# Crop Production with In-Situ Use of Shallow Saline Groundwater, Reuse of Drainage Water and Active Drainage System Management

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Final Report

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# INTRODUCTION

Drainage water disposal is limited due to environmental concerns related to high salt content and the presence of trace elements like selenium and boron in drainage water. Reducing the volume of drainage water and salt mass for disposal is a necessary part of a long term solution that will allow agriculture to maintain its current productivity levels. Reduction of drainage water volume can be obtained through source control (reduction of irrigation application) and/or through the reuse of drainage water (SJVDP, 1990). Applied irrigation water can be reduced when shallow in-situ groundwater is considered a useable water source for the crop (Ayars and Soppe, 2001a). Using in-situ groundwater is highly preferable over drainage water reuse since it is more energy efficient for the plants to extract water directly from the source than using pumps to irrigate. The potential of salinization of the rootzone exists when saline groundwater moves upward into the soil profile, although earlier research with cotton in the Broadview Water District and on Westlake Farms suggests that normal winter precipitation and pre-plant irrigation are adequate to prevent salt buildup in the rootzone (Ayars and Soppe, 2001a and b). Another option to reduce drainage water volume is to reuse drainage water directly as irrigation water or blend it with fresh water, depending on the quality and composition of the drainage water. Potential for salinization of the entire rootzone exists in this case as well, although a 3 year study in the Panoche Drainage District did not show a significant salt build-up in the rootzone (Ayars and Soppe, 2001b). When salts are added to a field, but do not accumulate in the rootzone, it is likely that the shallow groundwater quality is deteriorating. This might not immediately result in higher salinity in the drainage water, however, due to the buffering effect of the groundwater reservoir.

The concept of shallow groundwater management using subsurface drains has been developed and tested in humid areas, but more research is needed in arid areas under irrigated conditions (Fouss et al., 1990). It has been successful in areas with nearly level ground surface and drainage systems which have closely spaced laterals with shallower depth of placement (< 1.5 m). These are significantly different conditions than normally found in arid irrigated areas.

Restricting flow modifies the hydrology of the system and changes the timing of the peak drainage discharge. In situations where drainage water is being used it provides temporary storage for later use and increases the opportunity time for percolation through the impeding layer which would contribute to the reduction of total drainage flow.

**Objectives:**
The objectives of the project were: to demonstrate methods of drainage water volume reduction within a water district while maintaining sustainable crop production; and active management of the subsurface drainage system using modifications that are suitable for previously installed subsurface drainage systems in arid and semi-arid areas.

This is the final report on the project “Crop Production with In-Situ Use of Shallow Saline Groundwater, Reuse of Drainage Water and Active Drainage System Management” DWR Agreement 4600002265. The research period was from June 2001 to March 2005 and data included come from field 33 in the Broadview Water District, the Red Rock Ranch IFDM site. The results from each location are summarized in individual sections.

# BROADVIEW WATER DISTRICT

## 1.1 Experimental Design

A field (Field 33) was selected in the Broadview Water District (BWD) that had access to both good quality and drainage water. The site was owned by the BWD and was managed in cooperation with the district. The field was approximately 25 ha (60 ac) and was divided into 9 plots (Fig. 1) each approximately 2.4 ha (90m by 270 m) in size. The plots were divided with berms and further subdivided with shallower berms to aid in irrigation. There were 3 water quality treatments imposed on the site. The first treatment was “FRESH” water, the second was “DRAIN” water and the third was “GW” or “GWUSE” groundwater. The site was divided into 3 blocks and the irrigation treatments were assigned randomly within the blocks. The FRESH treatment was irrigated twice between cuttings with only good quality water. The DRAIN treatment was irrigated twice between cuttings with drainage water and the GW treatment was to be irrigated once between cuttings with drainage water. The original design was to not irrigate the GW treatment after establishment and have the alfalfa use only groundwater. This was not feasible because of the high (> 10 dS/m) groundwater salinity.

Irrigation was done by the BWD personnel with the schedule being determined by field operations, field soil characteristics, and limitations on the irrigation system. Sampling of soil, water, and plant materials was done by Agricultural Research Service (ARS) personnel.

## 1.2 Field Layout

Field 33 is located in the northwest corner of the Broadview Water District. The district collector drain and the Third Lift Canal (conveys irrigation water supply from the Delta Mendota Canal) border the northern edge of the field. The western side of the field is bordered by the district’s main irrigation supply canal. Other agricultural fields are located on the southern and eastern side.

### *1.2.1 Drain Layout*

Field 33 subsurface drain layout is shown in Fig. 2. The field is underlain by two drainage systems with the largest area of the field drained by a system that moves water to the west, while a smaller eastern area of the field is drained by a system that moves drainage water to the east. The eastern drainage system has air vents visible on the field surface (indicated by AV1, AV2, AV3 in Fig. 2). Both drainage systems were installed in 1971. A pumped sump (33-1) on the northwest corner of the field lifts drainage water from the western laterals into the district collector drain.

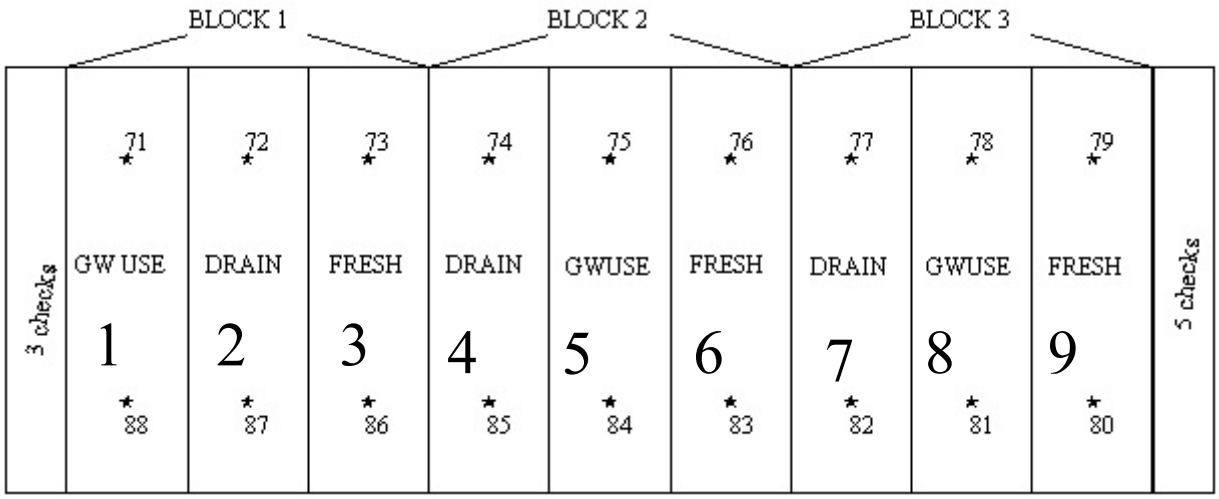



Figure 1. Plot layout for irrigation water quality treatments in field 33 of Broadview Water District. Plots number 1-9.

*1.2.2 Groundwater wells*

The locations of the groundwater wells used for measuring water table response and collecting groundwater samples is shown in Fig. 1 along with the irrigation treatment designation and in Fig.2 relative to subsurface drainage laterals. The sites have been labeled from 71 to 88 with two wells in each of the treatment replications. The wells are 2 m deep and are constructed from 50 mm diameter PVC pipe that is perforated over the lower 0.5 m. The water table position in the wells was read either manually and/or with a continuously recording pressure transducer (Fig. 3). Some wells were monitored continuously from December 2002 to the end of the project in 2005. All of the wells were sampled periodically for water quality analysis during the duration of the project.

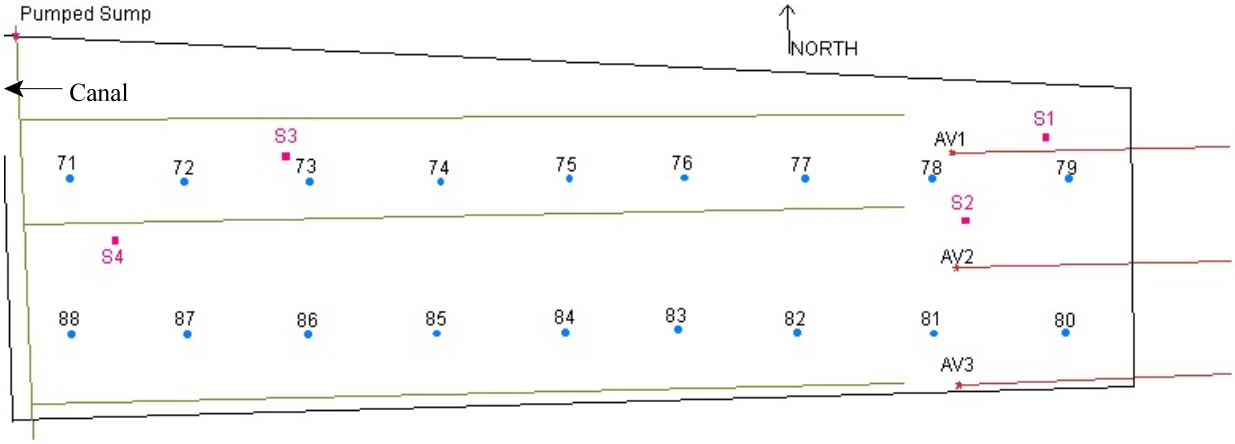



Figure 2. Subsurface drain layout and observation wells in field 33 of the Broadview water district.

Figure 3. Photo of automated groundwater level sensors being used in field 33.

*1.2.3 Soil physical description*

Soil samples were collected at four sites in the field at 30 cm intervals to a depth of 120 cm for particle size analysis. Silt, sand, and clay content were obtained using the Bouyoucos method (Table 1). Salts were washed from the samples using distilled water before analysis. Soil water retention parameters were obtained from established relations between particle size distribution and the water retention curve (Rawls and Brakensiek, 1989) (Fig. 4). The top 60 cm of the soil profile is classified as clay, with the depth from 60 to 120 cm classified as silty clay. Average bulk density based on the particle size distribution is approximately 1.2 $Mg/m^3$. The plant available moisture (defined as the difference between field capacity and permanent wilting point) for this soil is approximately 15%.

Table 1: Sand, Silt and Clay distribution over depth in field 33

| Depth (cm) | Sand % | Silt % | Clay % | Classification |
|---|---|---|---|---|
| 0-30 | 9.0 | 31.7 | 59.3 | Clay |
| 30-60 | 8.5 | 31.7 | 59.8 | Clay |
| 60-90 | 7.5 | 50.2 | 42.3 | Silty Clay |
| 90-120 | 13.3 | 43.8 | 42.9 | Silty Clay |

**1.3 Field Operations**

Field operations for the project are summarized for each year in the following sections

2001

A safflower crop was grown in 2001. It was planted in February, flowered at the end of May, and harvested at the end of July. It was not irrigated during the growing season to dry down the field in preparation for leveling prior to planting. After harvest of the safflower, the field was disced and laser leveled and prepared for planting of salt tolerant alfalfa in 2002 and remained fallow until planted in 2002.

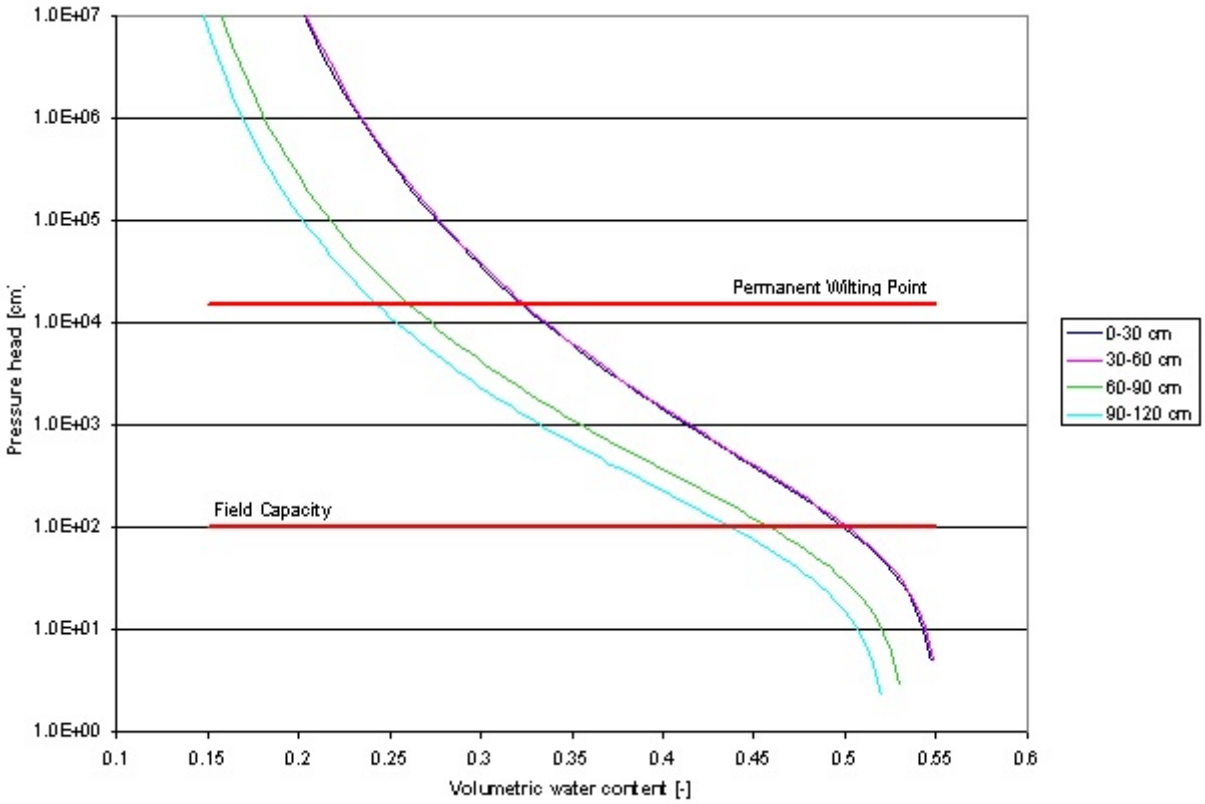



Figure 4: Water retention curve for soil in field 33, Broadview Water District based on particle size distribution.

2002

Salt tolerant alfalfa (var. SW9720) was planted on February 22, 2002. Soil samples were collected by personnel from the George E. Brown Jr. Salinity Laboratory (GEBJSL) between February 28 and March 1. The samples were taken to the GEBJSL for analysis of electrical conductivity (EC), and boron (B) and chloride (Cl) concentrations. The field was sprinkler irrigated on March 15, 2002 with good quality (low salinity) water to aid in germination. The field was flood irrigated with good quality water beginning on April 18, 2002 and all subsequent irrigations used good quality (low salinity) water until the last irrigation of the season. There were no differential treatments of water quality or numbers of irrigations during the period January to September 2002. The intent was to develop a uniform stand prior to initiating the irrigation water quality treatments. The last irrigation of the season applied saline (6 dS/m) drainage water to the groundwater (GW) and drainage (DRAIN) treatments.

2003

This was the second year of the alfalfa stand and the first full year for implementation of the irrigation water quality treatments. The only field operations required were those needed to harvest the crop. These operations included cutting the alfalfa, raking the dried hay into windrows, baling, and then picking up the bales. There were a total of 5 cuttings during the

growing season that were spaced roughly 4 to 6 weeks apart. The hay was cut in March, April, June, July, and September . It was apparent early in the season that the GW treatment was going to have to be irrigated to survive, so the irrigation treatments were modified to ensure the continued operation of the project. The treatments were modified so FRESH plots receiving the good quality water and the DRAIN plots receiving drainage water were irrigated twice between cuttings, while the groundwater GW treatment was irrigated once with drainage water immediately after harvest. The decision to harvest was made by a contractor working with the Broadview Water District while the irrigation and bale counts were the responsibility of district personnel.

No field operations were conducted from September 2003 to March 2004. An irrigation was applied following the last harvest in 2003 to maintain the alfalfa over the winter dormant period. An additional harvest was considered because of the warm Fall but lack of adequate growth precluded any further harvest.

2004
The first harvest of this cropping year was in April and there were a total of 4 harvests during the growing season. All harvest operations were the responsibility of an independent contractor employed by the BWD. Other than harvest there were no other cultural operations done on the plots during the 2004 growing season. Again, the bale counts and the irrigations were done by Broadview Water District personnel. The same irrigation protocols were used in 2004 as in 2003.

There were no field operations during the period from October 2004 to March 2005. Nothing was done because the Broadview Water District Board of Directors was in negotiation to sell the district and the uncertainty dictated that no unnecessary expenses be incurred by BWD. The sale of the BWD to the Westlands Water District was completed in March 2005, which coincided with the end of the project.

## 1.4 Water

### *1.4.1 Precipitation and Evapotranspiration*

Monthly precipitation data from the California Irrigation Management Information System (CIMIS) weather station #124 (Panoche Water District) are summarized in Table 2 for years 2001, 2002, 2003, 2004, and to March 2005. The potential evapotranspiration ($ET_o$) data for the same station and time period are given in Table 3.

### *1.4.2 Irrigation*

There were three irrigation treatments being used on the project. The “FRESH” treatment used good quality irrigation water and had 2 irrigations of approximately 100 mm each between cuttings. The “DRAIN” treatment used drain water with an EC of approximately 6 dS/m and had 2 irrigations of approximately 100 mm each between cuttings. The last treatment “groundwater” (GW) used drainage water for irrigation and had one irrigation of approximately

100 mm between cuttings. The GW treatment was designed to test whether the alfalfa could use any shallow groundwater in-situ.

Table 2. Monthly precipitation for CIMIS station #124 - Panoche in 2001, 2002, 2003, 2004, and 2005.

| | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|
| Month | (mm) | (mm) | (mm) | (mm) | (mm) |
| Jan | 37.8 | 16.9 | 11.9 | 16.2 | 43.2 |
| Feb | 33.2 | 3.3 | 32.9 | 40.0 | 47.7 |
| Mar | 25.6 | 15.8 | 15.6 | 4.3 | 35.9 |
| Apr | 19.1 | 6.1 | 15.3 | 0.0 | |
| May | 0 | 1.3 | 10.6 | .05 | |
| Jun | 0 | 0 | 0 | 0.0 | |
| Jul | 0 | 0 | 0 | 0.0 | |
| Aug | 0 | 0 | 7.3 | 0.0 | |
| Sep | 0.8 | 0 | 0 | 0.3 | |
| Oct | 9.6 | 0 | 0.1 | 34.9 | |
| Nov | 23.1 | 13.9 | 5.3 | 4 | |
| Dec | 38.1 | 52.6 | 33.3 | 45.2 | |
| Total | 187.3 | 109.6 | 132.3 | 91.4 | 159.3 |

Table 3. Monthly potential evapotranspiration from CIMIS station #124 in 2001, 2002, 2003, 2004, and 2005.

| | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|
| Month | (mm) | (mm) | (mm) | (mm) | (mm) |
| Jan | 39.5 | 30.7 | 18.1 | 33.3 | 16.9 |
| Feb | 52.9 | 60.0 | 51.8 | 48.9 | 47.1 |
| Mar | 107.1 | 107.5 | 113.7 | 122.8 | 92.8 |
| Apr | 146.3 | 147.8 | 121.7 | 181.9 | |
| May | 248.9 | 212.1 | 189.8 | 217.5 | |
| Jun | 243.3 | 237.0 | 219.3 | 221.1 | |
| Jul | 206.0 | 213.8 | 222.5 | 205.9 | |
| Aug | 194.9 | 180.7 | 192.6 | 182.4 | |
| Sep | 147.4 | 146.9 | 158.9 | 150.5 | |
| Oct | 108.8 | 103.9 | 116.2 | 86.2 | |
| Nov | 44.3 | 47.8 | 46.8 | 36.3 | |
| Dec | 24.6 | 28.0 | 27.9 | 22.6 | |
| Total | 1564.0 | 1516.2 | 1479.3 | 1509.4 | |

The characteristics of the soil in the field and the time between cutting limited the ability to apply more than two irrigations between cuttings. The soil is a clay and cracked heavily which slowed the advance time and restricted the total infiltrated depth of water. Irrigation took approximately 10 days to complete. Some time was needed after irrigation for the soil to dry to permit access of machinery to cut the crop.

The applied irrigation water and the water quality of the irrigation are summarized for each year in tables 4, 5, and 6. The total applied water is summarized in table 7.

Table 4. Summary of application depth and water quality for each of the irrigation treatments on field 33 in Broadview Water District in 2002.

| | FRESH | | DRAIN | | | | GW | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | NS (mm) | EC (dS/m) | NS (mm) | EC (dS/m) | S (mm) | EC (dS/m) | NS (mm) | EC (dS/m) | S (mm) | EC (dS/m) |
| 3/5/02 | 49 | 0.46 | 49 | 0.46 | | | 49 | 0.46 | | |
| 4/5/02 | 45 | 0.46 | 45 | 0.46 | | | 45 | 0.46 | | |
| 4/29/02 | 121 | 0.46 | 121 | 0.46 | | | 121 | 0.46 | | |
| 6/7/02 | 124 | 0.32 | 124 | 0.32 | | | 124 | 0.32 | | |
| 7/16/02 | 124 | 0.52 | 124 | 0.32 | | | 124 | 0.32 | | |
| 8/5/02 | 83 | 0.6 | 83 | 0.6 | | | 83 | 0.6 | | |
| 8/28/02 | 128 | 0.6 | | | | | | | | |
| 9/3/02 | | | | | 117 | 6.0 | | | 117 | 6.0 |
| 9/25/02 | 131 | 0.67 | | | | | | | | |
| 9/27/02 | | | | | 85 | 6.0 | | | | |
| TOTAL | 805 | | 546 | | 202 | | 546 | | 117 | |

NS - non-saline, low salinity
S - saline, high salinity

Table 5. Summary of application depth and water quality for the each of the irrigation treatments on field 33 in Broadview Water District in 2003

| | FRESH | | DRAIN | | | | GW | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | NS (mm) | EC (dS/m) | NS (mm) | EC (dS/m) | S (mm) | EC (dS/m) | NS (mm) | EC (dS/m) | S (mm) | EC (dS/m) |
| 3/17/03 | 109 | 0.4 | 109 | 0.4 | | | 109 | 0.4 | | |
| 4/28/03 | 89 | 0.4 | | | 102 | 6.0 | | | 102 | 6.0 |
| 5/30/03 | 96 | 0.4 | | | 117 | 6.0 | | | 0 | |
| 7/01/03 | 201 | 0.4 | | | 209 | 4.9 | | | 137 | 4.9 |
| 8/11/03 | 107 | 0.4 | | | 193 | 6.7 | | | 126 | 6.7 |
| 9/24/03 | 88 | 0.4 | | | 95 | 8.8 | | | 95 | 8.8 |
| 10/14/03 | 63 | 0.4 | | | 146 | 6.9 | | | | |
| TOTAL | 753 | | 109 | | 862 | | 109 | | 460 | |

NS - non-saline, low salinity
S - saline, high salinity

Table 6. Summary of application depth and water quality for each of the irrigation treatments on field 33 in Broadview Water District in 2004.

| | FRESH | | DRAIN | | | | GW | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | NS (mm) | EC (dS/m) | NS (mm) | EC (dS/m) | S (mm) | EC (dS/m) | NS (mm) | EC (dS/m) | S (mm) | EC (dS/m) |
| 4/21/04 | 115 | 0.44 | 115 | 0.44 | | | 115 | 0.44 | | |
| 5/11/04 | 96 | 0.44 | 96 | 0.44 | | | 96 | 0.44 | | |
| 6/7/04 | 125 | 0.81 | | | | | | | | |
| 6/14/04 | | | | | 130 | 6.82 | | | 130 | 6.28 |
| 6/28/04 | | | | | 93 | 7.12 | | | 93 | 7.12 |
| 7/6/24 | 114 | 0.69 | | | | | | | | |
| 7/22/04 | 104 | 0.65 | | | | | | | | |
| 7/29/04 | | | | | 103 | 4.22 | | | 103 | 4.22 |
| 8/16/04 | 104 | 0.38 | 104 | 0.38 | | | 104 | 0.38 | | |
| TOTAL | 658 | | 315 | | 326 | | 315 | | 326 | |

NS - non-saline, low salinity
S - saline, high salinity

Table 7. Summary of applied irrigation water in each treatment for three years of study .

| Year | FRESH | DRAIN | | GW | |
|---|---|---|---|---|---|
| | NS (mm) | NS (mm) | S (mm) | NS (mm) | S (mm) |
| 2002 | 805 | 546 | 202 | 546 | 117 |
| 2003 | 602 | 109 | 621 | 109 | 365 |
| 2004 | 658 | 315 | 326 | 315 | 326 |
| Total | 2216 | 970 | 1390 | 970 | 903 |

NS - non-saline, low salinity
S - saline, high salinity

The average volume weighted salinity was calculated for each treatment for each year of the experiment. The FRESH water treatment EC was 0.52 dS/m, 0.4 dS/m, and 0.58 dS/m in 2002, 2003, and 2004, respectively. The EC in the drainage treatment was 1.96 dS/m, 5.68 dS/m, and 3.23 dS/m for 2002, 2003, and 2004. The groundwater treatment received water with EC of 1.44 dS/m, 5.28 dS/m and 3.23 dS/m for 2002, 2033 and 2004, respectively.

*1.4.3 Drainage*

Drainage was provided to this field by a subsurface drainage system installed at a depth of approximately 2.1 m that discharges to a pumped sump (33-1) located on the northwest corner of the site (Fig. 2). The drainage water was discharged from the sump to a collector drain where it was either discharged to the San Joaquin River as part of a cooperative agreement with other drainage districts in the area (Grasslands Drainage Group) and the State of California or is mixed

back into the irrigation supply. The drainage volume discharged was regulated based on selenium (Se) loads and varied from month to month. Occasionally, sumps were turned off to reduce the district contribution and to meet Se load requirements for the Grasslands drainage group.

The drainage data for crop year (CY) 2000, 2001, 2002, and 2003 are given in Fig. 5. The crop year extends from October of one year to the end of September in the following year. The drainage data for CY03 from November to March are interesting because they are opposite the normal trend for this time period. The discharge increased in November and decreased until March when it began to increase again. In previous years the flow in this time has been low with increased discharge in January and February in response to pre-plant irrigation. This pattern is a reflection of the regulatory controls placed on the Grasslands drainage group. Drainage water was discharged when there was adequate flow available in the San Joaquin River to dilute the drainage flow in order to meet the concentration standards in the San Joaquin River.

The sump was turned off in 2003 to maintain the water table position at 2 m under field 33 during the experiment and as a result there was no drainage discharge from this site for the remainder of the experiment. Another field being served by the sump was fallow and did not require drainage.

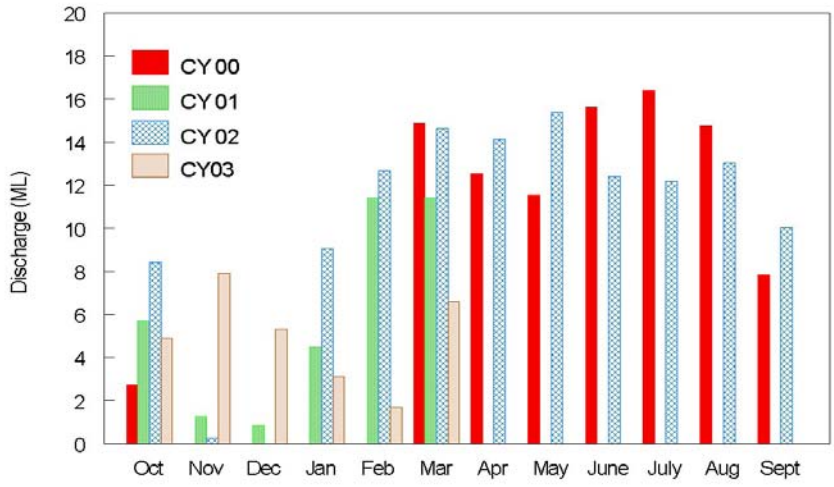



Figure 5. Monthly drainage flow from Sump 33-1 in Broadview Water District.

*1.4.4 Groundwater*

Groundwater position was monitored in each of the observation wells (71- 88) in Fig. 2. Measurements were taken manually in the period from March 2002 until July 2002. At the end

of July, automated groundwater depth (Fig. 3) sensors were installed. The sensors recorded groundwater levels at 1 hour increments. Problems encountered with the sensors, included water leaking into the sensor, discharged batteries for the datalogger inside the enclosure, and software restart problems after a download. This resulted in some “data gaps” and some wells without continuous groundwater observations. However, manually collected measurements of the groundwater depth continued and “missing” continuous data can often be interpolated based on the manual measurements and continuous observations made in other wells in the same field. The water table response for each of the irrigation treatments is summarized in Figs. 6, 7, and 8 from December 2002 to March 2005.

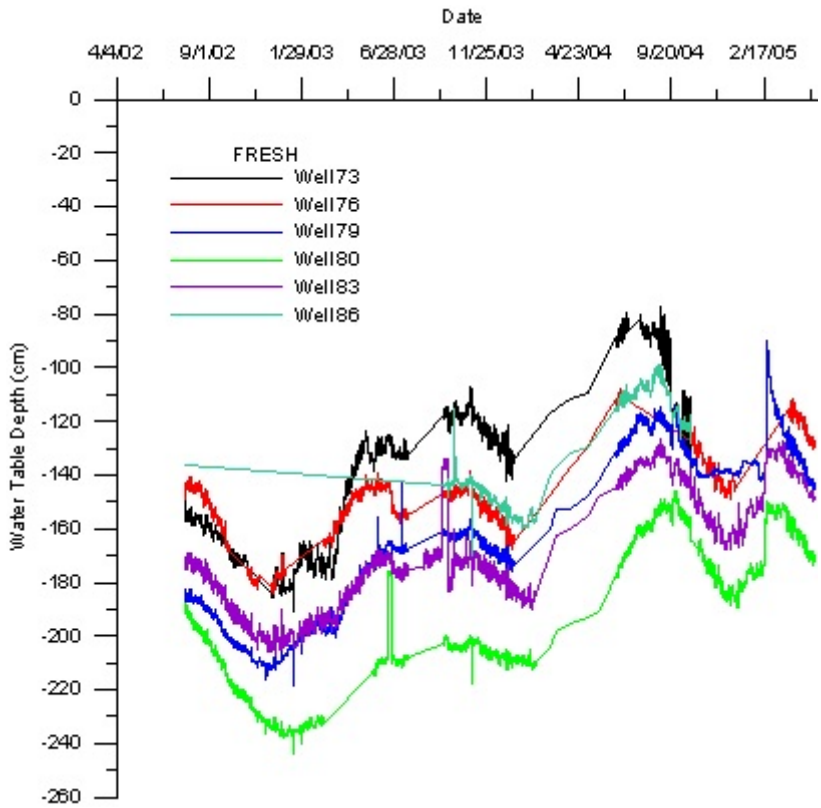



Figure 6. Water table response in FRESH irrigation water treatment plots in field 33.

In Fig. 6 the wells in the FRESH irrigation water treatment, the shallowest groundwater was in the area on the west side of the field adjacent to the main delivery canal and along the drainage line coming to the sump. This is possibly a result of seepage from the canal. There was a gradual decrease in the depth to the water table with time over the irrigation season. The water table then receded over the winter and started to increase with the start of the irrigation season. This pattern is repeated each year of the project in all treatments. The deepest water table depth was found on the east side of the field. The depth to the water table was less than 2 m which is acceptable for crop use from shallow groundwater with a fluctuating water table, particularly with a deep

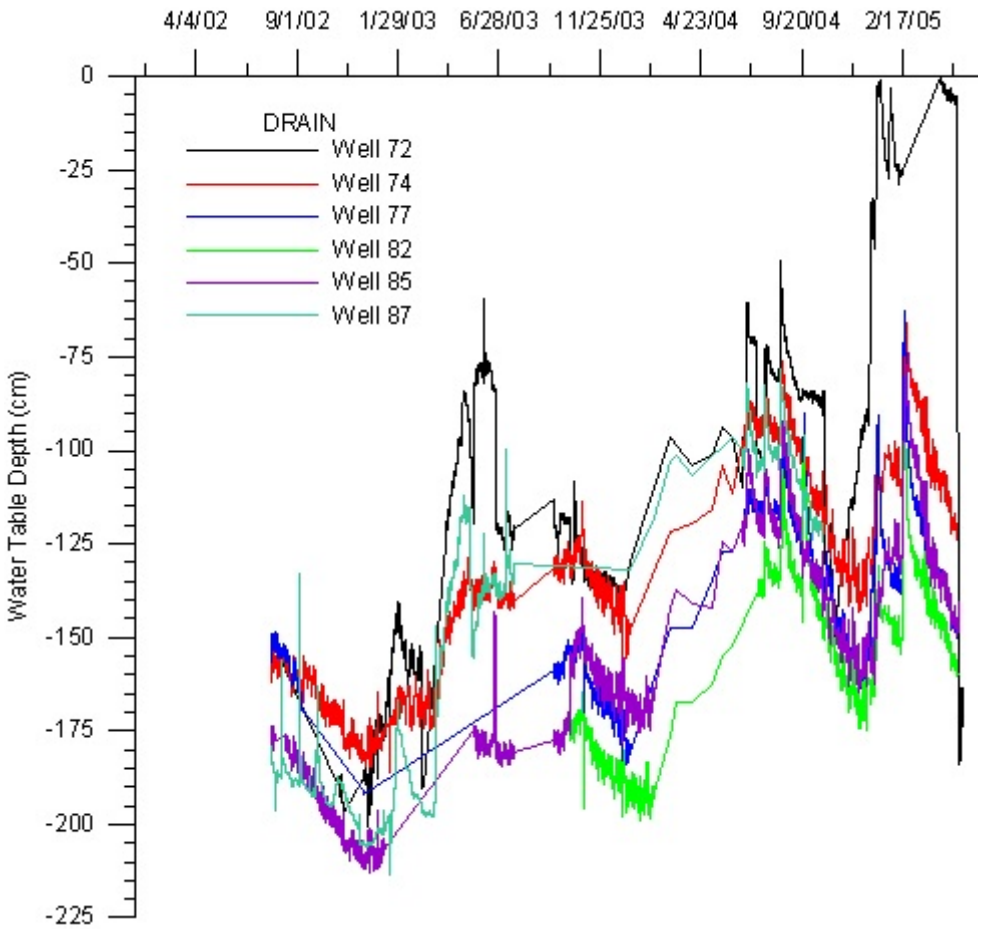



Figure 7. Water table response under DRAIN irrigation water treatment plots in field 33.

rooted crop like alfalfa. Note also that the average depth to the water table decreased over the duration of the project by approximately 1 m. The drainage sump was not operated after 2003 period so this is probably a response to regional subsurface flows, deep percolation losses, and low lateral flow under the field.

The water table response under the drain treatment is given in Fig. 7. It displays the same water table depth fluctuations as the water table under the treatments receiving fresh water. Recall that both treatments were irrigated twice between cuttings with approximately the same volume of water. The wells closest to the western boundary of the field have the shallowest depth to water. There was also a gradual decrease in the depth to water table as the season progressed and over the life of the project. The same trend was found in the plots irrigated only once between cuttings (GW plots). These data are given in Fig. 8. The wells on the west side of the field are responding to lateral flow from the Broadview supply canal. The water level in the DOS-IR valve located 5 m south of the field remained relatively constant during this period indicating some lateral flow to the site from outside of the district.

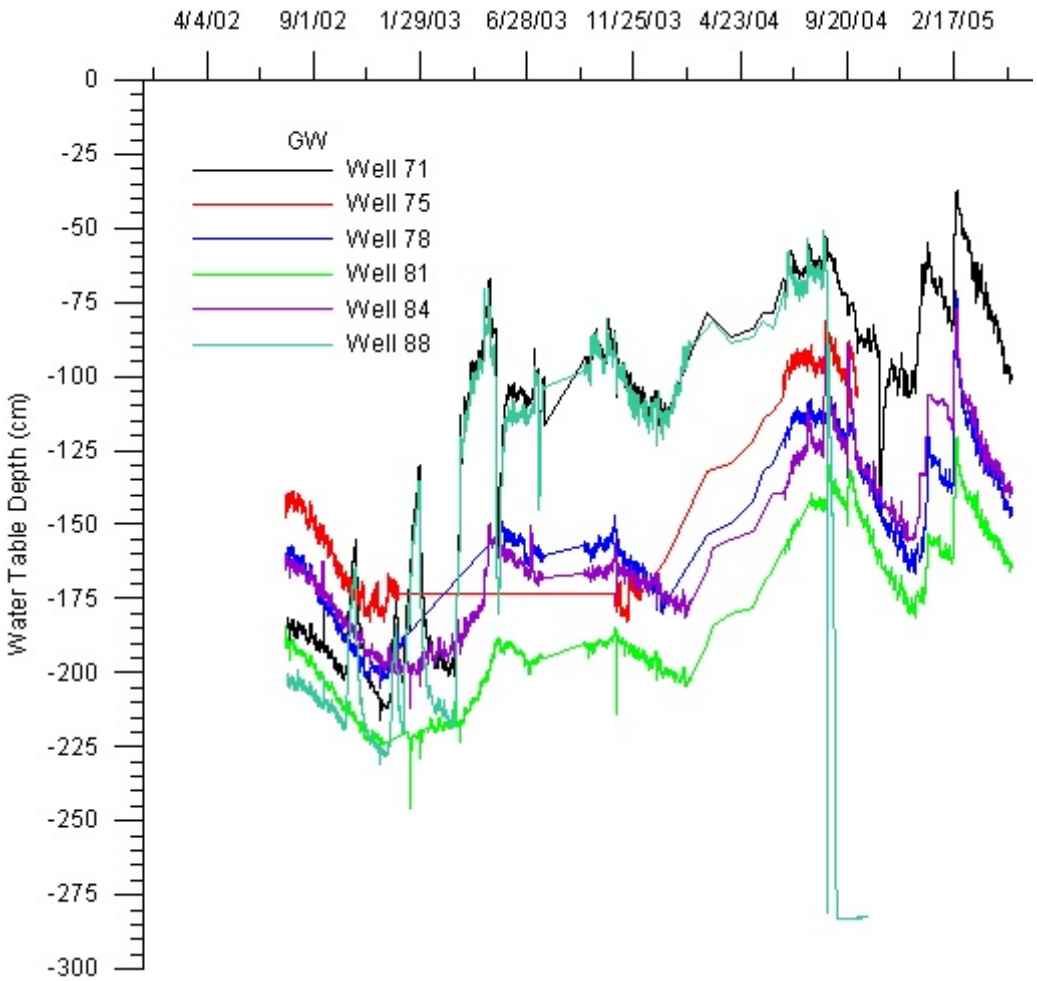



Figure 8. Water table response under GW irrigation water treatment plots in field 33.

*1.4.5 Soil Water Response*

Sentek[1] capacitance probes were installed in each treatment to monitor the soil water response to irrigation and to evaluate the potential for crop water uptake from shallow groundwater. The probes were installed early in the summer 2003 and came on line by the end of summer 2003. Data for the period Oct 2003 to March 2005 are given in Figs. 9, 10, and 11. The data for the reporting period show an accumulation of water in the profile and a rapid withdrawal beginning in March when the plants break dormancy. The data also show that most of the root water extraction occurs to a depth of 70 cm, which means there is a fairly restricted root zone for these plants. The limited root zone means that the available stored water is limited and might result in poor development and growth. Reasons for this limited root development will be considered. A value of 75% volumetric water content is not realistic for these soils but is a response to the high

[1]Mention of trade names does not imply endorsement by USDA-ARS.

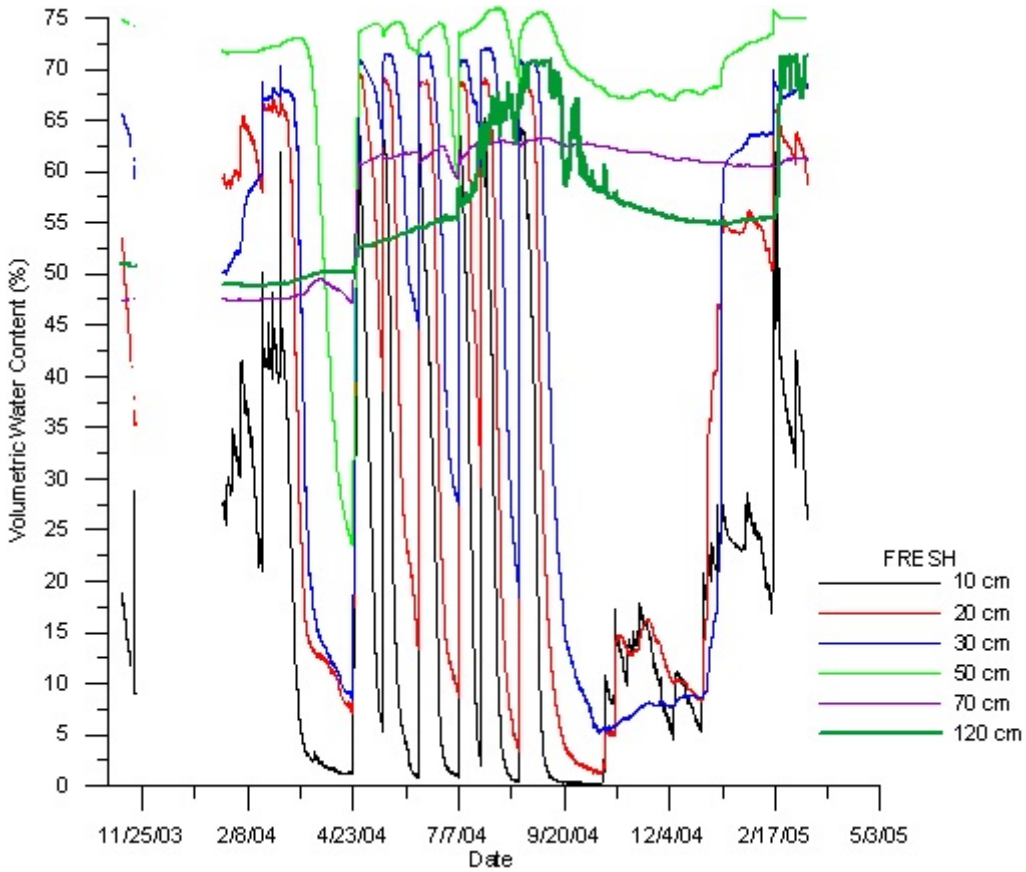



Figure 9. Soil water content in the FRESH irrigation treatment plots in field 33.

soil salinity in these plots. Field capacity is approximately 50% volumetric water content (Fig. 4). These data do give a good representation of the soil water variation and depth of extraction by the plants and are suitable for characterizing changes in soil water but without correction to account for the effects of salinity would be of limited use in numerical modeling of soil water. The soil water content graphs show the same pattern with most of the change occurring to a depth of 70 cm. The data also are very responsive to irrigation. The data in Fig. 9 show soil moisture increases for both irrigations in a cycle with a smaller increase during the second irrigation in the cycle. The soil water was depleted in the root zone to a depth of 70 cm. The soil water profile was replenished by the heavier than usual winter rain fall which is reflected in the increased water content in the 10 to 50 cm depths.

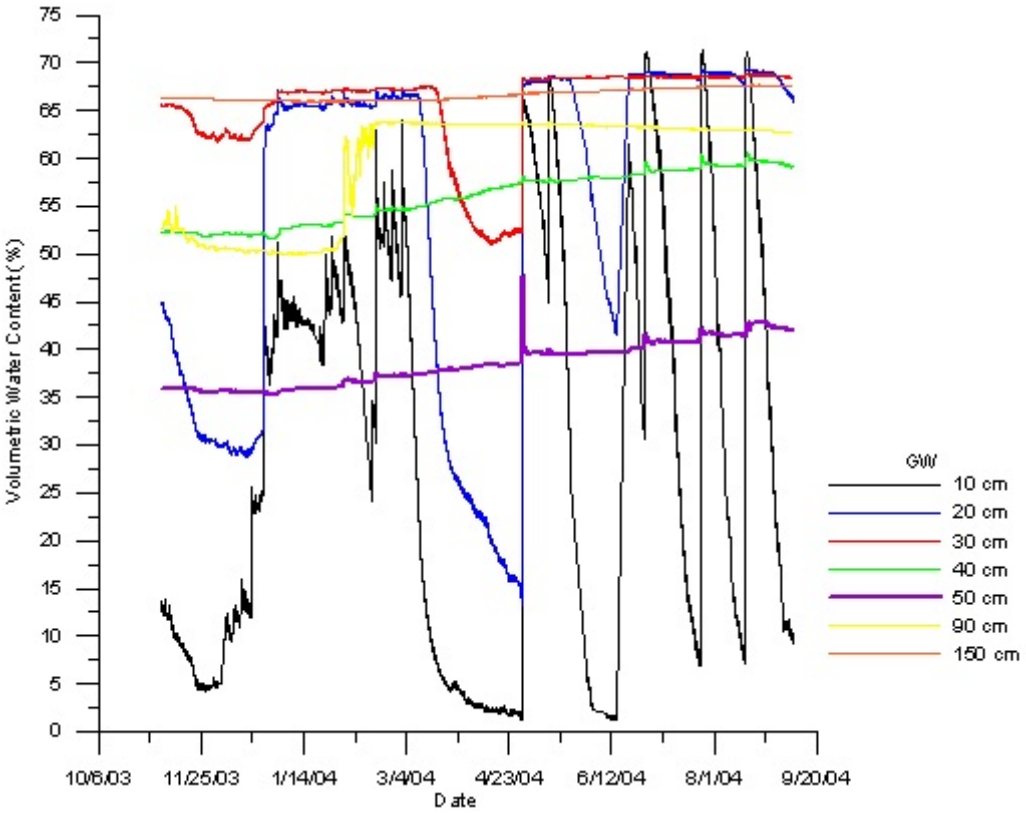



Figure 10. Soil water content in the GW irrigation treatment plots in field 33.

*1.4.6 Annual Crop Water Use*

Annual crop water use is characterized using a basic water balance calculation for the season. Seasonal crop water use was set equal to the depth of applied irrigation water and the estimated change in soil water content over the irrigation season plus any precipitation in the period. This assumes that the soil water content was at field capacity at the beginning of the growing season. Any rainfall that occurs after the beginning of the growing season was assumed to be effective and was included in the calculation.

2001

Capacitance type soil moisture sensors were installed in the safflower field in June at locations indicated by “S” in Fig. 2. Soil water content data indicated a low level of root water uptake after installation of the sensors. These data were not included because of the apparent lack of response. Soil water content data were taken above the water table using a neutron probe. These data were collected on two separate dates (5/15/01 and 7/19/01) using the groundwater wells as neutron probe access tubes (Fig. 12). An estimate of the soil water content measurements with depth based on the soil physical characteristics as shown in Fig. 4. The low water contents and small change in water content in the upper 70 cm of the profile show that most of the crop water use of non-irrigated safflower occurred before 5/15/01. Research at the USDA-ARS facility in Parlier showed that water use on irrigated safflower continued until 6/25/01.

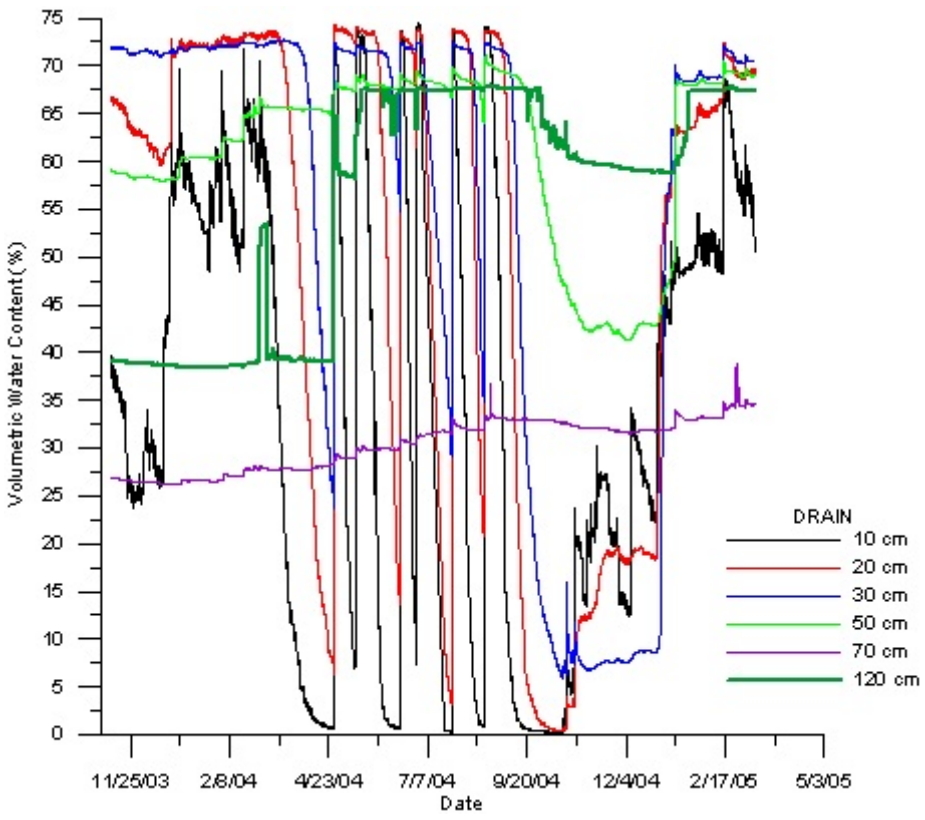



Figure 11. Soil water content in DRAIN irrigation water treatment plots in field 33.

2002

No direct measurements of crop water use were made at the field location in 2002. However, a weighing lysimeter experiment at the USDA research facility in Parlier, CA used the same variety of alfalfa as was grown in field 33 in Broadview Water District. The resulting measurements from the lysimeter experiment are presented here and discussed in relation to the field conditions in Broadview to estimate total crop water use for 2002 and as a basis for subsequent years.

Westlands Water District (WWD), just south of the Broadview Water District, distributes a weekly bulletin that gives the calculated total crop water use for a variety of crops grown in the district. These values are compared to the lysimeter measurements and the applicability of using these values to characterize crop water use in the Broadview field is discussed.

Reference evapotranspiration for the Panoche site and the Parlier site was determined from climatic data measured by California Irrigation Management Information Systems (CIMIS) weather stations. Weather station #124 located at the Panoche Water District, west of the Broadview Water District was used for the alfalfa at Broadview and weather station #39 located in Parlier was used to characterize crop water use on the Parlier lysimeters.

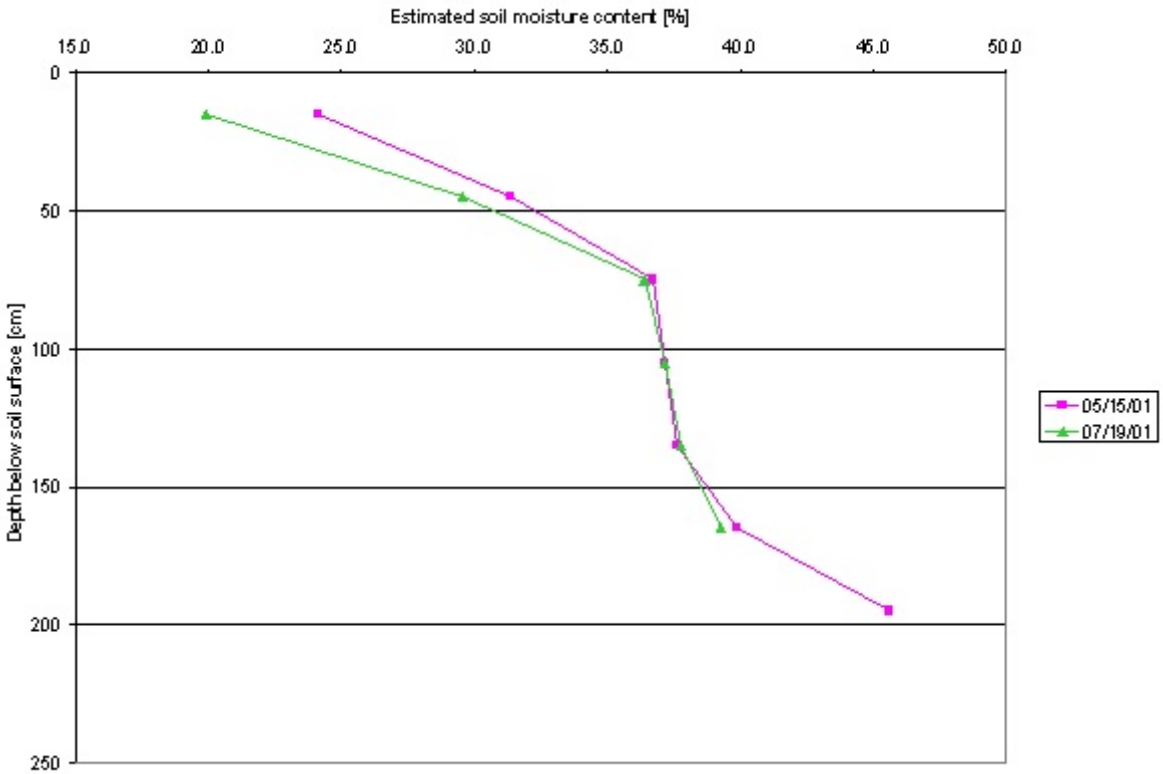



Figure 12. Estimated water content using neutron probe measurements in field 33, BWD (2001).

The cumulative crop water use for alfalfa grown on a lysimeter without a water table (RefTank), and on a lysimeter with a saline (15 dS/m) water table (GWTank) maintained at 90 cm below field level is shown in Fig. 13. The cumulative crop water use as predicted by the Westlands Water District Bulletin is shown as well.

The data given in Fig.13 demonstrate that the alfalfa grown in the RefTank, without saline groundwater, followed the reference evapotranspiration at Parlier (#39) very well, resulting in an average crop coefficient of 1.0 for the year. The crop evapotranspiration measured by the GWTank, with saline groundwater, was lower than on the lysimeter tank without saline groundwater, but followed the predicted crop water use from the WWD Bulletin very well. Reference evapotranspiration for the west side of the San Joaquin Valley (CIMIS #124) was higher than on the east side (CIMIS #39), suggesting that the crop production predicted by the WWD was more limited than the crop production on the GWTank. This is probably a result of irrigation practices. The GWTank was irrigated twice a week using drip irrigation, while a field crop on the west side is mainly irrigated using flood or furrow irrigation, thus resulting in more water stress than measured on the GWTank.

For the alfalfa grown in field 33 crop water use was lower than shown in Fig. 13. The alfalfa was planted in February 2002, and lagged in development of the fully developed crop used for the

WWD Bulletin. Visual observations of plant growth in the field showed a slower biomass development on field 33 than observed on the GWTank. Total crop water use on field 33 will therefore be less than the 1200 mm estimated for the GWtank.

The data in tables 8, 9 and 10 were used to estimate the seasonal crop water use in 2002, 2003, and 2004, respectively. The Westland's water conservation guide was used to estimate alfalfa water use ($ET_w$) water use in well water conditions with low salinity water. Crop water use in each treatment was estimated using the total applied water, the rainfall during the growing season, and an estimated change in soil water of 70 mm. The soil water content change was estimated based on a 70 cm rooting depth, 15% available water, and a depletion of 70% of AW.

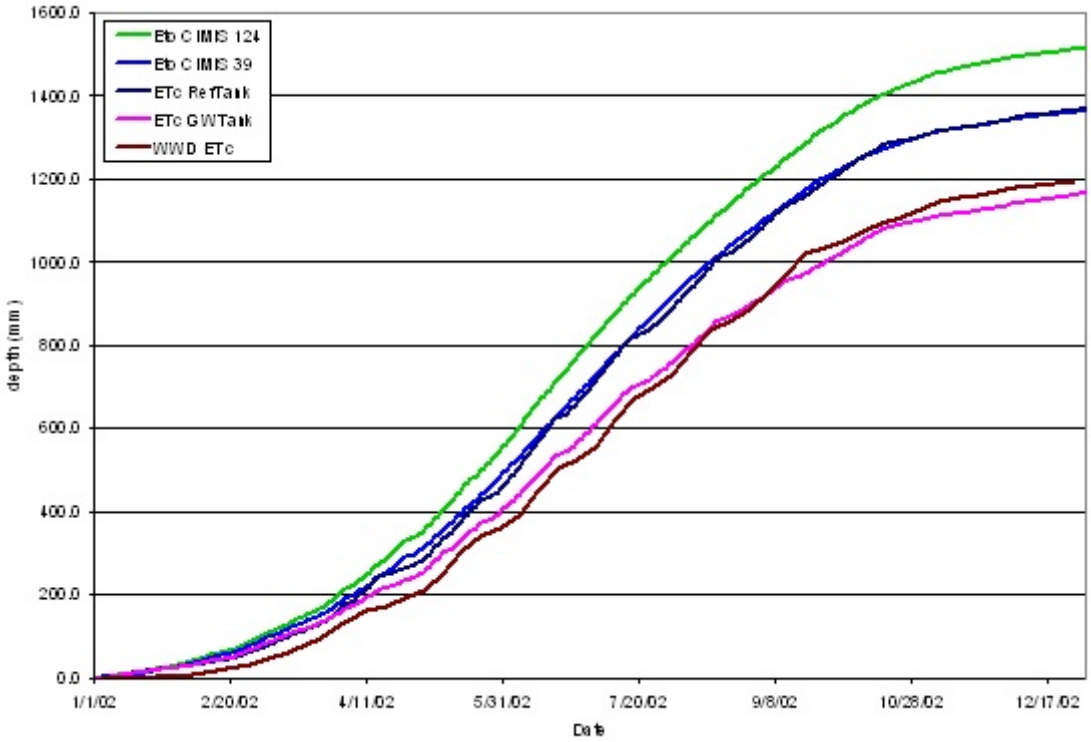



Figure 13 . Comparative values for cumulative alfalfa crop water use for a crop grown on weighing lysimeters and calculated reference evapotranspiration using CIMIS data from Panoche Water District and Parlier, and by Westlands Water District.

The water balance summary for all years is given in table 11. The data show that the plots received between 75 and 90 % of the water requirement calculated by the Westland's Water District water conservation guide.

Table 8. Summary of water balance components for 2002 at Broadview.

| | | | | Irrigation water | | |
|---|---|---|---|---|---|---|
| | Precip (mm) | $ET_o$ (mm) | $ET_w$ (mm) | FRESH (mm) | DRAIN (mm) | GW (mm) |
| Jan | 16.9 | 30.7 | 5.1 | | | |
| Feb | 3.3 | 60.0 | 27.9 | | | |
| March | 15.8 | 107.5 | 61 | 49 | 49 | 49 |
| April | 6.1 | 147.8 | 99 | 166 | 166 | 166 |
| May | 1.3 | 212.1 | 167.7 | | | |
| June | 0 | 237.0 | 165.1 | 124 | 124 | 124 |
| July | 0 | 213.8 | 170.2 | 124 | 124 | 124 |
| August | 0 | 180.7 | 187.9 | 211 | 83 | 83 |
| September | 0 | 146.9 | 152.4 | 131 | 202 | 117 |
| October | 0 | 103.9 | 94 | | | |
| November | 13.9 | 47.8 | 23.3 | | | |
| December | 52.6 | 28.0 | 12.7 | | | |
| Total Mar.-Sept | 23.2 | 1245.8 | 1003.3 | 805 | 748 | 663 |
| Total | 109.9 | 1516.1 | 1166.3 | 805 | 748 | 663 |

Table 9. Summary of water balance components for 2003 at Broadview.

| | | | | Irrigation Water | | |
|---|---|---|---|---|---|---|
| | Precip (mm) | $ET_o$ (mm) | $ET_w$ (mm) | FRESH (mm) | DRAIN (mm) | GW (mm) |
| Jan | 11.9 | 18.07 | 2.5 | | | |
| Feb | 32.9 | 51.85 | 20.3 | | | |
| March | 15.6 | 113.75 | 78.7 | 109 | 109 | 109 |
| April | 15.3 | 121.71 | 66 | 89 | 102 | 102 |
| May | 10.6 | 189.78 | 160 | | | |
| June | 0 | 219.3 | 172.7 | 96 | 117 | |
| July | 0.6 | 222.55 | 172.7 | 201 | 209 | 137 |
| August | 7.3 | 192.57 | 157.5 | 107 | 193 | 126 |
| September | 0 | 158.87 | 188 | 88 | 95 | 95 |
| October | 0.1 | 116.18 | 106 | | | |
| November | 5.3 | 46.82 | 40.6 | 63 | 146 | |
| December | 33.3 | 27.94 | 40.6 | | | |
| Total Mar.-Aug. | 49.4 | 1059.66 | 807.6 | 602 | 730 | 474 |
| Total | 132.9 | 1479.39 | 1205.6 | 753 | 971 | 569 |

Table 10. Summary of water balance components for 2004 at Broadview.

| | | | | Irrigation Water | | |
|---|---|---|---|---|---|---|
| | Precip | $ET_o$ | $ET_w$ | FRESH | DRAIN | GW |
| Jan | 16.2 | 23.3 | 2.5 | | | |
| Feb | 40 | 48.9 | 15.2 | | | |
| March | 4.3 | 122.8 | 63.5 | | | |
| April | 0.1 | 181.9 | 99 | 115 | 115 | 115 |
| May | 1.3 | 217.5 | 157.5 | 96 | 96 | 96 |
| June | 0 | 221.1 | 223.5 | 125 | 223 | 223 |
| July | 0 | 205.9 | 165 | 218 | 103 | 103 |
| August | 0.1 | 182.4 | 281.4 | 104 | 104 | 104 |
| September | 0.7 | 150.5 | 142.2 | | | |
| October | 34.9 | 86.2 | 68.6 | | | |
| November | 4 | 36.3 | 38.1 | | | |
| December | 45.2 | 22.7 | 17.8 | | | |
| Total Mar.-Aug. | 5.8 | 1131.6 | 989.9 | 658 | 641 | 641 |
| Total | 146.8 | 1499.5 | 1274.3 | 658 | 641 | 641 |

Table 11. Water balance summary for plots at Broadview.

| Year | $ET_c$ FRESH (mm) | $ET_c$ DRAIN (mm) | $ET_c$ GW (mm) | $ET_c$ WWD (mm) |
|---|---|---|---|---|
| 2002 | 907 | 841 | 756 | 1003 |
| 2003 | 721 | 849 | 593 | 807 |
| 2004 | 734 | 717 | 717 | 989 |

**1.5 Salt**

The sustainability of a reuse system will depend on the salt management within the soil profile and the accumulation of salt in the groundwater. The “salt balance” is a concept that is used to quantify the salt management within an agricultural area. Conventional thinking says that as much salt should leave the area as comes into it. This will ensure no accumulation of salt in the soil profile and should sustain the production system. This approach to salt management is no longer possible in the BWD on the westside of the San Joaquin Valley because of limitations on drainage water disposal. Instead, the approach will be to manage salt in the crop root zone to limit the accumulation to levels that are not injurious to crop production. Salt in the root zone will have to be moved out of the root zone and lower into the soil profile or into the groundwater. This suggests that without salt disposal there will be a finite life span for a field and there will be a progression of more salt tolerant crops as the soil becomes more saline. The following sections provide a basis for analyzing the salt balance within this field site.

*1.5.1 Drainage Salt load*

The flow and water quality data from sump 33-1 are given in Table 12 for 2002 and into 2003. The highest flows are in the spring and summer in response to the deep percolation from pre-plant irrigation and winter rainfall with the lowest flow occurring in the fall and winter. The electrical conductivity of the drainage water in the sump ranges from about 4 to 9 dS/m. This is a relatively high salinity and will restrict the potential for crop water use from shallow groundwater. The Maas-Hoffman (Maas 1990) threshold value for salinity tolerance of alfalfa is 2 dS/m. The EC in the drainage water is nearly 3 times the threshold and will be of limited value as a water supply (Ayars and Hutmacher, 1994).

Table 12. Summary of flow and water quality components of drainage water for 2002 and 5 months in 2003 at Sump 33-1 in Broadview Water District.

| Month | Flow (ML) | EC (dS/m) | B (ppm) | Se (ppm) | Mo (ppm) |
|---|---|---|---|---|---|
| Jan. | 9.0 | 5.16 | 6.23 | 0.223 | 0.05 |
| Feb. | 12.6 | 5.25 | 6.0 | 0.23 | 0.06 |
| March | 14.9 | 7.34 | 7.9 | 0.149 | 0.03 |
| April | 14.0 | 8.75 | 11.6 | 0.242 | 0.03 |
| May | 15.3 | 6.66 | 8.6 | 0.224 | 0.08 |
| June | 12.3 | 5.41 | 8.9 | 0.24 | 0.08 |
| July | 12.1 | 7.04 | 9.1 | 0.244 | 0.08 |
| August | 12.9 | 6.55 | 9.8 | 0.302 | 0.09 |
| Sept. | 10.0 | 6.2 | 10.0 | 0.3 | 0.09 |
| Oct. | 4.9 | 6.23 | 7.95 | .367 | .07 |
| Nov. | 7.9 | 6.12 | 9.06 | .262 | .09 |
| Dec. | 5.3 | 5.93 | 9.1 | .325 | .08 |
| Jan (03) | 3.1 | 5.58 | 7.2 | .264 | .07 |
| Feb (03) | 11.7 | 4.73 | 7.89 | .234 | .08 |
| Mar (03) | 6.6 | 4.14 | 7.5 | .276 | .07 |
| May (03) | 0 | 3.5 | 7.25 | .23 | .09 |
| July (03) | 0 | 4.5 | 6.2 | .211 | .08 |

The boron concentration is potentially a bigger problem. The concentrations in the drainage water exceed the boron tolerance values of most high value crops. However, most alfalfa varieties have been rated as very boron tolerant (Maas, 1990), so this should not be a problem in either in-situ groundwater use or in a supplemental irrigation supply. The extent of boron uptake by the plant will be a critical determination for using saline water for irrigation of plant material being fed to animals.

*1.5.2 Groundwater quality*

The groundwater observation wells in field 33 were sampled periodically starting in the summer of 2002. At the beginning of 2003 the sampling was done approximately monthly until October 2004. The electrical conductivity (EC), boron (B), and nitrate ($NO_3$) data are summarized in tables 13, 14, and 15, respectively. The EC and B data are higher in the groundwater under the

field than what is being measured in the discharge from sump 33-1 which collected water from the subsurface drainage system under the field and from fields south of the test field. This suggests that water coming from the fields south of the test site was of a relatively better quality than under the field. The net result was a dilution of the saline water being withdrawn from under the field when the sump operates.

The EC data were plotted in Fig. 14, 15, and 16 for the GW, DRAIN, and FRESH treatments, respectively. The values from all wells in the respective treatment have been plotted on the graph as a function of time. There is no readily discernable pattern of increasing or decreasing EC with time. The data from each treatment were averaged by sample date and the average data were plotted in Fig. 17. These data demonstrate a distinct pattern of concentration increasing during the irrigation season followed by a decrease over the winter months with an increase in the next irrigation season.

The relative position of the average salinity levels by the Sept. 2004 sampling is of interest because the relative position changes with time over the period. The highest salinity is in the DRAIN treatment that was irrigated twice between harvest with saline drainage water. The intermediate value is under the FRESH treatment which was irrigated twice between harvest with low salinity water. The lowest average salinity is in the GW treatment that was irrigated once between harvests with saline water. When the variability of the data are considered there is probably no difference between the treatments. There is a seasonal variation in all treatments in response to the applied irrigation water. The decrease in EC follows the winter with rainfall and pre-plant irrigation contributing to shallow groundwater.

The boron data were averaged over the same time period as the EC data and these data are presented in Fig. 18. These data tended to follow the same trends as did the EC data.

Table 13. Summary of electrical conductivity of groundwater in wells on field 33 Broadview Water District.

| | | EC (dS/m) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| well | Plot | 7/3/02 | 12/2/2003 | 1/28/2003 | 3/25/2003 | 5/29/2003 | 6/22/2003 | 8/22/2003 | 9/22/2003 | 11/13/2003 |
| 71 | 1 | 6.3 | 10.5 | 11.6 | 9.7 | 10.4 | 11.3 | 12.7 | 11.5 | 13.3 |
| 72 | 2 | 31.7 | 29.2 | 27.7 | 18.4 | 25.7 | 13.6 | 11.6 | 18.2 | 24.5 |
| 73 | 3 | 31.5 | 27.3 | 24.9 | 18.4 | 22.1 | 19.4 | 21.2 | 19.4 | 22.6 |
| 74 | 4 | 29.6 | 24.6 | 19.9 | 12.3 | 7.05 | 9.0 | 11.1 | 11.8 | 10.6 |
| 75 | 5 | 2.9 | 20.7 | 19.0 | 6.9 | 3.7 | 6.8 | 13.6 | 14.6 | 17.5 |
| 76 | 6 | 23.8 | 23.1 | 21.6 | 21.2 | 22.0 | 24.1 | 21.0 | 18.6 | 22.4 |
| 77 | 7 | 17.8 | 19.1 | 16.8 | 15.8 | 17.4 | 18.7 | 18.3 | 16.5 | 18.2 |
| 78 | 8 | 37.0 | 35.1 | 32.3 | 23.0 | 24.6 | 28.6 | 30.7 | 29.5 | 26.6 |
| 79 | 9 | 36.9 | 30.1 | 29.2 | 19.6 | 14.4 | 6.4 | 6.4 | 13.6 | 18.8 |
| 80 | 9 | 26.4 | 29.0 | 26.8 | 20.7 | 26.7 | 27.5 | 26.5 | 24.8 | 27.2 |
| 81 | 8 | 18.6 | 25.6 | * | 9.6 | 26.2 | 27.3 | 27.3 | 25.7 | 29.2 |
| 82 | 7 | 27.6 | 29.2 | * | 15.0 | 24.1 | 26.1 | 25.6 | 23.0 | 22.3 |
| 83 | 6 | 33.8 | 29.8 | 27.0 | 19.2 | 27.6 | 28.5 | 26.2 | 24.3 | 2.6 |
| 84 | 5 | 18.6 | 26.0 | * | 23.5 | 22.1 | 24.6 | 23.4 | 24.7 | 24.8 |
| 85 | 4 | 18.5 | 22.7 | 27.3 | 11.8 | 20.5 | 15.6 | 32.4 | 26.3 | 21.5 |
| 86 | 3 | 28.6 | 30.5 | 29.3 | 9.7 | 25.4 | 29.2 | 2.4 | 14.2 | 21.4 |
| 87 | 2 | 5.0 | 11.8 | 13.6 | 4.6 | 18.6 | 15.6 | 8.1 | 13.4 | 17.5 |
| 88 | 1 | 12.1 | 13.4 | 13.2 | 1.0 | 9.5 | 11.0 | 12.0 | 11.7 | 13.1 |

Table 13. Cont'd. Summary of electrical conductivity of groundwater in wells on field 33 Broadview Water District

| | | EC (dS/m) | | | | | |
|---|---|---|---|---|---|---|---|
| well | Plot | 3/25/2004 | 4/27/2004 | 5/18/2004 | 7/7/2004 | 8/24/2004 | 10/4/2004 |
| 71 | 1 | 13.7 | 13.1 | 12.3 | 14. | 13.2 | 13.6 |
| 72 | 2 | 29.4 | 28.5 | 22.4 | 28 | 27 | 30.1 |
| 73 | 3 | 25.4 | nd | 19.8 | 21.4 | 15.4 | 20 |
| 74 | 4 | 17.3 | 16.1 | 9.8 | 8.4 | 6.7 | 9.8 |
| 75 | 5 | 23.5 | 20.3 | 15.1 | 8.4 | 9.4 | 11.5 |
| 76 | 6 | 25.8 | 25.2 | 16.4 | 25 | 21.1 | 24.7 |
| 77 | 7 | 18.2 | 18.4 | 16.6 | 19.3 | 17.6 | 19.5 |
| 78 | 8 | 35.6 | 31.3 | 5.3 | 10.7 | 15.2 | 11.4 |
| 79 | 9 | 30.3 | 4.4 | 17.8 | 1.4 | 3.1 | 2.7 |
| 80 | 9 | 29.9 | 6.5 | 20.3 | 17.6 | 21.7 | 24.6 |
| 81 | 8 | 32 | 23.7 | 16.1 | 8.8 | 15.9 | 18.4 |
| 82 | 7 | 25.3 | 24.8 | 19.6 | 13.6 | 17.6 | 20.5 |
| 83 | 6 | 12.7 | 11.9 | 9.5 | 13.7 | 11.5 | 14.5 |
| 84 | 5 | 30.5 | 16 | 11.4 | 22.8 | 19.2 | 3.3 |
| 85 | 4 | 28.6 | 27.7 | 20.1 | 20.5 | 16.5 | 22.3 |
| 86 | 3 | 32.1 | 19.7 | 4.9 | 17.1 | 19.8 | 26.1 |
| 87 | 2 | 20.9 | nd | 18.7 | 22.2 | 21.8 | 22.6 |
| 88 | 1 | 14 | 12.5 | 11.7 | 13.4 | 13.2 | 13.6 |

Table 14. Summary of boron concentration in groundwater wells in field 33 Broadview Water District.

| | | B (mg/L) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| well | Plot | 7/3/02 | 12/2/2003 | 1/28/2003 | 3/25/2003 | 5/29/2003 | 6/22/2003 | 8/22/2003 | 9/22/2003 | 11/13/2003 |
| 71 | 1 | 7.9 | 17.4 | 24.5 | 17.8 | 20.5 | 20.5 | 21.7 | 22.3 | 33.2 |
| 72 | 2 | 41.4 | 49.1 | 50.6 | 29.7 | 43.1 | 15.7 | 13.6 | 25.0 | 43.0 |
| 73 | 3 | 37.0 | 39.9 | 43.3 | 32.4 | 41.2 | 33.8 | 29.5 | 32.6 | 49.7 |
| 74 | 4 | 48.5 | 50.5 | 43.9 | 28.0 | 13.7 | 20.0 | 13.6 | 21.7 | 21.8 |
| 75 | 5 | 2.1 | 20.5 | 18.9 | 7.1 | 8.0 | 15.2 | 7.2 | 16.1 | 23.8 |
| 76 | 6 | 24.0 | 29.6 | 28.9 | 29.8 | 31.7 | 26.9 | 16.5 | 24.2 | 35.9 |
| 77 | 7 | 24.3 | 32.8 | 30.2 | 31.1 | 22.6 | 31.9 | 19.5 | 28.7 | 39.2 |
| 78 | 8 | 49.3 | 59.3 | 58.3 | 28.5 | 35.9 | 47.7 | 32.0 | 47.5 | 50.1 |
| 79 | 9 | 53.9 | 53.9 | 53.9 | 37.4 | 23.2 | 11.4 | 32.6 | 20.9 | 36.6 |
| 80 | 9 | 43.7 | 59.4 | 60.1 | 45.2 | 58.4 | 55.4 | 38.4 | 55.9 | 70.1 |
| 81 | 8 | 28.2 | 44.8 | * | 18.3 | 49.7 | 50.1 | 37.9 | 20.6 | 66.6 |
| 82 | 7 | 35.9 | 36.8 | * | 26.6 | 43.4 | 41.4 | 26.2 | 39.5 | 44.7 |
| 83 | 6 | 44.5 | 34.0 | 51.7 | 32.7 | 46.9 | 45.1 | 27.3 | 40.2 | 7.2 |
| 84 | 5 | 14.7 | 23.1 | * | 25.1 | 24.6 | 25.5 | 12.6 | 27.0 | 32.3 |
| 85 | 4 | 14.8 | 21.6 | 63.2 | 17.4 | 32.2 | 21.9 | 33.8 | 44.4 | 39.5 |
| 86 | 3 | 42.5 | 36.9 | 15.6 | 18.2 | 51.1 | 55.0 | 7.1 | 23.8 | 44.0 |
| 87 | 2 | 4.1 | 11.1 | 33.5 | 5.1 | 27.2 | 21.2 | 3.6 | 18.0 | 29.0 |
| 88 | 1 | 22.5 | 44.6 | 20.6 | 0.04 | 24.1 | 25.1 | 18.0 | 26.7 | 37.4 |

Table 14. Cont'd. Summary of boron concentration in groundwater wells in field 33 Broadview Water District.

| | | B (mg/L) | | | | | |
|---|---|---|---|---|---|---|---|
| well | Plot | 3/25/2004 | 4/27/2004 | 5/18/2004 | 7/7/2004 | 8/24/2004 | 10/4/2004 |
| 71 | 1 | 31.0 | 14.8 | 38.4 | 29.0 | 27.4 | 29.5 |
| 72 | 2 | 41.8 | 14.7 | 42.8 | 37.0 | 35.9 | 43.4 |
| 73 | 3 | 43.7 | nd | 44.2 | 31.3 | 23.6 | 31.4 |
| 74 | 4 | 37.3 | 14.6 | 25.5 | 11.8 | 11.4 | 15.8 |
| 75 | 5 | 29.4 | 14.4 | 23.2 | 10.6 | 12.0 | 17.2 |
| 76 | 6 | 33.1 | 34.9 | 28.3 | 27.0 | 24.4 | 28.7 |
| 77 | 7 | 32.8 | 36.8 | 39.0 | 29.7 | 28.0 | 31.6 |
| 78 | 8 | 56.8 | 54.3 | 13.7 | 13.9 | 20.4 | 15.3 |
| 79 | 9 | 53.4 | 10.7 | 38.2 | 6.3 | 8.2 | 6.9 |
| 80 | 9 | 62.4 | 15.6 | 51.0 | 29.0 | 39.5 | 47.8 |
| 81 | 8 | 63.4 | 51.3 | 37.5 | 12.2 | 24.1 | 30.2 |
| 82 | 7 | 46.8 | 51.7 | 44.3 | 19.2 | 27.3 | 32.5 |
| 83 | 6 | 16.3 | 18.8 | 18.3 | 15.8 | 16.1 | 19.1 |
| 84 | 5 | 32.8 | 21.2 | 18.8 | 22.2 | 21.8 | 7.4 |
| 85 | 4 | 48.9 | 53.9 | 42.3 | 26.8 | 23.2 | 31.7 |
| 86 | 3 | 62.9 | 33.1 | 13.5 | 24.5 | 32.2 | 40.5 |
| 87 | 2 | 30.4 | nd | 34.2 | 27.8 | 28.4 | 32.2 |
| 88 | 1 | 35.3 | 38.1. | 39.9 | 82.7 | 29.8 | 33.4 |

Table 15. Summary of nitrate levels in groundwater wells in field 33 Broadview Water District.

| | | $NO_3$ (mg/L) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| well | Plot | 7/3/02 | 12/2/2003 | 1/28/2003 | 3/25/2003 | 5/29/2003 | 6/22/2003 | 8/22/2003 | 9/22/2003 | 11/13/2003 |
| 71 | 1 | 0.3 | 6.8 | 33.5 | 40.2 | 46.3 | 39.8 | 40.5 | 35.6 | 43.5 |
| 72 | 2 | 468.4 | 545.5 | 408.0 | 305.1 | 235.7 | 127.0 | 101.5 | 214.6 | 282.4 |
| 73 | 3 | 292.6 | 246.7 | 242.8 | 176.4 | 243.0 | 212.8 | 145.7 | 183.4 | 236.1 |
| 74 | 4 | 311.6 | 305.0 | 224.3 | 138.8 | 57.4 | 71.5 | 94.8 | 123.3 | 87.1 |
| 75 | 5 | 13.7 | 369.9 | 306.7 | 102.8 | 22.6 | 62.1 | 203.1 | 281.5 | 361.0 |
| 76 | 6 | 182.9 | 193.7 | 233.0 | 248.2 | 301.8 | 322.6 | 262.9 | 241.7 | 338.2 |
| 77 | 7 | 171.7 | 210.0 | 192.1 | 203.4 | 223.4 | 272.1 | 223.4 | 266.3 | 239.0 |
| 78 | 8 | 244.4 | 284.2 | 246.7 | 188.8 | 175.0 | 264.1 | 219.1 | 257.1 | 205.4 |
| 79 | 9 | 470.2 | 495.6 | 420.1 | 276.8 | 187.7 | 44.2 | 46.1 | 189.6 | 246.6 |
| 80 | 9 | 159.4 | 182.5 | 191.2 | 145.0 | 211.1 | 215.4 | 201.8 | 203.5 | 239.1 |
| 81 | 8 | 69.3 | 115.5 | * | 49.4 | 150.9 | 200.7 | 189.1 | 154.4 | 193.9 |
| 82 | 7 | 308.6 | 431.2 | * | 200.4 | 341.2 | 422.0 | 358.0 | 351.4 | 323.6 |
| 83 | 6 | 292.9 | 317.0 | 239.8 | 215.9 | 306.6 | 339.6 | 342.6 | 317.0 | 7.4 |
| 84 | 5 | 89.6 | 332.8 | * | 189.8 | 200.8 | 227.8 | 216.2 | 307.0 | 287.8 |
| 85 | 4 | 168.5 | 280.5 | 362.7 | 157.8 | 291.9 | 182.2 | 543.7 | 508.7 | 358.4 |
| 86 | 3 | 168.8 | 206.6 | 198.9 | 55.8 | 162.6 | 191.7 | 39.4 | 79.4 | 183.2 |
| 87 | 2 | 7.36 | 7.2 | 32.4 | 13.4 | 9.4 | 21.3 | 41.9 | 10.6 | 13.8 |
| 88 | 1 | 76.4 | 200.2 | 113.5 | 4.9 | 74.0 | 74.6 | 38.9 | 85.4 | 98.2 |

Table15. Cont'd. Summary of nitrate levels in groundwater wells in field 33 Broadview Water District.

| | | $NO_3$ (mg/L) | | | | | |
|---|---|---|---|---|---|---|---|
| well | Plot | 3/25/2004 | 4/27/2004 | 5/18/2004 | 7/7/2004 | 8/24/2004 | 10/4/2004 |
| 71 | 1 | 46.3 | 76.7 | 47.7 | 44.6 | 35.5 | 34.9 |
| 72 | 2 | 386.8 | 549.3 | 380.0 | 410.8 | 377.2 | 356.3 |
| 73 | 3 | 272.4 | nd | 187.4 | 174.8 | 143.9 | 146.9 |
| 74 | 4 | 200.0 | 212.3 | 98.5 | 40.3 | 33.9 | 63.0 |
| 75 | 5 | 678.3 | 445.8 | 356.4 | 38.3 | 76.3 | 119.5 |
| 76 | 6 | 303.8 | 387.4 | 224.6 | 347.8 | 258.1 | 294.7 |
| 77 | 7 | 217.1 | 257.3 | 211.6 | 243.3 | 206.9 | 212.8 |
| 78 | 8 | 234.4 | 273.3 | 25.4 | 58.0 | 73.9 | 51.3 |
| 79 | 9 | 490.6 | 45.3 | 237.9 | 1.9 | 4.8 | 5.1 |
| 80 | 9 | 219.5 | 52.1 | 172.2 | 109.2 | 153.1 | 157.8 |
| 81 | 8 | 161.0 | 179.0 | 94.9 | 42.3 | 75.6 | 68.5 |
| 82 | 7 | 325.3 | 405.4 | 277.2 | 121.0 | 211.9 | 236.7 |
| 83 | 6 | 118.0 | 149.0 | 91.8 | 121.5 | 94.6 | 122.5 |
| 84 | 5 | 332.8 | 215.2 | 134.3 | 235.3 | 199.7 | 7.3 |
| 85 | 4 | 427.2 | 549.3 | 323.7 | 245.1 | 194.9 | 232.1 |
| 86 | 3 | 263.5 | 52.6 | 27.3 | 119.5 | 149.7 | 142.6 |
| 87 | 2 | 54.1 | nd | 35.2 | 26.7 | 24.6 | 26.5 |
| 88 | 1 | 95.0 | 136.4 | 98.2 | 29.2 | 86.7 | 90.2 |

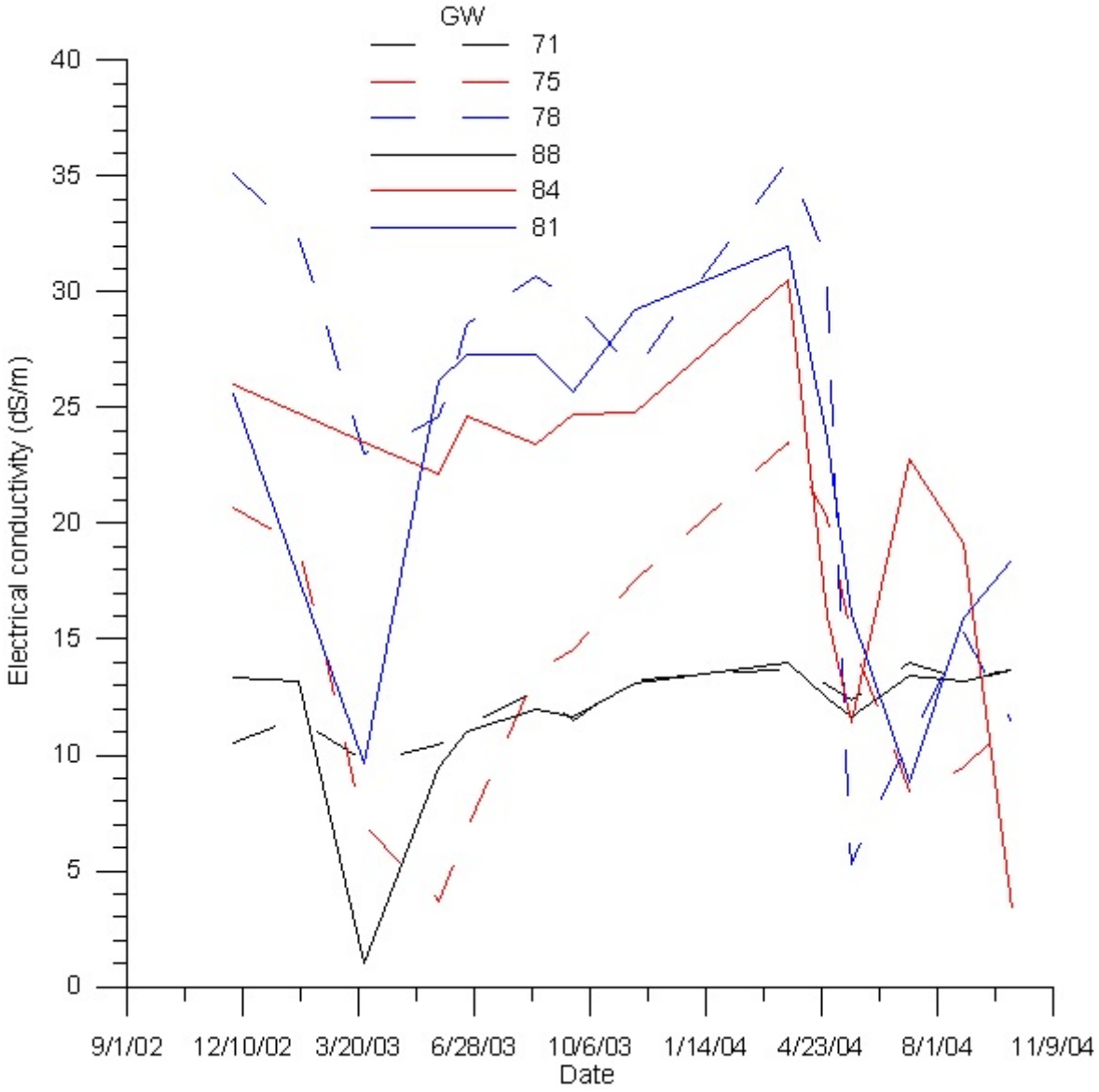



Figure 14. Electrical conductivity of shallow groundwater in GW treatment wells at Broadview Water District.

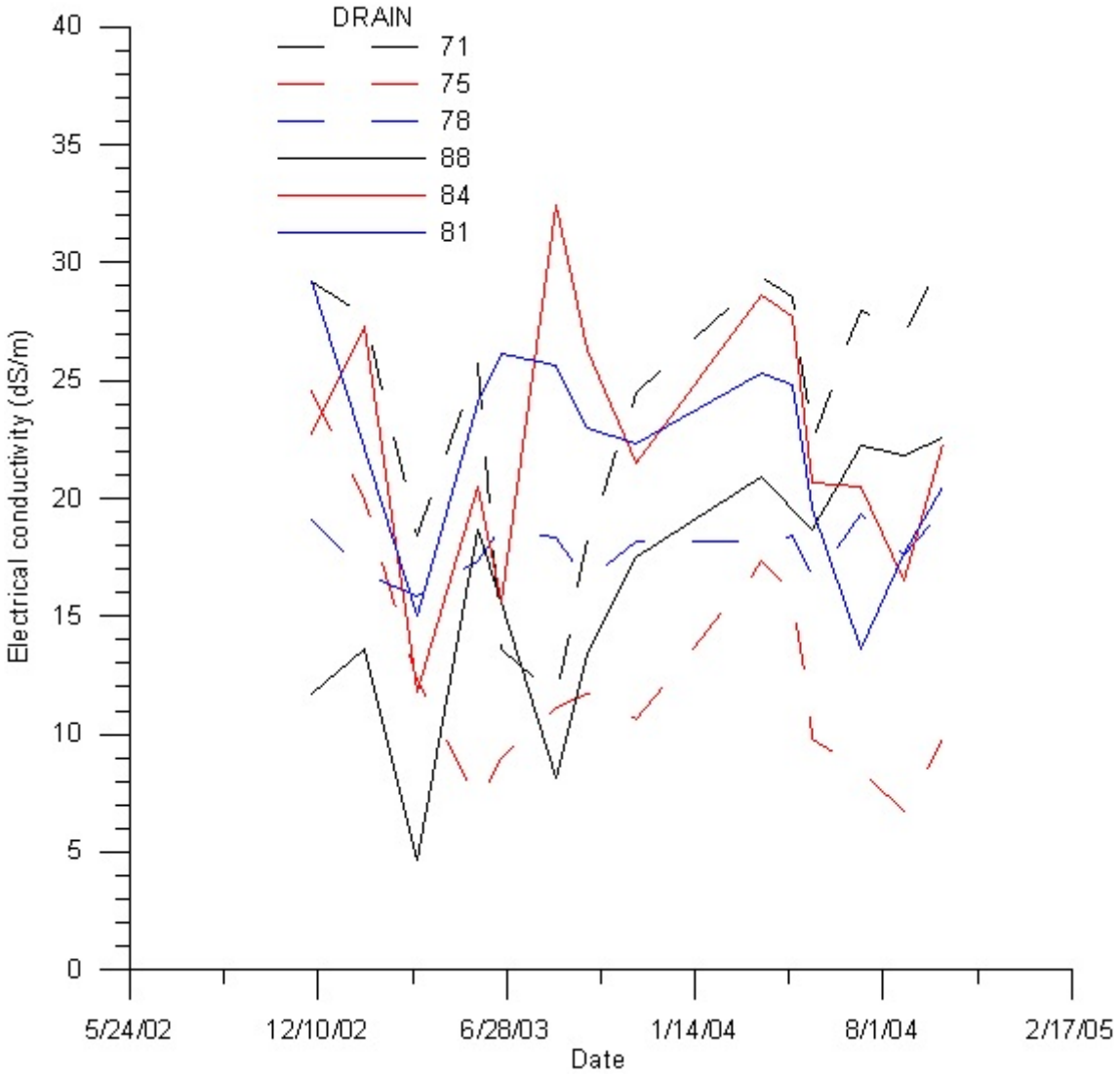



Figure 15. Electrical conductivity of shallow groundwater in DRAIN treatment wells at Broadview Water District.

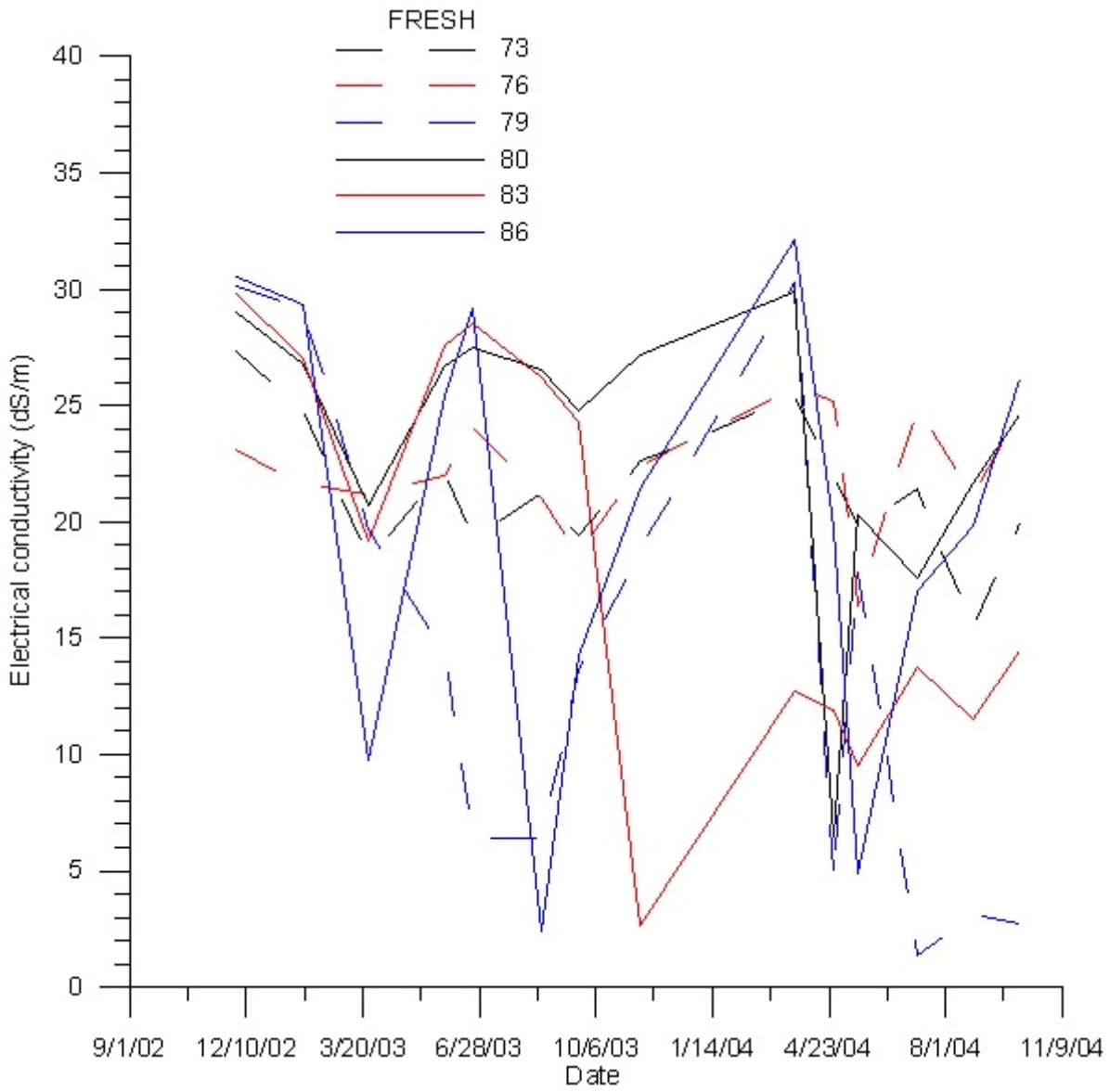



Figure 16. Electrical conductivity of shallow groundwater in FRESH treatment wells at Broadview Water District.

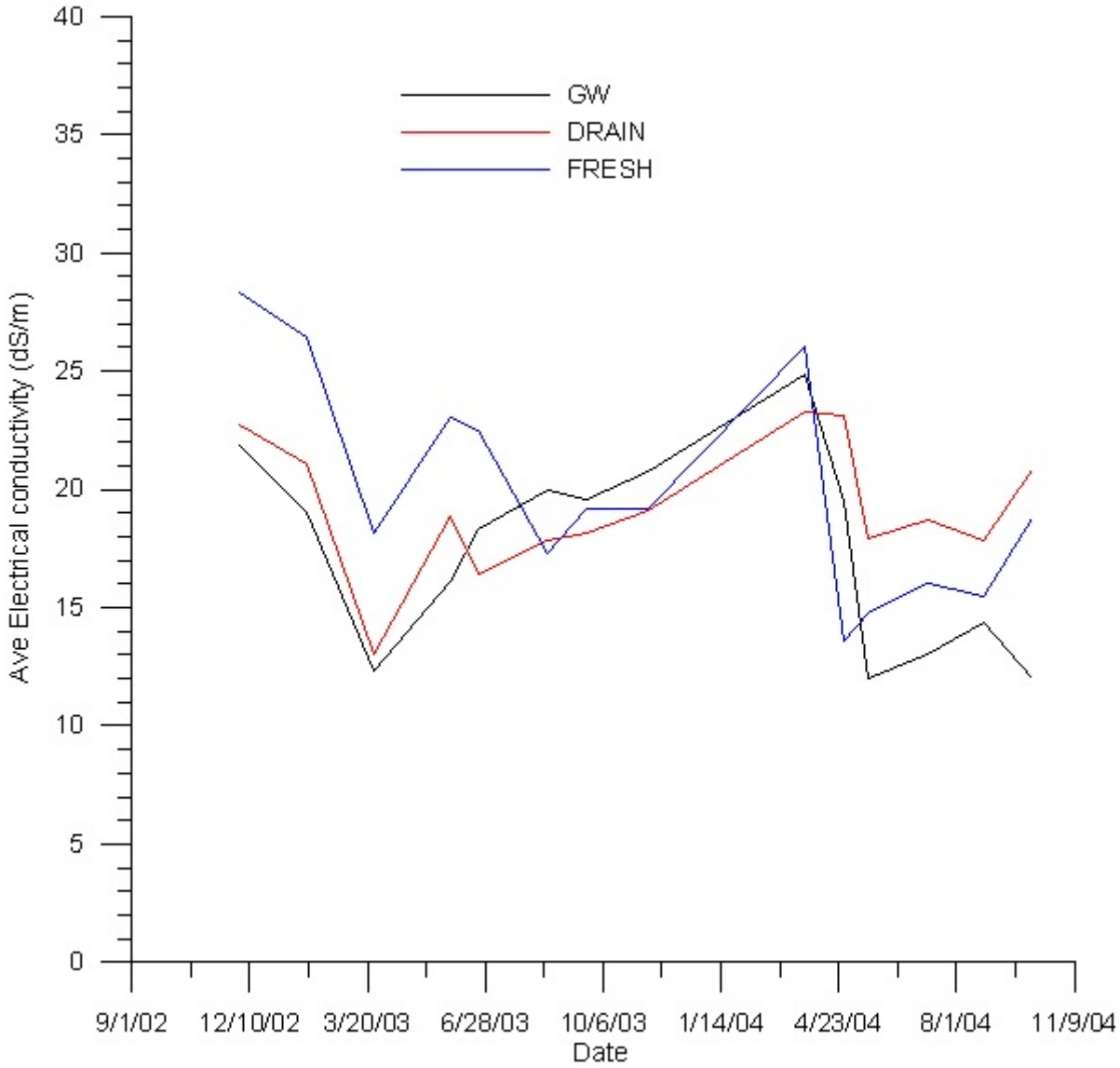



Figure 17. Average electrical conductivity of shallow groundwater under each of the irrigation treatments at Broadview Water District.

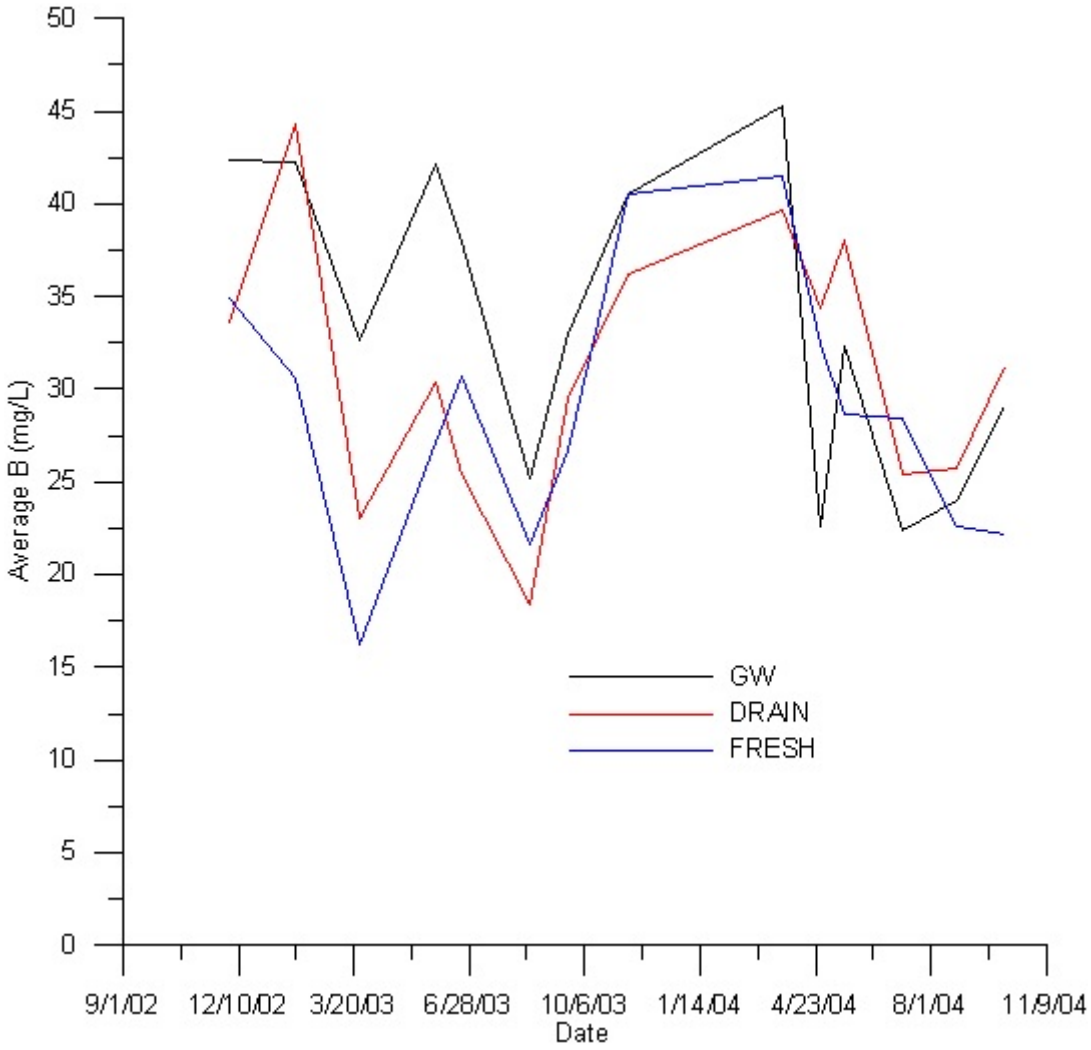



Figure 18. Average boron concentration in shallow groundwater under plots at Broadview Water District.

*1.5.3 Irrigation salt load*

The salt load applied each year was estimated based on the total applied irrigation water and the electrical conductivity assuming a value of 640 ppm salt for 1 dS/m. The results are summarized in tables 16 -19. The total salt load is directly proportional to the depth of applied water and the salinity of the water. In the two years of the project there was approximately 7 T/ha applied to the FRESH treatment, 55 T/ha applied to the Drain treatment, and 35 T/ha applied to the GW treatment. The change in salt mass in the soil profile is given in Fig. 19. These data are for the period before the start of the project in 2001 and at the end of the project in 2004. The accumulation of salt was primarily in the top 60 cm of the soil profile. The initial salinity profile in each treatment was similar at the beginning of the project.

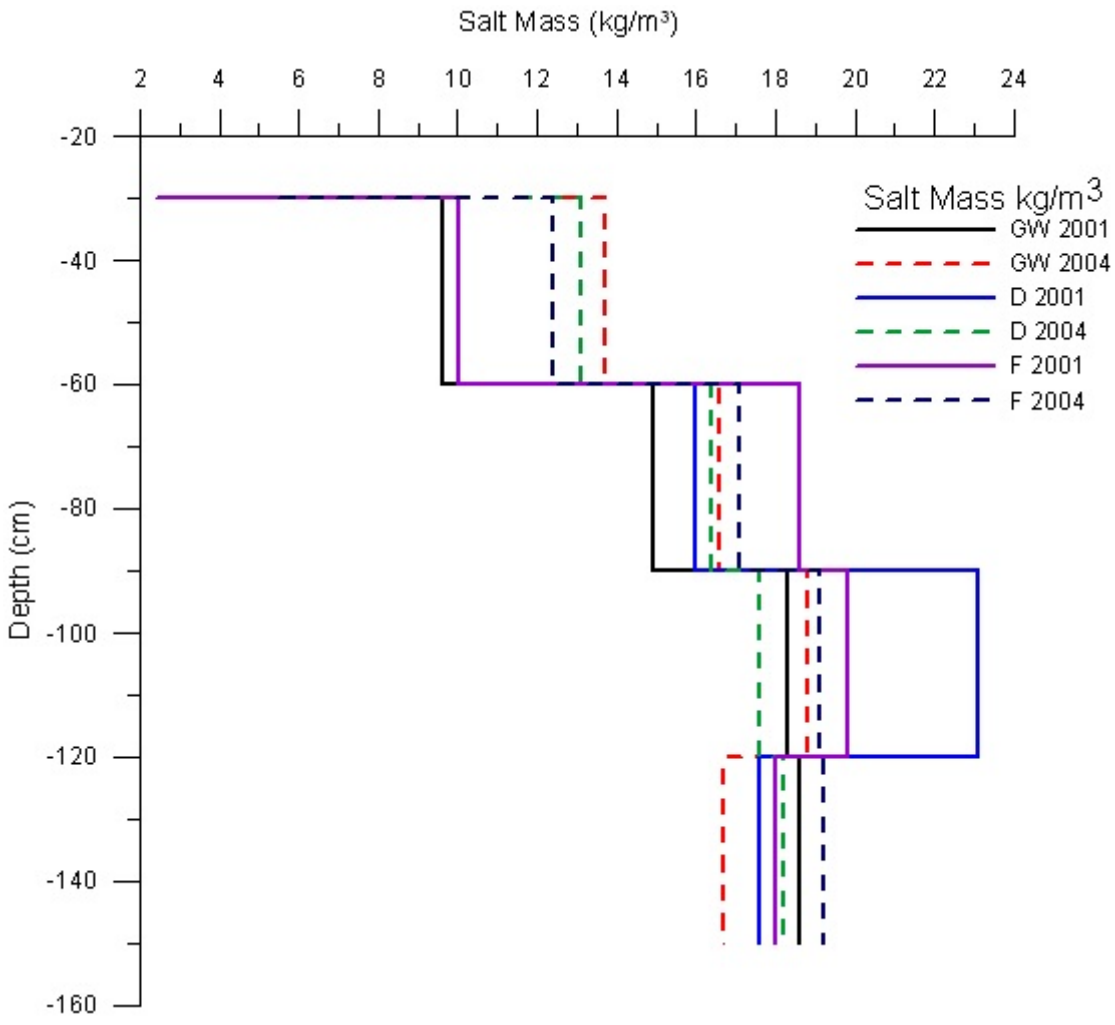



Figure 19. Salt mass in the soil profile by irrigation treatment for Spring 2001 and Fall 2004.

The data in Fig. 19 show that salinity increased in the 0 - 60 cm part of the soil profile during the course of the project. From 60 to 90 cm the salt mass increased in the DRAIN and GW treatments and decreased in the FRESH treatment. Below 90 cm there was leaching taking place with a reduction of salinity in all the treatments.

Table 16. Summary of salt load applied in 2002.

| | FRESH | DRAIN | | GW | |
|---|---|---|---|---|---|
| Date | NS (kg/ha) | NS (kg/ha) | S (kg/ha) | NS (kg/ha) | S (kg/ha) |
| 3/5/2002 | 144 | 144 | | 144 | |
| 4/5/2002 | 132 | 132 | | 132 | |
| 4/29/2002 | 356 | 356 | | 356 | |
| 6/7/2002 | 254 | 254 | | 254 | |
| 7/16/2002 | 413 | 254 | | 254 | |
| 8/5/2002 | 319 | 319 | | 319 | |
| 8/28/2002 | 492 | | | | |
| 9/3/2002 | | | 4493 | | 4493 |
| 9/25/2002 | 562 | | | | |
| 9/27/2002 | | | 3264 | | |
| Total | 2672 | 1460 | 7757 | 1460 | 4493 |

Table 17. Summary of applied salt load in 2003.

| | FRESH | DRAIN | | GW | |
|---|---|---|---|---|---|
| Date | NS (kg/ha) | NS (kg/ha) | S (kg/ha) | NS (kg/ha) | S (kg/ha) |
| 3/17/2003 | 279 | 279 | | 279 | |
| 4/28/2003 | 228 | | 3917 | | 3917 |
| 5/30/2003 | 246 | | 4493 | | 0 |
| 7/1/2003 | 515 | | 6554 | | 4296 |
| 8/11/2003 | 274 | | 8276 | | 5403 |
| 9/24/2003 | 225 | | 5350 | | 5350 |
| 10/14/2003 | 161 | | 6447 | | |
| Total | 1928 | 279 | 35037 | 279 | 18966 |

Table 18. Summary of salt load applied in 2004.

| Treatment | FRESH | DRAIN | | GW | |
|---|---|---|---|---|---|
| Date | NS (kg/ha) | NS (kg/ha) | S (kg/ha) | NS (kg/ha) | S (kg/ha) |
| 4/21/2004 | 324 | 324 | | 324 | |
| 5/11/2004 | 270 | 270 | | 270 | |
| 6/7/2004 | 648 | | | | |
| 6/14/2004 | | | 5674 | | 5225 |
| 6/28/2004 | | | 4238 | | 4238 |
| 7/6/2024 | 503 | | | | |
| 7/22/2004 | 433 | | | | |
| 7/29/2004 | | | | | |
| 8/16/2004 | 253 | | | | |
| total | 2431 | 594 | 9912 | 594 | 9463 |

Table 19. Summary of salt load applied from 2002 to 2004.

| | FRESH | DRAIN | | GW | |
|---|---|---|---|---|---|
| Year | NS (kg/ha) | NS (kg/ha) | S (kg/ha) | NS (kg/ha) | S (kg/ha) |
| 2002 | 2672 | 1460 | 7757 | 1460 | 4493 |
| 2003 | 1928 | 279 | 35037 | 279 | 18966 |
| 2004 | 2431 | 594 | 9912 | 594 | 9463 |
| Total | 7030 | 2333 | 52706 | 2333 | 32922 |

*1.5.4 Soil Salinity*

The distribution of soil salinity was characterized using soil sampling and by electromagnetic induction (EM) using an EM-38[2]. Protocols for mobile soil mapping methods developed by the personnel at the George E. Brown Jr. Salinity Laboratory were used for the EM-38 studies. The soil sampling occurred in the spring and fall of each year while the EM-38 was used in the Spring of 2003 and 2004. The EM-38 was operated in both horizontal and vertical modes to characterize the apparent salinity distribution in the surface layers and deeper into the profile. The data were tracked with a global position system (GPS) that enabled the data to be plotted on a map that corresponds to the other maps being used in the research.

The EM-38 data apparent electrical conductivity ($EC_a$) are mapped in figure 20a and 20b for 2003 and 21a and 21b for 2004. The scales were maintained from year to year but there are some differences in the color coding associated with the scales for subsequent years. It is important to realize that the data are averaged over depth and are good for indicating patterns of accumulation but don't provide data for specific depths. For this study the data demonstrate the effect of the different water qualities on the accumulation of salinity. Year to year variation can also be evaluated. These data are not the actual EC since the $EC_a$ data were not calibrated to EC using soil samples take at the time EM data were taken.

The data show there was a progressive accumulation of salt when saline water was applied compared to the application of fresh water. There is also a difference between the DRAIN and groundwater treatment. In this case the DRAIN treatment received two irrigations between harvests and the groundwater treatment only received one. This resulted in the drainage treatment becoming more saline than the groundwater treatment. The lowest salinity was found in the FRESH treatment as would be expected. The vertical measurements were more saline than the horizontal treatments for a given treatment demonstrating the increased soil salinity with depth.

The average EC for the soil samples are plotted by depth for each of the irrigation treatments for the fall of 2001, 2004 and the spring of 2005 in figure 22. The resident EC and the resident Cl

[2]Use of a trade name does not imply endorsement by USDA-ARS.

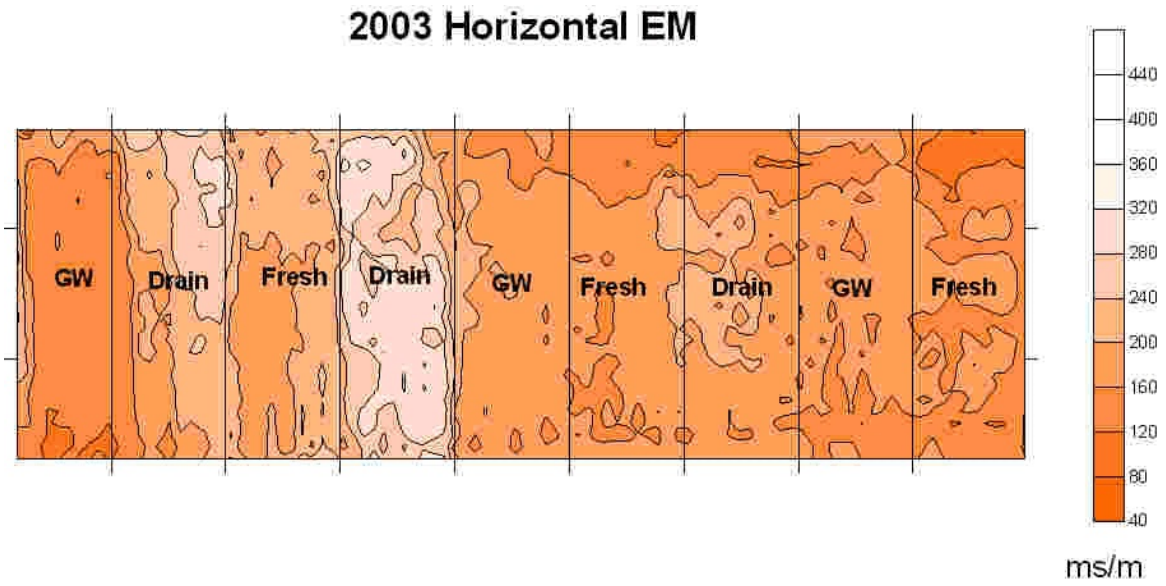
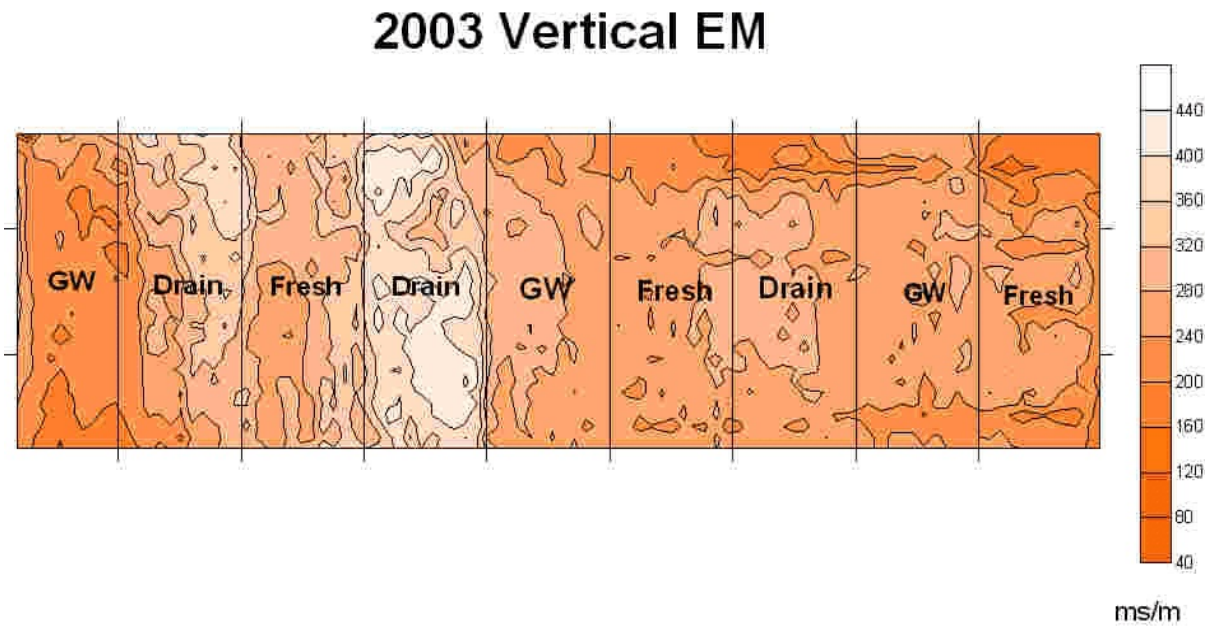



Figure 20a. Apparent soil electrical conductivity measured with EM-38 in horizontal mode in the spring 2003 on field 33 of the Broadview Water District.




20b. Apparent soil electrical conductivity measured with EM-38 in the vertical mode in the spring 2003 on field 33 of the Broadview Water District.

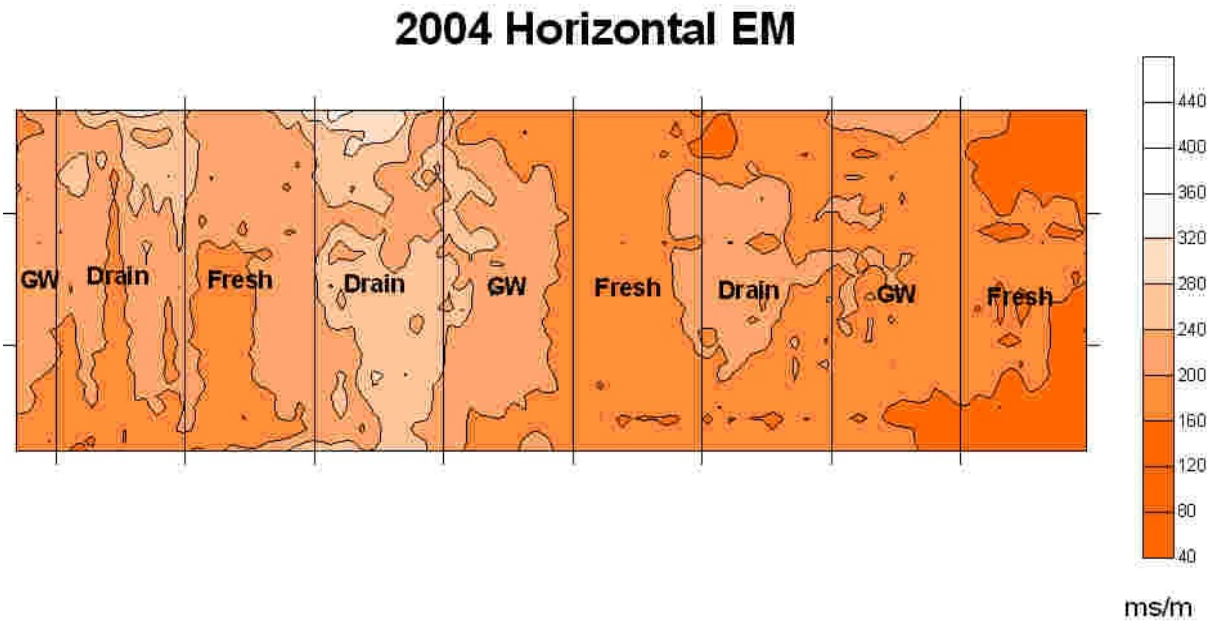



Figure 21a. Apparent soil electrical conductivity measured with EM-38 in horizontal mode in the spring 2004 on field 33 of the Broadview Water District.

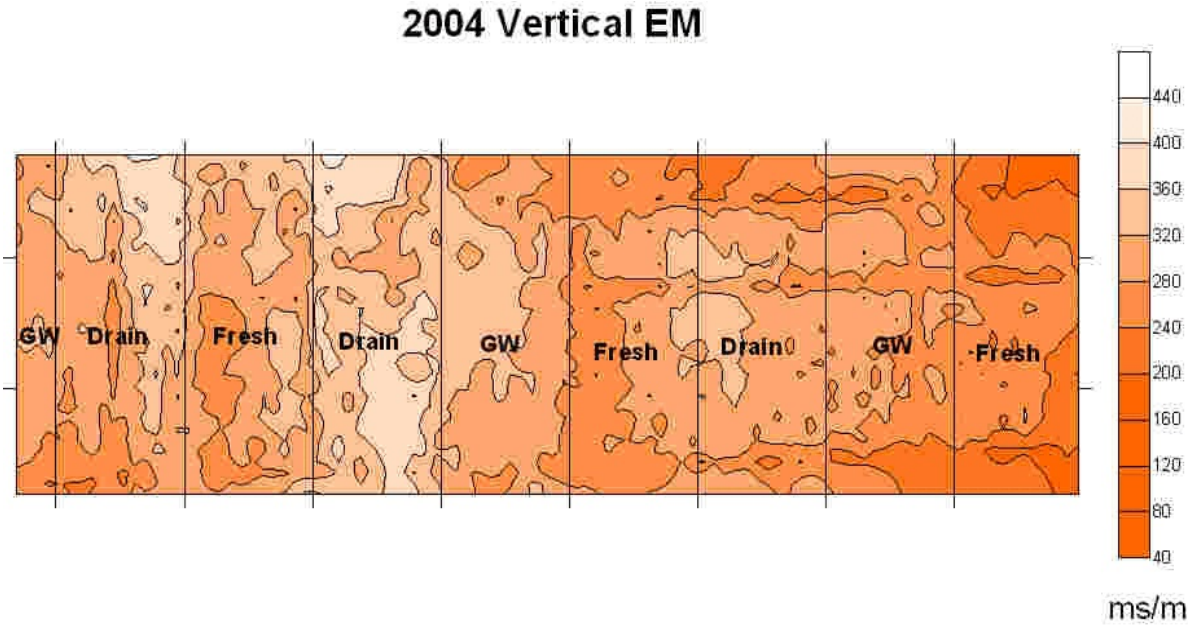



Figure 21b. Apparent soil electrical conductivity measured with EM-38 in the vertical mode in the spring 2004 on field 33 of the Broadview Water District.

concentrations are given figures 23 and 24 respectively. The resident values show the actual concentrations of the soil water at the time of sampling. These differ from the values in fig. 22 since those data were taken as 5 to 1 extracts.

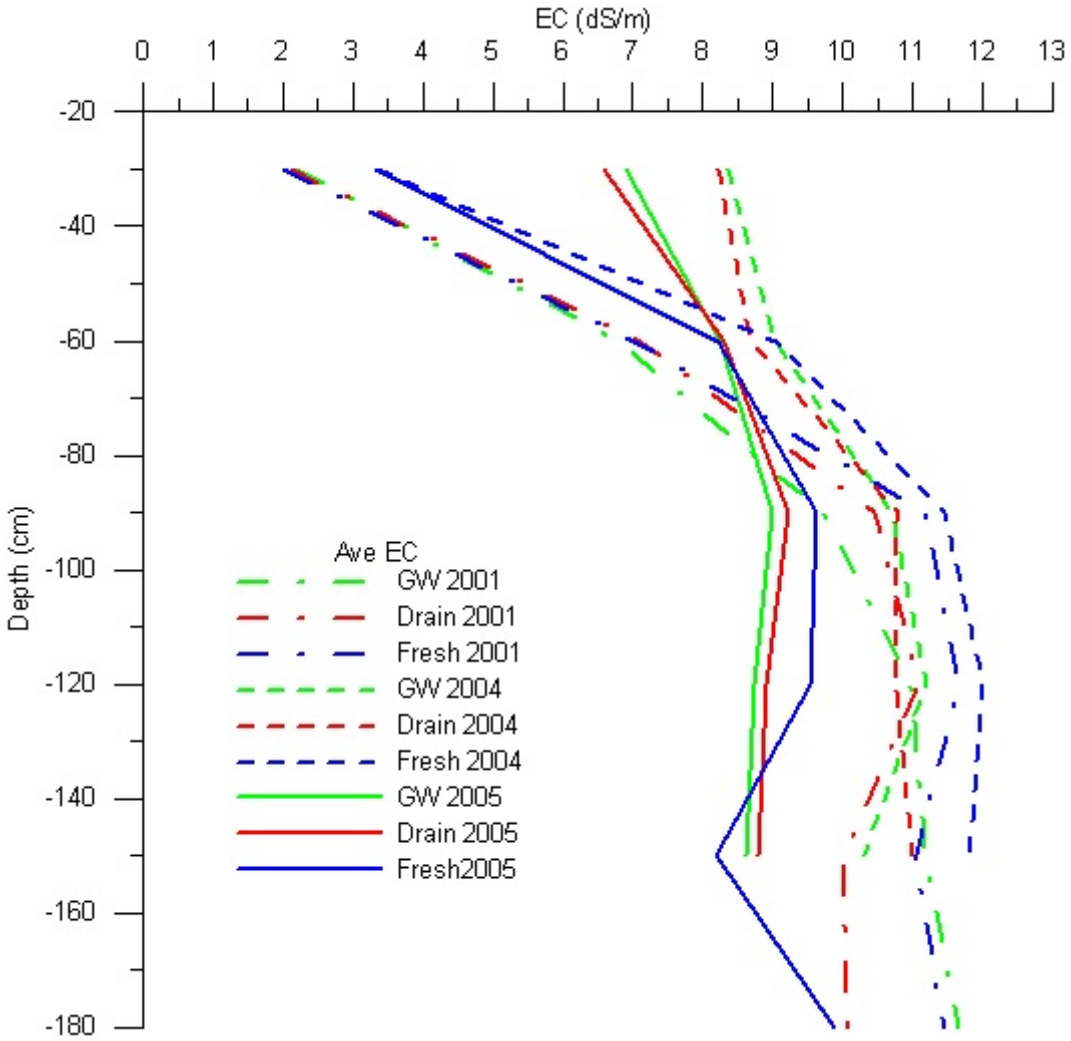



Figure 22. Soil salinity as a function of depth and irrigation treatment at Broadview project for fall 2001 and 2004 and spring 2005.

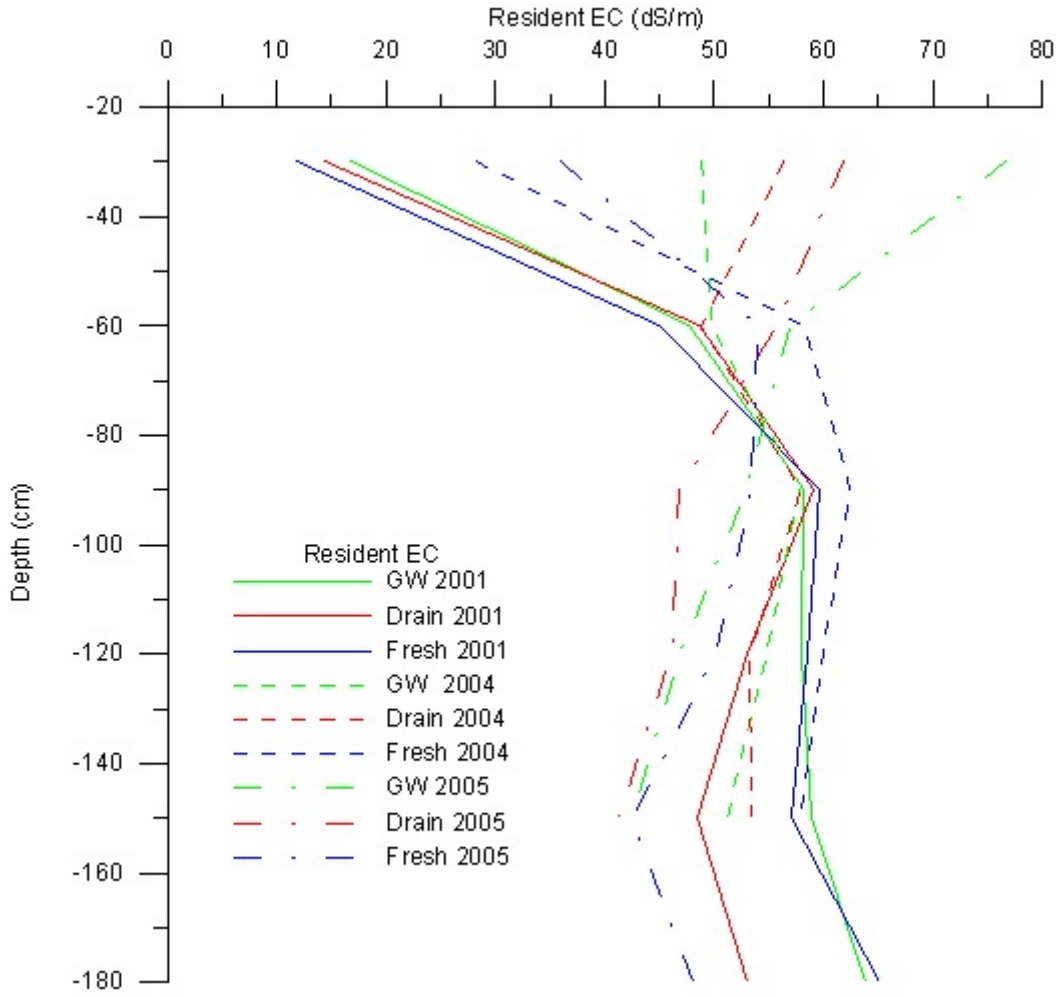



Figure 23. Resident electrical conductivity in th soil profile as a function of depth and irrigation treatment.

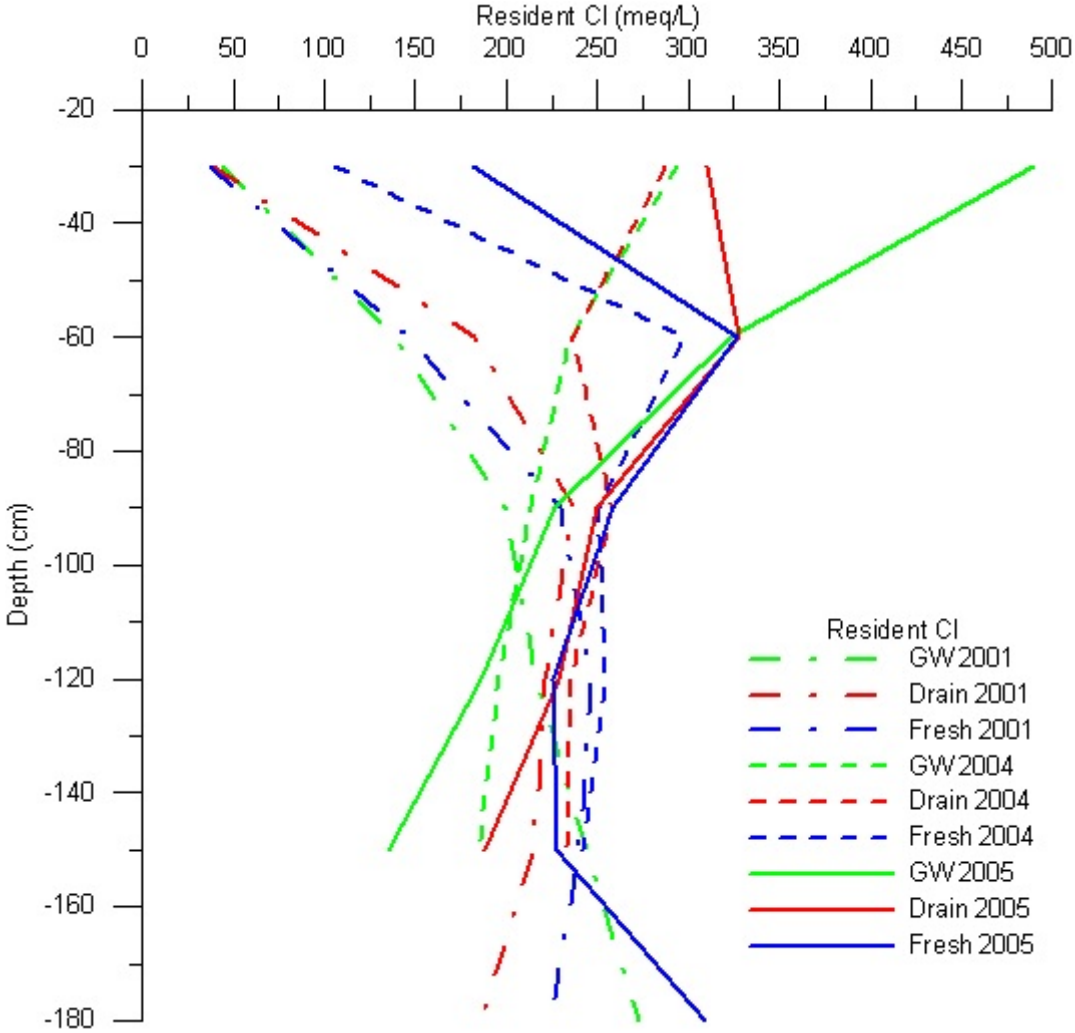



Figure 24. Resident chloride concentration in the soil profile as a function of depth and irrigation treatment at Broadview reuse project.

## 1.6 Plant Analysis

### *1.6.1 Yield*

Yield was characterized by the number of bales harvested from each treatment. The average bale weight was estimated to be approximately 68 kg (150 lbs).

2002
The last harvest of the first year alfalfa was on October 21 and produced a total of 412 bales. Total harvest for year 2002 was 1740 bales, or 118 Mg of biomass for the full field. After this harvest, there were no further field operations until first cut harvest began in the Spring of 2003.

Up to the third harvest, all treatments received the same quality and quantity of water to allow for an even stand establishment over the whole field. Irrigation water quality treatments were applied after the third cutting, and the yield in the fourth harvest was separated by treatment. Bale counts for each treatment and block are shown in table 20 for the fourth cutting.

Table 20 . Bale count by treatment and block for the fourth cutting during the stand establishment year on field 33 in the Broadview Water District.

| | Treatment | Yield (bales) |
|---|---|---|
| Block 1 | FRESH | 29 |
| | DRAIN | 39 |
| | GW | 54 |
| Total | | 122 |
| Block 2 | FRESH | 57 |
| | DRAIN | 20 |
| | GW | 12 |
| Total | | 89 |
| Block 3 | FRESH | 60 |
| | DRAIN | 51 |
| | GW | 36 |
| Total | | 147 |

Adding the harvest on the treatment in each block gives a total of 102 bales on the groundwater treatment, 110 bales on the DRAIN treatment, and 146 bales on the FRESH water treatment.

The data in Table 20 demonstrate the need for the statistical design used in the experiment. There are obviously some effects on yield in response to the position on the field. The effects can be minimized by blocking the field and randomly distributing the treatments with the block. Comparing the data for the yields by block and by treatment it is apparent that blocking reduces the effect of variability in the treatments.

Clearly, the variability in the field caused some unexpected results. The GW treatment in block 1 produced the highest yields in that block. Block 2 and 3 showed the highest yields in the FRESH water treatment, and the lowest yields in the groundwater treatments. However, the yield from the DRAIN water treatment in block two is closer to the yield on the GW treatment than the yield on the FRESH water treatment, which is unexpected. The variability is probably a result of the salinity distribution, the applied water, and several other management factors.

2003

The harvest data for 2003 are summarized in table 21

Table 21. Total harvest from Broadview Water District plots in 2003.

| Harvest | FRESH bales | DRAIN bales | GW bales |
|---|---|---|---|
| 1 | 346 | 314 | 360 |
| 2 | 242 | 222 | 256 |
| 3 | 111 | 73 | 24 |
| 4 | 106 | 62 | 39 |
| 5 | 78 | 45 | 28 |
| Total | 880 | 716 | 707 |

2004

The yield data for 2004 are given in tables 22and 23. The data in tables 22 and 23 show that the best yields occurred under the FRESH water treatment. The GW treatment had a slightly better yield than the DRAIN treatment even though the water management was the same in both treatments in 2004.

Table 22. Alfalfa yield on section 33 of Broadview Water District in 2004. Data sorted by irrigation treatment and block.

| | FRESH | DRAIN | GW | Total |
|---|---|---|---|---|
| Block | bales | bales | bales | bales |
| 1 | 104 | 66 | 72 | 242 |
| 2 | 103 | 35 | 57 | 195 |
| 3 | 132 | 77 | 102 | 311 |

note: Yield data distribution based on yields from harvests 1 and 3.

The data in table 23 show the same yield loss over the season that was demonstrated in 2003. The initial harvest after winter rain and leaching regained some vigor but by the middle of the summer the effects of good quality water were lost and the yields dropped in each treatment. The yield is summarized for 2003 and 2004 in table 24.

Table 23. Total alfalfa yield on section 33 of Broadview Water District in 2004. Data sorted by irrigation treatment

| | FRESH | DRAIN | GW |
|---|---|---|---|
| Harvest | bales | bales | bales |
| 1 | 206 | 141 | 171 |
| 2 | (220) | (117) | (151) |
| 3 | 133 | 37 | 59 |
| 4 | (66) | (36) | (46) |

note: Yields in parenthesis () were estimated from a total yield count using the bale distribution found in harvests 1 and 3.

Table 24. Bale summary for Broadview plots for 2003 and 2004.

| Year | FRESH | | DRAIN | | GW | |
|---|---|---|---|---|---|---|
| | Bales | Mass (T) | Bales | Mass (T) | Bales | Mass (T) |
| 2003 | 880 | 59.8 | 716 | 48.7 | 707 | 48.1 |
| 2004 | 625 | 42.5 | 331 | 22.5 | 427 | 29.0 |
| Total | 1505 | 102.3 | 1047 | 71.2 | 1134 | 77.1 |

The total area for each treatment was approximately 20 ha. Using the treatment area and the total mass produced for each treatment the average yields were 5 T/ha for the FRESH, 3.6 T/ha for the DRAIN, and 3.8 T/ha for the GW treatment. Use of saline water resulted in a significant yield loss when compared to plots irrigated solely with low salinity water. The data from table 21 to 23 demonstrate a steady yield decrease with each cutting during a given year. This is a common occurrence in alfalfa production and is a result of heat stress and reduced water availability as the season progresses. Note that in each year the yield was highest in the first cutting. However, the yield drop was significantly greater between cuttings in plots irrigated with saline water compared to those irrigated with low salinity water. This is a response to the increased salinity in the soil profile and osmotic stress associated with salinity in the irrigation water.

*1.6.2. Forage quality*

This section reports on the analysis of the alfalfa harvested during the summer of 2003 and 2004 at the Broadview test plots. The samples were sent to SDK laboratories for analysis using a 30 hour in-vitro analysis recommended by Peter Robinson, Dairy Nutritionist with U.C. Davis. Plant sampling was done prior to harvest at 3 locations in each plot. One location was a random selection in the center third of the field while the other 2 locations were located near the observation wells on each end of the plot and represented the north and south thirds of the field. A total of one square meter of alfalfa was sampled at each location. The samples were dried and ground before sending to the laboratory for analysis. A sub-sample of the ground hay was sent to the George Brown Salinity Laboratory for analysis of chemical constituents. The analysis for samples taken for 4 cuttings in 2003 and 3 cuttings in 2004 are given in tables 25 to 31.

Table 25. Analysis of first alfalfa cutting in 2003 at Broadview reuse project.

| | | | | | Data reported on Dry Weight Basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | CP | ADF | NDF | NDFD - 30 | NDFn | NFC | IVTDMD-30 |
| | | | % | % | % | % | % | % | % | % | % |
| 4/11/2003 | 1 | 71 | 8.5 | 91.5 | 28.6 | 25.3 | 32.1 | 45.5 | 29.8 | 28.5 | 82.5 |
| 4/11/2003 | 1 | 88 | 8.7 | 91.3 | 28.2 | 24.8 | 32.0 | 44.6 | 29.7 | 29.8 | 82.3 |
| 4/11/2003 | 1 | random | 8.4 | 91.6 | 26.7 | 26.9 | 33.1 | 44.7 | 30.8 | 29.2 | 81.7 |
| 4/11/2003 | 2 | 72 | 8.6 | 91.4 | 29.9 | 24.3 | 33.9 | 46.6 | 31.5 | 26.4 | 81.9 |
| 4/11/2003 | 2 | 87 | 8.7 | 91.3 | 27.5 | 26.3 | 34.3 | 41.9 | 31.9 | 23.4 | 80.1 |
| 4/11/2003 | 2 | random | 8.5 | 91.5 | 26.2 | 30.2 | 35.4 | 42.3 | 32.9 | 28.6 | 79.6 |
| 4/11/2003 | 3 | 73 | 8.5 | 91.5 | 27.4 | 27.3 | 35.4 | 46.1 | 33.0 | 26.8 | 80.9 |
| 4/11/2003 | 3 | 86 | 8.2 | 91.8 | 24.8 | 29.4 | 37.1 | 45.6 | 34.5 | 27.2 | 79.8 |
| 4/11/2003 | 3 | random | 8.2 | 91.8 | 25.4 | 28.9 | 36.3 | 41.3 | 33.7 | 28.8 | 78.7 |
| 4/11/2003 | 4 | 74 | 8.0 | 92.0 | 25.2 | 27.0 | 36.2 | 42.6 | 33.7 | 28.9 | 79.2 |
| 4/11/2003 | 4 | 85 | 8.3 | 91.7 | 26.1 | 25.4 | 34.2 | 45.8 | 31.8 | 29.3 | 81.5 |
| 4/11/2003 | 4 | random | 8.2 | 91.8 | 25.7 | 25.5 | 32.4 | 43.0 | 30.2 | 32.6 | 81.5 |
| 4/11/2003 | 5 | 75 | 8.0 | 92.0 | 25.3 | 28.3 | 36.4 | 41.8 | 33.9 | 25.7 | 78.8 |
| 4/11/2003 | 5 | 84 | 8.1 | 91.9 | 26.4 | 26.4 | 32.2 | 45.9 | 29.9 | 28.6 | 82.6 |
| 4/11/2003 | 5 | random | 8.5 | 91.5 | 25.4 | 27.5 | 34.5 | 45.0 | 32.1 | 29.4 | 81.0 |
| 4/11/2003 | 6 | 76 | 8.2 | 91.8 | 26.6 | 29.9 | 37.9 | 45.8 | 35.2 | 24.9 | 79.5 |
| 4/11/2003 | 6 | 83 | 8.5 | 91.5 | 27.2 | 26.1 | 34.7 | 47.9 | 32.3 | 27.5 | 81.9 |
| 4/11/2003 | 6 | random | 8.3 | 91.7 | 25.0 | 30.3 | 37.3 | 44.7 | 34.7 | 25.2 | 79.4 |
| 4/11/2003 | 7 | 77 | 8.4 | 91.6 | 26.3 | 28.3 | 34.1 | 40.4 | 31.7 | 28.7 | 79.7 |
| 4/11/2003 | 7 | 82 | 8.3 | 91.7 | 26.4 | 26.1 | 35.2 | 44.1 | 32.8 | 27.1 | 80.3 |
| 4/11/2003 | 7 | random | 8.3 | 91.7 | 22.5 | 31.6 | 40.2 | 42.5 | 37.4 | 26.6 | 76.9 |
| 4/11/2003 | 8 | 78 | 8.1 | 91.9 | 26.0 | 29.1 | 36.0 | 45.3 | 33.5 | 25.2 | 80.3 |
| 4/11/2003 | 8 | 81 | 8.1 | 91.9 | 25.4 | 29.4 | 35.2 | 46.1 | 32.8 | 27.3 | 81.0 |
| 4/11/2003 | 8 | random | 8.4 | 91.6 | 23.2 | 30.8 | 38.4 | 45.8 | 35.7 | 28.2 | 79.2 |
| 4/11/2003 | 9 | 79 | 8.2 | 91.8 | 23.9 | 32.0 | 40.1 | 41.3 | 37.3 | 25.1 | 76.5 |
| 4/11/2003 | 9 | 80 | 8.5 | 91.5 | 26.9 | 28.6 | 36.5 | 46.2 | 33.9 | 26.2 | 80.4 |
| 4/11/2003 | 9 | random | 8.4 | 91.6 | 24.9 | 31.3 | 39.3 | 45.5 | 36.5 | 26.1 | 78.6 |

Table 25. Continued.

| | | | | | Data reported on Dry Weight Basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | NEL | NEG | NEM | tdn | Fat(ee) | Fattty Acids | ASH |
| | | | % | % | Mcal/lb | Mcal/lb | Mcal/lb | % | % | % | % |
| 4/11/2003 | 1 | 71 | 8.5 | 91.5 | 0.64 | 0.36 | 0.69 | 62.4 | 1.59 | 0.59 | 11.5 |
| 4/11/2003 | 1 | 88 | 8.7 | 91.3 | 0.6 4 | 0.36 | 0.69 | 62.3 | 1.3 | 0.3 | 11.0 |
| 4/11/2003 | 1 | random | 8.4 | 91.6 | 0.62 | 0.35 | 0.67 | 61.0 | 1.35 | 0.35 | 11.9 |
| 4/11/2003 | 2 | 72 | 8.6 | 91.4 | 0.64 | 0.36 | 0.69 | 62.3 | 1.44 | 0.44 | 10.8 |
| 4/11/2003 | 2 | 87 | 8.7 | 91.3 | 0.62 | 0.34 | 0.66 | 60.5 | 1.32 | 0.32 | 10.9 |
| 4/11/2003 | 2 | random | 8.5 | 91.5 | 0.61 | 0.33 | 0.66 | 59.9 | 1.25 | 0.25 | 11.0 |
| 4/11/2003 | 3 | 73 | 8.5 | 91.5 | 0.62 | 0.34 | 0.67 | 60.5 | 1.24 | 0.24 | 11.6 |
| 4/11/2003 | 3 | 86 | 8.2 | 91.8 | 0.6 | 0.32 | 0.64 | 58.9 | 1.21 | 0.21 | 12.3 |
| 4/11/2003 | 3 | random | 8.2 | 91.8 | 0.6 | 0.32 | 0.65 | 59.2 | 1.23 | 0.23 | 10.9 |
| 4/11/2003 | 4 | 74 | 8.0 | 92.0 | 0.61 | 0.33 | 0.66 | 59.8 | 1.34 | 0.34 | 10.9 |
| 4/11/2003 | 4 | 85 | 8.3 | 91.7 | 0.63 | 0.35 | 0.68 | 61.4 | 1.38 | 0.38 | 11.4 |
| 4/11/2003 | 4 | random | 8.2 | 91.8 | 0.64 | 0.37 | 0.7 | 62.9 | 1.5 | 0.5 | 10.0 |
| 4/11/2003 | 5 | 75 | 8.0 | 92.0 | 0.58 | 0.29 | 0.61 | 56.7 | 1.4 | 0.4 | 13.8 |
| 4/11/2003 | 5 | 84 | 8.1 | 91.9 | 0.61 | 0.33 | 0.66 | 60.2 | 1.42 | 0.42 | 13.7 |
| 4/11/2003 | 5 | random | 8.5 | 91.5 | 0.62 | 0.34 | 0.66 | 60.4 | 1.21 | 0.21 | 11.8 |
| 4/11/2003 | 6 | 76 | 8.2 | 91.8 | 0.6 | 0.32 | 0.65 | 59.0 | 1.37 | 0.37 | 12.0 |
| 4/11/2003 | 6 | 83 | 8.5 | 91.5 | 0.62 | 0.35 | 0.67 | 61.1 | 1.2 | 0.2 | 11.8 |
| 4/11/2003 | 6 | random | 8.3 | 91.7 | 0.58 | 0.29 | 0.62 | 56.8 | 1.14 | 0.14 | 13.9 |
| 4/11/2003 | 7 | 77 | 8.4 | 91.6 | 0.6 | 0.32 | 0.65 | 59.0 | 1.27 | 0.27 | 12.0 |
| 4/11/2003 | 7 | 82 | 8.3 | 91.7 | 0.61 | 0.33 | 0.65 | 59.6 | 1.46 | 0.46 | 12.2 |
| 4/11/2003 | 7 | random | 8.3 | 91.7 | 0.57 | 0.28 | 0.61 | 56.1 | 1.12 | 0.12 | 12.4 |
| 4/11/2003 | 8 | 78 | 8.1 | 91.9 | 0.59 | 0.3 | 0.63 | 57.6 | 1.23 | 0.23 | 14.0 |
| 4/11/2003 | 8 | 81 | 8.1 | 91.9 | 0.6 | 0.32 | 0.65 | 59.1 | 1.29 | 0.29 | 13.2 |
| 4/11/2003 | 8 | random | 8.4 | 91. 2 | 0.6 | 0.32 | 0.64 | 58.9 | 1.1 | 0.1 | 11.7 |
| 4/11/2003 | 9 | 79 | 8.2 | 91.8 | 0.56 | 0.27 | 0.59 | 55.1 | 0.95 | 0 | 12.8 |
| 4/11/2003 | 9 | 80 | 8.5 | 91.5 | 0.6 1 | 0.33 | 0.65 | 59.6 | 1.11 | 0.11 | 11.9 |
| 4/11/2003 | 9 | random | 8.4 | 91.6 | 0.6 | 0.32 | 0.64 | 58.9 | 1.23 | 0.23 | 11.2 |

Table 26. Analysis of second alfalfa cutting at Broadview reuse project.

| | | | | | Data reported on dry weight basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | CP | ADF | NDF | NDFD - 30 | NDFn | NFC | IVTDMD-30 |
| | | | % | % | % | % | % | % | % | % | % |
| 5/21/2003 | 1 | 71 | 8.8 | 91.2 | 24.9 | 27.7 | 33.2 | 58.9 | 30.9 | 29.7 | 86.4 |
| 5/21/2003 | 1 | 88 | 8.8 | 91.2 | 23.8 | 26.6 | 33.0 | 45.6 | 30.6 | 32.2 | 82.1 |
| 5/21/2003 | 1 | random | 8.3 | 91.7 | 21.6 | 28.0 | 36.7 | 46.5 | 34.1 | 31.4 | 80.4 |
| 5/21/2003 | 2 | 72 | 9.1 | 90.9 | 25.3 | 23.3 | 29.9 | 60.5 | 27.8 | 32.7 | 88.2 |
| 5/21/2003 | 2 | 87 | 9.1 | 90.9 | 23.9 | 26.6 | 33.5 | 49.7 | 31.2 | 32.2 | 83.2 |
| 5/21/2003 | 2 | random | 8.7 | 91.3 | 24.2 | 27.1 | 31.7 | 47.9 | 29.5 | 33.2 | 83.5 |
| 5/21/2003 | 3 | 73 | 9.4 | 90.6 | 27.2 | 25.2 | 28.3 | 62.4 | 26.4 | 32.8 | 89.4 |
| 5/21/2003 | 3 | 86 | 8.9 | 91.1 | 25.3 | 26.6 | 35.2 | 47.8 | 32.8 | 27.2 | 81.6 |
| 5/21/2003 | 3 | random | 8.3 | 91.7 | 23.5 | 29.1 | 36.9 | 43.6 | 34.3 | 30.0 | 79.2 |
| 5/21/2003 | 4 | 74 | 9.0 | 91.0 | 24.9 | 26.3 | 32.3 | 58.4 | 30.0 | 30.5 | 86.6 |
| 5/21/2003 | 4 | 85 | 8.6 | 91.4 | 21.9 | 28.5 | 32.5 | 47.1 | 30.2 | 27.2 | 82.8 |
| 5/21/2003 | 4 | random | 9.0 | 91.0 | 24.3 | 24.3 | 32.6 | 50.3 | 30.3 | 32.0 | 83.8 |
| 5/21/2003 | 5 | 75 | 8.8 | 91.2 | 22.7 | 28.0 | 32.7 | 54.1 | 30.4 | 32.4 | 85.0 |
| 5/21/2003 | 5 | 84 | 8.8 | 91.2 | 23.9 | 26.8 | 32.7 | 50.6 | 30.4 | 29.3 | 83.8 |
| 5/21/2003 | 5 | random | 8.7 | 91.3 | 24.6 | 27.0 | 30.7 | 52.3 | 28.5 | 33.2 | 85.4 |
| 5/21/2003 | 6 | 76 | 9.1 | 90.9 | 25.5 | 26.8 | 33.5 | 57.2 | 31.2 | 28.4 | 85.7 |
| 5/21/2003 | 6 | 83 | 8.6 | 91.4 | 23.8 | 27.7 | 34.3 | 50.3 | 31.9 | 29.9 | 83.0 |
| 5/21/2003 | 6 | random | 8.6 | 91.4 | 23.7 | 29.5 | 34.4 | 48.6 | 32.0 | 30.6 | 82.3 |
| 5/21/2003 | 7 | 77 | 9.1 | 90.9 | 24.1 | 27.2 | 32.4 | 56.2 | 30.2 | 31.3 | 85. 8 |
| 5/21/2003 | 7 | 82 | 9.0 | 91.0 | 24.3 | 25.4 | 33.2 | 55.1 | 30.9 | 39.1 | 85.1 |
| 5/21/2003 | 7 | random | 9.2 | 90.8 | 22.8 | 27.2 | 33.8 | 49.1 | 31.4 | 32.2 | 82. 8 |
| 5/21/2003 | 8 | 78 | 9.0 | 91.0 | 23.7 | 27.3 | 32.8 | 55.1 | 30.5 | 31.8 | 85.3 |
| 5/21/2003 | 8 | 81 | 8.5 | 91.5 | 23.5 | 27.6 | 35.2 | 53.5 | 32.7 | 30.3 | 83.6 |
| 5/21/2003 | 8 | random | 8.7 | 91.3 | 23.2 | 27.7 | 34.5 | 50.3 | 32.1 | 30.6 | 82.9 |
| 5/21/2003 | 9 | 79 | 9.1 | 90.8 | 23.4 | 30.5 | 35.0 | 50.6 | 32.6 | 29.8 | 82.7 |
| 5/21/2003 | 9 | 80 | 9.0 | 91.0 | 24.8 | 27.4 | 35.0 | 53.2 | 32.5 | 28.4 | 83.6 |
| 5/21/2003 | 9 | random | 8.8 | 91.2 | 24.0 | 27.2 | 33.0 | 46.5 | 30.7 | 30.4 | 82.4 |

Table 26. Continued.

| | | | | | Data reported on dry weight basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | NEL | NEG | NEM | tdn | Fat(ee) | Fattty Acids | ASH |
| | | | % | % | Mcal/lb | Mcal/lb | Mcal/lb | % | % | % | % |
| 5/21/2003 | 1 | 71 | 8.8 | 91.2 | 0.67 | 0.4 | 0.72 | 65.0 | 1.7 | 0.7 | 12.8 |
| 5/21/2003 | 1 | 88 | 8.8 | 91.2 | 0.63 | 0.35 | 0.68 | 61.7 | 1.49 | 0.49 | 11.9 |
| 5/21/2003 | 1 | random | 8.3 | 91.7 | 0.62 | 0.34 | 0.67 | 60.5 | 1.36 | 0.36 | 11.5 |
| 5/21/2003 | 2 | 72 | 9.1 | 90.9 | 0.69 | 0.43 | 0.75 | 67.2 | 1.8 | 0.8 | 12.4 |
| 5/21/2003 | 2 | 87 | 9.1 | 90.9 | 0.65 | 0.37 | 0.7 | 63.2 | 1.43 | 0.43 | 11.3 |
| 5/21/2003 | 2 | random | 8.7 | 91.3 | 0.64 | 0.37 | 0.7 | 62.8 | 1.28 | 0.28 | 11.8 |
| 5/21/2003 | 3 | 73 | 9.4 | 90.6 | 0.71 | 0.45 | 0.77 | 68.6 | 1.82 | 0.82 | 11.8 |
| 5/21/2003 | 3 | 86 | 8.9 | 91.1 | 0.6 | 0.32 | 0.65 | 59.3 | 1.21 | 0.21 | 13.5 |
| 5/21/2003 | 3 | random | 8.3 | 91.7 | 0.61 | 0.33 | 0.66 | 60.0 | 1.39 | 0.39 | 10.8 |
| 5/21/2003 | 4 | 74 | 9.0 | 91.0 | 0.67 | 0.4 | 0.73 | 65.2 | 1.76 | 0.76 | 12.8 |
| 5/21/2003 | 4 | 85 | 8.6 | 91.4 | 0.56 | 0.26 | 0.59 | 54.9 | 1.27 | 0.27 | 19.4 |
| 5/21/2003 | 4 | random | 9.0 | 91.0 | 0.62 | 0.38 | 0.71 | 63.6 | 1.65 | 0.65 | 11.7 |
| 5/21/2003 | 5 | 75 | 8.8 | 91.2 | 0.66 | 0.39 | 0.72 | 64.3 | 1.85 | 0.85 | 12.5 |
| 5/21/2003 | 5 | 84 | 8.8 | 91.2 | 0.62 | 0.34 | 0.66 | 60.3 | 1.43 | 0.43 | 14.9 |
| 5/21/2003 | 5 | random | 8.7 | 91.3 | 0.67 | 0.4 | 0.72 | 64.8 | 1.66 | 0.66 | 12.0 |
| 5/21/2003 | 6 | 76 | 9.1 | 90.9 | 0.66 | 0.39 | 0.71 | 64.1 | 1.77 | 0.77 | 13.1 |
| 5/21/2003 | 6 | 83 | 8.6 | 91.4 | 0.63 | 0.35 | 0.68 | 61.6 | 1.47 | 0.47 | 12.9 |
| 5/21/2003 | 6 | random | 8.6 | 91.4 | 0.63 | 0.35 | 0.68 | 61.5 | 1.44 | 0.44 | 12.3 |
| 5/21/2003 | 7 | 77 | 9.1 | 90.9 | 0.66 | 0.39 | 0.72 | 64.5 | 1.64 | 0.64 | 12.7 |
| 5/21/2003 | 7 | 82 | 9.0 | 91.0 | 0.63 | 0.36 | 0.68 | 61.9 | 1.36 | 0.36 | 14.4 |
| 5/21/2003 | 7 | random | 9.2 | 90.8 | 0.64 | 0.36 | 0.69 | 62.3 | 1.48 | 0.48 | 12.0 |
| 5/21/2003 | 8 | 78 | 9.0 | 91.0 | 0.66 | 0.39 | 0.71 | 64.2 | 1.58 | 0.58 | 12.5 |
| 5/21/2003 | 8 | 81 | 8.5 | 91.5 | 0.65 | 0.38 | 0.7 | 63.4 | 1.6 | 0.6 | 11.9 |
| 5/21/2003 | 8 | random | 8.7 | 91.3 | 0.63 | 0.36 | 0.68 | 61.9 | 1.56 | 0.56 | 12.6 |
| 5/21/2003 | 9 | 79 | 9.1 | 90.8 | 0.63 | 0.35 | 0.68 | 61.6 | 1.53 | 0.53 | 12.8 |
| 5/21/2003 | 9 | 80 | 9.0 | 91.0 | 0.64 | 0.36 | 0.69 | 62.4 | 1.57 | 0.57 | 12.8 |
| 5/21/2003 | 9 | random | 8.8 | 91.1 | 0.62 | 0.34 | 0.67 | 60.9 | 1.7 | 0.7 | 13.3 |

Table 27. Analysis of fourth alfalfa cutting at Broadview reuse project.

| | | | | | Data reported on dry weight basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | CP | ADF | NDF | NDFD - 30 | NDFn | NFC | IVTDMD-30 |
| | | | %% | % | % | % | % | % | | % | % |
| 8/21/2003 | 1 | 71 | 10.6 | 89.4 | 24.0 | 21.1 | 28.1 | 57.3 | 26.1 | 37.2 | 88.0 |
| 8/21/2003 | 1 | 88 | 10.6 | 89.4 | 22.1 | 25.5 | 30.0 | 52.7 | 27.9 | 35.9 | 85.8 |
| 8/21/2003 | 1 | random | 10.5 | 89.5 | 21.8 | 22.7 | 29.4 | 49.3 | 27.3 | 37.1 | 85.1 |
| 8/21/2003 | 2 | 72 | 10.8 | 89.2 | 18.1 | 29.3 | 38.8 | 46.4 | 36.1 | 30.9 | 79.2 |
| 8/21/2003 | 2 | 87 | 10.0 | 90.0 | 19.8 | 29.0 | 35.7 | 44.3 | 33.2 | 33.9 | 80.1 |
| 8/21/2003 | 2 | random | 11.3 | 88.7 | 21.6 | 25.3 | 31.9 | 52 | 29.6 | 34.5 | 84.7 |
| 8/21/2003 | 3 | 73 | 10.0 | 90.0 | 20.3 | 30.4 | 35.2 | 46.5 | 32.7 | 34.1 | 81.2 |
| 8/21/2003 | 3 | 86 | 10.0 | 90.0 | 21.7 | 25.3 | 30.9 | 47.6 | 28.8 | 36.0 | 83.8 |
| 8/21/2003 | 3 | random | 9.8 | 90.2 | 20.5 | 28.8 | 37.0 | 48 | 34.4 | 32.9 | 80.8 |
| 8/21/2003 | 4 | 74 | 11.7 | 88.3 | 19.2 | 26.6 | 34.8 | 48.8 | 32.3 | 33.2 | 82.2 |
| 8/21/2003 | 4 | 85 | 10.6 | 89.4 | 20.5 | 26.8 | 32.5 | 47.4 | 30.3 | 35.7 | 82.9 |
| 8/21/2003 | 4 | random | 11.0 | 89.0 | 20.2 | 27.6 | 33.8 | 48.8 | 31.4 | 33.6 | 82.7 |
| 8/21/2003 | 5 | 75 | 10.5 | 89.5 | 23. 9 | 21.0 | 26.7 | 54.4 | 24.9 | 38.1 | 87.8 |
| 8/21/2003 | 5 | 84 | 10.2 | 89.8 | 20.8 | 26.2 | 33.2 | 51.4 | 30.8 | 35.3 | 83.9 |
| 8/21/2003 | 5 | random | 10.3 | 89.7 | 21.4 | 25.6 | 30.2 | 47.7 | 28.1 | 35.8 | 84.2 |
| 8/21/2003 | 6 | 76 | 10.6 | 89.4 | 22.2 | 25.9 | 34.2 | 59 | 31.8 | 33.7 | 86.0 |
| 8/21/2003 | 6 | 83 | 10.3 | 89.7 | 20.3 | 29.5 | 36.3 | 49.6 | 33.8 | 34.3 | 81.7 |
| 8/21/2003 | 6 | random | 9.7 | 90.3 | 19.9 | 29.8 | 36.1 | 46.3 | 33.6 | 34.8 | 80.6 |
| 8/21/2003 | 7 | 77 | 11.4 | 88.6 | 20.3 | 26.8 | 36.5 | 52 | 33.9 | 33.7 | 82.5 |
| 8/21/2003 | 7 | 82 | 10.2 | 89.8 | 20.9 | 27.0 | 35.2 | 49.5 | 32.8 | 34.8 | 82.2 |
| 8/21/2003 | 7 | random | 9.9 | 90.1 | 20.4 | 29.4 | 35. 7 | 47.6 | 33.2 | 33.8 | 81.3 |
| 8/21/2003 | 8 | 78 | 10.5 | 89.5 | 20.0 | 24.5 | 33.0 | 54.8 | 30.7 | 36.9 | 85.1 |
| 8/21/2003 | 8 | 81 | 10.3 | 89.7 | 22.3 | 24.0 | 30.0 | 54.7 | 27.9 | 37.4 | 86.4 |
| 8/21/2003 | 8 | random | 11.2 | 88.8 | 20.2 | 26.7 | 33.6 | 50.8 | 31.2 | 35.7 | 83.5 |
| 8/21/2003 | 9 | 79 | 10.3 | 89.7 | 22.3 | 27.3 | 34.4 | 50.1 | 32.0 | 34.3 | 82.8 |
| 8/21/2003 | 9 | 80 | 10.0 | 90.0 | 22.1 | 29.0 | 36.5 | 51 | 34.0 | 32.2 | 82.1 |
| 8/21/2003 | 9 | random | 9.7 | 90.3 | 20.6 | 30.3 | 36.9 | 43.7 | 34.3 | 35.0 | 79.2 |

Table 27. Continued.

| | | | | | Data reported on dry weight basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | NEL | NEG | NEM | TDN | Fat(ee) | Fattty Acids | ASH |
| | | | % | % | Mcal/lb | Mcal/lb | Mcal/lb | % | % | % | % |
| 8/21/2003 | 1 | 71 | 10.6 | 89.4 | 0.7 | 0.44 | 0.77 | 68.2 | 1.68 | 0.68 | 11.0 |
| 8/21/2003 | 1 | 88 | 10.6 | 89.4 | 0.67 | 0.41 | 0.73 | 65.6 | 1.99 | 0.99 | 12.1 |
| 8/21/2003 | 1 | random | 10.5 | 89.5 | 0.67 | 0.4 | 0.73 | 65.0 | 1.89 | 0.89 | 11.9 |
| 8/21/2003 | 2 | 72 | 10.8 | 89.2 | 0.58 | 0.29 | 0.62 | 56.8 | 1 | 0 | 13.9 |
| 8/21/2003 | 2 | 87 | 10.0 | 90.0 | 0.62 | 0.35 | 0.67 | 61.1 | 1.82 | 0.82 | 11.3 |
| 8/21/2003 | 2 | random | 11.3 | 88.7 | 0.66 | 0.38 | 0.71 | 64.0 | 1.69 | 0.69 | 12.5 |
| 8/21/2003 | 3 | 73 | 10.0 | 90.0 | 0.63 | 0.35 | 0.68 | 61.7 | 1.52 | 0.52 | 11.4 |
| 8/21/2003 | 3 | 86 | 10.0 | 90.0 | 0.66 | 0.39 | 0.72 | 64.5 | 2.07 | 1.07 | 11.5 |
| 8/21/2003 | 3 | random | 9.8 | 90.2 | 0.64 | 0.37 | 0.69 | 62.6 | 1.82 | 0.82 | 10.4 |
| 8/21/2003 | 4 | 74 | 11.7 | 88.3 | 0.61 | 0.33 | 0.66 | 59.9 | 1.31 | 0.31 | 13.9 |
| 8/21/2003 | 4 | 85 | 10.6 | 89.4 | 0.64 | 0.36 | 0.69 | 62.5 | 1.49 | 0.49 | 12.0 |
| 8/21/2003 | 4 | random | 11.0 | 89.0 | 0.64 | 0.36 | 0.69 | 62.2 | 1.94 | 0.94 | 12.8 |
| 8/21/2003 | 5 | 75 | 10.5 | 89.5 | 0.7 | 0.44 | 0.77 | 68.2 | 2 | 1 | 11.2 |
| 8/21/2003 | 5 | 84 | 10.2 | 89.8 | 0.66 | 0.39 | 0.71 | 64.1 | 1.6 | 0.6 | 11.5 |
| 8/21/2003 | 5 | random | 10.3 | 89.7 | 0.65 | 0.38 | 0.71 | 63.6 | 2.04 | 1.04 | 12.7 |
| 8/21/2003 | 6 | 76 | 10.6 | 89.4 | 0.7 | 0.43 | 0.76 | 67.4 | 1.93 | 0.93 | 10.4 |
| 8/21/2003 | 6 | 83 | 10.3 | 89.7 | 0.65 | 0.38 | 0.71 | 63.6 | 1.63 | 0.63 | 10.0 |
| 8/21/2003 | 6 | random | 9.7 | 90.3 | 0.64 | 0.37 | 0.69 | 62.7 | 1.73 | 0.73 | 10.0 |
| 8/21/2003 | 7 | 77 | 11.4 | 88.6 | 0.65 | 0.38 | 0.71 | 63.7 | 1.55 | 0.55 | 10.6 |
| 8/21/2003 | 7 | 82 | 10.2 | 89.8 | 0.65 | 0.38 | 0.71 | 63.7 | 1.42 | 0.42 | 10.0 |
| 8/21/2003 | 7 | random | 9.9 | 90.1 | 0.64 | 0.36 | 0.69 | 62.4 | 1.73 | 0.73 | 11.0 |
| 8/21/2003 | 8 | 78 | 10.5 | 89.5 | 0.69 | 0.42 | 0.75 | 66.6 | 1.92 | 0.92 | 10.5 |
| 8/21/2003 | 8 | 81 | 10.3 | 89.7 | 0.7 | 0.43 | 0.76 | 67.5 | 1.87 | 0.87 | 10.5 |
| 8/21/2003 | 8 | random | 11.2 | 88.8 | 0.66 | 0.39 | 0.72 | 64.7 | 1.94 | 0.94 | 10.9 |
| 8/21/2003 | 9 | 79 | 10.3 | 89.7 | 0.67 | 0.4 | 0.73 | 65.1 | 1.78 | 0.78 | 9.6 |
| 8/21/2003 | 9 | 80 | 10.0 | 90.0 | 0.65 | 0.38 | 0.71 | 63.7 | 1.58 | 0.58 | 10.1 |
| 8/21/2003 | 9 | random | 9.7 | 90.3 | 0.65 | 0.37 | 0.7 | 63.0 | 1.67 | 0.67 | 8.4 |

Table 28. Final alfalfa cutting in 2003 at the Broadview reuse project.

| | | | | | Data reported on dry weight basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | CP | ADF | NDF | NDFD - 30 | NDFn | NFC | IVTDMD-30 |
| | | | % | % % | % | % | % | % | | % | % |
| 11/25/2003 | 1 | 71 | 7.6 | 92.4 | 20.5 | 23.6 | 31.9 | 47.4 | 29.7 | 36.4 | 83.2 |
| 11/25/2003 | 1 | 88 | 8.0 | 92.0 | 21.2 | 25.0 | 32.4 | 44.8 | 30.1 | 34.7 | 82.1 |
| 11/25/2003 | 1 | random | 8.0 | 92.0 | 17.8 | 30.4 | 41.9 | 42 | 39.0 | 29.3 | 75.7 |
| 11/25/2003 | 2 | 72 | 7.7 | 92.3 | 20.0 | 26.1 | 35.1 | 44.1 | 32.6 | 34.4 | 80.4 |
| 11/25/2003 | 2 | 87 | 7.7 | 92.3 | 22.3 | 25.6 | 33.3 | 44.5 | 31.0 | 35.2 | 81.5 |
| 11/25/2003 | 2 | random | 8.2 | 91.8 | 22.0 | 26.7 | 35.6 | 47 | 33.2 | 31.6 | 81.1 |
| 11/25/2003 | 3 | 73 | 7.6 | 92.4 | 23.8 | 24.7 | 32.8 | 47.5 | 30.6 | 33.3 | 82.8 |
| 11/25/2003 | 3 | 86 | 7.4 | 92.6 | 24.3 | 26.7 | 34.1 | 47.9 | 31.8 | 33.1 | 82.2 |
| 11/25/2003 | 3 | random | 7.4 | 92.6 | 22.5 | 28.8 | 37.8 | 45.6 | 35.2 | 31.8 | 79.4 |
| 11/25/2003 | 4 | 74 | 7.8 | 92.2 | 19.1 | 27.3 | 36.3 | 45.7 | 33.7 | 34.5 | 80.3 |
| 11/25/2003 | 4 | 85 | 8.0 | 10.0 | 20.9 | 24.4 | 32.8 | 46.2 | 30.5 | 34.5 | 82.4 |
| 11/25/2003 | 4 | random | 7.9 | 92.1 | 20.9 | 25.4 | 34.8 | 46.6 | 32.4 | 34.2 | 81.4 |
| 11/25/2003 | 5 | 75 | 7.9 | 92.1 | 21.0 | 26.0 | 33.7 | 47.2 | 31.3 | 33.6 | 82.2 |
| 11/25/2003 | 5 | 84 | 7.3 | 92.7 | 23.2 | 26.7 | 33.8 | 49.1 | 31.4 | 33.6 | 82.8 |
| 11/25/2003 | 5 | random | 7.7 | 92.3 | 20.2 | 26.4 | 35.8 | 46.4 | 33.3 | 34.0 | 80.8 |
| 11/25/2003 | 6 | 76 | 7.6 | 92.4 | 25.9 | 23.5 | 30.8 | 50.7 | 28.7 | 32.1 | 84.8 |
| 11/25/2003 | 6 | 83 | 7.5 | 92.5 | 22.1 | 23.0 | 30.3 | 49.9 | 28.2 | 37.2 | 84.8 |
| 11/25/2003 | 6 | random | 7.4 | 92.6 | 23.5 | 28.0 | 34.7 | 45.5 | 32.3 | 33.6 | 81.1 |
| 11/25/2003 | 7 | 77 | 7.8 | 92.2 | 20.0 | 23.6 | 33.4 | 52.4 | 31.1 | 35.6 | 84.1 |
| 11/25/2003 | 7 | 82 | 7.5 | 92.5 | 20.4 | 24.6 | 33.7 | 45.7 | 31.4 | 36.2 | 81.7 |
| 11/25/2003 | 7 | random | 7.9 | 92.1 | 20.2 | 26.9 | 36.9 | 45.5 | 34.1 | 34.1 | 80 |
| 11/25/2003 | 8 | 78 | 7.3 | 92.7 | 20.3 | 29.3 | 32.3 | 46.7 | 30.0 | 30.9 | 82.8 |
| 11/25/2003 | 8 | 81 | 7.8 | 92.2 | 22.2 | 24.9 | 32.2 | 45.7 | 30.0 | 35.5 | 82.5 |
| 11/25/2003 | 8 | random | 7.9 | 92.1 | 22.0 | 25.8 | 32.3 | 46.1 | 30.0 | 35.5 | 82.6 |
| 11/25/2003 | 9 | 79 | 7.1 | 92.9 | 23.0 | 27.6 | 35.9 | 47.1 | 33.4 | 31.5 | 81 |
| 11/25/2003 | 9 | 80 | 7.4 | 92.6 | 22.6 | 27.9 | 35.9 | 50.9 | 33.4 | 32.6 | 82.4 |

Table 28. Continued.

| | | | | | Data reported on dry weight basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | M oisture | Dry Matter | NEL | NEG | NEM | TDN | Fat(ee) | Fattty Acids | ASH |
| | | | % | % | Mcal/lb | Mcal/lb | Mcal/lb | % | % | % | % |
| 11/25/2003 | 1 | 71 | 7.6 | 92.4 | 0.65 | 0.38 | 0.7 | 63.4 | 1.73 | 0.73 | 11.7 |
| 11/25/2003 | 1 | 88 | 8.0 | 92.0 | 0.63 | 0.35 | 0.67 | 61.2 | 1.39 | 0.39 | 12.5 |
| 11/25/2003 | 1 | random | 8.0 | 92.0 | 0.56 | 0.27 | 0.59 | 55.0 | 1.15 | 0.15 | 12.8 |
| 11/25/2003 | 2 | 72 | 7.7 | 92.3 | 0.62 | 35 | 0.67 | 61.1 | 1.6 | 0.6 | 11.3 |
| 11/25/2003 | 2 | 87 | 7.7 | 92.3 | 0.65 | 0.37 | 0.7 | 63.1 | 1.54 | 0.54 | 10.1 |
| 11/25/2003 | 2 | random | 8.2 | 91.8 | 0.63 | 0.35 | 0.67 | 61.1 | 1.49 | 0.49 | 11.7 |
| 11/25/2003 | 3 | 73 | 7.6 | 92.8 | 0.65 | 0.38 | 0.71 | 63.6 | 1.54 | 0.54 | 10.7 |
| 11/25/2003 | 3 | 86 | 7.4 | 92.6 | 0.66 | 0.39 | 0.71 | 64.1 | 1.38 | 0.38 | 9.5 |
| 11/25/2003 | 3 | random | 7.4 | 92.6 | 0.63 | 0.35 | 0.68 | 61.3 | 1.09 | 0.09 | 9.4 |
| 11/25/2003 | 4 | 74 | 7. 8 | 92.2 | 0.63 | 0.35 | 0.68 | 61.3 | 1.58 | 0.58 | 11.0 |
| 11/25/2003 | 4 | 85 | 8.0 | 10.0 | 0.63 | 0.36 | 0.68 | 61.9 | 1.7 | 0.7 | 12.4 |
| 11/25/2003 | 4 | random | 7. 9 | 92.1 | 0.64 | 0.36 | 0.69 | 62.2 | 1.52 | 0.52 | 11 |
| 11/25/2003 | 5 | 75 | 7.9 | 92.1 | 0.63 | 0.36 | 0.68 | 62.0 | 1.78 | 0.78 | 12.3 |
| 11/25/2003 | 5 | 84 | 7.3 | 92.7 | 0.66 | 0.38 | 0.71 | 64.0 | 1.49 | 0.49 | 10.3 |
| 11/25/2003 | 5 | random | 7.7 | 92.3 | 0.63 | 0.35 | 0.68 | 61.6 | 1.51 | 0.51 | 11.0 |
| 11/25/2003 | 6 | 76 | 7.6 | 92.4 | 0.66 | 0.39 | 0.72 | 64.6 | 1.73 | 0.73 | 11.6 |
| 11/25/2003 | 6 | 83 | 7.5 | 92.5 | 0.67 | 0.4 | 0.73 | 65.4 | 1.63 | 0.63 | 10.9 |
| 11/25/2003 | 6 | random | 7.4 | 92.6 | 0.65 | 0.38 | 0.71 | 63.6 | 1.48 | 0.48 | 9.1 |
| 11/25/2003 | 7 | 77 | 7.8 | 92.2 | 0.67 | 0.4 | 0.73 | 65.1 | 2.05 | 1.05 | 11.2 |
| 11/25/2003 | 7 | 82 | 7.5 | 92.5 | 0.64 | 0.37 | 0.7 | 62.8 | 1.45 | 0.45 | 10.6 |
| 11/25/2003 | 7 | random | 7.9 | 92.1 | 0.63 | 0.35 | 0.68 | 61.6 | 1.41 | 0.41 | 10.2 |
| 11/25/2003 | 8 | 78 | 7.3 | 92.7 | 0.58 | 0.3 | 0.63 | 57.5 | 1.59 | 0.59 | 17.2 |
| 11/25/2003 | 8 | 81 | 7.8 | 92.2 | 0.65 | 0.38 | 0.7 | 63.3 | 1.5 | 0.5 | 10.7 |
| 11/25/2003 | 8 | random | 7.9 | 92.1 | 0.65 | 0.38 | 0.7 | 63.4 | 1.6 | 0.6 | 10.9 |
| 11/25/2003 | 9 | 79 | 7.1 | 92.9 | 0.63 | 0.36 | 0.68 | 62.0 | 1.46 | 0.46 | 10.6 |
| 11/25/2003 | 9 | 80 | 7.4 | 92.6 | 0.65 | 0.38 | 0.71 | 63. 6 | 1.26 | 0.26 | 10.1 |
| 11/25/2003 | 9 | random | 7.4 | 92.6 | 0.62 | 0.34 | 0.66 | 60.0 | 1.39 | 0.39 | 9.8 |

Table 29. First alfalfa cutting in 2004 at the Broadview reuse project.

| | | | | | Data reported on dry weight basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | CP | ADF | NDF | NDFD - 30 | NDFn | NFC | IVTDMD-30 |
| | | | % | % | % | % | % | % | % | % | % |
| 4/1/2004 | 1 | 71 | 4.9 | 95.1 | 17.6 | 25.5 | 32.2 | 49.6 | 30.0 | 40.6 | 83.8 |
| 4/1/2004 | 1 | 88 | 5.3 | 94.7 | 16.1 | 32.4 | 43. 9 | 44.0 | 40.8 | 32.5 | 75.4 |
| 4/1/2004 | 1 | random | 4.9 | 95.1 | 17.2 | 28.2 | 38.6 | 42.0 | 35.9 | 35.3 | 77.7 |
| 4/1/2004 | 2 | 72 | 4.8 | 95.2 | 18.9 | 31.4 | 38.5 | 43.6 | 35.8 | 34.8 | 78.3 |
| 4/1/2004 | 2 | 87 | 5.2 | 94.8 | 20.9 | 27.0 | 35.2 | 46.1 | 32. 8 | 35 | 81 |
| 4/1/2004 | 2 | random | 4.9 | 95.1 | 19.4 | 26.0 | 36.0 | 42.7 | 33.5 | 35.6 | 79.4 |
| 4/1/2004 | 3 | 73 | 4.6 | 95.4 | 17.6 | 34.1 | 41.0 | 46.3 | 38.1 | 33.1 | 78 |
| 4/1/2004 | 3 | 86 | 4.8 | 85.2 | 18.0 | 28.8 | 38.3 | 46.5 | 35.6 | 34.6 | 79.5 |
| 4/1/2004 | 3 | random | 4.7 | 95.3 | 17.4 | 30.9 | 41.0 | 42.4 | 38.2 | 33.6 | 76.4 |
| 4/1/2004 | 4 | 74 | 4.8 | 95.2 | 19.4 | 26.8 | 32.7 | 47.8 | 30.4 | 37.2 | 83.0 |
| 4/1/2004 | 4 | 85 | 5.2 | 94.8 | 19.0 | 25.5 | 33.9 | 45.3 | 31.6 | 37.3 | 81.4 |
| 4/1/2004 | 4 | random | 4.8 | 95.2 | 17.5 | 27.7 | 36.6 | 44.3 | 34.1 | 36.8 | 79.6 |
| 4/1/2004 | 5 | 75 | 5.0 | 95.0 | 19.4 | 26.6 | 34.3 | 48.4 | 31.9 | 37.0 | 82.3 |
| 4/1/2004 | 5 | 84 | 5.3 | 94.9 | 19.4 | 28.1 | 34.7 | 48.2 | 32.3 | 35.6 | 82 |
| 4/1/2004 | 5 | random | 5.0 | 94.7 | 17.9 | 26.0 | 35.6 | 48.5 | 33.1 | 36.7 | 81.6 |
| 4/1/2004 | 6 | 76 | 5.2 | 94.8 | 19.0 | 30.8 | 37.6 | 45.4 | 35.0 | 34.8 | 79.4 |
| 4/1/2004 | 6 | 83 | 5.1 | 94.9 | 17.8 | 32.8 | 41.8 | 48.2 | 38.8 | 32.4 | 78.4 |
| 4/1/2004 | 6 | random | 4.8 | 95.2 | 19.3 | 27.8 | 37.3 | 46.3 | 34.7 | 34.9 | 80.0 |
| 4/1/2004 | 7 | 77 | 4.8 | 95.2 | 16.4 | 32.5 | 40.9 | 46.0 | 38.0 | 34.3 | 77.9 |
| 4/1/2004 | 7 | 82 | 5.2 | 94.8 | 17.6 | 28.7 | 35.8 | 51.0 | 33.3 | 35.2 | 82.4 |
| 4/1/2004 | 7 | random | 5.1 | 94.9 | 19.4 | 25.3 | 33. 6 | 46.4 | 31.2 | 37.3 | 82 |
| 4/1/2004 | 8 | 78 | 4.9 | 95.1 | 19.5 | 27.0 | 34.6 | 48.7 | 32.2 | 36.3 | 82.2 |
| 4/1/2004 | 8 | 81 | 5.3 | 84.7 | 20.6 | 28.2 | 35.6 | 50.8 | 33.1 | 34.8 | 82.5 |
| 4/1/2004 | 8 | random | 5.0 | 95.0 | 19.4 | 26.5 | 35.6 | 46.3 | 33.1 | 35.2 | 80.9 |
| 4/1/2004 | 9 | 79 | 5.4 | 95.5 | 19.9 | 32.1 | 38.9 | 469.9 | 36.2 | 32.8 | 79.4 |
| 4/1/2004 | 9 | 80 | 5.3 | 94.7 | 21.2 | 28.0 | 35.8 | 49.3 | 33.3 | 34.2 | 81.8 |
| 4/1/2004 | 9 | random | 5.0 | 95.0 | 19.6 | 29.4 | 38.6 | 42.3 | 35.8 | 34.1 | 77.8 |

Table 29. Continued.

| | | | | | Data reported on dry weight basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | NEL | NEG | NEM | TDN | Fat(ee) | Fattty Acids | ASH |
| | | | % | % | Mcal/lb | Mcal/lb | Mcal/lb | % | % | % | % |
| 4/1/2004 | 1 | 71 | 4.9 | 95.1 | 0.7 | 0.44 | 0.76 | | 2.74 | 1.74 | 9 |
| 4/1/2004 | 1 | 88 | 5.3 | 94.7 | 0.6 | 0.31 | 0.64 | | 1.35 | 0.35 | 9.3 |
| 4/1/2004 | 1 | random | 4.9 | 95.1 | 0.61 | 0.33 | 0.66 | | 1.69 | 0.69 | 9.9 |
| 4/1/2004 | 2 | 72 | 4.8 | 95.2 | 0.64 | 0.36 | 0.69 | | 2.04 | 1.04 | 8.5 |
| 4/1/2004 | 2 | 87 | 5.2 | 94.8 | 0.65 | 0.38 | 0.71 | | 1.89 | 0.89 | 9.4 |
| 4/1/2004 | 2 | random | 4.9 | 95.1 | 0.64 | 0.36 | 0.69 | | 1.97 | 0.97 | 9.5 |
| 4/1/2004 | 3 | 73 | 4.6 | 95.4 | 0.62 | 0.34 | 0.67 | | 1.67 | 0.67 | 9.6 |
| 4/1/2004 | 3 | 86 | 4.8 | 85.2 | 0.63 | 0.36 | 0.68 | | 1.84 | 0.84 | 10 |
| 4/1/2004 | 3 | random | 4.7 | 95.3 | 0.61 | 0.33 | 0.65 | | 1.6 | 0.6 | 9.3 |
| 4/1/2004 | 4 | 74 | 4. 8 | 95.2 | 0.67 | 0.4 | 0.72 | | 2.35 | 1.35 | 10.6 |
| 4/1/2004 | 4 | 85 | 5.2 | 94.8 | 0.66 | 0.39 | 0.72 | | 2.26 | 1.26 | 9.9 |
| 4/1/2004 | 4 | random | 4.8 | 95.2 | 0.64 | 0.36 | 0.69 | | 1.83 | 0.83 | 9.9 |
| 4/1/2004 | 5 | 75 | 5.0 | 95.0 | 0.67 | 0.4 | 0.73 | | 2.16 | 1.16 | 9.6 |
| 4/1/2004 | 5 | 84 | 5.3 | 94.9 | 0.65 | 0.37 | 0.7 | | 1.78 | 0.78 | 11.0 |
| 4/1/2004 | 5 | random | 5.0 | 94.7 | 0.66 | 0.38 | 0.71 | | 1.99 | 0.99 | 10.3 |
| 4/1/2004 | 6 | 76 | 5.2 | 94.8 | 0.64 | 0.37 | 0.69 | | 1.98 | 0.98 | 9.3 |
| 4/1/2004 | 6 | 83 | 5.1 | 94.9 | 0.63 | 0.35 | 0.68 | | 1.64 | 0.64 | 9.3 |
| 4/1/2004 | 6 | random | 4.8 | 95.2 | 0.65 | 0.37 | 0.7 | | 1.88 | 0.88 | 9.1 |
| 4/1/2004 | 7 | 77 | 4.8 | 95.2 | 0.63 | 0.35 | 0.67 | | 1.82 | 0.82 | 9.4 |
| 4/1/2004 | 7 | 82 | 5.2 | 94.8 | 0.64 | 0.37 | 0.69 | | 1.82 | 0.82 | 12.1 |
| 4/1/2004 | 7 | random | 5.1 | 94.9 | 0.66 | 0.39 | 0.72 | | 2.14 | 1.14 | 9.9 |
| 4/1/2004 | 8 | 78 | 4.9 | 95.1 | 0.67 | 0.4 | 0.72 | | 2.19 | 1.19 | 9.9 |
| 4/1/2004 | 8 | 81 | 5.3 | 84.7 | 0.67 | 0.4 | 0.73 | | 1.89 | 0.89 | 9.6 |
| 4/1/2004 | 8 | random | 5.0 | 95.0 | 0.64 | 0.36 | 0.69 | | 1.72 | 0.72 | 10. 7 |
| 4/1/2004 | 9 | 79 | 5.4 | 95.5 | 0.64 | 0.37 | 0.69 | | 1.94 | 0.94 | 9.1 |
| 4/1/2004 | 9 | 80 | 5.3 | 94.7 | 0.67 | 0.4 | 0.72 | | 2.04 | 1.04 | 9.3 |
| 4/1/2004 | 9 | random | 5.0 | 95.0 | 0.62 | 0.34 | 0.67 | | 1.51 | 0.51 | 9.0 |

Table 30. Second alfalfa cutting in 2004 at the Broadview reuse project.

| | | | | | Data reported on dry matter basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | CP | ADF | NDF | NDFD - 30 | NDFn | NFC | IVTDMD-30 |
| | | | % | % | % | % | % | % | % | % | % |
| 6/1/2004 | 1 | 71 | 5.6 | 94.4 | 22.3 | 19.8 | 26.4 | 48.4 | 24.5 | 41.9 | 86.4 |
| 6/1/2004 | 1 | 88 | 5.2 | 94.8 | 21.7 | 19.8 | 26.1 | 50.2 | 24.3 | 41.7 | 87 |
| 6/1/2004 | 1 | random | 4.8 | 95.2 | 22.8 | 18.8 | 27.8 | 56.5 | 25.9 | 40.3 | 87.9 |
| 6/1/2004 | 2 | 72 | 5.9 | 94.1 | 22.1 | 22.2 | 27.6 | 49.6 | 25.7 | 40.9 | 86.1 |
| 6/1/2004 | 2 | 87 | 4.6 | 95.4 | 22.5 | 21.6 | 27.4 | 51.4 | 25.5 | 40.6 | 86.7 |
| 6/1/2004 | 2 | random | 4. 8 | 95.2 | 21.4 | 22.6 | 31.3 | 50.5 | 29.1 | 38.7 | 84.5 |
| 6/1/2004 | 3 | 73 | 6.0 | 94.0 | 22.4 | 26.2 | 32.0 | 47.3 | 29.8 | 36.8 | 83.1 |
| 6/1/2004 | 3 | 86 | 4.7 | 95.3 | 19.6 | 26. 7 | 34.2 | 46.8 | 31.8 | 38.6 | 81.8 |
| 6/1/2004 | 3 | random | 4.7 | 95.3 | 21.7 | 23.1 | 31.8 | 48.1 | 29.6 | 37.8 | 83.5 |
| 6/1/2004 | 4 | 74 | 6.9 | 93.1 | 21.4 | 21.8 | 28.6 | 50 | 26.6 | 41.2 | 85.7 |
| 6/1/2004 | 4 | 85 | 5.3 | 94.7 | 19.5 | 23.2 | 29.2 | 55.1 | 27.2 | 42.5 | 86.9 |
| 6/1/2004 | 4 | random | 4.9 | 95.1 | 20.1 | 23.2 | 28.9 | 52.9 | 26.8 | 41.3 | 86.4 |
| 6/1/2004 | 5 | 75 | 6.5 | 93.5 | 22.0 | 21.9 | 26.4 | 47.8 | 24.6 | 43.1 | 86.2 |
| 6/1/2004 | 5 | 84 | 4.9 | 95.1 | 22.0 | 21.5 | 29.2 | 53.4 | 27.1 | 39.9 | 86.4 |
| 6/1/2004 | 5 | random | 4.9 | 95.1 | 21.4 | 22.3 | 28.8 | 47.1 | 26.7 | 41.2 | 84.8 |
| 6/1/2004 | 6 | 76 | 5.6 | 94.4 | 21.1 | 25.4 | 32.7 | 42.8 | 30.4 | 37.1 | 81.3 |
| 6/1/2004 | 6 | 83 | 5.4 | 94.6 | 21.3 | 23.6 | 31.5 | 47 | 29.3 | 38.3 | 83.3 |
| 6/1/2004 | 6 | random | 4.7 | 95.3 | 21.4 | 25. 6 | 32.5 | 45 | 30.3 | 27.5 | 82.1 |
| 6/1/2004 | 7 | 77 | 7.4 | 92.6 | 22.0 | 19.7 | 26.3 | 47.1 | 24.4 | 42.6 | 86.1 |
| 6/1/2004 | 7 | 82 | 5.0 | 95.0 | 22.0 | 22.6 | 27.6 | 49.7 | 25.7 | 41.3 | 86.1 |
| 6/1/2004 | 7 | random | 5.2 | 94.8 | 22.4 | 22.0 | 30.0 | 50.6 | 27.0 | 40.6 | 85.7 |
| 6/1/2004 | 8 | 78 | 5.5 | 94.5 | 22.4 | 20.2 | 25.5 | 50.5 | 23.7 | 43.0 | 87.4 |
| 6/1/2004 | 8 | 81 | 5.0 | 95.0 | 22.5 | 24.7 | 28.4 | 50.1 | 26.5 | 38.1 | 85.8 |
| 6/1/2004 | 8 | random | 5.0 | 95.0 | 21.6 | 24.1 | 30.5 | 52.5 | 28.4 | 39.8 | 85.5 |
| 6/1/2004 | 9 | 79 | 5.4 | 94.6 | 20.7 | 23.1 | 29.9 | 42.8 | 27.8 | 41.0 | 82.9 |
| 6/1/2004 | 9 | 80 | 4.8 | 95.2 | 21.3 | 24.8 | 31.3 | 46 | 29.1 | 39.3 | 83.1 |
| 6/1/2004 | 9 | random | 4.9 | 95.1 | 20.2 | 25.5 | 31.5 | 42.9 | 29.3 | 41.0 | 82 |

Table 30. Continued.

| | | | | | Data reported on dry matter basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | NEL | NEG | NEM | TDN | Fat(ee) | Fattty Acids | ASH |
| | | | % | % | Mcal/lb | Mcal/lb | Mcal/lb | % | % | % | % |
| 6/1/2004 | 1 | 71 | 5.6 | 94.4 | 0.72 | 0.46 | 0.79 | 69.7 | 2.41 | 1.41 | 8.9 |
| 6/1/2004 | 1 | 88 | 5.2 | 94.8 | 0.71 | 0.44 | 0.77 | 68.4 | 1.99 | 0.99 | 10.4 |
| 6/1/2004 | 1 | random | 4.8 | 95.2 | 0.72 | 0.46 | 0.79 | 70.1 | 1.83 | 0.83 | 9.2 |
| 6/1/2004 | 2 | 72 | 5.9 | 94.1 | 0.71 | 0.45 | 0.78 | 69.1 | 2.27 | 1.27 | 9.1 |
| 6/1/2004 | 2 | 87 | 4.6 | 95.4 | 0.72 | 0.45 | 0.78 | 69.2 | 2.1 | 1.1 | 9.3 |
| 6/1/2004 | 2 | random | 4.8 | 95.2 | 0.69 | 0.42 | 0.75 | 66.8 | 1.58 | 0.58 | 9.2 |
| 6/1/2004 | 3 | 73 | 6.0 | 94.0 | 0.69 | 0.42 | 0.75 | 66.6 | 2.32 | 1.32 | 9 |
| 6/1/2004 | 3 | 86 | 4.7 | 95.3 | 0.68 | 0.41 | 0.73 | 65.7 | 1.77 | 0.77 | 8.2 |
| 6/1/2004 | 3 | random | 4.7 | 95.3 | 0.68 | 0.41 | 0.74 | 65.9 | 1.66 | 0.66 | 9.3 |
| 6/1/2004 | 4 | 74 | 6.9 | 93.1 | 0.7 | 0.44 | 0.77 | 68.1 | 1.71 | 0.71 | 9.1 |
| 6/1/2004 | 4 | 85 | 5.3 | 94.7 | 0.72 | 0.46 | 0.79 | 69.6 | 1.86 | 0.86 | 9.0 |
| 6/1/2004 | 4 | random | 4.9 | 95.1 | 0.7 | 0.44 | 0.76 | 67.8 | 1.68 | 0.68 | 10.1 |
| 6/1/2004 | 5 | 75 | 6.5 | 93.5 | 0.72 | 0.46 | 0.79 | 69.7 | 2.05 | 1.05 | 8.3 |
| 6/1/2004 | 5 | 84 | 4.9 | 95.1 | 0.72 | 0.46 | 0.78 | 69.4 | 2.09 | 1.09 | 8.9 |
| 6/1/2004 | 5 | random | 4.9 | 95.1 | 0.69 | 0.43 | 0.76 | 67.4 | 1.67 | 0.67 | 8.9 |
| 6/1/2004 | 6 | 76 | 5.6 | 94.4 | 0.65 | 0.38 | 0.71 | 63.7 | 1.74 | 0.74 | 9.6 |
| 6/1/2004 | 6 | 83 | 5.4 | 94.6 | 0.68 | 0.42 | 0.74 | 66.4 | 2.03 | 1.03 | 9.1 |
| 6/1/2004 | 6 | random | 4.7 | 95.3 | 0.67 | 0.4 | 0.72 | 64.9 | 1.77 | 0.77 | 9.1 |
| 6/1/2004 | 7 | 77 | 7.4 | 92.6 | 0.71 | 0.45 | 0.78 | 69 | 2.05 | 1.05 | 8.9 |
| 6/1/2004 | 7 | 82 | 5.0 | 95.0 | 0.71 | 0.45 | 0.78 | 68.9 | 2.02 | 1.02 | 9.0 |
| 6/1/2004 | 7 | random | 5.2 | 94.8 | 0.71 | 0.45 | 0.78 | 69.0 | 1.81 | 0.81 | 8.2 |
| 6/1/2004 | 8 | 78 | 5.5 | 94.5 | 0.73 | 0.47 | 0.8 | 70.4 | 2.13 | 1.13 | 8.8 |
| 6/1/2004 | 8 | 81 | 5.0 | 95.0 | 0.69 | 0.42 | 0.75 | 66.9 | 2.09 | 1.09 | 10.9 |
| 6/1/2004 | 8 | random | 5.0 | 95.0 | 0.71 | 0.45 | 0.77 | 68.7 | 1.78 | 0.78 | 8.4 |
| 6/1/2004 | 9 | 79 | 5.4 | 94.6 | 0.7 | 0.43 | 0.76 | 67.5 | 2.45 | 1.45 | 8.0 |
| 6/1/2004 | 9 | 80 | 4.8 | 95.2 | 0.69 | 0.43 | 0.75 | 67.3 | 2.17 | 1.17 | 8.1 |
| 6/1/2004 | 9 | random | 4.9 | 95.1 | 0.68 | 0.42 | 0.74 | 66.5 | 1.91 | 0.91 | 7.6 |

Table 31. Third alfalfa cutting 2004 at the Broadview reuse project.

| | | | | | Data presented on a dry weight basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | CP | ADF | NDF | NDFD - 30 | NDFn | NFC | IVTDMD-30 |
| | | | % | % % | % | % | % | % | | % | % |
| 7/16/2004 | 1 | 71 | 5.5 | 94.5 | 22.3 | 24.0 | 29.4 | 51 | 27.3 | 36.6 | 85.6 |
| 7/16/2004 | 1 | 88 | 6.1 | 93.9 | 22.7 | 22.4 | 28.3 | 46.3 | 26.4 | 36.5 | 84.8 |
| 7/16/2004 | 1 | random | 5.2 | 94.8 | 20.8 | 23.7 | 29.9 | 52.5 | 27.8 | 38.5 | 85.8 |
| 7/16/2004 | 2 | 72 | 5.2 | 94.8 | 21.0 | 26.2 | 30.6 | 46.5 | 28.5 | 36.8 | 83.6 |
| 7/16/2004 | 2 | 87 | 5.4 | 94.6 | 20.8 | 25.9 | 31.2 | 45.4 | 29.0 | 36.6 | 83 |
| 7/16/2004 | 2 | random | 5.0 | 95.0 | 21.8 | 22.0 | 27.4 | 53.6 | 25.5 | 40.8 | 87.3 |
| 7/16/2004 | 3 | 73 | 4.8 | 95.2 | 19.0 | 24.1 | 31.4 | 47.1 | 29.2 | 35.6 | 83.4 |
| 7/16/2004 | 3 | 86 | 4.9 | 95.1 | 20.7 | 24.3 | 31.8 | 47.1 | 29.5 | 36.9 | 83.2 |
| 7/16/2004 | 3 | random | 4.7 | 95.3 | 20.8 | 22.3 | 27.1 | 56.4 | 25.2 | 42.5 | 88.2 |
| 7/16/2004 | 4 | 74 | 5.2 | 94.8 | 20.9 | 22.8 | 29.7 | 45.8 | 27.6 | 37.2 | 83.9 |
| 7/16/2004 | 4 | 85 | 5.2 | 94.8 | 20.8 | 25.3 | 33.6 | 47 | 31.2 | 35.2 | 82.2 |
| 7/16/2004 | 4 | random | 5.1 | 94.9 | 22.3 | 21.2 | 26.6 | 51.4 | 24.7 | 40.7 | 87.1 |
| 7/16/2004 | 5 | 75 | 5.1 | 94.9 | 20.7 | 25.1 | 32.4 | 41.1 | 30.2 | 35 | 80.9 |
| 7/16/2004 | 5 | 84 | 5.5 | 94.5 | 22.4 | 24.2 | 30.7 | 44.3 | 28.6 | 35.5 | 82.9 |
| 7/16/2004 | 5 | random | 5.1 | 94.9 | 22.2 | 20.9 | 28.5 | 54.4 | 26.5 | 39.1 | 87 |
| 7/16/2004 | 6 | 76 | 5.0 | 95.0 | 18.5 | 28.1 | 38.3 | 40.1 | 35.6 | 35.1 | 77.1 |
| 7/16/2004 | 6 | 83 | 4.8 | 95.2 | 19.9 | 27.9 | 35.5 | 40.8 | 33.0 | 34.7 | 79 |
| 7/16/2004 | 6 | random | 5.1 | 94.9 | 20.4 | 22.4 | 26.3 | 50.6 | 24.5 | 44.1 | 87 |
| 7/16/2004 | 7 | 77 | 5.0 | 95.0 | 21.1 | 24.8 | 30.7 | 45 | 28.6 | 36.3 | 83.1 |
| 7/16/2004 | 7 | 82 | 5.1 | 94.9 | 20.0 | 27.6 | 36.1 | 39.6 | 33.6 | 32.9 | 78.2 |
| 7/16/2004 | 7 | random | 4.9 | 95.1 | 21.5 | 21.9 | 28.7 | 41.8 | 26.7 | 39.7 | 83.3 |
| 7/16/2004 | 8 | 78 | 5.1 | 94.9 | 21.1 | 26.6 | 33.5 | 41.8 | 31.2 | 34.8 | 80.5 |
| 7/16/2004 | 8 | 81 | 4.9 | 95.1 | 20.6 | 27.8 | 34.4 | 41.8 | 32.0 | 34.2 | 80 |
| 7/16/2004 | 8 | random | 4.4 | 95. 6 | 21.3 | 24.4 | 31.4 | 42 | 29.2 | 38.2 | 81.8 |
| 7/16/2004 | 9 | 79 | 4.4 | 95.6 | 15.5 | 35.0 | 43.2 | 34.8 | 40.2 | 31.6 | 71.8 |
| 7/16/2004 | 9 | 80 | 4.7 | 95.3 | 20.6 | 28.2 | 35.7 | 39.3 | 33.2 | 35.0 | 78.3 |
| 7/16/2004 | 9 | random | 4.8 | 95.2 | 18.8 | 31.8 | 40.1 | 33.5 | 37.3 | 33.9 | 73.5 |

Table 31. Continued.

| | | | | | Data reported on dry matter basis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Plot | Location | Moisture | Dry Matter | NEL | NEG | NEM | TDN | Fat(ee) | Fattty Acids | ASH |
| | | | % | % | Mcal/lb | Mcal/lb | Mcal/lb | % | % | % | % |
| 7/16/2004 | 1 | 71 | 5.5 | 94.5 | 0.69 | 0.43 | 0.76 | 67.3 | 2.73 | 1.73 | 11.0 |
| 7/16/2004 | 1 | 88 | 6.1 | 93.9 | 0.66 | 0.39 | 0.72 | 64.3 | 2.01 | 1.01 | 12.4 |
| 7/16/2004 | 1 | random | 5.2 | 94.8 | 0.69 | 0.42 | 0.75 | 66.7 | 1.94 | 0.94 | 11.0 |
| 7/16/2004 | 2 | 72 | 5.2 | 94.8 | 0.68 | 0.41 | 0.74 | 66.0 | 2.92 | 1.92 | 10.8 |
| 7/16/2004 | 2 | 87 | 5.4 | 94.6 | 0.67 | 0.4 | 0.73 | 65.3 | 2.79 | 1.79 | 10.8 |
| 7/16/2004 | 2 | random | 5.0 | 95.0 | 0.72 | 0.46 | 0.78 | 69.5 | 2.18 | 1.18 | 9.8 |
| 7/16/2004 | 3 | 73 | 4.8 | 95.2 | 0.67 | 0.4 | 0.72 | 65.0 | 3.57 | 2.57 | 12.6 |
| 7/16/2004 | 3 | 86 | 4.9 | 95.1 | 0.69 | 0.42 | 0.75 | 66.6 | 2.96 | 1.96 | 9.9 |
| 7/16/2004 | 3 | random | 4.7 | 95.3 | 0.74 | 0.49 | 0.81 | 71.7 | 2.6 | 1.6 | 9.0 |
| 7/16/2004 | 4 | 74 | 5.2 | 94.8 | 0.69 | 0.42 | 0.75 | 66.6 | 3.33 | 2.33 | 11 |
| 7/16/2004 | 4 | 85 | 5.2 | 94.8 | 0.67 | 0.39 | 0.72 | 64.8 | 2.49 | 1.49 | 10.3 |
| 7/16/2004 | 4 | random | 5.1 | 94.9 | 0.78 | 0.45 | 0.78 | 69.0 | 2.23 | 1.23 | 10.1 |
| 7/16/2004 | 5 | 75 | 5.1 | 94.9 | 0.65 | 0.37 | 0.7 | 63.2 | 2.95 | 1.95 | 11.2 |
| 7/16/2004 | 5 | 84 | 5.5 | 94.5 | 0.66 | 0.39 | 0.72 | 64.4 | 2.45 | 1.45 | 11.2 |
| 7/16/2004 | 5 | random | 5.1 | 94.9 | 0.71 | 0.45 | 0.78 | 68.9 | 2.14 | 1.14 | 10.0 |
| 7/16/2004 | 6 | 76 | 5.0 | 95.0 | 0.62 | 0.35 | 0.97 | 61.1 | 2 | 1 | 8.8 |
| 7/16/2004 | 6 | 83 | 4.8 | 95.2 | 0.64 | 0.37 | 0.7 | 62.9 | 2.78 | 1.78 | 9.6 |
| 7/16/2004 | 6 | random | 5.1 | 94.9 | 0.73 | 0.47 | 0.79 | 70.3 | 2.19 | 1.19 | 8.8 |
| 7/16/2004 | 7 | 77 | 5.0 | 95.0 | 0.68 | 0.41 | 0.74 | 65. 9 | 3.22 | 2.22 | 10.8 |
| 7/16/2004 | 7 | 82 | 5.0 | 94.9 | 0.61 | 0.33 | 0.66 | 59.8 | 2.23 | 1.23 | 11.3 |
| 7/16/2004 | 7 | random | 4.9 | 95.1 | 0.67 | 0.4 | 0.73 | 65.5 | 2.15 | 1.15 | 10 |
| 7/16/2004 | 8 | 78 | 5.1 | 94.9 | 0.64 | 0.36 | 0.69 | 62.4 | 2.22 | 1.22 | 10.7 |
| 7/16/2004 | 8 | 81 | 4.9 | 95.1 | 0.63 | 0.36 | 0.68 | 61.8 | 2.29 | 1.29 | 11.0 |
| 7/16/2004 | 8 | random | 4.4 | 95.6 | 0.66 | 0.39 | 0.72 | 64.5 | 1.9 | 0.9 | 9.4 |
| 7/16/2004 | 9 | 79 | 4.4 | 95.6 | 0.55 | 0.26 | 0.59 | 54.6 | 2.06 | 1.06 | 10. 7 |
| 7/16/2004 | 9 | 80 | 4.7 | 95.3 | 0.65 | 0.37 | 0.7 | 63.0 | 2.56 | 1.56 | 8.5 |
| 7/16/2004 | 9 | random | 4.7 | 95.2 | 0.59 | 0.3 | 0.63 | 57.5 | 1.61 | 0.61 | 8.4 |

The data were used to determine the effect of the irrigation treatments and the location of the sample on the quality of the forage. Dr. Peter Robinson completed the analysis. The parameters used in the analysis were; crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), digestible NDF as a percentage NDF (dNDF), non-fibrous carbohydrates (NFC), net energy lactation ($Ne_l$), fat (EE), ash, in-vitro digestible dry matter(IVDDM). These data are summarized in table 32.

The statistical analysis of the forage quality is given in table 32. In 2003 there were statistical differences by treatment in the NDF, NFC, and EE as well as in the yield. The highest yield values were found in the FRESH treatment. In the second cut of 2003 differences were noted by location in the field between the north, center, and south. There were differences in yield both by treatment and location. Fresh had the highest yield and the south location was highest. By cut 3 differences were found in all forage quality parameters as a function of water quality treatment. Yields were significantly different by location in the field for all treatments. In cut 4 there were statistical variations by treatment and well as the CP.

In 2004 the yield variability was eliminated in cut 1. In the forage quality parameters there were differences in the ADF and the NFC by treatment and differences in EE by location. In cut 2 statistical differences developed in the ADF, NDF, dNDF, NFC, IVDDM by treatment. In cut 3 the CP was different by location and treatment. There were significant yield differences by treatment.

Since the plants are being grown in saline soils and irrigated with poor quality water there is a need to consider the accumulation of various ion in the plant material. The elemental concentrations of boron and chloride are given in tables 32 and 33, respectively. There appears to be an increase in the average concentrations of both B and Cl as the season progresses. This is followed by a reduction late in the season and with the first harvest the following year. The early harvests each year have approximately the same concentrations. Since all plots received the same quality irrigation water during 2002 except for the last irrigation, there should not be much separation in the values as a function of the irrigation water quality. The Cl and B concentrations were averaged for each treatment and plotted in Fig 25 and 26, respectively. The data show in 2003 and 2004 that the plant concentration was related to the total applied drainage water. The concentration increased from FRESH to GW to DRAIN. This is not the case in 2004

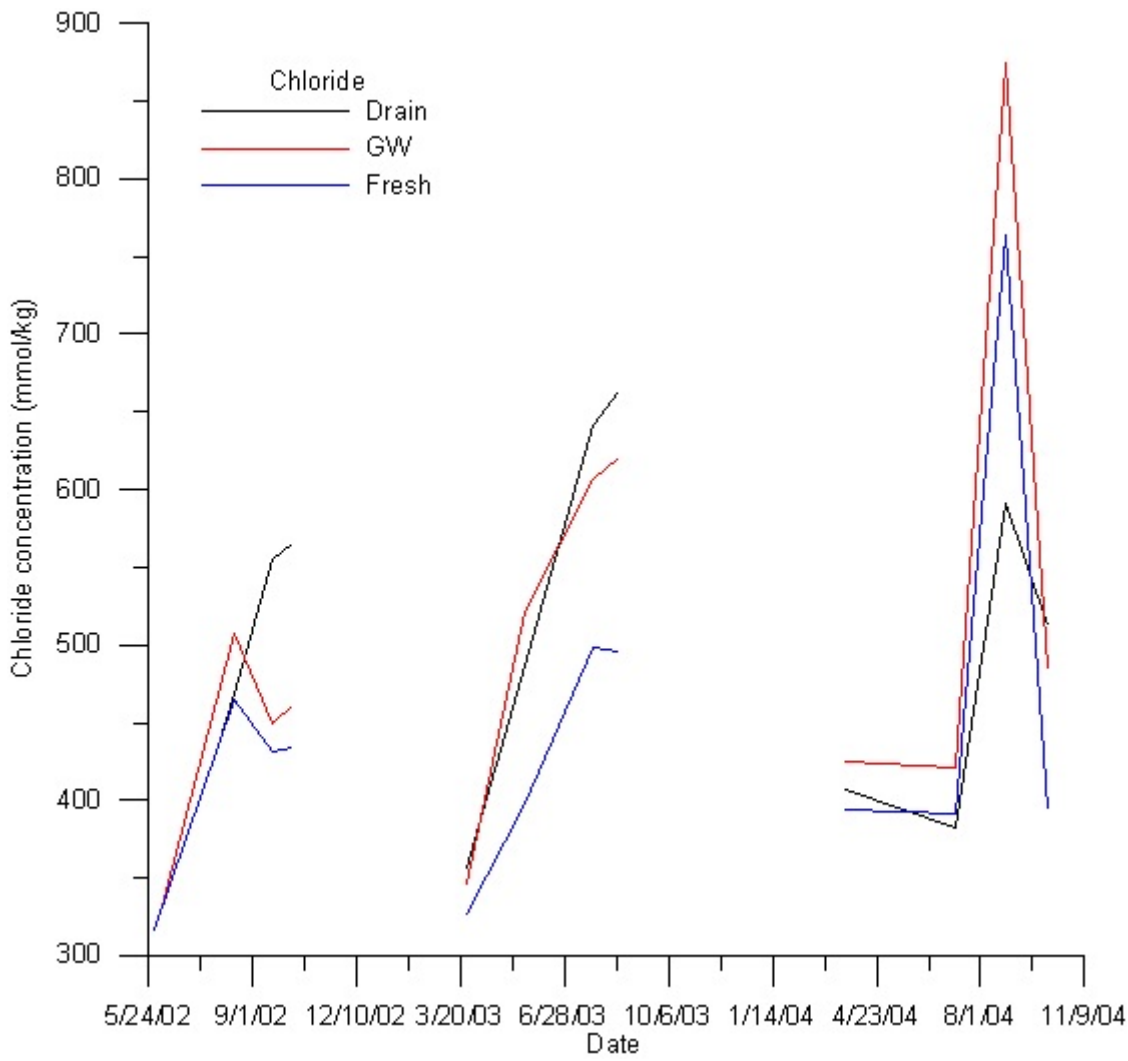



Figure 25. Average chloride concentration in alfalfa hay grown in Broadview drainage reuse project as a function of irrigation treatment.

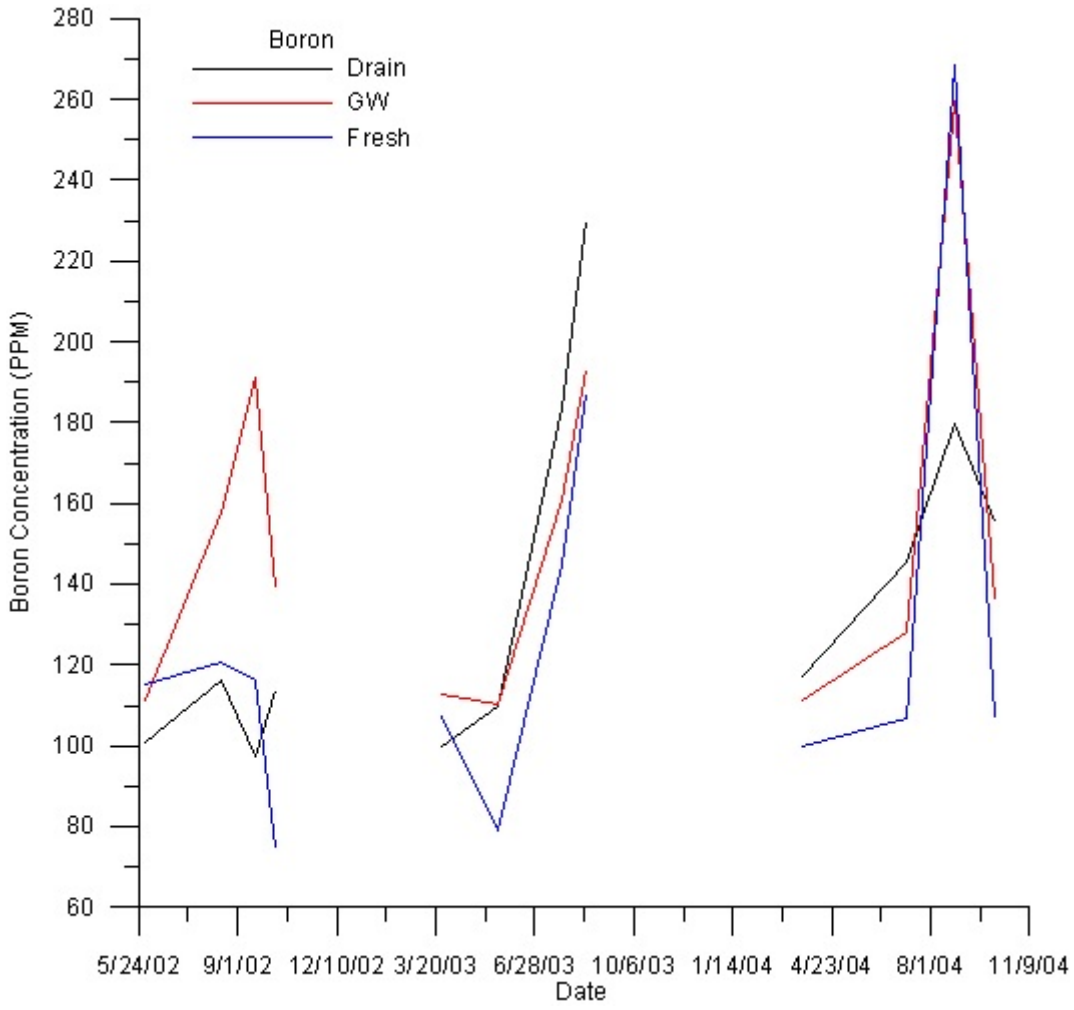



Figure 26. Average boron concentration in alfalfa hay grown in Broadview drainage reuse project as a function of irrigation treatment.

Table 32. Statistical analysis of the impacts of water source and harvest location relative to inlet water on chemical composition of alfalfa hay (values as % DM, except dNDF (% NDF), $NE_l$ (Mcal/lb DM).for 2003 and 2004.

**2003**

| | Treatment | | | Location | | | | Probability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FRESH | DRAIN | GW | No | Ctr | So | SEM | Trt | Loc | T*L |
| **Cut 1** | | | | | | | | | | |
| CP | 25.8 | 26.2 | 26.1 | 26.6 | 25.0 | 26.6 | .58 | .85 | .09 | .96 |
| ADF | 29.3 | 27.2 | 27.6 | 28.0 | 29.2 | 26.9 | .74 | .10 | .09 | .89 |
| NDF | 37.2[a] | 35.1 | 34.4[b] | 35.8 | 36.3 | 34.6 | .77 | .04 | .26 | .96 |
| dNDF | 44.9 | 43.2 | 45.0 | 43.9 | 43.9 | 45.3 | 1.91 | .12 | .21 | .82 |
| NFC | 26.4[a] | 28.5[b] | 28.0[b] | 26.7 | 28.3 | 27.9 | .24 | .03 | .11 | .84 |
| $NE_l$ | .60 | .61 | .61 | .60 | .60 | .62 | .008 | .32 | .49 | .94 |
| EE | 1.19[a] | 1.34[b] | 1.32[b] | 1.31 | 1.24 | 1.30 | .058 | .04 | .43 | .70 |
| Ash | 12.0 | 11.3 | 12.5 | 12.1 | 11.7 | 12.1 | .366 | .07 | .59 | .81 |
| IVDDM | 79.5 | 80.1 | 81.0 | 79.9 | 79.6 | 81.1 | .53 | .12 | .12 | .93 |
| Yield | 1105[x] | 798[y] | 941 | 918 | 1028 | 897 | 77.6 | .03 | .42 | .48 |
| **Cut 2** | | | | | | | | | | |
| CP | 24.6 | 24.0 | 23.5 | 24.6 | 23.5 | 23.9 | .38 | .16 | .12 | .72 |
| ADF | 27.8 | 26.2 | 27.4 | 26.9 | 27.5 | 27.0 | .51 | .08 | .70 | .70 |
| NDF | 34.0 | 32.4 | 33.5 | 32.3 | 33.8 | 33.8 | .66 | .23 | .15 | .92 |
| dNDF | 51.1 | 52.7 | 51.9 | 57.0[x] | 48.3[y] | 50.3[y] | 1.19 | .62 | <.01 | .79 |
| NFC | 29.7 | 32.3 | 31.2 | 31.0 | 31.5 | 30.6 | .84 | .10 | .74 | .84 |
| $NE_l$ | .64 | .64 | .65 | .67[x] | .63[y] | .62[y] | .008 | .76 | <.01 | .81 |
| EE | 1.54 | 1.52 | 1.58 | 1.72[x] | 1.50[y] | 1.43[y] | .050 | .66 | <.01 | .87 |
| Ash | 12.6 | 13.2 | 12.5 | 12.6 | 12.0 | 13.7 | .55 | .63 | .10 | .65 |
| IVDDM | 83.3 | 84.6 | 83.9 | 86.1[x] | 82.5[y] | 83.2[y] | .61 | .29 | <.01 | .89 |
| Yield | 995[x] | 732[y] | 728[y] | 727[a] | 861[b] | 866[b] | 43.8 | <.01 | .05 | .75 |

[a,b]- means with different superscripts within treatment or location differ (P<0.05).
[x,y]- means with different superscripts within treatment or location differ (P<0.01

| | Treatment | | | Location | | | | Probability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FRESH | DRAIN | GW | No | Ctr | So | SEM | Trt | Loc | T*L |
| **Cut 3** | | | | | | | | | | |
| CP | 21.1 | 20.1[x] | 21.8[y] | 21.1 | 20.7 | 21.2 | .39 | .01 | .65 | .15 |
| ADF | 28.5[x] | 27.5[x] | 24.1[y] | 25.9 | 27.3 | 26.9 | .63 | <.01 | .22 | .42 |
| NDF | 35.3[x] | 35.0[x] | 30.5[y] | 33.5 | 33.8 | 33.4 | .75 | <.01 | .90 | .33 |
| dNDF | 49.1[a] | 48.5[x] | 52.6[y,b] | 52.1[a] | 48.2[b] | 49.8 | 1.03 | .02 | .03 | .24 |
| NFC | 34.2[x] | 33.8[x] | 36.6[y] | 34.7 | 34.8 | 35.1 | .39 | <.01 | .77 | .13 |
| $NE_l$ | .65[a] | .63[x] | .68[y,b] | .66 | .65 | .66 | .007 | <.01 | .63 | .06 |
| EE | 1.75[b] | 1.55[a,x] | 1.88[y] | 1.63 | 1.83 | 1.72 | .068 | <.01 | .13 | .22 |
| Ash | 10.2[x] | 12.0[a,x] | 11.4[y] | 11.4 | 11.2 | 11.0 | .37 | <.01 | .76 | .25 |
| IVDDM | 82.0[x] | 82.0[x] | 85.5[y] | 83.9 | 82.5 | 83.2 | .54 | <.01 | .18 | .10 |
| Yield | 395[x] | 334[x] | 215[y] | 274 | 362 | 309 | 36.0 | <.01 | .21 | .89 |
| **Cut4** | | | | | | | | | | |
| CP | 23.3[x] | 20.7[y] | 20.9[y] | 21.5 | 21.3 | 22.2 | .40 | <.01 | .27 | .09 |
| ADF | 26.5 | 25.6 | 26.5 | 25.8 | 27.4 | 25.4 | .66 | .55 | .08 | .85 |
| NDF | 34.3 | 34.7 | 34.0 | 33.6 | 36.2 | 33.2 | .80 | .85 | .02 | .79 |
| dNDF | 47.2 | 46.4 | 46.2 | 47.6[a] | 44.9[b] | 47.2 | .83 | .62 | .05 | .21 |
| NFC | 33.1 | 34.5 | 33.7 | 33.6 | 33.0 | 34.7 | .65 | .32 | .16 | .90 |
| $NE_l$ | .65 | .64 | .63 | .64 | .63 | .65 | .008 | .23 | .17 | .85 |
| EE | 1.44 | 1.59 | 1.53 | 1.67[x,a] | 1.40[y] | 1.48[b] | .060 | .18 | .01 | .99 |
| Ash | 10.2[x] | 11.1 | 12.1[y] | 11.0 | 10.7 | 10.8 | .45 | .02 | .08 | .52 |
| IVDDM | 81.9 | 81.4 | 81.6 | 82.4 | 80.1 | 82.5 | .60 | .86 | .01 | .66 |
| Yield | 549[x] | 314[y] | 331[y] | 362 | 389 | 444 | 31.0 | <.01 | .15 | .97 |

[a,b]- means with different superscripts within treatment or location differ (P<0.05).
[x,y]- means with different superscripts within treatment or location differ (P<0.01).

**2004**

| | Treatment | | | Location | | | | Probability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FRESH | DRAIN | GW | No | Ctr | So | SEM | Trt | Loc | T*L |
| **Cut 1** | | | | | | | | | | |
| CP | 18.9 | 18.7 | 18.5 | 18.6 | 18.6 | 18.9 | .54 | .91 | .85 | .96 |
| ADF | 30.5[x] | 27.9[y] | 27.6[y] | 29.7 | 27.5 | 28.8 | .67 | <.01 | .09 | .07 |
| NDF | 38.9 | 35.9 | 36.1 | 36.7 | 37.0 | 37.2 | .97 | .06 | .93 | .31 |
| dNDF | 45.9 | 45.9 | 47.4 | 47.0[a] | 44.6[x,b] | 47.7[y] | .82 | .33 | .03 | .75 |
| NFC | 33.8[x] | 35.9[y] | 36.0[y] | 35.7 | 35.5 | 34.6 | .48 | <.01 | .25 | .09 |
| $NE_l$ | .63 | .65 | .65 | .65 | .64 | .64 | .020 | .20 | .27 | .24 |
| EE | 1.79 | 2.01 | 1.95 | 2.10[x] | 1.81[y] | 1.83[y] | .081 | .13 | .03 | .12 |
| Ash | 9.3 | 9.9 | 9.9 | 9.46 | 9.73 | 9.99 | .254 | .17 | .32 | .62 |
| IVDDM | 79.0 | 80.6 | 80.9 | 80.5 | 79.5 | 80.5 | .73 | .13 | .50 | .36 |
| Yield | 495 | 453 | 491 | 470 | 450 | 519 | 25.9 | .44 | .15 | .57 |
| **Cut 2** | | | | | | | | | | |
| CP | 21.1 | 21.5 | 22.1 | 21.8 | 21.4 | 21.4 | .32 | .09 | .53 | .99 |
| ADF | 24.9[x] | 22.1[y] | 21.5[y] | 22.3 | 23.0 | 23.2 | .58 | <.01 | .48 | .92 |
| NDF | 31.9[x] | 28.4[y] | 27.7[y] | 28.4[x] | 30.2[y,a] | 29.4[b] | .44 | <.01 | .02 | .41 |
| dNDF | 45.4[x] | 50.8[y] | 50.7[y] | 47.4 | 49.6 | 50.0 | .86 | <.01 | .08 | .93 |
| NFC | 37.5[x] | 41.1[y] | 41.0[y] | 40.8 | 38.7 | 40.0 | .94 | .02 | .25 | .73 |
| $NE_l$ | .68[x] | .71[y] | .71[y] | .70 | .69 | .70 | .004 | <.01 | .29 | .44 |
| EE | 1.98 | 1.90 | 2.00 | 2.12[y] | 1.74[x] | 2.01[y] | .070 | .50 | <.01 | .95 |
| Ash | 8.66 | 9.11 | 9.19 | 8.86 | 8.90 | 9.20 | .55 | .22 | .51 | .20 |
| IVDDM | 82.6[x] | 86.0[y] | 86.4[y] | 85.0 | 84.7 | 85.2 | .31 | <.01 | .46 | .84 |

[a,b] - means with different superscripts within treatment or location differ (P<0.05).
[x,y] - means with different superscripts within treatment or location differ (P<0.01).

**2004**

| | Treatment | | | Location | | | | Probability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FRESH | DRAIN | GW | No | Ctr | So | SEM | Trt | Loc | T*L |
| **Cut 3** | | | | | | | | | | |
| CP | 19.4[x] | 21.1[y] | 21.6[y] | 20.0[a] | 21.1[b] | 20.9[b] | .33 | <.01 | .05 | .06 |
| ADF | 27.1 | 24.2 | 24.3 | 26.3 | 23.4 | 26.0 | 1.07 | .09 | .11 | .81 |
| NDF | 34.4 | 30.5 | 30.9 | 33.3 | 29.5 | 33.0 | 1.31 | .08 | .09 | .53 |
| dNDF | 43.3 | 46.2 | 46.1 | 43.7 | 48.5 | 43.5 | 2.15 | .52 | .18 | .99 |
| NFC | 36.6 | 37.3 | 36.5 | 35.4[y] | 39.7[x] | 35.3[y] | .77 | .68 | <.01 | .61 |
| $NE_l$ | .65 | .69 | .67 | .65 | .70 | .65 | .015 | .31 | .06 | .57 |
| EE | 2.48 | 2.62 | 2.29 | 2.78[x] | 2.10[y,a] | 2.51[b] | .068 | .25 | <.01 | .42 |
| Ash | 9.57[x] | 10.55[y] | 10.89[y] | 10.85[x] | 9.61[y,a] | 10.55[b] | .28 | <.01 | .01 | .35 |
| IVDDM | 80.2 | 83.5 | 83.3 | 81.1 | 84.6 | 81.3 | .54 | .16 | .14 | .83 |
| Yield | 437[x] | 184[y] | 184[y] | 234 | | 301 | 70.1 | .02 | .38 | .31 |

[a,b] - means with different superscripts within treatment or location differ (P<0.05).

[x,y] - means with different superscripts within treatment or location differ (P<0.01).

Table 33. Boron concentrations in alfalfa harvested from field 33 in the Broadview Water District.

| | | B (ppm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well | Plot | 5-30-02 | 8-15-02 | 9-19-02 | 10-10-02 | 3-26-03 | 5-21-03 | 7-26-03 | 8-19-03 | 3-25-04 | 7-7-04 | 8-25-04 | 10-4-04 |
| 71 | 1 | 91.7 | 202 | 201 | 133 | 93.3 | 125 | 138 | 190 | 100 | 100 | | 139 |
| 72 | 2 | 92 | 128 | 110 | 121 | 82.7 | 120 | 218 | 256 | 134 | 134 | | 140 |
| 73 | 3 | 124 | 115 | 144 | 86.8 | 96.4 | 94.4 | 210 | 204 | 104 | 104 | 278 | 118 |
| 74 | 4 | 108 | 93.8 | 131 | 97.2 | 108 | 119 | 243 | 259 | 119 | 119 | | 165 |
| 75 | 5 | 141 | 204 | 251 | 165 | 113 | 109 | 188 | 177 | 125 | 125 | 314 | 144 |
| 76 | 6 | 112 | 139 | 125 | 73.8 | 95.7 | 78.3 | 136 | 190 | 95.8 | 95.8 | 200 | 106 |
| 77 | 7 | 101 | 130 | 100 | 92 | 93.8 | 93.8 | 169 | 219 | 117 | 117 | | 131 |
| 78 | 8 | 128 | 152 | 190 | 135 | 104 | 90.8 | 167 | 221 | 114 | 114 | 191 | 135 |
| 79 | 9 | 129 | 112 | 133 | 60.4 | 104 | 77.8 | 146 | 155 | 115 | 115 | 191 | 94.8 |
| 80 | 9 | 109 | 122 | 54.4 | 66.8 | 121 | 69.6 | 150 | 179 | 89.1 | 89.1 | 379 | 106 |
| 81 | 8 | 94.4 | 120 | 56.7 | 123 | 111 | 99.6 | 149 | 207 | 89.7 | 89.7 | 258 | 147 |
| 82 | 7 | 100 | 115 | 33.6 | 77.2 | 104 | 97.2 | 105 | 139 | 102 | 102 | 361 | 155 |
| 83 | 6 | 115 | 113 | 134 | 89.7 | 120 | 75.9 | 121 | 156 | 99.4 | 99.4 | 269 | 104 |
| 84 | 5 | 136 | 174 | 238 | 141 | 90 | 141 | 156 | 223 | 129 | 129 | 275 | 134 |
| 85 | 4 | 114 | 123 | 113 | 114 | 113 | 127 | 202 | 282 | 107 | 107 | 358 | 195 |
| 86 | 3 | 102 | 125 | 106 | 70.5 | 107 | 77.8 | 108 | 239 | 95 | 95 | 295 | 112 |
| 87 | 2 | 90.4 | 108 | 97 | 182 | 99.4 | 102 | 166 | 223 | 125 | 125 | | 146 |
| 88 | 1 | 77.3 | 95.6 | 209 | 138 | 166 | 98 | 168 | 140 | 109 | 109 | | 119 |
| avg. | | 109.2 | 131.7 | 134.8 | 109.2 | 106.8 | 99.8 | 163.3 | 203.3 | 109.4 | 126.9 | 280.8 | 132.8 |

Table 34. Chloride concentration in alfalfa harvested from field 33 in the Broadview Water District.

| | | Cl (mmol/kg) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well | Plot | 5-30-02 | 8-15-02 | 9-19-02 | 10-10-02 | 3-26-03 | 5-21-03 | 7-26-03 | 8-19-03 | 3-25-04 | 7-704 | 8-25-04 | 10-4-04 |
| 71 | 1 | 369 | 645 | 502 | 452 | 340 | 603 | 587 | 669 | 563 | 518 | | 627 |
| 72 | 2 | 354 | 495 | 545 | 554 | 331 | 557 | 777 | 805 | 410 | 414 | | 630 |
| 73 | 3 | 343 | 502 | 410 | 481 | 354 | 381 | 622 | 462 | 455 | 387 | 1017 | 468 |
| 74 | 4 | 281 | 505 | 550 | 540 | 379 | 467 | 648 | 786 | 441 | 372 | | 547 |
| 75 | 5 | 250 | 530 | 509 | 481 | 358 | 438 | 549 | 482 | 351 | 340 | 771 | 399 |
| 76 | 6 | 335 | 465 | 444 | 444 | 329 | 376 | 473 | 690 | 369 | 388 | 780 | 394 |
| 77 | 7 | 319 | 424 | 565 | 555 | 373 | 481 | 511 | 553 | 316 | 324 | | 381 |
| 78 | 8 | 289 | 477 | 442 | 466 | 308 | 523 | 598 | 611 | 356 | 378 | 945 | 347 |
| 79 | 9 | 266 | 430 | 435 | 431 | 305 | 452 | 420 | 390 | 376 | 386 | 606 | 375 |
| 80 | 9 | 322 | 476 | 454 | 416 | 322 | 402 | 480 | 446 | 402 | 431 | 625 | 363 |
| 81 | 8 | 226 | 424 | 387 | 429 | 295 | 450 | 637 | 560 | 397 | 389 | 1135 | 385 |
| 82 | 7 | 207 | 424 | 529 | 517 | 369 | 502 | 565 | 474 | 412 | 360 | 1134 | 341 |
| 83 | 6 | 320 | 453 | 445 | 438 | 348 | 383 | 467 | 414 | 375 | 352 | 884 | 330 |
| 84 | 5 | 297 | 487 | 567 | 499 | 348 | 515 | 583 | 513 | 380 | 388 | 646 | 357 |
| 85 | 4 | 315 | 510 | 575 | 587 | 368 | 371 | 742 | 665 | 476 | 444 | 1029 | 538 |
| 86 | 3 | 318 | 463 | 400 | 391 | 305 | 397 | 528 | 571 | 390 | 407 | 674 | 432 |
| 87 | 2 | 331 | 456 | 563 | 640 | 321 | 541 | 605 | 696 | 390 | 378 | | 639 |
| 88 | 1 | 446 | 484 | 291 | 442 | 433 | 601 | 689 | 890 | 503 | 517 | | 794 |
| | avg. | 310.4 | 480.6 | 478.5 | 486.8 | 343.7 | 461 | 582.3 | 593.2 | 409 | 398.5 | 870.5 | 463.7 |

**1.7 Summary and Conclusions:**

Integrated on farm drainage management (IFDM) systems will be an integral part of drainage and salt water management if agriculture is to survive in the San Joaquin Valley. The utility of a reuse system relies on the ability of the manger to dispose of saline water in a manner that maintains crop production, minimizes environmental impact, and is cost effective. Crop selection for these systems will be critical to maximize the economic return and insure sustainability. Generally, salt tolerant crops have lower economic value than salt sensitive crops and may not be the best selection for a reuse system from an economic standpoint. There is a need to evaluate crops that have both good economic potential and salt tolerance. Alfalfa is a moderately salt sensitive crop and the ability of using a moderately salt tolerant variety may be a significant improvement in a reuse system. In this research we evaluated the potential for using a moderately salt tolerant alfalfa, var. SW9720, in a reuse system.

We used three irrigation water management schemes to evaluate the suitability of this alfalfa variety. The control treatment (FRESH) was irrigated twice between cuttings using low salinity (EC, 0.4 dS/m) water; the second treatment (DRAIN) was irrigated twice between cuttings with drainage water with an EC of 6dS/m, and the third treatment (GW) was irrigated once between cuttings with saline water with EC of 6dS/m. There was an irrigation with low salinity water on all treatments prior to the break of dormancy each year.

The applied water in 2003 was 602 mm in the Fresh, 730 mm in the Drain, and 474 mm in the GW treatment. In 2004 the applied water was 658 for the FRESH and 641 for the DRAIN and GW. The estimated crop water use in the Westlands Water District was 807 mm in 2003 and 990 in 2004. The crop water use was estimated as 720 mm in 2003 and 734 mm in 2004 in the Fresh treatment. In the Drain treatment the crop water use was 849 and 717 mm in 2003 and 2004, respectively. Crop water use in the GW treatment was 593 and 171 mm in 2003 and 2004, respectively. It is apparent that the yields would be lower in this trial than in commercial fields grown with good water on good soil. During this study there was approximately 1390 mm of saline water applied to the drainage treatment and 903 mm applied to the GW treatment.

Crops respond to the average irrigation water salinity over the season. The weighted average for the FRESH treatment was 0.5, 0.4, and 0.4 dS/m for 2002, 2003, and 2004, respectively. In the DRAIN treatment the averages were 2.96, 5.68, and 3.23 dS/m for 2002, 2003, and 2004 respectively. The weighted irrigation water salinity in the GW treatment were 1.44, 5.28, and 3.23 dS/m for 2002, 2003, and 2004 respectively.

After three years of operation there were significant yield losses in the two treatments irrigated with saline water compared to the treatment irrigated with good water. The accumulation of salts in the saline irrigated treatments was sufficient to reduce the yield as a result of the increased soil salinity. The Maas-Hoffman threshold for yield reduction in alfalfa is approximately 2 dS/m and the initial root zone soil salinity in all the treatments averaged approximately 3 dS/m, so there was a yield reduction to be expected evan for the plots irrigated with low salinity water. However,

over the experimental period the average soil salinity increased from 3 to greater than 8 dS/m in the plots irrigated with saline water. This resulted in an additional potential reduction of 45 to 50% compared to the low salinity water treatment.

The yield varied in time throughout the season as well. The first cutting had the largest yield which was probably in response to leaching of the soil from rainfall and irrigation with good quality water prior to the break of dormancy. After the first cutting there is a pattern of reduced yields throughout the growing season in all the treatments. This is typical of alfalfa grown in the SJV. However, the yield reduction was accentuated by the use of saline water for irrigation compared to plots irrigated with good quality water.

The quality of the forage is also a critical consideration of the system. The data for the parameters that describe the forage quality show that the alfalfa quality benefitted from the use of saline water. The stress induced by the salinity reduced the forage mass but increased the net energy of lactation (NEL). Based on the values for crude protein (CP) and non-detergent fiber (NDF) and acid digestible fiber (ADF) the alfalfa was graded as premium or better which would result in good price for the forage. The boron (B) and chloride (Cl) concentrations increased with time in the plant tissue during the season but reduced to previous levels at the beginning of the next season so these ions should not be a problem.

Careful management is critical to the successful operation of a reuse system. This includes the irrigation management and salt management in the soil profile. A furrow irrigation system was used in this research and the furrow advance was limited by cracking in the clay soil which resulted in poor water distribution that affected the yield and salt accumulation. The cracks also controlled the applied depth of water. Analysis of the yield distribution data demonstrated that yield was reduced on the tail end of the field compared to the head end of the field which would be consistent with poor uniformity of applied water. The irrigation management will require the appropriate design to match flow and field length.

There were distinct differences in the salinity response in the two treatments being irrigated with saline water. The soil profile in the DRAIN treatment was accumulating salt faster that the GW treatment because of the larger volumes of applied water. The EC of the groundwater reflected the additional salt loading.

The drainage sumps were not used during the experiment which resulted in a rising water table and an increase in the soil salinity in the crop root zone. The sustainability of the system will require some level of drainage water disposal. Managing soil salinity will require tools to characterize the salt distribution and accumulation. A EM 38 electromagnetic induction device was used to monitor salinity accumulation and distribution during the course the project and was found to be very effective.

It was concluded that:

1. The salt tolerant alfalfa used in this study has potential for a reuse system but will be most effective with lower salinity irrigation water.

2. Drainage from a reuse site is needed to maintain root zone soil salinity at acceptable levels through periodic leaching.

3. A reuse system will require a well-managed irrigation system. Surface systems can be used but will require design to match available flow to field size to minimize distribution non-uniformity.

4. Yields can be maintained by periodic use of low salinity water to maintain the average soil salinity below the Maas-Hoffman threshold. Root zone soil salinity should be lowest when alfalfa breaks dormancy in the spring.

5. EM-38 monitoring is an effective tool to manage soil salinity levels and to characterize the salt accumulation.

6. Off-site disposal of salt will be required to maintain a sustainable system. Total area required will be determined by irrigation management throughout the site.

## RED ROCK RANCH

This section covers the activities and research in section 16-2 of Red Rock Ranch (Fig. 27) which is operated as an Integrated on-Farm Drainage Management (IFDM) system. This project was done with the cooperation with Mr. John Deiner and included participants from the California Department of Water Resources (DWR), and California State University, Fresno (CSUF). All four quarter sections are included in the IFDM system but research was concentrated in Areas B, C, and D. Area B is the area having the first reuse of drainage water collected from areas labeled A. The areas C and D are the successive reuse areas following area B. The A areas are used for production of salt sensitive high value crops.

The USDA-ARS role in the IFDM project on the Red Rock Ranch was to monitor the shallow groundwater response to water table management and the shallow groundwater quality in area B. We assisted in measuring water balance components on each of the fields in the area B (Fig 27).

### 2.1 Field Operations

The cropping and field operations in Areas A and B were the responsibility of Red Rock Ranch. The cropping and management of Areas C and D were the responsibility of the CSUF and DWR researchers. There was a gradual reclamation of portions of Area B over the course of the project and the cropping pattern changed to more salt sensitive crops as the reclamation was completed. Table 35 gives the progression of cropping for each of the three zones in Area B. The zones have been designated south, middle, and north, and are the relative positions in the field. In table 35 when multiple crops were grown in the middle section these were allocated to the east and west portions. The creeping wild rye was grown in the east section of the field.

Table 35 . Cropping pattern in area B of Red Rock Ranch IFDM system.

| Year | B (south) | B (middle) | B (north) |
|---|---|---|---|
| 2001 | Wheat | Cotton/Canola | Jose Tall Wheat Grass |
| 2002 | Alfalfa* | Creeping Wild Rye | Jose Tall Wheat Grass |
| 2003 | Alfalfa* | Creeping Wild Rye<br>SW9720 - Alfalfa | Jose Tall Wheat Grass |
| 2004 | Alfalfa* | Creeping Wild Rye<br>SW9720 - Alfalfa | Jose Tall Wheat Grass |
| 2005 | Wheat | Creeping Wild Rye<br>SW 9720 - Alfalfa | Jose Tall Wheat Grass |

* Salt tolerant variety
SW9720 - Salt tolerant variety of alfalfa

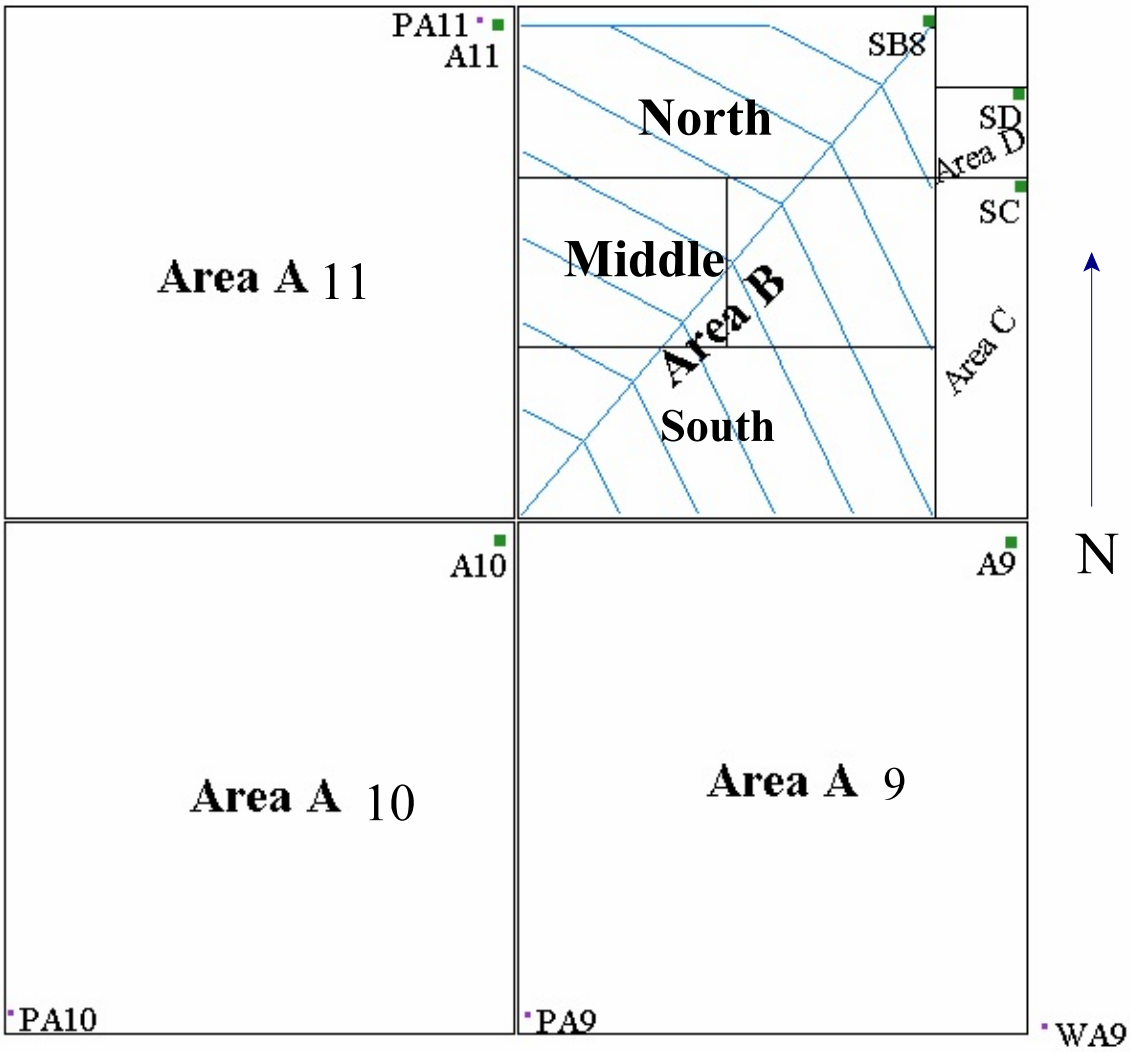



Figure 27. Integrated On-Farm Drainage Management farm layout.

Table 36 summarizes the cropping on the remainder of the IFDM system in Areas labeled A (Fig. 27). These are all high value crops with salt tolerance values ranging from sensitive (lettuce) to tolerant (cotton).

## 2.2 Field Characteristics

### *2.2.1 Irrigation system layout*

The section shown in Fig. 27 is an Integrated On-Farm Drainage Management (IFDM) system, that uses drainage water from the fields growing salt sensitive crops as irrigation water on fields

growing salt tolerant crops. The field studied in this research is identified as Area B (Fig. 27). This field is the first reuse area for drainage water collected from Areas A11, A10, and A9 which were irrigated with low salinity water obtained from Westlands Water District or a well on the farm. Drainage water from Area B is used in Area C to irrigate salt tolerant forage crops. Drainage water from area C is used in Area D to irrigate halophytes, and drainage water from Area D is discharged to an evaporation facility where the salts are removed from the system.

Table 36. Cropping pattern on Areas A11, A10, and A9 in Red Rock Ranch IFDM system.

| Year | A11 | A10 | A9 |
|---|---|---|---|
| 2001 | Wheat | Onions | Cotton/Tomatoes |
| 2002 | Tomatoes | Lettuce/Cotton | Wheat |
| 2003 | Tomatoes | Wheat | Alfalfa |
| 2004 | Tomatoes | Cotton | Alfalfa |
| 2005 | Tomatoes | Cotton/tomato | Garlic |

The locations on Fig. 27 and Fig. 28 indicated by PA9, PA10 and PA11 are delivery points for irrigation water obtained from the Westlands Water District. WA9 shows the location for a groundwater pump that is operated by the farm for additional irrigation water. Locations A9, A10 and A11 are drainage sumps for the fields in Area A. Water collected at these points and the tailwater pit is diverted to a blending sump that is the irrigation supply system for Area B (Fig. 28). Each delivery and drainage point is metered and these records are supplied to the Department of Water Resources. Sump (SB8) is the collection point for subsurface drainage from Area B. Water collected here is diverted to the irrigation system for Area C and SC is the sump for area C which is the irrigation water for Area D. Water from the sump SD is discharged to the evaporation facility.

*2.2.2 Drain layout*

Figure 29 shows the layout of the subsurface drains installed in Area B. A similar configuration was used for the subsurface drainage system in each of the area A fields. Drainage management structures are indicated by numbers 1 (water level control structure) and 2 (manholes). Areas indicated by ‘II’ and ‘III’ (Fig.29) will be impacted by water table management, while the area indicated by ‘I’ will be instrumented to collect data in an area not impacted by groundwater management. The manholes and water table control structures were installed in December 2001. Figure 30 shows a schematic representation of a drainage/groundwater management structure. Water flows into the control structure from the subsurface drains. A blocking structure forces the water to rise at levels higher than the tile drains, thus effectively raising the water table. Both water table control structures and manhole construction use the same principle, although the manhole construction allows for alternate methods of blocking drainage water and raising the

water table. The method used in Red Rock Ranch for the manholes consists of a PVC pipe that raises the outlet to the required groundwater level (Fig. 31).

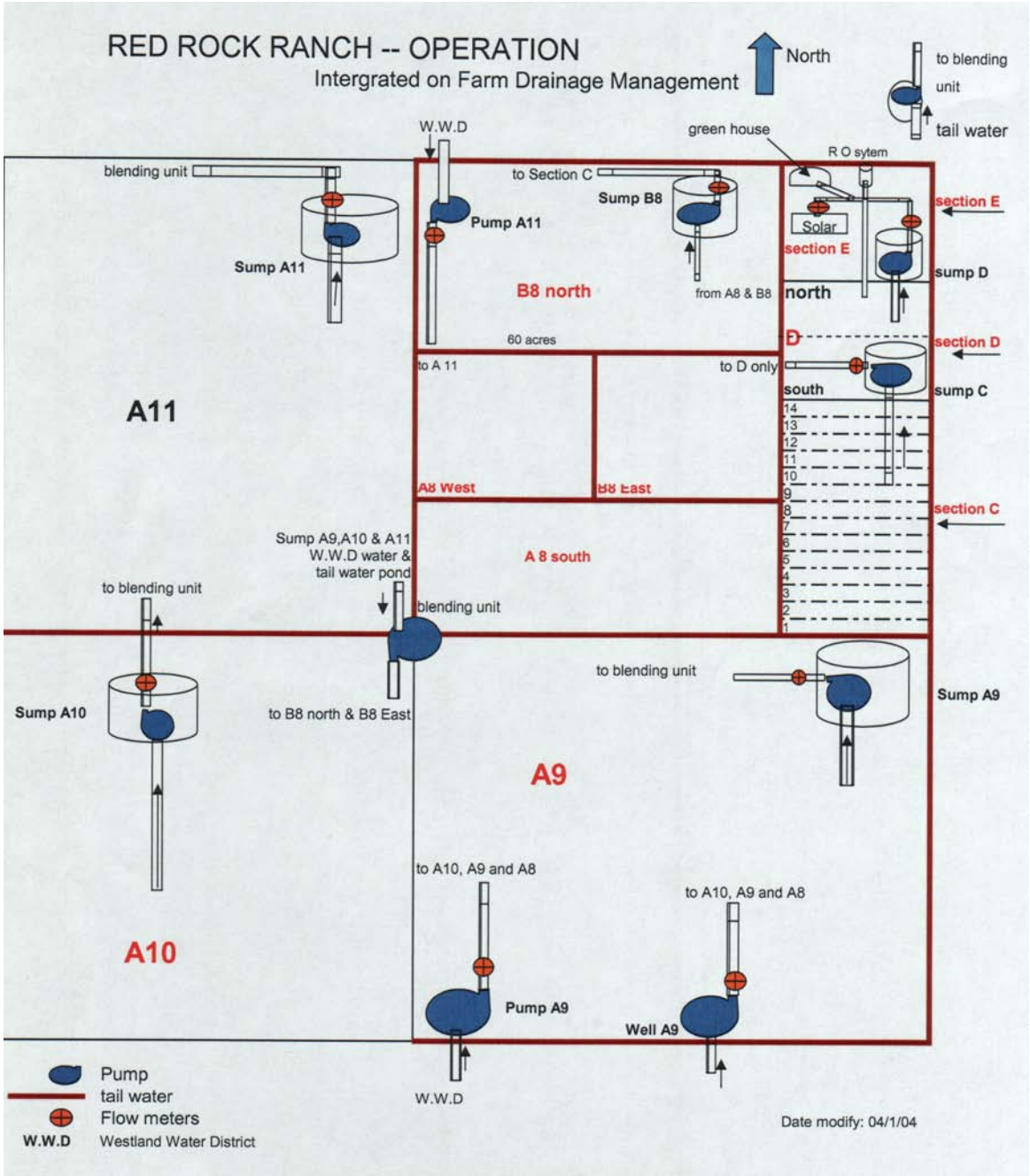



Figure 28. Schematic of water delivery and drainage sump system at Red Rock Ranch.

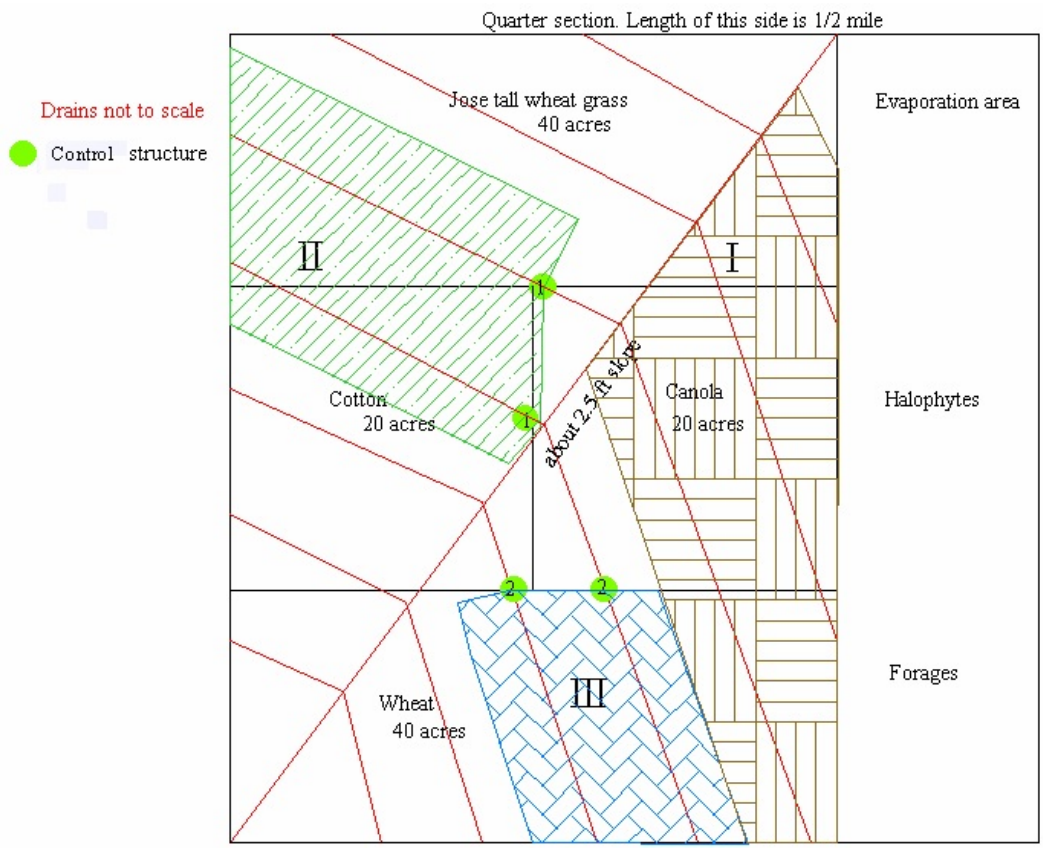



Figure 29. Drain layout for Area B in Red Rock Ranch IFDM system.

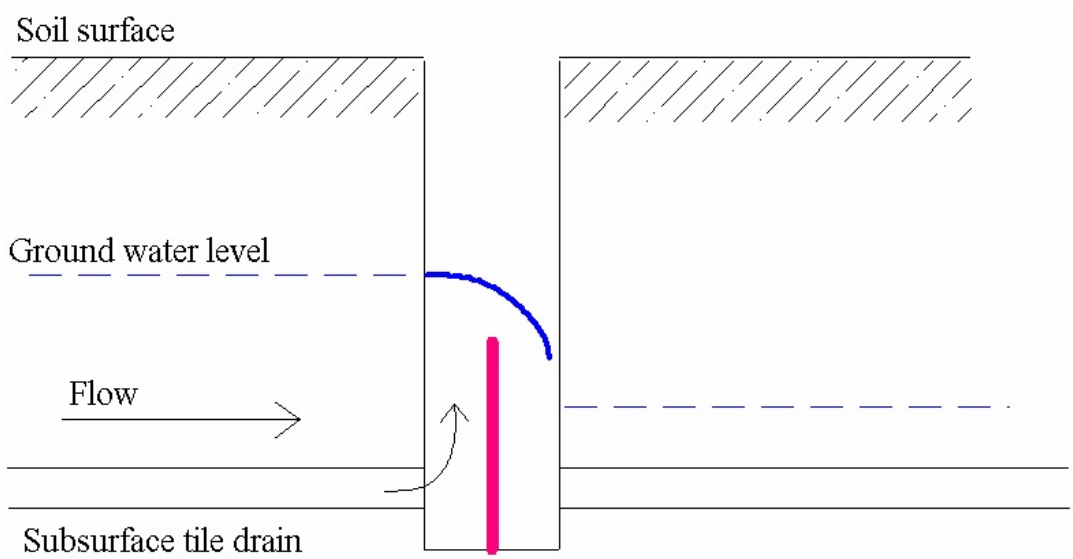



Figure 30. Schematic of drainage control structure.

Figure 31: Manhole construction before installation showing PVC elbow for water table control.

*2.2.3 Groundwater wells*

Groundwater wells were installed in Area B in the Spring of 2002 following the cultural operations. The relative location of the wells is given in Fig 32. This figure shows the south, middle and north parts of the field with the middle part of the field being further divided into east and west. The well installation configuration was selected to determine the variation in water table depth relative to the lateral. The water table depth and temperature were measured continuously using the sensor shown in Fig. 33.

*2.2.4 Soil physical description*

Soil samples were collected at four sites within the field at 30 cm intervals to a depth of 120 cm for particle size analysis. Silt, sand and clay content were obtained using the Bouyoucos method. Salts were washed from the samples before analysis using distilled water. These data are summarized in Table 37. Soil water retention curve parameters were obtained from established relations between particle size distribution and the water retention curve (Fig. 34) (Rawls and Brakensiek , 1989). Average bulk density for the profile is 1.3 $Mg/m^3$.

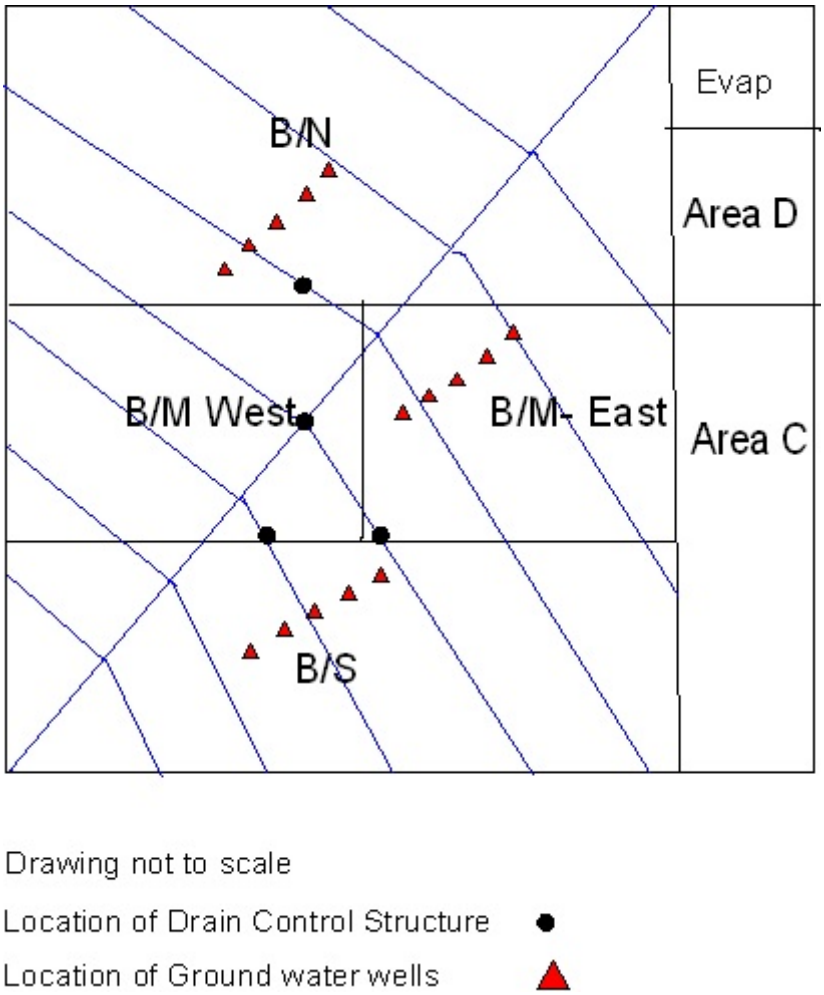



Figure 32. Location of groundwater wells in area B of Red Rock Ranch IFDM system

Table 37. Sand, silt and clay distribution over depth in red rock ranch

| | Sand | Silt | Clay | Classification |
|---|---|---|---|---|
| 0-30 | 37.5 % | 22.2 % | 40.1 % | CLAY |
| 30-60 | 32.5 % | 40.6 % | 26.9 % | LOAM |
| 60-90 | 22.3 % | 43.7 % | 34.1 % | CLAY LOAM |
| 90-120 | 21.7 % | 54.6 % | 23.7 % | SILT LOAM |

Figure 33. Photo of automated groundwater depth sensor used in Field 16 at Red Rock Ranch.

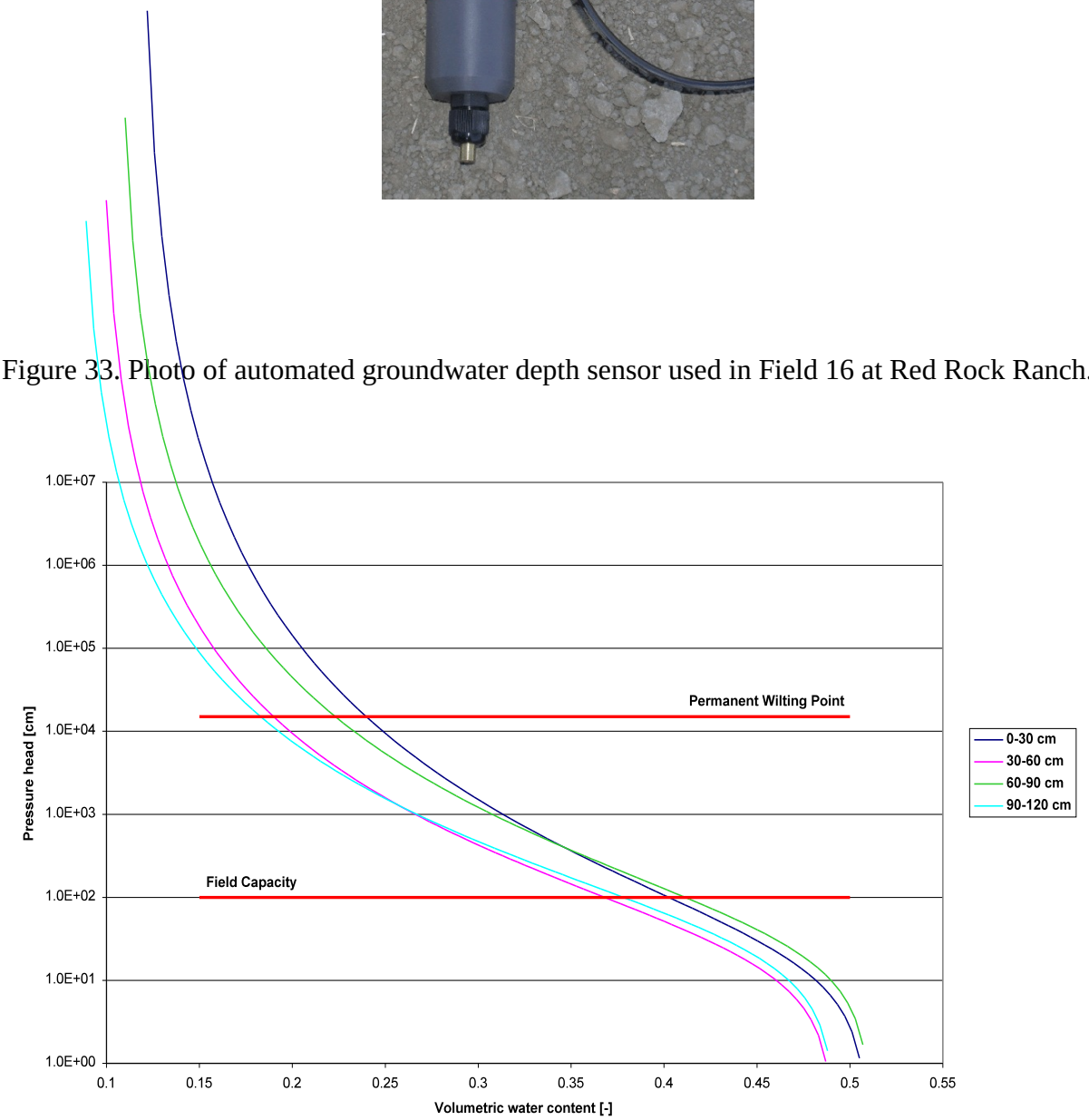



Figure 34. Water retention curve for soil in section 16 at Red Rock Ranch**.**

## 2.3 Water

Applied irrigation water was measured using flow meters on pumps P9, P10 and P11 and on the well WP 9 and reported monthly to the California Department of Water Resources (DWR). Drainage water was measured using flow meters on each sump A9, A10, and A11 on sump SB8 and also reported monthly to DWR. Several groundwater wells were installed around the site to characterize the regional hydrology. In December 2001, manholes and water table control structures were installed on single drain laterals in Area B (Fig. 29). The structures labeled 2 are the positions of the manhole structures that are being used to control the water table in the zone with the blue cross hatches labeled III. The structures labeled 1 are water table control structures that were used to control the water table depth in area II.

Water table observation wells were installed in the north section between the two controlled subsurface drains in area II (Fig. 32). Observation wells were installed in the middle section where the subsurface drains are not controlled and in the south section in the area III that is being controlled by the manholes. Initially, the depth to the water table was read manually using a sounder. However, the depth was read both manually and continuously using pressure transducers starting in the summer of 2002.

Water samples were taken periodically from the manholes, the control structures and the observation wells. Samples were also taken of the irrigation water quality and the tail water quality. Soil sampling was done twice a year (Spring and Fall) in the 3 sections of field B to track changes in the salinity and boron concentrations in the soil. The results of the sampling beginning in the Spring of 2002 are detailed in the following sections.

### *2.2.1 Groundwater quality*

The shallow groundwater was sampled approximately monthly in the north (N), middle (M), and South (S) in Area B of the IFDM site. The locations sampled are the observation wells used to measure the groundwater response to irrigation and water table management. As would be expected, there is quite a bit of variability in values between locations within a field and between fields.

The electrical conductivity (EC) data in table 38 and Fig. 35 show that the average EC data are approximately the same under the center and north field. These fields received saline irrigation water (7-15 dS/m) and with crop water use you would expect an increase in EC values. The south field is being irrigated with relatively good quality water and the lower EC values in the ground water probably reflect this. These data would also suggest that there has been considerable leaching in this field.

The data in Fig. 35 of the average EC show a decrease in groundwater salinity with time in the south field while there has been an increase in the middle field and the north has remained relatively constant.

Table 38 . Summary of electrical conductivity (EC) in groundwater beneath in the north, middle, and south fields in area B of the IFDM site at Red Rock Ranch.

| | EC (dS/m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 12/2/02 | 1/28/03 | 3/25/03 | 5/29/03 | 6/22/03 | 8/22/03 | 9/22/03 | 11/23/03 |
| N-1 | 17.7 | 25.4 | 26.3 | 26.6 | 26.1 | 25.7 | 27.9 | 25.2 |
| N-2 | 25.6 | 25.0 | 25.1 | 25.4 | 25.5 | 24.4 | 24.9 | 25.3 |
| N-3 | 27.8 | 13.5 | 14.3 | 15.7 | 15.5 | 14.9 | 15.7 | 17.7 |
| N-4 | 28.5 | 26.8 | 26.4 | 27.7 | 28.1 | 27.0 | 27.1 | 28.0 |
| N-5 | 26.7 | 26.0 | 25.8 | 26.5 | 26.7 | 26.3 | 26.1 | 26.9 |
| ave | 25.3 | 23.3 | 23.6 | 24.4 | 24.4 | 23.7 | 24.3 | 24.6 |
| M-1 | 28.6 | 28.2 | 28.0 | 29.5 | 29.4 | 28.1 | 16.1 | 29.4 |
| M-2 | 23.8 | 25.5 | 27.1 | 30.0 | 29.8 | 29.0 | 21.4 | 32.0 |
| M-3 | 32.1 | 31.9 | 32.0 | 33.6 | 28.4 | 30.0 | 31.0 | 34.1 |
| M-4 | 4.9 | 9.5 | 13.2 | 15.2 | 15.9 | 17.7 | 29.8 | 26.1 |
| M-5 | 16.5 | 15.7 | 15.5 | 16.5 | 16.7 | 16.0 | 27.0 | 17.1 |
| ave | 21.2 | 22.2 | 23.2 | 25.0 | 24.0 | 24.2 | 25.1 | 27.7 |
| S-1 | 10.8 | 10.4 | 10.0 | 10.3 | 10.6 | 11.4 | 10.4 | 11.8 |
| S-2 | 13.5 | 11.9 | 11.7 | 9.0 | 11.6 | 1.7 | 1.6 | 3.9 |
| S-3 | 13.2 | 11.9 | 11.9 | 12.6 | 12.9 | 1.4 | 12.8 | 13.8 |
| S-4 | 9.9 | 9.0 | 8.7 | 9.0 | 9.1 | 6.8 | 6.9 | 8.3 |
| S-5 | 6.3 | 6.2 | 6.4 | 3.2 | 4.2 | 6.0 | 6.2 | 7.0 |
| ave | 10.7 | 9.9 | 9.8 | 8.8 | 9.7 | 5.5 | 7.6 | 9.0 |

Table 38. Cont'd. Summary of electrical conductivity (EC) in groundwater beneath in the north, middle, and south fields in area B of the IFDM site at Red Rock Ranch.

| | EC (dS/m) | | | | | |
|---|---|---|---|---|---|---|
| | 3/25/04 | 4/27/04 | 5/18/04 | 7/7/04 | 8/24/04 | 10/4/04 |
| N-1 | 26 | 27.7 | 27.4 | 27.6 | 27.3 | 28.4 |
| N-2 | 24 | 24.2 | 25.1 | 25.6 | 24.3 | 24.9 |
| N-3 | 21.6 | 22.3 | 23.9 | 25.3 | 24.6 | 25.5 |
| N-4 | 27.1 | 27.3 | 29 | 29.6 | 27.4 | 27.9 |
| N-5 | 26.2 | 27.2 | 27.4 | 27.8 | 26.9 | 27.3 |
| ave | 24.98 | 25.74 | 26.56 | 27.18 | 26.1 | 26.8 |
| M-1 | 28.3 | 28.2 | 30 | 29 | 28 | 28.2 |
| M-2 | 32.7 | 32.7 | 34.9 | 34.8 | 32.7 | 29.8 |
| M-3 | 33.3 | 33.5 | 33.5 | 33.3 | 32.7 | 31.4 |
| M-4 | 30.4 | 31.8 | 34 | 34.2 | 32.2 | 32.8 |
| M-5 | 17.2 | 15.9 | 18.68 | 6.19 | 9.7 | 11.27 |
| ave | 28.38 | 28.42 | 30.22 | 27.50 | 27.06 | 26.70 |
| S-1 | 7.39 | 6.29 | 7.6 | 10.14 | 8.81 | 8.79 |
| S-2 | 8.01 | 8.55 | 9.9 | 9.87 | 10.06 | 9.8 |
| S-3 | 11.65 | 12.42 | 13.23 | 13.72 | 12.76 | 11.74 |
| S-4 | 6.62 | 8.76 | 10.13 | 12.43 | 8.2 | 8.54 |
| S-5 | 8.3 | 5.69 | 6.87 | 5.21 | 5.19 | 6.03 |
| ave | 8.394 | 8.342 | 9.546 | 10.274 | 9.004 | 8.98 |

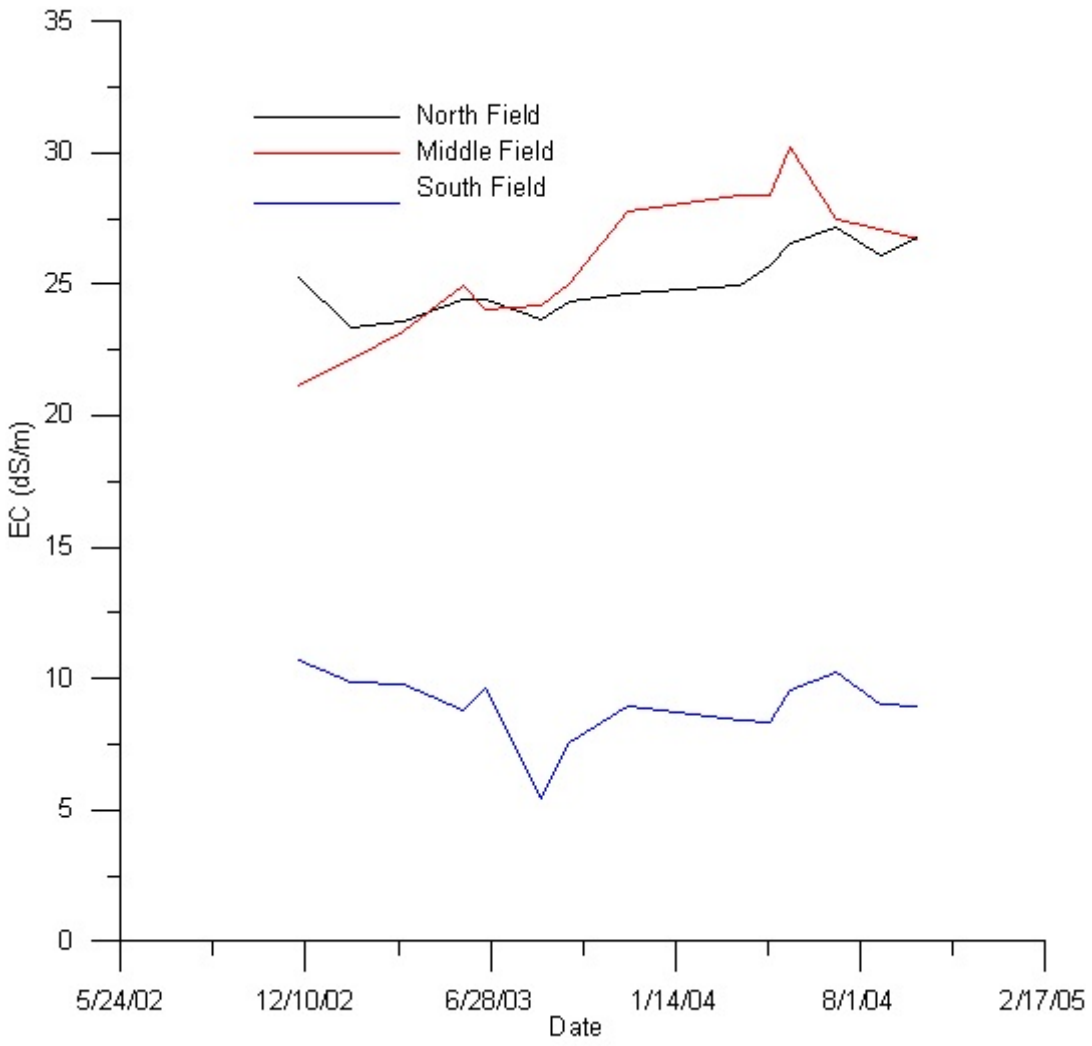



Figure 35. Average electrical conductivity in shallow groundwater in IFDM site at Red Rock Ranch in 2003 and 2004.

The chloride data in table 39 show a completely different pattern than the EC, or B data. The middle field has a higher concentration than the north field. If there is a progressive increase in concentration with subsequent irrigation, the north should have the highest concentration. The middle should be intermediate between the north and south field. The Cl concentrations in the south field are significantly lower than what is found in the other fields. The average chloride data are given in Fig. 36.

The boron data are summarized in table 40 and Fig. 37. These show a steady increase in concentration as the water is applied from the south to the center to the north field. There is no obvious trend of the concentration increasing or decreasing with time under any of these fields. The concentrations are high enough to be of concern when being used for supplemental irrigation.

Table 39. Summary of chloride (Cl) in the groundwater under the north, middle, and south fields in area B of the IFDM site at Red Rock Ranch.

| | Cl (mEq/L) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 12/2/02 | 1/28/03 | 3/25/03 | 5/29/03 | 6/22/03 | 8/22/03 | 9/22/03 | 11/23/03 |
| N-1 | 115.0 | 188.9 | 189.0 | 186.5 | 182.0 | 187.0 | 187.0 | 181.5 |
| N-2 | 184.0 | 181.5 | 176.5 | 162.0 | 166.0 | 159.5 | 161.0 | 158.0 |
| N-3 | 220.0 | 70.0 | 81.0 | 84.5 | 84.0 | 79.5 | 83.0 | 159.0 |
| N-4 | 138.5 | 125.5 | 116.0 | 124.0 | 118.0 | 109.5 | 113.0 | 116.0 |
| N-5 | 193.0 | 183.0 | 177.0 | 183.5 | 186.0 | 170.0 | 167.5 | 177.0 |
| ave | 170.1 | 149.8 | 147.9 | 148.1 | 147.2 | 141.1 | 142.3 | 158.3 |
| M-1 | 254.0 | 257.0 | 233.0 | 254.0 | 241.0 | 241.0 | 78.0 | 228.5 |
| M-2 | 210.5 | 239.5 | 246.0 | 263.0 | 263.0 | 258.5 | 203.0 | 282.5 |
| M-3 | 359.0 | 348.0 | 337.0 | 367.0 | 267.0 | 279.0 | 316.5 | 316.5 |
| M-4 | 43.3 | 83.6 | 123.0 | 134.0 | 139.0 | 156.0 | 288.0 | 230.0 |
| M-5 | 85.5 | 80.5 | 77.0 | 78.0 | 82.0 | 73.5 | 229.0 | 83.0 |
| ave | 190.5 | 201.7 | 203.2 | 219.2 | 198.4 | 201.6 | 222.9 | 228.1 |
| S-1 | 80.0 | 80.0 | 74.0 | 68.0 | 74.5 | 73.0 | 71.5 | 79.0 |
| S-2 | 51.5 | 52.0 | 48.5 | 38.0 | 51.0 | 4.5 | 5.0 | 13.0 |
| S-3 | 65.0 | 63.5 | 58.5 | 59.5 | 62.5 | 65.0 | 62.0 | 65.5 |
| S-4 | 54.5 | 53.0 | 48.0 | 46.0 | 45.0 | 22.5 | 29.0 | 32.0 |
| S-5 | 23.0 | 25.0 | 24.0 | 11.0 | 13.0 | 22.0 | 23.5 | 23.5 |
| ave | 54.8 | 54.7 | 50.6 | 44.5 | 49.2 | 37.4 | 38.2 | 42.6 |

Table 39. Cont'd. Summary of chloride (Cl) in the groundwater under the north, middle, and south fields in area B of the IFDM site at Red Rock Ranch.

| | Cl (mEq/L) | | | | | |
|---|---|---|---|---|---|---|
| | 3/25/04 | 4/27/04 | 5/18/04 | 7/7/04 | 8/24/04 | 10/4/04 |
| N-1 | 217 | 204.5 | 206 | 205 | 206 | 203.5 |
| N-2 | 184.5 | 170 | 171.5 | 174 | 172 | 159 |
| N-3 | 153 | 144 | 168 | 179 | 176 | 171 |
| N-4 | 125 | 122 | 131 | 130 | 125 | 130 |
| N-5 | 188 | 184 | 195 | 186.5 | 197 | 191 |
| ave | 173.5 | 164.9 | 174.3 | 174.9 | 175.2 | 170.9 |
| C-1 | 250 | 231 | 243 | 240.5 | 235 | 226 |
| C-2 | 302 | 322.5 | 332.5 | 324.5 | 334 | 288 |
| C-3 | 365 | 327 | 338.5 | 336 | 308 | 303.5 |
| C-4 | 302 | 328 | 331 | 339 | 326 | 322.5 |
| C-5 | 86 | 78.5 | 82 | 27 | 49 | 60.5 |
| ave | 261 | 257.4 | 265.4 | 253.4 | 250.4 | 240.1 |
| S-1 | 28.5 | 23 | 32 | 39 | 37 | 32 |
| S-2 | 35 | 34 | 40 | 43 | 46.5 | 44.6 |
| S-3 | 38 | 46 | 50 | 59.5 | 55 | 44 |
| S-4 | 27 | 36.5 | 55 | 76.5 | 41.5 | 45.8 |
| S-5 | 31 | 22 | 29 | 19.5 | 20.5 | 23.5 |
| ave | 31.9 | 32.3 | 41.2 | 47.5 | 40.1 | 37.98 |

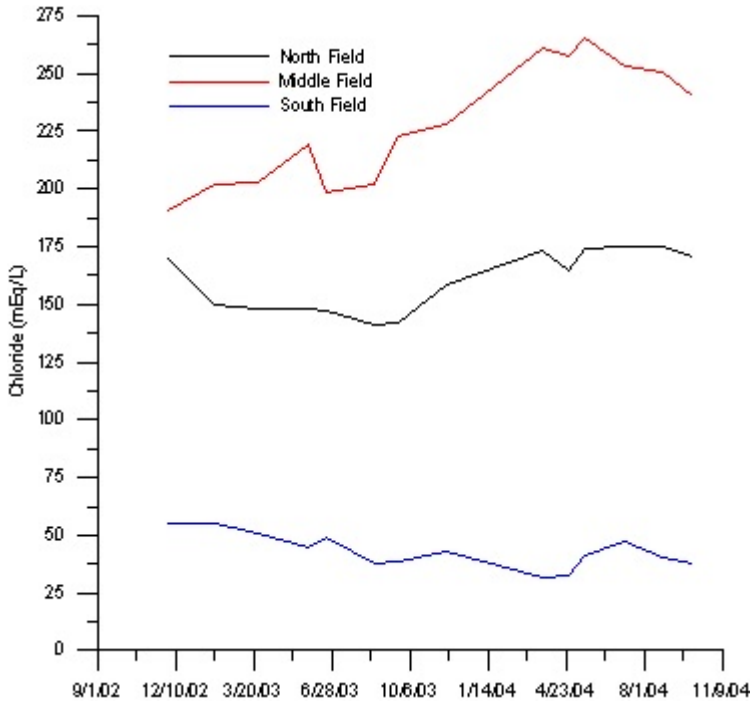



Figure 36. Average chloride data in shallow groundwater under the fields in Area B of the IFDM site at Red Rock Ranch in 2003 and 2004.

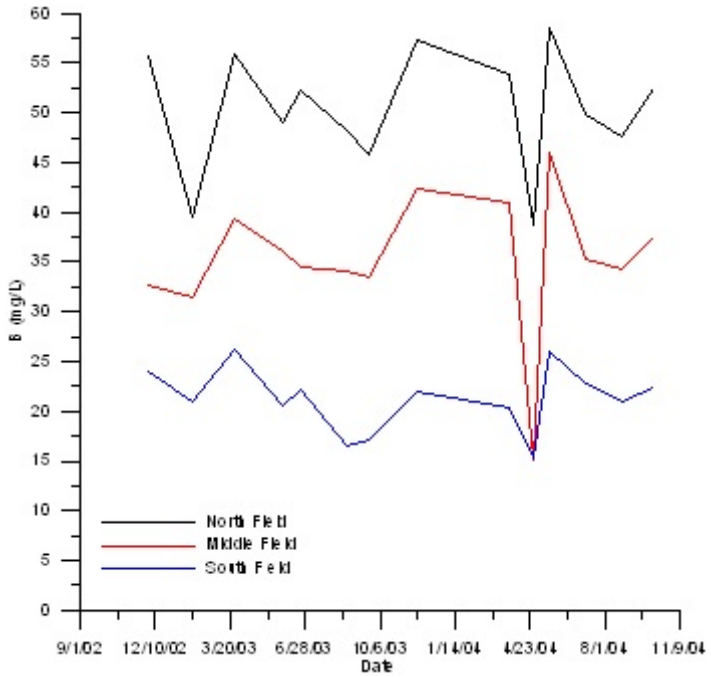



Figure 37. Boron concentration in shallow groundwater under Area B of the IFDM site at Red Rock Ranch in 2003 and 2004.

Table 40. Summary of boron (B) concentration in groundwater beneath the north, middle, and south field in area B of the IFDM site at Red Rock Ranch.

| | B (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 12/2/02 | 1/28/03 | 3/25/03 | 5/29/03 | 6/22/03 | 8/22/03 | 9/22/03 | 11/23/03 |
| N-1 | 36.6 | 32.4 | 46.9 | 42.0 | 43.4 | 42.7 | 39.1 | 50.8 |
| N-2 | 48.1 | 45.0 | 51.8 | 45.8 | 45.7 | 43.4 | 41.9 | 53.0 |
| N-3 | 55.2 | 32.5 | 35.4 | 35.2 | 43.6 | 33.2 | 31.1 | 40.5 |
| N-4 | 70.2 | 31.0 | 76.8 | 62.4 | 68.9 | 62.8 | 59.9 | 72.6 |
| N-5 | 68.2 | 57.1 | 68.9 | 59.4 | 59.2 | 58.6 | 57.0 | 69.8 |
| ave | 55.7 | 39.6 | 56.0 | 49.0 | 52.2 | 48.2 | 45.8 | 57.3 |
| M-1 | 59.8 | 54.0 | 65.6 | 57.5 | 54.5 | 52.8 | 27.7 | 61.0 |
| M-2 | 37.2 | 37.3 | 46.9 | 41.2 | 41.0 | 40.8 | 20.7 | 48.4 |
| M-3 | 33.9 | 30.2 | 36.5 | 35.6 | 31.5 | 31.7 | 31.8 | 37.8 |
| M-4 | 3.5 | 7.5 | 14.0 | 15.7 | 15.8 | 17.1 | 38.3 | 30.5 |
| M-5 | 29.4 | 28.5 | 33.9 | 30.4 | 29.6 | 28.3 | 49.3 | 34.3 |
| ave | 32.8 | 31.5 | 39.4 | 36.1 | 34.5 | 34.1 | 33.6 | 42.4 |
| S-1 | 17.2 | 16.3 | 19.8 | 18.7 | 18.5 | 17.7 | 16.9 | 22.4 |
| S-2 | 40.1 | 34.1 | 38.3 | 23.7 | 29.3 | 6.6 | 7.0 | 11.0 |
| S-3 | 35.7 | 34.6 | 39.1 | 33.1 | 35.0 | 33.7 | 35.5 | 43.4 |
| S-4 | 16.9 | 16.0 | 19.7 | 18.4 | 17.6 | 12.4 | 13.8 | 18.0 |
| S-5 | 9.8 | 3.6 | 13.9 | 9.0 | 10.3 | 12.6 | 12.6 | 15.4 |
| ave | 23.9 | 20.9 | 26.2 | 20.6 | 22.1 | 16.6 | 17.2 | 22.1 |

Table 40. Cont'd. Summary of boron (B) concentration in groundwater beneath the north, middle, and south field in area B of the IFDM site at Red Rock Ranch.

| | B (mg/L) | | | | | |
|---|---|---|---|---|---|---|
| | 3/25/04 | 4/27/04 | 5/18/04 | 7/7/04 | 8/24/04 | 10/4/04 |
| N-2 | 49.51 | 29.07 | 54.25 | 45.56 | 42.99 | 48.05 |
| N-3 | 45.04 | 41.52 | 48.39 | 41.08 | 40.97 | 45.78 |
| N-4 | 65.40 | 23.68 | 68.84 | 61.95 | 56.33 | 64.59 |
| N-5 | 61.26 | 34.99 | 67.61 | 57.62 | 56.71 | 58.71 |
| ave | 53.87 | 38.71 | 58.41 | 49.76 | 47.62 | 52.54 |
| M-1 | 55.79 | 14.92 | 60.09 | 50.32 | 48.12 | 53.05 |
| M-2 | 44.79 | 15.14 | 50.23 | 41.46 | 38.69 | 38.19 |
| M-3 | 33.86 | 15.01 | 38.13 | 32.03 | 29.07 | 32.99 |
| M-4 | 37.17 | 15.01 | 45.22 | 38.77 | 35.74 | 41.19 |
| M-5 | 32.60 | 15.63 | 35.77 | 13.66 | 20.17 | 22.51 |
| ave | 40.84 | 15.14 | 45.89 | 35.25 | 34.36 | 37.59 |
| S-1 | 18.78 | 15.17 | 21.29 | 21.44 | 20.31 | 21.70 |
| S-2 | 19.10 | 15.40 | 25.59 | 22.33 | 21.81 | 23.08 |
| S-3 | 31.29 | 15.21 | 41.02 | 35.26 | 32.74 | 35.08 |
| S-4 | 14.42 | 15.43 | 24.82 | 23.18 | 17.56 | 18.36 |
| S-5 | 17.80 | 15.73 | 17.77 | 11.33 | 12.27 | 13.42 |
| ave | 20.28 | 15.38 | 26.10 | 22.71 | 20.94 | 22.33 |

The nitrate concentration of the groundwater is given in table 41 and Fig. 38. The concentrations under the south field are relatively low and increase significantly from the middle to the north

field. There is also a significant increase in the concentration of nitrate under the middle field over the course of 2003 and 2004. The average value remained fairly constant in the north and south fields. The north field was cropped to Jose Tall Wheat grass (JTWG) and there was no attempt to fertilize this field and any nitrate would be what was contained in the irrigation water. The south field was planted to alfalfa and would not have received any nitrogen fertilizer and the center field was planted to creeping wild rye (CWR) and alfalfa with the samples being taken in the area with the creeping wild rye. The major differences across the plots was the quality and quantity of applied water. The JTWG and the CWR were irrigated with saline drainage water but the JTWG was irrigated more frequently than the other plots.

The drainage water being collected from Area B was applied to salt tolerant forages and then halophytes and eventually to the solar evaporator. It is important to track the sodium absorption ratio (SAR) and the accumulation of selenium in the groundwater. The SAR will impact the soil surface and infiltration characteristics of the site with the halophytes. The Se concentration will be indicative of the load for disposal.

The average SAR values for the north, middle and south wells are plotted in Fig. 39. There are distinct differences in these values with the highest values in the north wells that sample the field containing the Jose Tall Wheat grass that is being irrigated with saline water. The south field

Table 41. Summary of nitrate concentration in shallow groundwater beneath the north, middle, and south field in area B of the IFDM site at Red Rock Ranch.

| | $NO_3$ (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 12/2/02 | 1/28/03 | 3/25/03 | 5/29/03 | 6/22/03 | 8/22/03 | 9/22/03 | 11/23/03 |
| N-1 | 44.7 | 179.7 | 205.4 | 242.2 | 267.0 | 202.1 | 172.4 | 165.7 |
| N-2 | 368.5 | 330.2 | 362.7 | 402.3 | 438.7 | 399.4 | 403.1 | 351.9 |
| N-3 | 334.7 | 8.3 | 18.3 | 25.1 | 27.9 | 10.2 | 6.7 | 19.3 |
| N-4 | 18.4 | 45.6 | 57.2 | 73.3 | 74.6 | 65.0 | 57.4 | 38.4 |
| N-5 | 239.6 | 237.9 | 258.5 | 291.7 | 334.6 | 242.3 | 264.7 | 295.0 |
| ave | 201.2 | 160.3 | 180.4 | 206.9 | 228.5 | 183.8 | 180.9 | 174.1 |
| M-1 | 0.0 | 3.0 | 25.1 | 47.1 | 80.7 | 48.3 | 101.6 | 75.4 |
| M-2 | 0.1 | 9.7 | 35.8 | 109.6 | 134.7 | 99.4 | 152.0 | 135.4 |
| M-3 | 363.1 | 285.7 | 295.9 | 363.4 | 272.4 | 286.9 | 303.0 | 364.6 |
| M-4 | 20.3 | 38.1 | 68.8 | 84.8 | 86.9 | 102.8 | 96.8 | 206.8 |
| M-5 | 109.8 | 103.6 | 99.6 | 110.6 | 127.4 | 103.2 | 35.2 | 98.2 |
| ave | 98.7 | 88.0 | 105.0 | 143.1 | 140.4 | 128.1 | 137.7 | 176.1 |
| S-1 | 11.8 | 15.8 | 18.8 | 20.7 | 18.6 | 16.9 | 14.3 | 14.0 |
| S-2 | 21.4 | 17.4 | 24.7 | 25.1 | 18.5 | 0.5 | 1.9 | 1.4 |
| S-3 | 7.1 | 8.7 | 11.7 | 14.5 | 13.4 | 11.8 | 7.2 | 7.8 |
| S-4 | 26.7 | 26.5 | 19.3 | 18.6 | 16.7 | 14.8 | 29.8 | 7.5 |
| S-5 | 3.3 | 0.0 | 0.0 | 12.4 | 7.3 | 9.5 | 5.3 | 7.4 |
| ave | 14.0 | 13.7 | 14.9 | 18.3 | 14.9 | 10.7 | 11.7 | 7.6 |

Table 41. Cont'd. Summary of nitrate concentration in shallow groundwater beneath the north, middle, and south field in area B of the IFDM site at Red Rock Ranch.

| | $NO_3$-N (mg/L) | | | | | |
|---|---|---|---|---|---|---|
| | 3/25/04 | 4/27/04 | 5/18/04 | 7/7/04 | 8/24/04 | 10/4/04 |
| N-1 | 184.97 | 229.79 | 218.71 | 192.59 | 179.41 | 167.25 |
| N-2 | 390.70 | 326.32 | 324.64 | 332.56 | 216.49 | 212.65 |
| N-3 | 121.10 | 161.89 | 163.03 | 170.77 | 175.34 | 165.81 |
| N-4 | 66.54 | 73.84 | 73.12 | 50.60 | 49.18 | 51.81 |
| N-5 | 384.76 | 306.76 | 287.52 | 234.15 | 214.73 | 186.49 |
| ave | 229.61 | 219.72 | 213.40 | 196.13 | 167.03 | 156.80 |
| M-1 | 208.82 | 163.53 | 187.29 | 139.61 | 150.14 | 149.10 |
| M-2 | 385.72 | 372.07 | 254.49 | 255.42 | 254.97 | 200.86 |
| M-3 | 346.66 | 373.32 | 388.28 | 402.10 | 354.66 | 284.05 |
| M-4 | 231.00 | 348.16 | 268.99 | 302.41 | 275.39 | 250.96 |
| M-5 | 81.30 | 131.82 | 132.61 | 31.55 | 36.69 | 50.28 |
| ave | 250.70 | 277.78 | 246.33 | 226.22 | 214.37 | 187.05 |
| S-1 | 27.83 | 30.40 | 16.89 | 1.65 | 4.96 | 0.96 |
| S-2 | 9.00 | 9.33 | 2.22 | 1.99 | 3.94 | 4.43 |
| S-3 | 17.75 | 19.28 | 8.31 | 4.60 | 3.91 | 1.64 |
| S-4 | 22.84 | 29.25 | 12.44 | 5.06 | 14.83 | 13.24 |
| S-5 | 23.25 | 74.57 | 37.12 | 28.08 | 32.37 | 37.79 |
| ave | 20.13 | 32.57 | 15.40 | 8.28 | 12.00 | 11.61 |

contains alfalfa and is irrigated with low salt water and the middle section is a mix of crops being irrigated with moderate salinity water. The sampling is in the area irrigated with drainage water. The salinity of the irrigation water offsets potential adverse effects of the SAR.

The average data for Se are given in Fig. 40. The Se data are not as clear cut with the highest concentration occurring in the groundwater in the center section followed by the north wells and then the south wells. There is an accumulation of Se in the ground water under each of the reuse areas.

Sequential biological concentration of the drainage effluent is the underlying concept for an IFDM system. In theory, each reuse of drainage water results in a significant concentration of the salinity in the water and a reduction of the total volume. Often many sites have a large store of salt in the soil profile that dissolves in the ground water which dominates the concentration and masks any concentrating effects. This can be demonstrated using the groundwater salinity under various sections of area B and the sump data from area B and C. These data are plotted on Fig. 41. The sump data (SA-9, SA- 11, SB-8) show an average salinity ranging from 10 to 14 dS/m while the groundwater salinity values in area B extracted under the north and center sections (GW-N, GW-C) are significantly higher than the groundwater salinity from the sump(SB8). Note that the ground water salinity in the south section (GW-S) is approximately the same as the salinity in Sumps SA-9 and SA-11. This area is irrigated with low salinity water and this would be expected. The ground water EC data for the north and center sections suggest a leaching fraction of 60% based on irrigating with 15 dS/m water. .

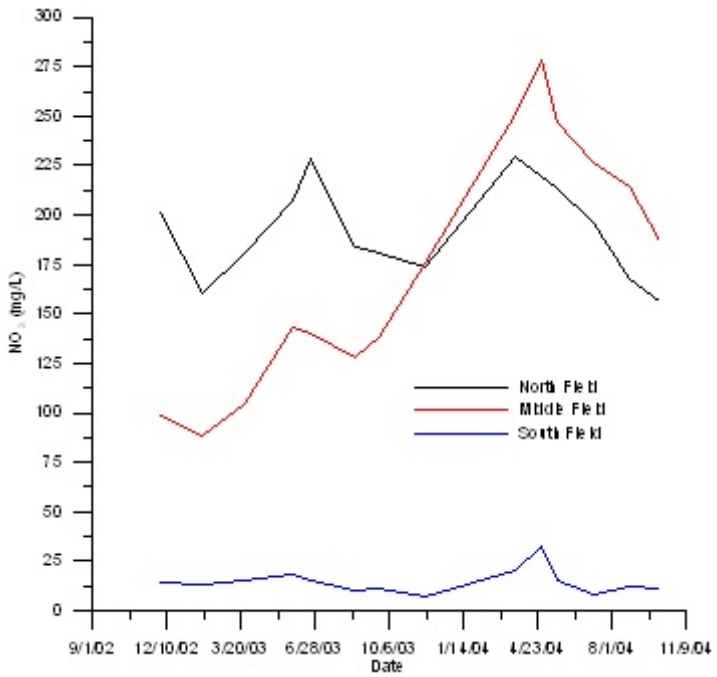



Figure 38. Nitrate concentration in shallow groundwater under Area B in the IFDM site at Red Rock Ranch in 2003 and 2004.

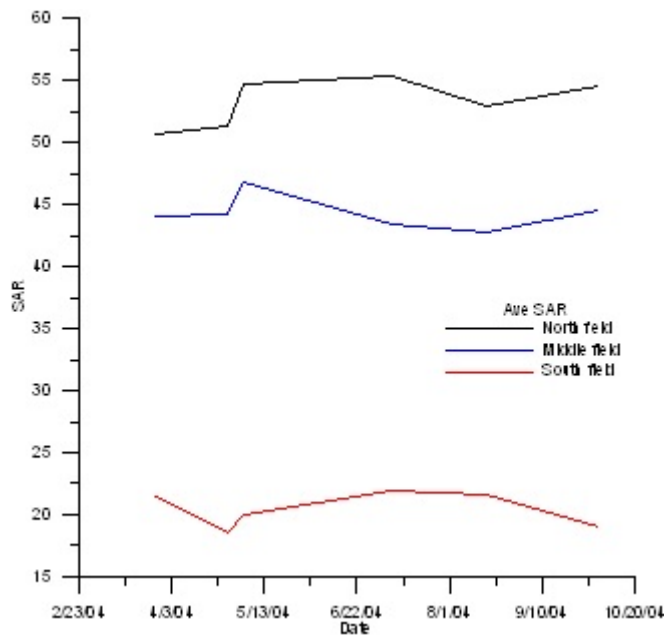



Figure 39. Average SAR in water in area B groundwater wells at Red Rock Ranch.

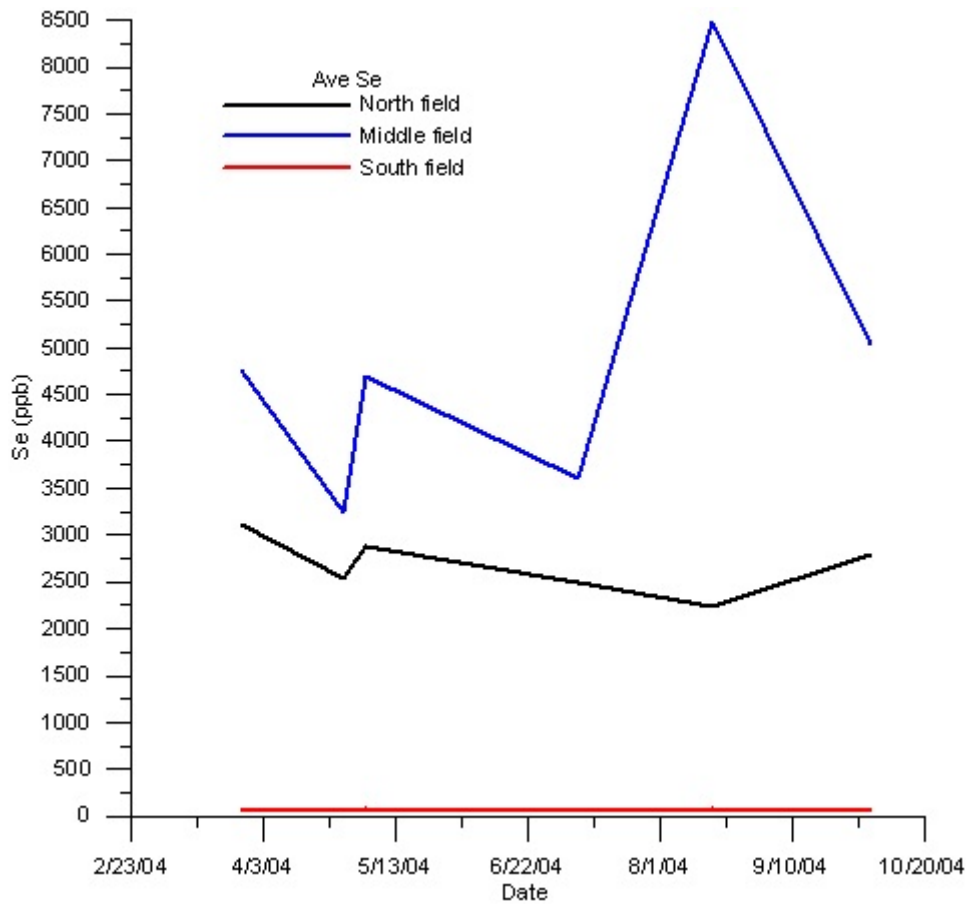



Figure 40. Average Se in water in area B groundwater wells at Red Rock Ranch.

These data demonstrate that concentration is occurring with reuse but the regional effect of stored salinity masks this concentrating effect. The impact on the management is that successive water reuse will have the same electrical conductivity, which will change the cropping pattern and reduced the need for halophytes. Also, this distorts the design of a IFDM system if groundwater samples are used to characterize drain water quality. Samples would indicate higher salinity values in the drain water than actually exist.

### 2.2.2 Groundwater response

The groundwater response in each of the fields in area B is being monitored using a recording pressure transducer system as well as with manual measurements. The observation wells were put in locations between the drains in the south, middle and north fields in area B. The sensors operated intermittently and in some cases there were no sensors available. However, the data from the operating sensor provides a picture of what happened in the shallow groundwater during the summer. The water table response is given in Figs. 42, 43, and 44.

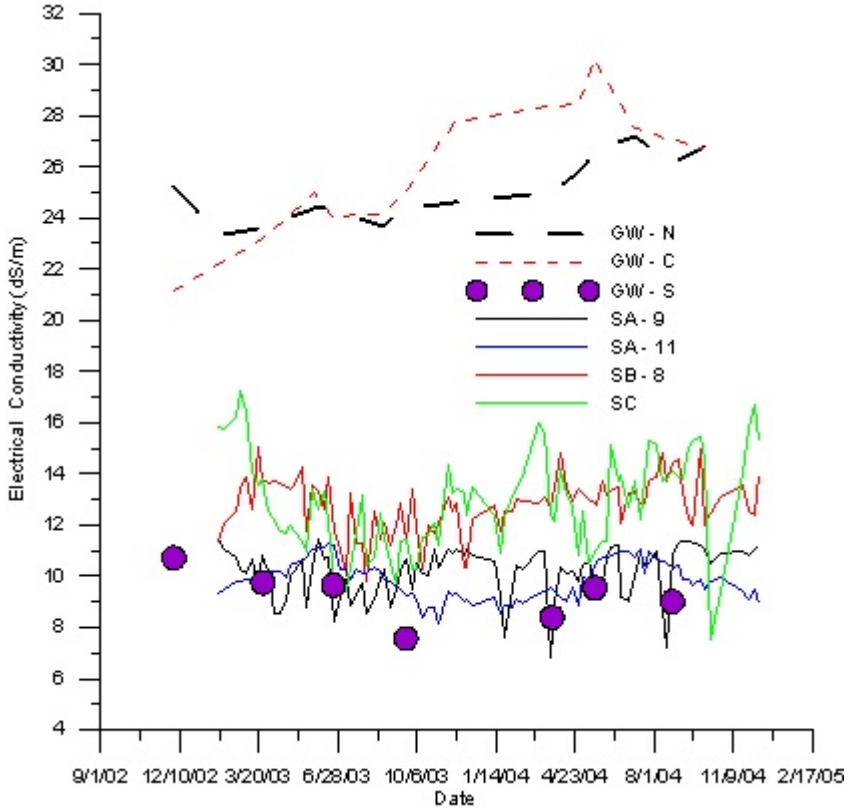



Figure 41. Average Electrical conductivity of groundwater under the north (N), center (C), a south section of area B compared to electrical conductivity of water from sumps under field 9 and ll in area A and sump 8 under area B.

There was a gradual buildup of the water table under the north field (Fig. 42). The depth to the water table stabilized at a depth of approximately 1.7 m. This was in response to continued application of drainage water from the other sites. Depending on the drain depth, there might not have been much drain flow from this site. This response is just opposite of what was observed in the center field (Fig. 43). The water table level in this portion of the field was maintained at a depth of 1.8 m (Fig. 44) showed an overall decline in depth with time from 2002 to 2004.

Water table depth varied significantly in response to irrigation over the summer period. Part of the decrease in depth of approximately 1.6 m over the summer occurred when the area was irrigated. After irrigation was completed, the water table has receded below the level of the drains. The water table in the south field varied in depth to water in 2003 was in response to the installation of control structures on the drainage system that help reduce flow throughout the entire area.

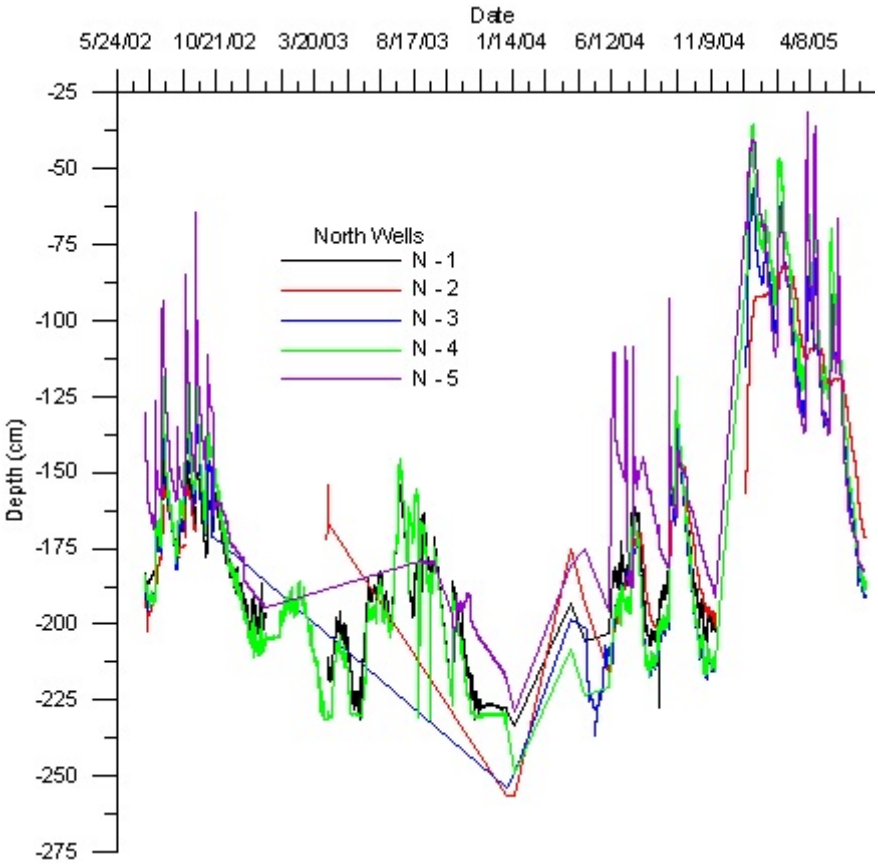



Figure 42. Water table response in one location under the north field in area B at Red Rock Ranch IFDM site.

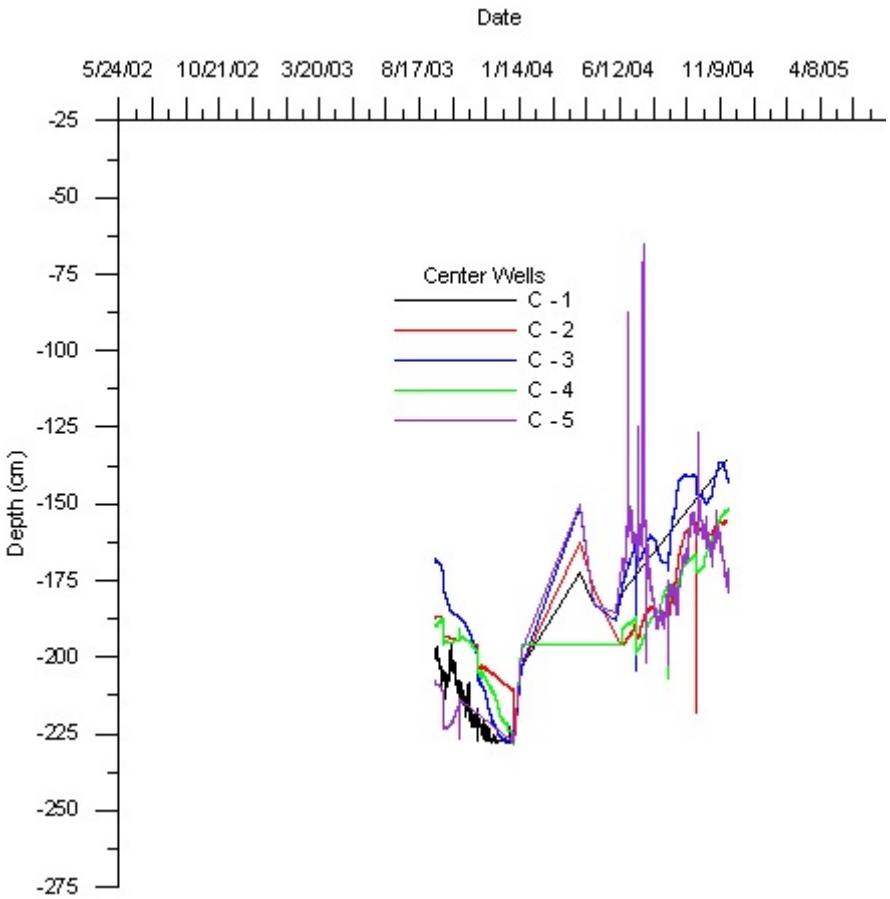



Figure 43. Water table response in the center field of area B at the Red Rock Ranch IFDM site.

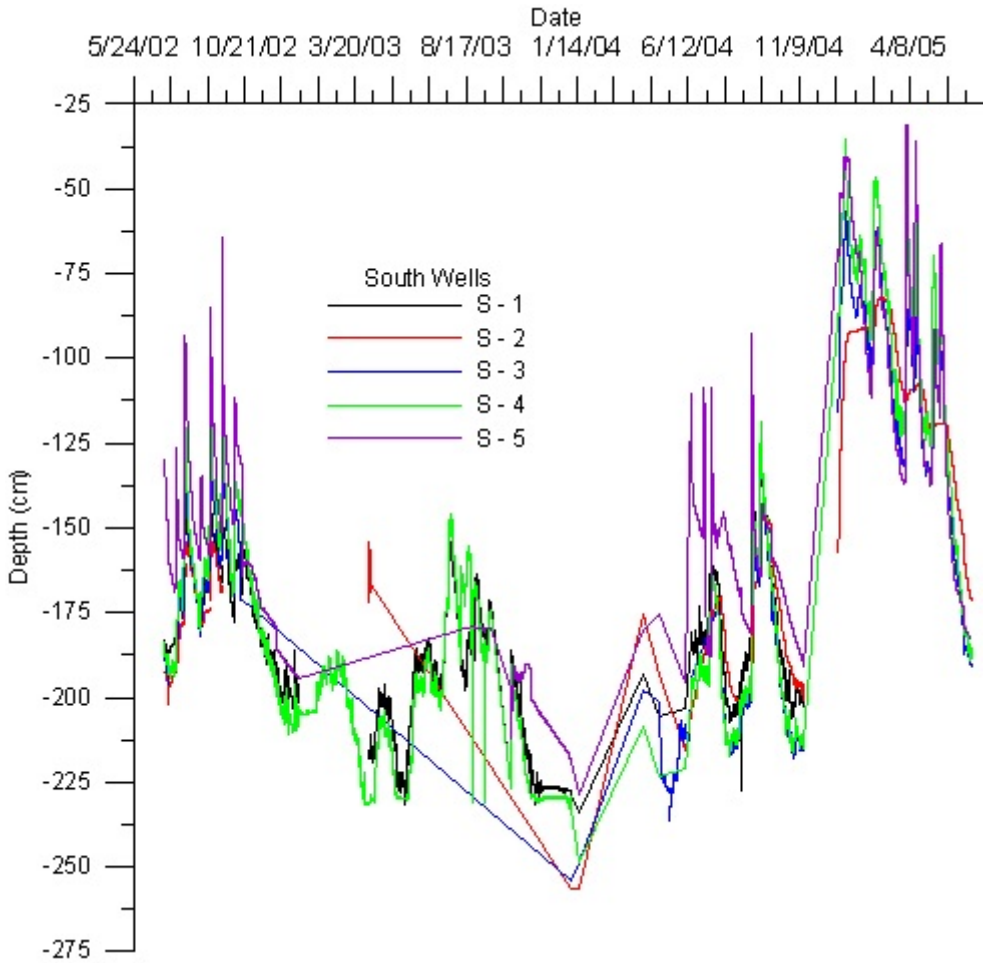



Figure 44. Water table response under South field in area B of the Red Rock Ranch IFDM site.

There are no sensors in areas without a control structure. However, we observed that with a flow control structure there was no flow through the drains. This suggests that the water table level would be below the levels of the drains. Depending on the irrigation frequency and amount, it is probable that the depth to the water table would increase due to seepage through the restricting soil layers and the reduced deep percolation from the improved irrigation management.

*2.2.3 Water balance*

Red Rock Ranch is an IFDM location that is demonstrating on-farm disposal of saline drainage water as a means to sustain irrigated agriculture in the San Joaquin Valley. The operation of the system involves the application of “good” low salinity water to salt sensitive crops (Areas A9, A10, A11) and the collection of deep percolation from this area for application on progressively smaller areas that are being used to grow more salt tolerant crops. In figure 27 the A areas are used for the salt sensitive crops with drainage water collected for application to Area B. The drainage

from B goes to C where the halophytes are grown and the drainage from C goes to the evaporator (D). This is summarized in detail in Fig. 28.

A water and salt balance is needed for the site to characterize the operation of the system and to help with the management. Figure 28 gives a diagrammatic representation of the hydraulic system being used at RRR to provide irrigation water and to collect drainage water from each field and move it to the next site.

The general flow path associated with Fig. 28 is water from pump A11 irrigates field A11 while water from well A9 or pump A9 irrigates fields A10, A9, and A8. Pumps A9 and A11 get water from the Westlands Water District. Drainage water from sumps A9, A10, and A11 is pumped to the blending unit and from there to B8 north and B8 east for application to salt tolerant forages. Drainage water from sump B8 is applied section C and finally drainage from C goes to section D. This is flow sequence is supposed to result in a progressive increase in salinity of the drainage water and a decrease in the volume.

A water balance was developed on individual fields in areas A and B to characterize the irrigation efficiencies and the volume reduction in the drainage water in the first reuse. Another objective was to determine if any outside influences on the balance were present. The water balance was done on a monthly basis using water data gathered at RRR as part of the reporting requirement to the Regional Water Quality Control Board. The Etc was estimated using crop water use for individual crops calculated in the Westlands Water District (WWD) irrigation guide for the central section. The cropping pattern for each field is given tables 35 and 36.

The basic water balance equation is given as

$$I + P - ET_c - SR \pm ÄSW \pm DP = 0 \qquad (1)$$

where I = irrigation, P = precipitation, $ET_c$ = crop evapotranspiration, SR = surface runoff, SW = change in soil water, and DP = deep percolation. It was assumed that there was no surface runoff and that there was no net change in soil water over the period of analysis. With these assumptions it is possible to estimate the deep percolation losses. These estimates can be compared to the discharge from the sumps to determine if there is additional water collected from lateral or whether the drains are not collecting all of the deep percolation lost from irrigation.

The water balance for fields A9 and A10 reduces to

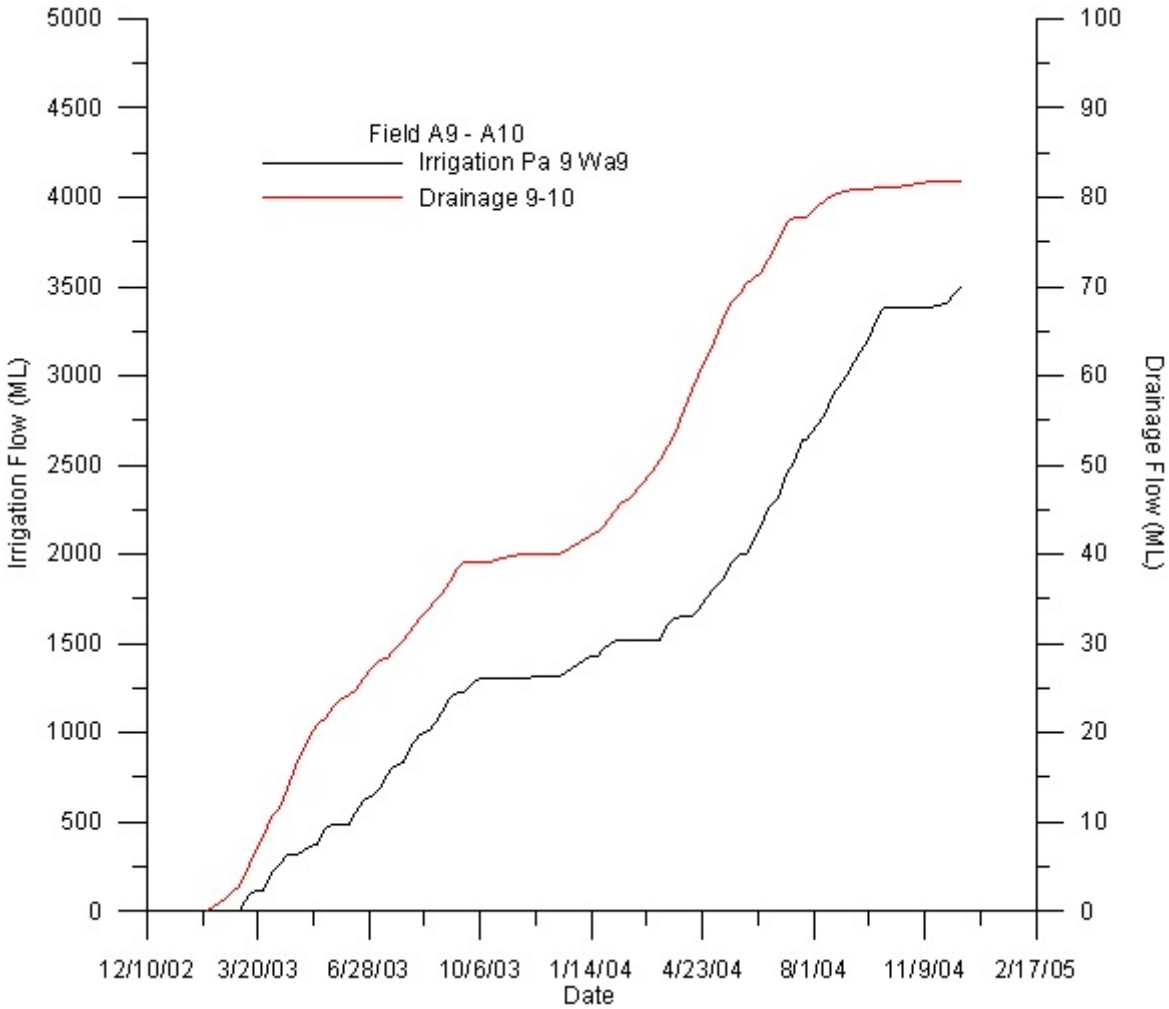



Figure 45. Cumulative applied irrigation and precipitation and drainage flow from fields A9 and A10.

$$WA9 + PA9 + P - ET_c = DP_{a9} \quad (2)$$

and the water balance for A11 reduces to

$$PA11 + P - ET_c = DP_{a11}.$$

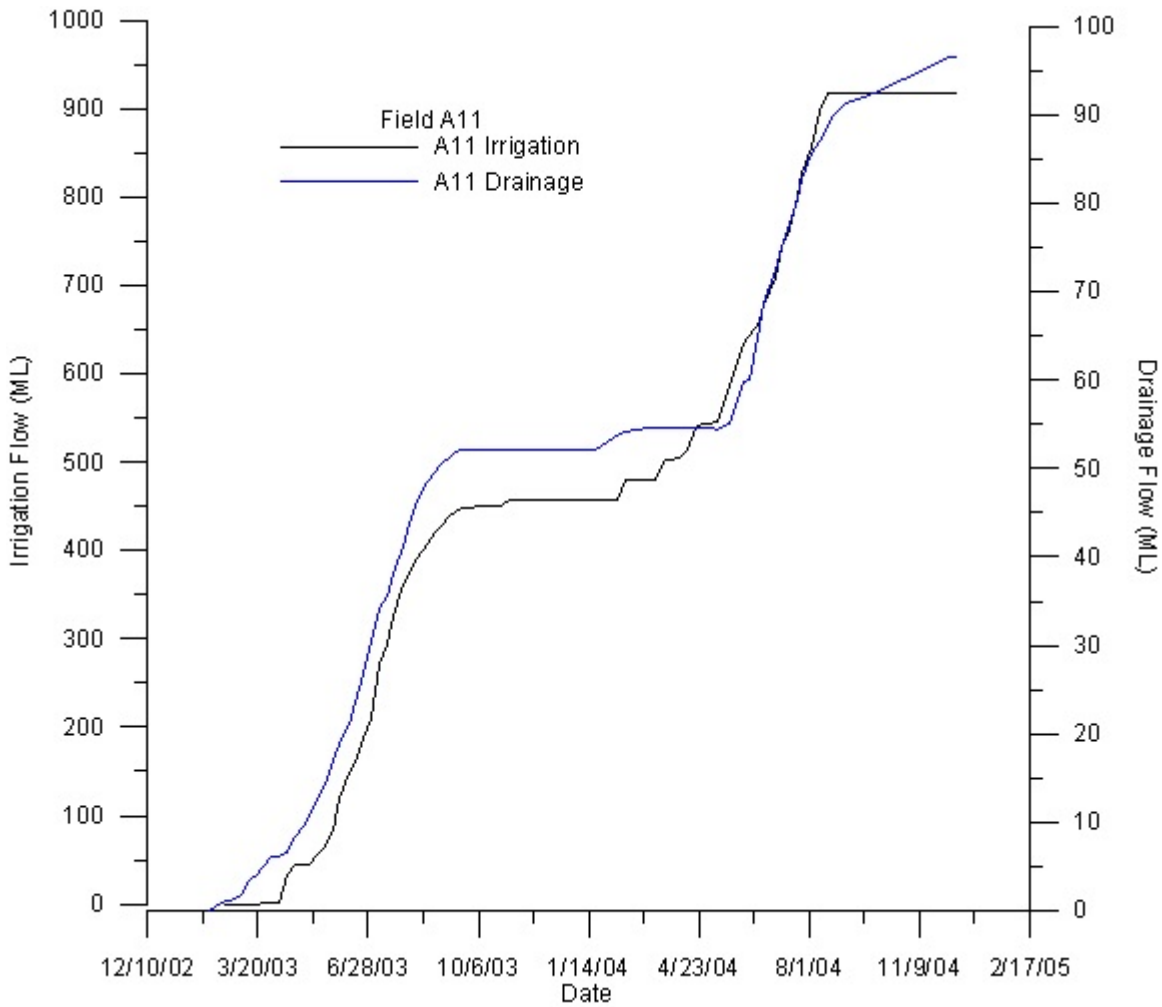



Figure 46. Cumulative applied irrigation and precipitation and drainage flow from field A11.

The value estimated DP values will be compared to SA9 + SA10 and SA 11 which are the sum of the flows from the drainage system serving field A9 and A10 and the discharge from sump serving field A11.

The water balance for section B reduces to

$$SA9 + SA10 + SA11 + P - ET_c = DP_b. \qquad (3)$$

In this case $DP_b$ should be approximately equal to SB8 the flow from sump 8.

The water balance for fields A9 and A10 is given in Fig. 45 along with the total drainage from fields A9 and A10. Using the irrigation plus rainfall data and the sump drainage flow data and the calculated leaching fraction, the ratio of drainage water divided by applied water, is approximately 2%. The cropping pattern in this field included alfalfa, wheat, and cotton. The cotton and alfalfa are both deep rooted crops and use significant quantities of water from shallow groundwater thus reducing irrigation requirements and total flow.

The water balance data for field A11 was determined using applied irrigation water and drainage water and these data are given in Fig. 46. The data demonstrate the leaching fraction of 10% but using the water quality data would indicate a leaching fraction of approximately 4%. Combining the data sets demonstrates that lateral flow is probably not a significant contributor to the total drainage flow in this area.

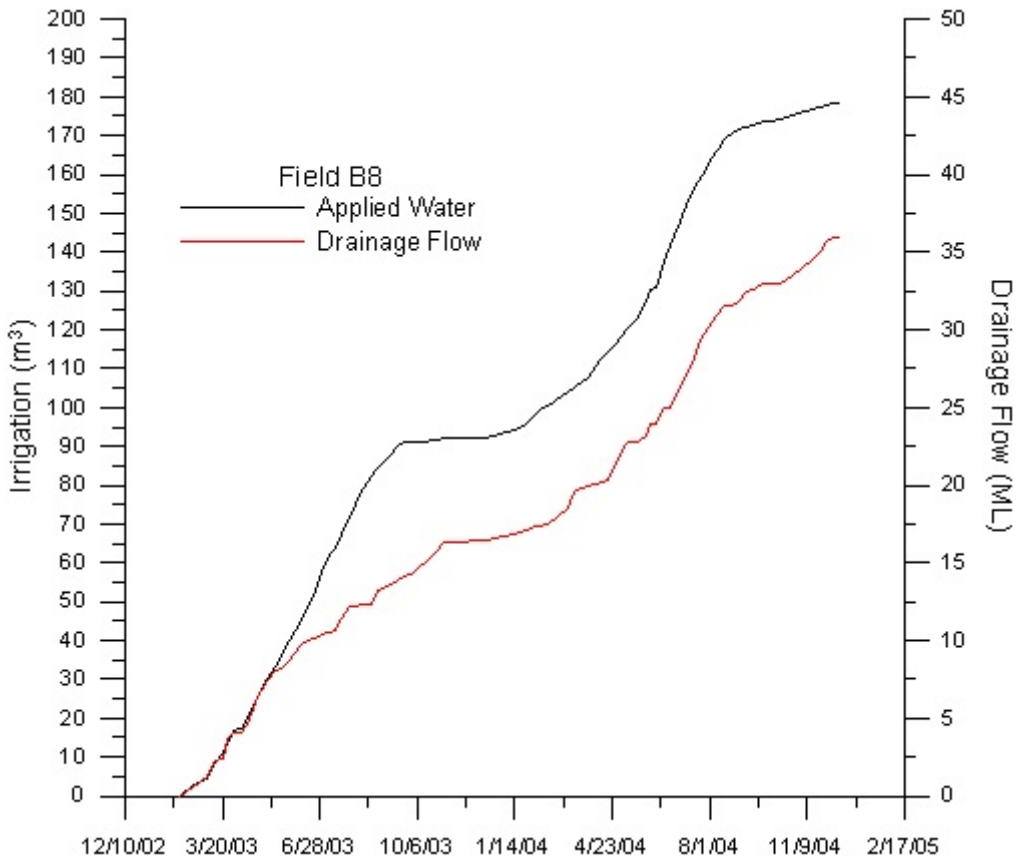



Figure 47. Applied irrigation flow, drainage flow and estimated evapotranspiration and surface runoff in area B north field.

A similar water balance was calculated for field B8 which is the first reuse area IFDM and is given in Fig. 47. The flow data demonstrate approximately 20% leaching fraction. However, if the applied irrigation water salinity, and the drainage water salinity are used to calculate the leaching

fraction the resulting value would be approximately 60%. This is an indication of effect of regional groundwater quality on the drainage water salinity.

**2.4 Salt**

One irrigation water sample was taken from groundwater well WA9 on 7/17/01. The electrical conductivity of the water was 1.6 dS/m, which is an indication of the salinity levels of deep groundwater. As irrigation water, this source is less suitable than water obtained from the Westlands Water District.

An EM38 survey (Fig. 48) was done on the southern part of area B on 7/6/01. High readings have a red color, while low readings have a green color. No soil samples for salinity analysis were collected in 2001, and no groundwater wells had been installed yet, thus no relation between EM38 readings, soil salinity and groundwater depth and quality could be obtained yet.

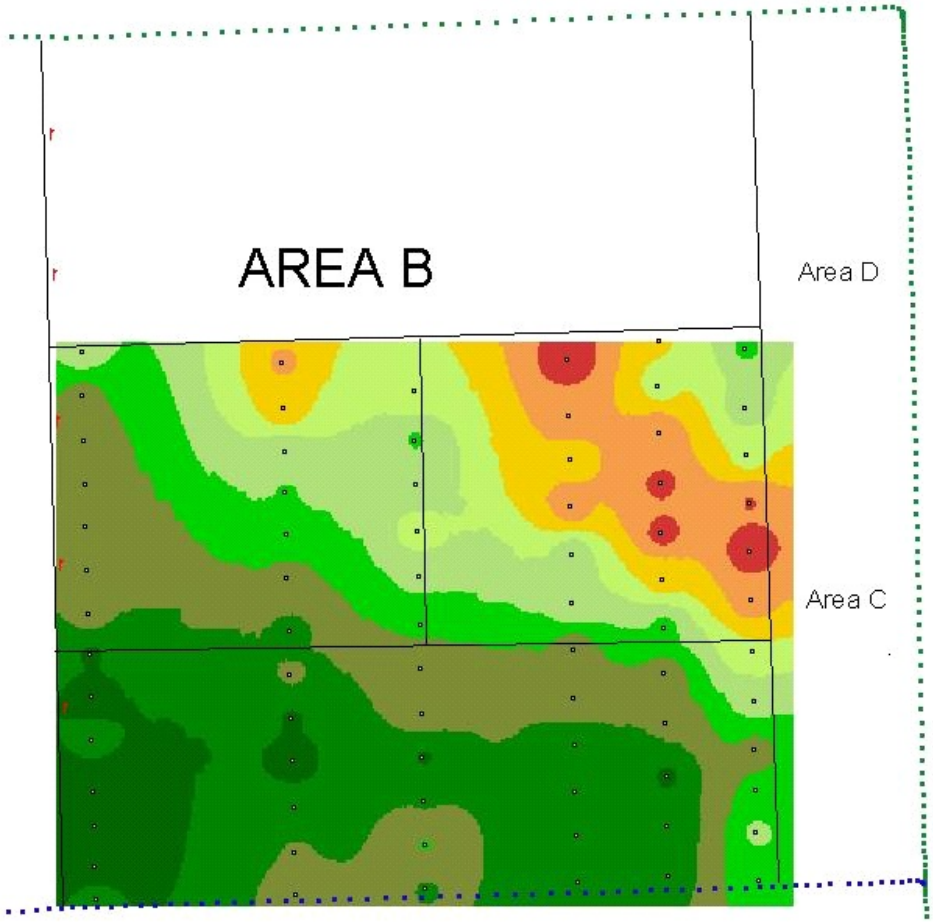



Figure 48.: EM38 survey of southern part of Area B. Red colors indicate high readings and dark green colors indicate low readings.

If the IFDM system is to be sustainable, salt will have to managed throughout the system to prevent accumulation of salt in the crop root zone by providing adequate leaching. This requires

periodic monitoring of soil salinity in each of the fields but particularly in area B which was irrigated with saline water. If good quality water is being used in Area A and there is excess application there will be leaching and probably reclamation.

A salt balance estimate was made for Area B using the total monthly drainage water flow coupled with the electrical conductivity of the water. The salt load is equal to concentration of salt in the drainage water multiplied by the average flow. The conversion factor used in the calculation was 1 dS/m = 640 ppm salt. The EC of the drainage water from the various sumps on the project is given in Fig. 49.

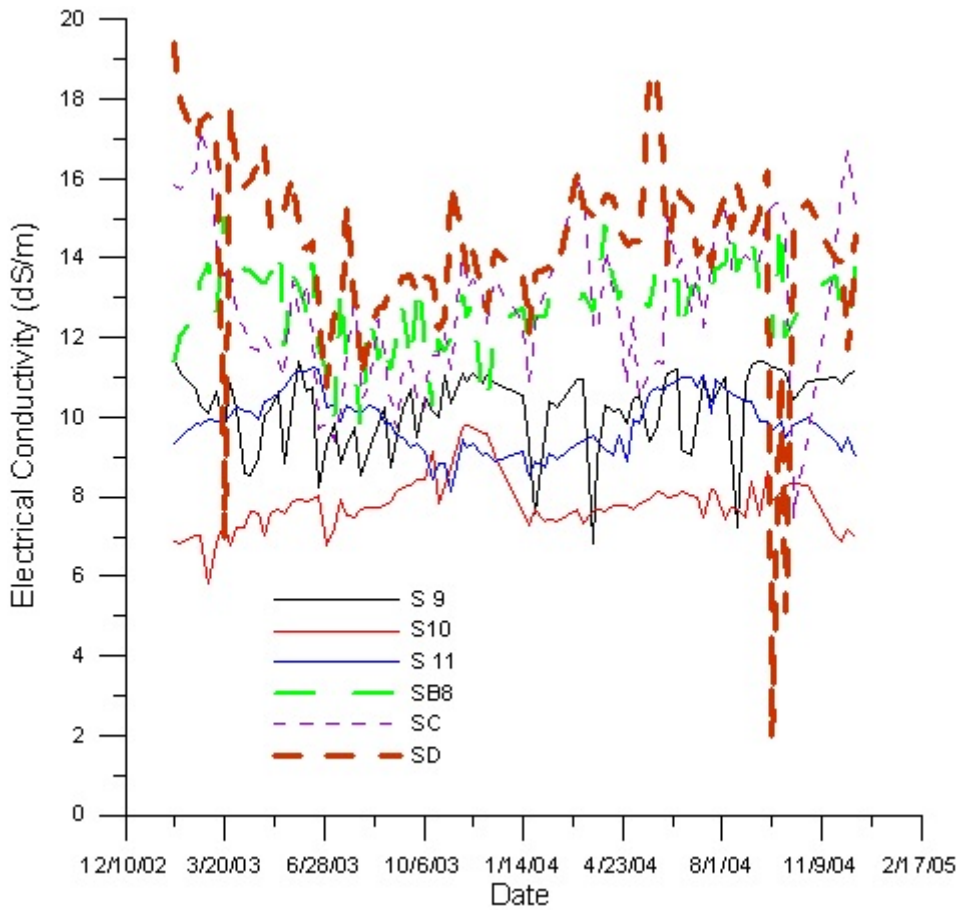



Figure 49. Electrical conductivity of drainage water in drainage sumps on Red Rock Ranch IFDM project.

The total irrigation water applied to Area B was assumed to be equal to the sum of the drainage flow measured for SA-9, SA10 and SA-11. The drainage flows for SA- 9, 10 and 11 are given in figure 50. The drainage water from field B was set equal to the flow from SB-8, the drainage sump for area B. The loading is then the difference between the salt load applied in the irrigation and the salt carried off in the drainage water from field B. This overestimates the loading since

there is a surface runoff component for this site. Area B is surface irrigated with considerable runoff. Not including this component will result in a larger apparent salt loading. The data are summarized in Fig. 51.

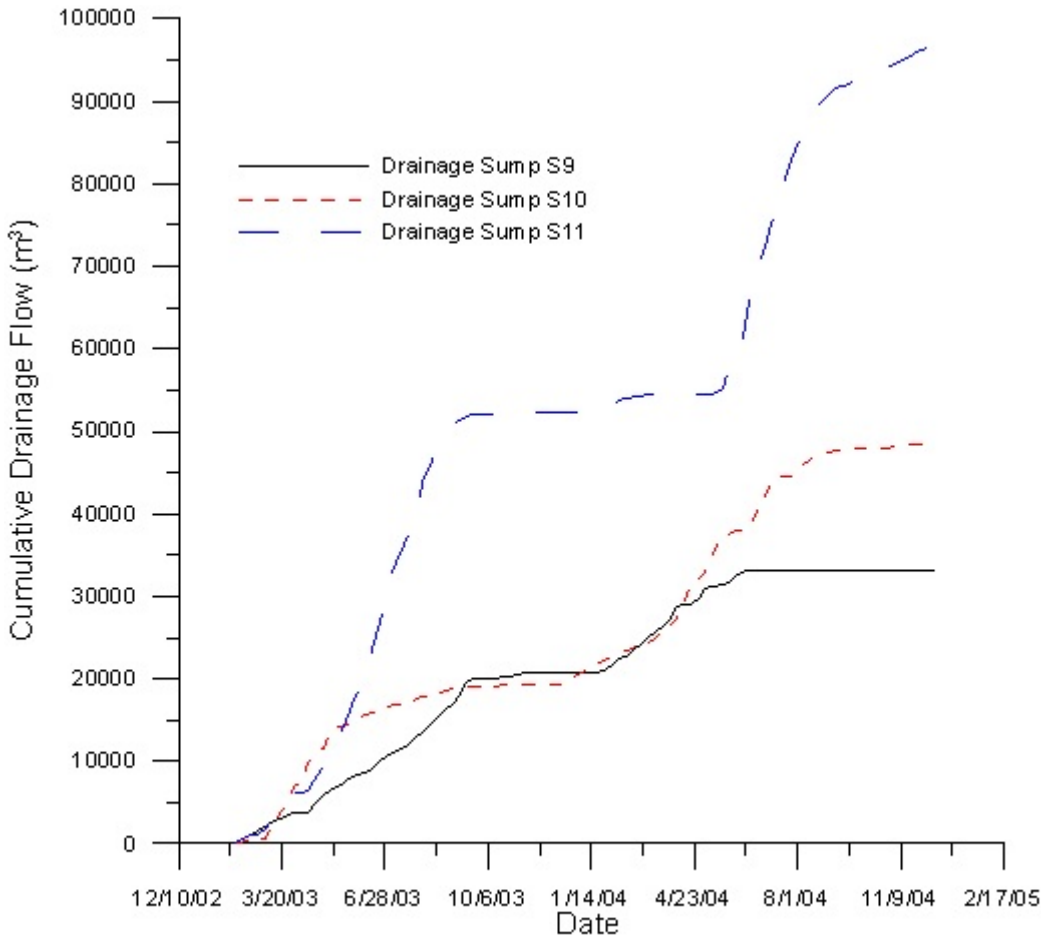



Figure 50. Cumulative drainage flow from fields A9, A10, A11 at the Red Rock Ranch IFDM site.

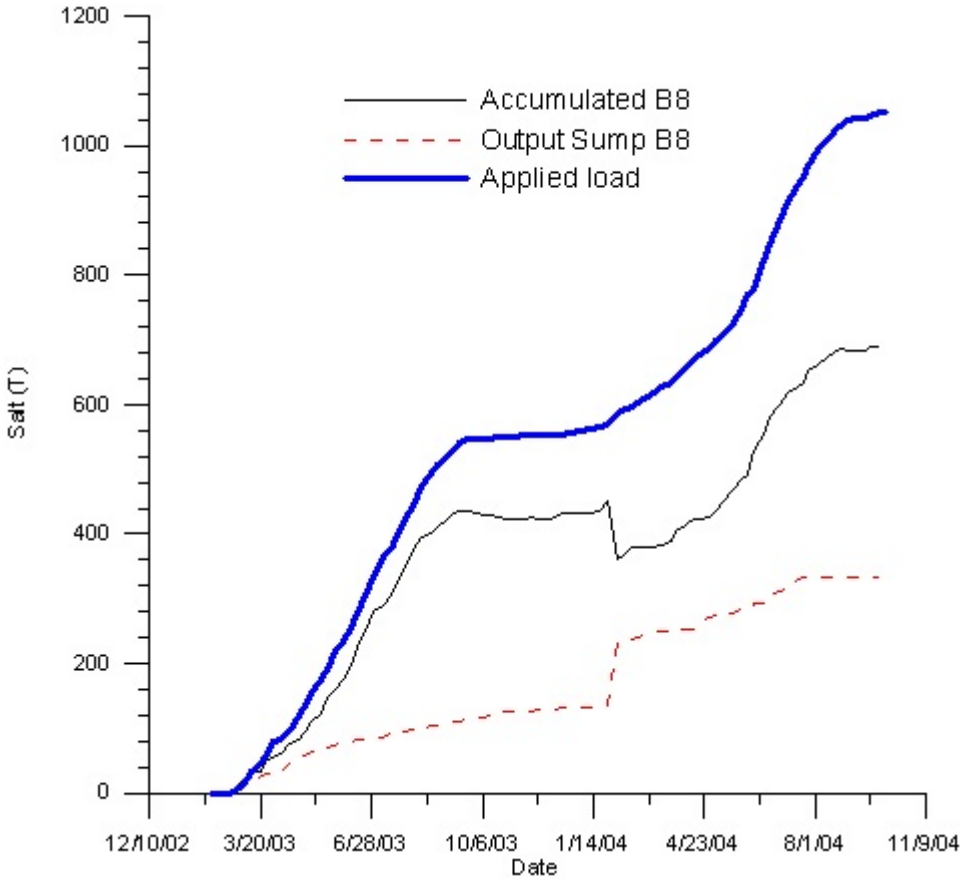



Figure 51. Estimated salt loading of Area B in Red Rock Ranch IFDM site.

These are accumulated data for a period of two years and show that there is a general increase in the salt loading of the soil at the site. Recall that if surface runoff was considered the applied load would be reduced and with the load from the sump staying the same the total salt load added to the field will be reduced.

The weekly salt load was characterized and given in Fig. 52. These data show that there is net leaching only during the winter months. The rate of accumulation varies widely but the largest additions occur during the summer when the largest applications occur.

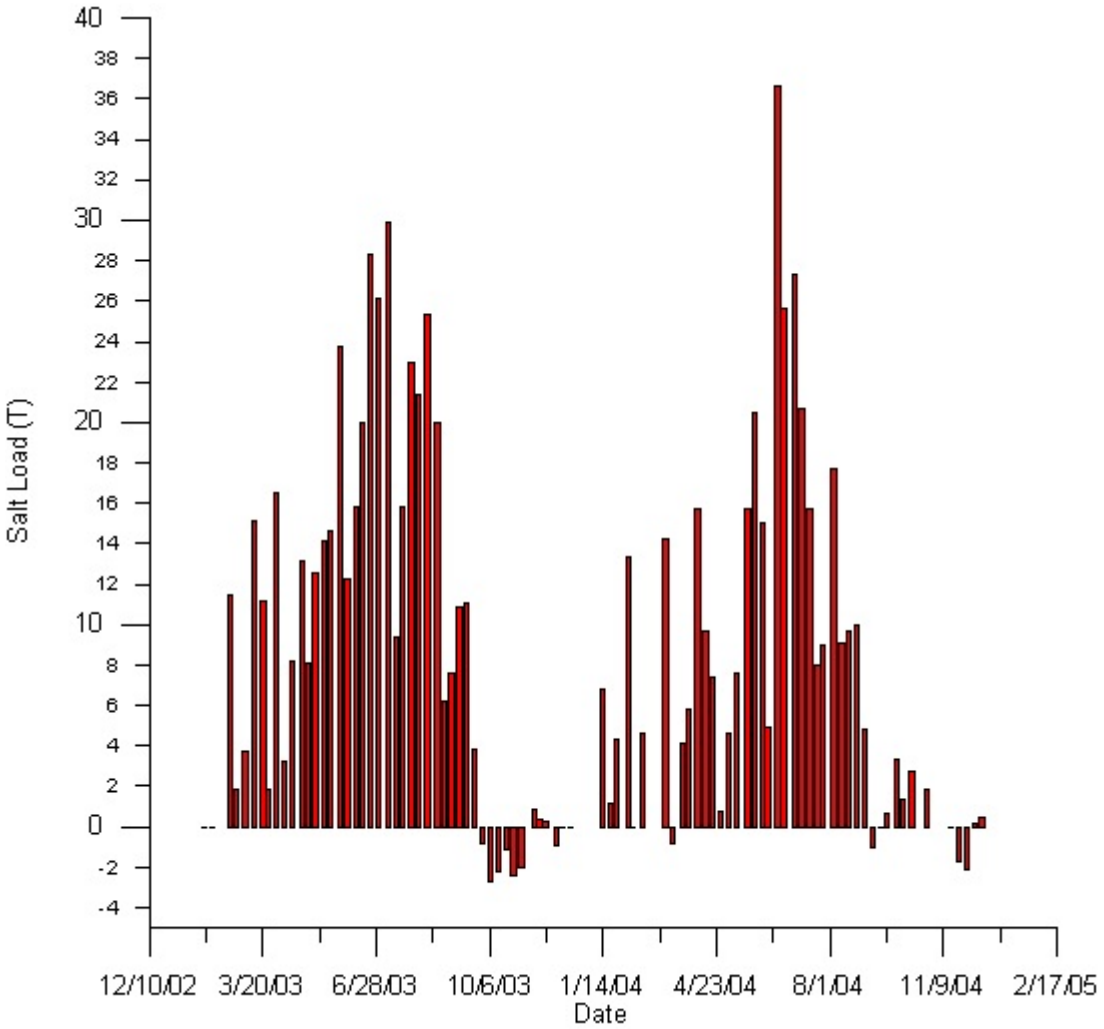



Figure 52. Weekly salt load added to Area B at Red Rock Ranch IFDM site.

The net salt loading was calculated to be 702,254 kg of salt added to 24 ha. of land. This reduces to approximately 29 kg/m$^2$.

The data from the spring and fall soil sampling in all sections of field B were used to characterize salt loading in the reuse area. The resident electrical conductivity values for the spring of 2002 and fall of 2003 are shown in figure 53.

The North section has received drainage water in excess of the crop water requirement and has shown a decrease salinity throughout the profile. The middle section was also irrigated with salt water but at levels below the north. There was some increase salinity in the range from 60 to 100

centimeters. In South section that was irrigated with good quality water, the salinity decreased in depths from 0 to 80 cm and remained constant over the remainder of the profile. It is interesting at with the higher values of applied water in the North section there was leaching
when one would assume that the salt load would increase from the excess water application in this area. The data in Fig. 53 are from 2002 to 2003 while the data in figure 52 are for the period 2003 to 2004.

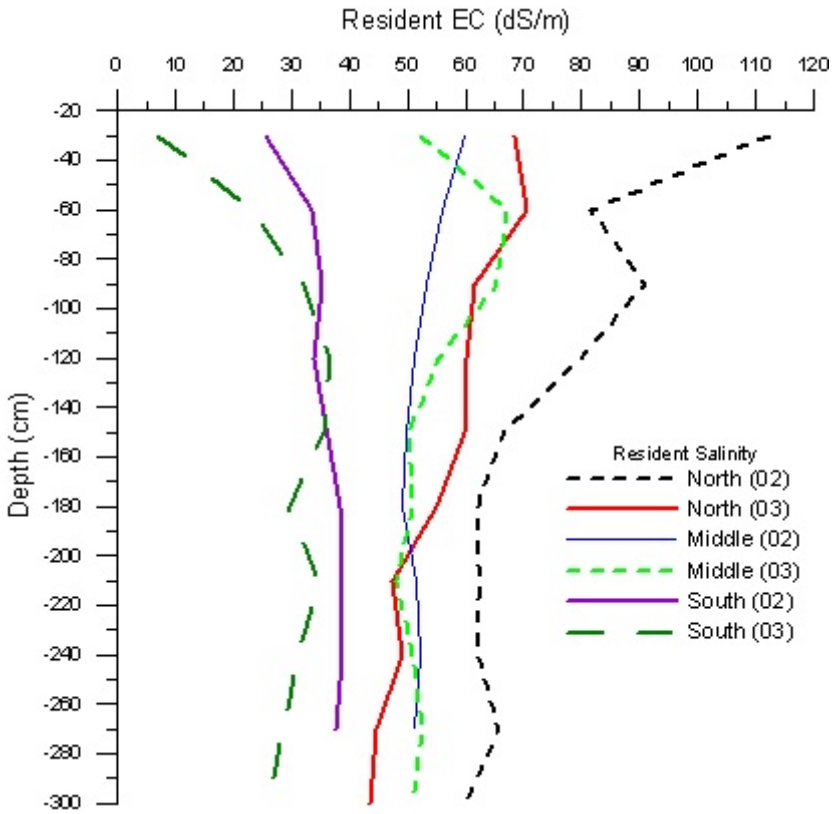



Figure 53. Resident EC in the north, middle, and south sections of field B.

**2.5 Summary and Conclusions:**

The lack of a valley wide solution to the San Joaquin Valley drainage water disposal problem has required developing alternate solutions for the problem. The San Joaquin Valley Drainage Program report (1990) outlined intermediate steps that should be implemented to address the disposal problem. These included source control (improved irrigation), reuse of drainage water, in-situ use by crops, land retirement, and evaporation ponds. These actions have been implemented to various degrees on the west side of the San Joaquin Valley (Ayars, 2003).

The next step in the solution process was to integrate these practices into a farming system that would result in drainage water reduction with ultimate disposal at the end of the system. This concept is called sequential biological concentration which is the successive reuse of drainage water until it no longer has value as a water supply. At this stage the remaining water is evaporated leaving only salt. In Australia this is called Serial Biological Concentration(Blackwell et al., 2005); in the United States it is Integrated on-Farm Drainage Management (IFDM)(Ayars and Basinal, 2005). This system has been evolving at Red Rock Ranch for the past 10 years.

Successful operation of an IFDM system will require that it is economically viable and agronomically sustainable. This means that the irrigation efficiency has to be maximized to reduce deep percolation to the lowest practical level. The largest area should be allocated to growing high value crops with least area possible allocated to low value crops. The area of the evaporation site also has to be kept to a minimum. Drainage systems will be required for each field and the design should minimize collection of the regional flow. Control structures are required in the drainage system to regulate flow and maintain water table position. If there are toxic elements in the drainage effluent the evaporation facility will have to be designed to account for this.

The data described in Section 2 detail the operation of the Red Rock Ranch IFDM system over a two-year period after the system was fully functional. The system includes 4 quarter sections with 3 of the quarter sections (A9, A10, A11) being used to grow high value crops (tomato, garlic, alfalfa) and the last quarter being used for the first reuse of saline water. This last quarter section was subdivided into three smaller fields with only 2 fields being used for salt tolerant crops and drainage water disposal. Drainage water is collected from the 3 sections containing good crops and applied to the fourth quarter. Water collected from the first reuse area is used to irrigate halophytes. The drainage from the halophytes goes to the evaporation facility.

The water balance studies across each of the 3 fields growing high value crops indicate high levels of irrigation efficiency. The leaching fraction calculated based on the applied irrigation water and rainfall and the measured drainage flow from fields resulted in approximately a 6% leaching fraction from field's A9 and A10 and a 10% leaching fraction on A11. These are excellent values of irrigation efficiency suggesting that there was a high level of irrigation management being practiced. In fact, the fields were irrigated with sprinkler and drip systems, which was reflected in the low values of drainage flow. The leaching fraction in the reuse area B was estimated to be approximately 20%, which is value that will sustain uniform salinity concentration in the root zone.

The drainage system in each field was installed at a depth of approximately 1.5 m rather that the traditional depth of 1.8 m to minimize interception of regional ground water flow. The drainage flow occurred in response to irrigation and ended during fallow periods. This is a good indication that regional flow was not being intercepted. There are no indications of salt accumulation so the shallower installation has not led to a salination problem.

One criteria for operating an IFDM system is to minimize the total area required for reusing drainage water and ultimately disposal of drainage water. The total area allocated to this

component of the system was less than 6% of the total area being served. This area will probably be reduced as irrigation efficiencies are improved throughout the system. This compares to a value of roughly 10% of the area served which was the estimate developed when surface irrigation was the predominating method and evaporation ponds were used for disposal.

Successful system operation will be characterized by an increase in the salinity of the deep percolate with each reuse and a reduction in the volume. The volume reduction has been demonstrated. The salinity data have to be considered carefully. Using the salinity of the drainage collected by the subsurface drains does not present an accurate picture of the system. These drains are collecting both deep percolate and regional ground water and the flow is dominated by the regional ground water salinity which has a lower value than the deep percolate. The salinity of the ground water collected at the water table is a better representation of the deep percolate salinity and this demonstrates that concentration is occurring. This is significant when a system is being designed because the volume and concentration of the drainage water will determine the crop and area needed for the reuse area.

The presence of selenium in the drainage flow eliminated evaporation basins as a disposal alternative and spray system was developed that did not permit accumulation of standing water.

Based on the research at the Red Rock Ranch IFDM system it was concluded that:

1.IFDM represents an economically viable alternative solution for drainage water disposal while the political and of technical issues are resolved for off farm disposal.

2. Improved irrigation efficiencies are essential to minimize the total required disposal area and can be achieved through sprinkler or drip irrigation.

3.Shallow installation of drainage systems and control of drainage systems does not adversely impact soil salinity.

4. Shallow drainage system installation or drainage control will be required to minimize collection of regional ground water flow.

5. Drainage water EC is not representative the concentrating effect of crop water use at this site but is the value needed to design a system.

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