GJO–2002–312–TAR
MAC–GW MON–28.7-1

UMTRA
Ground Water Project

Phytoremediation of Nitrogen Contamination in Subpile Soils and in the Alluvial Aquifer at the Monument Valley, Arizona, Uranium Mill Tailings Site

June 2002

Prepared by the
U.S. Department of Energy
Grand Junction Office

Work Performed Under DOE Contract No. DE–AC13–96GJ87335 for the U.S. Department of Energy
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Acknowledgements

This research project was funded by the Uranium Mill Tailings Remedial Action Ground Water Program managed by Donald Metzler, U.S. Department of Energy Grand Junction Office. Ken Karp, MACTEC Environmental Restoration Services, is manager of the Monument Valley project. The research was directed by Edward Glenn, Environmental Research Laboratory (ERL), University of Arizona, and Jody Waugh, Environmental Sciences Laboratory, U.S. Department of Energy Grand Junction Office. Co-authors were Casey McKeon, Amy Anchieta, Fiona Jordan, and Steve Nelson, all from ERL. Contributors included David Moore, ERL; Shawna Vance, Gretchen VanReyper, Greg Smith, and Susan Lyon, MACTEC Environmental Restoration Services; and Glendon Gee, Jason Ritter and Todd Caldwell, Pacific Northwest National Laboratory.

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Summary

The results of 5 years of study on the feasibility of phytoremediation of nitrate and ammonia at the Monument Valley UMTRA site are presented. The rationale for the studies is presented in Chapter 1. Chapter 2 presents results of a pilot study to remove nitrate and ammonia from the contaminated subpile soil, using a native shrub (*Atriplex canescens*). Although plant growth was inhibited by chemical constituents in the soil over part of the 1.6 ha farm, loss of nitrate from the soil was rapid. This loss could not be explained by uptake into plants alone, and may be due to denitrification and conversion of nitrate to microbial biomass. Ammonia removal was slower than nitrate removal. Chapter 3 presents results of a study to determine the rate at which native shrubs growing naturally over the plume could remove water and nitrate. Plants inside protective fences (exclosures) grew much more rapidly than those exposed to grazing. Isotope analyses showed that the two main shrubs, *Atriplex* and *Sarcobatus vermiculatus*, were probably both rooted into the contamination plume. It was concluded that the percent plant cover over most of the plume could be increased from the present value of < 10 percent to >25 percent by excluding grazers, and that native plants could remediate most of the plume nitrate within reasonable time spans if protected from grazing. Chapter 4 presents results of a greenhouse study conducted in support of a Land Farm option. Plant growth in the site soils is initially poor but can be improved by the addition of organic matter to the soil, which also allows plants to overcome the inhibitory effect of excess nitrate present in the well waters. Sudangrass accumulated high levels of hydrocyanic acid and nitrate, which lowers it's value as a forage crop, whereas alfalfa had safe levels when grown on diluted well water. Chapter 5 presents the feasibility of the Land Farm option, and addresses concerns such as sulfate concentrations, gypsum formation, and plant toxicity. The analysis in Chapter 5, building on the results of Chapters 3 and 4, shows that pumping of the plume water as a source of irrigation water and fertilizer could remediate plume nitrate over a reasonable time span with the added benefit of the production of forage and/or seed crops. Overall, the studies show that phytoremediation methods could be used in several ways to remove nitrate and ammonia from the soil and aquifer at this site. Further investigation of the rapid loss of nitrate from irrigated soils is especially warranted.

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1.0 Introduction

The Monument Valley Uranium Mill Tailings Remedial Action (UMTRA) Project site is located in Arizona, roughly 30 miles southeast of Mexican Hat, Utah. It is in a high desert, dune and swale environment on the Colorado Plateau. Some of the soil where the former uranium tailings piles were located (subpile soil) is contaminated with high levels of ammonium (NH_4) and nitrate (NO_3). In addition, a plume of groundwater contaminated with NO_3 and, to a lesser extent, sulfate (SO_4), is moving away from the former mill site. The nitrate plume is depicted in Figure 1–1. The surface (or subpile) soil has been scarred by extensive blading operations conducted to remove tailings and contaminated soil from the site. Initial attempts to establish new vegetative cover by direct seeding failed. As a result a large, bare area that is sparsely colonized by the annual Russian thistle (*Salsola kali*), an undesirable exotic weed, remains. Another 20 ha area covering what is considered the most contaminated portion of the plume was also bladed during the tailings cleanup leaving the area in poor range condition. Details covering the extent of contamination at the site are provided in the Final Site Observational Work Plan for the UMTRA Project Site at Monument Valley, Arizona (DOE 1999).

U.S. Department of Energy (DOE) proposed that management of the native vegetation at the site using land-farming and/or passive phytoremediation techniques could play a significant role in the remediation of the subpile soil and alluvial aquifer extending to the north. Phytoremediation could also improve the rangeland ecology and provide better forage conditions for livestock. The native vegetation found on site is a mixture of perennial shrubs, grasses, and herbaceous dicot species, dominated by two phreatophytes: greasewood (*Sarcobatus vermiculatus*) and fourwing saltbush (*Atriplex canescens*). Both plants are salt-tolerant, Chenopod shrubs. Not only are these plants capable of accumulating significant quantities of salts in the above ground tissue; they are valuable livestock forage plants and could also help to stabilize soil movement in this landscape of sand dunes (Blank et al. 1987; Glenn et al. 2001; Wood et al. 1995; Woods and Cade 1996). It was estimated from aerial photos taken after the pile was removed that these shrubs covered 25 percent of the ground area over the plume in some areas, although most of the area over the plume had <10 percent vegetation cover. Both of these plants can utilize groundwater to meet their transpiration needs (Charles et al. 1987; Osmond et al. 1980). Their presence suggested that deliberate planting of more such plants, in combination with protection of the existing plants by fencing out livestock, could significantly enhance the remediation of the nitrogenous contaminants from the soil and water at this site.

It was envisioned that fourwing saltbush plants installed in the subpile could utilize the ammonia and nitrate in that soil, if provided with irrigation water to stimulate plant growth and microbial activity. Further, it was hypothesized that greasewood and saltbush plants already growing over the plume, if protected from over-grazing, could remove water and nitrate from the plume through the process of transpiration and growth. Thus, the native phreatophytes at this site could conceivably be used for phytoremediation of ammonia and nitrate contamination as part of an overall program of site restoration and remediation. Finally, it was proposed that a phytoremediation farm, using conventional forage crops such as alfalfa, in combination with the more deeply rooted native shrubs such as fourwing saltbush that could be used for forage and/or as a seed source for reclamation elsewhere on the Navajo Nation, could be irrigated with contaminated plume water, converting plume nitrate and sulfate into biomass constituents.

The basic assumptions with regard to subpile soil phytoremediation are: (1) fourwing saltbush can be successfully established over the contaminated portions of the subpile area through the use of drip irrigation from uncontaminated (deep aquifer) water; (2) the phreatophyles will accumulate and transform the nitrogen sources available in the subpile soil; (3) irrigation can be managed so that this area does not become a source of runoff or recharge to the downgradient plume. The main assumptions with regard to passive phytoremediation over the plume are: (1) both species are rooted into the contaminated plume from which they withdraw water and nitrate; (2) primary production (growth and nitrogen uptake) is sufficient to contribute to nitrate remediation within the timescale planned for the total remediation effort (ca. 20 years); (3) protection against foraging of the existing phreatophyte community by fencing will enhance growth and nitrate uptake; 4) additional greasewood and saltbush plants can be established within the existing community to further enhance nitrate uptake. The main assumption regarding active phytoremediation using farming methods is that conventional forage crops can be grown in high yield on MV soil using plume water for irrigation. It is assumed that all three types of phytoremediation will neither accumulate nitrate or other chemicals of concern to harmful levels in above-ground tissues, nor will nitrates be appreciably recycled back to the aquifer through the decomposition of nitrogenous plant litter produced during phytoremediation.

Assumptions associated with each type of phytoremediation were tested by pilot studies conducted over three growing seasons at the site, supplemented by greenhouse studies conducted at the Environmental Research Laboratory in Tucson, Arizona. Furthermore, literature reviews were conducted to determine the state of knowledge concerning the assumptions. The following sections report the results of the pilot studies. The results of the subpile phytoremediation effort are presented in Chapter 2. Results of exclosure studies testing the feasibility of passive phytoremediation are in Chapter 3. Greenhouse studies in which alfalfa, sudan grass and saltbush were grown in native soils and irrigated with plume water are in Chapter 4. Chapter 5 discusses the overall feasibility of a Land Farm planted with a forage or seed crop and irrigated with water pumped from the plume.

A major assumption going into these studies was that uptake of nitrogen into plant material would be the main mechanism by which ammonia or nitrate would be removed from the soil or water. However, results of the subpile soil study (Chapter 2) show that much larger amounts of nitrate were removed from the soil than could be expected by plant uptake alone. Likely mechanisms are microbial denitrification and conversion of inorganic N into microbial N. These findings have important implications for the overall goal of remediating plume nitrate, in that phytoremediation in combination with the microbial processes going on in these soils when irrigated, could conceivably decontaminate the plume much faster than previously predicted.

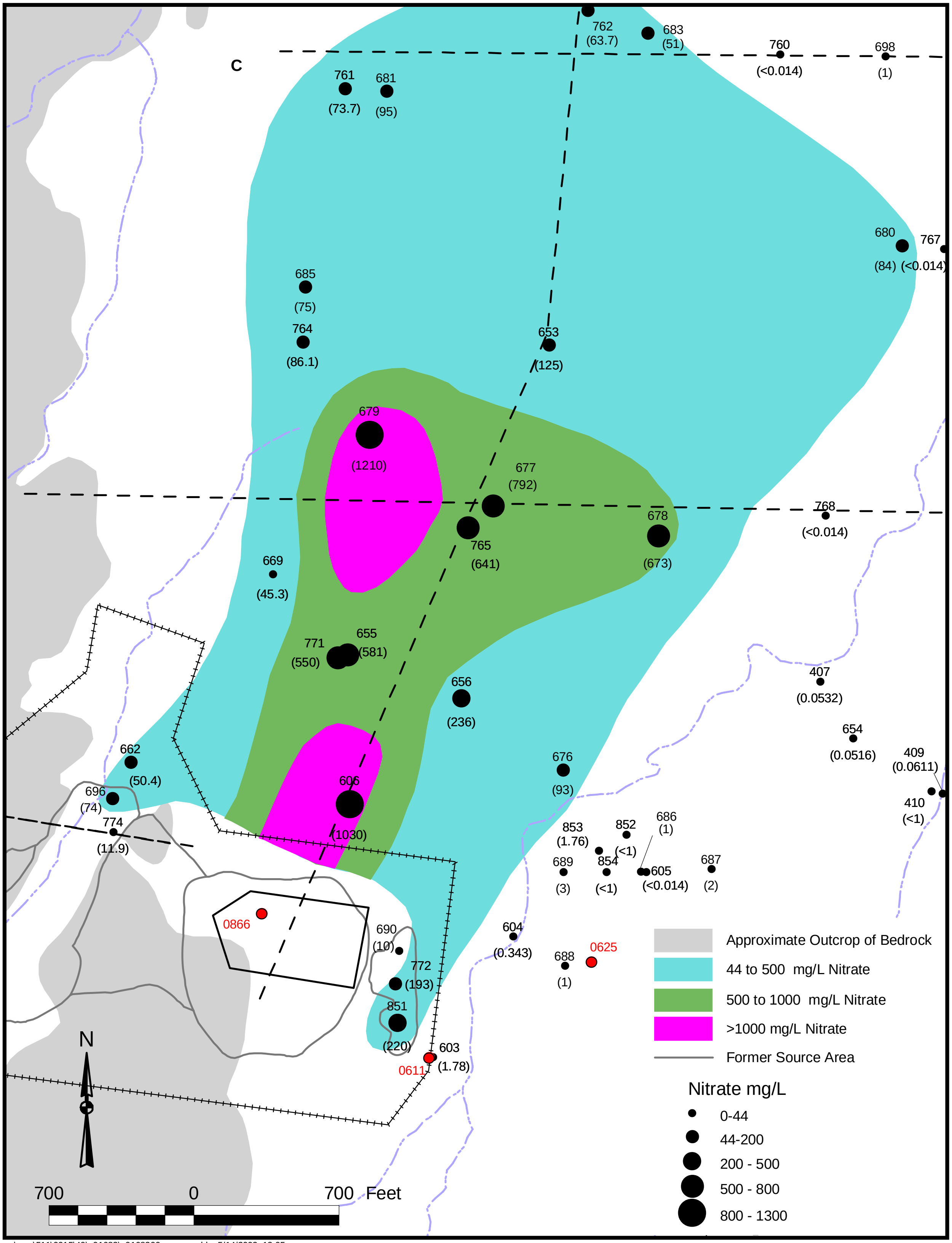

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Figure 1–1. Nitrate plume and approximate location of 1.6 ha subpile phytoremediation plot along with the location of sampling location # 866 and wells 611 and 625 (used for irrigation).

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2.0 Phytoremediation of Subpile Soil

2.1 Delineating Nitrate and Ammonia Concentrations in Subpile Soil

Initial soil sampling by DOE at the subpile site discovered a potential ammonia hot-spot in the New Tailings Pile (subpile) area, based on a single sample (#866; see Figure 1–1) which had high ammonia levels at all soil depths within the core (DOE 1998). That sampling program was too broad-based to delineate the true extent of the contamination. Subsequent efforts began with a more detailed soil survey (June 1997) in which nitrate and ammonia levels were measured in core samples taken in a radial pattern away from the location of #866 (see Figure 2–1, Appendix A). We ran transect lines at angles of 0^o, 45^o, 106^o, 180^o, 275^o and 308^o starting at the approximate location where #866 had been taken, and initially took soil samples at the origin of the transects and at 70 meter (m) intervals along each transect line until the line encountered bedrock or the fenceline delineating the site boundary. We took soil samples with a motorized, 3 inch diameter auger. Samples were composited from 0 to 1 m, 1 to 2 m, and 2 to 3 m soil depths at each sample point. After analysis in the field, we obtained additional samples at 30.5 m intervals along the transects that showed appreciable levels of ammonia or nitrate in order to better define the extent of the contamination. An extra sample set was taken at a point midway between the 106^o and 130^o transect lines, 152.5 m from the origin.

Samples were analyzed in the field by preparing 1:5 (w:w) soil:water extracts (dH_2O). These were allowed to settle for 2 minutes, then the supernatant was filtered through a 1 micron mesh, syringe-type filter. An aliquot was tested for ammonia levels using a colorimetric method (Hach Ammonia Test Kit, 1-50 ppm range). All samples were brought back to the laboratory for further analysis. Soil:water extracts (1:100) were prepared and ammonia and nitrate concentrations were determined with the appropriate Hach Test Kit. All procedures met the QA/QC recommendations for standards and controls (EPA 1979).

Initial soil concentrations determined for nitrate and ammonia were presented in Glenn et al. (1999). The highest ammonium and nitrate concentrations (regardless of soil depth) reported for the initial sampling locations are presented in Figures 2–1 and 2–2, respectively. Every sample had elevated nitrate levels ranging from 45-1060 ppm, with a mean of 378 mg per kg (ppm). There was no obvious clustering of high values within the area surveyed or at any particular soil depth (Glenn et al. 1999). Normal desert soils are reported to have levels < 5 ppm (Lash et al. 2000), this was selected as an arbitrary limit for delineating subpile soils. Unlike organic and cationic contaminants, nitrate exhibits few rate-limited mass transfer processes and is highly mobile in the soil solution. Assuming all the nitrate remaining in the soil is mobilized, recharge could result in nitrate contamination levels exceeding the drinking water standard of 44 mg/L downgradient of the subpile soil area. Ammonia concentrations, on the other hand, were significantly less, ranging from zero to 163 ppm, with a mean of 34.2 ppm. Twenty of the 62 samples, however, exceeded the 5 ppm limit. DOE considered the subpile soils to be a continuing source of nitrate moving into the alluvial aquifer.

Based on these results, DOE decided to plant native shrubs in the contaminated soil to phytoremediate nitrate and ammonia and, through plant transpiration, manage the soil water balance, thereby limiting further leaching of nitrate into the plume. An area of approximately 1.6 ha containing samples > 5 ppm ammonia was selected for a phytoremediation pilot study.

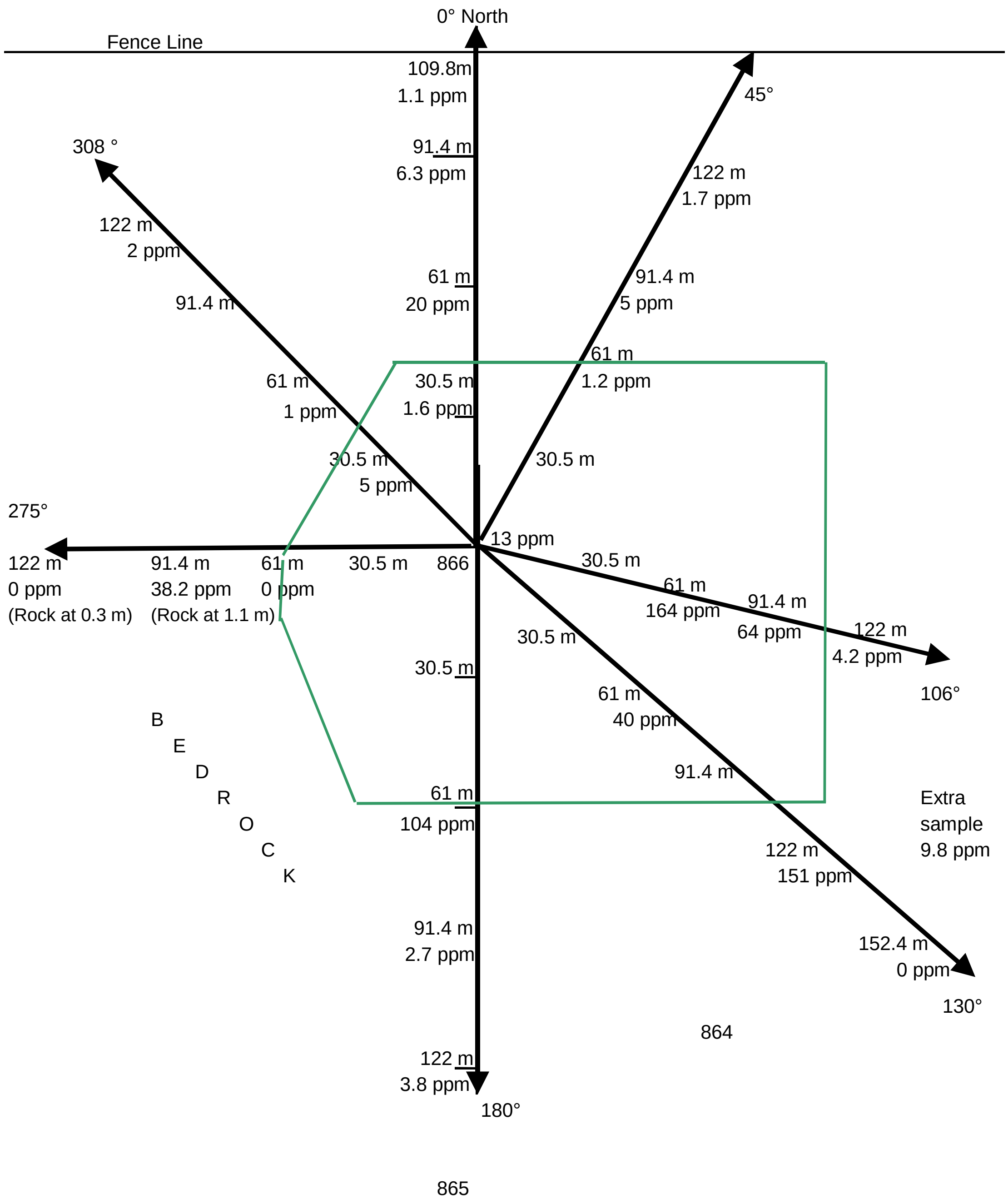


Figure 2–1. Map of ammonia concentrations radiating from sample location #866 taken in June 1997. Soil samples were composites of 0-1m, 1-2 m, and 2-3 m. The highest nitrate values for each site are shown. The 1.6 ha field site currently irrigated is outlined in green.

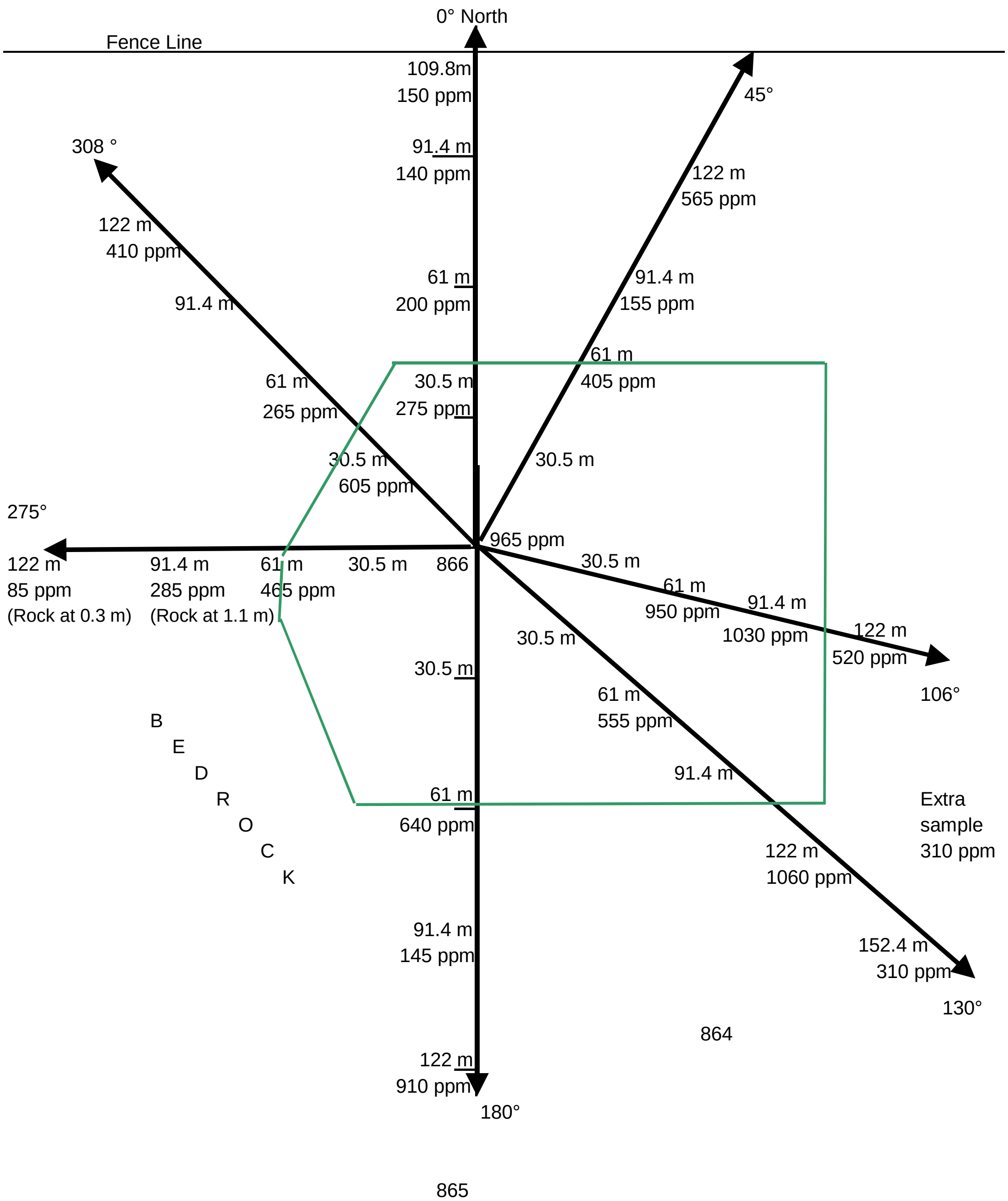


Figure 2–2. Map of nitrate concentrations radiating from sample location #866 taken in June 1997. Soil samples were composites of 0-1m, 1-2 m, and 2-3 m. The highest nitrate values for each site are shown. The 1.6 ha field site currently irrigated is outlined in green.

2.2 Planting the Subpile Soil Area

Pilot planting studies in small exclosure plots at the site showed that *Atriplex var. angustifolia* established and grew quickly under irrigation, whereas *Sarcobatus* grew much more slowly and had lower survival (Glenn et al. 1999). Hence, 99 percent of the plants used for phytoremediation of the subpile soil were *Atriplex* (some *Sarcobatus* were planted as a further test). The plot was planted with approximately 4,000 small (10 to 20 cm) transplants placed under drip irrigation in summer and fall, 1999. This report summarizes the earlier findings and extends them over the third growing season to October 2001.

The soil depth of the subpile site varied from 1 to 5 m. The soil was characterized as 84-88 percent sand, 5-6 percent silt, and 7-10 percent clay. Other chemical constituents are presented in Table 2–1. We also analyzed a composite soil sample from the subpile soil surface to determine if it could support plant growth. Aside from high levels of ammonia and nitrate, this soil was typical of other local sands that support native plant communities such as the values reported for the Tuba City UMTRA site soil sample (Glenn et al. 2001). Based on the initial soil survey results, we prepared an irrigation design for an approximately 1.6 ha, polygonal plot that encompassed much of the area containing > 5 ppm ammonia (Figure 2–1). However, note that not all the soil containing > 5 ppm ammonia is within this plot, and much of the area with elevated nitrate is outside the plot (Figure 2–2). The irrigation system consists of a buried (0.6 m depth), 3 inch PVC surface line that carries water from a well to the field, and a series of 5/8 inch, black polyethylene, drip lines equipped with in-line emitters at 2 m intervals. The lines are also spaced 2 m apart along the header pipe. The system contains 3,881 pressure-compensated, 0.5 gph emitters. Due to limited water capacity of the pump installed in the well, the field is divided into 4 zones, each containing approximately 970 plants, and the field is irrigated at a rate of 2 hr/zone/day, 5 days per week during the growing season, March through September or October.

Table 2–1. Chemical Analysis of the Monument Valley Subpile and Tuba City Soils. Values are Means ±Standard Error.

Lab Tests	Monument Valley	Tuba City
pH	7.2 ± 0	7.8 ± 0
EC, ds/m	3.7 ± 1.1	0.5 ± 0.1
Free Lime	Yes	No
Organic Matter, %	0.6 ± 0.1	0.4 ± 0
Nitrate, mg/kg	172 ± 32	48 ± 8
Available N, mg/kg	80 ± 5	29 ± 3
Available P, mg/kg	16 ± 4	3 ± 0
Exchangeable K, mg/kg	64 ± 5	93 ± 2
Exchangeable Mg, mg/kg	182 ± 10	121 ± 1
Exchangeable Ca, mg/kg	4,931 ± 9	2,048 ± 49
Exchangeable Na, mg/kg	27 ± 1	22 ± 1
Exchangeable Na, %	0.4 ± 0	0.8 ± 0
NH_4, mg/kg	6.1 ± 3.4	3.4 ± 0.4

Approximately 4,500 plants of *Atriplex canescens* var. *angustifolia* were established in a greenhouse at the Environmental Research Laboratory in Tucson, from seeds originally obtained from the Navajo Nation. The seed was a mixture of large-fruited (var. *angustifolia*) and small-fruited (var. *occidentalis*) types of fourwing saltbush collected from local sources. Plants were started in January 1999 in small planting cells in germination trays, and were held through the spring until needed for transplanting at Monument Valley. Survival was > 95 percent in the greenhouse.

Field work began April 18, 1999. The well first selected for irrigation water (Well 611) did not provide sufficient volume to operate the irrigation system; Well 625 was developed as an alternative (Figure 1–1). Most of the transplants were installed the week of June 20, 1999. However, the water supply was still inadequate, as the shallow well jet pump did not provide sufficient pressure to operate the system. Therefore, some areas of the field did not receive water and many transplants died. Between July 18 and August 15, 1999, the jet pump was replaced with a submersible pump and the generator (which overheated then shut off at frequent intervals during the irrigation cycle) was replaced. The irrigation system is now capable of operating 8 hrs/day with sufficient pressure to irrigate the entire field each day. Dead *Atriplex* were replaced in August 1999. In spring of 2000 and again in 2001, the plantings were inspected and dead *Atriplex* were replaced with transplants from the ERL greenhouse.

The subpile phytoremediation study plot is roughly rectangular with the long edge running east-west. It is divided into four irrigation zones, and most of the results presented below are compiled by zone. Figure 2–3 is an aerial photograph of the study site taken in September 2000. The location of plants, plant type, plant mortality, hydroprobe ports, irrigation zones, and plant and soil sampling for the third year (2001) are depicted in Figure 2–4. Similar data were collected in 2000.

2.3 Survival and Growth of Plants

Over the first growing season (1999), plant survival was 80 percent. Dead plants were replaced in the second season. Survival of plants was evaluated again in September 2000 and 2001. Overall survival of transplants for year 2000 and 2001 was 97.3 percent and 97.4 percent, respectively (Table 2–2, Appendix B), similar to survival rates for *Atriplex* grown in the Tucson greenhouse. Plant growth was evaluated by both non-destructive and destructive sampling. Non-destructive sampling consisted of measuring the height and width (in east-west and north-south directions) of plants at every other emitter in 2000 and at every 5th emitter in 2001. In years 2000 and 2001, a total of 1937 and 762 plants were measured, respectively (n = 402 - 638 per zone). These measurements were used to calculate ground cover (m^2) and canopy volume (m^3). Dead plants were not included in the analysis. Plant size differed significantly by zone ($P < 0.001$), with plants in Zone 4 achieving nearly 2 to 4 times as much volume as plants in Zones 1 and 2; plants increased significantly in volume in all zones between 2000 and 2001 (Figure 2–5, Appendix C). Plant canopy area increased more than 3-fold between 2000 and 2001 (Table 2–3). Canopies of some of the plants in Zone 4 have nearly grown together; plants are spaced approximately 2 m apart.

Table 2–2. Survival of plants over all growing seasons (through to October 2001) after replacing plants which did not survive the previous growing season. This was presumably due to lack of irrigation from the emitter or competition by invasive plants at the emitter

	Percent Survival for Each Growing Season		
Zone/Year	**1999**	**2000**	**2001**
1	83.2	96.7	97.9
2	66.9	96.9	96.7
3	84.6	96.8	97.3
4	90.3	99.3	97.9
Totals	79.3	97.3	97.4

Table 2–3. Mean plant area (standard error) calculations for year 2000 and 2001 for each irrigation zone. In order to compare plant coverage among zones, the 2001 data were log transformed prior to one-way ANOVA ($F_{3, 735} = 43.5; P < 0.005$)

	Mean Plant Area (m^2)	
Zone/Year	**2000**	**2001**
1	0.117 (0.011)	0.363 (0.042)
2	0.272 (0.019)	0.621 (0.051)
3	0.181 (0.014)	0.871 (0.068)
4	0.376 (0.300)	1.440 (0.1258)
Average	0.2368 (0.01)	0.783 (0.038)

The poor growth of plants in the northern sections of zones 1, 2 and 3 appeared to be related to a white stained area (as observed from aerial photographs) in those zones (Figure 2–6). However, because the zones do not exactly match the footprint of the white stain, we wanted to determine if the white stain was impacting growth of the plants in the different zones. We superimposed the plant locator map (Figure 2–4) with the close-up aerial photograph (Figure 2–6). Figure 2–7 is the plant locator map depicting which plants reside in the stained area (white area in the aerial photograph). An analysis was conducted whereby a random number generator program was used to identify the row and plant number of roughly 30 plants per zone. Each plant was designated as to whether it resided in the stained or unstained area. A two-way ANOVA was used to compare plant volumes in the two areas and the different zones. Plant growth (measured as volume) differed significantly between stained and unstained areas (Figure 2–8; $P < 0.0001$). Analyses of the chemical properties of stained and unstained soils are presented in Section 2.5.

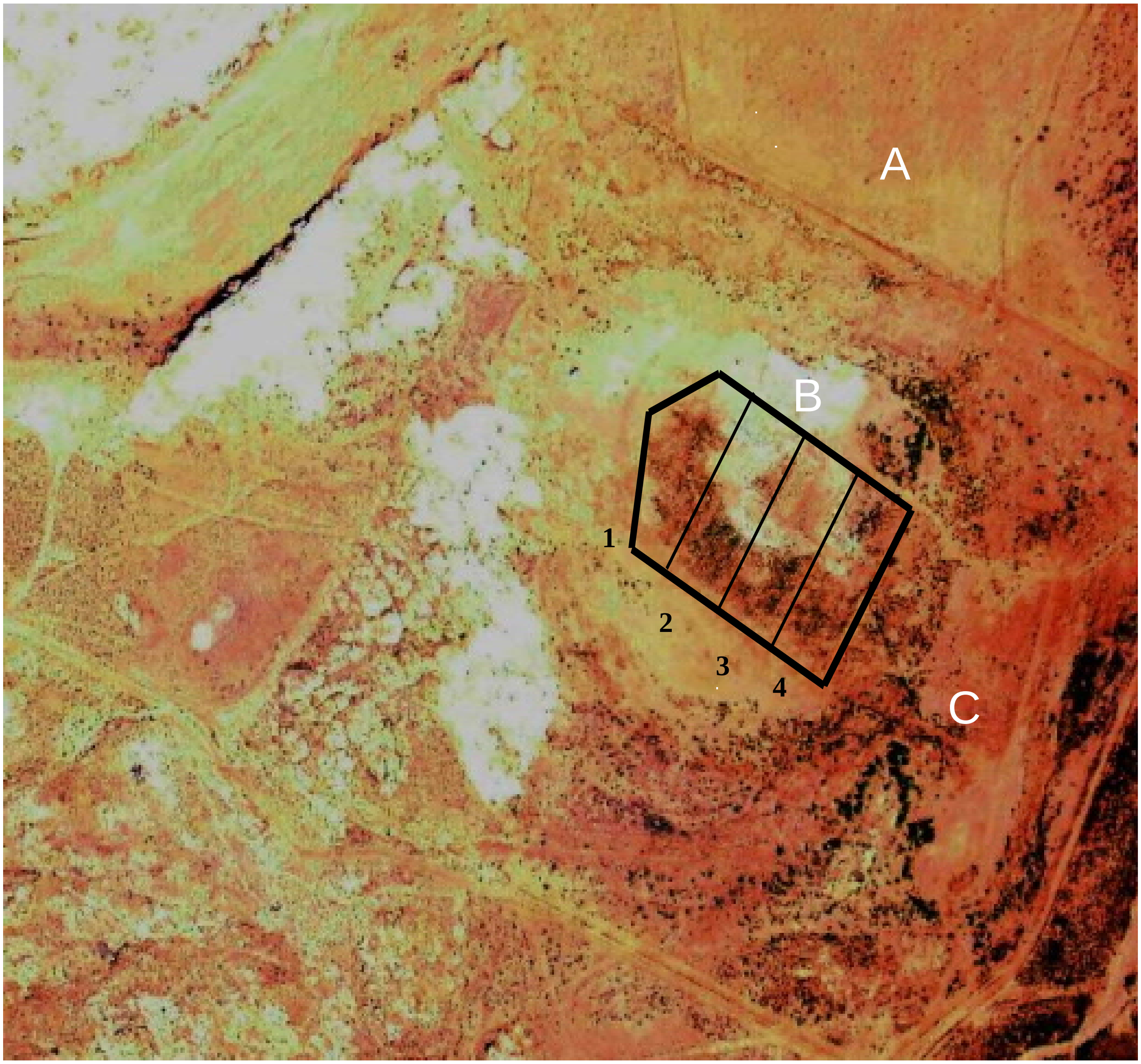


Figure 2–3. Aerial photograph of the Monument Valley Subpile Soil Phytoremediation Plot taken September 2000, showing the outline of the farm and the four irrigation zones. Areas of apparent chemical staining appear white. Sites where surface soil was collected for analysis are: (A) outside the fenceline, (B) the stained area inside fenceline, and (C) the unstained area inside the fence. Irrigation zones are numbered 1 through 4.

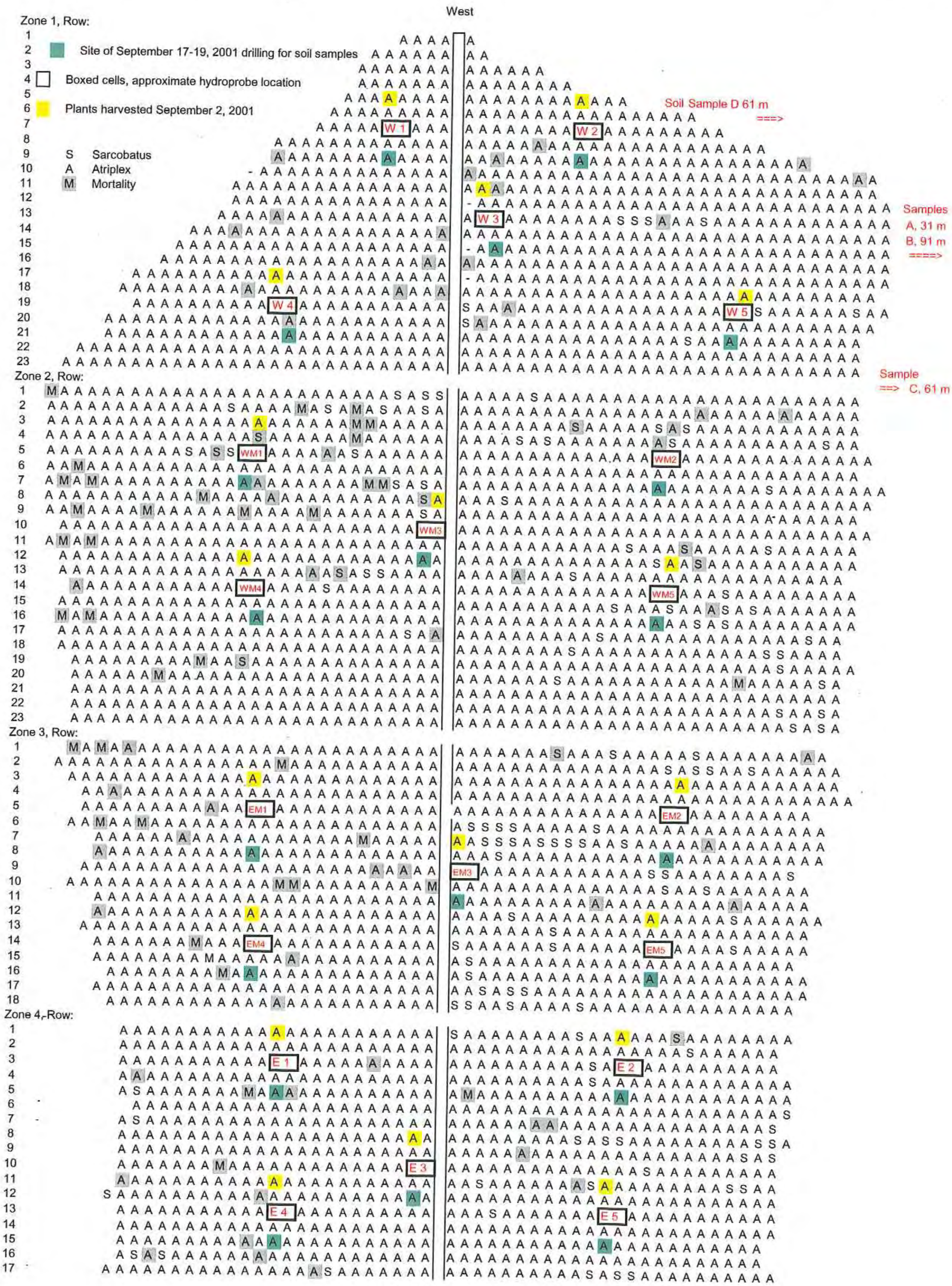


Figure 2–4. Locator Map of Plants and Sample Sites in Phytoremediation Plot

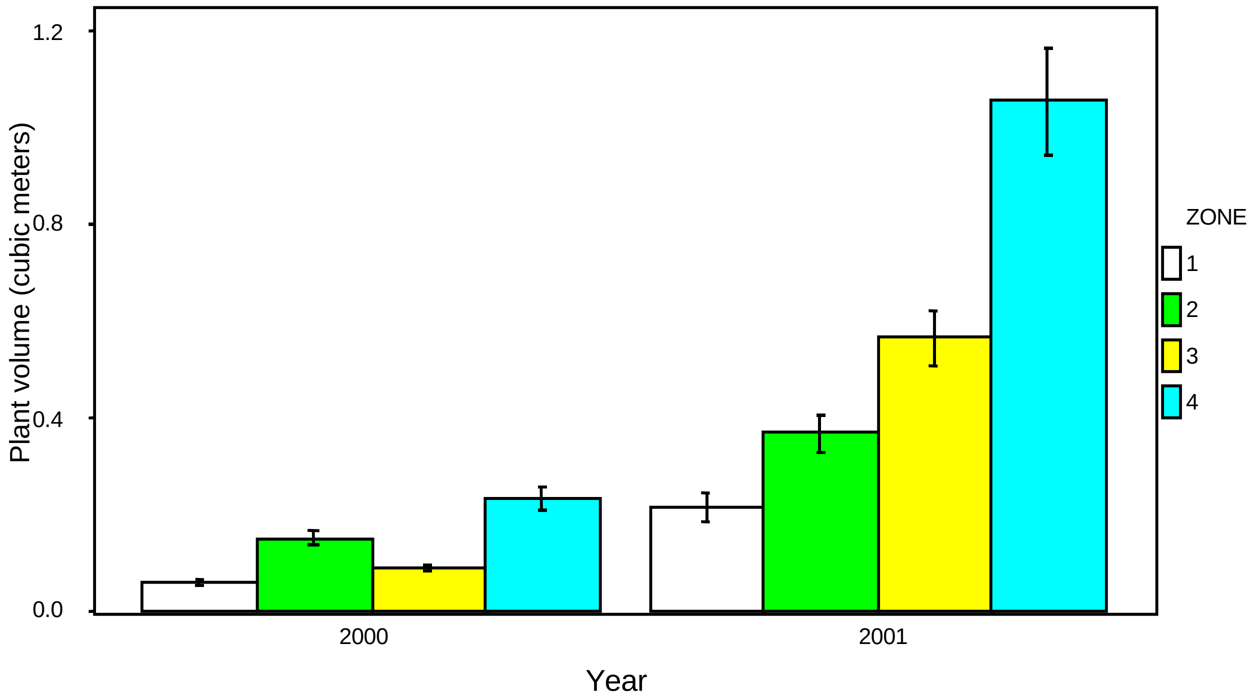


Figure 2–5. Mean plant growth (as measured in volume) by zone in the 1.6 ha field study for years 2000 and 2001. (Data were log transformed before conducting a one-way ANOVA to determine the effect of zone on plant volume (F = 44.01, P < 0.0001). Error bars represent standard errors of the means.

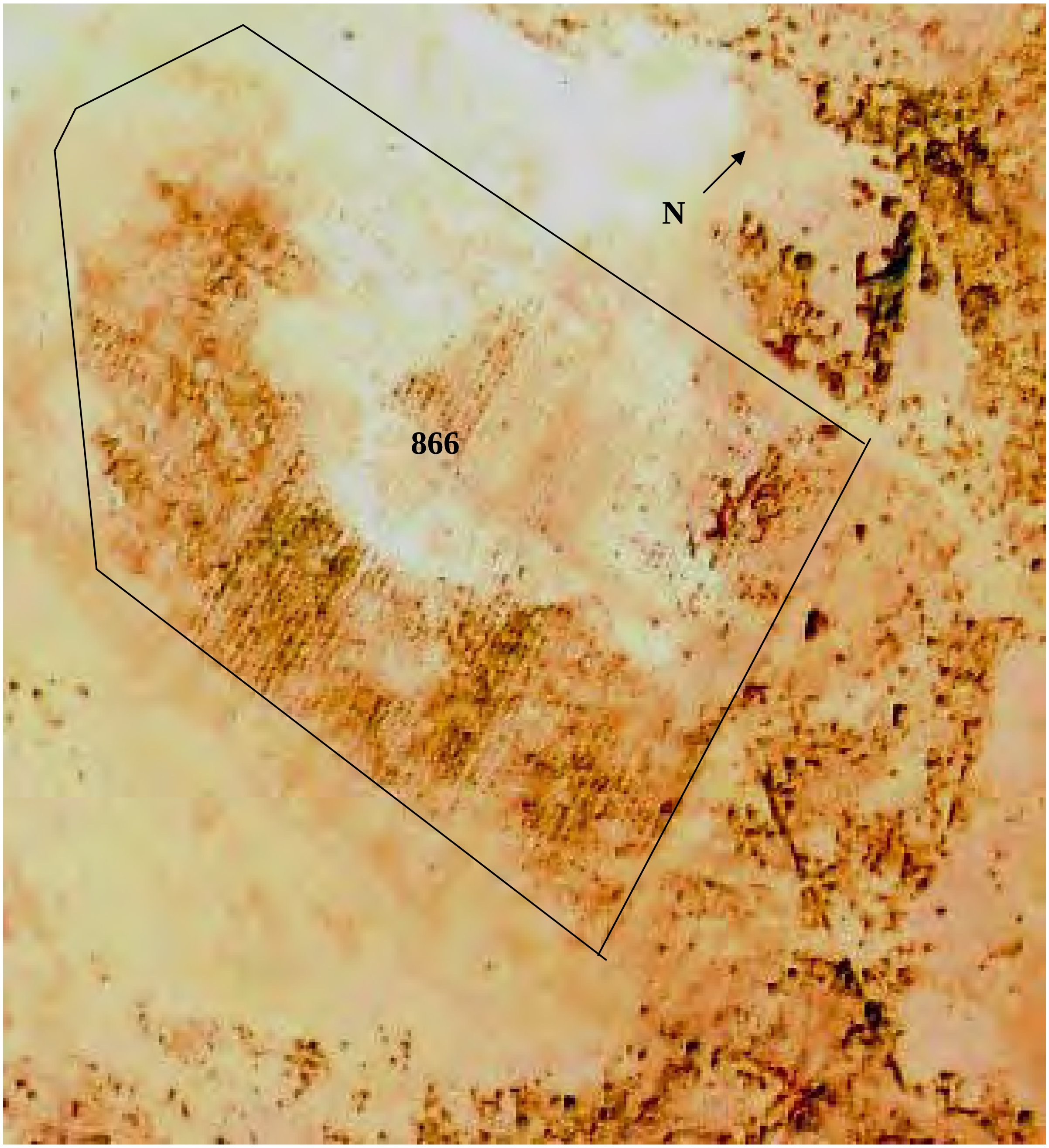


Figure 2–6. Close up Aerial View of the 1.6 ha Phytoremediation Plot. 866 is the site of initial ammonia sampling in 1997.

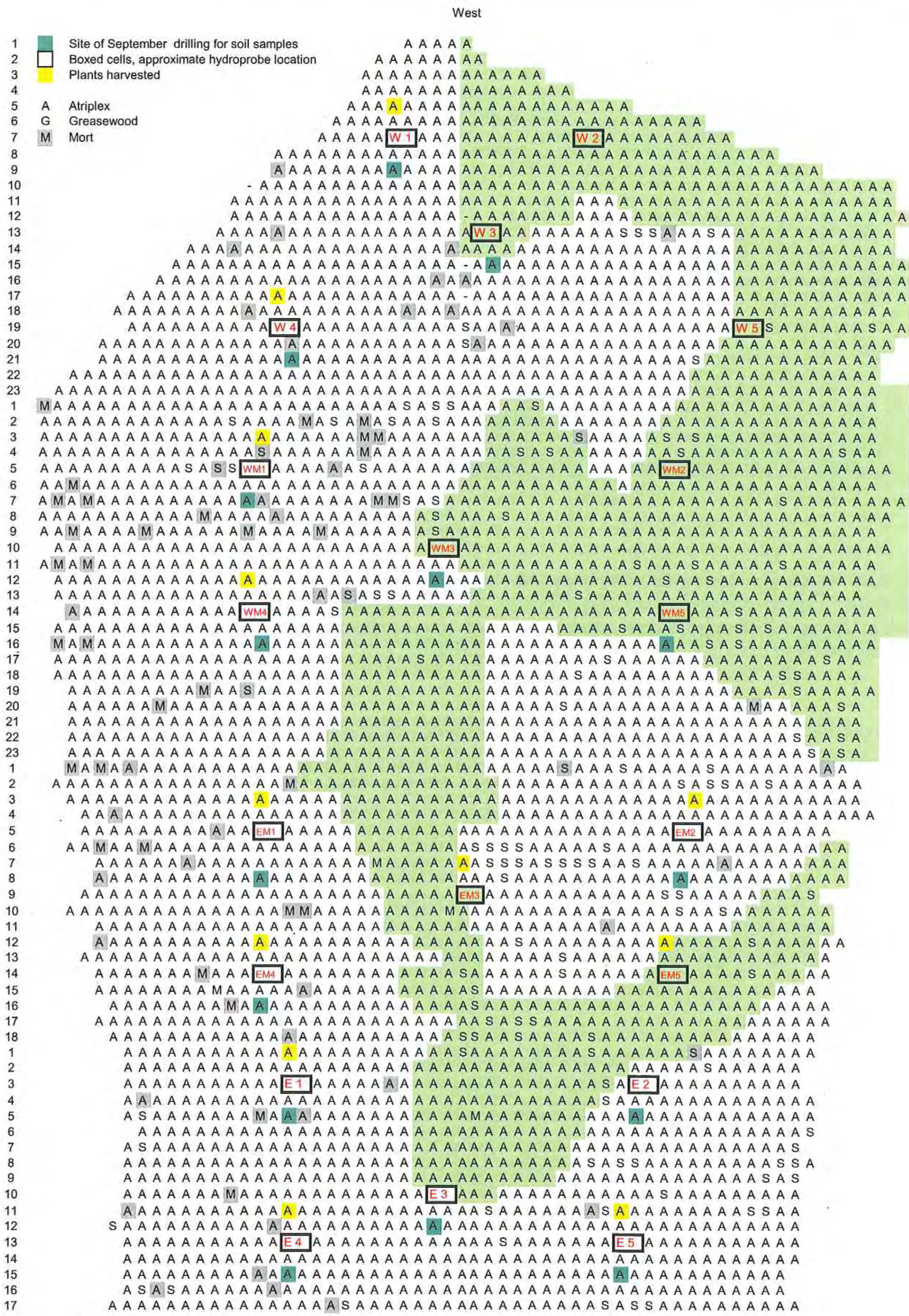


Figure 2–7. Distribution of Chemical Stain Area. The Stained area is in green.

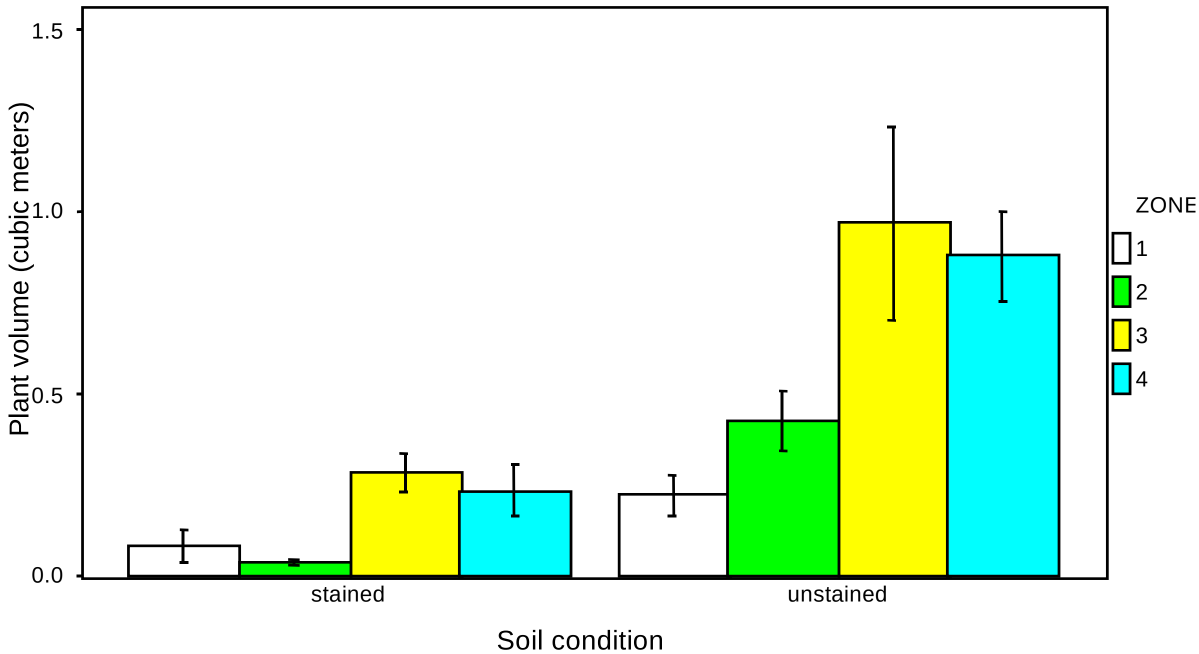


Figure 2–8. Mean volume measurements of 30 randomly selected plants from each zone growing in the stained or unstained area as identified in Figure 2–7.Error bars represent standard errors of the means. Data were log transformed before conducting a one-way ANOVA to determine the relationship between stained area and plant volume (F = 54.00, P < 0.0001).

Destructive plant sampling was conducted each year on 20 randomly selected plants (5 per zone, generally near a hydroport). See Figure 2–4 for the sampling scheme for year 2001. A similar schematic for year 2000 is reported in Glenn et al. 2000. All above-ground plant material was harvested and measured for dry weight and percent total Kjeldahl-nitrogen, total sulfur (2000 only), extractable nitrate-nitrogen, and extractable sulfur (2000 only). Similar data were collected for 0.25 m^2 (2000) and 1 m^2 (2001) quadrates of volunteer plants (mainly *Salsola iberica*), which grew in between plant rows, since these plants also removed soil nitrogen and therefore contributed to the overall phytoremediation. We pooled the volunteer data across all zones for statistical analysis because of the relatively small number of samples ($n \leq 5$) and high variability. These data are presented in Table 2–4 (see Appendix D).

Table 2–4. Average biomass, nitrogen and sulfur content of Atriplex and volunteer plants in the subpile soil phytoremediation plot for the 2000 and 2001 growing seasons. Biomass is per plant for Atriplex but per m^2 for volunteer plants. Chemical constituents are on a weight per kg of dry matter basis. Values are means and (standard errors). ND = not determined for 2001 growing season.

Variable/Plant type	*Atriplex* per plant		Volunteer Plants per m^2	
Growing Season	2000	2001	2000	2001
Plant biomass dry wt. (g)	128 (651)	643 (658)	251 (56)	26.8(7.8)
Nitrate-N (mg/kg)	665(59)	3,179 (2146)	2,906 (650)	5497(2138)
Total-N (mg/kg)	12,353 (1025)	19,900(6147)	14,875 (2036)	20,200(2555)
Sulfate-S (mg/kg)	774(78)	ND	1,724 (159)	ND
Total-S (mg/kg)	3,684 (289)	ND	3,475 (703)	ND

The estimated average *Atriplex* biomass yield after the second growing season was 1 t/ha/yr. This was lower than originally projected due to slow growth of plants in the stained area. For both years, volunteer plants *S. iberica* accumulated higher levels of nitrate-N and sulfate-S (2000 only) in the above ground tissue than *Atriplex*, but total plant levels of N and S were similar. After the second growing season, however, *Atriplex* tissues accumulated nitrate-N exceeding 1,000 ppm, which approaches levels of concern for use as a fodder. After both growing seasons, *Atriplex* accumulated roughly 51 kg total nitrogen in the above ground biomass. Volunteer plants contributed roughly 60 g in nitrogen uptake in the first year (2000), but due to limited establishment of *S. iberica* in the second year, nitrogen removal was only a 1/5 of what it was the year before. Below ground samples were not taken, but it is reasonable to assume that there was twice as much biomass below ground than above ground. Therefore, if we were to calculate for approximately 4,000 plants, *Atriplex* root biomass could have potentially contributed to 100 to 120 kg of nitrogen uptake from the soil.

2.4 Concentrations of Nitrate and Ammonia in Soil

Soils were sampled by mechanical auger at the end (September or October) of the 2000 and 2001 growing seasons, by collecting composite samples at 1 m increments from the soil surface to roughly 4 m depth depending on the physical limitations imposed by the presence or absence of bedrock. Holes were drilled at randomly chosen locations near each probe port (n = 20 per year, 5 samples per zone).

Results for both end-of-season sampling dates (2000 and 2001) are presented for ammonium-N (Table 2–5) and nitrate (NO_3)-N (Table 2–6, Appendix E). Nitrate-N concentrations were reduced significantly across all depths ($P < 0.001$) and zones (Figure 2–9) between September 2000 and September 2001. Mean nitrate concentrations for all samples taken during 2000 and 2001 were 164 mg/kg soil and 116 mg/kg, respectively. These values represent a 30 percent reduction in nitrate contamination over a 1-year period. The difference between years was significant at $P = 0.002$. The mean ammonium-N concentrations (across all zones and depths) for year 2000 and 2001 were 191 mg/kg and 168 mg/kg, respectively (Figure 2–10). This represents a 12 percent reduction over one growing season, but the between year difference in this case is not significant ($P = 0.28$).

Similar to what was observed for the previous year (2000), ammonium-N and nitrate-N concentrations were generally lower near the soil surface (mean < 20 ppm), increasing significantly with depth for year 2000 ($P < 0.05$) and only slightly in year 2001 (Tables 2–5 and 2–6).

Table 2–5. Concentrations of ammonia nitrogen in soil samples taken from the four zones at six depths of the Monument Valley Subpile Phytoremediation Plot for each year. Concentrations are expressed as ppm N. Standard errors of means are in parenthesis

Zone/Depth (m)	2000	2001	Number of Samples
Zone 1			
0.3	2.5 (1.2)	66.8 (53.5)	5
0.9	44.9 (45.5)	121.9 (62.1)	5
1.8	102.7 (93.2)	146.7 (109.1)	3
2.7	111.0 (104.0)	52.0 (47.5)	2
3.6	56.0	43.0	1
4.5	140	113.0	1
Zone 2			
0.3	8.2 (2.0)	55.3 (42.9)	5
0.9	155.2 (73.3)	110.8 (53.2)	5
1.8	329.6 (60.9)	200.2 (50.2)	5
2.7	287.0 (50.7)	226.1 (50.2)	4
3.6	310.0 (60.4)	255.3 (22.6)	3
4.5	360.0 (145.0)	349.5 (90.5)	2
Zone 3			
0.3	109.6 (87.0)	116.1 (91.6)	5
0.9	183.2 (113.6)	257.7 (87.5)	5
1.8	397.6 (70.1)	258.9 (72.9)	5
2.7	340.4 (49.2)	360.3 (48.9)	5
3.6	431.2 (69.2)	380.3 (45.2)	5, 4
4.5	432.0 (105.0)	206.8 (84.2)	4, 3
Zone 4			
0.3	4.8 (1.2)	19.2 (5.0)	5
0.9	11.4 (9.6)	19.9 (10.1)	5
1.8	90.5 (54.3)	94.1 (79.9)	5
2.7	316.8 (167.0)	114.4 (100.8)	5
3.6	203.0 (118.8)	206.1 (103.6)	5
4.5	159.4 (103.7)	230.0 (90.4)	5, 4
Average	**191**	**168**	

Table 2–6. Concentrations of nitrate nitrogen in soil samples taken from the four zones at six depths of the Monument Valley Subpile Phytoremediation Plot. Depths are in meters. Concentrations are expressed as ppm N. Standard error of means are in parenthesis.

Zone/Depth (m)	2000	2001	Number of Samples
Zone 1			
0.3	71.8 (37.6)	100.8 (41.1)	5
0.9	90.6 (25.2)	31.2 (10.5)	5
1.8	186.7 (73.9)	52.0 (21.1)	3
2.7	218.0 (103.0)	77.5 (60.5)	2
3.6	235.0	23.0	1
4.5	302.0	46.0	1
Zone 2			
0.3	92.6 (35.5)	112.6 (58.2)	5
0.9	154.4 (42.0)	44.0 (13.2)	5
1.8	111.2 (33.4)	69.8(34.3)	5
2.7	67.8 (24.6)	113.3 (35.8)	4
3.6	77.0 (31.9)	90.7 (73.3)	3
4.5	113.0 (12.0)	133.5 (35.5)	2
Zone 3			
0.3	126.0 (34.3)	95.0(30.1)	5
0.9	276.5 (141.1)	116.0 (52.2)	5
1.8	213.2 (64.4)	146.2(58.2)	5
2.7	180.4 (65.3)	119.0 (53.6)	5
3.6	123.6 (35.7)	95.7 (27.9)	5, 4
4.5	170.3 (28.8)	164.7(108.8)	4, 3
Zone 4			
0.3	62.0 (13.8)	131.8 (40.9)	5
0.9	217.8 (138.4)	181.8(81.6)	5
1.8	173.4 (70.9)	170.8 (43.8)	5
2.7	286.6 (85.4)	185.6(55.6)	5
3.6	227.0 (118.8)	166.8(27.5)	5
4.5	322.6 (106.1)	240.8 (20.3)	5, 4
Average	**164**	**116**	

Control samples were taken each year (2000 and 2001) outside of the field in accordance with the initial radial samples (Figure 2–1): 0° 61 m, 0° 91.4 m and 380° 61 m. No significant differences between years was observed for ammonia-N (Table 2–7, Appendix E; $P > 0.05$) or nitrate-N (Table 2–8; $P > 0.05$) concentrations at all depths.

Table 2–7. Concentrations of ammonia nitrogen in soil samples collected at 4 former sampling sites outside the plot that previously had low levels of contamination. Depths are in meters. Concentrations are expressed as ppm N.

Sample	0° 61 m		0° 91.4 m		45° 61 m		308° 61 m	
Depth	2000	2001	2000	2001	2000	2001	2000	2001
0.3	4	NA	7	NA	10	NA	0.6	NA
0.9	0.8	5	3	3	0.7	NA	0.8	5
1.8	0.7	4	2	4	0.6	NA	1	5
2.7	0.5	5	2	4	0.8	NA	0.8	4
3.6	12	19	1	3	0.7	NA	1.5	14
4.5	55	80	2	3	0.6	NA	NA	42

Table 2–8. Concentrations of nitrate nitrogen in soil samples collected at 4 former sampling sites outside the plot that previously had low levels of contamination. Depths are in meters. Concentrations are expressed as ppm N.

Sample	**0° 61 m**		**0° 91.4 m**		**45° 61 m**		**308° 61 m**	
Depth	2000	2001	2000	2001	2000	2001	2000	2001
0.3	32	NA	19	NA	13	NA	12	NA
0.9	25	15	12	179	16	NA	8	9
1.8	23	26	13	209	14	NA	28	8
2.7	28	109	10	10	14	NA	14	6
3.6	37	19	11	9	9	NA	12	11
4.5	98	28	8	10	11	NA	NA	15

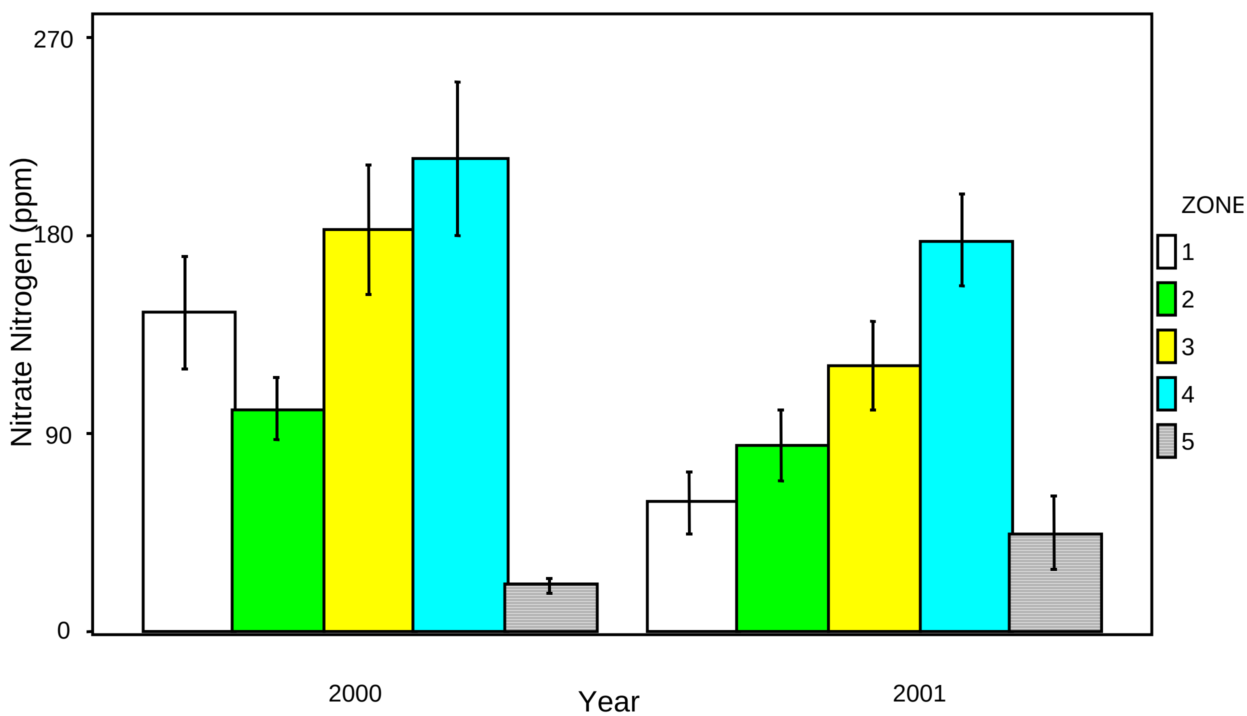


Figure 2–9. Mean soil nitrate concentrations across all depths for each zone over year 2000 and 2001. Zone 5 represents the mean across all depths for the 4 control samples taken outside of the field (see Table 2–8 for details). Error bars represent standard errors of the means.

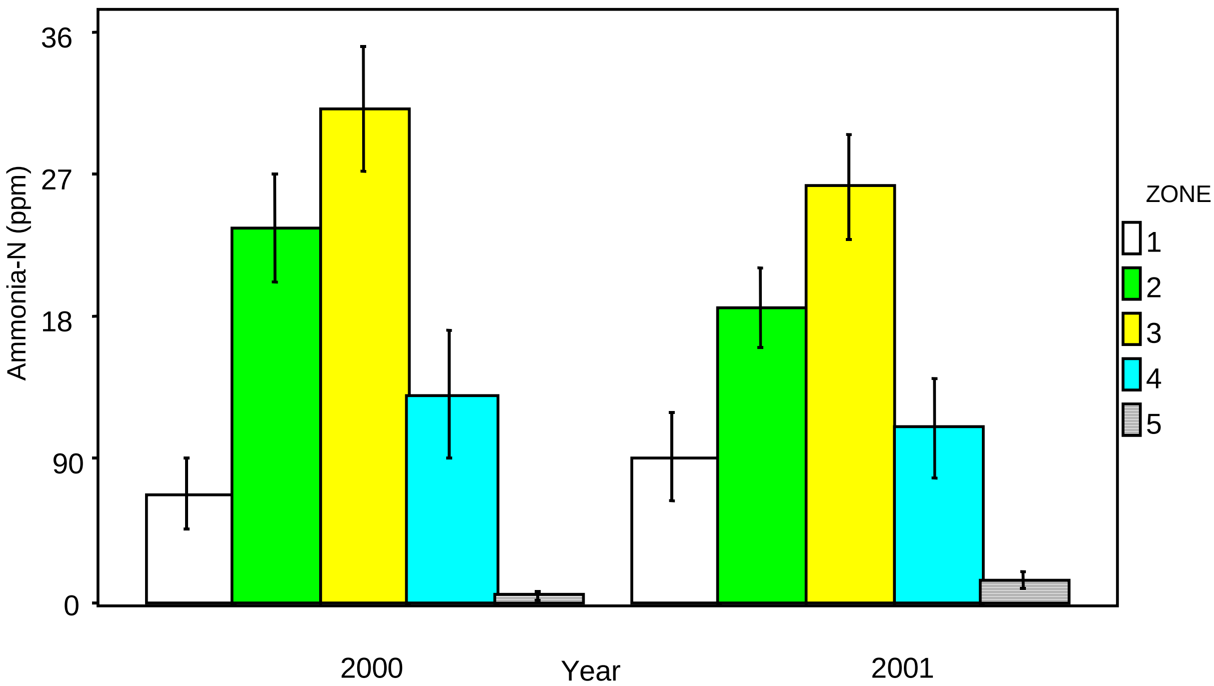


Figure 2–10. Mean soil ammonia concentrations across all depths for each zone over year 2000 and 2001. Zone 5 represents the mean across all depths for the 4 control samples taken outside of the field (see Table 2–8 for details). Error bars represent standard errors of the means.

The significant loss of nitrate-N over the entire 1.6 ha field over the course of the second growing season brought up some concerns as to the accuracy of the data obtained from Laboratory Consultants, LTD. In order to verify the results from Laboratory Consultants, we randomly selected 11 samples (different wells and depths) to test for nitrate levels by another method, the Hach Nitrate Kit. A standard curve was developed for the kit based on known concentrations of $NaNO_3$. Using the Hach kit, we were able to detect 0-15 ppm with reasonable accuracy. Ten gram soil subsamples were extracted with 0.1g $CaSO_4$ and 20 ml of double distilled water. The slurries were shaken vigorously for one minute prior to filtration on Whatman 40 filter paper. The extractant was stored overnight at 4^oC and a colorimetric Cd reduction assay was performed as described by the manufacture for the NitraVer 5 powder pillows. To our knowledge, Laboratory Consultants (LC) performed a similar 2:1 extraction procedure, using $AlSO_4$, but read nitrate-nitrogen concentrations in the extractant with an anion selective electrode for nitrate.

Statistical (Paired t-test and Pearson's correlation) analysis indicated no significant difference between the means reported by LC and those obtained at the laboratory for the year 2000 and 2001 samples, confirming a significant loss in soil NO_3-nitrogen.

2.5 Chemical Properties of Stained and Unstained Soils

Soils in the stained and unstained areas were sampled and analyzed in an to attempt to determine the cause of poor growth. The concentrations of nitrate-N and ammonium-N were averaged across depths for the hydroports inside and outside of the stained area (see Figure 2–7 to identify the well locations). ANOVA indicated no significant difference between ammonium-N and nitrate-N concentrations for soil samples taken inside versus outside the stain. Additionally, surface soil was sampled at three locations in an attempt to determine the cause of the relatively poor plant growth in the stained area. Three composite soil samples were taken: one from the stained area; another from inside the fence, an area that supported good plant growth; and the third sample was taken from outside the fence in a sandy area that was bladed during the original site remediation effort. All samples were analyzed for U.S. Environmental Protection Agency (EPA) metals of concern in addition to other soil properties (see Chapter 4), to determine if the factors responsible for reduced plant growth could be identified. Samples were also analyzed for ammonia and nitrate using 1:100 soil:water extracts and the Hach Ammonia and Nitrate Test Kits. The soil inside the fenceline differed from soil outside the fence in having higher levels of metals, but, based on these samples, there was no obvious difference between soils in the stained area where plant growth is poor and the unstained area inside the fence where growth is satisfactory.

The Environmental Sciences Laboratory in Grand Junction collected and analyzed soils from areas where *Atriplex* shrubs are thriving and from stained areas where the shrubs are growing poorly (DOE 2001). In each area, composite samples were collected from the surface and also from a depth of 5 to 15 cm below the surface. Soil sampled were first leached with 18 megaohm deionized water, and the remaining solid was leached with 5-percent hydrochloric acid. Concentrations of calcium, copper, iron, magnesium, manganese, nitrate, phosphate, potassium, sodium, strontium, uranium, vanadium, and zinc were determined on the water-leached and the acid-leached fractions. Measurements of alkalinity, chloride, silica, sulfate, total dissolved solids, and total inorganic carbon were made only on the water-leached fraction.

The results suggest that the stunted growth of *Atriplex* shrubs may be due to the combined effects of both an excess and a deficiency of ions. Concentrations of calcium, magnesium, strontium, and vanadium were higher in the soil samples collected from the stained area with stunted *Atriplex* than in areas where the shrubs are thriving. Iron, manganese, phosphate, potassium, sodium, and uranium concentrations were significantly lower in the area with stunted *Atriplex* than in areas with thriving *Atriplex*. Greenhouse studies were conducted at the Environmental Research Laboratory in Tucson to determine the best management practice for the stained area. These results are presented later in Chapter 4. We note, however, that plants grew significantly in all zones between 2000 and 2001 growing seasons, and some plants have become quite large even within the stained area. Apparently, once *Atriplex* plants root through the upper 20 cm of the soil profile, growth accelerates to near normal rates. In an attempt to further delineate the cause of the growth limitations in the stained area, and to test whether a soil amendment with mulch or fertilizer would help improve growth, a greenhouse study was conducted (Chapter 4). The greenhouse study identifies ways to significantly improve *Atriplex* growth in Zones 1 and 2. Implementation of this strategy should result in improved biomass yields and a more successful phytoremediation effort on the subpile soil.

2.6 Irrigation Volumes and Moisture Content of Subpile Soil

The irrigation system was tested in June 2000 by collecting water from 20 emitters per zone over an irrigation cycle (Table 2–9, Appendix F). Irrigation rates varied from 2.5-4.6 liter/hr because the original jet pump was not able to fully pressurize irrigation lines in the upper zones. The jet pump was replaced in September 2000, and the system now performs more uniformly. Using meter readings from a flow gauge connected to the irrigation line, we calculated the average irrigation volume across all zones at 8.08 liters/plant/day (standard error = 0.60) (see Appendix G), from April 5 to October 25, 2000. A total of 6,485 m^3 of water was applied over the 2000 growing season, equal to a depth of 0.36 m for that irrigation season. Approximately the same amount of water was applied in 2001 irrigation season (5201 m^3), or the equivalent of 0.325 m over the entire 1.6 ha field. These are relatively low application rates, less than potential evapotranspiration (see Section 2.7).

Table 2–9. Test of irrigation application rates, June 2000. Each datum is the mean of 20 emitters randomly selected within each zone

Zone	Mean Application Rate(liters/hr)	Standard Error
1	2.50	0.27
2	4.59	0.44
3	3.64	0.42
4	4.36	0.37

Soil moisture levels were determined monthly at 0.17 m intervals from 0-4.5 m depth in 20 hydroprobe ports within the subpile planting (Figure 2–4) using a Campbell Nuclear Neutron Probe. Neutron thermalization (NT) gauges consist of a probe containing a source of high-energy neutrons and a detector for slow neutrons, a cable to lower the probe down access tubes, a probe housing with lead and polyethylene shields to absorb gamma rays and neutrons, respectively, and a scalar for displaying slow neutron counts. High-energy neutrons released from an americium-beryllium source in the probe are scattered and slowed (thermalized) by elastic collisions with hydrogen nuclei in the soil water. The slow neutrons interact with gases in the probe detector, releasing an alpha particle, which causes an electric pulse recorded as a count in the scaling unit (Gardner 1986). The volume of soil measured by the probe varies depending on the concentration of hydrogen nuclei, and thus, primarily, on soil water content. Since the development of NT methods (Gardner and Kirkham 1952; Van Bavel et al. 1956), advances in electronics, and the use of less radioactive sources have improved efficiency, portability, safety, and precision. The standard error of estimated soil water content is often less than 0.01 cubic centimeters (cm^3) water per cm^3 dry soil (Gardner 1986). Details concerning the theory and operation of NT gauges can be found elsewhere (Greacen 1981; Gardner 1986).

The NT probe was calibrated with sandy soil obtained from the site in a 200-liter drum at the Environmental Research Laboratory. A PVC probe port identical to the ports at the site was centered in the drum. The drum was filled to within 40 cm of the top with soil compacted to 1.59 g/cm^3. Neutron probe measurements and soil samples for gravimetric analysis were obtained for air-dried soil and soil saturated and then drained to near field capacity (saturated and then allowed to drain for 24 hours). Raw counts were used to develop a calibration curve. Linear regression analysis of the curve allowed for a conversion factor of g moisture per cm^3 dry soil ($y = 0.0000193x - 0.0181$) where y equals soil moisture in g/cm^3 and x is counts per minute. Complete saturation of this sandy soil occurred at a moisture content of approximately 0.24 g/cm^3.

A box and whisker plot of field moisture measurements for all months of year 2001 is presented for all ports at all depths in Figure 2–11 (see Appendix H). Soil moisture patterns were virtually identical for year 2000 (data not shown). The soil was driest near the surface and increased to approximately 0.10 g/cm^3 (42 percent of saturation) at greater depths (Figure 2–12, Appendix H). Saturation occurred in two probe ports at the 5 m soil depth; moisture contents in these ports have varied little since their installation. For both years, soil moisture levels varied significantly by sampling date, depth, and zone (P<0.05),. However, mean soil moisture content was consistently less than 50 percent of saturation across depths, zones, and months. Even so, given the seasonally fluctuating soil moisture content at all depths, these data were inadequate to evaluate whether recharge and leaching of subpile nitrogen is occurring. To test the hypothesis that evapotranspiration from the *Atriplex* planting is limiting recharge and leaching of nitrogen into the alluvial aquifer, we installed instrumentation for direct measurement of soil moisture flux (see Section 2.7).

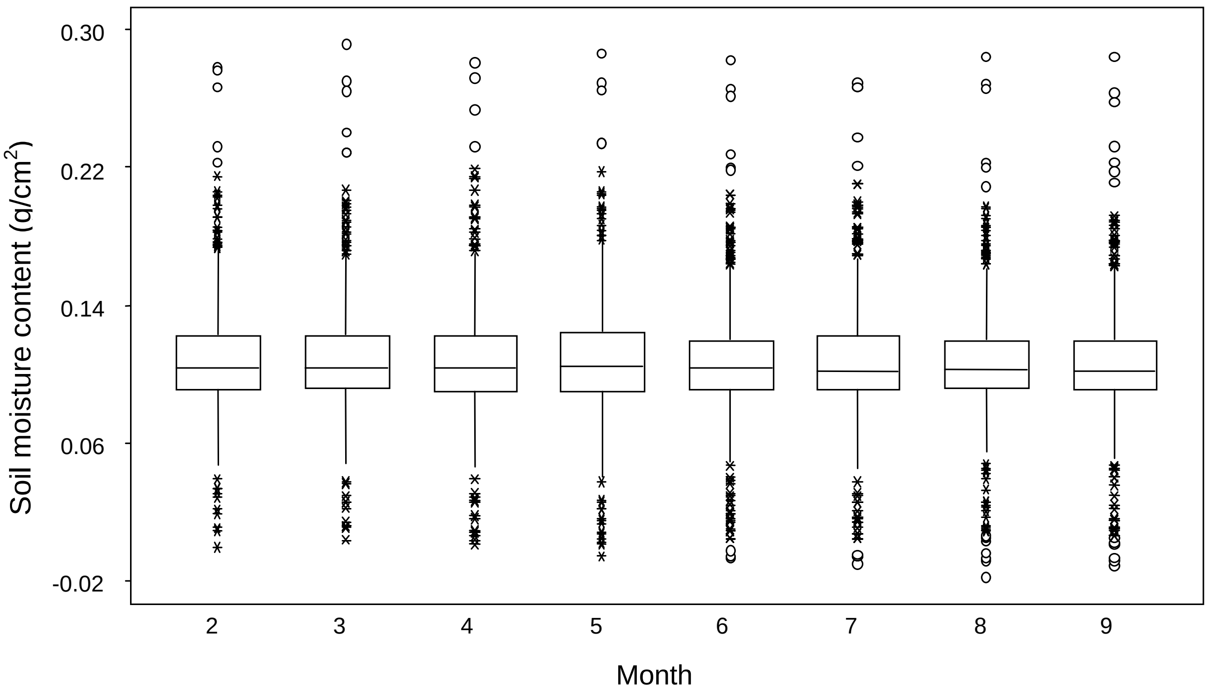
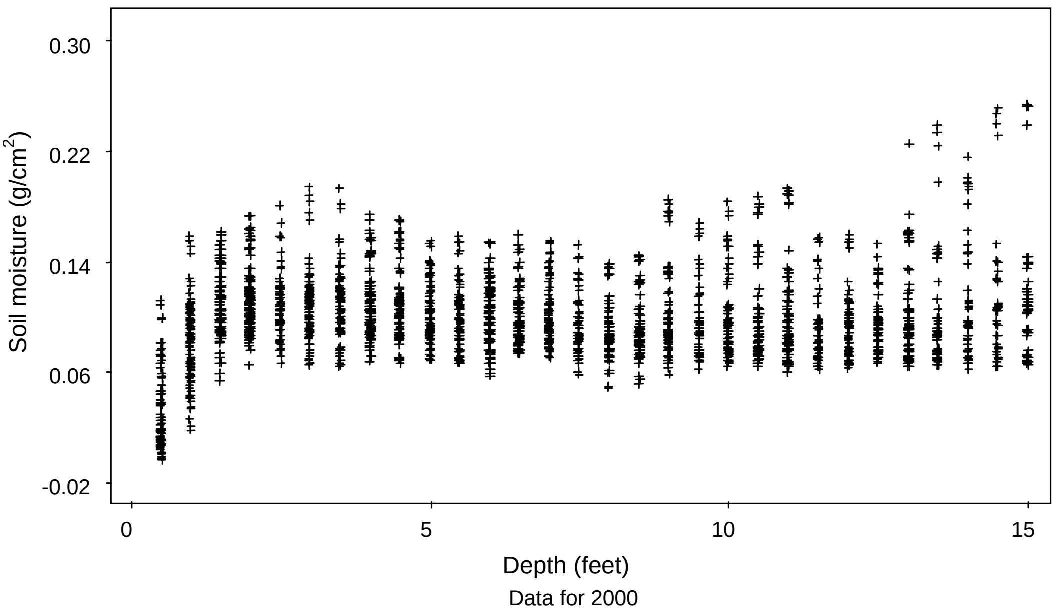


Figure 2–11. Box and Whisker plots of Soil Moisture Measurements Across all Zones and all Depths for February through September in the Year 2001. The box is bisected by a line at the value for the median. The vertical lines are “whiskers” indicating typical data values. Extreme outlines are “” for possible outliers 1 1/2 times the box size, and “0” for probable outliers, 3 times the size of the box.*



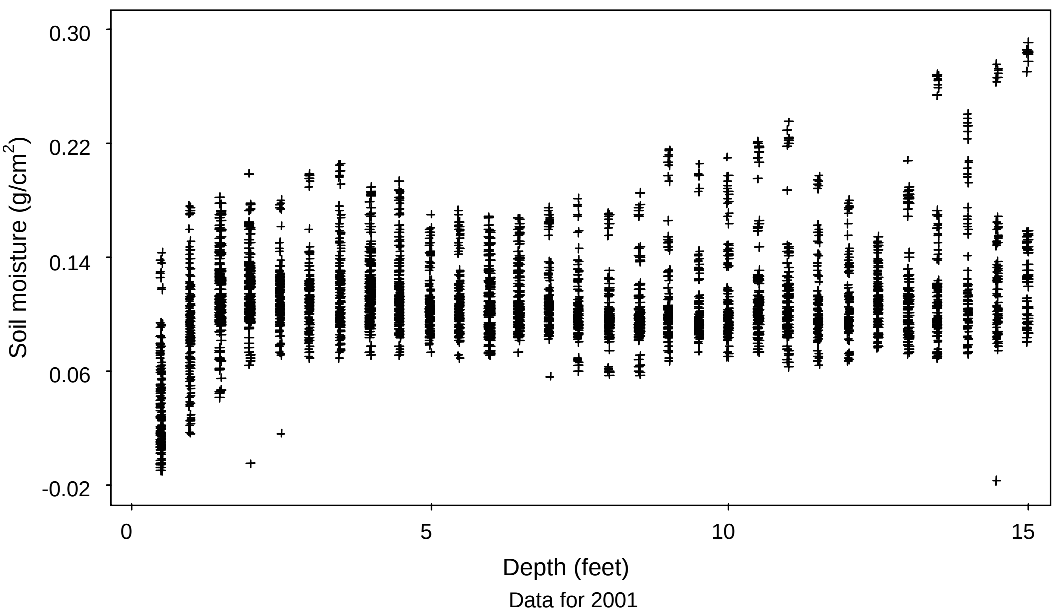


Figure 2–12. Soil Moisture Measurements Across all Zones and all Months at Each Depth for the Years 2000 and 2001

2.7 Recharge and Potential Evapotranspiration

In March 2001, instrumentation was installed within the subpile soil phytoremediation planting at Monument Valley for real-time monitoring of several parameters of the soil water balance. The primary purpose of the installation was to directly measure recharge, or water flux, from the lower root zone of *Atriplex*. In other words, our purpose was to determine whether the phytoremediation planting has contained the source of the alluvial plume. Measurements of other parameters in the soil water balance (precipitation, evapotranspiration, and change in water storage) provide indirect evidence of the performance of the planting and are of secondary importance. Measurement or estimation of the complete soil water balance can be input to predictive models of recharge, such as UNSAT-H (Fayer and Jones 1990). If verified using field data, soil water balance models can be used to evaluate performance over a range of scenarios. For example, a verified UNSAT-H simulation could estimate how much recharge would occur if actual precipitation were twice the annual average.

2.7.1 Monitoring Methods and Instrumentation

Direct measurement of all terms of the water balance (precipitation, evapotranspiration, recharge, and change in water storage) is not possible. At Monument Valley, precipitation, drainage, and water storage changes are monitored, and actual evapotranspiration (*AET*) is estimated by difference. Potential ET (*PET*) is estimated by calculation of the energy budget (Penman-Montieth equation) using the field parameters of wind speed, relative humidity, solar radiation, and air temperature (see Campbell Scientific, Inc., 1996).

Soil Profile Drainage or Recharge

Instrumentation installed within the subpile planting allows for two approaches for monitoring drainage. The first is an interpretation of the soil moisture content data monitored with neutron thermalization (Section 2.6) and water content reflectometers (described below). If moisture content values in the lower depths of the profile remain well below saturation and also remain relatively constant, we can infer that saturated flow is not occurring and any water flux would be unsaturated flow. This type of inference is possible because the homogeneity of the fine sandy soil profile allows us to assume a unit gradient. However, seasonal variability in NT measurements at 3 to 5 meter depths (Figure 2–12) leaves the question of recharge unanswered. The second approach is a direct measurement of water flux. Water flux meters designed by Pacific Northwest National Laboratory (PNNL) were installed within the subpile planting to provide direct measurements of water flux or recharge (Gee et al. in press). There are presently no commercially available sensors that directly measure water flux in unsaturated media.

The PNNL flux meter, or wicking lysimeter, is basically a passive wick system with a miniature tipping-bucket (Figure 2–13). It concentrates flow into a narrow sensing region filled with a fiberglass wick of known hydraulic properties. The wick applies suction, proportional to its length, and passively drains the meter. Water flux through the meter is measured with a self-calibrating tipping bucket, with a sensitivity of 4 mL/tip. PNNL field trials have shown that the passive wick system works well as long as the soil hydraulic properties of the material in the funnel are compatible with the material on the outside of the funnel. PNNL has encountered problems when the native soil is a clay or clay loam, has a low permeability, and flow through the funnel is retarded causing lateral flow divergence. Flow divergence typically does not occur in sandy soils as are found at the Monument Valley site.

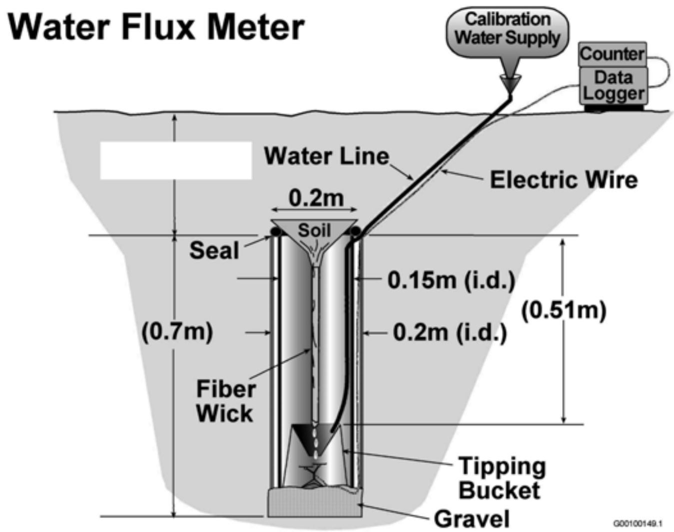


Figure 2–13. Schematic of the PNNL Water Flux Meter (Gee et al. in press)

PNNL water flux meters (WFMs) were placed at approximately 3 meters depth at three locations, two within the subpile planting adjacent to NT probe ports EM5 and WM5 (Figure 2–4), and the third in a denuded area north of the planting. Three and a half meter deep holes, 25 cm in diameter, were augered at each location. One-meter-tall “stovepipes” were attached to each WFM to prevent lateral moisture divergence at the top of the funnel. A ¾ inch PVC pipe, 3 meters long, was attached to the WFM and wiring and a moisture calibration tube were threaded through this pipe. After WFMs were lowered into the holes, excavated soil was compacted back into the holes. Fifty milliters of water was then added to each calibration line; all tipping bucket gauges registered tips.

Six Campbell Scientific CS-615 Water Content Reflectometers (WCRs) were installed above each WFM (Campbell 1996). WCRs consists of two, 30-cm long parallel rods attached to an electronic signal generator. A pulsed wavelength traveling down a coax, or waveguide, is influenced by the type of material surrounding the conductors. If the dielectric constant of the material is high, the signal propagates slower. Because the dielectric constant of water is much higher than most other materials, a signal within a wet or moist medium propagates slower than in the same medium when dry. The reflectometer measures the effective dielectric as a pulse transit time, which in turn is calibrated against water content. Changes in soil moisture are determined by reading the WCR probes hourly. WCRs were installed vertically with parallel rods placed within the following depth intervals: 213-243 cm, 153-183 cm, 92-122 cm, 61-91 cm, 30-60 cm, and 0-30 cm. Two WCRs were placed at the 213-243 cm depth, one inside and one outside the “stovepipe”. All WCR and tipping bucket leads were threaded through 1 ½ inch PVC conduit leading to a single CR23X datalogger which was also used for a weather station.

Soil water storage (*S*) is calculated from WCR measurements of soil water content θ using a modification (Waugh et al. 1994) of the trapezoidal approximation by Green et al. (1986) as follows:

$$S \approx \theta_1 z_1 + \sum_{i=2}^{n} \left[(\theta_{i-1} + \theta_i)/2 \right] \left(z_i - z_{i-1} \right)$$

where θ_1 and z_1 are the water content and depth for the uppermost measurement, θ_I is the volumetric water content measurement at the *i*th point in the soil profile, z_i is the depth of the *i*th point in the profile, and *n* is the total number of points.

Meteorological Conditions

A weather station was installed to monitor meteorological conditions. A Campbell Scientific weather station was installed because it provides the flexibility to easily change sensor configurations, data processing, and data storage and retrieval options. The meteorological equipment was mounted on a 10-ft high corrosion resistant tripod that provides support for sensors, solar panels, and enclosures. The tripod assembly was anchored in concrete within the subpile soil planting. The weather stations was configured to provide data for the following parameters:

Wind Speed:	cup anemometer
Wind Direction:	vanes that use precision potentiometer
Solar Radiation:	thermopile pyranometer
Air Temperature:	platinum resistance temperature detector
Relative Humidity:	capacity sensors that use integral signal conditioning
Precipitation:	tipping bucket rain gauge

The weather station uses a programmable CR23X Campbell Scientific data logger that measures sensors and stores data. Sensory measurements are stored hourly and daily. Conditional outputs, such as rainfall intensity, are also processed and stored. The power supply consists of a sealed rechargeable battery, which is recharged by a solar panel. The data logger, power supply, and data retrieval peripherals are housed in an environmental enclosure which reduces internal temperature extremes by reflecting solar radiation.

2.7.2 Recharge and PET Results

PNNL water flux meters were installed both within the subpile soil phytotemediation planting and in a denuded area just north of the planting consisting of the same soil series. These instruments were installed to test the hypothesis that the *Atriplex* planting is not only extracting ammonium and nitrate from the subpile soil, but also transpiring enough water to prevent recharge to the plume. The purpose of the planting is to both isolate and remediate the nitrate source. The two water flux meters placed within the planted area near NT probe ports EM5 and WM5 have registered zero recharge since they were installed, March 6, 2001. In contrast, a cumulative total drainage of 3.75 cm was recorded with the water flux meter placed outside the planting. We attribute the difference to transpiration.

The datalogger was programmed to calculated potential evapotranspiration (PET) on a daily basis using the Penman-Montieth energy budget equation (see Campbell Scientific, Inc. 1996). The calculation uses daily values of wind speed, relative humidity, solar radiation, and air temperature recorded with the weather station. Daily PET was then averaged by month for the 2001 growing season. Mean daily PET varied seasonally from 2.2 mm in March, increasing to a high of 9.0 mm in July, dropping to 6.5 mm in September, and then back to 2.1 mm in November. These high values indicate that PET exceeds the sum of precipitation and irrigation. The sum of irrigation (~325 mm) and precipitation (~105 mm) is only about 30 percent of the calculated cumulative PET (~1,400 mm) for the 2001-2002 growing season (March through November). These data corroborate the water flux meter results; a healthy stand of *Atriplex* should have no trouble curtailing recharge through the subpile soils. In contrast, recharge occurs when the fine sandy soil is denuded. Excessive grazing may likewise cause recharge at Monument Valley.

2.8 Rates of Nitrogen Removal from the Subpile Soil

Unfortunately, the nitrate and ammonia data collected in years 2000 and 2001 cannot be directly compared to initial samples, as the sampling protocol differed from those taken in the initial 1997 study. Additionally, the initial samples were analyzed in-house with Hach Test Kits, which are based on a colorimetric assay for the reduction of Cd. We were, however, able to calculate a N- balance for the concentration difference in nitrate and ammonium between year 2000 and 2001 using the mean ammonium-N and nitrate-N concentrations determined across all depths and all zones (Tables 2–5 and 2–6):

$$\text{Soil mass} = 16{,}000\ \text{m}^2 \times 4\ \text{m depth} \times 1{,}590\ \text{kg/m}^3 = 101{,}760{,}000\text{kg} \quad (2–1)$$

$$\text{ammonium-N loss} = 101{,}760{,}000\ \text{kg} \times 0.000027\ \text{kg/kg} = 2748\ \text{kg} \quad (2–2)$$

$$\text{nitrate-N loss} = 101{,}760{,}000\ \text{kg} \times 0.000048\ \text{kg/kg} = 4884\ \text{kg} \quad (2–3)$$

$$\text{Total loss between 2000 and 2001} = 2748\ \text{kg} + 4884\ \text{kg} = 7632\ \text{kg} \quad (2–4)$$

This rate is equal to 4770 kg/ha/yr or 0.21mg N/kg soil /day

As mentioned previously (Section 2.3), we can account for roughly 3.5 percent (170 kg) of the total loss in soil nitrogen in the plant biomass (both above and below ground), leaving 96.5 percent unaccounted for. Soil moisture and water flux measurements (see Sections 2.6 and 2.7) indicate that it is highly unlikely that missing nitrogen has migrated below the 5 meter sampling depth. The two possibilities that remain are: (1) loss of nitrate to denitrification and (2) conversion of nitrate to microbial biomass.

We have proposed to follow up on these findings to determine the microbial processes responsible for high nitrogen loss from this plot.

2.9 Conclusions and Recommendations

About half the plants (those in Zones 2 and 4) are growing normally. These should mature within 3 to 4 years. In Zones 1 and 3, survival is high but growth has been slow. Phytoremediation will be more effective if the cause of the slow growth can be discovered and corrected. The poor growth may be related to either an excess or a deficiency of mineral constituents. Concentrations of calcium, magnesium, strontium, and vanadium were significantly higher, and phosphorous, potassium and sodium were significantly lower, in poor growth areas. It is possible that application of mulch and fertilizer will make these areas productive (see Chapter 4). We recommend amending the plantings in the stained area with 4 liters each of organic matter enriched with phosphorous fertilizer to enable the plants to overcome the growth inhibition more quickly.

The high rate of nitrate loss from this soil was unexpected. Since it did not occur in the control (unirrigated) areas, it appears to be a result of irrigation. Since it proceeded about the same in the stained and unstained areas, it does not seem to depend upon plant growth, which in any case was too low to account for the rapid nitrogen loss from the soil. Dentrification and conversion to microbial N are both reasonable possibilities to account for the nitrate loss.

The rate of nitrate loss from this soil is within the range of values of denitrification reported for fertilized soils at field capacity in other studies, when results are expressed on a soil weight basis (Sanchez et al. 2001). What is unusual is the rate when expressed on a per ha basis. Denitrification rates vary significantly for most agricultural soils ranging from 0 to 438 kg/ha/yr with a mean value 167 kg/ha/yr (Sanchez et al. 2001; Loro et al. 1997; Marshall et al. 1999; Hoffman et al. 2000; Luo et al. 2000), whereas our plot lost approximately ten times as much as the highest of those estimates. The difference can be accounted for by soil depth. Denitrification in agricultural soils is usually calculated assuming a shallow soil depth, (10-50 cm) representing the plow depth (Sanchez et al. 2000). By contrast, our soil showed nitrate loss throughout the profile, to a mean depth of 4.1 m. Conversion of nitrate to microbial (organic) N throughout this depth would also sequester large amounts of N, which would not be expected to mineralize back to nitrate.

The results are of interest in considering what to do about the plume water. If this water is returned to the surface and used for irrigation, it can be assumed that denitrification will occur in irrigated plots similar to what happened in the subpile soil plot. At a denitrification rate of 4884 kg-N/ha/yr (2-4), loss of nitrate would be 21,490 kg and phytoremediation of the plume nitrate could take place in relatively few years, rather than the 25 years projected on the basis of plant uptake alone (see Chapter 3 calculations). However, the rate at which the plume water can be remediated is also dependent on the rate at which water can be recovered from the aquifer. Further investigation of the nitrate losses from the subpile soil area is warranted.

Soil water content and water flux monitoring results (see Sections 2.6 and 2.7) indicate that evapotranpsiration from the *Atriplex* planting prevents recharge of precipitation and irrigation water through the subpile soils–the phytoremediation planting also functions as an evapotranspiration cover. In contrast, water flux data show that recharge is occurring through denuded soil outside the planting. Soil sampling results (see Section 2.1) show that nitrate levels are elevated over a large area outside the current planting, therefore, leaching of nitrate to the alluvial aquifer is probably occurring in denuded areas. We recommend either extending the irrigated, subpile phytoremediation over denuded areas with elevated nitrate, or, at a minimum, reseed denuded areas in an effort to control recharge, to better contain the alluvial plume source.

3.0 Studies on the Potential for Passive Phytoremediation

3.1 Summary

Field, greenhouse, and laboratory experiments were conducted to determine the feasibility of using native plants to remove nitrates from the contamination plume at the Monument Valley, Arizona, UMTRA site. The rangeland over the contamination plume is dominated by two phreatophytic, native shrubs, *Atriplex canescens* (*Atriplex*) and *Sarcobatus vermiculatus* (*Sarcobatus*). We measured stable isotope signatures (δD and $\delta^{18}O$) in samples of water from rain, soils, wells, and plant material collected from the site, and conducted a control experiment in a greenhouse in Tucson, Arizona, to determine if plants were fractionating isotopes. The isotope signatures suggest that *Sarcobatus* and *Atriplex* are extracting water from the subsurface plume. Examination of the nitrogen isotope signatures in the plants and wells would be necessary to confirm the extent to which they are extracting nitrogen from the plume.

We surveyed the percent cover of *Atriplex* and *Sarcobatus* over the plume. Due to heavy grazing pressure, most of the area has <5 percent plant cover at present. However, exclosure studies in which *Atriplex* and *Sarcobatus* shrubs were fenced to exclude grazing, showed that plants rapidly increase in ground cover and volume when protected. Hence, extraction of water and nitrate from the plume could be enhanced by controlling grazing. Based on areas of maximum density of *Atriplex* and *Sarcobatus*, we projected that the area over the plume could reach 25 percent to 35 percent plant cover if the range was fenced. We also found that *Atriplex* transplants grew rapidly and rooted into the aquifer within 3 years, even though they were only irrigated during the first growing season.

Assuming *Atriplex* and *Sarcobatus* are rooted into the aquifer and are using nitrate from the plume, we calculated extraction rates based on annual biomass productivity, percent plant cover and nitrogen content of the plant tissues. Under current conditions, less than 40 kg nitrate per hectare per year are removed over most of the plume, whereas if grazing were controlled, as much as 400 kg per hectare per year could be removed. Approximate estimates of the amount of nitrate in the plume were compared with projected nitrate removal rates under different land management scenarios. Under current conditions an estimated 250 years would be required for passive phytoremediation to remove the plume nitrate, whereas combinations of passive phytoremediation and control of grazing could reduce the time to 20 to 50 years, depending upon which management strategy is adopted.

Further work is needed to confirm that the native shrubs are actively removing nitrate and to test the assumption that controlling grazing would, indeed, lead to high plant cover over the plume. Furthermore, the apparent rapid loss of nitrate from irrigated soils, noted in Chapter 2, if confirmed, may have implications for rates of passive phytoremediation of the nitrate plume.

3.1.1 Introduction

The Monument Valley Uranium Mill Tailings Remedial Action (UMTRA) Project site in northeastern Arizona is the location of a former uranium mill. Ground water beneath the mill site was contaminated by milling operations from 1955 through 1968. As detailed in the *Final Site Observational Work Plan for the UMTRA Project Site at Monument Valley, Arizona* (DOE 1999), a plume of shallow ground water moving north of the site, contains nitrate in excess of the EPA and DOE maximum concentration limit of 44.0 mg/L. Although sulfate levels are also elevated, nitrate is the main contaminant of concern at this site.

Earlier site work (DOE 1999), detailed the surface and subsurface conditions at this site, and made the observation that the native vegetation could conceivably intercept and remove at least part of the nitrate from the contamination plume. This was termed “passive phytoremediation” because no active pumping and treating of the plume would be necessary for this alternative. Two Chenopod shrubs dominate the rangeland over the plume: *Sarcobatus* and *Atriplex*. *Sarcobatus* is considered an obligate phreatophyte, meaning that it requires a subsurface aquifer as a source of water; while *Atriplex* is considered a facultative phreatophyte, able to use either ground water or water from the unsaturated zone. Both plants may be rooting into the plume water. A third Chenopod shrub, *Atriplex confertifolia*, is also present over the plume. Though smaller than *Atriplex* or *Sarcobatus*, it may also be rooted into shallower portions of the plume.

We investigated a possible role for passive phytoremediation for the Monument Valley site between 1998-2001, during which time we collected 3 years of field, greenhouse, and laboratory data. Our research addressed the following questions:

1) Are *Sarcobatus* and *Atriplex* actually rooted into the contamination plume;

2) If so, what are the removal rates of water and nitrate by these plants under current conditions;

3) What removal rates could be achieved by restricting grazing and replanting some areas, to enhance productivity over the plume.

These questions were addressed as follows:

1) We applied a stable isotope method to determine the source of water used by plants over the plume. We determined the stable isotope signature of water from rain, the alluvial aquifer, vadose zone soils, and plant tissues from the site, and conducted control studies in a greenhouse.

2) To evaluate the current condition of the range, we determined the percent cover and distribution of species of plants over a 20 ha representative portion of the plume, using aerial and ground survey methods. We also measured annual biomass production, nitrogen content and growth of *Sarcobatus* and *Atriplex* shrubs growing over the plume, to determine current nitrate and water extraction rates.

3) To project extraction rates under enhanced conditions, we compared the growth and nitrogen content of *Sarcobatus* and *Atriplex* shrubs growing under grazed conditions with shrubs that were fenced to keep out grazing animals for 3 years. We also investigated the feasibility of establishing new plants using transplants of *Atriplex* and *Sarcobatus*, planted into the soil over the plume. Finally, we determined the amount of natural regrowth that has occurred within the fenced portion of the Monument Valley site.

The following sections detail the Materials and Methods, Results and Conclusions of the passive phytoremediation studies at Monument Valley. These studies support the likelihood that *Atriplex* and *Sarcobatus* utilize mainly plume water for growth. Nitrate removal rates by these plants over the plume is low at present, due to heavy grazing and poor plant cover, but could be increased to significant levels (in comparison to how much nitrate is believed to be stored in the plume) if grazing were restricted. We also include calculations on nitrogen removal rates that could be achieved by active phytoremediation, through planting an alfalfa farm and irrigating it with plume water. This also appears to be a feasible option for remediating the plume.

3.2 Materials and Methods

3.2.1 Stable Isotopes Methods

As water changes from liquid to vapor, it becomes depleted in water molecules containing the heavy isotopes of hydrogen and oxygen, including deuterium (D) and ^{18}O, respectively; the opposite happens as water condenses out of vapor (Dawson 1993). Enrichment of water in heavy isotopes are expressed as δD and δ^{18}O values, with more negative numbers representing more enrichment relative to water without these isotopes. δD and δ^{18}O values for rain water become more negative at cooler ambient temperatures (Dawson 1993), and consequently there is a large difference between the isotope signatures of monsoonal rain and winter rain in locations on the Colorado Plateau (Lin et al. 1996). The stable isotopes of water can be extracted from plant tissue and compared to water extracted from rain water, soil water, or ground water to determine the source of water a plant uses for transpiration and growth. Plants may sometimes fractionate water as it is absorbed in the roots, changing its isotopic ratios. Therefore, control experiments are needed in which plants are grown on water of known isotope ratios to check for fractionation.

D and ^{18}O were analyzed in soil, plant, and well water samples. Soil, rain water, and plant samples were collected in September 2000. Sampling sites were near wells 606 and 675, established for ground water monitoring by DOE Grand Junction. Soil samples were obtained from depths between 50 and 90 cm, approximately 2 m from the base of each plant that was sampled. Soil was stored in 50 cm^3 glass vials. The woody stem tissue of six *Atriplex* and six *Sarcobatus* plants were collected from plants growing inside exclosures near each well and stored in 50 cm^3 glass vials. All samples were sealed with parafilm at the site and frozen upon arrival at the University of Arizona Environmental Research Laboratory to prevent water losses. A cryogenic vacuum distillation process was used to extract the water from the soil and plant samples (Ehleringer and Osmond 1989). The extracted water was refrigerated until isotope analysis was performed by the University of Arizona Geosciences Department. Water collected in August 2000 from wells 606, 653, 765, and 770 by MACTEC-ERS was also analyzed for D and ^{18}O.

To determine if plants were fractionating D and ^{18}O, two *Atriplex* plants were grown on two different water sources in a greenhouse in Tucson, Arizona, in soil (dune sand) collected from the Monument Valley UMTRA site. For 12 weeks, one *Atriplex* was irrigated with water from well 648 (collected by University of Arizona personnel in September 2000) and the other *Atriplex* was irrigated with Tucson rain water that was collected in October 2000. Stem tissue from each plant was collected and extracted the same way as the field samples. Plant and water samples were analyzed to determine if their D and ^{18}O signatures were similar to the waters with which they were irrigated.

3.2.2 Plant Cover Studies

A vegetation map of the site was previously prepared, based on qualitative methods (DOE 1999). We used line-intercept and plot methods (Cook and Bonham 1977) to estimate percent cover and shrub density, respectively, over an area of the plume that contained at least part of each plant association recognized as growing over the plume in the previous study. This survey was conducted in June 2000. The area between wells 606 and 664 was partitioned into 54 blocks (50 m x 70 m each) in a rectangle encompassing approximately 20 ha, and transects were established at the corners of each block (Figure 3–1). At the starting point for each transect, a random direction (1- 360 degrees) was selected to construct a 30 m baseline by laying a tape measure on the ground. Plant cover was measured by totaling the meters of tape that were intercepted by each plant type (length of tape intercepted divided by 30 m x 100 = percent cover). For example, if a total of 5 m of the line was intercepted by *Atriplex*, then 5/30 or 16.7 percent of the area within that plot was estimated to be covered by *Atriplex*. The height and cross sectional widths of the intersecting plant were also measured. To determine plant density, all *Atriplex* and *Sarcobatus* species were counted that were present within a parallel 20 m width plot along the 30-m transects. Plant density was computed as plant per block (3,600 m^2) by multiplying plants per plot (60 m^2) by 60. Only perennial shrubs were counted. Annual growth at this time of year was minimal, so the area not accounted for by shrubs was mainly bare soil.

We also measured percent cover in two plots (20 m x 20 m) inside the fenced area of the site where natural regrowth of plants has occurred. We then measured plant cover along 20 transects (each 20 m length, 1 m apart and parallel to sides) per plot, in October 2001.

Results of plant cover and exclosure studies are presented using the following plant acronyms:

ATCA Atriplex canescens
ATCO Atriplex confertifolia
SAVE Sarcobatus vermiculatus

3.2.3 Exclosure Study to Measure Biomass and Nitrogen Uptake by Grazed and UngrazedPlants

To quantify growth, biomass production, and nitrogen uptake under grazed and ungrazed conditions, we selected 24 plant pairs (12 *Atriplex* and 12 *Sarcobatus*) of similar initial size, scattered over the plume area (Figure 3–2). One plant in each pair was protected from grazing by enclosing it within a fence while the other plant was unprotected (Cook and Bonham 1977). Exclosures were constructed in June and July 1998. Each 3 m by 3 m by 1.5 m exclosure was constructed of chain-link wire fencing stretched between braced, steel corner posts. Barbed wire was strung between the top steel rail and the wire fence to prevent animals from climbing into the exclosure.

Each year for 3 years, we measured canopy volume, ground cover area, and biomass density for each shrub in the study. Samples of harvested biomass were measured for nitrate, total nitrogen and sulfate content. Baseline measurements of all plants were made on June 16, 1998. Subsequent measurements were made on October 12, 1998, March 24, 1999, and September 14, 2000.

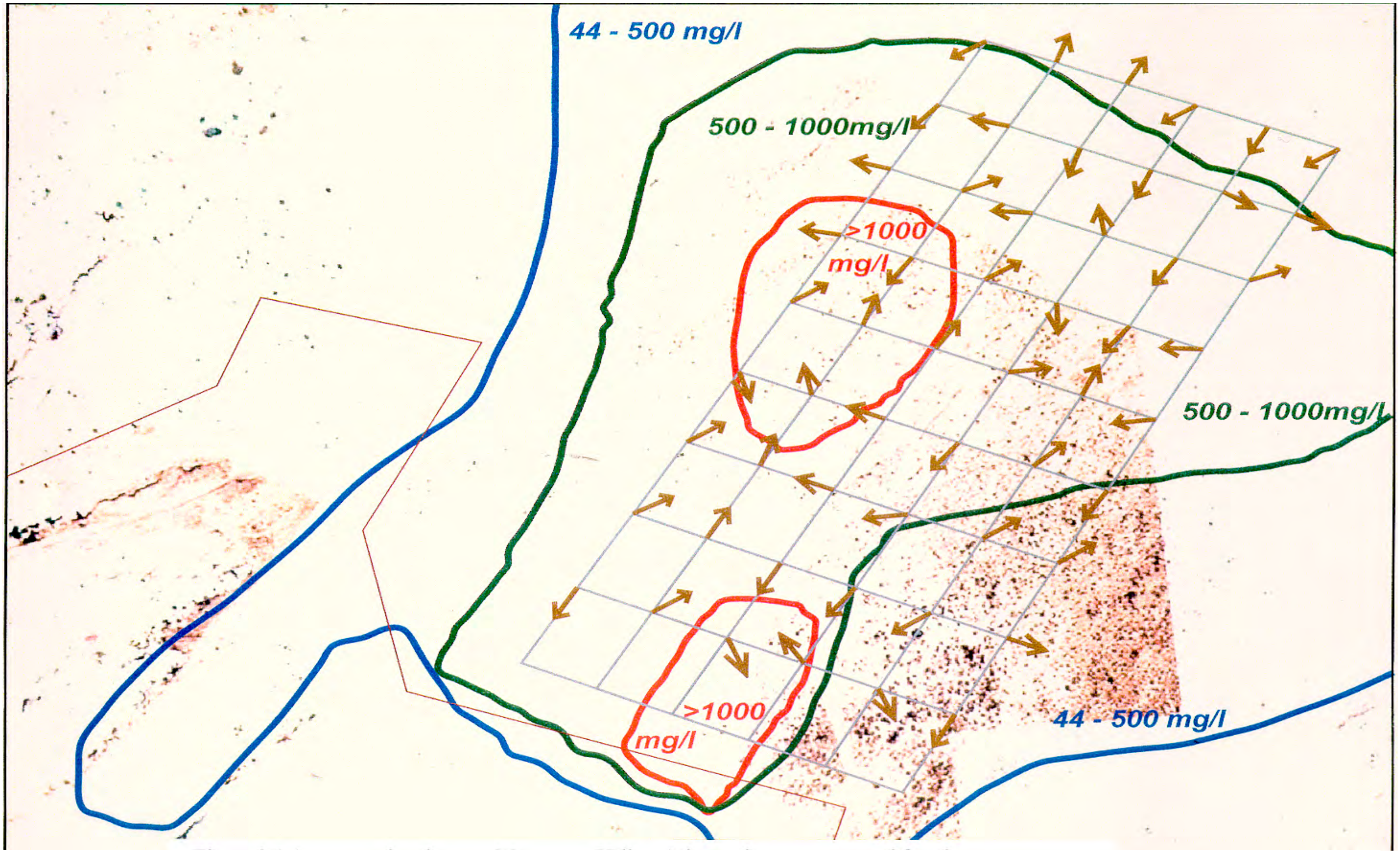


Figure 3–1. Area over the plume at Monument Valley, Arizona that was surveyed for plant cover and density in June 2000. Arrows denote the orientation of each 30 transect and 60 square meter plot.

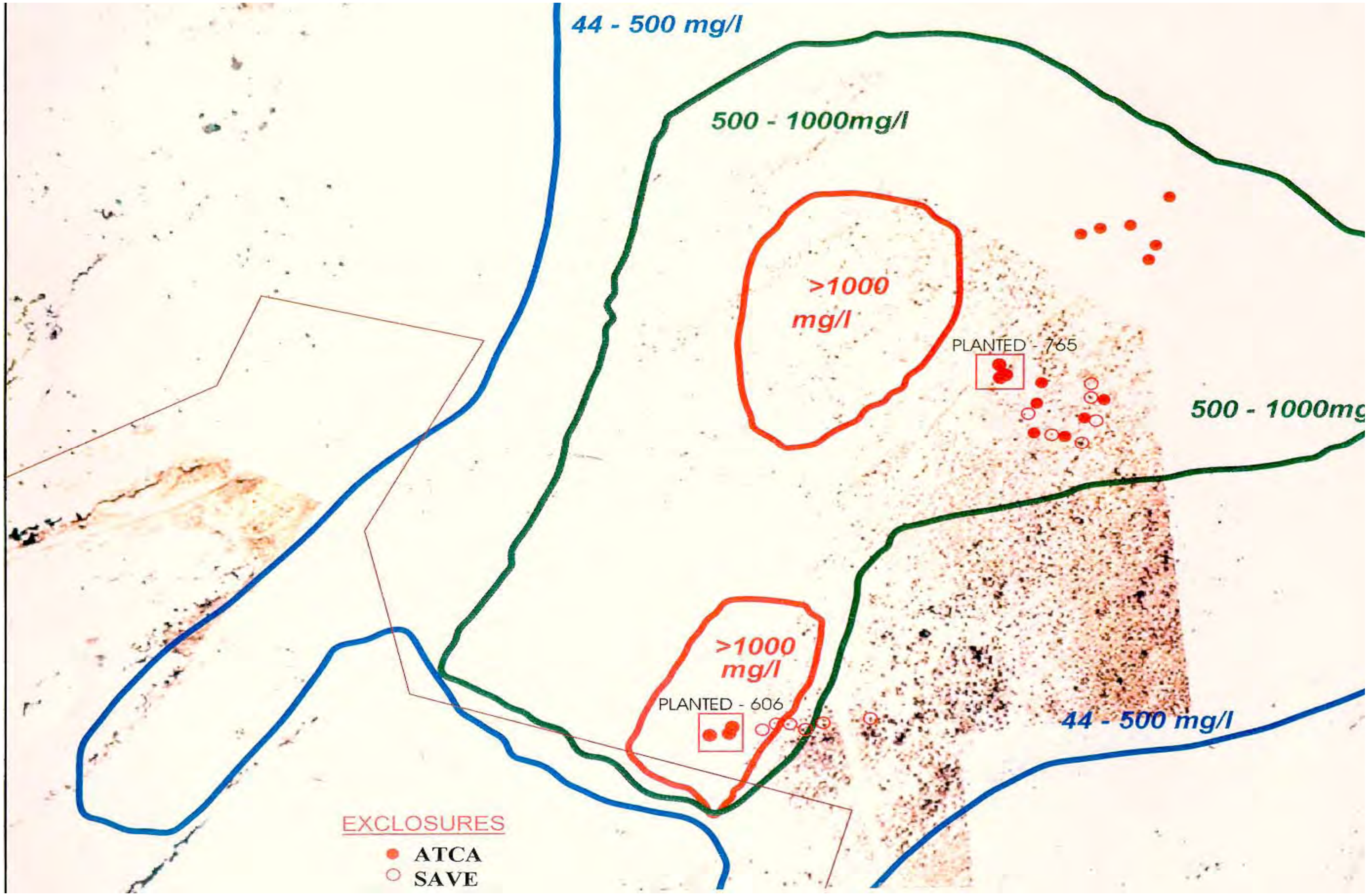


Figure 3–2. Location of Atriplex canescens (ATCA) and Sarcobatus vermiculatus (SAVE) Exclosures over the Plume at Monument Valley, Arizona

We calculated canopy volume using the lengths of two cross sectional widths and the height of each plant. The formula for a hemisphere ($2/3\ \pi r^3$) was applied. The ground cover area was calculated by measuring the lengths of two cross section widths and the formula for the area of a circle (πr^2) was applied. The plant was sectioned into four upper quadrants and four lower quadrants and one quadrant was chosen randomly for biomass sampling. A 0.0625 m^2 frame (0.25 m x 0.25 m internal dimensions), made of PVC tubing, was tossed haphazardly onto the canopy in the selected quadrant. Tissue samples representing all the new, annual growth inside the frame was collected. Samples consisted of leaves, small stems, and often seeds. The samples were returned to the Environmental Research Laboratory where they were dried for 2 weeks. A dry weight was obtained and portions of the samples were sent to Laboratory Consultants Ltd. (211 Shakespeare, Lordsburg, NM 88045) for chemical analysis. Three shrubs died during the study and were omitted from the data analysis.

Total nitrogen and percent ash were determined for each shrub at the end of each growing season. Extractable sulfur, total sulfur, and nitrate content were obtained from the tissue samples collected September 14, 2000. Total nitrogen was determined by the Kjeldahl technique using sulfuric acid and potassium sulfate/copper sulfate catalyst (Tabatabai 1996). An ammonia ion electrode was used to detect nitrogen, and nitrate nitrogen values were obtained by nitrate ion electrode (need ref.). Both extractable sulfur and total sulfur were determined turbidimetrically (Mulvaney 1996). Growth and chemical composition of plants were compared using a two-way analysis of variance, in which plant type (*Atriplex* or *Sarcobatus*) and grazing condition (Ungrazed or Grazed) were the independent variables.

Six additional exclosures were constructed over bare soil to determine if seedlings of *Sarcobatus* and *Atriplex* could be established artificially over the plume to enhance the natural shrub density. These exclosures were planted in June 1998, and irrigated weekly with uncontaminated well water over the first season (to October 1998), using approximately 20 L of water per m^2. Each exclosure contained 10 *Atriplex* and 10 *Sarcobatus* plants. Plants were monitored for height and survival at the end of each season.

3.3 Results and Discussion

3.3.1 Isotope Study

Results of all analyses are in Table 3–1. Note that as water becomes enriched in heavy isotopes of hydrogen and water, the δD and $\delta^{18}O$ become more negative. Summer-collected rain water from Tucson and Monument Valley in general had less negative δD and $\delta^{18}O$ values than Monument Valley well water. However, the sample of water from Well 648, used in the greenhouse study, had values similar to rain water. DOE Grand Junction samples came from wells that had been pumped for at least 24 hours, whereas the sample from Well 648 used in the greenhouse sample was taken after pumping for less than an hour and might have been contaminated with surface water (this sample also contained much lower nitrate than expected). Plants grown in the greenhouse on rain water or Well 648 water had δD and $\delta^{18}O$ values close to those of their respective water sources, indicating that these species do not appreciably fractionate isotopes. *Sarcobatus* and *Atriplex* collected in the field had δD and $\delta^{18}O$ values that were close to well values, whereas soil samples had values intermediate between rain water and well water samples.

The data are summarized in Figure 3–3, which is a cross-plot of δD and $\delta^{18}O$ values. Values for rain water, well water and plant tissues fall on the Meteoric Water Line (MWL) determined for well and rain samples from Page, Arizona (Lin et al. 1996), indicating they are a related series. *Sarcobatus* and *Atriplex* clustered close to the well data, while they were distinct from values from summer rain and soil samples collected at the same time as the plant samples, and they are lower than values for Page, Arizona, winter rain. Hence, it can be concluded that *Sarcobatus* and *Atriplex* were most likely relying on ground water with isotope signature similar to plume water, rather than rain water, for transpiration at the time of collection.

Table 3–1. Isotope values for plants, soil and water. Plants and soil are grouped by the well they were nearest. Plants within exclosures were sampled; note that ATCA1-4 were planted by UA as transplants in 1998; other plants are wild plants.

Sample Type	Sample Source	$\delta^{18}O$ Value	δD Value
Group 1			
Water	Well 606	-11.7	-87
ATCA 1	U of A Planted near 606	-8.5	-86
ATCA 1Soil A	85 cm	-5.4	-72
ATCA 1 Soil B	85 cm	-6.2	-78
SAVE 1	Exclosure 19A	-13.0	-102
SAVE 1 Soil	50cm	-3.6	-84
SAVE 2 Soil	Exclosure 24 A	-13.3	-101
SAVE 2 Soil	50cm	-4.9	-83
SAVE 3	Exclosure 22 A	-13.8	-105
SAVE 4	Exclosure 23 A	-12.2	-99
Group 2			
Water	Well 765	-11.6	-86
Water	Well 653	-11.9	-88
Water	Well 770	-11.8	-87
ATCA 2	U of A planted NE of well 765	-10.8	-96
ATCA 2 Soil	90cm	-7.1	-86
ATCA 3	U of A planted NE of well 765	-10.6	-95
ATCA 3 Soil	50cm	-5.5	-71
ATCA 4	U of A planted SE of well765	-10.2	-92
ATCA 4 Soil	85cm	-4.4	-73
ATCA 5	Exclosure 8A	-10.3	-94
ATCA 6	Exclosure 15A	-10.9	-94
ATCA 7	Exclosure 17A	-9.8	-94
SAVE 5	Exclosure 14A	-13.1	-103
SAVE 5 Soil	50cm	-5.0	-81
SAVE 6	Exclosure 16A	-12.0	-97
Water	Monument Valley Rain	-5.3	-38
Greenhouse Experiment			
Tucson Rain	Barrel Collected	-8.8	-57
ATCA	Grown on Tucson Rain	-8.2	-62
Water	Well 648 (pumped by U of A)	-3.3	-44
ATCA	Grown on Well 648 Water	-2.1	-49

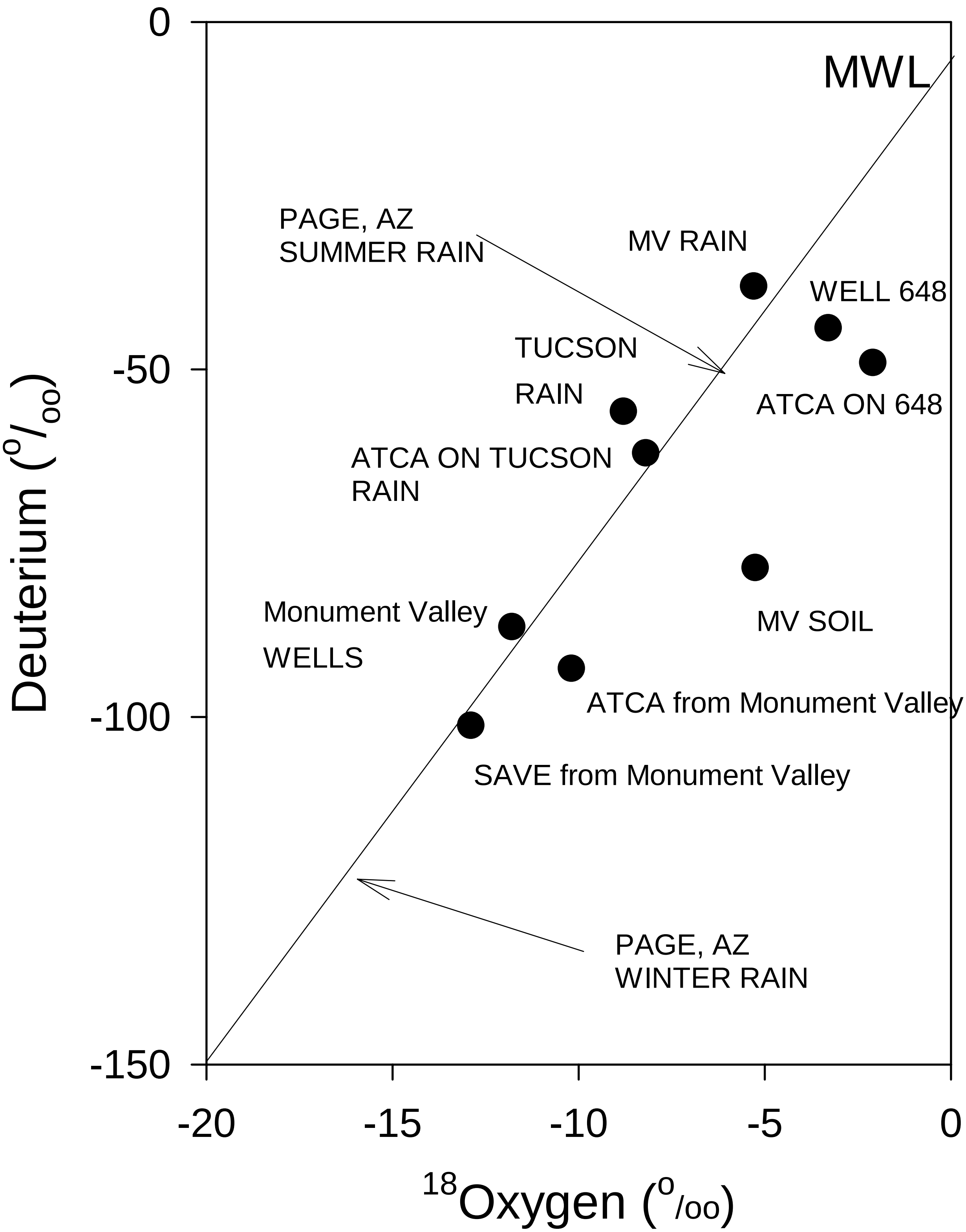


Figure 3–3. Plot of Deuterium and ^{18}O Values of water from rain, wells, soils and plants at the Monument Valley UMTRA Site, Arizona, plus control values for plants grown on two water sources in a greenhouse in Tucson, Arizona. MWL is the Meteoric Water Line for Page, Arizona.

3.3.2 Plant Cover

The results of the ground survey are in Table 3–2 (see Appendix I), with sampling blocks shaded to show their relationship to the major vegetation zones recognized by DOE (1999). Cover was sparse over the plume due to heavy grazing pressure, with many blocks having 0 percent cover as estimated by the line intercept or plot-density methods. A map of percent cover, using mean line-transect data for each plant type, is in Figure 3–4. The sparse *Atriplex* zone, which covers most of the plume, has under 5 percent plant cover. The area of highest total plant cover, approaching 15 percent, was the *Sarcobatus* zone, which is over the shallowest portion of the plume. This zone also had the highest densities of *Atriplex confertifolia* over the plume. Shrub density ranged from 0 - 200 plants per ha over most of the plume, but reached as high as 1,500 per ha in the *Sarcobatus* zone. We examined aerial photographs (1:4200) taken in September 2000, to determine how far the *Atriplex* zone extends. It appears to extend beyond the 44 ppm nitrate isoline over the plume. Shrub density by aerial photography was 1.67 percent in this zone (shrub counts multiplied by 2.2 m^2 per shrub/ divided by area surveyed).

The cover data was also used to estimate the extent of plant cover that could be achieved under enhanced range conditions. Areas of maximum cover exceeded 30 percent for both *Atriplex* and *Sarcobatus*. Also, *Sarcobatus* cover slightly exceeded 35% based on line intercept sampling (Bonham 1989) using a high-resolution aerial photograph taken in 1995, before the *Sarcobatus* stand overlying the plume was sprayed with herbicides (see Section 5.1). Hence, we picked a range of 25-35 percent as representing the percent cover that could be achieved over the plume if grazing were restricted and sparse areas replanted. This assumption was checked by measuring the percent cover that has been achieved inside the fenceline around the former pile (subpile soil area), where grazing has been controlled over the past 10 years. We selected plots that had good natural regrowth for measurement. The plant cover was nearly all *Sarcobatus*, ranging from 1-2 m in height. Plant cover in these two plots was 50.9 percent (S.E. = 5.1 percent) and 37.5 percent (S.E. = 2.5 percent) (see Appendix J); hence, the assumption that plants can achieve 25-35 percent cover when grazing is controlled may be conservative.

3.3.3 Exclosure Studies

Shrubs inside and outside exclosures (ungrazed and grazed, respectively) had similar starting sizes, averaging 2.48 m^2 and 1.61 m^2 ground cover for *Atriplex* and *Sarcobatus*, respectively. Over three growing seasons, shrubs in exclosures had increased their canopy volume (Figure 3–5, Appendix K) and canopy ground cover by 2-3 times the starting volume, whereas grazed plants outside the exclosures remained the same size at which they started. Each shrub produced a flush of new growth in spring, which appeared to be maximal by June; however, this growth was removed by sheep and cattle in the grazed plants. Differences in biomass density per m^2 of canopy were non-significant between grazed and ungrazed plant, but *Sarcobatus* produced more biomass than *Atriplex* (Table 3–3, Appendix L). However, because the ungrazed plants increased in canopy area over each growing season, their net annual productivity per m^2 of starting canopy area was approximately 1.5 times that of the grazed plants. Grazed *Atriplex* and *Sarcobatus* plants produced 0.81 kg/m^2 and 0.934 kg/m^2, respectively, while ungrazed plants produced 1.22 kg/m^2 and 1.40 kg/m^2. Grazed plants had significantly ($P<0.05$) less nitrogen content than ungrazed plants, and *Sarcobatus* (approximately 2.5 percent) had greater nitrogen content than *Atriplex* (approximately 2.1 percent) (Table 3–4, Appendix M). Analyses of plants harvested in September 2000 showed that nitrate, sulfate, and sulfur values (Table 3–5, Appendix M) of all plants were well below levels of concern for livestock (e.g., 1 percent total S or 1,500 ppm nitrate-N) (Oklahoma State University 2000). Plants inside exclosures had higher levels of nitrate and total sulfur than plants outside exclosures (P<0.05).

Table 3–2. Plant Cover and Plant Density from the June 2000 Line Intercept Study. Each box shows the percent cover along the 30 m transect and plant density of the 3600 m^2 area for Atriplex canescens, Atriplex confertifolia,and Sarcobatus vermiculatus. Plant density is based on the number of plants encountered along a 60 m^2 area parallel to the transect. The transects are labeled by strata number (1-9) followed by transect letter (A-F). The percent cover of each species is listed first in each box, followed by the number of plants of each species present. Shaded areas are an approximation of the vegetation map from the SOWP for Monument Valley (1999)

		BARE AREA (few ATCA or SAVE)	SAVE	SAVE/ATCA Transition	Sparse ATCA

9A	9B ATCA 32.0% 60 ATCA	9C	9D	9E	9F
8A	8B 60 ATCA 60 ATCO	8C	8D	8E	8F ATCA 30.0%
7A	7B 60 ATCA	7C 60 ATCA	7D 60 ATCO	7E	7F 60 SAVE
6A	6B ATCA 21.0% ATCO 11.3% 240 ATCA 60 ATCO	6C 60 ATCA	6D	6E 60 ATCA	6F ATCA 0.7% 180 ATCA
5A	5B	5C ATCA 21.0% 60 ATCA	5D ATCA 40.3% 120 ATCA	5E	5F ATCA 14.0% SAVE 8.0% 120 ATCA 60 SAVE
4A	4B ATCA 22.0% 300 ATCA	4C 180 ATCA	4D	4E SAVE 4.0% 60 ATCA 180 SAVE	4F 120 SAVE
3A	3B	3C	3D ATCA 13.7% SAVE 3.7% 60 ATCA 60 SAVE	3E SAVE 4.0% 120 ATCA 60 SAVE	3F ATCA 5.7% SAVE 37.3% 60 ATCA 600 SAVE
2A	2B	2C 60 ATCA	2D 60 ATCA	2E ATCA 5.3% SAVE 12.7% 180 ATCA 180 SAVE	2F ATCO12.0% SAVE 2.7% 300 ATCO 120 SAVE
1A 60 ATCA	1B	1C	1D 60 SAVE	1E ATCO 2.0% SAVE 21.0% 540 ATCO 300 SAVE	1F ATCO 6.3% SAVE 13.0% 300 ATCO 360 SAVE

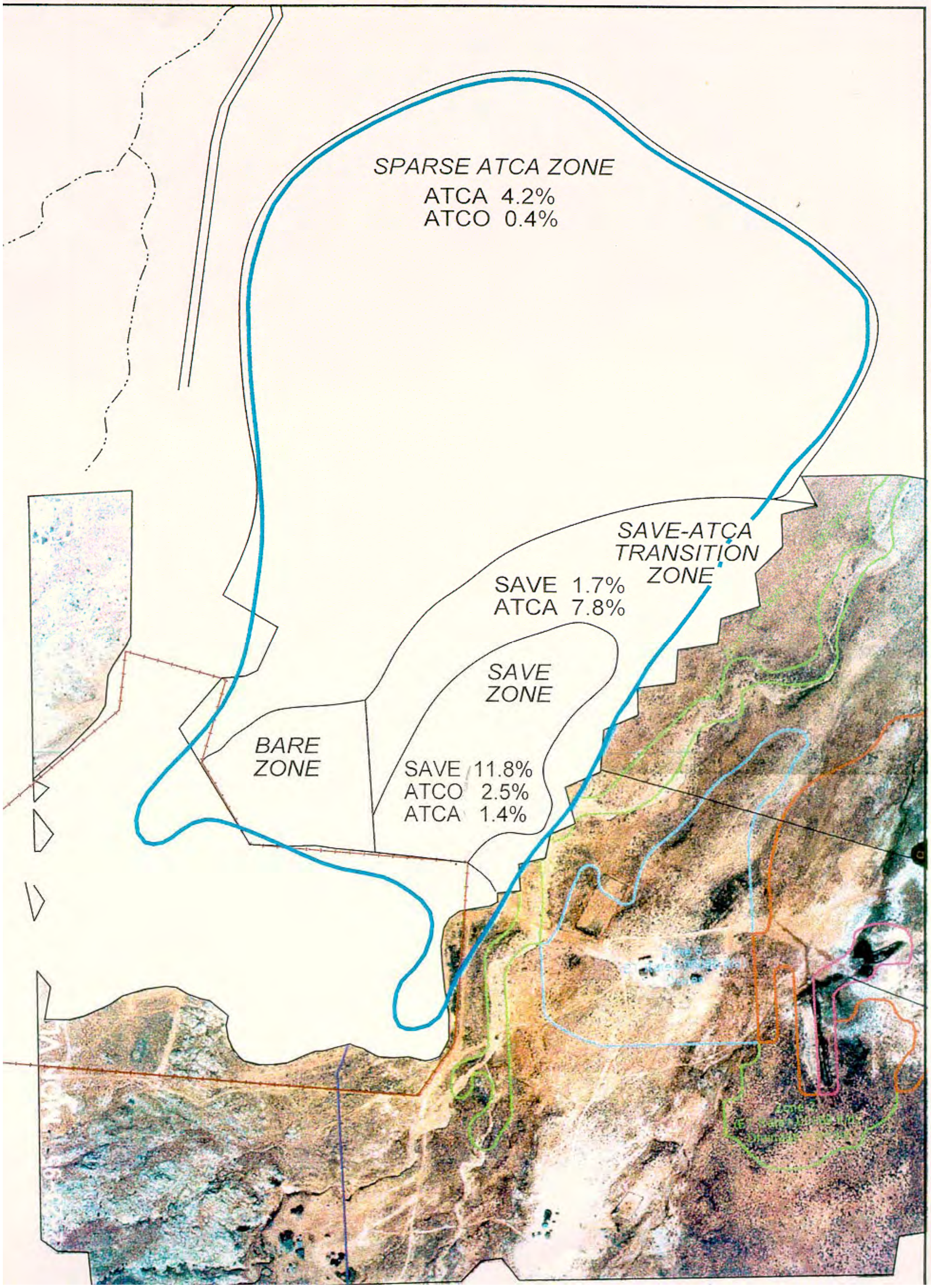


Figure 3–4. Percent cover (from line intercept) and plant density (plants per 3600 m^2) (from density plots) in different phytozones over the plume at Monument Valley, Arizona

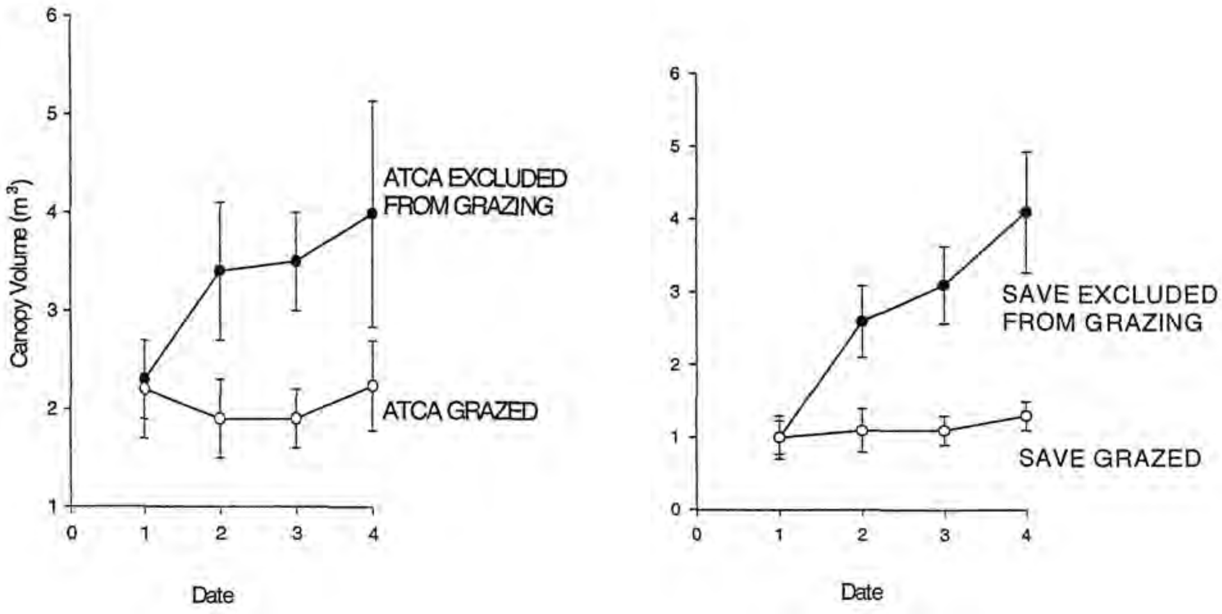


Figure 3–5. Monument Valley mean canopy volumes of ATCA and SAVE from 1998 to 2000. Standard error bars are shown. The left graph shows canopy volume means measured for 12 ATCA open to grazing and 12 ATCA excluded from grazing. The graph on the right shows the mean canopy volume for 12 grazed SAVE and 12 SAVE excluded from grazing. Date 1 is June 1998; Date 2 is October 1998; Date 3 is March 1999; Date 4 is September 2000. Error bars represent standard error of the mean.

Table 3–3. Biomass density (g dry wt./m^2) of ATCA and SAVE under Grazed and Ungrazed conditions, based on clippings of new growth harvested at the end of each season. 1998 and 1999 values are sums of harvests at the beginning and end of each season while 2000 data are for end of season harvests only. Three year means and standard deviation among years are in the last row. SAVE had significantly ($P<0.05$) greater biomass density than ATCA but Grazed and Ungrazed biomass density did not differ ($P>0.05$).

Year	ATCA Ungrazed	ATCA Grazed	SAVE Ungrazed	SAVE Grazed
1998	870	796	1154	1108
1999	748	790	836	694
2000	928	688	1040	784
Means:	849 (92)	758 (61)	1010 (161)	862 (217)

Table 3–4. Nitrogen concentrations (percent N on a dry weight basis) of ATCA and SAVE leaves for plants under Ungrazed and Grazed conditions for plants harvested in 2000. SAVE had significantly ($P<0.05$) higher nitrogen content than ATCA; SAVE plants under Ungrazed conditions has significantly higher nitrogen than under Grazed conditions. Number in parenthesis is standard deviation.

Plant	Ungrazed	Grazed
ATCA	2.14 (0.42)	2.05 (0.54)
SAVE	2.76 (0.59)	2.26 (0.27)

Table 3–5. Nitrate-N, Sulfate-S and Total Sulfur(dry weight basis) of ATCA and SAVE leaves for plants under Ungrazed and Grazed conditions for plants harvested in 2000. Results were not different by plant type (P>0.05) but Ungrazed plants had significantly greater Nitrate-N and Total Sulfur than Grazed plants. Table shows means and (standard deviations).

Plant	Nitrate-N Ungrazed (ppm)	Nitrate-N Grazed (ppm)	Sulfate-S Ungrazed (ppm)	Sulfate-S Grazed (ppm)	Total S Ungrazed (%)	Total S Grazed (%)
ATCA	727 (315)	590 (227)	513 (323)	374(257)	0.461 (0.244)	0.271 (0.156)
SAVE	951 (458)	558 (199)	430 (308)	375 (353)	0.332 (0.09)	0.253 (0.052)

Atriplex transplants established in exclosures had >90 percent survival over the first season, and grew from single-stemmed transplants approximately 10 cm in height to bushy plants up to 60 cm tall by the end of the first season. *Sarcobatus* transplants had only 65 percent survival and had little new growth. Despite the fact that dead plants were replaced in the second year of the study, none of the *Sarcobatus* transplants ultimately grew into large shrubs. By contrast, *Atriplex* plants continued to grow, filling the exclosures by September 2000 and reaching 1.5 m height. It is important to note that irrigation was only provided during the first growing season. Therefore, growth achieved by *Atriplex* in the second and third growing season was on soil or plume water. Isotope signatures of two *Atriplex* plants from these exclosures supports the conclusion that they were rooted into the plume (see Table 3–1).

The exclosure study showed that both grazed and ungrazed shrubs undergo natural mortality, as 6.25 percent of shrubs died over the sampling period. There was little evidence of natural replacement of shrubs. Heavy grazing pressure is especially damaging to newly established sprouts or seedlings. If grazing pressure was relaxed, *Sarcobatus* could be expected to sprout new juvenile plants from its underground rhizomes (see Section 5.1), whereas artificial establishment of *Atriplex* from seedling would be necessary, and feasible, as judging from the exclosure trials.

3.3.4 Water and Nitrate Extraction Rates under Current and Enhanced Production Scenarios

This section calculates approximate rates of water and nitrate by *Atriplex* and *Sarcobatus* plants growing over the plume. We divided the plume area into different plant zones as in Figure 3–4. The estimates are based on data collected in the studies above, but also contain some assumptions that should be tested by further analyses and pilot studies. We used plant cover data summarized in Figure 3–4 for the current scenario. For the enhanced scenarios we assumed that a low of 25 percent and a high of 35 percent plant cover could be achieved. For the irrigation scenarios, we have not entered in the effects of microbial conversion of nitrate (Chapter 2); only plant uptake was considered.

3.3.4.1 Assumptions for Calculating Extraction Rates

For water extraction, we used a consumptive use value of 665 m^3 of water for each 1,000 kg of dry (above-ground) biomass, based on yield and consumptive use data for *Atriplex* grown for 3 years in lysimeter basins at Tempe, Arizona (Glenn et al. 1998a). *Atriplex canescens* (ATCA) and *Sarcobatus vermiculatus* (SAVE) are both Chenopod shrubs and we assumed they had similar water use efficiencies.

For productivity, we used biomass yields of exclosure-experiment plants. In estimating the productivity of the range in its current condition, we used data for grazed plants, and for enhanced scenarios we used the same values multiplied by 1.5, to account for the additional biomass produced by growth in canopy volume over each season.

Biomass Yields of Plants (100 percent cover):

	Grazed	Ungrazed
ATCA	0.810 $kg/m^2/yr$	1.22 $kg/m^2/yr$
SAVE	0.934 $kg/m^2/yr$	1.402 $kg/m^2/yr$

For nitrate, we used the fraction of dry biomass that is nitrogen multiplied by 4.4 to convert to nitrate equivalents. We assumed that grazed and ungrazed plants had similar nitrogen content despite the small but significant ($P<0.05$) difference among treatments.

ATCA 0.0924 kg nitrate/kg biomass
SAVE 0.110 kg nitrate/kg biomass

In the Bare Zone, we assumed that a phytoremediation farm could be planted with alfalfa and irrigated with plume water to remove nitrogen (see Chapter 5). We used values from Arizona Crop Budgets (UA Ag. Extension Service) for Yuma, adjusted by 0.7 to account for the shorter growing season at Monument Valley.

Biomass production 16,000 kg/ha/yr
Water consumption 20,000 $m^3/ha/yr$
Nitrogen content 4 percent
Nitrate extraction 0.176 kg nitrate/kg biomass

Bare Zone, Current Condition

Cover: 0.68 percent ATCA (based on aerial survey - no plants encountered in line intercepts)
Water extraction: 36.6 m^3/ha

Nitrate: 5.08 kg/ha

Bare Zone, Converted to Alfalfa Farm

Cover: 80 -100 percent

Water Extraction: Low: 16,000 m^3/ha; High: 20,000 m^3/ha

Nitrate: Low: 2253 kg/ha; High: 2816 kg/ha

Sparse ATCA Zone, Current Condition

Cover: 4.2 percent ATCA

Water Extraction: 273 m^3/ha

Nitrate: 38.8 kg/ha

Enhanced ATCA Zone

Assume 25 percent - 35 percent cover (based on areas of maximum density in current condition)

Water Extraction: Low 2022 m^3/ha; High: 2830 m^3/ha

Nitrate: Low: 280 kg/ha; High: 391 kg/ha

Transition Zone between ATCA and SAVE Zones, Current Condition

Cover: ATCA 7.8 percent, SAVE 1.7 percent

Water Extraction: 632 m^3/ha

Nitrate: 90.8 kg/ha

Enhanced Transition Zone

Cover: Low: 12.5 percent ATCA, 12.5 percent SAVE; High: 17.5 percent ATCA, 17.5 percent SAVE

Water Extraction: Low: 2176 m^3/ha; High: 3046 m^3/ha

Nitrate: Low: 334 kg/ha; High: 466 kg/ha

SAVE Zone Current Condition

Cover: SAVE 11.8 percent, ATCA 1.4 percent

Water Extraction: 878 m^3/ha

Nitrate: 143 kg/ha

Enhanced SAVE Zone

Cover: Low: 5 percent ATCA, 20 percent SAVE; High: 5 percent ATCA, 30 percent SAVE

Water Extraction: Low: 2270 m^3/ha; High: 3202 m^3/ha

Nitrate: Low: 364 kg/ha; High: 518 kg/ha

Estimates of Areas of Zones (from Aerial Photographs)

1. Bare Zone

This appears to occupy about 12 ha, including the bladed area proposed for the pilot farm, the area where the evaporation pond used to be, and surrounding disturbed or sparsely-vegetated land between the UMTRA fenceline and the dirt road.

2. ATCA Zone

This is an extensive area that extends beyond the 500-1000 ppm nitrate isoline. The area over the plume out to the 44 ppm isoline is at least 50 ha after subtracting out the other zones.

3. High Density SAVE Zone3

Based on shrub density counted on the aerial, this appears to cover about 5.6 ha.

4. Transition Zone

This is an area of approximately 3.2 ha around the high-density SAVE zone.

3.3.4.2 Sample Calculations Annual Nitrate Removal and Years for Complete Removal

The calculations in Table 3–6 used mid-value estimates of water and nitrate extraction and the (approximate) area estimates in 3.4.10. They are not meant to replace values determined by detailed modeling of the plume, but are relevant to the conclusions in the final section. The total nitrate in the plume was estimated to be 760,000 kg; 420,000 kg in the 44-500 ppm zone and 360,000 in the 500-1000 ppm zone (DOE 1999). Since water is assumed to be replaced as it is used, no calculation of years for removal was made.

Table 3–6. Calculations of water and nitrate removal under current and enhanced scenarios for each zone and for several combined options

1. Zone	Water Extraction(m^3/yr)	Nitrate Extraction(kg/ha/yr)	Years for Nitrate Removal
Current Bare Zone	36.6 m^3/ha/yr x 12 ha = 439 m^3/yr	5.08 kg/ha/yr x 12 ha = 61 kg/yr	12,459
Bare Zone Converted to 10 ha Phtyo-Farm	18,000 m^3/ha/yr x 10 ha = 180,000 m^3/yr	2535 kg/ha/yr x 10 ha= 25,350 kg/yr	30
Current ATCA Zone	273 m^3/ha/yr x 50ha = 13,650 m^3/yr	38.8 kg/ha/yr x 50 ha= 1940 kg/yr	392
Enhanced ATCA Zone	2426 m^3/ha/yr x 50 ha = 121,300 m^3/yr	336 kg/ha/yr x 50 ha = 16,800 kg/yr	45
Current SAVE + Transition Zones	789 m^3/ha/yr x 8.8 ha = 6939 m^3/yr	124 kg/ha/yr x 8.8 ha = 1091 kg/yr	697
Enhanced SAVE + Transition Zones	2690 m^3/ha/yr x 8.8 ha = 23,672 m^3/yr	426 kg/ha/yr x 8.8 ha = 3748 kg/yr	203
Maintain Current Conditions	21,028 m^3/yr	3092 kg/yr	246
Fencing All Zones, No Phyto-Farm	145,283 m^3/yr	20,591 kg/yr	37
Phyto-Farm, No Fencing	201,028 m^3/yr	28,381 kg/yr	27
Phyto-Farm + Fencing	324,972 m^3/yr	45,898 kg/yr	17

3.4 Conclusions and Recommendations

Both *Atriplex* and *Sarcobatus* appear to be rooted into the contamination plume, judging by stable isotope signatures. The extent to which they are actually using plume nitrogen could be determined by investigating nitrogen isotope signatures in the plants and plume water. The plants surveyed so far extend only out to the 500 ppm nitrate isoline; further sampling out to the 44 ppm isoline should be conducted to determine the extinction depth at which plants no longer can reach the plume. Actual excavation of some plants to determine rooting profiles would be valuable.

Biomass production of plants at full cover is 8-9 tons/ha for grazed and 12-14 tons/ha for ungrazed *Sarcobatus* and *Atriplex* plants. Water use at full cover is 0.5-0.6 m/yr, within the range of literature values. However, the productivity of the range in its current condition is much lower than the full-cover values, due to the low plant cover, averaging <5 percent. This is due to the high grazing pressure on this land. Exclosure studies show that both *Sarcobatus* and *Atriplex* rapidly expand in cover when grazing is eliminated and that *Atriplex* can be artificially established over the plume, using irrigation for only the first year. The ultimate percent cover that can be achieved needs to be determined by fencing larger areas than those enclosed in the present exclosures, which have already filled with plant material. Dense planting might be susceptible to disease and predation.

Enhancement scenarios suggest that under current conditions, 300 years may be needed for the native plants to absorb nitrogen in the plume. On the other hand, fencing the land, installing a phytoremediation farm, or a combination of these remedial actions could reduce cleanup time to 20 to 40 years.

While both passive and active phytoremediation appear to be attractive options at this site, there are still unknowns, as noted above. A phyto-farm pilot study would help resolve these unknowns, while contributing immediately to remediation (see Chapters 4 and 5).

Finally, passive and active phytoremediation will improve the overall range quality of this land, which has been damaged by the milling operations and subsequent cleanup efforts.

4.0 Greenhouse Study for Pilot Phytoremediation Farm

4.1 Summary of Greenhouse Study

Five types of plants [alfalfa, (*Medicago sativa* L.), Piper sudan grass *(Sorghum sudanese* (Piper) Stapf.), Sweet sudan grass (*Sorghum X drummondii* (Steud.) Millsp. and Chase), Sorghum-sudan grass (*Sorghum X drummondii* (Steud.) Millsp. and Chase), and the native halophyte four-wing saltbush (*Atriplex canescens* Nutt)] were grown in a greenhouse in Tucson, Arizona to test the effects of irrigation with water from an alluvial aquifer contaminated with nitrate (NO_3) and sulfate (SO_4) from the processes of a former uranium milling site. The best plant growth occurred on soil from outside the former uranium milling site in Monument Valley, Arizona, at the site proposed by DOE for a pilot phytoremediation farm. Plant growth was inhibited in soils from within the fenceline around the former pile area. Growth on three soils from different areas in the vicinity of the site improved with the addition of organic matter, such as potting soil, to the soil.

One thousand mg nitrate (NO_3) kg^{-1} (measured as NO_3) concentration in water was lethal to most plants. This toxicity was alleviated by the addition of organic matter to the soil. One thousand and 500 mg NO_3 kg^{-1} concentrations in water resulted in plant tissue concentrations of NO_3 above recommended feeding values for cattle. At 83 mg NO_3 kg^{-1} concentration in the water, alfalfa did not accumulate NO_3 to excessive levels. All other plant types accumulated nitrate close to or above 5000 mg NO_3 kg^{-1}, the highest amount of nitrate considered safe for feeding to all cattle. Plants grown with organic matter and watered with 1000 mg NO_3 kg^{-1} accumulated NO_3 up to 20 times higher than the safe feeding level. Hydrocyanic acid (HCN) accumulation was lowest in Piper sudan grass with a mean below the lower toxic limit. Both Sweet and Sorghum-sudan grasses accumulated HCN above toxic levels. Sulfur as sulfate (SO_4) in dried plant tissues accumulated to harmful concentrations in alfalfa grown with water containing 83 mg NO_3 kg^{-1} and 620 mg SO_4 kg^{-1}. Plants did not accumulate Sr, Mn, V or U to harmful levels.

4.2 Literature Review: Effect on Plants of Water Contaminated By Mining Processes

Use of water contaminated by mining and milling processes to support plant growth has been tested in several studies. Water contaminated with uranium (U) at a former uranium processing facility in Ashtabula, OH, was remediated with hydroponically grown sunflowers (*Helianthus annuus* L.) placed in a rhizofiltration unit at six weeks of age. The contaminated water (21-874 µg U/L) ran through the unit submerging the plant roots. The outflow water from the system contained U levels below the EPA standard of (20 µg U/L) (Dushenkov et al. 1997).

Other remediation projects are using contaminated water for irrigation purposes. The Highland Uranium Project located near Glenrock in east-central Wyoming has been monitoring their use of treated process waters for sprinkler irrigation on the neighboring rangeland. The water applied has been treated for U and radon (Rn) but not for selenium (Se) and boron (B), which caused some concern. Uncertainty also surrounded the moderately high salinity of the irrigation water (2.8 dS m^{-1}). Plants monitored in the area included smooth brome (*Bromus inermis* Leyss.), Japanese brome (*B. japonicus* Thunb.), western wheatgrass (*Pascopyrum smithii* Rydb. (A. Löve)), intermediate wheatgrass (*Elytrigia intermedia* (Host) Nevski) and Kentucky bluegrass (*Poa pratensis* L.). The concentrations of Se, B, U and Rn were analyzed in the grasses from

1989-1996. The weighted means of these elements in the applied irrigation water were 1.06 mg L^{-1} Se, 0.11 mg L^{-1} B, 1.8 mg L^{-1} U and 6.8pCi L^{-1} Rn. The mean concentration of Se in harvested grasses (5.4mg kg^{-1}) was above the baseline concentration of 0.38 mg kg^{-1}obtained from plants in the same area that had not been irrigated. There was no evidence of phytotoxicity at the concentrations above background levels. Boron concentrations all decreased below the baseline concentration and no evidence of phytotoxicity emerged. Uranium concentrations in the plants increased over time from 0.597 mg kg^{-1} to 5.61 mg kg^{-1} with the baseline concentration at 0.014 mg kg^{-1}. Radon activity in the plants varied but never accumulated to toxic concentrations. Overall plant tissues remained safe for grazing wildlife, such as deer and antelope (Levy and Kearney 1999).

An important factor in the uptake of contaminants from mine wastewater by plants is the movement of contaminants through the root zone. Willett and Bond (1998) did extensive testing with the radionuclides 238-U, 226-Rn, 210-Lead (Pb) and 54-Manganese (Mn) to investigate their movement in the soil profile. The researchers studied this using sprinkler irrigation on a site in Northern Australia and with laboratory column experiments. The study indicated that ^{238}U, ^{226}Ra and ^{210}Pb were retained in the first few centimeters of soil. The ^{54}Mn migrated down at least 45 cm.

A study from the University of Arizona used groundwater contaminated as a result of a Uranium mill tailings operation as irrigation water for plants (Baumgartner et al. 2000a,b). This greenhouse study used water and soil from a site in Tuba City, AZ. Sudan grass (*Sorghum vulgare* var. *sudanense*) accumulated molybdenum (Mo), Se, U, nitrate (NO_3) and sulfur (S), while four-wing saltbush (*Atriplex*) accumulated Se and U. Although concentrations were found to be above background concentrations, they did not reach unacceptable levels (Baumgartner et al. 2000a,b).

Use of plants to clean groundwater and soil contaminated with NO_3 from a chemical fertilizer spill has also been studied. Russelle et al. (2001) irrigated three varieties of alfalfa (*Medicago sativa*, L.) with NO_3 contaminated groundwater on NO_3 contaminated soil. Plants were watered for 3 years with NO_3 concentrations in the water ranging from 101.2 to 303.6 mg NO_3 L^{-1}. The three alfalfa varieties were found to reduce both total inorganic nitrogen in the soil and NO_3 in the groundwater. No difference in plant tissue nitrogen concentration or content was found among the three alfalfa varieties grown. According to the authors, the alfalfa did not contain toxic levels of NO_3. The study described in this paper continues work in the area of using groundwater contaminated through anthropogenic activities to irrigate plants and remediate the water.

4.3 Chemicals of Concern at the Monument Valley Site

The present study investigated the use of different plants; alfalfa, (*Medicago sativa* L.), Piper sudan grass *(Sorghum sudanese* (Piper) Stapf.), Sweet sudan grass (*Sorghum X drummondii* (Steud.) Millsp. and Chase), Sorghum-sudan grass (*Sorghum X drummondii* (Steud.) Millsp. and Chase), and the native halophyte four-wing saltbush (*Atriplex* Nutt), for irrigation with water from an alluvial aquifer contaminated with NO_3 and sulfate (SO_4). The initial concern of the present project was accumulation of NO_3, SO_4, hydrocyanic acid (HCN), strontium (Sr), vanadium (V), U, and Mn within the plants, and how this affects their quality as forage for cattle and sheep.

Sudan grass is known for accumulating HCN, a derivative of NO_3. Hydrocyanic acid can cause death in livestock by interfering with the ability of oxygen to enter body cells thus causing suffocation at the cellular level (Strickland et al. 1995). The amount produced in the plant depends on environmental conditions. Young growth and stressed plants contain larger amounts of HCN. Leaves contain the most HCN (Knowles and Ottman 1997). Hydrocyanic acid levels at 0-500 μg HCN g^{-1} in dried plant tissue are safe for grazing. Feeding with levels higher than 500 μg HCN g^{-1} is not recommended and grazing should be monitored (Strickland et al. 1995a).

The accumulation of nitrate is also of concern when feeding livestock. High nitrate accumulation also results in oxygen deprivation and the suffocation of cattle. In sudan grass, nitrate concentrations tend to be the highest in stems and is higher in young plants than in mature plants. There is typically three times more nitrate in the lower six inches of stem than in the upper part of the plant (Strickland et al. 1995). There can be significant variability of nitrate accumulation within a field of sudan grass. One sampling of a 5-acre field produced a nitrate range of 7,930 to 43,600 μg NO_3 g^{-1} (Strickland et al. 1995). Nitrate levels lower than 5,000 μg NO_3 g^{-1} are considered safe for feeding to all cattle. Five thousand to 10,000 μg NO_3 g^{-1} contain risk for pregnant cows and young calves, and above 10,000 μg NO_3 g^{-1} can be hazardous to all cattle (Strickland et al. 1995b). The lethal dose of nitrate for cattle ranges from 88 to 110 mg NO_3/kg body weight. Ranges of 40 to 50 mg NO_3/kg body weight are lethal for sheep (Knowles and Ottman 1997).

Sulfur is an essential element for the survival of animals. It is involved in many different functions of both plant and mammalian cells. Sulfur toxicity occurs in the gastrointestinal tract where microflora convert S to hydrogen sulfide. It takes large amounts of S to start producing hydrogen sulfide. There are no established limits on S/SO_4 for cattle and sheep diets. An apparent maximum tolerable level for sheep is 0.4 percent dietary S as sodium sulfate (Subcommittee on Mineral Toxicity in Animals 1980).

Strontium is an alkaline earth metal closely related to calcium (Ca). Strontium is processed in plants and animals similarly to Ca but the processing is less efficient. The effects of Sr on livestock are more pronounced when there are small concentrations of Ca present. Young animals fed small Ca and large Sr concentrations develop “strontium rickets” which affects bone growth (Colvin and Creger 1967). Assuming that animals have adequate Ca in their diet, plants containing up to 2000 μg Sr g^{-1} can be tolerated (Subcommittee on Mineral Toxicity in Animals 1980).

Manganese is an essential element for both plant and animal growth. Manganese toxicity results from an interference with iron and results in the decreased production of hemoglobin. Sheep and cattle should not be fed diets containing more than 1,000 μg Mn g^{-1}(Subcommittee on Mineral Toxicity in Animals 1980).

Vanadium (V) has been shown to be an essential element in animal diets. The bright white metal can also be toxic by inhibiting enzymes and causing the lysis of cells. Feeding studies found 20 mg V kg^{-1} body weight fed daily to calves produced symptoms within 3 days. Sheep fed 40 mg V kg^{-1} body weight had a 65 percent death rate within 80 hours of feeding. There is no established maximum tolerable limit for V (Subcommittee on Mineral Toxicity in Animals 1980).

Uranium (U) has been shown to be essential in small amounts for plant growth but not essential for animal growth. Toxicity to animals by U occurs in the kidney due to cell damage. Most animals do not absorb large amounts of U through digestion and there is little data on feeding U to farm animals. A safe concentration of dietary U for rats appears to be 400 mg U kg^{-1} uranium. (Subcommittee on Mineral Toxicity in Animals 1980).

4.4 Plant Symptomology

At the outset of this experiment, the main concern of the project focused on plant accumulation of the chemicals listed above. A few weeks into the project it became apparent that plant growth on the site soil presented a problem. A similar greenhouse experiment using soil and water from northern Arizona had no problematic plant growth (Baumgartner et al. 2000b). This experiment, with soil from a different area of northern Arizona, developed problems within a few weeks of emergence. Presented here are the symptoms displayed by the plants and possible explanations for these symptoms. Confirmation through plant tissue analysis is the only definitive way to diagnose plant mineral deficiencies. Due to a small amount of plant tissue and lack of funding, no mineral nutrition analyses were performed on plants grown in this experiment to confirm deficiencies.

The first symptoms emerged only in sudan grass as interveinal chlorosis and twisting of the younger leaves. Interveinal chlorosis is a symptom of iron (Fe) deficiency in plants. This tends to occur in calcareous soils (>1 or 2 percent Ca) and especially in arid soils (Rending and Taylor 1989). To remedy the situation, Hoagland's trace mineral solution containing 5 mg Fe kg^{-1} chelated Fe was added to the watering regime. The interveinal chlorosis symptoms then ceased.

Another symptom emerged in the sudan grass as necrotic tips of young leaves sticking to necrotic edges on lower leaves. In corn this is a symptom of Ca deficiency (Hoffer 1941). Calcium is usually present in the soil solution at a rate of 10 times greater than potassium (K) (Mengel and Kirkby 1978). Subsequently plants are more efficient at taking up K than Ca (Mengel and Kirkby 1978). The soil these plants were grown in contained 6,120 mg Ca kg^{-1}, in addition to 260 mg kg^{-1} and 160 mg Ca kg^{-1} in the groundwater. Spiking water with KNO_3 resulted in the addition of 502.2 mg K kg^{-1} to the 1000 mg NO_3 kg^{-1} experimental concentration and 211 mg K kg^{-1} to the 500 mg NO_3 kg^{-1} concentration. Calcium uptake may have become inhibited by the change in Ca/K balance in the soil solution. Another possible inhibition of Ca uptake could be the presence of V (58 mg V kg^{-1} in soil). Vanadium has been found to inhibit Ca uptake in sorghum root tips (Wilkinson and Duncan 1993).

Large clear spots in the middle of intermediate-aged leaves in sudan grass also developed. The clear spots grew, breaking the leaf into two pieces with the lower half of the leaf proceeding to full necrosis. A possible cause of the clear breaks is Mn deficiency. Symptoms of Mn deficiency include breaking of the leaf at an advanced stage due to reduced turgor. This usually occurs at the base of the leaf rather than middle and is usually preceded by grey spots on the plant (Mengel and Kirkby 1978). Manganese was present in the soil and in the Hoagland's trace mineral solution. The uptake of Mn can be disrupted by the presence of other cations such as Ca, Mg, Fe, and Zn or by high soil pH (Mengel and Kirkby 1978). Mengel and Kirkby (1978) describe Mn-deficient plants as having 15-25 μg Mn kg^{-1} in dried tissue of upper plant parts. After sampling, sudan grass ranged from 33-40 μg Mn kg^{-1} which is very close to the deficient concentrations above.

The final symptom appeared on all sudan grass plants in all of the separate experiments. These plants had necrotic tips with necrosis proceeding up the margin of the leaf. This is commonly a symptom of salinity damage in plants (Gupta and Gupta 1987).

More sudan grass symptoms confirmed the problematic nature of the soil that was collected from the scraped subpile region (“plot” soil) in the soil performance experiment (see “stained area” in Chapter 2). Plants in this soil emerged and grew slowly with more purple on the stems than plants in the other soils. The plants quickly developed overall chlorosis of the leaf and proceeded to die. A possible explanation for this is the concentration of V in the soil. Vanadium levels have been inversely correlated to plant biomass production in previous studies (Kaplan, et. al. 1990). One study found that in a fluvo-aquic soil (low adsorption capacity) 30 mg V kg^{-1} significantly decreased dry matter yields. Symptoms of soybean (*Glycine max* L.) seedlings included chlorosis, withering of shoots, and short roots (Wang and Liu 1999). Cannon (1963) found that 10 mg V kg^{-1} in solution caused increased reddening in the lower stems and leaf tips of sorghum while 100 mg V kg^{-1} caused stunting and death within 2 weeks. Vanadium accumulation and translocation by plants has also been shown to increase in the presence of Ca (Morrell et al. 1983). Calcium concentrations in the “plot” soil reach 35,100 mg kg^{-1}. It should also be noted that the “plot” soil contained Sr (chemically similar to Ca) at 692 mg kg^{-1}.

4.5 Introduction to Study

Phytoremediation uses plants to clean contaminated soil and water. Plants acquire contaminants through the roots and either metabolize contaminants or store them in living tissues. Phytoremediation has been applied to a wide range of contaminants including trichloroethylene (Orchard, et al. 2000), selenium (Pilon-Smits et al. 1998) and metals such as cadmium (Cd), zinc (Zn), lead (Pb) and manganese (Mn) (Robinson et al. 1998). Additionally, water with large concentrations of nutrients such as nitrate can be remediated through the use of wetland systems with plants and microbes metabolizing the excess nutrients (Mandi et al. 1996). Another project used three varieties of alfalfa to successfully remediate excess nitrate (NO_3) from both soil and groundwater without toxic accumulation of NO_3 (Russelle et al. 2001). The ultimate goal of the present research is to remove excess nitrate and sulfate from groundwater by irrigating crop plants. The groundwater became contaminated when rainwater washed nitrate and sulfate, present in the soil due to a uranium mill tailings operation, into a shallow aquifer. Remediation would occur during the irrigation of crop plants with the contaminated groundwater. This greenhouse study was conducted using soil and water from the site to assess the feasibility of growing crop plants of forage quality. Previous research conducted with soil and water from a different mine tailings site found this to be a feasible approach with no accumulation of contaminants beyond acceptable concentrations in the plants (Baumgartner et al. 2000 a,b).

4.6 Materials and Methods

4.6.1 Plants

Plants used in this study include Piper sudan grass (*Sorghum sudanese* (Piper) Stapf.), Sweet and Sorghum-sudan grasses (*Sorghum X drummondii* (Steud.) Millsp. and Chase), Agate and Ineffective Agate alfalfa (*Medicago sativa* L.), and the native species four-wing saltbush (*Atriplex* (Pursh) Nutt). Piper and Sorghum-sudan grass were obtained from Browning Seed, Inc., Plainview, TX. Sweet sudan grass came from Fertizona Inc., Casa Grande, AZ. Ineffective Agate and Agate alfalfa were obtained from Carroll P. Vance and JoAnn F.S. Lamb, Plant Science Research Unit, USDA-ARS, University of MN, Department of Agronomy and Plant Genetics. The Ineffective Agate line is a non-nodulating form of Agate Alfalfa and could require more nitrogen (Barnes et. al. 1990). Four-wing saltbush seeds were collected from native plants from Monument Valley, Arizona.

4.6.2 Soils

Three soil samples were collected from a former mill tailings site in Monument Valley, Arizona, to determine differences in amount of plant growth supported by each soil. Topsoil around the site area is reddish-yellow sand (Mesic Arid, Typic Torripsamment, series Sheppard, 96 percent sand) and has been remediated for uranium (U). No detectable concentrations (<5 mg U kg^{-1} soil) of U were present in the soil. The first soil sample was collected outside of the milling area where no mining processes took place and was termed "outside" soil in this chapter. It contained no detectable U and 58 mg V kg^{-1} concentrations. The second soil was collected from an area where a nitric and sulfuric acid evaporation pond was previously located and contained 111 mg vanadium (V) kg^{-1} (termed "inside" soil in this chapter). The final soil sample collected came from the region of a former tailings pile. *Atriplex* growth has been problematic on this soil, which is covered in a white crust and contains 198 mg V kg^{-1} (termed "plot" soil in this chapter). Only topsoil (0-20 cm) was collected in all three locations. Table 4–1 displays the chemical composition of the soils from the three different areas.

4.6.3 Water

Water was collected from three wells that had been previously analyzed and contained three very different nitrate (NO_3) concentrations. After collection from those three wells, water was tested again for selected chemical constituents. The NO_3 concentrations in the water were shown to be similar in all three wells. To simulate three different concentrations of NO_3, water from one well was left at baseline level contamination and the two other wells were each spiked with KNO_3 from a 1000 X stock solution to 500 and 1000 mg NO_3 kg^{-1} as nitrate prior to each watering event. This was to simulate the range of concentrations present in the contaminated aquifer as a whole. Sulfate (SO_4) concentrations ranged from 290 to 620 mg SO_4 kg^{-1}, the specific electrical conductance ranged from 2.8 to 3.7 mS/cm and pH ranged from 6.59 to 7.81. Table 4–2 contains the chemical composition of the water from each of the three wells.

4.6.4 Experimental Design of Nitrate Concentration Experiment

The first watering event occurred on December 15, 2000, with all sudan grass directly seeded into outside soil. Each pot was thinned to one plant after emergence. Four-wing saltbush had to be transplanted due to its slow growth rate. Plants were transplanted one month after initial planting. This was to ensure the planting of non-nodulated Ineffective Agate alfalfa, as the germplasm is 5-10 percent contaminated with nodulating alfalfa (Barnes, et al. 1990). All plants remained non-nodulated when transplanted into the experiment. Transplanting of alfalfa occurred in river washed sand because of a shortage (due to insufficient collecting) of outside Monument Valley soil. Water treatments included 1000 mg NO_3 kg^{-1}, 500 mg NO_3 kg^{-1} and 83 mg NO_3 kg^{-1} calculated as nitrate. Well #648 received no added NO_3 and remained at base contamination concentration of 83 mg NO_3 kg^{-1}. Water from well #778 was amended from 159 mg NO_3 kg^{-1} to 500 mg NO_3 kg^{-1} and well #777 was amended from 185 mg NO_3 kg^{-1}to1000 mg NO_3 kg^{-1}. Each treatment also received 50 mg phosphate (PO_4) kg^{-1} as KH_2PO_4, and Hoagland's trace mineral solution. Each plant/water treatment combination was repeated in four replicates and set up in a random block design. All plants in the nitrate experiment were harvested after 69 days on February 22, 2000. Plants were not mature and had not set seed at harvesting.

Table 4–1. Composition of soil collected from three different areas around uranium milling site: outside - outside the perimeter, inside - from area of former evaporation pond, and plot - from area of former tailings pile

Component	Soil- Outside	Soil-Inside	Soil-Plot	Units
Calcium	6120	37540	35100	mg/Kg
Strontium	131	515	692	mg/Kg
Iron	3362	6411	7211	mg/Kg
Magnesium	1735	5427	4914	mg/Kg
Manganese	103	186	262	mg/Kg
Potassium	21	4217	<5	mg/Kg
Sodium	697	1186	313	mg/Kg
Uranium	<5	<5	<5	mg/Kg
Vanadium	58	111	194	mg/Kg
Nitrate	7.6	160	45	mg/Kg
Sulfate	5.7	420	860	mg/Kg
Salinity	0.5	5.6	5.6	ds/M
ESP	0.8	1.5	0.6	%
Boron	0.21	0.49	0.16	mg/Kg
P-Bicarb-soluble	5.7	19	12	mg/Kg
pH	8.72	7.94	8.02	S.U.

Table 4–2. Composition of contaminated groundwater used to grow forage crops before addition of nitrate. Well 778 was amended to 500 ppm nitrate and well 777 was amended to 1000 ppm nitrate to test for the effects of these levels of contamination

Analytes	Well 648	Well 777	Well 778
Calcium	260	160	160
Strontium	24.7	13.1	9.9
Iron	<0.1	<0.1	<0.1
Magnesium	290	130	140
Manganese	<0.01	0.02	<0.01
Potassium	5.1	23	18
Sodium	310	130	120
Uranium	<0.2	<0.2	<0.2
Vanadium	<0.1	<0.1	<0.1
Nitrate	83	185	159
Sulfate	620	300	290
Chloride	64	38	32
Bicarbonate	210	225	176
pH	7.81	6.82	6.59
EC (mS/cm)	3.7	3.1	2.8

4.6.5 Experimental Design of Soil Performance Experiment

Piper and Sweet sudan grass were planted in four replicates in each soil from different areas. Each plant/soil combination was replicated four times in a random block design. The watering regime consisted of Tucson well water amended with 200 mg NO_3 kg^{-1} as KNO_3 and 50 mg PO_4 kg^{-1} as KH_2PO_4. Planting occurred on December 19, 2000, with harvesting after 64 days on February 21, 2001. Plants were not mature and had not set seed at harvest.

4.6.6 Experimental Design for Soil Amendment

The final experiment was designed to determine if amending all three soils would improve growth rates. Soil treatments included a 2:1, v:v mix of Monument Valley soil: Unigro Organic Potting Mix (a mixture of forest products, peat moss and vermiculite) (Silverbell Nursery, Tucson, Arizona) with controls consisting of unamended Monument Valley soil and pure Unigro Organic Potting Mix potting soil. One water treatment included Tucson well water amended with ¼ strength Peter's 20-20-20 fertilizer containing micronutrients for the first 3 weeks and full strength after 1 month of growth. The other water treatment included well #777 water amended to 1000 mg NO_3 kg^{-1} by a Ca/KNO_3 mixture and Hoagland's trace mineral solution with 10 mg Fe kg^{-1}. For this experiment Sweet sudan grass was planted in three replicates on April 23, 2001, and harvested 48 days later on June 10, 2001.

4.6.7 Laboratory Analysis

All tissues were dried overnight at 70°C and ground in a hammermill. Tissues too small to be ground in a hammermill were ground by hand with a mortar and pestle. All leaves and stems were combined rather than separated for the grinding process. Hydrocyanic acid (HCN) was determined by Arizona Veterinary Diagnostic Laboratory, University of Arizona using an enzymatic digestion and spectrophotometric assay on dried leaf tissue. Nitrate and sulfate analyses were performed by the Soil, Water and Plant Analysis Laboratory (SWAPL) at the University of Arizona. This consisted of water extraction and ion chromatography (Johnson and Ulrich 1950) on ground leaf and stem tissue. Total nitrogen (N) was determined on a Carlo Erba NA 1500 N-C-S Analyzer (Costech, Valencia, CA). Metal analysis had to be performed on composite samples of all replicates for each plant type/water treatment due to the small amount of tissue available. After combining all four replications, shoots and roots were separated and digested in a closed vessel microwave procedure using nitric acid and hydrogen peroxide. Manganese (Mn) and strontium (Sr) were detected by ICP-Emission spectrometry on a Leeman UV1000 ICP unit at the SWPAL (EPA, SW-846 Method 6010). Uranium and V concentrations were determined by Copper State Analytical Laboratory, Tucson, Arizona, after redigestion and filtration of the original digestates done by SWPAL. Nitrate in sudan grass from the soil amendment experiment was analyzed at Laboratory Consultants in Lordsburg, New Mexico. Plants were digested with aluminum sulfate, and nitrate was measured as mg NO_3-N kg^{-1} by nitrate ion electrode. These values were then converted to mg NO_3 kg^{-1}. Plant performance was measured by dry weight of shoots (stems and leaves) in grams.

4.6.8 Statistical Analysis

Statistical analyses were performed with the SAS Institute's JMPIN version 4 software program. Analyses were carried out on growth data that had been transformed with the natural logarithm to normalize the distribution (Ramsey and Schafer 1997). The ANOVA framework using nesting was used where appropriate to perform linear combinations. This allowed for the comparison of different water treatment/plant type treatments. One-way ANOVAs were performed on data when analyzing single factor main effects such as water treatment or plant type.

4.7 Results and Discussion

Plant growth was poorer than expected with the 1000 mg NO_3 kg^{-1} water concentration. Plants at the 83 mg NO_3 kg^{-1} and the 500 mg NO_3 kg^{-1} concentrations grew 4.7-4.9 times larger than plants at the 1,000 mg NO_3 kg^{-1} concentration ($F = 24.68$, $p < 0.0001$). Growth data are presented in Figure 4–1 (Appendix N). Sweet sudan grass grown in potting soil receiving 1,000 mg NO_3 kg^{-1}grew 3.81 times larger than plants in outside soil receiving the same water treatment ($F = 8.26$, $p = 0.03$).

In the soil experiment, outside soil supported three times more plant growth than inside soil, and 27.8 times more growth than plot soil ($F = 46.27$, $p < 0.0001$). Sudan grass grown in the plot soil displayed symptoms of vanadium poisoning including overall chlorosis, clubbed roots and rapid death (Cannon 1963). All three soils benefited from the addition of organic matter in the form of potting soil. The amendment resulted in improved growth for all three Monument Valley soils watered with fertilizer ($F = 114.8$, $p < 0.0001$). The problematic plot soil supported 541.8 times more growth when amended ($F = 47.82$, $p = 0.0001$), the outside soil 203.3 times more growth ($F = 45.88$, $p < 0.0001$), and the inside soil 14.1 times more growth ($F = 19.90$, $p = 0.0006$). Amending soils did not have a significant effect when watering plants with 1000 mg NO_3 kg^{-1} (as Ca/KNO_3) ($F = 2.36$, $p = 0.1756$), but the amended soil data had large standard errors (mean = 9.87, SE = 3.258). Figure 4–2 (Appendix N) displays mean growth with error bars for this experiment.

Both NO_3 and HCN accumulation posed threats to livestock health in the plants studied. Hydrocyanic acid accumulation did not vary with the NO_3 concentration of the water ($F = 0.5875$, $p = 0.6291$). Leaves of the hybrid sudan grasses Sweet and Sorghum-sudan accumulated hydrocyanic acid above 500 µg HCN g^{-1}, a recommended safety threshold for feeding sorghum and sudan grass to cattle (Strickland et al. 1995a). Piper sudan grass contained the lowest amount of HCN with the mean concentration falling within the threshold (mean = 232.9, SE = 192.5).

Nitrate accumulation in plants differed with NO_3 concentration of the water used ($F = 12.01$, $p < 0.0001$). The 1000 mg NO_3 kg^{-1} water concentration resulted in 2.0 times more NO_3 accumulation than the 500 mg NO_3 kg^{-1} and 8.0 times more NO_3 accumulation than the 83 mg NO_3 kg^{-1} water concentration. All plants at the 500 and 1000 mg NO_3 kg^{-1} water concentrations accumulated NO_3 above 5000 mg NO_3 kg^{-1}, putting them above safety thresholds for cattle forage (Strickland et al. 1995b). Piper sudan grass was the safest sudan grass with HCN production, but accumulated NO_3 above 5000 mg NO_3 kg^{-1} at the lowest water NO_3 concentration. Four of the six plant types at the lowest water NO_3 concentration accumulated above 5000 mg NO_3 kg^{-1}. Figure 4–3 (Appendix N) displays the NO_3 accumulation by plant type and water NO_3 concentration. Only Agate alfalfa and Ineffective Agate alfalfa were able to process NO_3 efficiently at the lowest water NO_3 concentration. Agate alfalfa concentrated a mean of 2254.3 mg NO_3 kg^{-1} (SE = 847.3) and Ineffective Agate alfalfa concentrated 2308.3 ppm nitrate (SE = 652.4), both levels falling below the 5000 mg NO_3 kg^{-1} safety threshold. While the alfalfa plants had the smallest concentration of NO_3 they also had the greatest percentage of total N ($F = 7.22$, $p = 0.01$). This indicates that they processed the NO_3 into cellular components more efficiently than sudan grass and four-wing saltbush. The percentage of total N in the plants corresponded to the NO_3 concentration used in the water ($F = 29.76$, $p < 0.0001$). Figure 4–4 (Appendix N) displays the total N data.

Plants from the soil amendment experiment grown with 1000 mg NO_3 kg^{-1} water concentration were also tested for NO_3 accumulation. Sweet sudan grass did not accumulate less NO_3 in amended outside soil when compared to Sweet sudan grass grown in unamended soil ($F = 0.08$, $p = 0.795$). Sweet sudan grass grown in potting soil did result in a 47-48 percent reduction in NO_3 content ($F = 26.9$, $p = 0.007$). However, the NO_3 concentration was still beyond the safety threshold for feeding to cattle.

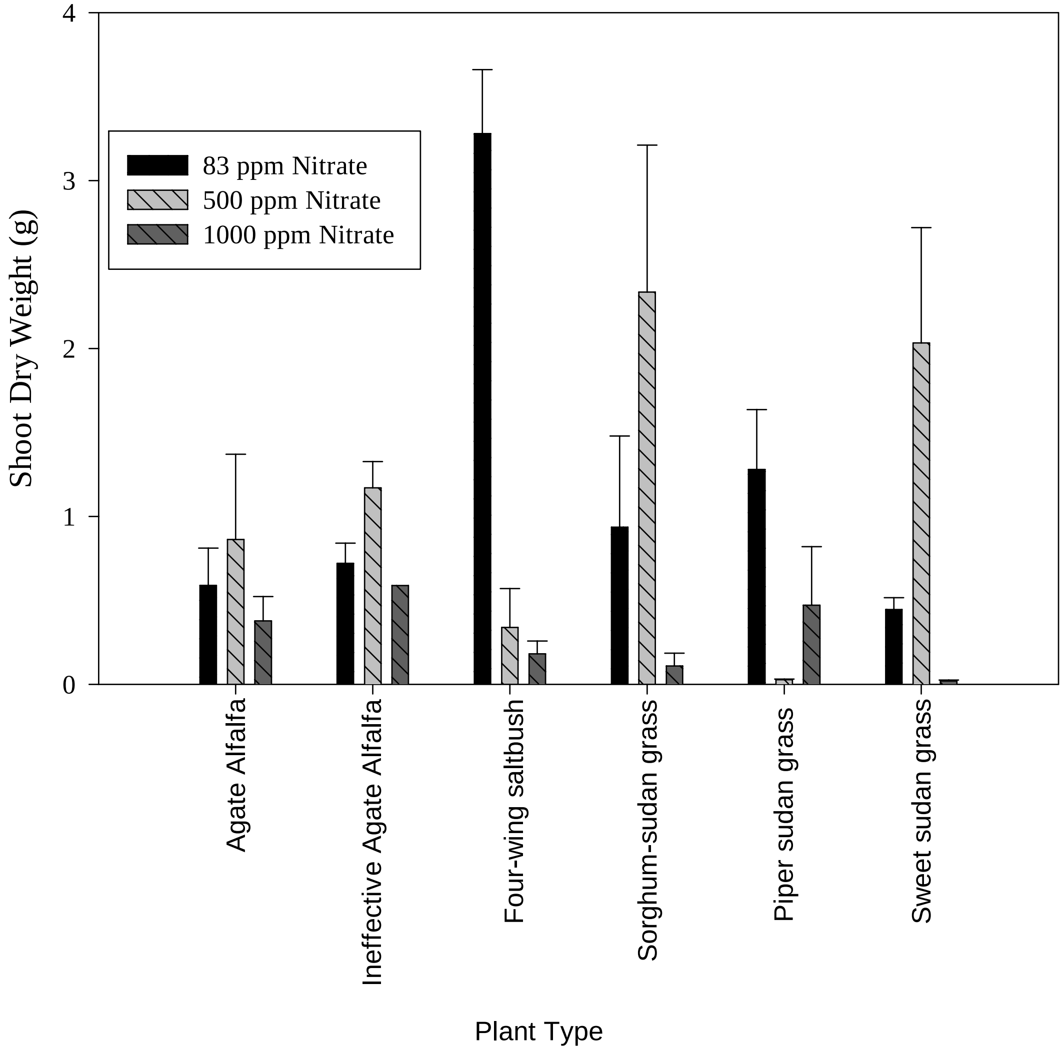


Figure 4–1. Mean plant growth measured as dry shoot weight for plants grown using groundwater contaminated with nitrate and sulfate. Error bars represent standard errors of the means.

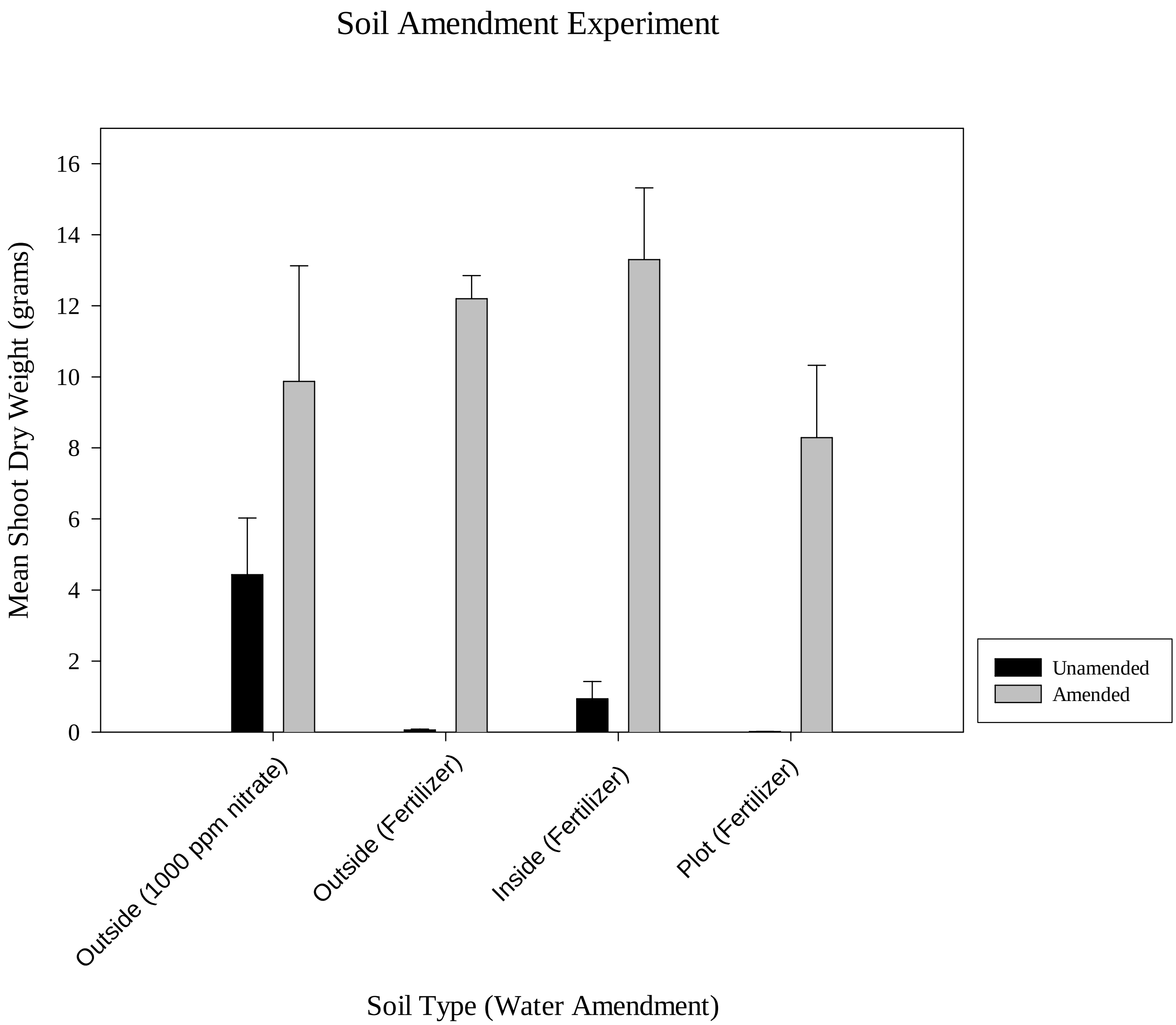


Figure 4–2. Mean plant growth measured as dry shoot weight for plant grown in site soil and site soil amended at a 2:1, v:v mixture of site soil: potting soil. Error bars represent standard errors of the means.

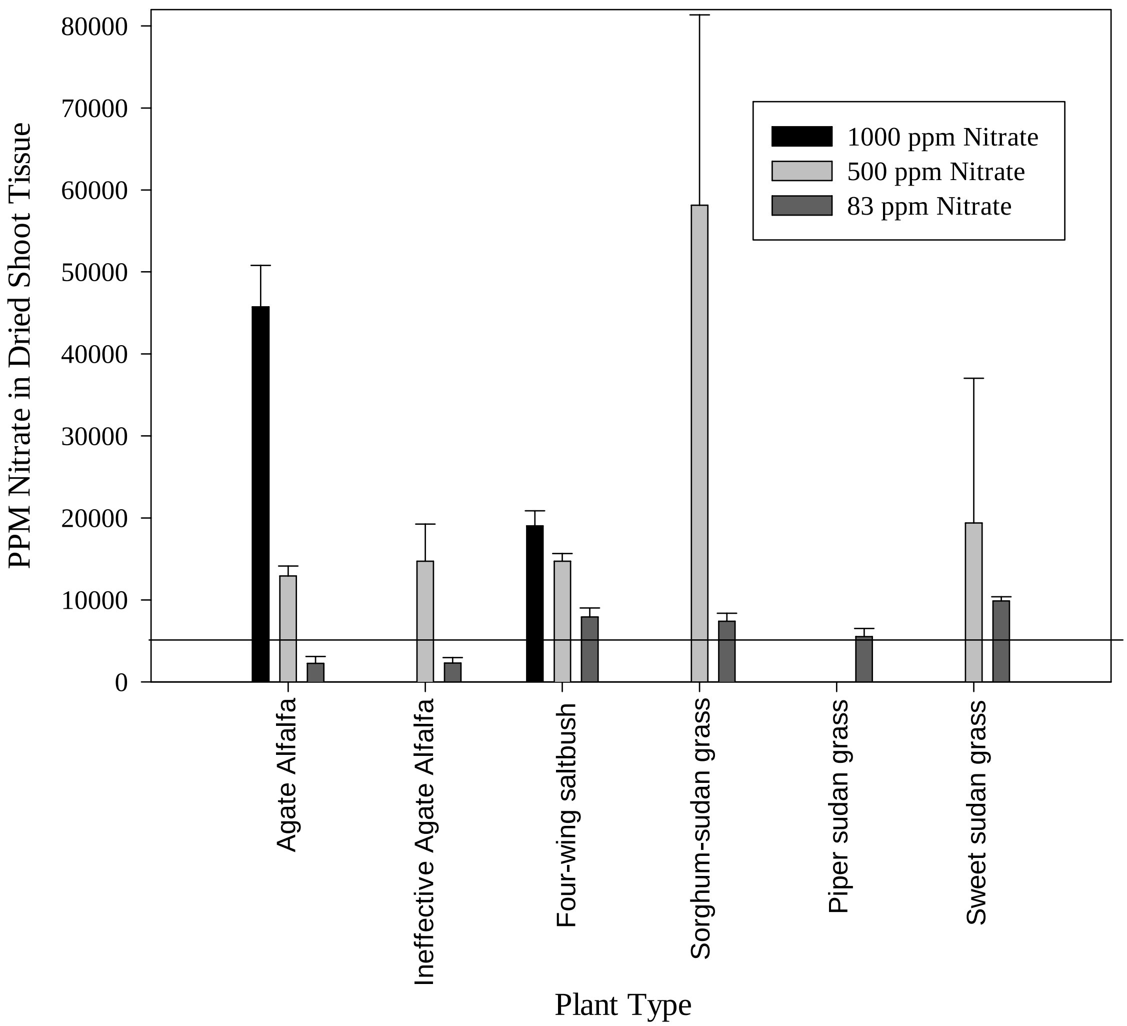


Figure 4–3. Mean nitrate (as NO_3) concentration in dry shoot tissue from plants grown with groundwater contaminated with nitrate and sulfate. Line represents lower boundary of recommended feeding concentrations for nitrate (5000 mg NO_3 kg^{-1}). Error bars represent standard errors of the means.

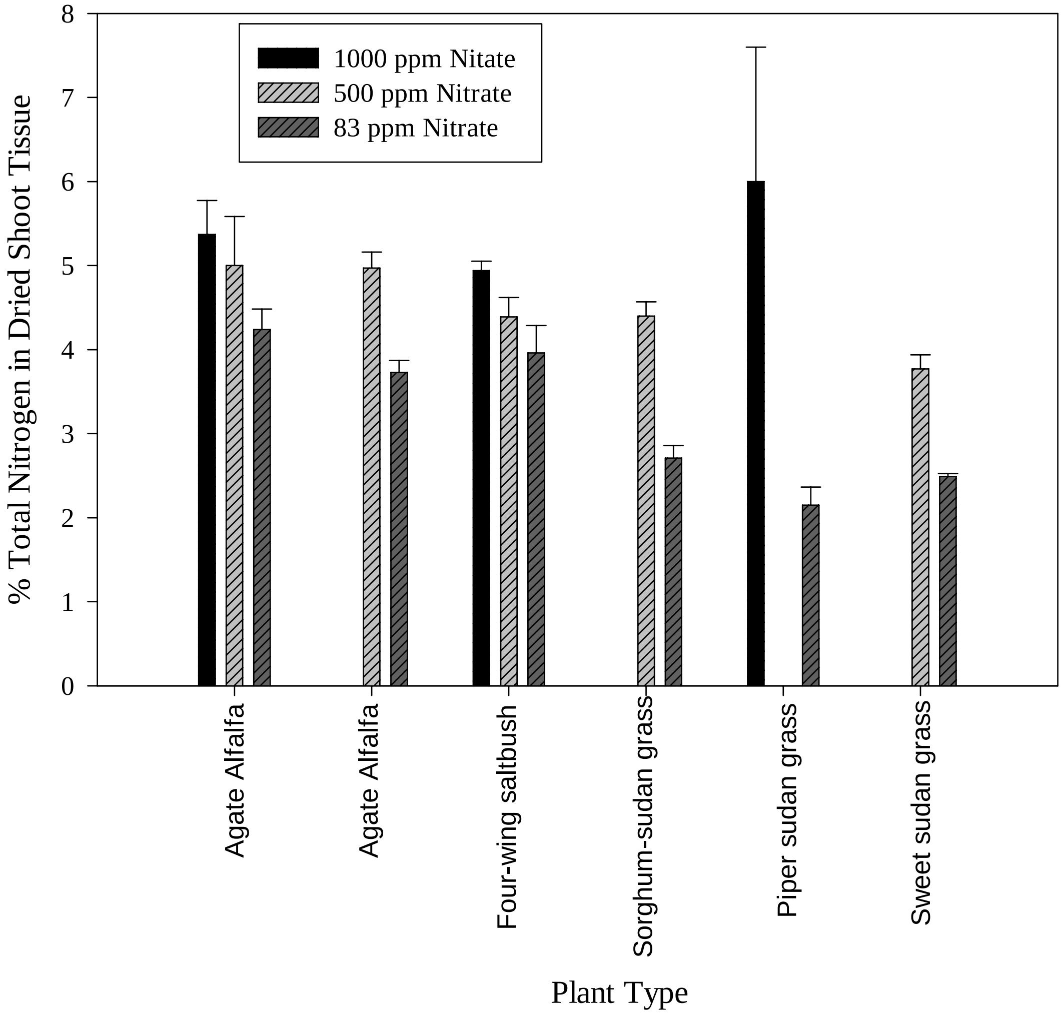


Figure 4–4. Mean percent total nitrogen in dry shoot tissue from plants grown with groundwater contaminated with nitrate and sulfate. Error bars represent standard errors of the means.

Sulfate accumulated at high enough concentrations to constitute 0.4 percent sulfur (S) in a sheep's diet, which has been shown to be a maximum tolerable limit of dietary S for sheep (Subcommittee on Mineral Toxicity in Animals 1980). The percent S data presented here was measured as SO_4 and then converted to percent S because of a faulty C-N-S analyzer. Agate and Ineffective Agate alfalfa grown at the 83 mg NO_3 kg^{-1} water concentration (containing 620 mg SO_4 kg^{-1}) had mean S percentages of 0.61 percent (SE = 0.23 percent) and 0.7 percent (SE = 0.41 percent). If the alfalfa were supplemented with another low S feed source, the percentage of S in the animal's diet would decrease, making the alfalfa safer for feed. Both alfalfa varieties accumulated more S than did sudan grass at the 83 mg NO_3 kg^{-1} water concentration ($F = 20.6$, $p < 0.0001$). Sulfate accumulated above background concentrations taken as Piper sudan grass grown in site soil with Tucson well water ($F = 75.9$, $p < 0.0001$). These data are presented in Figure 4–5.

Strontium did not accumulate to 2,000 mg Sr kg^{-1} and Mn did not accumulate to 1,000 mg Mn kg^{-1}, which are considered to be toxic levels to livestock (Subcommittee on Mineral Toxicity in Animals 1980). Vanadium did not accumulate to concentrations great enough to constitute lethal levels of 20 mg V kg^{-1} body weight for calves or 40 mg V kg^{-1} for sheep (Subcommittee on Mineral Toxicity in Animals 1980). Uranium was below detection limits (<0.01 mg/kg) in most plant samples. Three samples did accumulate U, with the highest concentration being 3 mg U kg^{-1}, well below the recommended dietary concentration for rats of 400 mg U kg^{-1} (Subcommittee on Mineral Toxicity in Animals 1980).

4.8 Conclusions

Sudan grass accumulates too much HCN and NO_3 to be good forage with these water treatments. Alfalfa would be a better choice because it was shown not to produce HCN; and, at the 83 mg NO_3 kg^{-1} water concentration, did not accumulate toxic amounts of NO_3. Sulfur concentrations in the alfalfa were above recommended feeding percentages and low S content forage would need to be supplemented to bring down the overall S percentage of the animals' diets. More testing needs to be done to determine if the alfalfa would extract enough NO_3 out of irrigation water to keep NO_3 from leaching back into the aquifer. Because the alfalfa was grown in river-washed sand due to a shortage of Monument Valley soil, alfalfa also should be grown in Monument Valley soil to see how growth would be affected. It might prove beneficial to grow alfalfa from seed in stands of five to ten plants per pot. This arrangement could be more representative of what would occur in the field. It could also be beneficial to obtain alfalfa varieties already grown in the Monument Valley area to compare to the Agate lines. Large NO_3 concentrations in water needs diluting before being used for irrigation purposes in a field setting. Four of the six plant types at the 83 mg NO_3 kg^{-1} water concentration accumulated above 5,000 mg NO_3 kg^{-1}.

The data indicate that a phytoremediation farm could perform best in amended soil rather than pure Monument Valley soil. Future soil amendments to be tested include sawdust and straw for their nitrogen processing capabilities and sphagnum peat moss for water retention capabilities. If using alfalfa, then amendment may only be needed the first year to help the alfalfa stand establish itself.

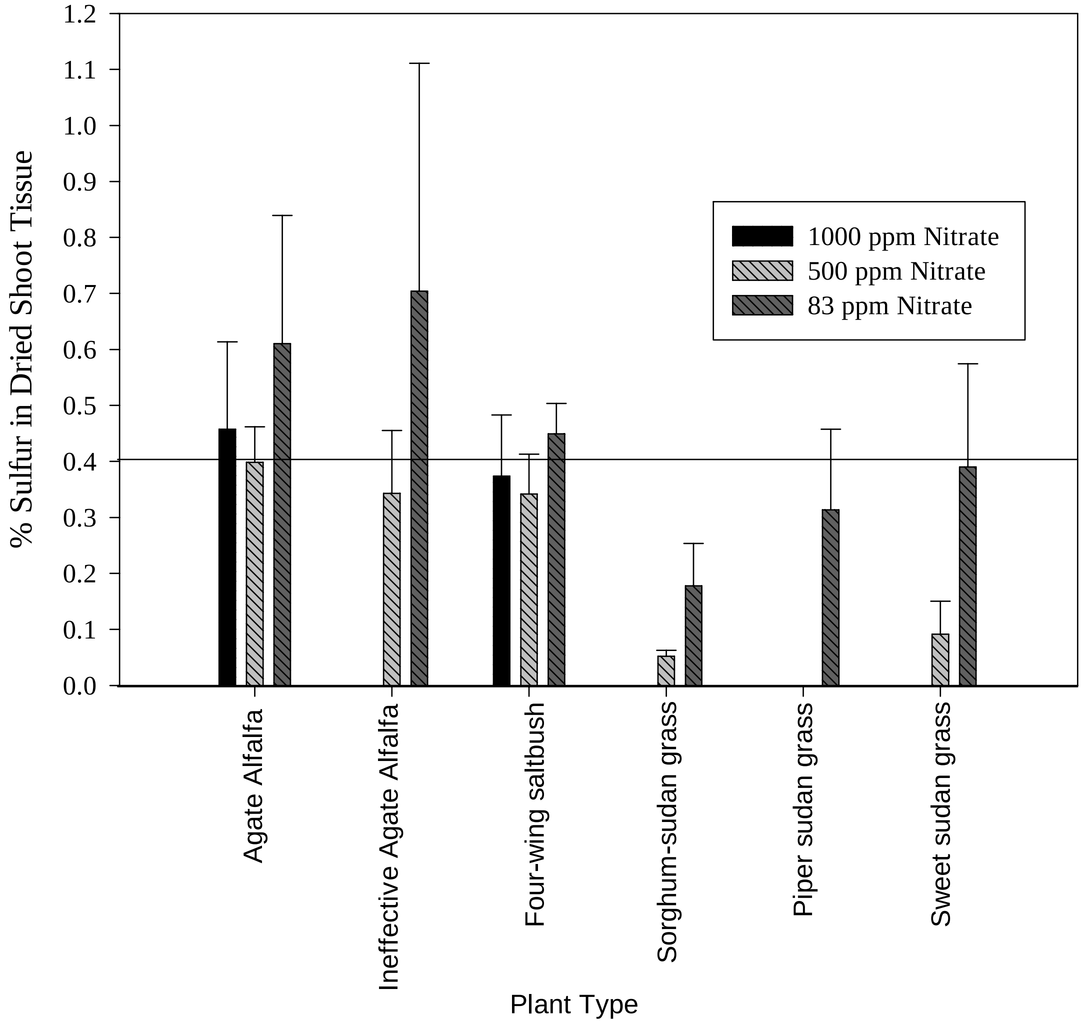


Figure 4–5. Mean percent sulfur calculated by sulfate content of dry shoot tissue from plants grown with groundwater contaminated with nitrate and sulfate. Line represents maximum tolerable dose (0.4 percent) of dietary sulfur. Error bars represent standard errors of the means.

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5.0 Pilot Farm Feasibility

5.1 Summary

The land-farming alternative for remediation of nitrates in the alluvial aquifer is a type of phytoremediation. The term phytoremediation (*phyto* = plant and *remediation* = to correct a wrong) is the name given to a set of technologies that use plants to clean contaminated sites (EPA 2000). Land farming is a phytoremediation technique that applies information that has been known for years in agriculture and range science to solving an environmental problem. Therefore, the phytoremediation farm is an application of plant ecology. Ideally, the farm will have several functions in the disturbed ecosystem: (1) extract nitrates in the alluvial plume or in irrigation water pumped from the plume; (2) convert nitrates into useful plant biomass; (3) minimize water infiltration and leachate movement; and (4) enhance restoration of the disturbed ecosystem.

The feasibility of directly extracting plume water from the alluvial aquifer using native phreatophytes at Monument Valley was addressed in Chapter 3. The feasibility of using the nitrate plume for irrigation water and fertilizer in a farming operation rests on several issues:

- local ecological impacts,
- land suitability for irrigation,
- choice, establishment, and value of cropping systems,
- water and cultural requirements of crops,
- nitrate uptake rates and toxicity,
- fate and toxicity of sulfate and other constituents in irrigation water, and
- irrigation management to preclude the return of nitrate to the aquifer.

A phytoremediation farm could be managed to improve the condition of rangeland ecology in the area. The current poor range condition, as evidenced by the dominance of exotic grasses and forbs in the plant community and the lack of recruitment of native forage species, can be attributed to a long history of heavy grazing. The vegetation of the proposed location for a farm, an area just north of the former millsite fenceline that was bladed during the surface remediation, consists of weedy plants with virtually no forage value. A high-yield hay or forage crop would improve the value of the disturbed land and, assuming no change in stocking rates, would provide enough fodder to reduce grazing pressures and give the plant ecology of surrounding rangelands and a chance to recover.

Classification of irrigation suitability on Navajo lands is based on several soil physical and chemical properties. Based on existing soil data, the proposed location for the farm would fall into the second highest arable land class. It drops out of the highest class because the sandy soil has higher permeability and lower water storage capacity than desirable. Nonetheless, the fine sands are suitable for many hay and forage crops. A more thorough soil characterization would be an early task in the development of a farming operation.

Cropping systems for hay production, grazing, and seed production are all practical alternatives for using nitrogen recovered from the alluvial aquifer. A University of Arizona (UA) greenhouse study (Chapter 4), designed primarily to evaluate varieties of sudan grass for hay production, found that alfalfa would be a better choice because sudan grass is more likely to accumulate toxic amounts of HCN and NO_3. Previous UA studies have demonstrated the practicality of growing and cutting fourwing saltbush, the dominant native shrub in the area, as a hay crop. Fourwing saltbush could also be grown for grazing. In this case, it would be allowed to grow through the summer to maximize productivity and nitrogen accumulation, and then grazed during the winter. A seed crop may be a more acceptable alternative because it would help alleviate toxicity concerns that must be addressed using forage crops. Seed would be harvested for use in rangeland improvement or mine land reclamation. Again, fourwing saltbush would be a valuable plant for seed production. Overall, we consider fourwing saltbush to be a very practical and versatile plant for a phytoremediation farm at Monument Valley.

Sulfate in the irrigation water would not likely be toxic to crop plants or animals that consume forage produced by the phyto-farm. Because of relatively high calcium in the irrigation water, most sulfate would probably precipitate as gypsum (calcium sulfate) in the soil profile. Such “gypsic horizons” are common in arid land soils. An irrigation system could be designed and managed to supply sufficient water for high yields of phytoremediation crops, to optimize nitrate uptake in plant tissues without reaching toxic levels, to prevent seepage of nitrate water back to the aquifer, and to precipitate gypsum at depth within the soil profile.

We recommend development of a pilot farm to collect data needed to address remaining uncertainties associated with a full-scale farming operation. The pilot study would be designed primarily to develop the best farm management practices given the objectives and constraints of pytoremediation. Objectives of a pilot farm include:

- determine optimum irrigation rates for managing the soil water balance,
- determine optimum nitrate concentrations to be applied in the irrigation water,
- monitor sulfate accumulation in the soil profile,
- monitor the safety of plant materials and accumulation of residual constituents in the soil,
- select a cropping system that will rapidly remove nitrate without causing toxicity problems, and is also a valuable crop for local residents.

5.2 Plant Ecology

If the phytoremediation farm is to provide realistic opportunities to improve the overall ecological health of the site, the design and long-term management of the farm must be based on a sound understanding of existing and potential plant communities, and of the biogeochemistry of contaminants (nitrate and sulfate). This section is a summary of the literature review and site characterization work completed to date on these topics.

5.2.1 Plant Community Characteristics

The plant ecology of the former mill site, the tailings areas, and the area overlying the nitrate plume, were first characterized in 1997 (DOE 1998; Section 4.7). The activity consisted of identifying species in these areas, defining and mapping plant associations, and estimating the abundance, distribution, and structure of plant populations. This information was acquired as part of an early evaluation of the feasibility of revegetating the site with useful native shrubs and of recovering ammonium and nitrate from subpile soils and from the alluvial aquifer using native plant farming and phytoremediation.

The 1997 characterization was repeated for shrub species using more quantitative methods in summer, 2000 (see Section 3.3). In the 2000 survey, the shrub vegetation on the subpile soil and plume areas was surveyed to species level, and plant heights, widths, and percent cover were determined using line transects and plant density plots. An aerial survey of the area was completed to update the 1995 survey with respect to vegetation cover. The aerial survey data, combined with the ground data, provide a baseline assessment of current species composition, vegetation cover, and vegetation vigor for latter comparison, as remediation of the site progresses.

5.2.1.1 Plant Species, Associations, and Vegetation Mapping

Table 5–1 lists plant species identified at the site. The occurrence and relative abundance of species, coupled with knowledge of their physiological and ecological tolerances, provide measures of the health of the ecosystem, and provide evidence of environmental conditions that are of importance for evaluating land farming and phytoremediation. A plant association is a vegetation classification unit. An association generally has a consistent floristic composition, a uniform appearance, and a distribution that reflects a certain mix of environmental factors that can be shown to be different from other associations. The association is a synthesis of local examples of vegetation called stands. Associations are named for their dominant species.

For the purpose of mapping vegetation at Monument Valley, a modified releve’ method was used to characterize plant cover in stands near monitoring wells and then stands were grouped into associations using simple ordination and gradient analysis techniques (e.g., Barbour et al. 1987). Associations were identified by first grouping stands with similar species composition and cover. Because species composition and cover vary across the site as a continuum rather than as discrete units, no clear breaks between groups of stands were apparent. A simple gradient analysis of dominant species was used to group stands. Figure 5–1 illustrates how the abundance of dominant species varies along a gradient from stand to stand.

Results of the gradient analysis suggest that some dominant species are associated and that associations overlap—a given stand may occur in more than one association. Four associations occur, named for their two most abundant shrubs:

- *Sarcobatus vermiculatus* (black greasewood) and *Atriplex confertifolia* (shadscale),
- *Atriplex canescens* (fourwing saltbush) and *Haplopappus pluriflorus* (jimmyweed),
- *Poliomintha inicana* (bush mint) and *Ephedra torreyana* (joint fir), and
- *Salsola iberica* (Russian thistle) and *Ambrosia acanthacarpa* (bur ragweed).

Production of a vegetation map (Figure 5–2) involved (1) mapping stand locations on the 1995 aerial photograph; (2) identifying vegetation patterns in the photograph, under magnification, that were consistent with the plant associations; (3) outlining mapping unit boundaries using a combination of stand locations and vegetation patterns; and (4) returning to the field to check the reliability of the photograph interpretation. Acronyms of dominant plants in associations are used for mapping unit titles in Figure 5–2.

Table 5–1. Plants Growing on the Reclaimed Tailings and Plume Areas of Monument Valley

Scientific Name[a]	Acronym[b]	Common Names[c]
Shrubs		
Artemisia filifolia Torr.	ARFI	sand sagebrush, old-man sagebrush
Atriplex canescens (Pursh) Nutt.	ATCA	fourwing saltbush, cenizo, chamizo
Atriplex confertifolia (Torr. & Frem.) Wats.	ATCO	shadscale, spiny saltbush, sheep fat
Chrysothamnus nauseosus (Pall.) Britt.	CHNA	rubber rabbitbrush, chamisa
Ephedra torreyana S. Wats.	EPTO	joint fir, Mormon tea, Brigham tea
Gutierrezia sarothrae (Pursh) Britt. & Rusby	GUSA	broom snakeweed,
Haplopappus pluriflorus (Gray) Hall	HAPL	jimmyweed, jimmy goldenbush
Lycium pallidium Miers	LYPA	tomatillo, desert wolfberry
Opuntia phaeacantha Engelm.	OPPH	prickly pear, many-spined cactus
Poliomintha incana (Torr.) Gray	POIN	bush mint, rosemary-mint, purple sage
Sarcobatus (Hook.) Torr.	SAVE	black greasewood, chico, chicobush
Senecio douglasii DC.	SEDO	threadleaf groundsel, creek senecio
Tamarix ramosissima Ledeb.	TARA	tamarisk, salt cedar, tamarisco
Yucca angustissima Engelm.	YUAN	Tsá'ázi'ts'óóz, narrowleaf yucca, fineleaf yucca
Grasses		
Aristida purpurea Nutt.	ARPU	Purple threeawn, wiregrass
Bromus tectorum L.	BRTE	Zéé'iilwo'ii, cheatgrass brome, downy brome
Festuca microstacys Nutt.	FEMI	small fescue, vulpia
Hilaria jamesii (Torr.) Benth.	HIJA	galleta, curly grass
Oryzopsis hymenoides (R. & S.) Ricker	ORHY	Indian ricegrass, sand bunchgrass
Sporabolis airoides (Torr.) Torr.	SPAI	alkali saccaton
Sporabolis cryptandrus (Torr.) Gray	SPCR	sand dropseed
Sporabolus contractus A.S. Hitchc.	SPCO	spike dropseed
Sporabolus giganteous Nash	SPGI	giant dropseed
Forbs		
Tripterocalyx carneus (Greene) Galloway	TRCA	wooton sandverbena
Chenopodium album L.	CHAL	common lambsquarter, goosefoot
Ambrosia acanthacarpa Hook.	AMAC	bur ragweed
Amsinkia tessellata Gray	AMTE	rough fiddleneck
Arabis L. species	AR sp.	rockcress mustard
Astragalus L. species	AS sp.	milkvetch, locoweed
Datura wrightii Regel	DAWR	sacred datura, angels trumpet
Descurainia pinnata (Walter) Britt.	DEPI	pinnate tansey-mustard
Erigeron L. species	ER sp1.	Daisy
Eriogonum Michx. Species	ER sp2.	wild buckwheat, skeletonweed
Kochia scoparia (L.) Schrader	KOSC	kochia, summer cypress
Lepidium L. species	LE sp.	pepperweed, peppergrass
Lupinus L. species	LU sp.	Lupine
Machaeranthera Nees. Species	MA sp.	Aster
Oenothera albicaulis Pursh	OEAL	white-stemmed evening primrose
Plantago patagonica Jacq.	PLPA	wooly plantain
Salsola iberica Sennen & Pau	SAIB	Russian thistle, tumbleweed
Sphaeralcea coccinea (Pursh) Rydb.	SPCO	scarlet globemallow, falsemallow
Sphaeralcea parvifolia A. Nels	SPPA	Nelson globemallow

[a]The scientific nomenclature and authorities is consistent with Voss (1983) and the choices of Welsh et al. (1987).
[b]Acronyms combine the first two letters of the genus and species names.
[c]English and Spanish common names are from a variety of sources (Mayes and Lacy 1989; Dodge 1985; Elmore and Janish 1976; Dunmire and Tierney 1995; Whitson 1992).

5.2.1.2 Native Phreatophyte Populations

Phreatophytes (literally "well plants") at the Monument Valley site may act, in essence, as passive, solar-powered, pump-and-treat systems for nitrates in the alluvial aquifer. Two phreatophyte populations grow over the plume area: *Sarcobatus* (black greasewood) and *Atriplex canescens* (fourwing saltbush). *Sarcobatus* is an obligate phreatophyte requiring a permanent ground water supply, and can transpire water from aquifers as deep as 18 meters below the land surface (Nichols 1993, 1994). *Atriplex* is a facultative phreatophyte; it takes advantage of ground water when present but can tolerate periods of low water availability. The rooting depth of *Atriplex* may exceed 12 meters (Foxx et al. 1984; Glenn et al. 2000).

A line intercept method (Bonham 1989) and high-resolution aerial photography were used to estimate *Sarcobatus* cover in the *Sarcobatus* /*Atriplex confertifolia* (1) mapping unit. The potential *Sarcobatus* cover was estimated using the February 1995 photograph (before the site was sprayed with herbicides), and not the current cover (DOE 1998; Section 4.7.2). The results show 37 percent *Sarcobatus* cover (95 percent C.I. = ±5.8 percent) in 1995. The percent cover of *Atriplex* in the *Atriplex* /HAPL mapping unit (Figure 5–2), estimated using a releve' method (Bonham 1989), was about 5 percent. *Atriplex* is a highly palatable browse species for livestock in the area and, therefore, a grazing decreaser. After 1995, the phreatophyte community was apparently sprayed with herbicide, damaging or killing many of the plants. Although the plant community appears to be recovering, the total plant cover over the plume area, determined by line intercept methods in 2000, is only 7 percent. The percent cover of *Sarcobatus* in the *Sarcobatus* / *Atriplex confertifolia* mapping unit is now only 5.5 percent, while *Atriplex* density is no higher than 4.4 percent in the *Atriplex* /HAPL unit (see Section 3.3).

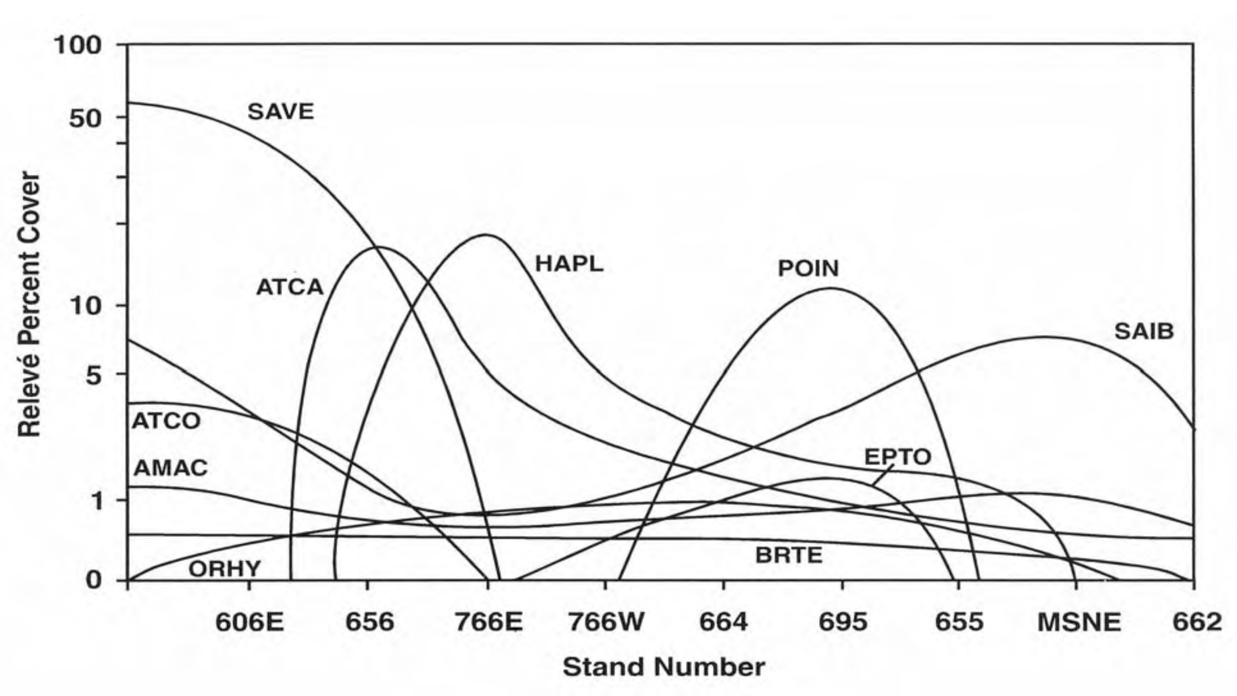

Figure 5–1. Potential Phytoremediation and Land Application Areas with Respect to Plant Associations Indirect Gradient Analysis of Monument Valley Vegetation. Stand numbers correspond to monitoring wells and hydropunch locations shown in Figure 5–2.

Volunteer *Sarcobatus* and *Atriplex* plants have established within the fence of the new tailings pile area. The age and size of these volunteer plants were evaluated in 1997 as measures of growth rate. Three *Sarcobatus* plants and two *Atriplex* plants that volunteered in the tailings subpile soils were sampled. Plant height, the long diameter of the canopy, and the short diameter of the canopy were measured for all five plants. Cross sections of the primary stem of each plant were cut and prepared for analysis using the methods of Fritts and Swetnam (1989). Stem sections that were cut at an oblique angle in the field were re-cut at a transverse angle. Specimens were polished with a power sander using sequentially finer grades of sandpaper until vascular cells were discernible under magnification. Entire cross sections were examined for locally absent and double rings and then the rings were counted. Once *Sarcobatus* plants become established in disturbed areas, reproduction occurs primarily as sprouting from underground stems that spread laterally from mature plants. This cloning of nurse plants was observed in the subpile soil area. The density of new *Sarcobatus* plants, most likely clones, was counted within a 6-meter radius of the three larger nurse plants. The results (Table 5–2) show that both species reach a mature size and begin reproduction in fewer than 4 years.

Table 5–2. Canopy Measurements and Annual Growth Rings of Volunteer Sarcobatus and Atriplex Canescens Growing in Tailings Subpile Soils in 1998

Plant Number[a]	Height (m)	Long Diameter (m)	Short Diameter (m)	Canopy Area[b] (m^2)	Clone Density[c] (100 m^{-2})	Annual Growth Rings
SAVE1	1.35	2.64	2.03	5.68	1.8	4
SAVE2	1.47	2.31	2.16	5.76	3.5	4
SAVE3	1.45	2.97	1.83	6.19	14.2	4
Atriplex 1	1.02	1.47	1.32	1.55	NA	4
Atriplex 2	0.89	1.52	1.01	1.07	NA	4

[a]Plant numbers include the genus/species acronyms given in Table 5–1.
[b]Canopy volume was calculated as the area of an ellipse—pi*(long diameter/2)*(short diameter/2)—multiplied by plant height. This overestimate of the volume suffices for comparative purposes.
[c]Seedlings with a 6-meter radius of nurse plants were assumed to be clones.

These dendrochronology findings were reinforced by studies undertaken by the University of Arizona from 1997 to 2000 (see Section 3.3). *Atriplex* and *Sarcobatus* seedlings grown in the greenhouse from local accessions were planted in grazing exclosures in the soil over the plume. Existing mature *Atriplex* and *Sarcobatus* were also protected from grazing by building fences around them. *Atriplex* transplants, irrigated over the first year only, grew to greater than 1.5-meter height by the third year and appear to be rooted into the alluvial plume. An isotope study has been done (see Chapter 3), and concluded that it is most likely that transpiration in *Atriplex* transplants originates in the alluvial aquifer. Mature *Sarcobatus* and *Atriplex* plants that were protected from grazing doubled their standing biomass over 3 years, while unprotected shrubs stayed the same size over those years.

The above characterization data suggests that phytoremediation is a viable option and is attractive at this site in part because it will improve the plant ecology, which has been severely degraded. However, a pilot study is required to answer questions of efficacy, safety, and cost.

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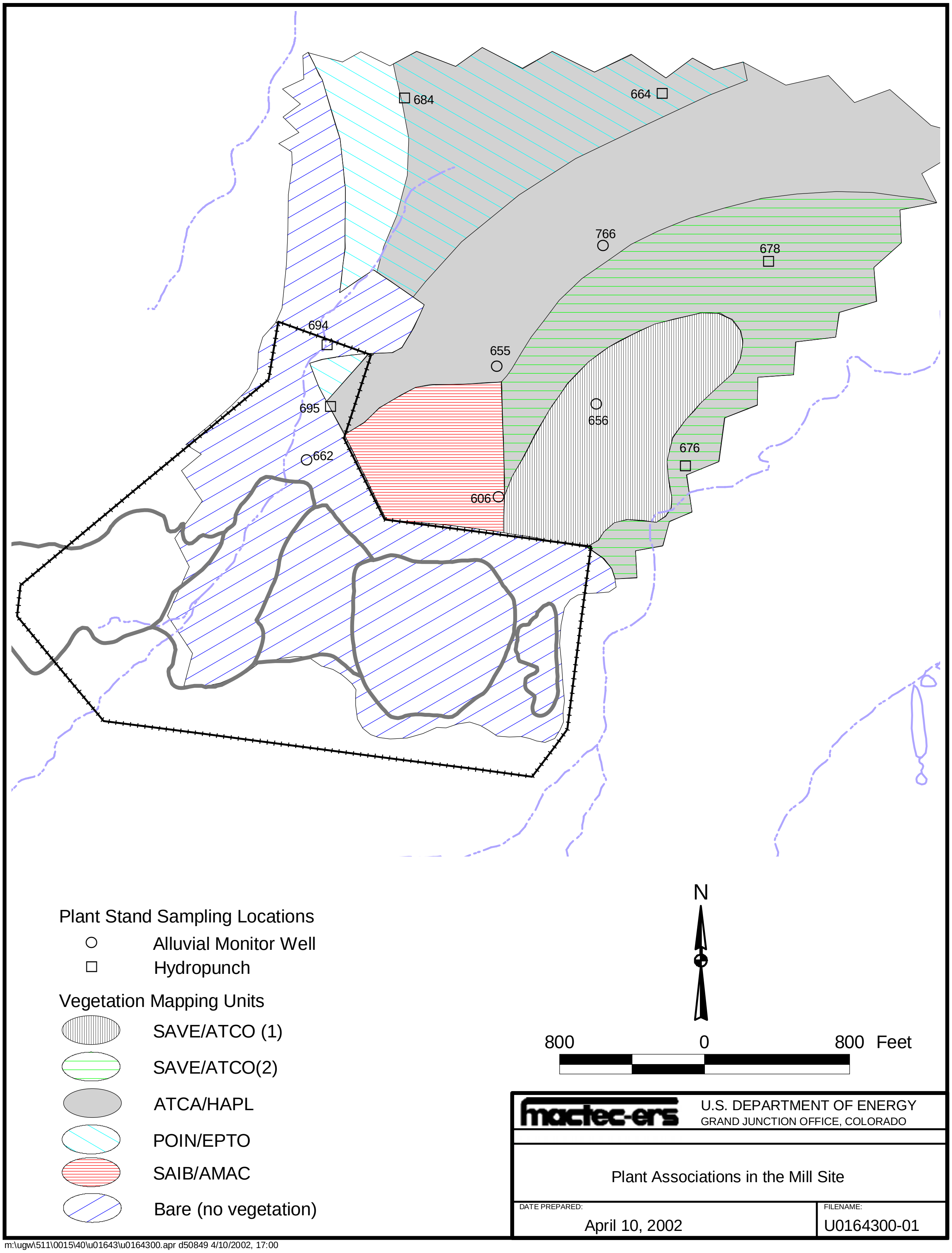

Figure 5–2. Plant Associations in the Mill Site

5.2.2 Nitrogen and Sulfur in Irrigated Desert Ecosystems

Since nitrogen and sulfur are above background levels in the plume water, it is important to consider how these elements will affect the soils and biota when they are brought to the surface for land farming.

5.2.2.1 Nitrogen Cycle

Nitrogen (N) is an essential macronutrient for the growth of higher plants. Nitrate (NO_3^-) and ammonium (NH_4^+) in soils and ground water are the most common plant-available forms of N in arid and semiarid ecosystems (Coyne et al. 1995). Utilization of NO_3^- by higher plants involves the uptake, storage, translocation, and incorporation of N into organic forms. Most N uptake is through roots, although foliar uptake may also occur. Nitrogen taken up from soil by the roots of terrestrial plants is either in the NO_3^- form or the NH_4^+ form. NO_3^- and NH_4^+ are taken in through the epidermis of plant roots and into the symplast of cortical and endodermal cells by way of a combination of passive diffusion and active transport, which requires expenditure of energy.

Once in the plant, NO_3^- is reduced to ammonia (NH_3) or NH_4^+, either in the root or after it is transported up the xylem into the leaves. NO_3^- may be stored in cell vacuoles for a period of time before it is reduced. Reduction of NO_3^- is driven by photochemical energy captured through photosynthesis. The NH_3 or NH_4^+ is converted to amides and, through reactions catalyzed by transferases, amides are converted to amino acids. The amino acids are the building blocks for complex nitrogenous compounds in the plant protoplasm including proteins, chlorophyll, growth regulators, alkaloids, nucleosides, nucleotides, and nucleic acids.

Some N bound in live plant protoplasm is lost as NH_3 through stomates to the atmosphere. However, most N is returned to the soil either by death and decay of plant tissue or removed by grazing animals. Most N in terrestrial ecosystems resides in soil organic matter. Bacteria and fungi decay dead plant protoplasm (litter) producing amino acids and other soil organic residues. This soil organic matter is eventually converted to NH_4^+ and NH_3 by amnifying bacteria. N in plant biomass ingested by grazing animals is excreted in urine or feces and then rapidly hydrolyzed to NH_4^+.

Nitrogen that has been returned to the soil as NH_4^+ and NH_3 is either taken up again by higher plants, used as an energy source by nitrifying bacteria, forming NO_3^-, or lost through volatilization or leaching (Coyne et al. 1995; Barbour et al. 1987). A combination of high temperatures and dry soil can result in substantial volatilization of NH_3. The potential for leaching of NH_4^+, NH_3, and NO_3^- is a function of the soil water balance which depends to a great degree on vegetation condition. Low transpiration rates for vegetation in poor condition may cause deep infiltration of precipitation and leaching of N compounds back towards the ground water. However, very little, if any, leaching would be expected where vegetation in good condition returns precipitation to the atmosphere.

A working hypothesis for phytoremediation, to be tested in the pilot study, is that most of the nitrate in the plume water will be converted to plant nitrogen (organic compounds) that will be exported from the site in crop biomass. A much smaller fraction of the plume nitrate is expected to be added to the soil as leaf litter, root tissues, and manure from grazing animals. It will then be converted to soil organic matter, which will increase soil water holding capacity and soil fertility.

It is not expected that secondary formation of inorganic nitrogen, as ammonia or nitrate, will accumulate in the soil profile or be leached back to the aquifer. However, it is expected that during the early stage of phytoremediation, the nitrate content of the plume water from the hotspots will exceed the capacity of the plants for uptake, and accumulation of nitrate in the soil profile may occur. As the nitrate level in the plume is lowered, the concentration in the irrigation water will eventually be lower than plant requirements, and the accumulated nitrate in the soil profile will then be absorbed. This process was modeled for a starting concentration of 500 parts per million (ppm) nitrate (see Section 5.3.2.1, Maximum Permissible Levels of Nitrate in the Irrigation Supply).

5.2.2.2 Sulfur Cycle

Desert soils usually contain sufficient sulfur compounds to provide plant sulfur needs (Fuller 1975). Sulfate, the most highly oxidized form, is abundant and widespread in arid soils (Miller and Gardiner 1998). Sulfur is also found in the organic fraction of soils, bonded to other elements. It is cycled in an oxidation-reduction system by soil microorganisms and chemical processes. A water chemistry analysis at the Monument Valley site (see Section 5.2.3, Sulfate Soil Chemistry and Toxicity) indicates that 78 percent of the sulfate present in the plume water will precipitate as calcium sulfate (gypsum) when applied to phytoremediation plots due to the low solubility of this compound and the high concentration of exchangeable calcium in the soil profile. Remaining sulfate will precipitate in the root zone as sodium sulfate or other more soluble forms, depending on the availability of cations. Calculations show that by the end of phytoremediation, the soil in the root zone will contain 1.2 to 2.3 percent gypsum by weight (Section 5.2.3). The literature was reviewed to see if this amount of gypsum could be damaging to the soil.

Gypsum is common in desert soils and in some locations is so abundant that it can be mined. Arid soils, including those at Monument Valley, may develop subsurface or sometimes surface gypsic horizons. These are weakly cemented or noncemented layers of gypsum precipitate within the soil. Gypsum does not form hardpans, and gypsum or sulfate accumulation is not considered a factor in soil degradation or pollution (Evangelou 1998; Miller and Gardiner 1998). In fact, gypsum is widely used as a soil amendment to improve soil tilth, especially under sodic soil conditions (Fuller 1975). Gypsum is added at rates up to 40 tons/hectare to sodic soils. By comparison, irrigation with 1-meter depth of plume water containing 2,000 ppm sulfate will also add approximately 40 tons/hectare gypsum, assuming all the sulfate precipitates as gypsum. Gypsum does not burn plants and can be applied immediately prior to sowing crops. Gypsum applications can be continued for an indefinite number of years without damage to the soil or crops.

This use of gypsum as a soil amendment, and the general literature on sulfate in soils, suggests that the formation of gypsum in Monument Valley soil when irrigating with plume water should not have a damaging effect on the soil or biota. Gypsum concentrations up to 5 percent of soil weight are considered beneficial to soil properties, and only when concentrations exceed 25 percent is soil tilth compromised. Gypsum is chemically inert, but above 25 percent it reduces permeability of water through physical effects. From these preliminary calculations and literature review, it is concluded that the benign deposition of sulfate from the plume water as gypsum in the root zone of a forage-crop farm would be an effective form of remediation of the excess sulfate in the plume water. However, it is recognized that results from agricultural systems cannot be applied directly to more natural ecosystems such as the Monument Valley site.

Furthermore, the application rates of sulfate in the plume water are at the high end of the rates at which gypsum is normally added to soil. Therefore, it is recommended that gypsum formation and its effects on soil properties be monitored during the pilot farm phase.

5.3 Farm Feasibility and Management

Nitrate in the alluvial aquifer could be recovered to irrigate a phytoremediation farming operation on areas disturbed during remediation of surface contamination. The operation could produce forage for livestock growers in the area, or another biomass product, until nitrate concentrations in the alluvial aquifer drop below the 44 milligrams per liter (mg/L) maximum concentration limit (MCL). To accomplish this, fourwing saltbush (*Atriplex* var. *angustifolia*) would be grown using nitrate-rich irrigation water recovered from the plume. After plants are established, a grazing and harvesting program would be implemented to allow utilization of the plants by livestock. Most of the harvest would be transported off-site, to be used as dried forage elsewhere, resulting in a net removal of nitrogen from the site. In the preferred cropping scenario, fourwing saltbush shrubs would be densely planted to develop a closed canopy within rows. Deep watering will be used to encourage deep-rooting of the shrubs during their establishment phase. The plant community, after irrigation ceases, would resemble native range in good condition.

The feasibility of recovering nitrogen from the alluvial aquifer for a phytoremediation farming operation rests on several issues:

- suitability of the remediated soils for irrigation,
- successful establishment of cropping systems,
- water and cultural requirements of crops,
- nitrate uptake rates and potential toxicity,
- soil chemistry of sulfate in the irrigation water,
- potential for toxicity from other constituents in the irrigation water, and
- sound management practices to control the return of water and nitrogen to the aquifer.

This section provides summaries of background information on these issues.

5.3.1 Land Suitability for Irrigation

Classification of irrigation suitability in arid regions considers soil texture, soil depth, soil water retention, soil permeability, soil chemistry (salinity, sodicity, and alkalinity), percent coarse fragments, and topography. Soils in the remediated area at Monument Valley range from a loamy sand, with about 70 percent fine sand, 25 percent silt, and less than 5 percent clay, to a sand with greater than about 90 percent fine sand, less than 5 percent silt, and virtually no clay (DOE 1998; Section 4.6.2). Given this range of soil textures, the field capacity should fall between about 7 and 15 percent volumetric water content (e.g., Brady 1974). The permeability of these soils averages about 1.0×10^{-4} centimeters per second (DOE 1998; Section 4.6.1). These soils are deep, have very few coarse fragments, and slopes do not exceed 8 percent. Salinization would not be expected for these deep, coarse-textured soils *under normal irrigation practices*.

Overall, based on an arable land classification system used by the Navajo Nation and the U.S. Bureau of Indian Affairs (Table 5–3), the soils in the remediated areas do not fall in the highest class, primarily because of the sand texture, but are suitable for irrigation of a forage crop (e.g., Glenn et al. 1998b). The U.S. Department of Agriculture (USDA) recommends a check for excessive concentrations of boron, heavy metals, and pH; baseline values of these parameters will be obtained during the initial stages of the pilot study.

5.3.2 Nitrate Toxicity and Irrigation Levels

5.3.2.1 Maximum Permissible Levels of Nitrate in the Irrigation Supply

Two simulations were performed to evaluate the maximum permissible nitrate concentrations in the irrigation water, each starting with 500 ppm (Figure 5–3). Previous research using nitrate-contaminated water (Baumgartner et al. 2000a,b) showed that saltbush grows normally up to 2,200 ppm. Therefore, 1,000 ppm was used as the maximum permissible level in the soil solution during phytoremediation. In the first simulation, it was assumed that plants removed 240 ppm nitrate and the remainder stayed in the soil, and that nitrate in the plume was diluted by an infinite supply of water containing 50 ppm nitrate as the plume was pumped (one reservoir model). In the second simulation, it was assumed that the actual volume of water in the hot-spot area (500 to 800 ppm nitrate) was diluted by the volume of water surrounding the hotspot (44 to 500 ppm nitrate) (two reservoir model). In both simulations, nitrate in the soil solution remained well below 1,000 ppm during the remediation process. It can be concluded that water initially containing 600 to 700 ppm nitrate could be used for irrigation of forage crops without yield reduction.

5.3.2.2 Potential Toxicity Problems from High-Nitrate Fertilization

Even the highest levels of nitrate in the plume should not cause direct phytotoxicity (damage to plants). In general, >9,000 ppm nitrate in plant tissues can produce toxic effects in animals (Lawrence et al. 1968). When grown on low-nitrate water, grasses like sudangrass had 3,500 ppm nitrate, but on 1,100 ppm and 2,200 ppm nitrate, it had 6,857 ppm and 5,028 ppm nitrate in leaf tissues, respectively (Baumgartner et al. 2000a). These exceed the highest standards but are less than what is considered the maximum safe level. Saltbush did not respond to nitrate fertilization by accumulating additional nitrate in the leaves, and levels never exceeded 4,300 ppm nitrate (Baumgartner et al. 2000a). The remedies for this potential problem are: (1) do not apply nitrate in excess of what can be safely absorbed by the crops and converted to plant protein; and (2) monitor levels of nitrate and prussic acid in saltbush.

Table 5–3. Irrigation Suitability Land Classification

Specifications for Land Classes[a]				
Land Characteristics	**Class 1**	**Class 2**	**Class 3**	**Class 6**
Soils[b]				
Texture (Surface 10 inch)	MC,M,MF	Any	Any	All other lands not meeting criteria for arability
Moisture Retention-AWHC 0-48 inch	>6.0 inch	>4.5 inch	>2.5 inch	
Effective Depth	>48 inch	>30 inch	>20 inch	
Salinity (EC H 103), 0-48 inch (at irrigation equilibrium)	<4	<8	<12	
Sodicity - SAR of Root Zone (0 to 48 inch)	<13	<13	<37.5	
Permeability, 10 to 48 inch	0.2-6.0 in/hr	0.06-6.0 in/hr	0.06-20 in/hr	
Coarse Fragments, 0 to10 inch [c]				
Gravel (% by volume)	<15	<35	<55	
Cobbles (% by volume)	<5	<10	<15	
Rock Outcrops (distance apart)	>200 ft	>100 ft	>50 ft	
Frequency of Overflow (years)	None (<1 in 10)	Rare (1 in 10)	Occasional (2 in 10)	
Depth to Calcic Horizon	>20 inch	>10 inch	Any	
Depth to Water Table	>60 inch	>48 inch	>30 inch	
Topography and Land Development				
Slope (percent)	<5	<8	<15	
Rock Fragments for Removal (cu yds/Ac)				
Cobble	<10	<35	<70	
Stone	<10	<25	<70	
Surface Grading[d]	None or light	Medium	Heavy	
Tree Removal (% canopy)	<10	<40	<70	
Reclamation required for Sodicity	None	Moderate	High	
Drainage				
Surface Drainage Requirement[e]	1	2	3	
Depth to Restrictive Layer (<0.01 inch/hour H.C.) When W.A.H.C. of the 4 ft to restrictive layer, or 4 ft to 10 ft layer				
(whichever is least) is > 0.15 inches/hour	>6 ft	>6 ft	>6 ft	
When W.A.H.C. of the 4 foot to restrictive layer, or 4 foot to 10 foot layer				
(whichever is least) is < 0.15 inches/hour	>8 ft	>8 ft	>8 ft	
If artificial drainage is required: Hydraulic Conductivity of zone to be drained[f]	>0.15 in/hr	>0.15 in/hr	>0.15 in/hr	
Depth to Drainage Barrier	>6 ft	>6 ft	>6 ft	

Notes on Specifications for Land Classes[a]

[a]Each individual factor represents a minimum requirement. Two or more interacting deficiencies may result in land being placed in lower class than single deficiencies specify.

[b]Specifications for the “Soil" group are representative of conditions after land is developed for irrigation.

[c]Less than 15% gravel for class 2 if surface texture is coarse or moderately coarse.
Less than 35% gravel for class 3 is surface texture is moderately coarse.

[d](1) Land is further downgraded if surface grading reduces effective depth or otherwise permanently reduces soil fertility.

(2) Degrees of leveling for hummocky areas:
- light: less than 1 foot of cut and fill.
- medium: 1 to 2 feet of cut and fill.
- heavy: 2 to 3 feet of cut and fill.

(3) Degrees of leveling for gullied areas:
- light:0-200 cubic yards of earth work per acre.
- medium: 200-400 cubic yards of earth work per acre.
- heavy: 400-800 cubic yards of earth work per acre.
- v. heavy: over 800 cubic yards of earth work per acre.

[e]Surface drainage refers to the natural ability to either shed or transmit water. It is not the same as overflow (which refers to the condition of inundation) or internal drainage.
- Category 1: Surface drainage is not limiting.
- Category 2: Surface drainage is limiting, but easily corrected.
- Category 3: Surface drainage is limiting and not easily corrected.

[f]Zone to be drained is least of the following:
(1) Four feet to a restrictive layer
(2) Four feet to bedrock
(3) Four feet to a drainage barrier
(4) Four feet to ten feet.

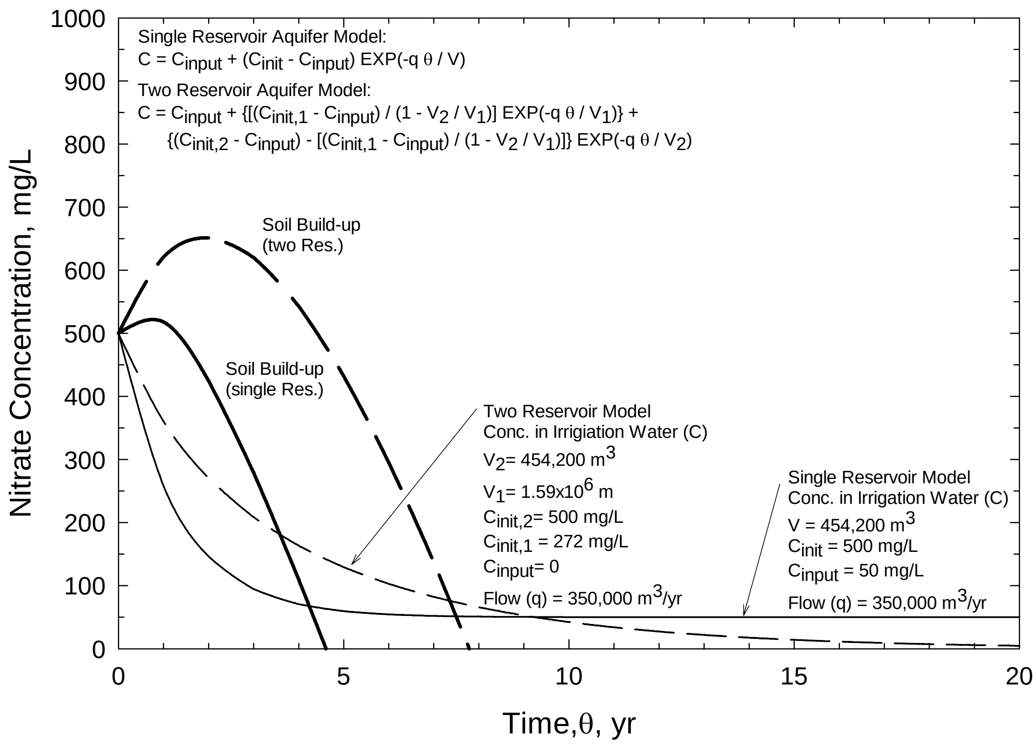

Figure 5–3. Simulated Nitrate Concentrations in the Soil Solution During the Remediation Process

5.3.3 Sulfate Soil Chemistry and Toxicity

The feasibility of using land farming for phytoremediation of ground water must consider the fate and potential toxicity of sulfate in irrigation water.

5.3.3.1 Gypsum Formation in the Soil

An analysis of the likely fate of sulfate in the plume water was conducted, based on the plume water chemistry (letter Thompson and Glenn 1998).

Because of the high calcium content of the water, evaporation could concentrate the liquid to the extent that $CaSO_4 \cdot 2H_2O$ (gypsum) precipitates in the soil profile. Because of the limited rainfall in Monument Valley, the gypsum would likely remain indefinitely in the soil and thus be removed from the aquifer. Gypsum is often used as a soil amendment and is not expected to harm the plants used for phytoremediation. An estimate of the extent to which sulfate can be removed from the ground water through concentration by evaporation when the water is used for irrigation is presented below.

Table 5–4 is a simplified chemical model of the average values for components in contaminated water prepared from DOE 1999, Table 5–8. Ammonia, present in the contaminated water at 53.5 ppm, has been omitted, as it is expected to either volatilize or be utilized by plants. Sulfides are assumed to be oxidized to sulfates (the contaminated water appears anoxic). Silica and minor components are omitted.

Table 5–4. Ground Water Constituents

Constituent	Concentration (ppm)
Ca^{++}	143.0
Mg^{++}	115.3
K^{+}	8.5
Na^{+}	115.2
Cl^{-}	24.6
NO_3^{-}	216.9
$SO_4^{=}$	768.2

Taking the case of *Atriplex* planted over 25 percent of the farm with an effective rooting depth of 14 ft, there appears to be ample volume in the soil pore space under the phytoremediation area to contain the precipitated gypsum. The percentage of pore space occupied by the gypsum would then be in the interval of 2.3 to 1.2 percent (Thompson and Glenn 1998). Other cropping scenarios also give small percentages of pore volume occupied by gypsum at the end of phytoremediation.

As the contaminated water is pumped from the aquifer it is supersaturated with calcium carbonate ($CaCO_3$ or calcite), dolomite [$CaMg(CO_3)_2$], and carbon dioxide. As the solution equilibrates with CO_2 in the atmosphere, the pH will increase while calcite and dolomite are likely to precipitate. The solution is not initially saturated with respect to calcium sulfate, and must be concentrated through evaporation until saturation is reached.

A number of ionization and solubility relationships will be required for this analysis:

$$[CO_2] = K_H \, P_{CO_2} \qquad \text{Equation 1}$$

That is, the concentration of dissolved carbon dioxide $[CO_2]$ (which is defined here to include un-ionized carbonic acid, H_2CO_3) is related to the partial pressure of carbon dioxide in the atmosphere, P_{co2}, by the Henry's law constant K_H in Equation 1.

$$[HCO_3^-] = K_{a1}\,[CO_2]\,/\,[H^+] \qquad \text{Equation 2}$$

$$[CO_3^=] = K_{a2}\,[HCO_3^-]\,/\,[H^+] = K_{a1}K_{a2}\,[CO_2]\,/\,[H^+]^2 \qquad \text{Equation 3}$$

K_{a1} and K_{a2} are the first and second ionization constants for carbonic acid, $[H^+]$ is the hydrogen ion concentration. Note that pH = - $\log_{10}$ $[H^+]$, and the ionization constant for water is K_w = $[H^+][OH^-]$.

$$[Ca^{++}] = K_{sO}\,/\,[CO_3^=] \qquad \text{Equation 4}$$

$$[Ca^{++}] = K_G\,/\,[SO_4^=] \qquad \text{Equation 5}$$

$$[Mg^{++}] = K_D\,/\,[Ca^{++}][CO_3^=]^2 \qquad \text{Equation 6}$$

Where K_{sO}, K_G, and K_D are the solubility products for calcium carbonate, gypsum, and dolomite, respectively. For a salt, MX, forming ions M^+ and X^-, $[M^+][X^-]$. K, otherwise the solution is supersaturated. The solubility products must be adjusted as the ionic strength of the of the solution changes (Butler 1991).

A charge balance of the ions in solution gives:

$$2\,[Ca^{++}] + 2\,[Mg^{++}] + [K^{+}] + [Na^{+}] - [Cl^{-}] - [NO_3^{-}] - 2\,[SO_4^{=}] = [HCO_3^{-}] + 2\,[CO_3^{=}] + [OH^{-}] - [H^{+}] \qquad \text{Equation 7}$$

The group on the right hand side of Equation 7 appears frequently in the literature dealing with natural waters, and is called the carbonate alkalinity (A). It does not change as CO_2 is added to or withdrawn from the solution.

Initially the solution is undersaturated with respect to gypsum, i.e., $K_G > [Ca^{++}][SO_4^{=}]$, and sulfate remains in solution; after equilibration with CO_2 in the atmosphere, calcite and dolomite precipitate and Equations 4 and 6 apply, which together with Equations 1 through 3 allow Equation 8 to be written:

$$\frac{2\,[H^{+}]^2}{P_{CO_2} K_H K_{a1} K_{a2}}\left(K_{sO} + \frac{K_D}{K_{sO}}\right) + [K^{+}] + [Na^{+}] - [Cl^{-}] - [NO_3^{-}] - 2\,[SO_4^{=}] = \frac{P_{CO_2} K_H K_{a1}}{[H^{+}]}\left(1 + \frac{2\,K_{a2}}{[H^{+}]}\right) + \frac{K_w}{[H^{+}]} - [H^{+}] \qquad \text{Equation 8}$$

This quadratic equation can be solved for $[H^{+}]$ when P_{CO2} is fixed at the partial pressure of CO_2 in the atmosphere. This allows the amount of $[Ca^{++}]$ remaining in solution to computed from:

$$[C_a^{+}] = \frac{2\,K_{sO}\,[H^{+}]^2}{P_{CO_2} K_H K_{a1} K_{a2}} \qquad \text{Equation 9}$$

which results from combining Equations 1 through 4. When $[Ca^{++}]$ is known, the relationship K_G $[Ca^{++}][SO_4^{=}]$ can be tested for varying degrees of concentration of the solution until the relationship is satisfied, which indicates the onset of gypsum precipitation. When $CaSO_4$ is at saturation, Equation 5 is substituted into Equation 8 yielding:

$$\frac{2\,[H^{+}]^2}{P_{CO_2} K_H K_{a1} K_{a2}}\left(K_{sO} + \frac{K_D}{K_{sO}}\right) + [K^{+}] + [Na^{+}] - [Cl^{-}] - [NO_3^{-}] = \frac{P_{CO_2} K_H K_{a1}}{[H^{+}]}\left[1 + \frac{2\,K_{a2}}{[H^{+}]}\left(1 + \frac{K_G}{K_{sO}}\right)\right] + \frac{K_w}{[H^{+}]} - [H^{+}] \qquad \text{Equation 10}$$

This expression is solved for $[H^{+}]$ and $[SO_4^{=}]$ [from Equations 9 and 5] as the volume of solution is decreased, allowing the amount of sulfate removed to be determined by comparing the total amount of $[SO_4^{=}]$ in the initial volume to that in the reduced volume. As mentioned previously, the solubility and ionization constants must be corrected as the ionic strength of the solution changes. The results of these calculations (Figure 5–4) indicate that as the volume of water in the soil profile is reduced to 5 percent of the starting volume through evapotranspiration, approximately 78 percent of the sulfate in the solution will precipitate as gypsum.

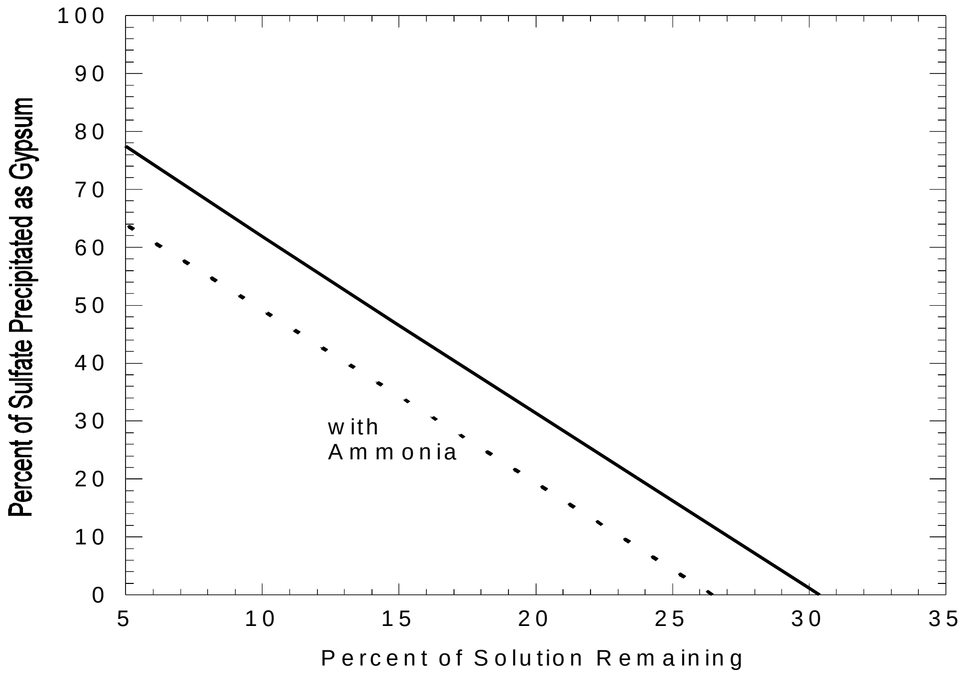

Figure 5–4. Percent gypsum precipitated as water volume is reduced through evapotranspiration.

5.3.3.2 Potential for Sulfate Toxicity in Animals Feeding on Plant Tissues

Plants can be irrigated with water saturated in calcium sulfate without showing growth inhibition but they accumulate high tissue levels of sulfate, ranging from 70 to 900 ppm as sulfur. Sulfate can also be toxic to animals at high levels in plant tissues (Watson et al. 1994;). Sulfate can be converted to hydrogen sulfide in animal's rumens, resulting in loss of appetite. This problem has not been documented for animals grazing on saltbush, but it is a potential problem given the high levels of sulfate in the irrigation supply. The remedy is to monitor plant tissues for excess sulfate. Since forages will not make up the complete diet for ruminants, levels as high as 1 percent sulfur in the forage component can be considered safe (Watson et al. 1994), but lower levels are desirable.

5.3.4 Irrigation Management

The management strategy for the land farm is to apply sufficient water to support high yields of the phytoremediation crops, and to maximize nitrate uptake into plant tissues while minimizing percolation of water past the root zone. Water and nitrate that pass beyond the root zone will reenter the aquifer, reducing the efficiency of the phytoremediation effort. However, since the land farm will be upgradient of the contamination plume, leachate water from the farm would eventually be recovered again in the well field. Hence, some leaching past the root zone to control soil levels of salts and nitrate can be accepted as part of the irrigation management strategy.

Two irrigation strategies could be used to minimize leaching of nitrates back to the aquifer: (1) deficit irrigation and (2) use of deep-rooted saltbush plants to absorb water and nitrate from deep within the soil profile.

For deficit irrigation, only part of the maximum crop water demand is applied. For example, if measurements of the soil water profile indicate that the root zone requires an application of 0.2 meter of water to reach field capacity, the irrigator might apply 0.18 meter of water (90 percent of crop water demand). This is sufficient to ensure good crop development as well as nearly complete uptake by the plant. Water can also be withheld at the end of the growing season, allowing the crop to absorb excess water in the soil profile as it matures. Deficit irrigation requires a good knowledge of crop water requirements and soil moisture conditions throughout the crop cycle, and it requires an efficient method of applying irrigation water. It requires a knowledge of soil chemistry as constituents in the water supply will accumulate in the root zone and may have to be controlled through a leaching fraction, natural precipitation, or uptake by more deeply rooted alley crop plants such as saltbush. The pilot farm should be designed to develop best management practices for deficit irrigation in each of the three cropping scenarios to be tested.

The most efficient irrigation system for saltbush is drip irrigation, using buried drip lines. Drip irrigation applies water directly to the roots of plants in controlled volumes; hence it has very high efficiency. Buried lines ensure that contaminated plume water would not be available to livestock or other animals as surface water. Therefore, buried drip lines are proposed as the irrigation method for the pilot farm.

Irrigation schedules would be set monthly, based on soil-moisture depletion curves determined by measurement of soil moisture levels before and after irrigation events, using a neutron hydroprobe and buried soil moisture sensors (see Section 5.3.2.1 for details of soil moisture monitoring).

5.3.5 Harvesting, Grazing, and/or Seed Production

Harvesting, grazing, and seed production are practical and productive alternatives for removing nitrogen from a phytoremediation farm at the Monument Valley site. An alfalfa farm would provide a harvesting alternative.Alfalfa would be cut four to five times during summer at Monument Valley, dried, and baled. The baled material would be tested by proximate analysis for nutritional content and, in addition, nitrate and sulfate levels would be determined. The baled hay would be provided to the local community in a method to be determined by the Navajo Nation and local chapter houses.

As a grazing alternative, fourwing saltbush would be allowed to grow throughout the summer, then end-of-season grazing would be permitted to remove the accumulated annual growth (thus removing plant nitrogen that originated as nitrate in the plume). Grazing rights would be determined by the Navajo Nation and local chapter houses. At a yield of 10 to 20 tons per acre, the pilot farm would provide 16 to 32 tons per year of potential fourwing saltbush browse at maturity.

Fourwing saltbush and possibly other native plants could also be grown to produce seed for reclamation of strip mines, mine tailings, and abandoned mines on the Navajo Nation and elsewhere. For this alternative, fourwing saltbush would be grown as above, but seed would be harvested before livestock are permitted to graze during late fall and winter months. In fall 2001 we harvested about 50 kg of fourwing saltbush seed; about 2 kg or more of seed from mature plants. There are about 4,000 plants in the subpile phytoremediation planting, half of which are female, so 2000 plants x 2 kg gives a potential yield of 4000 kg of seed. The field is 1.6 ha, so the potential yield is 2500 kg/ha. Seed charge up to $66/kg ($30/lb) for seed with the wings milled off. If the seed companies pay as little as $10/kg ($4.50/lb) for bulk seed, this would be a return of $25,000/ha (about $10,000/acre).

5.4 Data Needs, Methods and Instrumentation

5.4.1 Data Needs

The fundamental purpose of this pilot study is to collect the data required to address uncertainties in the land-farming alternative so that at the end of the 3-year study it can be determined if the land-farming alternative is acceptable as the final ground water remediation strategy. Scientists rarely answer any question definitively yes or no, but instead measure uncertainties about processes and assumptions. The assumptions presented are based on the scientific literature, and University of Arizona and DOE Environmental Sciences Laboratory research of phytoremediation and land farming on the Navajo Nation. The pilot study would be designed to address, as directly as possible, uncertainties that might remain, and how the proposed monitoring and testing programs would detect and correct any potential problems. Finally, the data and field experience gained during the pilot study would lead to more efficient and effective farm management practices.

The pilot study would directly evaluate the following uncertainties associated with the proposed land farm:

- Uncertainty as to the rates and patterns of water removal from the soil by evaporation and plant transpiration, minimizing the return of contaminated water to the aquifer, and therefore, uncertainty as to the optimum irrigation rates.
- Uncertainty as to the rate that crops will remove nitrate and other constituents from the soil, the maximum nitrate concentrations that can be tolerated by the crops, and therefore, uncertainty as to the optimum nitrate concentrations to be applied in irrigation water.
- Uncertainty as to the effects of sulfate and other constituents added to the soil as a result of irrigation with alluvial aquifer plume water.
- Uncertainty as to the safety and long-term acceptability of plant materials produced and of residual constituents in the farm soil.

5.4.2 Monitoring Methods and Instrumentation

5.4.2.1 Soil Water

Several climate and soil parameters of the soil water balance will be monitored as part of the pilot farm evaluation. Baseline engineering and hydrologic parameters of the soils will be collected prior to installation of the pilot farm. Meteorological conditions will be monitored using the existing weather station (see section 2.7.1).

5.4.2.2 Soil Moisture

Soil moisture content (θ) will be monitored using a combination of neutron thermalization (NT) gauges and water content reflectometers (see Sections 2.6 and 2.7). Volumetric water content will be monitored monthly using NT gauges lowered into 4.5 meter deep ports placed at the center of each plot. Readings will be taken at 30-cm intervals. WCR sensors will be placed at intervals of 15, 30, 45, 80, 125, 175, 250, 350, and 450 cm adjacent to NT ports in three plots, one of each cropping system. The WCR consists of two parallel rods attached to an electronic signal generator. A pulsed wavelength traveling down a coax, or waveguide, is influenced by the type of material surrounding the conductors. If the dielectric constant of the material is high, the signal propagates slower. Because the dielectric constant of water is much higher than most other materials, a signal within a wet or moist medium propagates slower than in the same medium when dry. The reflectometer measures the effective dielectric as a pulse transit time, which in turn is calibrated against water content. A manufacture's calibration is supplied with the sensor, but will be checked against specific site soil conditions since salinity and other soil properties such as mineralogy can affect the calibration. Changes in soil moisture will be determined by reading the WCR probes hourly. A manufacture's calibration is supplied with the sensor, but will be checked against specific site soil conditions since salinity and other soil properties such as mineralogy can affect the calibration. Changes in soil moisture will be determined by reading the WCR probes hourly.

Soil water storage (*S*) will be calculated from both the NT probe and WCR measurements of θ using a modification (Waugh et al. 1994) of the trapezoidal approximation by Green et al. (1986) as follows:

$$S \approx \theta_1 z_1 + \sum_{i=2}^{n} \left[(\theta_{i-1} + \theta_i)/2 \right] \left(z_i - z_{i-1} \right) \qquad \textit{Equation 11}$$

where θ_1 and z_1 are the water content and depth for the uppermost measurement, θ_1 is the volumetric water content measurement at the *i*th point in the soil profile, z_i is the depth of the *i*th point in the profile, and *n* is the total number of points.

Soil Profile Drainage

The drainage term (*D*) of the soil water balance equation will be monitored using the water flux meters designed by Pacific Northwest National Laboratory (PNNL) placed at the 4.5 meter depth below the deepest WCR at three locations (see Section 2.7).

The flux meter developed by PNNL, unlike a number of sensors such as heat dissipation units or tensiometers, is not a point measurement but an area measurement and captures the flux in a considerably larger area or zone than most of the conventional monitoring devices. There are several ways to place the sensor but the best and simplest way is to auger a hole. The disturbance of the fine sandy soil will be temporary. As with any vadose zone monitoring device, there will always be concerns about how representative the measurement is. However, since the flux is directly measured, not just water potential or water content, it will be a number that will be compared with drainage data estimated from the water content measurements.

Soil Physical and Hydraulic Properties

The physical and hydraulic properties of the pilot farm soils will be evaluated with a combination of laboratory measurements. Soil samples will be collected prior to the construction of the pilot farm for determination of particle-size distribution, Atterberg limits, moisture-density relationships, saturated hydraulic conductivity, specific gravity, and soil moisture retention characteristics. Table 5–5 gives a listing of the standard analytical methods and citations for each soil parameter.

Table 5–5. Analytical Measurements for Soil Physical and Hydraulic Properties

Parameter	Matrix	Method	Method Type
Saturated Hydraulic Conductivity	Soil	ASTM D5084	Flexible wall permeameter
Saturated hydraulic conductivity of Granular Soils	Soil	ASTM D2434	Constant head permeameter
Moisture-Density Relationships	Soil	ASTM D698	Physical compaction
Atterberg Limits	Soil	ASTM D4318	Liquid limit, plastic, water content
Particle Size Distribution	Soil	ASTM D422	Sieve and hydrometer
Soil Moisture Retention Curve	Soil	Klute (1986)	Hanging column, pressure plate, and chilled mirror hygrometer
Minimum / Maximum Density	Soil	ASTM D 4253	Vibration
Percent Moisture	Soil	ASTM D 2216	Oven-Drying
Specific Gravity	Soil	ASTM D 854	Gravimetric

Potential Evapotranspiration

Potential evapotranspiration (*pET*) is the amount of water transpired by plants plus the amount of water evaporated from the bare soil surface under conditions where water supply is not limited. By definition, actual evapotranspiration (*aET)* cannot exceed *pET*. If *aET* and *pET* are equivalent, and if the sum of precipitation and irrigation (*P&I*) exceeds *pET*, then drainage will occur. *pET* will be calculated from the Penman-Monteith equation using inputs from weather station instruments that will be installed at the site. The datalogger collecting the meteorological data is capable of making the measurements and computations to provide an estimate for a reference *pET*.

5.4.2.3 Soil Nitrogen and Sulfur

Three methods are planned for monitoring the nitrogen balance field-plot soil profiles: nitrate sensors in the irrigation stream, nitrate sensors or probes attached to the water flux meters for real-time nitrate flux monitoring in recharge water, and periodic extraction of soil cores to determine the amount and distribution of nitrogen in field-plot soil profiles. The sensors in the irrigation stream will monitor soil nitrogen input, the sensors attached to the water flux meters will monitor any loss from the system via recharge to ground water, and analysis of soil cores will monitor soil nitrate storage changes. The balance of the nitrogen lost from the soil profile via uptake by plants or volatilization can be calculated from these variables.

Nitrate in Irrigation Water

A sample metering station will be located on the water main line near the Control Building. This station will house a water meter that will record instantaneous flow and cumulative flow. In addition, a sample line will run from the station to a nitrate analyzer instrument located in the Control Building. This will allow continuous monitoring of the volume and nitrate concentration of the water that is being delivered to the field. Data from the water meter and the nitrate analyzer will be automatically recorded onto computer software.

Nitrate Flux from the Root Zone

Nitrate probes that detect real-time flux in the recharge stream leaving the bottom of the root zone will be attached to the water flux meters (Section 5.3.2.1). Each nitrate sensor unit is approximately 8 inches long with a ¾-inch diameter. They will each be installed within a PVC tube just above the tipping bucket gauge within the water flux meter unit. This pipe will also house the wick. As solution leaves the wick, it will drip into a 20-ml cup containing the nitrate sensor. This cup has a drain hole, so one drop in will allow one drop to leave and be collected into the tipping buckets of the rain gauge. The nitrate sensor uses a half bridge voltage measurement across a nitrogen-sensitive membrane. Voltage is converted to nitrate. The nitrate probes also have a sensor that will record solution temperature.

Three of the nitrate sensors have already been calibrated using nitrate plume water from Monument Valley wells (Figure 5–5). The curves are all exponential fits with highly significant coefficients of determination (r^2). Calibration equations will be used in the data logger program to produce an output in mg/L nitrate. These three probes are referred to by their serial numbers (800, 801, and 802) in Figure 5–5. When a flux meter unit is installed, a calibration tube will be installed that daylights at the soil surface and terminates within the sampling cup. These tubes will be used to recalibrate the sensors and the tipping buckets periodically after installation.

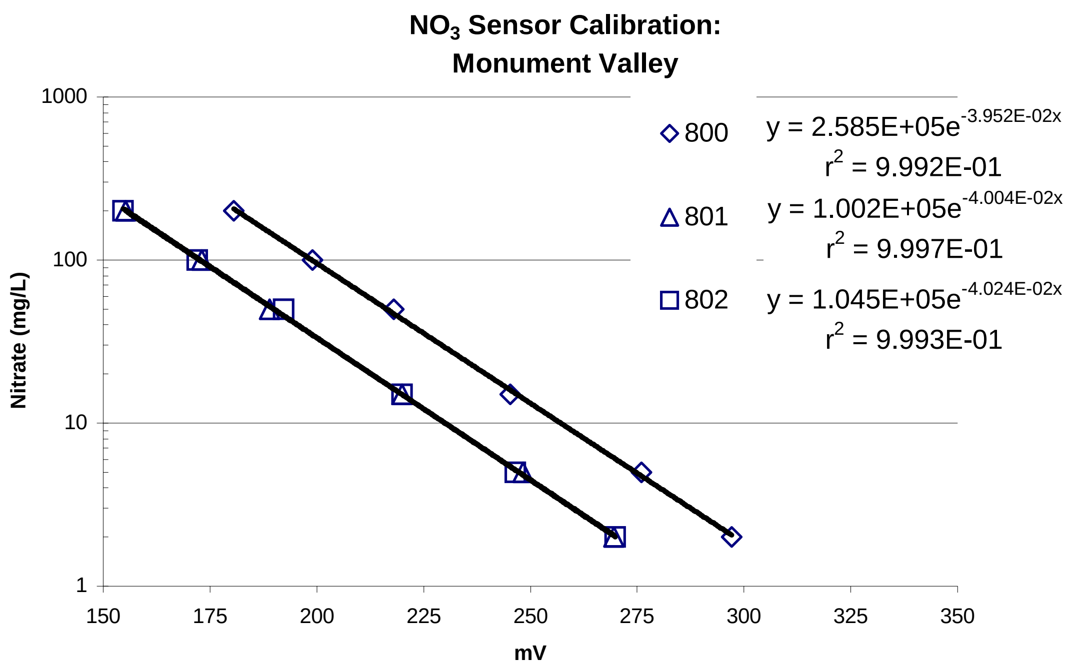

Figure 5–5. Calibration Curves for Three Real-Time Nitrate Sensors that will be Used to Measure Nitrate Concentrations (mg/L) in Water Leaving the Root Zone of the Field Plots

Soil Nitrate Storage Changes

At the start of the pilot study and annually thereafter, soil cores will be taken for determination of nitrogen and sulfur compounds and other chemicals of concern. After initial field preparation the first year, twenty soil cores will be taken, at soil depths of .3, .9, 1.8, 2.7, 3.7, and 4.6 m. Results will be subjected to analysis of variance to determine the sample size (number of cores) needed to give a 10 percent level of precision. This is the number of cores needed per treatment. All analytes will be determined in 1:1 soil:water extracts using EPA-certified methods. Nitrate will be determined by a nitrate ion electrode. Sulfur and extractable sulfates will be determined by a barium sulfate turbidimetric procedure; and metals will be determined by atomic absorption spectroscopy. In addition, gypsum will be qualitatively identified within cores by the formation of gypsum crystals, visible under a dissecting microscope (Black 1982).

5.4.2.4 Crop Nutrition and Toxicity

Each harvest of alfalfa during the growing season will be field-dried then baled. Bales will be cored to provide samples for analysis. Twenty bales from each harvest will be cored (one core per bale), using an auger made for this purpose. Each core will be analyzed for nutritional content by proximate analysis in which crude protein, ash, fiber, fat, lignin and energy content is determined. The methods are all A.O.A.C. procedures for analysis of feeds, described in detail in Swingle et al. 1996. Additionally, each sample will be analyzed for nitrate, prussic acid, sulfate, total sulfur, and metals of concern using EPA-certified methodology (prussic acid will be determined by the University of Arizona Veterinary Diagnostic Laboratory, and the other analytes as described in preceding sections). At the first harvest, the 20 core samples will be used for an analysis of variance to determine final sample size to provide 10 percent precision and accuracy. *Atriplex* will be sampled at the end of each growing season to provide the same information.

5.4.2.5 Natural Analogs of Soil Sulfate Distribution

Calculations of the likely fate of sulfate in plume water applied to the land farm suggests that, because of relatively high calcium in the water, approximately 75 percent will precipitate as $CaSO_4 \cdot 2H_2O$ (gypsum) within the farm soil profile (Section 5.2.2.2). Gypsiferous soils also form naturally in arid and semiarid landscapes of the Southwest and other deserts of the world (United Nations 1990). In these environments, the presence of gypsum reflects the characteristic of wetness present in geological time; ancient riverbeds and lagoons were ideal locations for the formation of secondary gypsum deposits. The sedimentary gypsum can be eroded, transported by water or wind, and re-deposited in new localities forming individual gypsum dunes or becoming incorporated with the soil. There, deposited secondary gypsum in soil is concentrated first in the cracks, voids and channels. Later, gypsum becomes diffused throughout the soil matrix.

The following statements concerning the origin and genesis of soils in which gypsum has accumulated are a summary from several sources (United Nations 1990):

- Gypsiferous soils usually develop in arid and semi-arid areas with less than 400 millimeters annual rainfall where abundant sources of gypsum exist.
- Gypsum accumulation in soils is primarily related to Quaternary deposits.

- Gypsiferous soils are widespread in areas affected by tectonic movement - exactly where the synclinal and anticlinal axes, faults, and underground ridges have a perpendicular orientation to the natural movement of water.
- Maximum accumulation of gypsum is observed on the fringe of terraces, detrital cones and slope deposits that are bordered by hills.
- A water table at less than 5 meters depth with mineralized waters, whose saline nature is either sulphato-chloride or chlorido-sulphate, leads to gypsum accumulation in the soils.
- Accumulation of gypsum and soluble salts may take place over a very short period of time.
- Gypsum and other soluble salts are precipitated simultaneously provided that they are in solution, that movement takes place over a short distance, and that evaporation is rapid.
- The form of the gypsum depends mainly upon the thermodynamic conditions of its precipitation, and is not related to the age of the deposits. It is sometimes difficult to distinguish recent gypsum from old or residual forms.

If natural gypsiferous soils are common in the area, as expected, they could be characterized as analogs of the genesis and long-term ecology of the land farm soils. The occurrence, genesis, morphology, and ecology of gypsiferous soils in the Cane Valley vicinity will be investigated. Results will be compared to expected gypsum loading from the proposed phytoremediation farm. After gypsiferous soils have been located, physical descriptions of undisturbed gypsic soil horizons in the area will be made. The profile morphology will be described, and samples of gypsic soil will be obtained for laboratory analysis to determine the quantity of gypsum and other salts. The plant ecology of the analog will also be characterized and contrasted with non-gypsiferous soils in the area.

Literature Search

First, literature will be searched to determine if gypsiferous soils and gypsic horizons have been previously located and described within the Cane Valley area. A gypsic soil horizon is defined as an alluvial horizon with accumulated secondary gypsum. A gypsic horizon must be at least 15 cm thick, 5 percent or more gypsum, and 1 percent or more by volume secondary visible gypsum. It should not be cemented or indurated, and the product of thickness in centimeters multiplied by gypsum content should be a percent of 150 or more.

Soil survey information and mapping of the Cane Valley area by the U.S. Natural Resource Conservation Service and by the Bureau of Indian Affairs will be reviewed to determine if any previous investigations have located gypsic soils. If gypsic soils have been located, these sites will be visited first. Otherwise, road cuts, side-walls of arroyos, stabilized sand dunes, and any other locations within 5 miles of the site in Cane Valley that might have been stable enough to allow soil development will be investigated. These locations will be identified and reported on United States Geologic Survey topographic maps.

Field Descriptions

Field methods discussed by Birkeland (1999) will be followed to describe soil properties and soil horizons. The following soil properties will be noted for each pedon. Terminology developed by the USDA Soil Survey Staff (1997) will be used to describe the soil horizons. Characteristics of the landform associated with the soil will also be described.

The following key soil profile characteristics will be recorded:

- Depth to the upper-most mineral horizon.
- Percentage by volume of various soil features (e.g., gravel, carbonate and gypsum development stage, mottles).
- Color, both moist and dry in accordance with the Munsell Soil Color Charts.
- Structure description of the type, grade, and structure size.
- Consistence, which measures the adherence of the soil, will be observed in dry, moist, and wet conditions.
- Texture, which is used to classify the soil in accordance with USDA nomenclature.
- pH.
- Stages of carbonate morphology will be described. Methods are taken from Gile et al. (1966).
- Stages of salt and silica development will be described in a fashion similar to that developed for carbonate accumulation.

Soil Sampling and Laboratory Analyses

Soil will be sampled from each horizon by channeling through the entire horizon. Soil will not be taken from near-horizon boundaries. Samples obtained from a road cut or sidewall of an arroyo will be taken by initially scraping the outer most ten centimeters of soil from the face. This assures that influence from salt accumulation at the surface will not bias the sample. Samples obtained from an excavated test pit will be taken directly from the sidewall. Samples will be analyzed in the GJO Environmental Sciences Laboratory for soil physical and chemical properties, described in the next step.

Physical properties will be determined in accordance with procedures in Klute (1986). Analysis of gypsum will follow Nelson (1982).

6.0 References

Barbour, M.G., J.H. Burk, and W.D. Pitts, 1987. *Terrestrial Plant Ecology*, Second Edition, Benjamin/Cummings Publishing Company, Menelo Park, California.

Barnes, D.K., G.H. Heichel, C.P. Vance, and R.N. Peaden, 1990. Registration of ‘Ineffective Agate’ and ‘Ineffective Saranac’ non-nitrogen-fixing alfalfa germplasms, *Crop Science* 30:752-753.

Baumgartner, D.J., E.P. Glenn, R.O. Kuehl, et al, 2000a. Plant uptake response to metals and nitrate in simulated uranium mill tailings contaminated groundwater, *Water, Air and Soil Pollution* 118:115-129.

Baumgartner, D.J., E.P. Glenn, G. Moss, et al, 2000b. Effect of irrigation water contaminated with uranium mill tailings on Sudan grass, Sorghum vulgare var. sudanense, and fourwing saltbush, *Atriplex canescens*, *Arid Soil Research and Rehabilitation* 14:43-57.

Birkeland, P.W., 1999. *Soils and Geomorphology,* third edition, Oxford University Press, New York.

Black, A. (ed.), 1982. *Methods of Soil Analysis, Volumes I & II,* American Society of Agronomy, Madison, Wisconsin.

Blake, G.R. and K.H. Hartge, 1986. *Methods of Soil Analysis Part I Physical and Mineralogical Methods,* second edition, edited by A. Klute, Soil Science Society of America, Madison, Wisconsin.

Blank, R., J. Young, J. Trent, and D. Palmquist, 1998. Natural history of a saline mound ecosystem, *Great Basin Naturalist* 58:217-230.

Bonham, C.D., 1989. *Measurements for Terrestrial Vegetation,* John Wiley and Sons, New York.

Brady, N.C., 1974. *The Nature and Properties of Soils,* Eighth Edition, MacMillan Publishing Co., Inc., New York.

Butler, J.N., 1991. *Carbon Dioxide Equilibria and Their Applications,* Lewis Publishers, Inc., Chelsea, Michigan.

Campbell Scientific, Inc., 1996. Water Content Reflectometer Model CS 615, Campbell Scientific, Inc., Logan, UT.

Cannon, H.L, 1963. The Biogeochemistry of Vanadium, *Soil Science* 96:196-204.

Charles, F., J. Morgan, and W. Bausch, 1987. Evapotranspiration of phreatophytes in the San Luis Valley, Colorado, Technical Report, Colorado Water Resources Research Institute, Fort Collins, Colorado.

Colvin, L.B. and C.R. Creger, 1967. Stable strontium and experimental bone anomalies, Fed. Proc. 26:416

Cook, W. and C. Bonham, 1977. Techniques for measurements and analysis for a pre- and post-mining inventory, Colorado State University Range Science Department, Science Series No. 28.

Coyne, P.I., M.J. Trlica, and C.E. Owensby, 1995. "Carbon and Nitrogen Dynamics in Range Plants," *Wildland Plants: Physiological Ecology and Developmental Morphology, Society for Range Management*, D.J. Bedunah and R.E. Sosebee (Eds.), Denver, Colorado, pp 59-167.

Dawson, T. E., 1993. Water sources of plants as determined form xylem-water isotopic composition: perspectives on plant competition, distribution, and water relations pp 465-495 *In*: Stable Isotopes and Plant Carbon-Water Relations, Academic Press: San Diego, California.

Dushenkov, S., D. Vasudev, Y. Kapulnik, D. Gleba, D. Fleisher, K.C. Ting, and B. Ensley, 1997. Removal of Uranium from Water Using Terrestrial Plants, *Environmental Science and Technology*, 31:3468-3474.

Ehleringer, J. R. and C.B. Osmond, 1989. Stable isotopes pp 281-300 *In*: R.W. Pearcy, J. Ehleringer, H.A. Mooney, and P.W. Rundel, (eds). Plant physiological ecology, Field methods and instrumentation, Chapman & Hall, London, United Kingdom.

Evangelou, V., 1998. *Environmental Soil and Water Chemistry*, John Wiley and Sons, New York.

Fayer, MJ, and TL Jones, 1990. *UNSAT-H version 2.0: Unsaturated Soil Water and Heat Flow Model*, PNL-6779, Pacific Northwest Laboratory, Richland, Washington

Foxx, T.S., G.D. Tierney, and J.M. Williams, 1984. *Rooting Depths of Plants on Low-Level Waste Disposal Sites*, LA–10253–MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

Fritts, H.C. and T.W. Swetnam, 1989. "Dendroecology: a Tool for Evaluating Variations in Past and Present Forest Environments," *Advances in Ecological Research*, 19:111–118.

Fuller, W., 1975. *Management of Southwestern Soils*, University of Arizona Press, Tucson, Arizona.

Gardner, W.H., 1986. *Water Content,* Pp. 493-554, *In* A. Klute (ed.) Methods of Soil Analysis, Part 1, 2nd Edition, Agronomy Monograph 9, Soil Science Society of America, Madison, Wisconsin.

Gardner, W. and D. Kirkham, 1952. Determination of soil moisture by neutron scattering, *Soil Science*, 73:391-401.

Gee, G.W., A.L. Ward, T.G. Caldwell, and J.C. Ritter (in press). A vadose-zone water-flux meter with divergence control, *Soil Science Society of America Journal*.

Gee, G.W. and J.W. Bauder, 1986. *Methods of Soil Analysis Part I Physical and Mineralogical Methods,* second edition, edited by A. Klute, Soil Science Society of America, Madison, Wisconsin.

Gile, L.H., F.F. Peterson, and R.B. Grossman, 1966. "Morphological and Genetic Sequences of Carbonate Accumulation in Desert Soils," *Soil Science,* 101:347–360.

Glenn, E.P., D. Moore, S. Sanderson, J.J. Brown, D. Lash, M. Nelson, and J. Waugh, 1998a. Comparison of growth and morphology of *Atriplex canescens* varieties *occidentalis* and *angustifolia*, Southwest Naturalist 43: 176-182.

Glenn, E., R. Tanner, S. Miyamoto, K. Fitzsimmons, and J. Boyer, 1998b. "Water Use, Productivity and Forage Quality of the Halophyte *Atriplex nummularia* Grown on Saline Waste Water in a Desert Environment," *Journal of Arid Environments*, 38:45–62.

Glenn, E., J. Waugh, D. Moore, C. McKeon, and S. Nelson, 2001. Revegetation of a former uranium mill site in the Great Basin Desert, Journal of Environmental Quality 30:1154-1162.

Glenn, E., J. Waugh, C. McKeon, and D. Moore, 1999. Monument Valley Phytoremediation Pilot Studies: Report to MacTech, Inc., Grand Junction, Colorado.

Greacen, E.L., 1981. *Soil water assessment by the neutron method,* CSIRO, Melbourne, Australia.

Green, R.E., L.R. Ahuja, and S.K. Chong, 1986. Hydraulic conductivity, diffusivity, and sorptivity of unsaturated soils: Field methods, p. 771-798, *In* A. Klute (ed.) Methods of soil analysis, Part 1, 2nd ed. Agron, Monogr, 9, ASA and SSSA, Madison, Wisconsin.

Gupta, S.K. and I.C. Gupta, 1987. *Management of Saline Soils and Waters,* Oxford and IBH Publishing Co. PVT, LTD, New Delhi, pg. 100.

Hoffer, G. N 1941, Deficiency Symptoms of Corn and Small Grains, In *Hunger Signs in Crops*, Edited by G. Hambidge, The American Society of Agronomy and The National Fertilizer Association, Washington, D.C. pg. 88.

Hoffmann, C., S. Rysgaard, and P. Berg, 2000. Denitrification rates predicted by nitrogen-15 labeled nitrate microcosm studies, in situ measurements and modeling, J. Environ, Quality 29: 2020-2028.

Johnson, C.M. and A. Ulrich, 1950. Determination of nitrate in plant material, *Analytical Chemistry*, 22:1526-1529.

Kaplan, D.I., D.C. Adriano, C.I. Carlson, and K.S. Sajwan, 1990. Vanadium: Toxicity and Accumulation by Beans, *Water, Air, and Soil Pollution,* 49:81-91.

Klute, A. (ed.), 1986. *Methods of Soil Analysis*, Part 1, 2nd Edition, Agronomy Monograph 9, Soil Science Society of America, Madison, Wisconsin.

Knowles, T.C. and M.J. Ottman, 1997. Sudangrass Hay Production in the Irrigated Deserts of Arizona and California, Cooperative Extension of The University of Arizona 197002.

Lash, D., E. Glenn, J. Waugh, and D. Baumgartner, 1998. Effects of grazing exclusion and reseeding on a former uranium mill site in the Great Basin Desert, Arizona, *Arid Soil Research and Rehabilitation* 13:253-264.

Lawrence, T., F.G. Warder, and R. Ashford, 1968. "Nitrate Accumulation in Intermediate Wheatgrass," *Canadian Journal of Plant Science*, 48:85–88.

Levy, D.B. and W.F. Kearney, 1999. Irrigation of Native Rangeland Using Treated Wastewater from In Situ Uranium Processing, *Journal of Environmental Quality*, 28:208-217.

Lin, G., S. Phillips and J. Ehleringer, 1996. Monsoonal precipitation responses of shrubs in a cold desert community on the Colorado Plateau, *Oecologia* 106:8-17.

Loro, P., D. Bergstrom, and E. Beauchamp, 1997. Intensity and duration of denitrification following application of manure and ferilizer to soil, *J. Environ, Quality* 26: 706-713.

Luo, J., R. Tillman, and P. Ball, 2000. Nitrogen loss through denitrification in a soil under pasture in New Zealand, Soil Biology and Biochemistry 32: 497-509.

Mandi L., B. Houhoum, S. Asmama, and J. Schwartzbrod, 1996. Wastewater Treatment by Reed Beds an Experimental Approach, *Water Research*, 30(9):2009-2016.

Marshall, S., M. Cabrera, L. Braun, C. Wood, M. Mullen, and E. Guertal. 1999. Denitrification from fescue pastures in the southeastern USA fertilized with broiler litter, *J. Environ. Quality* 28: 1978-1983.

Mengel, K. and E.A. Kirkby, 1978. *Principles of Plant Nutrition*, Eds.International Potash Institute, Worblaufen-Bern/Switzerland, pgs. 397, 405, 446.

Miller, R., and D. Gardiner, 1998. *Soils in Our Environment*, Prentice Hall, New Jersey.

Morrell, B.G., N.W. Lepp, and D.A. Phipps, 1983. Vanadium Uptake by Higher Plants, *Minerals and Environment*, 5:79-81.

Mulvaney, R.L., 1996. *Methods of Soil Analysis*, Part 3, edited by D.L. Sparks, Soil Science Society of America, Madison, Wisconsin.

Nelson, R.E., 1982. *Methods of Soil Analysis Part II Chemical and Microbiological Properties*, second edition, edited by A.L. Page, R.H. Miller, and D.R. Keeney, Soil Science Society of America, Madison, Wisconsin.

Nichols, W.D., 1993. “Estimating Discharge of Shallow Groundwater by Transpiration from Greasewood in the Northern Great Basin,” *Water Resources Research*, 29:2771–2778.

Nichols, W., 1994. Groundwater discharge by phreatophyte shrubs in the Great Basin as related to depth to groundwater, *Water Resources Research* 30:3265-3274.
Oklahoma State University Agricultural Extension Service, 2000, Fact Sheet F-2903, Oklahoma State University, Oklahoma.

Orchard, Brady J., W.J. Doucette, J.K. Chard, and B. Bugbee, 2000. Uptake of Trichloroethylene by Hybrid Poplar Trees Grown Hydroponically in Flow-Through Plant Growth Chambers, *Environmental Toxicology and Chemistry*, 19(4):895-903.

Osmond, C., O. Bjorkman, and D. Anderson, 1980. Physiological processes in plant ecology: towards a synthesis with Atriplex, Springer-Verlag, Berlin.

Pilon-Smits, E.A.H., M.P. de Souza, Lytle, C.M., Shange, C., Lugo, T., and Terry, N.. 1998. Selenium volatilization and assimilation by hybrid poplar (*Populus tremula x alba*). *Journal of Experimental Botany*. 49(328):1889-1892.

Ramsey, F.L. and D.W. Schafer, 1997. *The Statistical Sleuth*, p. 65-69, Duxbury Press, Belmont, California.

Rending, V.V. and H.M. Taylor, 1989. *Principles of Soil-Plant Interrelationships,* McGraw-Publishing Company, United States of America, Pgs. 29, 225.

Robinson B.H., M. Leblanc, P. Daniel, R.R. Brooks, J.H. Kirkman, and P.E.H. Gregg,1998. The potential of *Thlaspi caerlescens* for phytoremediation of contaminated soils, *Plant and soil*, 203:47-56.

Russelle M.P., J.F.S. Lam, B.R. Montgomery, D.W. Elsenheimer, B.S. Miller, and C.P. Vance, 2001. Alfalfa rapidly remediates excess inorganic nitrogen at a fertilizer spill site, *Journal of Environmental Quality*, 30:30-36.

Sanchez, L., J. Diez, A. Vallejo, M. Cartagena, 2001. Denitrification losses from irrigated crops in central Spain, *Soil Biology & Biochemistry* 33 :1201-1209.

Strickland G., G, Selk, E. Allen, and T. Thedford, 1995a. *Prussic Acid Poisoning in Livestock*, Oklahoma Cooperative Extension Service, OSU Extension Fact Sheet, F-2904.

Strickland G., G. Selk, E. Allen, and T. Thedford, 1995b. *Nitrate Toxicity in Livestock*, Oklahoma Cooperative Extension Service, OSU Extension Fact Sheet F-2903.

Subcommittee on Mineral Toxicity in Animals, 1980. *Mineral Tolerance of Domestic Animals*, Committee on Animal Nutrition, Board of Agriculture and Renewable Resources, Commission on Natural Resources, and Natural Resource Council, The National Academy of Sciences, Washington D.C. pgs. 290-296, 459-462, 525-530, 534-541.

Swingle, R., E. Glenn, and V. Squires, 1996. "Growth Performance of Lambs Fed Mixed Diets Containing Halophyte Ingredients" *Animal Feed Science and Technology,* 63:137–148.

Tabatabai, M.A., 1996. *Methods of Soil Analysis,* Part 3, edited by D.L. Sparks, Soil Science Society of America, Madison, Wisconsin.

Thompson T.L. and Glenn, 1998. Precipitation of Gypsum from Contaminated Ground Water Used in Phytoremediation, Letter report to Department of Energy

U.S. Department of Agriculture Soil Survey Staff, 1997. *Keys to Soil Taxonomy,* seventh edition, U.S. Department of Agriculture Pochontas Press, Blacksburg, Virginia.

U.S. Department of Energy, 1999. *Final Site Observational Work Plan for the UMTRA Project Site at Monument Valley, Arizona*, prepared by MACTEC–ERS for U.S. Department of Energy, April.

———, 2001. Chemistry of Phase I Phytoremediation Soils: Results of the First Sampling, UMTRA Ground Water Project, Monument Valley, Arizona, Site, GJO-2001-266-TAR (ESL-RPT-2002-01), Environmental Sciences Laboratory, U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado.

U.S. Environmental Protection Agency, 2000. *Introduction to Phytoremediation*, EPA/600/R-99/107, National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio.

United Nations, 1990. "Management of Gypsiferous Soils, Food and Agriculture Organization of the United Nations," FAO Soils Bulletin – 62, New York.

Van Bavel, C.H.M., N. Underwood, and R.W. Swanson, 1956. Soil moisture measurement by neutron moderation, *Soil Science,* 82:29-41.

Wang, J.F. and Z. Liu, 1999. Effect of vanadium on the growth of soybean seedlings, *Plant and Soil*, 216:47-51.

Watson, M., G. Banuelos, J. O'Leary, and J. Riley, 1994. Trace-element composition of Atriplex grown with saline drainage water, *Agriculture, Ecosystems and Environment* 48:157-162.

Waugh, W.J., M.E. Thiede, D.J. Bates, L.L. Cadwell, G.W. Gee, and C.J. Kemp, 1994. Plant cover and water balance in gravel admixtures at an arid waste-burial site, *Journal of Environmental Quality,* 23:676-685.

Waugh, W.J., D.A. Baker, M.K. Kastens, J.A. Abraham, 1996. Calibration Precision of Capacitance and Neutron Soil Water Content in Arid Soils, *Arid Soil Research and Rehabilitation,* 10:391-401.

Wilkinson, R.E. and R.R. Duncan, 1993. Vanadium influence on calcium ($^{45}Ca^{2+}$) absorption by sorghum root tips, *Journal of Plant Nutrition*, 16:1991-1994.

Willett, I.R. and W.J. Bond, 1998. Fate of Manganese and Radionuclides applied in Uranium Mine Waste Water to a Highly Weathered Soil, *Geoderma*, 84:195-211.

Wood, M., B. Buchanan, and W. Skeet, 1995. Shrub preference and utilization by big game on New Mexico reclaimed mine land, *Journal of Range Management* 48:431-437.

Woods, C. and T. Cade, 1996. Nesting habits of the loggerhead shrike in sagebrush, *Condor* 98:75-81.

Appendix A

Initial Ammonia and Nitrate Concentrations for Subpile Soil

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Ammonia (mg/kg) shaded areas are samples with highest concentrations, used in Figure 2–1

	Degrees from 0^0 N						
	0	**45**	**106**	**130**	**180**	**275**	**308**
100 ft							
0-3'	0.8	*	*	*	*	*	3.7
3'-6'	1.6	*	*	*	*	*	1.4
6'-9'	0.8	*	*	*	*	*	5.0
200 ft							
0-3'	6.8	1.2	3.2	31.5	50.5	0	0.8
3'-6'	20.2	1.1	126.5	36.5	(3-4.5 ft)103.5	0	0.9
6'-9'	3.0	0.9	163.5	39.7	*	*	0.9
300 ft							
0-3'	0	2.5	0.8	*	(0-2.5ft) 2.7	38.2	*
3'-6'	0	0	64	*	*	(3-3.5ft) 3.2	*
6'-9'	6.3	5.0	24.55	*	*	*	*
400 ft	[370 ft]						
0-3'	0	1.0	0	0	(0-2ft) 3.8	(0-1ft) 0	1.6
3'-6'	0.9	1.7	0	151.5	*	*	1.9
6'-9'	1.1	0	4.5	50.5	*	*	0.8
500 ft							
0-3'	*	*	*	0	*	*	*
3'-6'	*	*	*	0	*	*	*
6'-9'	*	*	*	0	*	*	*

	center	**extra**
0-3'	0	9.8
3-6'	13.1	0.7
6-9'	11.8	3.6

Nitrate (ppm)

	Degrees from 0^0 N						
	0	**45**	**106**	**130**	**180**	**275**	**308**
100 ft							
0-3'	205	*	*	*	*	*	605
3'-6'	150	*	*	*	*	*	410
6'-9'	275	*	*	*	*	*	400
200 ft							
0-3'	200	365	950	495	640	405	170
3'-6'	110	265	755	555	420 (to 4.5ft)	465	165
6'-9'	80	405	565	340	*	*	265
300 ft							
0-3'	70	45	630	*	145(2.5ft)	170	*
3'-6'	140	155	1030	*	*	285	*
6'-9'	70	0	310	*	*	*	*
400 ft	(370 ft.)						
0-3'	105	70	520	690	910 (2 ft)	85 (1 ft)	135
3'-6'	150	565	460	1060	*	*	255
6'-9'	130	435	345	885	*	*	410
500 ft							
0-3'	*	*	*	260	*	*	*
3'-6'	*	*	*	190	*	*	*
6'-9'	*	*	*	310	*	*	*

	center	**extra**
0-3'	315	80
3-6'	730	60
6-9'	965	310

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Appendix B

Plant Survival for 2000 and 2001

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	Live		Dead		No Plant		Total		Survival	
Zone	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
1	874	874	30	19	5	5	904	893	96.7%	97.9%
2	1272	1272	41	43	0	0	1313	1315	96.9%	96.7%
3	909	909	30	25	0	0	939	934	96.8%	97.3%
4	754	754	5	16	0	0	759	770	99.3%	97.9%
Total	3,809	3,809	106	103	5	5	3915	3912	97.3%	97.4%

	2000	**2001**
No plant:	5	5
Emitters:	3920	3917
Plants needed following spring:	111	108

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Appendix C

Subpile Plant Growth Data for 2000 and 2001

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Row	Zone	Plant #	Plant type	Canopy (m^2)	Volume (m^3)
1	1	1	A	1288.25235	36071.0658
1	1	2	A	3739.2894	124642.98
1	1	3	A	7.0686	108.3852
1	1	4	A	283.5294	5292.5488
1	1	5	A	283.5294	2079.2156
1	1	6	A	9.62115	76.9692
1	1	7	A	8494.8864	464387.1232
1	1	8	A	962.115	16035.25
1	1	9	A	8091.38715	463906.1966
1	1	10	A	730.61835	21918.5505
1	1	11	A	213.82515	3563.7525
1	1	12	A	14848.96875	722649.8125
1	1	13	A	7854	575960
1	1	14	A	2375.835	114040.08
1	1	15	A	10843.42875	672292.5825
1	1	16	A	754.7694	28681.2372
1	1	17	A	165.13035	2862.2594
1	1	18	A	2290.2264	85501.7856
1	1	19	A	17319.83715	1085376.461
1	1	20	A	8011.8654	427299.488
1	1	21	A	314.16	9005.92
1	1	22	A	213.82515	3421.2024
1	1	23	A	683.49435	18226.516
1	1	24	A	4417.875	176715
2	1	1	A	363.05115	6776.9548
2	1	2	A	1418.62875	42558.8625
2	1	3	A	3117.2526	133002.7776
2	1	4	A	50.2656	971.8016
2	1	5	A	8171.3016	370432.3392
2	1	6	A	593.95875	10691.2575
2	1	7	A	41547.66	3960876.92
2	1	8	A	5153.0094	223297.074
2	1	9	A	3959.2014	155728.5884
2	1	10	A	56.74515	870.0923
2	1	11	A	226.9806	2572.4468
2	1	12	A	1288.25235	54106.5987
2	1	13	A	298.64835	10353.1428
2	1	14	A	4596.35715	263524.4766
2	1	15	A	4536.4704	226823.52
2	1	16	A	165.13035	1100.869
2	1	17	A	2002.96635	93471.763
2	1	18	A	3318.315	141581.44
2	1	19	A	754.7694	16101.7472
2	1	20	A	452.3904	7539.84
2	1	21	A	38.4846	102.6256
2	1	22	A	78.54	523.6
2	1	23	A	165.13035	1210.9559
2	1	24	A	551.54715	7721.6601
3	1	1	A	165.13035	1761.3904
3	1	2	A	5741.47035	237314.1078
3	1	3	A	7238.2464	400516.3008
3	1	4	A	226.9806	6506.7772
3	1	5	A	510.70635	11235.5397
3	1	6	A	1256.64	29321.6
3	1	7	A	33006.435	2750536.25
3	1	8	A	5026.56	217817.6
3	1	9	A	7542.9816	352005.808

Row	Zone	Plant #	Plant type	Canopy (m^2)	Volume (m^3)
3	1	10	A	530.9304	14866.0512
3	1	11	A	314.16	8168.16
3	1	12	A	28.2744	263.8944
3	1	13	A	176.715	2002.77
3	1	14	A	8251.60875	495096.525
3	1	15	A	132.7326	3008.6056
3	1	16	A	86.59035	923.6304
3	1	17	A	1590.435	57255.66
3	1	18	A	8332.3086	583261.602
3	1	19	A	804.2496	21446.656
3	1	20	A	122.71875	1963.5
3	1	21	A	1809.5616	66350.592
3	1	22	A	2248.01115	74933.705
4	1	1	A	7238.2464	482549.76
4	1	2	A	15393.84	872317.6
4	1	3	A	9940.21875	795217.5
4	1	4	A	2970.57915	174273.9768
4	1	5	A	4901.6814	294100.884
4	1	6	A	268.80315	9318.5092
4	1	7	A	86.59035	2366.8029
4	1	8	A	13273.26	902581.68
4	1	9	A	6503.8974	429257.2284
4	1	10	A	132.7326	1769.768
4	1	11	A	1134.1176	37047.8416
4	1	12	A	2827.44	109327.68
4	1	13	A	95.0334	1583.89
4	1	14	A	12.5664	83.776
4	1	15	A	551.54715	14707.924
4	1	16	A	298.64835	6769.3626
4	1	17	A	2551.7646	139496.4648
4	1	18	A	2507.19315	142074.2785
4	1	19	A	95.0334	2851.002
4	1	20	A	12.5664	184.3072
4	1	21	A	2733.9774	131230.9152
4	1	22	A	1555.28835	44584.9327
4	1	23	A	2002.96635	54747.7469
4	1	24	A	283.5294	3780.392
5	1	1	A	22698.06	1467807.88
5	1	2	A	7932.73635	401925.3084
5	1	3	A	10751.3406	602075.0736
5	1	4	A	5345.62875	299355.21
5	1	5	A	283.5294	6615.686
5	1	6	A	153.9384	1949.8864
5	1	7	A	363.05115	5808.8184
5	1	8	A	20106.24	1715732.48
5	1	9	A	103.86915	1315.6759
5	1	10	A	16286.0544	1259454.874
5	1	11	A	12.5664	108.9088
5	1	12	A	530.9304	16635.8192
5	1	13	A	153.9384	2873.5168
5	1	14	A	330.06435	7701.5015
5	1	15	A	683.49435	13669.887
5	1	16	A	153.9384	2976.1424
5	1	17	A	660.5214	25099.8132
5	1	18	A	143.13915	3244.4874
5	1	19	A	4071.5136	195432.6528
5	1	20	A	4596.35715	165468.8574

Row	Zone	Plant #	Plant type	Canopy	Volume
5	1	21	A	1134.1176	22682.352
5	1	22	A	DEAD PLANT	
5	1	23	A	1075.2126	24371.4856
5	1	24	A	4242.92715	107487.4878
6	1	1	A	10843.42875	665063.63
6	1	2	A	4839.83115	225858.787
6	1	3	A	8251.60875	533604.0325
6	1	4	A	7088.235	472549
6	1	5	A	24745.00875	1600177.233
6	1	6	A	95.0334	1773.9568
6	1	7	A	0	0
6	1	8	A	165.13035	6495.1271
6	1	9	A	254.4696	5089.392
6	1	10	A	143.13915	1431.3915
6	1	11	A	3848.46	184726.08
6	1	12	A	103.86915	2146.6291
6	1	13	A	907.9224	36316.896
6	1	14	A	254.4696	5598.3312
6	1	15	A	201.0624	3485.0816
6	1	16	A	1698.23115	56607.705
6	1	17	A	706.86	23562
6	1	18	A	38.4846	769.692
6	1	19	A	5674.515	340470.9
6	1	20	A	660.5214	13650.7756
6	1	21	A	122.71875	2454.375
6	1	22	A	433.73715	17638.6441
6	1	23	A	989.80035	13197.338
6	1	24	A	268.80315	5913.6693
6	1	25	A	15.90435	106.029
7	1	1	A	20739.46875	1382631.25
7	1	2	A	12.5664	100.5312
7	1	3	A	16513.035	1299025.42
7	1	4	A	27025.81035	2252150.863
7	1	5	A	56.74515	718.7719
7	1	6	A	12.5664	75.3984
7	1	7	A	1809.5616	100129.0752
7	1	8	A	44.17875	176.715
7	1	9	A	70.88235	1181.3725
7	1	10	A	7.0686	61.2612
7	1	11	A	10843.42875	513255.6275
7	1	12	A	283.5294	7749.8036
7	1	13	A	2206.1886	92659.9212
7	1	14	A	551.54715	11766.3392
7	1	15	A	3117.2526	139237.2828
7	1	16	A	4476.97635	205940.9121
7	1	17	A	3267.46035	113271.9588
7	1	18	A	881.41515	36431.8262
7	1	19	A	346.3614	9005.3964
7	1	20	A	1734.9486	61301.5172
7	1	21	A	510.70635	10214.127
7	1	22	A	113.0976	1734.1632
7	1	23	A	#DIV/0!	#VALUE!
8	1	1	A	471.43635	10057.3088
8	1	2	A	113.0976	1357.1712
8	1	3	A	615.7536	7389.0432
8	1	4	A	2290.2264	90082.2384
8	1	5	A	2375.835	95033.4

Row	Zone	Plant #	Plant type	Canopy	Volume
8	1	6	A	3793.67835	227620.701
8	1	7	A	804.2496	30561.4848
8	1	8	A	95.0334	1393.8232
8	1	9	A	153.9384	4515.5264
8	1	10	A	78.54	1256.64
8	1	11	A	5944.6926	348755.2992
8	1	12	A	70.88235	945.098
8	1	13	A	2332.83435	87092.4824
8	1	14	A	176.715	5183.64
8	1	15	A	143.13915	3149.0613
8	1	16	A	213.82515	3421.2024
8	1	17	A	9331.3374	814936.7996
8	1	18	A	6792.9246	384932.394
8	1	19	A	11499.0414	988917.5604
8	1	20	A	7313.84115	492465.3041
8	1	21	A	8576.76435	583219.9758
8	1	22	A	26446.18515	2292002.713
8	1	23	A	9589.93035	562609.2472
8	1	24	A	13684.8096	912320.64
9	1	1	A	78.54	2094.4
9	1	2	S	23.75835	174.2279
9	1	3	A	16399.34835	1093289.89
9	1	4	A	11594.27115	881164.6074
9	1	5	A	10386.915	671687.17
9	1	6	A	26302.2606	2279529.252
9	1	7	A	26880.315	2401308.14
9	1	8	A	38013.36	4054758.4
9	1	9	A	2922.4734	113002.3048
9	1	10	A	17087.35875	1310030.838
9	1	11	A	8576.76435	486016.6465
9	1	12	A	572.5566	18321.8112
9	1	13	A	855.3006	19957.014
9	1	14	A	122.71875	1309
9	1	15	A	240.52875	6414.1
9	1	16	A	70.88235	661.5686
9	1	17	A	176.715	4241.16
9	1	18	A	4901.6814	215673.9816
9	1	19	A	7389.8286	305446.2488
9	1	20	A	3267.46035	130698.414
9	1	21	A	9331.3374	534996.6776
9	1	22	A	2463.0144	75532.4416
9	1	23	A	1046.34915	25809.9457
10	1	1	A	2164.75875	86590.35
10	1	2	A	86.59035	2539.9836
10	1	3	A	2596.72875	115987.2175
10	1	4	A	226.9806	6809.418
10	1	5	A	433.73715	13012.1145
10	1	6	A	1486.17315	94124.2995
10	1	7	A	5026.56	341806.08
10	1	8	A	1486.17315	72327.0933
10	1	9	A	38.4846	564.4408
10	1	10	A	63.6174	1272.348
10	1	11	A	63.6174	1781.2872
10	1	12	A	7.0686	70.686
10	1	13	A	86.59035	1847.2608
10	1	14	A	7163.04435	362927.5804
10	1	15	A	56.74515	1059.2428

Row	Zone	Plant #	Plant type	Canopy	Volume
10	1	16	A	7163.04435	286521.774
10	1	17	A	50.2656	201.0624
10	1	18	A	86.59035	1096.8111
10	1	19	A	143.13915	3435.3396
10	1	20	A	113.0976	2186.5536
10	1	21	A	706.86	21677.04
10	1	22	A	2827.44	118752.48
10	1	23	A	380.1336	6588.9824
10	1	24	A	33.18315	1106.105
11	1	1	S	165.13035	1541.2166
11	1	2	A	2206.1886	89718.3364
11	1	3	A	7542.9816	502865.44
11	1	4	A	6361.74	360498.6
11	1	5	A	8011.8654	427299.488
11	1	6	A	2551.7646	45931.7628
11	1	7	A	706.86	16493.4
11	1	8	A	14633.76915	1024363.841
11	1	9	A	7854	408408
11	1	10	A	7466.20875	298648.35
11	1	11	A	28.2744	471.24
11	1	12	A	24190.51635	1677209.134
11	1	13	A	143.13915	3053.6352
11	1	14	A	1963.5	78540
11	1	15	A	86.59035	1327.7187
11	1	16	A	50.2656	971.8016
11	1	17	A	2596.72875	109062.6075
11	1	18	A	8332.3086	588816.4744
11	1	19	A	4839.83115	248444.6657
11	1	20	A	855.3006	31361.022
11	1	21	A	6432.62235	428841.49
11	1	22	A	5026.56	224519.68
11	1	23	A	6575.56515	394533.909
11	1	24	A	4596.35715	214496.667
12	1	1	A	143.13915	3339.9135
12	1	2	A	730.61835	36530.9175
12	1	3	A	5153.0094	309180.564
12	1	4	A	5876.55915	313416.488
12	1	5	A	779.31315	25977.105
12	1	6	A	4242.92715	248918.3928
12	1	7	A	1698.23115	56607.705
12	1	8	A	38.4846	615.7536
12	1	9	A	1075.2126	50893.3964
12	1	10	A	95.0334	1203.7564
12	1	11	A	1452.2046	61960.7296
12	1	12	A	28.2744	452.3904
12	1	13	A	12.5664	226.1952
12	1	14	A	113.0976	2186.5536
12	1	15	A	8011.8654	518100.6292
12	1	16	A	2687.83515	134391.7575
12	1	17	A	8251.60875	550107.25
12	1	18	A	1772.05875	93328.4275
12	1	19	A	5410.6206	274138.1104
12	1	20	A	14741.1726	776368.4236
12	1	21	A	10386.915	630139.51
12	1	22	A	1075.2126	26521.9108
12	1	23	A	471.43635	11943.0542
12	1	24	S	86.59035	230.9076

Row	Zone	Plant #	Plant type	Canopy	Volume
13	1	1	A	346.3614	8312.6736
13	1	2	A	9417.14235	546194.2563
13	1	3	A	38.4846	461.8152
13	1	4	A	12568.16715	728953.6947
13	1	5	A	1963.5	108647
13	1	6	A	5410.6206	313815.9948
13	1	7	A	5089.58835	234121.0641
13	1	8	A	9245.92515	573247.3593
13	1	9	A	989.80035	44870.9492
13	1	10	A	11309.76	753984
13	1	11	A	298.64835	7764.8571
13	1	12	A	240.52875	7696.92
13	1	13	A	176.715	3652.11
13	1	14	A	415.4766	9694.454
13	1	15	A	213.82515	6129.6543
13	1	16	A	490.875	10144.75
13	1	17	A	226.9806	2269.806
13	1	18	A	3216.9984	165139.2512
13	1	19	A	78.54	418.88
13	1	20	A	#DIV/0!	#VALUE!
13	1	21	A	5345.62875	210261.3975
13	1	22	A	1625.97435	63954.9911
13	1	23	A	6082.1376	283833.088
13	1	24	S	56.74515	870.0923
14	1	1	A	7238.2464	342610.3296
14	1	2	A	33653.6046	2288445.113
14	1	3	A	4839.83115	151648.0427
14	1	4	A	989.80035	32333.4781
14	1	5	A	2687.83515	94970.1753
14	1	6	A	8251.60875	396077.22
14	1	7	A	7163.04435	243543.5079
14	1	8	A	10843.42875	614460.9625
14	1	9	A	240.52875	1763.8775
14	1	10	A	2248.01115	86923.0978
14	1	11	A	13375.55835	1034376.512
14	1	12	A	5089.58835	169652.945
14	1	13	A	346.3614	7850.8584
14	1	14	A	86.59035	1674.0801
14	1	15	A	730.61835	17047.7615
14	1	16	A	11028.78315	676432.0332
14	1	17	A	3631.6896	162215.4688
14	1	18	A	5541.7824	254921.9904
14	1	19	A	4778.3736	197506.1088
14	1	20	A	70.88235	1228.6274
14	1	21	A	4128.25875	233934.6625
14	1	22	A	2780.51235	142732.9673
14	1	23	A	1847.45715	71435.0098
14	1	24	A	2687.83515	96762.0654
14	1	25	A	28.2744	395.8416
15	1	1	A	1885.7454	40229.2352
15	1	2	A	10207.0584	537571.7424
15	1	3	A	363.05115	6534.9207
15	1	4	A	28.2744	735.1344
15	1	5	A	19.635	183.26
15	1	6	A	38.4846	923.6304
15	1	7	S	3.1416	18.8496
15	1	8	A	804.2496	18229.6576

Row	Zone	Plant #	Plant type	Canopy	Volume
15	1	9	A	14313.915	877920.12
15	1	10	A	7697.7054	461862.324
15	1	11	A	132.7326	2477.6752
15	1	12	A	530.9304	10972.5616
15	1	13	A	380.1336	9123.2064
15	1	14	A	56.74515	1588.8642
15	1	15	A	3216.9984	147981.9264
15	1	16	A	28.2744	358.1424
15	1	17	A	4359.16635	232488.872
15	1	18	A	510.70635	12597.4233
15	1	19	A	7542.9816	346977.1536
15	1	20	A	226.9806	3329.0488
15	1	21	A	2206.1886	79422.7896
15	1	22	A	122.71875	981.75
15	1	23	A	1385.4456	42486.9984
16	1	1	A	2551.7646	61242.3504
16	1	2	A	2827.44	92363.04
16	1	3	A	201.0624	4423.3728
16	1	4	S	38.4846	76.9692
16	1	5	A	19.635	248.71
16	1	6	A	6151.44915	323976.3219
16	1	7	A	8332.3086	455499.5368
16	1	8	A	38.4846	384.846
16	1	9	A	683.49435	14581.2128
16	1	10	A	8741.69835	588607.6889
16	1	11	A	660.5214	19375.2944
16	1	12	A	907.9224	37527.4592
16	1	13	A	314.16	7120.96
16	1	14	A	15836.8056	1024113.429
16	1	15	A	7389.8286	408903.8492
16	1	16	A	33.18315	287.5873
16	1	17	A	7932.73635	428367.7629
16	1	18	A	165.13035	1981.5642
16	1	19	A	254.4696	4071.5136
16	1	20	A	572.5566	7252.3836
16	1	21	A	95.0334	1520.5344
16	1	22	A	1352.65515	37874.3442
16	1	23	A	268.80315	5913.6693
16	1	24	A	1194.5934	31059.4284
17	1	1	A	1847.45715	88677.9432
17	1	2	A	1924.42635	47469.1833
17	1	3	A	2827.44	107442.72
17	1	4	A	706.86	6597.36
17	1	5	S	33.18315	88.4884
17	1	6	A	132.7326	973.3724
17	1	7	A	4778.3736	200691.6912
17	1	8	A	33.18315	685.7851
17	1	9	A	1256.64	20944
17	1	10	A	15.90435	201.4551
17	1	11	A	962.115	19883.71
17	1	12	A	2687.83515	89594.505
17	1	13	A	DEAD PLANT	
17	1	14	A	660.5214	13650.7756
17	1	15	A	63.6174	1696.464
17	1	16	A	5153.0094	223297.074
17	1	17	A	3421.2024	180183.3264
17	1	18	A	6361.74	322328.16
17	1	19	A	176.715	2945.25
17	1	20	A	201.0624	4691.456
17	1	21	A	989.80035	27054.5429
17	1	22	A	2290.2264	96189.5088
17	1	23	A	3117.2526	118455.5988
17	1	24	A	804.2496	27880.6528
17	1	25	A	855.3006	28510.02
18	1	1	A	19.635	327.25
18	1	2	A	268.80315	3046.4357
18	1	3	A	44.17875	795.2175
18	1	4	A	1734.9486	63614.782
18	1	5	A	3019.0776	78496.0176
18	1	6	A	28.2744	207.3456
18	1	7	A	56.74515	1626.6943
18	1	8	A	8091.38715	372203.8089
18	1	9	A	17671.5	1284129
18	1	10	A	779.31315	12988.5525
18	1	11	S	44.17875	117.81
18	1	12	A	5876.55915	305581.0758
18	1	13	S	530.9304	7433.0256
18	1	14	A	283.5294	6615.686
18	1	15	A	314.16	6702.08
18	1	16	A	3019.0776	124788.5408
18	1	17	A	1385.4456	49876.0416
18	1	18	A	3578.47875	155067.4125
18	1	19	A	86.59035	1558.6263
18	1	20	A	5216.82315	253885.3933
18	1	21	A	226.9806	5144.8936
18	1	22	A	1134.1176	44608.6256
18	1	23	A	1963.5	70686
18	1	24	A	188.69235	3773.847
18	1	25	A	730.61835	24353.945
19	1	1	A	201.0624	2680.832
19	1	2	A	7163.04435	472760.9271
19	1	3	A	18869.235	1308266.96
19	1	4	A	50.2656	670.208
19	1	5	A	103.86915	1661.9064
19	1	6	A	3903.63435	98892.0702
19	1	7	A	3848.46	177029.16
19	1	8	A	50.2656	670.208
19	1	9	A	3631.6896	94423.9296
19	1	10	A	DEAD PLANT	
19	1	11	S	176.715	706.86
19	1	12	S	363.05115	6776.9548
19	1	13	A	122.71875	2781.625
19	1	14	A	779.31315	14547.1788
19	1	15	A	1164.15915	45014.1538
19	1	16	A	188.69235	3648.0521
19	1	17	A	213.82515	4561.6032
19	1	18	A	1418.62875	55799.3975
19	1	19	A	298.64835	8163.0549
19	1	20	A	1352.65515	55909.7462
19	1	21	A	2507.19315	133716.968
19	1	22	A	226.9806	3177.7284
19	1	23	A	1225.42035	47382.9202
19	1	24	A	330.06435	12102.3595
19	1	25	A	2248.01115	101909.8388

Row	Zone	Plant #	Plant type	Canopy	Volume
19	1	26	A	213.82515	4419.0531
20	1	1	A	283.5294	6993.7252
20	1	2	A	2463.0144	65680.384
20	1	3	A	78.54	733.04
20	1	4	A	7854	424116
20	1	5	A	5876.55915	238980.0721
20	1	6	A	1164.15915	23283.183
20	1	7	A	143.13915	2481.0786
20	1	8	A	1017.8784	30536.352
20	1	9	A	240.52875	7055.51
20	1	10	A	730.61835	26789.3395
20	1	11	A	1352.65515	27053.103
20	1	12	A	268.80315	5913.6693
20	1	13	A	962.115	27580.63
20	1	14	A	3631.6896	159794.3424
20	1	15	A	551.54715	15811.0183
20	1	16	A	6720.07875	349444.095
20	1	17	A	2248.01115	100411.1647
20	1	18	A	2733.9774	147634.7796
20	1	19	A	1661.9064	59828.6304
20	1	20	A	934.82235	40508.9685
20	1	21	A	#DIV/0!	#VALUE!
20	1	22	A	2042.8254	73541.7144
20	1	23	A	2463.0144	90310.528
20	1	24	A	3267.46035	150303.1761
20	1	25	A	2290.2264	67179.9744
21	1	1	A	452.3904	6936.6528
21	1	2	A	855.3006	17676.2124
21	1	3	A	363.05115	5566.7843
21	1	4	A	122.71875	2045.3125
21	1	5	A	962.115	19883.71
21	1	6	A	804.2496	25199.8208
21	1	7	A	7.0686	94.248
21	1	8	A	176.715	3298.68
21	1	9	A	3959.2014	190041.6672
21	1	10	A	153.9384	2565.64
21	1	11	A	143.13915	1431.3915
21	1	12	A	201.0624	2948.9152
21	1	13	S	1885.7454	47772.2168
21	1	14	A	4128.25875	178891.2125
21	1	15	A	268.80315	8064.0945
21	1	16	A	5741.47035	340660.5741
21	1	17	A	4071.5136	228004.7616
21	1	18	A	363.05115	10649.5004
21	1	19	A	2970.57915	128725.0965
21	1	20	A	1486.17315	41612.8482
21	1	21	A	397.60875	10337.8275
21	1	22	A	615.7536	22577.632
21	1	23	A	38.4846	461.8152
21	1	24	A	1452.2046	54215.6384
21	1	25	A	165.13035	2421.9118
22	2	1	A	213.82515	2280.8016
22	2	2	A	213.82515	5274.3537
22	2	3	A	637.94115	24241.7637
22	2	4	A	314.16	6283.2
22	2	5	A	1847.45715	60350.2669
22	2	6	A	122.71875	2290.75

Row	Zone	Plant #	Plant type	Canopy	Volume
22	2	7	A	346.3614	6696.3204
22	2	8	A	551.54715	12134.0373
22	2	9	A	95.0334	1710.6012
22	2	10	A	2419.22835	91930.6773
22	2	11	A	881.41515	25267.2343
22	2	12	A	4717.30875	194982.095
22	2	13	S	510.70635	8511.7725
22	2	14	A	1963.5	65450
22	2	15	A	1046.34915	14648.8881
22	2	16	A	706.86	11309.76
22	2	17	A	1772.05875	64975.4875
22	2	18	A	6151.44915	377288.8812
22	2	19	A	12.5664	418.88
22	2	20	A	363.05115	10891.5345
22	2	21	A	12.5664	33.5104
22	2	22	A	4901.6814	205870.6188
22	2	23	A	7313.84115	375443.8457
22	2	24	A	213.82515	4704.1533
23	2	1	A	56.74515	983.5826
23	2	2	A	19.635	117.81
23	2	3	A	33.18315	508.8083
23	2	4	A	188.69235	1886.9235
23	2	5	A	63.6174	933.0552
23	2	6	A	1924.42635	44903.2815
23	2	7	A	572.5566	16031.5848
23	2	8	A	226.9806	2723.7672
23	2	9	A	380.1336	8616.3616
23	2	10	A	15.90435	63.6174
23	2	11	A	962.115	31429.09
23	2	12	A	8576.76435	394531.1601
23	2	13	A	1017.8784	32572.1088
23	2	14	A	1194.5934	20706.2856
23	2	15	A	240.52875	4970.9275
23	2	16	A	8251.60875	445586.8725
23	2	17	S	1256.64	40212.48
23	2	18	A	4717.30875	257879.545
23	2	19	A	254.4696	6785.856
23	2	20	A	122.71875	1718.0625
23	2	21	A	3793.67835	225091.5821
23	2	22	A	3685.29315	162152.8986
23	2	23	A	1625.97435	81298.7175
23	2	24	A	3421.2024	205272.144
23	2	25	A	165.13035	2862.2594
23	2	26	A	1075.2126	18637.0184
24	2	1	A	188.69235	2138.5133
24	2	2	A	314.16	2932.16
24	2	3	A	23.75835	221.7446
24	2	4	A	907.9224	24211.264
24	2	5	A	103.86915	1384.922
24	2	6	A	779.31315	14547.1788
24	2	7	A	213.82515	3563.7525
24	2	8	A	433.73715	13012.1145
24	2	9	A	70.88235	1134.1176
24	2	10	A	363.05115	7018.9889
24	2	11	A	397.60875	6626.8125
24	2	12	A	3019.0776	120763.104
24	2	13	A	934.82235	23682.1662

Row	Zone	Plant #	Plant type	Canopy	Volume
24	2	14	A	1134.1176	35535.6848
24	2	15	A	804.2496	33242.3168
24	2	16	A	15948.52875	978176.43
24	2	17	A	380.1336	12924.5424
24	2	18	A	2332.83435	138414.8381
24	2	19	A	165.13035	3632.8677
24	2	20	A	176.715	3534.3
24	2	21	A	660.5214	29503.2892
24	2	22	A	9.62115	38.4846
24	2	23	A	706.86	24504.48
24	2	24	A	1320.2574	44008.58
24	2	25	A	490.875	12435.5
25	2	1	A	176.715	2591.82
25	2	2	A	122.71875	2454.375
25	2	3	A	86.59035	923.6304
25	2	4	S	44.17875	117.81
25	2	5	A	33.18315	575.1746
25	2	6	A	165.13035	2531.9987
25	2	7	A	153.9384	1539.384
25	2	8	A	706.86	8482.32
25	2	9	A	226.9806	5144.8936
25	2	10	A	143.13915	3149.0613
25	2	11	A	1104.46875	33870.375
25	2	12	S	86.59035	981.3573
25	2	13	A	5476.00515	321258.9688
25	2	14	A	1017.8784	39357.9648
25	2	15	A	1486.17315	53502.2334
25	2	16	A	683.49435	17315.1902
25	2	17	A	20106.24	1863178.24
25	2	18	A	14420.14035	845981.5672
25	2	19	A	3421.2024	177902.5248
25	2	20	A	7088.235	458372.53
25	2	21	A	28.2744	94.248
25	2	22	A	8908.20315	451348.9596
25	2	23	A	19.635	52.36
25	2	24	A	15.90435	63.6174
25	2	25	A	4242.92715	260232.8652
25	2	26	A	1625.97435	47695.2476
26	2	1	A	165.13035	2091.6511
26	2	2	A	1772.05875	50799.0175
26	2	3	A	2642.0856	59887.2736
26	2	4	A	2002.96635	69436.1668
26	2	5	A	415.4766	6924.61
26	2	6	A	188.69235	4025.4368
26	2	7	A	363.05115	9923.3981
26	2	8	A	298.64835	6172.0659
26	2	9	A	7313.84115	409575.1044
26	2	10	A	3631.6896	167057.7216
26	2	11	A	2375.835	109288.41
26	2	12	A	6503.8974	346874.528
26	2	13	A	6792.9246	375875.1612
26	2	14	A	1924.42635	59015.7414
26	2	15	A	855.3006	19386.8136
26	2	16	A	7013.81835	336663.2808
26	2	17	A	11594.27115	718844.8113
26	2	18	A	452.3904	17794.0224
26	2	19	A	804.2496	21446.656
26	2	20	A	6866.16315	320420.947
26	2	21	A	2083.07715	88877.9584
26	2	22	A	1320.2574	50169.7812
26	2	23	A	5607.95235	261704.443
26	2	24	A	1046.34915	41853.966
26	2	25	A	4901.6814	245084.07
27	2	1	A	240.52875	3688.1075
27	2	2	A	779.31315	17664.4314
27	2	3	A	103.86915	1107.9376
27	2	4	S	12.5664	33.5104
27	2	5	A	78.54	1047.2
27	2	6	A	754.7694	11573.1308
27	2	7	A	132.7326	1504.3028
27	2	8	A	240.52875	4489.87
27	2	9	A	3318.315	179189.01
27	2	10	A	19.635	366.52
27	2	11	A	8413.40115	555284.4759
27	2	12	A	8011.8654	475370.6804
27	2	13	A	7854	387464
27	2	14	A	NO DATA	
27	2	15	A	510.70635	9192.7143
27	2	16	A	433.73715	9831.3754
27	2	17	A	804.2496	14476.4928
27	2	18	A	962.115	25014.99
27	2	19	A	103.86915	1523.4142
27	2	20	A	78.54	523.6
27	2	21	A	615.7536	20935.6224
27	2	22	A	7542.9816	407321.0064
27	2	23	A	95.0334	950.334
27	2	24	A	103.86915	2215.8752
27	2	25	A	907.9224	19974.2928
27	2	26	A	NO DATA	
28	2	1	A	153.9384	1949.8864
28	2	2	A	95.0334	1013.6896
28	2	3	A	95.0334	1393.8232
28	2	4	A	23.75835	253.4224
28	2	5	S	122.71875	899.9375
28	2	6	A	314.16	5864.32
28	2	7	A	113.0976	2111.1552
28	2	8	A	314.16	9843.68
28	2	9	A	3267.46035	143768.2554
28	2	10	A	254.4696	2205.4032
28	2	11	A	1661.9064	59828.6304
28	2	12	A	4242.92715	192346.0308
28	2	13	A	934.82235	18696.447
28	2	14	A	3019.0776	114724.9488
28	2	15	A	6503.8974	372890.1176
28	2	16	A	4359.16635	185991.0976
28	2	17	A	7088.235	340235.28
28	2	18	A	226.9806	6355.4568
28	2	19	A	201.0624	7372.288
28	2	20	A	70.88235	708.8235
28	2	21	A	44.17875	353.43
28	2	22	A	551.54715	13237.1316
28	2	23	A	2551.7646	96967.0548
28	2	24	A	268.80315	6809.6798
28	2	25	A	3369.56235	125796.9944

Row	Zone	Plant #	Plant type	Canopy	Volume
29	2	1	A	132.7326	1946.7448
29	2	2	A	56.74515	870.0923
29	2	3	A	188.69235	3270.6674
29	2	4	A	615.7536	9441.5552
29	2	5	S	50.2656	167.552
29	2	6	A	855.3006	20527.2144
29	2	7	A	113.0976	1960.3584
29	2	8	A	44.17875	589.05
29	2	9	A	78.54	575.96
29	2	10	A	283.5294	2268.2352
29	2	11	A	153.9384	4515.5264
29	2	12	A	19.635	143.99
29	2	13	A	551.54715	11398.6411
29	2	14	A	4596.35715	150147.6669
29	2	15	A	1352.65515	48695.5854
29	2	16	A	1225.42035	60454.0706
29	2	17	A	NO DATA	
29	2	18	A	433.73715	8096.4268
29	2	19	A	132.7326	3628.0244
29	2	20	A	122.71875	1309
29	2	21	A	213.82515	2138.2515
29	2	22	A	240.52875	4329.5175
29	2	23	A	530.9304	12742.3296
29	2	24	A	4185.3966	259494.5892
29	2	25	A	363.05115	13553.9096
29	2	26	A	380.1336	8616.3616
30	2	1	A	415.4766	6370.6412
30	2	2	A	122.71875	1799.875
30	2	3	A	471.43635	9743.0179
30	2	4	A	226.9806	3934.3304
30	2	5	S	881.41515	18803.5232
30	2	6	A	201.0624	4155.2896
30	2	7	A	2642.0856	82785.3488
30	2	8	A	2164.75875	77931.315
30	2	9	A	4417.875	209112.75
30	2	10	A	380.1336	8109.5168
30	2	11	A	615.7536	16830.5984
30	2	12	A	1104.46875	17671.5
30	2	13	A	1256.64	1675.52
30	2	14	A	804.2496	21446.656
30	2	15	A	7389.8286	374417.9824
30	2	16	A	1385.4456	50799.672
30	2	17	A	380.1336	7095.8272
30	2	18	A	4536.4704	220774.8928
30	2	19	A	12568.16715	896529.2567
30	2	20	A	6575.56515	429603.5898
30	2	21	A	907.9224	28448.2352
30	2	22	A	283.5294	6993.7252
30	2	23	A	363.05115	6776.9548
30	2	24	A	5089.58835	230728.0052
30	2	25	A	95.0334	1900.668
31	2	1	A	56.74515	1134.903
31	2	2	A	254.4696	3732.2208
31	2	3	A	132.7326	1769.768
31	2	4	A	19.635	183.26
31	2	5	S	188.69235	1635.3337
31	2	6	A	1963.5	39270
31	2	7	A	6151.44915	369086.949
31	2	8	A	706.86	16022.16
31	2	9	A	1625.97435	39023.3844
31	2	10	A	551.54715	12501.7354
31	2	11	A	1847.45715	23401.1239
31	2	12	A	1194.5934	26281.0548
31	2	13	A	593.95875	13067.0925
31	2	14	A	397.60875	9542.61
31	2	15	A	4417.875	244455.75
31	2	16	A	881.41515	22916.7939
31	2	17	A	510.70635	16342.6032
31	2	18	A	433.73715	5783.162
31	2	19	A	240.52875	2886.345
31	2	20	A	18505.79115	1320079.769
31	2	21	A	1046.34915	20229.4169
31	2	22	A	70.88235	1512.1568
31	2	23	A	201.0624	6299.9552
31	2	24	A	23.75835	411.8114
31	2	25	A	5541.7824	258616.512
31	2	26	A	95.0334	1773.9568
32	2	1	A	1288.25235	34353.396
32	2	2	A	934.82235	20566.0917
32	2	3	A	1924.42635	65430.4959
32	2	4	A	NO DATA	
32	2	5	A	86.59035	1269.9918
32	2	6	A	962.115	32711.91
32	2	7	A	7238.2464	482549.76
32	2	8	A	13892.9406	1065125.446
32	2	9	A	1885.7454	94287.27
32	2	10	A	7466.20875	393220.3275
32	2	11	A	2290.2264	79394.5152
32	2	12	A	2042.8254	87160.5504
32	2	13	A	551.54715	14340.2259
32	2	14	A	510.70635	14299.7778
32	2	15	A	779.31315	26496.6471
32	2	16	A	1017.8784	19678.9824
32	2	17	A	1134.1176	28730.9792
32	2	18	A	2002.96635	30712.1507
32	2	19	A	1075.2126	17203.4016
32	2	20	A	2463.0144	83742.4896
32	2	21	A	132.7326	1150.3492
32	2	22	A	113.0976	1357.1712
32	2	23	A	188.69235	2641.6929
32	2	24	A	637.94115	11908.2348
32	2	25	A	283.5294	5670.588
32	2	26	A	298.64835	6172.0659
32	2	27	A	19.635	248.71
32	2	28	A	113.0976	1357.1712
33	2	1	A	615.7536	11083.5648
33	2	2	A	132.7326	2035.2332
33	2	3	A	572.5566	10306.0188
33	2	4	A	113.0976	980.1792
33	2	5	A	363.05115	12827.8073
33	2	6	A	380.1336	7349.2496
33	2	7	A	490.875	9817.5
33	2	8	A	1104.46875	21353.0625
33	2	9	A	1847.45715	59118.6288

Row	Zone	Plant #	Plant type	Canopy	Volume
33	2	10	A	452.3904	6936.6528
33	2	11	A	962.115	21166.53
33	2	12	A	12271.875	654500
33	2	13	A	4901.6814	192799.4684
33	2	14	A	1075.2126	18637.0184
33	2	15	A	510.70635	11576.0106
33	2	16	A	779.31315	20262.1419
33	2	17	A	363.05115	8713.2276
33	2	18	A	1486.17315	46566.7587
33	2	19	A	4901.6814	261423.008
33	2	20	A	298.64835	4380.1758
33	2	21	A	113.0976	2111.1552
33	2	22	A	2551.7646	163312.9344
33	2	23	A	2874.76035	120739.9347
33	2	24	A	165.13035	3302.607
33	2	25	A	510.70635	16683.0741
33	2	26	A	4300.8504	249449.3232
33	2	27	A	1809.5616	50667.7248
33	2	28	A	754.7694	503.1796
34	2	1	A	730.61835	12176.9725
34	2	2	A	113.0976	1432.5696
34	2	3	A	1452.2046	21299.0008
34	2	4	S	23.75835	110.8723
34	2	5	A	615.7536	12315.072
34	2	6	S	19.635	78.54
34	2	7	S	7.0686	28.2744
34	2	8	A	132.7326	1238.8376
34	2	9	A	593.95875	9899.3125
34	2	10	A	2332.83435	49767.1328
34	2	11	A	3525.6606	169231.7088
34	2	12	A	153.9384	3386.6448
34	2	13	A	4476.97635	170125.1013
34	2	14	A	989.80035	26394.676
34	2	15	A	1075.2126	28672.336
34	2	16	A	1104.46875	33134.0625
34	2	17	A	989.80035	28374.2767
34	2	18	A	1225.42035	29410.0884
34	2	19	A	3067.96875	110446.875
34	2	20	A	NO DATA	
34	2	21	A	3739.2894	249285.96
34	2	22	A	9503.34	430818.08
34	2	23	A	5281.0296	232365.3024
34	2	24	A	730.61835	22405.6294
34	2	25	A	2733.9774	125762.9604
34	2	26	A	397.60875	8482.32
34	2	27	A	415.4766	8309.532
34	2	28	A	33.18315	265.4652
35	2	1	A	56.74515	491.7913
35	2	2	A	19.635	117.81
35	2	3	A	510.70635	11235.5397
35	2	4	A	380.1336	6335.56
35	2	5	A	213.82515	4276.503
35	2	6	A	56.74515	945.7525
35	2	7	A	330.06435	5060.9867
35	2	8	A	2827.44	107442.72
35	2	9	A	452.3904	5428.6848
35	2	10	A	3216.9984	98654.6176

Row	Zone	Plant #	Plant type	Canopy	Volume
35	2	11	A	1225.42035	22057.5663
35	2	12	A	1661.9064	43209.5664
35	2	13	A	4300.8504	215042.52
35	2	14	A	1809.5616	59112.3456
35	2	15	A	1017.8784	20357.568
35	2	16	A	8251.60875	550107.25
35	2	17	A	1075.2126	30105.9528
35	2	18	A	188.69235	3648.0521
35	2	19	A	113.0976	1960.3584
35	2	20	A	44.17875	1413.72
35	2	21	A	122.71875	1309
35	2	22	A	38.4846	590.0972
35	2	23	A	15.90435	265.0725
35	2	24	A	15.90435	190.8522
35	2	25	A	490.875	16035.25
35	2	26	A	63.6174	848.232
36	2	1	A	268.80315	3763.2441
36	2	2	A	95.0334	1140.4008
36	2	3	A	268.80315	4659.2546
36	2	4	A	397.60875	8747.3925
36	2	5	A	4417.875	176715
36	2	6	A	268.80315	2688.0315
36	2	7	A	8332.3086	544377.4952
36	2	8	A	4839.83115	235538.4493
36	2	9	A	7088.235	330784.3
36	2	10	A	16513.035	1001790.79
36	2	11	A	7854	366520
36	2	12	A	16856.45115	1000149.435
36	2	13	A	15393.84	923630.4
36	2	14	A	29407.14315	2136919.069
36	2	15	A	1661.9064	53181.0048
36	2	16	A	8413.40115	364580.7165
36	2	17	A	1520.5344	46629.7216
36	2	18	A	1256.64	34348.16
36	2	19	A	6221.1534	244698.7004
36	2	20	A	8659.035	484905.96
36	2	21	A	6361.74	237504.96
36	2	22	A	63.6174	593.7624
36	2	23	A	2687.83515	82426.9446
36	2	24	A	7775.65635	518377.09
36	2	25	A	380.1336	6335.56
36	2	26	A	2922.4734	140278.7232
36	2	27	A	380.1336	8109.5168
37	2	1	A	1963.5	71995
37	2	2	A	593.95875	17026.8175
37	2	3	A	363.05115	9197.2958
37	2	4	A	7697.7054	441335.1096
37	2	5	A	3318.315	119459.34
37	2	6	A	13478.2494	772752.9656
37	2	7	A	1520.5344	62848.7552
37	2	8	A	11309.76	753984
37	2	9	A	3793.67835	177038.323
37	2	10	A	1963.5	70686
37	2	11	A	3267.46035	128520.1071
37	2	12	A	3793.67835	182096.5608
37	2	13	A	3525.6606	178633.4704
37	2	14	A	1590.435	57255.66

Row	Zone	Plant #	Plant type	Canopy	Volume
37	2	15	A	31416	2974048
37	2	16	A	19236.21315	1744083.326
37	2	17	A	14313.915	1154655.81
37	2	18	A	8332.3086	322182.5992
37	2	19	A	3739.2894	209400.2064
37	2	20	A	4015.16115	200758.0575
37	2	21	A	16627.11435	1041965.833
37	2	22	A	15948.52875	946279.3725
37	2	23	A	637.94115	14885.2935
37	2	24	A	1590.435	51954.21
37	2	25	A	330.06435	7481.4586
37	2	26	S	38.4846	179.5948
37	2	27	A	9.62115	134.6961
37	2	28	A	593.95875	15046.955
38	2	1	A	415.4766	11356.3604
38	2	2	A	452.3904	8444.6208
38	2	3	A	153.9384	1847.2608
38	2	4	A	683.49435	19137.8418
38	2	5	A	551.54715	16178.7164
38	2	6	A	240.52875	4329.5175
38	2	7	A	510.70635	13959.3069
38	2	8	A	5674.515	291291.77
38	2	9	A	254.4696	6955.5024
38	2	10	A	10751.3406	587739.9528
38	2	11	A	8091.38715	388386.5832
38	2	12	A	6013.21875	308678.5625
38	2	13	A	11404.20435	729869.0784
38	2	14	A	28802.38515	2304190.812
38	2	15	A	2780.51235	100098.4446
38	2	16	A	8011.8654	363204.5648
38	2	17	A	#DIV/0!	#VALUE!
38	2	18	A	2123.7216	83533.0496
38	2	19	A	2248.01115	77931.0532
38	2	20	A	12867.9936	754922.2912
38	2	21	A	5541.7824	251227.4688
38	2	22	A	4963.92435	304454.0268
38	2	23	A	3959.2014	208517.9404
38	2	24	A	1418.62875	67148.4275
38	2	25	A	7013.81835	355366.7964
38	2	26	A	3631.6896	164636.5952
38	2	27	A	3318.315	148218.07
38	2	28	A	5607.95235	194409.0148
39	2	1	A	363.05115	7745.0912
39	2	2	A	490.875	9490.25
39	2	3	A	989.80035	21115.7408
39	2	4	A	510.70635	14640.2487
39	2	5	A	1320.2574	36087.0356
39	2	6	A	397.60875	9277.5375
39	2	7	A	143.13915	2290.2264
39	2	8	A	19606.7256	1137190.085
39	2	9	A	13478.2494	790723.9648
39	2	10	A	881.41515	16453.0828
39	2	11	A	10751.3406	444388.7448
39	2	12	A	10386.915	616290.29
39	2	13	A	10207.0584	660056.4432
39	2	14	A	5944.6926	289308.3732
39	2	15	A	1134.1176	47632.9392
39	2	16	A	1924.42635	53883.9378
39	2	17	A	855.3006	24518.6172
39	2	18	A	2206.1886	76481.2048
39	2	19	A	3067.96875	147262.5
39	2	20	A	11785.90875	707154.525
39	2	21	A	11404.20435	661443.8523
39	2	22	A	9940.21875	563279.0625
39	2	23	A	6503.8974	381561.9808
39	2	24	A	4300.8504	255183.7904
39	2	25	A	#DIV/0!	#VALUE!
39	2	26	A	4536.4704	193556.0704
39	2	27	A	2083.07715	72213.3412
40	2	1	A	165.13035	2752.1725
40	2	2	A	934.82235	18073.2321
40	2	3	S	530.9304	5309.304
40	2	4	A	298.64835	6769.3626
40	2	5	A	829.57875	10507.9975
40	2	6	A	471.43635	5971.5271
40	2	7	A	50.2656	469.1456
40	2	8	A	779.31315	31692.0681
40	2	9	A	3959.2014	253388.8896
40	2	10	A	5541.7824	243838.4256
40	2	11	A	5808.8184	247842.9184
40	2	12	A	9940.21875	669308.0625
40	2	13	A	15174.7134	880133.3772
40	2	14	A	10843.42875	665063.63
40	2	15	A	907.9224	27237.672
40	2	16	A	1164.15915	27163.7135
40	2	17	A	1809.5616	9650.9952
40	2	18	A	1555.28835	36290.0615
40	2	19	A	1625.97435	33603.4699
40	2	20	A	3685.29315	179350.9333
40	2	21	A	8171.3016	501173.1648
40	2	22	S	0.7854	2.618
40	2	23	A	4359.16635	296423.3118
40	2	24	A	4717.30875	245300.055
40	2	25	A	2970.57915	160411.2741
40	2	26	A	7238.2464	477724.2624
40	2	27	A	9417.14235	608975.2053
40	2	28	A	1590.435	37110.15
41	3	1	A	298.64835	6968.4615
41	3	2	A	490.875	9490.25
41	3	3	A	855.3006	13114.6092
41	3	4	A	415.4766	9971.4384
41	3	5	A	6939.7944	439520.312
41	3	6	A	779.31315	15586.263
41	3	7	A	254.4696	3053.6352
41	3	8	A	14526.7584	910343.5264
41	3	9	A	3216.9984	113667.2768
41	3	10	A	10935.9096	736351.2464
41	3	11	A	19.635	52.36
41	3	12	A	17671.5	624393
41	3	13	A	18145.8816	1185530.931
41	3	14	A	14848.96875	950334
41	3	15	A	5153.0094	267956.4888
41	3	16	A	1017.8784	25107.6672
41	3	17	A	1772.05875	63794.115

Row	Zone	Plant #	Plant type	Canopy	Volume
41	3	18	A	1452.2046	37757.3196
41	3	19	A	706.86	15079.68
41	3	20	A	1225.42035	46565.9733
41	3	21	A	19482.82875	1130004.068
41	3	22	A	2507.19315	118673.8091
41	3	23	A	10386.915	616290.29
41	3	24	A	7542.9816	306747.9184
41	3	25	A	2164.75875	59170.0725
41	3	26	A	5876.55915	336922.7246
41	3	27	A	5476.00515	251896.2369
41	3	28	A	2780.51235	103805.7944
45	3	1	A	330.06435	3080.6006
45	3	2	A	188.69235	3773.847
45	3	3	A	989.80035	27714.4098
45	3	4	A	15.90435	127.2348
45	3	5	A	314.16	8377.6
45	3	6	A	660.5214	12770.0804
45	3	7	A	1555.28835	31105.767
45	3	8	A	1134.1176	43852.5472
45	3	9	A	397.60875	7687.1025
45	3	10	A	804.2496	24127.488
45	3	11	A	730.61835	14125.2881
45	3	12	A	829.57875	23781.2575
45	3	13	A	2332.83435	74650.6992
45	3	14	A	660.5214	14531.4708
45	3	15	A	397.60875	7687.1025
45	3	16	A	330.06435	5501.0725
45	3	17	A	2248.01115	70437.6827
45	3	18	A	2290.2264	94662.6912
45	3	19	A	2042.8254	81713.016
45	3	20	A	510.70635	14299.7778
45	3	21	A	6432.62235	428841.49
45	3	22	A	17789.50635	1185967.09
45	3	23	A	63.6174	508.9392
45	3	24	A	19113.4944	1325202.278
45	3	25	A	5741.47035	237314.1078
45	3	26	A	17436.6654	964828.8188
45	3	27	A	6792.9246	357760.6956
45	3	28	A	2596.72875	86557.625
45	3	29	A	2002.96635	98813.0066
46	3	1	A	132.7326	2212.21
46	3	2	A	23.75835	79.1945
46	3	3	A	165.13035	1871.4773
46	3	4	A	530.9304	4601.3968
46	3	5	A	103.86915	1246.4298
46	3	6	A	706.86	32044.32
46	3	7	A	86.59035	1616.3532
46	3	8	A	165.13035	1321.0428
46	3	9	A	730.61835	13151.1303
46	3	10	A	934.82235	24305.3811
46	3	11	A	989.80035	27054.5429
46	3	12	A	380.1336	4308.1808
46	3	13	A	1164.15915	51999.1087
46	3	14	A	2375.835	77610.61
46	3	15	A	510.70635	7149.8889
46	3	16	A	1486.17315	41612.8482
46	3	17	S	0.7854	3.1416

Row	Zone	Plant #	Plant type	Canopy	Volume
46	3	18	A	1885.7454	57829.5256
46	3	19	A	1017.8784	31214.9376
46	3	20	A	6432.62235	325919.5324
46	3	21	A	13788.67875	1259365.993
46	3	22	A	14420.14035	1076703.813
46	3	23	A	11689.8936	857258.864
46	3	24	A	11404.20435	851513.9248
46	3	25	A	7932.73635	449521.7265
46	3	26	A	13478.2494	889564.4604
46	3	27	A	9331.3374	547438.4608
46	3	28	A	9076.27875	272288.3625
49	3	1	A	70.88235	708.8235
49	3	2	A	95.0334	1267.112
49	3	3	A	56.74515	378.301
49	3	4	A	122.71875	981.75
49	3	5	A	78.54	628.32
49	3	6	A	754.7694	21636.7228
49	3	7	A	78.54	1099.56
49	3	8	A	330.06435	7041.3728
49	3	9	A	122.71875	1963.5
49	3	10	A	201.0624	2814.8736
49	3	11	A	829.57875	16591.575
49	3	12	A	471.43635	6600.1089
49	3	13	A	201.0624	2278.7072
49	3	14	A	829.57875	25440.415
49	3	15	A	2332.83435	94868.5969
49	3	16	A	143.13915	2576.5047
49	3	17	A	2419.22835	74189.6694
49	3	18	A	2164.75875	43295.175
49	3	19	A	1924.42635	57732.7905
49	3	20	A	10935.9096	685317.0016
49	3	21	A	11499.0414	643946.3184
49	3	22	A	8576.76435	526041.5468
49	3	23	A	9940.21875	490384.125
49	3	24	A	8091.38715	447723.4223
49	3	25	A	12469.0104	714889.9296
49	3	26	A	8011.8654	475370.6804
49	3	27	A	10843.42875	802413.7275
49	3	28	A	6221.1534	290320.492
49	3	29	A	2970.57915	104960.4633
50	3	1	A	86.59035	1674.0801
50	3	2	A	176.715	2120.58
50	3	3	A	143.13915	1813.0959
50	3	4	A	132.7326	1415.8144
50	3	5	A	132.7326	707.9072
50	3	6	A	962.115	24373.58
50	3	7	A	346.3614	6234.5052
50	3	8	A	240.52875	2084.5825
50	3	9	A	153.9384	1847.2608
50	3	10	A	268.80315	5196.8609
50	3	11	A	254.4696	3053.6352
50	3	12	A	63.6174	636.174
50	3	13	A	415.4766	6647.6256
50	3	14	A	213.82515	4561.6032
50	3	15	A	3.1416	14.6608
50	3	16	A	0.7854	0.5236
50	3	17	A	510.70635	15661.6614

Row	Zone	Plant #	Plant type	Canopy	Volume
50	3	18	A	122.71875	1390.8125
50	3	19	A	2083.07715	120818.4747
50	3	20	A	4417.875	273908.25
50	3	21	A	188.69235	5409.1807
50	3	22	A	0.7854	4.7124
50	3	23	A	3525.6606	155129.0664
50	3	24	A	1555.28835	82948.712
50	3	25	A	4476.97635	241756.7229
50	3	26	A	9331.3374	491450.4364
50	3	27	A	4071.5136	203575.68
50	3	28	A	NO DATA	
50	3	29	A	1625.97435	59619.0595
52	3	1	A	346.3614	5310.8748
52	3	2	A	19.635	117.81
52	3	3	A	103.86915	1038.6915
52	3	4	A	122.71875	1881.6875
52	3	5	S	9.62115	51.3128
52	3	6	S	3.1416	2.0944
52	3	7	A	56.74515	605.2816
52	3	8	A	268.80315	5196.8609
52	3	9	A	132.7326	1504.3028
52	3	10	A	122.71875	981.75
52	3	11	A	86.59035	865.9035
52	3	12	A	363.05115	8955.2617
52	3	13	A	143.13915	2099.3742
52	3	14	A	23.75835	269.2613
52	3	15	A	33.18315	265.4652
52	3	16	A	50.2656	536.1664
52	3	17	S	0.7854	2.618
52	3	18	A	4.90875	19.635
52	3	19	A	19.635	170.17
52	3	20	A	19.635	314.16
52	3	21	A	44.17875	618.5025
52	3	22	A	176.715	5890.5
52	3	23	A	380.1336	11910.8528
52	3	24	A	829.57875	24334.31
52	3	25	A	2551.7646	81656.4672
52	3	26	A	3525.6606	162180.3876
52	3	27	A	5089.58835	213762.7107
52	3	28	A	153.9384	2565.64
54	3	1	A	95.0334	760.2672
54	3	2	A	153.9384	2463.0144
54	3	3	A	593.95875	9503.34
54	3	4	A	95.0334	1267.112
54	3	5	A	268.80315	5734.4672
54	3	6	A	44.17875	618.5025
54	3	7	A	314.16	4188.8
54	3	8	A	176.715	3652.11
54	3	9	A	165.13035	2752.1725
54	3	10	A	122.71875	1390.8125
54	3	11	A	201.0624	3485.0816
54	3	12	A	153.9384	1744.6352
54	3	13	A	113.0976	1130.976
54	3	14	A	19.635	183.26
54	3	15	A	33.18315	265.4652
54	3	16	A	3.1416	8.3776
54	3	17	A	15.90435	84.8232

Row	Zone	Plant #	Plant type	Canopy	Volume
54	3	18	A	56.74515	907.9224
54	3	19	S	0.7854	2.0944
54	3	20	A	3166.92915	158346.4575
54	3	21	A	254.4696	6616.2096
54	3	22	A	213.82515	4704.1533
54	3	23	A	1046.34915	34878.305
54	3	24	A	0.7854	3.1416
54	3	25	A	3.1416	20.944
54	3	26	A	4417.875	265072.5
54	3	27	A	730.61835	15586.5248
54	3	28	A	188.69235	4654.4113
54	3	29	A	1452.2046	37757.3196
54	3	30	A	1017.8784	27143.424
56	3	1	A	86.59035	865.9035
56	3	2	A	254.4696	3053.6352
56	3	3	A	38.4846	384.846
56	3	4	A	33.18315	243.3431
56	3	5	A	33.18315	464.5641
56	3	6	A	23.75835	300.9391
56	3	7	S	28.2744	113.0976
56	3	8	S	9.62115	12.8282
56	3	9	A	298.64835	7167.5604
56	3	10	A	103.86915	1592.6603
56	3	11	S	7.0686	37.6992
56	3	12	A	165.13035	2642.0856
56	3	13	A	28.2744	226.1952
56	3	14	A	4.90875	42.5425
56	3	15	A	113.0976	1583.3664
56	3	16	A	1164.15915	26387.6074
56	3	17	A	829.57875	18250.7325
56	3	18	A	NO DATA	
56	3	19	A	346.3614	12699.918
56	3	20	A	4071.5136	206290.0224
56	3	21	A	3166.92915	171014.1741
56	3	22	A	2687.83515	71675.604
56	3	23	A	95.0334	1773.9568
56	3	24	A	165.13035	3742.9546
56	3	25	A	962.115	33994.73
56	3	26	A	254.4696	7973.3808
56	3	27	A	103.86915	1869.6447
56	3	28	A	572.5566	12596.2452
56	3	29	A	188.69235	2767.4878
58	4	1	A	415.4766	6924.61
58	4	2	A	143.13915	2003.9481
58	4	3	A	176.715	2945.25
58	4	4	A	NO DATA	
58	4	5	A	23.75835	126.7112
58	4	6	A	19.635	274.89
58	4	7	A	122.71875	1227.1875
58	4	8	A	153.9384	3284.0192
58	4	9	A	201.0624	1876.5824
58	4	10	A	330.06435	7041.3728
58	4	11	A	283.5294	4725.49
58	4	12	A	0.7854	2.618
58	4	13	A	10117.71915	607063.149
58	4	14	A	NO DATA	
58	4	15	S	0.7854	4.7124

Row	Zone	Plant #	Plant type	Canopy	Volume
58	4	16	A	NO DATA	
58	4	17	A	NO DATA	
58	4	18	A	103.86915	1384.922
58	4	19	A	3216.9984	190875.2384
58	4	20	A	363.05115	7261.023
58	4	21	A	2596.72875	129836.4375
58	4	22	A	3019.0776	142903.0064
58	4	23	A	153.9384	4515.5264
58	4	24	A	70.88235	1228.6274
58	4	25	A	1847.45715	114542.3433
58	4	26	A	2419.22835	87092.2206
58	4	27	A	153.9384	2770.8912
58	4	28	A	1288.25235	25765.047
58	4	29	A	0.7854	3.1416
60	4	1	A	201.0624	3216.9984
60	4	2	A	380.1336	7856.0944
60	4	3	A	143.13915	2576.5047
60	4	4	A	44.17875	353.43
60	4	5	A	95.0334	1457.1788
60	4	6	A	3.1416	16.7552
60	4	7	S	103.86915	969.4454
60	4	8	A	15.90435	116.6319
60	4	9	A	452.3904	9650.9952
60	4	10	A	254.4696	5937.624
60	4	11	A	1352.65515	36972.5741
60	4	12	A	165.13035	2311.8249
60	4	13	A	12968.72115	613852.8011
60	4	14	A	8992.0446	551512.0688
60	4	15	A	8908.20315	486981.7722
60	4	16	A	3019.0776	177119.2192
60	4	17	A	330.06435	7261.4157
60	4	18	A	1847.45715	62813.5431
60	4	19	A	637.94115	21264.705
60	4	20	A	7013.81835	444208.4955
60	4	21	A	4536.4704	202629.0112
60	4	22	A	1486.17315	47557.5408
60	4	23	A	1320.2574	48409.438
60	4	24	A	6939.7944	328483.6016
60	4	25	A	2123.7216	72206.5344
60	4	26	A	4015.16115	165959.9942
60	4	27	A	1772.05875	73245.095
60	4	28	A	1486.17315	54493.0155
61	4	1	A	143.13915	1813.0959
61	4	2	A	70.88235	661.5686
61	4	3	A	38.4846	538.7844
61	4	4	A	19.635	130.9
61	4	5	A	143.13915	2003.9481
61	4	6	A	95.0334	1267.112
61	4	7	A	188.69235	3522.2572
61	4	8	A	660.5214	20696.3372
61	4	9	A	363.05115	6292.8866
61	4	10	A	490.875	9817.5
61	4	11	A	188.69235	1383.7439
61	4	12	A	1555.28835	71543.2641
61	4	13	A	12.5664	83.776
61	4	14	A	6575.56515	271790.0262
61	4	15	A	56.74515	453.9612
61	4	16	A	2206.1886	83835.1668
61	4	17	A	254.4696	5089.392
61	4	18	A	551.54715	19487.9993
61	4	19	A	314.16	6702.08
61	4	20	A	452.3904	9952.5888
61	4	21	A	5410.6206	313815.9948
61	4	22	A	1590.435	37110.15
61	4	23	A	4359.16635	200521.6521
61	4	24	A	1924.42635	75694.1031
61	4	25	A	855.3006	28510.02
61	4	26	A	7854	476476
61	4	27	A	346.3614	5079.9672
62	4	1	A	201.0624	3753.1648
62	4	2	A	86.59035	981.3573
62	4	3	A	153.9384	1231.5072
62	4	4	A	63.6174	720.9972
62	4	5	A	226.9806	3329.0488
62	4	6	A	23.75835	237.5835
62	4	7	A	12.5664	351.8592
62	4	8	A	165.13035	1321.0428
62	4	9	A	44.17875	559.5975
62	4	10	A	7.0686	75.3984
62	4	11	A	201.0624	3082.9568
62	4	12	A	226.9806	3783.01
62	4	13	A	44.17875	589.05
62	4	14	A	8251.60875	539105.105
62	4	15	A	4.90875	62.1775
62	4	16	A	201.0624	7774.4128
62	4	17	A	2780.51235	152001.3418
62	4	18	A	254.4696	7294.7952
62	4	19	A	829.57875	21569.0475
62	4	20	A	5476.00515	357765.6698
62	4	21	A	#DIV/0!	#VALUE!
62	4	22	A	8992.0446	581485.5508
62	4	23	A	122.71875	2863.4375
62	4	24	A	314.16	10262.56
62	4	25	A	1017.8784	38679.3792
62	4	26	A	1104.46875	43442.4375
62	4	27	A	#DIV/0!	#VALUE!
62	4	28	A	330.06435	8801.716
64	4	1	A	330.06435	8141.5873
64	4	2	A	44.17875	795.2175
64	4	3	A	132.7326	1327.326
64	4	4	A	165.13035	1871.4773
64	4	5	A	6720.07875	362884.2525
64	4	6	A	70.88235	661.5686
64	4	7	A	23.75835	174.2279
64	4	8	A	3.1416	8.3776
64	4	9	A	33.18315	376.0757
64	4	10	A	153.9384	4002.3984
64	4	11	A	78.54	785.4
64	4	12	A	19.635	209.44
64	4	13	A	551.54715	20223.3955
64	4	14	A	6939.7944	351616.2496
64	4	15	A	1320.2574	63372.3552
64	4	16	A	9076.27875	465915.6425
64	4	17	A	143.13915	4007.8962

Row	Zone	Plant #	Plant type	Canopy	Volume
64	4	18	A	415.4766	15234.142
64	4	19	A	330.06435	6381.2441
64	4	20	A	551.54715	20223.3955
64	4	21	A	433.73715	12144.6402
64	4	22	A	397.60875	7422.03
64	4	23	A	33.18315	575.1746
64	4	24	A	363.05115	6050.8525
64	4	25	A	6939.7944	453399.9008
64	4	26	A	730.61835	26302.2606
65	4	1	A	804.2496	25199.8208
65	4	2	A	298.64835	2787.3846
65	4	3	A	44.17875	765.765
65	4	4	A	213.82515	1568.0511
65	4	5	A	201.0624	4021.248
65	4	6	A	201.0624	2948.9152
65	4	7	A	103.86915	1107.9376
65	4	8	A	70.88235	1464.9019
65	4	9	A	113.0976	1960.3584
65	4	10	A	38.4846	461.8152
65	4	11	A	7.0686	103.6728
65	4	12	A	213.82515	3421.2024
65	4	13	A	2827.44	118752.48
65	4	14	A	3685.29315	213747.0027
65	4	15	A	298.64835	5773.8681
65	4	16	A	NO DATA	
65	4	17	A	NO DATA	
65	4	18	A	2596.72875	121180.675
65	4	19	A	4359.16635	247019.4265
65	4	20	A	490.875	10144.75
65	4	21	A	70.88235	803.3333
65	4	22	A	471.43635	16971.7086
65	4	23	A	1104.46875	36079.3125
65	4	24	A	9940.21875	669308.0625
65	4	25	A	754.7694	15095.388
65	4	26	A	16173.15315	1056646.006
65	4	27	A	298.64835	6769.3626
66	4	1	A	380.1336	8869.784
66	4	2	A	86.59035	1731.807
66	4	3	A	113.0976	1055.5776
66	4	4	A	95.0334	760.2672
66	4	5	A	380.1336	9630.0512
66	4	6	A	7.0686	98.9604
66	4	7	A	70.88235	945.098
66	4	8	A	44.17875	88.3575
66	4	9	A	3.1416	18.8496
66	4	10	A	165.13035	2311.8249
66	4	11	A	122.71875	1718.0625
66	4	12	A	706.86	15550.92
66	4	13	A	6291.25035	373280.8541
66	4	14	A	3117.2526	139237.2828
66	4	15	A	10477.43235	698495.49
66	4	16	A	4300.8504	226511.4544
66	4	17	A	415.4766	9971.4384
66	4	18	A	551.54715	12134.0373
66	4	19	A	779.31315	17664.4314
66	4	20	A	706.86	18378.36
66	4	21	A	103.86915	1869.6447
66	4	22	A	660.5214	20696.3372
66	4	23	A	415.4766	6093.6568
66	4	24	A	86.59035	1327.7187
66	4	25	A	188.69235	2641.6929
66	4	26	A	226.9806	5144.8936
68	4	1	A	103.86915	1384.922
68	4	2	A	363.05115	6776.9548
68	4	3	A	70.88235	708.8235
68	4	4	A	86.59035	808.1766
68	4	5	A	38.4846	256.564
68	4	6	A	113.0976	1130.976
68	4	7	A	143.13915	1813.0959
68	4	8	A	78.54	1151.92
68	4	9	A	19.635	117.81
68	4	10	A	86.59035	750.4497
68	4	11	A	3.1416	14.6608
68	4	12	A	314.16	6702.08
68	4	13	A	3.1416	20.944
68	4	14	A	907.9224	29658.7984
68	4	15	A	2687.83515	107513.406
68	4	16	A	779.31315	29094.3576
68	4	17	A	4015.16115	157929.6719
68	4	18	A	4015.16115	219495.4762
68	4	19	A	2206.1886	111780.2224
68	4	20	A	4963.92435	321000.4413
68	4	21	A	3369.56235	159492.6179
68	4	22	A	3019.0776	102648.6384
68	4	23	A	#DIV/0!	#VALUE!
68	4	24	A	188.69235	3648.0521
68	4	25	A	471.43635	12257.3451
70	4	1	A	50.2656	636.6976
70	4	2	A	213.82515	1710.6012
70	4	3	A	188.69235	2893.2827
70	4	4	A	240.52875	3046.6975
70	4	5	A	15.90435	106.029
70	4	6	A	113.0976	1281.7728
70	4	7	A	268.80315	4659.2546
70	4	8	A	240.52875	3046.6975
70	4	9	A	779.31315	22859.8524
70	4	10	A	551.54715	10663.2449
70	4	11	A	433.73715	9542.2173
70	4	12	A	240.52875	3688.1075
70	4	13	A	188.69235	3648.0521
70	4	14	A	433.73715	6939.7944
70	4	15	A	0.7854	5.236
70	4	16	A	63.6174	1441.9944
70	4	17	A	7620.14715	487689.4176
70	4	18	A	2002.96635	76112.7213
70	4	19	A	593.95875	18214.735
70	4	20	A	551.54715	13237.1316
70	4	21	A	6720.07875	394244.62
70	4	22	A	7163.04435	386804.3949
70	4	23	A	4071.5136	211718.7072
70	4	1	A	9.62115	64.141
71	4	2	A	86.59035	692.7228
71	4	3	A	490.875	10799.25
71	4	4	A	283.5294	7371.7644

Row	Zone	Plant #	Plant type	Canopy	Volume
71	4	5	A	188.69235	2641.6929
71	4	6	A	113.0976	1809.5616
71	4	7	A	213.82515	2423.3517
71	4	8	A	86.59035	808.1766
71	4	9	A	44.17875	618.5025
71	4	10	A	165.13035	3302.607
71	4	11	A	95.0334	823.6228
71	4	12	A	132.7326	1327.326
71	4	13	A	56.74515	378.301
71	4	14	A	363.05115	10165.4322
71	4	15	A	NO DATA	
71	4	16	A	268.80315	7884.8924
71	4	17	A	86.59035	1443.1725
71	4	18	A	3848.46	182160.44
71	4	19	A	4015.16115	179343.8647
71	4	20	A	471.43635	12257.3451
71	4	21	A	1017.8784	33250.6944
71	4	22	A	4071.5136	190003.968
71	4	23	A	3793.67835	144159.7773
71	4	24	A	2780.51235	111220.494
72	4	1	A	132.7326	796.3956
72	4	2	A	962.115	28863.45
72	4	3	A	254.4696	3732.2208
72	4	4	A	201.0624	3619.1232
72	4	5	A	226.9806	2572.4468
72	4	6	A	298.64835	4579.2747
72	4	7	A	28.2744	150.7968
72	4	8	A	113.0976	1583.3664
72	4	9	A	12.5664	117.2864
72	4	10	A	56.74515	605.2816
72	4	11	A	363.05115	7018.9889
72	4	12	A	78.54	942.48
72	4	13	A	490.875	6217.75
72	4	14	A	3.1416	8.3776
72	4	15	A	730.61835	19970.2349
72	4	16	A	63.6174	1441.9944
72	4	17	A	2332.83435	111976.0488
72	4	18	A	143.13915	3721.6179
72	4	19	A	683.49435	21416.1563
72	4	20	A	201.0624	3753.1648
72	4	21	A	471.43635	15714.545
72	4	22	A	2970.57915	184175.9073
73	4	1	A	DEAD PLANT	
73	4	2	A	50.2656	536.1664
73	4	3	A	38.4846	333.5332
73	4	4	A	44.17875	559.5975
73	4	5	A	23.75835	110.8723
73	4	6	A	7.0686	89.5356
73	4	7	A	122.71875	1063.5625
73	4	8	A	188.69235	2012.7184
73	4	9	A	510.70635	8171.3016
73	4	10	A	7.0686	75.3984
73	4	11	A	7.0686	127.2348
73	4	12	A	0.7854	2.618
73	4	13	A	95.0334	1520.5344
73	4	14	A	DEAD PLANT	
73	4	15	A	363.05115	11375.6027

Row	Zone	Plant #	Plant type	Canopy	Volume
73	4	16	A	1352.65515	30660.1834
73	4	17	A	132.7326	2831.6288
73	4	18	A	572.5566	19848.6288
73	4	19	A	DEAD PLANT	
74	4	1	A	213.82515	2708.4519
74	4	2	A	254.4696	6785.856
74	4	3	A	165.13035	1431.1297
74	4	4	A	122.71875	1227.1875
74	4	5	A	44.17875	323.9775
74	4	6	A	188.69235	1886.9235
74	4	7	A	70.88235	708.8235
74	4	8	A	78.54	837.76
74	4	9	A	86.59035	1385.4456
74	4	10	A	298.64835	8163.0549
74	4	11	A	213.82515	2708.4519
74	4	12	A	510.70635	1702.3545
74	4	13	A	143.13915	2767.3569
74	4	14	A	490.875	15708
74	4	15	A	1164.15915	33372.5623
74	4	16	A	2042.8254	93969.9684
74	4	17	A	1924.42635	71845.2504
74	4	18	A	1520.5344	50684.48
75	4	1	A	226.9806	3026.408
75	4	2	A	70.88235	708.8235
75	4	3	A	153.9384	1949.8864
75	4	4	A	433.73715	7228.9525
75	4	5	A	240.52875	3046.6975
75	4	6	A	95.0334	1267.112
75	4	7	A	213.82515	2993.5521
75	4	8	A	415.4766	8032.5476
75	4	9	A	213.82515	3563.7525
75	4	10	A	804.2496	17693.4912
75	4	11	A	103.86915	1038.6915
75	4	12	A	254.4696	3901.8672
75	4	13	A	1418.62875	53907.8925
75	4	14	A	2083.07715	93044.1127
76	4	1	A	23.75835	190.0668
76	4	2	A	268.80315	2867.2336
76	4	3	A	15.90435	222.6609
76	4	4	A	86.59035	1269.9918
76	4	5	A	415.4766	7755.5632
76	4	6	A	132.7326	1238.8376
76	4	7	A	7.0686	14.1372
76	4	8	A	363.05115	5082.7161
76	4	9	A	103.86915	1384.922
76	4	10	A	615.7536	14778.0864
76	4	11	A	19.635	65.45
76	4	12	A	0.7854	3.1416
76	4	13	A	330.06435	10782.1021
77	4	1	A	103.86915	1523.4142
77	4	2	A	103.86915	1454.1681
77	4	3	A	530.9304	11326.5152
77	4	4	A	330.06435	6601.287
77	4	5	A	490.875	9817.5
77	4	6	A	143.13915	1717.6698
77	4	7	A	363.05115	5324.7502
77	4	8	A	86.59035	1385.4456

Row	Zone	Plant #	Plant type	Canopy	Volume
77	4	9	A	240.52875	4169.165
77	4	10	A	213.82515	4276.503
77	4	11	A	363.05115	7261.023
78	4	1	A	56.74515	416.1311
78	4	2	A	397.60875	8482.32
78	4	3	A	86.59035	981.3573
78	4	4	A	9.62115	153.9384
78	4	5	A	934.82235	23682.1662
78	4	6	A	268.80315	6630.4777
78	4	7	A	298.64835	5176.5714
78	4	8	A	706.86	10838.52
79	4	1	A	132.7326	1769.768
79	4	2	A	510.70635	12256.9524
79	4	3	A	268.80315	5734.4672
79	4	4	A	471.43635	8485.8543
79	4	5	A	38.4846	282.2204
79	4	6	A	86.59035	923.6304

Row	Zone	Plant #	Plant type	Canopy	Volume

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Appendix D

Results of Destructive Sampling of Subpile Plants

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Each plant is from 2 rows north of each hydroprobe. The entire plant was harvested from the soil surface (no roots). Plants were dried for 2 weeks, then weighed and taken to Laboratory Consultants for analysis.

			Dry weight (g)		**Nitrate N ppm**		**Total Nitrate N**		**Total Kjeldahl N %**		**Extractable S**	**Total Sulfur %**
zone	station	Plant	2000	2001	2000	2001	2000	2001	2000	2001	ppm (2000)	(2000)
4	1	E 1	53.4		717		38.2878		1.21		730	0.36
4	2	E 2	6.1	200	822	5120	5.0142	1024	1.15	3.43	*	0.64
4	3	E 3	3.1	850	769	8060	2.3839	6851	1.07	2.57	*	0.49
4	4	E 4	3.6	150	1090	2860	3.924	429	2.54	2.59	*	0.69
4	5	E 5	38.4	2300	514	4900	19.7376	11270	0.97	2.21	798	0.32
3	1	EM1	260.6	750	594	6860	154.7964	5145	1.53	2.74	927	0.39
3	2	EM2	666.3	1300	489	2220	325.8207	2886	1.03	1.82	448	0.26
3	3	EM3	39.6	1100	1470	6240	58.212	6864	2.16	3.10	1548	0.39
3	4	EM4	2	200	723	882	1.446	176.4	1.24	2.24	*	0.22
3	5	EM5	2.4	900	*	2220	*	1998	1.47	2.00	*	0.23
2	1	WM1	36.6	1600	358	1000	13.1028	1600	1.44	1.79	434	0.23
2	2	WM2	1.6	3.5	576	1562	0.9216	5.467	1.02	1.10	*	0.39
2	3	WM3	6.1	11	471	3180	2.8731	34.98	*	0.93	*	*
2	4	WM4	238	1200	464	2260	110.432	2712	1.18	1.67	645	0.21
2	5	WM5	19.3	100	774	2800	14.9382	280	0.88	1.17	893	0.41
1	1	W1	5.5	50	658	1006	3.619	50.3	1.04	1.06	*	0.37
1	2	W2	3.2	12.6	690	1452	2.208	18.2952	1.06	1.12	*	0.37
1	3	W3	3.5	250	483	2300	1.6905	575	0.79	2.26	*	0.4
1	4	W4	1175.9	600	485	2300	570.3115	1380	0.97	2.22	545	0.26
1	5	W5	3.6		481		1.7316		0.72		*	0.37

Volunteer Data

2000

Volunteer	Dry weight (g)	Nitrate N ppm	Total Kjeldahl N %	Extractable S ppm	Total Sulfur %
E 1	41.8	1803	1.62	2308	0.46
E 4	31	7060	2.71	1320	0.8
EM1	111.9	1980	1.53	1417	0.39
EM4	71.8	1460	1.75	1394	0.27
EM5	0.5	7460	*	*	*
WM1	36.6	2450	1.46	2069	0.21
WM4	45.6	2970	1.25	2446	0.13
W3	101.7	586	0.79	1581	0.21
W4	125.1	389	0.79	1254	0.31
average	**62.89**	**2906.44**	**1.48750**	**1723.63**	**0.35**

2001

Zone	Volunteer	Dry weight (g)	Nitrate N ppm	Total Kjeldahl N %
1	1	5.1	1682	1.98
1	3	8.4	1534	1.09
1	4	34.8	698	1.63
2	1	25.6	3520	1.99
3	2	0.3	15100	3.07
3	4	56.6	1732	1.68
4	4	35.1	10400	2.66
2				
	average	**26.80**	**5497.33**	**2.02**

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Appendix E

Soil Ammonia and Nitrate Concentrations of Subpile for Years 2000 and 2001

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		2000							2001		
location	Depth (ft)	Depth (m)	Ammonia N (ppm)	Nitrate N (ppm)		Zone	Depth (ft)	Depth (m)	Lab Cons. Data (not corr for dilution)	Ammonia N (ppm)	Nitrate N (ppm)
0 N 200'	1	0.030	4	32							
	3	0.091	0.8	25			3	0.091	0.9	4.5	15
	6	0.183	0.7	23			6	0.183	0.7	3.5	26
	9	0.274	0.5	28			9	0.274	0.9	4.5	109
	12	0.366	12	37			12	0.366	3.9	19.5	19
	15	0.457	55	98			15	0.457	16	80	28
0 N 300'	1	0.030	7	19							
	3	0.091	3	12			3	0.091	1.2	6	179
	6	0.183	2	13			6	0.183	0.8	4	209
	9	0.274	2	10			9	0.274	0.8	4	10
	12	0.366	1	11			12	0.366	0.6	3	9
	15	0.457	2	8			15	0.457	0.6	3	10
45 N 200'	1	0.030	10	13							
	3	0.091	0.7	16							
	6	0.183	0.6	14							
	9	0.274	0.8	14							
	12	0.366	0.7	9							
	15	0.457	0.6	11							
308 N 200'	1	0.030	0.6	12			3	0.091	1	5	9
	3	0.091	0.8	8			6	0.183	1	5	8
	6	0.183	1	28			9	0.274	0.8	4	6
	9	0.274	0.8	14			12	0.366	2.9	14.5	11
	12	0.366	0.5	12			14	0.427	8.5	42.5	15
	15	0.457									
E 1	1	0.030	4	97	4	unstain	1	0.030	3.1	15.5	24
	3	0.091	5	229	4	unstain	3	0.091	2.7	13.5	21
	6	0.183	108	343	4	unstain	6	0.183	5.4	27	20
	9	0.274	835	240	4	unstain	9	0.274	3.1	15.5	21
	12	0.366	104	279	4	unstain	12	0.366	19	95	21
	15	0.457	90	285	4						
E 2	1	0.030	9	79	4	unstain	1	0.030	2.8	14	20
	3	0.091	50	750	4	unstain	3	0.091	12	60	51
	6	0.183	293	349	4	unstain	6	0.183	82.7	413.5	32
	9	0.274	578	490	4	unstain	9	0.274	103	515	39
	12	0.366	635	162	4	unstain	12	0.366	112.4	562	13
	15	0.457	560	153	4	unstain	15	0.457	89	445	28
E 3	1	0.030	6	15	4	unstain	1	0.030	5.4	27	50
	3	0.091	1	11	4	unstain	3	0.091	2	10	24
	6	0.183	50	30	4	unstain	6	0.183	2	10	84
	9	0.274	169	485	4	unstain	9	0.274	4.6	23	90
	12	0.366	272	333	4	unstain	12	0.366	63.1	315.5	17
	15	0.457	144	404	4	unstain	15	0.457	43.1	215.5	30
E 4	1	0.030	3	53	4	unstain	1	0.030	6.8	34	15
	3	0.091	0.8	34	4	unstain	3	0.091	1.6	8	93
	6	0.183	0.8	77	4	unstain	6	0.183	1.5	7.5	91
	9	0.274	1	114	4	unstain	9	0.274	1.8	9	85
	12	0.366	0.8	115	4	unstain	12	0.366	1.2	6	89
	15	0.457	0.7	85	4	unstain	15	0.457	0.8	4	11
E 5	1	0.030	2	66	4	unstain	1	0.030	1.1	5.5	27
	3	0.091	1	65	4	unstain	3	0.091	1.6	8	95
	6	0.183	0.7	68	4	unstain	6	0.183	2.5	12.5	16
	9	0.274	1	104	4	unstain	9	0.274	1.9	9.5	16
	12	0.366	3	243	4	unstain	12	0.366	10.4	52	24
	15	0.457	3	686	4	unstain	15	0.457	51.1	255.5	28

			2000						2001		
location	Depth (ft)	Depth (m)	Ammonia N (ppm)	Nitrate N (ppm)	Zone		Depth (ft)	Depth (m)	Lab Cons. Data (not corr for dilution)	Ammonia N (ppm)	Nitrate N (ppm)
EM 1	1	0.030	452	99	3	unstain	1	0.030	96	480	13
	3	0.091	561	93	3	unstain	3	0.091	81	405	98
	6	0.183	452	82	3	unstain	6	0.183	61.1	305.5	18
	9	0.274	407	46	3	unstain	9	0.274	67.4	337	80
	12	0.366	494	48	3	unstain	12	0.366	64	320	10
	15	0.457			3						
		0.000			3						
EM 2	1	0.030	6	11	3	stain	1	0.030	2.7	13.5	12
	3	0.091	14	95	3	stain	3	0.091	94.6	473	15
	6	0.183	153	245	3	stain	6	0.183	65.8	329	27
	9	0.274	191	142	3	stain	9	0.274	53.3	266.5	46
	12	0.366	377	101	3	stain	12	0.366	68.6	343	11
	15	0.457	364	114	3	stain	15	0.457	62	310	76
EM 3	1	0.030	84	134	3	stain	1	0.030	1	5	48
	3	0.091	333	46	3	stain	3	0.091	15.8	79	42
	6	0.183	569	45	3	stain	6	0.183	6.6	33	39
	9	0.274	425	53	3	stain	9	0.274	56.5	282.5	31
	12	0.366	485	60	3	stain	12	0.366	68.6	343	21
	15	0.457	351	129	3	stain	15	0.457	54.1	270.5	37
EM 4	1	0.030	2	210	3	unstain	1	0.030	13.1	65.5	100
	3	0.091	6	350	3	unstain	3	0.091	60.1	300.5	11
	6	0.183	352	330	3	unstain	6	0.183	91.8	459	
	9	0.274	254	283	3	unstain	9	0.274	75.1	375.5	
	12	0.366	195	237	3						
	15	0.457	272	232	3						
EM 5	1	0.030	4	176	3	unstain	1	0.030	3.3	16.5	
	3	0.091	2	799	3	unstain	3	0.091	6.2	31	
	6	0.183	462	364	3	unstain	6	0.183	33.6	168	
	9	0.274	425	378	3	unstain	9	0.274	108	540	33
	12	0.366	605	172	3	unstain	12	0.366	103	515	16
	15	0.457	741	206	3	unstain	15	0.457	8	40	
W 1	1	0.030	0.6	35	1	unstain	1	0.030	1.2	6	
	3	0.091	1	75	1	unstain	3	0.091	1.1	5.5	
	5	0.152	0.9	54	1	unstain	5	0.152	1	5	
W 2	1	0.030	1	52	1	stain	1	0.030	0.1	0.5	
	3	0.091	0.9	65	1	stain	3	0.091	17.5	87.5	34
	6	0.183	16	334	1	stain	6	0.183	15	75	89
	9	0.274	215	321	1	stain	9	0.274	19.9	99.5	14
	11	0.335	226	380	1						
W 3	1	0.030	7	221	1	stain	1	0.030	7.7	38.5	16
	3	0.091	215	191	1	stain	3	0.091	66.4	332	71
	6	0.183	289	123	1	stain	6	0.183	72.2	361	51
	7	0.213	185	110	1						
W 4	1	0.030	3	21	1	unstain	1	0.030	55.8	279	71
	3	0.091	5	63	1	unstain	3	0.091	36.6	183	21
W 5	1	0.030	1	30	1	stain	1	0.030	2	10	18
	3	0.091	3	59	1	stain	3	0.091	0.3	1.5	18
	6	0.183	3	103	1	stain	6	0.183	0.8	4	16
	9	0.274	7	115	1	stain	9	0.274	0.9	4.5	17
	12	0.366	56	235	1	stain	12	0.366	8.6	43	23
	15	0.457	140	302	1	stain	15	0.457	22.7	113.5	46
WM 1	1	0.030	5	57	2	unstain	1	0.030	1.6	8	24
	3	0.091	1	113	2	unstain	3	0.091	42.3	211.5	63
	6	0.183	462	54	2	unstain	6	0.183	44.7	223.5	20
WM 2	1	0.030	5	217	2	stain	1	0.030	2.2	11	24
	3	0.091	416	168	2	stain	3	0.091	1.6	8	40
	6	0.183	400	151	2	stain	6	0.183	15.5	77.5	20
	9	0.274	251	81	2	stain	9	0.274	44.2	221	19
	12	0.366	307	71	2	stain	12	0.366	59.2	296	24
	15	0.457	505	125	2	stain	14	0.427	56.5	282.5	38

		2000							2001		
location	Depth (ft)	Depth (m)	Ammonia N (ppm)	Nitrate N (ppm)		Zone	Depth (ft)	Depth (m)	Lab Cons. Data (not corr for dilution)	Ammonia N (ppm)	Nitrate N (ppm)
WM 3	1	0.030	8	31	2	stain	1	0.030	45.3	226.5	13
	3	0.091	75	39	2	stain	3	0.091	52.5	262.5	19
	6	0.183	220	15	2	stain	6	0.183	73.7	368.5	21
	9	0.274	265	20	2	stain	9	0.274	68.6	343	18
	12	0.366	416	25	2	stain	11	0.335	72.3	361.5	25
	14	0.427	445	61	2						
WM 4	1	0.030	16	33	2	unstain	1	0.030	2.4	12	17
.	3	0.091	209	156	2	unstain	3	0.091	1.4	7	14
	6	0.183	416	139	2	unstain	6	0.183	24	120	85
	9	0.274	433	39	2	unstain	9	0.274	19.7	98.5	13
	10	0.305	452	35	2	unstain	12	0.366	50.4	252	24
						unstain	15	0.457	88	440	17
WM 5	1	0.030	7	125	2	unstain	1	0.030	3.7	18.5	27
	3	0.091	75	296	2	unstain	3	0.091	13	65	84
	6	0.183	150	197	2	unstain	6	0.183	42.3	211.5	25
	9	0.274	199	131	2	unstain	9	0.274	48.4	242	11
	12	0.366	207	135	2	unstain	12	0.366	43.6	218	11
	15	0.457	215	101	2	unstain	15	0.457	51.8	259	98

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Appendix F

Irrigation Rates per Zone

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4 acre Irrigation emitter output test.
24 emitters in each zone were randomly selected.
The test was performed May 2, 2000.
Results are listed in gallons per hour.

Emitter number	**Zone 4 gallons**	**Zone 3 gallons**	**Zone2 gallons**	**Zone 1 gallons**
1	1.03	1.24	1.55	1.03
2	0.69	0.28	1.03	1.03
3	1.24	1.24	1.55	0.27
4	1.03	1.55	1.24	0.56
5	1.24	1.03	1.55	0.41
6	0.88	0.28	3.09	0.69
7	0.69	1.24	1.24	0.62
8	0.69	1.03	1.03	0.77
9	1.03	0.56	0.77	0.88
10	0.69	2.06	1.24	0.24
11	1.03	1.24	0.69	1.03
12	1.24	1.03	1.24	0.69
13	1.24	1.24	2.06	0.36
14	2.06	0.34	1.03	0.88
15	0.25	0.88	1.24	1.55
16	1.24	0.62	0.88	0.44
17	0.62	0.77	1.03	0.69
18	2.06	0.88	1.55	0.62
19	1.55	0.56	0.88	0.77
20	1.24	0.25	1.03	0.48
21	1.24	0.69	0.62	0.41
22	1.55	2.06	0.77	0.12
23	1.55	1.24	0.88	0.48
24	1.55	0.69	0.77	0.77
average output of each zone	**1.15**	**0.96**	**1.21**	**0.66**
Standard deviation of output	0.44	0.50	0.53	0.32

Zone	**Avg in gallons**	**Avg converted to liters**	**Standard deviation**
1	0.66	2.5014	1.21
2	1.21	4.5859	2.00
3	0.96	3.6384	1.89
4	1.15	4.3585	1.67

Appendix G

Water Use for all Subpile Zones

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Date	Time	Meter Gallon	Used Gallon	Liters used	Liters/Plant/ Day
03/28/00	10:00	306,006			
04/05/00	14:00	329,922	23,916	90641.64	3.3
04/18/00	10:30	392,720	62,798	238004.42	7.6
04/19/00	10:15	400,750	8,030	30433.7	8
05/02/00	10:15	480,480	79,730	302176.7	8.6
05/03/00	13:30	498,260	17,780	67386.2	8.5
05/17/00	12:15	584,800	86,540	327986.6	9.3
05/25/00	7:45	638,200	53,400	202386	8.7
06/07/00	13:30	738,610	100,410	380553.9	9.7
06/28/00	17:00	916,700	178,090	674961.1	11.5
07/25/00	12:45	1,090,130	173,430	657299.7	8.8
08/30/00	10:45	1,357,390	267,260	1012915.4	7.4
09/14/00	13:00	1,441,700	84,310	319534.9	5.5
10/25/00	11:00	1,558,220	116,520	441610.8	8.1
				Average:	8.07692308
05/30/01	11:30	1,725,650			
07/12/01	14:00	1,918,010	192,360	729044.4	6.42131854
09/19/01	9:15	2,263,170	345,160	1308156.4	6.96124095
11/01/01	14:00	2,435,710	172,540	653926.6	5.567702

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Appendix H

Hydroprobe Readings for 2001

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month	depth	zone	station	hp reading	moisture content
2	0.5	1	1	2724	0.034
2	1.0	1	1	5812	0.094
2	1.5	1	1	6172	0.101
2	2.0	1	1	5792	0.094
2	2.5	1	1	5512	0.088
2	3.0	1	1	5452	0.087
2	3.5	1	1	5848	0.095
2	4.0	1	1	6864	0.114
2	4.5	1	1	7580	0.128
2	0.5	1	2	1516	0.011
2	1.0	1	2	6760	0.112
2	1.5	1	2	7660	0.130
2	2.0	1	2	6996	0.117
2	2.5	1	2	6304	0.104
2	3.0	1	2	6224	0.102
2	3.5	1	2	6272	0.103
2	4.0	1	2	6432	0.106
2	4.5	1	2	6204	0.102
2	5.0	1	2	6300	0.103
2	5.5	1	2	5948	0.097
2	6.0	1	2	5584	0.090
2	6.5	1	2	5708	0.092
2	7.0	1	2	5628	0.091
2	7.5	1	2	5712	0.092
2	8.0	1	2	5660	0.091
2	8.5	1	2	5944	0.097
2	9.0	1	2	6100	0.100
2	9.5	1	2	7784	0.132
2	10.0	1	2	10204	0.179
2	0.5	1	3	884	-0.001
2	1.0	1	3	5572	0.089
2	1.5	1	3	6760	0.112
2	2.0	1	3	6464	0.107
2	2.5	1	3	5856	0.095
2	3.0	1	3	5552	0.089
2	3.5	1	3	5768	0.093
2	4.0	1	3	6324	0.104
2	4.5	1	3	6300	0.103
2	5.0	1	3	5536	0.089
2	5.5	1	3	5744	0.093
2	0.5	1	4	1400	0.009
2	1.0	1	4	5064	0.080
2	1.5	1	4	6328	0.104
2	2.0	1	4	7040	0.118
2	0.5	1	5	2036	0.021
2	1.0	1	5	5772	0.093
2	1.5	1	5	7756	0.132
2	2.0	1	5	7048	0.118
2	2.5	1	5	6748	0.112
2	3.0	1	5	7668	0.130
2	3.5	1	5	8544	0.147
2	4.0	1	5	9028	0.156
2	4.5	1	5	9952	0.174
2	5.0	1	5	7800	0.132
2	5.5	1	5	6596	0.109
2	6.0	1	5	5660	0.091
2	6.5	1	5	6960	0.116
2	7.0	1	5	9204	0.160
2	7.5	1	5	8028	0.137
2	8.0	1	5	5532	0.089
2	8.5	1	5	5328	0.085
2	9.0	1	5	5668	0.091
2	9.5	1	5	5576	0.090
2	10.0	1	5	5456	0.087
2	10.5	1	5	5620	0.090
2	11.0	1	5	5460	0.087
2	11.5	1	5	5824	0.094
2	12.0	1	5	5196	0.082
2	12.5	1	5	5000	0.078
2	13.0	1	5	5552	0.089
2	13.5	1	5	5808	0.094
2	14.0	1	5	5768	0.093
2	14.5	1	5	5916	0.096
2	0.5	2	1	5028	0.079
2	1.0	2	1	5888	0.096
2	1.5	2	1	5880	0.095
2	2.0	2	1	6412	0.106
2	2.5	2	1	6600	0.109
2	3.0	2	1	5304	0.084
2	3.5	2	1	5172	0.082
2	4.0	2	1	7044	0.118
2	4.5	2	1	7204	0.121
2	5.0	2	1	6208	0.102
2	5.5	2	1	5384	0.086
2	6.0	2	1	4616	0.071
2	6.5	2	1	5332	0.085
2	0.5	2	2	8036	0.137
2	1.0	2	2	8472	0.145
2	1.5	2	2	9184	0.159
2	2.0	2	2	8152	0.139
2	2.5	2	2	7096	0.119
2	3.0	2	2	7004	0.117
2	3.5	2	2	7500	0.127
2	4.0	2	2	7080	0.119
2	4.5	2	2	6696	0.111
2	5.0	2	2	6084	0.099
2	5.5	2	2	5420	0.087
2	6.0	2	2	5796	0.094
2	6.5	2	2	6116	0.100
2	7.0	2	2	6064	0.099
2	7.5	2	2	6240	0.102
2	8.0	2	2	5676	0.091
2	8.5	2	2	5828	0.094
2	9.0	2	2	5748	0.093
2	9.5	2	2	5016	0.079
2	10.0	2	2	4516	0.069
2	10.5	2	2	4776	0.074
2	11.0	2	2	4372	0.066
2	11.5	2	2	4488	0.069
2	12.0	2	2	4620	0.071
2	12.5	2	2	4920	0.077
2	13.0	2	2	5012	0.079
2	13.5	2	2	4796	0.074
2	14.0	2	2	4688	0.072
2	14.5	2	2	5148	0.081
2	0.5	2	3	2384	0.028
2	1.0	2	3	5288	0.084
2	1.5	2	3	6224	0.102
2	2.0	2	3	6204	0.102
2	2.5	2	3	6088	0.099
2	3.0	2	3	5508	0.088
2	3.5	2	3	6900	0.115
2	4.0	2	3	5588	0.090
2	4.5	2	3	5500	0.088

month	depth	zone	station	hp reading	moisture content
2	5.0	2	3	5584	0.090
2	5.5	2	3	5220	0.083
2	6.0	2	3	5584	0.090
2	6.5	2	3	5364	0.085
2	7.0	2	3	5528	0.089
2	7.5	2	3	5692	0.092
2	8.0	2	3	5108	0.080
2	8.5	2	3	5560	0.089
2	9.0	2	3	5464	0.087
2	9.5	2	3	5380	0.086
2	10.0	2	3	5432	0.087
2	10.5	2	3	5580	0.090
2	11.0	2	3	5704	0.092
2	11.5	2	3	5972	0.097
2	12.0	2	3	6156	0.101
2	12.5	2	3	6564	0.109
2	0.5	2	4	1908	0.019
2	1.0	2	4	5332	0.085
2	1.5	2	4	5692	0.092
2	2.0	2	4	5760	0.093
2	2.5	2	4	5576	0.090
2	3.0	2	4	5224	0.083
2	3.5	2	4	5812	0.094
2	4.0	2	4	5960	0.097
2	4.5	2	4	5492	0.088
2	5.0	2	4	5280	0.084
2	5.5	2	4	5388	0.086
2	6.0	2	4	4948	0.077
2	6.5	2	4	5604	0.090
2	7.0	2	4	6384	0.105
2	0.5	2	5	2684	0.034
2	1.0	2	5	7736	0.131
2	1.5	2	5	8304	0.142
2	2.0	2	5	6476	0.107
2	2.5	2	5	6776	0.113
2	3.0	2	5	7276	0.122
2	3.5	2	5	7392	0.125
2	4.0	2	5	6778	0.113
2	4.5	2	5	6584	0.109
2	5.0	2	5	6556	0.108
2	5.5	2	5	7288	0.123
2	6.0	2	5	6908	0.115
2	6.5	2	5	6744	0.112
2	7.0	2	5	6416	0.106
2	7.5	2	5	5812	0.094
2	8.0	2	5	5972	0.097
2	8.5	2	5	5556	0.089
2	9.0	2	5	5600	0.090
2	9.5	2	5	5484	0.088
2	10.0	2	5	6192	0.101
2	10.5	2	5	6232	0.102
2	11.0	2	5	6344	0.104
2	11.5	2	5	6220	0.102
2	12.0	2	5	5720	0.092
2	12.5	2	5	5944	0.097
2	13.0	2	5	5388	0.086
2	13.5	2	5	5556	0.089
2	14.0	2	5	5480	0.088
2	14.5	2	5	5444	0.087
2	15.0	2	5	5568	0.089
2	0.5	3	1	3376	0.047
2	1.0	3	1	6444	0.106

month	depth	zone	station	hp reading	moisture content
2	1.5	3	1	6352	0.104
2	2.0	3	1	6044	0.099
2	2.5	3	1	6544	0.108
2	3.0	3	1	6340	0.104
2	3.5	3	1	5892	0.096
2	4.0	3	1	5724	0.092
2	4.5	3	1	5452	0.087
2	5.0	3	1	5412	0.086
2	5.5	3	1	5572	0.089
2	6.0	3	1	5324	0.085
2	6.5	3	1	5516	0.088
2	7.0	3	1	5848	0.095
2	7.5	3	1	5384	0.086
2	8.0	3	1	5580	0.090
2	8.5	3	1	5484	0.088
2	9.0	3	1	5520	0.088
2	9.5	3	1	5868	0.095
2	10.0	3	1	6068	0.099
2	10.5	3	1	6704	0.111
2	11.0	3	1	7764	0.132
2	0.5	3	2	3952	0.058
2	1.0	3	2	7000	0.117
2	1.5	3	2	7348	0.124
2	2.0	3	2	7360	0.124
2	2.5	3	2	6976	0.117
2	3.0	3	2	7188	0.121
2	3.5	3	2	7680	0.130
2	4.0	3	2	7540	0.127
2	4.5	3	2	6936	0.116
2	5.0	3	2	6324	0.104
2	5.5	3	2	6228	0.102
2	6.0	3	2	6284	0.103
2	6.5	3	2	7032	0.118
2	7.0	3	2	6604	0.109
2	7.5	3	2	6408	0.106
2	8.0	3	2	6464	0.107
2	8.5	3	2	5932	0.096
2	9.0	3	2	6308	0.104
2	9.5	3	2	6444	0.106
2	10.0	3	2	6608	0.109
2	10.5	3	2	7152	0.120
2	11.0	3	2	6868	0.114
2	11.5	3	2	6812	0.113
2	12.0	3	2	6880	0.115
2	12.5	3	2	6628	0.110
2	13.0	3	2	6688	0.111
2	13.5	3	2	7220	0.121
2	14.0	3	2	6664	0.111
2	14.5	3	2	6372	0.105
2	15.0	3	2	6520	0.108
2	0.5	3	3	4836	0.075
2	1.0	3	3	6448	0.106
2	1.5	3	3	7228	0.121
2	2.0	3	3	7076	0.118
2	2.5	3	3	6140	0.100
2	3.0	3	3	6160	0.101
2	3.5	3	3	5784	0.094
2	4.0	3	3	5836	0.095
2	4.5	3	3	5632	0.091
2	5.0	3	3	5952	0.097
2	5.5	3	3	6452	0.106
2	6.0	3	3	6076	0.099

month	depth	zone	station	hp reading	moisture content
2	6.5	3	3	6380	0.105
2	7.0	3	3	6908	0.115
2	7.5	3	3	6552	0.108
2	8.0	3	3	5648	0.091
2	8.5	3	3	5956	0.097
2	9.0	3	3	6116	0.100
2	9.5	3	3	5784	0.094
2	10.0	3	3	5976	0.097
2	10.5	3	3	6228	0.102
2	11.0	3	3	6132	0.100
2	11.5	3	3	6248	0.102
2	12.0	3	3	5900	0.096
2	12.5	3	3	6328	0.104
2	13.0	3	3	6012	0.098
2	13.5	3	3	6400	0.105
2	14.0	3	3	6136	0.100
2	14.5	3	3	6192	0.101
2	15.0	3	3	6128	0.100
2	0.5	3	4	2976	0.039
2	1.0	3	4	5264	0.083
2	1.5	3	4	6500	0.107
2	2.0	3	4	7244	0.122
2	2.5	3	4	6840	0.114
2	3.0	3	4	6800	0.113
2	3.5	3	4	7352	0.124
2	4.0	3	4	7184	0.121
2	4.5	3	4	6556	0.108
2	5.0	3	4	6144	0.100
2	5.5	3	4	6332	0.104
2	6.0	3	4	6556	0.108
2	6.5	3	4	5972	0.097
2	7.0	3	4	5508	0.088
2	7.5	3	4	5348	0.085
2	8.0	3	4	5412	0.086
2	8.5	3	4	5836	0.095
2	9.0	3	4	5460	0.087
2	9.5	3	4	5224	0.083
2	10.0	3	4	5672	0.091
2	10.5	3	4	5800	0.094
2	11.0	3	4	5588	0.090
2	11.5	3	4	5724	0.092
2	12.0	3	4	5476	0.088
2	12.5	3	4	5692	0.092
2	13.0	3	4	5660	0.091
2	13.5	3	4	5720	0.092
2	14.0	3	4	6728	0.112
2	14.5	3	4	7520	0.127
2	15.0	3	4	7696	0.130
2	0.5	3	5	4288	0.065
2	1.0	3	5	9944	0.174
2	1.5	3	5	10344	0.182
2	2.0	3	5	9492	0.165
2	2.5	3	5	10028	0.175
2	3.0	3	5	11212	0.198
2	3.5	3	5	11528	0.204
2	4.0	3	5	8496	0.146
2	4.5	3	5	6732	0.112
2	5.0	3	5	7020	0.117
2	5.5	3	5	6896	0.115
2	6.0	3	5	7000	0.117
2	6.5	3	5	7948	0.135
2	7.0	3	5	8056	0.137

month	depth	zone	station	hp reading	moisture content
2	7.5	3	5	7928	0.135
2	8.0	3	5	7392	0.125
2	8.5	3	5	7228	0.121
2	9.0	3	5	7536	0.127
2	9.5	3	5	7976	0.136
2	10.0	3	5	8324	0.143
2	10.5	3	5	7520	0.127
2	11.0	3	5	7064	0.118
2	11.5	3	5	6636	0.110
2	12.0	3	5	6472	0.107
2	12.5	3	5	7100	0.119
2	13.0	3	5	10408	0.183
2	13.5	3	5	14792	0.267
2	14.0	3	5	12944	0.232
2	14.5	3	5	9356	0.162
2	15.0	3	5	8800	0.152
2	0.5	4	1	5340	0.085
2	1.0	4	1	5628	0.091
2	1.5	4	1	6864	0.114
2	2.0	4	1	7084	0.119
2	2.5	4	1	6864	0.114
2	3.0	4	1	6716	0.112
2	3.5	4	1	6324	0.104
2	4.0	4	1	6992	0.117
2	4.5	4	1	5760	0.093
2	5.0	4	1	5628	0.091
2	5.5	4	1	6212	0.102
2	6.0	4	1	6140	0.100
2	6.5	4	1	5988	0.097
2	7.0	4	1	6328	0.104
2	7.5	4	1	6120	0.100
2	8.0	4	1	6028	0.098
2	8.5	4	1	5704	0.092
2	9.0	4	1	6052	0.099
2	9.5	4	1	5824	0.094
2	10.0	4	1	5748	0.093
2	10.5	4	1	5780	0.093
2	11.0	4	1	5640	0.091
2	11.5	4	1	5860	0.095
2	12.0	4	1	5864	0.095
2	12.5	4	1	5956	0.097
2	13.0	4	1	6280	0.103
2	13.5	4	1	7112	0.119
2	0.5	4	2	5348	0.085
2	1.0	4	2	7036	0.118
2	1.5	4	2	7244	0.122
2	2.0	4	2	7824	0.133
2	2.5	4	2	8516	0.146
2	3.0	4	2	8368	0.143
2	3.5	4	2	8728	0.150
2	4.0	4	2	8328	0.143
2	4.5	4	2	8544	0.147
2	5.0	4	2	9060	0.157
2	5.5	4	2	9296	0.161
2	6.0	4	2	8560	0.147
2	6.5	4	2	8816	0.152
2	7.0	4	2	9492	0.165
2	7.5	4	2	9748	0.170
2	8.0	4	2	9256	0.161
2	8.5	4	2	9648	0.168
2	9.0	4	2	12092	0.215
2	9.5	4	2	11094	0.196

month	depth	zone	station	hp reading	moisture content
2	10.0	4	2	10860	0.191
2	10.5	4	2	11636	0.206
2	11.0	4	2	12468	0.223
2	11.5	4	2	10840	0.191
2	12.0	4	2	8156	0.139
2	12.5	4	2	6796	0.113
2	13.0	4	2	6564	0.109
2	13.5	4	2	6492	0.107
2	14.0	4	2	6572	0.109
2	14.5	4	2	7452	0.126
2	0.5	4	3	2520	0.031
2	1.0	4	3	7496	0.127
2	1.5	4	3	9912	0.173
2	2.0	4	3	10084	0.177
2	2.5	4	3	7872	0.134
2	3.0	4	3	7296	0.123
2	3.5	4	3	6776	0.113
2	4.0	4	3	7860	0.134
2	4.5	4	3	8168	0.140
2	5.0	4	3	7940	0.135
2	5.5	4	3	8692	0.150
2	6.0	4	3	9028	0.156
2	6.5	4	3	8132	0.139
2	7.0	4	3	7544	0.127
2	7.5	4	3	6756	0.112
2	8.0	4	3	7376	0.124
2	8.5	4	3	7084	0.119
2	9.0	4	3	7048	0.118
2	9.5	4	3	6568	0.109
2	10.0	4	3	6600	0.109
2	10.5	4	3	6520	0.108
2	11.0	4	3	7136	0.120
2	11.5	4	3	7948	0.135
2	12.0	4	3	8060	0.137
2	12.5	4	3	7824	0.133
2	13.0	4	3	7416	0.125
2	13.5	4	3	6432	0.106
2	14.0	4	3	6452	0.106
2	14.5	4	3	7336	0.123
2	15.0	4	3	7856	0.134
2	0.5	4	4	3492	0.049
2	1.0	4	4	6832	0.114
2	1.5	4	4	8704	0.150
2	2.0	4	4	8948	0.155
2	2.5	4	4	7458	0.126
2	3.0	4	4	7044	0.118
2	3.5	4	4	7072	0.118
2	4.0	4	4	6722	0.112
2	4.5	4	4	6452	0.106
2	5.0	4	4	6288	0.103
2	5.5	4	4	6488	0.107
2	6.0	4	4	7804	0.133
2	6.5	4	4	9344	0.162
2	7.0	4	4	5564	0.089
2	7.5	4	4	4300	0.065
2	8.0	4	4	3856	0.056
2	8.5	4	4	4184	0.063
2	9.0	4	4	4712	0.073
2	9.5	4	4	5336	0.085
2	10.0	4	4	5652	0.091
2	10.5	4	4	5404	0.086
2	11.0	4	4	5300	0.084
2	11.5	4	4	5560	0.089
2	12.0	4	4	6624	0.110
2	12.5	4	4	8124	0.139
2	13.0	4	4	8144	0.139
2	13.5	4	4	8940	0.154
2	14.0	4	4	11388	0.202
2	14.5	4	4	15252	0.276
2	15.0	4	4	15328	0.278
2	0.5	4	5	5744	0.093
2	1.0	4	5	6728	0.112
2	1.5	4	5	7084	0.119
2	2.0	4	5	6404	0.105
2	2.5	4	5	6174	0.101
2	3.0	4	5	7316	0.123
2	3.5	4	5	9920	0.173
2	4.0	4	5	10396	0.183
2	4.5	4	5	10528	0.185
2	5.0	4	5	9152	0.159
2	5.5	4	5	9836	0.172
2	6.0	4	5	8904	0.154
2	6.5	4	5	6876	0.115
2	7.0	4	5	5856	0.095
2	7.5	4	5	5808	0.094
2	8.0	4	5	5652	0.091
2	8.5	4	5	8036	0.137
2	9.0	4	5	8764	0.151
2	9.5	4	5	7424	0.125
2	10.0	4	5	8612	0.148
2	10.5	4	5	9284	0.161
2	11.0	4	5	8176	0.140
2	11.5	4	5	9060	0.157
2	12.0	4	5	9760	0.170
2	12.5	4	5	8628	0.148
2	13.0	4	5	10088	0.177
2	13.5	4	5	9408	0.163
2	14.0	4	5	9292	0.161
2	14.5	4	5	8604	0.148
2	15.0	4	5	8768	0.151
3	0.5	1	1	2864	0.037
3	1.0	1	1	5840	0.095
3	1.5	1	1	6944	0.116
3	2.0	1	1	5872	0.095
3	2.5	1	1	5712	0.092
3	3.0	1	1	5744	0.093
3	3.5	1	1	5984	0.097
3	4.0	1	1	5680	0.092
3	4.5	1	1	8080	0.138
3	0.5	1	2	1672	0.014
3	1.0	1	2	7024	0.117
3	1.5	1	2	7516	0.127
3	2.0	1	2	7248	0.122
3	2.5	1	2	6268	0.103
3	3.0	1	2	6472	0.107
3	3.5	1	2	6048	0.099
3	4.0	1	2	6028	0.098
3	4.5	1	2	6076	0.099
3	5.0	1	2	6276	0.103
3	5.5	1	2	6368	0.105
3	6.0	1	2	6044	0.099
3	6.5	1	2	5412	0.086
3	7.0	1	2	5496	0.088
3	7.5	1	2	5440	0.087

month	depth	zone	station	hp reading	moisture content
3	8.0	1	2	5564	0.089
3	8.5	1	2	5936	0.096
3	9.0	1	2	6100	0.100
3	9.5	1	2	7936	0.135
3	10.0	1	2	9616	0.167
3	0.5	1	3	1140	0.004
3	1.0	1	3	5212	0.082
3	1.5	1	3	6852	0.114
3	2.0	1	3	6596	0.109
3	2.5	1	3	5780	0.093
3	3.0	1	3	5588	0.090
3	3.5	1	3	5900	0.096
3	4.0	1	3	6228	0.102
3	4.5	1	3	6424	0.106
3	5.0	1	3	5992	0.098
3	5.5	1	3	5568	0.089
3	0.5	1	4	1504	0.011
3	1.0	1	4	4720	0.073
3	1.5	1	4	6192	0.101
3	2.0	1	4	7648	0.130
3	0.5	1	5	1548	0.012
3	1.0	1	5	5524	0.089
3	1.5	1	5	7440	0.125
3	2.0	1	5	7188	0.121
3	2.5	1	5	6880	0.115
3	3.0	1	5	7384	0.124
3	3.5	1	5	8196	0.140
3	4.0	1	5	8680	0.149
3	4.5	1	5	9676	0.169
3	5.0	1	5	8332	0.143
3	5.5	1	5	6380	0.105
3	6.0	1	5	5720	0.092
3	6.5	1	5	7288	0.123
3	7.0	1	5	9404	0.163
3	7.5	1	5	7332	0.123
3	8.0	1	5	5800	0.094
3	8.5	1	5	5500	0.088
3	9.0	1	5	5184	0.082
3	9.5	1	5	5480	0.088
3	10.0	1	5	5568	0.089
3	10.5	1	5	5352	0.085
3	11.0	1	5	5704	0.092
3	11.5	1	5	5596	0.090
3	12.0	1	5	5396	0.086
3	12.5	1	5	5320	0.085
3	13.0	1	5	5420	0.087
3	13.5	1	5	5800	0.094
3	14.0	1	5	5580	0.090
3	14.5	1	5	5606	0.090
3	0.5	2	1	4992	0.078
3	1.0	2	1	5840	0.095
3	1.5	2	1	6000	0.098
3	2.0	2	1	6020	0.098
3	2.5	2	1	6720	0.112
3	3.0	2	1	4976	0.078
3	3.5	2	1	5280	0.084
3	4.0	2	1	6656	0.110
3	4.5	2	1	8064	0.138
3	5.0	2	1	5884	0.095
3	5.5	2	1	5152	0.081
3	6.0	2	1	4784	0.074
3	6.5	2	1	5712	0.092

month	depth	zone	station	hp reading	moisture content
3	0.5	2	2	8292	0.142
3	1.0	2	2	8452	0.145
3	1.5	2	2	9152	0.159
3	2.0	2	2	8492	0.146
3	2.5	2	2	6916	0.115
3	3.0	2	2	6992	0.117
3	3.5	2	2	7312	0.123
3	4.0	2	2	7240	0.122
3	4.5	2	2	6652	0.110
3	5.0	2	2	6100	0.100
3	5.5	2	2	5884	0.095
3	6.0	2	2	5588	0.090
3	6.5	2	2	5540	0.089
3	7.0	2	2	6460	0.107
3	7.5	2	2	5976	0.097
3	8.0	2	2	5992	0.098
3	8.5	2	2	5808	0.094
3	9.0	2	2	5944	0.097
3	9.5	2	2	5444	0.087
3	10.0	2	2	4512	0.069
3	10.5	2	2	4660	0.072
3	11.0	2	2	4300	0.065
3	11.5	2	2	4508	0.069
3	12.0	2	2	4448	0.068
3	12.5	2	2	4900	0.076
3	13.0	2	2	4984	0.078
3	13.5	2	2	4688	0.072
3	14.0	2	2	4968	0.078
3	14.5	2	2	5028	0.079
3	0.5	2	3	2272	0.026
3	1.0	2	3	4912	0.077
3	1.5	2	3	5824	0.094
3	2.0	2	3	6256	0.103
3	2.5	2	3	6000	0.098
3	3.0	2	3	5856	0.095
3	3.5	2	3	5616	0.090
3	4.0	2	3	5344	0.085
3	4.5	2	3	5200	0.082
3	5.0	2	3	5424	0.087
3	5.5	2	3	5872	0.095
3	6.0	2	3	5104	0.080
3	6.5	2	3	5328	0.085
3	7.0	2	3	5312	0.084
3	7.5	2	3	5344	0.085
3	8.0	2	3	5936	0.096
3	8.5	2	3	5728	0.092
3	9.0	2	3	5712	0.092
3	9.5	2	3	4960	0.078
3	10.0	2	3	5544	0.089
3	10.5	2	3	5952	0.097
3	11.0	2	3	5968	0.097
3	11.5	2	3	5256	0.083
3	12.0	2	3	6048	0.099
3	12.5	2	3	6880	0.115
3	0.5	2	4	1536	0.012
3	1.0	2	4	4736	0.073
3	1.5	2	4	5424	0.087
3	2.0	2	4	5904	0.096
3	2.5	2	4	6160	0.101
3	3.0	2	4	4992	0.078
3	3.5	2	4	5632	0.091
3	4.0	2	4	6464	0.107

month	depth	zone	station	hp reading	moisture content
3	4.5	2	4	5904	0.096
3	5.0	2	4	5248	0.083
3	5.5	2	4	4560	0.070
3	6.0	2	4	4944	0.077
3	6.5	2	4	5664	0.091
3	7.0	2	4	6304	0.104
3	0.5	2	5	2288	0.026
3	1.0	2	5	7268	0.122
3	1.5	2	5	8600	0.148
3	2.0	2	5	6612	0.110
3	2.5	2	5	6760	0.112
3	3.0	2	5	7208	0.121
3	3.5	2	5	7412	0.125
3	4.0	2	5	7032	0.118
3	4.5	2	5	6348	0.104
3	5.0	2	5	6456	0.107
3	5.5	2	5	7092	0.119
3	6.0	2	5	7096	0.119
3	6.5	2	5	6532	0.108
3	7.0	2	5	6416	0.106
3	7.5	2	5	5632	0.091
3	8.0	2	5	5618	0.090
3	8.5	2	5	5912	0.096
3	9.0	2	5	5468	0.087
3	9.5	2	5	5324	0.085
3	10.0	2	5	6000	0.098
3	10.5	2	5	6012	0.098
3	11.0	2	5	6320	0.104
3	11.5	2	5	6284	0.103
3	12.0	2	5	6208	0.102
3	12.5	2	5	6096	0.100
3	13.0	2	5	5260	0.083
3	13.5	2	5	5348	0.085
3	14.0	2	5	5204	0.082
3	14.5	2	5	5336	0.085
3	15.0	2	5	5456	0.087
3	0.5	3	1	3428	0.048
3	1.0	3	1	5796	0.094
3	1.5	3	1	6576	0.109
3	2.0	3	1	6400	0.105
3	2.5	3	1	6092	0.099
3	3.0	3	1	6464	0.107
3	3.5	3	1	5792	0.094
3	4.0	3	1	5552	0.089
3	4.5	3	1	5880	0.095
3	5.0	3	1	5516	0.088
3	5.5	3	1	5256	0.083
3	6.0	3	1	5756	0.093
3	6.5	3	1	5424	0.087
3	7.0	3	1	5728	0.092
3	7.5	3	1	5740	0.093
3	8.0	3	1	5508	0.088
3	8.5	3	1	5812	0.094
3	9.0	3	1	5560	0.089
3	9.5	3	1	5996	0.098
3	10.0	3	1	5948	0.097
3	10.5	3	1	6592	0.109
3	11.0	3	1	7540	0.127
3	0.5	3	2	4164	0.062
3	1.0	3	2	6984	0.117
3	1.5	3	2	7352	0.124
3	2.0	3	2	7184	0.121

month	depth	zone	station	hp reading	moisture content
3	2.5	3	2	7376	0.124
3	3.0	3	2	7092	0.119
3	3.5	3	2	8064	0.138
3	4.0	3	2	7268	0.122
3	4.5	3	2	7376	0.124
3	5.0	3	2	6320	0.104
3	5.5	3	2	6304	0.104
3	6.0	3	2	6512	0.108
3	6.5	3	2	6836	0.114
3	7.0	3	2	6688	0.111
3	7.5	3	2	6152	0.101
3	8.0	3	2	6104	0.100
3	8.5	3	2	5948	0.097
3	9.0	3	2	6208	0.102
3	9.5	3	2	6576	0.109
3	10.0	3	2	6936	0.116
3	10.5	3	2	7488	0.126
3	11.0	3	2	7364	0.124
3	11.5	3	2	6764	0.112
3	12.0	3	2	6704	0.111
3	12.5	3	2	6656	0.110
3	13.0	3	2	6856	0.114
3	13.5	3	2	7228	0.121
3	14.0	3	2	7028	0.118
3	14.5	3	2	6248	0.102
3	15.0	3	2	6264	0.103
3	0.5	3	3	4048	0.060
3	1.0	3	3	6672	0.111
3	1.5	3	3	7204	0.121
3	2.0	3	3	6864	0.114
3	2.5	3	3	6520	0.108
3	3.0	3	3	6128	0.100
3	3.5	3	3	5972	0.097
3	4.0	3	3	5680	0.092
3	4.5	3	3	5708	0.092
3	5.0	3	3	6040	0.098
3	5.5	3	3	6452	0.106
3	6.0	3	3	6372	0.105
3	6.5	3	3	6428	0.106
3	7.0	3	3	6544	0.108
3	7.5	3	3	6172	0.101
3	8.0	3	3	5900	0.096
3	8.5	3	3	5972	0.097
3	9.0	3	3	5756	0.093
3	9.5	3	3	5752	0.093
3	10.0	3	3	5896	0.096
3	10.5	3	3	5972	0.097
3	11.0	3	3	6332	0.104
3	11.5	3	3	5716	0.092
3	12.0	3	3	5888	0.096
3	12.5	3	3	6300	0.103
3	13.0	3	3	6310	0.104
3	13.5	3	3	5992	0.098
3	14.0	3	3	6308	0.104
3	14.5	3	3	5902	0.096
3	15.0	3	3	5964	0.097
3	0.5	3	4	2416	0.029
3	1.0	3	4	5488	0.088
3	1.5	3	4	6528	0.108
3	2.0	3	4	7296	0.123
3	2.5	3	4	6640	0.110
3	3.0	3	4	6384	0.105

month	depth	zone	station	hp reading	moisture content
3	3.5	3	4	7332	0.123
3	4.0	3	4	6942	0.116
3	4.5	3	4	6596	0.109
3	5.0	3	4	6344	0.104
3	5.5	3	4	6100	0.100
3	6.0	3	4	6520	0.108
3	6.5	3	4	5588	0.090
3	7.0	3	4	5128	0.081
3	7.5	3	4	5336	0.085
3	8.0	3	4	5164	0.082
3	8.5	3	4	5348	0.085
3	9.0	3	4	5532	0.089
3	9.5	3	4	5408	0.086
3	10.0	3	4	5576	0.090
3	10.5	3	4	5672	0.091
3	11.0	3	4	5636	0.091
3	11.5	3	4	5504	0.088
3	12.0	3	4	5516	0.088
3	12.5	3	4	5780	0.093
3	13.0	3	4	5856	0.095
3	13.5	3	4	5360	0.085
3	14.0	3	4	6464	0.107
3	14.5	3	4	7940	0.135
3	15.0	3	4	7728	0.131
3	0.5	3	5	4608	0.071
3	1.0	3	5	9764	0.170
3	1.5	3	5	10164	0.178
3	2.0	3	5	9236	0.160
3	2.5	3	5	10040	0.176
3	3.0	3	5	11120	0.197
3	3.5	3	5	11364	0.201
3	4.0	3	5	8408	0.144
3	4.5	3	5	6788	0.113
3	5.0	3	5	7124	0.119
3	5.5	3	5	6660	0.110
3	6.0	3	5	7252	0.122
3	6.5	3	5	7724	0.131
3	7.0	3	5	7588	0.128
3	7.5	3	5	7728	0.131
3	8.0	3	5	7616	0.129
3	8.5	3	5	7016	0.117
3	9.0	3	5	7688	0.130
3	9.5	3	5	7564	0.128
3	10.0	3	5	8312	0.142
3	10.5	3	5	7468	0.126
3	11.0	3	5	7104	0.119
3	11.5	3	5	6828	0.114
3	12.0	3	5	6608	0.109
3	12.5	3	5	7216	0.121
3	13.0	3	5	9584	0.167
3	13.5	3	5	14592	0.264
3	14.0	3	5	13376	0.240
3	14.5	3	5	9360	0.163
3	15.0	3	5	8944	0.155
3	0.5	4	1	5536	0.089
3	1.0	4	1	5616	0.090
3	1.5	4	1	6736	0.112
3	2.0	4	1	7280	0.122
3	2.5	4	1	6896	0.115
3	3.0	4	1	6528	0.108
3	3.5	4	1	6496	0.107
3	4.0	4	1	5840	0.095

month	depth	zone	station	hp reading	moisture content
3	4.5	4	1	5888	0.096
3	5.0	4	1	5856	0.095
3	5.5	4	1	6056	0.099
3	6.0	4	1	6272	0.103
3	6.5	4	1	6192	0.101
3	7.0	4	1	6448	0.106
3	7.5	4	1	5920	0.096
3	8.0	4	1	5968	0.097
3	8.5	4	1	6272	0.103
3	9.0	4	1	5952	0.097
3	9.5	4	1	6032	0.098
3	10.0	4	1	5760	0.093
3	10.5	4	1	6224	0.102
3	11.0	4	1	5632	0.091
3	11.5	4	1	6160	0.101
3	12.0	4	1	5632	0.091
3	12.5	4	1	5728	0.092
3	13.0	4	1	6416	0.106
3	13.5	4	1	6576	0.109
3	0.5	4	2	5600	0.090
3	1.0	4	2	7312	0.123
3	1.5	4	2	7584	0.128
3	2.0	4	2	7456	0.126
3	2.5	4	2	8688	0.150
3	3.0	4	2	9152	0.159
3	3.5	4	2	8944	0.155
3	4.0	4	2	8448	0.145
3	4.5	4	2	8816	0.152
3	5.0	4	2	8688	0.150
3	5.5	4	2	9184	0.159
3	6.0	4	2	9600	0.167
3	6.5	4	2	8944	0.155
3	7.0	4	2	9296	0.161
3	7.5	4	2	10304	0.181
3	8.0	4	2	9360	0.163
3	8.5	4	2	9840	0.172
3	9.0	4	2	10944	0.193
3	9.5	4	2	11264	0.199
3	10.0	4	2	10752	0.189
3	10.5	4	2	11040	0.195
3	11.0	4	2	12784	0.229
3	11.5	4	2	10656	0.188
3	12.0	4	2	7872	0.134
3	12.5	4	2	6884	0.115
3	13.0	4	2	5984	0.097
3	13.5	4	2	6336	0.104
3	14.0	4	2	6032	0.098
3	14.5	4	2	7600	0.129
3	0.5	4	3	2084	0.022
3	1.0	4	3	7500	0.127
3	1.5	4	3	9488	0.165
3	2.0	4	3	9872	0.172
3	2.5	4	3	7728	0.131
3	3.0	4	3	7368	0.124
3	3.5	4	3	6368	0.105
3	4.0	4	3	8064	0.138
3	4.5	4	3	7648	0.130
3	5.0	4	3	7824	0.133
3	5.5	4	3	8960	0.155
3	6.0	4	3	8256	0.141
3	6.5	4	3	8192	0.140
3	7.0	4	3	7312	0.123

3	7.5	4	3	6976	0.117
3	8.0	4	3	6800	0.113
3	8.5	4	3	6928	0.116
3	9.0	4	3	6864	0.114
3	9.5	4	3	6800	0.113
3	10.0	4	3	6288	0.103
3	10.5	4	3	6784	0.113
3	11.0	4	3	6816	0.113
3	11.5	4	3	7968	0.136
3	12.0	4	3	7904	0.134
3	12.5	4	3	7970	0.136
3	13.0	4	3	6928	0.116
3	13.5	4	3	6272	0.103
3	14.0	4	3	6512	0.108
3	14.5	4	3	6976	0.117
3	15.0	4	3	7120	0.119
3	0.5	4	4	2800	0.036
3	1.0	4	4	6240	0.102
3	1.5	4	4	9184	0.159
3	2.0	4	4	7264	0.122
3	2.5	4	4	7280	0.122
3	3.0	4	4	6384	0.105
3	3.5	4	4	6032	0.098
3	4.0	4	4	6000	0.098
3	4.5	4	4	6880	0.115
3	5.0	4	4	7224	0.121
3	5.5	4	4	9152	0.159
3	6.0	4	4	6288	0.103
3	6.5	4	4	4736	0.073
3	7.0	4	4	3808	0.055
3	7.5	4	4	4032	0.060
3	8.0	4	4	4832	0.075
3	8.5	4	4	4560	0.070
3	9.0	4	4	5392	0.086
3	9.5	4	4	5984	0.097
3	10.0	4	4	4656	0.072
3	10.5	4	4	5760	0.093
3	11.0	4	4	6704	0.111
3	11.5	4	4	8304	0.142
3	12.0	4	4	8992	0.155
3	12.5	4	4	8688	0.150
3	13.0	4	4	11664	0.207
3	13.5	4	4	9008	0.156
3	14.0	4	4	12800	0.229
3	14.5	4	4	14944	0.270
3	15.0	4	4	16000	0.291
3	0.5	4	5	5680	0.092
3	1.0	4	5	6416	0.106
3	1.5	4	5	6800	0.113
3	2.0	4	5	6816	0.113
3	2.5	4	5	6912	0.115
3	3.0	4	5	8272	0.142
3	3.5	4	5	9712	0.169
3	4.0	4	5	10512	0.185
3	4.5	4	5	10368	0.182
3	5.0	4	5	9280	0.161
3	5.5	4	5	8496	0.146
3	6.0	4	5	9376	0.163
3	6.5	4	5	7488	0.126
3	7.0	4	5	5760	0.093
3	7.5	4	5	6144	0.100
3	8.0	4	5	6352	0.104
3	8.5	4	5	8192	0.140
3	9.0	4	5	9488	0.165
3	9.5	4	5	7760	0.132
3	10.0	4	5	8208	0.140
3	10.5	4	5	9072	0.157
3	11.0	4	5	7952	0.135
3	11.5	4	5	8720	0.150
3	12.0	4	5	9936	0.174
3	12.5	4	5	8064	0.138
3	13.0	4	5	9952	0.174
3	13.5	4	5	9328	0.162
3	14.0	4	5	9648	0.168
3	14.5	4	5	8800	0.152
3	15.0	4	5	8656	0.149
4	0.5	1	1	2556	0.031
4	1.0	1	1	5176	0.082
4	1.5	1	1	5508	0.088
4	2.0	1	1	5824	0.094
4	2.5	1	1	5492	0.088
4	3.0	1	1	5396	0.086
4	3.5	1	1	5940	0.097
4	4.0	1	1	6484	0.107
4	4.5	1	1	7524	0.127
4	0.5	1	2	1332	0.008
4	1.0	1	2	5712	0.092
4	1.5	1	2	7496	0.127
4	2.0	1	2	6756	0.112
4	2.5	1	2	6324	0.104
4	3.0	1	2	6472	0.107
4	3.5	1	2	6232	0.102
4	4.0	1	2	6484	0.107
4	4.5	1	2	5996	0.098
4	5.0	1	2	6020	0.098
4	5.5	1	2	6224	0.102
4	6.0	1	2	5652	0.091
4	6.5	1	2	5768	0.093
4	7.0	1	2	5468	0.087
4	7.5	1	2	5372	0.086
4	8.0	1	2	5716	0.092
4	8.5	1	2	5840	0.095
4	9.0	1	2	6076	0.099
4	9.5	1	2	7376	0.124
4	10.0	1	2	9740	0.170
4	0.5	1	3	992	0.001
4	1.0	1	3	4672	0.072
4	1.5	1	3	6388	0.105
4	2.0	1	3	6632	0.110
4	2.5	1	3	6096	0.100
4	3.0	1	3	5484	0.088
4	3.5	1	3	5620	0.090
4	4.0	1	3	6304	0.104
4	4.5	1	3	6132	0.100
4	5.0	1	3	5652	0.091
4	5.5	1	3	5708	0.092
4	0.5	1	4	1160	0.004
4	1.0	1	4	4440	0.068
4	1.5	1	4	5876	0.095
4	2.0	1	4	6620	0.110
4	0.5	1	5	1388	0.009
4	1.0	1	5	5132	0.081
4	1.5	1	5	7312	0.123
4	2.0	1	5	6852	0.114

month	depth	zone	station	hp reading	moisture content
4	2.5	1	5	6500	0.107
4	3.0	1	5	7544	0.127
4	3.5	1	5	8400	0.144
4	4.0	1	5	9136	0.158
4	4.5	1	5	9940	0.174
4	5.0	1	5	7696	0.130
4	5.5	1	5	6428	0.106
4	6.0	1	5	5584	0.090
4	6.5	1	5	6960	0.116
4	7.0	1	5	9440	0.164
4	7.5	1	5	7348	0.124
4	8.0	1	5	5652	0.091
4	8.5	1	5	5516	0.088
4	9.0	1	5	5404	0.086
4	9.5	1	5	5708	0.092
4	10.0	1	5	5320	0.085
4	10.5	1	5	5428	0.087
4	11.0	1	5	5624	0.090
4	11.5	1	5	5320	0.085
4	12.0	1	5	5088	0.080
4	12.5	1	5	5252	0.083
4	13.0	1	5	5336	0.085
4	13.5	1	5	5076	0.080
4	14.0	1	5	5544	0.089
4	14.5	1	5	6036	0.098
4	0.5	2	1	3932	0.058
4	1.0	2	1	5516	0.088
4	1.5	2	1	6272	0.103
4	2.0	2	1	6292	0.103
4	2.5	2	1	6688	0.111
4	3.0	2	1	5428	0.087
4	3.5	2	1	5096	0.080
4	4.0	2	1	6940	0.116
4	4.5	2	1	7312	0.123
4	5.0	2	1	6224	0.102
4	5.5	2	1	5308	0.084
4	6.0	2	1	4604	0.071
4	6.5	2	1	5692	0.092
4	0.5	2	2	7592	0.128
4	1.0	2	2	7844	0.133
4	1.5	2	2	8896	0.154
4	2.0	2	2	7952	0.135
4	2.5	2	2	6764	0.112
4	3.0	2	2	6840	0.114
4	3.5	2	2	7316	0.123
4	4.0	2	2	7344	0.124
4	4.5	2	2	6664	0.111
4	5.0	2	2	6176	0.101
4	5.5	2	2	5552	0.089
4	6.0	2	2	5424	0.087
4	6.5	2	2	6044	0.099
4	7.0	2	2	6472	0.107
4	7.5	2	2	5936	0.096
4	8.0	2	2	5884	0.095
4	8.5	2	2	5996	0.098
4	9.0	2	2	5800	0.094
4	9.5	2	2	5460	0.087
4	10.0	2	2	4740	0.073
4	10.5	2	2	4732	0.073
4	11.0	2	2	4556	0.070
4	11.5	2	2	4380	0.066
4	12.0	2	2	4456	0.068

month	depth	zone	station	hp reading	moisture content
4	12.5	2	2	4996	0.078
4	13.0	2	2	4888	0.076
4	13.5	2	2	4572	0.070
4	14.0	2	2	4736	0.073
4	14.5	2	2	5144	0.081
4	0.5	2	3	1756	0.016
4	1.0	2	3	5028	0.079
4	1.5	2	3	5836	0.095
4	2.0	2	3	5808	0.094
4	2.5	2	3	5608	0.090
4	3.0	2	3	5692	0.092
4	3.5	2	3	5664	0.091
4	4.0	2	3	5776	0.093
4	4.5	2	3	5220	0.083
4	5.0	2	3	5056	0.079
4	5.5	2	3	5352	0.085
4	6.0	2	3	5236	0.083
4	6.5	2	3	5128	0.081
4	7.0	2	3	5492	0.088
4	7.5	2	3	5328	0.085
4	8.0	2	3	5340	0.085
4	8.5	2	3	5428	0.087
4	9.0	2	3	5276	0.084
4	9.5	2	3	5124	0.081
4	10.0	2	3	5548	0.089
4	10.5	2	3	5538	0.089
4	11.0	2	3	5516	0.088
4	11.5	2	3	5532	0.089
4	12.0	2	3	5740	0.093
4	12.5	2	3	6552	0.108
4	0.5	2	4	1224	0.006
4	1.0	2	4	4552	0.070
4	1.5	2	4	5632	0.091
4	2.0	2	4	6060	0.099
4	2.5	2	4	5468	0.087
4	3.0	2	4	5400	0.086
4	3.5	2	4	5900	0.096
4	4.0	2	4	5620	0.090
4	4.5	2	4	5484	0.088
4	5.0	2	4	5424	0.087
4	5.5	2	4	5136	0.081
4	6.0	2	4	5352	0.085
4	6.5	2	4	5392	0.086
4	7.0	2	4	6032	0.098
4	0.5	2	5	2408	0.028
4	1.0	2	5	6996	0.117
4	1.5	2	5	7484	0.126
4	2.0	2	5	6376	0.105
4	2.5	2	5	6588	0.109
4	3.0	2	5	7184	0.121
4	3.5	2	5	7472	0.126
4	4.0	2	5	6916	0.115
4	4.5	2	5	6752	0.112
4	5.0	2	5	6712	0.111
4	5.5	2	5	7036	0.118
4	6.0	2	5	7328	0.123
4	6.5	2	5	6580	0.109
4	7.0	2	5	6168	0.101
4	7.5	2	5	5648	0.091
4	8.0	2	5	5616	0.090
4	8.5	2	5	5768	0.093
4	9.0	2	5	5564	0.089

month	depth	zone	station	hp reading	moisture content
4	9.5	2	5	5516	0.088
4	10.0	2	5	6040	0.098
4	10.5	2	5	5856	0.095
4	11.0	2	5	6336	0.104
4	11.5	2	5	6472	0.107
4	12.0	2	5	5676	0.091
4	12.5	2	5	5840	0.095
4	13.0	2	5	5668	0.091
4	13.5	2	5	5360	0.085
4	14.0	2	5	5468	0.087
4	14.5	2	5	5476	0.088
4	15.0	2	5	5108	0.080
4	0.5	3	1	2964	0.039
4	1.0	3	1	5428	0.087
4	1.5	3	1	6404	0.105
4	2.0	3	1	6248	0.102
4	2.5	3	1	6220	0.102
4	3.0	3	1	6144	0.100
4	3.5	3	1	5808	0.094
4	4.0	3	1	5496	0.088
4	4.5	3	1	5628	0.091
4	5.0	3	1	5608	0.090
4	5.5	3	1	5508	0.088
4	6.0	3	1	5316	0.084
4	6.5	3	1	5320	0.085
4	7.0	3	1	53668	1.018
4	7.5	3	1	5872	0.095
4	8.0	3	1	5540	0.089
4	8.5	3	1	5448	0.087
4	9.0	3	1	5736	0.093
4	9.5	3	1	5596	0.090
4	10.0	3	1	5992	0.098
4	10.5	3	1	6476	0.107
4	11.0	3	1	7548	0.128
4	0.5	3	2	3308	0.046
4	1.0	3	2	6188	0.101
4	1.5	3	2	7360	0.124
4	2.0	3	2	6992	0.117
4	2.5	3	2	6748	0.112
4	3.0	3	2	7088	0.119
4	3.5	3	2	8008	0.136
4	4.0	3	2	7620	0.129
4	4.5	3	2	6960	0.116
4	5.0	3	2	6608	0.109
4	5.5	3	2	6584	0.109
4	6.0	3	2	6360	0.105
4	6.5	3	2	6820	0.114
4	7.0	3	2	6296	0.103
4	7.5	3	2	6248	0.102
4	8.0	3	2	5936	0.096
4	8.5	3	2	6060	0.099
4	9.0	3	2	6004	0.098
4	9.5	3	2	6100	0.100
4	10.0	3	2	6992	0.117
4	10.5	3	2	7540	0.127
4	11.0	3	2	7164	0.120
4	11.5	3	2	6884	0.115
4	12.0	3	2	6788	0.113
4	12.5	3	2	6296	0.103
4	13.0	3	2	6700	0.111
4	13.5	3	2	7048	0.118
4	14.0	3	2	6544	0.108

month	depth	zone	station	hp reading	moisture content
4	14.5	3	2	6336	0.104
4	15.0	3	2	6644	0.110
4	0.5	3	3	3688	0.053
4	1.0	3	3	6108	0.100
4	1.5	3	3	6948	0.116
4	2.0	3	3	6800	0.113
4	2.5	3	3	6308	0.104
4	3.0	3	3	5973	0.097
4	3.5	3	3	6160	0.101
4	4.0	3	3	5504	0.088
4	4.5	3	3	5268	0.084
4	5.0	3	3	5728	0.092
4	5.5	3	3	6384	0.105
4	6.0	3	3	6264	0.103
4	6.5	3	3	6332	0.104
4	7.0	3	3	6268	0.103
4	7.5	3	3	6536	0.108
4	8.0	3	3	6068	0.099
4	8.5	3	3	5500	0.088
4	9.0	3	3	5768	0.093
4	9.5	3	3	5700	0.092
4	10.0	3	3	5596	0.090
4	10.5	3	3	6472	0.107
4	11.0	3	3	5924	0.096
4	11.5	3	3	5932	0.096
4	12.0	3	3	5792	0.094
4	12.5	3	3	6080	0.099
4	13.0	3	3	6512	0.108
4	13.5	3	3	5848	0.095
4	14.0	3	3	6092	0.099
4	14.5	3	3	5692	0.092
4	15.0	3	3	5784	0.094
4	0.5	3	4	1884	0.018
4	1.0	3	4	4540	0.070
4	1.5	3	4	6528	0.108
4	2.0	3	4	7272	0.122
4	2.5	3	4	6768	0.113
4	3.0	3	4	6536	0.108
4	3.5	3	4	7244	0.122
4	4.0	3	4	6944	0.116
4	4.5	3	4	6396	0.105
4	5.0	3	4	5928	0.096
4	5.5	3	4	6080	0.099
4	6.0	3	4	6464	0.107
4	6.5	3	4	5744	0.093
4	7.0	3	4	5332	0.085
4	7.5	3	4	5224	0.083
4	8.0	3	4	5408	0.086
4	8.5	3	4	5584	0.090
4	9.0	3	4	5308	0.084
4	9.5	3	4	5520	0.088
4	10.0	3	4	5428	0.087
4	10.5	3	4	5600	0.090
4	11.0	3	4	5504	0.088
4	11.5	3	4	5184	0.082
4	12.0	3	4	5384	0.086
4	12.5	3	4	5604	0.090
4	13.0	3	4	5600	0.090
4	13.5	3	4	5324	0.085
4	14.0	3	4	6212	0.102
4	14.5	3	4	7840	0.133
4	15.0	3	4	7268	0.122

month	depth	zone	station	hp reading	moisture content
4	0.5	3	5	5260	0.083
4	1.0	3	5	9844	0.172
4	1.5	3	5	9756	0.170
4	2.0	3	5	9304	0.161
4	2.5	3	5	9984	0.175
4	3.0	3	5	11120	0.197
4	3.5	3	5	10860	0.191
4	4.0	3	5	8328	0.143
4	4.5	3	5	6716	0.112
4	5.0	3	5	6908	0.115
4	5.5	3	5	6640	0.110
4	6.0	3	5	7112	0.119
4	6.5	3	5	7884	0.134
4	7.0	3	5	7848	0.133
4	7.5	3	5	7540	0.127
4	8.0	3	5	7372	0.124
4	8.5	3	5	6940	0.116
4	9.0	3	5	7448	0.126
4	9.5	3	5	7700	0.131
4	10.0	3	5	8112	0.138
4	10.5	3	5	7512	0.127
4	11.0	3	5	6672	0.111
4	11.5	3	5	6512	0.108
4	12.0	3	5	6264	0.103
4	12.5	3	5	7084	0.119
4	13.0	3	5	10236	0.179
4	13.5	3	5	14028	0.253
4	14.0	3	5	12952	0.232
4	14.5	3	5	9588	0.167
4	15.0	3	5	8540	0.147
4	0.5	4	1	4856	0.076
4	1.0	4	1	5888	0.096
4	1.5	4	1	6728	0.112
4	2.0	4	1	7064	0.118
4	2.5	4	1	7000	0.117
4	3.0	4	1	6956	0.116
4	3.5	4	1	6472	0.107
4	4.0	4	1	5808	0.094
4	4.5	4	1	5964	0.097
4	5.0	4	1	6304	0.104
4	5.5	4	1	5980	0.097
4	6.0	4	1	6108	0.100
4	6.5	4	1	6284	0.103
4	7.0	4	1	6444	0.106
4	7.5	4	1	6392	0.105
4	8.0	4	1	5828	0.094
4	8.5	4	1	5736	0.093
4	9.0	4	1	5852	0.095
4	9.5	4	1	5528	0.089
4	10.0	4	1	5600	0.090
4	10.5	4	1	5728	0.092
4	11.0	4	1	5780	0.093
4	11.5	4	1	5796	0.094
4	12.0	4	1	5736	0.093
4	12.5	4	1	5584	0.090
4	13.0	4	1	6440	0.106
4	13.5	4	1	6792	0.113
4	0.5	4	2	5036	0.079
4	1.0	4	2	7188	0.121
4	1.5	4	2	7664	0.130
4	2.0	4	2	7620	0.129
4	2.5	4	2	8412	0.144
4	3.0	4	2	8572	0.147
4	3.5	4	2	8504	0.146
4	4.0	4	2	8744	0.151
4	4.5	4	2	8740	0.151
4	5.0	4	2	8872	0.153
4	5.5	4	2	9256	0.161
4	6.0	4	2	8884	0.153
4	6.5	4	2	8788	0.152
4	7.0	4	2	9504	0.165
4	7.5	4	2	9604	0.167
4	8.0	4	2	9624	0.168
4	8.5	4	2	9732	0.170
4	9.0	4	2	12098	0.215
4	9.5	4	2	11172	0.198
4	10.0	4	2	10788	0.190
4	10.5	4	2	12040	0.214
4	11.0	4	2	12304	0.219
4	11.5	4	2	10856	0.191
4	12.0	4	2	8380	0.144
4	12.5	4	2	7140	0.120
4	13.0	4	2	6260	0.103
4	13.5	4	2	6528	0.108
4	14.0	4	2	6896	0.115
4	14.5	4	2	7768	0.132
4	0.5	4	3	2328	0.027
4	1.0	4	3	6792	0.113
4	1.5	4	3	9284	0.161
4	2.0	4	3	9932	0.174
4	2.5	4	3	7860	0.134
4	3.0	4	3	6696	0.111
4	3.5	4	3	9272	0.161
4	4.0	4	3	7424	0.125
4	4.5	4	3	7848	0.133
4	5.0	4	3	7828	0.133
4	5.5	4	3	8412	0.144
4	6.0	4	3	9172	0.159
4	6.5	4	3	8164	0.139
4	7.0	4	3	7024	0.117
4	7.5	4	3	6656	0.110
4	8.0	4	3	6964	0.116
4	8.5	4	3	6948	0.116
4	9.0	4	3	6644	0.110
4	9.5	4	3	6684	0.111
4	10.0	4	3	6476	0.107
4	10.5	4	3	6872	0.115
4	11.0	4	3	7076	0.118
4	11.5	4	3	7660	0.130
4	12.0	4	3	7784	0.132
4	12.5	4	3	7444	0.126
4	13.0	4	3	7424	0.125
4	13.5	4	3	6468	0.107
4	14.0	4	3	6216	0.102
4	14.5	4	3	6824	0.114
4	15.0	4	3	7948	0.135
4	0.5	4	4	2304	0.026
4	1.0	4	4	5760	0.093
4	1.5	4	4	8400	0.144
4	2.0	4	4	8496	0.146
4	2.5	4	4	7568	0.128
4	3.0	4	4	7136	0.120
4	3.5	4	4	7008	0.117
4	4.0	4	4	6880	0.115

month	depth	zone	station	hp reading	moisture content
4	4.5	4	4	5936	0.096
4	5.0	4	4	6368	0.105
4	5.5	4	4	6640	0.110
4	6.0	4	4	7344	0.124
4	6.5	4	4	9136	0.158
4	7.0	4	4	5856	0.095
4	7.5	4	4	4016	0.059
4	8.0	4	4	4112	0.061
4	8.5	4	4	4016	0.059
4	9.0	4	4	4416	0.067
4	9.5	4	4	4704	0.073
4	10.0	4	4	5264	0.083
4	10.5	4	4	4992	0.078
4	11.0	4	4	5376	0.086
4	11.5	4	4	5824	0.094
4	12.0	4	4	6544	0.108
4	12.5	4	4	8448	0.145
4	13.0	4	4	7776	0.132
4	13.5	4	4	8288	0.142
4	14.0	4	4	11648	0.207
4	14.5	4	4	15056	0.272
4	15.0	4	4	15488	0.281
4	0.5	4	5	4644	0.072
4	1.0	4	5	6364	0.105
4	1.5	4	5	6464	0.107
4	2.0	4	5	6772	0.113
4	2.5	4	5	6644	0.110
4	3.0	4	5	7684	0.130
4	3.5	4	5	9456	0.164
4	4.0	4	5	10456	0.184
4	4.5	4	5	9392	0.163
4	5.0	4	5	9728	0.170
4	5.5	4	5	9440	0.164
4	6.0	4	5	9536	0.166
4	6.5	4	5	6406	0.106
4	7.0	4	5	5616	0.090
4	7.5	4	5	5648	0.091
4	8.0	4	5	5760	0.093
4	8.5	4	5	8128	0.139
4	9.0	4	5	8928	0.154
4	9.5	4	5	7744	0.131
4	10.0	4	5	8480	0.146
4	10.5	4	5	9424	0.164
4	11.0	4	5	8368	0.143
4	11.5	4	5	8944	0.155
4	12.0	4	5	9968	0.174
4	12.5	4	5	8480	0.146
4	13.0	4	5	10368	0.182
4	13.5	4	5	9648	0.168
4	14.0	4	5	9936	0.174
4	14.5	4	5	8752	0.151
4	15.0	4	5	8496	0.146
5	0.5	1	1	2012	0.021
5	1.0	1	1	5084	0.080
5	1.5	1	1	6740	0.112
5	2.0	1	1	6644	0.110
5	2.5	1	1	6244	0.102
5	3.0	1	1	6280	0.103
5	3.5	1	1	6764	0.112
5	4.0	1	1	7864	0.134
5	4.5	1	1	9164	0.159
5	0.5	1	2	1624	0.013

month	depth	zone	station	hp reading	moisture content
5	1.0	1	2	6712	0.111
5	1.5	1	2	7420	0.125
5	2.0	1	2	7860	0.134
5	2.5	1	2	7508	0.127
5	3.0	1	2	7296	0.123
5	3.5	1	2	7236	0.122
5	4.0	1	2	7048	0.118
5	4.5	1	2	7216	0.121
5	5.0	1	2	7136	0.120
5	5.5	1	2	7376	0.124
5	6.0	1	2	6512	0.108
5	6.5	1	2	5984	0.097
5	7.0	1	2	5976	0.097
5	7.5	1	2	6208	0.102
5	8.0	1	2	6036	0.098
5	8.5	1	2	5724	0.092
5	9.0	1	2	6224	0.102
5	9.5	1	2	7664	0.130
5	10.0	1	2	9420	0.164
5	0.5	1	3	616	-0.006
5	1.0	1	3	4160	0.062
5	1.5	1	3	6568	0.109
5	2.0	1	3	7052	0.118
5	2.5	1	3	5932	0.096
5	3.0	1	3	5676	0.091
5	3.5	1	3	6184	0.101
5	4.0	1	3	6324	0.104
5	4.5	1	3	6628	0.110
5	5.0	1	3	6140	0.100
5	5.5	1	3	5916	0.096
5	0.5	1	4	964	0.001
5	1.0	1	4	4208	0.063
5	1.5	1	4	6612	0.110
5	2.0	1	4	7896	0.134
5	0.5	1	5	1060	0.002
5	1.0	1	5	6084	0.099
5	1.5	1	5	8332	0.143
5	2.0	1	5	7980	0.136
5	2.5	1	5	8052	0.137
5	3.0	1	5	8392	0.144
5	3.5	1	5	9720	0.169
5	4.0	1	5	9972	0.174
5	4.5	1	5	10644	0.187
5	5.0	1	5	8336	0.143
5	5.5	1	5	7524	0.127
5	6.0	1	5	6316	0.104
5	6.5	1	5	7716	0.131
5	7.0	1	5	9432	0.164
5	7.5	1	5	7572	0.128
5	8.0	1	5	5952	0.097
5	8.5	1	5	5564	0.089
5	9.0	1	5	5280	0.084
5	9.5	1	5	5280	0.084
5	10.0	1	5	5548	0.089
5	10.5	1	5	5440	0.087
5	11.0	1	5	5244	0.083
5	11.5	1	5	5536	0.089
5	12.0	1	5	5108	0.080
5	12.5	1	5	5256	0.083
5	13.0	1	5	5152	0.081
5	13.5	1	5	5576	0.090
5	14.0	1	5	5532	0.089

month	depth	zone	station	hp reading	moisture content
5	14.5	1	5	*	*
5	0.5	2	1	4528	0.069
5	1.0	2	1	6036	0.098
5	1.5	2	1	6868	0.114
5	2.0	2	1	7156	0.120
5	2.5	2	1	7000	0.117
5	3.0	2	1	5776	0.093
5	3.5	2	1	5092	0.080
5	4.0	2	1	6612	0.110
5	4.5	2	1	7232	0.121
5	5.0	2	1	6376	0.105
5	5.5	2	1	5016	0.079
5	6.0	2	1	4612	0.071
5	6.5	2	1	5584	0.090
5	0.5	2	2	7592	0.128
5	1.0	2	2	8064	0.138
5	1.5	2	2	9216	0.160
5	2.0	2	2	7904	0.134
5	2.5	2	2	6872	0.115
5	3.0	2	2	6424	0.106
5	3.5	2	2	7168	0.120
5	4.0	2	2	7244	0.122
5	4.5	2	2	6516	0.108
5	5.0	2	2	5796	0.094
5	5.5	2	2	5504	0.088
5	6.0	2	2	5596	0.090
5	6.5	2	2	6284	0.103
5	7.0	2	2	5944	0.097
5	7.5	2	2	6188	0.101
5	8.0	2	2	5936	0.096
5	8.5	2	2	6048	0.099
5	9.0	2	2	6132	0.100
5	9.5	2	2	5520	0.088
5	10.0	2	2	5120	0.081
5	10.5	2	2	4808	0.075
5	11.0	2	2	4444	0.068
5	11.5	2	2	4432	0.067
5	12.0	2	2	4344	0.066
5	12.5	2	2	4904	0.077
5	13.0	2	2	4724	0.073
5	13.5	2	2	4492	0.069
5	14.0	2	2	4936	0.077
5	14.5	2	2	5020	0.079
5	0.5	2	3	1212	0.005
5	1.0	2	3	4492	0.069
5	1.5	2	3	6116	0.100
5	2.0	2	3	6356	0.105
5	2.5	2	3	6288	0.103
5	3.0	2	3	5916	0.096
5	3.5	2	3	5724	0.092
5	4.0	2	3	5612	0.090
5	4.5	2	3	5368	0.086
5	5.0	2	3	5172	0.082
5	5.5	2	3	5348	0.085
5	6.0	2	3	5308	0.084
5	6.5	2	3	5216	0.083
5	7.0	2	3	5424	0.087
5	7.5	2	3	5156	0.081
5	8.0	2	3	5172	0.082
5	8.5	2	3	5320	0.085
5	9.0	2	3	5284	0.084
5	9.5	2	3	5400	0.086
5	10.0	2	3	5364	0.085

month	depth	zone	station	hp reading	moisture content
5	10.5	2	3	5252	0.083
5	11.0	2	3	5348	0.085
5	11.5	2	3	5700	0.092
5	12.0	2	3	6020	0.098
5	12.5	2	3	6388	0.105
5	0.5	2	4	1320	0.007
5	1.0	2	4	4272	0.064
5	1.5	2	4	5644	0.091
5	2.0	2	4	6596	0.109
5	2.5	2	4	6320	0.104
5	3.0	2	4	5956	0.097
5	3.5	2	4	6100	0.100
5	4.0	2	4	6100	0.100
5	4.5	2	4	5416	0.086
5	5.0	2	4	5396	0.086
5	5.5	2	4	5400	0.086
5	6.0	2	4	4996	0.078
5	6.5	2	4	5484	0.088
5	7.0	2	4	6168	0.101
5	0.5	2	5	2332	0.027
5	1.0	2	5	6392	0.105
5	1.5	2	5	7556	0.128
5	2.0	2	5	6232	0.102
5	2.5	2	5	6504	0.107
5	3.0	2	5	6952	0.116
5	3.5	2	5	7464	0.126
5	4.0	2	5	6896	0.115
5	4.5	2	5	6528	0.108
5	5.0	2	5	6096	0.100
5	5.5	2	5	6728	0.112
5	6.0	2	5	6856	0.114
5	6.5	2	5	6364	0.105
5	7.0	2	5	6492	0.107
5	7.5	2	5	5492	0.088
5	8.0	2	5	6060	0.099
5	8.5	2	5	5580	0.090
5	9.0	2	5	5340	0.085
5	9.5	2	5	5544	0.089
5	10.0	2	5	5972	0.097
5	10.5	2	5	6280	0.103
5	11.0	2	5	6476	0.107
5	11.5	2	5	6104	0.100
5	12.0	2	5	5660	0.091
5	12.5	2	5	6044	0.099
5	13.0	2	5	5420	0.087
5	13.5	2	5	5348	0.085
5	14.0	2	5	5164	0.082
5	14.5	2	5	5456	0.087
5	15.0	2	5	5464	0.087
5	0.5	3	1	1724	0.015
5	1.0	3	1	5040	0.079
5	1.5	3	1	6552	0.108
5	2.0	3	1	6428	0.106
5	2.5	3	1	5976	0.097
5	3.0	3	1	6612	0.110
5	3.5	3	1	6124	0.100
5	4.0	3	1	5400	0.086
5	4.5	3	1	5648	0.091
5	5.0	3	1	5516	0.088
5	5.5	3	1	5456	0.087
5	6.0	3	1	5480	0.088
5	6.5	3	1	5572	0.089
5	7.0	3	1	5496	0.088

month	depth	zone	station	hp reading	moisture content
5	7.5	3	1	5676	0.091
5	8.0	3	1	5816	0.094
5	8.5	3	1	5320	0.085
5	9.0	3	1	5448	0.087
5	9.5	3	1	5904	0.096
5	10.0	3	1	6212	0.102
5	10.5	3	1	6476	0.107
5	11.0	3	1	7628	0.129
5	0.5	3	2	2880	0.037
5	1.0	3	2	6104	0.100
5	1.5	3	2	6768	0.113
5	2.0	3	2	6992	0.117
5	2.5	3	2	6812	0.113
5	3.0	3	2	7160	0.120
5	3.5	3	2	7568	0.128
5	4.0	3	2	7428	0.125
5	4.5	3	2	7032	0.118
5	5.0	3	2	6556	0.108
5	5.5	3	2	6640	0.110
5	6.0	3	2	6248	0.102
5	6.5	3	2	6740	0.112
5	7.0	3	2	6408	0.106
5	7.5	3	2	5792	0.094
5	8.0	3	2	5872	0.095
5	8.5	3	2	6028	0.098
5	9.0	3	2	6296	0.103
5	9.5	3	2	6652	0.110
5	10.0	3	2	6980	0.117
5	10.5	3	2	7480	0.126
5	11.0	3	2	6984	0.117
5	11.5	3	2	6660	0.110
5	12.0	3	2	6740	0.112
5	12.5	3	2	6444	0.106
5	13.0	3	2	6856	0.114
5	13.5	3	2	7112	0.119
5	14.0	3	2	6872	0.115
5	14.5	3	2	6480	0.107
5	15.0	3	2	6278	0.103
5	0.5	3	3	2276	0.026
5	1.0	3	3	4440	0.068
5	1.5	3	3	6444	0.106
5	2.0	3	3	6292	0.103
5	2.5	3	3	6200	0.102
5	3.0	3	3	6108	0.100
5	3.5	3	3	5756	0.093
5	4.0	3	3	5612	0.090
5	4.5	3	3	5408	0.086
5	5.0	3	3	5476	0.088
5	5.5	3	3	6120	0.100
5	6.0	3	3	6152	0.101
5	6.5	3	3	6296	0.103
5	7.0	3	3	6772	0.113
5	7.5	3	3	6484	0.107
5	8.0	3	3	5912	0.096
5	8.5	3	3	5740	0.093
5	9.0	3	3	5792	0.094
5	9.5	3	3	5644	0.091
5	10.0	3	3	5664	0.091
5	10.5	3	3	5908	0.096
5	11.0	3	3	6000	0.098
5	11.5	3	3	5532	0.089
5	12.0	3	3	5784	0.094
5	12.5	3	3	6428	0.106

month	depth	zone	station	hp reading	moisture content
5	13.0	3	3	5868	0.095
5	13.5	3	3	5956	0.097
5	14.0	3	3	5868	0.095
5	14.5	3	3	5692	0.092
5	15.0	3	3	5740	0.093
5	0.5	3	4	1360	0.008
5	1.0	3	4	4516	0.069
5	1.5	3	4	6636	0.110
5	2.0	3	4	7528	0.127
5	2.5	3	4	7076	0.118
5	3.0	3	4	6916	0.115
5	3.5	3	4	7136	0.120
5	4.0	3	4	7076	0.118
5	4.5	3	4	6492	0.107
5	5.0	3	4	6220	0.102
5	5.5	3	4	6288	0.103
5	6.0	3	4	6508	0.108
5	6.5	3	4	5936	0.096
5	7.0	3	4	5408	0.086
5	7.5	3	4	5080	0.080
5	8.0	3	4	5168	0.082
5	8.5	3	4	5128	0.081
5	9.0	3	4	4908	0.077
5	9.5	3	4	5436	0.087
5	10.0	3	4	5520	0.088
5	10.5	3	4	5504	0.088
5	11.0	3	4	5302	0.084
5	11.5	3	4	5404	0.086
5	12.0	3	4	5648	0.091
5	12.5	3	4	5268	0.084
5	13.0	3	4	5392	0.086
5	13.5	3	4	5564	0.089
5	14.0	3	4	6624	0.110
5	14.5	3	4	7708	0.131
5	15.0	3	4	7436	0.125
5	0.5	3	5	3044	0.041
5	1.0	3	5	9716	0.169
5	1.5	3	5	9540	0.166
5	2.0	3	5	9354	0.162
5	2.5	3	5	9904	0.173
5	3.0	3	5	11028	0.195
5	3.5	3	5	11136	0.197
5	4.0	3	5	8052	0.137
5	4.5	3	5	6780	0.113
5	5.0	3	5	6740	0.112
5	5.5	3	5	6652	0.110
5	6.0	3	5	7284	0.122
5	6.5	3	5	7880	0.134
5	7.0	3	5	7608	0.129
5	7.5	3	5	7608	0.129
5	8.0	3	5	7136	0.120
5	8.5	3	5	7172	0.120
5	9.0	3	5	7384	0.124
5	9.5	3	5	7652	0.130
5	10.0	3	5	7844	0.133
5	10.5	3	5	7376	0.124
5	11.0	3	5	6840	0.114
5	11.5	3	5	6452	0.106
5	12.0	3	5	5968	0.097
5	12.5	3	5	6884	0.115
5	13.0	3	5	10396	0.183
5	13.5	3	5	14668	0.265
5	14.0	3	5	13052	0.234

month	depth	zone	station	hp reading	moisture content
5	14.5	3	5	8908	0.154
5	15.0	3	5	8492	0.146
5	0.5	4	1	4792	0.074
5	1.0	4	1	6092	0.099
5	1.5	4	1	7580	0.128
5	2.0	4	1	7588	0.128
5	2.5	4	1	7216	0.121
5	3.0	4	1	7016	0.117
5	3.5	4	1	6480	0.107
5	4.0	4	1	5964	0.097
5	4.5	4	1	6052	0.099
5	5.0	4	1	6160	0.101
5	5.5	4	1	6048	0.099
5	6.0	4	1	6208	0.102
5	6.5	4	1	6156	0.101
5	7.0	4	1	6408	0.106
5	7.5	4	1	6308	0.104
5	8.0	4	1	5844	0.095
5	8.5	4	1	5884	0.095
5	9.0	4	1	5980	0.097
5	9.5	4	1	5860	0.095
5	10.0	4	1	6108	0.100
5	10.5	4	1	5744	0.093
5	11.0	4	1	5540	0.089
5	11.5	4	1	5900	0.096
5	12.0	4	1	5748	0.093
5	12.5	4	1	5660	0.091
5	13.0	4	1	6792	0.113
5	13.5	4	1	*	#VALUE!
5	0.5	4	2	4872	0.076
5	1.0	4	2	7088	0.119
5	1.5	4	2	7324	0.123
5	2.0	4	2	7496	0.127
5	2.5	4	2	8648	0.149
5	3.0	4	2	8356	0.143
5	3.5	4	2	8668	0.149
5	4.0	4	2	8152	0.139
5	4.5	4	2	8788	0.152
5	5.0	4	2	9000	0.156
5	5.5	4	2	9184	0.159
5	6.0	4	2	8388	0.144
5	6.5	4	2	9008	0.156
5	7.0	4	2	9540	0.166
5	7.5	4	2	9576	0.167
5	8.0	4	2	9676	0.169
5	8.5	4	2	10108	0.177
5	9.0	4	2	11592	0.206
5	9.5	4	2	11496	0.204
5	10.0	4	2	10924	0.193
5	10.5	4	2	12176	0.217
5	11.0	4	2	13044	0.234
5	11.5	4	2	11112	0.196
5	12.0	4	2	8316	0.142
5	12.5	4	2	7592	0.128
5	13.0	4	2	6760	0.112
5	13.5	4	2	6516	0.108
5	14.0	4	2	6836	0.114
5	14.5	4	2	7376	0.124
5	0.5	4	3	1792	0.016
5	1.0	4	3	7060	0.118
5	1.5	4	3	9348	0.162
5	2.0	4	3	10152	0.178
5	2.5	4	3	7824	0.133

month	depth	zone	station	hp reading	moisture content
5	3.0	4	3	7392	0.125
5	3.5	4	3	6704	0.111
5	4.0	4	3	7644	0.129
5	4.5	4	3	7876	0.134
5	5.0	4	3	7756	0.132
5	5.5	4	3	8600	0.148
5	6.0	4	3	8904	0.154
5	6.5	4	3	8116	0.139
5	7.0	4	3	7068	0.118
5	7.5	4	3	6968	0.116
5	8.0	4	3	6680	0.111
5	8.5	4	3	6748	0.112
5	9.0	4	3	6684	0.111
5	9.5	4	3	6788	0.113
5	10.0	4	3	6112	0.100
5	10.5	4	3	6572	0.109
5	11.0	4	3	6968	0.116
5	11.5	4	3	7480	0.126
5	12.0	4	3	8008	0.136
5	12.5	4	3	7332	0.123
5	13.0	4	3	7024	0.117
5	13.5	4	3	6316	0.104
5	14.0	4	3	6120	0.100
5	14.5	4	3	7004	0.117
5	15.0	4	3	7440	0.125
5	0.5	4	4	2008	0.021
5	1.0	4	4	5800	0.094
5	1.5	4	4	8368	0.143
5	2.0	4	4	8792	0.152
5	2.5	4	4	7280	0.122
5	3.0	4	4	6964	0.116
5	3.5	4	4	6796	0.113
5	4.0	4	4	6864	0.114
5	4.5	4	4	6312	0.104
5	5.0	4	4	6184	0.101
5	5.5	4	4	6808	0.113
5	6.0	4	4	7720	0.131
5	6.5	4	4	9304	0.161
5	7.0	4	4	6468	0.107
5	7.5	4	4	4388	0.067
5	8.0	4	4	4028	0.060
5	8.5	4	4	3892	0.057
5	9.0	4	4	4472	0.068
5	9.5	4	4	5384	0.086
5	10.0	4	4	5472	0.088
5	10.5	4	4	5368	0.086
5	11.0	4	4	5224	0.083
5	11.5	4	4	5332	0.085
5	12.0	4	4	6576	0.109
5	12.5	4	4	8308	0.142
5	13.0	4	4	8296	0.142
5	13.5	4	4	8676	0.149
5	14.0	4	4	11540	0.205
5	14.5	4	4	14872	0.269
5	15.0	4	4	15748	0.286
5	0.5	4	5	4012	0.059
5	1.0	4	5	6248	0.102
5	1.5	4	5	6368	0.105
5	2.0	4	5	6228	0.102
5	2.5	4	5	6604	0.109
5	3.0	4	5	7688	0.130
5	3.5	4	5	9520	0.166
5	4.0	4	5	10790	0.190

month	depth	zone	station	hp reading	moisture content
5	4.5	4	5	10924	0.193
5	5.0	4	5	9092	0.157
5	5.5	4	5	9728	0.170
5	6.0	4	5	9096	0.157
5	6.5	4	5	6720	0.112
5	7.0	4	5	6080	0.099
5	7.5	4	5	5936	0.096
5	8.0	4	5	5616	0.090
5	8.5	4	5	8060	0.137
5	9.0	4	5	8800	0.152
5	9.5	4	5	7652	0.130
5	10.0	4	5	8636	0.149
5	10.5	4	5	9148	0.158
5	11.0	4	5	8324	0.143
5	11.5	4	5	8828	0.152
5	12.0	4	5	10260	0.180
5	12.5	4	5	8936	0.154
5	13.0	4	5	10260	0.180
5	13.5	4	5	9680	0.169
5	14.0	4	5	9404	0.163
5	14.5	4	5	8868	0.153
5	15.0	4	5	9064	0.157
6	0.5	1	1	1720	0.015
6	1.0	1	1	4364	0.066
6	1.5	1	1	6028	0.098
6	2.0	1	1	6260	0.103
6	2.5	1	1	6180	0.101
6	3.0	1	1	5720	0.092
6	3.5	1	1	6660	0.110
6	4.0	1	1	7724	0.131
6	4.5	1	1	8216	0.140
6	0.5	1	2	1680	0.014
6	1.0	1	2	6072	0.099
6	1.5	1	2	7260	0.122
6	2.0	1	2	7128	0.119
6	2.5	1	2	1760	0.016
6	3.0	1	2	6596	0.109
6	3.5	1	2	6532	0.108
6	4.0	1	2	6388	0.105
6	4.5	1	2	6620	0.110
6	5.0	1	2	6528	0.108
6	5.5	1	2	6316	0.104
6	6.0	1	2	6100	0.100
6	6.5	1	2	6024	0.098
6	7.0	1	2	6336	0.104
6	7.5	1	2	6060	0.099
6	8.0	1	2	6200	0.102
6	8.5	1	2	6332	0.104
6	9.0	1	2	6724	0.112
6	9.5	1	2	8400	0.144
6	10.0	1	2	10308	0.181
6	0.5	1	3	652	-0.006
6	1.0	1	3	2420	0.029
6	1.5	1	3	4652	0.072
6	2.0	1	3	5900	0.096
6	2.5	1	3	5916	0.096
6	3.0	1	3	5648	0.091
6	3.5	1	3	6068	0.099
6	4.0	1	3	6684	0.111
6	4.5	1	3	6692	0.111
6	5.0	1	3	6544	0.108
6	5.5	1	3	6168	0.101
6	0.5	1	4	824	-0.002

month	depth	zone	station	hp reading	moisture content
6	1.0	1	4	2920	0.038
6	1.5	1	4	5100	0.080
6	2.0	1	4	6720	0.112
6	0.5	1	5	1220	0.005
6	1.0	1	5	5172	0.082
6	1.5	1	5	7748	0.131
6	2.0	1	5	6992	0.117
6	2.5	1	5	7296	0.123
6	3.0	1	5	7680	0.130
6	3.5	1	5	9044	0.156
6	4.0	1	5	9616	0.167
6	4.5	1	5	10500	0.185
6	5.0	1	5	8308	0.142
6	5.5	1	5	7216	0.121
6	6.0	1	5	6172	0.101
6	6.5	1	5	7176	0.120
6	7.0	1	5	9560	0.166
6	7.5	1	5	8444	0.145
6	8.0	1	5	6236	0.102
6	8.5	1	5	5896	0.096
6	9.0	1	5	6316	0.104
6	9.5	1	5	6172	0.101
6	10.0	1	5	6016	0.098
6	10.5	1	5	6280	0.103
6	11.0	1	5	6188	0.101
6	11.5	1	5	5996	0.098
6	12.0	1	5	5840	0.095
6	12.5	1	5	5916	0.096
6	13.0	1	5	5844	0.095
6	13.5	1	5	5656	0.091
6	14.0	1	5	5652	0.091
6	14.5	1	5	5756	0.093
6	0.5	2	1	1980	0.020
6	1.0	2	1	4124	0.061
6	1.5	2	1	5876	0.095
6	2.0	2	1	6444	0.106
6	2.5	2	1	6596	0.109
6	3.0	2	1	5644	0.091
6	3.5	2	1	5376	0.086
6	4.0	2	1	6740	0.112
6	4.5	2	1	7312	0.123
6	5.0	2	1	6212	0.102
6	5.5	2	1	5424	0.087
6	6.0	2	1	4740	0.073
6	6.5	2	1	5992	0.098
6	0.5	2	2	6988	0.117
6	1.0	2	2	7964	0.136
6	1.5	2	2	8592	0.148
6	2.0	2	2	7884	0.134
6	2.5	2	2	6744	0.112
6	3.0	2	2	6612	0.110
6	3.5	2	2	7340	0.124
6	4.0	2	2	7072	0.118
6	4.5	2	2	6888	0.115
6	5.0	2	2	6172	0.101
6	5.5	2	2	5784	0.094
6	6.0	2	2	5380	0.086
6	6.5	2	2	6384	0.105
6	7.0	2	2	6152	0.101
6	7.5	2	2	6356	0.105
6	8.0	2	2	5916	0.096
6	8.5	2	2	5692	0.092
6	9.0	2	2	6180	0.101

month	depth	zone	station	hp reading	moisture content
6	9.5	2	2	5532	0.089
6	10.0	2	2	5128	0.081
6	10.5	2	2	4796	0.074
6	11.0	2	2	4848	0.075
6	11.5	2	2	4268	0.064
6	12.0	2	2	4684	0.072
6	12.5	2	2	5264	0.083
6	13.0	2	2	5204	0.082
6	13.5	2	2	4572	0.070
6	14.0	2	2	4872	0.076
6	14.5	2	2	5028	0.079
6	0.5	2	3	1192	0.005
6	1.0	2	3	4348	0.066
6	1.5	2	3	5884	0.095
6	2.0	2	3	6428	0.106
6	2.5	2	3	6156	0.101
6	3.0	2	3	6060	0.099
6	3.5	2	3	6064	0.099
6	4.0	2	3	5764	0.093
6	4.5	2	3	5556	0.089
6	5.0	2	3	5396	0.086
6	5.5	2	3	5528	0.089
6	6.0	2	3	5448	0.087
6	6.5	2	3	5720	0.092
6	7.0	2	3	5524	0.089
6	7.5	2	3	5420	0.087
6	8.0	2	3	5584	0.090
6	8.5	2	3	5268	0.084
6	9.0	2	3	5440	0.087
6	9.5	2	3	5316	0.084
6	10.0	2	3	5296	0.084
6	10.5	2	3	5540	0.089
6	11.0	2	3	5388	0.086
6	11.5	2	3	5684	0.092
6	12.0	2	3	5676	0.091
6	12.5	2	3	6728	0.112
6	0.5	2	4	596	-0.007
6	1.0	2	4	2156	0.024
6	1.5	2	4	3360	0.047
6	2.0	2	4	4564	0.070
6	2.5	2	4	5496	0.088
6	3.0	2	4	5072	0.080
6	3.5	2	4	5992	0.098
6	4.0	2	4	5972	0.097
6	4.5	2	4	6104	0.100
6	5.0	2	4	5692	0.092
6	5.5	2	4	5556	0.089
6	6.0	2	4	5604	0.090
6	6.5	2	4	5592	0.090
6	7.0	2	4	6316	0.104
6	0.5	2	5	2360	0.027
6	1.0	2	5	6456	0.107
6	1.5	2	5	7416	0.125
6	2.0	2	5	6012	0.098
6	2.5	2	5	6384	0.105
6	3.0	2	5	6804	0.113
6	3.5	2	5	7048	0.118
6	4.0	2	5	6964	0.116
6	4.5	2	5	6580	0.109
6	5.0	2	5	6240	0.102
6	5.5	2	5	6956	0.116
6	6.0	2	5	6816	0.113
6	6.5	2	5	6336	0.104

month	depth	zone	station	hp reading	moisture content
6	7.0	2	5	6292	0.103
6	7.5	2	5	5812	0.094
6	8.0	2	5	5580	0.090
6	8.5	2	5	5740	0.093
6	9.0	2	5	5368	0.086
6	9.5	2	5	5624	0.090
6	10.0	2	5	5956	0.097
6	10.5	2	5	6292	0.103
6	11.0	2	5	6236	0.102
6	11.5	2	5	5948	0.097
6	12.0	2	5	5628	0.091
6	12.5	2	5	6104	0.100
6	13.0	2	5	5260	0.083
6	13.5	2	5	5444	0.087
6	14.0	2	5	5200	0.082
6	14.5	2	5	5468	0.087
6	15.0	2	5	5172	0.082
6	0.5	3	1	1380	0.009
6	1.0	3	1	3532	0.050
6	1.5	3	1	5812	0.094
6	2.0	3	1	6356	0.105
6	2.5	3	1	6220	0.102
6	3.0	3	1	6660	0.110
6	3.5	3	1	5756	0.093
6	4.0	3	1	5428	0.087
6	4.5	3	1	5796	0.094
6	5.0	3	1	5312	0.084
6	5.5	3	1	5316	0.084
6	6.0	3	1	5124	0.081
6	6.5	3	1	5548	0.089
6	7.0	3	1	5472	0.088
6	7.5	3	1	5692	0.092
6	8.0	3	1	5700	0.092
6	8.5	3	1	5556	0.089
6	9.0	3	1	5740	0.093
6	9.5	3	1	6156	0.101
6	10.0	3	1	6152	0.101
6	10.5	3	1	6580	0.109
6	11.0	3	1	7380	0.124
6	0.5	3	2	3000	0.040
6	1.0	3	2	5288	0.084
6	1.5	3	2	6548	0.108
6	2.0	3	2	6296	0.103
6	2.5	3	2	6496	0.107
6	3.0	3	2	6936	0.116
6	3.5	3	2	7272	0.122
6	4.0	3	2	7296	0.123
6	4.5	3	2	6848	0.114
6	5.0	3	2	6360	0.105
6	5.5	3	2	6612	0.110
6	6.0	3	2	6436	0.106
6	6.5	3	2	6836	0.114
6	7.0	3	2	6444	0.106
6	7.5	3	2	5928	0.096
6	8.0	3	2	5872	0.095
6	8.5	3	2	6144	0.100
6	9.0	3	2	6264	0.103
6	9.5	3	2	6552	0.108
6	10.0	3	2	6736	0.112
6	10.5	3	2	7712	0.131
6	11.0	3	2	6836	0.114
6	11.5	3	2	6660	0.110
6	12.0	3	2	6772	0.113

month	depth	zone	station	hp reading	moisture content
6	12.5	3	2	6316	0.104
6	13.0	3	2	6708	0.111
6	13.5	3	2	7140	0.120
6	14.0	3	2	7156	0.120
6	14.5	3	2	6212	0.102
6	15.0	3	2	6328	0.104
6	0.5	3	3	1468	0.010
6	1.0	3	3	2780	0.036
6	1.5	3	3	4064	0.060
6	2.0	3	3	4988	0.078
6	2.5	3	3	4948	0.077
6	3.0	3	3	4780	0.074
6	3.5	3	3	4988	0.078
6	4.0	3	3	4932	0.077
6	4.5	3	3	4896	0.076
6	5.0	3	3	5252	0.083
6	5.5	3	3	5728	0.092
6	6.0	3	3	6288	0.103
6	6.5	3	3	6232	0.102
6	7.0	3	3	6760	0.112
6	7.5	3	3	6196	0.101
6	8.0	3	3	5620	0.090
6	8.5	3	3	5560	0.089
6	9.0	3	3	5468	0.087
6	9.5	3	3	5620	0.090
6	10.0	3	3	5872	0.095
6	10.5	3	3	6092	0.099
6	11.0	3	3	6164	0.101
6	11.5	3	3	5840	0.095
6	12.0	3	3	5740	0.093
6	12.5	3	3	5872	0.095
6	13.0	3	3	6140	0.100
6	13.5	3	3	5892	0.096
6	14.0	3	3	5912	0.096
6	14.5	3	3	5768	0.093
6	15.0	3	3	6040	0.098
6	0.5	3	4	1428	0.009
6	1.0	3	4	3500	0.049
6	1.5	3	4	6144	0.100
6	2.0	3	4	7140	0.120
6	2.5	3	4	7148	0.120
6	3.0	3	4	7164	0.120
6	3.5	3	4	7288	0.123
6	4.0	3	4	7684	0.130
6	4.5	3	4	7100	0.119
6	5.0	3	4	6648	0.110
6	5.5	3	4	7180	0.120
6	6.0	3	4	6776	0.113
6	6.5	3	4	6372	0.105
6	7.0	3	4	5912	0.096
6	7.5	3	4	5888	0.096
6	8.0	3	4	5780	0.093
6	8.5	3	4	6036	0.098
6	9.0	3	4	5700	0.092
6	9.5	3	4	5408	0.086
6	10.0	3	4	5812	0.094
6	10.5	3	4	5732	0.093
6	11.0	3	4	5524	0.089
6	11.5	3	4	5728	0.092
6	12.0	3	4	5432	0.087
6	12.5	3	4	5592	0.090
6	13.0	3	4	5464	0.087
6	13.5	3	4	5576	0.090

month	depth	zone	station	hp reading	moisture content
6	14.0	3	4	6572	0.109
6	14.5	3	4	7572	0.128
6	15.0	3	4	7396	0.125
6	0.5	3	5	3928	0.058
6	1.0	3	5	9244	0.160
6	1.5	3	5	9804	0.171
6	2.0	3	5	9424	0.164
6	2.5	3	5	10132	0.177
6	3.0	3	5	11256	0.199
6	3.5	3	5	11528	0.204
6	4.0	3	5	8476	0.145
6	4.5	3	5	6848	0.114
6	5.0	3	5	6720	0.112
6	5.5	3	5	7028	0.118
6	6.0	3	5	7432	0.125
6	6.5	3	5	7732	0.131
6	7.0	3	5	7936	0.135
6	7.5	3	5	7356	0.124
6	8.0	3	5	6792	0.113
6	8.5	3	5	6932	0.116
6	9.0	3	5	7648	0.130
6	9.5	3	5	7676	0.130
6	10.0	3	5	8200	0.140
6	10.5	3	5	6972	0.116
6	11.0	3	5	6928	0.116
6	11.5	3	5	6700	0.111
6	12.0	3	5	6292	0.103
6	12.5	3	5	6784	0.113
6	13.0	3	5	10572	0.186
6	13.5	3	5	14472	0.261
6	14.0	3	5	12772	0.228
6	14.5	3	5	9176	0.159
6	15.0	3	5	8404	0.144
6	0.5	4	1	4112	0.061
6	1.0	4	1	6160	0.101
6	1.5	4	1	6992	0.117
6	2.0	4	1	7696	0.130
6	2.5	4	1	7320	0.123
6	3.0	4	1	7024	0.117
6	3.5	4	1	6656	0.110
6	4.0	4	1	6232	0.102
6	4.5	4	1	6208	0.102
6	5.0	4	1	5960	0.097
6	5.5	4	1	6332	0.104
6	6.0	4	1	6520	0.108
6	6.5	4	1	6124	0.100
6	7.0	4	1	6320	0.104
6	7.5	4	1	6400	0.105
6	8.0	4	1	5888	0.096
6	8.5	4	1	5636	0.091
6	9.0	4	1	6000	0.098
6	9.5	4	1	5744	0.093
6	10.0	4	1	5828	0.094
6	10.5	4	1	5760	0.093
6	11.0	4	1	5660	0.091
6	11.5	4	1	5928	0.096
6	12.0	4	1	5620	0.090
6	12.5	4	1	5540	0.089
6	13.0	4	1	6452	0.106
6	13.5	4	1	6892	0.115
6	0.5	4	2	3528	0.050
6	1.0	4	2	5996	0.098
6	1.5	4	2	6240	0.102

month	depth	zone	station	hp reading	moisture content
6	2.0	4	2	6756	0.112
6	2.5	4	2	7664	0.130
6	3.0	4	2	7968	0.136
6	3.5	4	2	8120	0.139
6	4.0	4	2	8316	0.142
6	4.5	4	2	8364	0.143
6	5.0	4	2	8932	0.154
6	5.5	4	2	9048	0.157
6	6.0	4	2	8692	0.150
6	6.5	4	2	8976	0.155
6	7.0	4	2	9648	0.168
6	7.5	4	2	10032	0.176
6	8.0	4	2	9524	0.166
6	8.5	4	2	9928	0.174
6	9.0	4	2	11500	0.204
6	9.5	4	2	11072	0.196
6	10.0	4	2	11084	0.196
6	10.5	4	2	12324	0.220
6	11.0	4	2	12216	0.218
6	11.5	4	2	10972	0.194
6	12.0	4	2	8460	0.145
6	12.5	4	2	7280	0.122
6	13.0	4	2	6996	0.117
6	13.5	4	2	6880	0.115
6	14.0	4	2	7100	0.119
6	14.5	4	2	7384	0.124
6	0.5	4	3	1928	0.019
6	1.0	4	3	6276	0.103
6	1.5	4	3	8632	0.148
6	2.0	4	3	9380	0.163
6	2.5	4	3	7080	0.119
6	3.0	4	3	5864	0.095
6	3.5	4	3	5488	0.088
6	4.0	4	3	6132	0.100
6	4.5	4	3	6176	0.101
6	5.0	4	3	6084	0.099
6	5.5	4	3	7624	0.129
6	6.0	4	3	8596	0.148
6	6.5	4	3	7632	0.129
6	7.0	4	3	6408	0.106
6	7.5	4	3	6308	0.104
6	8.0	4	3	6352	0.104
6	8.5	4	3	6668	0.111
6	9.0	4	3	6600	0.109
6	9.5	4	3	6500	0.107
6	10.0	4	3	6196	0.101
6	10.5	4	3	6620	0.110
6	11.0	4	3	7144	0.120
6	11.5	4	3	7516	0.127
6	12.0	4	3	7912	0.135
6	12.5	4	3	7968	0.136
6	13.0	4	3	7040	0.118
6	13.5	4	3	6408	0.106
6	14.0	4	3	6296	0.103
6	14.5	4	3	6684	0.111
6	15.0	4	3	7436	0.125
6	0.5	4	4	1900	0.019
6	1.0	4	4	5376	0.086
6	1.5	4	4	8616	0.148
6	2.0	4	4	9344	0.162
6	2.5	4	4	7664	0.130
6	3.0	4	4	7120	0.119
6	3.5	4	4	6976	0.117

month	depth	zone	station	hp reading	moisture content
6	4.0	4	4	7152	0.120
6	4.5	4	4	6640	0.110
6	5.0	4	4	6336	0.104
6	5.5	4	4	6800	0.113
6	6.0	4	4	7552	0.128
6	6.5	4	4	9536	0.166
6	7.0	4	4	6768	0.113
6	7.5	4	4	4272	0.064
6	8.0	4	4	4208	0.063
6	8.5	4	4	4272	0.064
6	9.0	4	4	4928	0.077
6	9.5	4	4	5008	0.079
6	10.0	4	4	5520	0.088
6	10.5	4	4	5728	0.092
6	11.0	4	4	4864	0.076
6	11.5	4	4	5408	0.086
6	12.0	4	4	7024	0.117
6	12.5	4	4	7584	0.128
6	13.0	4	4	8368	0.143
6	13.5	4	4	9280	0.161
6	14.0	4	4	11040	0.195
6	14.5	4	4	14704	0.266
6	15.0	4	4	15536	0.282
6	0.5	4	5	2552	0.031
6	1.0	4	5	4976	0.078
6	1.5	4	5	5808	0.094
6	2.0	4	5	5568	0.089
6	2.5	4	5	5756	0.093
6	3.0	4	5	7160	0.120
6	3.5	4	5	9684	0.169
6	4.0	4	5	10160	0.178
6	4.5	4	5	10508	0.185
6	5.0	4	5	8776	0.151
6	5.5	4	5	9392	0.163
6	6.0	4	5	8680	0.149
6	6.5	4	5	5996	0.098
6	7.0	4	5	5468	0.087
6	7.5	4	5	5668	0.091
6	8.0	4	5	5564	0.089
6	8.5	4	5	8488	0.146
6	9.0	4	5	8712	0.150
6	9.5	4	5	7644	0.129
6	10.0	4	5	8304	0.142
6	10.5	4	5	9500	0.165
6	11.0	4	5	8572	0.147
6	11.5	4	5	9204	0.160
6	12.0	4	5	9404	0.163
6	12.5	4	5	8788	0.152
6	13.0	4	5	10480	0.184
6	13.5	4	5	9836	0.172
6	14.0	4	5	8968	0.155
6	14.5	4	5	8880	0.153
6	15.0	4	5	9068	0.157
7	0.5	1	1	1656	0.014
7	1.0	1	1	4480	0.068
7	1.5	1	1	5892	0.096
7	2.0	1	1	5872	0.095
7	2.5	1	1	5704	0.092
7	3.0	1	1	5708	0.092
7	3.5	1	1	6348	0.104
7	4.0	1	1	7320	0.123
7	4.5	1	1	8536	0.147
7	0.5	1	2	1288	0.007

month	depth	zone	station	hp reading	moisture content
7	1.0	1	2	6136	0.100
7	1.5	1	2	7332	0.123
7	2.0	1	2	7264	0.122
7	2.5	1	2	7068	0.118
7	3.0	1	2	6736	0.112
7	3.5	1	2	6512	0.108
7	4.0	1	2	6428	0.106
7	4.5	1	2	6548	0.108
7	5.0	1	2	5980	0.097
7	5.5	1	2	6300	0.103
7	6.0	1	2	6092	0.099
7	6.5	1	2	5768	0.093
7	7.0	1	2	6000	0.098
7	7.5	1	2	5616	0.090
7	8.0	1	2	6032	0.098
7	8.5	1	2	6464	0.107
7	9.0	1	2	6772	0.113
7	9.5	1	2	8236	0.141
7	10.0	1	2	11088	0.196
7	0.5	1	3	428	-0.010
7	1.0	1	3	2292	0.026
7	1.5	1	3	4512	0.069
7	2.0	1	3	5828	0.094
7	2.5	1	3	5704	0.092
7	3.0	1	3	5688	0.092
7	3.5	1	3	5752	0.093
7	4.0	1	3	6564	0.109
7	4.5	1	3	6836	0.114
7	5.0	1	3	6164	0.101
7	5.5	1	3	6288	0.103
7	0.5	1	4	704	-0.005
7	1.0	1	4	2428	0.029
7	1.5	1	4	4784	0.074
7	2.0	1	4	*	#VALUE!
7	0.5	1	5	1192	0.005
7	1.0	1	5	5248	0.083
7	1.5	1	5	7748	0.131
7	2.0	1	5	7476	0.126
7	2.5	1	5	7316	0.123
7	3.0	1	5	7804	0.133
7	3.5	1	5	8820	0.152
7	4.0	1	5	9260	0.161
7	4.5	1	5	10216	0.179
7	5.0	1	5	8348	0.143
7	5.5	1	5	6976	0.117
7	6.0	1	5	6156	0.101
7	6.5	1	5	7924	0.135
7	7.0	1	5	9772	0.170
7	7.5	1	5	7704	0.131
7	8.0	1	5	5960	0.097
7	8.5	1	5	5892	0.096
7	9.0	1	5	6016	0.098
7	9.5	1	5	6056	0.099
7	10.0	1	5	6072	0.099
7	10.5	1	5	6120	0.100
7	11.0	1	5	6084	0.099
7	11.5	1	5	5104	0.080
7	12.0	1	5	5896	0.096
7	12.5	1	5	5796	0.094
7	13.0	1	5	5788	0.094
7	13.5	1	5	5964	0.097
7	14.0	1	5	5844	0.095
7	14.5	1	5	6072	0.099

month	depth	zone	station	hp reading	moisture content
7	0.5	2	1	1840	0.017
7	1.0	2	1	3644	0.052
7	1.5	2	1	5420	0.087
7	2.0	2	1	6104	0.100
7	2.5	2	1	6048	0.099
7	3.0	2	1	5504	0.088
7	3.5	2	1	5172	0.082
7	4.0	2	1	6956	0.116
7	4.5	2	1	6524	0.108
7	5.0	2	1	5572	0.089
7	5.5	2	1	4476	0.068
7	6.0	2	1	5212	0.082
7	6.5	2	1	5792	0.094
7	0.5	2	2	7016	0.117
7	1.0	2	2	8136	0.139
7	1.5	2	2	8572	0.147
7	2.0	2	2	7900	0.134
7	2.5	2	2	6692	0.111
7	3.0	2	2	6648	0.110
7	3.5	2	2	6988	0.117
7	4.0	2	2	7032	0.118
7	4.5	2	2	6648	0.110
7	5.0	2	2	5928	0.096
7	5.5	2	2	5660	0.091
7	6.0	2	2	5380	0.086
7	6.5	2	2	6100	0.100
7	7.0	2	2	6620	0.110
7	7.5	2	2	6052	0.099
7	8.0	2	2	6048	0.099
7	8.5	2	2	6132	0.100
7	9.0	2	2	6280	0.103
7	9.5	2	2	5624	0.090
7	10.0	2	2	4784	0.074
7	10.5	2	2	5148	0.081
7	11.0	2	2	4184	0.063
7	11.5	2	2	4460	0.068
7	12.0	2	2	4636	0.071
7	12.5	2	2	5104	0.080
7	13.0	2	2	5016	0.079
7	13.5	2	2	4812	0.075
7	14.0	2	2	4948	0.077
7	14.5	2	2	4940	0.077
7	0.5	2	3	1220	0.005
7	1.0	2	3	4156	0.062
7	1.5	2	3	6028	0.098
7	2.0	2	3	6240	0.102
7	2.5	2	3	6344	0.104
7	3.0	2	3	6092	0.099
7	3.5	2	3	6216	0.102
7	4.0	2	3	6228	0.102
7	4.5	2	3	5804	0.094
7	5.0	2	3	5676	0.091
7	5.5	2	3	5544	0.089
7	6.0	2	3	5712	0.092
7	6.5	2	3	5620	0.090
7	7.0	2	3	5524	0.089
7	7.5	2	3	5608	0.090
7	8.0	2	3	5460	0.087
7	8.5	2	3	5560	0.089
7	9.0	2	3	5400	0.086
7	9.5	2	3	5388	0.086
7	10.0	2	3	5236	0.083
7	10.5	2	3	5292	0.084

month	depth	zone	station	hp reading	moisture content
7	11.0	2	3	5688	0.092
7	11.5	2	3	5468	0.087
7	12.0	2	3	5540	0.089
7	12.5	2	3	6588	0.109
7	0.5	2	4	616	-0.006
7	1.0	2	4	1788	0.016
7	1.5	2	4	3264	0.045
7	2.0	2	4	4700	0.073
7	2.5	2	4	4964	0.078
7	3.0	2	4	5092	0.080
7	3.5	2	4	5648	0.091
7	4.0	2	4	5876	0.095
7	4.5	2	4	5440	0.087
7	5.0	2	4	5432	0.087
7	5.5	2	4	5408	0.086
7	6.0	2	4	5476	0.088
7	6.5	2	4	6208	0.102
7	7.0	2	4	6180	0.101
7	0.5	2	5	1988	0.020
7	1.0	2	5	6736	0.112
7	1.5	2	5	7948	0.135
7	2.0	2	5	613	-0.006
7	2.5	2	5	6432	0.106
7	3.0	2	5	6804	0.113
7	3.5	2	5	7172	0.120
7	4.0	2	5	7156	0.120
7	4.5	2	5	6244	0.102
7	5.0	2	5	6188	0.101
7	5.5	2	5	7168	0.120
7	6.0	2	5	6832	0.114
7	6.5	2	5	6224	0.102
7	7.0	2	5	5908	0.096
7	7.5	2	5	5668	0.091
7	8.0	2	5	5776	0.093
7	8.5	2	5	5848	0.095
7	9.0	2	5	5244	0.083
7	9.5	2	5	5504	0.088
7	10.0	2	5	5908	0.096
7	10.5	2	5	6040	0.098
7	11.0	2	5	6064	0.099
7	11.5	2	5	6088	0.099
7	12.0	2	5	5800	0.094
7	12.5	2	5	5732	0.093
7	13.0	2	5	5288	0.084
7	13.5	2	5	5448	0.087
7	14.0	2	5	4868	0.076
7	14.5	2	5	5308	0.084
7	15.0	2	5	5536	0.089
7	0.5	3	1	1520	0.011
7	1.0	3	1	3568	0.051
7	1.5	3	1	6044	0.099
7	2.0	3	1	6360	0.105
7	2.5	3	1	6568	0.109
7	3.0	3	1	6820	0.114
7	3.5	3	1	6108	0.100
7	4.0	3	1	5380	0.086
7	4.5	3	1	5916	0.096
7	5.0	3	1	5592	0.090
7	5.5	3	1	5580	0.090
7	6.0	3	1	5548	0.089
7	6.5	3	1	5812	0.094
7	7.0	3	1	5584	0.090
7	7.5	3	1	6576	0.109

month	depth	zone	station	hp reading	moisture content
7	8.0	3	1	5676	0.091
7	8.5	3	1	5488	0.088
7	9.0	3	1	5560	0.089
7	9.5	3	1	5424	0.087
7	10.0	3	1	6064	0.099
7	10.5	3	1	6576	0.109
7	11.0	3	1	7460	0.126
7	0.5	3	2	2304	0.026
7	1.0	3	2	5148	0.081
7	1.5	3	2	5940	0.097
7	2.0	3	2	6352	0.104
7	2.5	3	2	6460	0.107
7	3.0	3	2	6876	0.115
7	3.5	3	2	7624	0.129
7	4.0	3	2	7508	0.127
7	4.5	3	2	6768	0.113
7	5.0	3	2	6416	0.106
7	5.5	3	2	6348	0.104
7	6.0	3	2	6408	0.106
7	6.5	3	2	6600	0.109
7	7.0	3	2	6184	0.101
7	7.5	3	2	5920	0.096
7	8.0	3	2	6108	0.100
7	8.5	3	2	6052	0.099
7	9.0	3	2	5992	0.098
7	9.5	3	2	6268	0.103
7	10.0	3	2	6908	0.115
7	10.5	3	2	7260	0.122
7	11.0	3	2	6876	0.115
7	11.5	3	2	6720	0.112
7	12.0	3	2	6664	0.111
7	12.5	3	2	6520	0.108
7	13.0	3	2	6804	0.113
7	13.5	3	2	7288	0.123
7	14.0	3	2	6868	0.114
7	14.5	3	2	6248	0.102
7	15.0	3	2	6312	0.104
7	0.5	3	3	1804	0.017
7	1.0	3	3	2856	0.037
7	1.5	3	3	4472	0.068
7	2.0	3	3	4864	0.076
7	2.5	3	3	4640	0.071
7	3.0	3	3	4644	0.072
7	3.5	3	3	4752	0.074
7	4.0	3	3	4916	0.077
7	4.5	3	3	4800	0.075
7	5.0	3	3	5344	0.085
7	5.5	3	3	6040	0.098
7	6.0	3	3	6164	0.101
7	6.5	3	3	6048	0.099
7	7.0	3	3	6684	0.111
7	7.5	3	3	6228	0.102
7	8.0	3	3	5968	0.097
7	8.5	3	3	5576	0.090
7	9.0	3	3	5672	0.091
7	9.5	3	3	5816	0.094
7	10.0	3	3	5944	0.097
7	10.5	3	3	6000	0.098
7	11.0	3	3	5924	0.096
7	11.5	3	3	5820	0.094
7	12.0	3	3	5572	0.089
7	12.5	3	3	6200	0.102
7	13.0	3	3	6356	0.105

month	depth	zone	station	hp reading	moisture content
7	13.5	3	3	5860	0.095
7	14.0	3	3	5984	0.097
7	14.5	3	3	5516	0.088
7	15.0	3	3	5940	0.097
7	0.5	3	4	1320	0.007
7	1.0	3	4	3700	0.053
7	1.5	3	4	6536	0.108
7	2.0	3	4	7912	0.135
7	2.5	3	4	7536	0.127
7	3.0	3	4	7256	0.122
7	3.5	3	4	7804	0.133
7	4.0	3	4	7932	0.135
7	4.5	3	4	7168	0.120
7	5.0	3	4	6688	0.111
7	5.5	3	4	6688	0.111
7	6.0	3	4	6812	0.113
7	6.5	3	4	6372	0.105
7	7.0	3	4	6084	0.099
7	7.5	3	4	5780	0.093
7	8.0	3	4	5860	0.095
7	8.5	3	4	6068	0.099
7	9.0	3	4	5740	0.093
7	9.5	3	4	5752	0.093
7	10.0	3	4	5768	0.093
7	10.5	3	4	6228	0.102
7	11.0	3	4	5928	0.096
7	11.5	3	4	5388	0.086
7	12.0	3	4	5660	0.091
7	12.5	3	4	5468	0.087
7	13.0	3	4	5320	0.085
7	13.5	3	4	5636	0.091
7	14.0	3	4	6488	0.107
7	14.5	3	4	7404	0.125
7	15.0	3	4	7452	0.126
7	0.5	3	5	3524	0.050
7	1.0	3	5	10012	0.175
7	1.5	3	5	10148	0.178
7	2.0	3	5	9316	0.162
7	2.5	3	5	10196	0.179
7	3.0	3	5	10980	0.194
7	3.5	3	5	11324	0.200
7	4.0	3	5	7980	0.136
7	4.5	3	5	6796	0.113
7	5.0	3	5	6860	0.114
7	5.5	3	5	6656	0.110
7	6.0	3	5	7248	0.122
7	6.5	3	5	7576	0.128
7	7.0	3	5	7840	0.133
7	7.5	3	5	7384	0.124
7	8.0	3	5	7052	0.118
7	8.5	3	5	7168	0.120
7	9.0	3	5	7644	0.129
7	9.5	3	5	8012	0.137
7	10.0	3	5	7816	0.133
7	10.5	3	5	7404	0.125
7	11.0	3	5	6744	0.112
7	11.5	3	5	6476	0.107
7	12.0	3	5	6240	0.102
7	12.5	3	5	7056	0.118
7	13.0	3	5	10508	0.185
7	13.5	3	5	14780	0.267
7	14.0	3	5	13284	0.238
7	14.5	3	5	8856	0.153

month	depth	zone	station	hp reading	moisture content
7	15.0	3	5	8428	0.145
7	0.5	4	1	4224	0.063
7	1.0	4	1	6184	0.101
7	1.5	4	1	7296	0.123
7	2.0	4	1	7756	0.132
7	2.5	4	1	7120	0.119
7	3.0	4	1	6988	0.117
7	3.5	4	1	6584	0.109
7	4.0	4	1	6164	0.101
7	4.5	4	1	6032	0.098
7	5.0	4	1	6236	0.102
7	5.5	4	1	6244	0.102
7	6.0	4	1	6472	0.107
7	6.5	4	1	6284	0.103
7	7.0	4	1	6324	0.104
7	7.5	4	1	6052	0.099
7	8.0	4	1	6076	0.099
7	8.5	4	1	5892	0.096
7	9.0	4	1	5784	0.094
7	9.5	4	1	6004	0.098
7	10.0	4	1	5464	0.087
7	10.5	4	1	5724	0.092
7	11.0	4	1	5692	0.092
7	11.5	4	1	5856	0.095
7	12.0	4	1	5576	0.090
7	12.5	4	1	5804	0.094
7	13.0	4	1	6720	0.112
7	13.5	4	1	7028	0.118
7	0.5	4	2	3308	0.046
7	1.0	4	2	5644	0.091
7	1.5	4	2	6104	0.100
7	2.0	4	2	6032	0.098
7	2.5	4	2	7348	0.124
7	3.0	4	2	7708	0.131
7	3.5	4	2	8888	0.153
7	4.0	4	2	8244	0.141
7	4.5	4	2	8088	0.138
7	5.0	4	2	8400	0.144
7	5.5	4	2	8984	0.155
7	6.0	4	2	8404	0.144
7	6.5	4	2	8604	0.148
7	7.0	4	2	9352	0.162
7	7.5	4	2	10084	0.177
7	8.0	4	2	9748	0.170
7	8.5	4	2	10512	0.185
7	9.0	4	2	11844	0.210
7	9.5	4	2	11156	0.197
7	10.0	4	2	10536	0.185
7	10.5	4	2	11800	0.210
7	11.0	4	2	12368	0.221
7	11.5	4	2	10948	0.193
7	12.0	4	2	7968	0.136
7	12.5	4	2	7456	0.126
7	13.0	4	2	6892	0.115
7	13.5	4	2	6880	0.115
7	14.0	4	2	7144	0.120
7	14.5	4	2	7292	0.123
7	0.5	4	3	1668	0.014
7	1.0	4	3	6560	0.109
7	1.5	4	3	8876	0.153
7	2.0	4	3	9376	0.163
7	2.5	4	3	7072	0.118
7	3.0	4	3	6176	0.101

month	depth	zone	station	hp reading	moisture content
7	3.5	4	3	5548	0.089
7	4.0	4	3	6164	0.101
7	4.5	4	3	6216	0.102
7	5.0	4	3	6160	0.101
7	5.5	4	3	7500	0.127
7	6.0	4	3	8084	0.138
7	6.5	4	3	7212	0.121
7	7.0	4	3	6168	0.101
7	7.5	4	3	6448	0.106
7	8.0	4	3	6248	0.102
7	8.5	4	3	6684	0.111
7	9.0	4	3	6336	0.104
7	9.5	4	3	6144	0.100
7	10.0	4	3	6228	0.102
7	10.5	4	3	6660	0.110
7	11.0	4	3	7144	0.120
7	11.5	4	3	7856	0.134
7	12.0	4	3	7548	0.128
7	12.5	4	3	7504	0.127
7	13.0	4	3	6784	0.113
7	13.5	4	3	5908	0.096
7	14.0	4	3	6196	0.101
7	14.5	4	3	7400	0.125
7	15.0	4	3	7488	0.126
7	0.5	4	4	3392	0.047
7	1.0	4	4	8816	0.152
7	1.5	4	4	10096	0.177
7	2.0	4	4	11216	0.198
7	2.5	4	4	7808	0.133
7	3.0	4	4	7248	0.122
7	3.5	4	4	6704	0.111
7	4.0	4	4	6400	0.105
7	4.5	4	4	6288	0.103
7	5.0	4	4	6112	0.100
7	5.5	4	4	6672	0.111
7	6.0	4	4	8208	0.140
7	6.5	4	4	9312	0.162
7	7.0	4	4	6576	0.109
7	7.5	4	4	4496	0.069
7	8.0	4	4	3952	0.058
7	8.5	4	4	4048	0.060
7	9.0	4	4	4352	0.066
7	9.5	4	4	5808	0.094
7	10.0	4	4	5376	0.086
7	10.5	4	4	5248	0.083
7	11.0	4	4	5376	0.086
7	11.5	4	4	5024	0.079
7	12.0	4	4	6192	0.101
7	12.5	4	4	7696	0.130
7	13.0	4	4	7504	0.127
7	13.5	4	4	8400	0.144
7	14.0	4	4	11200	0.198
7	14.5	4	4	14768	0.267
7	15.0	4	4	14864	0.269
7	0.5	4	5	2536	0.031
7	1.0	4	5	5012	0.079
7	1.5	4	5	6424	0.106
7	2.0	4	5	6136	0.100
7	2.5	4	5	6132	0.100
7	3.0	4	5	7344	0.124
7	3.5	4	5	9268	0.161
7	4.0	4	5	10464	0.184
7	4.5	4	5	10296	0.181

month	depth	zone	station	hp reading	moisture content
7	5.0	4	5	8564	0.147
7	5.5	4	5	9448	0.164
7	6.0	4	5	8696	0.150
7	6.5	4	5	6448	0.106
7	7.0	4	5	5576	0.090
7	7.5	4	5	5560	0.089
7	8.0	4	5	5568	0.089
7	8.5	4	5	8576	0.147
7	9.0	4	5	8556	0.147
7	9.5	4	5	7748	0.131
7	10.0	4	5	8596	0.148
7	10.5	4	5	9304	0.161
7	11.0	4	5	8380	0.144
7	11.5	4	5	9012	0.156
7	12.0	4	5	10004	0.175
7	12.5	4	5	8708	0.150
7	13.0	4	5	10168	0.178
7	13.5	4	5	9692	0.169
7	14.0	4	5	9540	0.166
7	14.5	4	5	8712	0.150
7	15.0	4	5	8856	0.153
8	0.5	1	1	1412	0.009
8	1.0	1	1	4376	0.066
8	1.5	1	1	5924	0.096
8	2.0	1	1	6192	0.101
8	2.5	1	1	5940	0.097
8	3.0	1	1	5924	0.096
8	3.5	1	1	6192	0.101
8	4.0	1	1	7164	0.120
8	4.5	1	1	8588	0.148
8	0.5	1	2	1528	0.011
8	1.0	1	2	6400	0.105
8	1.5	1	2	7688	0.130
8	2.0	1	2	7600	0.129
8	2.5	1	2	7100	0.119
8	3.0	1	2	6932	0.116
8	3.5	1	2	6828	0.114
8	4.0	1	2	6808	0.113
8	4.5	1	2	6584	0.109
8	5.0	1	2	6608	0.109
8	5.5	1	2	6540	0.108
8	6.0	1	2	6120	0.100
8	6.5	1	2	5948	0.097
8	7.0	1	2	6084	0.099
8	7.5	1	2	5808	0.094
8	8.0	1	2	6044	0.099
8	8.5	1	2	6184	0.101
8	9.0	1	2	6776	0.113
8	9.5	1	2	8088	0.138
8	10.0	1	2	10524	0.185
8	0.5	1	3	468	-0.009
8	1.0	1	3	2116	0.023
8	1.5	1	3	4036	0.060
8	2.0	1	3	5956	0.097
8	2.5	1	3	5716	0.092
8	3.0	1	3	5720	0.092
8	3.5	1	3	6104	0.100
8	4.0	1	3	6644	0.110
8	4.5	1	3	6748	0.112
8	5.0	1	3	6252	0.103
8	5.5	1	3	6108	0.100
8	0.5	1	4	580	-0.007
8	1.0	1	4	2268	0.026

month	depth	zone	station	hp reading	moisture content
8	1.5	1	4	4768	0.074
8	2.0	1	4	6696	0.111
8	0.5	1	5	1096	0.003
8	1.0	1	5	5304	0.084
8	1.5	1	5	7988	0.136
8	2.0	1	5	7692	0.130
8	2.5	1	5	7628	0.129
8	3.0	1	5	8084	0.138
8	3.5	1	5	9088	0.157
8	4.0	1	5	9664	0.168
8	4.5	1	5	10240	0.180
8	5.0	1	5	8352	0.143
8	5.5	1	5	7132	0.120
8	6.0	1	5	6076	0.099
8	6.5	1	5	7568	0.128
8	7.0	1	5	9860	0.172
8	7.5	1	5	8112	0.138
8	8.0	1	5	6288	0.103
8	8.5	1	5	6068	0.099
8	9.0	1	5	6036	0.098
8	9.5	1	5	5840	0.095
8	10.0	1	5	5936	0.096
8	10.5	1	5	5760	0.093
8	11.0	1	5	6028	0.098
8	11.5	1	5	5896	0.096
8	12.0	1	5	5832	0.094
8	12.5	1	5	5856	0.095
8	13.0	1	5	5908	0.096
8	13.5	1	5	5908	0.096
8	14.0	1	5	6112	0.100
8	14.5	1	5	6228	0.102
8	0.5	2	1	1992	0.020
8	1.0	2	1	3424	0.048
8	1.5	2	1	4892	0.076
8	2.0	2	1	5968	0.097
8	2.5	2	1	6264	0.103
8	3.0	2	1	5256	0.083
8	3.5	2	1	5188	0.082
8	4.0	2	1	6796	0.113
8	4.5	2	1	7532	0.127
8	5.0	2	1	6632	0.110
8	5.5	2	1	5708	0.092
8	6.0	2	1	4768	0.074
8	6.5	2	1	5960	0.097
8	0.5	2	2	7476	0.126
8	1.0	2	2	8268	0.141
8	1.5	2	2	9080	0.157
8	2.0	2	2	8364	0.143
8	2.5	2	2	6972	0.116
8	3.0	2	2	6992	0.117
8	3.5	2	2	7188	0.121
8	4.0	2	2	7176	0.120
8	4.5	2	2	6708	0.111
8	5.0	2	2	6048	0.099
8	5.5	2	2	5576	0.090
8	6.0	2	2	5356	0.085
8	6.5	2	2	6136	0.100
8	7.0	2	2	6416	0.106
8	7.5	2	2	6468	0.107
8	8.0	2	2	5952	0.097
8	8.5	2	2	6184	0.101
8	9.0	2	2	5948	0.097
8	9.5	2	2	5424	0.087

month	depth	zone	station	hp reading	moisture content
8	10.0	2	2	5352	0.085
8	10.5	2	2	5096	0.080
8	11.0	2	2	4596	0.071
8	11.5	2	2	4616	0.071
8	12.0	2	2	4420	0.067
8	12.5	2	2	5100	0.080
8	13.0	2	2	4848	0.075
8	13.5	2	2	4748	0.074
8	14.0	2	2	4720	0.073
8	14.5	2	2	4920	0.077
8	0.5	2	3	1272	0.006
8	1.0	2	3	4456	0.068
8	1.5	2	3	6472	0.107
8	2.0	2	3	6724	0.112
8	2.5	2	3	6476	0.107
8	3.0	2	3	6424	0.106
8	3.5	2	3	6380	0.105
8	4.0	2	3	6512	0.108
8	4.5	2	3	6104	0.100
8	5.0	2	3	5740	0.093
8	5.5	2	3	6060	0.099
8	6.0	2	3	6064	0.099
8	6.5	2	3	6248	0.102
8	7.0	2	3	6128	0.100
8	7.5	2	3	6256	0.103
8	8.0	2	3	6004	0.098
8	8.5	2	3	6160	0.101
8	9.0	2	3	6140	0.100
8	9.5	2	3	5772	0.093
8	10.0	2	3	6004	0.098
8	10.5	2	3	6056	0.099
8	11.0	2	3	5728	0.092
8	11.5	2	3	6080	0.099
8	12.0	2	3	6220	0.102
8	12.5	2	3	6920	0.115
8	0.5	2	4	720	-0.004
8	1.0	2	4	1812	0.017
8	1.5	2	4	3228	0.044
8	2.0	2	4	4568	0.070
8	2.5	2	4	4856	0.076
8	3.0	2	4	5120	0.081
8	3.5	2	4	5656	0.091
8	4.0	2	4	5880	0.095
8	4.5	2	4	5932	0.096
8	5.0	2	4	5672	0.091
8	5.5	2	4	5368	0.086
8	6.0	2	4	5208	0.082
8	6.5	2	4	5664	0.091
8	7.0	2	4	6524	0.108
8	0.5	2	5	2176	0.024
8	1.0	2	5	6660	0.110
8	1.5	2	5	8380	0.144
8	2.0	2	5	7032	0.118
8	2.5	2	5	6904	0.115
8	3.0	2	5	7196	0.121
8	3.5	2	5	7552	0.128
8	4.0	2	5	7364	0.124
8	4.5	2	5	6740	0.112
8	5.0	2	5	6720	0.112
8	5.5	2	5	6832	0.114
8	6.0	2	5	6760	0.112
8	6.5	2	5	6088	0.099
8	7.0	2	5	6132	0.100

month	depth	zone	station	hp reading	moisture content
8	7.5	2	5	5356	0.085
8	8.0	2	5	5300	0.084
8	8.5	2	5	5724	0.092
8	9.0	2	5	5240	0.083
8	9.5	2	5	5608	0.090
8	10.0	2	5	6144	0.100
8	10.5	2	5	6128	0.100
8	11.0	2	5	6232	0.102
8	11.5	2	5	6072	0.099
8	12.0	2	5	5788	0.094
8	12.5	2	5	5612	0.090
8	13.0	2	5	5332	0.085
8	13.5	2	5	5448	0.087
8	14.0	2	5	5208	0.082
8	14.5	2	5	5360	0.085
8	15.0	2	5	5484	0.088
8	0.5	3	1	1544	0.012
8	1.0	3	1	3808	0.055
8	1.5	3	1	6564	0.109
8	2.0	3	1	6464	0.107
8	2.5	3	1	6732	0.112
8	3.0	3	1	6912	0.115
8	3.5	3	1	5884	0.095
8	4.0	3	1	5724	0.092
8	4.5	3	1	5412	0.086
8	5.0	3	1	5420	0.087
8	5.5	3	1	5456	0.087
8	6.0	3	1	5384	0.086
8	6.5	3	1	5740	0.093
8	7.0	3	1	5784	0.094
8	7.5	3	1	5204	0.082
8	8.0	3	1	5512	0.088
8	8.5	3	1	5416	0.086
8	9.0	3	1	5628	0.091
8	9.5	3	1	5632	0.091
8	10.0	3	1	6068	0.099
8	10.5	3	1	6764	0.112
8	11.0	3	1	7492	0.126
8	0.5	3	2	2298	0.026
8	1.0	3	2	4720	0.073
8	1.5	3	2	5776	0.093
8	2.0	3	2	6052	0.099
8	2.5	3	2	6444	0.106
8	3.0	3	2	7032	0.118
8	3.5	3	2	7508	0.127
8	4.0	3	2	7036	0.118
8	4.5	3	2	6892	0.115
8	5.0	3	2	6144	0.100
8	5.5	3	2	5912	0.096
8	6.0	3	2	6072	0.099
8	6.5	3	2	6368	0.105
8	7.0	3	2	6352	0.104
8	7.5	3	2	5604	0.090
8	8.0	3	2	5860	0.095
8	8.5	3	2	5752	0.093
8	9.0	3	2	6128	0.100
8	9.5	3	2	6364	0.105
8	10.0	3	2	6864	0.114
8	10.5	3	2	7288	0.123
8	11.0	3	2	7088	0.119
8	11.5	3	2	6752	0.112
8	12.0	3	2	6720	0.112
8	12.5	3	2	6428	0.106

month	depth	zone	station	hp reading	moisture content
8	13.0	3	2	6704	0.111
8	13.5	3	2	7096	0.119
8	14.0	3	2	6776	0.113
8	14.5	3	2	6300	0.103
8	15.0	3	2	6264	0.103
8	0.5	3	3	1380	0.009
8	1.0	3	3	3096	0.042
8	1.5	3	3	4140	0.062
8	2.0	3	3	4528	0.069
8	2.5	3	3	4592	0.071
8	3.0	3	3	4816	0.075
8	3.5	3	3	4904	0.077
8	4.0	3	3	4776	0.074
8	4.5	3	3	4724	0.073
8	5.0	3	3	4984	0.078
8	5.5	3	3	5940	0.097
8	6.0	3	3	5832	0.094
8	6.5	3	3	6072	0.099
8	7.0	3	3	6792	0.113
8	7.5	3	3	6260	0.103
8	8.0	3	3	5584	0.090
8	8.5	3	3	5436	0.087
8	9.0	3	3	5728	0.092
8	9.5	3	3	5724	0.092
8	10.0	3	3	5784	0.094
8	10.5	3	3	6116	0.100
8	11.0	3	3	6316	0.104
8	11.5	3	3	5564	0.089
8	12.0	3	3	5504	0.088
8	12.5	3	3	6484	0.107
8	13.0	3	3	6020	0.098
8	13.5	3	3	6104	0.100
8	14.0	3	3	6060	0.099
8	14.5	3	3	5804	0.094
8	15.0	3	3	5724	0.092
8	0.5	3	4	1412	0.009
8	1.0	3	4	4012	0.059
8	1.5	3	4	6768	0.113
8	2.0	3	4	8256	0.141
8	2.5	3	4	7040	0.118
8	3.0	3	4	6992	0.117
8	3.5	3	4	7360	0.124
8	4.0	3	4	7952	0.135
8	4.5	3	4	7664	0.130
8	5.0	3	4	7328	0.123
8	5.5	3	4	7712	0.131
8	6.0	3	4	7556	0.128
8	6.5	3	4	7056	0.118
8	7.0	3	4	6576	0.109
8	7.5	3	4	5984	0.097
8	8.0	3	4	6208	0.102
8	8.5	3	4	6240	0.102
8	9.0	3	4	6368	0.105
8	9.5	3	4	5600	0.090
8	10.0	3	4	6496	0.107
8	10.5	3	4	6592	0.109
8	11.0	3	4	6576	0.109
8	11.5	3	4	6592	0.109
8	12.0	3	4	6016	0.098
8	12.5	3	4	5200	0.082
8	13.0	3	4	6112	0.100
8	13.5	3	4	5968	0.097
8	14.0	3	4	6304	0.104

month	depth	zone	station	hp reading	moisture content
8	14.5	3	4	7296	0.123
8	15.0	3	4	7344	0.124
8	0.5	3	5	3292	0.045
8	1.0	3	5	9780	0.171
8	1.5	3	5	9852	0.172
8	2.0	3	5	9444	0.164
8	2.5	3	5	9952	0.174
8	3.0	3	5	10792	0.190
8	3.5	3	5	11108	0.196
8	4.0	3	5	8224	0.141
8	4.5	3	5	6376	0.105
8	5.0	3	5	6708	0.111
8	5.5	3	5	6464	0.107
8	6.0	3	5	7024	0.117
8	6.5	3	5	7592	0.128
8	7.0	3	5	7580	0.128
8	7.5	3	5	7340	0.124
8	8.0	3	5	6872	0.115
8	8.5	3	5	6800	0.113
8	9.0	3	5	7660	0.130
8	9.5	3	5	7756	0.132
8	10.0	3	5	7880	0.134
8	10.5	3	5	7296	0.123
8	11.0	3	5	6668	0.111
8	11.5	3	5	6584	0.109
8	12.0	3	5	6088	0.099
8	12.5	3	5	7044	0.118
8	13.0	3	5	10408	0.183
8	13.5	3	5	14820	0.268
8	14.0	3	5	12516	0.223
8	14.5	3	5	9264	0.161
8	15.0	3	5	8372	0.143
8	0.5	4	1	4246	0.064
8	1.0	4	1	5972	0.097
8	1.5	4	1	6852	0.114
8	2.0	4	1	7300	0.123
8	2.5	4	1	7244	0.122
8	3.0	4	1	6492	0.107
8	3.5	4	1	6420	0.106
8	4.0	4	1	6284	0.103
8	4.5	4	1	5944	0.097
8	5.0	4	1	6312	0.104
8	5.5	4	1	5804	0.094
8	6.0	4	1	6016	0.098
8	6.5	4	1	6320	0.104
8	7.0	4	1	6476	0.107
8	7.5	4	1	6004	0.098
8	8.0	4	1	5972	0.097
8	8.5	4	1	6124	0.100
8	9.0	4	1	5940	0.097
8	9.5	4	1	6316	0.104
8	10.0	4	1	5564	0.089
8	10.5	4	1	5508	0.088
8	11.0	4	1	5692	0.092
8	11.5	4	1	5820	0.094
8	12.0	4	1	5872	0.095
8	12.5	4	1	5784	0.094
8	13.0	4	1	6556	0.108
8	13.5	4	1	7116	0.119
8	0.5	4	2	2984	0.039
8	1.0	4	2	5528	0.089
8	1.5	4	2	6036	0.098
8	2.0	4	2	6136	0.100

month	depth	zone	station	hp reading	moisture content
8	2.5	4	2	7264	0.122
8	3.0	4	2	7716	0.131
8	3.5	4	2	8020	0.137
8	4.0	4	2	8240	0.141
8	4.5	4	2	8080	0.138
8	5.0	4	2	8196	0.140
8	5.5	4	2	8496	0.146
8	6.0	4	2	8276	0.142
8	6.5	4	2	8416	0.144
8	7.0	4	2	9428	0.164
8	7.5	4	2	9148	0.158
8	8.0	4	2	8980	0.155
8	8.5	4	2	9716	0.169
8	9.0	4	2	11144	0.197
8	9.5	4	2	10504	0.185
8	10.0	4	2	11772	0.209
8	10.5	4	2	12324	0.220
8	11.0	4	2	10620	0.187
8	11.5	4	2	8184	0.140
8	12.0	4	2	7168	0.120
8	12.5	4	2	6664	0.111
8	13.0	4	2	6568	0.109
8	13.5	4	2	6832	0.114
8	14.0	4	2	7620	0.129
8	14.5	4	2		-0.018
8	0.5	4	3	1448	0.010
8	1.0	4	3	5908	0.096
8	1.5	4	3	8280	0.142
8	2.0	4	3	8672	0.149
8	2.5	4	3	6160	0.101
8	3.0	4	3	5192	0.082
8	3.5	4	3	4820	0.075
8	4.0	4	3	5200	0.082
8	4.5	4	3	5304	0.084
8	5.0	4	3	5260	0.083
8	5.5	4	3	6064	0.099
8	6.0	4	3	7280	0.122
8	6.5	4	3	6532	0.108
8	7.0	4	3	5788	0.094
8	7.5	4	3	6140	0.100
8	8.0	4	3	6244	0.102
8	8.5	4	3	6224	0.102
8	9.0	4	3	6216	0.102
8	9.5	4	3	6028	0.098
8	10.0	4	3	6076	0.099
8	10.5	4	3	6236	0.102
8	11.0	4	3	7224	0.121
8	11.5	4	3	7532	0.127
8	12.0	4	3	7580	0.128
8	12.5	4	3	7248	0.122
8	13.0	4	3	7328	0.123
8	13.5	4	3	6368	0.105
8	14.0	4	3	6052	0.099
8	14.5	4	3	6168	0.101
8	15.0	4	3	7544	0.127
8	0.5	4	4	1216	0.005
8	1.0	4	4	3964	0.058
8	1.5	4	4	7356	0.124
8	2.0	4	4	8000	0.136
8	2.5	4	4	6972	0.116
8	3.0	4	4	7020	0.117
8	3.5	4	4	6896	0.115
8	4.0	4	4	6592	0.109

month	depth	zone	station	hp reading	moisture content
8	4.5	4	4	6428	0.106
8	5.0	4	4	6436	0.106
8	5.5	4	4	6736	0.112
8	6.0	4	4	7788	0.132
8	6.5	4	4	9596	0.167
8	7.0	4	4	6500	0.107
8	7.5	4	4	4456	0.068
8	8.0	4	4	4084	0.061
8	8.5	4	4	4468	0.068
8	9.0	4	4	4828	0.075
8	9.5	4	4	5828	0.094
8	10.0	4	4	5232	0.083
8	10.5	4	4	5540	0.089
8	11.0	4	4	5352	0.085
8	11.5	4	4	5124	0.081
8	12.0	4	4	6760	0.112
8	12.5	4	4	6124	0.100
8	13.0	4	4	7496	0.127
8	13.5	4	4	8092	0.138
8	14.0	4	4	10864	0.192
8	14.5	4	4	14724	0.266
8	15.0	4	4	15640	0.284
8	0.5	4	5	2640	0.033
8	1.0	4	5	5400	0.086
8	1.5	4	5	6112	0.100
8	2.0	4	5	6192	0.101
8	2.5	4	5	5824	0.094
8	3.0	4	5	6996	0.117
8	3.5	4	5	8884	0.153
8	4.0	4	5	9776	0.171
8	4.5	4	5	9760	0.170
8	5.0	4	5	8568	0.147
8	5.5	4	5	8922	0.154
8	6.0	4	5	8028	0.137
8	6.5	4	5	5992	0.098
8	7.0	4	5	5436	0.087
8	7.5	4	5	5800	0.094
8	8.0	4	5	5584	0.090
8	8.5	4	5	8140	0.139
8	9.0	4	5	8420	0.144
8	9.5	4	5	7620	0.129
8	10.0	4	5	8448	0.145
8	10.5	4	5	9268	0.161
8	11.0	4	5	8620	0.148
8	11.5	4	5	8908	0.154
8	12.0	4	5	9992	0.175
8	12.5	4	5	8732	0.150
8	13.0	4	5	10136	0.178
8	13.5	4	5	9736	0.170
8	14.0	4	5	9608	0.167
8	14.5	4	5	8684	0.150
8	15.0	4	5	8948	0.155
9	0.5	1	1	1408	0.009
9	1.0	1	1	4120	0.061
9	1.5	1	1	6168	0.101
9	2.0	1	1	6084	0.099
9	2.5	1	1	6064	0.099
9	3.0	1	1	5728	0.092
9	3.5	1	1	6528	0.108
9	4.0	1	1	7284	0.122
9	4.5	1	1	9052	0.157
9	0.5	1	2	1476	0.010
9	1.0	1	2	5880	0.095

month	depth	zone	station	hp reading	moisture content
9	1.5	1	2	7484	0.126
9	2.0	1	2	7288	0.123
9	2.5	1	2	7440	0.125
9	3.0	1	2	6532	0.108
9	3.5	1	2	6820	0.114
9	4.0	1	2	6668	0.111
9	4.5	1	2	6576	0.109
9	5.0	1	2	6516	0.108
9	5.5	1	2	6596	0.109
9	6.0	1	2	6088	0.099
9	6.5	1	2	6136	0.100
9	7.0	1	2	6020	0.098
9	7.5	1	2	6052	0.099
9	8.0	1	2	6060	0.099
9	8.5	1	2	6208	0.102
9	9.0	1	2	6296	0.103
9	9.5	1	2	8208	0.140
9	10.0	1	2	10176	0.178
9	0.5	1	3	388	-0.011
9	1.0	1	3	2016	0.021
9	1.5	1	3	4352	0.066
9	2.0	1	3	5904	0.096
9	2.5	1	3	5856	0.095
9	3.0	1	3	5736	0.093
9	3.5	1	3	6068	0.099
9	4.0	1	3	6700	0.111
9	4.5	1	3	6680	0.111
9	5.0	1	3	5948	0.097
9	5.5	1	3	5952	0.097
9	0.5	1	4	460	-0.009
9	1.0	1	4	2160	0.024
9	1.5	1	4	4756	0.074
9	2.0	1	4	6588	0.109
9	0.5	1	5	1260	0.006
9	1.0	1	5	5368	0.086
9	1.5	1	5	8160	0.139
9	2.0	1	5	7836	0.133
9	2.5	1	5	7472	0.126
9	3.0	1	5	8308	0.142
9	3.5	1	5	9416	0.164
9	4.0	1	5	9444	0.164
9	4.5	1	5	10168	0.178
9	5.0	1	5	8732	0.150
9	5.5	1	5	6972	0.116
9	6.0	1	5	6076	0.099
9	6.5	1	5	7484	0.126
9	7.0	1	5	10004	0.175
9	7.5	1	5	8056	0.137
9	8.0	1	5	6316	0.104
9	8.5	1	5	5916	0.096
9	9.0	1	5	5912	0.096
9	9.5	1	5	6016	0.098
9	10.0	1	5	6260	0.103
9	10.5	1	5	5896	0.096
9	11.0	1	5	6148	0.101
9	11.5	1	5	5908	0.096
9	12.0	1	5	5896	0.096
9	12.5	1	5	5696	0.092
9	13.0	1	5	5752	0.093
9	13.5	1	5	5924	0.096
9	14.0	1	5	5956	0.097
9	14.5	1	5	6372	0.105
9	0.5	2	1	1708	0.015

month	depth	zone	station	hp reading	moisture content
9	1.0	2	1	3236	0.044
9	1.5	2	1	4404	0.067
9	2.0	2	1	5552	0.089
9	2.5	2	1	6092	0.099
9	3.0	2	1	5372	0.086
9	3.5	2	1	4972	0.078
9	4.0	2	1	6912	0.115
9	4.5	2	1	7420	0.125
9	5.0	2	1	6412	0.106
9	5.5	2	1	5224	0.083
9	6.0	2	1	4868	0.076
9	6.5	2	1	5816	0.094
9	0.5	2	2	7960	0.136
9	1.0	2	2	8512	0.146
9	1.5	2	2	9704	0.169
9	2.0	2	2	8700	0.150
9	2.5	2	2	7492	0.126
9	3.0	2	2	7692	0.130
9	3.5	2	2	7540	0.127
9	4.0	2	2	8000	0.136
9	4.5	2	2	6976	0.117
9	5.0	2	2	6340	0.104
9	5.5	2	2	5844	0.095
9	6.0	2	2	5772	0.093
9	6.5	2	2	6164	0.101
9	7.0	2	2	6464	0.107
9	7.5	2	2	6366	0.105
9	8.0	2	2	6100	0.100
9	8.5	2	2	6324	0.104
9	9.0	2	2	6076	0.099
9	9.5	2	2	5624	0.090
9	10.0	2	2	4880	0.076
9	10.5	2	2	4876	0.076
9	11.0	2	2	4820	0.075
9	11.5	2	2	4792	0.074
9	12.0	2	2	4600	0.071
9	12.5	2	2	5324	0.085
9	13.0	2	2	4636	0.071
9	13.5	2	2	4620	0.071
9	14.0	2	2	4692	0.072
9	14.5	2	2	4820	0.075
9	0.5	2	3	1060	0.002
9	1.0	2	3	4180	0.063
9	1.5	2	3	6200	0.102
9	2.0	2	3	6524	0.108
9	2.5	2	3	6008	0.098
9	3.0	2	3	6336	0.104
9	3.5	2	3	6456	0.107
9	4.0	2	3	6040	0.098
9	4.5	2	3	5868	0.095
9	5.0	2	3	5464	0.087
9	5.5	2	3	5680	0.092
9	6.0	2	3	6172	0.101
9	6.5	2	3	5815	0.094
9	7.0	2	3	6288	0.103
9	7.5	2	3	5984	0.097
9	8.0	2	3	6088	0.099
9	8.5	2	3	6088	0.099
9	9.0	2	3	6028	0.098
9	9.5	2	3	6192	0.101
9	10.0	2	3	5940	0.097
9	10.5	2	3	6028	0.098
9	11.0	2	3	6184	0.101

month	depth	zone	station	hp reading	moisture content
9	11.5	2	3	6352	0.104
9	12.0	2	3	6336	0.104
9	12.5	2	3	7408	0.125
9	0.5	2	4	592	-0.007
9	1.0	2	4	1776	0.016
9	1.5	2	4	3036	0.040
9	2.0	2	4	4352	0.066
9	2.5	2	4	4924	0.077
9	3.0	2	4	4948	0.077
9	3.5	2	4	5444	0.087
9	4.0	2	4	5544	0.089
9	4.5	2	4	5524	0.089
9	5.0	2	4	5140	0.081
9	5.5	2	4	5412	0.086
9	6.0	2	4	5444	0.087
9	6.5	2	4	5620	0.090
9	7.0	2	4	6344	0.104
9	0.5	2	5	1476	0.010
9	1.0	2	5	6688	0.111
9	1.5	2	5	8224	0.141
9	2.0	2	5	6832	0.114
9	2.5	2	5	7132	0.120
9	3.0	2	5	7468	0.126
9	3.5	2	5	7568	0.128
9	4.0	2	5	7344	0.124
9	4.5	2	5	6964	0.116
9	5.0	2	5	6764	0.112
9	5.5	2	5	7516	0.127
9	6.0	2	5	7440	0.125
9	6.5	2	5	6792	0.113
9	7.0	2	5	6436	0.106
9	7.5	2	5	5788	0.094
9	8.0	2	5	5852	0.095
9	8.5	2	5	5712	0.092
9	9.0	2	5	5108	0.080
9	9.5	2	5	5264	0.083
9	10.0	2	5	6036	0.098
9	10.5	2	5	6108	0.100
9	11.0	2	5	6364	0.105
9	11.5	2	5	5868	0.095
9	12.0	2	5	5512	0.088
9	12.5	2	5	5752	0.093
9	13.0	2	5	5472	0.088
9	13.5	2	5	5064	0.080
9	14.0	2	5	5340	0.085
9	14.5	2	5	5168	0.082
9	15.0	2	5	5100	0.080
9	0.5	3	1	1484	0.011
9	1.0	3	1	3600	0.051
9	1.5	3	1	6120	0.100
9	2.0	3	1	6580	0.109
9	2.5	3	1	6116	0.100
9	3.0	3	1	6732	0.112
9	3.5	3	1	6048	0.099
9	4.0	3	1	5616	0.090
9	4.5	3	1	5424	0.087
9	5.0	3	1	5216	0.083
9	5.5	3	1	5556	0.089
9	6.0	3	1	5308	0.084
9	6.5	3	1	5676	0.091
9	7.0	3	1	5336	0.085
9	7.5	3	1	5528	0.089
9	8.0	3	1	5316	0.084

month	depth	zone	station	hp reading	moisture content
9	8.5	3	1	5640	0.091
9	9.0	3	1	5612	0.090
9	9.5	3	1	5756	0.093
9	10.0	3	1	5964	0.097
9	10.5	3	1	6472	0.107
9	11.0	3	1	7252	0.122
9	0.5	3	2	1696	0.015
9	1.0	3	2	4260	0.064
9	1.5	3	2	5696	0.092
9	2.0	3	2	6108	0.100
9	2.5	3	2	6372	0.105
9	3.0	3	2	6696	0.111
9	3.5	3	2	7104	0.119
9	4.0	3	2	7080	0.119
9	4.5	3	2	6612	0.110
9	5.0	3	2	6312	0.104
9	5.5	3	2	5980	0.097
9	6.0	3	2	5992	0.098
9	6.5	3	2	6936	0.116
9	7.0	3	2	6360	0.105
9	7.5	3	2	5856	0.095
9	8.0	3	2	5920	0.096
9	8.5	3	2	5764	0.093
9	9.0	3	2	6104	0.100
9	9.5	3	2	6436	0.106
9	10.0	3	2	6620	0.110
9	10.5	3	2	7440	0.125
9	11.0	3	2	7068	0.118
9	11.5	3	2	6648	0.110
9	12.0	3	2	6700	0.111
9	12.5	3	2	6584	0.109
9	13.0	3	2	6672	0.111
9	13.5	3	2	7176	0.120
9	14.0	3	2	7064	0.118
9	14.5	3	2	6024	0.098
9	15.0	3	2	6372	0.105
9	0.5	3	3	1488	0.011
9	1.0	3	3	2744	0.035
9	1.5	3	3	3720	0.054
9	2.0	3	3	4276	0.064
9	2.5	3	3	4648	0.072
9	3.0	3	3	4556	0.070
9	3.5	3	3	4772	0.074
9	4.0	3	3	4768	0.074
9	4.5	3	3	4728	0.073
9	5.0	3	3	4972	0.078
9	5.5	3	3	6060	0.099
9	6.0	3	3	5548	0.089
9	6.5	3	3	5752	0.093
9	7.0	3	3	6412	0.106
9	7.5	3	3	5692	0.092
9	8.0	3	3	5668	0.091
9	8.5	3	3	5136	0.081
9	9.0	3	3	5328	0.085
9	9.5	3	3	5844	0.095
9	10.0	3	3	5532	0.089
9	10.5	3	3	6044	0.099
9	11.0	3	3	6024	0.098
9	11.5	3	3	5640	0.091
9	12.0	3	3	5772	0.093
9	12.5	3	3	6268	0.103
9	13.0	3	3	5888	0.096
9	13.5	3	3	5888	0.096

month	depth	zone	station	hp reading	moisture content
9	14.0	3	3	5860	0.095
9	14.5	3	3	6076	0.099
9	15.0	3	3	5800	0.094
9	0.5	3	4	1240	0.006
9	1.0	3	4	3000	0.040
9	1.5	3	4	5920	0.096
9	2.0	3	4	7424	0.125
9	2.5	3	4	7132	0.120
9	3.0	3	4	6952	0.116
9	3.5	3	4	7744	0.131
9	4.0	3	4	7516	0.127
9	4.5	3	4	6520	0.108
9	5.0	3	4	6572	0.109
9	5.5	3	4	6636	0.110
9	6.0	3	4	6832	0.114
9	6.5	3	4	6696	0.111
9	7.0	3	4	6228	0.102
9	7.5	3	4	6140	0.100
9	8.0	3	4	6164	0.101
9	8.5	3	4	6048	0.099
9	9.0	3	4	5888	0.096
9	9.5	3	4	5920	0.096
9	10.0	3	4	6484	0.107
9	10.5	3	4	6376	0.105
9	11.0	3	4	6508	0.108
9	11.5	3	4	6028	0.098
9	12.0	3	4	5780	0.093
9	12.5	3	4	6216	0.102
9	13.0	3	4	6188	0.101
9	13.5	3	4	6048	0.099
9	14.0	3	4	7400	0.125
9	14.5	3	4	7964	0.136
9	15.0	3	4	7624	0.129
9	0.5	3	5	3292	0.045
9	1.0	3	5	9920	0.173
9	1.5	3	5	9692	0.169
9	2.0	3	5	9236	0.160
9	2.5	3	5	9257	0.161
9	3.0	3	5	10876	0.192
9	3.5	3	5	10068	0.176
9	4.0	3	5	7396	0.125
9	4.5	3	5	6168	0.101
9	5.0	3	5	6284	0.103
9	5.5	3	5	6576	0.109
9	6.0	3	5	7228	0.121
9	6.5	3	5	7456	0.126
9	7.0	3	5	7480	0.126
9	7.5	3	5	7028	0.118
9	8.0	3	5	6860	0.114
9	8.5	3	5	6640	0.110
9	9.0	3	5	7656	0.130
9	9.5	3	5	7788	0.132
9	10.0	3	5	7908	0.135
9	10.5	3	5	7540	0.127
9	11.0	3	5	6556	0.108
9	11.5	3	5	6608	0.109
9	12.0	3	5	6136	0.100
9	12.5	3	5	6976	0.117
9	13.0	3	5	10752	0.189
9	13.5	3	5	14324	0.258
9	14.0	3	5	12964	0.232
9	14.5	3	5	9416	0.164
9	15.0	3	5	8352	0.143

month	depth	zone	station	hp reading	moisture content
9	0.5	4	1	3696	0.053
9	1.0	4	1	5284	0.084
9	1.5	4	1	6512	0.108
9	2.0	4	1	7132	0.120
9	2.5	4	1	7124	0.119
9	3.0	4	1	6748	0.112
9	3.5	4	1	6052	0.099
9	4.0	4	1	5960	0.097
9	4.5	4	1	5884	0.095
9	5.0	4	1	6272	0.103
9	5.5	4	1	5908	0.096
9	6.0	4	1	6304	0.104
9	6.5	4	1	6212	0.102
9	7.0	4	1	6520	0.108
9	7.5	4	1	6248	0.102
9	8.0	4	1	5836	0.095
9	8.5	4	1	5664	0.091
9	9.0	4	1	5936	0.096
9	9.5	4	1	5924	0.096
9	10.0	4	1	5732	0.093
9	10.5	4	1	5812	0.094
9	11.0	4	1	5820	0.094
9	11.5	4	1	5832	0.094
9	12.0	4	1	5916	0.096
9	12.5	4	1	5952	0.097
9	13.0	4	1	6556	0.108
9	13.5	4	1	6940	0.116
9	0.5	4	2	3392	0.047
9	1.0	4	2	5396	0.086
9	1.5	4	2	5864	0.095
9	2.0	4	2	6112	0.100
9	2.5	4	2	6892	0.115
9	3.0	4	2	7840	0.133
9	3.5	4	2	7892	0.134
9	4.0	4	2	7852	0.133
9	4.5	4	2	7920	0.135
9	5.0	4	2	8036	0.137
9	5.5	4	2	8868	0.153
9	6.0	4	2	8264	0.141
9	6.5	4	2	8040	0.137
9	7.0	4	2	8916	0.154
9	7.5	4	2	9060	0.157
9	8.0	4	2	8968	0.155
9	8.5	4	2	9584	0.167
9	9.0	4	2	11856	0.211
9	9.5	4	2	10696	0.188
9	10.0	4	2	10448	0.184
9	10.5	4	2	12196	0.217
9	11.0	4	2	12508	0.223
9	11.5	4	2	10628	0.187
9	12.0	4	2	7744	0.131
9	12.5	4	2	6968	0.116
9	13.0	4	2	6784	0.113
9	13.5	4	2	6496	0.107
9	14.0	4	2	6960	0.116
9	14.5	4	2	7676	0.130
9	0.5	4	3	1012	0.001
9	1.0	4	3	4356	0.066
9	1.5	4	3	6832	0.114
9	2.0	4	3	7716	0.131
9	2.5	4	3	5336	0.085
9	3.0	4	3	4524	0.069
9	3.5	4	3	4440	0.068

month	depth	zone	station	hp reading	moisture content
9	4.0	4	3	4640	0.071
9	4.5	4	3	4560	0.070
9	5.0	4	3	4652	0.072
9	5.5	4	3	5600	0.090
9	6.0	4	3	6140	0.100
9	6.5	4	3	5876	0.095
9	7.0	4	3	5380	0.086
9	7.5	4	3	5660	0.091
9	8.0	4	3	5980	0.097
9	8.5	4	3	6144	0.100
9	9.0	4	3	6404	0.105
9	9.5	4	3	6060	0.099
9	10.0	4	3	6152	0.101
9	10.5	4	3	6404	0.105
9	11.0	4	3	6828	0.114
9	11.5	4	3	7240	0.122
9	12.0	4	3	7780	0.132
9	12.5	4	3	7420	0.125
9	13.0	4	3	6968	0.116
9	13.5	4	3	6172	0.101
9	14.0	4	3	6148	0.101
9	14.5	4	3	6856	0.114
9	15.0	4	3	7240	0.122
9	0.5	4	4	1212	0.005
9	1.0	4	4	3752	0.054
9	1.5	4	4	6812	0.113
9	2.0	4	4	7636	0.129
9	2.5	4	4	6696	0.111
9	3.0	4	4	6680	0.111
9	3.5	4	4	6784	0.113
9	4.0	4	4	6592	0.109
9	4.5	4	4	6412	0.106
9	5.0	4	4	5880	0.095
9	5.5	4	4	6828	0.114
9	6.0	4	4	7712	0.131
9	6.5	4	4	9408	0.163
9	7.0	4	4	5868	0.095
9	7.5	4	4	4220	0.063
9	8.0	4	4	4116	0.061
9	8.5	4	4	4204	0.063
9	9.0	4	4	4832	0.075
9	9.5	4	4	5312	0.084
9	10.0	4	4	5556	0.089
9	10.5	4	4	5704	0.092
9	11.0	4	4	5376	0.086
9	11.5	4	4	5728	0.092
9	12.0	4	4	6836	0.114
9	12.5	4	4	7828	0.133
9	13.0	4	4	7544	0.127
9	13.5	4	4	8104	0.138
9	14.0	4	4	8168	0.140
9	14.5	4	4	14588	0.263
9	15.0	4	4	15660	0.284
9	0.5	4	5	2460	0.029
9	1.0	4	5	4484	0.068
9	1.5	4	5	5336	0.085
9	2.0	4	5	5284	0.084
9	2.5	4	5	5268	0.084
9	3.0	4	5	6588	0.109
9	3.5	4	5	6736	0.112
9	4.0	4	5	8664	0.149
9	4.5	4	5	8908	0.154
9	5.0	4	5	7356	0.124

month	depth	zone	station	hp reading	moisture content
9	5.5	4	5	8300	0.142
9	6.0	4	5	7372	0.124
9	6.5	4	5	5576	0.090
9	7.0	4	5	5288	0.084
9	7.5	4	5	5416	0.086
9	8.0	4	5	5468	0.087
9	8.5	4	5	8212	0.140
9	9.0	4	5	8552	0.147
9	9.5	4	5	7376	0.124
9	10.0	4	5	8372	0.143
9	10.5	4	5	8556	0.147
9	11.0	4	5	8452	0.145
9	11.5	4	5	9400	0.163
9	12.0	4	5	10088	0.177
9	12.5	4	5	8632	0.148
9	13.0	4	5	10244	0.180
9	13.5	4	5	9344	0.162
9	14.0	4	5	9224	0.160
9	14.5	4	5	8632	0.148
9	15.0	4	5	8708	0.150
10	0.5	1	1	2452	0.029
10	1.0	1	1	5268	0.084
10	1.5	1	1	6604	0.109
10	2.0	1	1	6632	0.110
10	2.5	1	1	6032	0.098
10	3.0	1	1	6012	0.098
10	3.5	1	1	6480	0.107
10	4.0	1	1	7784	0.132
10	4.5	1	1	8664	0.149
10	0.5	1	2	1748	0.016
10	1.0	1	2	5964	0.097
10	1.5	1	2	7524	0.127
10	2.0	1	2	7252	0.122
10	2.5	1	2	7308	0.123
10	3.0	1	2	7056	0.118
10	3.5	1	2	6864	0.114
10	4.0	1	2	6792	0.113
10	4.5	1	2	6616	0.110
10	5.0	1	2	6460	0.107
10	5.5	1	2	6740	0.112
10	6.0	1	2	6300	0.103
10	6.5	1	2	6064	0.099
10	7.0	1	2	6128	0.100
10	7.5	1	2	5900	0.096
10	8.0	1	2	6304	0.104
10	8.5	1	2	6276	0.103
10	9.0	1	2	6820	0.114
10	9.5	1	2	8220	0.141
10	10.0	1	2	10760	0.190
10	0.5	1	3	540	-0.008
10	1.0	1	3	2440	0.029
10	1.5	1	3	4720	0.073
10	2.0	1	3	6080	0.099
10	2.5	1	3	6072	0.099
10	3.0	1	3	5612	0.090
10	3.5	1	3	6336	0.104
10	4.0	1	3	6784	0.113
10	4.5	1	3	6696	0.111
10	5.0	1	3	6276	0.103
10	5.5	1	3	6064	0.099
10	0.5	1	4	1004	0.001
10	1.0	1	4	3800	0.055
10	1.5	1	4	5304	0.084

month	depth	zone	station	hp reading	moisture content
10	2.0	1	4	6736	0.112
10	0.5	1	5	1208	0.005
10	1.0	1	5	5124	0.081
10	1.5	1	5	7456	0.126
10	2.0	1	5	7256	0.122
10	2.5	1	5	7364	0.124
10	3.0	1	5	8172	0.140
10	3.5	1	5	9140	0.158
10	4.0	1	5	9504	0.165
10	4.5	1	5	10064	0.176
10	5.0	1	5	8436	0.145
10	5.5	1	5	6612	0.110
10	6.0	1	5	6208	0.102
10	6.5	1	5	7436	0.125
10	7.0	1	5	9836	0.172
10	7.5	1	5	8008	0.136
10	8.0	1	5	6120	0.100
10	8.5	1	5	6000	0.098
10	9.0	1	5	6040	0.098
10	9.5	1	5	6100	0.100
10	10.0	1	5	5920	0.096
10	10.5	1	5	6116	0.100
10	11.0	1	5	5792	0.094
10	11.5	1	5	6030	0.098
10	12.0	1	5	5804	0.094
10	12.5	1	5	5688	0.092
10	13.0	1	5	5812	0.094
10	13.5	1	5	6036	0.098
10	14.0	1	5	5612	0.090
10	14.5	1	5	6444	0.106
10	0.5	2	1	2040	0.021
10	1.0	2	1	3188	0.043
10	1.5	2	1	4788	0.074
10	2.0	2	1	5384	0.086
10	2.5	2	1	6108	0.100
10	3.0	2	1	4920	0.077
10	3.5	2	1	5452	0.087
10	4.0	2	1	6644	0.110
10	4.5	2	1	7464	0.126
10	5.0	2	1	6304	0.104
10	5.5	2	1	5428	0.087
10	6.0	2	1	4680	0.072
10	6.5	2	1	5932	0.096
10	0.5	2	2	8132	0.139
10	1.0	2	2	9072	0.157
10	1.5	2	2	9956	0.174
10	2.0	2	2	8856	0.153
10	2.5	2	2	8068	0.138
10	3.0	2	2	7964	0.136
10	3.5	2	2	8628	0.148
10	4.0	2	2	8416	0.144
10	4.5	2	2	7916	0.135
10	5.0	2	2	7512	0.127
10	5.5	2	2	6504	0.107
10	6.0	2	2	6888	0.115
10	6.5	2	2	6748	0.112
10	7.0	2	2	6816	0.113
10	7.5	2	2	6468	0.107
10	8.0	2	2	5968	0.097
10	8.5	2	2	5708	0.092
10	9.0	2	2	6504	0.107
10	9.5	2	2	5620	0.090
10	10.0	2	2	5084	0.080

month	depth	zone	station	hp reading	moisture content
10	10.5	2	2	4936	0.077
10	11.0	2	2	4868	0.076
10	11.5	2	2	4492	0.069
10	12.0	2	2	4824	0.075
10	12.5	2	2	5132	0.081
10	13.0	2	2	4732	0.073
10	13.5	2	2	4604	0.071
10	14.0	2	2	4700	0.073
10	14.5	2	2	5004	0.078
10	0.5	2	3	1736	0.015
10	1.0	2	3	4776	0.074
10	1.5	2	3	6448	0.106
10	2.0	2	3	6372	0.105
10	2.5	2	3	6668	0.111
10	3.0	2	3	6272	0.103
10	3.5	2	3	6104	0.100
10	4.0	2	3	6268	0.103
10	4.5	2	3	6176	0.101
10	5.0	2	3	5924	0.096
10	5.5	2	3	5788	0.094
10	6.0	2	3	6092	0.099
10	6.5	2	3	6464	0.107
10	7.0	2	3	5924	0.096
10	7.5	2	3	5920	0.096
10	8.0	2	3	6008	0.098
10	8.5	2	3	6024	0.098
10	9.0	2	3	6144	0.100
10	9.5	2	3	5900	0.096
10	10.0	2	3	5920	0.096
10	10.5	2	3	5976	0.097
10	11.0	2	3	6008	0.098
10	11.5	2	3	6200	0.102
10	12.0	2	3	6568	0.109
10	12.5	2	3	7736	0.131
10	0.5	2	4	632	-0.006
10	1.0	2	4	2088	0.022
10	1.5	2	4	3436	0.048
10	2.0	2	4	4472	0.068
10	2.5	2	4	4616	0.071
10	3.0	2	4	5092	0.080
10	3.5	2	4	5536	0.089
10	4.0	2	4	5564	0.089
10	4.5	2	4	5228	0.083
10	5.0	2	4	5292	0.084
10	5.5	2	4	4868	0.076
10	6.0	2	4	5200	0.082
10	6.5	2	4	6088	0.099
10	7.0	2	4	6276	0.103
10	0.5	2	5	2168	0.024
10	1.0	2	5	7512	0.127
10	1.5	2	5	8452	0.145
10	2.0	2	5	7132	0.120
10	2.5	2	5	7012	0.117
10	3.0	2	5	7660	0.130
10	3.5	2	5	7540	0.127
10	4.0	2	5	7648	0.130
10	4.5	2	5	6972	0.116
10	5.0	2	5	6868	0.114
10	5.5	2	5	7456	0.126
10	6.0	2	5	7300	0.123
10	6.5	2	5	6796	0.113
10	7.0	2	5	6544	0.108
10	7.5	2	5	5964	0.097

month	depth	zone	station	hp reading	moisture content
10	8.0	2	5	6012	0.098
10	8.5	2	5	6044	0.099
10	9.0	2	5	5620	0.090
10	9.5	2	5	5708	0.092
10	10.0	2	5	6036	0.098
10	10.5	2	5	6084	0.099
10	11.0	2	5	6424	0.106
10	11.5	2	5	5996	0.098
10	12.0	2	5	5428	0.087
10	12.5	2	5	5460	0.087
10	13.0	2	5	5436	0.087
10	13.5	2	5	5508	0.088
10	14.0	2	5	5012	0.079
10	14.5	2	5	5260	0.083
10	15.0	2	5	5304	0.084
10	0.5	3	1	2308	0.026
10	1.0	3	1	5536	0.089
10	1.5	3	1	6844	0.114
10	2.0	3	1	6876	0.115
10	2.5	3	1	6680	0.111
10	3.0	3	1	7116	0.119
10	3.5	3	1	5928	0.096
10	4.0	3	1	5496	0.088
10	4.5	3	1	5960	0.097
10	5.0	3	1	5424	0.087
10	5.5	3	1	5448	0.087
10	6.0	3	1	5524	0.089
10	6.5	3	1	5516	0.088
10	7.0	3	1	5636	0.091
10	7.5	3	1	5688	0.092
10	8.0	3	1	5444	0.087
10	8.5	3	1	5568	0.089
10	9.0	3	1	5308	0.084
10	9.5	3	1	5608	0.090
10	10.0	3	1	5792	0.094
10	10.5	3	1	6448	0.106
10	11.0	3	1	7316	0.123
10	0.5	3	2	2760	0.035
10	1.0	3	2	4836	0.075
10	1.5	3	2	5436	0.087
10	2.0	3	2	6052	0.099
10	2.5	3	2	6104	0.100
10	3.0	3	2	6328	0.104
10	3.5	3	2	7100	0.119
10	4.0	3	2	7012	0.117
10	4.5	3	2	6340	0.104
10	5.0	3	2	6212	0.102
10	5.5	3	2	6208	0.102
10	6.0	3	2	6224	0.102
10	6.5	3	2	6308	0.104
10	7.0	3	2	6216	0.102
10	7.5	3	2	5688	0.092
10	8.0	3	2	5704	0.092
10	8.5	3	2	5816	0.094
10	9.0	3	2	6064	0.099
10	9.5	3	2	6556	0.108
10	10.0	3	2	6900	0.115
10	10.5	3	2	6908	0.115
10	11.0	3	2	7004	0.117
10	11.5	3	2	6708	0.111
10	12.0	3	2	6628	0.110
10	12.5	3	2	6412	0.106
10	13.0	3	2	6636	0.110

month	depth	zone	station	hp reading	moisture content
10	13.5	3	2	7160	0.120
10	14.0	3	2	7084	0.119
10	14.5	3	2	6116	0.100
10	15.0	3	2	6600	0.109
10	0.5	3	3	2672	0.033
10	1.0	3	3	5148	0.081
10	1.5	3	3	5856	0.095
10	2.0	3	3	5152	0.081
10	2.5	3	3	4872	0.076
10	3.0	3	3	4564	0.070
10	3.5	3	3	4920	0.077
10	4.0	3	3	4880	0.076
10	4.5	3	3	5032	0.079
10	5.0	3	3	4968	0.078
10	5.5	3	3	6012	0.098
10	6.0	3	3	5916	0.096
10	6.5	3	3	5884	0.095
10	7.0	3	3	6160	0.101
10	7.5	3	3	6192	0.101
10	8.0	3	3	5204	0.082
10	8.5	3	3	5412	0.086
10	9.0	3	3	5384	0.086
10	9.5	3	3	5536	0.089
10	10.0	3	3	5472	0.088
10	10.5	3	3	5588	0.090
10	11.0	3	3	5856	0.095
10	11.5	3	3	5296	0.084
10	12.0	3	3	5440	0.087
10	12.5	3	3	5944	0.097
10	13.0	3	3	5868	0.095
10	13.5	3	3	5516	0.088
10	14.0	3	3	5804	0.094
10	14.5	3	3	5712	0.092
10	15.0	3	3	5824	0.094
10	0.5	3	4	1582	0.012
10	1.0	3	4	4092	0.061
10	1.5	3	4	6396	0.105
10	2.0	3	4	7436	0.125
10	2.5	3	4	7536	0.127
10	3.0	3	4	7240	0.122
10	3.5	3	4	7776	0.132
10	4.0	3	4	7568	0.128
10	4.5	3	4	6676	0.111
10	5.0	3	4	6376	0.105
10	5.5	3	4	6832	0.114
10	6.0	3	4	7220	0.121
10	6.5	3	4	6492	0.107
10	7.0	3	4	6056	0.099
10	7.5	3	4	5764	0.093
10	8.0	3	4	6012	0.098
10	8.5	3	4	5968	0.097
10	9.0	3	4	5524	0.089
10	9.5	3	4	6080	0.099
10	10.0	3	4	6000	0.098
10	10.5	3	4	6308	0.104
10	11.0	3	4	6100	0.100
10	11.5	3	4	5872	0.095
10	12.0	3	4	5948	0.097
10	12.5	3	4	5852	0.095
10	13.0	3	4	5732	0.093
10	13.5	3	4	6012	0.098
10	14.0	3	4	7172	0.120
10	14.5	3	4	7976	0.136

month	depth	zone	station	hp reading	moisture content
10	15.0	3	4	7952	0.135
10	0.5	3	5	3656	0.052
10	1.0	3	5	9656	0.168
10	1.5	3	5	9864	0.172
10	2.0	3	5	9296	0.161
10	2.5	3	5	9572	0.167
10	3.0	3	5	10324	0.181
10	3.5	3	5	10864	0.192
10	4.0	3	5	7008	0.117
10	4.5	3	5	6192	0.101
10	5.0	3	5	5860	0.095
10	5.5	3	5	5892	0.096
10	6.0	3	5	6832	0.114
10	6.5	3	5	7640	0.129
10	7.0	3	5	7236	0.122
10	7.5	3	5	7248	0.122
10	8.0	3	5	7016	0.117
10	8.5	3	5	6752	0.112
10	9.0	3	5	7568	0.128
10	9.5	3	5	7804	0.133
10	10.0	3	5	7580	0.128
10	10.5	3	5	7228	0.121
10	11.0	3	5	6748	0.112
10	11.5	3	5	6128	0.100
10	12.0	3	5	6524	0.108
10	12.5	3	5	7164	0.120
10	13.0	3	5	11088	0.196
10	13.5	3	5	14708	0.266
10	14.0	3	5	12608	0.225
10	14.5	3	5	8736	0.151
10	15.0	3	5	8088	0.138
10	0.5	4	1	4204	0.063
10	1.0	4	1	5672	0.091
10	1.5	4	1	6800	0.113
10	2.0	4	1	7304	0.123
10	2.5	4	1	7328	0.123
10	3.0	4	1	6528	0.108
10	3.5	4	1	6124	0.100
10	4.0	4	1	6128	0.100
10	4.5	4	1	6076	0.099
10	5.0	4	1	6052	0.099
10	5.5	4	1	5820	0.094
10	6.0	4	1	6168	0.101
10	6.5	4	1	6364	0.105
10	7.0	4	1	6364	0.105
10	7.5	4	1	5976	0.097
10	8.0	4	1	5704	0.092
10	8.5	4	1	5864	0.095
10	9.0	4	1	5628	0.091
10	9.5	4	1	5796	0.094
10	10.0	4	1	5640	0.091
10	10.5	4	1	5744	0.093
10	11.0	4	1	5836	0.095
10	11.5	4	1	5824	0.094
10	12.0	4	1	5652	0.091
10	12.5	4	1	5872	0.095
10	13.0	4	1	6716	0.112
10	13.5	4	1	7132	0.120
10	0.5	4	2	3620	0.052
10	1.0	4	2	5128	0.081
10	1.5	4	2	5700	0.092
10	2.0	4	2	5888	0.096
10	2.5	4	2	7340	0.124

month	depth	zone	station	hp reading	moisture content
10	3.0	4	2	7716	0.131
10	3.5	4	2	7948	0.135
10	4.0	4	2	7692	0.130
10	4.5	4	2	7688	0.130
10	5.0	4	2	8696	0.150
10	5.5	4	2	8316	0.142
10	6.0	4	2	8080	0.138
10	6.5	4	2	8144	0.139
10	7.0	4	2	9048	0.157
10	7.5	4	2	9216	0.160
10	8.0	4	2	8572	0.147
10	8.5	4	2	9592	0.167
10	9.0	4	2	11272	0.199
10	9.5	4	2	10240	0.180
10	10.0	4	2	10448	0.184
10	10.5	4	2	11588	0.206
10	11.0	4	2	12120	0.216
10	11.5	4	2	10184	0.178
10	12.0	4	2	7848	0.133
10	12.5	4	2	6388	0.105
10	13.0	4	2	6180	0.101
10	13.5	4	2	6316	0.104
10	14.0	4	2	6848	0.114
10	14.5	4	2	7380	0.124
10	0.5	4	3	1408	0.009
10	1.0	4	3	4768	0.074
10	1.5	4	3	6832	0.114
10	2.0	4	3	7492	0.126
10	2.5	4	3	4836	0.075
10	3.0	4	3	4244	0.064
10	3.5	4	3	4948	0.077
10	4.0	4	3	4584	0.070
10	4.5	4	3	4472	0.068
10	5.0	4	3	4172	0.062
10	5.5	4	3	4684	0.072
10	6.0	4	3	5412	0.086
10	6.5	4	3	5012	0.079
10	7.0	4	3	4672	0.072
10	7.5	4	3	5156	0.081
10	8.0	4	3	5316	0.084
10	8.5	4	3	5784	0.094
10	9.0	4	3	5636	0.091
10	9.5	4	3	5832	0.094
10	10.0	4	3	5844	0.095
10	10.5	4	3	6416	0.106
10	11.0	4	3	6688	0.111
10	11.5	4	3	7656	0.130
10	12.0	4	3	7556	0.128
10	12.5	4	3	7548	0.128
10	13.0	4	3	7188	0.121
10	13.5	4	3	6108	0.100
10	14.0	4	3	6004	0.098
10	14.5	4	3	6544	0.108
10	15.0	4	3	7508	0.127
10	0.5	4	4	3196	0.044
10	1.0	4	4	7588	0.128
10	1.5	4	4	10328	0.181
10	2.0	4	4	10512	0.185
10	2.5	4	4	9308	0.162
10	3.0	4	4	8688	0.150
10	3.5	4	4	7732	0.131
10	4.0	4	4	7528	0.127
10	4.5	4	4	6868	0.114

month	depth	zone	station	hp reading	moisture content
10	5.0	4	4	6744	0.112
10	5.5	4	4	6928	0.116
10	6.0	4	4	7660	0.130
10	6.5	4	4	9344	0.162
10	7.0	4	4	6220	0.102
10	7.5	4	4	4388	0.067
10	8.0	4	4	3944	0.058
10	8.5	4	4	3976	0.059
10	9.0	4	4	4488	0.069
10	9.5	4	4	5148	0.081
10	10.0	4	4	5248	0.083
10	10.5	4	4	5668	0.091
10	11.0	4	4	5632	0.091
10	11.5	4	4	5540	0.089
10	12.0	4	4	6488	0.107
10	12.5	4	4	7748	0.131
10	13.0	4	4	7204	0.121
10	13.5	4	4	8004	0.136
10	14.0	4	4	10460	0.184
10	14.5	4	4	14468	0.261
10	15.0	4	4	15864	0.288
10	0.5	4	5	4480	0.068
10	1.0	4	5	6600	0.109
10	1.5	4	5	6884	0.115
10	2.0	4	5	6808	0.113
10	2.5	4	5	6868	0.114
10	3.0	4	5	7272	0.122
10	3.5	4	5	8436	0.145
10	4.0	4	5	9292	0.161
10	4.5	4	5	8648	0.149
10	5.0	4	5	7828	0.133
10	5.5	4	5	8048	0.137
10	6.0	4	5	7280	0.122
10	6.5	4	5	5452	0.087
10	7.0	4	5	5180	0.082
10	7.5	4	5	8336	0.143
10	8.0	4	5	5548	0.089
10	8.5	4	5	8040	0.137
10	9.0	4	5	8052	0.137
10	9.5	4	5	7328	0.123
10	10.0	4	5	8736	0.151
10	10.5	4	5	9064	0.157
10	11.0	4	5	8424	0.144
10	11.5	4	5	8600	0.148
10	12.0	4	5	10112	0.177
10	12.5	4	5	8660	0.149
10	13.0	4	5	10232	0.179
10	13.5	4	5	9876	0.173
10	14.0	4	5	9568	0.167
10	14.5	4	5	8660	0.149
10	15.0	4	5	8632	0.148
	0.5	1	1		
	1.0	1	1		
	1.5	1	1		
	2.0	1	1		
	2.5	1	1		
	3.0	1	1		
	3.5	1	1		
	4.0	1	1		
	4.5	1	1		
	0.5	1	2		
	1.0	1	2		
	1.5	1	2		

month	depth	zone	station	hp reading	moisture content
	2.0	1	2		
	2.5	1	2		
	3.0	1	2		
	3.5	1	2		
	4.0	1	2		
	4.5	1	2		
	5.0	1	2		
	5.5	1	2		
	6.0	1	2		
	6.5	1	2		
	7.0	1	2		
	7.5	1	2		
	8.0	1	2		
	8.5	1	2		
	9.0	1	2		
	9.5	1	2		
	10.0	1	2		
	0.5	1	3		
	1.0	1	3		
	1.5	1	3		
	2.0	1	3		
	2.5	1	3		
	3.0	1	3		
	3.5	1	3		
	4.0	1	3		
	4.5	1	3		
	5.0	1	3		
	5.5	1	3		
	0.5	1	4		
	1.0	1	4		
	1.5	1	4		
	2.0	1	4		
	0.5	1	5		
	1.0	1	5		
	1.5	1	5		
	2.0	1	5		
	2.5	1	5		
	3.0	1	5		
	3.5	1	5		
	4.0	1	5		
	4.5	1	5		
	5.0	1	5		
	5.5	1	5		
	6.0	1	5		
	6.5	1	5		
	7.0	1	5		
	7.5	1	5		
	8.0	1	5		
	8.5	1	5		
	9.0	1	5		
	9.5	1	5		
	10.0	1	5		
	10.5	1	5		
	11.0	1	5		
	11.5	1	5		
	12.0	1	5		
	12.5	1	5		
	13.0	1	5		
	13.5	1	5		
	14.0	1	5		
	14.5	1	5		
	0.5	2	1		
	1.0	2	1		

month	depth	zone	station	hp reading	moisture content
	1.5	2	1		
	2.0	2	1		
	2.5	2	1		
	3.0	2	1		
	3.5	2	1		
	4.0	2	1		
	4.5	2	1		
	5.0	2	1		
	5.5	2	1		
	6.0	2	1		
	6.5	2	1		
	0.5	2	2		
	1.0	2	2		
	1.5	2	2		
	2.0	2	2		
	2.5	2	2		
	3.0	2	2		
	3.5	2	2		
	4.0	2	2		
	4.5	2	2		
	5.0	2	2		
	5.5	2	2		
	6.0	2	2		
	6.5	2	2		
	7.0	2	2		
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	10.5	2	2		
	11.0	2	2		
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	13.0	2	2		
	13.5	2	2		
	14.0	2	2		
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	8.5	2	3		
	9.0	2	3		
	9.5	2	3		
	10.0	2	3		
	10.5	2	3		
	11.0	2	3		
	11.5	2	3		

month	depth	zone	station	hp reading	moisture content
	12.0	2	3		
	12.5	2	3		
	0.5	2	4		
	1.0	2	4		
	1.5	2	4		
	2.0	2	4		
	2.5	2	4		
	3.0	2	4		
	3.5	2	4		
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	5.0	2	4		
	5.5	2	4		
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	7.0	2	4		
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	8.0	2	5		
	8.5	2	5		
	9.0	2	5		
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	10.0	2	5		
	10.5	2	5		
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	11.5	2	5		
	12.0	2	5		
	12.5	2	5		
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	14.0	2	5		
	14.5	2	5		
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	5.5	3	1		
	6.0	3	1		
	6.5	3	1		
	7.0	3	1		
	7.5	3	1		
	8.0	3	1		
	8.5	3	1		

month	depth	zone	station	hp reading	moisture content
	9.0	3	1		
	9.5	3	1		
	10.0	3	1		
	10.5	3	1		
	11.0	3	1		
	0.5	3	2		
	1.0	3	2		
	1.5	3	2		
	2.0	3	2		
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	14.5	3	2		
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	6.5	3	3		
	7.0	3	3		
	7.5	3	3		
	8.0	3	3		
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	9.5	3	3		
	10.0	3	3		
	10.5	3	3		
	11.0	3	3		
	11.5	3	3		
	12.0	3	3		
	12.5	3	3		
	13.0	3	3		
	13.5	3	3		
	14.0	3	3		

month	depth	zone	station	hp reading	moisture content
	14.5	3	3		
	15.0	3	3		
	0.5	3	4		
	1.0	3	4		
	1.5	3	4		
	2.0	3	4		
	2.5	3	4		
	3.0	3	4		
	3.5	3	4		
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	6.5	3	4		
	7.0	3	4		
	7.5	3	4		
	8.0	3	4		
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	10.5	3	4		
	11.0	3	4		
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	13.0	3	4		
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	14.0	3	4		
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	15.0	3	4		
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	6.0	3	5		
	6.5	3	5		
	7.0	3	5		
	7.5	3	5		
	8.0	3	5		
	8.5	3	5		
	9.0	3	5		
	9.5	3	5		
	10.0	3	5		
	10.5	3	5		
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	13.0	3	5		
	13.5	3	5		
	14.0	3	5		
	14.5	3	5		
	15.0	3	5		
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month	depth	zone	station	hp reading	moisture content
	1.0	4	1		
	1.5	4	1		
	2.0	4	1		
	2.5	4	1		
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	6.0	4	1		
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	7.0	4	1		
	7.5	4	1		
	8.0	4	1		
	8.5	4	1		
	9.0	4	1		
	9.5	4	1		
	10.0	4	1		
	10.5	4	1		
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	11.5	4	1		
	12.0	4	1		
	12.5	4	1		
	13.0	4	1		
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	1.0	4	2		
	1.5	4	2		
	2.0	4	2		
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	3.0	4	2		
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	7.5	4	2		
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	9.0	4	2		
	9.5	4	2		
	10.0	4	2		
	10.5	4	2		
	11.0	4	2		
	11.5	4	2		
	12.0	4	2		
	12.5	4	2		
	13.0	4	2		
	13.5	4	2		
	14.0	4	2		
	14.5	4	2		
	0.5	4	3		
	1.0	4	3		
	1.5	4	3		
	2.0	4	3		
	2.5	4	3		
	3.0	4	3		
	3.5	4	3		
	4.0	4	3		

month	depth	zone	station	hp reading	moisture content
	4.5	4	3		
	5.0	4	3		
	5.5	4	3		
	6.0	4	3		
	6.5	4	3		
	7.0	4	3		
	7.5	4	3		
	8.0	4	3		
	8.5	4	3		
	9.0	4	3		
	9.5	4	3		
	10.0	4	3		
	10.5	4	3		
	11.0	4	3		
	11.5	4	3		
	12.0	4	3		
	12.5	4	3		
	13.0	4	3		
	13.5	4	3		
	14.0	4	3		
	14.5	4	3		
	15.0	4	3		
	0.5	4	4		
	1.0	4	4		
	1.5	4	4		
	2.0	4	4		
	2.5	4	4		
	3.0	4	4		
	3.5	4	4		
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	6.5	4	4		
	7.0	4	4		
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	8.5	4	4		
	9.0	4	4		
	9.5	4	4		
	10.0	4	4		
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	11.0	4	4		
	11.5	4	4		
	12.0	4	4		
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	13.0	4	4		
	13.5	4	4		
	14.0	4	4		
	14.5	4	4		
	15.0	4	4		
	0.5	4	5		
	1.0	4	5		
	1.5	4	5		
	2.0	4	5		
	2.5	4	5		
	3.0	4	5		
	3.5	4	5		
	4.0	4	5		
	4.5	4	5		
	5.0	4	5		
	5.5	4	5		

month	depth	zone	station	hp reading	moisture content
	6.0	4	5		
	6.5	4	5		
	7.0	4	5		
	7.5	4	5		
	8.0	4	5		
	8.5	4	5		
	9.0	4	5		
	9.5	4	5		
	10.0	4	5		
	10.5	4	5		
	11.0	4	5		
	11.5	4	5		
	12.0	4	5		
	12.5	4	5		
	13.0	4	5		
	13.5	4	5		
	14.0	4	5		
	14.5	4	5		
	15.0	4	5		
12	0.5	1	1	2384	0.0279112
12	1.0	1	1	5600	0.08998
12	1.5	1	1	5904	0.0958472
12	2.0	1	1	5712	0.0921416
12	2.5	1	1	6144	0.1004792
12	3.0	1	1	4992	0.0782456
12	3.5	1	1	6448	0.1063464
12	4.0	1	1	6752	0.1122136
12	4.5	1	1	8400	0.14402
12	0.5	1	2	1296	0.0069128
12	1.0	1	2	6048	0.0986264
12	1.5	1	2	7648	0.1295064
12	2.0	1	2	6926	0.1155718
12	2.5	1	2	6528	0.1078904
12	3.0	1	2	6000	0.0977
12	3.5	1	2	6416	0.1057288
12	4.0	1	2	6128	0.1001704
12	4.5	1	2	6320	0.103876
12	5.0	1	2	6592	0.1091256
12	5.5	1	2	6416	0.1057288
12	6.0	1	2	5920	0.096156
12	6.5	1	2	5856	0.0949208
12	7.0	1	2	6240	0.102332
12	7.5	1	2	5584	0.0896712
12	8.0	1	2	6016	0.0980088
12	8.5	1	2	6336	0.1041848
12	9.0	1	2	6624	0.1097432
12	9.5	1	2	9056	0.1566808
12	10.0	1	2	10304	0.1807672
12	0.5	1	3	768	-0.0032776
12	1.0	1	3	3280	0.045204
12	1.5	1	3	4656	0.0717608
12	2.0	1	3	6192	0.1014056
12	2.5	1	3	5520	0.088436
12	3.0	1	3	6224	0.1020232
12	3.5	1	3	6560	0.108508
12	4.0	1	3	6640	0.110052
12	4.5	1	3	6512	0.1075816
12	5.0	1	3	6176	0.1010968
12	5.5	1	3	6576	0.1088168
12	0.5	1	4	1072	0.0025896
12	1.0	1	4	3952	0.0581736
12	1.5	1	4	5376	0.0856568
12	2.0	1	4	6448	0.1063464

month	depth	zone	station	hp reading	moisture content
12	0.5	1	5	1888	0.018338
12	1.0	1	5	5664	0.091215
12	1.5	1	5	7088	0.118698
12	2.0	1	5	6758	0.112329
12	2.5	1	5	7024	0.117463
12	3.0	1	5	7104	0.119007
12	3.5	1	5	8016	0.136609
12	4.0	1	5	9232	0.160078
12	4.5	1	5	10176	0.178297
12	5.0	1	5	8112	0.138462
12	5.5	1	5	6384	0.105111
12	6.0	1	5	6384	0.105111
12	6.5	1	5	8160	0.139388
12	7.0	1	5	9216	0.159769
12	7.5	1	5	7552	0.127654
12	8.0	1	5	5744	0.092759
12	8.5	1	5	5808	0.093994
12	9.0	1	5	5520	0.088436
12	9.5	1	5	6096	0.099553
12	10.0	1	5	5920	0.096156
12	10.5	1	5	6224	0.102023
12	11.0	1	5	5824	0.094303
12	11.5	1	5	5792	0.093686
12	12.0	1	5	5744	0.092759
12	12.5	1	5	5712	0.092142
12	13.0	1	5	6112	0.099862
12	13.5	1	5	6176	0.101097
12	14.0	1	5	5856	0.094921
12	14.5	1	5	5968	0.097082
12	0.5	2	1	3520	0.049836
12	1.0	2	1	4352	0.065894
12	1.5	2	1	4800	0.07454
12	2.0	2	1	5776	0.093377
12	2.5	2	1	6176	0.101097
12	3.0	2	1	5360	0.085348
12	3.5	2	1	4880	0.076084
12	4.0	2	1	6480	0.106964
12	4.5	2	1	7440	0.125492
12	5.0	2	1	6096	0.099553
12	5.5	2	1	5200	0.08226
12	6.0	2	1	4400	0.06682
12	6.5	2	1	5072	0.07979
12	0.5	2	2	7936	0.135065
12	1.0	2	2	8928	0.15421
12	1.5	2	2	9040	0.156372
12	2.0	2	2	8720	0.150196
12	2.5	2	2	6832	0.113758
12	3.0	2	2	8048	0.137226
12	3.5	2	2	7440	0.125492
12	4.0	2	2	8144	0.139079
12	4.5	2	2	7024	0.117463
12	5.0	2	2	6608	0.109434
12	5.5	2	2	6768	0.112522
12	6.0	2	2	6112	0.099862
12	6.5	2	2	6880	0.114684
12	7.0	2	2	7328	0.12333
12	7.5	2	2	7248	0.121786
12	8.0	2	2	7760	0.131668
12	8.5	2	2	7386	0.12445
12	9.0	2	2	7664	0.129815
12	9.5	2	2	6704	0.111287
12	10.0	2	2	5904	0.095847
12	10.5	2	2	5808	0.093994
12	11.0	2	2	5248	0.0831864
12	11.5	2	2	5168	0.0816424
12	12.0	2	2	4560	0.069908
12	12.5	2	2	5488	0.0878184
12	13.0	2	2	5376	0.0856568
12	13.5	2	2	4832	0.0751576
12	14.0	2	2	4928	0.0770104
12	14.5	2	2	5040	0.079172
12	0.5	2	3	1920	0.018956
12	1.0	2	3	4864	0.0757752
12	1.5	2	3	6320	0.103876
12	2.0	2	3	6688	0.1109784
12	2.5	2	3	5728	0.0924504
12	3.0	2	3	5760	0.093068
12	3.5	2	3	5984	0.0973912
12	4.0	2	3	5472	0.0875096
12	4.5	2	3	5600	0.08998
12	5.0	2	3	5604	0.0900572
12	5.5	2	3	5024	0.0788632
12	6.0	2	3	5760	0.093068
12	6.5	2	3	5840	0.094612
12	7.0	2	3	5808	0.0939944
12	7.5	2	3	6114	0.0999002
12	8.0	2	3	5616	0.0902888
12	8.5	2	3	5808	0.0939944
12	9.0	2	3	5568	0.0893624
12	9.5	2	3	5852	0.0948436
12	10.0	2	3	5904	0.0958472
12	10.5	2	3	6304	0.1035672
12	11.0	2	3	5496	0.0879728
12	11.5	2	3	5856	0.0949208
12	12.0	2	3	6304	0.1035672
12	12.5	2	3	7840	0.133212
12	0.5	2	4	992	0.0010456
12	1.0	2	4	2480	0.029764
12	1.5	2	4	3536	0.0501448
12	2.0	2	4	4464	0.0680552
12	2.5	2	4	5136	0.0810248
12	3.0	2	4	4912	0.0767016
12	3.5	2	4	5200	0.08226
12	4.0	2	4	6016	0.0980088
12	4.5	2	4	5728	0.0924504
12	5.0	2	4	4992	0.0782456
12	5.5	2	4	5040	0.079172
12	6.0	2	4	4832	0.0751576
12	6.5	2	4	6048	0.0986264
12	7.0	2	4	5632	0.0905976
12	0.5	2	5	3760	0.054468
12	1.0	2	5	7408	0.1248744
12	1.5	2	5	7888	0.1341384
12	2.0	2	5	6768	0.1125224
12	2.5	2	5	7084	0.1186212
12	3.0	2	5	8096	0.1381528
12	3.5	2	5	7360	0.123948
12	4.0	2	5	7184	0.1205512
12	4.5	2	5	7200	0.12086
12	5.0	2	5	6784	0.1128312
12	5.5	2	5	7042	0.1178106
12	6.0	2	5	6992	0.1168456
12	6.5	2	5	6704	0.1112872
12	7.0	2	5	6672	0.1106696
12	7.5	2	5	5856	0.0949208
12	8.0	2	5	5744	0.0927592

month	depth	zone	station	hp reading	moisture content
12	8.5	2	5	6064	0.098935
12	9.0	2	5	5504	0.088127
12	9.5	2	5	6032	0.098318
12	10.0	2	5	6752	0.112214
12	10.5	2	5	6608	0.109434
12	11.0	2	5	6576	0.108817
12	11.5	2	5	6160	0.100788
12	12.0	2	5	5360	0.085348
12	12.5	2	5	5408	0.086274
12	13.0	2	5	4928	0.07701
12	13.5	2	5	5360	0.085348
12	14.0	2	5	5296	0.084113
12	14.5	2	5	4624	0.071143
12	15.0	2	5	5520	0.088436
12	0.5	3	1	3280	0.045204
12	1.0	3	1	5600	0.08998
12	1.5	3	1	7168	0.120242
12	2.0	3	1	6288	0.103258
12	2.5	3	1	6832	0.113758
12	3.0	3	1	7568	0.127962
12	3.5	3	1	6002	0.097739
12	4.0	3	1	5744	0.092759
12	4.5	3	1	5104	0.080407
12	5.0	3	1	5648	0.090906
12	5.5	3	1	5760	0.093068
12	6.0	3	1	6080	0.099244
12	6.5	3	1	6192	0.101406
12	7.0	3	1	5936	0.096465
12	7.5	3	1	5424	0.086583
12	8.0	3	1	5480	0.087664
12	8.5	3	1	5040	0.079172
12	9.0	3	1	5936	0.096465
12	9.5	3	1	5504	0.088127
12	10.0	3	1	5392	0.085966
12	10.5	3	1	6736	0.111905
12	11.0	3	1	7360	0.123948
12	0.5	3	2	3584	0.051071
12	1.0	3	2	5120	0.080716
12	1.5	3	2	5680	0.091524
12	2.0	3	2	6192	0.101406
12	2.5	3	2	6112	0.099862
12	3.0	3	2	6128	0.10017
12	3.5	3	2	7376	0.124257
12	4.0	3	2	6992	0.116846
12	4.5	3	2	6080	0.099244
12	5.0	3	2	5712	0.092142
12	5.5	3	2	5664	0.091215
12	6.0	3	2	5808	0.093994
12	6.5	3	2	5904	0.095847
12	7.0	3	2	6304	0.103567
12	7.5	3	2	5744	0.092759
12	8.0	3	2	5824	0.094303
12	8.5	3	2	5888	0.095538
12	9.0	3	2	6080	0.099244
12	9.5	3	2	5744	0.092759
12	10.0	3	2	6128	0.10017
12	10.5	3	2	6752	0.112214
12	11.0	3	2	6384	0.105111
12	11.5	3	2	6912	0.115302
12	12.0	3	2	6544	0.108199
12	12.5	3	2	6208	0.101714
12	13.0	3	2	6144	0.100479
12	13.5	3	2	7232	0.121478

month	depth	zone	station	hp reading	moisture content
12	14.0	3	2	6656	0.1103608
12	14.5	3	2	6544	0.1081992
12	15.0	3	2	6546	0.1082378
12	0.5	3	3	3856	0.0563208
12	1.0	3	3	5568	0.0893624
12	1.5	3	3	6304	0.1035672
12	2.0	3	3	6208	0.1017144
12	2.5	3	3	6048	0.0986264
12	3.0	3	3	5616	0.0902888
12	3.5	3	3	6128	0.1001704
12	4.0	3	3	4784	0.0742312
12	4.5	3	3	5360	0.085348
12	5.0	3	3	5600	0.08998
12	5.5	3	3	6000	0.0977
12	6.0	3	3	5632	0.0905976
12	6.5	3	3	5504	0.0881272
12	7.0	3	3	5568	0.0893624
12	7.5	3	3	6112	0.0998616
12	8.0	3	3	5728	0.0924504
12	8.5	3	3	4928	0.0770104
12	9.0	3	3	5568	0.0893624
12	9.5	3	3	5264	0.0834952
12	10.0	3	3	5536	0.0887448
12	10.5	3	3	5792	0.0936856
12	11.0	3	3	5632	0.0905976
12	11.5	3	3	4976	0.0779368
12	12.0	3	3	5632	0.0905976
12	12.5	3	3	6192	0.1014056
12	13.0	3	3	6288	0.1032584
12	13.5	3	3	5744	0.0927592
12	14.0	3	3	6048	0.0986264
12	14.5	3	3	5696	0.0918328
12	15.0	3	3	5552	0.0890536
12	0.5	3	4	2048	0.0214264
12	1.0	3	4	4736	0.0733048
12	1.5	3	4	7072	0.1183896
12	2.0	3	4	7664	0.1298152
12	2.5	3	4	7616	0.1288888
12	3.0	3	4	6640	0.110052
12	3.5	3	4	7936	0.1350648
12	4.0	3	4	6960	0.116228
12	4.5	3	4	6384	0.1051112
12	5.0	3	4	6386	0.1051498
12	5.5	3	4	6704	0.1112872
12	6.0	3	4	6848	0.1140664
12	6.5	3	4	6016	0.0980088
12	7.0	3	4	6272	0.1029496
12	7.5	3	4	5680	0.091524
12	8.0	3	4	6048	0.0986264
12	8.5	3	4	6368	0.1048024
12	9.0	3	4	6016	0.0980088
12	9.5	3	4	5840	0.094612
12	10.0	3	4	6272	0.1029496
12	10.5	3	4	6336	0.1041848
12	11.0	3	4	6336	0.1041848
12	11.5	3	4	6048	0.0986264
12	12.0	3	4	5536	0.0887448
12	12.5	3	4	5969	0.0971017
12	13.0	3	4	5888	0.0955384
12	13.5	3	4	6176	0.1010968
12	14.0	3	4	7024	0.1174632
12	14.5	3	4	8272	0.1415496
12	15.0	3	4	7664	0.1298152

month	depth	zone	station	hp reading	moisture content
12	0.5	3	5	5536	0.088745
12	1.0	3	5	9504	0.165327
12	1.5	3	5	9808	0.171194
12	2.0	3	5	9680	0.168724
12	2.5	3	5	9920	0.173356
12	3.0	3	5	10992	0.194046
12	3.5	3	5	10736	0.189105
12	4.0	3	5	7872	0.13383
12	4.5	3	5	5874	0.095268
12	5.0	3	5	6000	0.0977
12	5.5	3	5	6114	0.0999
12	6.0	3	5	6848	0.114066
12	6.5	3	5	7248	0.121786
12	7.0	3	5	6464	0.106655
12	7.5	3	5	6656	0.110361
12	8.0	3	5	6752	0.112214
12	8.5	3	5	5776	0.093377
12	9.0	3	5	7712	0.130742
12	9.5	3	5	7584	0.128271
12	10.0	3	5	7168	0.120242
12	10.5	3	5	7088	0.118698
12	11.0	3	5	6384	0.105111
12	11.5	3	5	6368	0.104802
12	12.0	3	5	5806	0.093956
12	12.5	3	5	7072	0.11839
12	13.0	3	5	10976	0.193737
12	13.5	3	5	15232	0.275878
12	14.0	3	5	13056	0.233881
12	14.5	3	5	9184	0.159151
12	15.0	3	5	8544	0.146799
12	0.5	4	1	4576	0.070217
12	1.0	4	1	5904	0.095847
12	1.5	4	1	6400	0.10542
12	2.0	4	1	6976	0.116537
12	2.5	4	1	6720	0.111596
12	3.0	4	1	7056	0.118081
12	3.5	4	1	5664	0.091215
12	4.0	4	1	5696	0.091833
12	4.5	4	1	5984	0.097391
12	5.0	4	1	5504	0.088127
12	5.5	4	1	5424	0.086583
12	6.0	4	1	5888	0.095538
12	6.5	4	1	6304	0.103567
12	7.0	4	1	6480	0.106964
12	7.5	4	1	6160	0.100788
12	8.0	4	1	6384	0.105111
12	8.5	4	1	5584	0.089671
12	9.0	4	1	5856	0.094921
12	9.5	4	1	5728	0.09245
12	10.0	4	1	5584	0.089671
12	10.5	4	1	5136	0.081025
12	11.0	4	1	6048	0.098626
12	11.5	4	1	5584	0.089671
12	12.0	4	1	6096	0.099553
12	12.5	4	1	5296	0.084113
12	13.0	4	1	6256	0.102641
12	13.5	4	1	7184	0.120551
12	0.5	4	2	3424	0.047983
12	1.0	4	2	5408	0.086274
12	1.5	4	2	5664	0.091215
12	2.0	4	2	6688	0.110978
12	2.5	4	2	7824	0.132903
12	3.0	4	2	7056	0.118081

month	depth	zone	station	hp reading	moisture content
12	3.5	4	2	7712	0.1307416
12	4.0	4	2	7904	0.1344472
12	4.5	4	2	8002	0.1363386
12	5.0	4	2	8528	0.1464904
12	5.5	4	2	8288	0.1418584
12	6.0	4	2	8336	0.1427848
12	6.5	4	2	7792	0.1322856
12	7.0	4	2	8816	0.1520488
12	7.5	4	2	9024	0.1560632
12	8.0	4	2	9072	0.1569896
12	8.5	4	2	9456	0.1644008
12	9.0	4	2	11088	0.1958984
12	9.5	4	2	10608	0.1866344
12	10.0	4	2	9902	0.1730086
12	10.5	4	2	12032	0.2141176
12	11.0	4	2	11282	0.1996426
12	11.5	4	2	10384	0.1823112
12	12.0	4	2	7472	0.1261096
12	12.5	4	2	6224	0.1020232
12	13.0	4	2	6144	0.1004792
12	13.5	4	2	5648	0.0909064
12	14.0	4	2	6944	0.1159192
12	14.5	4	2	6528	0.1078904
12	0.5	4	3	2368	0.0276024
12	1.0	4	3	5904	0.0958472
12	1.5	4	3	7808	0.1325944
12	2.0	4	3	7792	0.1322856
12	2.5	4	3	5312	0.0844216
12	3.0	4	3	4064	0.0603352
12	3.5	4	3	4224	0.0634232
12	4.0	4	3	4384	0.0665112
12	4.5	4	3	4400	0.06682
12	5.0	4	3	3984	0.0587912
12	5.5	4	3	4944	0.0773192
12	6.0	4	3	4880	0.076084
12	6.5	4	3	4864	0.0757752
12	7.0	4	3	4480	0.068364
12	7.5	4	3	5008	0.0785544
12	8.0	4	3	5184	0.0819512
12	8.5	4	3	5760	0.093068
12	9.0	4	3	5792	0.0936856
12	9.5	4	3	5312	0.0844216
12	10.0	4	3	5584	0.0896712
12	10.5	4	3	5552	0.0890536
12	11.0	4	3	6560	0.108508
12	11.5	4	3	7312	0.1230216
12	12.0	4	3	7232	0.1214776
12	12.5	4	3	7120	0.119316
12	13.0	4	3	7024	0.1174632
12	13.5	4	3	7288	0.1225584
12	14.0	4	3	5376	0.0856568
12	14.5	4	3	6496	0.1072728
12	15.0	4	3	7344	0.1236392
12	0.5	4	4	3200	0.04366
12	1.0	4	4	6448	0.1063464
12	1.5	4	4	9168	0.1588424
12	2.0	4	4	8816	0.1520488
12	2.5	4	4	6960	0.116228
12	3.0	4	4	6768	0.1125224
12	3.5	4	4	7280	0.122404
12	4.0	4	4	7232	0.1214776
12	4.5	4	4	6272	0.1029496
12	5.0	4	4	6224	0.1020232

month	depth	zone	station	hp reading	moisture content
12	5.5	4	4	7520	0.127036
12	6.0	4	4	7568	0.127962
12	6.5	4	4	9424	0.163783
12	7.0	4	4	6816	0.113449
12	7.5	4	4	4384	0.066511
12	8.0	4	4	3744	0.054159
12	8.5	4	4	4752	0.073614
12	9.0	4	4	4960	0.077628
12	9.5	4	4	5808	0.093994
12	10.0	4	4	5824	0.094303
12	10.5	4	4	5428	0.08666
12	11.0	4	4	5712	0.092142
12	11.5	4	4	5280	0.083804
12	12.0	4	4	7216	0.121169
12	12.5	4	4	8320	0.142476
12	13.0	4	4	7232	0.121478
12	13.5	4	4	8672	0.14927
12	14.0	4	4	10176	0.178297
12	14.5	4	4	15120	0.273716
12	15.0	4	4	15104	0.273407
12	0.5	4	5	4864	0.075775
12	1.0	4	5	5568	0.089362
12	1.5	4	5	6256	0.102641
12	2.0	4	5	6288	0.103258
12	2.5	4	5	6416	0.105729
12	3.0	4	5	6800	0.11314
12	3.5	4	5	7904	0.134447
12	4.0	4	5	10032	0.175518
12	4.5	4	5	8560	0.147108
12	5.0	4	5	8160	0.139388
12	5.5	4	5	8384	0.143711
12	6.0	4	5	7744	0.131359
12	6.5	4	5	6176	0.101097
12	7.0	4	5	4752	0.073614
12	7.5	4	5	5184	0.081951
12	8.0	4	5	5296	0.084113
12	8.5	4	5	8048	0.137226
12	9.0	4	5	7888	0.134138
12	9.5	4	5	7104	0.119007
12	10.0	4	5	7600	0.12858
12	10.5	4	5	9440	0.164092
12	11.0	4	5	8032	0.136918
12	11.5	4	5	9442	0.164131
12	12.0	4	5	9760	0.170268
12	12.5	4	5	8352	0.143094
12	13.0	4	5	9472	0.16471
12	13.5	4	5	8976	0.155137
12	14.0	4	5	8848	0.152666
12	14.5	4	5	8784	0.151431
12	15.0	4	5	9200	0.15946

month	depth	zone	station	hp reading	moisture content

Appendix I

Vegetation Mapping Data for Area Over Plume

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Strata	Transect	Degree	Meters crossing line							% Cover							Actual # of plants along transect						
number	number	Heading	ATCA	ATCO	EPTO	GUSA	HAPL	POIN	SAVE	ATCA	ATCO	EPTO	GUSA	HAPL	POIN	SAVE	ATCA	ATCO	EPTO	GUSA	HAPL	POIN	SAVE
2	1	180	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.00	0.00	1	0	0	3	3	0	0
2	2	30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	4	2	0	0
2	3	130	0.00	0.00	0.00	0.00	1.21	0.00	0.00	0.00	0.00	0.00	0.00	4.03	0.00	0.00	0	0	0	1	18	0	0
2	4	300	0.00	0.00	0.00	0.00	3.48	0.00	0.00	0.00	0.00	0.00	0.00	11.60	0.00	0.00	0	0	0	0	9	0	1
2	5	130	0.00	0.63	0.00	0.00	0.00	0.00	5.47	0.00	2.10	0.00	0.00	0.00	0.00	18.23	0	9	0	1	0	0	5
2	6	180	0.00	1.29	0.00	0.00	0.00	0.00	1.50	0.00	4.30	0.00	0.00	0.00	0.00	5.00	0	5	0	0	0	0	6
3	1	35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	1	0	0
3	2	0	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.00	0.00	0	0	0	1	3	0	0
3	3	180	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0	0	0	1	0	0
3	4	190	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.00	0.00	1	0	2	3	8	0	0
3	5	210	1.45	0.00	0.00	0.00	0.00	0.00	0.93	4.83	0.00	0.00	0.00	0.00	0.00	3.10	3	0	0	0	0	0	3
3	6	90	0.00	2.34	0.00	0.00	0.00	0.00	0.33	0.00	7.80	0.00	0.00	0.00	0.00	1.10	0	5	0	0	0	0	2
4	1	30	0.00	0.00	0.00	0.00	1.94	0.00	0.00	0.00	0.00	0.00	0.00	6.47	0.00	0.00	0	0	0	0	7	0	0
4	2	350	0.00	0.00	0.00	0.00	1.42	0.00	0.00	0.00	0.00	0.00	0.00	4.73	0.00	0.00	0	0	0	0	21	0	0
4	3	270	0.00	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	4.90	0.00	0.00	0	0	0	0	1	0	0
4	4	240	2.47	0.00	0.00	0.00	0.00	0.00	0.88	8.23	0.00	0.00	0.00	0.00	0.00	2.93	1	0	0	0	0	0	1
4	5	30	0.00	0.00	0.00	0.00	1.29	0.00	1.45	0.00	0.00	0.00	0.00	4.30	0.00	4.83	2	0	2	0	3	0	1
4	6	30	0.24	0.00	0.00	0.00	0.38	0.00	2.00	0.80	0.00	0.00	0.00	1.27	0.00	6.67	1	0	4	3	0	0	10
5	1	135	0.00	0.00	0.00	0.00	0.59	0.13	0.00	0.00	0.00	0.00	0.00	1.97	0.43	0.00	0	0	0	0	14	1	0
5	2	320	3.93	0.00	0.00	0.00	0.00	0.00	0.00	13.10	0.00	0.00	0.00	0.00	0.00	0.00	5	0	4	0	0	0	0
5	3	270	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	1.03	0.00	0.00	3	0	0	0	2	0	0
5	4	190	0.00	0.00	0.00	0.00	3.49	0.00	0.00	0.00	0.00	0.00	0.00	11.63	0.00	0.00	0	0	8	30	17	0	0
5	5	20	0.00	0.00	0.00	0.00	0.00	0.00	4.95	0.00	0.00	0.00	0.00	0.00	0.00	16.50	1	0	1	6	2	0	3
5	6	185	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	4	2	0	2
6	1	30	0.00	0.00	0.00	0.00	1.36	0.95	0.00	0.00	0.00	0.00	0.00	4.53	3.17	0.00	0	0	0	0	17	1	0
6	2	350	0.00	0.00	0.00	0.00	3.24	0.00	0.00	0.00	0.00	0.00	0.00	10.80	0.00	0.00	0	0	0	0	6	0	0
6	3	5	0.73	0.00	0.00	0.00	0.96	0.00	0.00	2.43	0.00	0.00	0.00	3.20	0.00	0.00	1	0	7	0	3	0	0
6	4	60	4.28	0.00	0.00	0.05	0.00	0.00	0.00	14.27	0.00	0.00	0.17	0.00	0.00	0.00	2	0	0	1	3	0	0
6	5	355	0.00	0.00	0.00	0.00	6.05	0.00	0.00	0.00	0.00	0.00	0.00	20.17	0.00	0.00	0	0	0	0	10	0	0
6	6	240	2.62	0.00	0.00	0.00	0.22	0.00	2.44	8.73	0.00	0.00	0.00	0.73	0.00	8.13	2	0	0	0	4	0	1
7	1	258	0.00	0.00	0.00	0.00	1.53	1.01	0.00	0.00	0.00	0.00	0.00	5.10	3.37	0.00	0	0	0	0	11	5	0
7	2	186	0.65	2.24	0.00	0.00	1.26	0.00	0.00	2.17	7.47	0.00	0.00	4.20	0.00	0.00	4	1	0	0	2	0	0
7	3	30	0.00	0.00	0.00	0.00	1.93	0.00	0.00	0.00	0.00	0.00	0.00	6.43	0.00	0.00	1	0	7	0	7	0	0
7	4	150	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	7	0	0
7	5	190	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0	0	0	2	0	0
7	6	250	0.64	0.00	0.00	0.00	0.63	0.00	0.00	2.13	0.00	0.00	0.00	2.10	0.00	0.00	3	0	1	3	13	0	0
8	1	264	0.00	0.00	0.00	0.53	0.00	1.35	0.00	0.00	0.00	0.00	1.77	0.00	4.50	0.00	0	0	0	0	10	14	0
8	2	42	0.00	0.00	1.37	0.00	0.42	1.52	0.00	0.00	0.00	4.57	0.00	1.40	5.07	0.00	1	0	2	0	4	2	0
8	3	252	0.00	0.00	1.38	0.00	1.03	0.45	0.00	0.00	0.00	4.60	0.00	3.43	1.50	0.00	1	0	1	0	9	2	0
8	4	324	0.00	0.00	0.00	0.00	0.78	0.00	0.00	0.00	0.00	0.00	0.00	2.60	0.00	0.00	0	1	0	0	12	0	0
8	5	186	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0
8	6	45	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0	0	1	0	3	0	1
9	1	192	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	3	0	0
9	2	262	0.00	0.00	0.00	0.00	1.72	0.76	0.00	0.00	0.00	0.00	0.00	5.73	2.53	0.00	1	1	0	0	4	6	0
9	3	168	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.00	0.00	5.53	0.00	0.00	0.00	0.00	0	0	4	0	12	0	0
9	4	174	0.00	0.00	0.00	0.00	0.70	0.58	0.00	0.00	0.00	0.00	0.00	2.33	1.93	0.00	0	0	0	1	12	10	0
9	5	102	0.00	0.00	0.86	0.10	0.00	0.00	0.00	0.00	0.00	2.87	0.33	0.00	0.00	0.00	0	0	14	2	4	0	0
9	6	96	2.23	0.00	0.02	0.00	0.90	0.00	0.00	7.43	0.00	0.07	0.00	3.00	0.00	0.00	0	0	2	0	6	0	0
10	1	210	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0
10	2	350	0.49	0.00	0.00	0.00	0.00	0.00	0.00	1.63	0.00	0.00	0.00	0.00	0.00	0.00	1	0	0	0	0	0	0
10	3	0	0.00	0.00	0.00	0.00	1.13	1.02	0.00	0.00	0.00	0.00	0.00	3.77	3.40	0.00	0	0	0	0	3	13	0
10	4	210	0.00	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00	3.30	0.00	0.00	0	0	0	0	15	4	0
10	5	180	0.00	0.00	3.60	0.00	0.69	1.11	0.00	0.00	0.00	12.00	0.00	2.30	3.70	0.00	0	0	3	2	5	4	0
10	6	210	0.00	0.00	0.54	0.20	0.22	0.00	0.00	0.00	0.00	1.80	0.67	0.73	0.00	0.00	0	0	4	2	8	0	0

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Appendix J

Density Data for Fenced Area

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Plot #	Line #	Total area covered (m)	(%)
1	1	3.7721	18.8605
1	2	3.62	18.1
1	3	7.39	36.95
1	4	5.38	26.9
1	5	6.38	31.9
1	6	13.97	69.85
1	7	11.55	57.75
1	8	10.08	50.4
1	9	9.46	47.3
1	10	7.58	37.9
1	11	8.4	42
1	12	9.08	45.4
1	13	11.7	58.5
1	14	13.32	66.6
1	15	14.94	74.7
1	16	15.5	77.5
1	17	16	80
1	18	17	85
1	19	15.93	79.65
1	20	2.41	12.05
		average	**50.86553**
		stddev	**22.7751**
		stderr	**5.061133**

Plot #	Line #	Total area covered (m)	(%)
2	1	3.97	19.85
2	2	7.66	38.3
2	3	4.14	20.7
2	4	4.56	22.8
2	5	7.66	38.3
2	6	6.87	34.35
2	7	5.45	27.25
2	8	9.16	45.8
2	9	12.36	61.8
2	10	9.84	49.2
2	11	9.01	45.05
2	12	7.03	35.15
2	13	10.78	53.9
2	14	9.12	45.6
2	15	4.19	20.95
2	16	8.11	40.55
2	17	8.22	41.1
2	18	7.27	36.35
2	19	6.27	31.35
2	20	8.14	40.7
			37.4525
			11.39018
			2.531151

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Appendix K

Exclosure Study Plant Data for 3 Years

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Plant Type	Field Position	Plant ID	Date of Study	Height cm	Height m	NS width cm	EW width cm	Avg Dia. cm	Avg Dia. m	Groundcover M2	Canopy Area
1	1	1	Jun-98	125	1.25	210	225	217.5	2.175	3.715432875	3.0961941
			Oct-98	135	1.35	282	265	273.5	2.735	5.874968715	5.2874718
			Sep-99	124	1.24	270	255	262.5	2.625	5.411896875	4.4738348
			Sep-00			NO DATA				0	0
1	1	2	Jun-98	135	1.35	205	215	210	2.1	3.463614	3.1172526
			Oct-98	121	1.21	222	201	211.5	2.115	3.513270915	2.8340385
			Sep-99	130	1.3	270	235	252.5	2.525	5.007415875	4.3397604
			Sep-00	139	1.39	275	262	268.5	2.685	5.662125315	5.2469028
1	1	3	Jun-98	145	1.45	185	195	190	1.9	2.835294	2.7407842
			Oct-98	150	1.5	220	198	209	2.09	3.43070574	3.4307057
			Sep-99	135	1.35	200	200	200	2	3.1416	2.82744
			Sep-00	142	1.42	192	210	201.0	2.01	3.17309454	3.0038628
1	1	4	Jun-98	100	1	195	195	195	1.95	2.9864835	1.990989
			Oct-98	110	1.1	150	196	173	1.73	2.35062366	1.7237907
			Sep-99	100	1	210	172	191.0	1.91	2.86521774	1.9101452
			Sep-00	107	1.07	201	180	190.5	1.905	2.850236235	2.0331685
1	1	5	Jun-98	115	1.15	180	190	185	1.85	2.6880315	2.0608242
			Oct-98	140	1.4	233	220	226.5	2.265	4.029278715	3.7606601
			Sep-99	128	1.28	260	260	260.0	2.6	5.309304	4.5306061
			Sep-00	131	1.31	152	155	153.5	1.535	1.850579115	1.6161724
1	1	6	Jun-98	90	0.9	105	10	57.5	0.575	0.259672875	0.1558037
			Oct-98	73	0.73	164	146	155	1.55	1.8869235	0.9183028
			Sep-99	105	1.05	185	155	170.0	1.7	2.269806	1.5888642
			Sep-00			NO DATA				0	0
1	1	7	Jun-98	130	1.3	265	280	272.5	2.725	5.832085875	5.0544744
			Oct-98	171	1.71	304	292	298	2.98	6.97466616	7.9511194
			Sep-99	168	1.68	280	290	285.0	2.85	6.3794115	7.1449409
			Sep-00	283	2.83	282	327	304.5	3.045	7.282248435	13.739175
1	1	8	Jun-98	120	1.2	140	170	155	1.55	1.8869235	1.5095388
			Oct-98	88	0.88	118	155	136.5	1.365	1.463376915	0.8585145
			Sep-99	115	1.15	185	185	185.0	1.85	2.6880315	2.0608242
			Sep-00	116	1.16	202	200	201.0	2.01	3.17309454	2.4538598
1	1	10	Jun-98	120	1.2	185	165	175	1.75	2.4052875	1.92423
			Oct-98	137	1.37	207	204	205.5	2.055	3.316763835	3.029311
			Sep-99	115	1.15	235	235	235.0	2.35	4.3373715	3.3253182
			Sep-00	122	1.22	153	163	158.0	1.58	1.96067256	1.5946803
1	1	12	Jun-98	170	1.7	220	210	215	2.15	3.6305115	4.1145797
			Oct-98	188	1.88	269	253	261	2.61	5.35022334	6.7056133
			Sep-99	125	1.25	230	265	247.5	2.475	4.811065875	4.0092216
			Sep-00	130	1.3	222	269	245.5	2.455	4.733625435	4.1024754
1	1	15	Jun-98	90	0.9	145	170	157.5	1.575	1.948282875	1.1689697
			Oct-98	120	1.2	237	163	200	2	3.1416	2.51328
			Sep-99	162	1.62	220	205	212.5	2.125	3.546571875	3.8302976
			Sep-00	177	1.77	166	272	219.0	2.19	3.76685694	4.4448912
1	1	17	Jun-98	75	0.75	135	145	140	1.4	1.539384	0.769692
			Oct-98	79	0.79	182	179	180.5	1.805	2.558852835	1.3476625
			Sep-99	82	0.82	205	185	195.0	1.95	2.9864835	1.632611
			Sep-00	80	0.8	200	218	209.0	2.09	3.43070574	1.8297097
1	2	1.5	Jun-98	90	0.9	210	210	210	2.1	3.463614	2.0781684
			Oct-98	93	0.93	225	198	211.5	2.115	3.513270915	2.178228
			Sep-99	90	0.9	230	210	220.0	2.2	3.801336	2.2808016
			Sep-00	104	1.04	210	240	225.0	2.25	3.9760875	2.756754
1	2	2.5	Jun-98	150	1.5	140	175	157.5	1.575	1.948282875	1.9482829
			Oct-98	50	0.5	202	157	179.5	1.795	2.530578435	0.8435261
			Sep-99	145	1.45	210	162	186.0	1.86	2.71716984	2.6265975
			Sep-00	157	1.57	270	192	231.0	2.31	4.19097294	4.3865517

Plant Type	Field Position	Plant ID	Date of Study	Height cm	Height m	NS width cm	EW width cm	Avg Dia. cm	Avg Dia. m	Groundcover M2	Canopy Area
1	2	3.5	Jun-98	130	1.3	225	225	225	2.25	3.9760875	3.4459425
			Oct-98	188	1.88	119	229	174	1.74	2.37787704	2.9802726
			Sep-99	130	1.3	230	240	235.0	2.35	4.3373715	3.7590553
			Sep-00	125	1.25	216	200	208.0	2.08	3.39795456	2.8316288
1	2	4.5	Jun-98	90	0.9	180	180	180	1.8	2.544696	1.5268176
			Oct-98	106	1.06	164	124	144	1.44	1.62860544	1.1508812
			Sep-99	103	1.03	116	165	140.5	1.405	1.550399235	1.0646075
			Sep-00			NO DATA				0	0
1	2	5.5	Jun-98	95	0.95	130	130	130	1.3	1.327326	0.8406398
			Oct-98	91	0.91	122	115	118.5	1.185	1.102878315	0.6690795
			Sep-99	117	1.17	163	116	139.5	1.395	1.528408035	1.1921583
			Sep-00	105	1.05	111	135	123.0	1.23	1.18823166	0.8317622
1	2	6.5	Jun-98	75	0.75	165	175	170	1.7	2.269806	1.134903
			Oct-98	121	1.21	119	124	121.5	1.215	1.159427115	0.9352712
			Sep-99	75	0.75	163	160	161.5	1.615	2.048499915	1.02425
			Sep-00	66	0.66	177	170	173.5	1.735	2.364230715	1.0402615
1	2	7.5	Jun-98	150	1.5	310	275	292.5	2.925	6.719587875	6.7195879
			Oct-98	129	1.29	217	299	258	2.58	5.22793656	4.4960254
			Sep-99	158	1.58	170	160	165.0	1.65	2.1382515	2.2522916
			Sep-00	157	1.57	246	268	257.0	2.57	5.18748846	5.4295713
1	2	8.5	Jun-98	95	0.95	130	145	137.5	1.375	1.484896875	0.9404347
			Oct-98	110	1.1	183	153	168	1.68	2.21671296	1.6255895
			Sep-99	110	1.1	195	200	197.5	1.975	3.063550875	2.246604
			Sep-00	104	1.04	213	167	190.0	1.9	2.835294	1.9658038
1	2	10.5	Jun-98	120	1.2	255	230	242.5	2.425	4.618642875	3.6949143
			Oct-98	130	1.3	156	164	160	1.6	2.010624	1.7425408
			Sep-99	120	1.2	230	148	189.0	1.89	2.80552734	2.2444219
			Sep-00	81	0.81	160	200	180.0	1.8	2.544696	1.3741358
1	2	12.5	Jun-98	85	0.85	90	125	107.5	1.075	0.907627875	0.5143225
			Oct-98	86	0.86	96	84	90	0.9	0.636174	0.3647398
			Sep-99	82	0.82	102	74	88.0	0.88	0.60821376	0.3324902
			Sep-00	70	0.7	172	107	139.5	1.395	1.528408035	0.7132571
1	2	15.5	Jun-98	95	0.95	195	215	205	2.05	3.3006435	2.0904076
			Oct-98	189	1.89	211	203	207	2.07	3.36536046	4.2403542
			Sep-99	105	1.05	205	215	210.0	2.1	3.463614	2.4245298
			Sep-00	96	0.96	189	200	194.5	1.945	2.971187835	1.9015602
1	2	17.5	Jun-98	110	1.1	160	120	140	1.4	1.539384	1.1288816
			Oct-98	112	1.12	110	164	137	1.37	1.47411726	1.1006742
			Sep-99	120	1.2	130	155	142.5	1.425	1.594852875	1.2758823
			Sep-00	123	1.23	160	131	145.5	1.455	1.662711435	1.3634234
2	1	9	Jun-98	115	1.15	145	150	147.5	1.475	1.708735875	1.3100308
			Oct-98	132	1.32	235	229	232	2.32	4.22733696	3.7200565
			Sep-99	145	1.45	270	260	265.0	2.65	5.5154715	5.3316225
			Sep-00	161	1.61	257	268	262.5	2.625	5.411896875	5.8087693
2	1	11	Jun-98	60	0.6	125	165	145	1.45	1.6513035	0.6605214
			Oct-98	78	0.78	202	179	190.5	1.905	2.850236235	1.4821228
			Sep-99	95	0.95	210	205	207.5	2.075	3.381637875	2.141704
			Sep-00	117	1.17	148	122	135.0	1.35	1.4313915	1.1164854
2	1	13	Jun-98	90	0.9	165	145	155	1.55	1.8869235	1.1321541
			Oct-98	133	1.33	210	168	189	1.89	2.80552734	2.4875676
			Sep-99	160	1.6	225	200	212.5	2.125	3.546571875	3.78301
			Sep-00	163	1.63	247	133	190.0	1.9	2.835294	3.0810195
2	1	14	Jun-98	55	0.55	130	110	120	1.2	1.130976	0.4146912
			Oct-98	113	1.13	158	163	160.5	1.605	2.023210035	1.5241516
			Sep-99	135	1.35	205	170	187.5	1.875	2.761171875	2.4850547
			Sep-00	179	1.79	243	203	223.0	2.23	3.90571566	4.6608207

Plant Type	Field Position	Plant ID	Date of Study	Height cm	Height m	NS width cm	EW width cm	Avg Dia. cm	Avg Dia. m	Groundcover M2	Canopy Area
2	1	16	Jun-98	105	1.05	170	155	162.5	1.625	2.073946875	1.4517628
			Oct-98	191	1.91	259	188	223.5	2.235	3.923249715	4.9956046
			Sep-99	160	1.6	205	195	200.0	2	3.1416	3.35104
			Sep-00	180	1.8	186	240	213.0	2.13	3.56328126	4.2759375
2	1	18	Jun-98	125	1.25	240	180	210	2.1	3.463614	2.886345
			Oct-98	194	1.94	205	266	235.5	2.355	4.355848035	5.6335635
			Sep-99	192	1.92	255	290	272.5	2.725	5.832085875	7.4650699
			Sep-00	305	3.05	292	261	276.5	2.765	6.004559715	12.209271
2	1	19	Jun-98	115	1.15	80	105	92.5	0.925	0.672007875	0.515206
			Oct-98	138	1.38	151	98	124.5	1.245	1.217389635	1.1199985
			Sep-99	150	1.5	155	133	144.0	1.44	1.62860544	1.6286054
			Sep-00	170	1.7	193	179	186.0	1.86	2.71716984	3.0794592
2	1	20	Jun-98	45	0.45	100	95	97.5	0.975	0.746620875	0.2239863
			Oct-98	96	0.96	130	138	134	1.34	1.41026424	0.9025691
			Sep-99	103	1.03	140	130	135.0	1.35	1.4313915	0.9828888
			Sep-00	105	1.05	182	140	161.0	1.61	2.03583534	1.4250847
2	1	21	Jun-98	105	1.05	165	190	177.5	1.775	2.474500875	1.7321506
			Oct-98	137	1.37	250	177	213.5	2.135	3.580029915	3.2697607
			Sep-99	130	1.3	245	200	222.5	2.225	3.888220875	3.3697914
			Sep-00	142	1.42	200	263	231.5	2.315	4.209135315	3.9846481
2	1	22	Jun-98	45	0.45	85	80	82.5	0.825	0.534562875	0.1603689
			Oct-98	97	0.97	132	136	134	1.34	1.41026424	0.9119709
			Sep-99	130	1.3	160	176	168.0	1.68	2.21671296	1.9211512
			Sep-00	150	1.5	170	204	187.0	1.87	2.74646526	2.7464653
2	1	23	Jun-98	85	0.85	95	95	95	0.95	0.7088235	0.4016667
			Oct-98	130	1.3	102	133	117.5	1.175	1.084342875	0.9397638
			Sep-99	133	1.33	142	149	145.5	1.455	1.662711435	1.4742708
			Sep-00	160	1.6	181	169	175.0	1.75	2.4052875	2.56564
2	1	24	Jun-98	110	1.1	145	145	145	1.45	1.6513035	1.2109559
			Oct-98	149	1.49	228	226	227	2.27	4.04708766	4.0201071
			Sep-99	132	1.32	170	235	202.5	2.025	3.220630875	2.8341552
			Sep-00	148	1.48	244	203	223.5	2.235	3.923249715	3.8709397
2	2	9.5	Jun-98	50	0.5	170	200	185	1.85	2.6880315	0.8960105
			Oct-98	48	0.48	174	165	169.5	1.695	2.256473835	0.7220716
			Sep-99	55	0.55	188	171	179.5	1.795	2.530578435	0.9278788
			Sep-00	64	0.64	222	190	206.0	2.06	3.33292344	1.4220473
2	2	11.5	Jun-98	70	0.7	170	150	160	1.6	2.010624	0.9382912
			Oct-98	64	0.64	147	200	173.5	1.735	2.364230715	1.0087384
			Sep-99	72	0.72	175	160	167.5	1.675	2.203537875	1.0576982
			Sep-00	68	0.68	160	200	180.0	1.8	2.544696	1.1535955
2	2	13.5	Jun-98	80	0.8	155	170	162.5	1.625	2.073946875	1.106105
			Oct-98	75	0.75	162	163	162.5	1.625	2.073946875	1.0369734
			Sep-99	113	1.13	170	162	166.0	1.66	2.16424824	1.6304003
			Sep-00	125	1.25	183	164	173.5	1.735	2.364230715	1.9701923
2	2	14.5	Jun-98	80	0.8	165	135	150	1.5	1.76715	0.94248
			Oct-98	75	0.75	171	169	170	1.7	2.269806	1.134903
			Sep-99	55	0.55	130	75	102.5	1.025	0.825160875	0.302559
			Sep-00	101	1.01	157	171	164.0	1.64	2.11241184	1.4223573
2	2	16.5	Jun-98	65	0.65	95	90	92.5	0.925	0.672007875	0.2912034
			Oct-98	76	0.76	98	122	110	1.1	0.950334	0.4815026
			Sep-99	80	0.8	105	155	130.0	1.3	1.327326	0.7079072
			Sep-00	92	0.92	174	102	138.0	1.38	1.49571576	0.9173723
2	2	18.5	Jun-98	155	1.55	205	225	215	2.15	3.6305115	3.7515286
			Oct-98	165	1.65	251	205	228	2.28	4.08282336	4.4911057
			Sep-99	175	1.75	128	215	171.5	1.715	2.310038115	2.6950445
			Sep-00	193	1.93	146	160	153.0	1.53	1.83854286	2.3655918

Plant Type	Field Position	Plant ID	Date of Study	Height cm	Height m	NS width cm	EW width cm	Avg Dia. cm	Avg Dia. m	Groundcover M2	Canopy Area
2	2	19.5	Jun-98	85	0.85	175	115	145	1.45	1.6513035	0.9357387
			Oct-98	70	0.7	183	112	147.5	1.475	1.708735875	0.7974101
			Sep-99	95	0.95	130	183	156.5	1.565	1.923621315	1.2182935
			Sep-00	106	1.06	195	142	168.5	1.685	2.229927315	1.5758153
2	2	20.5	Jun-98	75	0.75	75	125	100	1	0.7854	0.3927
			Oct-98	74	0.74	123	84	103.5	1.035	0.841340115	0.4150611
			Sep-99	72	0.72	122	112	117.0	1.17	1.07513406	0.5160643
			Sep-00	80	0.8	105	144	124.5	1.245	1.217389635	0.6492745
2	2	21.5	Jun-98	105	1.05	120	130	125	1.25	1.2271875	0.8590313
			Oct-98	98	0.98	117	118	117.5	1.175	1.084342875	0.7084373
			Sep-99	101	1.01	119	140	129.5	1.295	1.317135435	0.8868712
			Sep-00	100	1	105	134	119.5	1.195	1.121570835	0.7477139
2	2	22.5	Jun-98	80	0.8	120	125	122.5	1.225	1.178590875	0.6285818
			Oct-98	66	0.66	161	151	156	1.56	1.91134944	0.8409938
			Sep-99	85	0.85	115	136	125.5	1.255	1.237024635	0.7009806
			Sep-00	85	0.85	190	123	156.5	1.565	1.923621315	1.0900521
2	2	23.5	Jun-98	145	1.45	115	130	122.5	1.225	1.178590875	1.1393045
			Oct-98	150	1.5	151	131	141	1.41	1.56145374	1.5614537
			Sep-99	155	1.55	150	135	142.5	1.425	1.594852875	1.6480146
			Sep-00	157	1.57	152	150	151.0	1.51	1.79079054	1.8743608
2	2	24.5	Jun-98	90	0.9	100	120	110	1.1	0.950334	0.5702004
			Oct-98	38	0.38	109	122	115.5	1.155	1.047743235	0.2654283
			Sep-99	105	1.05	106	94	100.0	1	0.7854	0.54978
			Sep-00	111	1.11	126	62	94.0	0.94	0.69397944	0.5135448

Plant Type
1: Atriplex
2: Sarcobatus

Field Position
1: inside fence
2: outside fence

Plant ID's
1: 1A on data sheet, Atriplex inside exclosure
1.5: 1B on data sheet, paired Atriplex outside exclosure.

Diameter: average of NS width, EW width
Ground cover (area of circle): Pi * R2
Canopy- sphere, pi*d*d*h/6

Appendix L

Biomass Data for Exclosure Study

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All units are g/m^2 dry weight

Atriplex

	Inside Exclosure						Outside Exclosure				
Plant	Jun-98	Oct-98	Mar-99	Sep-99	Sep-00	Plant	Jun-98	Oct-98	Mar-99	Sep-99	Sep-00
1 A	394.4	169.9	66.4	87.0	dead	1 B	241.6	221.7	115.2	80.6	909.6
2 A	199.2	191.5	123.2	592.6	799.2	2 B	148.8	85.0	28.8	412.8	311.2
3 A	303.2	62.8			dead	3 B	104.8	112.2	114.4	314.1	dead
4 A	64.0	37.9		9.1	361.6	4 B	320.0	62.2			dead
5 A	213.6	129.7	134.4	200.9	dead	5 B	100.0	160.6	107.2	71.5	270.4
6 A	288.8	52.4			dead	6 B	509.6	219.1	7.2	380.3	328
7 A	155.2	187.2	52.8	297.1	489.6	7 B	178.4	143.0	96.8	331.8	180
8 A	379.2	101.2		93.0	24.8	8 B	216.8	150.7	8.8	577.8	310.4
10 A	316.0	125.5	143.2	272.9	1160.8	10 B	325.6	343.2	42.4	273.4	387.2
12 A	454.4	187.3	180.0	538.8	360.8	12 B	124.8	19.5			37.6
15 A	125.6	119.0	113.6	150.6	385.6	15 B	387.2	215.5	74.4	221.4	358.4
17 A	704.0	249.6	181.6	259.6	141.6	17 B	248.0	133.0	312.8	382.6	320.8
Avg	299.80	134.51	124.40	250.17	465.5		242.13	155.48	90.80	304.63	341.36

Sarcobatus

	Inside Exclosure						Outside Exclosure				
Plant	Jun-98	Oct-98	Mar-99	Sep-99	Sep-00	Plant	Jun-98	Oct-98	Mar-99	Sep-99	Sep-00
9 A	424.0	113.0	58.4	62.2	776.8	9 B	659.2	39.2	252.8	242.4	272.8
11 A	660.8	90.7	218.4	294.8	264.8	11 B	597.6	138.8	21.6	269.1	314.4
13 A	434.4	125.2	8.1	286.3	844.8	13 B	358.4	137.6	88.0	318.3	236.8
14 A	368.0	131.8		457.4	755.2	14 B	349.6	168.7	470.4	306.6	301.6
16 A	307.2	150.8	69.6	153.6	360.8	16 B	496.0	114.7	13.6	72.3	175.2
18 A	668.0	122.2	180.0	892.1	620	18 B	323.2	132.8	96.8	193.7	206.4
19 A	406.4	184.4		31.8	638.4	19 B	280.8	154.6	100.0	173.4	293.6
20 A	566.4	49.6	168.8	163.4	240	20 B	676.8	111.9	236.8	372.9	772
21 A	441.6	55.7	4.0	244.7	273.6	21 B	430.4	107.2	1.6	327.6	699.2
22 A	504.0	138.0	80.8	252.8	455.2	22 B	125.6	224.0	31.2	191.0	539.2
23 A	468.0	107.0	35.2	365.3	514.4	23 B	309.6	168.5	89.6	137.0	524
24 A	265.6	137.3	327.2	432.0	488.8	24 B	408.0	138.2	20.8	144.7	396
Avg	459.53	117.14	115.05	303.04	519.40		417.93	136.35	118.60	229.10	394.27

Appendix M

Nitrogen Concentrations for 2000 Exclosure Study

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Dry weights for plants collected from exclosures on 9/14/00

Plant	Dry sample wt (g)	Nitrate-N ppm	Total Kjeldahl N %	Extractable S ppm	total S %	g total N
1a	dead					
1b	113.7	484	0.89	208	0.09	1.01
2a	99.9	723	1.8	798	0.12	1.80
2b	38.9	524	1.44	360	0.12	0.56
3a	dead					.
3b	dead					.
4a	45.2	1460	1.51	709	0.28	0.68
4b	dead					.
5a	dead					.
5b	33.8	442	1.49	450	0.09	0.50
6a	dead					.
6b	41	568	1.34	398	0.11	0.55
7a	61.2	577	1.89	741	0.47	1.16
7b	22.5	1150	1.77	679	0.45	0.40
8a	3.1	465	1.35	531	0.49	0.04
8b	38.8	761	1.03	456	0.33	0.40
9a	97.1	1720	2.57	429	0.43	2.50
9b	34.1	677	1.17	148	0.25	0.40
10a	145.1	622	1.54	188	0.85	2.23
10b	48.4	366	1.44	93	0.26	0.70
11a	33.1	451	1.55	102	0.28	0.51
11b	39.3	277	1.45	67	0.21	0.57
12a	45.1	506	1.56	117	0.31	0.70
12b	4.7	458	1.78	95	0.4	0.08
13a	105.6	1150	3.14	207	0.32	3.32
13b	29.6	806	2.04	190	0.24	0.60
14a	94.4	307	1.33	81	0.19	1.26
14b	37.7	405	1.47	82	0.24	0.55
15a	48.2	681	1.19	124	0.41	0.57
15b	44.8	664	0.97	133	0.4	0.43
16a	45.1	678	2.26	115	0.3	1.02
16b	21.9	599	1.89	119	0.32	0.41
17a	17.7	786	1.45	895	0.76	0.26
17b	40.1	482	1.44	872	0.46	0.58
18a	77.5	1260	2.21	817	0.44	1.71
18b	25.8	810	1.96	717	0.27	0.51
19a	79.8	890	1.87	724	0.36	1.49
19b	36.7	517	1.42	804	0.15	0.52
20a	30	744	1.92	686	0.43	0.58
20b	96.5	380	1.89	866	0.24	1.82
21a	34.2	1360	2.33	711	0.24	0.80
21b	87.4	408	1.31	963	0.17	1.14
22a	56.9	2000	2.37	1279	0.49	1.35
22b	67.4	403	1.37	573	0.2	0.92
23a	64.3	1320	2.59	889	0.27	1.67
23b	65.5	612	1.78	656	0.2	1.17
24a	61.1	435	1.42	791	0.23	0.87
24b	49.5	412	1.5	734	0.27	0.74

* See Appendix L for plant type and location

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Appendix N

Chemical Constituents of Test Plants for Greenhouse Study

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Code	Lab ID	Plant #	DW-Shoot	Amt Used	initial NO3	NO3(100)	ppm NO3-N	%NO3-N	total N(CNS)	ppm HCN
Ag	01007-1	346	0.3115	0.05	586.7	58670	13253.55	1.33	no data	
Ag	01007-2	336	0.3782	0.05	477.6	47760	10788.98	1.08	4.96	
Ag	01007-3	326	0.7612	0.0502	348.4	34840	7870.36	0.79	5.77	
Ag	01007-4	316	0.0579	0.0563	417.0	41700	9420.03	0.94	no sample	
Ag	01007-5	236	2.16	0.1007	106.4	10640	2403.58	0.24	5.3	
Ag	01007-6	226	0.72	0.0507	133.7	13370	3020.28	0.30	5.82	
Ag	01007-7	216	0.57	0.0507	147.6	14760	3334.28	0.33	3.87	
Ag	01007-8	146	0.44	0.0503	16.28	1628	367.77	0.04	4.62	
Ag	01007-9	136	0.77	0.1003	39.37	3937	889.37	0.09	4.32	
Ag	01007-10	126	0.055	0.0464	397.1	39710	8970.49	0.90	no sample	
Ag	01007-11	116	1.09	0.1006	12.13	1213	274.02	0.03	3.79	
Ag-In	01007-12	315	0.5879	0.0501	no sample				5.61	
Ag-In	01007-13	245	0.89	0.0501	48.68	4868	1099.68	0.11	5.01	
Ag-In	01007-14	235	0.93	0.0507	92.32	9232	2085.51	0.21	4.63	
Ag-In	01007-15	225	1.53	0.1003	222.5	22250	5026.28	0.50	no sample	
Ag-In	01007-16	145	0.52	0.1007	15.70	1570	354.66	0.04	3.92	
Ag-In	01007-17	135	1.03	0.1001	17.94	1794	405.26	0.04	3.98	
Ag-In	01007-18	125	0.79	0.0508	16.09	1609	363.47	0.04	3.67	
Ag-In	01007-19	115	0.5428	0.1001	42.60	4260	962.33	0.10	3.36	
Atriplex	01007-20	344	0.2606	0.0505	224.9	22490	5080.49	0.51	5.14	
Atriplex	01007-21	334	0.0913	0.0506	163.7	16370	3697.98	0.37	4.75	
Atriplex	01007-22	324	0.3521	0.0503	182.7	18270	4127.19	0.41	4.92	
Atriplex	01007-23	314	0.0202	0.0205	no sample				no sample	
Atriplex	01007-24	244	0.1922	0.5	129.8	12980	2932.18	0.29	4.7	
Atriplex	01007-25	234	0.0337	0.0276	929.0	92900	20986.11	2.10	no sample	
Atriplex	01007-26	224	0.1067	0.05	149.2	14920	3370.43	0.34	3.94	
Atriplex	01007-27	214	1.0251	0.0502	162.5	16250	3670.88	0.37	4.54	
Atriplex	01007-28	144	2.5	0.1005	60.22	6022	1360.37	0.14	3.65	
Atriplex	01007-29	134	3.39	0.1005	74.20	7420	1676.18	0.17	no sample	
Atriplex	01007-30	124	2.95	0.1008	72.16	7216	1630.09	0.16	4.3	
Atriplex	01007-31	114	4.28	0.1	110.6	11060	2498.45	0.25	3.94	
Sorghumsudan	01007-33	333	0.0261	0.0267	1287	128700	29073.33	2.91	no sample	
Sorghumsudan	01007-34	323	0.3383	0.0502	566.5	56650	12797.24	1.28	5.09	503
Sorghumsudan	01007-35	313	0.0457	0.0409	1163	116300	26272.17	2.63	no sample	
Sorghumsudan	01007-36	243	0.068	0.0504	1272	127200	28734.48	2.87	no sample	
Sorghumsudan	01007-37	233	2.26	0.1003	298.7	29870	6747.63	0.67	4.08	202
Sorghumsudan	01007-38	223	4.32	0.1	436.6	43660	9862.79	0.99	4.48	110
Sorghumsudan	01007-39	213	2.69	0.1004	318.4	31840	7192.66	0.72	4.64	1145
Ag-In	01007-40	215	1.33	0.0501	225.3	22530	5089.53	0.51	5.28	
Sorghumsudan	01007-41	143	1.48	0.1003	52.33	5233	1182.13	0.12	2.35	
Sorghumsudan	01007-42	133	0.64	0.1003	99.90	9990	2256.74	0.23	2.90	176
Sorghumsudan	01007-43	123	0.84	0.0508	73.60	7360	1662.62	0.17	3.00	1253
Sorghumsudan	01007-44	113	0.78	0.1006	69.56	6956	1571.36	0.16	2.59	198
Piper	01007-47	322	1.49					0.00	4.70	132
Piper	01007-48	312	0.3586	0.0504	1387	138700	31332.33	3.13	7.30	182
Piper	01007-50	232	0.0202	0.0138	994.4	99440	22463.50	2.25	no sample	
Piper	01007-52	212	0.0395	0.0366	1209	120900	27311.31	2.73	no sample	
Piper	01007-53	142	0.79	0.1006	58.52	5852	1321.97	0.13	1.53	153
Piper	01007-54	132	1.25	0.0508	78.25	7825	1767.67	0.18	2.53	401
Piper	01007-55	122	1.59	0.1006	54.16	5416	1223.47	0.12	2.25	86
Piper	01007-56	112	1.49	0.0503	29.81	2981	673.41	0.07	2.28	537
Sweet	01007-59	321	No sample					0.00	7.79	
Sweet	01007-60	311	0.0353	0.0312	1151	115100	26001.09	2.60	no sample	
Sweet	01007-61	241	0.54	0.0503	226.0	22600	5105.34	0.51	3.80	158
Sweet	01007-62	231	3.09	0.1005	222.8	22280	5033.05	0.50	4.11	771
Sweet	01007-63	221	3.3	0.1004	164.4	16440	3713.80	0.37	3.52	187
Sweet	01007-64	211	1.2	0.0509	162.4	16240	3668.62	0.37	3.63	165
Sweet	01007-65	141	0.53	0.0503	98.77	9877	2231.21	0.22	2.55	1005
Sweet	01007-66	131	0.39	0.0503	84.05	8405	1898.69	0.19	2.49	1083
Sweet	01007-67	121	0.5887	0.1	105.3	10530	2378.73	0.24	2.43	203
Sweet	01007-68	111	0.273	0.05	106.7	10670	2410.35	0.24	no sample	921
SE-P	01007-69	12 Out	0.2394	0.0502	125.3	12530	2830.53	0.28	1.68	165
SE-P	01007-70	11 Out	0.3253	0.0502	171.7	17170	3878.70	0.39	2.46	110-180
SE-P	01007-71	13Out	0.4838	0.05	158.1	15810	3571.48	0.36	2.41	260
SE-P	01007-72	14 Out	0.66	0.1008	99.01	9901	2236.64	0.22	2.13	
Sweet	01007-89	pf	13.77	0.1	129.9	12990	2934.44	0.29	5.64	
Sweet	01007-90	pf	14.13	0.1	358	35800	8087.22	0.81	4.65	

Key:
Ag: Agate alfalfa
Ag-In: Inefficient Agate alfalfa
Atriplex: Four-wing saltbush
Sorghumsudan: Sorghum sudan grass
Piper: Piper sudan grass
Sweet: Sweet sudan grass
SE-P: