

In rock-free uniform soils at shallow depths, use a 2" screw or bucket auger for coring the hole.

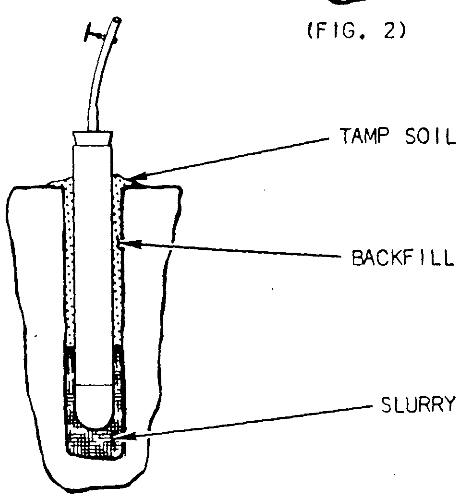
If the soil is rocky, a 4" auger should be used. The soil should then be sifted through a 1/4" mesh screen to free it of pebbles and rocks. This will provide a reasonably uniform backfill soil for filling in around the soil water sampler. The Model 230 Series Soil Augers can be used for this purpose.



(FIG. 1)



(FIG. 2)



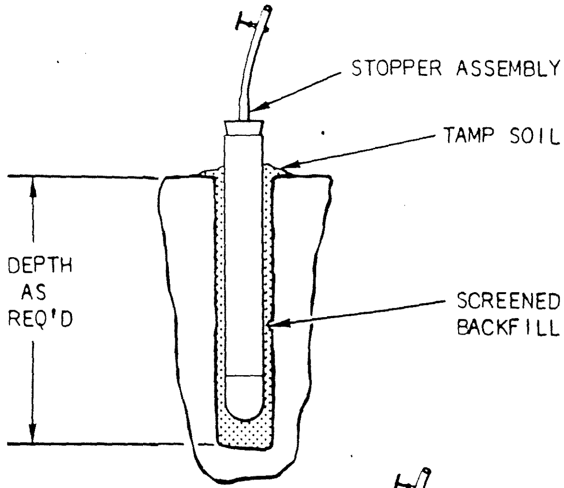
(FIG. 3)

INSTALLATION OF SOIL WATER SAMPLER USING A SOIL SLURRY

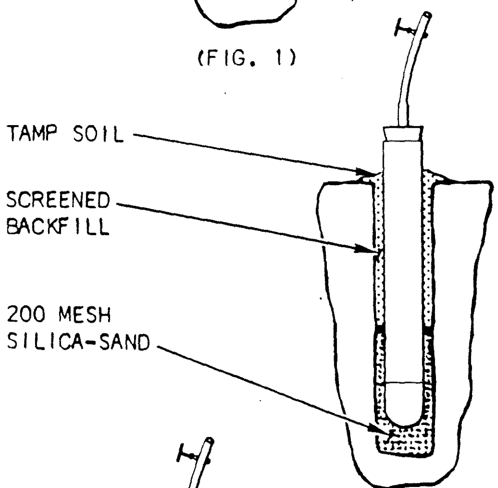
(Fig. 1) After the hole has been cored, mix a substantial quantity of soil from the bottom of the hole with water to make a slurry which has a consistency of cement mortar. This slurry is then poured down to the bottom of the cored hole to insure a good soil contact with the porous ceramic cup.

(Fig. 2) Immediately after the slurry has been poured, push the soil water sampler down into the hole so that the porous ceramic cup is completely embedded in the soil slurry.

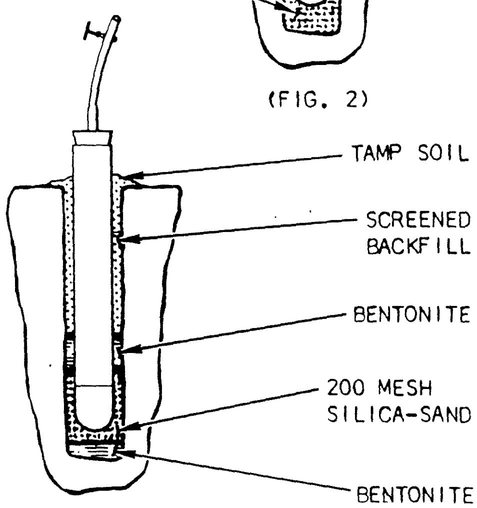
(Fig. 3) Backfill the remaining area around the soil water sampler, tamping soil firmly, to prevent surface water from running down the cored hole. Backfill hole with native soil free of pebbles and rocks.



(FIG. 1)



(FIG. 2)



(FIG. 3)

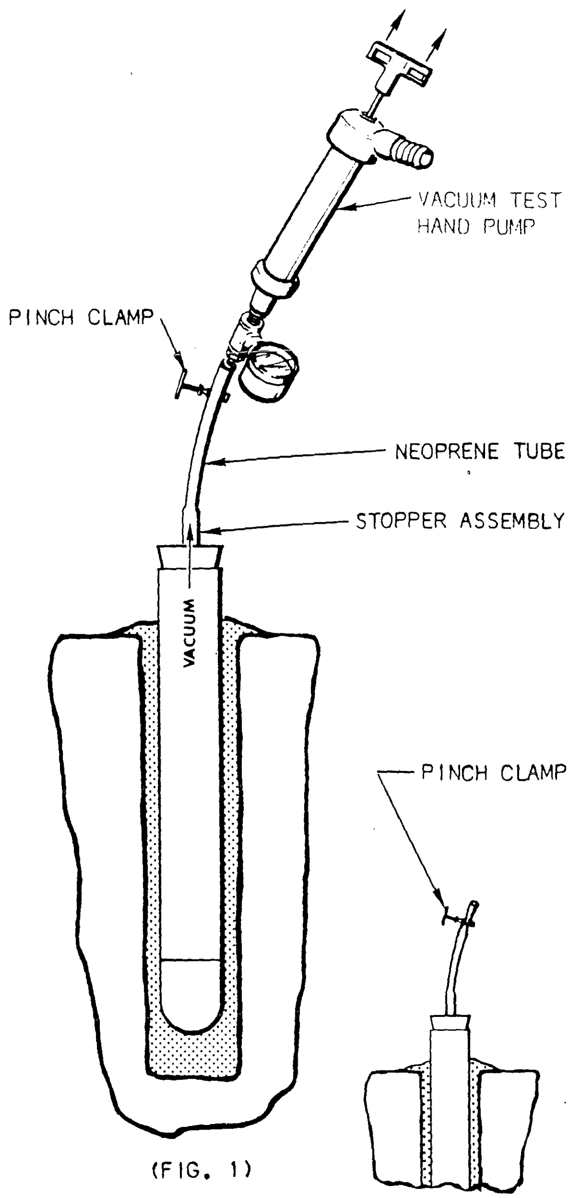
ADDITIONAL METHODS OF INSTALLING THE SOIL WATER SAMPLER

(Fig.1) Core hole to desired depth, insert soil water sampler and backfill the hole with native soil, tamping continuously to insure good soil contact with the porous ceramic cup and complete sealing of the cored hole.

(Fig.2) Core hole to desired depth, pour in a small quantity of crushed 200 mesh pure silica-sand of almost talcum powder consistency (commercially available under trade names of Super-Sil and Silica Flour). Insert soil water sampler and pour another layer of the 200 mesh silica-sand at least six inches deep around cup of the soil water sampler. Backfill the hole with soil free of pebbles and rocks, tamping continuously with a long metal rod to insure against surface water channeling down between the soil and the body tube of the sampler.

(Fig. 3) Core hole to desired depth, pour in a small quantity of wet bentonite clay. This will isolate the sampler from the soil below. Pour in a small quantity of 200 mesh silica-sand and insert soil water sampler. Pour another layer of 200 mesh silica-sand at least six inches deep around the cup of the soil water sampler. Again, add a small quantity of bentonite as a plug to further isolate the ceramic cup and guard against possible channeling of water down the hole. Backfill the remainder of the hole with native soil free of pebbles and rocks, tamping continuously with a long metal rod.

There are other methods of installing the soil water sampler that may be used, largely dictated by the type of soil you are concerned with and the tools available. The primary concern in any method of installation is that the porous cup of the sampler be in tight, intimate contact with the soil, so that soil moisture can move readily from the pores of the soil through the pores in the ceramic cup and into the soil water sampler.



(FIG. 1)

(FIG. 2)

COLLECTING SOIL WATER SAMPLE

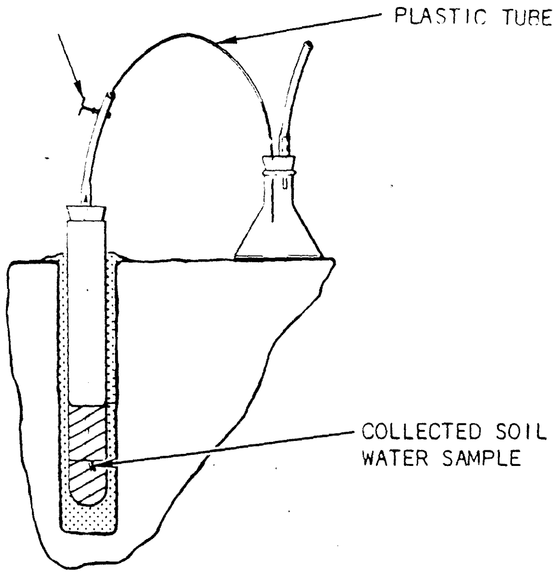
After the soil water sampler has been installed in the field, the accessory items as shown on page 6 are used for collecting a soil water sample.

(Fig.1) To collect a sample, the pinch clamp on the stopper assembly is opened. The serrated tube fitting on the end of the vacuum dial gauge adapter is then inserted into the neoprene tube of the stopper assembly. The vacuum hand pump is then stroked until a vacuum of perhaps 60 centibars (18" of mercury) is created within the sampler, as read out on the vacuum dial gauge.

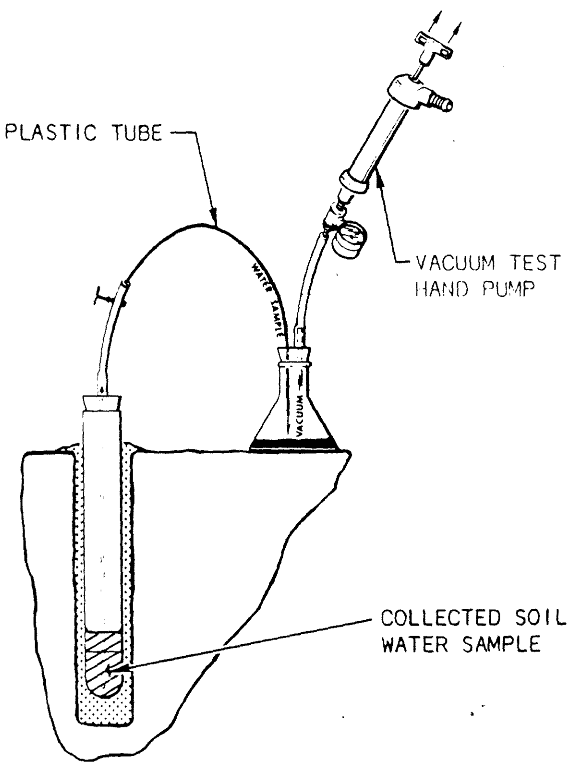
(Fig.2) The pinch clamp is then closed securely to seal the sampler under vacuum. The hand pump can then be removed for other uses. The sampler is allowed to set for a period of time under vacuum.

The vacuum within the sampler causes the moisture to move from the soil, through the porous ceramic cup, and into the sampler. The rate at which the soil solution will collect within the sampler depends on the capillary conductivity of the soil, the soil suction value within the soil (as measured with tensiometers), and the amount of vacuum that has been created within the sampler. In moist soils of good conductivity, at field capacity (10 to 30 centibars of soil suction as read on a tensiometer substantial soil water samples can be collected within a few hours. Under more difficult conditions it may require several days to collect an adequate sample.

In general, vacuums of 50 to 85 centibars (15" to 25" of mercury) are normally applied to the soil water sampler. In very sandy soils it has been noted, however, that very high vacuums applied to the soil water sampler seem to result in slower rate of collection of the sample than lower applied vacuums. It is our feeling that in these coarse, sandy soils, the high vacuum within the sampler may deplete the moisture in the immediate vicinity of the porous ceramic cup and hence reduce the capillary conductivity, which creates a barrier to the flow of moisture to the cup under these circumstances. In loams and gravelly clay loams, users have reported collection of 300 to 500 ml of solution over a period of a day with applied vacuum of 15" of mercury (50 centibars) when soils are at field capacity. On waste water disposal sites,



(FIG. 3)



(FIG. 4)

some users have obtained up to 1500 ml of sample within 24 hours after cessation of irrigation with 1" to 2" waste water on sandy or clay loam soil.

(Fig.3) To remove the soil water sample from the sampler, a simple assembly is usually made up consisting of a small diameter (3/32" O.D. or less) plastic tube, a two-hole rubber stopper, a flask or bottle, as shown.

The pinch clamp on the sampler is opened and the small diameter plastic tube is inserted into the end of the neoprene tube on the stopper assembly and pushed down until it reaches the bottom of the sampler.

(Fig.4) The vacuum hand pump is then connected to the other hole in the stopper. Stroking the hand pump creates a vacuum within the bottle or flask which in turn sucks the sample up from the sampler and into the collection bottle or flask.

If it is more convenient, the stopper assembly can be removed from the sampler so that the collected sample can be removed with a pipette or other means. However, repeated removal and replacement of the rubber stopper assembly can disturb the seal between the soil and the body tube of the sampler, particularly on shallow units.

Subsequent samples are collected by again creating a vacuum within the sampler and following the steps as outlined above.

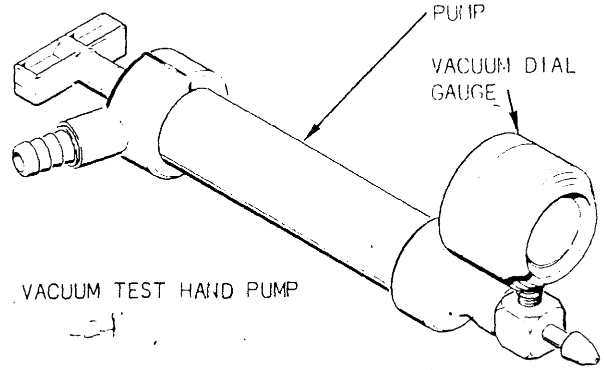
MAINTENANCE

There are no maintenance requirements for the soil water samplers other than protecting the exposed end of the body tube and the stopper assembly from physical damage. The end of the neoprene tube on the stopper assembly should be covered or plugged to prevent debris from entering the tube and later contaminating the sample.

Freezing conditions will not damage the samplers. The samplers are normally left permanently in place throughout the year.

ACCESSORY ITEMS FOR OPERATION OF THE SOIL WATER SAMPLER

1900K1 SERVICE KIT CONSISTING OF:



TUBING

1/16" O.D. X 1/64" WALL NYLON TUBE

5/64" O.D. X 1/64" WALL NYLON TUBE

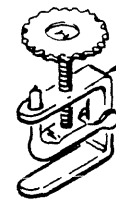
3/32" O.D. X 1/64" WALL NYLON TUBE

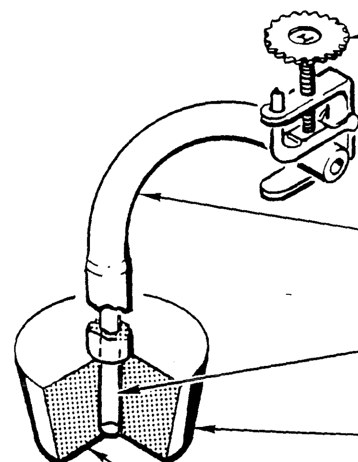
3/16" I.D. X 1/8" WALL NEOPRENE TUBE

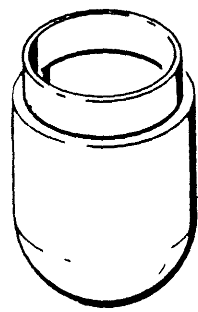
(ORDER NUMBER OF FEET REQUIRED)

NOTE:
ALL ACCESSORY ITEMS ARE AVAILABLE FROM SOILMOISTURE EQUIPMENT CORP.

REPLACEMENT ITEMS FOR THE SOIL WATER SAMPLER







SOILMOISTURE EQUIPMENT CORP. P.O. BOX 30025, SANTA BARBARA, CALIF. 93105 U.S.A.

Appendix 12

Timeline

1996

April 25	Lysimeter plots: stripped about 18 total inches of topsoil (6-8") and subsoil (~12"), installed lysimeter pans (lowest comer 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 NVS 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. Finished placing "topsoil" rows on the slope; horizontal grading completed.
May 9	Spreading of MSW, NVS 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. Placed/spread 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 NVS 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 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.
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 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.
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.
July 13-18	Rain gage malfunctioned (pen was lodged under rotating drum).
July 16	Video taken of lysimeter and waste sand plots.
Aug 1	Inspected demo slope - no odors detected despite 1.2" rain last week.
Aug 6-8	Percent cover and biomass measurements from demo plots.
Aug 7	Percent cover and biomass measurements from lysimeter plots.
Aug 16	Percent cover and biomass measurements from waste sand plots.
Aug 29 - Sep 11	Rain gage malfunctioned. (A screw on the wind up motor was loose.)
Oct 17	Inspected demo slope. Noticed filling in of ditches, but brought no camera.
Oct 26	Video made of demo plots, showing filling in of ditches on control and fertilizer plot. Saw some grass-like species coming up, particularly on upper 1/3 of slope. No odors despite recent rain. Pink flags placed at tops of erosion channels on demo plots.
Nov 7	Winterized the rain gage. Put up rain shield, added antifreeze, calibrated.
Note: The lysimeter plots were visited approximately every 7-10 days throughout the growing season to wind up the motor in the rain gage, and the demo and waste sand plots were also usually inspected during these visits.	

1997

June 6	Started rain gage, using battery operated motor instead of manual version.
July 3	Applied vacuum to suction lysimeters. Couldn't return till July 7 due to holiday weekend.
July 7	Attempted to collect water quality samples from all pan and suction lysimeters, but only successful at obtaining samples from some of the suction lysimeters, and the volume obtained from them varied substantially, precluding analyses of all desired parameters.
July 21	Collected w.q. samples from all pans except #6 (probably due to plumbing leak) and from all suction lysimeters. Pumped entire volume from pans 1 and 3, but not enough time to complete pumping of other pans. A second water quality sample was collected from plot 3 near the end of pumping because s.c. had decreased during pumping.
July 25	Attempted to complete pumping of pans, but all now dry.
Aug 7-11	Conducted percent cover and biomass measurements on demo plots.
Aug 22	Conducted percent cover and biomass measurements on lysimeter plots.
Aug 25	Conducted percent cover and biomass measurements on waste sand plots.

1998

July 13	Eger/Wagner site visit (field notes in Appendix 6).
July 23	Collection of initial set of p.c. and biomass measurments started, but these data were at odds with visual observations made later in the summer, and were replaced by the later measurements (the original data for the lys. and w.s. plots are presented in Appendix 7).
Aug 25	Bob Jacobson (MNDOT) toured the demonstration slope and identified species growing on the plots. Percent cover and biomass measurements made on lysimeter plots.
Sep 1	Percent cover and biomass measurements of top 1/3 of demo slope.
Sep 9	Percent cover and biomass measurements of bottom 2/3 of demo slope and on the waste sand plots.

2000

Apr 28	Controlled burn of demonstration slope.
Aug 14	Visit to demonstration plots by Eger, Wagner, Bob Djupstrom (MNDOT) and Kim Hennings to identify species.
Aug 25	Eger/Wagner inspected demo slope (see field notes in Appendix 6).

Appendix 13

Nitrogen addition rates

The goal of an agronomic rate of nitrogen application is to provide a plant community with enough plant-available nitrogen to maximize crop production, without causing nitrogen losses to surrounding ground and surface waters. The nitrogen supplied by organic waste materials such as NVS and MSW must be present (or be able to be converted into) forms that the plants can utilize, and the optimal level of plant-available nitrogen varies from species to species. The rate is also affected by factors such as soil pH and organic matter, the density of the plants, and the season when application occurs, which can affect nitrogen mobility in the soil. Also, plants (i.e. soybeans, alfalfa, clover) with the ability to fix nitrogen from the atmosphere typically need less nitrogen addition via biosolid application.

Thus the "agronomic" rate of NVS and MSW application on the demonstration plots depends on the "crops" being grown, which in the case of the demonstration slope are mostly prairie grasses such as little blue stem, switch grass, and side oats grama, which are unable to fix nitrogen from the atmosphere. According to the University of Minnesota's Extension Service, a typical agronomic rate of plant-available N for "grass hay and grass pasture" in Minnesota is approximately 100 to150 lb/acre (Rehm et al., 2001), though this rate is dependent upon the production goals of the particular land in question. For the sake of this discussion, a rate of 125 lbs plant available N per acre is selected as the "agronomic" rate for the grasses grown on the demonstration slope, while acknowledging this number could vary substantially from site to site.

The rates of NVS and MSW application on the demonstration plots were largely based on empirical observations made of vegetative success in previous applications of these materials. But the fact that annual weeds (which can efficiently utilize sudden increases in nutrients) were still widespread on the NVS demo plot five years after its creation suggests that the application rate may have been too high, and therefore exceeds the "agronomic rate" and continues to release more nitrogen than the prairie species can use. The rates of nitrogen addition to the NVS, fertilizer, and MSW plots have therefore been compared to the assumed "agronomic rate" of 125 lb/acre.

Nitrogen addition rates The amount of nitrogen added to the NVS, MSW and Fertilizer demonstration plots can be calculated as total nitrogen, or plant-available nitrogen. The data sheets supplied by the Met Council for NVS include both total (TKN) and plant-available N contents (lbs/ton), and the plant-available N applied to the fertilizer plot is essentially the same as the total N added to the plot (i.e. all the N in the fertilizer was plant-available). But it was not possible to calculate plant-available N from the MSW compost, because the soil test reports available for the MSW express their results as the pounds per acre that would be necessary to raise the 0-6" soil layer to a given nitrogen content. Therefore, total nitrogen addition is calculated below for all three plots, but plant-available N is shown only for the NVS and fertilizer plots.

Total N

NVS plot 138 wet tons (71.6 dry tons) of NVS was spread on the 3-acre plot, an average of 23.8 dry tons/acre. The average TKN reported for the NVS in early 1996 (when the NVS used in this project was created) was 0.87%, on a dry weight basis, so 0.208 tons TKN were applied per acre (415 lbs/acre, or 188 kg/acre).

MSW plot 23 dry tons/acre MSW were applied to the demonstration plot. Lot 24 (the lot from which our MSW was obtained) was reported to have a TKN content of 11,500 mg/kg, on a dry weight basis.

(23 dry tons/acre) x (2000 lbs/ton) = 46,000 lbs/acre = 20,865 kg/acre

11,500 mg/kg x 20,865 kg/acre = 240 kg/acre.

Fertilizer plot The top 1/3rd of the plot, the portion planted with the MNDOT 50 mix, received 330 lbs/acre of 12-12-12, or 220 lbs on its 0.67 acre. The bottom 2/3rds received 165 lbs/acre of 12-12-12, or 110 lbs on its 1.33 acres, which means a total of 330 lbs of 12-12-12 was added to the 2-acre plot, or 115 lbs/acre. Assuming that 12% of the 12-12-12 was nitrogen, the total nitrogen applied was 13.8 kg/acre.

Much more total nitrogen was added to the NVS and MSW plots than to the fertilizer plot. But this isn't necessarily relevant, since the nitrogen contained in the inorganic fertilizer is quickly released to the environment (generally in days or weeks), while the nitrogen in NVS and MSW is generally released in a more time-release fashion.

Plant-available N

NVS plot (23.8 dry tons/acre) x (3.6 lbs plant-available N/ton) = 85.7 lbs/acre = 38.9 kg/acre

Fertilizer plot Same as total N; 13.8 kg/acre (30.4 lbs/acre)

In comparison to the case for total N, when much more was added to the NVS plot than the fertilzier plot, the amount of plant-available N added to the NVS plot was much closer to the amount added to the fertilizer plot.

References

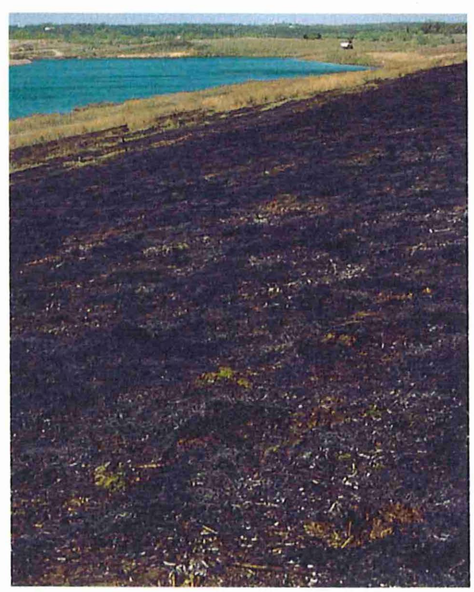
Rehm, G., Schmitt M. and R. Munter. 2001. Fertilizer recommendations for agronomic crops in Minnesota. This document was located via the web site of the University of Minnesota's Extension Service (http://www.extension.umn.edu).

Appendix 14

Controlled burn of demonstration slope, 4/28/2000





Appendix 15

1998 photos of waste sand and lysimeter plots

Figuer A15.1. NVS 60 (waste sand plots).

Figuer A15.2. NVS 30 (waste sand plots).

Figure A15.3. MSW (waste sand plots).

Figure A15.4. NVS 15 (waste sand plots).

Figure A15.5. 4" topsoil+fertilizer (waste sand plots).

Figure A15.6. 2" topsoil (waste sand plots).

Figure A15.7. MSW (lysimeter plots). The two white PVC pipes are the 6" and 24" suction lysimeters that were installed in 1997.

Figure A15.8. Topsoil+fertilizer (lysimeter plots).

Figure A15.9. NVS (lysimeter plots).

Figure A15.10. Closeup view of NVS (lysimeter plots). Note the presence of several large gopher mounds, which were numerous on the lysimeter plots.