WASHINGTON STATE
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Vadose Zone Monitoring at Deer Park, Washington A Municipal Effluent Land Application Site

March 1995

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Vadose Zone Monitoring at Deer Park, Washington
A Municipal Effluent Land Application Site

by
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Acknowledgements

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Abstract

Vadose zone sampling equipment was installed and sampled at two locations on the City of Deer Park land application site near Deer Park, Washington. Effluent from the municipal wastewater treatment plant in Deer Park is applied on a 160-acre field to irrigate alfalfa. The purpose of the study was to evaluate treatment in the unsaturated zone and to compare three devices for sampling soil-pore water quality. Capillary wick, suction, and barrel lysimeters were used to obtain water quality samples. Total nitrogen (total N), total dissolved solids (TDS), specific conductance, chloride, sodium, potassium, calcium, iron, magnesium, pH, and chemical oxygen demand (COD) samples were collected at least five times during the period of May 6 to October 1, 1993.

Vadose zone monitoring showed that total N was partially treated in the top three to six feet. The range of total N treatment was low (26-35%), despite a relatively low application rate for total N of 100 lb/acre/year. Low treatment was likely due to frequent wet weather which caused irregular timing of effluent application over the season.

Suction and wick lysimeters provided more representative samples than the barrel lysimeters. Concentrations from the wick lysimeters tended to be higher than those from the suction lysimeters and, because the wicks sample continuously, are likely more representative of water leaving the root zone. Barrel samplers did not provide representative estimates of treatment at this site because of their shallow depth.

The mean total N concentration in the wick and suction lysimeters was 17 mg/L. The mean TDS concentration was 362 mg/L. The projected increases above background in ground water concentrations of total N and TDS are 5-7 mg/L for total N and 110-170 mg/L for TDS. Increases in nitrate+nitrite-N and TDS concentrations from the facility's downgradient monitoring wells suggest that effluent loading is affecting ground water quality.

Summary

Effluent and Soil Pore-Water Quality

Effluent characteristics varied little during the study. The range of total N concentrations was 20 to 24 mg/L; for TDS, 347 to 355 mg/L.

Soil pore-water concentrations varied considerably in the three types of samplers. The range for total N in the lysimeters was 0.8 to 64 mg/L; for TDS, 144 to 618 mg/L. At Field 4, where data were more consistently available, the mean total N concentrations for the three samplers were:

Wick Lysimeters: 17 mg/L
Suction Lysimeters: 8.6 mg/L
Barrel Lysimeters: 1.7 mg/L

Reasons for the differences between lysimeter types include:

- Sample integration. Wick and barrel lysimeters sampled continuously over time, while suction lysimeters sampled over a limited time only.

- Pore accessibility. Wick and barrel lysimeters obtain soil pore-water from larger soil pores. Suction lysimeters can pull water from smaller soil pores.

- Vegetative cover. Plant regrowth near the trenches overlying the wick lysimeters was gradual over the summer. Reduced vegetation early in the summer probably caused faster infiltration and less plant uptake than normal. Suction lysimeters caused the least disturbance to vegetation.

- Sampler depth. As expected, deeper wick and suction lysimeters (four to six feet) had lower total N concentrations than shallower ones. Barrels two feet deep are not representative of soil pore-water moving below the four-foot deep root zone.

- Timing. Samples collected too soon after effluent was applied may have represented residual soil pore-water rather than recently applied effluent.

The mean total N concentration for the capillary wick (wick) and suction lysimeters at the two sites was 17 mg/L (S.D.=16, n=17).

Treatment

Application rates for total N and TDS were moderate for alfalfa growth: 100 lb/acre/year for total N, 1,700 lb/acre/year for TDS. Likewise, the annual amount of water applied, 22 inches, was moderate.

Mean total N treatment was 26 to 35% of that applied.

As expected, little change in TDS concentration occurred in the top six feet of the vadose zone.

Due to wet weather early in the summer, effluent was applied heavily in late summer to reduce storage. The higher than normal application rate late in the season probably led to lower than normal annual total N treatment.

The facility exceeded effluent discharge limits in August at Field 6 and possibly at five other fields not included in this study as well as one field in May and two fields in June.

Estimated Nitrate and TDS Impacts to Ground Water

The projected annual increase in ground water nitrate-N concentration compared to background is 5 to 7 mg/L; for TDS, 110 to 170 mg/L.

Ground water nitrate-N and TDS concentrations in facility monitoring wells indicate increases downgradient of the land application site.

Sampler Comparison

Wick lysimeters provided the most representative water quality data for water percolating below the root zone. Wick lysimeters provided continuous, integrated samples of both saturated and unsaturated flow. Saturated flow, typically not well characterized by suction lysimeters, often comprises the bulk of subsurface flow.

Suction lysimeters were the easiest and cheapest to install. They were also the most reliable and caused the least disturbance to nearby vegetation. However, results from suction lysimeters may underestimate loading to ground water, unless samples are collected frequently following effluent application.

Wick lysimeters provided the greatest volume of sample. Suction samplers larger than the one-liter samplers used in this study would provide more representative samples.

Residual water in the wick itself could not be removed, thereby possibly biasing future samples.

Barrel samplers two feet deep were not effective in this setting, where the bottom of the alfalfa root zone is about four feet. It would be difficult to install barrel lysimeters deeper than two feet.

Recommendations

Vadose zone monitoring is useful at Deer Park, because it provides an early warning of ground water contamination. The following should be included in a vadose zone monitoring program.

Recommendations for Deer Park Vadose Zone Monitoring

1. The City of Deer Park should continue sampling wick and suction lysimeters for total N (nitrate+nitrite-N plus total Kjeldahl N), TDS, sodium, magnesium, calcium, and bicarbonate to evaluate trends over time. Spring sampling should be added to assess effects of snowmelt on nitrate and TDS movement. The city should measure application rates in the spray fields to validate the rates found in this study.

2. Install tensiometers near soil pore-water samplers to monitor soil moisture changes during and after application to evaluate flow of soil pore-water. Tensiometer results can also be used to calibrate effluent application and avoid over-application.

3. Determine the appropriate sample timing after effluent application based on tensiometer results above. Allow sufficient time for percolating water to reach samplers three to six feet deep before sampling.

4. Manage vegetation near the soil pore-water samplers similar to the surrounding field, i.e., harvesting.

5. Determine seasonal ground water flow direction more accurately using new monitoring wells. (This is now being done.)

6. Install new wells that meet the state's well construction standards (Chapter 173-160 WAC and Chapter 18.104 RCW, 1994 revisions) in the following areas:

   - Effluent application areas
   - Close to the application area boundaries upgradient and downgradient.

   Wells in the application area can be used to verify whether all the effluent leaving the root zone reaches the water table and increases nitrate-N and TDS concentrations as projected.

General Recommendations

Vadose zone monitoring should be included in certain land application permits. Vadose zone monitoring can help evaluate land application practices at individual sites and allow prompt adjustments to improve treatment and protect ground water. The following items are recommended for vadose zone monitoring at land application sites.

1. Future permits for facilities that apply municipal wastewater to land should require that total nitrogen (including total Kjeldahl nitrogen) be added to the list of parameters sampled in the effluent and monitoring wells.
2. Pre-clean wicks for wick lysimeters (Knutson *et al.*, 1993)
3. If deionized water is used to prime the wick samplers, discard the first sample to avoid dilution.
4. If preferential flow along the sides of the suction samplers is a concern, install them horizontally into a trench sidewall.
5. Although rinsing the sample collection assembly (tubing and side-arm flask) several times with deionized water between samplers did not lead to significant cross contamination, future sampling should include dedicated sample tubing.

Recommendations for follow-up work to be done by Ecology's Environmental Investigations and Laboratory Services (EILS) Program are:

1. Use 1993 nitrogen loadings estimated in this study (amount of water and nitrogen passing through the root zone) to simulate ground water impacts over time using a solute transport or contaminant transport model.
2. Conduct a study to estimate nitrogen effects on ground water at an alfalfa field where no nitrogen is applied, so that factors other than nutrient addition can be evaluated.
3. Compare wick and suction lysimeters at other sites. Larger suction lysimeters sampled frequently following effluent application may provide more representative information than obtained from suction lysimeters in this study.

Introduction

Treated effluent is applied to cropland in many rural locations in eastern Washington to treat and dispose of effluent and at the same time provide needed water and nutrients for plants. The degree of treatment in the vadose zone (the subsurface layer above the water table) is important, because dissolved substances that pass below the root zone will likely reach the underlying ground water.

Washington State ground water standards (Chapter 173-200 WAC) and Ecology's implementation guidance establish limits for changes to ground water quality due to permitted discharges such as land application. One method to provide an early warning of potential impacts on ground water is to monitor soil pore-water in the vadose zone.

The Water Quality Program's Eastern Regional Office staff requested that the EILS Program conduct a vadose zone study of the Deer Park land application facility to provide information on effluent treatment as well as to test and compare different vadose zone water quality sampling devices.

The study objectives were to:

1. characterize the quality of soil pore-water beneath land application fields before mixing with ground water;

2. estimate the degree of effluent treatment in the vadose zone, especially for nitrogen and TDS;

3. estimate the rate of soil pore-water movement;

4. compare three lysimeter designs: capillary wick, suction, and barrel lysimeters; and

5. evaluate the effectiveness of vadose zone monitoring.

Site Description

The Deer Park land application site shown in Figure 1 is located at the City of Deer Park Airport about 15 miles north of Spokane. Wastewater is treated in an aerated lagoon and two large storage lagoons 1.5 miles west of the airport. Effluent is then piped underground to a solid-set irrigation system as shown in Figure 2.

The spray field consists of 160 acres cultivated in alfalfa (Figure 3). The acreage is divided into 9 fields of about 17 acres each. Effluent is applied to one field per day, creating a 9-day cycle between waterings. However, this schedule is subject to change according to cultivation needs. The largest interruptions occur when precipitation interferes with cutting and baling. Repeated precipitation early in the summer of 1993 prevented normal effluent application, resulting in very frequent applications later in the summer to dispose of accumulated effluent.

The State Waste Discharge Permit, No. ST 8016, allows effluent to be applied from April through September. The total of precipitation and applied effluent cannot exceed 8.2 inches/month or 608,000 gallons/day.

We chose two sites for study, one in Field 4 and the other in Field 6 (Figure 3). These fields were selected based on the health of the alfalfa crop and accessibility.

Soils

Steve Campbell of the U.S. Department of Agriculture Natural Resources Conservation Service in Spokane, Washington characterized the top 72 inches of soil at the two study sites. The results of his analysis are shown in Appendix A. He found coarse sand of the Marble series at both sites. Although typically very permeable, Campbell found that soils at these sites had greater moisture-holding capacity than typical due to thin layers of loamier soil. He estimated the saturated rate of vertical water movement at 6 to 20 inches/hour.

Soil samples, collected before land application began in May 1993, indicated that little nitrogen was stored in the soil over the winter. Nitrate-N was highest in the top four inches (20-42 ug/g). Below that, however, little nitrate-N was present. Ammonia-N concentrations were low throughout the profile. Other soil characteristics reported in Appendix A include pH, soil moisture retention, percent carbon, percent organic matter, and cation exchange capacity.

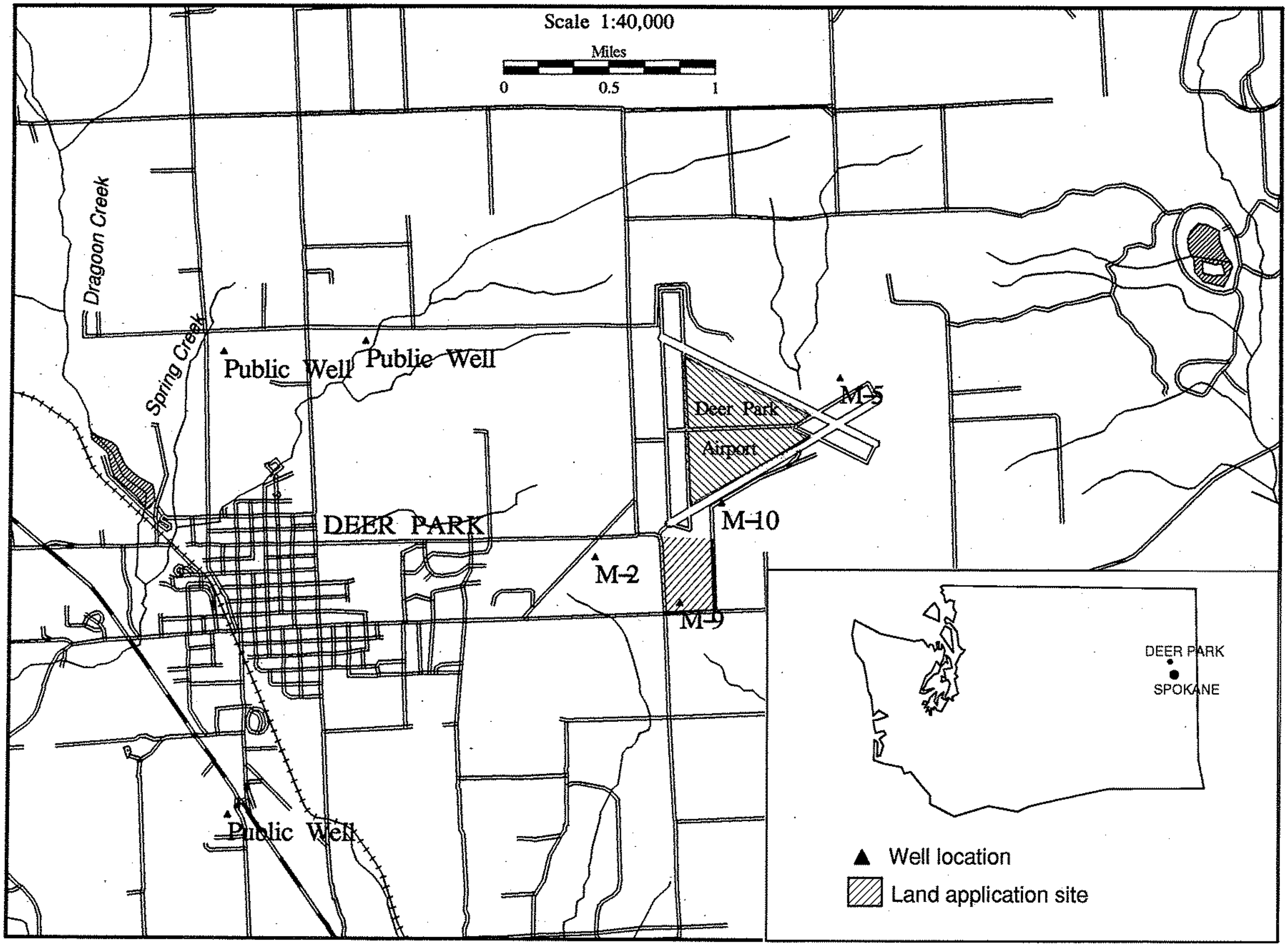

Figure 1. Map of the City of Deer Park and vicinity.

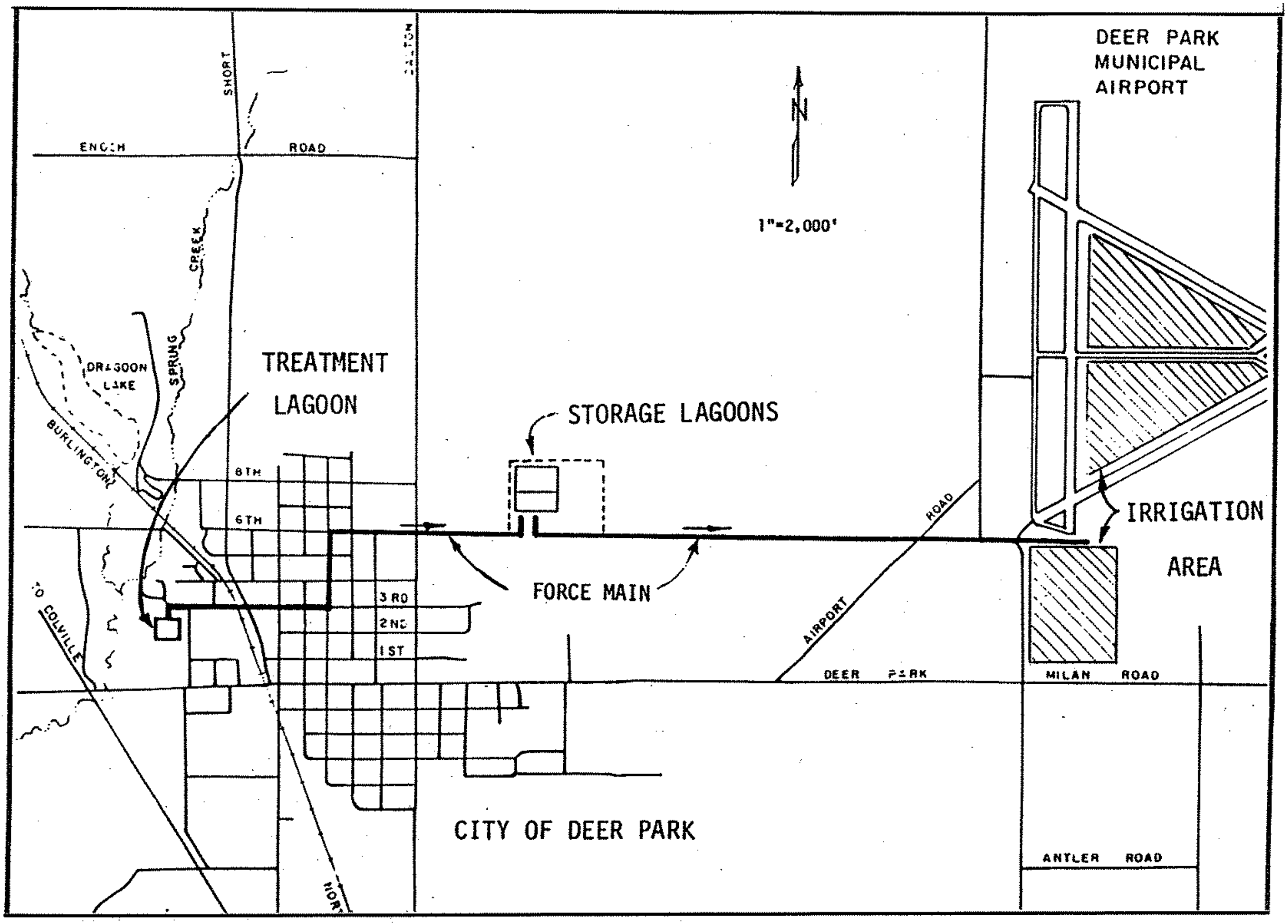

Figure 2. City of Deer Park wastewater facilities and land application (irrigation) area (from Esvelt Environmental Engineering, Spokane, Washington).

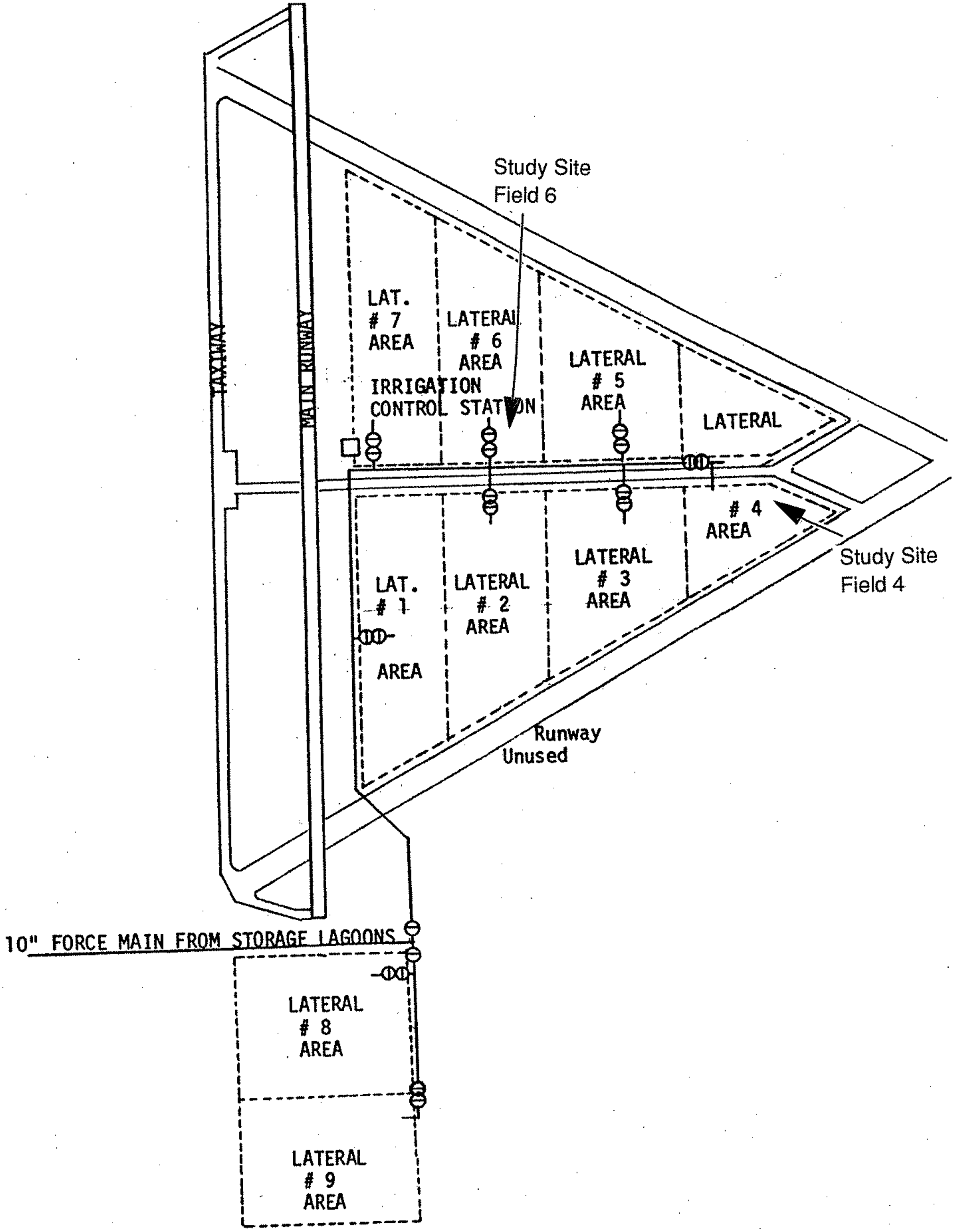

Figure 3. Land application area showing the study site locations and irrigation system (from Esvelt Environmental Engineering, Spokane, Washington).

Hydrogeology

The hydrogeology of the site is complex. Recent drilling to install new monitoring wells has led to a reevaluation of the ground water flow system (Henry, 1994). The eastern one-third of the site apparently overlies a bedrock ridge running north-south. Perched layers of water caused by clay lenses are found in the sand and gravels overlying the basalt ridge, but not in quantities that can be monitored. The top of the basalt layer slopes to the west.

Abutting each side of the ridge is a sand and gravel channel up to 200 feet deep interspersed with clay layers. The western two-thirds of the site overlies the "west channel." Discontinuous clay layers and large horizontal variability over short distances make interpretation of ground water movement difficult. Recent water level measurements suggest that the flow direction is south to southeasterly (Henry, 1995)

This study was conducted before the recent well drilling and reinterpretation by Henry (1994). The monitoring wells referred to in this study were abandoned in November 1994. Well logs and water table elevations for 1993 are shown in Appendix B.

Similar to recent findings, information from subsequently abandoned wells M-2, M-5, M-9 and M-10 shown in Figure 1 indicated that ground water flows to the south and west based on water level elevations. Water levels fluctuated up to 2.5 feet in 1993, with the highest measurements observed in the spring and the lowest in the fall (City of Deer Park, 1993).

Climate

The Deer Park plateau has mild, dry summers and cold, wet winters. The annual rainfall in Spokane is less than 20 inches (Adolfson *et al.*, 1992), slightly lower than at Deer Park. About three-fourths of the precipitation falls during the fall and winter, one-half as snow. The growing season is usually from mid-April to mid-October. In 1993, however, there was still snow on the ground in early April. The average summer temperature in Spokane is 66° F (19° C).

Methods

Art Larson and Bernard Strong of EILS and I installed samplers at various distances from sprinkler heads near the corner of Field 4 and the middle of Field 6 as shown in Figures 4 and 5. The sampler locations within each field were intended to represent the range of application intensities in each field.

Lysimeter Installations

We installed three types of lysimeters (devices to sample soil pore-water) at each site:

1. Capillary wick lysimeters, six at each site (Figure 6),
2. Barrels lysimeters, five at each site (two 16-inch and three 8-inch diameter) (Figure 7), and
3. Suction lysimeters, seven at Field 4 and five at Field 6 (Figure 8).

All of the barrel and wick lysimeters and two suction lysimeters were installed May 3-5, 1993. The other ten suction lysimeters were installed on July 21, 1993. Installation procedures are described in Appendix C.

Sampling and Analysis Procedures

We collected the first lysimeter samples two to three days after installation and one to two days after effluent was applied on Fields 4 and 6. Thereafter we sampled monthly from June through October following effluent applications. Table 1 shows the schedule for sampling.

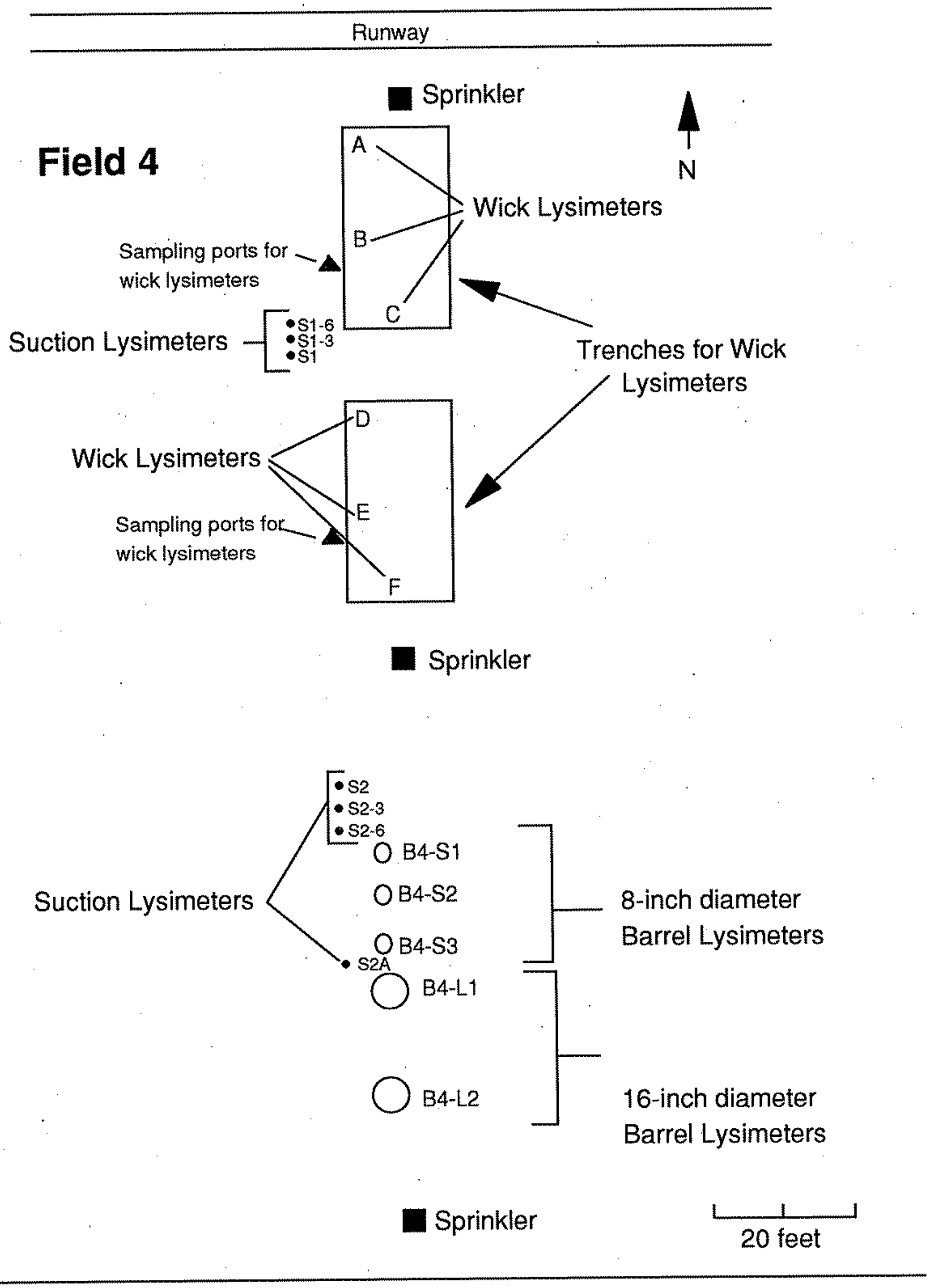

Figure 4. Field 4 sampling equipment locations.

sampl4b.drw

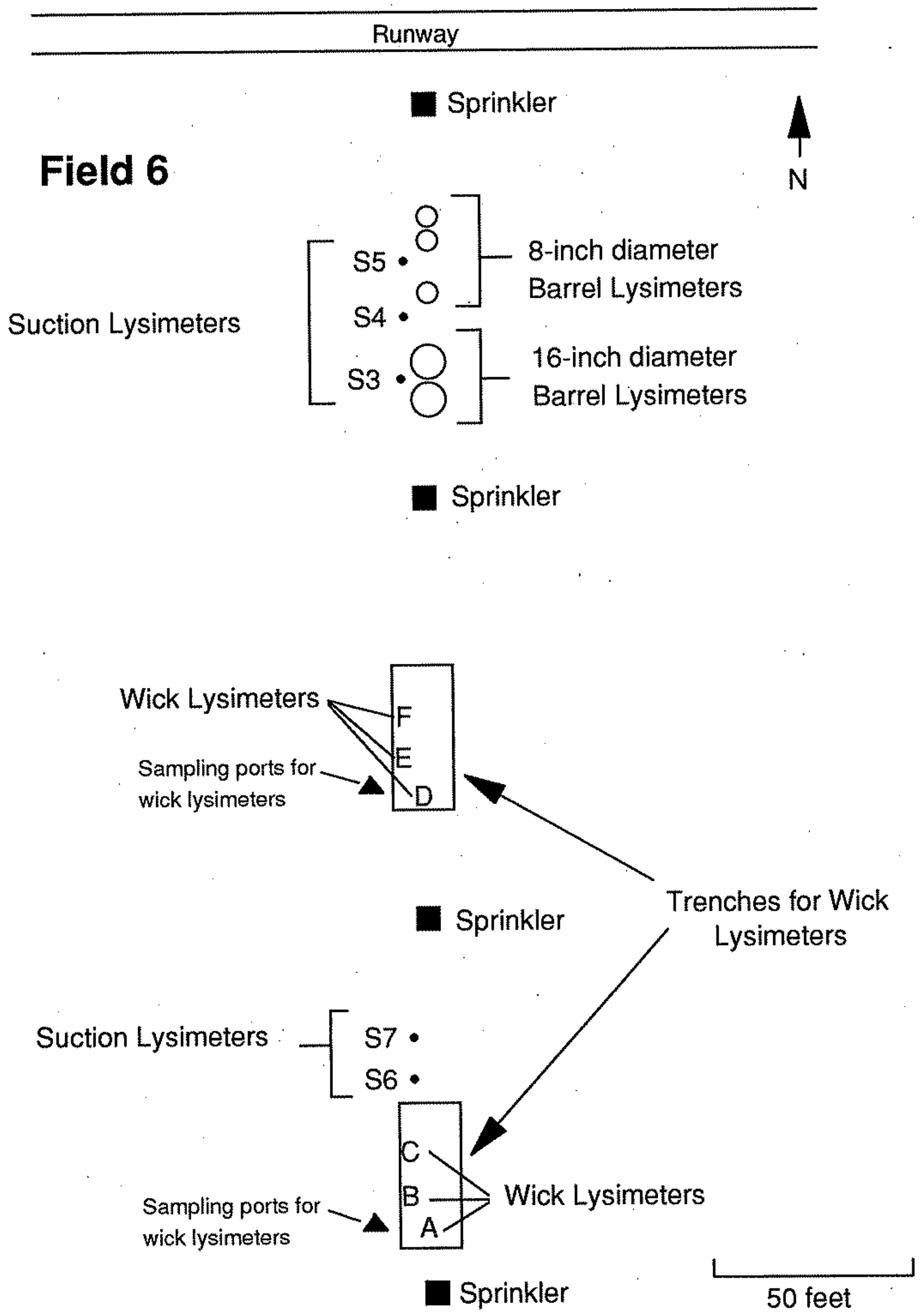

Figure 5. Field 6 sampling equipment locations.

sampl6b.drw

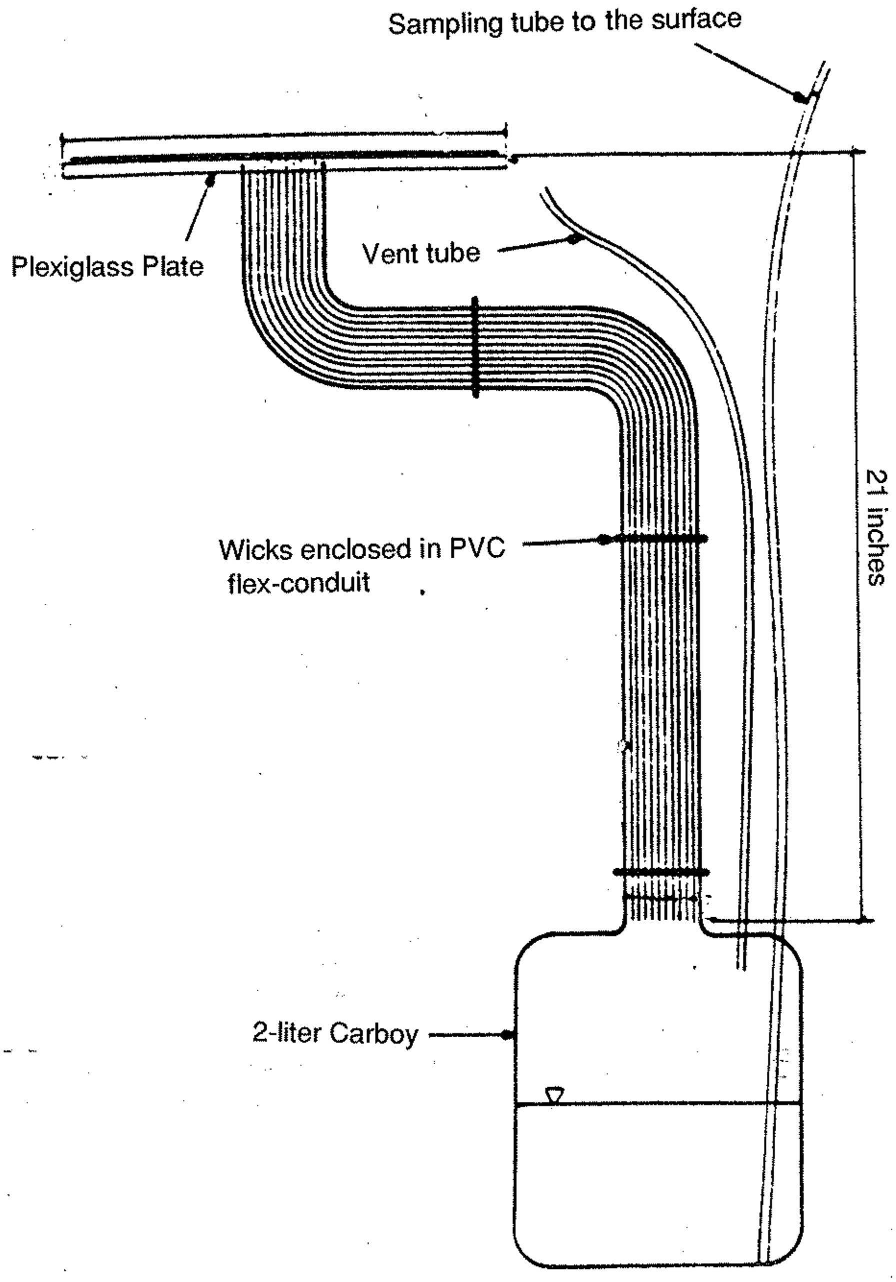

Figure 6. Diagram of a capillary wick lysimeter.

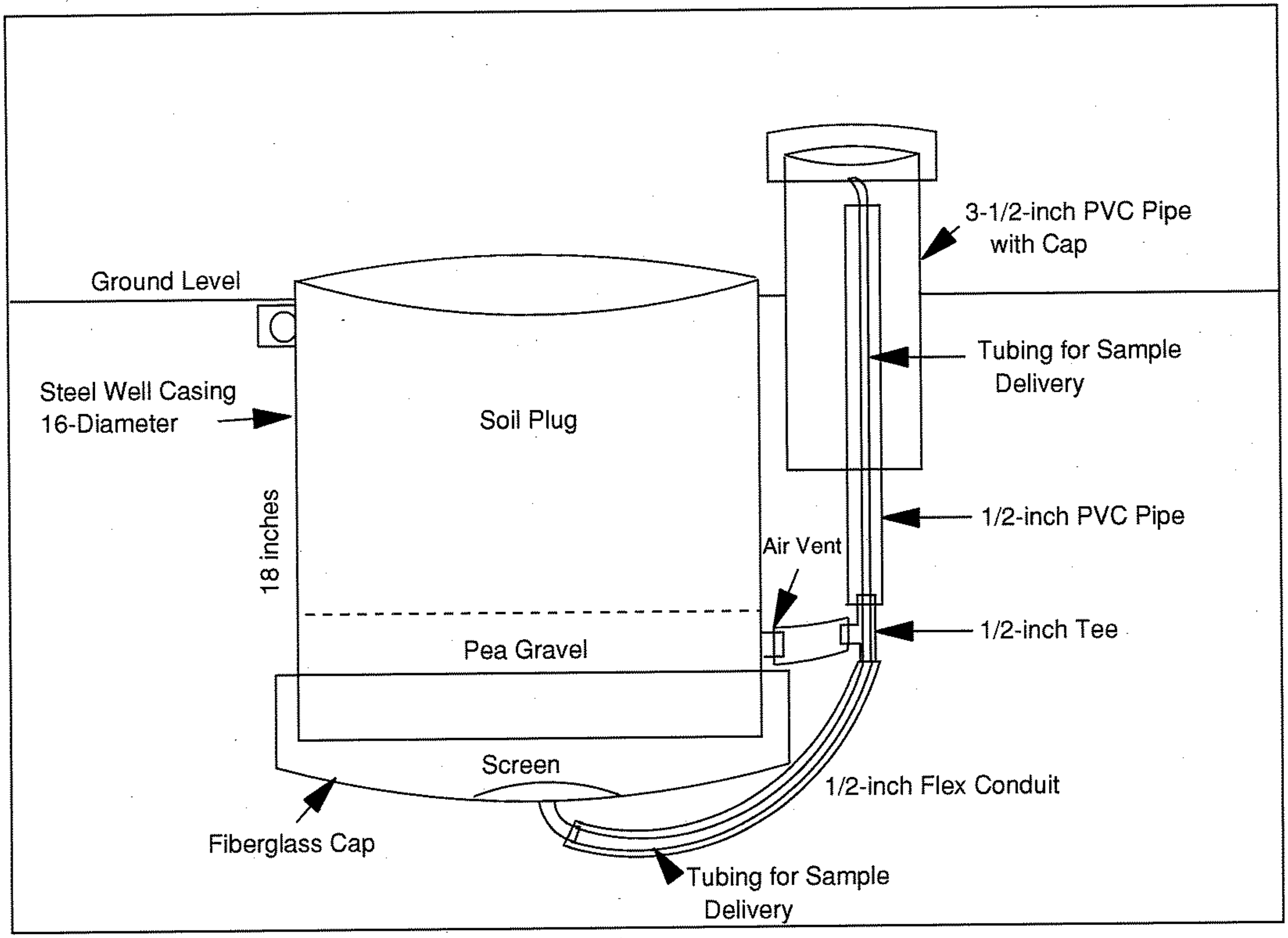

Figure 7. Diagram of barrel lysimeter.

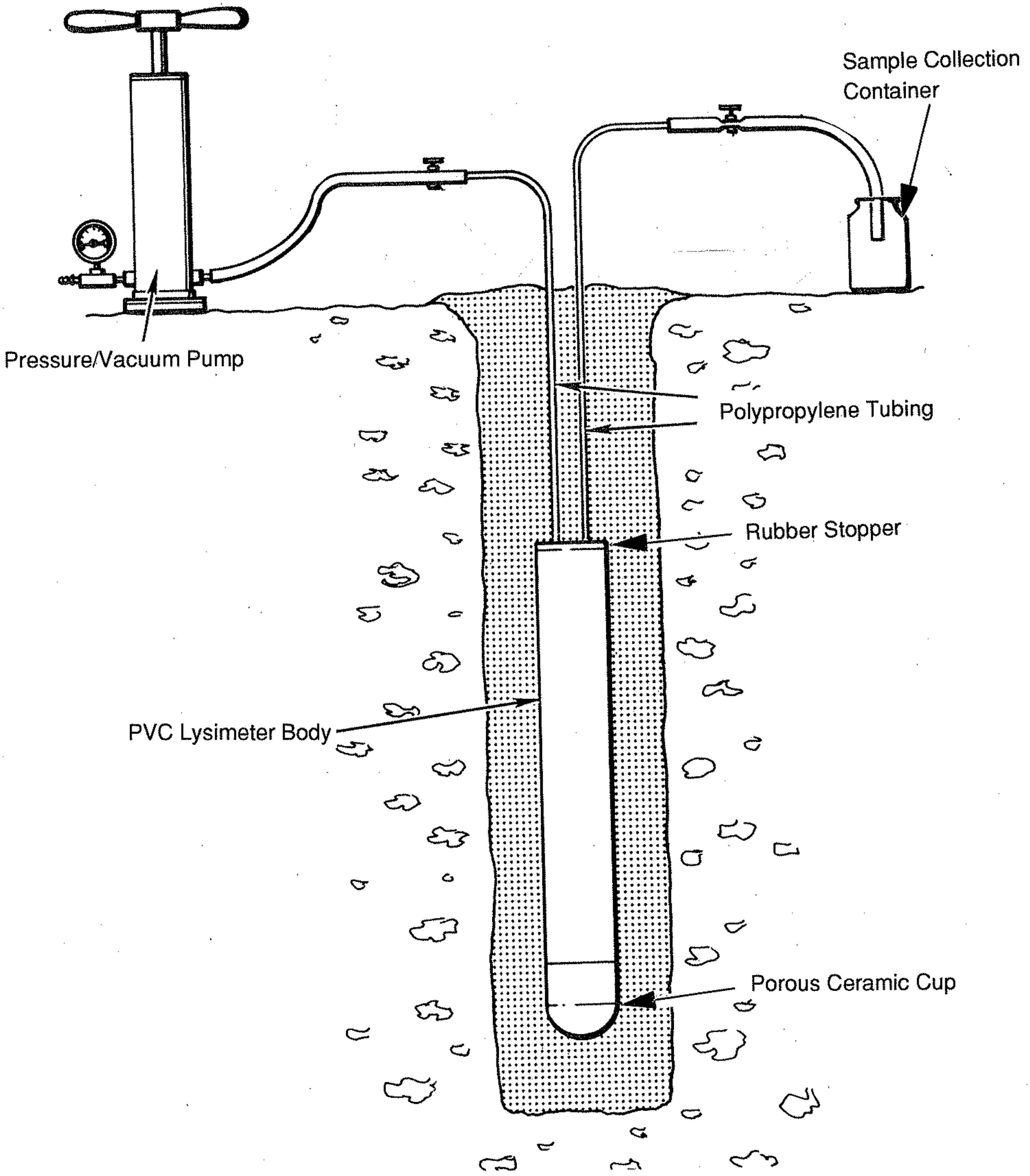

Figure 8. Diagram of a suction lysimeter and sampling apparatus.

Table 1. Purging and sampling schedule.

Dates	Sampling	Purging
5/6/93	X	
6/3/93		X
6/11/93	X	
7/21/93		X (plus 3 samples)
7/23-24/93	X	
8/5-6/93	X	
9/15/93		X (plus 7 samples)
10/1/93	X	

Two to sixteen days prior to a sampling event, we purged all the samplers to remove accumulated water. In July and September, we also analyzed the purge water in a few of the samplers as shown in Table 1. After purging, effluent was applied to the two sites. August was an exception; samplers were not purged, because they had been sampled less than two weeks previously. In September and October, effluent was not applied at Field 6. Methods for collecting soil pore-water and effluent are described in Appendix D.

The following parameters were analyzed in soil pore-water and effluent samples:

Total N (Sum of nitrate+nitrite-N and total Kjeldahl N)
Ammonia-N
TDS (Total Dissolved Solids)
pH
COD (Chemical Oxygen Demand)
Chloride
Specific conductance
Sulfate
Dissolved and total iron
Dissolved and total calcium
Dissolved and total magnesium
Dissolved and total sodium
Dissolved and total potassium

The analytical methods used are listed in Appendix Table D.2. In some cases, due to limited sample volume, not all parameters could be tested.

We also tried to sample three of the nearby monitoring wells: M-5 and M-10 on June 10, and M-9 on July 22, 1993. However, all three wells were dry.

Data Analysis

The methods used to calculate effluent application rate, treatment, and projected changes in ground water nitrate and TDS concentrations are summarized below. Further details of each method are discussed in Appendix E.

Application rate is the volume of effluent applied per acre times the concentration for each application event (or the concentration on the closest date sampled) divided by the hours applied.

Treatment refers to the mass of either total N or TDS taken up before reaching the bottom of the root zone divided by the mass applied. I estimated treatment for total N and TDS by comparing the total annual mass of constituent moving below the root zone (based on lysimeter concentrations and the volume of leaching water) to the mass applied. To calculate the volume of water leached per acre for each application event, I used a water balance method that takes into account consumptive use by the crop. I multiplied the volume of water moving below the root zone for each application event by the mean total N or TDS concentration for the wicks and suction lysimeters to estimate the mass leached.

I projected changes in ground water nitrate and TDS concentrations by assuming that the annual input of water, nitrate, and TDS moving below the root zone completely mixes with the top ten feet of the underlying aquifer, as suggested by Darr (1994). I assumed that nitrate and TDS leached at the same rate over the entire 160 acres as at the study sites, because effluent is applied at about the same rate on the whole field, and soil properties are similar throughout the site. I also assumed that the porosity of the aquifer is 0.25-0.30 based on the soil characteristics shown in Appendix A.

Quality Assurance

Data quality was good based on laboratory and field checks. Duplicate samples were collected on each sampling date from one lysimeter that contained sufficient volume for two sets of samples. Not all analyses could be duplicated on each date due to limited sample volume.

The average relative percent difference (RPD) in duplicate total N estimates shown in Appendix F was 25% which meets the data quality objectives for this project. Most of that difference was due to variability in the TKN analysis at low concentrations. We obtained one elevated nitrate+nitrite-N rinsate blank of 3.3 mg/L on August 6, 1993. All other nitrate+nitrite-N rinsate blanks were 0.5 mg/L or below the detection limit of 0.01 mg/L.

The RPD for TDS was low (0-1.3%), which indicates good laboratory precision. However, slight field contamination occurred based on the first two TDS rinsate blanks collected on May 5 and June 11, 1993, (83 and 32 mg/L respectively). On June 11, 1993, specific conductance and COD rinsate blanks were likewise elevated compared to other dates (37 umhos/cm and 28 mg/L respectively). Higher than expected concentrations on these dates may be due to inadequate cleaning of sample tubing between samplers.

The range of RPD for chloride and sulfate was 0.2-5.7%; for dissolved calcium, magnesium, sodium, and potassium on July 24, 1993, 15-18%.

Further details of quality assurance procedures and results are described in Appendix F.

Results and Discussion

Results of the soil pore-water quality analyses are discussed below. Each of the following topics to be discussed corresponds to a project objective:

- Effluent and soil pore-water quality,
- Treatment of total N and TDS,
- Comparison of lysimeter types,
- Projected changes in ground water quality, and
- Effectiveness of vadose zone monitoring.

Water Quality

Total N and TDS were the primary constituents of concern and are the focus of the following discussion. Other parameters of interest that were analyzed include specific conductance, pH, chloride, chemical oxygen demand (COD), dissolved and total iron, potassium, sulfate, sodium, calcium, and magnesium. Results for all water quality parameters are shown in Appendix G. The ranges of concentrations are shown in Table 2.

Effluent

Concentrations of most effluent constituents varied little during the study (Table 2). The range for total N was 20-24 mg/L. [Total N is defined as the sum of total Kjeldahl N (organic N and ammonia-N) and nitrate+nitrite-N.] Ammonia-N composed 68-88% of the effluent total N, except in October when ammonia-N made up only 30%. Nitrate+nitrite-N concentrations in the effluent were typically very low, except in October when 43% of the total N was nitrate+nitrite-N. TDS was consistently in the range of 344-347 mg/L.

Results for other effluent constituents, such as pH, specific conductance, chloride, sodium, calcium, magnesium, potassium, and sulfate shown in Appendix G varied little throughout the study.

Soil Pore-Water

General

Soil pore-water quality varied more than effluent quality (Table 2). Upper ranges were 3-100 times higher than the lower ranges. For

Table 2. Ranges in effluent and soil pore–water concentrations in mg/L for major constituents.

Parameter	Effluent	Soil Pore–Water
Ammonia–N	5.8–21.2	0.01–0.80
Nitrate+nitrite–N	0.02–8.5	0.05–63
Total Kjeldahl N	11–24	0.7–2.8
Total N	20–24	0.8–64
TDS	344–347	144–618
Specific conductance	628–657	200–910
pH	7.4–8.0	6.7–7.7
Chloride	42–49	1.8–175
COD	38–120	10–200
Dissolved Sodium	53–55	26.9–121
Dissolved Calcium	38–40	7.3–53
Dissolved Magnesium	7.2–8.2	3.5–23
Dissolved Potassium	10.7–10.9	2.4–7.3
Dissolved Sulfur	18–22	5.9–53
Dissolved Iron	0.02–0.23	0.005–0.11

instance, the range for chloride was 1.8 to 175 mg/L, or one-fourth to four times the effluent mean.

Total N

The range of total N concentration was 0.9 to 64 mg/L. On the average, 75% of soil pore-water total N was composed of nitrate+nitrite-N in the lysimeters. A large portion of the remaining 25%, mainly ammonia-N and organic N, is probably converted to nitrate-N in the soil which then becomes soluble and mobile (Stevens, 1994).

Total N concentrations typically were highest in the wick lysimeters, second highest in the suction lysimeters, and lowest in the barrel lysimeters. At Field 4, the mean concentration in the wick lysimeters, 17 mg/L, was significantly higher than that from the suction samplers, 8.6 mg/L, or the barrel lysimeters, 1.7 mg/L, at the 95% significance level (Table 3).

Figure 9 shows the dates when the wick lysimeter total N concentrations exceeded those in the suction lysimeters. The barrel lysimeter total N concentrations were always lowest.

Table 3. Mean total N estimates based on results of three lysimeter types at Field 4.

Lysimeter	Mean*	Standard Deviation	No. of sampling dates	Range
Wick	16.9	8.4	4	1.5-64
Suction	8.6	4.5	4	1.4-21.5
Barrel	1.7	0.5	3	0.9-6.1

* See Table 4 for mean values on each date. Data from May 5-6, 1993, are not included due to dilution of the wick concentrations immediately after installation.

Although fewer data were available for comparison at Field 6 than at Field 4 (Table 4), the highest total N concentrations, 64 and 44 mg/L, were found in the wick lysimeters.

Magid and Christensen (1993) also found significant differences between results from wick and suction lysimeters, including nitrate-N.

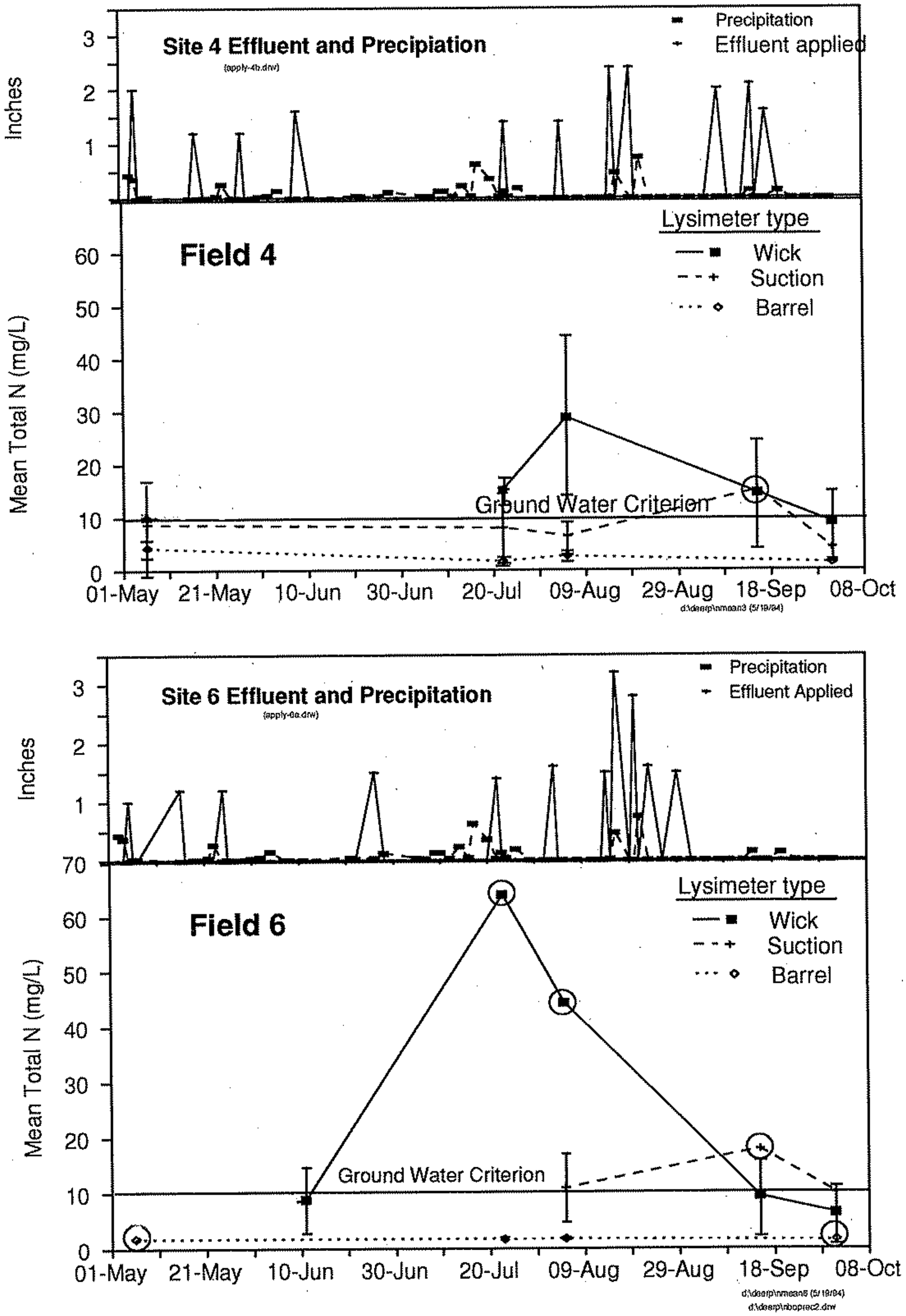

Figure 9. Mean total N concentrations and standard deviations at Field 4 (top) and Field 6 (bottom). Applied effluent and precipitation shown above in each. Circles indicate that only one sample was collected.

Table 4. Means of total N and TDS concentrations in wick, suction, and barrel lysimeters.
Total N values include estimated TKN's, i.e., mean TKN value for that sampler type in that field.

FIELD 4

Total N	Wick Lysimeters				Suction Lysimeters				Barrel Lysimeters			
	Mean	S.D.	n	St Error*	Mean	S.D.	n	St Error	Mean	S.D.	n	St Error
05/06/93	--				8.5	9.3	2	0.77	4.3	1.5	4	0.17
07/22/93	15.1	2.9	2	0.14	7.9	7.3	2	0.65	1.7	0.1	4	0.03
08/05/93	28.9	14.9	5	0.23	6.2	3.0	6	0.20	2.2	1.0	5	0.20
09/15/93	14.5	10.1	3	0.40	15.1	--	1	--		--		--
10/01/93	9.0	6.6	2	0.52	5.1	6.5	3	0.74	1.3	0.2	4	0.08

TDS	Wick Lysimeters				Suction Lysimeters				Barrel Lysimeters			
	Mean	S.D.	n	St Error*	Mean	S.D.	n	St Error	Mean	S.D.	n	St Error
05/06/93	--				263		1		289	106	4	0.18
07/24/93	335	145	2	0.31	229		1		244	39	3	0.09
08/05/93	431	187	4	0.22	294		1		273	51	5	0.08
09/15/93	267		1		--		--		--	--		--
10/01/93	292		1		401	117	2	0.21	417	85	3	0.12

FIELD 6

Total N	Wick Lysimeters				Suction Lysimeters				Barrel Lysimeters			
	Mean	S.D.	n	St Error*	Mean	S.D.	n	St Error	Mean	S.D.	n	St Error
05/06/93	--				--	--			1.9	--	1	
06/11/93	8.8	6.0	3	0.39	--	--			--	--		
07/23/93	64.0	--	1	--	--	--			1.5	0.1	4	0.03
08/06/93	44.3	--	1	--	10.7	5.1	3	0.28	1.6	0.1	4	0.03
09/15/93	9.4	7.1	3	0.44	17.9	--	1	--	--			
10/01/93	6.4	5.0	3	0.45	9.4	7.4	5	0.35	1.6	--	1	

TDS	Wick Lysimeters				Suction Lysimeters				Barrel Lysimeters			
	Mean	S.D.	n	St Error*	Mean	S.D.	n	St Error	Mean	S.D.	n	St Error
05/06/93	--				--				--			
06/11/93	305	42	3	0.08	--				--			
08/06/93	614	--	1	--	411	76	2	0.13	290	84	4	0.14
09/15/93	391	--	1	--	495	--	--	--	274	67	2	0.17
10/01/93	358	49	2	0.10	342	40	4	0.06	--			

* St Error = Standard error = (Standard deviation/square root of n)/mean

The mean total N concentration for the wick and suction lysimeters, 17 mg/L, is considerably higher than those reported in EPA (1981) for soil pore-water and ground water beneath land application sites. Results for the barrel lysimeters are not included in the Deer Park study mean because of their shallow depth. The range in nitrate-N values in the EPA (1981) guide was 3.9-10.7 mg/L based on data from four land application sites. However, some of the data represent a mixture of samples from both ground water and soil pore-water.

TDS

The range of TDS values in the lysimeters was 144 to 618 mg/L. About one-quarter of the TDS values were calculated as:

TDS (mg/L) = Specific Conductance x 0.68 (Metcalf and Eddy, 1991)

The mean concentration for the three lysimeter types was 344 mg/L. The mean for each type of sampler is shown in Table 5. There was no significant difference between the means for the different types of sampler. Likewise, as shown in Figure 10, on specific dates no difference in TDS was observed.

Table 5. Mean TDS estimates based on the results of three lysimeter types at Field 4.

Lysimeter	Mean*	Standard Deviation	No. of sampling dates	Range
Wick	331	72	4	292-431
Suction	308	87	3	229-401
Barrel	311	93	3	244-417

* See Table 4 for mean values on each date. Data from May 5-6, 1993 are not included due to dilution of the wick concentrations by deionized water immediately after installation.

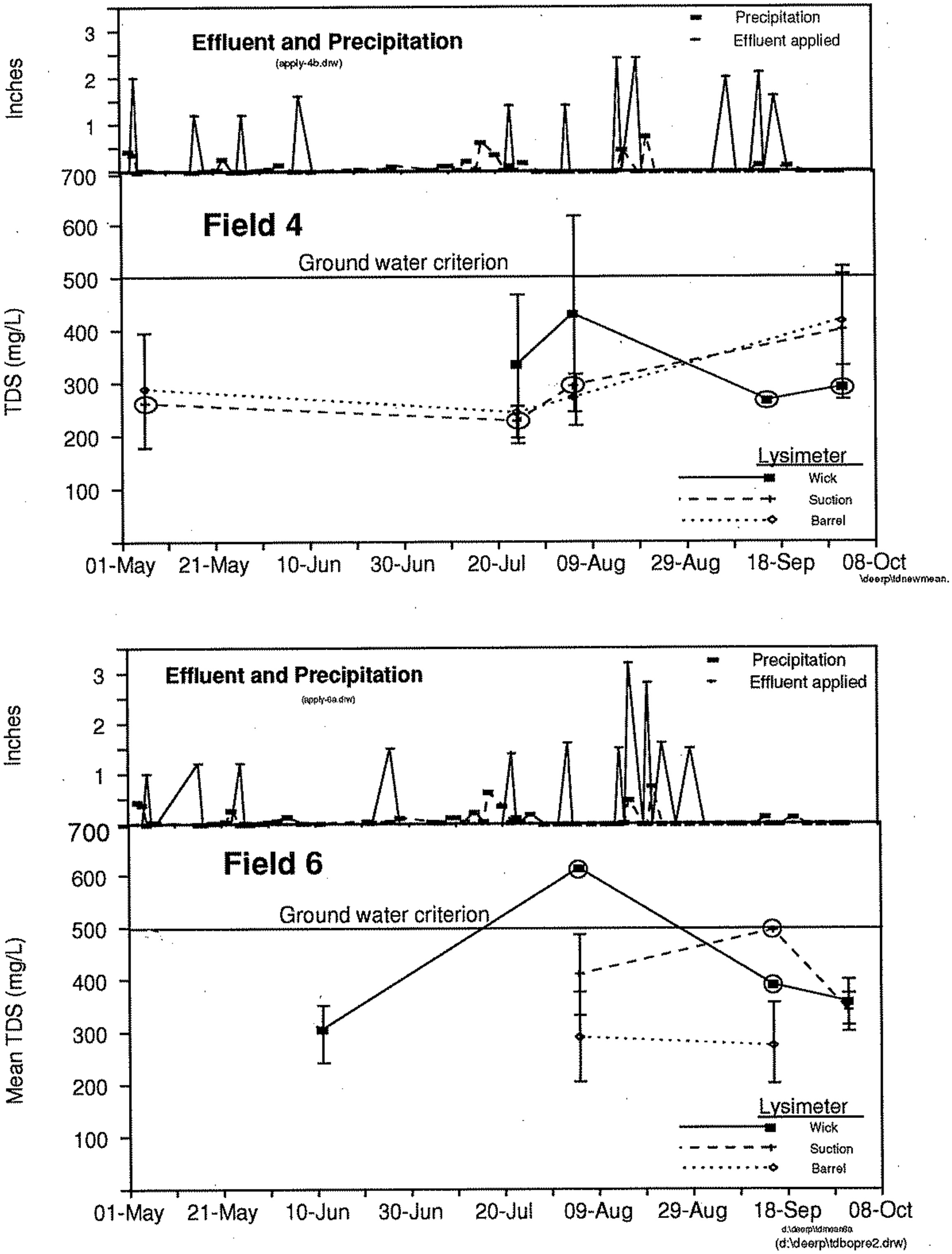

Figure 10. Mean TDS concentrations and standard deviations at Field 4 (top) and Field 6 (bottom). Applied effluent and precipitation are shown above in each. Circles indicate that only one sample was collected.

Factors Affecting Lysimeter Results

Many factors contributed to the variability of the soil pore water quality results, including:

- Sample integration and timing,
- Pore accessibility,
- Vegetative cover, and
- Sampling depth.

These items are discussed below.

Sample Integration and Timing

The three lysimeters collected samples over different time intervals. The wick and barrel lysimeters collect water continuously if available, while the suction lysimeter requires a vacuum. When the one-liter volume typical of the suction lysimeters is filled, the suction lysimeter stops sampling. The wick lysimeters in this study had nine times the capacity of the suction lysimeter. Therefore, the parcel of water that the suction lysimeter collects usually represents a shorter time frame than either the wick or barrel lysimeters.

Purge samples collected from wick and barrel lysimeters on July 22 and September 15, 1993, represented soil pore-water moving into the sampler over a period of five to six weeks. Suction lysimeter samples, on the other hand, probably represented soil pore-water moving during the first few days after the vacuum was set.

A different problem arose when the lysimeters were sampled too soon after effluent application, i.e., one to three days after effluent was applied. In several such cases the wick samplers were empty, while the vacuum lysimeters contained samples. The sample from the vacuum lysimeter may not have represented the recently applied effluent, because the suction can pull slow-moving residual water in small pores left from previous applications.

Pore Accessibility

Because all three lysimeter types function differently, they receive water from differently sized soil pores (Magid and Christensen, 1993; Barbee and Brown, 1986; Haines *et al.*, 1982). Barrels depend on gravity alone to capture water under saturated conditions. Suction lysimeters, on the other hand, can pull water out of smaller pores under unsaturated conditions. The wick lysimeters theoretically capture and integrate both rapid, saturated flow and slower, unsaturated flow (Knutson and Selker, 1994; Boll *et al.*, 1991; Holder *et al.*, 1991; Barbee and Brown, 1986, Haines *et al.*, 1982).

Vegetative Cover

Vegetation in the study areas differed somewhat from that of the surrounding fields. Flagging around the perimeter of the study areas was used to protect the lysimeters from farm equipment. However, this also prevented vegetation near the lysimeters from being harvested with the surrounding field.

Soil overlying the trenches for the wick lysimeters was seeded with alfalfa following construction. Bare patches early in the summer probably caused faster than normal infiltration and less uptake of nitrogen by plants. In addition, more weeds and grass grew near the trenches than in the surrounding alfalfa fields.

The barrel lysimeters seemed to contain more grass and weeds with little alfalfa. The area near the suction lysimeters contained the largest fraction of alfalfa. Suction lysimeters also caused the least disturbance to vegetation.

Sampling Depth

The lowest total N concentrations were found in the two-foot deep barrel lysimeters. The impermeable bottom cap trapped water inside the barrel, possibly allowing more plant uptake than occurred near the uncontained wick and suction lysimeters. Although less likely, denitrification may also have occurred in the barrels if locally anoxic conditions existed after ammonia-N was converted to nitrate-N.

As expected, the shallower wick and suction lysimeters produced the highest total N concentrations as shown in Figures 11 and 12. Likewise, the highest total N value at Field 6 was from a three-foot deep wick lysimeter on July 23, 1993. On a few occasions, however, deeper samples had higher total N concentrations than those from shallower depths.

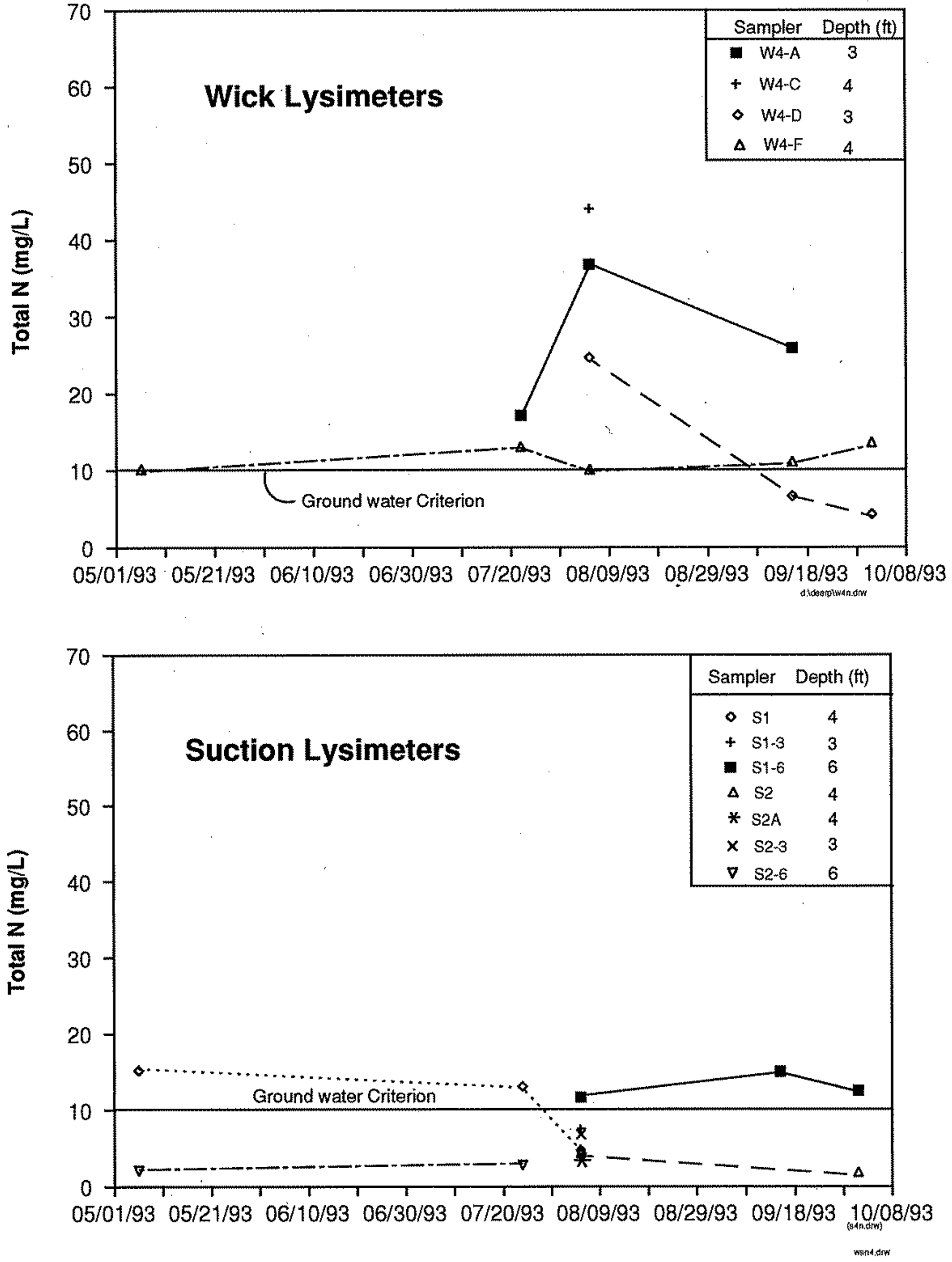

Figure 11. Total N concentrations in wick (top) and suction (bottom) lysimeters at Field 4.

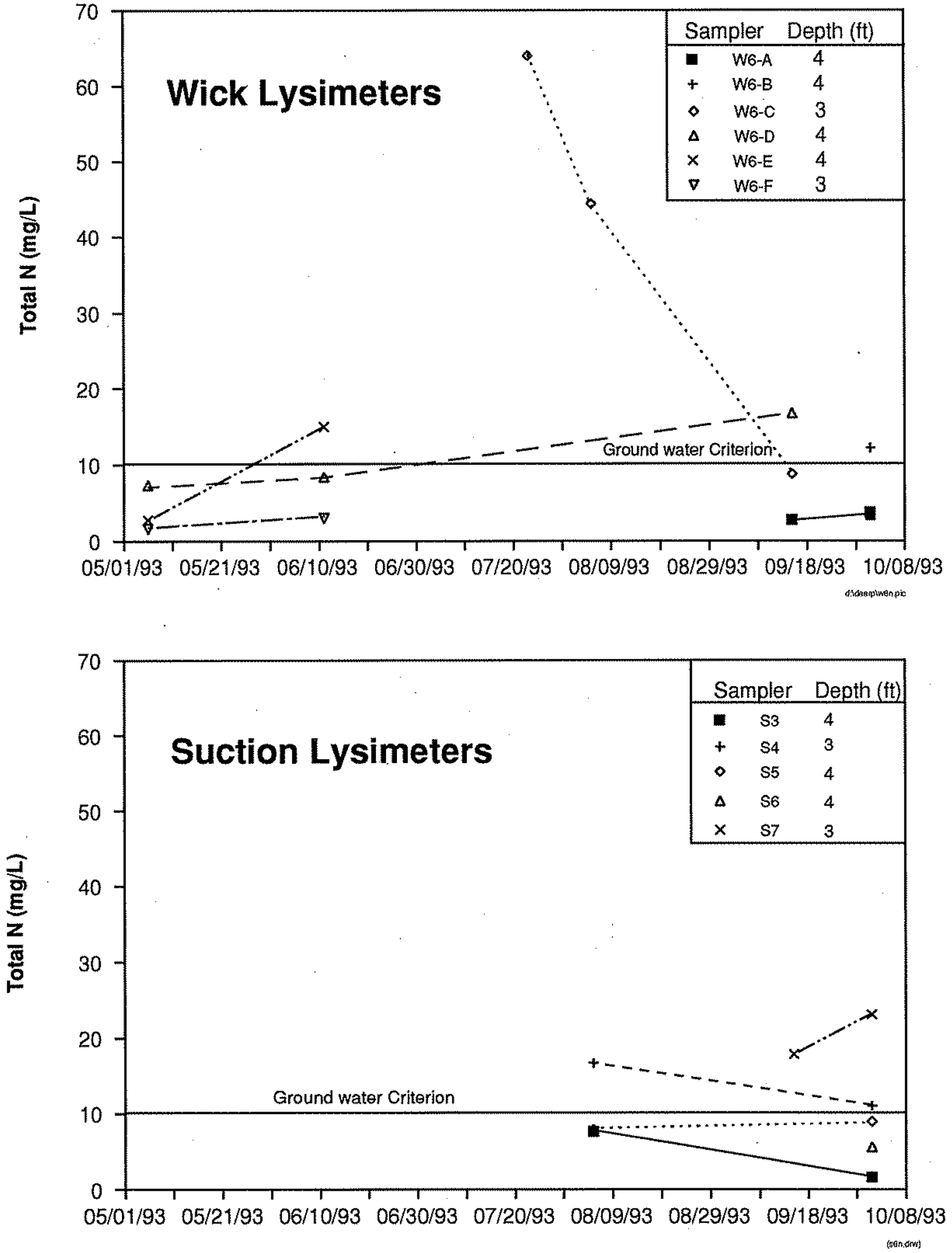

Figure 12. Total N concentrations in wick (upper) and suction (lower) lysimeters at Field 6.

Treatment

Treatment, in this discussion, refers to the difference between the mass of total N or TDS applied in the effluent and that reaching the lower part of the root zone. The estimates for application rate are explained below followed by the treatment estimates.

The mechanisms for treatment were not addressed in this study but include some or all of the following: plant uptake, volatilization, denitrification, and adsorption. See Appendix E for the method used to estimate treatment.

Application Rates

Effluent application rates observed in the field were double, on the average, those recorded in the facility's Discharge Monitoring Reports (DMR's) (Appendix Table D.1). The average application rate for the two sites based on data from the precipitation collectors was 21.7 inches for 1993 (Appendix H), while the facility's estimate is about 11 inches (Appendix I). The facility's application rate is based on the estimated discharge rate from the sprinkler nozzles, 0.09 inch/hour/nozzle, multiplied by the number of nozzles and the amount of time that effluent is applied.

Application rates for total N and TDS are the product of the effluent concentration and the volume of water applied during each application event.

Total N

The application rate for total N was about 100 lb/acre/year as shown in Table 6. This is only about 25 to 30% of the nitrogen application rate typically used to stimulate alfalfa growth (Stevens, 1994). Because much of the effluent was applied late in the growing season at higher than normal rates (12 inches in August at Field 6, and 12 inches in August-September at Field 4), the capacity of the soil and plants to hold and take up nitrogen was exceeded. This apparently resulted in significant nitrogen leaching below the root zone.

TDS

The application rate for TDS was 1,600 to 1,800 lb/acre/year as shown in Table 7. This is probably in the normal range for irrigated agriculture, because

Table 6. Application rates for total N in 1993. See Table H.1 for details of calculations.

Field 4				Field 6			
Date	Applied (In)	N Load (lb/acre)		Date	Applied (In)	N Load (lb/acre)	
05/04/93	2.5	13.6		05/05/93	1.0	5.4	
05/17/93	1.2	6.5		05/16/93	1.2	6.5	
05/24/93	1.4	7.6		05/25/93	1.2	6.5	
05/27/93	1.2	6.5		06/26/93	1.5	6.8	
06/08/93	1.6	7.2		07/22/93	1.4	7.0	
07/23/93	1.4	7.0		08/03/93	1.6	8.0	
08/04/93	1.4	7.0		08/14/93	1.5	7.5	
08/15/93	2.4	11.9		08/16/93	3.2	15.9	
08/16/93	2.4	11.9		08/20/93	2.8	13.9	
09/07/93	2.0	10.0		08/23/93	1.6	8.0	
09/14/93	2.1	9.5		08/29/93	1.5	7.5	
09/17/93	1.6	7.2		10/08/93	0.7	3.2	
10/06/93	0.7	3.2		10/25/93	1.4	6.3	
10/20/93	0.8	3.6					
		113	**Total**			103	**Total**

Table 7. Application rates for TDS in 1993. See Table H.2 for details of calculations.

Field 6				Field 6			
Date	Applied (In)	TDS Load (lb/acre)		Date	Applied (In)	TDS Load (lb/acre)	
05/04/93	2.5	195		05/05/93	1	78	
05/17/93	1.2	94		05/16/93	1.2	94	
05/24/93	1.4	109		05/25/93	1.2	94	
05/27/93	1.2	94		06/26/93	1.5	117	
06/08/93	1.6	125		07/22/93	1.4	109	
07/23/93	1.4	109		08/03/93	1.6	125	
08/04/93	1.4	109		08/14/93	1.5	117	
08/15/93	2.4	187		08/16/93	3.2	250	
08/16/93	2.4	187		08/20/93	2.8	218	
09/07/93	2.0	156		08/23/93	1.6	125	
09/14/93	2.1	164		08/29/93	1.5	117	
09/17/93	1.6	125		10/08/93	0.7	55	
10/06/93	0.7	55		10/25/93	1.4	109	
10/20/93	0.8	62					
		1,771	**Total**			1,607	**Total**

both the TDS concentration in the effluent, 344-357 mg/L, and the volume of water applied were moderate.

Permit Limits

Assuming that the volume of effluent applied in 1993 was twice the facility's estimates, the maximum allowable monthly application rate, 8.2 inches, was exceeded in August at Field 6 by about four inches. Application rates also may have exceeded the permit limit at five of the other fields not included in this study in August, one field in May, and two fields in June (Appendix I).

Total N Treatment

Total N treatment was 23% at Field 6 and 46% at Field 4. The mean treatment was 35% (Appendix Table J.1). This represents an annual loading to ground water of 61-77 lb/acre. These results are based on the mean total N concentration for each date in the wick and suction lysimeters. Data from the barrel samplers were not used, because I did not consider them representative of the pore-water leaving the root zone.

Change in TDS

The range for TDS change was -14 to 18%, with a mean of 2% as shown in Appendix J. This represents an annual loading to ground water of 1,500-1,800 lb/acre. The lower end of the ranges represents Field 4, the higher end Field 6.

Like total N treatment, estimates of TDS changes are based on the mean concentration in the wick and suction lysimeters.

The mean estimate for the change in TDS, 2%, is reasonable, because the components of TDS neither react with the soil, nor are they significantly taken up by plants. However, the negative value at Field 6, -14%, may indicate an increase in the TDS concentration as the water percolates through the soil. See Sodium Adsorption Ratio p. 32 for further explanation.

Estimated Impacts to Ground Water

Total N and TDS

Total N and TDS that reached the three- to six-foot deep samplers are assumed to eventually move downward to the water table about 50 feet below, because alfalfa roots extend to about four feet (Campbell, 1994). Both nitrate-N and TDS are very mobile. The effects of loading to the ground water are assessed in this section by estimating the change in concentrations in the top 10 feet of the aquifer below the spray field.

The estimates of ground water concentrations are based on several assumptions. All water percolating below four feet and the dissolved constituents are assumed to mix with the top ten feet of the aquifer. I also assume that water moves from four-foot depth to the water table within a few weeks and that ground water movement is slow enough that most ground water below the 160-acre site received all of the nitrate and TDS that percolated below four feet during 1993. This method does not take into account the transient nature of unsaturated flow and the uncertainty in the rate of unsaturated water movement. See Appendix E for more details.

I assume that any organic N is converted to nitrate-N before reaching the water table. I also extrapolated the amount of water, nitrogen, and TDS percolating below four feet from Fields 4 and 6 (from **Treatment-Total N** Section above) to the entire 160 acres.

The estimated increase in nitrate-N above background was 5 to 7 mg/L; for TDS 110 to 170 mg/L (Appendix K). The estimated nitrate-N increase is 8 to 12 times the mean background concentration of 0.7 mg/L for 1992-93, as shown in Table 8. The estimated change in TDS is 1 to 1.5 times the background concentration of 115 mg/L (Table 8).

Quarterly compliance data from downgradient monitoring wells concur with these estimates. Concentrations of nitrate-N and TDS in downgradient monitoring wells are greater than concentrations in upgradient wells (Table 8; City of Deer Park, 1992 and 1993). During 1992-93, the mean downgradient nitrate-N concentration, 7.6 mg/L, is about eleven times higher than the upgradient mean of 0.7 mg/L. The mean downgradient TDS concentration is nearly double the upgradient TDS concentration of 211 mg/L.

Table 8. Nitrate + nitrite–N and estimated TDS values from monitoring wells M–5 (upgradient) and M–9 (downgradient) from City of Deer Park Discharge Monitoring Reports. TDS values are estimated as (specific conductance x 0.68).

Monitoring Well	Date	Nitrate+ Nitrite–N (mg/L)	Conductivity (umhos/cm)	TDS (mg/L)
M5	1/14/92	0.7	176	120
	2/11/92	0.7	172	117
	3/2/92	0.7	165	112
	4/4/92	0.9	180	122
	5/13/92	0.6	200	136
	6/92	0.5		
	11/19/92	0.8	175	119
	4/12/93	0.5	180	122
	6/28/93	0.4	175	119
	9/28/93	0.5	141	96
	11/18/93	0.8	130	88
	Mean	0.65		115
	St Dev	0.15		13
M9	1/14/92	8	240	163
	2/11/92	8.1	240	163
	3/2/92	8	320	218
	4/4/92	8.3	320	218
	5/13/92	6.4	360	245
	6/92	4.4		
	11/19/92	10	400	272
	4/12/93	6.8	360	245
	6/28/93	5.1	315	214
	9/28/93	9	305	207
	11/18/93	9.2	250	170
	Mean	7.6		211
	St Dev	1.6		35

Although the monitoring wells were not constructed to current standards, consistently elevated nitrate-N and TDS concentrations in downgradient wells suggest that ground water has been affected by land application.

Sodium Adsorption Ratio

The mean sodium adsorption ratio (SAR) for effluent and soil pore-water samples, 2, is in the range that Metcalf and Eddy (1991) classify as requiring slight to moderate restrictions (Table 9).

High SAR values can indicate high sodium input that can cause decreased soil permeability, especially in the top few inches of soil. However, Campbell (1994), who characterized the soils, did not believe that sodium posed a significant problem at the site due to the coarse, sandy nature of the soils.

Lysimeter Comparison

Wick, suction, and barrel lysimeters have various advantages and disadvantages. The samplers are compared below on the basis of reliability, representativeness, ease of installation, sample volume, variation between replicates, costs, and time to construct. The results are summarized in Table 10.

Table 10. Comparison of wick, suction, and barrel lysimeters at the Deer Park site.

Performance Criteria	Wick Lysimeters	Suction Lysimeters	Barrel Lysimeters
Reliability	Good	Very good	Very good
Representativeness	Good	Good	Poor
Ease of installation	Difficult	Easy	Difficult
Variation between replicates	Good	Good	Very good
Volume	Good	Limited	Good
Costs and time	High	Low	High

Table 9. Sodium adsorption ratio (SAR) calculations. Concentrations are in mg/L.

Site	Date	Total Calcium	Dissolved Calcium	Total Magnesium	Dissolved Magnesium	Total Sodium	Dissolved Sodium	SAR*	Specific Conductanc (umhos/cm)	Use Restriction**
Field 4										
W4-A	07/22/93		12.9		5.2		121	7.2	638	S-M
W4-D	08/05/93		23.4		6.53		112	5.3	686	S-M
W4-F	07/22/93		7.28		2.72		58.3	4.7	328	S-M
	8/05/93		8.08		3.06		65.6	5.0	369	S-M
	10/01/93		9.24		3.46		67.2	4.8	418	S-M
S1	05/06/93	25.4		4.87		35.5		1.7	381	S-M
	07/24/93		15.1		3.18		42	2.6	322	S-M
B4-S2	07/24/93		11.9		5.00		42.1	2.6	296	S-M
B4-L1	05/06/93	16.9		6.64		37.2		1.9	295	S-M
	07/22/93		23.5		8.39		38.4	1.7	410	S-M
	07/24/93		20.6		7.32		42.8	2.1	332	S-M
Dup	07/24/93		16.8		6.32		36.7	1.9	332	S-M
	10/01/93		25.7		9.32		45.7	2.0	501	S-M
B4-L2		11.2		4.5		30.1		1.9	221	S-M
Field 6										
W6-C	08/06/93		52.7		22.7		97.5	2.8	565	S-M
W6-D	05/06/93	36.6		6.47		50.5		2.0	353	S-M
	06/11/93	6.59		2.35		64.1		5.4	346	S-M
W6-E	06/11/93	11.5		5.42		78.6		4.8	476	S-M
W6-F	06/11/93	12.9		4.53		78.2		4.8	446	S-M
S4	10/01/93		15.4		4.93		65.7	3.7	497	S-M
S6	10/01/93		10.8		2.87		68.9	4.8	457	S-M
B6-S1	07/23/93		21.9		8.9		26.9	1.2	340	S-M
B6-L2	07/22/93		29.9		11.0		58.4	2.3	533	S-M
Effluent 1	05/05/93	37.2		6.57		51.1		2.0	657	S-M
	06/11/93	38.3		6.73		49.3		1.9	628	S-M
	10/01/93		39.8		8.24		53.2	2.0	628	S-M
Effluent 2	07/23/93		38.1		7.19		55.4	2.2	631	S-M

* $SAR = Na/\sqrt{(Ca + Mg/2)}$. Concentrations are in meq/L.

** S-M: Slight to moderate. See Metcalf & Eddy, 1991.

N: None

SV: Severe

Reliability

All three samplers were reliable in collecting samples when sufficient time was allowed for water to reach the samplers. All 24 suction and wick lysimeters produced samples on at least one occasion. It is important to allow sufficient time after purging for wick lysimeters to collect water before sampling. Nine out of ten barrel lysimeters also produced samples.

Representativeness

We experienced the fewest problems obtaining representative samples with the suction lysimeters. The suction lysimeters caused the least disturbance to surrounding vegetation and could easily be placed at the depths of interest (three to six feet). The disadvantage of the suction lysimeter is that it collects discrete samples and, unless sampled at frequent intervals, can miss large pulses of water. These infrequent, large pulses may comprise much of the flow leaving the root zone. Suction lysimeters can also misrepresent the concentration of substances leaving the root zone by drawing out slow-moving water in small pores that may not be leaving the root zone (see Pore Accessibility under **Water Quality Results** above).

Wick lysimeters provide a more continuous sample than the suction samplers. For constituents that are fairly conservative, such as total N and TDS, infrequent sampling can still provide an accurate estimate of the quality of the water leaving the root zone. More frequent sampling is needed for non-conservative substances (Magid and Christensen, 1993; Boll, et. al, 1992; Barbee and Brown, 1986).

Trenches needed to install the wick lysimeters are a drawback initially, because they disturb surrounding vegetation. Distilled water added to the wick during installation to "prime" the sampler also dilutes the initial sample concentrations. Likewise, after samples are collected, the hanging wick can hold residual water that eventually empties into the collection vessel affecting future sample concentrations. Residual water does not pose a problem if the results are used to estimate a mean over time, i.e., a season or a year. In this case the wick lysimeters can effectively serve as continuous samplers.

Samples from the barrels were probably least representative of soil pore-water moving below the root zone due to their depth two feet above the root depth for alfalfa.

Ease of Installation

Suction lysimeters were the easiest of the three types to install. Only the suction samplers did not require a back-hoe for installation. We hand-augured each hole for the suction lysimeters within a few minutes.

Wick lysimeters were difficult to install in the sandy, loose soils due to caving. The 2-gallon collection vessel undermined the overlying soil which we tried not to disturb. Soil caving, combined with the lack of soil structure, made it impossible to install the wicks as prescribed: with a smooth, flat, undisturbed soil ceiling and the plate tightly pressed against it. Selker (1994) is developing an easier, above-ground installation method.

Barrels were also difficult to install in the coarse, loose sand. When the back-hoe extracted the barrel, instead of pulling out an intact soil plug, often at least part of the contents of the barrel slid out. We replaced the loose soil in the barrels manually.

Variation Between Replicates

Results from the barrel lysimeters were less variable than those from the wick or suction lysimeters. TDS variability was less than that for total N in all samplers (Table 11).

Table 11. Coefficient of variation estimates for total N and TDS for each lysimeter.

Lysimeter Type	Total N	TDS
Wick	14-52	22-31
Suction	19-77	6-21
Barrel	3-20	8-18

The mean coefficient of variation for total N in the wick and suction lysimeter samples, which are most representative of water passing through the root zone, was 43% (n=14); that for TDS 15% (n=8).

Volume of Sample

The wick and barrel lysimeters contained the greatest volume of sample, nine to ten liters (Table 12). The suction lysimeters had the smallest capacity, one liter. The smaller capacity limited the number of sample analyses possible.

Table 12. Volume capacity for the three lysimeters.

Lysimeter Type	Volume (L)
Suction	1
Wick	9
Barrel (16-inch diameter)	10
Barrel (8-inch diameter)	2.5

Costs and Time

The range in costs for constructing individual samplers shown in Table 13 was $55 to $200. Installation costs for the wick and barrel lysimeters was significantly higher than for the suction lysimeters, because a back-hoe was required.

Shoring for the five- to six-foot deep trenches also added to the cost of the wick lysimeters and to the time needed for construction.

In addition to being the least expensive option, suction lysimeters were also the fastest to install at the Deer Park site. However, at sites with significant gravel content, suction lysimeters could be difficult to install. Likewise, if suction lysimeters were installed horizontally or at an angle to minimize flow along the sidewalls, a trench would also be needed. Costs would then be similar to those for the wick lysimeters.

Table 13. Cost estimates for building and installing the wick, barrel, and suction lysimeters.

Lysimeter	Preinstallation Cost	Backhoe Cost	Time to Construct and Install (hr)
Suction	$55–70	$0	1.5–2.5
Barrel			
16–inch	$200	$55/hr	7–12
8–inch	$75	$55/hr	5–10
Wick	$60–80	$55/hr	7–12
(Shoring)	$200		

Effectiveness of Vadose Zone Monitoring

Vadose zone monitoring is effective at the Deer Park site. Samples obtained from wick and suction lysimeters show that nitrogen treatment is not complete, indicating a potential for ground water contamination. The rapid response of soil pore-water can be used to evaluate modifications to effluent application scheduling.

Characteristics of the Deer Park site that make vadose zone monitoring useful are:

- The depth to ground water is about 50 feet,
- The soil is suitable for installing and operating vadose zone monitoring devices,
- The geology is sufficiently complex that installing an adequate number of monitoring wells to detect contamination due to the facility may be infeasible.

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Appendices

Appendix A. Soils characterization.

United States Department of Agriculture

Soil Conservation Service

Rock Pointe Tower II, Suite 451
W. 316 Boone Avenue
Spokane, WA 99201-2349
(509) 353-2364

Date: December 1, 1993

Subject: Soils Data for Deer Park Airport Wastewater Land Application Study

To: Barbara Carey
Washington State Department of Ecology
Mail Stop 7710
7171 Cleanwater Lane, Bldg. 8
Olympia, WA 98504-7710

Dear Barbara:

I've finished putting together the soils information for the Deer Park Wastewater Study. I received the soil moisture data from the University of Idaho in October. Enclosed are soil profile descriptions, soil particle-size analyses, and tables of chemical and soil moisture information taken from the University of Idaho data.

One interesting aspect of the soil moisture retention data is that these sandy soils hold more water than would normally be expected for soils with these textures. I suspect the reason for this is the presence of the loamy lamellae (thin layers) that occur in the soils at both sample sites. These thin layers probably also slow the rate at which water moves through the soil from what would be expected in coarse sand soils. Our estimate of the saturated hydraulic conductivity of these soils, from the attached Soil Interpretation Record for the Marble Series, ranges from 6 to 20 inches per hour.

The nitrate data shows that the highest concentrations by far were in the surface layers and dropped off rapidly in the deeper horizons. Of course the samples were collected in May, and nitrate levels could change as wastewater is applied throughout the growing season.

We are available to provide assistance on irrigation water management for this site. We could assist in developing an irrigation schedule that would base application rates on consumptive use of the crop, available water capacity of the soils, and climatic data. Deep leaching of irrigation water could be minimized by using proper application rates.

Please feel free to call me. We'd like to help in any way we can.

Steve Campbell
Steve Campbell
Area Soil Scientist

cc: Jim Carley, SCS State Soil Scientist
Jud Melton, SCS District Conservationist

DEPARTMENT OF ECOLOGY - DEER PARK AIRPORT WASTEWATER LAND APPLICATION STUDY

SITE NO. 1 - LATERAL AREA 4

USDA - Soil Conservation Service
Pedon Narrative Description
Nov 29, 1993

Soil Series: Marble
Soil Survey # S93-WA-063-001
Survey Area ID: 063
Description Type: description for research study
Pedon Type: Within range of series
Correlated Name: Marble
Location: Spokane County, Washington; 2500 feet north, 1500 feet west of the SE corner of section 31, T. 29 N., R. 43 E. W.M.
Latitude: 47 degrees, 57 min., 55 sec. N
Longitude: 117 degrees, 25 min., 37 sec. W
Classification: mixed, mesic Alfic Xeropsamment
Physiography: Glacial Outwash Plain
Slope Characteristics: 2.5% plane horizontal, plane vertical
Elevation: 2180 ft MSL
Mean Annual Precipitation: 22 in.; xeric moisture regime
MLRA: 44
Hydraulic Conductivity: high
Air Temperature: Mean Annual - 45 degrees F
Soil Temperature: Mean Annual - 47 degrees F
Drainage Class: excessively drained
Land Use: alfalfa hayland
Particle Size Control Section: 10 to 40 in.
Described By: Steven B. Campbell
Date: 05/3/93

Ap--0 to 4 inches; brown to dark brown (10YR 4/3) coarse sand; pale brown (10YR 6/3) dry; weak fine granular structure; soft, very friable, non sticky, non plastic; many very fine and fine roots, common medium roots; neutral (pH 6.4); clear smooth boundary.

C1--4 to 22 inches; brown (10YR 5/3) coarse sand; very pale brown (10YR 7/3) dry; single grain; loose, non sticky, non plastic; common very fine and fine roots and few medium roots; mildly alkaline (pH 7.3); gradual smooth boundary.

C2--22 to 36 inches; brown (10YR 5/3) coarse sand; very pale brown (10YR 7/3) dry; single grain; loose, non sticky, non plastic; few very fine and fine roots; loamy lamellae 1/4 to 1/2 inch thick about 8 to 12 inches apart; moderately alkaline (pH 7.7); gradual smooth boundary.

C3--36 to 52 inches; brown (10YR 5/3) coarse sand; very pale brown (10YR 7/3) dry; massive; soft, very friable, non sticky, non plastic; few very fine and fine roots; loamy lamellae 1/4 to 1/2 inch thick about 8 to 12 inches apart; neutral (pH 6.4); clear smooth boundary.

C4--52 to 72 inches; brown (10YR 5/3) coarse sand; very pale brown (10YR 7/3) dry; massive; loose, non sticky, few very fine and fine roots non plastic; neutral (pH 6.9).

DEPARTMENT OF ECOLOGY - DEER PARK AIRPORT WASTEWATER LAND APPLICATION STUDY

SITE NO. 2 - LATERAL AREA 6

USDA - Soil Conservation Service
Pedon Narrative Description
Nov 29, 1993

Soil Series: Marble
Soil Survey # S93-WA-063-002
Survey Area ID: 063
Description Type: description for research study
Pedon Type: Within range of series
Correlated Name: Marble
Location: Spokane County, Washington; 2450 feet south, 2200 feet east of the NW corner of section 31, T. 29 N., R. 43 E. W.M.
Latitude: 47 degrees, 58 min., 05 sec. N
Longitude: 117 degrees, 26 min., 02 sec. W
Classification: mixed, mesic Alfic Xeropsamment
Physiography: Glacial Outwash Plain
Slope Characteristics: 1% plane horizontal, plane vertical
Elevation: 2190 ft MSL
Mean Annual Precipitation: 22 in.; xeric moisture regime
MLRA: 44
Hydraulic Conductivity: high
Air Temperature: Mean Annual - 45 degrees F
Soil Temperature: Mean Annual - 47 degrees F
Drainage Class: excessively drained
Land Use: alfalfa hayland
Particle Size Control Section: 10 to 40 in.
Described By: Steven B. Campbell
Date: 05/4/93

Ap--0 to 4 inches; brown to dark brown (10YR 4/3) coarse sand; pale brown (10YR 6/3) dry; weak fine granular structure; soft, very friable, non sticky, non plastic; many very fine and fine roots, common medium roots; neutral (pH 6.7); clear smooth boundary.

C1--4 to 29 inches; brown (10YR 4/4) coarse sand; light brown (10YR 6/4) dry; single grain; loose, non sticky, non plastic; common very fine and fine roots and few medium roots; loamy lamellae 1/4 to 1/2 inch thick about 12 to 18 inches apart; moderately alkaline (pH 7.9); gradual smooth boundary.

C2--29 to 56 inches; brown (10YR 5/3) coarse sand; very pale brown (10YR 7/3) dry; single grain; loose, non sticky, non plastic; few very fine roots; moderately alkaline (pH 7.9); gradual smooth boundary.

C3--56 to 72 inches; brown (10YR 5/3) sand; very pale brown (10YR 7/3) dry; massive; soft, very friable, non sticky, non plastic; no roots observed; loamy lamellae 1/4 to 1/2 inch thick about 12 to 18 inches apart; mildly alkaline (pH 6.4).

SOIL LABORATORY DATA - UNIVERSITY OF IDAHO

CITY OF DEER PARK LAND APPLICATION STUDY

AUGUST 2, 1993

SITE NO.	SAMPLE NO.	HORIZON	DEPTH (IN.)	pH	CATION EXCHANGE CAPACITY (cmol/kg)	ORGANIC CARBON (%)	ORGANIC MATTER (%)	NO3-N (ug/g)	NH4-N (ug/g)
1	1-1	Ap	0-4	6.4	5.5	0.71	1.21	41.7	1.3
	1-2	C1	4-22	7.3	4.1	0.09	0.15	1.6	0.5
	1-3	C2	22-36	7.7	---	----	----	0.8	0.4
	1-4	C3	36-52	6.4	---	----	----	2.7	0.5
	1-5	C4	52-72	6.9	---	----	----	1.1	0.4
2	2-1	Ap	0-4	6.7	4.2	0.29	0.50	19.6	1.1
	2-2	C1	4-29	7.9	4.1	0.05	0.09	0.9	0.5
	2-3	C2	29-56	7.9	---	----	----	0.3	0.5
	2-4	C3	56-72	7.7	---	----	----	0.2	0.4

SOIL MOISTURE RETENTION DATA FOR DEPARTMENT OF ECOLOGY
DEER PARK AIRPORT WASTEWATER LAND APPLICATION STUDY

DECEMBER 1, 1993

SITE NO.	SAMPLE NO.	HORIZON	DEPTH (IN.)	**SOIL MOISTURE RETENTION** (PERCENT BY WEIGHT)			MOIST BULK DENSITY (G/CC)	**AVAILABLE WATER CAPACITY**		
				0.1 BAR	1.0 BAR	15 BAR		IN./IN.	IN./ HORIZON	CUMULATIVE INCHES
1	1-1	Ap	0 - 4	14.61	6.62	3.30	1.45	0.16	0.66	0.66
	1-2	C1	4 - 22	6.21	5.32	2.43	1.50	0.06	1.02	1.68
	1-3	C2	22 - 36	11.00*	5.00*	2.40*	1.55	0.13	1.87	3.54
	1-4	C3	36 - 52	11.33	5.09	2.48	1.55	0.14	2.19	5.74
	1-5	C4	52 - 72	6.00*	3.00*	2.00*	1.55	0.06	1.24	6.98
2	2-1	Ap	0 - 4	11.83	4.70	2.58	1.45	0.13	0.54	0.54
	2-2	C1	4 - 29	10.00*	5.00*	2.50*	1.50	0.11	2.81	3.35
	2-3	C2	29 - 56	4.94	2.74	1.71	1.50	0.05	1.31	4.66
	2-4	C3	56 - 72	9.00*	5.00*	2.20*	1.55	0.11	1.69	6.34

* SOIL MOISTURE RETENTION ESTIMATED BY EXTRAPOLATING DATA FROM OTHER HORIZONS

$$\text{AVAILABLE WATER CAPACITY} = \frac{(\text{0.1 BAR MOISTURE} - \text{15 BAR MOISTURE})(\text{MOIST BULK DENSITY})}{100}$$

SOIL MOISTURE RETENTION AT 0.1 BAR IS CONSIDERED TO BE FIELD CAPACITY
SOIL MOISTURE RETENTION AT 15 BAR IS CONSIDERED TO BE THE PERMANENT WILTING POINT

MOISTURE RETENTION DATA IS FROM THE UNIVERSITY OF IDAHO ANALYTICAL LAB

BULK DENSITY DATA IS FROM CORE SAMPLES COLLECTED BY STEVE CAMPBELL, SOIL CONSERVATION SERVICE

SOIL ANALYSIS FOR: STEVE CAMPBELL
USDA SCS
ROCK POINT TOWER II SUITE 451
W. 316 BOONE AVE.
SPOKANE, WA 99201-2349

FROM: U of I ANALYTICAL LABORATORY
HOLM CENTER
UNIVERSITY OF IDAHO
MOSCOW ID 83843

Date Received: JUNE 4, 1993 Fee: $347.00 BILL File: SJN9312
Date Report Sent: OCTOBER 5, 1993

Analyst/QC: Date: 10-5-93

Group Leader: Date: 10-5-93

SAMPLE ID	LAB # SJN93-12	pH	CEC cmol(+)/Kg-	WBOM O.C. %	O.M. %	NO3-N ug/g	NH4-N ug/g	SOIL MOISTURE RETENSION 0.1 BAR	1.0 BAR	15 BAR
1-1	1524	6.4	5.5	0.71	1.21	41.7	1.3	14.61	6.62	3.30
1-2	1525	7.3	4.1	0.09	0.15	1.6	0.5	6.21	5.32	2.43
1-3	1526	7.7	---	---	---	0.8	0.4	---	---	---
1-4	1527	6.4	---	---	---	2.7	0.5	11.33	5.09	2.48
1-5	1528	6.9	---	---	---	1.1	0.4	---	---	---
2-1	1529	6.7	4.2	0.29	0.50	19.6	1.1	11.83	4.70	2.58
2-2	1530	7.9	4.1	0.05	0.09	0.9	0.5	---	---	---
2-3	1531	7.9	---	---	---	0.3	0.5	4.94	2.74	1.71
2-4	1532	7.7	---	---	---	0.2	0.4	---	---	---

WA0213

SOIL INTERPRETATIONS RECORD

MARBLE SERIES

MLRA(S): 44
REV. CW, 6-90
ALFIC XEROPSAMMENTS, MIXED, MESIC

MARBLE SERIES CONSISTS OF DEEP EXCESSIVELY DRAINED SOILS FORMED IN WINDWORKED SANDY OUTWASH ON TERRACES. ELEVATION IS 1500 TO 2500 FEET. VEGETATION IS TREES AND GRASS. MAP IS 15 TO 22 INCHES. MAAT IS 46 TO 50F; FFS IS 110 TO 150 DAYS. TYPICALLY, THESE SOILS HAVE A THIN MAT OF ORGANIC LITTER, A GRAYISH-BROWN LOAMY SAND SURFACE LAYER, 3 INCHES THICK. UNDERLYING MATERIAL IS A BROWN LOAMY SAND, 3 IN. THICK, UNDERLAIN BY LIGHT BROWNISH-GRAY AND MULTICOLORED SAND TO A DEPTH TO MORE THAN 60 INCHES. SLOPES RANGE FROM 0 TO 45 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
46-50	110-150	15-22	1500-2500	E	0-45

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-3	LS, LCOS	SM	A-1, A-2	0	0	90-100	85-100	45-70	10-20	2-5
0-3	SL	SM	A-2	0	0	95-100	90-100	60-70	20-35	5-10
3-60	LS, S, COS	SP-SM, SP, SM	A-1, A-2, A-3	0	0	90-100	80-100	30-60	0-20	0-2

DEPTH (IN.)	LIQUID LIMIT	PLAS-TICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEA-BILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-3	-	NP	1.30-1.50	6.0-20	0.06-0.08	6.1-7.3	-				
0-3	20-30	NP-5	1.15-1.35	2.0-6.0	0.11-0.13	6.1-7.3	-				
3-60	-	NP	1.40-1.60	6.0-20	0.05-0.08	6.1-7.3	-				

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-3	1-3	LOW	.20	5	2	134	MODERATE	LOW
0-3	1-3	LOW	.24	5	3	86		
3-60		LOW	.10					

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		A	LOW

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	0-15%: SEVERE-POOR FILTER 15+%: SEVERE-POOR FILTER,SLOPE
SEWAGE LAGOON AREAS	0-7%: SEVERE-SEEPAGE 7+%: SEVERE-SEEPAGE,SLOPE
SANITARY LANDFILL (TRENCH)	0-15%: SEVERE-SEEPAGE,TOO SANDY 15+%: SEVERE-SEEPAGE,SLOPE,TOO SANDY
SANITARY LANDFILL (AREA)	0-15%: SEVERE-SEEPAGE 15+%: SEVERE-SEEPAGE,SLOPE
DAILY COVER FOR LANDFILL	0-15%: POOR-SEEPAGE,TOO SANDY 15+%: POOR-SEEPAGE,TOO SANDY,SLOPE

BUILDING SITE DEVELOPMENT

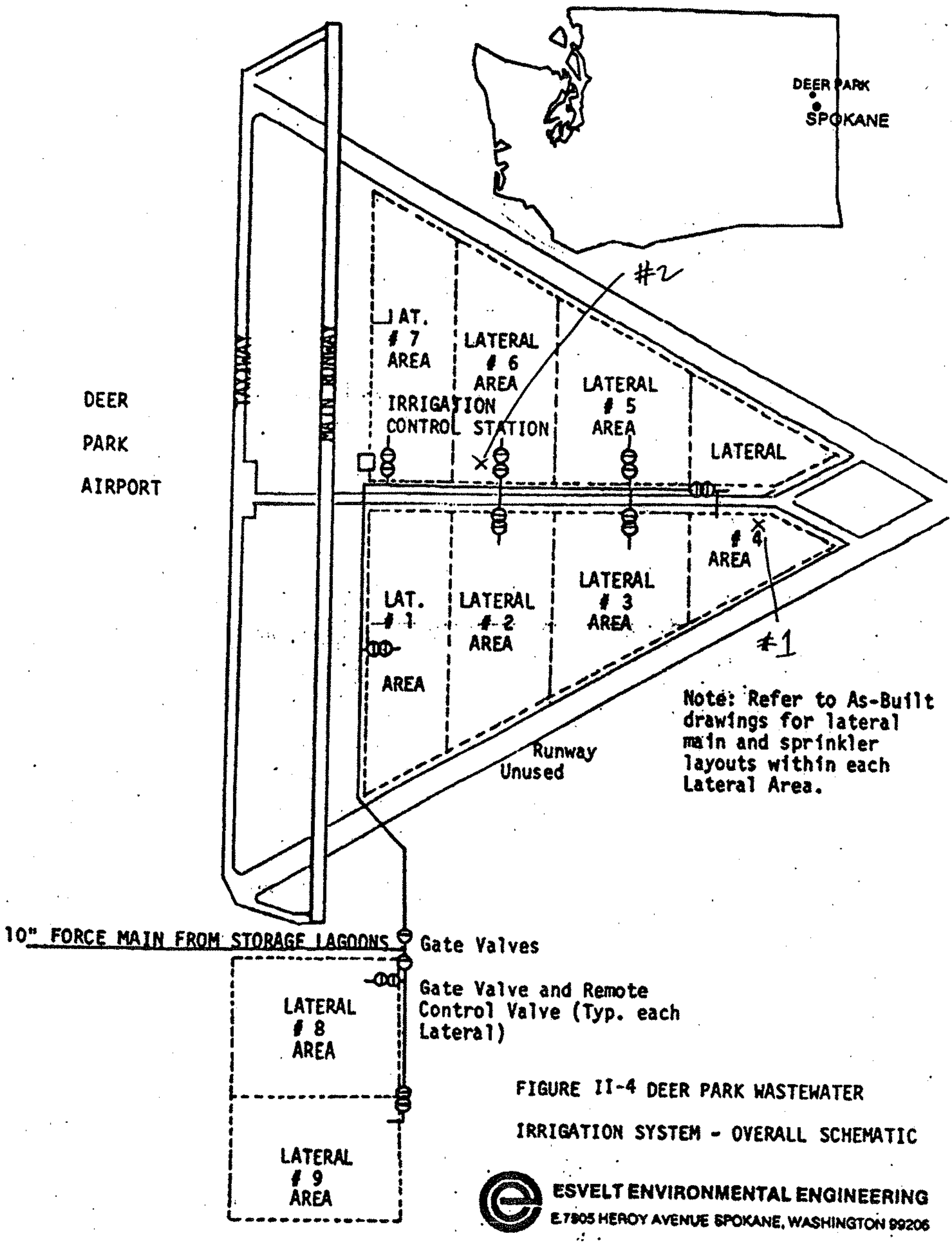
SHALLOW EXCAVATIONS	0-15%: SEVERE-CUTBANKS CAVE 15+%: SEVERE-CUTBANKS CAVE,SLOPE
DWELLINGS WITHOUT BASEMENTS	0-8%: SLIGHT 8-15%: MODERATE-SLOPE 15+%: SEVERE-SLOPE
DWELLINGS WITH BASEMENTS	0-8%: SLIGHT 8-15%: MODERATE-SLOPE 15+%: SEVERE-SLOPE
SMALL COMMERCIAL BUILDINGS	0-4%: SLIGHT 4-8%: MODERATE-SLOPE 8+%: SEVERE-SLOPE
LOCAL ROADS AND STREETS	0-8%: SLIGHT 8-15%: MODERATE-SLOPE 15+%: SEVERE-SLOPE
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	0-8% LS,SL: MODERATE-DROUGHTY 8-15% LS,SL: MODERATE-DROUGHTY,SLOPE 0-8% LCOS: MODERATE-DROUGHTY,TOO SANDY 8-15%LCOS: MODERATE-DROUGHTY,SLOPE,TOO SANDY 15+%: SEVERE-SLOPE

CONSTRUCTION MATERIAL

ROADFILL	0-15%: GOOD 15-25%: FAIR-SLOPE 25+%: POOR-SLOPE
SAND	PROBABLE
GRAVEL	IMPROBABLE-TOO SANDY
TOPSOIL	0-15%: POOR-TOO SANDY 15+%: POOR-TOO SANDY,SLOPE

WATER MANAGEMENT

POND RESERVOIR AREA	0-8%: SEVERE-SEEPAGE 8+%: SEVERE-SEEPAGE,SLOPE
EMBANKMENTS DIKES AND LEVEES	SEVERE-SEEPAGE,PIPING
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	DEEP TO WATER
IRRIGATION	0-3% SL: DROUGHTY 3+% SL: SLOPE,DROUGHTY 0-3% LS,LCOS: DROUGHTY,FAST INTAKE 3+% LS,LCOS: SLOPE,DROUGHTY,FAST INTAKE
TERRACES AND DIVERSIONS	0-8%: TOO SANDY,SOIL BLOWING 8+%: SLOPE,TOO SANDY,SOIL BLOWING
GRASSED WATERWAYS	0-8%: DROUGHTY 8+%: SLOPE,DROUGHTY



Note: Refer to As-Built drawings for lateral main and sprinkler layouts within each Lateral Area.

Figure 1. Map of Deer Park land application site at Deer Park Airport.

SOIL PARTICLE SIZE ANALYSIS

CITY OF DEER PARK WASTEWATER LAND APPLICATION STUDY

JUNE 2, 1993

-- ALL WEIGHTS IN GRAMS --

			GRAVEL (> 2 MM)			VERY COARSE SAND (1.0 -2.0 MM)			COARSE SAND (0.5 - 1.0 MM)			MEDIUM SAND (0.25 - 0.5 MM)			FINE SAND (0.10 - 0.25 MM)			VERY FINE SAND (0.05 - 0.10 MM)			SILT & CLAY (< 0.05 MM)			
SAMPLE NO.	DEPTH (IN.)	TOTAL SAMPLE	SIEVE & SAMPLE	SAMPLE	PCT.	SIEVE & SAMPLE	SAMPLE	PCT.	SIEVE & SAMPLE	SAMPLE	PCT.	SIEVE & SAMPLE	SAMPLE	PCT.	SIEVE & SAMPLE	SAMPLE	PCT.	SIEVE & SAMPLE	SAMPLE	PCT.	SIEVE & SAMPLE	SAMPLE	PCT.	TEXTURE
1-1	0-4	139.6	110.4	0.6	0.4	110.0	6.3	4.5	160.5	65.3	46.8	127.5	36.4	26.1	103.9	9.9	7.1	98.6	12.2	8.7	74.6	8.9	6.4	COARSE SAND
1-2	4-22	183.0	110.5	0.7	0.4	112.4	8.7	4.8	172.4	77.2	42.2	163.9	72.8	39.8	104.4	10.4	5.7	91.7	5.3	2.9	73.6	7.9	4.3	COARSE SAND
1-3	22-36	187.5	109.9	0.1	0.1	108.1	4.4	2.3	164.1	68.9	36.7	168.7	77.6	41.4	114.8	20.8	11.1	95.4	9.0	4.8	72.4	6.7	3.6	COARSE SAND
1-4	36-52	184.2	109.9	0.1	0.1	105.1	1.4	0.8	142.5	47.3	25.7	165.0	73.9	40.1	118.3	24.3	13.2	103.5	17.1	9.3	85.8	20.1	10.9	COARSE SAND
1-5	52-72	187.0	113.4	3.6	1.9	129.8	26.1	14.0	153.7	58.5	31.3	162.0	70.9	37.9	112.9	18.9	10.1	90.2	3.8	2.0	70.9	5.2	2.8	COARSE SAND
2-1	0-4	113.6	109.9	0.1	0.1	107.7	4.0	3.5	136.5	41.3	36.4	132.0	40.9	36.0	105.9	11.9	10.5	91.8	5.4	4.8	75.7	10.0	8.8	COARSE SAND
2-2	4-29	148.3	110.6	0.8	0.5	111.6	7.9	5.3	148.7	53.5	36.1	151.0	59.9	40.4	106.2	12.2	8.2	92.0	5.6	3.8	74.1	8.4	5.7	COARSE SAND
2-3	29-56	166.1	110.5	0.7	0.4	113.6	9.9	6.0	164.8	69.6	41.9	163.8	72.7	43.8	102.6	8.6	5.2	88.0	1.6	1.0	68.7	3.0	1.8	COARSE SAND
2-4	56-72	140.5	109.9	0.1	0.1	103.8	0.1	0.1	108.8	13.6	9.7	159.8	68.7	48.9	130.2	36.2	25.8	101.4	15.0	10.7	72.5	6.8	4.8	SAND

Appendix B. Well construction information for monitoring wells, M–2, M–5, and and water level elevations for M–5 and M–9.

West Engineering Corporation

SUBSURFACE EXPLORATION LOG

SHEET 1 OF 2

JOB NO. 3095.003.03 JOB TITLE DEER PARK SEWER
LOCATION ______ FEATURE ______ COORDINATES ______ DATE 11.9.82
DRILL MOBILE B.40 ANGLE ______ BEARING ______ REF. EL. 2189 DATUM MSL
DRILLING CONTRACTOR BUDINGER & ASSOC. DRILLER D.J. INSPECTOR M.C.A.
SAMPLE HAMMER: WT. ______ DROP ______ TYPE ______

DEPTH FEET	LITHOLOGY	SAMPLE C-CORE B-BAG CK-CHUNK R-RING	TUBE SAMPLE NO.	PENETRATION RESISTANCE BLOW/FT.	DRY DENSITY PCF	MOISTURE CONTENT, %	SOIL CLASS., (U.S.C.S.)	MATERIAL DESCRIPTION	GROUNDWATER
							SW	0-5' SAND-LT. BROWN, LOOSE, DAMP TO DRY, MEDIUM TO FINE.	
10							SW	5' SAND-LT. BROWN, LOOSE, DAMP, MEDIUM TO COARSE. APPROX. 70% MEDIUM, 20-30% COARSE. MICAEOUS, GRANITIC SAND. MOISTURE CONTENT INCREASES TO MOIST AT 10'.	
20								NO CHANGE TO 25'.	
								25' 3 GRAVEL PIECES RETURNED. 1" SUBROUNDED.	
30							SW	30' SAND-LT. BROWNISH, LOOSE, MOIST, FINE TO MEDIUM. APPROX. 40% FINE, 50% MEDIUM. POSSIBLY INCREASE IN SILT (10%) AT 35'.	
40							CL	CLAY LAYERS AT 40'. GREENISH GRAY, SLIGHTLY ORGANIC, LOW PLASTICITY. CLUMPS OBSERVED IN RETURN. 3 OR 4 BASALT GRAVEL PIECES OF 2" SIZE RETURNED.	
								WATER AT 48'-50'	
50							SP	50' SAND-LT. GRAYISH BROWN, MOD. DENSE TO LOOSE, WET, MEDIUM TO COARSE (20%), WITH VERY MINOR FINE (5%), SAME COMPOSITION AS ABOVE. NOTABLE QUARTZ PIECES-COARSE SIZE.	
									▼

OTE: THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DAT NDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

WEST ENGINEERING
CORPORATION

SUBSURFACE

SHEET 2 OF 2

EXPLORATION LOG

JOB NO. 3095·003·D3 JOB TITLE DEER PARK SEWER

LOCATION ____ FEATURE ____ COORDINATES ____ DATE 11·9·82

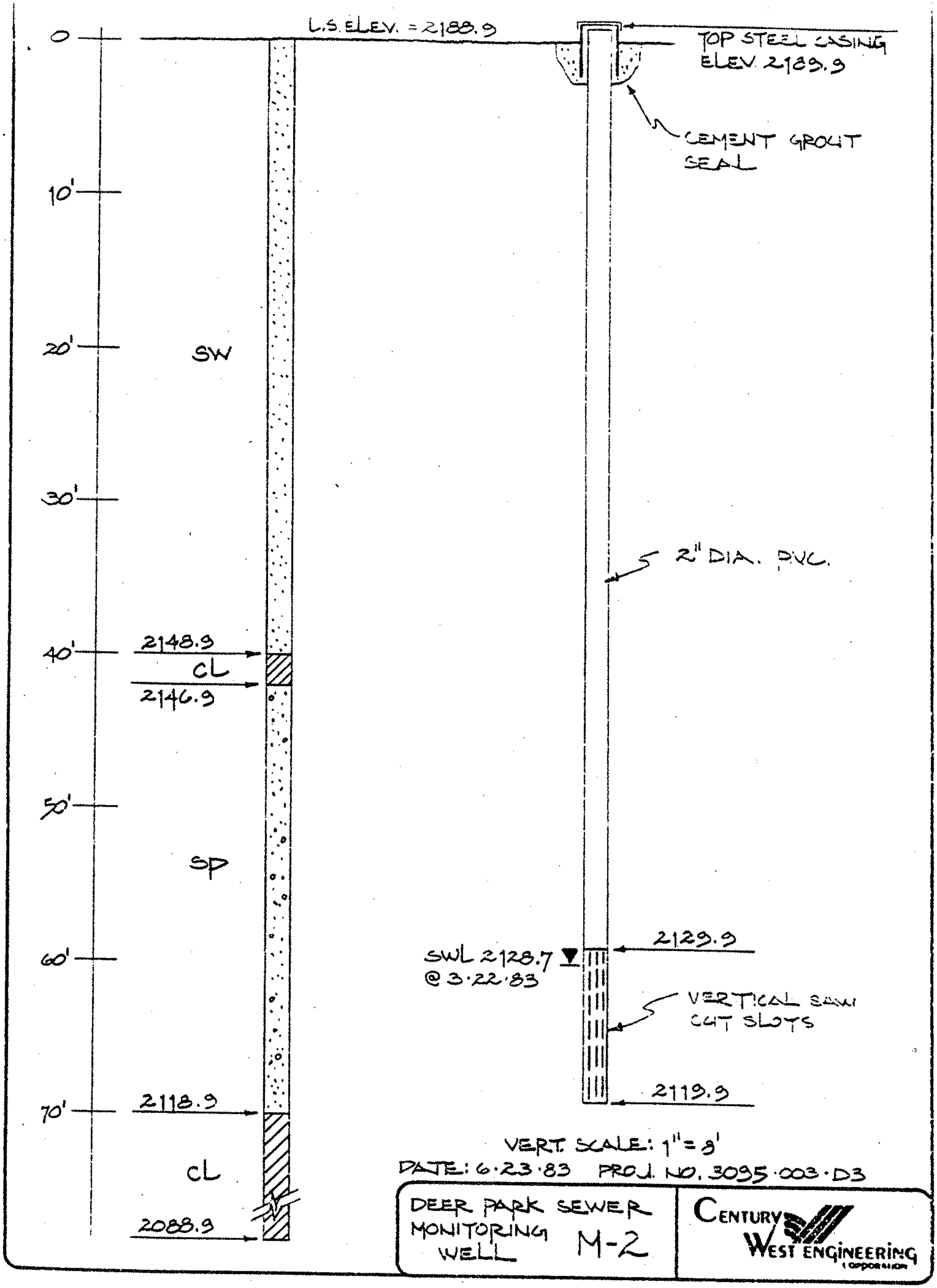
DRILL MOBILE B·40 ANGLE ____ BEARING ____ REF. EL. ____ DATUM ____

DRILLING CONTRACTOR BUDINGER & ASSOC. DRILLER D.J INSPECTOR M.L.A.

SAMPLE HAMMER: WT. ____ DROP ____ TYPE ____

DEPTH FEET	LITHOLOGY	SAMPLE C-CORE B-BAG CK-CHUNK R-RING	TUBE SAMPLE NO.	PENETRATION RESISTANCE BLOW/FT.	DRY DENSITY PCF	MOISTURE CONTENT, %	SOIL CLASS., (U.S.C.S.)	MATERIAL DESCRIPTION	GROUNDWATER
60							SP	60' SAND - LT. GRAYISH BROWN, MOD. DENSE, WET SATURATED, MEDIUM TO COARSE (30-40%) WITH LITTLE OR NO FINE SAND. MICAEOUS WITH COARSE-GRAINED SIZE QUARTZ (ANGULAR). SMALL LAYER OF GRAVELS FELT AT 63'-65'. 66'-70' - LUMPS OF RUST COLOR, PINKISH, SAND/SILT CLAY IN RETURN	
70							CL	70'-75' SAND, SILT CLAY - RUST COLOR, MOD. DENSE CLUMPS AND LARGE BALLS OF SILT WITH MED. SAND AND SLIGHTLY PLASTIC CLAY.	
								NO RETURN - DRILLING IS LIKE IN STIFF CLAY/SILT, TIGHT BUT SMOOTH.	
80									
								SAME AT 85'. MEASURED S.W.L AT 82'.	
90									
								NO RETURN TO 100'. LT. BLUISH GRAY, STIFF SILTY CLAY STUCK ON AUGERS.	
100								BOTTOM @ 100'	
								SWL 2128.7 ON 3·22·83	

OTE: THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DAT
NDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

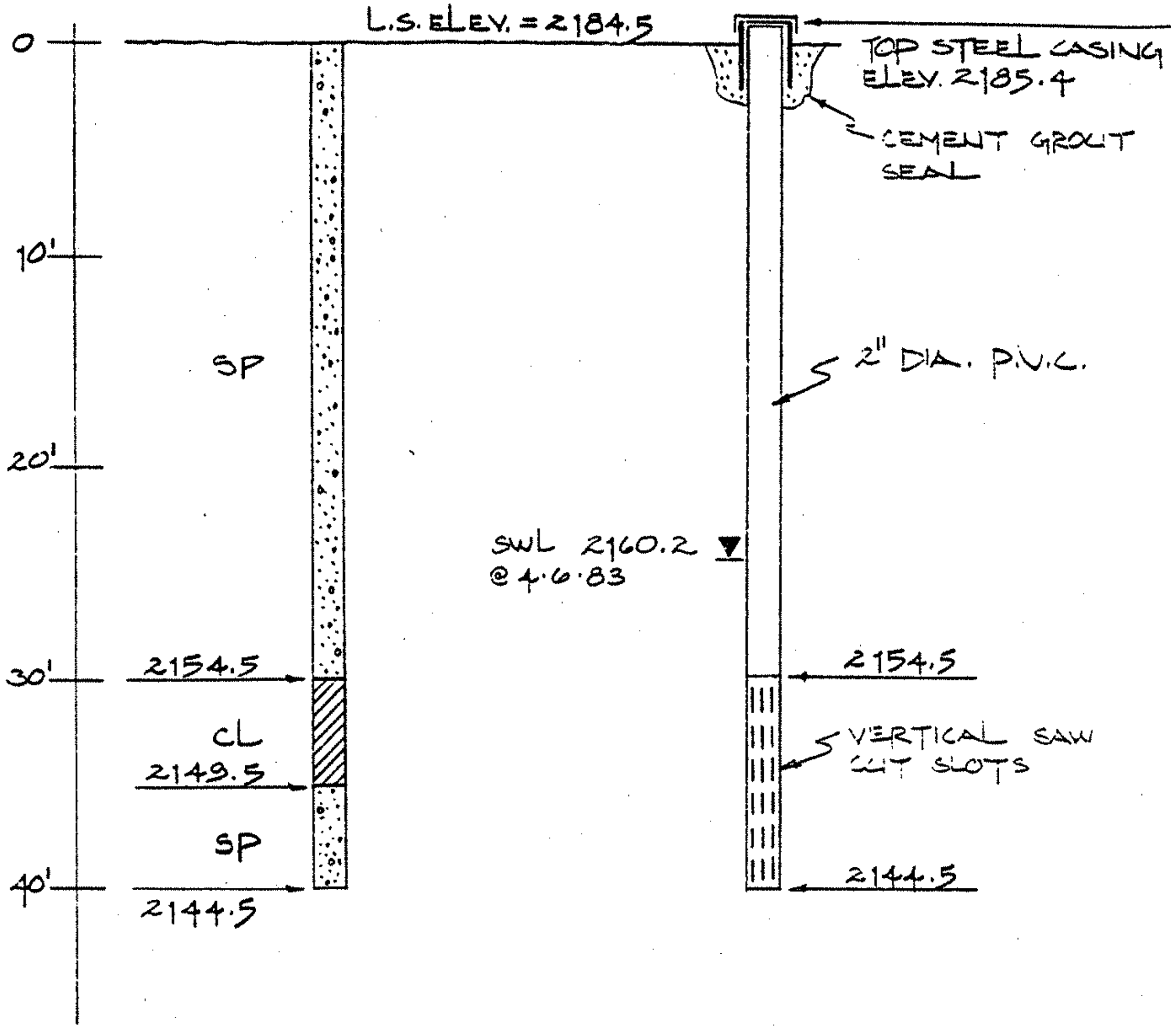


VERT. SCALE: 1" = 8'

DATE: 6·23·83 PROJ. NO. 3095·003·D3

DEER PARK SEWER MONITORING WELL M-2

CENTURY WEST ENGINEERING CORPORATION



VERT. SCALE: 1" = 8'

DATE: 6·23·83 PROJ. NO. 3095·003·D3

DEER PARK SEWER
MONITORING
WELL M-5

CENTURY WEST ENGINEERING CORPORATION

West Engineering Corporation

SUBSURFACE EXPLORATION LOG

SHEET ______ OF ______

JOB NO. 3095·003·D.3 JOB TITLE DEER PARK SEWER

LOCATION ______ FEATURE ______ COORDINATES ______ DATE 11·11·82

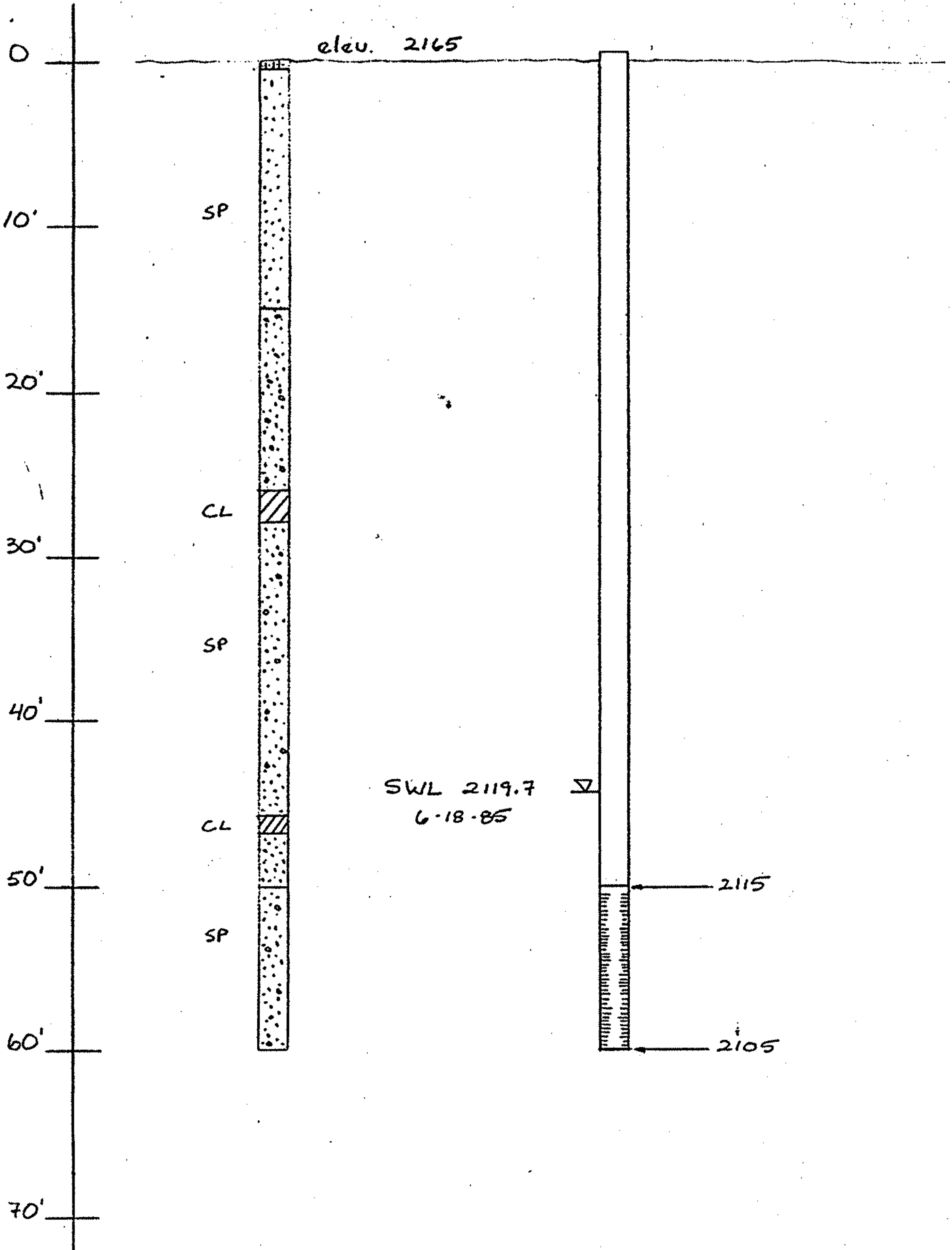
DRILL MOBILE B·40 ANGLE ______ BEARING ______ REF. EL. 2184.5 DATUM MSL

DRILLING CONTRACTOR BUDINGER & ASSOC. DRILLER D.J. INSPECTOR M.C.A.

SAMPLE HAMMER: WT. ______ DROP ______ TYPE ______

DEPTH FEET	LITHOLOGY	SAMPLE C-CORE B-BAG CK-CHUNK R-RING	TUBE SAMPLE NO.	PENETRATION RESISTANCE BLOW/FT.	DRY DENSITY PCF	MOISTURE CONTENT, %	SOIL CLASS., (U.S.C.S.)	MATERIAL DESCRIPTION	GROUNDWATER
0								0-½' SILTY SAND	
							SP	½' SAND - LT. BROWN, MOIST, LOOSE, MEDIUM (20%) TO FINE (80%). MICAEOUS GRANITIC SAND. NO SILT.	
10									
								15' NO CHANGE	
20							SP	20' SAND - LT. BROWNISH GRAY, MED. DENSE, WET, MEDIUM (30%) AND 70% FINE. SAME COMP. AS ABOVE.	▼
								25'-30' SAND - DK. GRAY, MOD. DENSE, SATURATED, FINE (80%) TO MEDIUM (10%), WITH 10% SILT. BASALT & QUARTZ SAND. NO RETURN, DESCRIPTION FROM AUGER.	
30							CL	30'-35' CLAY - DK. GRAY, SATURATED, STIFF.	
								35'-40' DRILLING EASIER - SAND.	
40							SP	40'-41' SAND - LT. GRAYISH WHITE, MOD. DENSE, FINE SAND (70%) WITH 20% MEDIUM. APPROX. 10% OR LESS SILT. DRIVE SAMPLE.	
								40' BOTTOM OF HOLE.	
50									
								S.W.L. 2160.2 ON 4·6·83	

NOTE: THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DA INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.



M-9	APPROVED m.c.a. DATE 6-25-85	CENTURY WEST ENGINEERING CORPORATION

Appendix B. (Continued)

Table 1. Water table elevations for monitoring wells M-5 and M-9 in 1993..

Well	Depth to Water (ft)			
	3/26	6/15	9/27	11/18
M-5	2157.6	2158.8	2156.8	2156.3
M-9	2111.3	2111.3	2110.5	2110.8

c:\main\deerp\grad2.wk1

Appendix C. Lysimeter Construction and Installation

Activities conducted to build and prepare equipment are described below followed by the procedures used for installation. The location of samplers are shown in Figures 4 and 5.

Pre-installation

We constructed most of the wick and barrel lysimeter parts before installing the samplers. Pre-installation activities are described below.

Capillary wick lysimeters

Each capillary wick lysimeter consisted of a bundle of three, 1/2-inch diameter woven fiberglass wicks (Pepperell Braiding Co., E. Pepperell, MA) glued to a 10-inch square plexiglass plate (Figure 6). The wicks hung down through a hole in the center of the plexiglass plate into a five-gallon HDPE rectangular carboy roughly 20 inches below. We used PVC connectors and non-metallic flexible conduit to enclose the hanging wicks between the plate and the carboy lid (about 21 inches). The wicks hung 2-3 inches below the top of the carboy preventing them from conducting water upward after the sample had been collected.

Before assembling the wick samplers, all plexiglass plates and pieces of flex conduit pipe were cleaned with Alconox© and tap water followed by an acid wash with 10% sulfuric acid. The final four rinses were with deionized water.

After threading the wick through the flexible conduit, a piece of wick about five inches long extended out of the hole in the middle of the plate. I unbraided the wick and spread the strands flat on the plate using surgical gloves. I then wove additional short pieces of fiberglass into the flattened pieces to form a spider-web configuration. This helped maximize the space on the plate covered by the wick.

I then glued the outer ends of the "spider-web" to the plate using Sikaflex adhesive. I cut off any strands hanging over the edge of the plate to prevent water from flowing off the plate.

Two 1/4-inch diameter holes were drilled in the upper part of the carboy: one for connecting the 1/4-inch diameter polypropylene sample tubing from the bottom of the carboy to the sampling station at the surface, and the other for a vent to the surface to prevent a vacuum when sampling. The sample tube was installed in two pieces and connected in the field using a compression fitting: one piece from the carboy hole to the bottom of the carboy and the other from the carboy hole to the sampling station at the surface. Another 1-1/2-inch hole was drilled in the screw-on cap for the carboy to fit the wick and flexible conduit.

The carboys were cleaned using the same procedure used for the plexiglass plates and flexible conduit described above. The three holes in each carboy and cap were covered with aluminum foil after cleaning to prevent contamination. The wick assembly was also covered in heavy-duty plastic bags fastened with rubber bands.

Barrel lysimeters

Each of the ten barrels (five at each site) consisted of a 24-inch length of steel well casing (Figure 7). Three of the barrels at each site were 8-inch diameter, and two were 16-inch. The bottom edge of the casing was bevelled for inserting into the ground. A PVC cap covered the bottom to capture percolating soil pore-water.

Polypropylene sample tubing, enclosed in flexible conduit and PVC pipe, led from the hole in the cap to the ground surface. An 8-inch long PVC pipe and threaded cap was installed to protect the sample tubing. Tubing was also connected to an air vent drilled into the lower end of the barrel to prevent a vacuum when samples were extracted.

The PVC cap and attached tubing were cleaned with Alconox© and tap water, rinsed with tap water, acid washed with 10% sulfuric acid, and rinsed four times with deionized water. The cleaned cap assemblies were sealed in heavy-duty plastic bags until installed.

Suction lysimeters

We used twelve, two-inch diameter PVC suction lysimeters with ceramic cups at the bottom and rubber stoppers at the surface (Figure 8). The lysimeters and stoppers were cleaned in Alconox© and tap water followed by four distilled water rinses. The ceramic cups were then soaked in distilled water for 3-5 days to remove any remaining mobile contaminants.

Two, 1/4-inch polypropylene tubes were installed in each suction lysimeter. The sample tubing extended to the bottom of the cup. The shorter tube extended a few inches below the rubber stopper and was used for setting the vacuum and applying pressure to discharge the sample.

Installation

We installed the wick and barrel lysimeters May 3-5, 1993. We also installed two of the twelve suction lysimeters at Field 4 at that time. We installed the remaining ten suction lysimeters on July 23, 1993. Installation procedures for each lysimeter type are described below.

Wick lysimeters

We installed 12 capillary wick lysimeters, 6 at each site. At each site, two six- to seven-foot deep trenches were excavated and shored to prevent caving, while we installed three samplers in each trench. We installed two of the wick lysimeters four feet below the surface in each trench and one lysimeter at three feet.

To install each wick lysimeter we planned to carve a slot about 20 inches into the sidewall of the trench to fit the wick/plate portion of the lysimeter and an indentation below that for the sheath and carboy portion. Following the suggestion of Thomas (1993), we tried to make the top of the cave above the "spider-web" wick area as flat and smooth as possible to allow water movement from the soil to the wick. We used a simulated assembly without a wick for sizing the hole. We used mason's trowels and screwdrivers to dig the slots. However, because the sandy soil had so little structure, caving was a major problem.

We had the most success when we first carved the outline of the cave, fit the assembly into the sidewall as well as possible and carefully laid soil from the caving sidewall on top of the wick/plate area. To prime the system, we also moistened the wick with about 0.5-1.0 L of deionized water before placing the assembly in the trench. We then carefully backfilled around the assembly, taking care to label and protect the sample tubing.

Sample tubing from all three samplers in each trench were joined at one exit. A four-inch PVC pipe and cap protected the sample tubes at the surface. We took care to protect tubing and samplers when the backhoe filled the trench. To prevent contamination of the sample tubing, we covered the ends with a short piece of gum rubber tubing folded on top of itself and fastened with a rubber band.

Barrel lysimeters

We installed ten barrel lysimeters, five at each site (Figure 8). Barrel samplers were filled with soil by slowly pushing the barrel, bevelled bottom edge first, into the ground with the bottom of the backhoe bucket. The barrels easily penetrated the coarse sand. The backhoe then extracted the barrel containing an intact soil monolith using a chain hooked to two steel tabs on the top end of the barrel. In many cases, soil fell out of the barrel when it was pulled out. We then shovelled the soil back into the barrel.

To complete the installation, we laid the barrel upside down on the ground and replaced the bottom six inches of soil with pea gravel sandwiched between two layers of filter fabric to prevent soil from moving into the pea gravel. We then epoxied the cap onto the bottom of the barrel with pre-attached sample tubing and housing.

The backhoe enlarged the original hole and placed the barrel with the soil monolith back into the ground. The barrels were then leveled on 2x4-inch cedar boards, and backfilled so that the top of the barrel sampler was about one to two inches above the ground surface.

We covered the sample and vent tubing for each barrel in four-inch diameter PVC pipe and cap that was about 8-10 inches above the ground. We covered the end of the sample tubing with a short piece of gum rubber tubing folded on top of itself and fastened with a rubber band to prevent contamination.

Suction lysimeters

We used a four-inch diameter hand auger to dig holes for the two-inch diameter suction lysimeters. Sampler depths are shown below.

Depth of sampler (feet)	No. of samplers in Field 4	No. of samplers in Field 6
3	2	2
4	3	3
6	2	0

After digging the hole, we mixed a slurry of silica flour and deionized water. We poured a small amount of slurry into the hole and then placed the sampler in the hole. We then poured the remaining slurry around the sides of the sampler to cover the ceramic cup. Finally we backfilled with soil from the hole.

Appendix D. Sampling and Analysis Procedures

The following procedures were used to estimate effluent application rate and to sample the lysimeters and effluent.

Application Rate Estimate

On three dates we placed three to six coffee cans in each field at varying distances from the sprinkler heads to serve as precipitation gages before effluent was applied. After effluent had been applied, we measured the depth of water in each can with a measuring tape to the nearest 0.1 inch. On the average, water depths in the cans were twice those estimated by the City of Deer Park (mean=2.1, S.D.=0.3, n=4)(Table D.1).

Sampling

Wick Lysimeters

To collect samples from the wick lysimeters, we attached a vacuum/pressure hand pump to the side-arm of a 1,000-ml polypropylene filtering flask. The 1/4-inch diameter exit tubing from the wick lysimeter was inserted into a rubber stopper in the top of the filtering flask. We operated the hand pump periodically to set and maintain a vacuum, causing the sample to flow into the flask.

Barrel Lysimeters

We used the same procedure to sample the barrel lysimeters as for the wick lysimeters described above.

Suction Lysimeters

A few days before effluent was to be applied, we set the suction lysimeters using a vacuum/pressure hand pump. We attached neoprene tubing on the end of the shorter tube to the vacuum pump and set the tension at 60 centibars. Before removing the vacuum, we tightened the screw fitting on the neoprene tube to hold the vacuum. The other tube exiting the sampler (sample discharge tube) was stoppered while we set the tension.

To sample after effluent had been applied, we first released the tension by unscrewing the fitting on the shorter tube. We then connected the discharge tube to a clean 1,000 ml filtering flask via a rubber stopper. After attaching the short tube to the pressure part of the pump we pushed the accumulated water out of the sampler and into the flask via the tube extending to the bottom of the ceramic cup.

Table D.1. Comparison of application rate estimates between on-site collectors and City of Deer Park.

Field 4			Field 6		
Date	On-site estimate (Inches/day)	City estimate (Inches/day)	Date	On-site estimate (Inches/day)	City estimate (Inches/day)
6/11/93	2.0	**0.8**	5/5/93	1.2	**0.52**
	1.1			1.0	
	1.9			1.0	
	1.7 Mean			0.9	
				0.8	
7/24/93	1.6	0.76		0.9	
	1.8			**1.0 Mean**	
	2.0				
	1.8 Mean		7/23/93	1.5	0.69
				1.5	
				1.0	
				1.3 Mean	

Effluent

On May 5, June 11, and October 1, we collected samples from the pump house located several miles above the sprayfield. On July 22 and 23, we collected samples directly from sprinkler heads at Field 6 using a 5-gallon bucket rinsed with distilled water and effluent.

The analytical methods used and detection limits are listed in Table D.2.

Table D.2. Analytical parameters, methods, and method detection limits for Deer Park land application study.

Parameter	Method of Analysis	Reference	Method Detection Limit
pH	Beckman pH Meter	NA	0.1 Std Unit
Specific Conductance	Std Method #2510	APHA (1989)	10 umhos/cm
Total Dissolved Solids	Std Method #209B	APHA (1989)	10 mg/L
Ammonia-N	EPA #350.1	EPA (1983)	0.01 mg/L
Nitrate+ Nitrite-N	EPA # 353.2	EPA (1983)	0.01 mg/L
Kjeldahl-N	Std Methods #4500-N org	APHA (1989)	
Chloride	Std Methods #4110B	APHA (1989)	0.1 mg/L
Total Dissolved Iron	ICP 200.7	EPA (1986)	0.005 mg/L
Total Dissolved Calcium	ICP 200.7	EPA (1986)	0.025 mg/L
Total Dissolved Magnesium	ICP 200.7	EPA (1986)	0.025 mg/L
Total Dissolved Sodium	ICP 200.7	EPA (1986)	0.025 mg/L
Total Dissolved Potassium	ICP 200.7	EPA (1986)	0.4 mg/L
Chemical Oxygen Demand	Std Method #508C	APHA (1989)	4 mg/L

EPA, 1983. Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020. Revised March 1983.

American Public Health Association, 1992. Methods for the Examination of Water and Wastewater, 18th Edition.

Appendix E. Data Analysis

Application Rates

Application rate refers to the amount of a substance (total N or TDS) applied through irrigation to an area over a period of time (e.g., lb/acre/year). Details of the process are shown below:

> Application Rate (lb/acre/day) = (Volume Applied/Acre x Effluent Concentration x Conversion Factor)/Time Applied

where

> Volume Applied (L) = Rate effluent applied (cm/hr) x Hours applied x Area $(cm^2)/(1{,}000\ cm^3/L)$
>
> Concentration Applied (mg/L) = Effluent concentration (mg/L)
>
> Time Applied (days) = Number of days or fraction of days water applied per irrigation episode
>
> Conversion Factor = 2.2×10^{-3} lb/mg

The total annual application rates for 1993 are the sums of the amounts applied for all individual applications. Application rates are estimated for Fields 4 and 6.

Treatment

The method for estimating treatment for total N and TDS is based on the following two equations:

> (1) Mass applied - Mass leached = Mass treated
> (2) % Treatment = Mass treated/Mass applied x 100

The mass applied is the total annual application rate described above (lb/acre/year). The mass leached is the sum of the estimated amounts leached following each application event.

The steps in calculating the mass leached for each application event are shown below:

1. Estimate consumptive use (CU) for the field on each day that effluent was applied as follows:

   Estimate consumptive use (CU) for alfalfa by multiplying the pan evaporation value for Spokane on the day effluent was applied (Western Climate Center, 1994) by the average pan factor for alfalfa in Spokane, 0.76 (SCS, 1990) to obtain a consumptive use estimate, i.e.,

CU = Evap (Inches) x 0.76

2. Subtract the CU from the inches applied to calculate the inches leached.

3. Calculate the leachate concentration as the mean concentration of the wick and suction samplers for the date closest to the application date. (The mean of the wick samplers and the mean of the suction samplers at the site are used to calculate the mean for the date.)

4. Multiply the volume of leachate per acre by the concentration in the leachate to obtain the mass of substance leached.

The steps to estimate the percent treatment after the amounts leached for each event are estimated are:

1. Take the sum of the masses leached for each application date in 1993 to yield the total leached for the year.

2. Subtract the total annual mass of substance leached from the mass applied to obtain the mass treated.

3. Divide the mass treated by the mass applied to obtain the percent treatment.

Projected Changes in Ground Water Nitrate-N and TDS Concentrations

I estimated the increase in ground water concentrations of nitrate and TDS due to 1993 land application by assuming that the total leachate for the year mixes with the top 10 feet of the aquifer.

The estimated increase in nitrate-N and TDS is based on the following equation:

GW Increase (mg/L) = Mass leached (mg)/(Volume of water in the top 10 feet of aquifer + Volume leached)(L)

where

Mass leached = Total mass leached below 160 acres from Treatment above (Site 4: 4.4×10^9 mg; Site 6: 5.7×10^9 mg)

Volume of water in aquifer = Void space in top 10 feet of the aquifer using porosities of 0.25 and 0.30 = 400 or 480 acre-ft respectively

Volume leached = Site 4: 276 acre-feet
Site 6: 250 acre-feet

(1 acre-foot x 1.23×10^6 = L/acre-foot)

Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio was calculated as:

$$SAR = Na/\sqrt{(Ca + Mg)/2}$$

where concentrations are in meq/L.

Appendix F. Quality Assurance

Quality Assurance Procedures

Standard laboratory quality assurance procedures were followed for all samples, including calibration standards, spikes, and laboratory duplicates. In addition, blind duplicate samples were collected on July 22 and 24, August 5 and 6, and October 1, 1993.

Rinsate blanks were also collected during each sampling event except July 22-23 and September 15, 1993. These samples consisted of laboratory deionized water pumped through the same collection system used for the lysimeters after the tubing and flask had been thoroughly rinsed with deionized water. In this way it was possible to assess the effectiveness of rinsing the sampling apparatus several times with deionized water between samplers.

Quality Assurance Results

All data were usable, although most total Kjeldahl-N (TKN) values for October 21, 1992, are qualified. All samples on that date with reported values less than five times the blank value (0.23 mg/L) are qualified with a "B" in Appendix G.

Relative Percent Difference

Relative percent difference values (RPD) were calculated for duplicate samples collected using the following formula:

$$[(C_1-C_2)/(\text{mean of } C_1 \text{ and } C_2)] \times 100$$

where C_1= Concentration of one sample
C_2= Concentration of other sample

Relative percent difference was used to measure the effects of combined field and laboratory errors on data precision. Results are shown in Table F.1.

Nitrogen (Ammonia, Nitrate + Nitrite, and TKN)

The difference between total N values in duplicate samples was moderate. The RPD range was 5-55% (Table F.1). The TKN component accounted for almost all of the variability in the total N values. Nitrate + nitrite RPD's were only 1-15%, while TKN values were 5-57%. The lowest RPD for TKN and total N was found in the effluent sample which also had about 20 times higher concentration than the lysimeter samples.

Table F.1. Relative percent difference for duplicate samples. Concentrations are in mg/L unless specified otherwise.

Site	Date	pH	Conductance (umhos/cm)	Ammonia-N	NO3+NO2 N	Total Kjeldahl-N	Total N	Chloride	TDS	COD	Sulfate	Dissolved Fe	Dissolved Ca	Dissolved Mg	Dissolved Na	Dissolved K
W4-C	08/05/93	6.8	888	0.1	43.2			53.5	617	33	22.1					
	08/05/93	6.7	893	0.8	40.4			54.7	612	31	22.4					
RPD		1.5	0.6	156	6.7			2.2	0.8	6.3	1.3					
S1	08/05/93			0.5	3.5											
	08/05/93			0.1 U	3.3											
RPD				133	5.9											
S2-A	10/01/93			0.17	0.05 U	0.72 J	0.8			25						
	10/01/93			0.04 U	0.05 U	1.3 J	1.4			38						
RPD				124		57	55			41						
B4-L1	07/24/93	7.2	332	0.119	0.154	1.2	1.4	47.2	235 E	31	12.6	0.06 B	20.6	7.32	42.8	4.24 B
	07/24/93	7.2	332	0.040	0.152	1.4	1.6	46.9	235 E	24	12.5	0.05 B	16.8	6.32	36.7	3.60 J
RPD		0	0	99	1.3	15	14	0.6	0	25	0.8	18	20	15	15	16
W6-C	08/06/93	7.0	911	0.1 U	46.2			35.9	618	38	26.7					
	08/06/93	7.1	904	0.1 U	39.9			38.0	610	39	26.5					
RPD		1.4	0.8		15			5.7	1.3	2.6	0.8					
Effluent	07/22/93	7.8	635	14.8	0.617	20	21	46.3		64						
	07/22/93	7.9	632	14.8	0.673	21	22	46.2		38						
RPD		1.3	0.5	0	8.7	4.9	5.0	0.2		51						

RPD = Relative percent difference (ratio of the difference between duplicate results divided by the mean and expresed as a percent).

B = Value less than 5 times the rinsate blank.

U = Analyte not detected above listed detection limit.

P = Analyte detected above the instrument detection limit but below the established minimum quantitation limit.

Ammonia RPD values, although higher than those for either nitrate+nitrite or TKN in the lysimeters, had little effect on the total N RPD. This is because ammonia made up only small portion of the total N in the lysimeters.

Total Dissolved Solids (TDS)

Variation between TDS replicates was very low, 0-1.3% relative percent difference (Table F.1).

Rinsate Blanks

Results for rinsate blanks are shown in Table F.2. Sample values less than five times the blank value on that date are qualified with a "B" in Appendix G. Many of the lysimeter TKN values are just below the blank-qualified level. Because that limit is very conservative, the blank values close to the blank-qualified level are used in data analyses.

Table F.2. Rinsate and transfer blank results in mg/L.

Date	pH	Conductance (umhos/cm)	Ammonia N	NO3+NO2 N	Total Kjeldahl-N	Total N	Chloride	TDS	COD	Sulfate	Total Fe	Dissolved Fe	Total Ca	Dissolved Ca	Total Mg	Dissolved Mg	Total Na	Dissolved Na	Dissolved K
Rinsate blank																			
05/06/93	7.6	1.95	0.01 U	0.01 U	0.24	0.25	0.12	83		0.26		0.005 UJ	0.07 J		0.008 J		0.048 J		
06/11/93	4.9	37	0.01 U	0.01 U	0.29	0.30	0.22 U	32	28	8.5			0.42		0.171		0.278 B		
08/05/93	4.5	13	0.1 U	0.5			0.1 U	1	10 U	2.1									
08/06/93			0.1 U	3.3					10 U										
10/01/93	9.0	1.26	0.06	0.05 U	0.22 J	0.33	0.17		5	0.5 U		0.005 U		0.043 B		0.020 B		0.078 PB	0.500
Transfer blank																			
07/24/93	7.1	1.7	0.102	0.01 U	0.23	0.34	0.1 U		10 U	0.5 U		0.005 U		0.011 J		0.001 J		0.048 J	0.400

U = Analyte not detected above listed detection limit.

J = Estimated value

B = Value less than 5 times the method blank.

P = Analyte detected above the instrument detection limit but below the established minimum quantitation limit.

Appendix G. Water quality data. Duplicates are indicated as "Dup." Concentrations are in mg/L except where noted.

Site	Date	pH	Conductance (Lab)	Ammonia N	NO3+NO2 N	Total Kjeldahl-N	Total N	Cl	TDS	COD	Sulfate	Total Fe	Dissolved Fe	Total Ca	Dissolved Ca	Total Mg	Dissolved Mg	Total Na	Dissolved Na	Dissolved K
Field 4																				
Wicks																				
W4-A	07/22/93	7.7	638	0.118	16.1	0.95 B	17.1	11.8			5.9		0.008 J		12.9		5.2		121	3.80 J
	08/05/93	7.0	875	0.2	34.7	1.9 X	36.6	38.7	616	148	10.4									
	09/15/93				24.0	1.9 X	25.9													
W4-B																				
W4-C	08/05/93	6.8	888	0.1	43.2	1.9 X	45.1	53.5	617	33	22.1									
Dup	08/05/93	6.7	893	0.8	40.4	1.9 X	42.3	54.7	612	31	22.4									
W4-D	08/05/93	7.0	686	0.8	22.0	1.9 X	23.9	46.5	438	44	9.6		0.008 J		23.4		6.53		112	5.98 J
	09/15/93				4.7	1.9 X	6.6													
	10/01/93			0.11	2.4	1.8 J	4.2			44										
W4-E																				
W4-F	05/06/93	7.6	349	0.01	7.5	2.72	10.2	11.9	308		16.9									
	07/22/93	6.9	328	0.091	10.6	2.4	13.0	13.2	233 E	110	9.3		0.006 J		7.28		2.72		58.3	2.40
	08/05/93	7.0	369	0.1	8.1	1.9 X	10.0	15.3	240	45	8.4		0.008 J		8.08		3.06		65.6	3.20
	09/15/93		380		9.2	1.9 X	11.1	24.1	267 E											
	10/01/93	6.5	418	0.11	12	1.5 J	13.5	43.4	292 E	13	8.4		0.005 U		9.24		3.46		67.2	3.30
W4-E+F	07/24/93			0.029	10.8	1.9	12.7			390										

Site	Date	pH	Conduc- tance (Lab)	Ammonia N	NO3+NO2 N	Total Kjel- dahl-N	Total N	Cl	TDS	COD	Sulfate	Total Fe	Dissolved Fe	Total Ca	Dissolved Ca	Total Mg	Dissolved Mg	Total Na	Dissolved Na	Dissolved K
Field 4																				
Suctions																				
S1	05/06/93	7.4	381	0.129	14.1	0.97 B	15.1	18.9	263		37.6		0.005	25.4		4.87		35.5		
	07/24/93	7.0	322	0.161	12.2	0.78 B	13.0	5.6	229 E	10	27.7		0.007 J		15.1		3.18		42	5.37 B
	08/05/93	7.1	196	0.5	3.5	1.0 X	4.5	5.1	144	10	15.4									
Dup	08/05/93			0.1	3.3	1.0 X	4.3													
S1-3	08/05/93	7.2	612	0.3	6.2	1.0 X	7.2	63.9	398	28	23.0									
S1-6	08/05/93	7.1	516	0.2	10.5	1.0 X	11.5	29.7	339	75	20.4									
	09/15/93				14.1	1.0 X	15.1													
	10/01/93	7.3	457	0.04	11	1.6 J	12.6	47.7	318 E	11	19.7									
S2	05/06/93			0.115	0.94	1.0 X	1.9													
	07/24/93			0.092	1.85	0.87 B	2.7			12										
S2-3	08/05/93			0.1	5.7	1.0 X	6.7	71.3		21										
S2-6	08/05/93			0.3	3.1	1.0 X	4.1	73.1		34										
	10/01/93			0.04	0.83	1.0 J	1.8	5.1		18	16.4									
S2-A	08/05/93			0.1	2.3	1.0 X	3.3	53.9		41										
	10/01/93	6.9	708	0.17	0.05	0.72 JB	0.8	127	484 E	25	14.7									
Dup	10/01/93			0.04	0.05	1.3 J	1.4			38										

Site	Date	pH	Conductance (Lab)	Ammonia N	NO3+NO2 N	Total Kjeldahl-N	Total N	Cl	TDS	COD	Sulfate	Total Fe	Dissolved Fe	Total Ca	Dissolved Ca	Total Mg	Dissolved Mg	Total Na	Dissolved Na	Dissolved K
Field 4																				
Barrels																				
B4-S1	08/05/93	6.9	369	0.700	0.2	1.6 X		46.6	265	95	21.3									
	10/01/93	6.7	749	0.04	0.05	1.2 J	1.3	175	512 E	33	45.0									
B4-S2	05/06/93	7.2	204	0.027	2.40	2.21	4.6	8.1			20.9									
	07/24/93	7.3	296	0.140	0.056	1.7	1.8	27.9	211 E	38	7.3		0.09 B		11.9		5.00		42.1	3.60 J
	08/05/93	7.1	418	0.4	0.2	1.6 X	1.8	44.7	281	44	12.1									
	10/01/93	6.8	570	0.14	0.17	1.0 JB	1.2	87.0	393 E	22	26.0									
B4-S3	05/06/93	7.1	310	0.027	3.34	2.80	6.1	25.6	369		22.6									
	07/24/93			0.104	0.030	1.6 X	1.6													
	08/05/93	6.9	561	0.1	0.2	1.6 X	1.8	87.0	353	90	25.2									
	10/01/93			0.06	0.05	1.5 J	1.6			65										
B4-L1	05/06/93	7.1	295	0.031	1.10	1.47	2.6	23.0	263		8.4		0.11	16.9		6.64		37.2		
	07/22/93	7.2	410	0.121	0.075	1.5	1.6	61.1	287 E	47	18.7		0.04 J		23.5		8.39		38.4	4.03 B
	07/24/93	7.2	332	0.119	0.154	1.2	1.4	47.2	235 E	31	12.6		0.06 B		20.6		7.32		42.8	4.24 B
Dup	07/24/93	7.2	332	0.040	0.152	1.4	1.6	46.9	235 E	24	12.5		0.05 B		16.8		6.32		36.7	3.60 J
	08/05/93	7.0	365	0.2	0.2	1.6 X	1.8	46.2	217	41	14.9									
	10/01/93	6.8	501	0.18	0.05	0.89 JB	0.9	83.5	347 E	26	24.2		0.24		25.7		9.32		45.7	4.12 P
B4-L2	05/06/93	7.3	221	0.067	1.78	2.05	3.8	5.7	374		7.0		0.10			4.5		30.1		
	08/05/93	7.0	274	0.8	2.4	1.6 X	4.0	28.1	248	107	1.4									

Site	Date	pH	Conductance (Lab)	Ammonia N	NO3+NO2 N	Total Kjeldahl-N	Total N	Cl	TDS	COD	Sulfate	Total Fe	Dissolved Fe	Total Ca	Dissolved Ca	Total Mg	Dissolved Mg	Total Na	Dissolved Na	Dissolved K
Field 6																				
Wicks																				
W6-A	09/15/93		558		1.50	1.20 X	2.7	45.3	379 E											
	10/01/93	7.3	565	0.23	2.3	1.2 J	3.5	48.0	392 E	48	20.3									
W6-B	10/01/93			0.04	11	1.20 X	12.2			25										
W6-C	07/23/93			0.163	62.8	1.20 X	64.0													
	08/06/93	7.0	911	0.1	46.2	1.20 X	47.4	35.9	618	38	26.7		0.005 J		52.7		22.7		97.5	5.94 J
Dup	08/06/93	7.1	904	0.1	39.9	1.20 X	41.1	38.0	610	39	26.5									
	09/15/93		563		7.6	1.20 X	8.8	49.1	391 E											
W6-D	05/06/93	7.4	353	0.015	5.41	1.91	7.3	3.9	445		24.3		0.08	36.6		6.47		50.5		
	06/11/93	6.9	346	0.029	6.84	1.5	8.3	4.0	270	31	9.7	0.24		6.59		2.35		64.1		
	09/15/93				15.6	1.2 X	16.8	47.2												
	10/01/93	7.3	455	0.04	2.4	1.0 JB	3.4	57.4	323 E	20	17.2									
W6-E	05/06/93	5.5	466	0.086	1.59	0.99 B	2.6	4.1	559		52.9									
	06/11/93	6.9	476	0.01	13.2	1.8	15.0	9.6	351	200	21.0	0.05		11.5		5.42		78.6		
W6-F	05/06/93	7.6	464	0.039	0.78	0.74 B	1.5	1.8	473		7.1									
	06/11/93	6.9	446	0.01	2.29	0.72 B	3.0	5.4	294	110	9.0	0.00 P		12.9		4.53		78.2		

Site	Date	pH	Conduc-tance (Lab)	Ammonia N	NO3+NO2 N	Total Kjel-dahl-N	Total N	Cl	TDS	COD	Sulfate	Total Fe	Dissolved Fe	Total Ca	Dissolved Ca	Total Mg	Dissolved Mg	Total Na	Dissolved Na	Dissolved K
Field 6																				
Suctions																				
S3	08/06/93			0.1	5.8	1.90 X	7.7			38										
	10/01/93	7.2	418	0.04	1.1	0.52 JB	1.6	49.5	300 E	10	25.0									
S4	08/06/93	7.4	693	0.1	14.7	1.90 X	16.6	45.1	465	32	32.3									
	10/01/93	7.1	497	1.8	5.8	3.5 J	9.3	51.4	349 E	22	29.2		0.011 P		15.4		4.93		65.7	7.30
S5	08/06/93	7.6	519	0.1	5.9	1.90 X	7.8	19.5	357	38	23.3									
	10/01/93	7.2	458	0.04	8.1	0.84 J	8.9	50.8	325 E	14	23.1		0.007 P							
S6	10/01/93			0.04	4.4	1.20 J	5.6			20					10.8		2.87		68.9	6.76
S7	09/15/93		730		16.0	1.90 X	17.9	54.9	495 E		15.0									
	10/01/93	7.9	569	1.6	18	3.5	21.5	60.3	394 E	30										
Barrels																				
B6-S1	07/23/93	6.9	340	0.102	0.220	1.40	1.6	39.7	181	85	18.7		0.09 B		21.9		8.9		26.9	4.32 B
	08/06/93	6.8	300	0.1	0.2	1.4 X	1.6	28.3	226 E	49	25.7									
B6-S2	05/06/93			0.033	0.83	1.07 B	1.9													
	07/23/93	7.0	456	0.022	0.032	1.4	1.4	97.2	323 E	160	22.8									
	08/06/93			0.1	0.2	1.4 X	1.6			135										
B6-S3																				
B6-L1	07/23/93	7.5	547	0.116	0.022	1.60	1.6	92.2	380 E	200	30.4									
	08/06/93			0.1	0.2	1.4 X	1.6			132										
	10/01/93			0.11	0.05	1.4 X	1.5			70										
B6-L2	07/22/93	7.1	533	0.130	0.020	1.5	1.5	69.2	274	77	13.5		0.02 J		29.9		11.0		58.4	4.56 B
	08/06/93	7.2	452	0.4	0.2	1.4 X	1.6	64.8	321 E	90	12.4									

Site	Date	pH	Conductance (Lab)	Ammonia N	NO3+NO2 N	Total Kjeldahl-N	Total N	Cl	TDS	COD	Sulfate	Total Fe	Dissolved Fe	Total Ca	Dissolved Ca	Total Mg	Dissolved Mg	Total Na	Dissolved Na	Dissolved K
Effluent	05/05/93	7.5	657	21.2	0.02	24	24	41.7	347		18.5		0.226	37.2		6.57		51.1		
	06/11/93	7.4	628	16.6	0.094	20	20	43.3	344	62	18.2	0.57		38.3		6.73		49.3		
	07/22/93	7.8	635	14.8	0.617	20	21	46.3		64	19.6									
	07/22/93	7.9	632	14.8	0.673	21	22	46.2		38	19.6									
	07/23/93	8.0	631	14.6	0.613	21	22	46.2		62	19.6		0.09 B		38.1		7.19		55.4	10.9
	10/01/93	7.4	628	5.8	8.5	11 J	20	49.1		120	22.0		0.02 P		39.8		8.24		53.2	10.7

RPD = Relative percent difference (ratio of the difference of duplicate results divided by the mean and expresed as a percent).

X = Mean TKN for that sampler type (i.e., wicks at Field 4) used for dates when TKN sample was not available.

E = Estimated as Specific conductance x 0.68.

U = Analyte not detected above listed detection limit.

J = Estimated value

B = Value less than 5 times the rinsate blank.

P = Analyte detected above the instrument detection limit but below the established minimum quantitation limit.

Appendix H. Application rate calculations for total N and TDS.

Table H.1. Effluent application rates for each day when effluent was applied in 1993.

Field 4

Date	Applied (In)	Cm applied	Vol Applied/ Acre(L/acre)	Concentration of Total N Applied (mg/L)*	N Load (mg/acre)	N Load (g/acre)	N Load (lb/acre)
05/04/93	2.5	6.4	2.57E+05	24	6.17E+06	6.17E+03	13.6
05/17/93	1.2	3.0	1.23E+05	24	2.96E+06	2.96E+03	6.5
05/24/93	1.4	3.6	1.44E+05	24	3.45E+06	3.45E+03	7.6
05/27/93	1.2	3.0	1.23E+05	24	2.96E+06	2.96E+03	6.5
06/08/93	1.6	4.1	1.64E+05	20	3.29E+06	3.29E+03	7.2
07/23/93	1.4	3.6	1.44E+05	22	3.17E+06	3.17E+03	7.0
08/04/93	1.4	3.6	1.44E+05	22	3.17E+06	3.17E+03	7.0
08/15/93	2.4	6.1	2.47E+05	22	5.43E+06	5.43E+03	11.9
08/16/93	2.4	6.1	2.47E+05	22	5.43E+06	5.43E+03	11.9
09/07/93	2.0	5.1	2.06E+05	22	4.52E+06	4.52E+03	10.0
09/14/93	2.1	5.3	2.16E+05	20	4.32E+06	4.32E+03	9.5
09/17/93	1.6	4.1	1.64E+05	20	3.29E+06	3.29E+03	7.2
10/06/93	0.7	1.8	7.20E+04	20	1.44E+06	1.44E+03	3.2
10/20/93	0.8	2.0	8.22E+04	20	1.64E+06	1.64E+03	3.6
Total							113

Field 6

Date	Applied (In)	Cm applied	Vol Applied/ Acre(L/acre)	Concentration of Total N Applied (mg/L)*	N Load (mg/acre)	N Load (g/acre)	N Load (lb/acre)
05/05/93	1	2.5	1.03E+05	24	2.47E+06	2.47E+03	5.4
05/16/93	1.2	3.0	1.23E+05	24	2.96E+06	2.96E+03	6.5
05/25/93	1.2	3.0	1.23E+05	24	2.96E+06	2.96E+03	6.5
06/26/93	1.5	3.8	1.54E+05	20	3.08E+06	3.08E+03	6.8
07/22/93	1.4	3.6	1.44E+05	22	3.17E+06	3.17E+03	7.0
08/03/93	1.6	4.1	1.64E+05	22	3.62E+06	3.62E+03	8.0
08/14/93	1.5	3.8	1.54E+05	22	3.39E+06	3.39E+03	7.5
08/16/93	3.2	8.1	3.29E+05	22	7.24E+06	7.24E+03	15.9
08/20/93	2.8	7.1	2.88E+05	22	6.33E+06	6.33E+03	13.9
08/23/93	1.6	4.1	1.64E+05	22	3.62E+06	3.62E+03	8.0
08/29/93	1.5	3.8	1.54E+05	22	3.39E+06	3.39E+03	7.5
10/08/93	0.7	1.8	7.20E+04	20	1.44E+06	1.44E+03	3.2
10/25/93	1.4	3.6	1.44E+05	20	2.88E+06	2.88E+03	6.3
Total							102

* Total N concentration in the effluent sample collected on that date or the closest date if no effluent sample were collected on that date.

Table H.2. TDS applied during 1993 for each application date.

Field 4

Date	Applied (In)	Cm Applied	Vol Applied/ Acre(L/acre)	TDS Concentration Applied (mg/L)*	TDS Load (mg/acre)	TDS Load (g/acre)	TDS Load (lb/acre)
05/04/93	2.5	6.4	2.57E+05	345	8.87E+07	8.87E+04	195
05/17/93	1.2	3.0	1.23E+05	345	4.26E+07	4.26E+04	94
05/24/93	1.4	3.6	1.44E+05	345	4.96E+07	4.96E+04	109
05/27/93	1.2	3.0	1.23E+05	345	4.26E+07	4.26E+04	94
06/08/93	1.6	4.1	1.64E+05	345	5.67E+07	5.67E+04	125
07/23/93	1.4	3.6	1.44E+05	345	4.96E+07	4.96E+04	109
08/04/93	1.4	3.6	1.44E+05	345	4.96E+07	4.96E+04	109
08/15/93	2.4	6.1	2.47E+05	345	8.51E+07	8.51E+04	187
08/16/93	2.4	6.1	2.47E+05	345	8.51E+07	8.51E+04	187
09/07/93	2.0	5.1	2.06E+05	345	7.09E+07	7.09E+04	156
09/14/93	2.1	5.3	2.16E+05	345	7.45E+07	7.45E+04	164
09/17/93	1.6	4.1	1.64E+05	345	5.67E+07	5.67E+04	125
10/06/93	0.7	1.8	7.20E+04	345	2.48E+07	2.48E+04	55
10/20/93	0.8	2.0	8.22E+04	345	2.84E+07	2.84E+04	62
Total							1,771

Field 6

Date	Applied (In)	Cm Applied	Vol Applied/ Acre(L/acre)	TDS Concentration Applied (mg/L)*	TDS Load (mg/acre)	TDS Load (g/acre)	TDS Load (lb/acre)
05/05/93	1	2.5	1.03E+05	345	3.55E+07	3.55E+04	78
05/16/93	1.2	3.0	1.23E+05	345	4.26E+07	4.26E+04	94
05/25/93	1.2	3.0	1.23E+05	345	4.26E+07	4.26E+04	94
06/26/93	1.5	3.8	1.54E+05	345	5.32E+07	5.32E+04	117
07/22/93	1.4	3.6	1.44E+05	345	4.96E+07	4.96E+04	109
08/03/93	1.6	4.1	1.64E+05	345	5.67E+07	5.67E+04	125
08/14/93	1.5	3.8	1.54E+05	345	5.32E+07	5.32E+04	117
08/16/93	3.2	8.1	3.29E+05	345	1.13E+08	1.13E+05	250
08/20/93	2.8	7.1	2.88E+05	345	9.93E+07	9.93E+04	218
08/23/93	1.6	4.1	1.64E+05	345	5.67E+07	5.67E+04	125
08/29/93	1.5	3.8	1.54E+05	345	5.32E+07	5.32E+04	117
10/08/93	0.7	1.8	7.20E+04	345	2.48E+07	2.48E+04	55
10/25/93	1.4	3.6	1.44E+05	345	4.96E+07	4.96E+04	109
Total							1,607

* TDS concentration in the effluent sample collected on that date or the closest date if no effluent samples were collected on that date.

Appendix I. 1993 Discharge Monitoring Reports for the City of Deer Park sprayfield.

Entity Name **Deer Park,** City of (STP) **DISCHARGE MONITORING REPORT** (Subunit Worksheet)

Permit No. **ST 8016** County: Spokane Month May Year 93

	Irrigation Subunits - Total Water Accumulation																			
	Subunit # 1				Subunit # 2				Subunit # 3				Subunit # 4				Subunit # 5			
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.
1																				
2																				
3																				
4													13.8	1.25	.08	1.33				
5																				
6	5.8	.52	–	.52																
7									6.9	.62	.01	.63								
8					6.9	.62	–	.62												
9									6.2	.56	–	.56								
10																				
11																				
12	7.1	.64	–	.64																
13					6.7	.60	–	.60												
14									7.1	.64	–	.64								
15													6.9	.62	.001	.621				
16																				
17																	6.6	.60	–	.60
18																				
19																				
20																				
21					6.9	.62	.08	.70												
22									7.1	.64	–	.64								
23													8.1	.73	–	.73				
24																	7.3	.66	–	.66
25																				
26																				
27													7.1	.64	–	.64				
28																				
29																				
30																				
31																				
Total	12.9	1.16	–	1.16	20.5	1.84	.08	1.93	27.3	2.46	.01	2.47	35.9	3.24	.081	3.32	13.9	1.26	–	1.26
Max.	7.1	.64	–	.64	6.9	.62	.08	.70	7.1	.64	.01	.64	13.8	1.25	.08	1.33	7.3	.66	–	.66
Avg.	6.5	.58	–	.58	6.8	.61	.08	.64	6.8	.61	.01	.62	8.9	.81	.04	.83	6.9	.63	–	.63

I CERTIFY UNDER PENALTY OF LAW, THAT THIS DOCUMENT AND ALL ATTACHMENTS WERE PREPARED UNDER MY DIRECTION OR SUPERVISION IN ACCORDANCE WITH A SYSTEM DESIGNED TO ASSURE THAT QUALIFIED PERSONNEL PROPERLY GATHERED AND EVALUATED THE INFORMATION SUBMITTED. BASED ON MY INQUIRY OF THE PERSON OR PERSONS WHO MANAGE THE SYSTEM OR THOSE PERSONS DIRECTLY RESPONSIBLE FOR GATHERING INFORMATION, THE INFORMATION SUBMITTED IS, TO THE BEST OF MY KNOWLEDGE AND BELIEF, TRUE, ACCURATE, AND COMPLETE. I AM AWARE THAT THERE ARE SIGNIFICANT PENALTIES FOR SUBMITTING FALSE INFORMATION, INCLUDING THE POSSIBILITY OF FINE AND IMPRISONMENT FOR WILLFUL VIOLATIONS.

Comments: Water accumulation was worked around DOE land application study

Signature: Mark

Title: Wastewater Operator

04/09/93 10:35 WDOE → 2765764

Entity Name: Deer Park, City of (STP) **DISCHARGE MONITORING REPORT** (Subunit Worksheet)

Permit No. ST 8016 County: Spokane Month: June Year: 93

	Irrigation Subunits - Total Water Accumulation																			
	Subunit # 1				Subunit # 2				Subunit # 3				Subunit # 4				Subunit # 5			
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.
1									9.6	87	–	.87								
2					8.0	.73	–	.73												
3																	6.9	.63	–	.63
4																				
5																				
6																				
7									6.0	.55	–	.55								
8													8.7	.79	-	.79				
9																				
10																				
11																				
12	8.2	.75	–	.75																
13																				
14																				
15	224	204	–	204													8.8	.80	–	.80
16																				
17																				
18																				
19																				
20	95	.86	–	.86													6.9	.63	–	.6
21																				
22																				
23	7.2	.66		.66																
24					7.7	.70	–	.70									7.5	.68	–	.6
25																				
26																				
27																				
28	24.1	2.19	–	2.91																
29					8.1	.74	–	.74									7.7	.70	–	.7
30																				
31																				
Total	71.9	6.50	–	6.50	23.80	2.17	–	2.17	15.60	1.42	–	1.42	8.7	.79	–	.79	37.80	3.44	–	3.
Max.	24.1	2.19	–	2.19	8.1	.74	–	.74	9.6	.87	–	.87	8.7	.79	–	.79	8.8	.80	–	.8
Avg.	14.2	1.30	–	1.30	7.93	.72	–	.72	7.8	.71	–	.71	8.7	.79	–	.79	7.56	.69	–	.6

I CERTIFY UNDER PENALTY OF LAW, THAT THIS DOCUMENT AND ALL ATTACHMENTS WERE PREPARED UNDER MY DIRECTION OR SUPERVISION IN ACCORDANCE WITH A SYSTEM DESIGNED TO ASSURE THAT QUALIFIED PERSONNEL PROPERLY GATHERED AND EVALUATED THE INFORMATION SUBMITTED. BASED ON MY INQUIRY OF THE PERSON OR PERSONS WHO MANAGE THE SYSTEM OR THOSE PERS DIRECTLY RESPONSIBLE FOR GATHERING INFORMATION, THE INFORMATION SUBMITTED IS, TO THE BEST OF MY KNOWLEDGE AND BELIEF, TRUE, ACCURATE, AND COMPLETE. I AM AWARE THAT THE ARE SIGNIFICANT PENALTIES FOR SUBMITTING FALSE INFORMATION, INCLUDING THE POSSIBILITY OF FINE AND IMPRISONMENT FOR KNOWING VIOLATIONS.

Comments:

Signature: Mark [illegible]

Title: Operator I

Phone No.

June 93 (cont)

Deer Park

SUBUNIT WORKSHEET (continued from page 1)

Irrigation Subunits - Total Water Accumulation

	Subunit # 6				Subunit # 7				Subunit # 8				Subunit # 9							
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water				
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily				
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.				
1																				
2																				
3																				
4					7.3	.66	—	.66												
5									7.5	.68	—	.68								
6													7.8	.71	—	.71				
7																				
8																				
9					9.9	.90	—	.90												
10									7.1	.65	—	.65								
11													9.4	.86	—	.86				
12																				
13									8.1	.74	—	.74								
14					8.2	.75	-	.75												
15																				
16																				
17					8.0	.73	—	.73												
18									12.9	1.17	—	1.17								
19													5.3	.48	-	.48				
20																				
21																				
22					8.3	.76	-	.76												
23																				
24																				
25																				
26	8.5	.77	—	.77																
27					7.2	.66	-	.66												
28																				
29																				
30																				
31																				
Total	8.5	.77	—	.77	46.9	4.46	-	4.46	35.60	3.14	—	3.14	22.50	2.05	-	2.05				
Max.	8.6	.77	—	.77	9.9	.90	—	.90	12.9	1.17	—	1.17	9.4	.86	—	.86				
Avg.	8.5	.72	—	.72	8.15	.74	—	.74	8.90	.81	—	.81	7.50	.68	—	.68				

↑

Entity Name: Deer Park, City of (STP) **DISCHARGE MONITORING REPORT** (Subunit Worksheet)

Permit No. ST 8016 County: Spokane Month July Year 93

Irrigation Subunits - Total Water Accumulation

	Subunit # 1				Subunit # 2				Subunit # 3				Subunit # 4				Subunit # 5			
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.
1																				
2					7.3	.66	.01	.67												
3																				
4																				
5																				
6					7.9	.72	.2	.94												
7																	7.7	.70	–	.70
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				
16																				
17																				
18																				
19																				
20					7.9	.72	.3	.75												
21									7.8	.71	–	.71								
22																				
23													8.4	.76	–	.76				
24																				
25																				
26													8.0	.73	–	.73				
27	7.9	.72	–	.72																
28					8.3	.76	–	.76												
29									7	64	–	.64								
30													7.8	.71	–	.71				
31																				
Total								3.12												
Max.																				
Avg.																				

I CERTIFY UNDER PENALTY OF LAW, THAT THIS DOCUMENT AND ALL ATTACHMENTS WERE PREPARED UNDER MY DIRECTION OR SUPERVISION IN ACCORDANCE WITH A SYSTEM DESIGNED TO ASSURE THAT QUALIFIED PERSONNEL PROPERLY GATHERED AND EVALUATED THE INFORMATION SUBMITTED. BASED ON MY INQUIRY OF THE PERSON OR PERSONS WHO MANAGE THE SYSTEM OR THOSE PERSONS DIRECTLY RESPONSIBLE FOR GATHERING INFORMATION, THE INFORMATION SUBMITTED IS, TO THE BEST OF MY KNOWLEDGE AND BELIEF, TRUE, ACCURATE, AND COMPLETE. I AM AWARE THAT THERE ARE SIGNIFICANT PENALTIES FOR SUBMITTING FALSE INFORMATION, INCLUDING THE POSSIBILITY OF FINE AND IMPRISONMENT FOR WILLFUL VIOLATIONS.

Comments: ______

Signature: Mark Lewis

Title: Wastewater Operator I

Phone No

July 93

Entity Name: Deer Park, City of [illegible]

SUBUNIT WORKSHEET (continued from page 1)

	Irrigation Subunits = Total Water Accumulation																			
	Subunit # 6				Subunit # 7				Subunit # 8				Subunit # 9							
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water				
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily				
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.				
1					7.6	.69	–	.69												
2																				
3																				
4																				
5																				
6																				
7																				
8					9.7	.88	–	.88												
9																				
10																				
11																				
12																				
13																				
14																				
15																				
16																				
17																				
18																				
19																				
20																				
21																				
22	7.6	.69	–	.69																
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				
31																				
Total																				
Max.																				
Avg.																				

Entity Name **Deer Park,** City of (STP) **DISCHARGE MONITORING REPORT** (Subunit Worksheet)

Permit No. **ST 8016** County: Spokane Month august Year 93

	Irrigation Subunits - Total Water Accumulation																			
	Subunit # 1				Subunit # 2				Subunit # 3				Subunit # 4				Subunit # 5			
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.
1																				
2									9.3	.84	–	.84								
3																				
4													7.9	.71	–	.71				
5																				
6																				
7																				
8																				
9																				
10																				
11																	9.6	.87	–	.87
12									7.6	.69	–	.69								
13																				
14																				
15													13.4	1.21	–	1.21				
16																	7.5	.68	–	.68
17																				
18																				
19													13	1.18	–	1.18	13.6	1.23	–	1.23
20																				
21																				
22																	7.5	.68	–	.68
23																				
24					8.6	.78	–	.78												
25					9.5	.86	–	.86									7.6	.69	–	.69
26					19	1.72	–	1.72												
27					16	1.45	–	1.45												
28																				
29																				
30																				
31																	9.9	.90	–	.90
Total					53.1	4.81	–	4.81	16.9	1.53	–	1.53	34.3	3.1	–	3.1	55.7	5.05	–	5.05
Max.					19	1.72	–	1.72	9.3	.84	–	.84	13.4	1.21	–	1.21	13.6	1.23	–	1.23
Avg.					13.2	1.20	–	1.20	8.4	.76	–	.76	11.4	1.03	–	1.03	9.28	1.01	–	1.01

I CERTIFY UNDER PENALTY OF LAW, THAT THIS DOCUMENT AND ALL ATTACHMENTS WERE PREPARED UNDER MY DIRECTION OR SUPERVISION IN ACCORDANCE WITH A SYSTEM DESIGNED TO ASSURE THAT QUALIFIED PERSONNEL PROPERLY GATHERED AND EVALUATED THE INFORMATION SUBMITTED. BASED ON MY INQUIRY OF THE PERSON OR PERSONS WHO MANAGE THE SYSTEM OR THOSE PERSONS DIRECTLY RESPONSIBLE FOR GATHERING INFORMATION, THE INFORMATION SUBMITTED IS, TO THE BEST OF MY KNOWLEDGE AND BELIEF, TRUE, ACCURATE, AND COMPLETE. I AM AWARE THAT THERE ARE SIGNIFICANT PENALTIES FOR SUBMITTING FALSE INFORMATION, INCLUDING THE POSSIBILITY OF FINE AND IMPRISONMENT FOR WILLFUL VIOLATIONS.

Comments: ____________________

Signature: Mark Lewis

Title: Wastewater Operator I

Aug 93 (cont)

Brdy Name: Deer Park. Cty. of (SJD)

SUBUNIT WORKSHEET (continued from page 1)

	Irrigation Subunits - Total Water Accumulation																			
	Subunit # 6				Subunit # 7				Subunit # 8				Subunit # 9							
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water				
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily				
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.				
1																				
2																				
3	9.0	.81	—	.81																
4																				
5									7.5	.68	—	.68								
6									7.3	.66	—	.66								
7													6.7	.60	—	.60				
8													7.5	.68	—	.68				
9									7.5	.68	—	.68								
10													8.2	.74	—	.74				
11																				
12																				
13					7.7	.70	—	.70												
14	8.2	.74	—	.74																
15																				
16	18	1.63	—	1.63																
17					9	.81	—	.81												
18									13	1.18	—	1.18	8.5	.77	—	.77				
19																				
20	15.3	1.39	—	1.39	223	202	—	202												
21									8.4	.76	—	.76	5.9	.53	—	.53				
22					16.9	1.53	—	1.53					7.1	.64	—	.64				
23	8.5	.77	—	.77																
24													13.3	121	—	1.21				
25																				
26																				
27									8	.72	—	.72								
28					222	202	—	202												
29	8.3	.75	—	.75																
30													7.6	.69	—	.69				
31																				
Total	67.3	6.09	—	6.09	78.1	7.08	—	7.08	51.7	4.68	—	4.68	64.8	5.86	—	5.86				
Max.	15.3	1.63	—	1.63	22.2	2.02	—	2.02	13	1.18	—	1.18	13.3	1.21	—	1.21				
Avg.	11.2	1.01	—	1.01	15.6	1.41	—	1.41	8.61	.78	—	.78	8.1	.73	—	.73				

Entity Name **Deer Park,** City of (STP) **DISCHARGE MONITORING REPORT** (Subunit Worksheet)

Permit No. **ST 8016** County: **Spokane** Month Sept Year 93

Irrigation Subunits - Total Water Accumulation

	Subunit # 1				Subunit # 2				Subunit # 3				Subunit # 4				Subunit # 5			
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.
1																				
2																				
3																				
4																				
5																				
6																				
7									5.1	.46	–	.46	10.5	.95	–	.95				
8																	10.4	.95	–	.95
9									10.5	.95	–	.95								
10					8.7	.79	–	.79												
11																				
12	7.1	.65	–	.65																
13																				
14													11.8	1.07	-	1.07				
15																	9.6	.87	–	.87
16									10.5	.95	-	.95								
17													9.0	.82	–	.82				
18																				
19																				
20																				
21																				
22																				
23									8.3	.75	–	.75								
24	8.8	.80	–	.80																
25																				
26																				
27																				
28																				
29																				
30																				
31																				
Total	15.9	1.45	–	1.45	8.7	.79	–	.79	34.4	3.11	--	3.11	31.3	2.84	–	2.84	20.0	1.82	–	1.82
Max.	8.8	.80	–	.80	–	–	–	-	10.5	.95	–	.95	11.8	1.07	-	1.07	10.4	.95	--	.95
Avg.	7.95	.73	–	.73	8.7	.79	–	.79	8.6	.78	–	.78	10.4	.95	–	.95	10.0	.91	–	.91

I CERTIFY UNDER PENALTY OF LAW, THAT THIS DOCUMENT AND ALL ATTACHMENTS WERE PREPARED UNDER MY DIRECTION OR SUPERVISION IN ACCORDANCE WITH A SYSTEM DESIGNED TO ASSURE THAT QUALIFIED PERSONNEL PROPERLY GATHERED AND EVALUATED THE INFORMATION SUBMITTED. BASED ON MY INQUIRY OF THE PERSON OR PERSONS WHO MANAGE THE SYSTEM OR THOSE PERSONS DIRECTLY RESPONSIBLE FOR GATHERING INFORMATION, THE INFORMATION SUBMITTED IS, TO THE BEST OF MY KNOWLEDGE AND BELIEF, TRUE, ACCURATE, AND COMPLETE. I AM AWARE THAT THERE ARE SIGNIFICANT PENALTIES FOR SUBMITTING FALSE INFORMATION, INCLUDING THE POSSIBILITY OF FINE AND IMPRISONMENT FOR WILLFUL VIOLATIONS.

Comments: ______________________

Signature: Mark Zavaria

Title: Wastewater Operator I

Phone No.

Sept 93 (cont)

ity Name: **Deer Park.** City of Deer Park

SUBUNIT WORKSHEET (continued from page 1)

	Irrigation Subunits - Total Water Accumulation																			
	Subunit # 6				Subunit # 7				Subunit # 8				Subunit # 9							
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water				
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily				
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.				
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13					14.3	1.30	-	1.30												
14																				
15																				
16																				
17																				
18					8.0	.73	-	.73												
19																				
20																				
21																				
22																				
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				
31																				
Total					22.3	2.03	-	2.30												
Max.					14.3	1.30	-	1.30												
Avg.					11.1	1.0	-	1.0												

Entity Name: **Deer Park,** City of (STP)

DISCHARGE MONITORING REPORT (Subunit Worksheet)

Permit No. **ST 8016** County: **Spokane** Month *Oct* Year *1993*

Irrigation Subunits - Total Water Accumulation

	Subunit # 1				Subunit # 2				Subunit # 3				Subunit # 4				Subunit # 5			
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.
1	5.0	.46	—	.46																
2																				
3																				
4					4.3	.39	—	.39												
5									3.8	.35	—	.35								
6													3.9	.35	—	.35	4.2	.38	—	.38
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				
16																				
17																				
18																				
19																				
20													4.1	.37	—	.37				
21																	5.3	.48	—	.48
22																				
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				
31																				
Total	5.0	.46	—	.46	4.3	.39	—	.39	3.8	.35	—	.35	8.0	.72	—	.72	9.5	.86	—	.86
Max.	5.0	.46	—	.46	4.3	.39	—	.39	3.8	.35	—	.35	4.1	.37	—	.37	5.3	.48	—	.48
Avg.	5.0	.46	—	.46	4.3	.39	—	.39	3.8	.35	—	.35	4.0	.36		.36	4.7	.43	—	.43

I CERTIFY UNDER PENALTY OF LAW, THAT THIS DOCUMENT AND ALL ATTACHMENTS WERE PREPARED UNDER MY DIRECTION OR SUPERVISION IN ACCORDANCE WITH A SYSTEM DESIGNED TO ASSURE THAT QUALIFIED PERSONNEL PROPERLY GATHERED AND EVALUATED THE INFORMATION SUBMITTED. BASED ON MY INQUIRY OF THE PERSON OR PERSONS WHO MANAGE THE SYSTEM OR THOSE PERSONS DIRECTLY RESPONSIBLE FOR GATHERING INFORMATION, THE INFORMATION SUBMITTED IS, TO THE BEST OF MY KNOWLEDGE AND BELIEF, TRUE, ACCURATE, AND COMPLETE. I AM AWARE THAT THERE ARE SIGNIFICANT PENALTIES FOR SUBMITTING FALSE INFORMATION, INCLUDING THE POSSIBILITY OF FINE AND IMPRISONMENT FOR WILLFUL VIOLATIONS.

Comments: *End of Seasonal Irrigation.*

Signature: *Mark Lewis*

Title: *Wastewater Operator I*

Phone No. *(509) 276-8802*

Entity Name: Deer Park, City of (STP) **SUBUNIT WORKSHEET (continued from page 1)**

	Irrigation Subunits - Total Water Accumulation																			
	Subunit # 6				Subunit # 7				Subunit # 8				Subunit # 9							
	Appl. Time	Waste water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste Water	Precip.	Total Water	Appl. Time	Waste water	Precip.	Total Water				
Freq.	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily				
Date	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.	Hrs.	In.	In.	In.				
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8	3.9	.35	–	35	4.9	.45	–	.45												
9																				
10																				
11									4.1	.37	–	.37								
12																				
13																				
14																				
15																				
16																				
17																				
18																				
19													4.0	.36	–	.36				
20																				
21																				
22																				
23																				
24																				
25	7.6	.69	–	.69																
26																				
27																				
28																				
29																				
30																				
31																				
Total	11.5	1.04	–	1.04	4.9	.45	–	.45	4.1	.37	–	.37	4.0	.36	–	.36				
Max.	7.6	.69	–	.69	4.9	.45	–	.45	4.1	.37	–	.37	4.0	.36	–	.36				
Avg.	5.7	.52	–	.52	4.9	.45	–	.45	4.1	.37	–	.37	4.0	.36	–	.36				

Appendix J. Total N and TDS percent treatment.

Table J.1. Annual percent treatment estimates for total N.

Field	Total N Applied (lb/acre/yr)*	Total N Leached (lb/acre/yr)**	Total N Treated (lb/acre/yr)^	% Treatement^^
	(1)	(2)	(3)	(4)
4	113	61	52	46
6	103	77	24	23

* See Appendix I for details.

** See Table K.3 for details.

^ (3)=(1)-(2)

^^ (4)=(3)/(1) x 100

Table J.2. Annual percent treatment estimates for TDS.

Field	TDS Applied (lb/acre/yr)*	TDS Leached (lb/acre/yr)**	TDS Treated (lb/acre/yr)^	% Treatement^^
	(1)	(2)	(3)	(4)
4	1,770	1,460	310	18
6	1,600	1,823	-223	-14

* See Appendix I for details.

** See Table K.4 for details.

^ (3)=(1)-(2)

^^ (4)=(3)/(1) x 100

Table J.3. Estimates of total N mass moving below the root zone for each application date at Fields 4 and 6.

Field 4

Date	Amount Applied (In) (1)	ET for day of application (In) (2)	Consumptive Use (In)* (3)	Leached (In)** (4)	Leached (cm) (5)	Leached (L/acre) *** (6)	Leachate Total N (mg/L)^ (7)	N load (g/acre) ^^ (8)	N load (lb/acre) ^^^ (9)
05/04/93	2.5	0.10	0.08	2.4	6.2	2.5E+05	9.5	2E+03	5.2
05/17/93	1.2	0.32	0.24	1.0	2.4	9.8E+04	9.5	9E+02	2.1
05/24/93	1.4	0.41	0.31	1.1	2.8	1.1E+05	9.5	1E+03	2.3
05/27/93	1.2	0.15	0.11	1.1	2.8	1.1E+05	9.5	1E+03	2.3
06/08/93	1.6	0.30	0.23	1.4	3.5	1.4E+05	9.5	1E+03	2.9
07/23/93	1.4	0.17	0.13	1.3	3.2	1.3E+05	11.6	2E+03	3.3
08/04/93	1.4	0.35	0.27	1.1	2.9	1.2E+05	17.7	2E+03	4.5
08/15/93	2.4	0.17	0.13	2.3	5.8	2.3E+05	17.7	4E+03	9.1
08/16/93	2.4	0.10	0.08	2.3	5.9	2.4E+05	17.7	4E+03	9.3
09/07/93	2.0	0.28	0.21	1.8	4.5	1.8E+05	14.8	3E+03	6.0
09/14/93	2.1	0.08	0.06	2.0	5.2	2.1E+05	14.8	3E+03	6.8
09/17/93	1.6	0.17	0.13	1.5	3.7	1.5E+05	14.8	2E+03	4.9
10/06/93	0.7	0	0	0.7	1.8	7.2E+04	7.1	5E+02	1.1
10/20/93	0.8	0	0	0.8	2.0	8.2E+04	7.1	6E+02	1.3
Total				20.7					61.3

Field 6

Date	Amount Applied (In) (1)	ET for day of application (In) (2)	Consumptive Use (In)* (3)	Leached (In)** (4)	Leached (cm) (5)	Leached (L/acre) *** (6)	Leachate Total N (mg/L)^ (7)	N load (g/acre) ^^ (8)	N load (lb/acre) ^^^ (9)
05/05/93	1	0.15	0.11	0.9	2.3	9.1E+04	3.9	4E+02	0.8
05/16/93	1.2	0.38	0.29	0.9	2.3	9.4E+04	3.9	4E+02	0.8
05/25/93	1.2	0.33	0.25	0.9	2.4	9.8E+04	3.9	4E+02	0.8
06/26/93	1.5	0.48	0.36	1.1	2.9	1.2E+05	8.8	1E+03	2.3
07/22/93	1.4	0.02	0.02	1.4	3.5	1.4E+05	27.6	4E+03	8.6
08/03/93	1.6	0.43	0.33	1.3	3.2	1.3E+05	27.6	4E+03	7.9
08/14/93	1.5	0.22	0.17	1.3	3.4	1.4E+05	27.6	4E+03	8.3
08/16/93	3.2	0.10	0.08	3.1	7.9	3.2E+05	27.6	9E+03	19.5
08/20/93	2.8	0.28	0.21	2.6	6.6	2.7E+05	20	5E+03	11.7
08/23/93	1.6	0.51	0.39	1.2	3.1	1.2E+05	20	2E+03	5.5
08/29/93	1.5	0.15	0.11	1.4	3.5	1.4E+05	20	3E+03	6.3
10/08/93	0.7	0	0	0.7	1.8	7.2E+04	8.3	6E+02	1.3
10/25/93	1.4	0	0	1.4	3.6	1.4E+05	8.3	1E+03	2.6
Total				18.3					76.5

* CU= (Pan Evap on the day of application) x 0.76 for alfalfa.

** Leached = (In applied) - (In CU)

*** L/acre= (cm leached) x (4.047x107 cm2/acre)/(1,000 cm3/L)

^ Mean concentration of suction and wick lysimeters on the nearest sampling date

^^ N load (g/acre) = (6) x (7) mg/1,000 g/mg

^^^ N load (lb/acre) = (8) g x 0.0022 lb/g

Table J.4. Estimates of the TDS mass moving below the root zone for each application date at Fields 4 and 6.

Field 4

Date	Amount Applied (In) (1)	ET for day of application (In) (2)	Consumptive Use (In)* (3)	Leached (In)** (4)	Leached (cm) (5)	Leached (L/acre) *** (6)	Leachate TDS (mg/L)^ (7)	TDS load (g/acre) ^^ (8)	TDS load (lb/acre) ^^^ (9)
05/04/93	2.5	0.10	0.076	2.4	6.2	2.5E+05	286	7E+04	157
05/17/93	1.2	0.32	0.24	1.0	2.4	9.8E+04	286	3E+04	62
05/24/93	1.4	0.41	0.31	1.1	2.8	1.1E+05	286	3E+04	70
05/27/93	1.2	0.15	0.11	1.1	2.8	1.1E+05	286	3E+04	70
06/08/93	1.6	0.30	0.23	1.4	3.5	1.4E+05	286	4E+04	89
07/23/93	1.4	0.17	0.13	1.3	3.2	1.3E+05	282	4E+04	81
08/04/93	1.4	0.35	0.27	1.1	2.9	1.2E+05	386	4E+04	99
08/15/93	2.4	0.17	0.13	2.3	5.8	2.3E+05	386	9E+04	198
08/16/93	2.4	0.10	0.08	2.3	5.9	2.4E+05	386	9E+04	203
09/07/93	2.0	0.28	0.21	1.8	4.5	1.8E+05	267	5E+04	108
09/14/93	2.1	0.08	0.06	2.0	5.2	2.1E+05	267	6E+04	123
09/17/93	1.6	0.17	0.13	1.5	3.7	1.5E+05	267	4E+04	89
10/06/93	0.7	0	0	0.7	1.8	7.2E+04	315	2E+04	50
10/20/93	0.8	0	0	0.8	2.0	8.2E+04	315	3E+04	57
Total				20.7					1,456

Field 6

Date	Amount Applied (In) (1)	ET for day of application (In) (2)	Consumptive Use (In)* (3)	Leached (In)** (4)	Leached (cm) (5)	Leached (L/acre) *** (6)	Leachate TDS (mg/L)^ (7)	TDS load (g/acre) ^^ (8)	TDS load (lb/acre) ^^^ (9)
05/05/93	1.0	0.15	0.11	0.9	2.3	9.1E+04	492	4E+04	99
05/16/93	1.2	0.38	0.29	0.9	2.3	9.4E+04	492	5E+04	101
05/25/93	1.2	0.33	0.25	0.9	2.4	9.8E+04	305	3E+04	65
06/26/93	1.5	0.48	0.36	1.1	2.9	1.2E+05	305	4E+04	78
07/22/93	1.4	0.02	0.02	1.4	3.5	1.4E+05	305	4E+04	96
08/03/93	1.6	0.43	0.33	1.3	3.2	1.3E+05	512	7E+04	147
08/14/93	1.5	0.22	0.17	1.3	3.4	1.4E+05	512	7E+04	154
08/16/93	3.2	0.10	0.08	3.1	7.9	3.2E+05	512	2E+05	362
08/20/93	2.8	0.28	0.21	2.6	6.6	2.7E+05	476	1E+05	279
08/23/93	1.6	0.51	0.39	1.2	3.1	1.2E+05	476	6E+04	131
08/29/93	1.5	0.15	0.11	1.4	3.5	1.4E+05	476	7E+04	149
10/08/93	0.7	0	0	0.7	1.8	7.2E+04	342	2E+04	54
10/25/93	1.4	0	0	1.4	3.6	1.4E+05	342	5E+04	108
Total				18.3					1,823

* CU= (Pan Evap on the day of application) x 0.76 for alfalfa

** Leached = (In applied) - (In CU)

*** L/acre= (cm leached) x (4.047x107 cm2/acre)/(1,000 cm3/L)

^ Mean concentration of suctions and wicks on nearest date

^^ TDS load (g/acre) = (6) x (7) mg/1,000 g/mg

^^^ TDS load (lb/acre) = (8) g x 0.0022 lb/g

Appendix K. Estimated increases in ground water nitrate–N and TDS concentrations resulting from 1993 land applicati

Table K.1. Estimated increases in ground water nitrate–N concentrations.

Field No.	Volume leached (acre–ft/yr) (1)	Volume of voids in the top 10 feet of aquifer (acre–ft) (2)	Volume total* (acre–ft) (3)	Volume total (L)** (4)	N mass leached (lb/acre)^ (5)	Total acreage (acres) (6)	N mass total leached (lb) (7)	N mass total leached (mg) (8)	Total N increase above background (mg/L) (9)
Porosity = 0.25									
4	276	400	676	8.3E+08	61	160	9,760	4.4E+09	5.3
6	250	400	650	8.0E+08	79	160	12,640	5.7E+09	7.2
Porosity = 0.30									
4	276	480	756	9.3E+08	61	160	9,760	4.4E+09	4.8
6	250	480	730	9.0E+08	79	160	12,640	5.7E+09	6.4

(2)=160 acres x porosity

* Volume total= Volume leached + volume in top 10 ft of the aquifer voids

** Volume total (L) = volume total (acre-ft) x 1.23 x 10(exp6) L/acre-ft

^ See Table J.3 for calculations of N leached.

(7)=(5)x(6)

(8)=(7) x 453,600 mg/kg

(9)=(8)/(4)

Table K.2. Estimated increases in ground water TDS concentration resulting from 1993 land application.

Field No.	Volume leached (acre–ft/yr) (1)	Volume of voids in the top 10 feet of aquifer (acre–ft) (2)	Volume total* (acre–ft) (3)	Volume total (L)** (4)	TDS mass leached (lb/acre)^ (5)	Total acreage (acres) (6)	TDS mass total leached (lb) (7)	TDS mass total leached (mg) (8)	TDS increase above background (mg/L) (9)
Porosity = 0.25									
4	276	400	676	8.3E+08	1,456	160	232,960	1.1E+11	127
6	250	400	650	8.0E+08	1,890	160	302,400	1.4E+11	172
Porosity = 0.30									
4	276	480	756	9.3E+08	1,456	160	232,960	1.1E+11	114
6	250	480	730	9.0E+08	1,890	160	302,400	1.4E+11	153

(2)=160 acres x porosity

* Volume total= Volume leached + volume in top 10 ft of the aquifer voids

** Volume total (L) = volume total (acre-ft) x 1.23 x 10(exp6) L/acre-ft

^ See Appendix K.4 for calculations of TDS leached.

(7)=(5)x(6)

(8)=(7) x 453,600 mg/kg

(9)=(8)/(4)