Section 20 Compliance Analysis for Discharges into Horse Creek, Hay Creek, Squaw Creek, Spring Creek, Dry Gulch, Ruff Draw, Gas Draw and Other Associated Drainages, Campbell County, Wyoming

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EXECUTIVE SUMMARY
HORSE CREEK SECTION 20 ANALYSIS REPORT

Five coal bed natural gas (CBNG) producers cooperated in a joint study to analyze the irrigation, soils and vegetation within the Horse Creek watershed (TNP 53N-55N, RNG 71W-74W, Campbell County) in an effort to determine if discharge of produced CBNG water would comply with Section 20 of the WDEQ/WQD agricultural use policy. The Section 20 Analysis included investigations of approximately 142 stream miles along Horse Creek and its tributaries; collection 730 soil samples composited into 144 samples for analysis; 86 soil profile descriptions; 36 vegetation transects; and comprehensive modeling to evaluate the impacts of applying produced CBNG water on lands in the Horse Creek watershed which were identified from CIR photos as receiving enhanced water supply. The field investigations indicated that managed irrigation has not been practiced in the recent past, although 22 active irrigation surface water rights are present downstream of proposed and existing discharge points. The results of the soils and vegetation analysis showed applying produced CBNG water to irrigated and/or subirrigated lands would not cause a detrimental impact to agricultural production, and in many cases would be beneficial to the soils and vegetation. The results of the study also show the soils and vegetation could tolerate EC and SAR values up to 4 dS/m and 25, respectively. The Section 20 Analysis presented herein demonstrates that untreated CBNG-produced water could be discharged within the Horse Creek watershed without causing a measurable decrease in crop or livestock production.

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Section 20 Compliance Analysis for Discharges into Horse Creek, Hay Creek, Squaw Creek, Spring Creek, Dry Gulch, Ruff Draw, Gas Draw and Other Associated Drainages, Campbell County, Wyoming

INTRODUCTION

The purpose of this report is to present an evaluation of the potential impact from discharge of untreated Coal Bed Natural Gas (CBNG) produced water on the agricultural uses of surface waters within the Horse Creek Drainage. The evaluation is required by the Wyoming Department of Environmental Quality, Water Quality Division (WDEQ/WQD) Agricultural Use Protection Policy (Chapter 1, Section 20), which states that:

"All Wyoming surface waters which have the natural water quality potential for use as an agricultural water supply shall be maintained at a quality which allows continued use of such waters for agricultural purposes. Degradation of such water shall not be of such an extent to cause a measurable decrease in crop or livestock production. Unless otherwise demonstrated, all Wyoming surface waters have the natural water quality potential for use as an agricultural water supply."

Analyses of this type are typically referred to as Section 20 Analyses.

Several CBNG producers with developments within the Horse Creek watershed agreed to participate in the Section 20 Analysis. The project participants include Pinnacle Gas Resources, Inc., Redstone Resources Inc., Windsor Energy Group, LLC, Yates Petroleum Corporation, Thomas Operating Company, Inc., and Lance Oil & Gas Company, LP, an Anadarko Company (Operators). The Operators provided locations of existing and proposed outfalls on the mainstem and tributaries of Horse Creek, along with chemical analyses representative of water to be discharged at these outfalls. The analysis included an evaluation of irrigated areas within the Horse Creek watershed

downstream of CBNG outfalls which may discharge produced CBNG water into a stream or storage reservoir. The Overview Map depicting locations of the proposed and existing outfalls and the overall study area is provided at the back of this report. Mapping includes a 1 in = 1 mi overview map, along with detail plates presented at 1 in = 1,000 ft scale. Sites were sampled for crop species and soil analysis in compliance with the Section 20 guidance. Without the Section 20 Analysis, the default agricultural water quality limits for Horse Creek include an electrical conductivity (EC) value of 1,340 µmhos/cm and a sodium adsorption ratio (SAR) value of 7.5. The analysis presented herein demonstrates that the limits for EC and SAR for water discharged to Horse Creek and its tributaries may be increased substantially without a measurable decrease in livestock and agricultural production in the Horse Creek watershed. Compliance with Section 20 guidance is demonstrated through a detailed impact analysis using baseline soils, water and vegetation information in combination with the quality of the CBNG-produced water.

The majority of the fields that were studied on Horse Creek were not under managed flood irrigation. However, color IR photos indicated enhanced vegetation during late summer. The sources of water supplying the fields are variable, but the primary source of water for the hydrologic budget of the typical watershed is precipitation. The precipitation which falls upon the land is dispersed in several ways. The largest portion is temporarily retained in the soil near where it falls and is ultimately returned to the atmosphere by evaporation and transpiration by plants (collectively termed evapotranspiration (ET) or consumptive use). Smaller portions of the water become

runoff, finding its way over and through the surface soils to stream channels, while minor portions can in some situations penetrate farther into the ground to become groundwater. The amount of precipitation which becomes runoff is a function of soil type and cover, precipitation type (i.e., rain or snow), topography and precipitation intensity. Surface runoff will continue to infiltrate and evaporate as it moves across the soil to stream channels. Groundwater may be discharged to the surface water system in stream channels or at spring locations generally controlled by local geology.

When water returns to the atmosphere through ET, salts are left behind. Over time, salts are concentrated in the soil. These salts are naturally present in the soils, and the chemical makeup of these salts is a function of the parent materials of the soils.

Although most of the precipitation which falls to the ground is lost to ET (the annual potential ET in northeastern Wyoming far exceeds the average annual precipitation), the average annual amount which falls in northeastern Wyoming is less than the ideal requirement for forage crops (grass and hay). Without added water from some source other than precipitation, forage crops' growing seasons are shortened. The difference between a crop's ideal water requirement and that portion of the requirement supplied by precipitation is termed the "consumptive irrigation requirement." Application of irrigation water can prolong the growing season for forage crops, and it can also affect the salt content of the soils, either beneficially or detrimentally, depending upon the relationship between the salinity and salt composition of the water and soil to which it is applied.

The complex interaction of precipitation and irrigation on the soils and plants in the Horse Creek watershed is studied in this report, with the overall goal of determining whether application of CBNG-produced water, if used for irrigation of soils along Horse Creek and its tributaries, would have a detrimental effect on livestock or crop production.

The impact analysis on soils included a detailed evaluation of EC and EC-SAR relationships of the soils studied and a simulation (model) of how irrigating with waters mixed with CBNG-produced water may impact soil chemistry of the irrigated soils. The simulation was completed using the FAO-SWS model, which is a geochemical/transport model under development by Dr. D. Suarez, Director of the U.S.D.A. Salinity Laboratory in Riverside, California. This model is currently used by Poudre Valley Environmental Sciences, Inc. (PVES) as an analytical tool to assess the geochemistry and soil water changes resulting from the application of CBNG-produced water to Powder River Basin soils.

The alluvial groundwater collected at several sites showing late-season enhanced vegetation along Horse Creek was also analyzed to provide documentation of the quality of water currently used by agricultural plants at such sites. Mixing the alluvial groundwater with the CBNG-produced water was simulated with a geochemical model (EQ3/6) to provide an indication of how the produced water may impact the existing or ambient waters currently present in the Horse Creek watershed. The simulation is

based on the water quality of CBNG-produced water found at the well head (under atmospheric conditions) without interaction with other materials. This is a conservative analysis that neglects how the make-up of the dissolved constituents in this water will become more like the natural water quality in the watershed during contact with the native soils.

Vegetation evaluations were conducted throughout the Horse Creek watershed to provide the baseline assessment of species diversity, percent occurrences and corresponding plant tolerances to salinity and elemental toxicity. This information was used to evaluate how the CBNG-produced water may impact the plant community if used for irrigation purposes.

An investigation of the Horse Creek watershed downstream of proposed and existing CBNG discharge outfalls using USGS 7.5 minute quadrangle maps, the SEO water rights database, and a field investigation of the area shows the existence of 22 valid surface water rights with irrigation as a permitted use. The surface water rights are tabulated and provided in Appendix A. Copies of the water right permits are also provided in Appendix A. The locations of the permitted diversions for each water right are depicted on the Overview Map.

PART 1: HORSE CREEK (MAIN STEM)

The site evaluations conducted over several months demonstrated that no active irrigation management is occurring along Horse Creek from the headwaters to its confluence with the Little Powder River. There is some evidence that irrigation was attempted in the past with the existence of headgates and spreader dike systems. However, observations and discussions with many of the landowners provided a good indication that active irrigation management has not occurred for a long period of time. All areas considered to be previously flood irrigated using water management and all stream-bottom lands that showed red on CIR photos were sampled during this investigation. These sites are currently used for hay production in much of the Horse Creek valley. The sites noted red on the CIR photos were not currently benefiting from managed flood irrigation but show enhanced vegetation late in the growing season and were interpreted to be subirrigated and/or naturally flood irrigated. Subirrigated areas receive groundwater that is supplied by an alluvial aquifer. Recharge to alluvium is supplied by a number of sources including bedrock aquifers, infiltration of direct precipitation and snowmelt, and ephemeral flows in Horse Creek. The irrigated sites observed in the field were sampled as described in the Methods section provided later in this report.

COALBED NATURAL GAS PRODUCED WATER

Characteristics of CBNG-produced water representing the water at the well head that may be discharged into collection reservoirs or into Horse Creek or contributing reaches of Horse Creek are provided in Table 1 and summarized in Appendix B. In

general, the water meets quality standards for livestock and wildlife. The CBNG-produced

Table 1. CBNG-produced Water Analysis for Waters Discharged in the Horse Creek Watershed

Sample Location	Sec 18, T54N, R72W	Sec 18 T54N R72W	Sec 24, T54N, R74W	Sec 6, T53N, R73W	Sec 20, T54N, R73W	Sec 21, T54N, R73W	Sec 24, T55N, R74W	Sec 36, T55N, R75W	Sec 3, T54N, R74W
Permit No.	WY0052493	WY0052493	WY0050652	WY0050911	NA	NA	WY0053651	WY0037362	WY0050610
Outfall	001	001	001	001	NA	NA	NA	001	003
Parameter									
pH (su)	8.05	8.00	8.28	8.2	7.71	7.89	8.5	7.34	7.95
EC (dS/m)	0.615	1.18	1.05	1.5	1.2	1.49	1.67	1.84	2.33
TDS (mg/L) (calc)	381	729	654	910	733	916	1060	1132	1433
SAR	9.2	9.4	11.6	11.5	10	10.4	13.8	23.6	17.1
Ca (mg/L)	9	27	17	34	25	29	32	14	35
Mg (mg/L)	3	12	9	18	11	18	18	7	23
K (mg/L)	NA	NA	NA	NA	11	14	18	15	13
Na (mg/L)	126	232	236	332	238	293	395	430	528
HCO_3(mg/L)	390	766	690	1060	803	1040	1160	1270	1690
SO_4^{-2} (mg/L)	<10	14	<10	<10	<10	<10	<10	<10	<10
Cl (mg/L)	11	13	12	8	14	9	9	17	9

NA - not available

water is characterized with EC values ranging from 0.6 to 2.3 dS/m, SAR values ranging from 9.2 to 23.6, pH values from 7.1 to 8.28 and bicarbonate levels from 390 to 1690 mg/L.

The Agricultural Use Protection Policy requires that the water quality at the well head be used to assess potential impacts to agricultural use. However, CBNG-produced water discharged into any stream channel in the Horse Creek watershed will be modified to reflect its new environment within a short distance or time frame. Mechanisms associated with dilution, chemical reaction, and soil mineral and salt dissolution will quickly modify the chemical characteristics of the produced water. The initial characteristics of the produced water may have little if any impact on downstream agricultural use due to modifications in quality as the water moves down the flow path.

METHODS – BASELINE DATA COLLECTION

Baseline conditions for soils and vegetation associated with managed flood irrigation and subirrigated or naturally flood irrigated areas used for agricultural purposes were determined along Horse Creek from the headwaters to its confluence with the Little Powder River. The alluvial groundwater conditions were determined at several locations where water samples could be collected. The baseline sampling locations for soils, alluvial groundwater and vegetation are depicted on the Overview Map (all Plates).

Soils

Soils were collected and evaluated at each site with historic managed flood irrigation and/or naturally flood irrigated or subirrigated agricultural activities. At least one soil sample was collected for each landowner with irrigated lands provided the landowner granted access. Land ownership is depicted on the Plates. Landowner contact information is listed in Table 2.

Table 2. Horse Creek Landowners with Flood Irrigated or Subirrigated Fields

Landowner	Address
Brown-Kennedy Ranch	PO Box 847, Sheridan, WY 82801-0854
Dave Magnuson Ranch	15051 State Highway 59 N, Weston, WY 82731-8807
Larry Shippy Ranch	281 Horse Creek Rd, Weston, WY 82731-8818
Carl Kretschman	456 Horse Creek Rd, Gillette, WY 82731
Loren Peyrot Ranch	PO Box 1208, Gillette, WY 82717-1208
Stevan Mueller Ranch	673 Horse Creek Rd, Gillette, WY 82716-8823
Paulette Parks Ranch	510 Horse Cores Creek Rd, Weston, WY82731-8819
Marsha Pownall Ranch	1843 Collins Rd, Gillette, WY 82716-8831
Twenty Mile Land Co. (John Daly)	PO Box 69, Gillette, WY 82717-0069
State of Wyoming	122 W 25th St Cheyenne WY 82001-3004
Tarver, Donna Trust	8185 N US Highway 14-16, Gillette, WY 82716-1211

Two techniques of evaluation were used for soils sampled on these sites. Soil samples in the form of 3-inch diameter cores were collected using a Giddings probe. Samples collected from an irrigated site representing one soil type were composited into one sample. If the characteristics of the soils changed within an irrigated field, additional samples were collected. The number of samples collected for the overall sample composite was determined by the acreage of the irrigation site as required by the Agriculture Use Protection Policy. Samples were also collected from the other irrigated agricultural sites present on each landowner to determine if these sites were characterized with the same soil previously sampled for analysis. If the profile was similar to the sampled site, it was described using a selected list of parameters presented in the standard Natural Resources Conservation Service (NRCS) field methods (Soil Survey Division Staff, 1993). In these cases, the data collected from the sampled soil profile would represent the described but unsampled profile. This is a rational approach for the naturally irrigated agricultural areas since the landowner doesn't have any input into the irrigation system. The concept also is legitimate for any managed irrigation site since the only variable is irrigation management, which should be consistent for a specific landowner. In some cases, several sites associated with the same landowner were sampled for analysis. For example, all irrigated/subirrigated fields located at the Loren Peyrot and Larry Shippy ranches were sampled for analysis.

Composite samples were collected at 1-foot intervals to depths of 4 feet for grass vegetation communities and to 6 feet for sites occupied by alfalfa. Irrigated fields were

never dominated by alfalfa but rather alfalfa plants were sparse (10 to 15 feet apart) and appeared to have unfavorable growth characteristics. Samples were kept cold and submitted to Inter-Mountain Laboratories, Inc. (IML) in Sheridan, Wyoming for analysis. Parameters for analysis included pH, EC, SAR, particle size, saturation percentage, and organic matter. Organic matter was evaluated on the 0 to 1-foot depth interval. Photos were collected at soil sample sites and at sites investigated but not sampled. The photos are provided in Appendix C.

Alluvial Groundwater

During the soil sampling activities, groundwater was encountered at several irrigated sites in the Horse Creek drainage. Water samples were collected, where possible, from several of the sites using a Teflon water bailer. Collected samples were kept cold and submitted to IML. The alluvial groundwater sampling locations are shown on the Overview Map (Plates 1-3). The samples were analyzed for pH, EC, SAR, Ca, Mg and Na. Results are summarized in Table 3 and provided in Appendix D.

Table 3. Alluvial Groundwater Quality Analysis for Samples Collected at Subirrigated Fields at the L. Peyrot, P. Parks and M. Pownall Ranches Located on Horse Creek

Parameter		LP2-1	LP2-2	LP3-3	PP8-1	MP1-1	MP1-3	MP5-1
pH	(su)	8.2	8	8.4	8	7.9	7.9	7.7
EC	(dS/m)	3.1	3.2	2.9	5.4	6.9	5.2	5.2
SAR		6.7	5	4.1	5.7	6.4	4.4	4.7
Ca	(mg/L)	90	182	179	436	458	523	518
Mg	(mg/L)	145	181	147	359	577	377	319
Na	(mg/L)	443	394	306	664	867	544	557

*See Overview Map (Plates 1-3) for Sample Sites

Vegetation

A vegetation inventory was conducted to determine crop species and their salinity tolerances. The purpose of the inventory was to obtain inferences about larger areas from an appropriate number of samples within a smaller area. Vegetation was sampled in order to estimate species abundance expressed by percent occurrence. The point transect survey procedure was used.

The point transect method is based on point sampling to determine species composition. The method is based on placing a number of sampling points within a pre-determined area and analyzing the proportion of the points that encompass (i.e. intercept) vegetation. Species composition refers to the contribution of each plant species to the vegetation biomass and is expressed as a percent, so that all species components add up to 100 percent.

Managed irrigation and/or naturally irrigated areas that were located downstream of existing or proposed CBNG-produced water discharge were selected as study areas. Infrared photos, USGS maps, and data from the SEO website were used to assist with selecting the sampling sites.

The vegetative inventory for each survey point was collected by walking a straight line transect through the study area. Latitude and longitude were recorded at each end of

the transect. Vegetation "point" readings were recorded along a tape measure at either 10 or 25-foot intervals. The "sample point" or interval was based on the length of the transect. Ten-foot intervals were recorded for transects 0 to 200 feet long, and 25-foot intervals were recorded for transects greater than 200 feet in length. Transects were divided into vegetation types, such as uplands, irrigated fields, and stream channel. Photos were taken at each transect. A list of vegetative species encountered, including subcategories of annuals and perennials is provided in Attachment E. The vegetation transect summaries, photos and field documentation are included in Appendix F.

Vegetation species at each transect were grouped into two categories: annuals and perennials. Typically, perennial plants are better competitors than annual plants, especially under stable, resource-poor conditions. This is due to the development of larger root systems, which can access water and soil nutrients deeper in the soil, and to earlier emergence in the spring. In addition, as soil salinity levels increase, the stress on germinating seedlings also increases. Perennial plants tolerate salinity better than annual plants (Alberta Agriculture and Food, 2001). Changes in vegetation species groupings can be determined with future surveys.

RESULTS – BASELINE

Soils

The baseline soil evaluations include soil profile descriptions, which allow correlation between the same soils found on a specific landowner, and soil chemistry, which

provides an indication of how a soil will react to irrigation with CBNG-produced water. More importantly, soil chemistry provides evidence of the water quality that has impacted the soil from prior irrigation management or from natural flooding and subirrigation.

The soil profile descriptions for each sampling site are presented in Appendix G. It should be noted that the subirrigated soils collected along Horse Creek reflected similar characteristics. Generally, the soils found in the Horse Creek alluvium were characterized with an A, Bw, Bk and C horizon sequence, usually with multiple Bk and C horizons.

The chemical analyses of the soil samples are presented in Table 4. Laboratory analyses are included in Appendix H. Samples collected from subirrigated areas throughout the Horse Creek watershed often have salt levels greater than 4 dS/m, which is considered to be saline as defined in USDA Handbook 60 (1959). The average EC value for all samples collected along Horse Creek was 7.02 dS/m with a range of 0.66 dS/m to 15.7 dS/m. Averaged EC values by one-foot depth increments were 4.75 dS/m (0 to 1 foot depth increment), 8.85 dS/m (1 to 2 feet), 8.87 dS/m (2 to 3 feet), 7.29 dS/m (3 to 4 feet), 6.15 dS/m (4 to 5 feet) and 5.59 dS/m (5 to 6 feet). Table 4 also presents EC values corresponding to each landowner. The high salt levels found in these soils indicate that water containing high levels of salts has impacted the soils. The origin of the salt is most likely from soluble minerals in the bedrock, and the high levels of salt are due to concentration by ET. This characteristic is typical of much

of the alluvial groundwater in the PRB. Salts originating from adjacent areas will continue to collect in the alluvium of Horse Creek with or without the discharge of CBNG-

Table 4. Chemical Analyses of the Soil Samples Collected from Subirrigated Lands Along Horse Creek*.

Sample ID	Depth Interval (ft)	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR	Sand %	Silt %	Clay %	Texture
Dave Magnuson Ranch													
DM1	0-1	7.5	56.7	6.19	3.5	21.6	25.5	29.2	6.0	40	34	26	Loam
DM1	1-2	8.2	49.8	9.9		19.2	43.3	68.2	12.2	42	33	25	Loam
DM1	2-3	8.5	38.5	12		19.6	51.3	83.2	14.0	71	13	16	Sandy Loam
DM1	3-4	8.4	36.9	10.5		18.7	49.2	69.6	11.9	78	10	12	Sandy Loam
DM1	4-5	8.2	35.8	8.81		19.6	41.4	52.1	9.4	66	22	12	Sandy Loam
DM1	5-6	8.2	35.8	8.35		19.4	36.9	50.2	9.5	70	19	11	Sandy Loam
DM1-A	2-3									62	14	24	Sandy Clay Loam
DM1-A	3-4									70	14	16	Sandy Loam
DM1-A	4-5									68	16	16	Sandy Loam
DM1-A	5-6									74	10	16	Sandy Loam
Larry Shippy Ranch													
LS1	0-1	6.6	60.2	0.83	2.9	3.23	2.54	1.35	0.80	20	49	31	Clay Loam
LS1	1-2	7.6	52.8	0.71		2.42	1.28	2.14	1.57	21	49	30	Clay Loam
LS1	2-3	7.6	42.0	0.72		2.49	1.31	2.03	1.48	51	29	20	Loam
LS1	3-4	7.7	42.7	0.70		2.47	1.12	1.95	1.46	49	32	19	Loam
LS1	4-5	7.7	43.0	0.79		3.20	1.41	2.17	1.43	50	32	18	Loam
LS1	5-6	7.8	39.6	0.86		3.41	1.65	2.10	1.32	46	31	23	Loam
LS1 was determined to be irrigated by an adjacent watershed to Horse Creek and was not significantly impacted by the Horse Creek alluvium – See Overview Map													
LS6	0-1	7.2	60.3	1.00	2.8	3.33	2.5	1.81	1.06	27	41	32	Clay Loam
LS6	1-2	8.0	51.7	6.97		17.7	24.6	38.4	8.35	24	46	30	Clay Loam
LS6	2-3	8.3	48.7	9.06		17.2	33.8	57.3	11.4	32	44	24	Loam
LS6	3-4	8.3	48.8	8.48		16.3	30.2	51.0	10.6	31	43	26	Loam
LS6	4-5	8.2	53.1	7.16		15.1	24.6	41.4	9.29	22	48	30	Clay Loam
LS6	5-6	8.1	53.4	6.38		15.6	20.3	34.6	8.17	20	48	32	Clay Loam
Carl Kretschman Ranch													
CK-1	0-1	7.5	50.4	4.85	3.3	20.0	26.3	13.8	2.9	44	28	28	Clay Loam
CK-1	1-2	8.4	44.2	11.7		17.5	72.6	79.0	11.8	52	23	25	Sandy Clay Loam
CK-1	2-3	8.3	46.2	9.65		15.5	53.4	58.6	10.0	43	27	30	Clay Loam
CK-1	3-4	8.2	43.2	7.64		17.9	38.6	43.3	8.1	46	29	25	Loam

Table 4. Chemical analyses of the soil samples collected from subirrigated lands along Horse Creek* (Continued)

Sample ID	Depth Interval (ft)	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR	Sand %	Silt %	Clay %	Texture
Carl Kretschman Ranch (Continued)													
CK-1	4-5	8.0	50.3	5.01		17.6	23.7	22.7	5.0	34	34	32	Clay Loam
CK-1	5-6	7.9	50.4	4.68		18.3	22.3	19.2	4.3	35	34	31	Clay Loam
CK-2	0-1	7.1	74.6	3.91	3.0	20.4	17.3	14.3	3.3	14	29	57	Silt Clay
CK-2	1-2	7.9	66.3	5.92		16.8	22.2	32.2	7.3	22	30	48	Clay
CK-2	2-3	7.9	71.2	5.15		15.0	17.0	28.3	7.1	22	29	49	Clay
CK-2	3-4	7.9	72.8	4.88		15.8	16.0	25.4	6.4	13	30	57	Silt Clay
CK-2	4-5	7.8	48.4	4.09		17.4	15.7	16.8	4.1	40	21	39	Clay Loam
CK-2	5-6	7.8	41.5	3.47		17.7	13.1	11.6	3.0	57	8	35	Sandy Clay
CK-3	0-1	7.5	56.4	4.09	5.4	20.6	20.4	8.73	1.9	50	25	25	Sandy Clay Loam
CK-3	1-2	8.2	42.3	8.55		18.5	41.2	51.2	9.4	52	26	22	Sandy Clay Loam
CK-3	2-3	8.1	37.3	9.17		16.6	46.2	54.9	9.8	60	21	19	Sandy Loam
CK-3	3-4	8.1	35.2	7.59		19.4	35.7	44.3	8.5	70	13	17	Sandy Loam
CK-3	4-5	8.1	40.5	6.04		15.5	26.5	31.6	6.9	50	29	21	Loam
CK-3	5-6	8.0	43.3	5.08		16.9	24.3	25.2	5.6	51	22	27	Sandy Clay Loam
CK4-A	0-1	6.9	57.5	3.23	4.8	19.3	15.2	4.51	1.1	39	33	28	Clay Loam
CK4-A	1-2	8.1	40.8	8.61		17.0	49.0	54.8	9.6	50	29	21	Loam
CK4-A	2-3	8.3	41.6	10.5		16.9	60.0	69.7	11.2	53	31	16	Sandy Loam
CK4-A	3-4	8.2	41.9	7.37		16.8	37.9	42.7	8.2	59	25	16	Sandy Loam
CK4-A	4-5	8.0	34.7	5.95		16.5	26.9	29.2	6.3	68	18	14	Sandy Loam
CK4-A	5-6	8.1	36.8	6.03		17.0	30.6	31.5	6.5	61	23	16	Sandy Loam
CK4-B	0-1	7.3	50.4	5.32	1.8	19.8	27.1	22.5	4.6	30	35	35	Clay Loam
CK4-B	1-2	7.7	51.4	11.2		18.6	74.9	68.7	10.1	21	43	36	Clay Loam
CK4-B	2-3	8.1	67.2	9.28		15.3	71.0	54.0	8.2	22	35	43	Clay
CK4-B	3-4	8.0	65.2	9.55		16.4	69.4	57.9	8.8	21	34	45	Clay
CK4-B	4-5	8.0	56.6	7.35		13.9	42.1	43.0	8.1	20	35	45	Clay
CK4-B	5-6	8.0	55.7	8.39		16.3	47.9	48.3	8.5	40	22	38	Clay Loam
CK5	0-1	7.2	52.2	4.25	4.1	20.4	27.6	8.25	1.7	32	39	29	Clay Loam
CK5	1-2	8.0	45.6	6.93		16.6	49.0	30.8	5.4	49	31	20	Loam
CK5	2-3	8.1	42.4	7.84		16.8	48.2	41.1	7.2	47	34	19	Loam
CK5	3-4	8.1	45.3	8.08		16.0	57.2	44.0	7.3	50	30	20	Loam
CK5	4-5	8.1	48.9	7.45		15.6	50.4	41.5	7.2	35	41	24	Loam

Table 4. Chemical analyses of the soil samples collected from subirrigated lands along Horse Creek* (Continued)

Sample ID	Depth Interval (ft)	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR	Sand %	Silt %	Clay %	Texture
Carl Kretschman Ranch (Continued)													
CK5	5-6	8.0	46.8	6.10		14.7	37.6	31.2	6.1	38	39	23	Loam
CK6	0-1	7.1	53.8	3.83	4.3	16.0	19.9	11.9	2.8	30	39	31	Clay Loam
CK6	1-2	8.2	43.4	8.98		16.4	49.4	59.8	10.4	42	38	20	Loam
CK6	2-3	8.1	37.0	8.22		16.4	41.4	50.1	9.3	61	25	14	Sandy Loam
CK6	3-4	8.2	35.3	7.70		18.3	39.3	44.9	8.4	67	18	15	Sandy Loam
CK6	4-5	8.1	31.9	6.46		16.1	29.8	32.7	6.8	75	15	10	Sandy Loam
CK6	5-6	7.7	31.5	5.70		16.4	26.1	27.9	6.0	77	13	10	Sandy Loam
CK7	0-1	8.7	52.0	7.68	3.5	17.3	40.8	38.5	7.1	43	31	26	Loam
CK7	1-2	8.6	51.0	15.7		15.5	111	112	14.1	40	35	25	Loam
CK7	2-3	8.6	43.5	14.6		16.7	95.4	104	13.9	60	21	19	Sandy Loam
CK7	3-4	8.3	38.8	7.85		16.8	43.6	45.5	8.3	68	15	17	Sandy Loam
CK7	4-5	8.1	40.7	5.21		17.7	26.5	19.9	4.2	67	17	16	Sandy Loam
CK7	5-6	8.0	36.7	4.85		18.0	23.8	16.6	3.6	51	22	27	Sandy Clay Loam
Loren Peyrot Ranch													
LP1	0-1	7.1	53.7	4.48	3.4	20.3	21.7	17.6	3.9	24	50	26	Silt Loam
LP1	1-2	8.3	47.2	13.7		19.0	107	101	12.7	53	24	23	Sandy Clay Loam
LP1	2-3	8.4	43.9	13.8		14.3	82.3	91.4	13.1	42	40	18	Loam
LP1	3-4	8.3	39.0	11.2		17.3	69.2	84.1	12.8	56	25	19	Sandy Loam
LP1	4-5	8.0	45.6	7.06		18.0	35.6	44.9	8.7	45	33	22	Loam
LP1	5-6	7.8	42.7	6.53		20.0	34.0	38.3	7.4	45	33	22	Loam
LP2	0-1	7.6	54.4	7.97	2.9	18.5	45.1	49.3	8.7	37	38	25	Loam
LP2	1-2	8.0	42.0	6.79		17.5	33.5	44.3	8.8	55	26	19	Sandy Loam
LP2	2-3	7.7	54.1	4.99		19.2	23.6	25.0	5.4	32	41	27	Clay Loam
LP2	3-4	7.5	48.4	4.06		20.0	19.3	15.6	3.5	35	38	27	Clay Loam
LP-3	0-1	7.4	52.1	5.01	3.5	18.4	21.0	21.2	4.8	39	32	29	Clay Loam
LP-3	1-2	8.0	48.3	7.42		16.8	28.6	45.4	9.5	41	32	27	Clay Loam
LP-3	2-3	8.3	47.3	9.98		16.4	42.9	69.5	12.8	46	30	24	Loam
LP-3	3-4	8.3	40.0	8.10		15.4	33.1	55.2	11.2	50	27	23	Sandy Clay Loam
LP-3	4-5	7.9	51.2	4.92		17.0	16.1	25.4	6.2	37	36	27	Clay Loam
LP-3	5-6	7.9	49.0	2.78		9.12	8.20	10.9	3.7	42	31	27	Clay Loam
LP-4	0-1	7.6	50.3	1.57	3.1	5.58	4.10	5.01	2.3	34	38	28	Clay Loam

Table 4. Chemical analyses of the soil samples collected from subirrigated lands along Horse Creek* (Continued)

Sample ID	Depth Interval (ft)	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR	Sand %	Silt %	Clay %	Texture
Loren Peyrot Ranch (Continued)													
LP-4	1-2	8.3	52.9	8.17		16.5	32.1	55.0	11.1	38	34	28	Clay Loam
LP-4	2-3	8.2	50.2	6.95		14.7	24.2	42.6	9.7	36	38	26	Loam
LP-4	3-4	8.2	44.5	7.82		15.6	21.8	51.7	12.0	55	22	23	Sandy Clay Loam
LP-4	4-5	8.0	40.7	5.92		17.3	21.8	32.1	7.3	55	26	19	Sandy Loam
LP-4	5-6	7.7	46.6	4.91		15.2	15.8	23.6	6.0	56	21	23.	Sandy Clay Loam
LP-5	0-1	7.3	54.5	4.08	3.8	20.0	17.8	11.2	2.6	38	35	27	Clay Loam
LP-5	1-2	8.2	56.4	7.67		16.8	45.6	40.7	7.3	24	40	36.	Clay Loam
LP-5	3-4	7.9	35.2	5.46		20.2	26.3	23.4	4.9	68	15	17	Sandy Loam
LP-6	0-1	7.1	48.5	3.61	3.5	21.1	12.9	7.34	1.8	44	31	25	Loam
LP-6	1-2	7.8	46.5	5.53		19.2	22.2	26.7	5.9	44	29	27	Clay Loam
LP-6	2-3	7.9	35.3	5.77		18.6	22.9	28.4	6.2	74	9	17	Sandy Loam
LP-6	3-4	7.9	33.7	5.67		17.0	22.3	28.2	6.4	78	5.	17	Sandy Loam
LP-7	0-1	6.8	54.3	5.28	4.3	20.3	23.1	25.0	5.4	39	34	27	Clay Loam
LP-7	1-2	8.1	54.8	11.5		16.6	66.1	75.3	11.7	34	35	31	Clay Loam
LP-7	2-3	8.4	51.5	11.1		16.9	53.8	80.2	13.5	49	24	27	Sandy Clay Loam
LP-7	3-4	8.0	40.3	7.02		17.3	31.1	41.6	8.5	56	25	19	Sandy Loam
LP-8	0-1	7.2	56.6	4.87	3.7	18.5	24.8	18.7	4.0	32	38	30	Clay Loam
LP-8	1-2	7.9	49.8	7.47		17.9	37.2	44.0	8.4	44	29	27	Clay Loam
LP-8	2-3	7.9	43.1	6.45		18.2	27.9	35.3	7.4	62	19	19	Sandy Loam
LP-8	3-4	7.9	40.9	5.12		15.6	21.1	25.5	6.0	63	18	19	Sandy Loam
LP8-7	3-4	7.9	73.6	7.9		20.2	25	45.7	9.6	20	34	46	Clay
Stevan Mueller Ranch													
SM1	0-1	7.5	55.1	4.8	3.7	17.4	15.8	11.7	2.9	30	46	24	Loam
SM1	1-2	8.2	55.4	11.7		14.3	57.4	56.5	9.3	26	49	25	Loam
SM1	2-3	8.2	44.0	11.0		16.1	50.9	47.5	8.2	58	30	12	Sandy Loam
SM1	3-4	8.2	40.5	11.6		15.7	52.6	53.4	9.2	64	25	11	Sandy Loam
SM1	4-5	8.1	39.3	9.2		15.3	37.3	43.4	8.5	61	28	11	Sandy Loam
SM1	5-6	7.9	32.5	6.8		16.3	25.7	27.4	6.0	73	21	6	Sandy Loam
SM1-2	2-3	8.3	71.0	14.3		14.7	73.9	70.6	10.6	10	82	8	Silt
SM1-2	3-4	8.5	57.9	15.0		16.0	75.8	79.7	11.8	22	54	24	Silt Loam
SM1-4	2-3	8.5	50.4	15.4		18.0	67.9	79.5	12.1	40	42	18	Loam

Table 4. Chemical analyses of the soil samples collected from subirrigated lands along Horse Creek* (Continued)

Sample ID	Depth Interval (ft)	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR	Sand %	Silt %	Clay %	Texture
Stevan Mueller Ranch (Continued)													
SM1-4	3-4	8.5	49.8	17.6		16.8	81.5	95.5	13.6	35	46	19	Loam
SM1-7	2-3	8.4	61.2	16.1		16.9	77.1	77.6	11.3	27	52	21	Silt Loam
Paulette Parks Ranch													
PP1	0-1	7.3	64.6	0.66	2.8	2.64	2.19	0.61	0.4	19.0	50.0	31.0	Silty Clay Loam
PP1	1-2	7.8	52.4	1.35		4.67	4.12	3.66	1.7	25	46	29	Clay Loam
PP1	2-3	8.0	52.6	5.63		17.3	25.7	24.3	5.3	32	43	25	Loam
PP1	3-4	8.1	47.0	6.49		16.7	30.7	31.7	6.5	44	34	22	Loam
PP1	4-5	8.0	45.5	5.25		17.7	21.3	21.0	4.8	51	28	21	Loam
PP1	5-6	7.8	44.6	4.02		17.6	15.5	12.8	3.1	46	32	22	Loam
PP10	0-1	7.8	64.8	7.04	3.0	16.5	42.8	33.3	6.1	14	50	36	Silty Clay Loam
PP10	1-2	8.4	59.9	13.5		16.3	114	87.6	10.9	16	50	34	Silty Clay Loam
PP10	2-3	8.3	60.7	13.7		17.2	115	90.8	11.2	20	44	36	Clay Loam
PP10	3-4	8.2	54.4	10.4		13.2	69.4	58.9	9.2	28.	44	28	Clay Loam
Marsha Pownall Ranch													
MPI	0-1	7.6	68.1	7.83	3.7	18.9	51.7	36.0	6.1	24	38	38	Clay Loam
MPI	1-2	8.2	55.2	10.1		17.8	72.0	58.3	8.7	18	49	33	Silty Clay Loam
MPI	2-3	8.1	57.8	8.45		18.7	62.3	45.1	7.1	16	52	32	Silty Clay Loam
MPI	3-4	7.8	61.0	7.92		17.3	55.0	40.5	6.7	17	47	36	Silty Clay Loam
MPI	4-5	7.8	51.3	6.42		18.3	36.3	28.3	5.4	28	40	32	Clay Loam
MPI	5-6	7.8	50.4	6.62		19.2	42.0	28.6	5.2	36	38	26	Loam
Donna Tarver Ranch													
DT1	0-1	7.4	64.9	0.87	3.7	3.15	1.86	1.26	0.8	24	41	35	Clay Loam
DT1	1-2	7.6	58.5	4.83		20.8	21.8	22.5	4.9	18	48	34	Silty Clay Loam
DT1	2-3	7.9	41.2	6.1		18.6	31.4	31.3	6.3	52	26	22	Sandy Clay Loam
DT1	3-4	8	47.8	7.1		18.6	44.3	36.8	6.6	38	36	26	Loam

*See Overview Map for Soil Sample Locations

produced water in the watershed. The high salt levels found in the soils provide threshold electrolyte concentrations that should allow the application of water characterized with high SAR values.

The average SAR for soil samples collected from subirrigated sites along Horse Creek was 7.2 with a range from 0.39 to 14.1. SAR values averaged 3.6, 9.1, 9.4, 8.2, 6.7, and 5.8 for the 1-foot depth increments to the total depth sampled of 6 feet. The averaged SAR values are considered to be non-sodic and would not be expected to be associated with sodic soil conditions. Elemental toxicities should not result from soil conditions present in the Horse Creek drainage.

Alluvial Groundwater

The results of the alluvial groundwater analyses are summarized in Table 3. The alluvial water was characterized with EC values ranging from 2.9 dS/m to 6.9 dS/m with an average of 4.3 dS/m. These values are much higher than the CBNG water produced in the Horse Creek watershed. The SAR values associated with the alluvial groundwater are considered non-sodic and would not be expected to cause a sodic soil problem. The average SAR value was 5.3, with a range from 4.1 to 6.7. The anticipated impact of the CBNG-produced water on the alluvial water is discussed in the Impact Analysis section of the report.

Vegetation

A total of 21 vegetation species were documented during the vegetative inventory within the Horse Creek project area. Of the 21 species identified, 11 were evaluated as salt tolerant and include: Field Pennycress, Japanese Brome, Western Wheatgrass, Wheat, Kochia, Crested Wheatgrass, Smooth Brome, Foxtail Barley, Alfalfa, Intermediate Wheatgrass, and Inland Saltgrass. The two most frequently occurring salt tolerant species are Japanese Brome (occurring in 29 transects) and Crested Wheatgrass (occurring in 17 transects).

Japanese Brome was found in 29 of the 36 transects and was the dominant occurring species in ten of those transects. Crested Wheatgrass was found in 17 of the 36 transects and was the dominant species in six of those transects. The percent occurrence of the top four vegetative species by transect are summarized in Table 5.

The vegetation transect summaries, photos and field documentation are attached in Appendix F. The summaries include the date of the survey, transect location, landowner, vegetative species encountered, percent occurrence, species grouping and photo points. Photo points of areas investigated (but not surveyed) for possible subirrigated fields in Upper Squaw Creek are included in Appendix I.

Salt Tolerance

The salt tolerance of individual plant species is dependent upon numerous factors, including soil type, precipitation, climate, plant species and age, and soil salt

concentration. Some plants will tolerate high levels of salinity while others can tolerate little or no salinity. The relative growth of plants in the presence of salinity is directly correlated to salt tolerance.

Table 5. Percent Occurrence of the Top Four Vegetative Species by Transect for the Horse Creek Project Area

Transect	Total Sample Points	Field Pennycress *Thlaspi arvense*	Prairie Cordgrass *Spartina pectinata*	Japanese Brome *Bromus japonicus*	Western Wheatgrass *Agropyron smithii*	Cloaked Bulrush *Scirpus pallidus*	Silver Sagebrush *Artemisia cana*	Wheat *Triticum spp.*	Wavyleaf thistle *Cirsium undulatum*	Kochia *Kochia scoparia*	Crested Wheatgrass *Agropyron cristatum*	Smooth Brome *Bromus inermis*	Foxtail Barley *Hordeum jubatum*	Wild Licorice *Glycyrrhiza lepidota*	Alfalfa *Medicago sativa*	Threadleaf Sedge *Carex filifolia*	Intermediate Wheatgrass *Agropyron intermedium*	Inland Saltgrass *Distichlis spicata*	Dandelion *Taraxacum officinale*	Equisetum *Equisetum spp.*	Boxelder *Acer negundo*	Cattails *Typha spp.*	% Occurrence Of Top 4 Species
W1	14	**21.43**	**21.43**	14.29	14.29																		71.44
W2	10		**40.00**	30.00	10.00	20.00																	100.00
W3	19	5.26	10.53	**63.16**			10.53																89.48
SS1	15							**86.67**	6.67	6.67													100.01
DJ1	8	12.50		**37.50**						12.50	**37.50**												100.00
DT1	19	10.53		**36.84**	15.79		21.05																84.21
DT2	11			18.18		9.09				9.09		**27.27**											63.63
DT3	23			**17.39**						13.04			**17.39**			4.35							52.17
DT4	16			25.00						6.25			**31.25**				18.75						81.25
DT5	12			16.67									**33.33**	8.33				25.00					83.33
DT6	9			**88.89**			11.11																100.00
DT7	16			18.75						18.75	12.50		**25.00**										75.00
DT8	14			**50.00**			14.29										21.43		7.14				92.86
DT9	21			4.76			9.52				19.05						**42.86**						76.19
MP2	66			13.64						16.67	**31.82**												75.77
MP1	18		16.67	11.11								**50.00**					16.67						94.45
MP3	72	4.17		25.00							27.78	**34.72**											91.67
MP4	47	4.26		**48.94**							17.02				19.15								89.37
LO2	36				**33.33**						25.00		13.89					16.67					88.89
W4	12	8.33			**50.00**							8.33						16.67					83.33
PP2	44		11.36	11.36							**22.73**	**22.73**											68.18

Table 5. Percent Occurrence of the Top Four Vegetative Species by Transect for the Horse Creek Project Area (Continued)

Transect	Total Sample Points	Field Pennycress *Thlaspi arvense*	Prairie Cordgrass *Spartina pectinata*	Japanese Brome *Bromus japonicus*	Western Wheatgrass *Agropyron smithii*	Cloaked Bulrush *Scirpus pallidus*	Silver Sagebrush *Artemisia cana*	Wheat *Triticum spp.*	Wavyleaf thistle *Cirsium undulatum*	Kochia *Kochia scoparia*	Crested Wheatgrass *Agropyron cristatum*	Smooth Brome *Bromus inermis*	Foxtail Barley *Hordeum jubatum*	Wild Licorice *Glycyrrhiza lepidota*	Alfalfa *Medicago sativa*	Threadleaf Sedge *Carex filifolia*	Intermediate Wheatgrass *Agropyron intermedium*	Inland Saltgrass *Distichlis spicata*	Dandelion *Taraxacum officinale*	Equisetum *Equisetum spp.*	Boxelder *Acer negundo*	Cattails *Typha spp.*	% Occurrence Of Top 4 Species
PP1	55		5.45	12.73							**67.27**	5.45											90.90
SM1	78	19.23		11.54							**48.72**				2.56								82.05
LP2	40											**25.00**					22.50			10.00		12.50	70.00
LP1	23		**21.74**	17.39						13.04		17.39											69.56
AK1	31			**41.94**	3.23						3.23	29.03											77.43
AK2	38			**26.32**							13.16										15.79	31.58	86.85
LS1	41		9.76	12.20							24.39				**29.27**								75.62
DM1	41			**29.27**	24.39										17.07		4.88						75.61
ER1	120	7.50									**72.50**				5.83		4.17						90.00
JW1	28		21.43	10.71	**25.00**						10.71												67.85
JW2	38			18.42	**31.58**								13.16					18.42					81.58
LO1	24			8.33	**50.00**									4.17				29.17					91.67
MP5	24	**29.17**		25.00								25.00			8.33								87.50
MP6	55	12.73									21.82	**43.64**						5.45					83.64
LK1	43										9.30	**67.44**		4.65	2.33								83.72
# of Transects Observed		11	9	29	10	2	5	1	1	8	17	12	6	3	7	1	6	7	1	1	1	2	
# as Dominant Species		2	3	10	5	0	0	1	0	0	6	7	4	0	1	0	1	0	0	0	0	0	
Average Percent Occurrence		12.28	17.60	25.70	25.76	14.55	13.30	86.67	6.67	12.00	27.32	29.67	22.34	5.72	12.08	4.35	18.75	18.56	7.14	10.00	15.79	22.04	

The threshold salt tolerance level of a plant is the maximum soil salinity level at which plant yield is not reduced (Hanson, *et al*. 1999). Salt tolerance levels are determined experimentally by comparing plant growth or yield under varying soil salinity levels. Table 6 provides five typical salinity categories ranging from non-saline to very strongly saline. These terms are used throughout the remainder of this report.

Table 6. Salinity Correlation Values

Soil Depth	Non-Saline	Weakly Saline	Moderately Saline	Strongly Saline	Very Strongly Saline
0-60 cm (0-2 ft.)	<2 dS/m*	2-4 dS/m	4-8 dS/m	8-16 dS/m	>16 dS/m
60-120 cm (2-4 ft)	<4 dS/m	4-8 dS/m	8-16 dS/m	16-24 dS/m	>24 dS/m

* dS/m = deciSiemens per meter.

A high concentration of salt in soil interferes with the germination of new seeds. Salinity results in a drought-like effect on plants, preventing roots from performing their osmotic activity. If soil salt levels are high, water and nutrients cannot move into the plant roots. Threshold soil salinity tolerances for the top four dominant vegetative species encountered at each transect are summarized in Appendix J.

IMPACT ANALYSIS FOR SOILS, ALLUVIAL GROUNDWATER AND VEGETATION

The impact analysis was conducted assuming CBNG-produced water was used on irrigated soils along Horse Creek.

Soils Evaluations

Chemical evaluations (see Table 4) of the soils associated with irrigated lands along Horse Creek indicate that most sites are characterized by high levels of salt. However,

most native vegetation can often tolerate these high levels of salt due to their genetic disposition. Within the study areas, the main species of concern at such salt levels is alfalfa. Alfalfa was identified in seven transects, but its distribution was sparse, a likely result of salt toxicity.

The primary purpose of this section is to evaluate if CBNG-produced water would negatively impact the current soil conditions and thus forage production in irrigated fields found in the Horse Creek drainage. This evaluation was conducted using several tools. First, an evaluation of the CBNG-produced water and the potential for the produced water to impact the soils was made using saline-sodic chemistry and the guidelines for interpretations of water quality for irrigation as provided by Ayers and Westcot (1985) and Hanson *et al*. (1999). Second, an irrigation simulation was conducted assuming that 30 inches of water per year was applied to the soil surface. The evaluation approximated the impact of CBNG-produced water on the characteristics of the average soil conditions existing on each landowner along Horse Creek. This evaluation was accomplished using the FAO-SWS geochemical transport model. The model considers water flow, carbon dioxide production and transport, transport and chemistry of major dissolved ion species including cation exchange, mineral dissolution and precipitation, and plant water extraction with consideration of water and salt stress. The model was used to simulate the effects (five years of continuous irrigation) of using CBNG-produced water to irrigate each soil associated with the landowners along Horse Creek. The five-year irrigation period provided a trend of how the CBNG-produced water would impact soils in the watershed. The

application of larger amounts of water and the application of water for a longer period of time are expected to follow and enhance the trends observed during the five-year simulation.

The third method of evaluation was to assume that CBNG-produced water moved into the alluvial aquifer reacting with the groundwater geochemically to form an alluvial groundwater that would subirrigate the current irrigated sites along Horse Creek. The results of the model simulation were used along with guidelines for interpretations of water quality for irrigation (Ayers and Westcot, 1985; Hanson *et al*. 1999) to determine the impact of the plant growth capability based on resulting soil conditions. This evaluation was performed for each landowner that allowed field access along Horse Creek, and assumed that the baseline alluvial groundwater quality was similar to the samples collected from the five sites noted previously.

Surface flooding with CBNG-produced water using natural irrigation is not expected to negatively impact sites along Horse Creek. This scenario was demonstrated by the results of the irrigation simulation. The irrigation simulation assumes application of 30 inches of CBNG-produced water on the surface without dilution by the (natural) flood waters. If the soils are not negatively impacted by managed irrigation at such high rates, flood waters containing CBNG-produced water should not impact these agricultural lands.

Salinity

The salinity of irrigation water is measured as the EC. Guidelines for interpretation of water quality for irrigation (Ayers and Westcot, 1985; Hanson *et al*. 1999) indicate that water with an EC less than 0.7 dS/m will be suitable for all crops without restriction. Water exhibiting an EC between 0.7 and 3.0 dS/m can be used to irrigate moderately salt tolerant crops with no restrictions, while water with an EC between 3.0 and 6.0 dS/m can be used to irrigate salt-tolerant crops with no restrictions on use. For waters with an EC greater than 6.0 dS/m, only salt-tolerant crops should be considered. Most plants growing on irrigated lands in the Horse Creek watershed are considered to be moderately salt tolerant, especially since these plants are most often found growing on saline soils. If managed irrigation practices are used, including careful implementation of the leaching requirement to prevent the excess accumulation of salts in the root zone, moderately tolerant plant species can be irrigated with water exhibiting an EC between 3.0 and 6.0 dS/m.

The characteristics of the CBNG-produced water proposed for discharge in the Horse Creek watershed are shown in Table 1. The produced water has relatively low salt levels with EC values ranging from 0.62 dS/m to 2.33 dS/m with an average of 1.41 dS/m. Irrigating with CBNG-produced water in the Horse Creek watershed would not be detrimental to plant growth.

Sodicity and Salinity Interactions

Irrigation water with an elevated SAR can result in changes to the physical structure of a soil and its hydraulic properties such as infiltration and hydraulic conductivity. Under low salt conditions, increases in soil SAR can lead to the swelling and dispersion of soil clay particles that in turn can lead to soil sealing and reduced hydraulic conductivity. In general, soils with moderately high to high clay contents are at greater risk. However, the types of clay materials that dominate the clay fraction is also important. The clay minerals associated with the soils sampled within the Horse Creek watershed are likely 2:1 layered clays with low swelling capacity. Percent saturation values were less than 80% with an average of 48.1% for all samples collected, ranging from 31.5% to 74.6%. The soils found in the Horse Creek watershed, therefore, tend not to swell or disperse under high or moderately high SAR conditions.

The potential impact of elevated sodium on soil physical properties is closely related to salinity, as discussed above. For example, the structure of a highly sodic soil can be maintained with the appropriate level of EC. However, if the EC is low (the water is very clean), the highly sodic soil will tend to slake and disperse. Similarly, the application of low EC water can cause degradation of soil structure. It is generally accepted that soil structure can be maintained when the EC of the applied water is relatively high.

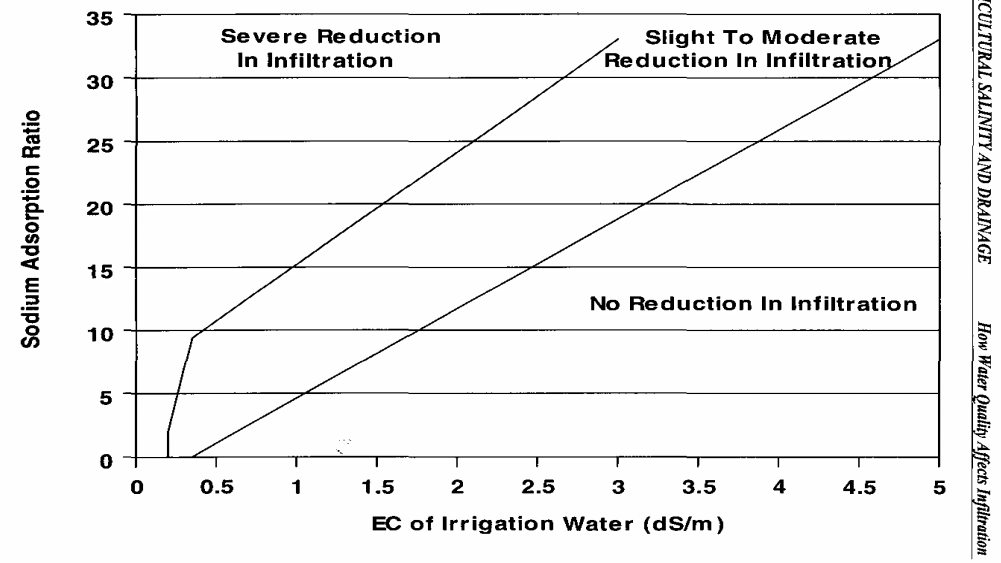
The SAR of a soil is based on the dissolved concentrations of sodium, calcium and magnesium in the soil solution (saturated paste extract) via the formula:

$$SAR = [Na^{+}] / (([Ca^{2+}] + [Mg^{2+}])/2)^{1/2} \qquad \text{(concentrations in meq/L)}$$

The SAR formula indicates that if calcium and magnesium concentrations are low and sodium is high, then the SAR will be high. Conversely, if calcium and/or magnesium concentrations increase relative to sodium, then SAR will decrease. What is not apparent from the SAR formula is the fact that the higher the salinity of the water, the higher the SAR can be without impairing soil infiltration and permeability. Similarly, for a given salt concentration (measured as EC), infiltration rates generally decrease as SAR increases.

Criteria for evaluating the risk of a particular SAR value for irrigation water applied at the soil surface in relation to the EC of the water are provided in Ayers and Westcot (1985) and Hanson *et al*. (1999). At this time, WDEQ prefers that the maximum SAR in irrigation water should be determined in conjunction with EC so that the relationship of SAR to EC remains within the "no reduction in rate of infiltration" zone as developed by Ayers and Westcot (1985) and Hanson *et al.* (1999). The maximum SAR criteria are, therefore, set below the line separating the "no reduction in rate of infiltration" zone from the "slight to moderate reduction in infiltration" zone (Figure 1).

Figure 1 The Effect of Salinity and Sodium Adsorption Ratio on Infiltration Rate



Chemical analysis of the CBNG-produced water for all sources sampled within the Horse Creek watershed falls into the Hanson *et al*. (1999) “slight to moderate reduction in infiltration” zone. Although the produced water is characterized by relatively low SAR values with an average value of 13.0, the salt content is also low, averaging about 1.41 dS/m. Therefore, the salt concentrations are beneath the salt threshold that results in clay flocculation. The resulting combination falls in the range of the “slight to moderate reduction in infiltration” per the EC-SAR relationship shown in Figure 1.

It is important to note, however, that the soils sampled in the Horse Creek watershed generally are characterized with high salt levels from the surface to the lower depths sampled. The soil contains significant amounts of soluble salts from the dissolution or weathering of minerals such as gypsum, calcite, and other soluble minerals common in semiarid soils. The high salt levels generated from the weathering processes would promote soil particle flocculation, thereby enhancing infiltration of the irrigation water.

The dissolution of soil salts is expected to quickly influence the EC values of the CBNG-produced water to levels comparable to the soil EC values of 4 or 5 dS/m. The average root zone EC of 7.02 dS/m provides a threshold electrolyte concentration that will maintain flocculated soil conditions at SAR values near 40 (refer to Figure 1). The weathering process is addressed in a condensed form in the next paragraph. A more detailed explanation is provided in the attached literature review (T.H. Brown, 2004) provided in Appendix K.

In general, the saline nature of the soil and the tendency for mineral dissolution will prevent excessive dispersion at the soil surface even with the application of low-salt CBNG-produced water, rainfall, and snowmelt events. This fact is demonstrated in the irrigation modeling section of this evaluation as water movement into and through the soil profiles located along Horse Creek remains adequate with an annual irrigation application of 30 inches of CBNG-produced water. Dispersion is important in reducing the permeability of sodic soils, however, no adequate hypothesis is available to explain why some soils are more susceptible to clay dispersion than others when leached with distilled water. This is an important problem since the irrigation season is usually followed by a rainy season or snowmelt. Salt is usually concentrated in the soil during the irrigation season, when the EC is high enough to prevent deterioration of the physical properties. However, when these soils are inundated with rainwater or spring runoff, the salts may be leached from the surface portion of the soil and the physical conditions at the surface may become susceptible to degradation.

The Threshold Electrolyte Concentration (TEC = amount of salt in meq/L required to maintain flocculation of a soil for a specific SAR) of Ca-montmorillonite clays has been reported by Van Olphen (1977) to be 0.17 to 0.23 meq/L. The TEC for Na-montmorillonite clay is 12 to 16 meq/L. Soils capable of releasing salt through weathering processes at rates sufficient to maintain salt levels above the TEC values for specific clay materials should maintain their physical condition. These soils will not disperse and their infiltration rate and hydraulic conductivity should not be affected significantly by rainfall or spring runoff. Rhoades *et al*. (1968) showed that arid land soils increased the levels of calcium and magnesium by 3 to 5 meq/L due to weathering processes and determined that the dissolution of plagioclase, feldspars, hornblende, and other common mafic minerals accounted for the release. Oster and Shainberg, (1979) in their evaluation of the dissolution of three arid zone soils observed that the release of calcium, magnesium and potassium from silicate minerals and the hydrolysis of exchangeable sodium and calcium varied significantly. These researchers demonstrated that when salt-free soils were mixed with distilled water at a 1:5 ratio, the release of salts increased solution concentrations from 0.5 to 4.0 meq/L within four hours. The salts likely result from the dissolution of calcite, gypsum or other soluble minerals present in the soil.

Shainberg *et al*. (1981a) showed that low salt concentrations (2 to 3 meq/L) in leaching water prevented clay dispersion and reductions in hydraulic conductivity for ESP values below 30. These observations suggest that mineral dissolution is a major factor causing differences in susceptibility to sodic conditions when leached with water low in

salt content. These scientists hypothesized that sodic soils containing minerals such as calcite ($CaCO_3$) feldspars and hornblende that readily release soluble electrolytes will result in electrolyte levels high enough to prevent dispersion if leached with distilled water, which simulates rainfall and runoff. Shainberg *et al*. (1981b) showed that soils containing minerals that readily release soluble electrolytes will not disperse when leached with distilled water (simulated rainwater). This is very important for materials that have moderate ESP levels that are able to maintain physical conditions through the soil profile but may be susceptible to dispersion near the surface. Electrolytes resulting from weathering, especially soils in arid or semiarid environments, can maintain the physical structure of the surface materials. Rhoades *et al*. (1968) found similar results studying arid soils treated with irrigation water characterized by SAR values varying from 5 to 20. The total salt content of the displaced soil solutions was 3 to 5 meq/L higher than the salt levels applied in the irrigation water. Much of the increase in salt levels resulted from weathering of the soil materials, which released significant amounts of calcium, magnesium and bicarbonate ions. The net effect of the weathering processes was a 30% to 90% reduction in the SAR of the soil solutions. These researchers determined that the weathering phenomenon reduces the sodium hazard and therefore should be considered in water quality evaluations.

The discussion above strongly implies that irrigation water containing relatively high levels of sodium may be used successfully for irrigation of soils that have similar characteristics to those evaluated in this study.

In view of the above discussion concerning mineral weathering, Rhoades (1968) developed a modification to the sodium hazard equation developed by Bower *et al*. (1963) for irrigation waters containing bicarbonate. This modification was based on the results of research that evaluated the impact that mineral weathering had on soils containing calcite. The evaluation was complicated by the presence of calcium and bicarbonate in solution, which would tend to precipitate at the same time mineral weathering is releasing calcium and magnesium into solution at relatively high rates. This study showed that the increases in calcium and magnesium content produced by mineral weathering processes were greater than the decreases produced by calcite precipitation processes. These data show that the evaluation of the sodium hazard of irrigation water containing bicarbonate based on the assumption of $CaCO_3$ precipitation is inaccurate at least for soil water contents near saturation. It also demonstrates that mineral weathering must be considered in evaluating the sodium hazard of irrigation waters in semiarid and arid soils.

Another important aspect of weathering is the influence of CO_2 on the weathering of soils containing $CaCO_3$. The presence of CO_2 significantly enhances the dissolution of $CaCO_3$ (Nadler, *et al*. 1996). As a result, the development of a good plant cover on a soil containing calcite will result in significant levels of Ca in solution and on the exchange sites. Nadler *et al*. (1996) determined that solutions containing CO_2 will dissolve larger amounts of $CaCO_3$ as the contact time increases. As a result, soils

supporting good vegetative cover and containing high levels of calcite such as those present in the PRB would be expected to provide significant levels of Ca to the soil solution.

As discussed in the literature, most investigations concerning the effect of salts on the transport of water and solutes in soil have been described under steady-state saturated conditions. However, in field conditions the transport of solutes and water almost always occurs under unsaturated flow conditions. Information is limited on the impact of sodic/saline conditions on the hydraulic properties of soils, although several studies have been completed. Russo and Bresler (1977) found that low soil water content compensates for the negative effects of high ESP and low salt levels. This work was done in a laboratory study using the Gilat loam soil with various combinations of salt concentrations, compositions, and soil water contents. This study showed that maintaining the soil under unsaturated conditions allows a higher ratio of sodium to calcium for any given EC without impacting the physical condition of the soil. These relationships are directly dependent on the degree of soil saturation. Since low water contents result in low repulsion forces, unsaturated systems would be expected to have higher attractive forces between clays and soil particles as compared to saturated systems.

Another important factor when evaluating if water of certain chemistry will impact a soil is that the soils in the PRB possess structure that is bound with very strong forces. Considerable force is required to break the bonding between soil particles, especially if

the system is not saturated, which is the condition often used in studies of clay chemistry as presented in the literature. This fact suggests that the research recently published by Suarez (2006) was conducted under conditions that only remotely relate to the actual field conditions. Suarez and his colleagues collected disturbed samples from a number of fields in Wyoming, transported the samples to California, and set the experiment up in the laboratory. The samples were packed in containers at some density and various types of water were applied. The resulting system was characterized with no soil structure, soil hydraulic characteristics that do not represent any field conditions, and disturbed soil conditions at the surface that were susceptible to physical compaction from the energy impacting the soil via the applied water. Under these conditions, they found that SAR 5 water decreased infiltration rates. The laboratory experiment does not relate to field conditions found in the PRB, and represents a laboratory "dirt" study. The results of the experiment should be considered unreliable when compared to a natural soil characterized with good soil development where soil peds are strongly bonded together as noted previously.

The Section 20 Analysis presented in this document includes an evaluation based on the assumption that CBNG-produced water generated in the Horse Creek watershed will be used to surface irrigate agricultural lands. Based on field investigations, almost all irrigated agricultural lands in the watershed are naturally flood irrigated or subirrigated. Subirrigated areas will not be impacted directly by the CBNG-produced water since such water will react with the soil profile and then mix with alluvial groundwater prior to impacting plants growing in subirrigated areas. The interaction

between the CBNG-produced water and the groundwater is addressed via geochemical modeling in the next section of this report.

The soil impact expected with the application of CBNG-produced water to a soil is dependent on the chemical characteristics of the soil receiving the water. The saturated paste data from the soils collected at the sampling sites along Horse Creek show EC and SAR values that fall into the "No Reduction in Infiltration Rate" zone. The soils, as noted in Table 4, are characterized by high EC values, low SAR values, and non-swelling clays. This chemistry is expected to greatly influence the impact CBNG-produced water may have on the infiltration rate and hydraulic conductivity of the soils. The FAO-SWS Model previously described in this report was used to provide a means of determining how CBNG-produced water may potentially impact irrigated soils. The following section provides an evaluation pertaining to agricultural lands for each individual landowner located along Horse Creek.

RESULTS OF THE EC AND EC/ SAR EVALUATION

1. If used for irrigation purposes, CBNG-produced water would be expected to **decrease** the salt levels in the soil profiles due to leaching and thus enhance plant growth potential.

2. The CBNG-produced water is classified as nonsaline and nonsodic. The low salt concentrations of the water would likely have a slight tendency to cause a reduction in infiltration (Figure 1). Slight tendency was used since the EC/SAR intersect is either close to the middle or below the middle of this zone of the graph.

3. The high salt levels that characterize most of the irrigated soils in the Horse Creek watershed provide a large capacity to replenish salt to the soil solution by weathering processes. Although the application of CBNG-produced water, precipitation and snowmelt will have a tendency to remove salts at the surface

and promote clay dispersion, weathering of soluble minerals will occur simultaneously thereby maintaining relatively high salt levels, thus preventing clay dispersion.

4. The salt generated from the weathering process is expected to greatly influence the EC of the CBNG-produced water resulting in EC values of > 4 dS/m which should keep soils flocculated with SAR values of near 25 (Figure 1). The average EC value for all soil samples collected was 7.02 dS/m, which provides a threshold electrolyte concentration that will allow SAR values of about 45 before entering into the slight reduction in infiltration.

5. CBNG-produced water should not impact the hydraulic conductivity of irrigated soils. The high salinity levels of the soils will overwhelm any increased SAR levels that might result while irrigating with the CBNG-produced water.

6. The relationships shown in Figure 1 were developed by Ayers and Westcot (1985) and Hanson, *et al*. (1999) for soils found in California that had been irrigated for crop production. Such soil conditions do not exist in the irrigated agricultural lands along Horse Creek. Soils in the PRB and in the Horse Creek watershed, which contain high levels of soluble salts that will weather during the irrigation process, will likely react much differently to irrigation water containing relatively low salt levels. CBNG-produced water used for surface application could conceivably contain higher sodium levels without causing a detrimental impact to agricultural lands.

7. The EC/SAR soil chemistry discussed in this section provides a strong basis for establishing an SAR limit of > 20 without causing a measurable decrease in crop or livestock production on agricultural lands irrigated with CBNG-produced water.

FAO-SWS MODEL SIMULATIONS

As noted previously, the irrigation simulations were based on managed surface irrigation of agricultural lands, even though almost all of the irrigated lands sampled in the Horse Creek watershed were naturally flood irrigated and/or subirrigated. Model simulations were conducted for each landowner with irrigated agricultural fields from the confluence of Horse Creek with the Little Powder River to the headwaters of Horse Creek. Separate evaluations specific to agricultural lands associated with each landowner were compiled based on the information collected during the field

investigations. No evaluations were performed on landowners who did not allow field access to their lands.

The horizonation and soil chemistry of the soils sampled along Horse Creek are similar from the headwaters to the confluence with the Little Powder River. As a result, the irrigation modeling results are also very similar. Therefore, one entire irrigation simulation is provided in the body of the Section 20 evaluation. The remaining evaluations are included in Appendix L. The site sampled at the Dave Magnuson Ranch is described in detail in the body of the report.

The irrigation simulations are discussed in ownership sequence from the confluence of Horse Creek with the Little Powder River upstream to the outfalls located in the headwaters of the Horse Creek watershed.

BROWN-KENNEDY RANCH COMPANY

In order of ownership sequence, the Brown-Kennedy Ranch is the first property to be discussed, as it is located between the David Magnuson Ranch and the confluence of Horse Creek with the Little Powder River. This reach of Horse Creek did not contain managed irrigation or subirrigated agricultural lands. Therefore, field data collection was not required as per Chapter 1, Section 20 of the Wyoming Water Quality Rules and Regulations.

DAVE MAGNUSON RANCH

The Dave Magnuson Ranch is located immediately upstream of the Brown-Kennedy Ranch. Several agricultural areas adjacent to the stream are subirrigated and the same areas appear to have spreader dikes that were constructed to concentrate runoff over specific areas. The spreader dikes have not been maintained for a long period of time and several of the areas behind them are now occupied by native species including shrubs such as sagebrush. The landowner indicated that managed flood irrigation was not conducted on the ranch. A significant portion of the subirrigated land at this ranch was considered as wetland area, not haylands or significant grazing lands. As a result, such areas were not considered in the sampling program.

One site that was sampled (designated as DM1 on the Overview Map (Plate 1)) is currently subirrigated and appears to have been flood irrigated in the past. The field is less than five acres; therefore, three samples were collected. The samples were composited in 1-foot increments up to 6 feet in depth. The site was sampled to a depth of 6 feet because alfalfa was found at the site. The analytical results are provided in Table 4 with averaged values for EC and SAR presented in Table 7. An adjacent field, DM2, was also sampled. Since DM2 has soil characteristics similar to DM1, the DM2 profile was described and correlated to DM1. DM2 was not sampled. Photos were taken at each DM1 sampling point. Photos were also taken at Photo Point DM-A (Overview Map, Plate 1) and DM-B to depict current site conditions. Photo Points DM-A and DM-B are neither flood or subirrigated. Extensive areas adjacent to Horse Creek are considered to be wetlands and therefore may not have been used for agricultural

purposes in the past. In general terms, the analyses indicate that the soils are saline with EC values ranging from a low of 6.19 dS/m in the top one foot to a high of 12.0 dS/m in the 2 to 3 foot depth increment. The soils possess rather high SAR values, ranging from 6 in the 0 to 1 foot increment to 14 in the 2 to 3 foot depth increment. The pH values ranged from 7.5 to 8.5 in the sampled profile. The texture of the material is loam in the top 2 feet and sandy loam in the 2 to 6 foot interval.

The physical and chemical characteristics determined from the soil sampled at DM1 were input into the FAO-SWS irrigation model to assess potential soil impacts related to irrigating with CBNG-produced water. The simulation was conducted for a 5-year period using an annual irrigation rate of 30 inches in addition to the application of average annual precipitation. The CBNG-produced water characterized with the highest SAR value (SAR = 23.6, EC = 1.84 dS/m) was used in the irrigation simulations. In addition, one simulation was conducted using water with an EC of 1.1 dS/m and a SAR of 25. The application of soil amendments was not included in the simulation. Subirrigated sites that may be impacted with CBNG-produced water entering the alluvial groundwater were evaluated (using a geochemical approach), and results are summarized in the next section of this report.

The primary goal of the irrigation modeling was to determine the impact that CBNG-produced water would have on the major chemical parameters of the soil, if CBNG-

Table 7. Averaged EC and SAR Values for Sites Sampled in the Horse Creek Watershed.

Electrical Conductivity (EC)									
Soils Data Averages (Horse Creek)									
Sample ID	C. Kretschman	D. Tarver	L. Peyrot	M. Pownall	P. Parks	D. Magnuson	L. Shippy	L Shippy	Average
Avg EC - dS/M	**7.12 (n=48)**	**4.73 (n=4)**	**6.78 (n=38)**	**7.89 (n=6)**	**6.80 (n=10)**	**9.29 (n=6)**	**6.51 (n=6)**	**0.77 (n=6)**	**7.02**
Range of EC	3.23 to 7.68	0.87 to 7.10	1.57 to 7.97	7.83 to 10.1	0.66 to 13.7	6.19 to 12.0	1.0 to 9.06	0.7 to 0.86	
Avg EC - 0 to 1	**5.5 (n=8)**	**0.87 (n=1)**	**4.61 (n=8)**	**7.83 (n=1)**	**3.85 (n=2)**	**6.19 (n=1)**	**1.00 (n=1)**	**0.83**	**4.75**
Range of EC 0 to 1	3.23 to 7.68		1.57 to 7.97		0.66 to 7.04				
Avg EC - 1 to 2	**9.7**	**4.83**	**8.53**	**10.1**	**7.43**	**9.9**	**6.97**	**0.71**	**8.85**
Range of EC	5.92 to 15.7		5.53 to 13.7		1.35 to 13.5				
Avg EC - 2 to 3	**9.3**	**6.1**	**8.23**	**8.45**	**9.67**	**12**	**9.06**	**0.72**	**8.87**
Range of EC	5.15 to 14.6		4.99 to 13.8		5.63 to 13.7				
Avg EC - 3 to 4	**7.58**	**7.1**	**6.1**	**7.92**	**8.45**	**10.5**	**8.48**	**0.7**	**7.29**
Range of EC	4.88 to 9.55		4.06 to 11.2		6.49 to 10.4				
Avg EC - 4 to 5	**5.83**		**5.97 (n=3)**	**6.42**	**5.25 (n=1)**	**8.81**	**7.16**	**0.79**	**6.15**
Range of EC	4.09 to 7.45		4.92 to 7.06						
Avg EC - 5 to 6	**5.54**		**4.74 (n=3)**	**6.62**	**4.02**	**8.35**	**6.38**	**0.86**	**5.59**
Range of EC	3.47 to 8.39		2.78 to 6.53						
Soils Data Averages (Hay Creek)									
Sample ID	E Rule	J. Wolfe							
Parameter									
Avg EC - dS/M	**6.68 (n=4)**	**15.55 (n=4)**							
Range of EC	6.7 to 7.8	12.2 to 17.1							
Avg EC - 0 to 1	**3.51 (n=1)**	**12.2 (n=1)**							
Range of EC 0 to 1									
Avg EC - 1 to 2	**6.09**	**16.8**							
Range of EC									
Soils Data Averages (Hay Creek)									
Avg EC - 2 to 3	**8.34**	**16.1**							
Range of EC									
Avg EC - 3 to 4	**8.77**	**17.1**							
Range of EC									
Avg EC - 4 to 5									

Table 7. Averaged EC and SAR values for sites sampled in the Horse Creek watershed. (Continued)

Electrical Conductivity (EC)									
Soils Data Averages (Hay Creek) (Continued)									
Range of EC									
Avg EC - 5 to 6									
Range of EC									
Soils Data Averages (Spring Creek)									
Sample ID	M. Pownall								
Parameter									
Avg EC - dS/M	**7.00 (n=12)**								
Range of EC	0.88 to 11.4								
Avg EC - 0 to 1	**1.48 (n=2)**								
Range of EC 0 to 1	0.88 to 2.07								
Avg EC - 1 to 2	**5.95**								
Range of EC	3.96 to 7.94								
Avg EC - 2 to 3	**9.06**								
Range of EC	6.71 to 11.4								
Avg EC - 3 to 4	**8.91**								
Range of EC	8.05 to 9.76								
Avg EC - 4 to 5	**8.61**								
Range of EC	8.20 to 9.01								
Avg EC - 5 to 6	**8.05**								
Range of EC	6.74 to 9.36								
SAR									
Soils Data Averages (Horse Creek)									
Sample ID	C. Kretschman	D. Tarver	L. Peyrot	M. Pownall	P. Parks	D. Magnuson	L. Shippy	L Shippy	Average
							LS6	LS1	Excl LS1
Parameter									
Avg SAR	**7.01 (n=48)**	**4.62 (n=4)**	**7.57 (n=38)**	**6.53 (n=6)**	**5.92 (n=10)**	**10.50 (n=6)**	**8.15 (n=6)**	**1.34 (n=6)**	**7.23**
Range of SAR	1.09 to 14.1	0.80 to 6.56	1.78 to 13.5	5.18 to 8.69	0.39 to 11.2	6.02 to 14.0	1.06 to 11.4	0.80 to 1.57	
Avg SAR - 0 to 1	**3.18 (n=8)**	**0.80 (n=1)**	**4.18 (n=8)**	**6.05 (n=1)**	**3.25 (n=2)**	**6.02 (n=1)**	**1.06 (n=1)**	**0.8 (n=1)**	**3.61**
SAR									
Range of SAR 0 to 1	1.09 to 7.14		1.78 to 8.74		0.39 to 6.11				

Table 7. Averaged EC and SAR values for sites sampled in the Horse Creek watershed. (Continued)

SAR									
Soils Data Averages (Horse Creek) (Continued)									
Avg SAR - 1 to 2	**9.75**	**4.87**	**9.42**	**8.69**	**6.32**	**12.2**	**8.35**	**1.57**	**9.10**
Range of SAR	5.37 to 14.1		5.86 to 12.7		1.74 to 10.9				
Avg SAR - 2 to 3	**9.58**	**6.25**	**9.3**	**7.08**	**8.23**	**14**	**11.4**	**1.48**	**9.37**
Range of SAR	7.07 to 13.9		5.41 to 13.5		5.25 to 11.2				
Avg SAR - 3 to 4	**7.99**	**6.56**	**8.14**	**6.74**	**7.84**	**11.9**	**10.6**	**1.46**	**8.15**
Range of SAR	6.37 to 8.84		3.52 to 12.8		6.50 to 9.17				
Avg SAR - 4 to 5	**6.09**		**7.39 (n=3)**	**5.42**	**4.75 (n=1)**	**9.43**	**9.29**	**1.43**	**6.65**
Range of SAR	4.14 to 8.13		6.24 to 8.67						
Avg SAR - 5 to 6	**5.44**		**5.69**	**5.18**	**3.14**	**9.46**	**8.17**	**1.32**	**5.77**
Range of SAR	2.96 to 8.52		3.70 to 7.36						
Soils Data Averages (Hay Creek)									
Sample ID	E. Rule	J. Wolfe							
Parameter									
Avg SAR	**1.80 (n=4)**	**2.50 (n=4)**							
Range of SAR	0.38 to 2.58	2.07 to 2.83							
Avg SAR - 0 to 1	**0.38 (n=1)**	**2.07 (n=1)**							
Range of SAR 0 to 1									
Avg SAR - 1 to 2	**1.84**	**2.83**							
Range of SAR									
Avg SAR - 2 to 3	**2.58**	**2.59**							
Range of SAR									
Avg SAR - 3 to 4	**2.4**	**2.52**							
Range of SAR									
Avg SAR - 4 to 5									
Range of SAR									
SAR									
Avg SAR - 5 to 6									
Soils Data Averages (Spring Creek)									
Sample ID	M. Pownall								
Parameter									
Avg SAR	4.84 (n=12)								

Table 7. Averaged EC and SAR values for sites sampled in the Horse Creek watershed. (Continued)

SAR									
Soils Data Averages (Spring Creek) (Continued)									
Range of SAR	0.62 to 7.59								
Avg SAR - 0 to 1	**0.66 (n=2)**								
Range of SAR 0 to 1	0.62 to 0.70								
Avg SAR - 1 to 2	**4.05**								
Range of SAR	1.77 to 6.33								
Avg SAR - 2 to 3	**5.95**								
Range of SAR	4.31 to 7.59								
Avg SAR - 3 to 4	**6.42**								
Range of SAR	5.52 to 7.31								
Avg SAR - 4 to 5	**6.35**								
Range of SAR	6.29 to 6.41								
Avg SAR - 5 to 6	**5.62**								
Range of SAR	4.88 to 6.35								

produced water was used for managed irrigation. Soil chemical characteristics such as EC, SAR, and solution concentrations of calcium, magnesium, sodium and sulfate were evaluated over the 5-year simulation period. The model was also used to determine the expected movement and deposition of chemical constituents in the soil profile. In addition, an estimate of the osmotic pressure head and relative crop yield (over the 5-year period) was determined.

FAO-SWS MODEL RESULTS FOR MAGNUSON RANCH

One concern with applying CBNG-produced water to surface irrigated crops and rangeland plant communities is the influence the water may have on the salinity and sodicity characteristics of the irrigated soils. The expected salinity and sodicity characteristics of soils located at the irrigation site over the 5-year simulation period are presented in Figures 2 and 3, respectively.

The data shown in Figure 2 provide an estimate of the salt accumulation (in terms of EC) expected at the site under the projected irrigation application rates and the average precipitation levels. In general, the simulation shows that during the initial stages of irrigation, salts are leaching to lower levels in the soil profile. At the beginning of the simulation, the salt levels are about 5.9 dS/m at the surface. As the simulation progresses, the peak levels of salt tend to migrate to lower depths below the root zone with low salt levels at the surface. At the end of Year 1, the levels found in the surface to 100 cm interval increase from about 0.5 dS/m near the surface to about 9 dS/m at 100 cm. Following the 5-year simulation, salt levels found in the soil are

approximately 0.5 dS/m near the surface and approximately 3.0 dS/m at the 100 cm depth. Following

Figure 2. Salt Concentrations (EC) by Soil Depth Over the 5-Year Irrigation Period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

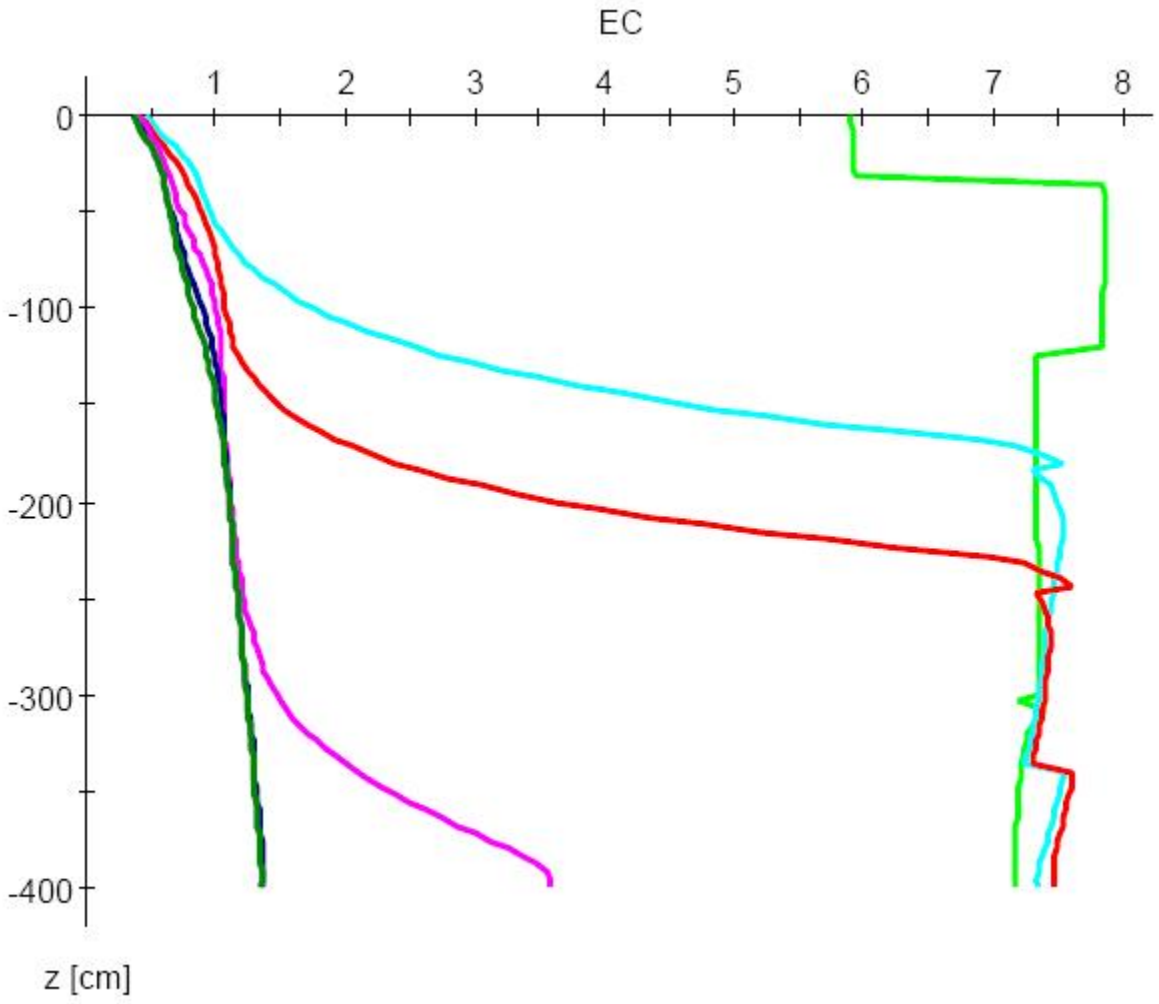
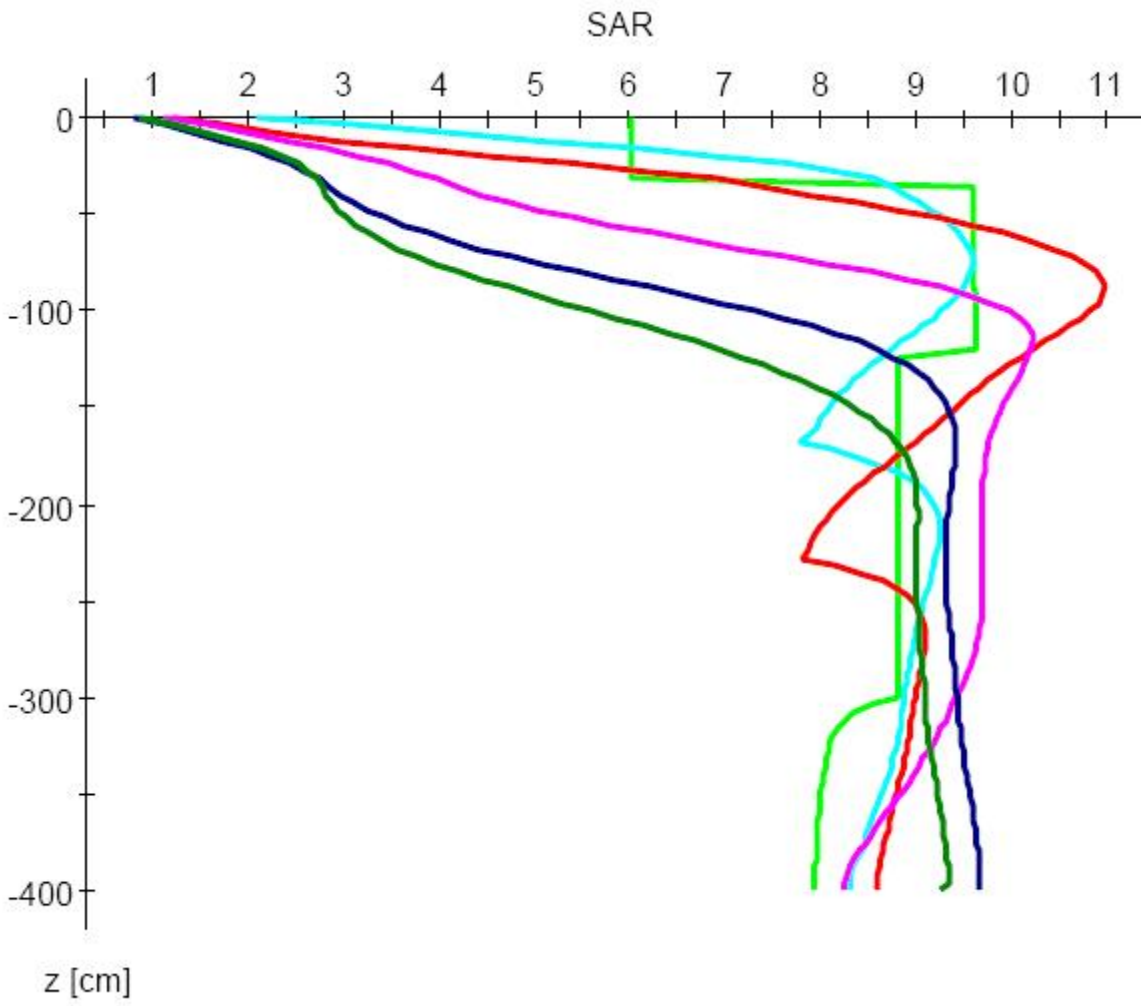


Figure 3. SAR by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



the 5-year irrigation period, the salt levels found in the soil root zone are expected to further decrease with time as soil water is leaching salts to lower levels in the profile. The data show that salt levels in root zone are more favorable for plant growth as a result of the irrigation promoting leaching of salt from the root zone.

The simulation of the changing SAR conditions in the soil profile is provided in Figure 3. The values projected in time and by depth show a gradual reduction in SAR at the surface with an accumulation at depth. With time, the sodium levels are leached lower in the profile resulting in a gradual decline in SAR with time. At the termination of the simulation, SAR values at the surface are approximately 3 increasing to about 15 at a depth of 100 cm. As a result, the development of sodic soil conditions should not occur at the Magnuson Ranch. The solution levels of calcium are initially high at the surface in the baseline condition (Figure 4). After 1 year of irrigation, the solution calcium level at the surface has decreased to about 1 meq/L. Calcium levels are migrating to lower levels in the profile due to leaching while solution levels near the surface stabilize as the system reaches a state of equilibrium with respect to calcite. A portion of the calcium moving to lower depths in the profile is a product of the dissolution of gypsum, which is present in the lower two-thirds of the root zone at time zero (Figure 5).

The high levels of magnesium initially present at the surface tend to migrate to lower levels of the soil profile with continued reductions over the simulation period (Figure 6). Root zone magnesium levels are expected to decline with time as magnesium is

leached from the root zone and the initial source of the magnesium is not replenished. After year four of the simulation, magnesium levels become constant in the upper

Figure 4. Solution Calcium Levels by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

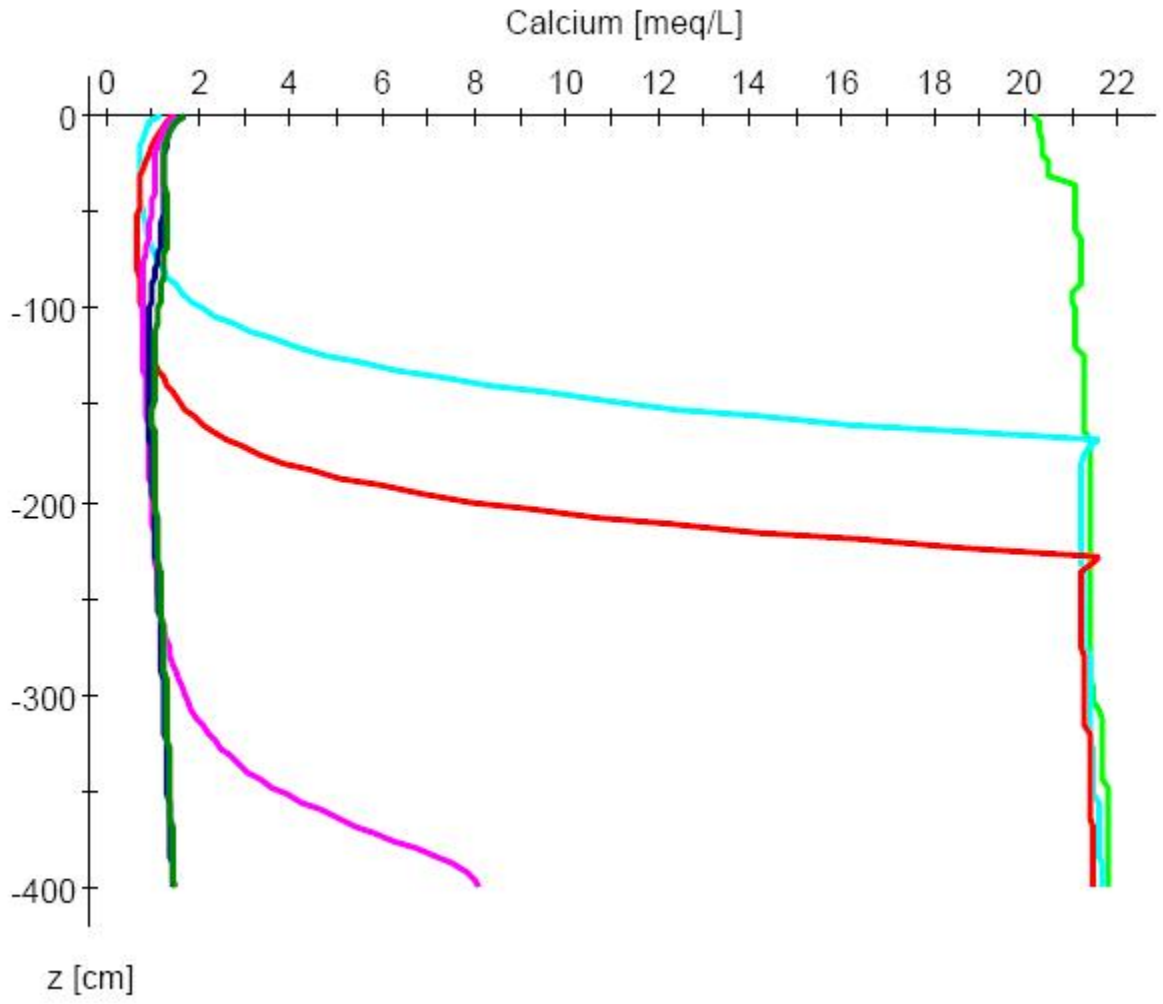


Figure 5. Gypsum Levels by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

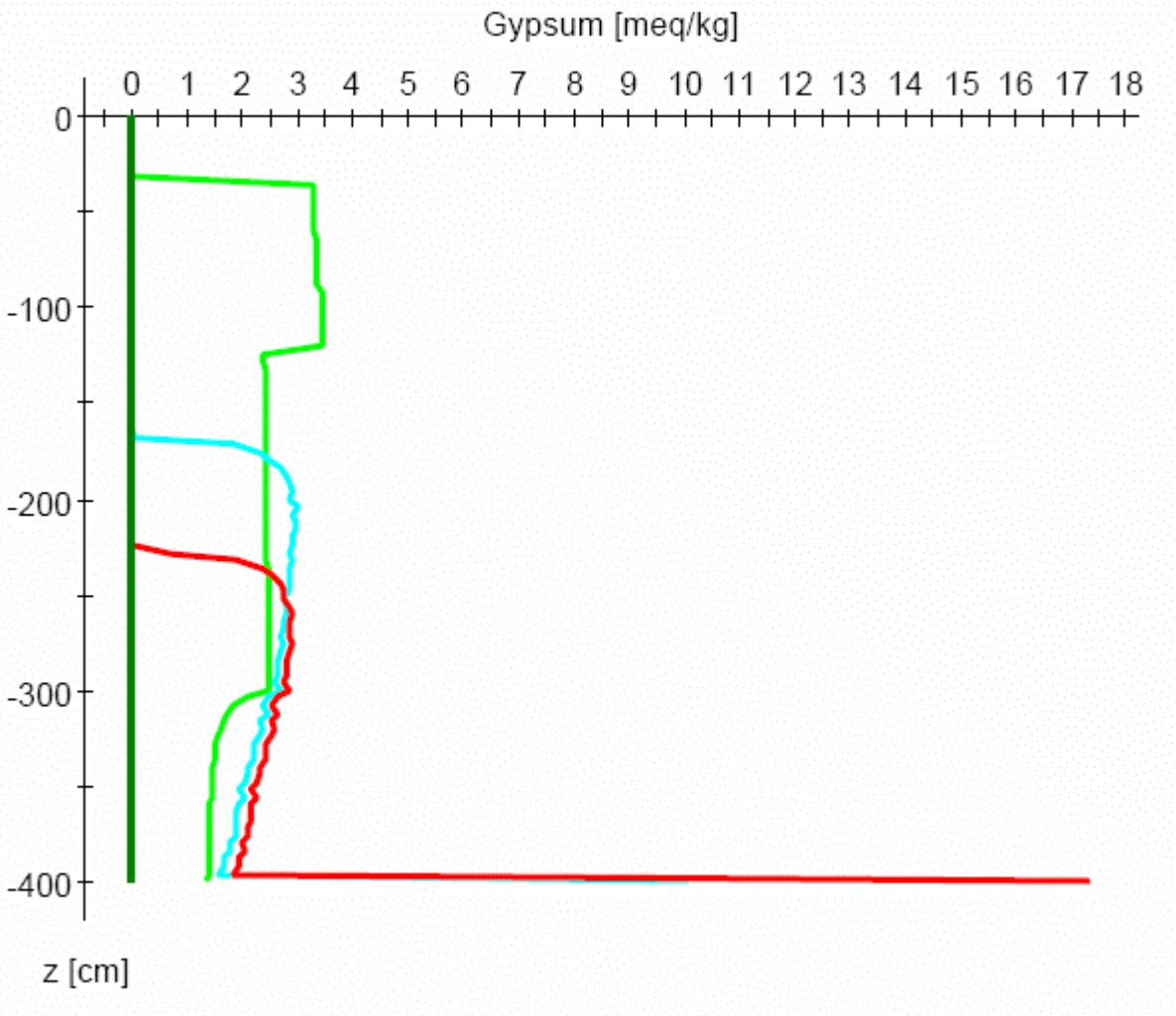
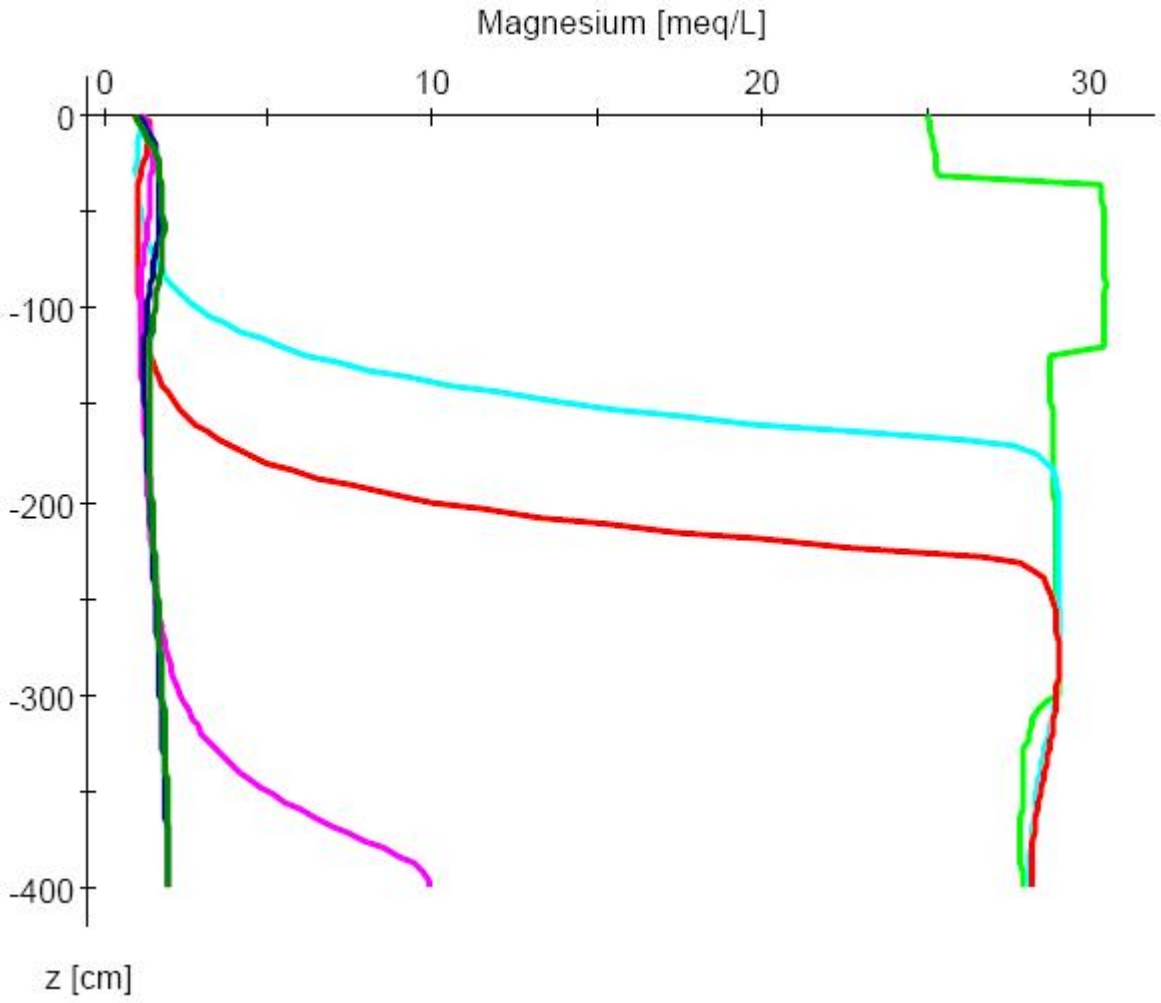


Figure 6. Solution Magnesium Levels by Soil Depth Over the 5-Year Simulation Period
(green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



400 cm of the soil and overburden profile at a level of about 1.5 meq/L. The simulation does not consider the enhancement of magnesium levels resulting from mineral dissolution in the alluvium and in adjacent areas to Horse Creek.

Sodium levels are relatively high in the natural conditions as noted for time 0 (Figure 7). Over time, the high initial surface levels are leached to lower levels of the profile. Since sodium is relatively mobile in this system, it will tend to migrate to lower levels in the profile with time without resulting in an accumulation in the upper 400 cm of the profile.

The concentration levels for sulfate with soil depth are shown in Figure 8. The distribution of sulfate in the soil profile during the simulation closely resembles the sodium distribution. This relationship can be explained by the fact that sodium and sulfate are present in high concentrations and are relatively mobile in this soil environment. As a result, both constituents should travel similarly with respect to soil water movement. Since much of the soluble constituents are sodium and sulfate, the EC of the soil solution follows a similar distribution with time.

The simulation demonstrates that over time, CBNG-produced water tends to increase soil pH throughout the profile (Figure 9). Following the initial pH increase at the surface resulting from the application of the CBNG-produced water, pH tends to decrease over the 5-year simulation period. These changes are likely due to changes in alkalinity and the solubility relationships with calcite and gypsum. The pH would be

expected to decrease during periods when CBNG-produced waters are not impacting the soil. The increased pH of the soil will impact the dissolution chemistry of the soil and the plant

Figure 7. Solution Sodium Levels by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

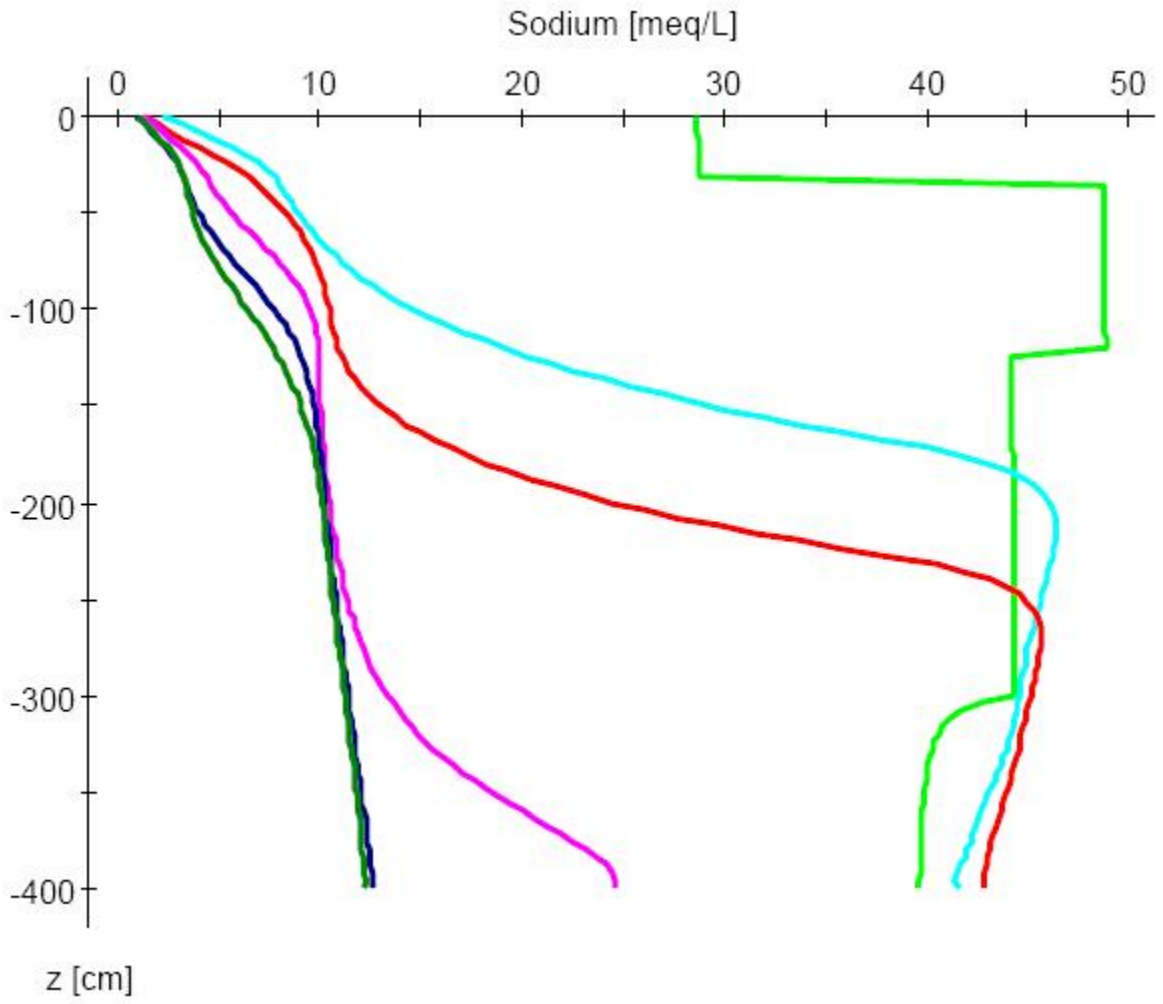


Figure 8. Solution Sulfate Levels by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

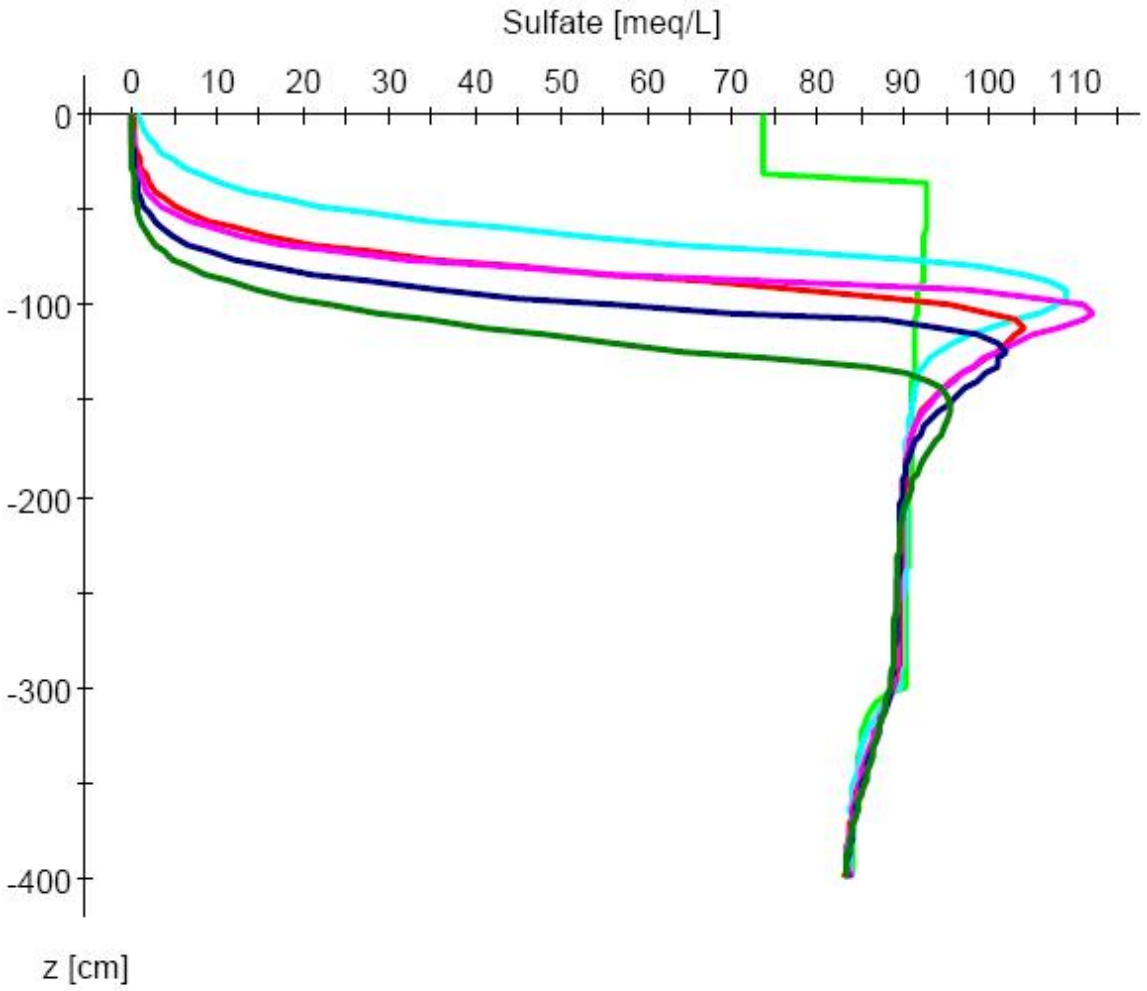
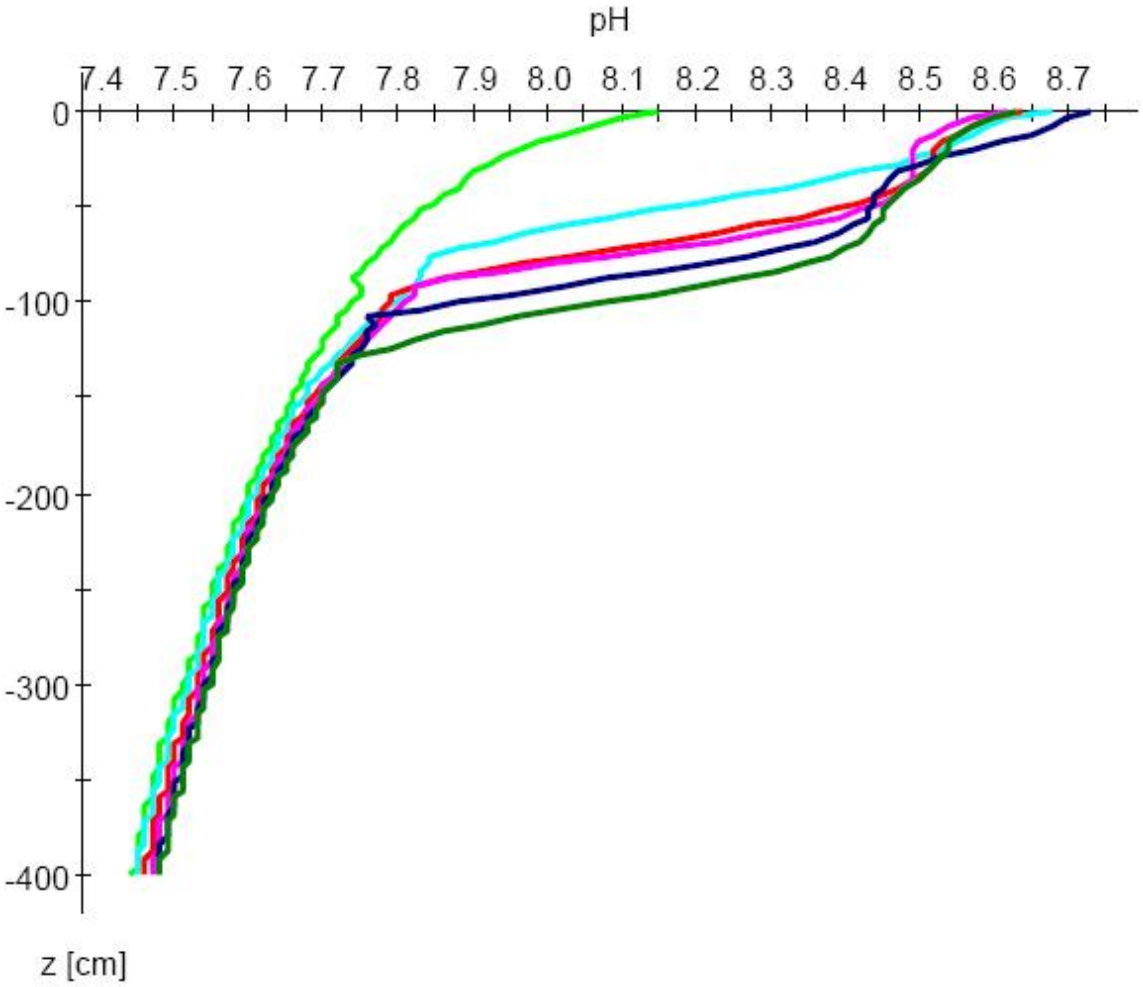


Figure 9. pH by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



nutritional characteristics. However, such changes are not expected to cause significant detrimental impacts to plant growth.

The FAO-SWS model provides an evaluation of how the soil conditions might affect plant growth. The impact is based on relative productivity due to water and salt stress. The simulation assumes that soil fertility and agriculture management are at optimum conditions for crop production. The relative yield simulation is provided in Figure 10.

The simulation indicates that the potential crop production is maintained in the 98% to 100% of maximum growth under the conditions generated during the 5-year irrigation period with CBNG-produced water under surface irrigation management. The lowest level of plant yield of about 98.4% occurs during year one of the simulation and tends to stabilize at about 99.6% at the end of year one to the end of the 5-year simulation. An important physical condition that impacts plant growth potential is the osmotic pressure of the system, which is associated with the amount of work required for a plant to absorb water. Plants must utilize more energy to absorb water from the soil with increases in negative osmotic pressure head. The osmotic pressure head of the soil over the 5-year simulation period is shown in Figure 11. The simulation clearly shows that the osmotic pressure decreases in the root zone throughout the evaluation period due to the application of water and the decreased levels of salt found in the profile. The reduction in osmotic pressure head due to irrigation with CBNG-produced water would benefit plant growth.

Figure 10. Relative Crop Yield Over the 5-Year Simulation Period

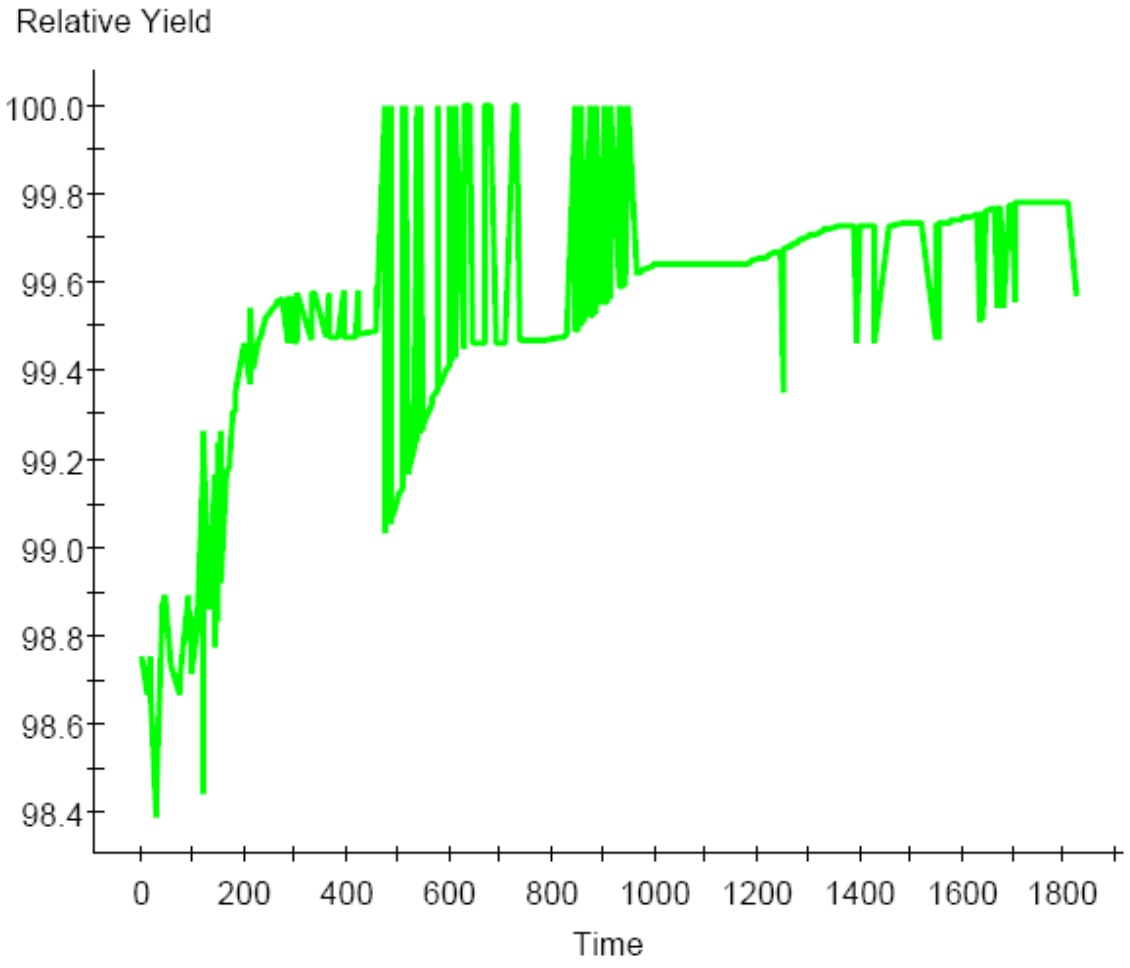
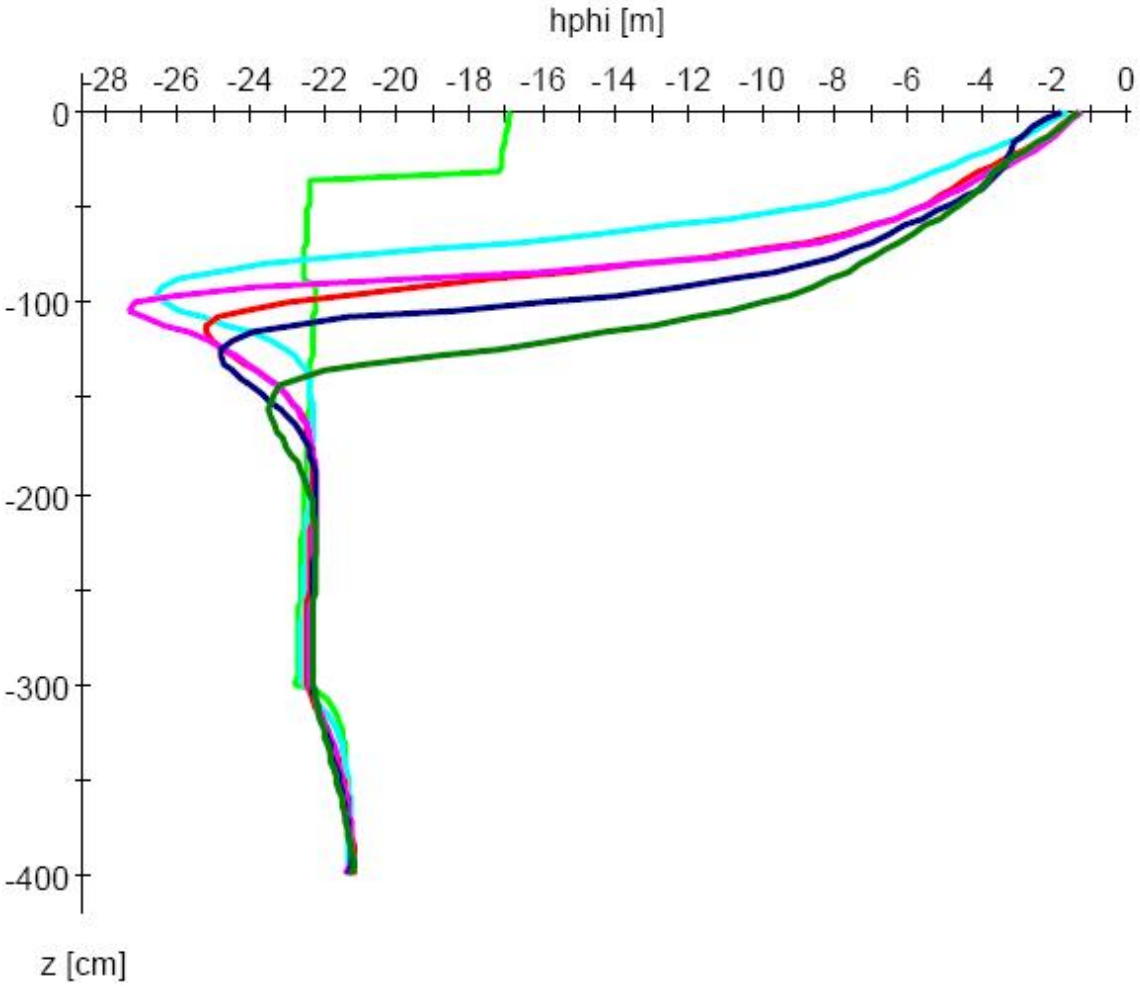


Figure 11. Osmotic Pressure Head by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



The FAO-SWS simulation for the Dave Magnuson Ranch demonstrates that using CBNG-produced water for irrigation purposes should not cause negative impacts to the soil and the surrounding environment. Salts, initially in the root zone, will be leached to levels below the root zone. Sodium and sulfate are expected to move deeper in the soil profile below the root zone. Similar findings for each of the parameters discussed were observed for all the irrigated and subirrigated lands along Horse Creek. Therefore, the simulations associated with each landowner are not presented in the body of the report but were placed in Appendix L in graphic form.

The significant outcomes of the simulations are presented for each landowner evaluation in the following sections.

Irrigation Model Results for Site DM1

- High salt levels are leached from the root zone under irrigation, improving plant growth conditions.
- SAR values decrease at the surface from 6.0 to approximately 3.0 after five years of irrigation with CBNG-produced water. Sodium accumulation within the soil profile does not occur.
- The pH values tend to increase throughout the profile. However, the increased pH values are at levels that would not cause measurable decrease in plant productivity.
- The relative yield (plant production) increased from near 98.5% to 99.8% during the five-year simulation.
- The osmotic pressure head becomes less negative in the root zone throughout the irrigation period. Thus plant growth conditions are improved throughout the 5-year irrigation period.
- This evaluation clearly demonstrates that CBNG water characterized with an EC of 1.84 dS/m and a SAR of 23.6 will not detrimentally impact irrigated soils at the David Magnuson Ranch.

Larry Shippy Ranch

The Larry Shippy Ranch is located upstream of Dave Magnuson. Mr. Shippy advised of the presence of some managed flood irrigation associated with a side drainage named Wild Horse Creek but does not flood irrigate from Horse Creek. There is evidence, however, that some type of flood irrigation has occurred along this stretch of Horse Creek in the past as spreader dikes have been constructed to contain water in fields adjacent to the stream channel. In addition, most of the diked area is also subirrigated. As a result, such fields were evaluated during the field sampling program. As noted earlier, wetland areas were not considered in the sampling program.

Seven irrigated fields were evaluated at the Larry Shippy Ranch. The soil profile descriptions show that all soils (15 profiles evaluated) possessed similar properties. Soil profile descriptions are presented in Appendix G. Two sites were sampled to a depth of 6 feet since some alfalfa was found at the sites. Samples were collected from sites LS1 and LS6. Site LS1 was characterized with soils of low EC values throughout the profile. As a result, the site was further evaluated to determine whether or not irrigation was associated with a side drainage rather than Horse Creek. Following a detailed evaluation that included a site visit, LS1 was determined to be associated with flood irrigation from an adjacent watershed. Inspection of Plate 1 indicates that the LS1 site is in a field behind a berm that separates the field from the mainstem of Horse Creek. This berm spreads water from the southeast-flowing tributary that emanates from Section 29. Apparently, surface flows not from Horse Creek but from the tributary

have leached the soil profile. It is important to note that this field is not receiving flow from Horse Creek, and that no CBNG discharges are proposed in the Section 29 Tributary that supplies the field. Photos taken at the site are presented in Appendix C. The data are included in the evaluation as a comparison to the subirrigated fields along Horse Creek. The field was less than 5 acres and was sampled using 1-foot depth increments to a depth of 6 feet at three locations and compositing by depth. At LS6, samples were collected at five sampling locations in 1-foot increments to 6 feet and composited by depth. The size of the subirrigated area was less than 10 acres. Averaged EC and SAR values by depth are presented in Table 7 and the laboratory results of the soil analysis are provided in Table 4. The unsampled sites are considered to have similar chemistry to LS6 due to consistent soil types and subirrigation.

The soil analyses indicate a large contrast between fields LS1 and LS6. Samples collected from LS1 are non-saline with EC values ranging from 0.86 dS/m at the 5- to 6-foot depth increment to 0.79 dS/m for the 2- to 3-foot depth increment. SAR values associated with profile were less than 2 with the high of 1.57 associated with the 1- to 2-foot depth increment. In contrast, field LS6 has EC values of 1.0 dS/m from 0 to 1 foot and 6.97 dS/m from 1 to 2 feet. EC values reached a high of 9.06 dS/m in the second foot of the profile. Textures in the profile were clay loam in the upper 2 feet and loam to clay loam in the mid to lower portions of the profile. Some variation occurred at site LS2 and LS6-5 where the surface foot ranged from clay to silty clay. Samples

collected at LS7 also were characterized with a clay texture. Based on the clay saturation percentage, the soil materials at both sample sites are non-swelling, and therefore could tend to resist sodic conditions. The high-clay soils would not be appropriate for managed flood irrigation but are not problematic for subirrigation, which is currently occurring at the site.

The physical and chemical characteristics collected from the soil sampled at LS6 were used as input into an irrigation model (FAO-SWS) to assess whether or not surface irrigating with CBNG-produced water (Table 1) would negatively impact the soils found at the site. The soils associated with LS6 soils are associated with subirrigated conditions.

Irrigation model results for the Larry Shippy Ranch are very similar to those described for the David Magnuson Ranch. The exact numbers for each of the parameters vary, but the general relationships are the same. Detailed diagrams are presented in Appendix L.

Loren Peyrot Ranch

The Loren Peyrot Ranch is located upstream of the Larry Shippy Ranch on Horse Creek as shown on the Overview Map (Plate 1). The landowner indicated that no managed flood irrigation exists on his land but several areas along Horse Creek are naturally flood irrigated and/or subirrigated. These areas are used for hay, containing

grass with some alfalfa, which is scattered with marginal production. Several of these areas were bermed, which might indicate that some type of flood irrigation had been used on the sites at some time in the past. However, irrigation ditches, headgates or other irrigation components were not found at any of the sites.

Eight subirrigated fields were sampled on the Peyrot Ranch. Each field was characterized with the same soil type. The number of samples collected for each composite was based on the area of each field. The averaged values for EC and SAR are presented in Table 7. The average EC value for all samples collected at the Peyrot Ranch was 6.78 dS/m with a range of 1.57 dS/m to 7.97 dS/m. The lowest EC value in the soil profile was at the surface with an average value of 4.61 dS/m, which is considered to be saline. The highest average EC value in the profiles sampled was 8.53 dS/m, which was present in the second foot.

The SAR values associated with the soils sampled were non-sodic with an average for all samples of 7.57 and a range of 1.78 to 13.5. In general, the lowest SAR values were associated with the surface foot (average SAR = 4.18) and the highest values (average SAR = 9.42) were associated with the second foot. Soil salinity is the only baseline parameter of concern pertaining to agricultural use of the land on this reach of Horse Creek.

The physical and chemical characteristics collected from the soil sampled at LP1, LP2, LP3, LP4, LP5, LP6, LP7 and LP8 were input into the FAO-SWS irrigation model to

assess whether or not surface irrigating with CBNG-produced water would negatively impact the soils found at the site. The soil analysis results for the sample sites were averaged for use in the simulation since the data were similar from field to field. The results of the irrigation model are similar to those identified previously.

Irrigation model results for the Loren Peyrot Ranch are very similar to those described for the David Magnuson Ranch. The exact numbers for each of the parameters vary, but the general relationships are the same. Detailed diagrams are presented in Appendix L.

Stevan Mueller Ranch

The Stevan Mueller Ranch is located upstream of the Loren Peyrot Ranch on Horse Creek as shown on the Overview Map (Plates 2 and 3). The landowner indicated that currently no managed flood irrigation exists on his land but the previous landowner had one viable flood irrigation system. The irrigation system consisted of a ditch that collected water from an upstream location on Horse Creek and conveyed it to a field that is currently subirrigated. The irrigation ditch has a diversion structure but has not been used for several decades. This field was sampled at seven locations to a depth of 6 feet and composited by 1-foot intervals. All soils sampled were characterized with very similar profile descriptions. The laboratory data are presented in Table 4. Averaged results for EC and SAR are presented in Table 7. Another subirrigated site was sampled, and is designated as field SM2-1 on the Overview Map (Plate 3). The

soil profile was documented, but no samples were collected. The soil profile closely resembled SM1 and therefore was correlated to the data collected at SM1.

Like the other baseline soils associated with subirrigated sites along Horse Creek, the soil at field SM1 is saline with an average EC of 9.2 dS/m, ranging from 4.77 dS/m at the surface to about 11.7 dS/m in the second foot of the profile. These saline soil conditions may be somewhat limiting for plant production, although the vegetation appears to be healthy without any toxic symptoms. Apparently, the vegetation is genetically adapted to higher soil salt conditions. The SAR values associated with the soil profiles sampled are non-sodic with an average SAR value of 7.3 ranging from 2.9 at the surface to 9.3 in the second foot of the soil profile. The pH values range from 7.5 to 8.2 and the textures allow good infiltration and water movement. The baseline conditions of the soils at the Mueller Ranch appear to be adequate to support the vegetation occupying the site. However, the site conditions may be limiting as the alfalfa appears to be scattered and somewhat dwarfed.

The physical and chemical characteristics collected from the soil sampled at SM1 was used as input into the FAO-SWS irrigation model to assess if surface irrigating with CBNG-produced water (Table 1) would negatively impact the soils found at the site.

Irrigation model results for the Stevan Mueller Ranch are very similar to those described for the David Magnuson Ranch. The exact numbers vary but the general relationships are the same. Detailed diagrams are presented in Appendix L.

Paulette Parks Ranch

The Paulette Parks Ranch is located upstream of the Stevan Mueller Ranch on Horse Creek as shown on the Overview Map (Plates 2, 3, 5 and 6). The landowner indicated that no managed flood irrigation exists on the property but several areas along Horse Creek on this property are subirrigated. The subirrigated areas support hay, containing grass with some alfalfa, which is scattered with marginal growth. Several of the subirrigated areas were bermed, which might indicate that some type of flood irrigation had been attempted on the sites at some time in the past. However, irrigation ditches, headgates or other irrigation components were not found on any of the sites.

Eleven subirrigated fields that are currently used for agricultural purposes were evaluated. Soil profile descriptions were taken in each field (Appendix G) and two of the fields were sampled. Field PP1 contained grass intermixed with alfalfa and therefore was sampled to a depth of 6 feet. Samples were collected from five sites in the field (area < 10 acres) and composited by one-foot depth increments to 6 feet. Samples were also collected from field PP10. Since this field did not contain alfalfa, samples were collected to a depth of 4 feet at 1-foot depth intervals. Samples were collected from seven sites and composited by depth increment for fields in excess of ten acres. Soil profile descriptions were also taken for soils in fields PP2 through PP9. The soils resemble the soils found in fields PP1 and PP10 and therefore were not sampled for analysis. The soil profile descriptions are presented in Appendix G.

Sample analyses for all parameters are presented in Table 4. The averaged values for EC and SAR are presented in Table 7. In general, the soils located on the ranch are characterized as saline with an overall average of 6.80 dS/m and a range of 3.85 dS/m to 9.67 dS/m for all samples collected. The surface soils averaged 3.85 dS/m and ranged from a non-saline 0.66 dS/m to 7.04 dS/m, which is saline. The high salt levels in the profile were found at the 2 to 3-foot depth increment with an average EC of 9.67 dS/m with a range of 5.63 dS/m to 13.7 dS/m. The baseline EC conditions would likely retard growth of non-native plant species, and would be especially detrimental for alfalfa. Grass species found at the subirrigated sites would be expected to tolerate the saline soil conditions.

SAR values were low for all the soil depths sampled. The average SAR value for all samples was 5.9 with a range of 3.3 to 8.2. The soil baseline SAR condition is not sodic and appears to be adequate to support the native vegetation occupying the site. Site conditions may be somewhat limiting for alfalfa as this species appears to be scattered and somewhat dwarfed.

The physical and chemical characteristics collected from the soil sampled at PP1 and PP10 were input into the FAO-SWS irrigation model to assess if surface irrigating with CBNG-produced water (Table 1 – EC = 1.84 dS/m, SAR = 23.6) would negatively impact the soils found at the site. Each sample site was simulated separately because of the differences in soil chemistry that existed in the baseline conditions.

Irrigation model results for the Paulette Parks Ranch are very similar to those described for the David Magnuson Ranch. The exact numbers for each of the parameters vary, but the general relationships are the same. Detailed diagrams are presented in Appendix L.

Marsha Pownall Ranch

The Marsha Pownall Ranch is located upstream of the Paulette Parks Ranch on Horse Creek as shown on the Overview Map (Plates 2, 3 4, and 6). No managed flood irrigation exists on the property, but several areas along Horse Creek on this property are subirrigated. These areas are used for hay containing grass with some alfalfa, which is scattered with marginal production. Several sites are actively farmed, and the current species growing on the sites consists of field pennygrass, smooth brome, crested wheatgrass and alfalfa (see Table 5). Several of the subirrigated areas were bermed which indicates that some type of flood irrigation had been attempted on the sites in the past. No components of managed irrigation systems were found on any of the sites.

Seven subirrigated sites located on Horse Creek were evaluated during the field visits. The fields evaluated included MP1, MP3, MP4, MP5, MP6, MP7, and MP9. Fields identified as MP2 and MP8 are associated with the Spring Creek watershed and are described in a subsequent section of this report. All Horse Creek profiles sampled were very similar as shown in the profile descriptions presented in Appendix G. As a result of this similarity, MP1 was sampled at seven sites by one-foot depth increments

to a total depth of 6 feet. The field was greater than 10 acres in area. The soils associated with the other six fields evaluated were correlated to MP1 and were not sampled.

The chemical analysis associated with the samples collected at MP1 was very similar to the results for the downstream fields located along Horse Creek. The baseline soil conditions are saline, with EC values for all samples analyzed averaging 7.9 dS/m with a range from 6.42 dS/m to 10.1 dS/m. The EC value associated with the surface foot was 7.83 and the highest salt level found in the soil profile was 10.1 dS/m located in the 1 to 2 foot depth interval.

SAR values characterizing field MP1 are non-sodic with values ranging from 5.2 to 8.7. Such conditions should not be detrimental to soil structure.

The FAO-SWS irrigation model results for the Marsha Pownall Ranch (site MP1) are very similar to those described for the David Magnuson Ranch. The exact numbers for each of the parameters vary, but the general relationships are the same. Detailed diagrams are presented in Appendix L.

Twenty Mile Land Company – John Daly

John Daly denied access on and through Twenty Mile Land Company property for field evaluations. A small amount of the area along Horse Creek on the Twenty Mile Ranch shows up red on the CIR photos. Since irrigated or subirrigated fields have been

evaluated both upstream and downstream, the information obtained from this portion of Horse Creek is not expected to be important in the overall Section 20 Analysis. Therefore, the Section 20 Analysis of Horse Creek should provide adequate coverage without the inclusion of analysis derived from this property.

State of Wyoming

John Daly denied access through Twenty Mile Land Company to assess state land. Therefore, no field work was conducted in this area.

Donna Tarver Ranch

The Donna Tarver Ranch is located upstream of the Twenty Mile Ranch on Horse Creek as shown on the Overview Map (Plates 8 and 10). No managed flood irrigation exists on the property, but several areas along Horse Creek are subirrigated and are used to produce grass hay. No alfalfa was encountered on the property during the field investigations. Several of the hay fields were bermed, suggesting past attempts at flood irrigation. No components of managed irrigation systems were found on any of the sites. Lands exhibiting wetland characteristics were not sampled. Six subirrigated sites were evaluated during the field visit. The soil associated with Field DT1 was sampled. Samples were collected by one-foot depth increments to 4 feet from three sampling sites and composited by depth for analysis. Soils located in the other five subirrigated agricultural fields closely resemble soils found at field DT1 (profile descriptions are presented in Appendix G) and were not sampled.

The baseline EC values range from 0.87 dS/m for the surface foot to 7.1 dS/m for the 3 to 4 foot depth increment. The average EC for the profile is 4.73 dS/m. The soil is considered to be saline, and may restrict the growth potential of grass species that currently occupy the site.

SAR values calculated from the analysis indicate the soil at field DT1 is non-sodic. The average SAR value for all samples collected is 4.6 with a range of 0.8 to 6.6. The baseline SAR conditions indicate that sodic soil conditions should not impact soil structure or reduce the potential for plant growth.

Irrigation model results for the Donna Tarver Ranch (site DT1) are very similar to those described for the David Magnuson Ranch. The exact numbers for each of the parameters vary, but the general relationships are the same. Detailed diagrams are presented in Appendix L.

State of Wyoming

Flood irrigated and/or subirrigated agricultural lands were not present in the State lands located upstream of the Donna Tarver Ranch in Sections 34, 35, and 36, T54N, R74W. Photos taken at SW-A, identified on the Overview Map (Plates 8 and 10), describe ground conditions for this reach of Horse Creek. Several small areas of enhanced vegetation, less than one acre in size, exist along the stream. These areas have not been separately evaluated for significant or unique agricultural values.

Discharge of CBNG-produced water is not planned above the State lands at this time.

FAO-SWS IRRIGATION MODEL SIMULATION USING CBNG-PRODUCED WATER CHARACTERIZED WITH SAR OF 25

The irrigation simulation compiled for the Marsha Pownall Ranch located upstream of the Paulette Parks Ranch on Horse Creek was modified to simulate surface irrigation using a CBNG-produced water with a SAR of 25. This evaluation was completed to determine if the clay loam soils characterizing subirrigated fields at the site would be adversely impacted using nonsaline, sodic water for irrigation.

Irrigation model results for Field MP1 modified with water with an SAR of 25 (5-year simulation)

(see detailed diagrams in Appendix L) are summarized as follows:

- High salt levels initially in the root zone are leached, improving plant growth conditions. An EC value of about 6.4 dS/m (model baseline conditions) at the surface decreased to about 0.5 dS/m after the first irrigation season. The EC tended to stabilize at the surface (at 0.5 dS/m) throughout the simulation probably due to mineral dissolution (calcite, etc). The high baseline EC conditions tend to migrate deeper in the profile during the 5-year irrigation period due to leaching.
- Surface SAR values decreased from about 5.8 to about 0.5 after the first year and tended to increase to about 1 after 5 years of irrigation. A SAR value of about 4.4 occurred at the end of Year 4 probably due to timing differences in natural precipitation used in the simulation. SAR values tend to increase with depth but decrease with time due to leaching of sodium.
- The pH values increased from about 8.1 at baseline conditions to about 8.7 following the first year of irrigation. In subsequent years of irrigation, the pH declined to about 8.7 at the end of the 5-year simulation. The

increased pH values would not be expected to cause a measurable decrease in plant productivity.

- The relative plant yield approaches about 99+% at the end of the 5-year irrigation period.
- The osmotic pressure head becomes less negative throughout the irrigation period. Thus plant growth conditions are improved through out the 5-year irrigation period.

SUMMARY RESULTS OF THE FAO-SWS IRRIGATION MODEL SIMULATIONS FOR ALL SITES ON HORSE CREEK

The irrigation simulations indicate that the CBNG-produced water can be used to irrigate the bottom land along Horse Creek without any detrimental impacts. The simulation shows that irrigating these lands with the CBNG-produced water, as characterized in Table 1 (EC = 1.84, SAR = 23.6, and EC = 1.35, SAR = 25), will tend to improve soil plant growth conditions by leaching the high salt levels found in the root zone to lower levels in the profile. SAR values increase with depth but decrease with time due to leaching of sodium. The pH values increase to about 8.7 at the end of the 5-year simulation. The increased pH values would not cause a measurable decrease in plant productivity. The relative yield for plant growth is maintained at a high level as the osmotic pressure head becomes less negative throughout the irrigation period and the hydraulic characteristics of the soils are maintained.

The irrigation simulation demonstrates that the CBNG-produced water generated in the Horse Creek drainage will not adversely impact agricultural soils whether the sites are subjected to managed irrigation or to natural flood events that include produced water. In addition, the simulation shows that such irrigated land would not suffer negative

impacts when irrigated with CBNG-produced water characterized with SAR values of up to 25.

GEOCHEMICAL INTERACTIONS OF THE ALLUVIAL GROUNDWATER AND THE CBNG-PRODUCED WATER

As noted previously, most of the irrigation agricultural activities along Horse Creek are in the form of subirrigation. This includes the sites that have also been flood irrigated in the past. Therefore, it is important to provide an evaluation of how the CBNG-produced water might impact the alluvial groundwater that is providing late-season plant growth in the subirrigated areas. This evaluation was done using the geochemical model EQ3/6 developed at Lawrence Livermore Laboratories. The model assumed a 1:1 mix of the alluvial groundwater with CBNG-produced water. The results of the evaluation were used along with the relationships described in Figure 1, to determine the anticipated impact of the resultant water upon soils and vegetation at such locations along Horse Creek. The model simulation mixed alluvial water collected from three sites with the CBNG-produced water. The results of the simulation are presented in Table 8. The resultant water quality should not impact soils or vegetation in the watershed. The EC conditions are non-saline and the SAR conditions are non-sodic. The EC-SAR relationship as described in Figure 1 places the mixed water in the "no reduction in infiltration" portion of the graph. In addition, the pH of the mixed water is approximately 7.0, which will provide near optimum conditions for plant growth. Therefore, addition of CBNG-produced water into the alluvium of Horse Creek would

not cause a measurable decrease to livestock or crop yields. In fact, results of the simulation indicate the quality of the alluvial water in the Horse Creek drainage would improve.

Table 8. Results of Geochemical Reactions Between CBNG-produced Water and the Alluvial Groundwater Collected Along Horse Creek.

Parameter*	Units	L. Peyrot	P. Parks	M. Pownall	M. Pownall with SAR 25 CBNG-produced water
pH	(s.u.)	7.3	7.1	7.0	7.0
EC	(dS/m)	2.0	2.9	3.1	3.4
SAR		6.8	6.0	5.8	7.9
Ca^{+2}	(mg/L)	42	110	135	127
Mg^{+2}	(mg/L)	79	181	212	214
Na^{+1}	(mg/L)	325	464	460	627
K^{+1}	(mg/L)	3.0	3.0	3.0	3.0
HCO_3^{-1}	(mg/L)	660	458	427	447
SO_4^{-2}	(mg/L)	440	441	441	441

* HCO_3^{-1} and SO_4^{-2} were calculated based on cation-anion balance.

A simulation was also conducted using CBNG-produced water with an SAR of 25 to assess the impact on the alluvial groundwater. The SAR of the CBNG-produced water was the only variable different from the simulation discussed previously. The chemical characteristics of the combined water are also presented in Table 8. The resulting water was characterized with an EC value of about 3.4 dS/m and an SAR of 7.9. The pH of the combined water was 7.0. The resulting SAR values are still non-sodic and would not be expected to cause sodic soil conditions. EC values also increased from approximately 3.1 dS/m taken from the M. Pownall model run with the typical CBNG-produced water generated in the Horse Creek watershed to 3.4 dS/m using the SAR 25 produced water. This increase does not degrade potential vegetation growth in relation

to altered chemistry and should not impact the agricultural use of the irrigated lands. Discharging SAR 25 CBNG-produced water into the alluvial groundwater system would not cause any significant degradation to the alluvial groundwater, the soils associated with the subirrigated fields, or the vegetation production on these sites.

COMPLIANCE SUMMARY

Agricultural Compliance Summary

The Operators may propose several water management alternatives, including discharge of CBNG-produced water directly into tributaries to or the mainstem of Horse Creek and/or into reservoirs on tributaries of Horse Creek. The Section 20 evaluation presented in this section of the report discusses the discharge alternatives for Horse Creek.

Potential impacts to irrigated agricultural fields were evaluated primarily using three methods: (1) Application of CBNG-produced water generated in the watershed was evaluated with respect to changes in the baseline EC/SAR relationship, (2) the FAO-SWS irrigation model was used to evaluate the impact of irrigating with the CBNG-produced water, and (3) a geochemical model (EQ3/EQ6) was used to mix the CBNG-produced water with alluvial groundwater to determine if the resultant water would influence the soil chemistry and plant growth at subirrigated sites.

In general, the results of the analysis show that the CBNG-produced water would have a positive impact on the agricultural lands in the Horse Creek drainage. The CBNG-

produced water is nonsaline and nonsodic. Based on the EC/SAR relationship (Figure 1), the low salt concentrations of the produced water suggest that such water would have a slight tendency to cause a reduction in infiltration. However, high salt levels currently characterizing most of the irrigated soils in the Horse Creek watershed will provide a large capacity to replenish salt to the soil solution by weathering processes.

The irrigation simulation represents a traditional managed flood irrigation system with positive results for the agricultural lands in the Horse Creek watershed. The salt levels present in the soils during baseline conditions are shown to improve substantially with salts leaching from the root zone. In addition, non-sodic conditions are maintained at the soil surface and in the root zone resulting in a stable soil structure. Plant growing conditions are improved over baseline conditions as the osmotic pressure head of the soil system is reduced by irrigation with the CBNG-produced water.

The geochemical evaluation of mixing the CBNG-produced water with alluvial groundwater shows a positive impact associated with the discharge of such water. The resultant alluvial water is characterized with lower EC and SAR values compared to the baseline alluvial groundwater. The evaluation of the water chemistry of the mixed water with regard to Figure 1 indicates that the water fits in the “no reduction in infiltration” portion of the graph.

These results provide a strong basis to support approving the discharge of the CBNG-produced water and establishing irrigation water quality limits in excess of the default irrigation water quality limits.

Vegetation Summary

The baseline evaluation shows that the soils are characterized with high salt levels averaging 7.02 dS/m for all soil samples collected during. Therefore, the plants currently growing on almost all of the irrigated agricultural land are either tolerant of high levels of soil salinity or are currently negatively impacted by the pre-discharge soil conditions. Irrigation with the low-EC CBNG-produced water would result in a decrease of salt levels in the root zone, improving plant growth conditions.

Livestock Compliance Summary

To assess the Horse Creek Section 20 Compliance for water quality for use in livestock production, the expected CBNG-produced water quality data (Table 9) were compared to standards in Wyoming Water Quality Division Rules and Regulations (WDEQ/WQD, 2004) and suggested guidelines for levels of toxic substances in livestock drinking water (National Academy of Sciences, 1972 and 1974). The CBNG-produced water quality was used in the livestock watering suitability assessment because unblended produced water may be available to stock. As shown in Table 9, the CBNG-produced water meets all livestock drinking water guidelines and will not cause a measurable decrease in livestock production.

Conclusion

The Section 20 evaluation for Horse Creek provides strong evidence that irrigated agricultural lands (flood or subirrigated) can be safely irrigated with CBNG-produced waters characterized with a SAR of up to 25 and with EC values of 4 dS/m or higher. The EC values of CBNG-produced water will have little influence on soil EC values since the soils are characterized with high salt levels in the baseline condition.

Table 9. Summary of Livestock Watering Standards Compared with Expected CBNG-produced Water Quality

Analyte	Units	Livestock Watering Standards[1]	Average CBNG-produced Water Quality
pH	*s.u.*	6.5 to 9	7.3 to 8.5
Electric Conductivity (EC)	*dS/m*	7.5	1.43
Total Dissolved Solids (TDS)	*mg/L*	5,000	883
Sodium Adsorption Ratio (SAR)		--	13.0
Anions			
Bicarbonate	*mg/L*	--	985
Chloride	*mg/L*	2,000	11.3
Fluoride	*mg/L*	2.0	0.4
Sulfate	*mg/L*	3,000	<10
Cations			
Calcium	*mg/L*	--	25
Magnesium	*mg/L*	--	13
Sodium	*mg/L*	--	312
Metals[7]			
Arsenic	*µg/L*	200	1.2
Boron	*µg/L*	5,000	144
Cadmium	*µg/L*	50	<0.1
Chromium	*µg/L*	1,000	<1
Copper	*µg/L*	500	1.4
Lead	*µg/L*	100	<2
Mercury	*µg/L*	10	<1
Selenium	*µg/L*	50	<5
Zinc	*µg/L*	24,000	<10

1 Livestock watering standards are from WDEQ/WQD (2004) and National Academy of Sciences (1972 and 1974).

PART 2: HAY CREEK

Hay Creek is a tributary of Horse Creek as shown on the Overview Map (Plates 6, 7 and 9). Hay Creek was evaluated separately from Horse Creek, but with the same methodology and guidance as described in the Horse Creek Introduction and Methodology Sections. The results of the analysis for Hay Creek are summarized in the following sections.

RESULTS - BASELINE

The information collected from the baseline evaluations includes soil profile descriptions and soil chemistry characterizations. The soil profile descriptions for each sampling site are presented in Appendix G. The soil profiles sampled in the upper reaches of Hay Creek resemble the soils found in the Horse Creek drainage. Generally, the soils in Hay Creek were characterized with an A, Bw, Bk, and C horizon sequence usually with multiple Bk and C horizons.

The chemical analyses of the Hay Creek soil samples are presented in Table 10. Two sites were sampled in the Hay Creek drainage. Samples collected from subirrigated areas in the Hay Creek watershed show salt levels often greater than 4 dS/m, which is considered to be saline as defined in USDA Handbook 60 (1959). The average EC value for the samples collected at the Wolff and Rule Ranches were 15.55 dS/m and 6.68 dS/m, respectively. EC values by one-foot depth increments for the Wolff Ranch site were 12.2 dS/m (0 to 1-foot depth increment), 16.8 dS/m (1 to 2 feet), 16.1 dS/m (2 to 3 feet), and 17.1 dS/m (3 to 4 feet), while samples collected at

Table 10. Soil Analysis for Samples Collected in the Hay Creek Watershed.

Sample ID	Depth Interval (ft)	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR	Sand %	Silt %	Clay %	Texture
James Wolff Ranch													
JW1	0-1	7.6	66.8	12.2	2.0	18.8	223	22.7	2.1	22	41	37	Clay Loam
JW1	1-2	8.0	72.5	16.8		17.9	383	40.0	2.8	32	68	0	Silty Loam
JW1	2-3	7.9	76.3	16.1		19.6	384	36.7	2.6	28	72	0	Silty Loam
JW1	3-4	7.8	77.8	17.1		19.4	425	37.6	2.5	30	70	0	Silty Loam
Eric Rule Ranch													
ER1	0-1	6.7	54.2	3.51	2.8	23.1	21.7	1.81	0.4	38	34	28	Clay Loam
ER1	1-2	7.6	61.2	6.09		20.0	60.0	11.6	1.8	30	42	28	Clay Loam
ER1	2-3	7.8	74.9	8.34		18.0	95.4	19.4	2.6	20	63	17	Silt Loam
ER1	3-4	7.8	76.8	8.77		17.4	104	18.6	2.4	22	39	39	Clay Loam

the Rule Ranch site were 3.51 dS/m (0 to 1 foot), 6.09 dS/m (1 to 2 feet), 8.34 dS/m (2 to 3 feet), and 8.77 dS/m (3 to 4 feet).

The average SAR for soil samples collected from the two subirrigated sites sampled in the Hay Creek drainage were 2.5 and 1.8 for the Wolff and Rule Ranches, respectively. SAR values associated with the Wolff Ranch were 2.1, 2.8, 2.6, and 2.5 for the 1-foot depth increments to the total depth sampled of 4 feet. SAR values associated with the Rule Ranch were 0.4, 1.8, 2.6, and 2.4 for the 1-foot depth increments to the total depth sampled of 4 feet. The SAR values are non-sodic and would not be expected to be associated with sodic soil conditions.

Elemental toxicities are not expected to result from soil conditions present in the Hay Creek agricultural sites sampled.

IMPACT ANALYSIS: SOILS, ALLUVIAL GROUNDWATER AND VEGETATION

Soils

The chemical evaluations of the soils associated with the subirrigated agricultural lands along Hay Creek indicate that both sites possess saline conditions (Table 10). With the exception of the surface foot of the soil profile associated with the Rule Ranch, the salt levels in each of the sampling intervals exceed the level of salt considered saline (4 dS/m). It should also be noted, however, that most native vegetation can often tolerate these high levels of salt due to their genetic disposition. The only species of concern at such salt levels is alfalfa, but alfalfa was not found at either field sampled in

the Hay Creek watershed, and therefore was not included in the Hay Creek analysis results.

An identical evaluation to the Horse Creek analysis was completed for the irrigated sites located on the Wolff and Rule Properties. The results are summarized as follows.

Results of the EC and EC/ SAR Comparison – Hay Creek

1. The EC values associated with the use of CBNG-produced water for irrigation purposes would be expected to **decrease** the salt levels in the soil profiles and thus enhance plant growth potential.

2. The CBNG-produced water is nonsaline and nonsodic. In terms of the EC/SAR relationship, the low salt concentrations of the water would have a slight tendency to cause a reduction in infiltration. Slight tendency was used since the EC/SAR intersect is either close to the middle or below the middle of this zone of the graph.

3. The high salt levels currently characterizing most of the irrigated soils in the Hay Creek watershed will provide a large capacity to replenish salt to the soil solution by weathering processes. Although the application of CBNG-produced water, precipitation and snowmelt will have a tendency to remove salts at the surface and promote clay dispersion, weathering of soluble minerals will occur simultaneously thereby maintaining relatively high salt levels and preventing clay dispersion.

4. The salt generated from the weathering process is expected to greatly influence the EC of the CBNG-produced water resulting in EC values of > 4 dS/m which would keep soils flocculated even up to SAR values near 25 (Figure 1).

5. CBNG-produced water should not impact the hydraulic conductivity of irrigated soils. The high salinity levels of the soils will overwhelm any increased SAR levels that might result while irrigating with the produced CBNG water.

6. The relationships shown in Figure 1 were developed by Ayers and Westcot (1985) and Hanson *et al*. (1999), for soils found in California that had been irrigated for crop production. Such soil conditions do not exist in the subirrigated agricultural lands along Hay Creek. Soils in the PRB and in the Hay Creek watershed contain high levels of soluble salts. These salts will dissolve during the irrigation process, and will likely react much different to irrigation water

containing relatively low salt levels. As a result, CBNG-produced water used for surface application could conceivably contain higher sodium levels without causing a detrimental impact to agricultural lands.

7. The EC/SAR soil chemistry discussed in this section provides a strong basis for establishing an SAR limit of 25 without causing soil infiltration problems in agricultural lands irrigated with CBNG-produced water.

FAO-SWS MODEL SIMULATIONS

Model simulations were conducted for each sampling site located at the James Wolff and Eric Rule Ranches located in the headwaters of Hay Creek. Separate evaluations were made for each landowner based on the information collected during the field sampling program. The Twenty Mile Ranch did not allow field access to their lands and therefore the fields located at the confluence of Hay Creek with Horse Creek were not included in the evaluation. The soils sampled in the upper reaches of Hay Creek are similar to each other and to soils evaluated along Horse Creek. The model simulation for the subirrigated site located on the Eric Rule Ranch is presented in the body of the report while the results of the simulation for the subirrigated site located on the James Wolff Ranch are presented in Appendix L. Photo points associated with other landowners along Hay Creek are shown on the Overview Map (Plates 6, 7 and 9) with photos documenting the landscape along the reaches of Hay Creek that are not associated with managed flood irrigation or naturally irrigated agricultural lands. The following evaluation is based on individual landowners starting from the confluence of Hay Creek with Horse Creek progressing to the upper reaches of the Hay Creek watershed.

Twenty Mile Land Company – John Daly, Owner

The Twenty Mile Land Company owns the area that includes the confluence of Hay Creek with Horse Creek. Access to the land for field evaluations was not provided by John Daly. However, observations made from adjacent areas indicate that some of the agricultural land located at the confluence of Hay Creek with Horse Creek may be subirrigated. Since flood irrigated or subirrigated fields have been evaluated on both sides of the ranch, information can be extrapolated from data collected in the head waters of Hay Creek and from adjacent sites on Horse Creek to provide an indication of how these inaccessible lands might be impacted. Therefore, the Section 20 analysis of Hay Creek and Horse Creek should provide adequate coverage without the inclusion of this property.

State of Wyoming

The State of Wyoming owns the land on Hay Creek upstream of the Twenty Mile Land Company Ranch located along Horse Creek and downstream of another stretch of land owned by the Twenty Mile Land Company Ranch. Access through the Twenty Mile Land Company Ranch to reach the State of Wyoming property was not provided. No field work was conducted in this area.

Twenty Mile Land Company – John Daly, Owner

The Twenty Mile Land Company owns the land upstream of the State of Wyoming land and downstream of the Fred Oedekoven Family Trust Land. John Daly, owner of the Twenty Mile Land Company, did not allow access to the property. However, it appears

that managed irrigation or subirrigated agricultural lands do not exist in this portion of the Hay Creek Watershed.

Fred Oedekoven Family Trust Land

The Fred Oedekoven Family Trust Land is located between Twenty Mile Land Company and the James Wolff Ranch. No managed flood irrigation or subirrigated agricultural lands were found. As a result, field sampling was not conducted. The area was photo documented (photos presented in Appendix C) with the photo points shown on Plate 7.

James Wolff Ranch

The James Wolff Ranch is located immediately upstream of the Fred Oedekoven Family Trust Ranch and downstream of the Eric Rule Ranch. One subirrigated site was found and this site also appeared to have berms that might hold water associated with flood irrigation. The portion of Hay Creek located between the subirrigated site designated as site ER1 and the Oedekoven Family Trust Land did not contain irrigated or subirrigated agricultural lands. This reach of Hay Creek is photo documented (Appendix C) with photo points shown on Plate 9.

The subirrigated agricultural area (designated as ER1 on Plate 9) was sampled at seven locations also shown on Plate 9. Seven sites were sampled since the field was larger than 10 acres. Since only grass was present, samples were collected and composited by one-foot depth increments to a depth of 4 feet. The soil analytical

results are provided in Table 10 and the averaged values for EC and SAR results are presented in Table 7.

In general, the analyses indicate that the soils are saline with EC values ranging from a low of 12.2 dS/m in the surface foot to a high of 17.1 dS/m in the 3 to 4 foot depth increment. The soil samples also show low SAR values of 2.1 in the surface foot to a high of 2.8 in the 1 to 2 foot depth increment. The pH values ranged from 7.6 to 8.0 in the sampled profile. The texture of the material was clay loam in the top foot and silty loam from the 1 to 4 foot depth.

The physical and chemical characteristics collected from the soil sampled at JW1 were input into the FAO-SWS irrigation model (as described above) to assess if irrigating with CBNG-produced water would negatively impact the soils found at the site. Subirrigated sites that may be impacted with CBNG-produced water entering the alluvial groundwater were also evaluated using a geochemical approach, as described below.

FAO-SWS MODEL RESULTS FOR THE JAMES WOLFF RANCH

The primary concerns with using CBNG-produced water to surface irrigate crops and rangeland plant communities are associated with the influence that such water has on the salinity and sodicity characteristics of the irrigated soils. The expected salinity and SAR characteristics of soils located at the irrigation site over the 5-year simulation period are presented in Figures 12 and 13, respectively.

Figure 12 provides an estimate of the salt accumulation (described in terms of EC) expected at the site under the projected irrigation application rates and the average precipitation levels. In general, the simulation shows that during the initial stages of

Figure 12. Salt Concentrations (EC) by Soil Depth Over the 5-Year Irrigation Period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

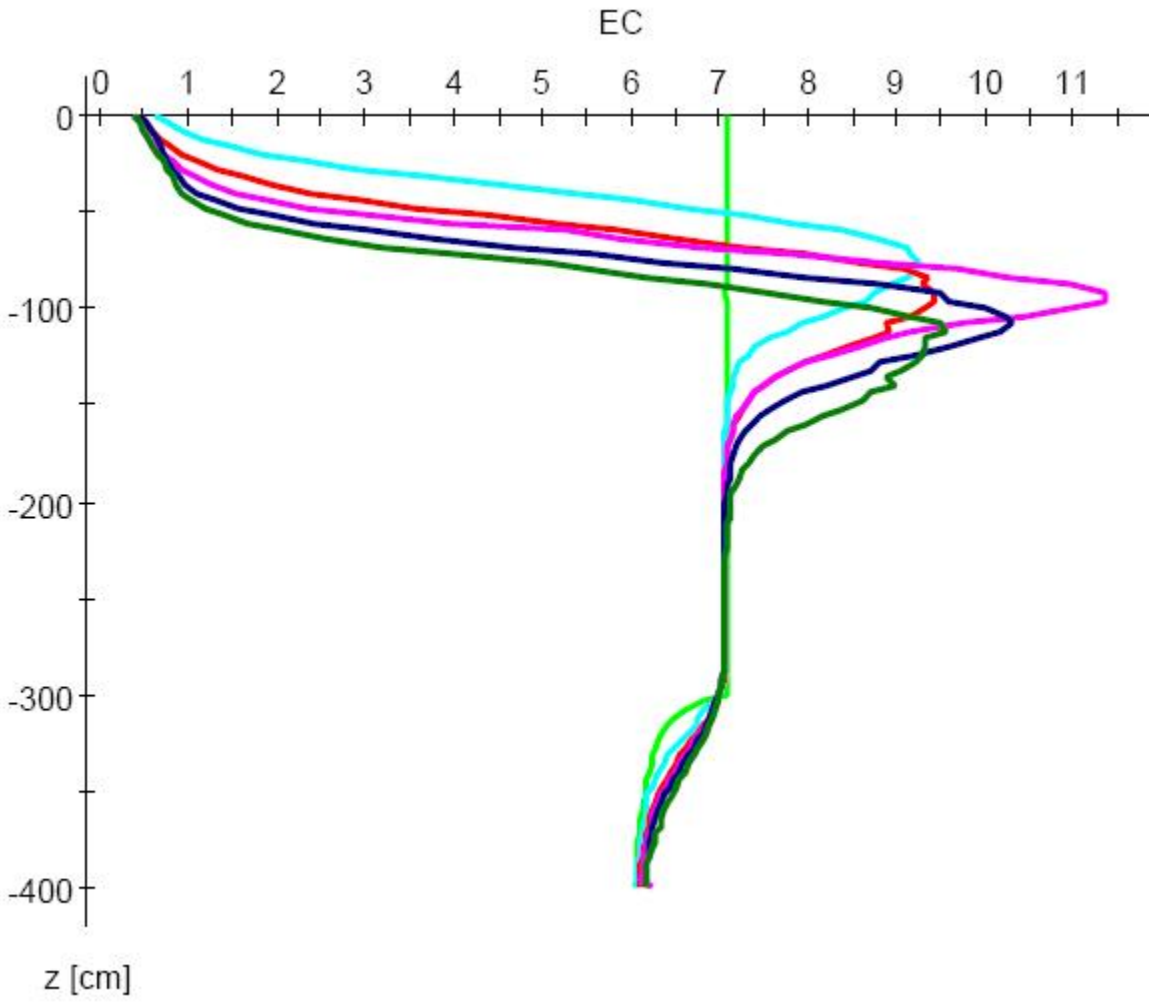
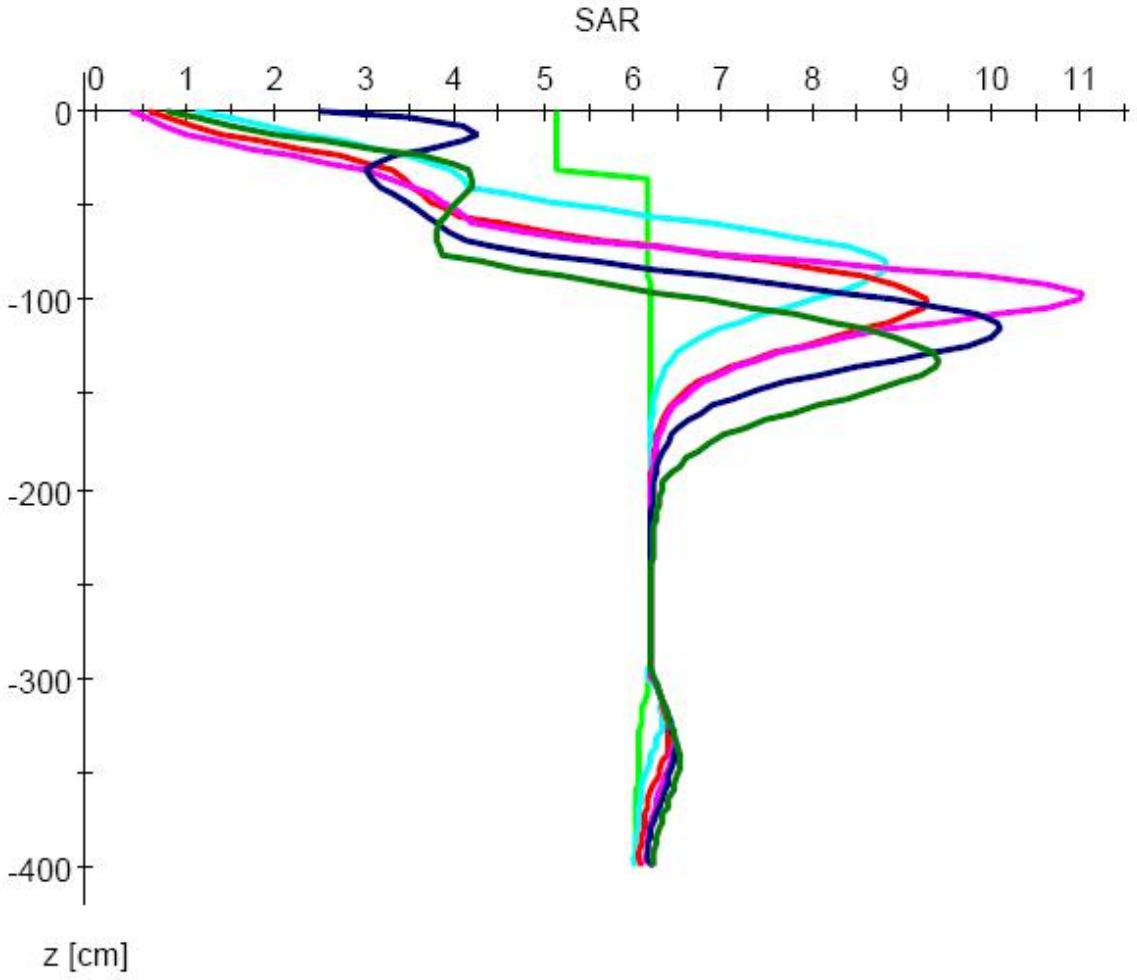


Figure 13. SAR by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



irrigation, salt levels are leaching to lower levels in the soil profile. At time zero of the simulation, the salt levels are about 7.1 dS/m at the surface. As the simulation progresses, the peak levels of salt migrate to depths below the root zone with low salt levels at the surface. At the end of year one the levels found in the surface 100 cm increase from about 0.5 dS/m near the surface to about 9 dS/m at 100 cm.

Following the 5-year simulation, salt levels found in the soil are approximately 0.5 dS/m near the surface and about 0.8 dS/m at 100 cm. Following the 5-year irrigation period, the salt levels found in the soil are expected to further decrease with time due to leaching. The data show that salt levels in root zone are more favorable for plant growth as a result of the irrigation leaching salt from the root zone.

Simulation of changing SAR conditions in the soil profile is provided in Figure 13. Over time, SAR values decrease at the surface and increase with depth. This relationship demonstrates that sodium is leaching preferentially compared to calcium. With time, SAR values are expected to decrease throughout the root zone. As a result, sodic soil conditions will not be an issue for soils irrigated with CBNG-produced water at the Wolff Ranch.

The solution levels of calcium are initially high at the surface in the baseline condition (Figure 14). After one year of irrigation, the solution calcium level at the surface has decreased to about 2 meq/L. At the end of the five-year simulation, calcium levels at

the surface decrease to about 1 meq/L. This decrease probably corresponds to the depletion of gypsum at the surface (Figure 15). Calcium levels are migrating to lower

Figure 14. Solution Calcium Levels by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

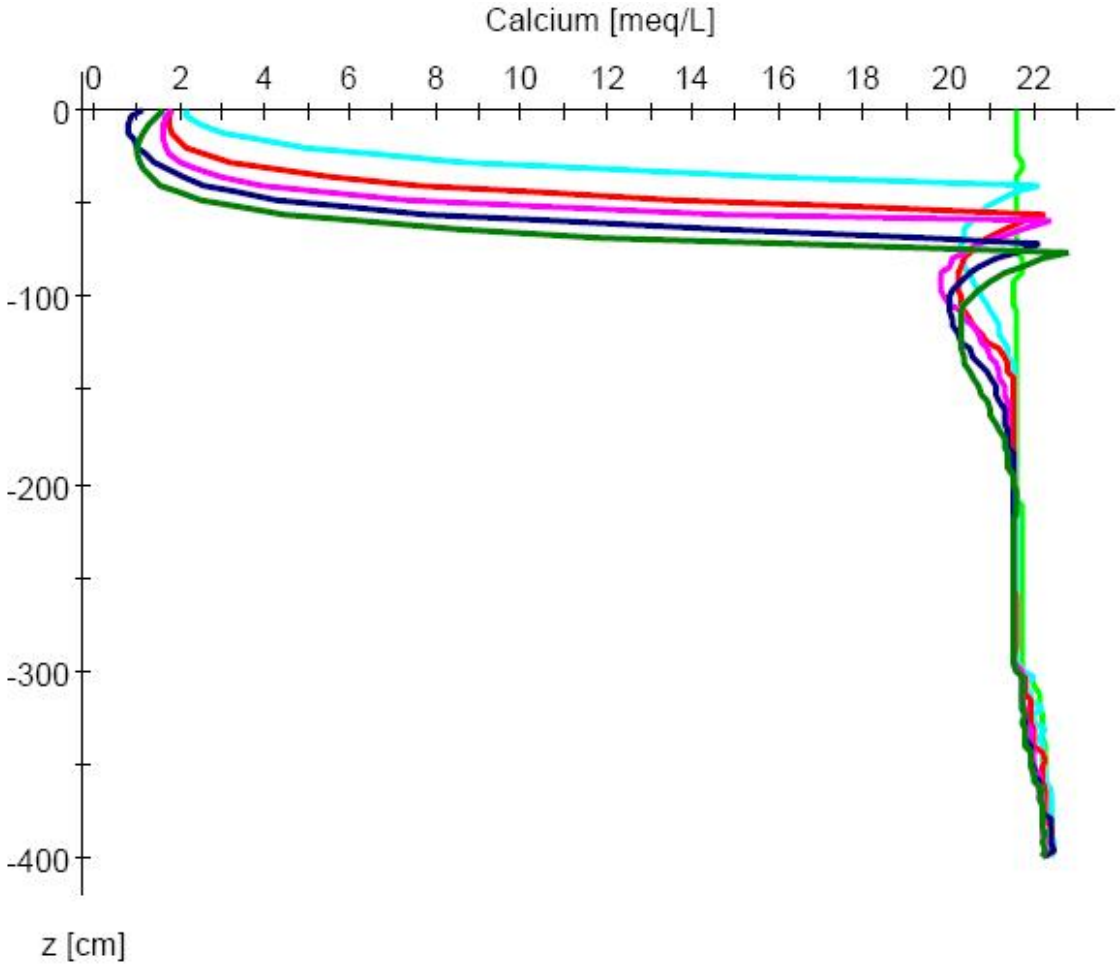
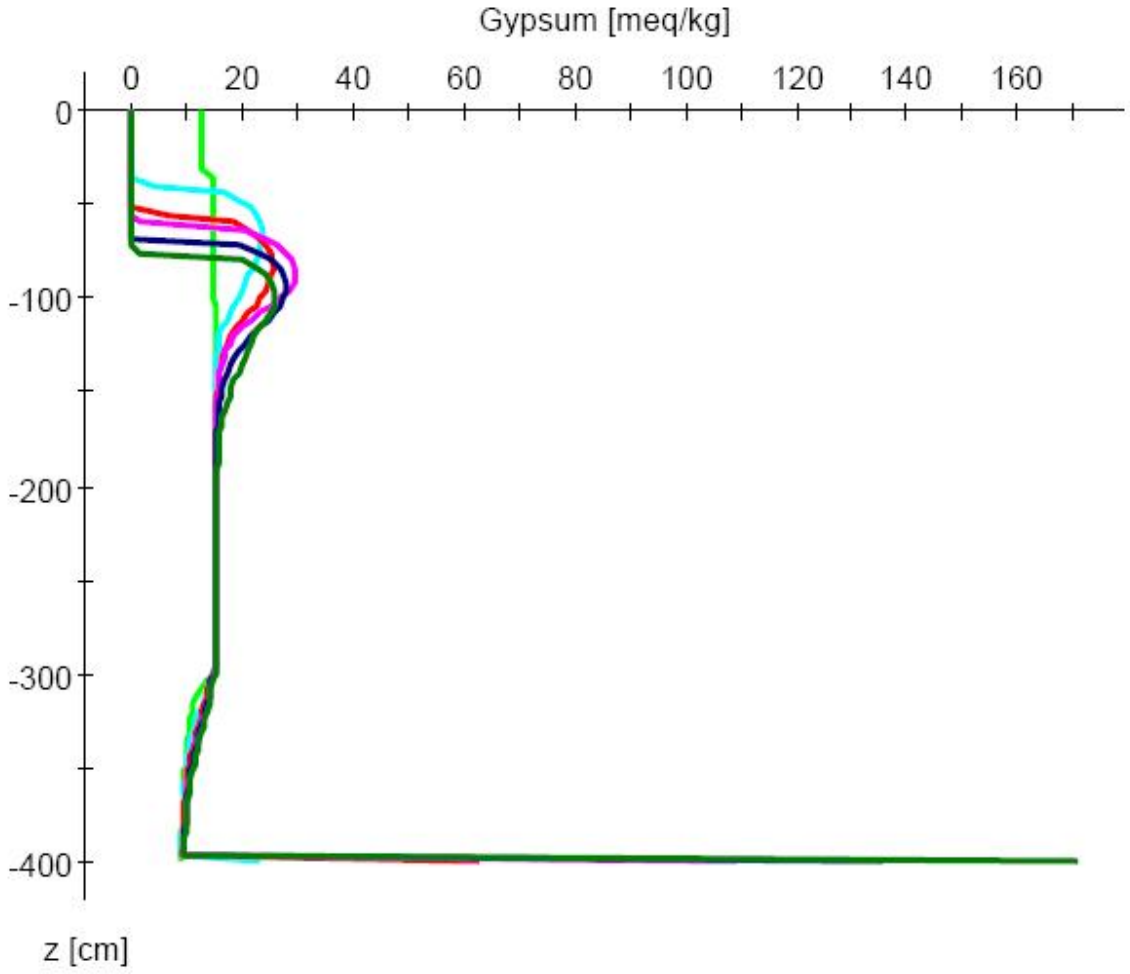


Figure 15. Gypsum Levels by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



levels in the profile due to leaching until solution levels stabilize as the soil solution becomes in equilibrium with calcite at about 1 meq/L.

The high levels of magnesium initially present at the surface tend to migrate to lower levels of the soil profile with continued reductions over the simulation period (Figure 16). Magnesium levels are expected to decline in the root zone with time as it is leached from the root zone if the initial source of the magnesium is not replenished with time.

Sodium levels are relatively high in the natural conditions as noted for year 0 (Figure 17). The high initial levels at the surface are leached to lower levels of the profile with time. Since this element is rather mobile in this system, it will migrate to lower levels in the profile showing accumulation in the depth range near 100 cm. Additional irrigation and natural precipitation beyond the five-year simulation period will result in the continued leaching of sodium to lower levels in the profile.

The concentration levels for sulfate at various soil depths are shown in Figure 18. Sulfate in the soil profile shows a high initial concentration that is leached from the profile with time. After 5 years of irrigation, gypsum is depleted at the surface and the sulfate levels approach zero. The depletion and accumulation zones for sulfate closely resemble those shown for sodium. This relationship can be explained by the fact that sodium and sulfate are present in high concentrations and are relatively mobile in this soil environment. As a result, both constituents should travel with respect to soil water

movement. Since much of the soluble constituents are sodium and sulfate, the EC of the soil solution follows a similar distribution with time.

Figure 16. Solution Magnesium Levels by Soil Depth Over the 5-Year Simulation Period
(green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

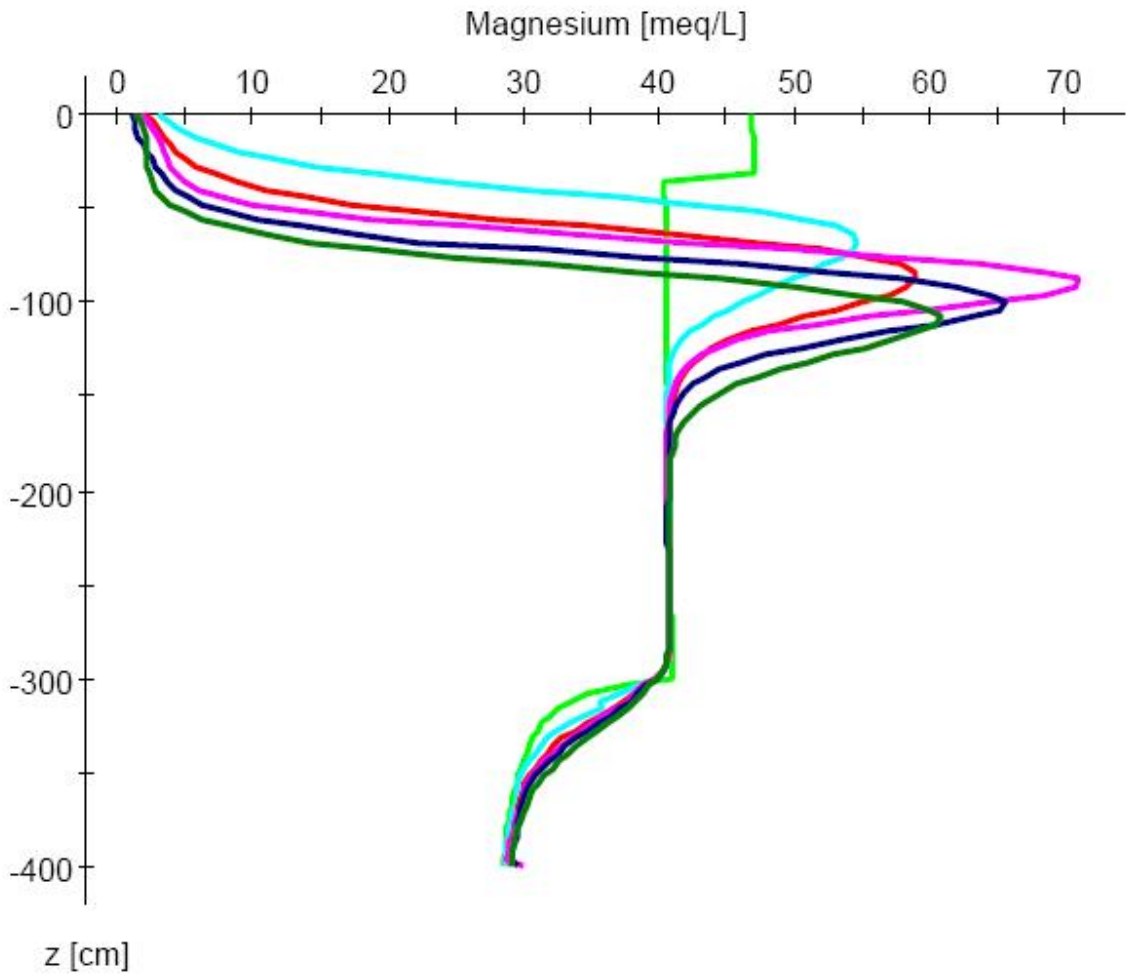


Figure 17. Solution Sodium Levels by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

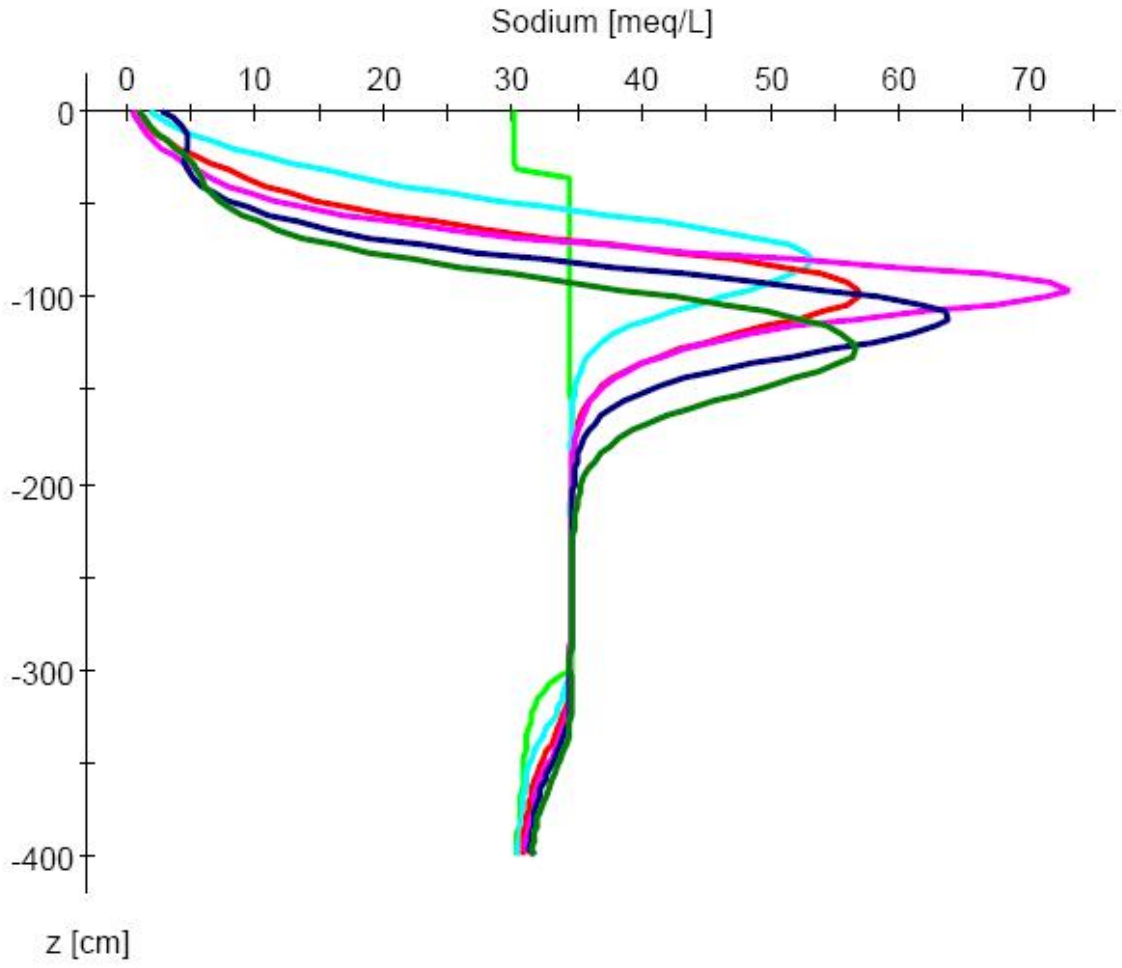
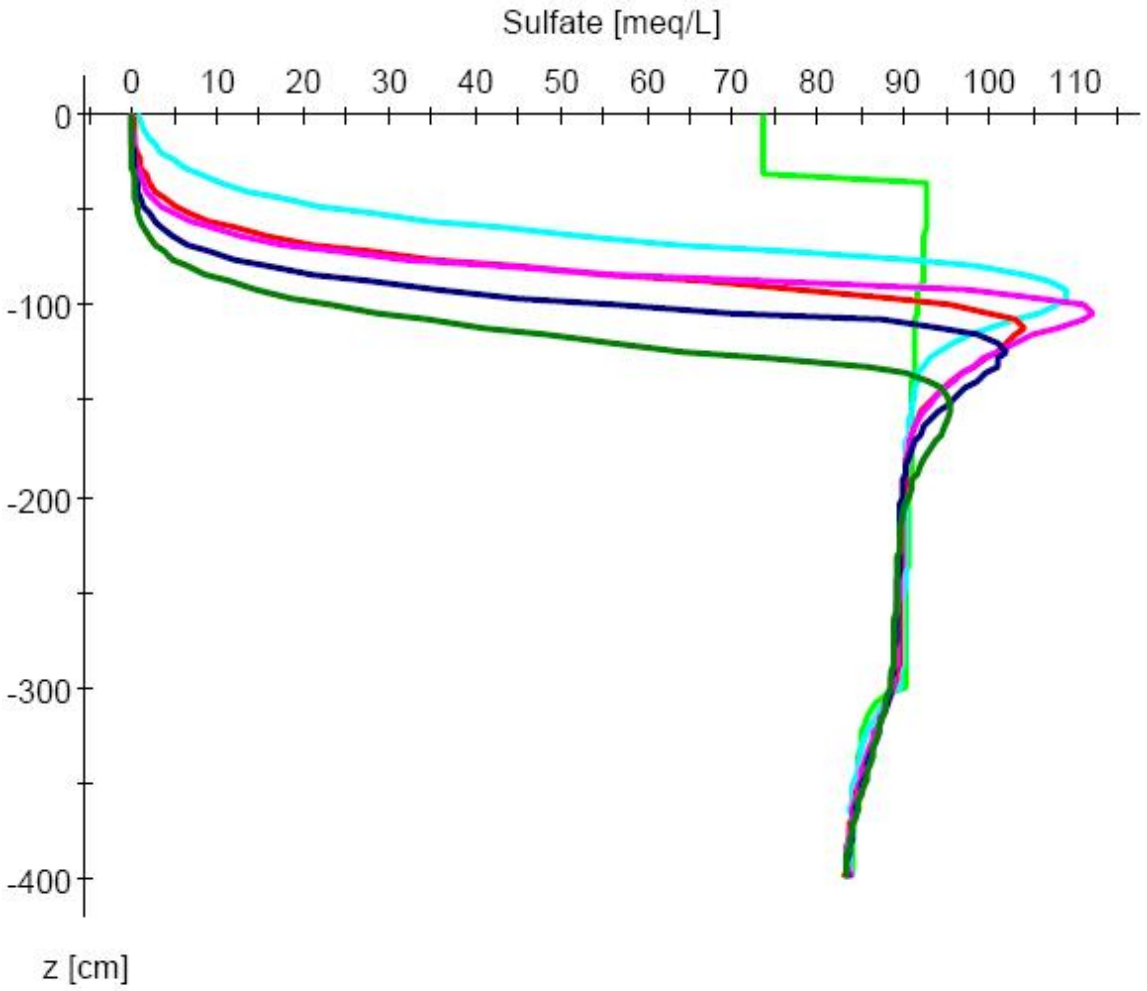


Figure 18. Solution Sulfate Levels by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



In general, the simulation shows that CBNG-produced water increases soil pH throughout the profile with time (Figure 19). The pH would be expected to decrease during periods when CBNG-produced waters are not being applied to the soil. The increased pH of the soil will affect the dissolution chemistry of the soil and the plant nutritional characteristics. However, such changes are not expected to cause significant plant growth problems.

The FAO-SWS model provides an evaluation of how the soil conditions might affect plant growth productivity due to water and salt stress. The simulation assumes that soil fertility and agriculture management are at optimum conditions for crop production. The relative yield simulation is provided in Figure 20. The simulation indicates that the potential crop production is not expected to decrease below 98% under the conditions generated during the 5-year irrigation period with CBNG-produced water under surface irrigation management. The lowest level of plant yield of about 98.3% occurs during year one of the simulation and tends to stabilize at that level to the end of the 5-year simulation. An important physical condition that impacts plant growth potential is the osmotic pressure of the system, which is associated with the amount of work required for a plant to absorb water. The osmotic pressure head of the soil over the 5-year simulation period is shown in Figure 21. The simulation clearly shows that the osmotic pressure decreases in the upper portion of the root zone throughout the evaluation period due to the application of water and the decreased levels of salt found in the

profile. The reduction in osmotic pressure head of the due to irrigation with CBNG-produced water would improve plant growth.

Figure 19. pH by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

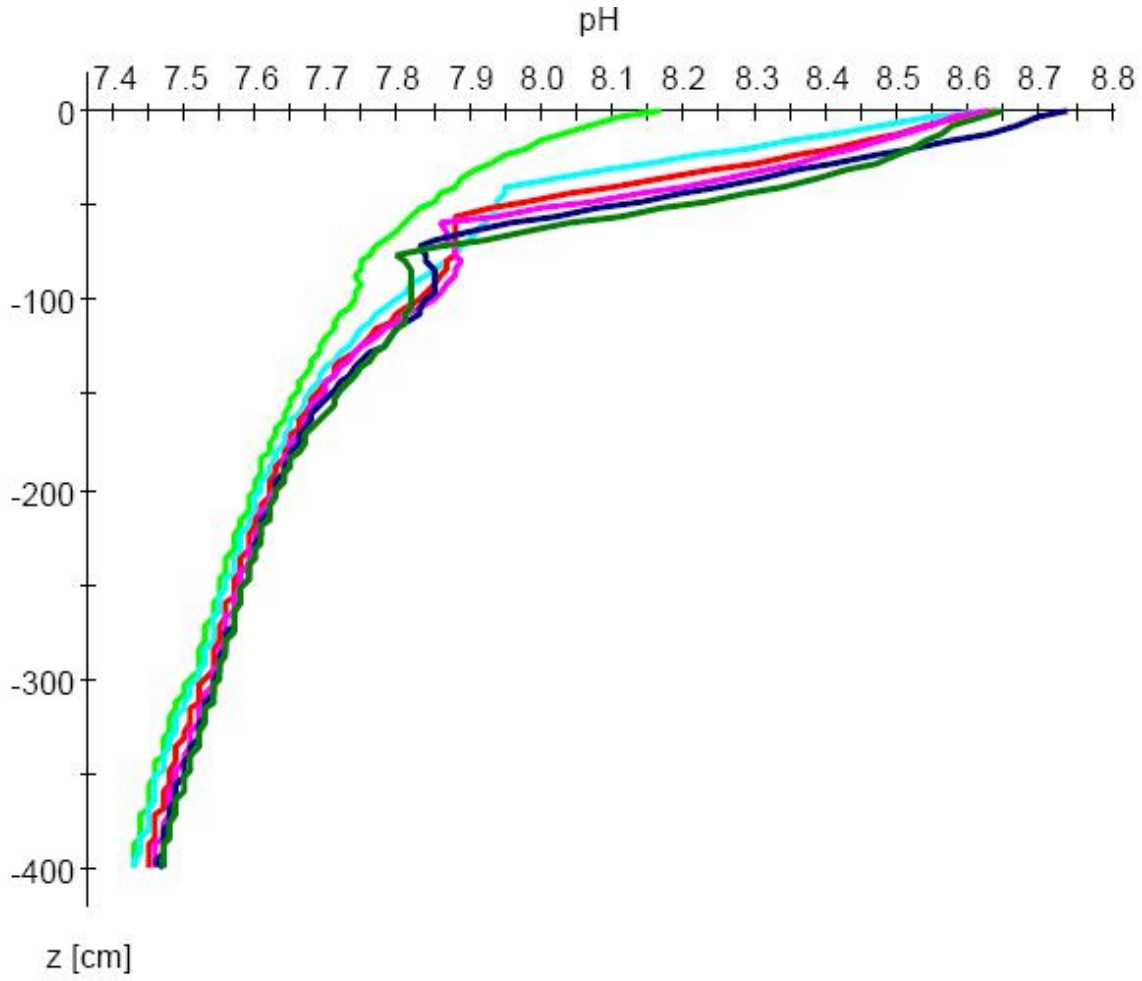


Figure 20. Relative Crop Yield Over the 5-Year Simulation Period

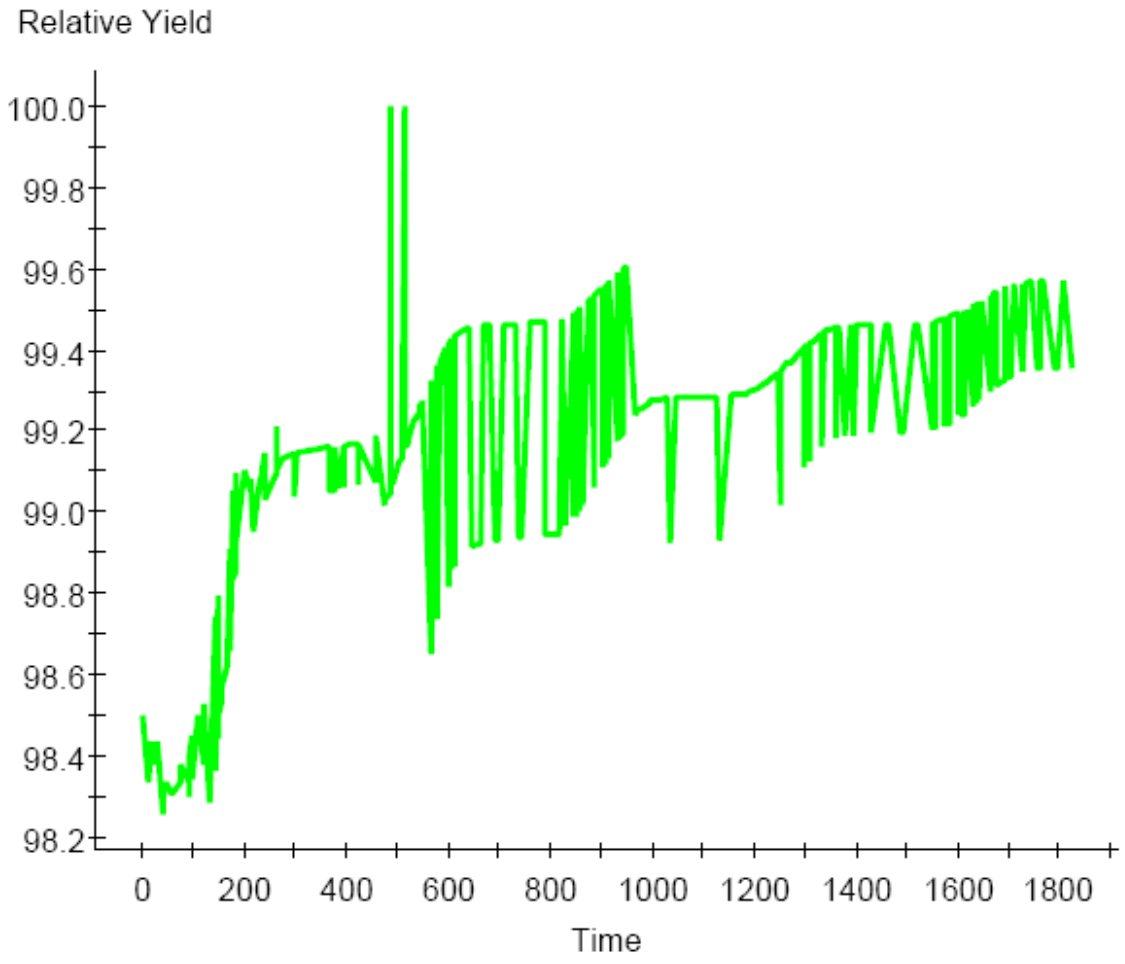
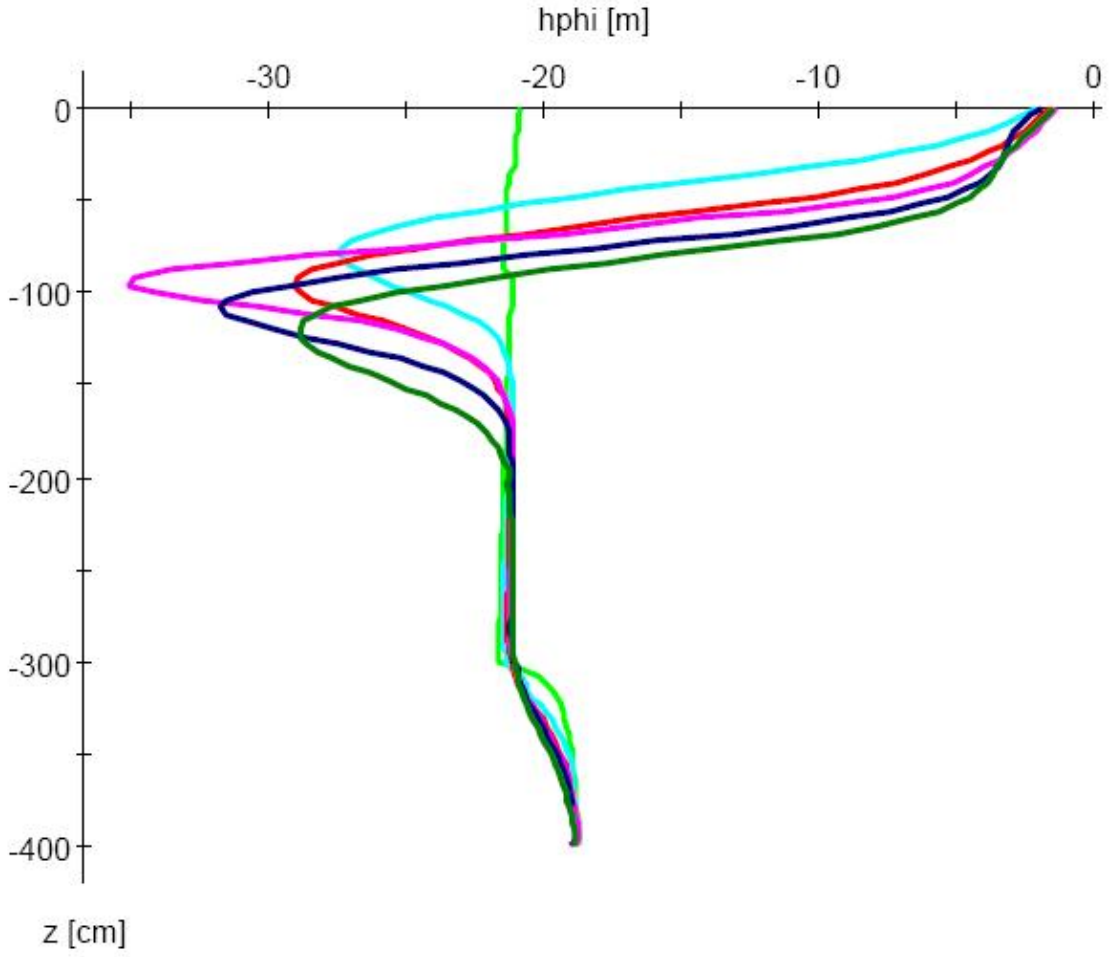


Figure 21. Osmotic Pressure Head by Soil Depth Over the 5-Year Simulation Period (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



The FAO-SWS simulation for the Wolff Ranch demonstrates that using CBNG-produced water for irrigation purposes would not cause negative impacts to the soil and the surrounding environment. Salts initially in the root zone will be leached and should concentrate below the root zone. Sodium and sulfate are expected to move deeper in the soil profile below the root zone. Similar findings for each of the parameters discussed were observed for both the subirrigated fields evaluated along Hay Creek. The simulation associated with the Rule Ranch is not presented in the body of the report but was placed in the Appendix L in graphic form. The significant outcomes of the simulation are presented in the next section.

Eric Rule Ranch

The Eric Rule Ranch is located upstream of the Wolff Ranch on Hay Creek. No managed flood irrigation currently exists on this land but the existence of impoundments equipped with gated outflow systems, channels, and dikes reflects historic irrigation. A portion of the field is also subirrigated and currently supports a hay crop containing several grass species.

ER1 was sampled at seven sites by depth increments to a total depth of 4 feet. The field was larger than 10 acres and characterized with a single soil series. The chemical analyses associated with the samples collected at ER1 were similar to the results found in the previous fields located along Hay Creek and Horse Creek. The baseline soil conditions are saline with EC values for all samples analyzed averaging 6.7 dS/m with a range from 3.51 dS/m to 8.77 dS/m. The EC value associated with the surface foot

was 3.51 dS/m and the highest EC found in the soil profile was 8.77 dS/m located in the 3 to 4-feet depth interval.

SAR values characterizing field ER1 are non-sodic with values ranging from 0.4 to 2.6. Such conditions should not cause any issues with soil structure.

The physical and chemical characteristics collected from the soil sampled at ER1 were input into the FAO-SWS irrigation model as discussed above. Each sample site was simulated separately because of the differences in baseline soil chemistry. The results of the irrigation model are very similar to those identified previously.

GEOCHEMICAL INTERACTIONS OF THE HAY CREEK ALLUVIAL GROUNDWATER AND THE CBNG-PRODUCED WATER

The evaluations made for the irrigated sites in the Horse Creek watershed are assumed also to apply to the Hay Creek drainage. The geology of the area and the soils occupying the subirrigated fields are very similar. Therefore, the alluvial groundwater present in the Hay Creek drainage is expected to be similar to that described in the alluvium associated with Horse Creek.

COMPLIANCE SUMMARY

The agricultural and livestock compliance summaries for Hay Creek are very similar to those presented for Horse Creek in Part 1 of this report. The same three analytical techniques were utilized to evaluate the parameters presented for Hay Creek sample

data. The results show that the CBNG-produced water would have a positive impact for the utilization of agricultural lands in the Hay Creek drainage. The CBNG-produced water is nonsaline and nonsodic. Based on the EC/SAR relationship as shown in Figure 1, the low salt concentrations of the water would have a slight tendency to cause a reduction in infiltration. However, high salt levels currently characterizing the two subirrigated agricultural fields in the Hay Creek watershed will provide a large capacity for maintaining high salt levels in the soil solution by weathering processes, thus keeping the system flocculated.

The irrigation simulation shows that a traditional managed irrigation system would provide positive results. The salt levels present in the soils during baseline conditions are shown to improve substantially with salts leaching from the root zone. In addition, non-sodic conditions are maintained at the soil surface and in the root zone maintaining adequate hydraulic conductivity. Plant growing conditions are improved over baseline conditions as the osmotic pressure head of the soil system is much reduced due to irrigation with the CBNG-produced water.

The geochemical evaluation of mixing the CBNG-produced water with alluvial groundwater provides a positive impact associated with the discharge of such water. The resultant alluvial water is characterized with lower EC and SAR values compared to the baseline alluvial water. The evaluation of the water chemistry of the mixed water

with regard to Figure 1 indicates that the water fits in the “no reduction in infiltration” portion of the graph.

These results provide a strong basis to support approving the discharge of the CBNG-produced water, and establishing irrigation water quality limits in excess of the default irrigation water quality limits for Hay Creek.

Conclusion

The Section 20 evaluation for Hay Creek provides strong evidence that irrigated agricultural lands (flood or subirrigated) can be safely irrigated with CBNG-produced waters characterized with SAR values up to 25 and with EC values of 4 dS/m or higher. The EC values of CBNG-produced water will have little influence on soil EC values since the soils are characterized with high salt levels in the baseline condition.

PART 3: SQUAW CREEK WATERSHED

Squaw Creek is a tributary of Horse Creek as shown on the Overview Map (Plates 3 and 6). Squaw Creek was evaluated separately from Horse Creek, but with the same methodology and guidance as described in the Horse Creek Introduction and Methodology Sections. The results of the analysis for Squaw Creek are summarized in the following sections.

TWENTY MILE LAND COMPANY – JOHN DALY, OWNER

The Twenty Mile Land Company owns the area that includes the confluence of Squaw Creek with Horse Creek. Access to the land for field evaluations was not provided by John Daly. Observations made from adjacent areas indicate that some of the land located at the confluence of Squaw Creek with Horse Creek may be subirrigated agricultural land. This area is very near Horse Creek so the data collected from Horse Creek may provide an indication of the site conditions and how CBNG-produced water would potentially impact the field.

MARSHA POWNALL RANCH

The Marsha Pownall Ranch occupies a short section of Squaw Creek upstream of the Twenty Mile Land Company Ranch. The area was evaluated and no managed irrigation or subirrigated agricultural lands were found, and field sampling was not conducted. The topography of the area was photo documented with the photo points

(OT - A through C) shown on the Overview Map (Plate 6). The photos are presented in Appendix C.

LEON OEDEKOVEN FAMILY TRUST LAND

Leon Oedekoven Family Trust Land is located upstream of the Marsha Pownall Ranch properties. The area does not have any flood or subirrigated agricultural lands, and field sampling was not conducted. The topography of the area was photo documented with the photo points (OT - A through E, Appendix C) shown on the Overview Map (Plate 6).

JAMES WOLFF RANCH (SOUTH SQUAW CREEK)

The James Wolff Land is located between on the headwaters of a side steam located upstream of the Leon Oedekoven Family Trust Land. No flood or subirrigated agricultural lands were found and field sampling was not conducted. The topography of the area was photo documented with the photo points (JW-A through C, Appendix C) shown on the Overview Map (Plate 6).

DUANE OEDEKOVEN TRUST LAND

Duane Oedekoven Trust Land is located upstream of the Leon Oedekoven Ranch Properties. No flood or subirrigated agricultural lands were found and field sampling was not conducted. The topography of the area was photo documented with the photo points (OT - D through I, Appendix C) shown on the Overview Map (Plate 6).

DON BROWN FAMILY TRUST

Don Brown Family Trust Land is located upstream of the Duane Oedekoven Trust Land. No flood or subirrigated agricultural lands were found and field sampling was not conducted. The topography of the area was photo documented with the photo points (DO - A through F, Appendix C) shown on the Overview Map (Plate 6).

These results provide a strong basis to support approving the discharge of the CBNG-produced water, and establishing irrigation water quality limits in excess of the default irrigation water quality limits for Squaw Creek.

Conclusion

The site evaluation concluded that no irrigated or subirrigated agricultural lands were found in the Squaw Creek watershed. As a result CBNG-produced waters characterized with SAR values up to 25 and with EC values of 4 dS/m or higher can be safely discharged in this drainage. The impact of such waters on non-agricultural lands in this drainage should not be negatively impacted based on the Section 20 evaluation for other smaller watersheds in the Horse Creek watershed.

PART 4: SPRING CREEK WATERSHED

Spring Creek is a tributary of Horse Creek as shown on the Overview Map (Plates 2, 3 5, and 6). Spring Creek was evaluated separately from Horse Creek, but with the same methodology and guidance as described in the Horse Creek Introduction and Methodology Sections. The results of the analysis for Spring Creek are summarized in the following sections.

RESULTS - BASELINE

The information collected from the baseline evaluations includes soil profile descriptions and soil chemistry characterization. Baseline soil chemistry provides an indication of how a soil will react to irrigation with CBNG-produced water and provides evidence of the water quality that has impacted the soil from prior irrigation management or from natural subirrigation.

The soil profile descriptions for each sampling site are presented in Appendix G. The soil profiles sampled in the lower reaches of Spring Creek resemble the soils found in the Horse Creek and Hay Creek drainages. Generally, the soils found in Spring Creek were characterized with an A, Bw, Bk, and C horizon sequence usually with multiple Bk and C horizons.

The chemical analyses of the Spring Creek soil samples collected are presented in Table 11. Two sites were sampled in the Spring Creek drainage. Samples collected

from subirrigated areas in the Spring Creek watershed show high salt levels often greater than 4 dS/m, which is considered to be saline as defined in USDA Handbook 60

Table 11. Soil Analysis for Samples Collected in the Spring Creek Watershed

Sample ID	Depth Interval (ft)	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR	Sand %	Silt %	Clay %	Texture
Marsha Pownall Ranch													
MP2	0-1	7.4	54.3	2.07	2.7	14.1	10.9	2.48	0.7	28	45	27	Clay Loam
MP2	1-2	7.9	52.4	7.94		22.8	55.6	39.6	6.3	20	47	33	Clay Loam
MP2	2-3	8	55.8	11.40		23.3	85.1	55.8	7.6	22	46	32	Clay Loam
MP2	3-4	8.1	55.4	9.76		22.1	74.2	50.7	7.3	24	45	31	Clay Loam
MP2	4-5	8	55.4	8.20		21.8	57.9	40.5	6.4	26	45	29	Clay Loam
MP2	5-6	7.9	54.4	6.74		21.4	45.7	28.3	4.9	22	42	36	Clay Loam
MP8	0-1	7.1	57.8	0.88	2.9	3.58	3.31	1.15	0.6	18	50	32	Silty Clay Loam
MP8	1-2	7.5	54.8	3.96		20.4	22.5	8.20	1.8	14	49	37	Silty Clay Loam
MP8	2-3	7.8	54.5	6.71		20.0	43.4	24.3	4.3	18	46	36	Silty Clay Loam
MP8	3-4	7.9	58.8	8.05		16.2	55.1	33.0	5.5	10	46	44	Silty Clay
MP8	4-5	7.9	62.2	9.01		17.9	67.6	41.1	6.3	10	50	40	Silty Clay
MP8	5-6	7.9	54.3	9.36		17.7	67.7	41.5	6.4	24	44	32	Clay Loam

(1959). The average EC value for the samples collected at the MP2 and MP8 subirrigated sites were 7.69 dS/m and 6.33 dS/m, respectively. EC values by one-foot depth increments for the MP2 site were 2.07 dS/m (0 to 1-foot depth increment), 7.94 dS/m (1 to 2 feet), 11.40 dS/m (2 to 3 feet), and 9.76 dS/m (3 to 4 feet), 8.20 (4 to 5 feet), and 6.74 (5 to 6 feet), while samples collected at the MP8 site were 0.88 dS/m (0 to 1 foot), 3.96 dS/m (1 to 2 feet), 6.71 dS/m (2 to 3 feet), 8.05 dS/m (3 to 4 feet), 9.01 (4 to 5 feet), and 9.36 (5 to 6 feet).

The average SAR for soil samples collected from the two subirrigated sites sampled in the Spring Creek drainage were 5.5 and 4.2 for MP2 and MP8, respectively. SAR values associated with MP2 were 0.7, 6.3, 7.6, 7.3, 6.4 and 4.9 for the 1-foot depth increments to the total depth sampled of 6 feet. SAR values associated with MP8 were 0.6, 1.8, 4.3, 5.5, 6.3 and 6.4 for the 1-foot depth increments to the total depth sampled of 6 feet. The SAR values are non-sodic and would not be expected to be associated with sodic soil conditions.

Elemental toxicities are not expected to result from soil conditions present at the Spring Creek subirrigated agricultural sites sampled.

IMPACT ANALYSIS: SOILS, ALLUVIAL GROUNDWATER AND VEGETATION

Soils

The chemical evaluations of the soils associated with the subirrigated agricultural lands along Spring Creek indicate that both sites possess non-saline conditions in the

surface foot and saline conditions in the 1 to 5-foot depth increment (Table 11). However, most native vegetation can often tolerate these high levels of salt due to their genetic disposition. The only species of concern at such salt levels is alfalfa. Alfalfa was found at both subirrigated fields sampled in the Spring Creek watershed, but it was scattered.

As proposed in previous parts of this report, the following evaluation was compiled to determine if the CBNG-produced water would impact the current soil conditions found in the Spring Creek drainage, if such water were used to irrigate soils or discharged into the alluvium, impacting current subirrigated conditions or resulting in subirrigation conditions. The same model was used to simulate the long-term effects of using CBNG-produced water to irrigate the soil present at MP2 and MP8 located along Spring Creek.

Results of the EC and EC/ SAR Comparison

1. The use of CBNG-produced water for irrigation purposes would **decrease** the salt levels in the soil profiles and thus enhance plant growth potential.

2. The CBNG-produced water is nonsaline and nonsodic. Based on the EC/SAR relationship (Figure 1), the low salt concentrations of the water would have a slight tendency to cause a reduction in infiltration. Slight tendency was used since the EC/SAR intersect is either close to the middle or below the middle of this zone of the graph.

3. The high salt levels currently characterizing most of the irrigated soils in the Spring Creek watershed will provide a large capacity to replenish salt to the soil solution by weathering processes. Therefore, although the application of CBNG-produced water, precipitation and snowmelt will have a tendency to remove salts at the surface promoting clay dispersion, weathering of soluble minerals will occur simultaneously maintaining relatively high salt levels preventing clay dispersion.

4. The salt generated from the weathering process is expected to be approximately 5 meq/L, which has been shown to keep soils flocculated with SAR values of near 30.

5. CBNG-produced water should not impact the hydraulic conductivity of irrigated soils. The high salinity levels of the soils will overwhelm any increased SAR levels that might result while irrigating with the CBNG-produced water.

6. The relationships shown in Figure 1 were developed by Ayers and Westcot (1985) and Hanson *et al*. (1999) for soils found in California that had been irrigated for crop production. Such soil conditions do not exist in the subirrigated agricultural lands along Horse Creek. As a result, soils in the PRB and in the Horse Creek watershed, which contain high levels of soluble salts that will weather during the irrigation process, will likely react much differently to irrigation water containing relatively low salt levels. As a result, CBNG-produced water used for surface application could conceivably contain higher sodium levels without causing a detrimental impact to agricultural lands.

7. The EC/SAR soil chemistry discussed in this section provides a strong basis for establishing an SAR limit of up to 25 without causing soil infiltration problems in agricultural lands irrigated with CBNG-produced water.

FAO-SWS MODEL SIMULATIONS

Model simulations were conducted for two sampling sites located at the Marsha Pownall Ranch located in the Spring Creek near its confluence with Horse Creek. Separate evaluations were made for each site based on the information collected during the field sampling program. The soils sampled in the lower reaches of Spring Creek closely resemble each other and compare well to soils evaluated along Horse Creek. The greatest difference is that MP2 is characterized with a clay loam surface soil texture and MP8 has a silty clay loam surface texture. The results of the model simulation for the subirrigated site are presented in the body of the report while the detailed diagrams of the simulations are presented in Appendix L.

Photo points associated with other landowners along Spring Creek documenting the landscape along the reaches of Spring Creek that are not associated with managed irrigation or subirrigated agricultural lands are shown on the Overview Map (Plates 2, 3, 5 and 6). The corresponding photos are included in Appendix C. The following evaluation is based on individual landowners starting from the confluence of Spring Creek with Horse Creek progressing to the upper reaches of the Spring Creek watershed.

Marsha Pownall - MP2

The Marsha Pownall Ranch is located at the confluence of Spring Creek with Horse Creek and extends several miles upstream. One site was found to be subirrigated and appeared to have berms that might act to hold water causing flood irrigation.

FAO-SWS MODEL RESULTS FOR POWNALL – MP2

(Detailed diagrams are presented in Appendix L)

- High initial root zone salt levels are leached due to surface irrigation improving plant growth conditions. An EC value of about 2.5 dS/m (model baseline conditions) at the surface decreased to about 0.5 dS/m after the first irrigation season. Salt levels tended to increase with depth as the high salt levels initially present at the surface were leached to lower depths in the root zone. With additional irrigation and precipitation, the salt levels would be expected to leach from the root zone.
- SAR values decrease at the surface from about 7.36 to about 1 after 5 years of irrigation. SAR values tend to increase with depth but tend to decrease with time due to leaching of sodium.
- pH values tend to increase from about 8.4 at baseline conditions to about 8.65 following the first year of irrigation. In subsequent years of irrigation, the pH tends to stabilize in the 8.6 to 8.7 range. The increased pH values are not expected to cause significant problems with plant productivity. Following the irrigation, the pH is expected to decrease to baseline conditions.

- Relative yield values ranged between 99 and 100% during the 5-year simulation. Plant growing conditions are not impacted.
- The simulation clearly shows that the osmotic pressure decreases in the upper portion of the root zone throughout the evaluation period due to the application of water and the decreased levels of salt found in the profile. The reduction in osmotic pressure head due to irrigation with CBNG-produced water should enhance plant growth.

FAO-SWS MODEL RESULTS FOR POWNALL – MP8

The subirrigated field MP8 is located upstream of MP2 as noted on the Overview Map (Plate 2). The information collected in the field (Table 11) was used with the water quality information characterizing the CBNG-produced water. The physical and chemical characteristics collected from the soil sampled at MP8 were input into the FAO-SWS irrigation model as discussed above. Each sample site was simulated separately because of the differences in baseline soil chemistry. The results of the irrigation model are similar to those identified for site MP2. The results are presented as a set of figures in Appendix L.

Marsha Pownall Ranch

Several side drainages to Spring Creek (west and slightly south of MP8) are projected to contain CBNG-produced water outfalls. The area was evaluated for flood irrigation or subirrigated agricultural lands, and none was noted. Field sampling was not conducted. The topography of the area was photo documented with the photo points (MP A through C) shown on the Overview Map (Plates 2 and 3) with the photos included in Appendix C.

Paulette Parks Ranch

The Paulette Parks Ranch is located along Spring Creek upstream of the Marsha Pownall Ranch and downstream of the State of Wyoming land. The Parks Ranch encompasses many side stream channels that are associated with CBNG-produced water outfalls. The area was evaluated and found not to have any flood irrigation or subirrigated agricultural lands, and field sampling was not conducted. The topography of the area was photo documented with the photo points (PPA through I) shown on the Overview Map (Plates 2, 5 and 6).

State of Wyoming Lands

The State of Wyoming land is located upstream of the Paulette Parks Ranch and downstream of Brug Land and Livestock. The area was evaluated and found not to have any flood irrigation or subirrigated agricultural lands, and field sampling was not conducted. The area was photo documented with a photo point taken at DB-A, shown on the Overview Map (Plate 6) with the photos presented in Appendix C.

Brug Land and Livestock

The Brug Land and Livestock land is upstream of the State of Wyoming land and downstream of the Robert Held Ranch. The area was evaluated and found not to have any flood irrigation or subirrigated agricultural lands, and field sampling was not conducted. The area was photo documented with the photo points (RH A through C) shown on the Overview Map (Plate 5) with the photos presented in Appendix C.

Robert Held Ranch

The Robert Held Land is upstream of the Brug Land and Livestock property. The area was evaluated and found not to have any flood irrigation or subirrigated agricultural lands, and field sampling was not conducted. The area was photo documented with the photo points (RH A through C) shown on the Overview Map (Plate 5) with the photos presented in Appendix C.

Curtis Elliott Trust

The Curtis Elliot Trust Land is located upstream of the Paulette Parks ranch on a side drainage to the north. The area was evaluated and found not to have any flood irrigation or subirrigated agricultural lands, and field sampling was not conducted. The topography of the area was photo documented with the photo points (PP-G, PP-H, and PP-I) shown on the Overview Map (Plates 5 and 6) with the photos presented in Appendix C.

Mary Jane Harris Ranch

The Mary Jane Harris Land is located to the north of the State of Wyoming land and the Paulette Parks Ranch. The area was evaluated and found not to have any flood irrigation or subirrigated agricultural lands, and field sampling was not conducted.

COMPLIANCE SUMMARY

The agricultural and livestock compliance summaries for Spring Creek are very similar to those presented for Horse Creek in Part 1 of this report. The same three evaluation techniques were utilized to evaluate the parameters presented for Spring Creek sample

data. The results show that the CBNG-produced water would have a positive impact for the utilization of agricultural lands in the Spring Creek drainage. The CBNG-produced water is nonsaline and nonsodic. The EC/SAR relationship is consistent with those areas discussed above.

The irrigation simulation represents a traditional managed irrigation system with positive results for Field MP2 and MP8. The baseline soil salt levels are shown to improve substantially with salts leaching from the root zone. In addition, non-sodic conditions are maintained at the soil surface and in the root zone maintaining an adequate hydraulic conductivity. Plant growing conditions are improved over baseline conditions as the osmotic pressure head of the soil system is much reduced due to irrigation with the CBNG-produced water.

The geochemical evaluation of mixing the CBNG-produced water with alluvial groundwater illustrates a positive impact associated with the discharge of such water. The resultant alluvial water is characterized with lower EC and SAR values compared to the baseline alluvial water. The evaluation of the water chemistry of the mixed water with regard to Figure 1 indicates that the water fits in the “no reduction in infiltration” portion of the graph.

These results provide a strong basis to support approving the discharge of the CBNG-produced water, and establishing irrigation water quality limits in excess of the default irrigation water quality limits for Spring Creek.

Conclusion

The Section 20 evaluation for Spring Creek, agricultural fields MP2 and MP8, provides strong evidence that irrigated agricultural lands (managed or natural irrigation methods) can be safely irrigated or impacted with CBNG-produced waters characterized with SAR values of up to 25 and with EC values of 4 dS/m or higher. The EC values of CBNG-produced water will have little influence on soil EC values since the soils are characterized with high salt levels in the baseline condition.

PART 5: DRY GULCH CREEK

Dry Gulch Creek is a tributary of Horse Creek as shown on the Overview Map (Plates 8 and 10). Dry Gulch Creek was evaluated separately from Horse Creek, but with the same methodology and guidance as described in the Horse Creek Introduction and Methodology Sections. The results of the analysis for Dry Gulch Creek are summarized in the following sections.

STATE OF WYOMING

Flood irrigated and/or subirrigated agricultural lands were not present in the State of Wyoming lands located at the confluence of Dry Gulch with Horse Creek. As a result field sampling was not conducted. Photos taken at BS-A and at SSA identified on the Overview Map (Plates 8 and 10) show much of this confluence area. SSA is presented in Appendix C.

SORENSON RANCH COMPANY

The Sorenson Ranch occupies the upper reaches of Dry Gulch. The area was evaluated and found not to have any managed irrigation or subirrigated agricultural lands. The landowner indicated that the groundwater was about 30 feet below ground surface. If true, no subirrigation could occur. Field sampling was not conducted. The area was photo documented with the photo points (SR-A and SR-B see Appendix C) and shown on the Overview Map (Plate 10).

WILLIAM HENSLEY TRUST LAND

The William Hensley land is located on a drainage that flows into Dry Gulch upstream of the State of Wyoming land. For the same reasons stated above, no sampling was conducted. The area was photo documented with the photo points (BS-A see Appendix C) and shown on the Overview Map (Plate 10).

COMPLIANCE SUMMARY

The agricultural and livestock compliance summaries for Dry Gulch Creek are identical to those presented for Horse Creek in Part 1 of this report. The same three evaluation techniques were utilized to analyze Dry Gulch Creek. Since no irrigated areas were identified along Dry Creek Gulch, the results of the Horse Creek analysis apply directly for Dry Creek Gulch. Please refer to the Horse Creek Section of the report for the summary of results.

These results provide a strong basis to support approving the discharge of the CBNG-produced water, and establishing irrigation water quality limits in excess of the default irrigation water quality limits for Dry Gulch Creek.

Conclusion

The Section 20 evaluation for Dry Gulch Creek provides strong evidence that irrigated agricultural lands (managed or natural irrigation methods) can be safely irrigated or impacted with CBNG-produced waters characterized with SAR values of up to 25 and with EC values of 4 dS/m or higher. The EC values of CBNG-produced water will have

little influence on soil EC values since the soils are characterized with high salt levels in the baseline condition.

PART 6: RUFF DRAW

Ruff Draw is a tributary of Horse Creek as shown on the Overview Map (Plate 8). Ruff Draw was evaluated separately from Horse Creek, but with the same methodology and guidance as described in the Horse Creek Introduction and Methodology Sections. The results of the analysis for Hay Creek are summarized in the following sections.

DONNA TARVER TRUST

The Donna Tarver Trust occupies the lower portion of Ruff Draw from the confluence with Horse Creek to the upper reaches, which are on the Roy Knutson Ranch. No field sampling was necessary. The area was photo documented with the photo points (lower reaches = DT - A and State -1; area near Highway 14-16 = DT-B presented in Appendix C) shown on the Overview Map (Plate 8).

ROY KNUTSON RANCH

The Roy Knutson land is located in the upper reaches of Ruff Draw upstream of Donna Tarver. Field sampling was not necessary. The area was photo documented with photo point (RK-A see Appendix C) shown on the Overview Map (Plate 8).

COMPLIANCE SUMMARY

The agricultural and livestock compliance summaries for Ruff Draw are identical to those presented for Horse Creek in Part 1 of this report. The same three evaluation techniques were utilized to analyze Ruff Draw. Since no irrigated areas were identified

along Ruff Draw, the results of the Horse Creek analysis apply directly for Ruff Draw. Please refer to the Horse Creek Section of the report for the summary of results.

These results provide a strong basis to support approving the discharge of the CBNG-produced water, and establishing irrigation water quality limits in excess of the current irrigation water quality limits for Ruff Draw.

Conclusion

The Section 20 evaluation for Ruff Draw provides strong evidence that irrigated agricultural lands (managed or natural irrigation methods) can be safely irrigated or impacted with CBNG-produced waters characterized with SAR values of up to 25 and with EC values of 4 dS/m or higher. The EC values of CBNG-produced water will have little influence on soil EC values since the soils are characterized with high salt levels in the baseline condition.

PART 7: GAS DRAW

Gas Draw is a tributary of Horse Creek as shown on the Overview Map (Plate 7, 8, 9 and 10. Gas Draw was evaluated separately from Horse Creek, but with the same methodology and guidance as described in the Horse Creek Introduction and Methodology Sections. The results of the analysis for Gas Draw are summarized in the following sections.

DONALD JOSLYN PROPERTIES

The Donald Joslyn Properties occupies the southern reach of the headwater area of Gas Draw upstream of the State of Wyoming land. Access to the area was not allowed. However, the area was evaluated from distance and was found not to have any managed irrigation or subirrigated agricultural lands. The topography of the area was photo documented at photo point (BB-A see Appendix C) taken from Highway 14-16 shown on the Overview Map (Plate 10).

C & F RANCH

The C & F Ranch land is located in the upper reaches (northern portion) of Gas Draw upstream of Donald Joslyn Properties land. Access to the area was not allowed. However, the area was evaluated from distance and found not to have any managed irrigation or subirrigated agricultural lands. The topography of the area was photo documented at photos point (RL-A and B; CF-A see Appendix C) shown on the Overview Map (Plate 9).

COMPLIANCE SUMMARY

The agricultural and livestock compliance summaries for Gas Draw are identical to those presented for Horse Creek in Part 1 of this report. The same three evaluation techniques were utilized to analyze Gas Draw. Since no irrigated areas were identified along Gas Draw, the results of the Horse Creek analysis apply directly for Gas Draw. Please refer to the Horse Creek Section of the report for the summary of results.

These results provide a strong basis to support approving the discharge of the CBNG-produced water, and establishing irrigation water quality limits in excess of the current irrigation water quality limits for Gas Draw.

Conclusion

The Section 20 evaluation for Gas Draw provides strong evidence that irrigated agricultural lands (managed or natural irrigation methods) can be safely irrigated or impacted with CBNG-produced waters characterized with SAR values of up to 25 and with EC values of 4 dS/m or higher. The EC values of CBNG-produced water will have little influence on soil EC values since the soils are characterized with high salt levels in the baseline condition.

PART 8: OTHER ASSOCIATED DRAINAGES ALONG HORSE CREEK WHERE SITE ACCESS WAS DENIED

A number of CBNG outfalls that discharge into a stream or into a reservoir were identified at six side drainage locations to Horse Creek that were not visited due to the denial of access. Twenty Mile Ranch administered by John Daly would not allow access for the evaluation as required by Chapter 1, Section 20 evaluation. As noted in the Agricultural Use Protection Policy, “in circumstances where a landowner chooses to deny access for the purpose of developing a Section 20 analysis, EC and SAR limits may not be required on discharges that may affect that land.” Therefore, it is understood that the sites identified in the attached Overview Map (Plates 3, 4, 6, 7 and 8) as access denied fall under this portion of the Policy and therefore, discharges at such areas may not be assigned EC and SAR limits.

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APPENDIX A

PERMITTED IRRIGATION WATER RIGHTS

APPENDIX B

PRODUCED CBNG WATER QUALITY ANALYSES

APPENDIX C

PHOTO DOCUMENTATION OF SOIL SAMPLING POINTS AND SITES INVESTIGATED BUT NOT SAMPLED

APPENDIX D

ALLUVIAL GROUNDWATER QUALITY SAMPLE ANALYES

APPENDIX E

VEGETATION LIST

APPENDIX F

VEGETATION TRANSECT SUMMARIES, PHOTOS AND FIELD DOCUMENTATION

APPENDIX G

SOIL PROFILE DESCRIPTIONS

APPENDIX H

LABORATORY DATA SHEETS FOR THE SOILS ANALYSIS

APPENDIX I

ADDITIONAL PHOTO POINTS (POSSIBLE SUBIRRIGATED FIELDS IN UPPER SQUAW CREEK)

APPENDIX J

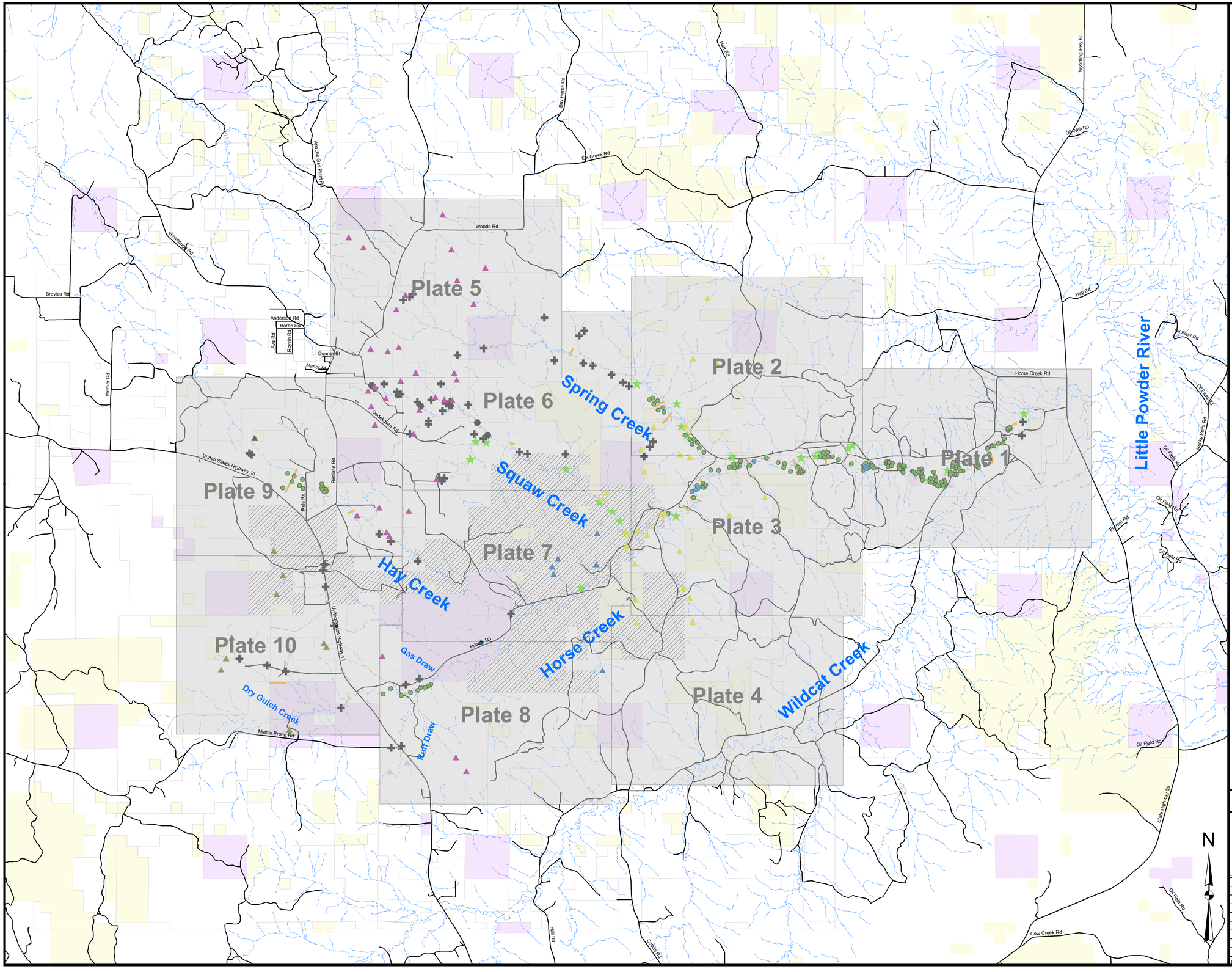
DOMINANT VEGETATIVE SPECIES, PERCENT OCCURRENCE AND THRESHOLD SOIL SALINITY TOLERANCES

APPENDIX K

LITERATURE REVIEW – SALINE – SODIC SOILS

APPENDIX L

RESULTS OF THE FAO-SES IRRIGATION SIMULATIONS FOR LAND ASSOCIATED WITH HORSE CREEK



Legend

Streams/Rivers

- Perennial
- Intermittent/Ephemeral

Existing and Proposed Outfalls

- Lance Oil & Gas Co., an Anadarko Co.
- Pinnacle Gas Resources, Inc.
- Redstone Resources, Inc.
- Thomas Operating Company, Inc.
- Windsor Energy Group, LLC
- Yates Petroleum Corporation

Sample Sites

- Alluvial Groundwater Sampling Point
- Soil Sampling Point
- Soil Sampling Photo Point
- Vegetation Photo Point
- Vegetation Survey Transect
- Permitted Diversion Structure
- Road
- Surface Ownership
- Denied Access Area

Public Lands

- Bureau of Land Management
- State of Wyoming

Horse Creek Section 20 Study Overview Map

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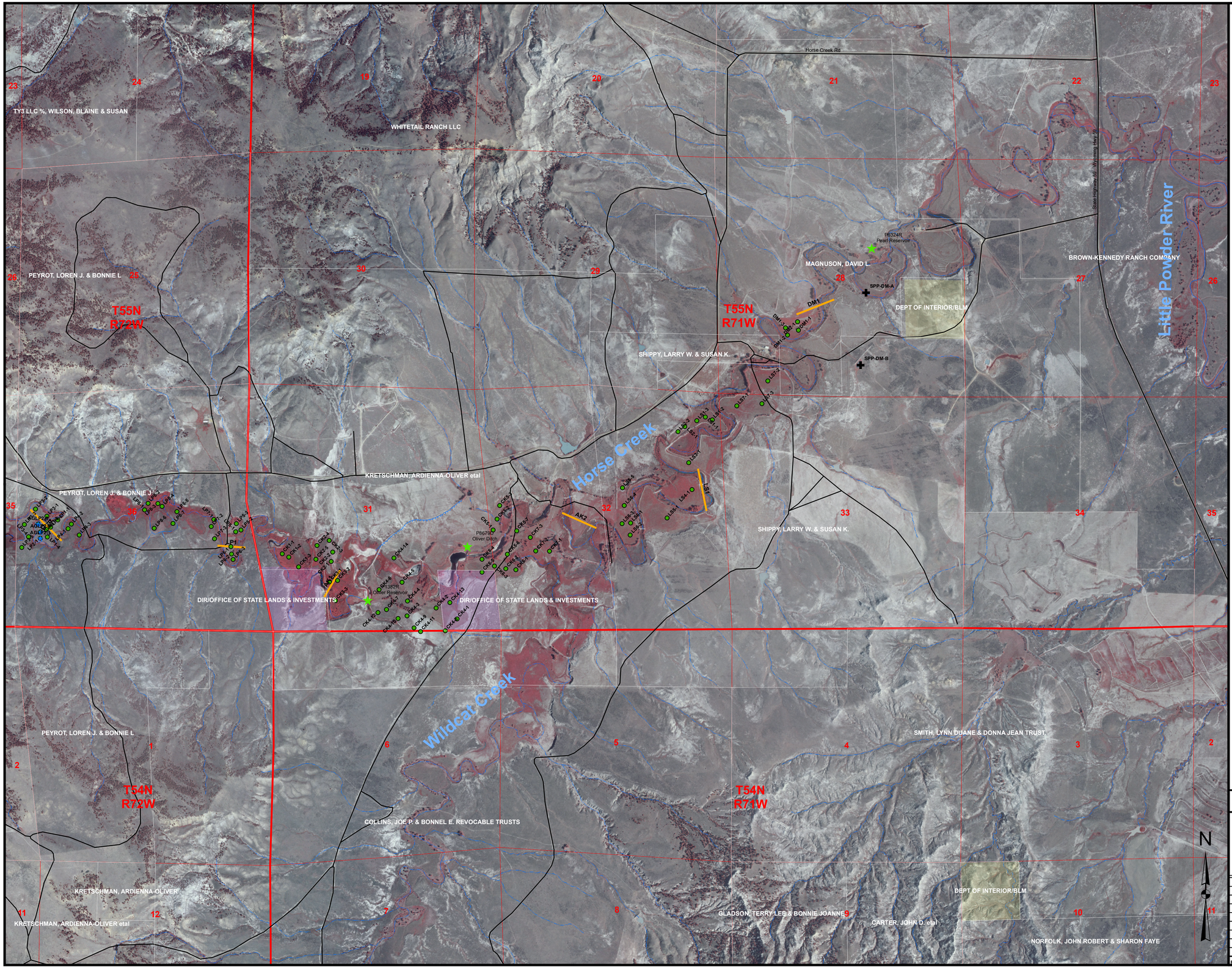

Legend

Streams/Rivers

- Perennial
- Intermittent/Ephemeral
- Canal/Ditch
- Connector

Existing and Proposed Outfalls

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Public Lands

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Horse Creek Section 20 Study Plate 1

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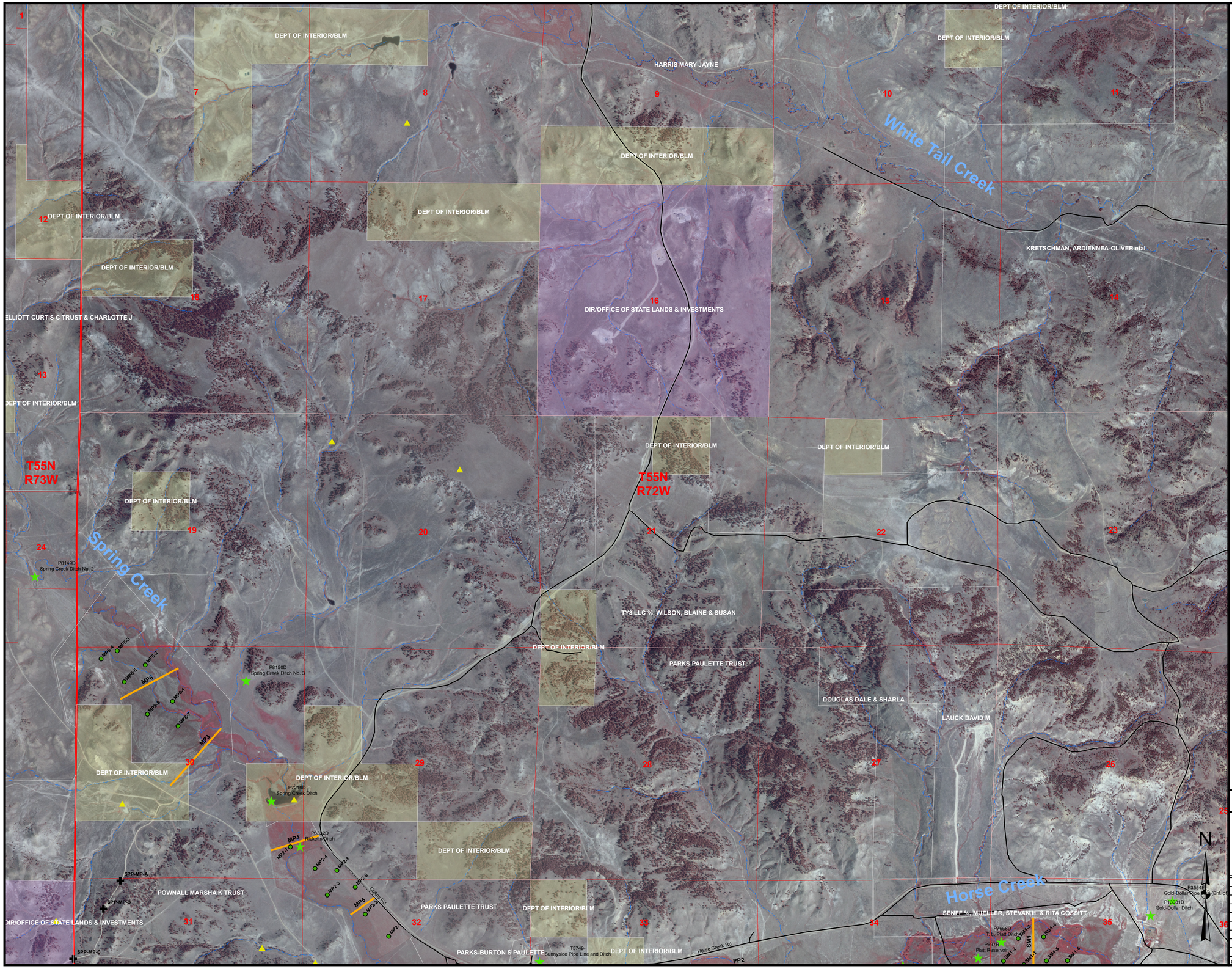

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Public Lands

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Horse Creek Section 20 Study Plate 2

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Streams/Rivers

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- Intermittent/Ephemeral
- Canal/Ditch
- Connector

Existing and Proposed Outfalls

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- Surface Ownership
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Public Lands

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Horse Creek
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Plate 3

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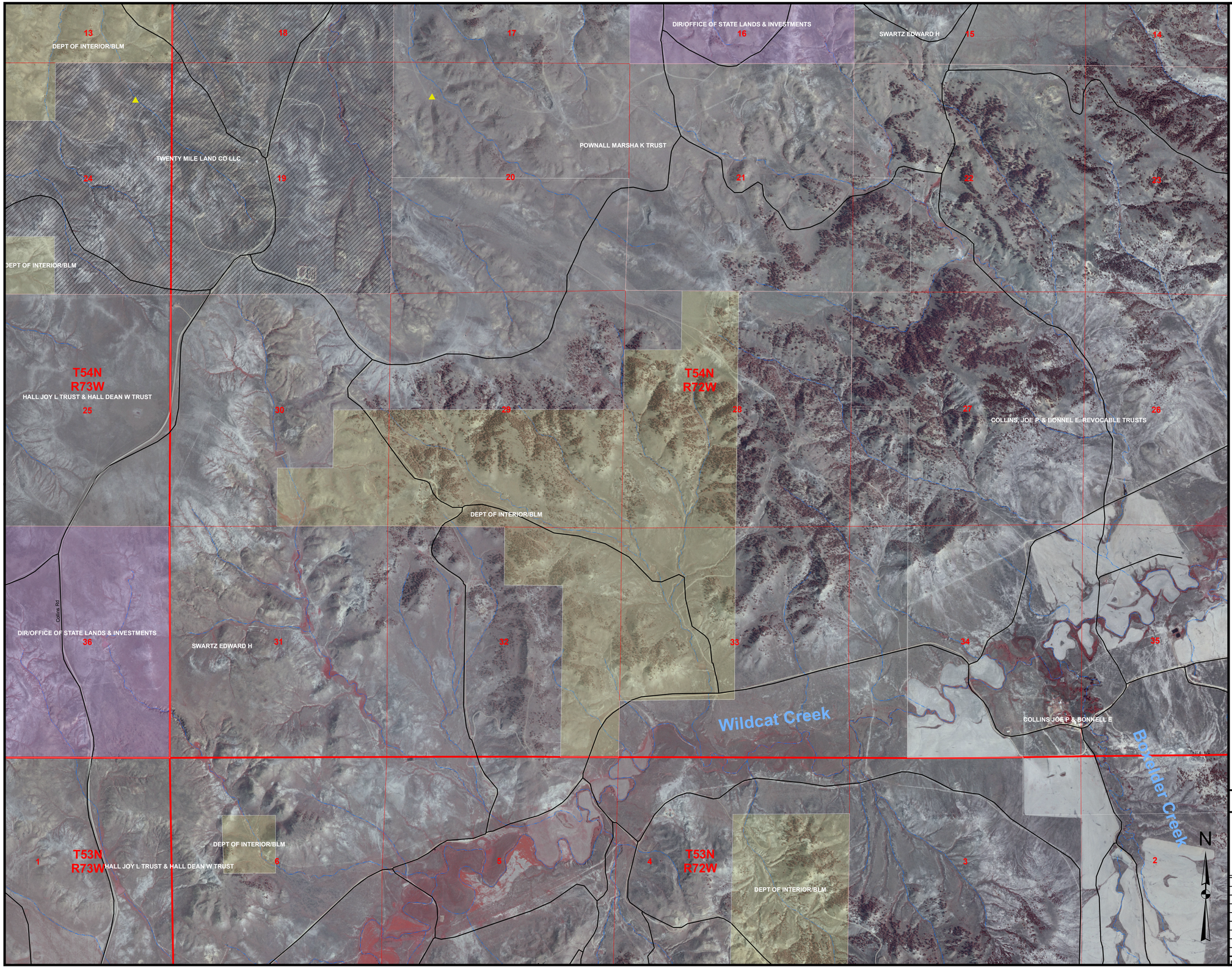

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Streams/Rivers

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Public Lands

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Horse Creek
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Plate 4

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Existing and Proposed Outfalls

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Public Lands

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Horse Creek
Section 20 Study
Plate 5

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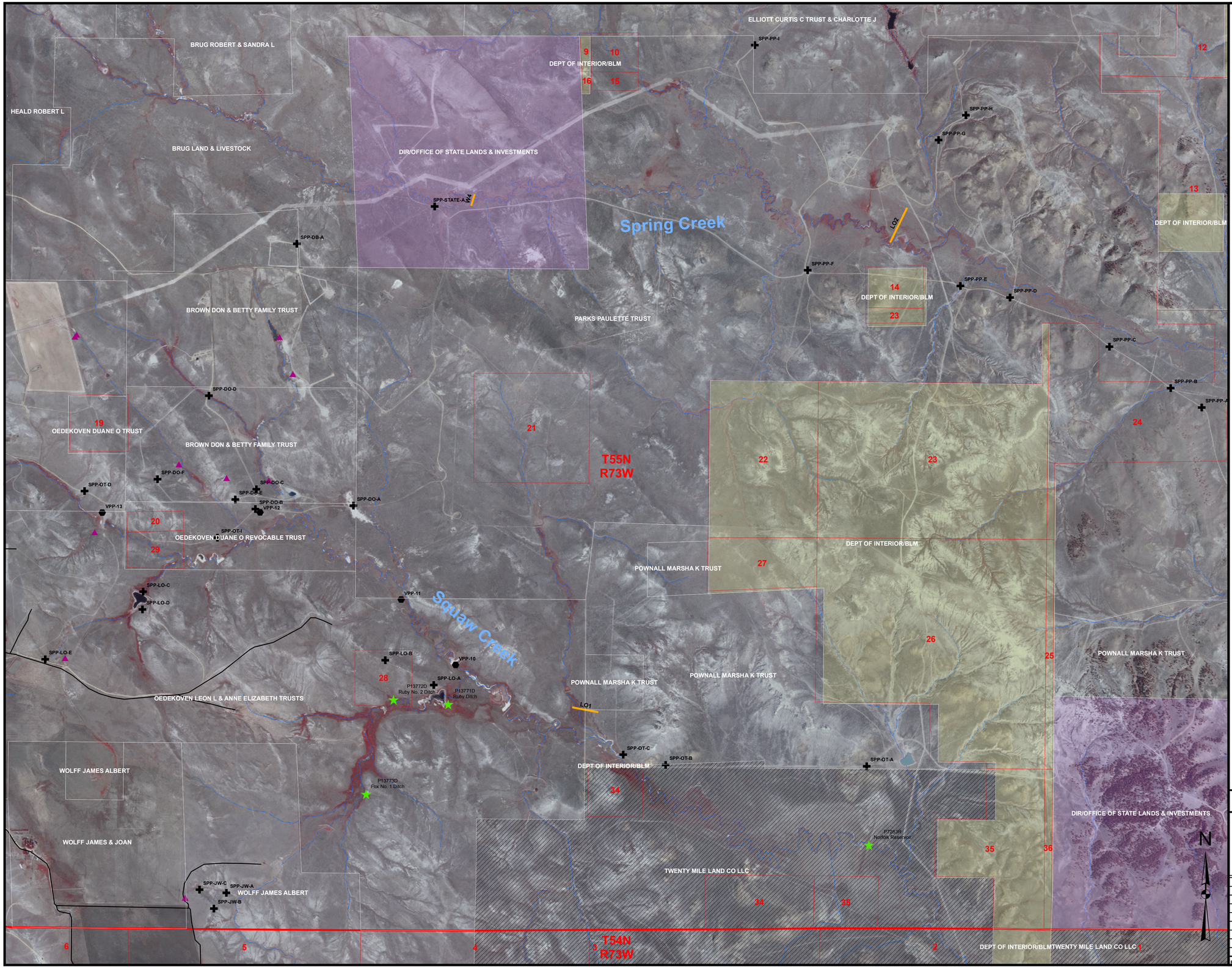

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Streams/Rivers

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Existing and Proposed Outfalls

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Public Lands

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- State of Wyoming

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Horse Creek
Section 20 Study
Plate 6

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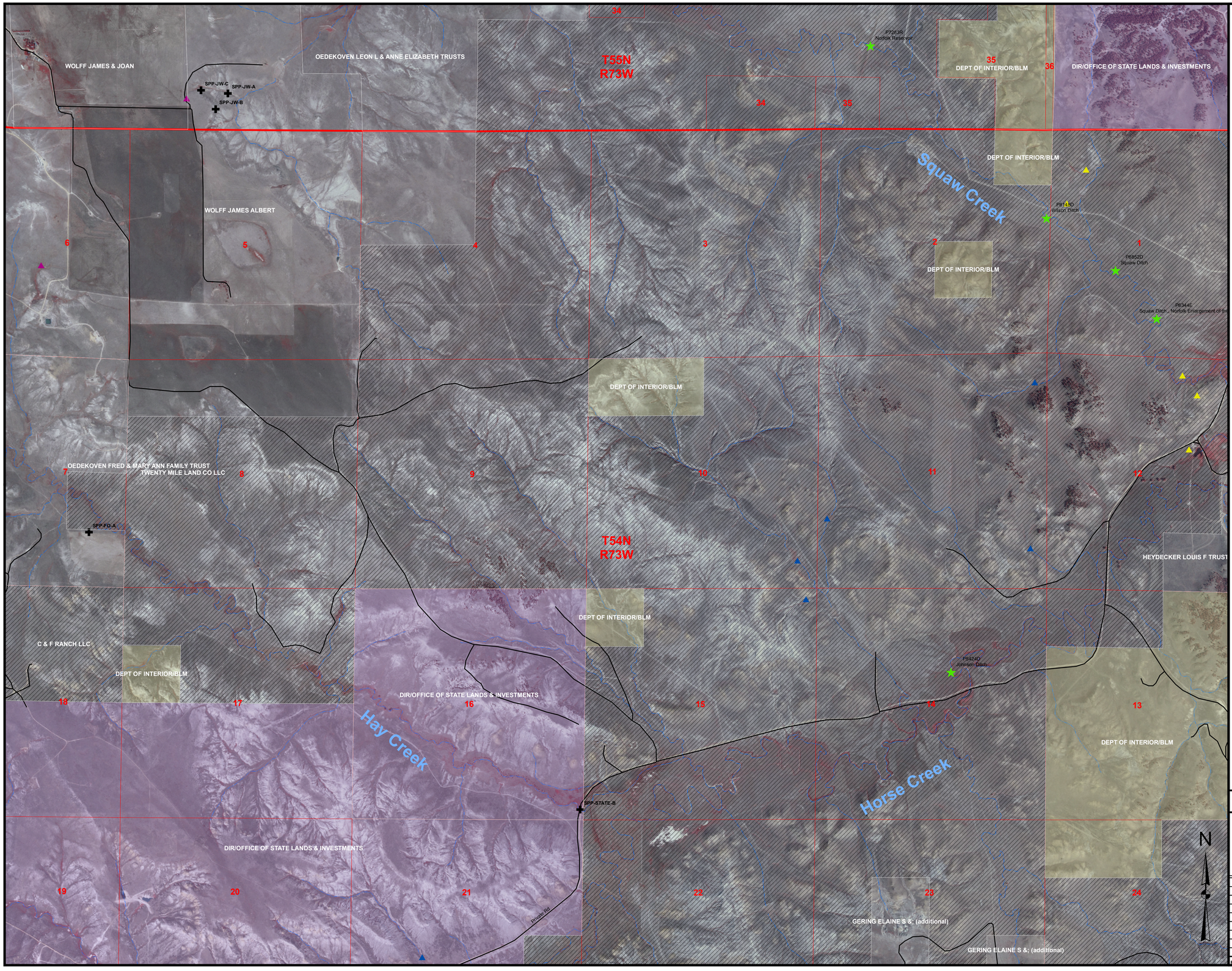

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Streams/Rivers

- Perennial
- Intermittent/Ephemeral
- Canal/Ditch
- Connector

Existing and Proposed Outfalls

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Public Lands

- Bureau of Land Management
- State of Wyoming

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Horse Creek
Section 20 Study
Plate 7

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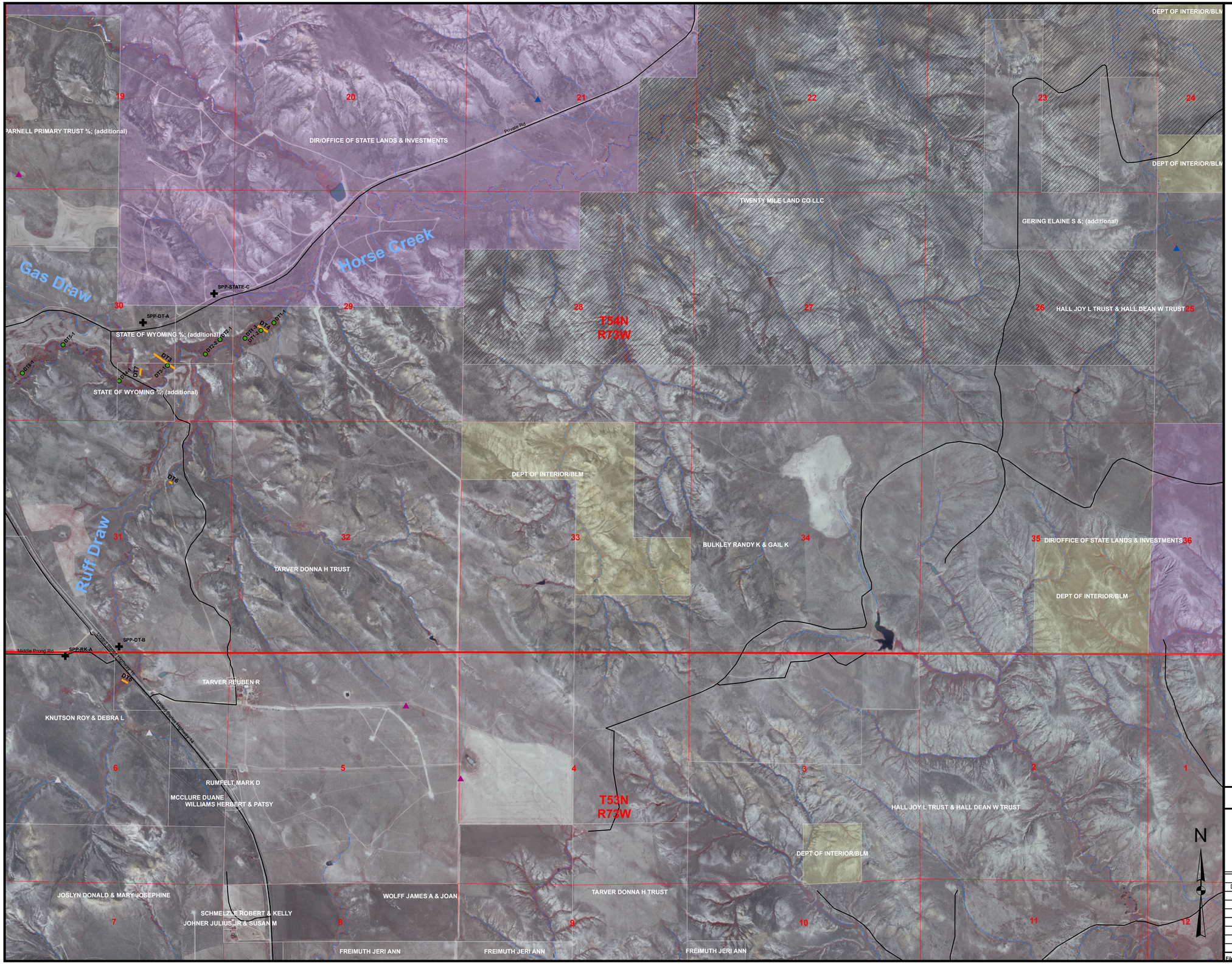

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Streams/Rivers

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Existing and Proposed Outfalls

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Public Lands

- Bureau of Land Management
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Horse Creek
Section 20 Study
Plate 8

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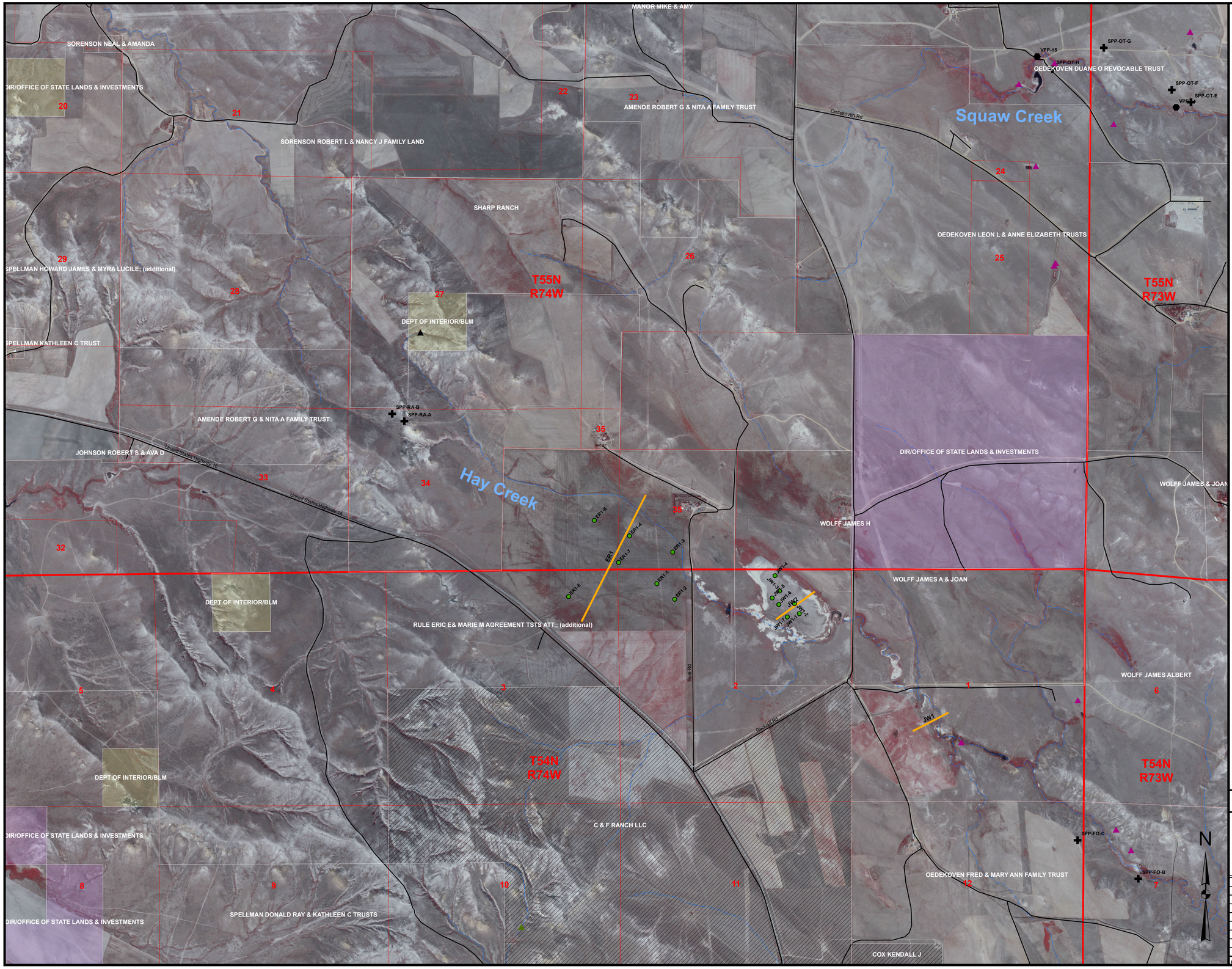

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Streams/Rivers

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- Connector

Existing and Proposed Outfalls

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Public Lands

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Horse Creek Section 20 Study Plate 9

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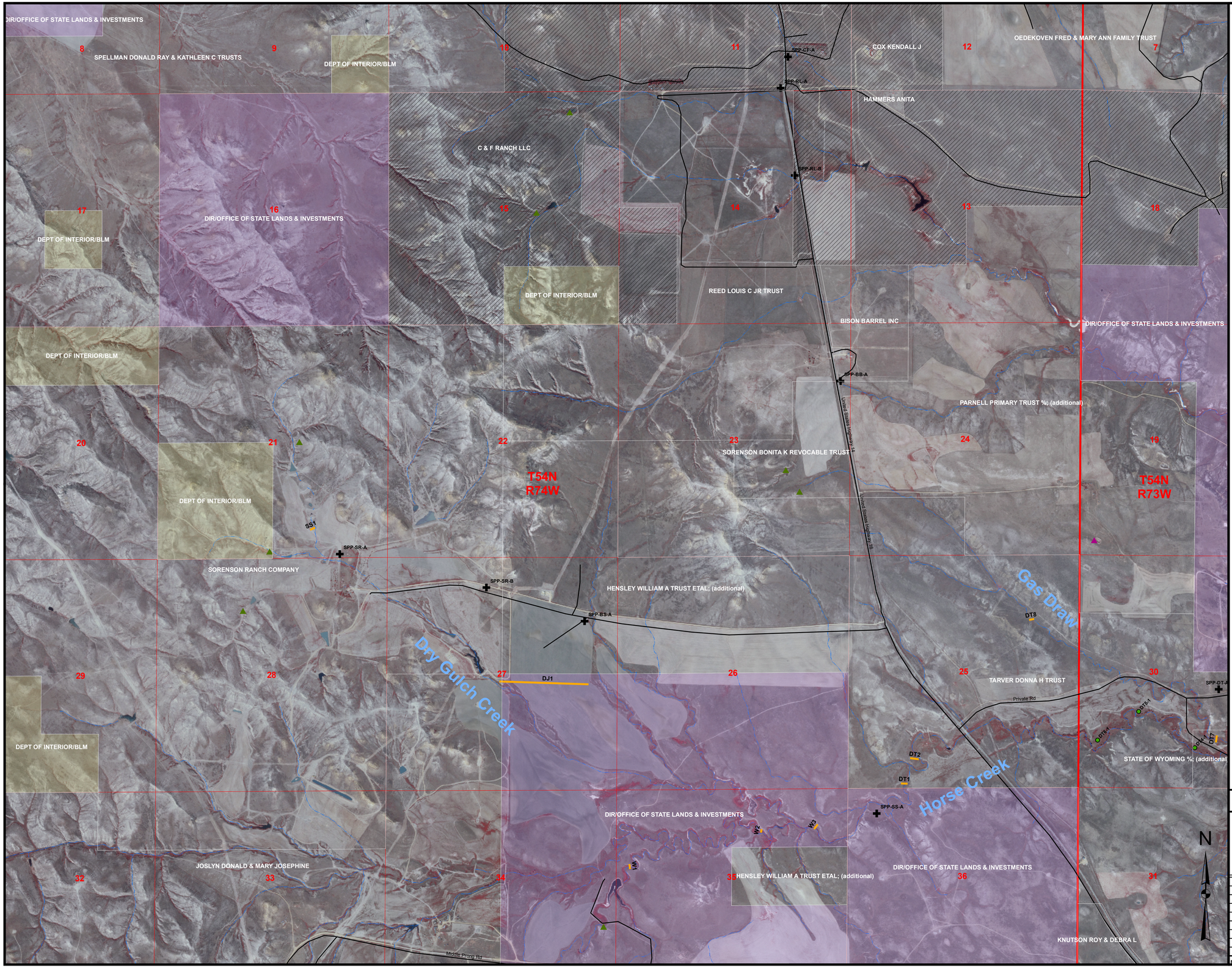


Legend

Streams/Rivers

- Perennial
- Intermittent/Ephemeral
- Canal/Ditch
- Connector

Existing and Proposed Outfalls

- Lance Oil & Gas Co., an Anadarko Co.
- Pinnacle Gas Resources, Inc.
- Redstone Resources, Inc.
- Thomas Operating Company, Inc.
- Windsor Energy Group, LLC
- Yates Petroleum Corporation

Sample Sites

- Alluvial Groundwater Sampling Point
- Soil Sampling Point
- Soil Sampling Photo Point
- Vegetation Photo Point
- Vegetation Survey Transect
- Permitted Diversion Structure
- Road
- Township and Range
- Sections
- Surface Ownership
- Denied Access Area

Public Lands

- Bureau of Land Management
- State of Wyoming

Photo base from Wyoming Geographic Information Advisory Council (2002)

Horse Creek
Section 20 Study
Plate 10

REVISIONS	
Date	By

WWC ENGINEERING
1849 TERRA AVE.
SHERIDAN, WY 82801
(307) 672-0761

File: Plate10.mxd | Drawn By: JELo | Checked By: | Date: 21 Feb 2007 | Scale: 1"=1000ft

APPENDIX A

PERMITTED IRRIGATION WATER RIGHTS

Permitted Irrigation Surface Water Rights within Horse Creek Watershed Below Proposed and Existing CBNG Outfalls																				
Prefix	Permit-Proof	Suffix	Proof	Approp.	TNP		RNG		SEC	Qtrqtr	Acres	Head Gate-Outlet-Well	Status	Supply type	Adj Uses	Adj Facility Name	Adj Appropriation	Adj Priority	Adj Amount	Adj Unit	Adj. Source
T	5749	-	5749	C13/056A	55	N	72	W	33	SWNW	5		ADJ	ORI	IRR,STO,DOM	Sunnyside Pipe Line and Ditch	W. P. Ricketts	12/31/1884	0.07	CFS	Horse Creek
P	5424	D	5750	C13/057A	54	N	73	W	14	SWNE	8		ADJ	ORI	IRR	Johnson Ditch	John E. Johnson	4/21/1903			Horse Creek
P	5424	D	5750	C13/057A	54	N	73	W	14	SWNE		X	PUD	ORI	IRR	Johnson Ditch	John E. Johnson	4/21/1903			Horse Creek
P	5424	D	5750	C13/057A	54	N	73	W	14	SENE	6		ADJ	ORI	IRR	Johnson Ditch	John E. Johnson	4/21/1903			Horse Creek
P	6332	D	5751	C13/058A	55	N	72	W	32	NENW	15		ADJ	ORI	IRR	Ricketts Ditch	W. P. Ricketts	11/11/1904			Spring Creek
P	6332	D	5751	C13/058A	55	N	72	W	32	NWNW	15		ADJ	ORI	IRR	Ricketts Ditch	W. P. Ricketts	11/11/1904			Spring Creek
P	6332	D	5751	C13/058A	55	N	72	W	29	SWSW	7		ADJ	ORI	IRR	Ricketts Ditch	W. P. Ricketts	11/11/1904			Spring Creek
P	6332	D	5751	C13/058A	55	N	72	W	29	SWSW		X	PUD	ORI	IRR	Ricketts Ditch	W. P. Ricketts	11/11/1904			Spring Creek
P	697	R	7280	C23/039A	55	N	72	W	34	SENE			PU	ORI	IRR	Platt Reservoir	Thomas L. Platt	7/7/1905			Horse Creek
P	697	R	7280	C23/039A	55	N	72	W	34	SENE		X	PUO	ORI	IRR	Platt Reservoir	Thomas L. Platt	7/7/1905			Horse Creek
P	7220	D	8546	C26/283A	54	N	72	W	6	NESE	6		ADJ	ORI	IRR	Horse Creek Ditch	W. P. Ricketts	6/7/1906			Horse Creek
P	7220	D	8546	C26/283A	54	N	72	W	6	NESE		X	PUD	ORI	IRR	Horse Creek Ditch	W. P. Ricketts	6/7/1906			Horse Creek
P	7220	D	8546	C26/283A	54	N	72	W	5	NWSW	9		ADJ	ORI	IRR	Horse Creek Ditch	W. P. Ricketts	6/7/1906			Horse Creek
P	7219	D	8552	C26/289A	55	N	72	W	30	SESE	5		ADJ	ORI	IRR	Spring Creek Ditch	W. P. Ricketts	6/7/1906	0.07	CFS	Spring Creek
P	7219	D	8552	C26/289A	55	N	72	W	30	NESE		X	PUD	ORI	IRR	Spring Creek Ditch	W. P. Ricketts	6/7/1906			Spring Creek
P	6852	D	8553	C26/290A	54	N	73	W	1	SESE	30		ADJ	ORI	IRR	Squaw Ditch	W. P. Ricketts	8/19/1905			Squaw Creek
P	6852	D	8553	C26/290A	54	N	73	W	1	NESW		X	PUD	ORI	IRR	Squaw Ditch	W. P. Ricketts	8/19/1905			Squaw Creek
P	6852	D	8553	C26/290A	54	N	72	W	6	SWSW	40		ADJ	ORI	IRR	Squaw Ditch	W. P. Ricketts	8/19/1905			Squaw Creek
P	6852	D	8553	C26/290A	54	N	72	W	6	SESW	10		ADJ	ORI	IRR	Squaw Ditch	W. P. Ricketts	8/19/1905			Squaw Creek
P	7668	D	8554	C26/291A	55	N	72	W	34	SENE	15		ADJ	ORI	IRR,DOM	T. L. Platt Ditch	T. L. Platt	2/23/1907			Joe Creek
P	7668	D	8554	C26/291A	55	N	72	W	35	SWNW	20		ADJ	ORI	IRR,DOM	T. L. Platt Ditch	T. L. Platt	2/23/1907			Joe Creek
P	1382	R	10788	C31/444A	55	N	71	W	31	SESW			PU	ORI	IRR,DOM	Oliver Reservoir	William Oliver	9/30/1908			Horse Creek
P	1382	R	10788	C31/444A	55	N	71	W	31	SESW		X	PUO	ORI	IRR,DOM	Oliver Reservoir	William Oliver	9/30/1908			Horse Creek
P	8679	D	10789	C31/445A	55	N	71	W	31	SWSE	6.4		ADJ	SEC	IRR,DOM	Oliver Ditch	William Oliver	9/30/1908			Horse Creek
P	8679	D	10789	C31/445A	55	N	71	W	32	SENW	8.2		ADJ	SEC	IRR,DOM	Oliver Ditch	William Oliver	9/30/1908			Horse Creek
P	8679	D	10789	C31/445A	55	N	71	W	32	NESW	9.4		ADJ	SEC	IRR,DOM	Oliver Ditch	William Oliver	9/30/1908			Horse Creek
P	8679	D	10789	C31/445A	55	N	71	W	31	NESE	6		ADJ	SEC	IRR,DOM	Oliver Ditch	William Oliver	9/30/1908			Horse Creek
P	8679	D	10789	C31/445A	55	N	71	W	32	NWSW	10.3		ADJ	SEC	IRR,DOM	Oliver Ditch	William Oliver	9/30/1908			Horse Creek
P	8149	D	11049	C32/217A	55	N	72	W	19		25		ADJ	ORI	IRR	Spring Creek Ditch No. 2	Nettie C. Ricketts	1/10/1908			Spring Creek
P	8149	D	11049	C32/217A	55	N	72	W	19				PU	ORI	IRR	Spring Creek Ditch No. 2	Nettie C. Ricketts	1/10/1908			Spring Creek

Prefix	Permit-Proof	Suffix	Proof	Approp.	TNP		RNG		SEC	Qtrqtr	Acres	Head Gate-Outlet-Well	Status	Supply type	Adj Uses	Adj Facility Name	Adj Appropriation	Adj Priority	Adj Amount	Adj Unit	Adj. Source
P	8149	D	11049	C32/217A	55	N	72	W	30		20		ADJ	ORI	IRR	Spring Creek Ditch No. 2	Nettie C. Ricketts	1/10/1908			Spring Creek
P	8149	D	11049	C32/217A	55	N	72	W	30				PU	ORI	IRR	Spring Creek Ditch No. 2	Nettie C. Ricketts	1/10/1908			Spring Creek
P	8149	D	11049	C32/217A	55	N	72	W	30	SWNE	15		ADJ	ORI	IRR	Spring Creek Ditch No. 2	Nettie C. Ricketts	1/10/1908			Spring Creek
P	8149	D	11049	C32/217A	55	N	72	W	30	NENW	30		ADJ	ORI	IRR	Spring Creek Ditch No. 2	Nettie C. Ricketts	1/10/1908			Spring Creek
P	8149	D	11049	C32/217A	55	N	72	W	30	SENW	20		ADJ	ORI	IRR	Spring Creek Ditch No. 2	Nettie C. Ricketts	1/10/1908			Spring Creek
P	8149	D	11049	C32/217A	55	N	73	W	24	NESE		X	PUD	ORI	IRR	Spring Creek Ditch No. 2	Nettie C. Ricketts	1/10/1908			Spring Creek
P	8149	D	11049	C32/217A	55	N	73	W	24	SESE	15		ADJ	ORI	IRR	Spring Creek Ditch No. 2	Nettie C. Ricketts	1/10/1908			Spring Creek
P	8150	D	11050	C32/218A	55	N	72	W	30	NENE		X	PUD	ORI	IRR	Spring Creek Ditch No. 3	Nettie C. Ricketts	1/10/1908			Dry Creek
P	8150	D	11050	C32/218A	55	N	72	W	30	SENE	12		ADJ	ORI	IRR	Spring Creek Ditch No. 3	Nettie C. Ricketts	1/10/1908	0.17	CFS	Dry Creek
P	8148	D	11051	C32/219A	54	N	73	W	1	NWSW	15		ADJ	ORI	IRR	Wilson Ditch	Sallie M. Wilson	1/10/1908			Squaw Creek
P	8148	D	11051	C32/219A	54	N	73	W	2	SENE		X	PUD	ORI	IRR	Wilson Ditch	Sallie M. Wilson	1/10/1908			Squaw Creek
P	8148	D	11051	C32/219A	54	N	73	W	1	SWNW	6		ADJ	ORI	IRR	Wilson Ditch	Sallie M. Wilson	1/10/1908			Squaw Creek
P	8148	D	11051	C32/219A	54	N	73	W	1	NESW	8		ADJ	ORI	IRR	Wilson Ditch	Sallie M. Wilson	1/10/1908			Squaw Creek
P	13081	D	14426	C38/045A	55	N	72	W	35	NWNE	1		ADJ	ORI	IRR,DOM	Gold-Dollar Ditch	T. L. Platt	4/10/1915	0.01	CFS	Gold Dollar Spring
P	3554	E	14470	C38/089A	55	N	72	W	35	NENE	1.5		ADJ	ORI	IRR,DOM	Gold Dollar Pipe Line {Enl. of}	T. L. Platt	1/13/1916			Gold Dollar Spring
P	3554	E	14470	C38/089A	55	N	72	W	35	NWNE	1		ADJ	ORI	IRR,DOM	Gold Dollar Pipe Line {Enl. of}	T. L. Platt	1/13/1916			Gold Dollar Spring
P	13771	D	16417	C41/120A	55	N	73	W	28	NESW	3		ADJ	ORI	IRR	Ruby Ditch	Ruby Smith	12/28/1915	0.04	CFS	Squaw Creek
P	13771	D	16417	C41/120A	55	N	73	W	28	NESW		X	PUD	ORI	IRR	Ruby Ditch	Ruby Smith	12/28/1915			Squaw Creek
P	13772	D	16418	C41/121A	55	N	73	W	28	NWSW	5		ADJ	ORI	IRR	Ruby No. 2 Ditch	Ruby Smith	12/28/1915			Squaw Creek
P	13772	D	16418	C41/121A	55	N	73	W	28	NWSW		X	PUD	ORI	IRR	Ruby No. 2 Ditch	Ruby Smith	12/28/1915			Squaw Creek
P	13772	D	16418	C41/121A	55	N	73	W	28	SESW	11		ADJ	ORI	IRR	Ruby No. 2 Ditch	Ruby Smith	12/28/1915			Squaw Creek
P	13772	D	16418	C41/121A	55	N	73	W	28	SWSE	6		ADJ	ORI	IRR	Ruby No. 2 Ditch	Ruby Smith	12/28/1915			Squaw Creek
P	13772	D	16418	C41/121A	55	N	73	W	28	NESW	4		ADJ	ORI	IRR	Ruby No. 2 Ditch	Ruby Smith	12/28/1915			Squaw Creek
P	13773	D	16419	C41/122A	55	N	73	W	33	NENW	6		ADJ	ORI	IRR	Fox No. 1 Ditch	Ella Fox	12/28/1915	0.09	CFS	South Squaw Creek or Stallion Draw
P	13773	D	16419	C41/122A	55	N	73	W	33	NWNW		X	PUD	ORI	IRR	Fox No. 1 Ditch	Ella Fox	12/28/1915			South Squaw Creek or Stallion Draw
P	6344	E	29962	C70/108A	54	N	73	W	1	SESW		X	PUD	ORI	IRR	Squaw Ditch, Norfolk Enlargement of the	Edward S. Norfolk, et ux	12/19/1969			Squaw Creek
P	6344	E	29962	C70/108A	54	N	73	W	1	NESE	4.13		ADJ	ORI	IRR	Squaw Ditch, Norfolk Enlargement of the	Edward S. Norfolk, et ux	12/19/1969			Squaw Creek
P	6344	E	29962	C70/108A	54	N	72	W	6	NESW	11.02		ADJ	ORI	IRR	Squaw Ditch, Norfolk Enlargement of the	Edward S. Norfolk, et ux	12/19/1969			Squaw Creek
P	6344	E	29962	C70/108A	54	N	72	W	6	NWSW	31.22		ADJ	ORI	IRR	Squaw Ditch, Norfolk Enlargement of the	Edward S. Norfolk, et ux	12/19/1969			Squaw Creek
P	7283	R	29982	CR6/170A	55	N	73	W	34				PU	ORI	IRR,STO,REC	Norfolk Reservoir	Edward S. Norfolk a/k/a Ted S. Norfolf	12/19/1969			Squaw Creek

Prefix	Permit-Proof	Suffix	Proof	Approp.	TNP		RNG		SEC	Qtrqtr	Acres	Head Gate-Outlet-Well	Status	Supply type	Adj Uses	Adj Facility Name	Adj Appropriation	Adj Priority	Adj Amount	Adj Unit	Adj. Source
P	7283	R	29982	CR6/170A	55	N	73	W	0				PU	ORI	IRR,STO,REC	Norfolk Reservoir	Edward S. Norfolk a/k/a Ted S. Norfolf	12/19/1969			Squaw Creek
P	7283	R	29982	CR6/170A	55	N	73	W	0				DSC	ORI	IRR,STO,REC	Norfolk Reservoir	Edward S. Norfolk a/k/a Ted S. Norfolf	12/19/1969			Squaw Creek
P	7283	R	29982	CR6/170A	55	N	73	W	0				PU	ORI	IRR,STO,REC	Norfolk Reservoir	Edward S. Norfolk a/k/a Ted S. Norfolf	12/19/1969			Squaw Creek
P	7283	R	29982	CR6/170A	55	N	73	W	0				DSC	ORI	IRR,STO,REC	Norfolk Reservoir	Edward S. Norfolk a/k/a Ted S. Norfolf	12/19/1969			Squaw Creek
P	7283	R	29982	CR6/170A	55	N	73	W	35				PU	ORI	IRR,STO,REC	Norfolk Reservoir	Edward S. Norfolk a/k/a Ted S. Norfolf	12/19/1969			Squaw Creek
P	6776	D	7281	C23/040A	55	N	72	W	34	SENE	5		ADJ	SEC	RES	Platt Discharge Ditch	Thomas L. Platt	7/7/1905			Horse Creek
P	6776	D	7281	C23/040A	55	N	72	W	34	SENE	5		ADJ	SEC	RES,IRR	Platt Discharge Ditch	T. L. PLATT	7/7/1905	0.24	CFS	Horse Creek
P	6776	D	7281	C23/040A	55	N	72	W	34	SWNE		X	PUD	SEC	RES,IRR	Platt Discharge Ditch	T. L. PLATT	7/7/1905	0.24	CFS	Horse Creek
P	6776	D	7281	C23/040A	55	N	72	W	35	SWNW	12		ADJ	SEC	RES	Platt Discharge Ditch	Thomas L. Platt	7/7/1905			Horse Creek
P	6324	R			55	N	71	W	28	SWNE		X	UNA	ORI	STO,IRR	Pearl Reservoir	DAVID L MAGNUSON	5/10/1956	49.25	ACFT	Horse Creek
P	6324	R			55	N	71	W	28	SENW			UNA	ORI	STO,IRR	Pearl Reservoir	DAVID L MAGNUSON	5/10/1956	49.25	ACFT	Horse Creek
P	6324	R			55	N	71	W	28	NESW			UNA	ORI	STO,IRR	Pearl Reservoir	DAVID L MAGNUSON	5/10/1956	49.25	ACFT	Horse Creek
P	6324	R			55	N	71	W	28	NWSW			UNA	ORI	STO,IRR	Pearl Reservoir	DAVID L MAGNUSON	5/10/1956	49.25	ACFT	Horse Creek
P	6324	R			55	N	71	W	28	SESW			UNA	ORI	STO,IRR	Pearl Reservoir	DAVID L MAGNUSON	5/10/1956	49.25	ACFT	Horse Creek

16418

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER

CERTIFICATE RECORD No. 41 PAGE 121

WHEREAS, Ruby Smith has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Squaw Creek tributary of Little Powder River through the Ruby No. 2 Ditch under Permit No. 13772 for irrigation of the lands herein described, lying and being in Campbell County, Wyoming.

NOW KNOW YE, That the Board of Control, under the provisions of Chapter 61, Compiled Statutes of Wyoming, 1910, has, by an order duly made and entered on the 21st day of November, A. D. 1919, in Order Record No. 5, Page 602, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator Ruby Smith; Postoffice Address Gillette, Wyoming; Amount of Appropriation 0.37 cu. ft. per sec.; Date of Appropriation Dec. 28, 1915; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Twenty Six (26) Acres

TWP.	RANGE	SEC.	NE¼				NW¼				SW¼				SE¼				TOTALS
			NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	
55	73	23									4	5		11			6		26

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, Frank C. Emerson, President of the State Board of Control, have hereunto set my hand this 5th day of March, A. D. 1920, and caused the seal of said Board to be hereunto affixed.

ATTEST: Julia Bartlett Freeborn, *Secretary*. Frank C. Emerson, *President*.

16419

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER

CERTIFICATE RECORD No. 41 PAGE 122

WHEREAS, Ella Fox has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Squaw Creek tributary of Little Powder River through the Fox No. 1 Ditch under Permit No. 13773 for irrigation of the lands herein described, lying and being in Campbell County, Wyoming.

NOW KNOW YE, That the Board of Control, under the provisions of Chapter 61, Compiled Statutes of Wyoming, 1910, has, by an order duly made and entered on the 21st day of November, A. D. 1919, in Order Record No. 5, Page 602, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator Ella Fox; Postoffice Address Gillette, Wyoming; Amount of Appropriation 0.09 cu. ft. per sec.; Date of Appropriation Dec. 23, 1915; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Six (6) Acres

TWP.	RANGE	SEC.	NE¼				NW¼				SW¼				SE¼				TOTALS
			NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	
55	73	33					6												6

The right to water hereby confirmed and established is limited to irrigation ____ and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, Frank C. Emerson, President of the State Board of Control, have hereunto set my hand this 5th day of March, A. D. 1920, and caused the seal of said Board to be hereunto affixed.

ATTEST: Julia Bartlett Freeborn, *Secretary*. Frank C. Emerson, *President*.

14470

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER CERTIFICATE RECORD No. 38 PAGE 89

WHEREAS, T. L. Platt has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Gold Dollar Spring tributary of Horse Creek through the Ext. Gold Dollar Pipe Line Ditch under Permit No. 3554 Enl. for irrigation of the lands herein described, lying and being in Campbell County, Wyoming,

NOW KNOW YE, That the Board of Control, under the provisions of Chapter 61, Compiled Statutes of Wyoming, 1910, has, by an order duly made and entered on the 15th day of November, A. D. 1916, in Order Record No. 5, Page 257, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator T. L. Platt; Postoffice Address Gillette, Wyoming; Amount of Appropriation .03 cu. ft. per sec.; Date of Appropriation Jan. 13, 1916; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Two and five-tenths (2.5) acres

1.5 A NW¼NE¼ Sec. 35 T. 55 N.R. 72 W.
1.0 A SW¼NE¼ Sec. 35 T. 55 N.R. 72 W.
2.5 A. Total acreage

The right to water hereby confirmed and established is limited to irrigation and domestic and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, Jas. B. True, President of the State Board of Control, have hereunto set my hand this 15th day of January, A. D. 1917, and caused the seal of said Board to be hereunto affixed.

ATTEST: Florence L. Miller, *Secretary.* Jas B True, *President.*

14426

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER

CERTIFICATE RECORD No. 38 PAGE 45

WHEREAS, T. L. Platt has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Gold Dollar Springs, Tri. Horse Cr., tributary of Little Powder River through the Gold Dollar Pipe Line Ditch under Permit No. 13081 for irrigation of the lands herein described, lying and being in Campbell County, Wyoming,

NOW KNOW YE, That the Board of Control, under the provisions of Chapter 61, Compiled Statutes of Wyoming, 1910, has, by an order duly made and entered on the 15th day of November, A. D. 1916, in Order Record No. 5, Page 254, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator T.L. Platt; Postoffice Address Gillette, Wyoming; Amount of Appropriation .01 cu. ft. per sec.; Date of Appropriation Apr. 10, 1915; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage One (1) acre

1 A NW¼NE¼ Sec. 35 T. 55 NR 72 W.
1 A. Total acreage

The right to water hereby confirmed and established is limited to irrigation and domestic and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, Jas. B. True, President of the State Board of Control, have hereunto set my hand this 15th day of January, A. D. 1917, and caused the seal of said Board to be hereunto affixed.

ATTEST: Florence L. Miller, *Secretary.* Jas. B. True, *President.*

11051

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER

CERTIFICATE RECORD NO. 32 PAGE 219

WHEREAS, Sallie M. Wilson has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Squaw Creek, tributary of Horse Creek, tributary of Little Powder River through the Wilson Ditch under Permit No. 8148 for irrigation of the lands herein described, lying and being in Crook County, Wyoming,

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 16th day of November, A. D. 1911, in Order Record No. 4 Page 492, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator Sallie M. Wilson; Postoffice Address Gillette, Wyoming; Amount of Appropriation .41 cu. ft. per. sec.; Date of Appropriation January 10, 1908; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Twenty-nine (29) acres.

6 A. SW¼ NW¼ Sec. 1, Tp. 54 N. R. 73 W.

8 A. NE¼ SW¼ " " " " " " " "

15 A. NW¼ SW¼ " " " " " " " "

29 A. Total acreage.

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I. A. J. Parshall, President of the State Board of Control, have hereunto set my hand this JAN 29 1912 day of, A. D. 19, and caused the seal of said Board to be hereunto affixed.

ATTEST: LOUISE JAEHLMANN, *Secretary.* A. J. Parshall, *President.*

11049

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER

CERTIFICATE RECORD NO. 32 PAGE 217

WHEREAS, Nettie C. Ricketts has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Spring Creek, tributary of Horse Creek, tributary of Little Powder River through the Spring Creek No. 2 Ditch under Permit No. 8149 for irrigation of the lands herein described, lying and being in Crook County, Wyoming,

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 16th day of November, A. D. 1911, in Order Record No. 4 Page 492, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator Nettie C. Rickette; Postoffice Address Gillette, Wyoming; Amount of Appropriation 1.78 cu. ft. per. sec.; Date of Appropriation January 10, 1908; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage One hundred twenty-five (125) acres.

15 A. $SE\frac{1}{4}$ $SE\frac{1}{4}$ Sec. 24, Tp. 55 N, R. 73 W.

25 A. Lot 4, Sec. 19, Tp. 55 N. R. 72 W.

15 A. $SW\frac{1}{4}$ $NE\frac{1}{4}$ Sec. 30, Tp. 55 N. R. 72 W.

30 A. $NE\frac{1}{4}$ $NW\frac{1}{4}$ Sec. 30, Tp. 55 N. R. 72 W.

20 A. Lot 1, Sec. 30, Tp. 55 N. R. 72 W.

20 A. $SE\frac{1}{4}$ $NW\frac{1}{4}$ Sec. 30, Tp. 55 N. R. 72 W.

125 A. Total acreage.

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, A. J. Parshall, President of the State Board of Control, have hereunto set my hand this JAN 29 1912 day of, A. D. 19..., and caused the seal of said Board to be hereunto affixed.

ATTEST: LOUISE JABELMANN, *Secretary.* A. J. Parshall, *President.*

10,789

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER

CERTIFICATE RECORD NO. 31 PAGE 145

WHEREAS, William Oliver has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Horse Creek tributary of Little Powder River through the Oliver Ditch under Permit No. 8679 for irrigation of the lands herein described, lying and being in Crook County, Wyoming, and for domestic purposes.

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 17th day of November, A. D. 1910, in Order Record No. 4 Page 421, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator William Oliver; Postoffice Address Gillette, Wyoming; Amount of Appropriation .57 cu. ft. per. sec.; Date of Appropriation September 30, 1908; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Forty and three tenths (40.3) acres.

6.0 A. NE¼ SE¼, Sec. 31, Tp. 55 N. R. 71 W.
6.4 A. SW¼ SE¼, " " " " " " " "
8.2 A. SE¼ NW¼, Sec. 32, " " " " " "
9.4 A. NE¼ SW¼, " " " " " " " "
10.3 A. NW¼ SW¼, " " " " " " " "
40.3 A. Total acreage.

Said appropriation of water before being used to irrigate said lands is stored in the Oliver Reservoir, Permit No. 1382 Res., Cert. Record No. 31, page 444.

The right to water hereby confirmed and established is limited to irrigation and domestic purposes, and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this DEC 20 1910 day of ....., A. D. 19....., and caused the seal of said Board to be hereunto affixed.

ATTEST: LOUISE JAELLMANN, *Secretary.* Clarence T. Johnston, *President.*

10,788

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER

CERTIFICATE RECORD NO. 31 PAGE 144

WHEREAS, William Oliver has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Horse Creek tributary of Little Powder River through the Oliver Reservoir Ditch under Permit No. 1382 Res. for irrigation of the lands herein described, lying and being in ..... County, Wyoming, and for domestic purposes.

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 17th day of November, A. D. 1910, in Order Record No. 4 Page 421, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator William Oliver; Postoffice Address Gilletto, Wyoming;

Amount of Appropriation 15.2 acre feet cu. ft. per. sec.; Date of Appropriation September 30, 1908; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage .....

Said reservoir is located in the SE¼ SW¼ Sec. 31, Tp. 55 N. R. 71 W., Crook County, Wyoming, and said appropriation of water stored therein is for the irrigation of lands described under the Oliver Ditch, Permit No. 8679, Cert. Record No. 31, page 445.

The right to water hereby confirmed and established is limited to irrigation and domestic purposes, and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this DEC 23 1910 day of ....., A. D. 19....., and caused the seal of said Board to be hereunto affixed.

ATTEST: LOUISE [illegible]MANN, *Secretary.* Clarence T. Johnston, *President.*

8554

THE STATE OF WYOMING.

CERTIFICATE OF APPROPRIATION OF WATER. CERTIFICATE RECORD NO. 26 PAGE 291

WHEREAS, T. L. Platt has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Joe Creek tributary of Horse Creek through the T. L. Platt Ditch under Permit No. 7668 for irrigation of the lands herein described, lying and being in Crook County, Wyoming. , and for domestic purposes.

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 12th day of December, A. D. 1907, in Order Record No. 4 Page 50, determined and established the priority and amount of such apppropriation as follows:

Name of Appropriator T. L. Platt; Postoffice Address Gillette, Wyoming; Amount of Appropriation .5 cu. ft. per. sec.; Date of Appropriation February 23, 1907; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Thirty-five (35) acres.

15 A. SE¼ NE¼ Sec. 34, Tp. 55 N., R. 72 W.
20 A. SW¼ NW¼ " 35 " " " " " "
35 A. Total acreage.

The right to water hereby confirmed and established is limited to irrigation and domestic purposes and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this JAN 13 1908 day of ....., A. D. 190..., and caused the seal of said Board to be hereunto affixed.

ATTEST: MARTHA KALITZ, *Secretary.* Clarence Johnston, *President.*

8553

THE STATE OF WYOMING.

CERTIFICATE OF APPROPRIATION OF WATER. CERTIFICATE RECORD NO. 26 PAGE 290

WHEREAS, W. P. Ricketts has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Squaw Creek tributary of Horse Creek through the Squaw Ditch under Permit No. 6852 for irrigation of the lands herein described, lying and being in Crook County, Wyoming.

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 12th day of December, A. D. 190 7, in Order Record No. 4 Page 50, determined and established the priority and amount of such apppropriation as follows:

Name of Appropriator W. P. Ricketts; Postoffice Address Gillette, Wyoming; Amount of Appropriation 1.14 cu. ft. per. sec.; Date of Appropriation August 19, 1905; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Eighty (80) acres.

30 A. SE¼ SE¼ Sec. 1, Tp. 54 N., R. 73 W.
40 A. SW¼ SW¼ Sec. 6, Tp. 54 N., R. 72 W.
10 A. SE¼ SW¼ " " " " " " " "
80 A. Total acreage.

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this JAN 13 1908 day of ....., A. D. 190..., and caused the seal of said Board to be hereunto affixed.

ATTEST: MARTHA KALITZ, *Secretary.* Clarence T. Johnston, *President.*

8552.

THE STATE OF WYOMING.

CERTIFICATE OF APPROPRIATION OF WATER. CERTIFICATE RECORD NO. 26 PAGE 289.

WHEREAS, W. P. Ricketts has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Spring Creek tributary of Horse Creek through the Spring Ditch under Permit No. 7219 for irrigation of the lands herein described, lying and being in Crook County, Wyoming.

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 12th day of December, A. D. 1907, in Order Record No. 4 Page 50, determined and established the priority and amount of such apppropriation as follows:

Name of Appropriator W. P. Ricketts; Postoffice Address Gillette, Wyoming; Amount of Appropriation .07 cu. ft. per sec.; Date of Appropriation June 7, 1906; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Five (5) acres.

5 A. SE¼ SE¼ Sec. 30, Tp. 55 N., R. 72 W.

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this JAN 15 1908 day of , A. D. 190, and caused the seal of said Board to be hereunto affixed.

ATTEST: MARTHA KALITZ, *Secretary.* , *President.*

8546.

THE STATE OF WYOMING.

CERTIFICATE OF APPROPRIATION OF WATER.

CERTIFICATE RECORD No. 26 PAGE 283

WHEREAS, W. P. Ricketts has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Horse Creek tributary of Little Powder River through the Horse Creek Ditch under Permit No. 7220 for irrigation of the lands herein described, lying and being in Crook County, Wyoming.

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 12th day of December, A. D. 1907, in Order Record No. 4 Page 50, determined and established the priority and amount of such apppropriation as follows:

Name of Appropriator W. P. Ricketts; Postoffice Address Gillette, Wyoming; Amount of Appropriation .21 cu. ft. per. sec.; Date of Appropriation June 7, 1906; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Fifteen (15) acres.

6 A. NE¼ SE¼ Sec. 6, Tp. 54 N., R. 72 W.
9 A. NW¼ SW¼ Sec. 5, " " " " " "
15 A. Total acreage.

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this JAN 13 1908 day of ....., A. D. 190..., and caused the seal of said Board to be hereunto affixed.

ATTEST: MARTHA KALITZ, *Secretary*. Clarence T. Johnston, *President*.

7281

40

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER CERTIFICATE RECORD NO. 23 PAGE 40

WHEREAS, Thomas L. Platt has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Horse Creek tributary of Little Powder River through the Platt Ditch under Permit No. 697R for irrigation of the lands herein described, lying and being in Crook County, Wyoming, and for irrigation

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 20th day of November, A. D. 1905, in Order Record No. 3 Page 440, determined and established the priority and amount of such apppropriation as follows:

Name of Appropriator Thomas L. Platt; Postoffice Address Gillette, Wyoming; General Priority Number on main stream ; Priority Number on

Amount of Appropriation 7/ cu. ft. per sec.; Date of Appropriation July 7th 1905; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Seventeen (17) acres

5 acres SE¼ NE¼ Section 34 Tp. 55 N. R. 72 W.

12 " SW¼ NW¼ " 35 " " " " " "

17 " Total acreage

Said appropriation of water is stored in the Platt Reservoir, under Permit No. 697R, Certificate Record No. 23 page 39; thence diverted through said ditch on to said lands.

Said Platt Ditch is also used as a supply ditch to the Platt Reservoir, under Permit No. 697R.

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this 18th day of June, A. D. 1907, and caused the seal of said Board to be hereunto affixed.

ATTEST: Martha Kelly, Secretary. Clarence T. Johnston, President.

7280

39

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER

CERTIFICATE RECORD NO. 23 PAGE 39

WHEREAS, Thomas L. Platt has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Horse Creek tributary of Little Powder River through the Platt Reservoir Ditch under Permit No. 6975 for irrigation of the lands herein described, lying and being in [illegible] County, Wyoming, and for irrigation

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 7th day of November, A. D. 1905, in Order Record No. 3 Page 40, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator Thomas L. Platt; Postoffice Address Gillette, Wyoming; General Priority Number on main stream ; Priority Number on

Amount of Appropriation 5.75 cu. ft. per sec.; Date of Appropriation July 7, 1905; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage

Said reservoir is located in Section 34, T. 54 N. R. 72 W., Crook County, Wyoming.

Said appropriation of water stored in said reservoir is for the irrigation of lands described in certificate issued under Permit No. 6776, Certificate Record No. 23, page 40, through the Platt Ditch.

Said appropriation of water is diverted into said reservoir through the Platt Ditch under Permit No. 6776.

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this 18th day of June, A.D. 1907, and caused the seal of said Board to be hereunto affixed.

ATTEST: Martha Kabis, *Secretary.* Clarence T. Johnston, *President.*

5751

THE STATE OF WYOMING.

CERTIFICATE OF APPROPRIATION OF WATER. CERTIFICATE RECORD No. 13 PAGE 58

WHEREAS, W.P. Ricketts has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Horse Creek tributary of Little Powder River through the Ricketts Ditch under Permit No. 6332 for irrigation of the lands herein described, lying and being in Crook County, Wyoming, ~~and for irrigation~~

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 27th day of November, A. D. 1905, in Order Record No. 3, Page 391, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator W.P. Ricketts; Postoffice Address Gillette, Wyoming; General Priority Number on main stream 4; Priority Number on Horse Creek 3 Amount of Appropriation .5 cu. ft. per sec.; Date of Appropriation November 11, 1904; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Thirty-seven (37) acres.

7 acres SW¼SW¼ Sec. 29 Tp 55 N R. 72 W
15 " NW¼NW¼ " 32 " " " " " "
15 " NE¼NW¼ " " " " " " " "
37 " Total acreage

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this 20th day of January, A. D. 1906, and caused the seal of said Board to be hereunto affixed.

ATTEST: Robert P. Quest. Secretary. Clarence T. Johnston President.

5750

THE STATE OF WYOMING.

CERTIFICATE OF APPROPRIATION OF WATER. CERTIFICATE RECORD No. 13 PAGE 57

WHEREAS, John E. Johnson has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Horse Creek tributary of Little Powder River through the Johnson Ditch under Permit No. 5424 for irrigation of the lands herein described, lying and being in Crook County, Wyoming, ~~and for irrigation~~

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 27th day of November, A. D. 1905, in Order Record No. 3, Page 321, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator John E. Johnson; Postoffice Address Gillette, Wyoming; General Priority Number on main stream 9; Priority Number on Horse Creek 2 Amount of Appropriation .70 cu. ft. per sec.; Date of Appropriation April 21, 1903; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Fourteen (14) acres.

8 acres S. W¼ NE¼ Sec 14 Tp 54 N. R 73 W

6 " SE¼ NE¼ " " " " " " "

14 " Total Acreage

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this 20th day of January, A. D. 1906, and caused the seal of said Board to be hereunto affixed.

ATTEST: Robert P. Quest. Secretary.

Clarence T. Johnston President.

5749

THE STATE OF WYOMING.

CERTIFICATE OF APPROPRIATION OF WATER.

CERTIFICATE RECORD NO. 13 PAGE 56

WHEREAS, W.P. Ricketts has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Horse Creek tributary of Little Powder River through the Sunnyside Pipe Line and Ditch under Permit No. Ten for irrigation of the lands herein described, lying and being in Crook County, Wyoming, and for ~~irrigation~~ domestic & stock purposes

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 27th day of November, A. D. 190~~5~~, in Order Record No. 3, Page 321, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator W.P. Ricketts; Postoffice Address Gillette, Wyoming; General Priority Number on main stream 1; Priority Number on Horse Creek 1 Amount of Appropriation .04 cu. ft. per sec.; Date of Appropriation 1884; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Five (5) acres

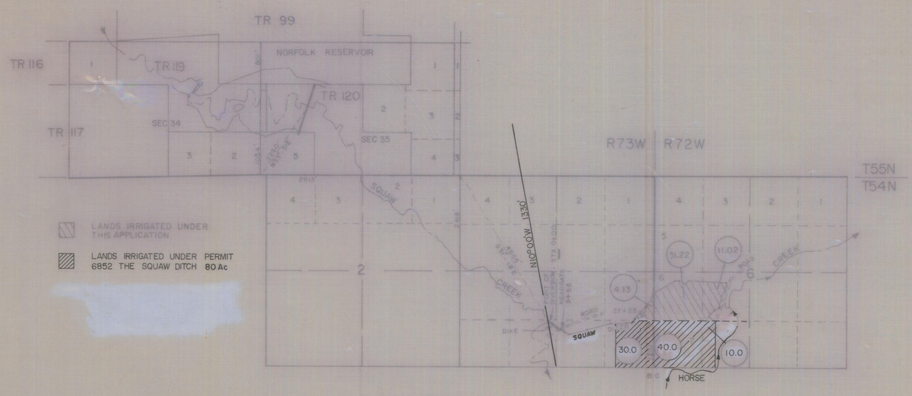
5 acres S½ NE¼ NW¼ Sec. 33 T. 55 R. 72 W.

The right to water hereby confirmed and established is limited to irrigation, domestic & stock purposes and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

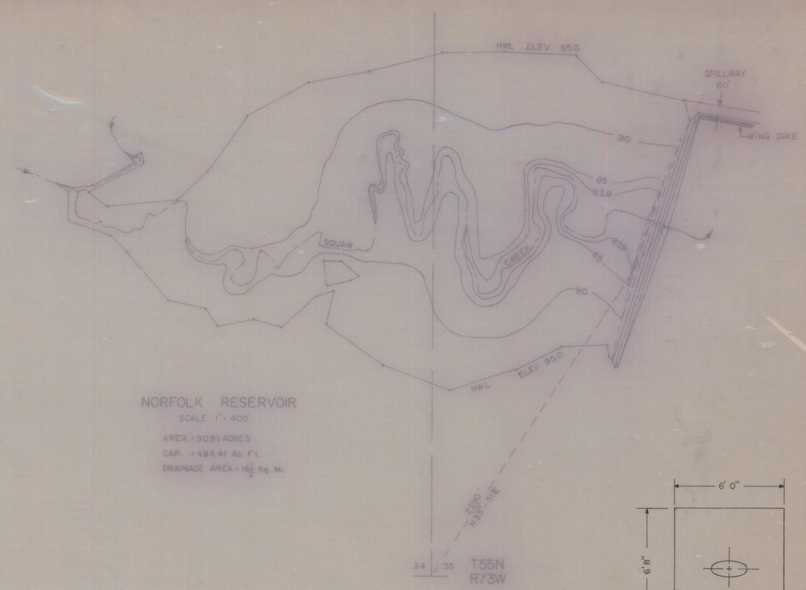
IN TESTIMONY WHEREOF, I, CLARENCE T. JOHNSTON, President of the State Board of Control, have hereunto set my hand this 20th day of January, A. D. 1906 and caused the seal of said Board to be hereunto affixed.

ATTEST: Robert P. Quest. Secretary.

Clarence T. Johnston President.

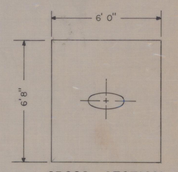


LOCATION MAP
SCALE 1"=2000'

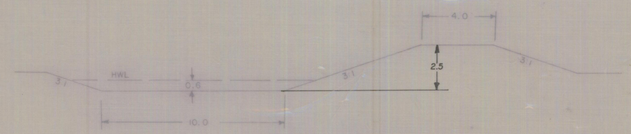


NORFOLK RESERVOIR
SCALE 1"=400'

AREA = 90.91 ACRES
CAP. = 494.41 Ac. Ft.
DRAINAGE AREA = 16½ Sq. Mi.



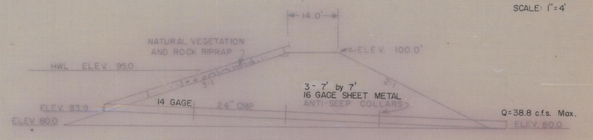
CROSS SECTION OF OUTLET
SCALE: 1"=4'



DITCH AND DIKE X' SECTION
SCALE 1"=4

s = .002
r = .513
V = 1.701 ft/sec

A = 7.08 ft²
n = .025
Q = 12.04 cu.ft/sec

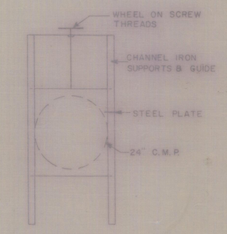


MAXIUM CROSS SECTION OF DAM
SCALE: 1"=20'

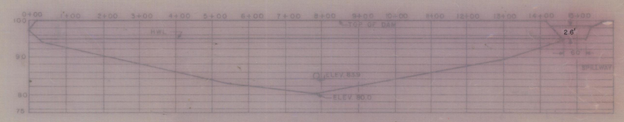
RESERVOIR CAPACITY TABLE

CONTOUR	AREA	AVERAGE	CAPACITY	
80	0	2.56	2.56	
83.9	5.11	8.82	9.70	19.5 ACRE FEET STOCKWATER
85	12.53	27.68	39.40	
90	43.23	270*	335.35	474.75 ACRE FEET IRRIGATION
95	90.91			

TOTAL AVAILABLE CAPACITY 494.41



HEADGATE
SCALE: 1"=2'

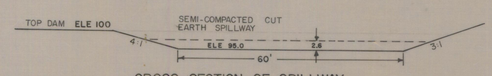


PROFILE OF DAMSITE AND SPILLWAY X'-SECTION
SCALE: Horiz. 1"=200
Vert. 1"=20'

State of Wyoming)
County of Campbell) SS CERTIFICATE OF SURVEYOR

I, Robert F. Lusby, of Gillette, Wyoming, hereby certify that this map was made from notes taken during an actual survey made by me on November 17 to 20th, 1969; and that it correctly represents the proposed irrigation works, the location and area of the lands proposed to be irrigated in each subdivision, and the location of streams, as described in the accompanying application.

Registration No. 487 L.S. Robert F. Lusby
Surveyor



CROSS SECTION OF SPILLWAY
SCALE: 1"=20'

S = .003
r = 2.275
V = 7.04 ft/sec

A = 179.66
n = .020
Q = 1265 cu.ft/sec.

APPROVED June 27, 1970
Floyd A. Bishop
FLOYD A. BISHOP STATE ENGINEER

MAP TO ACCOMPANY APPLICATION FOR
NORFOLK RESERVOIR AND THE NORFOLK ENL OF THE SQUAW DITCH

APPLICANT
TED S. NORFOLK
BOX 1048
GILLETTE, WYOMING

E-14

6344ENL.
7283 RES.
20 344/264

BY GLOBAL ENGINEERING and LAND SURVEYING CASPER, WYOMING

THE STATE OF WYOMING
Certificate of Construction of Reservoir

Proof No. 29982

Certificate Record No. R-6 Page 170

WHEREAS, Edward S. Norfolk a/k/a Ted S. Norfolk has presented to the State Board of Control of the State of Wyoming, proof of construction of the Norfolk Reservoir, Permit No. 7283 Res., located in Tracts 99, 119 and 120, T. 55 N., R. 73 W., Resurvey & Lot 2 Sec. 34, Lot 5 Section 35, T. 55 N., R 73 W. Resurvey; Campbell County, Wyoming; and Outlet: Tract 120-55-73, Resurvey

Whereas, the proof of construction sets forth that said reservoir has been completed in accordance with the terms of said permit to a capacity sufficient to impound ----494.41- acre-feet of water; and that the source of the quantity of water authorized to be stored in the Norfolk Reservoir is obtained from Squaw Creek, tributary Horse Creek, tributary Little Powder River, tributary Powder River on which the reservoir is located, ~~and~~ ~~through the~~ ~~Ditch, Permit No.~~

NOW KNOW YE, That the State Board of Control, under the provisions of the Statutes of Wyoming, has by an order duly made and entered on the 31st day of December, A. D. 19 71, in Order Record No. 19, Page 182, determined the priority and capacity of said reservoir as follows:

Name of Owner Edward S. Norfolk a/k/a Ted S. Norfolk; Address Box 1048, Gillette, Wyoming;

Date of Priority December 19, 1969; Total available storage capacity in the Norfolk Reservoir, as constructed under provisions of Permit No. 7283 Res., is ----494.41---------- acre-feet.

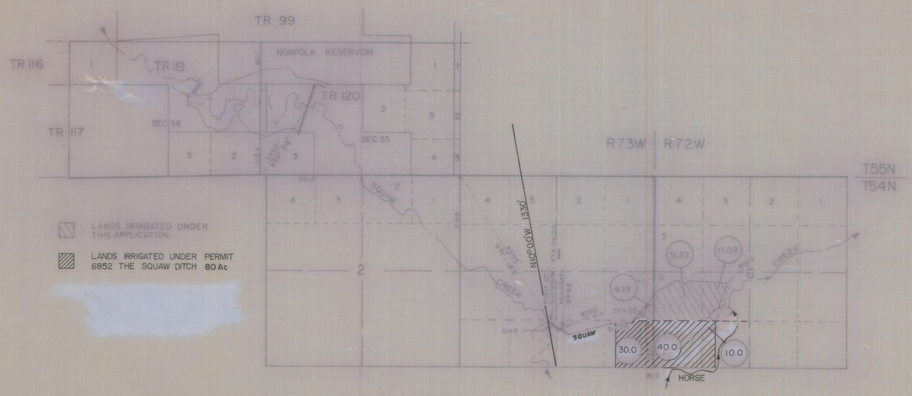
The right to store water is limited to such an amount as shall be beneficially used, not to exceed one filling annually of said reservoir, for irrigation, stock and recreation ---------- use.

IN TESTIMONY WHEREOF, I, FLOYD A. BISHOP, President of the State Board of Control, have hereunto set my hand this 31st day of December, A. D. 19 71, and caused the seal of said Board to be hereunto affixed.

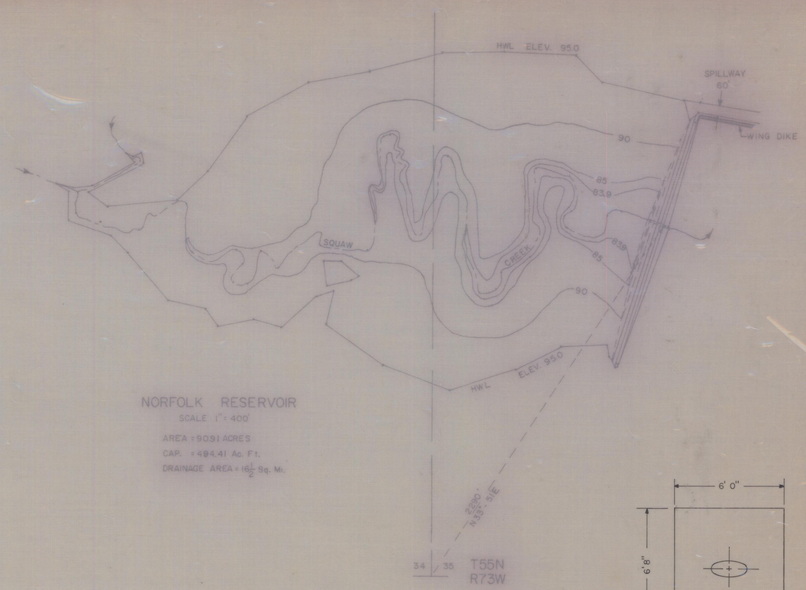
ATTEST: Peggy L. Christopulos
Ex-officio Secretary.

Floyd A. Bishop
President.

THE MILLS COMPANY, SHERIDAN 123077

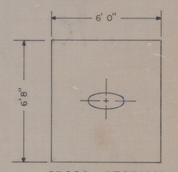


LOCATION MAP
SCALE 1"=2000'

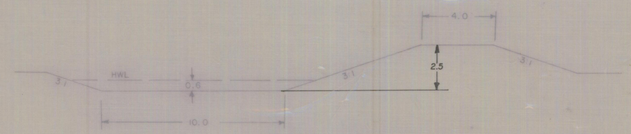


NORFOLK RESERVOIR
SCALE 1"=400'

AREA = 90.91 ACRES
CAP. = 494.41 Ac. Ft.
DRAINAGE AREA = 16½ Sq. Mi.



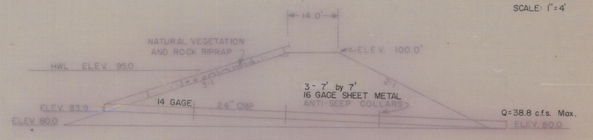
CROSS SECTION OF OUTLET
SCALE: 1"=4'



DITCH AND DIKE X' SECTION
SCALE 1"=4

s = .002
r = .513
V = 1.701 ft/sec

A = 7.08 ft²
n = .025
Q = 12.04 cu.ft/sec

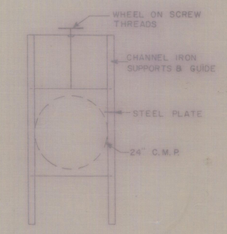


MAXIUM CROSS SECTION OF DAM
SCALE: 1"=20'

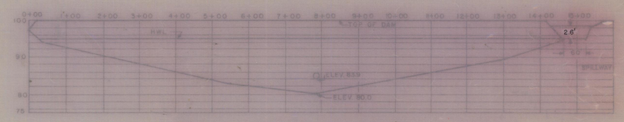
RESERVOIR CAPACITY TABLE

CONTOUR	AREA	AVERAGE	CAPACITY	
80	0	2.56	2.56	
83.9	5.11	8.82	9.70	19.5 ACRE FEET STOCKWATER
85	12.53	27.68	39.40	
90	43.23	270*	335.35	474.75 ACRE FEET IRRIGATION
95	90.91			

TOTAL AVAILABLE CAPACITY 494.41



HEADGATE
SCALE: 1"=2'

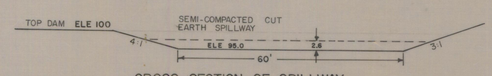


PROFILE OF DAMSITE AND SPILLWAY X'-SECTION
SCALE: Horiz. 1"=200
Vert. 1"=20'

State of Wyoming)
County of Campbell) SS CERTIFICATE OF SURVEYOR

I, Robert F. Lusby, of Gillette, Wyoming, hereby certify that this map was made from notes taken during an actual survey made by me on November 17 to 20th, 1969; and that it correctly represents the proposed irrigation works, the location and area of the lands proposed to be irrigated in each subdivision, and the location of streams, as described in the accompanying application.

Registration No. 487 L.S. Robert F. Lusby
Surveyor



CROSS SECTION OF SPILLWAY
SCALE: 1"=20'

S = .003
r = 2.275
V = 7.04 ft/sec

A = 179.66
n = .020
Q = 1265 cu.ft/sec.

APPROVED June 27, 1970
Floyd A. Bishop
FLOYD A. BISHOP STATE ENGINEER

MAP TO ACCOMPANY APPLICATION FOR
NORFOLK RESERVOIR AND THE NORFOLK ENL OF THE SQUAW DITCH

APPLICANT
TED S. NORFOLK
BOX 1048
GILLETTE, WYOMING

E-14

6344ENL.
7283 RES.
20 344/264

BY GLOBAL ENGINEERING and LAND SURVEYING CASPER, WYOMING

THE STATE OF WYOMING
Certificate of Appropriation of Water

Proof No. 29962

Certificate Record No. 70, Page 108

WHEREAS, Edward S. Norfolk, et ux has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Squaw Creek, tributary Horse Creek, tributary Little Powder River, tributary Powder River through the Enlargement Squaw Ditch under Permit No. 6344 Enlargement for irrigation of the lands herein described, lying and being in Campbell County, Wyoming.

NOW KNOW YE, That the State Board of Control, under the provisions of the Statutes of Wyoming, has, by an order duly made and entered on the 30th day of December, A. D. 19 71, in Order Record No. 19, Page 177, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator Edward S. Norfolk, et ux; Postoffice Address Box 1048, Gillette, Wyoming;

Date of Appropriation December 19, 1969; Total Acreage Forty-Six and Thirty-Seven Hundredths (46.37) Acres;

Amount of Appropriation 0.66 cu. ft. per sec.; Description of land to be irrigated and for which this appropriation is determined and established:

TWP.	RANGE	SEC.	NE¼				NW¼				SW¼				SE¼				TOTAL
			NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	
54 N.	72 W.	6									11.02	L. 6 31.22							42.24
54 N.	73 W.	1													4.13				4.13
																		TOTAL	46.37

h.g. SE¼SW¼ Sec. 1-54-73

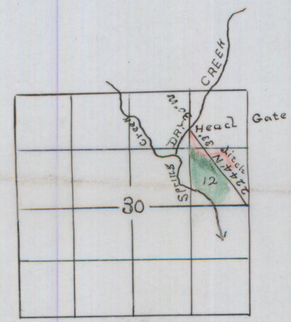
The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot of water per second for each seventy acres of land for which the appropriation is herein determined and established, except when there is surplus water in the stream as provided by Sections 41-181 to 41-189, Wyoming Statutes, 1957.

IN TESTIMONY WHEREOF, I, FLOYD A. BISHOP, President of the State Board of Control, have hereunto set my hand this 30th day of December, A. D. 19 71, and caused the seal of said Board to be hereunto affixed.

Attest: Grace L. Christopulos Ex-officio Secretary.

F. A. Bishop President.

THE MILLS COMPANY, SHERIDAN 123077



STATE OF WYOMING, } ss
COUNTY OF CROOK.

I, J. L. Bryant of Sundance Wyo hereby certify that this map was made from notes taken during an actual survey made by me on the 26 day of October A. D. 1907 and that it correctly represents the irrigation works described in the accompanying application, together with a meander of streams, and shows accurately the location and area of the lands proposed to be irrigated in each forty acre tract.

J. L. Bryant
Surveyor.

8150

11050

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER

CERTIFICATE RECORD NO. 32 PAGE 218

WHEREAS, Nettie C. Ricketts has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Dry Creek, tributary of Spring Creek, tributary of Horse Creek through the Spring Creek No. 3 Ditch under Permit No. 8150 for irrigation of the lands herein described, lying and being in Crook County, Wyoming,

NOW KNOW YE, That the Board of Control, under the provisions of Division 1, Title 9, Chapters 10 and 14 of the Revised Statutes of Wyoming, 1899, has, by an order duly made and entered on the 16th day of November, A. D. 19 11., in Order Record No. 4 Page 492, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator Nettie C. Ricketts; Postoffice Address Gillette, Wyoming; Amount of Appropriation .17 cu. ft. per. sec.; Date of Appropriation January 10, 1908; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Twelve (12) acres.

12 A. SE¼ NE¼ Section 30, Township 55 North, Range 72 West.

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, A. J. Parshall, President of the State Board of Control, have hereunto set my hand this JAN 29 19[illegible] day of ....., A. D. 19....., and caused the seal of said Board to be hereunto affixed.

ATTEST: LOUISE JABELMANN, *Secretary*. A. J. Parshall, *President*.

MAP

TO ACCOMPANY APPLICATIONS FOR

RUBY AND RUBY NO. 2 DITCHES.

APPLICANT

RUBY SMITH, GILLETTE, WYOMING.

Scale 1 inch = 1200 feet.

CERTIFICATE OF SURVEYOR.

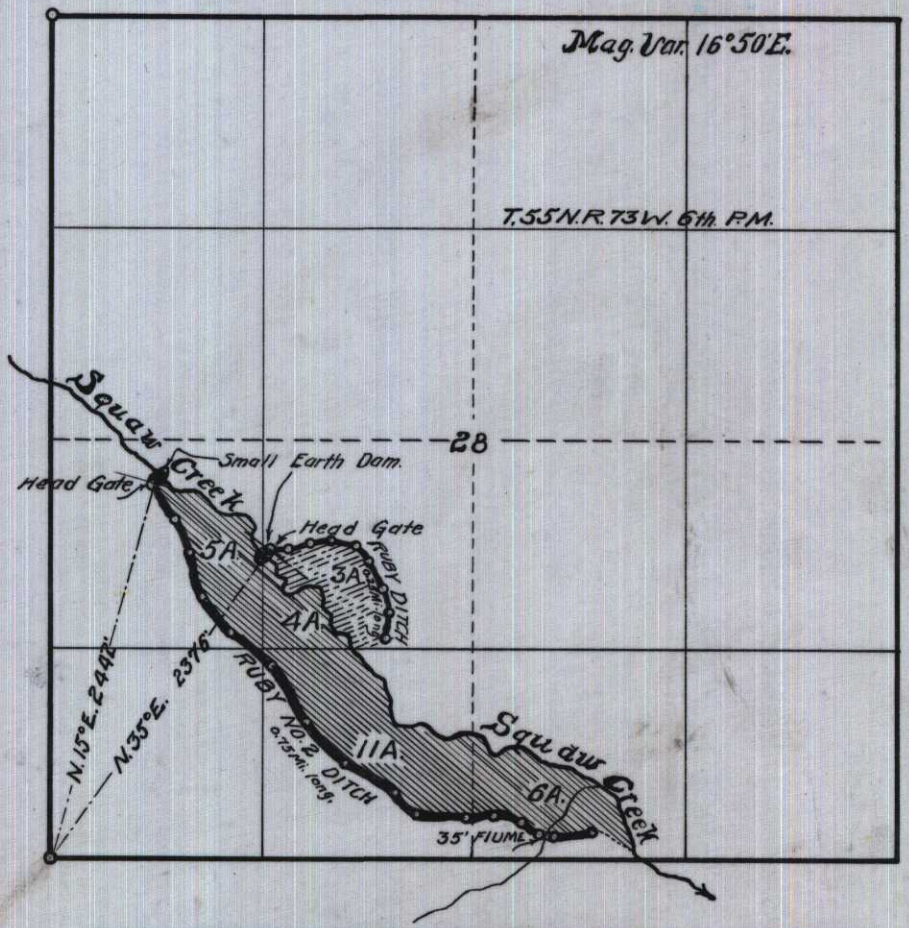
STATE OF COLORADO } ss:
COUNTY OF DENVER }

I, Royal D. Salisbury, of Denver, Colorado, hereby certify that this map was made from notes taken during an actual survey made by my assistant, W.R. Fox, of Gillette, Wyo, on November 27th and 28th 1915, and that it correctly represents the irrigation works described in the accompanying applications, together with a meander of streams, and shows accurately the location and area of the lands proposed to be irrigated in each subdivision.

Grade 1 foot pr. 1000 feet.
Velocity 0.98 ft pr. Second.
Capacity 4.30 Cu. Ft. pr. Sec.

Royal D. Salisbury.

SURVEYOR No. 135.



STATE ENGINEER'S ENDORSEMENT.

Approved December 29th. 1915.

John C. Trout
State Engineer.

13771
13772

105-9/2009

a1

16417

THE STATE OF WYOMING

CERTIFICATE OF APPROPRIATION OF WATER

CERTIFICATE RECORD No. 41 PAGE 120

WHEREAS, Ruby Smith has presented to the Board of Control of the State of Wyoming proof of the appropriation of water from Squaw Creek tributary of Little Powder River through the Ruby Ditch under Permit No. 13771 for irrigation of the lands herein described, lying and being in Campbell County, Wyoming.

NOW KNOW YE, That the Board of Control, under the provisions of Chapter 61, Compiled Statutes of Wyoming, 1910, has, by an order duly made and entered on the 21st day of November, A. D. 19 19, in Order Record No. 5, Page 602, determined and established the priority and amount of such appropriation as follows:

Name of Appropriator Ruby Smith; Postoffice Address Gillette, Wyoming; Amount of Appropriation 0.04 cu. ft. per sec.; Date of Appropriation Dec. 28, 1915; Description of land to be irrigated and for which this appropriation is determined and established; Total Acreage Three (3) Acres

TWP.	RANGE	SEC.	NE¼				NW¼				SW¼				SE¼				TOTALS
			NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	
55	73	28									3								3

The right to water hereby confirmed and established is limited to irrigation and the use is restricted to the place where acquired and to the purpose for which acquired; rights for irrigation not to exceed one cubic foot per second for each seventy acres of land for which appropriation is herein determined and established.

IN TESTIMONY WHEREOF, I, Frank C. Emerson, President of the State Board of Control, have hereunto set my hand this 5th day of March, A. D. 19 20, and caused the seal of said Board to be hereunto affixed.

ATTEST: Julia Bartlett Freeborn, *Secretary*. Frank C. Emerson, *President*.

MAP

TO ACCOMPANY APPLICATIONS FOR

RUBY AND RUBY NO. 2 DITCHES.

APPLICANT

RUBY SMITH, GILLETTE, WYOMING.

Scale 1 inch = 1200 feet.

CERTIFICATE OF SURVEYOR.

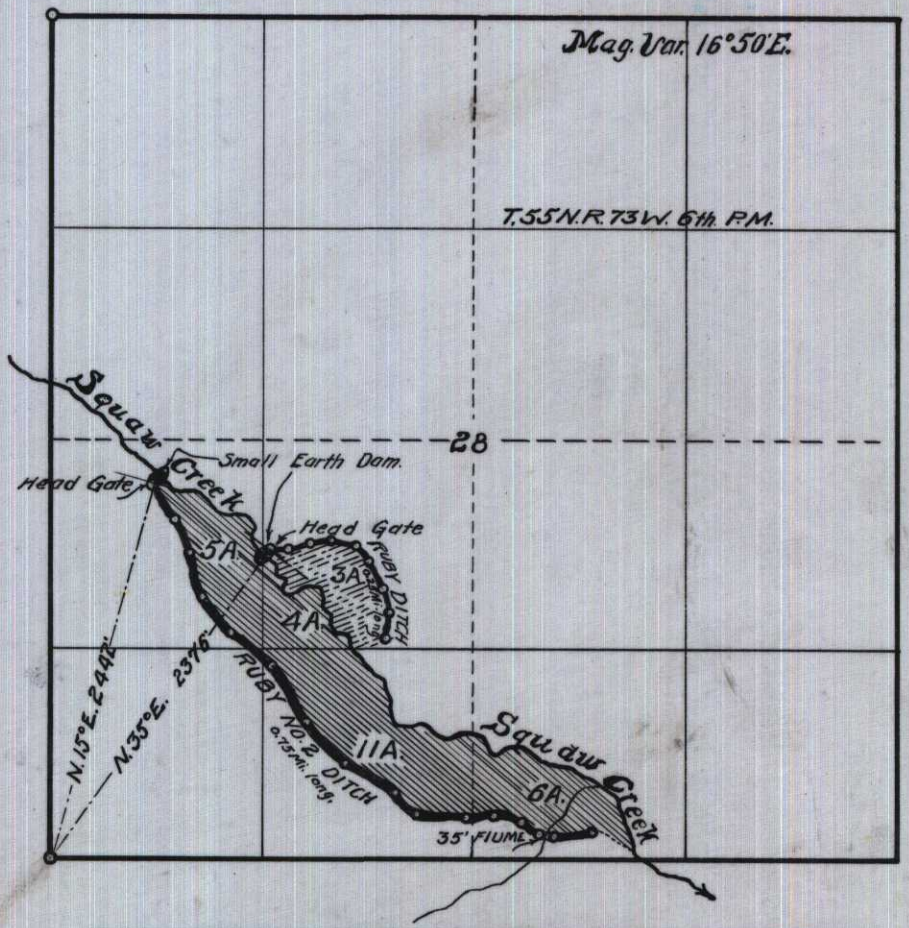
STATE OF COLORADO } ss:
COUNTY OF DENVER }

I, Royal D. Salisbury, of Denver, Colorado, hereby certify that this map was made from notes taken during an actual survey made by my assistant, W.R. Fox, of Gillette, Wyo, on November 27th and 28th 1915, and that it correctly represents the irrigation works described in the accompanying applications, together with a meander of streams, and shows accurately the location and area of the lands proposed to be irrigated in each subdivision.

Grade 1 foot pr. 1000 feet.
Velocity 0.98 ft pr. Second.
Capacity 4.30 Cu. Ft. pr. Sec.

Royal D. Salisbury.

SURVEYOR No. 135.



STATE ENGINEER'S ENDORSEMENT.

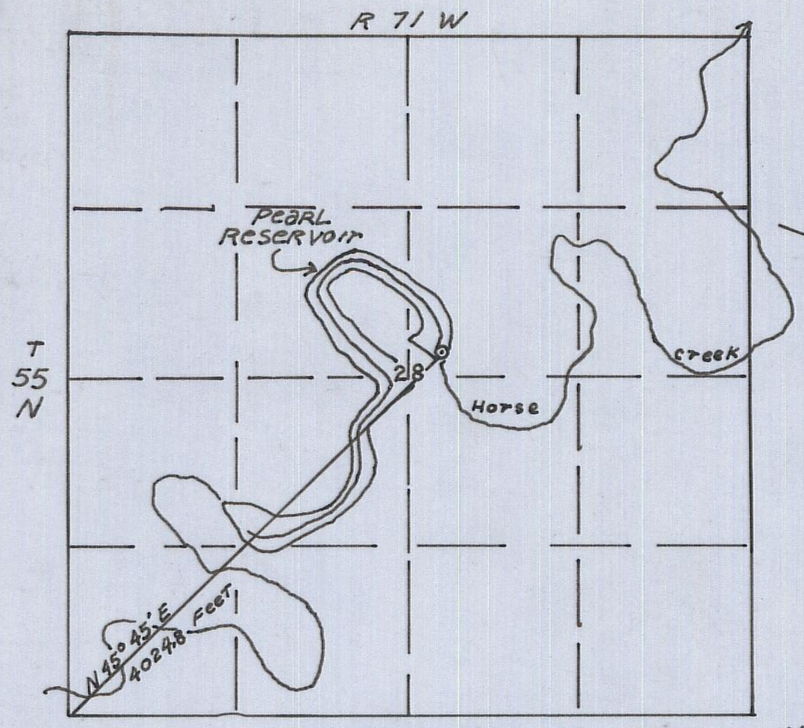
Approved December 29th. 1915.

John C. Trout
State Engineer.

13771
13772

105-9/2009

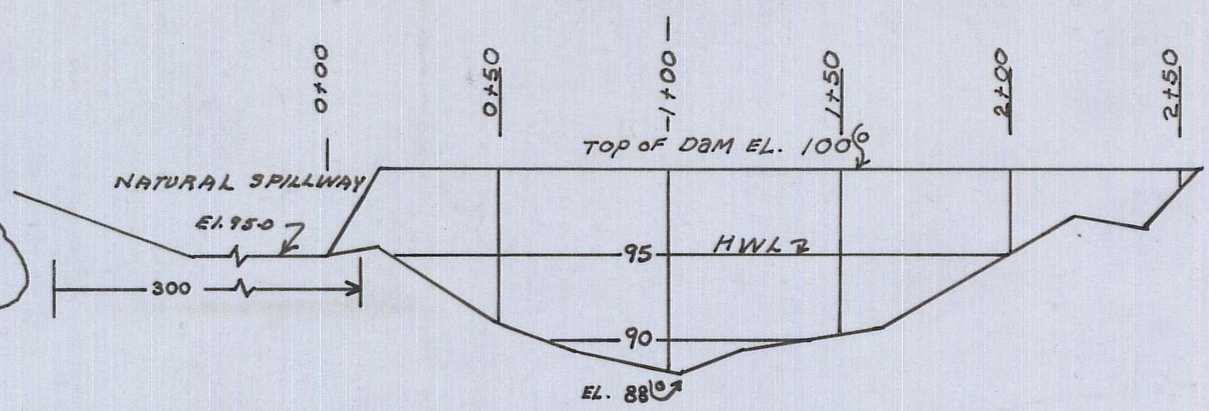
a1



LOCATION MAP

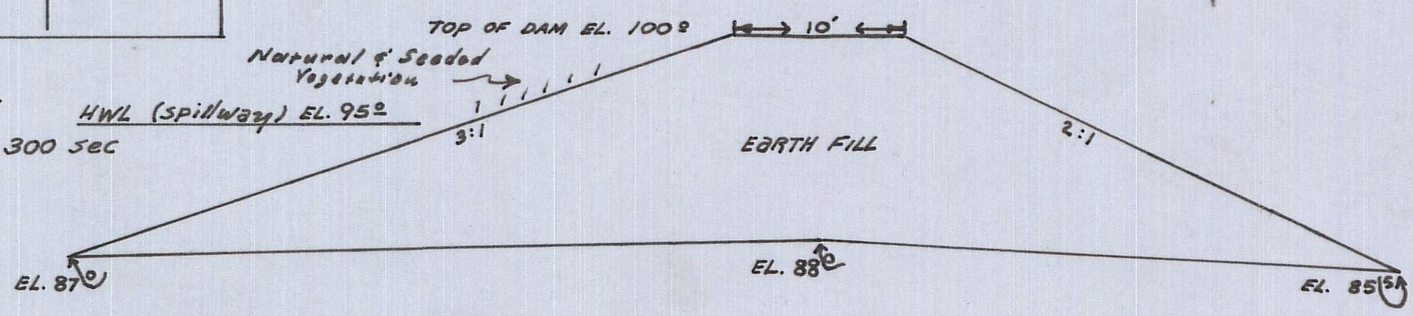
Scale: 4" = 1 Mi

DRAINAGE AREA Approx. 300 sec



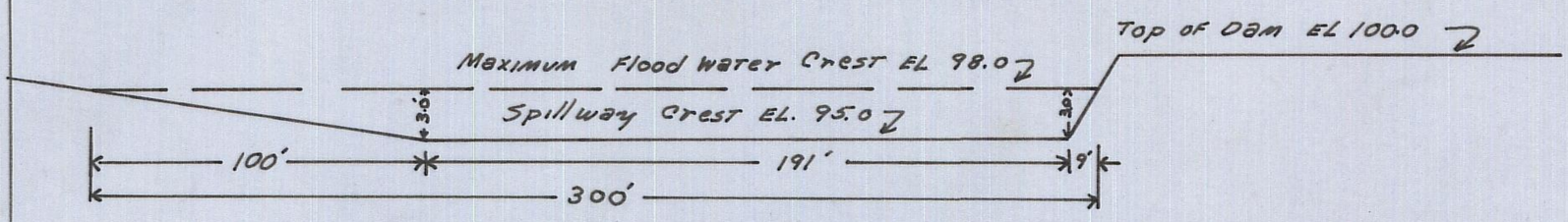
PROFILE OF DAMSITE

scale: HOR - 1" = 50'
VER - 1" = 10'



MAXIMUM CROSS-SECTION OF DAM

Scale: Hor. 1 inch = 10'



SPILLWAY CROSS SECTION

Scales: Hor - 1" = 50'
Ver - 1" = 10'

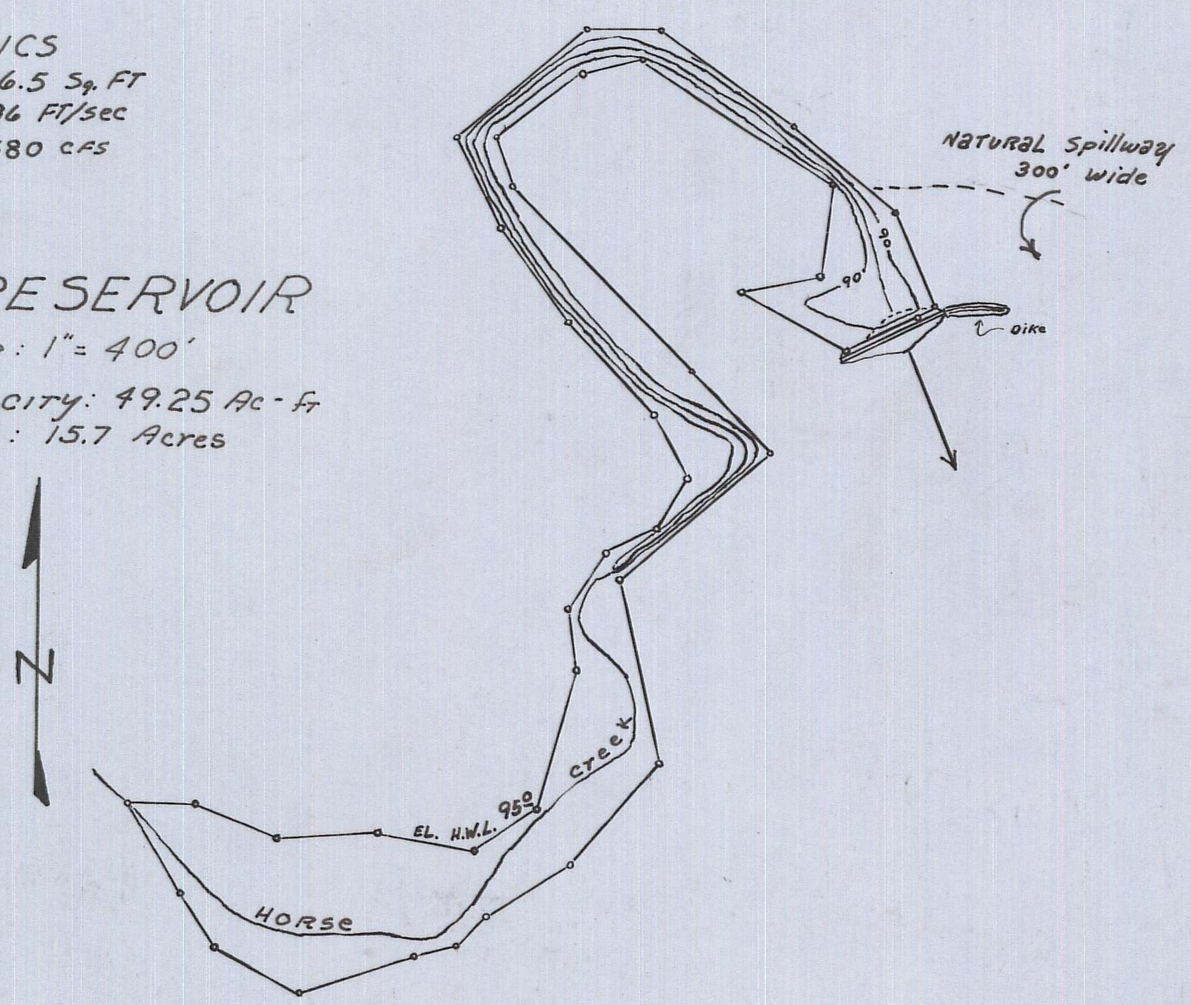
SPILLWAY HYDRAULICS

$n = 0.035$	$A = 736.5$ Sq. FT
$S = 0.004$	$v = 4.86$ FT/sec
$r = 2.45$	$Q = 3580$ CFS

PEARL RESERVOIR

Scale: 1" = 400'

Total Capacity: 49.25 Ac-ft
Area: 15.7 Acres



CAPACITY TABLE

ELEVATION	AREA	AVE. AREA	CAPACITY
87.0	0.0		
		1.25	3.75
90.0	2.5		
		9.1	45.50
95.0	15.7		
TOTAL AVAILABLE CAPACITY			49.25

CERTIFICATE OF SURVEYOR

STATE OF WYOMING }
COUNTY OF CAMPBELL } ss

I, John R Long, of Gillette, Wyoming, hereby certify that this map was made from notes taken during an actual survey made under my direction by D. I. Johnson and M. O. Schiermeister, both of Gillette, Wyoming, on MARCH 19, 1956; And that it correctly represents the location of streams, and the location, Area and capacity of the Pearl Reservoir as described in the Accompanying Application.

License No. 227

John R. Long
Surveyor

MAP
TO ACCOMPANY APPLICATION
FOR
PEARL RESERVOIR
APPLICANT:
Jess Boardman
Weston, Wyoming

Approved October 9, 1956
L. C. Bishop
L. C. Bishop, State Engineer

6324 Res.
17 1/6

APPENDIX B

PRODUCED CBNG WATER QUALITY ANALYSES

Squaw Cr POD
1 of 2

Inter·Mountain Laboratories, Inc.

1673 Terra Avenue
Sheridan, WY 82801

RECEIVED
SEP 22 2006
BY:

Sample Analysis Report

CLIENT: Pinnacle Gas Resources, Inc.
1 East Alger
Suite 206
Sheridan, WY 82801

Date Reported: 9/21/2006
Report ID: S0608606001

Work Order: S0608606
Collection Date: 8/31/2006 2:30 PM
Date Received: 8/31/2006 4:30 PM
Sampler: SK

Project: Initial Discharge
Lab ID: S0608606-001
Client Sample ID: 0053651-0105 Squaw Creek POD
Matrix: Water

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	8.5	0.1		s.u.	09/01/2006 2253 AT	EPA 150.1
Electrical Conductivity	1670	5		µmhos/cm	09/01/2006 2253 AT	SM 2510B
Total Dissolved Solids (180)	1060	10		mg/L	09/01/2006 000 AF	SM 2540
Alkalinity, Total (As CaCO3)	1000	5		mg/L	09/01/2006 2253 AT	SM 2320B
Hardness, Calcium/Magnesium (As CaCO3)	156	1		mg/L	09/07/2006 1336 AT	SM 2340B
Cyanide, Total	ND	5		µg/L	09/05/2006 1643 LM	EPA 335.4
Phenolics, Total Recoverable	ND	10		µg/L	09/01/2006 1308 LM	EPA 420.2
Radium 226	1.15 ± 0.26	0.2		pCi/L	09/18/2006 1336 SH	SM 7500 RA B
TPH 418.1	ND	1		mg/L	09/06/2006 1622 HG	EPA 418.1
Sodium Adsorption Ratio	13.8	0.1			09/07/2006 1336 AT	Calculation
Anions						
Alkalinity, Bicarbonate as HCO3	1160	5		mg/L	09/01/2006 2253 AT	SM 2320B
Chloride	9	5		mg/L	09/01/2006 1358 LK	EPA 300.0
Fluoride	0.8	0.1		mg/L	09/01/2006 2253 AT	SM 4500FC
Sulfate	ND	10		mg/L	09/01/2006 1358 LK	EPA 300.0
Cations						
Calcium	32	1		mg/L	09/05/2006 1622 AB	EPA 200.7
Magnesium	18	1		mg/L	09/05/2006 1622 AB	EPA 200.7
Potassium	18	1		mg/L	09/05/2006 1622 AB	EPA 200.7
Sodium	395	1		mg/L	09/05/2006 1622 AB	EPA 200.7
Cation/Anion-Milliequivalents						
Bicarbonate as HCO3	18.93	0.01		meq/L	09/07/2006 1336 AT	SM 1030F
Chloride	0.26	0.01		meq/L	09/07/2006 1336 AT	SM 1030F
Fluoride	0.04	0.01		meq/L	09/07/2006 1336 AT	SM 1030F
Sulfate	ND	0.01		meq/L	09/07/2006 1336 AT	SM 1030F
Calcium	1.61	0.01		meq/L	09/07/2006 1336 AT	SM 1030F
Magnesium	1.50	0.01		meq/L	09/07/2006 1336 AT	SM 1030F
Potassium	0.45	0.01		meq/L	09/07/2006 1336 AT	SM 1030F
Sodium	17.19	0.01		meq/L	09/07/2006 1336 AT	SM 1030F

These results apply only to the samples tested.

Qualifiers:

*	Value exceeds Maximum Contaminant Level	B	Analyte detected in the associated Method Blank
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit	S	Spike Recovery outside accepted recovery limits

Reviewed by: Patricia A Quade
Patricia Quade, Project Manager

Inter·Mountain Laboratories, Inc.
1673 Terra Avenue
Sheridan, WY 82801

RECEIVED
SEP 22 2006
BY:

Sample Analysis Report

CLIENT: Pinnacle Gas Resources, Inc.
1 East Alger
Suite 206
Sheridan, WY 82801

Project: Initial Discharge
Lab ID: S0608606-001
Client Sample ID: 0053651-0105
Matrix: Water

Date Reported: 9/21/2006
Report ID: S0608606001
Work Order: S0608606
Collection Date: 8/31/2006 2:30 PM
Date Received: 8/31/2006 4:30 PM
Sampler: SK

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
Dissolved Metals						
Boron	200	100		µg/L	09/05/2006 1622 AB	EPA 200.7
Cadmium	ND	0.1		µg/L	09/01/2006 1018 MS	EPA 200.8
Chromium	ND	1		µg/L	09/05/2006 1622 AB	EPA 200.7
Copper	ND	1		µg/L	09/01/2006 1018 MS	EPA 200.8
Iron	ND	30		µg/L	09/05/2006 1622 AB	EPA 200.7
Lead	ND	2		µg/L	09/01/2006 1018 MS	EPA 200.8
Manganese	40	10		µg/L	09/05/2006 1622 AB	EPA 200.7
Mercury	ND	1		µg/L	09/07/2006 926 DG	EPA 245.1
Nickel	ND	10		µg/L	09/05/2006 1622 AB	EPA 200.7
Silver	ND	3		µg/L	09/01/2006 1018 MS	EPA 200.8
Zinc	10	10		µg/L	09/05/2006 1622 AB	EPA 200.7
Total Metals (200.2)						
Aluminum	ND	50		µg/L	09/05/2006 1646 AB	EPA 200.7
Antimony	ND	5		µg/L	09/01/2006 1159 MS	EPA 200.8
Arsenic	ND	1		µg/L	09/01/2006 1159 MS	EPA 200.8
Barium	700	100		µg/L	09/01/2006 1159 MS	EPA 200.8
Beryllium	3.6	0.9		µg/L	09/05/2006 1646 AB	EPA 200.7
Selenium	ND	5		µg/L	09/01/2006 1159 MS	EPA 200.8
Thallium	ND	10		µg/L	09/01/2006 1159 MS	EPA 200.8

These results apply only to the samples tested.

Qualifiers:

*	Value exceeds Maximum Contaminant Level
E	Value above quantitation range
J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit
B	Analyte detected in the associated Method Blank
H	Holding times for preparation or analysis exceeded
L	Analyzed by a contract laboratory
S	Spike Recovery outside accepted recovery limits

Reviewed by: Patricia A Quade
Patricia Quade, Project Manager

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LABORATORY ANALYTICAL REPORT

Client: Arcadis
Project: Horse Creek North
Client Sample ID: HCN/Twenty Mile W34-18-42
Location:
Samp FRQ/Type: Arcadis G&M Inc
Lab ID: G06100055-001

Report Date: 10/17/06
Collection Date: 10/03/06 12:10
DateReceived: 10/03/06
Matrix: Aqueous
Sampled By: Kerri Shoup

Analyses	Result	Units	Result	Units	Qualifier	Method	Analysis Date / By
MAJOR IONS, DISSOLVED							
Bicarbonate as HCO3	766	mg/L	12.6	meq/L		A2320 B	10/04/06 09:36 / mli
Chloride	13	mg/L	0.38	meq/L		E300.0	10/04/06 12:15 / mli
Fluoride	0.6	mg/L	0.03	meq/L		E300.0	10/04/06 12:15 / mli
Sulfate	14	mg/L	0.30	meq/L		E300.0	10/04/06 12:15 / mli
Calcium	27	mg/L	1.33	meq/L		E200.7	10/05/06 04:38 / eli-b
Magnesium	12	mg/L	0.98	meq/L		E200.7	10/05/06 04:38 / eli-b
Sodium	232	mg/L	10.1	meq/L		E200.7	10/05/06 04:38 / eli-b
METALS, DISSOLVED							
Cadmium	<0.1	ug/L				E200.8	10/04/06 13:59 / eli-b
Copper	<1	ug/L				E200.8	10/04/06 13:59 / eli-b
Iron	<30	ug/L				E200.7	10/05/06 04:38 / eli-b
Lead	<2	ug/L				E200.8	10/04/06 13:59 / eli-b
Manganese	48	ug/L				E200.7	10/05/06 04:38 / eli-b
Mercury	<0.06	ug/L				E200.8	10/04/06 13:59 / eli-b
Zinc	<10	ug/L				E200.7	10/05/06 04:38 / eli-b
METALS, TOTAL RECOVERABLE							
Aluminum	<50	ug/L				E200.8	10/06/06 16:33 / eli-b
Arsenic	0.2	ug/L				E200.8	10/06/06 16:33 / eli-b
Barium	604	ug/L				E200.7	10/06/06 11:07 / eli-b
Selenium	<5	ug/L				E200.8	10/06/06 16:33 / eli-b
NON-METALS							
Alkalinity, Total as CaCO3	628	mg/L				A2320 B	10/04/06 09:36 / mli
Conductivity @ 25 C	1180	umhos/cm				A2510 B	10/03/06 15:09 / clb
Hardness as CaCO3	120	mg/L				A2340 B	10/10/06 08:18 / tlc
Nitrogen, Ammonia as N	0.9	mg/L				E350.1	10/04/06 11:00 / eli-b
pH	8.00	s.u.				A4500-H B	10/03/06 15:11 / clb
Sodium Adsorption Ratio (SAR)	9.4	unitless				Calculation	10/10/06 08:19 / tlc
Solids, Total Dissolved TDS @ 180 C	729	mg/L				A2540 C	10/04/06 10:03 / mli
Temperature	16.20	°C				A4500-H B	10/03/06 15:11 / clb
RADIOCHEMICAL							
Radium 226	0.6	pCi/L				E903.0M	10/11/06 14:01 / eli-c
Radium 226 precision (±)	0.2	pCi/L				E903.0M	10/11/06 14:01 / eli-c
Radium 228	<1.0	pCi/L				RA-05	10/16/06 12:42 / eli-c
Radium 226 + Radium 228	<1.00	pCi/L				Calculation	10/16/06 17:34 / eli-c

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Arcadis
Project: Horse Creek North
Client Sample ID: HCN/Twenty Mile P34-18-42
Location:
Samp FRQ/Type: Arcadis G&M Inc
Lab ID: G06100055-002

Report Date: 10/17/06
Collection Date: 10/03/06 12:10
DateReceived: 10/03/06
Matrix: Aqueous
Sampled By: Kerri Shoup

Analyses	Result	Units	Result	Units	Qualifier	Method	Analysis Date / By
MAJOR IONS, DISSOLVED							
Bicarbonate as HCO3	390	mg/L	6.38	meq/L		A2320 B	10/04/06 09:59 / mli
Chloride	11	mg/L	0.30	meq/L		E300.0	10/04/06 12:51 / mli
Fluoride	0.9	mg/L	0.05	meq/L		E300.0	10/04/06 12:51 / mli
Sulfate	<1	mg/L	<0.02	meq/L		E300.0	10/04/06 12:51 / mli
Calcium	9	mg/L	0.43	meq/L		E200.7	10/05/06 04:42 / eli-b
Magnesium	3	mg/L	0.28	meq/L		E200.7	10/05/06 04:42 / eli-b
Sodium	126	mg/L	5.47	meq/L		E200.7	10/05/06 04:42 / eli-b
METALS, DISSOLVED							
Cadmium	<0.1	ug/L				E200.8	10/04/06 14:07 / eli-b
Copper	<1	ug/L				E200.8	10/04/06 14:07 / eli-b
Iron	121	ug/L				E200.7	10/05/06 04:42 / eli-b
Lead	<2	ug/L				E200.8	10/04/06 14:07 / eli-b
Manganese	22	ug/L				E200.7	10/05/06 04:42 / eli-b
Mercury	<0.06	ug/L				E200.8	10/04/06 14:07 / eli-b
Zinc	<10	ug/L				E200.7	10/05/06 04:42 / eli-b
METALS, TOTAL RECOVERABLE							
Aluminum	<50	ug/L				E200.8	10/06/06 16:40 / eli-b
Arsenic	<0.1	ug/L				E200.8	10/06/06 16:40 / eli-b
Barium	211	ug/L				E200.7	10/06/06 11:12 / eli-b
Selenium	<5	ug/L				E200.8	10/06/06 16:40 / eli-b
NON-METALS							
Alkalinity, Total as CaCO3	319	mg/L				A2320 B	10/04/06 09:59 / mli
Conductivity @ 25 C	615	umhos/cm				A2510 B	10/03/06 15:10 / clb
Hardness as CaCO3	35	mg/L				A2340 B	10/10/06 08:18 / tlc
Nitrogen, Ammonia as N	0.6	mg/L				E350.1	10/04/06 11:02 / eli-b
pH	8.05	s.u.				A4500-H B	10/03/06 15:13 / clb
Sodium Adsorption Ratio (SAR)	9.2	unitless				Calculation	10/10/06 08:19 / tlc
Solids, Total Dissolved TDS @ 180 C	381	mg/L				A2540 C	10/04/06 10:54 / mli
Temperature	16.00	°C				A4500-H B	10/03/06 15:13 / clb
RADIOCHEMICAL							
Radium 226	0.5	pCi/L				E903.0M	10/11/06 14:01 / eli-c
Radium 226 precision (±)	0.2	pCi/L				E903.0M	10/11/06 14:01 / eli-c
Radium 228	<1.0	pCi/L				RA-05	10/16/06 15:02 / eli-c
Radium 226 + Radium 228	<1.00	pCi/L				Calculation	10/16/06 17:34 / eli-c

Report Definitions:
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MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Lance Oil and Gas
Site Name: Parnell_Trust
Project: WYPDES
Client Sample ID: DP_WY0050652_001_TP
Location: SWNW_24_54N_74W
Samp FRQ/Type: IN_A_S1_M
Lab ID: G06010274-001

Report Date: 01/25/06
Collection Date: 01/11/06 10:45
DateReceived: 01/11/06
Sampled By: Lesley Roth
Matrix: AQUEOUS
Tracking Number: 65344

Analyses	Result	Units	Result	Units	Qualifier	Method	Analysis Date / By
FIELD PARAMETERS							
pH, field	8.28	s.u.				FIELD	01/11/06 10:45 / ***
*** Performed by Sampler							
MAJOR IONS, DISSOLVED							
Bicarbonate as HCO3	690	mg/L	11.3	meq/L		A2320 B	01/12/06 13:55 / mli
Chloride	12	mg/L	0.34	meq/L		E300.0	01/14/06 01:30 / mli
Sulfate	<1	mg/L	<0.02	meq/L		E300.0	01/14/06 01:30 / mli
Calcium	17	mg/L	0.82	meq/L		E200.7	01/16/06 16:45 / rlh
Magnesium	9	mg/L	0.74	meq/L		E200.7	01/16/06 16:45 / rlh
Sodium	236	mg/L	10.3	meq/L		E200.7	01/16/06 16:45 / rlh
METALS, DISSOLVED							
Cadmium	<0.1	ug/L				E200.8	01/17/06 05:35 / jjw
Copper	4	ug/L				E200.8	01/17/06 05:35 / jjw
Iron	<30	ug/L				E200.7	01/16/06 16:45 / rlh
Lead	<2	ug/L				E200.8	01/17/06 05:35 / jjw
Manganese	15	ug/L				E200.8	01/17/06 05:35 / jjw
Mercury	<0.06	ug/L				E200.8	01/17/06 05:35 / jjw
Zinc	<10	ug/L				E200.8	01/17/06 05:35 / jjw
METALS, TOTAL							
Barium	629	ug/L				E200.7	01/16/06 12:45 / rlh
METALS, TOTAL RECOVERABLE							
Aluminum	<50	ug/L				E200.7	01/16/06 12:45 / rlh
Arsenic	<0.1	ug/L				E200.8	01/18/06 00:10 / jjw
Beryllium	<0.03	ug/L				E200.8	01/17/06 04:41 / jjw
Selenium	<5	ug/L				E200.8	01/17/06 04:41 / jjw
NON-METALS							
Alkalinity, Total as CaCO3	589	mg/L				A2320 B	01/12/06 13:55 / mli
Conductivity @ 25 C	1050	umhos/cm				A2510 B	01/11/06 17:29 / mb
Hardness as CaCO3	78	mg/L				A2340 B	01/18/06 17:33 / tlc
Sodium Adsorption Ratio (SAR)	11.6	unitless				Calculation	01/18/06 17:33 / tlc
Solids, Total Dissolved TDS @ 180 C	654	mg/L				A2540 C	01/13/06 11:28 / mli
Total Petroleum Hydrocarbons	<1.0	mg/L				SW1664A	01/18/06 17:51 / ton
RADIOCHEMICAL							
Radium 226	0.3	pCi/L				E903.0M	01/13/06 16:20 / df
Radium 226 precision (±)	0.3	pCi/L				E903.0M	01/13/06 16:20 / df

Report Definitions: RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

David Poelstra
David Poelstra
Project Manager

Inter·Mountain Laboratories, Inc.

1673 Terra Avenue
Sheridan, WY 82801

Sample Analysis Report

CLIENT: Redstone Resources Inc
410 17th Street Suite 400
Denver, CO 80202

Date Reported: 1/23/2006
Report ID: S0601016001

Work Order: S0601016
Project: Hensley Draw_Horse Creek
Collection Date: 12/30/2005 11:26:00 AM
Lab ID: S0601016-001
Date Received: 12/30/2005 3:39:00 PM
Client Sample ID: WY0050911-001
Sampler: JD
Matrix: Water

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
Field						
pH	7.1	0.01		s.u.	12/30/2005 1126	Field
Conductivity	1346	0.01		µmhos/cm	12/30/2005 1126	Field
Flow Rate	0.1	0.01		cfs	12/30/2005 1126	Field
General Parameters						
pH	8.2	0.1		s.u.	01/04/2006 1229 MD	EPA 150.1
Electrical Conductivity	1500	5		µmhos/cm	01/04/2006 1229 MD	SM 2510B
Total Dissolved Solids (180)	910	10		mg/L	01/04/2006 907 EB	SM 2540
Alkalinity, Total (As CaCO3)	865	5		mg/L	01/04/2006 1229 MD	SM 2320B
Hardness, Calcium/Magnesium (As CaCO3)	158	1		mg/L	01/10/2006 1026 MD	SM 2340B
Radium 226	0.48 ± 0.19	0.2		pCi/L	01/06/2006 1229 SH	SM 7500 RA B
Sodium Adsorption Ratio	11.5	0.1			01/10/2006 1026 MD	Calculation
Anions						
Alkalinity, Bicarbonate as HCO3	1060	5		mg/L	01/04/2006 1229 MD	SM 2320B
Chloride	8	5		mg/L	01/03/2006 1547 LK	EPA 300.0
Sulfate	ND	10		mg/L	01/03/2006 1547 LK	EPA 300.0
Cations						
Calcium	34	1		mg/L	01/09/2006 1301 TC	EPA 200.7
Magnesium	18	1		mg/L	01/09/2006 1301 TC	EPA 200.7
Sodium	332	1		mg/L	01/09/2006 1301 TC	EPA 200.7
Cation/Anion-Milliequivalents						
Calcium	1.71	0.01		meq/L	01/10/2006 1026 MD	SM 1030F
Magnesium	1.45	0.01		meq/L	01/10/2006 1026 MD	SM 1030F
Sodium	14.45	0.01		meq/L	01/10/2006 1026 MD	SM 1030F
Dissolved Metals						
Cadmium	ND	0.1		µg/L	01/03/2006 1343 MS	EPA 200.8
Copper	ND	1		µg/L	01/03/2006 1343 MS	EPA 200.8
Iron	200	30		µg/L	01/09/2006 1301 TC	EPA 200.7
Lead	ND	2		µg/L	01/03/2006 1343 MS	EPA 200.8
Manganese	30	10		µg/L	01/09/2006 1301 TC	EPA 200.7
Mercury	ND	0.06		µg/L	01/10/2006 1056 PQ	EPA 245.1
Zinc	ND	10		µg/L	01/09/2006 1301 TC	EPA 200.7
Total Metals (200.2)						
Arsenic	ND	1		µg/L	01/04/2006 1622 MS	EPA 200.8
Barium	700	100		µg/L	01/04/2006 1622 MS	EPA 200.8

These results apply only to the samples tested.

Qualifiers:

*	Value exceeds Maximum Contaminant Level	B	Analyte detected in the associated Method Blank
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit	S	Spike Recovery outside accepted recovery limits

Reviewed by:
Wade Nieuwsma, Project Manager

Inter·Mountain Laboratories, Inc.

1673 Terra Avenue
Sheridan, WY 82801

Sample Analysis Report

CLIENT: Redstone Resources Inc
410 17th Street Suite 400
Denver, CO 80202

Date Reported: 1/23/2006
Report ID: S0601016001

Work Order: S0601016
Project: Hensley Draw_Horse Creek
Collection Date: 12/30/2005 11:26:00 AM
Lab ID: S0601016-001
Date Received: 12/30/2005 3:39:00 PM
Client Sample ID: WY0050911-001
Sampler: JD
Matrix: Water

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
Total Recoverable Metals						
Aluminum	70	50		µg/L	01/10/2006 1309 TC	EPA 200.7
Selenium	ND	5		µg/L	01/04/2006 1622 MS	EPA 200.8

These results apply only to the samples tested.

Qualifiers:

*	Value exceeds Maximum Contaminant Level	B	Analyte detected in the associated Method Blank
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit	S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Project Manager

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LABORATORY ANALYTICAL REPORT

Client: Yates Petroleum Corp
Project: Store Draw/Compass
Client Sample ID: WY0037362-001
Location:
Samp FRQ/Type:
Lab ID: G06120304-001

Report Date: 12/20/06
Collection Date: 12/14/06 13:20
DateReceived: 12/14/06
Matrix: Aqueous
Sampled By: Mike Stevens

Analyses	Result	Units	Result	Units	Qualifier	Method	Analysis Date / By
FIELD PARAMETERS							
pH, field	7.34	s.u.				FIELD	12/14/06 13:20 / ***
*** Performed by Sampler							
MAJOR IONS, DISSOLVED							
Bicarbonate as HCO3	1270	mg/L	20.8	meq/L		A2320 B	12/15/06 12:32 / mli
Chloride	17	mg/L	0.48	meq/L		E300.0	12/15/06 17:03 / mli
Fluoride	0.8	mg/L	0.04	meq/L		E300.0	12/15/06 17:03 / mli
Sulfate	<1	mg/L	<0.02	meq/L		E300.0	12/15/06 17:03 / mli
Calcium	14	mg/L	0.70	meq/L		E200.7	12/16/06 09:04 / eli-b
Magnesium	7	mg/L	0.56	meq/L		E200.7	12/16/06 09:04 / eli-b
Potassium	15	mg/L	0.39	meq/L		E200.7	12/16/06 09:04 / eli-b
Sodium	430	mg/L	18.7	meq/L		E200.7	12/16/06 09:04 / eli-b
NON-METALS							
Alkalinity, Total as CaCO3	1040	mg/L				A2320 B	12/15/06 12:32 / mli
Conductivity @ 25 C	1840	umhos/cm				A2510 B	12/14/06 15:06 / sim
Sodium Adsorption Ratio (SAR)	23.6	unitless				Calculation	12/18/06 12:49 / tlc
DATA QUALITY							
A/C Balance	-2.33	%				A1030 E	12/18/06 12:48 / tlc
Anions	21.3	meq/L				A1030 E	12/18/06 12:48 / tlc
Cations	20.4	meq/L				A1030 E	12/18/06 12:48 / tlc

Report Definitions: RL - Analyte reporting limit. QCL - Quality control limit. MCL - Maximum contaminant level. ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Yates Petroleum Corp
Project:
Client Sample ID: WY0050610-003
Location:
Samp FRQ/Type:
Lab ID: G06080323-001

Report Date: 08/15/06
Collection Date: 08/09/06 13:15
DateReceived: 08/09/06
Matrix: Aqueous
Sampled By: Brock Schell

Analyses	Result	Units	Result	Units	Qualifier	Method	Analysis Date / By
FIELD PARAMETERS							
pH, field	7.95	s.u.				FIELD	08/09/06 13:15 / ***
*** Performed by Sampler							
MAJOR IONS, DISSOLVED							
Bicarbonate as HCO3	1690	mg/L	27.7	meq/L		A2320 B	08/11/06 16:32 / mli
Chloride	9	mg/L	0.26	meq/L		E300.0	08/11/06 02:13 / mb
Fluoride	0.9	mg/L	0.04	meq/L		E300.0	08/11/06 02:13 / mb
Sulfate	<1	mg/L	<0.02	meq/L		E300.0	08/11/06 02:13 / mb
Calcium	35	mg/L	1.73	meq/L		E200.7	08/12/06 22:49 / eli-b
Magnesium	23	mg/L	1.87	meq/L		E200.7	08/12/06 22:49 / eli-b
Potassium	13	mg/L	0.33	meq/L		E200.7	08/12/06 22:49 / eli-b
Sodium	528	mg/L	22.9	meq/L		E200.7	08/12/06 22:49 / eli-b
NON-METALS							
Alkalinity, Total as CaCO3	1380	mg/L				A2320 B	08/11/06 16:32 / mli
Conductivity @ 25 C	2330	umhos/cm				A2510 B	08/09/06 17:50 / clb
Sodium Adsorption Ratio (SAR)	17.1	unitless				Calculation	08/14/06 17:10 / clw
DATA QUALITY							
A/C Balance	-2.03	%				A1030 E	08/14/06 17:09 / tlc
Anions	28.0	meq/L				A1030 E	08/14/06 17:09 / tlc
Cations	26.9	meq/L				A1030 E	08/14/06 17:09 / tlc

Report Definitions: RL - Analyte reporting limit. QCL - Quality control limit. MCL - Maximum contaminant level. ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Thomas Operating Co.
Project: Dugout Draw
Samp FRQ/Type:
Lab ID: G04100403-001
Client Sample ID: Thomas Oper HC 01WP-20-54-73
Location:

Report Date: 11/11/04
Collection Date: 10/28/04 11:00
DateReceived: 10/28/04
Sampled By: Robert Davis
Matrix: AQUEOUS

Analyses	Result	Units	Qualifiers	RL	QCL	Method	Analysis Date / By
MAJOR IONS							
Bicarbonate as HCO3	803	mg/L		5		A2320 B	11/01/04 12:59 / mli
Chloride	14	mg/L		1		E300.0	11/01/04 17:07 / mli
Fluoride	0.8	mg/L		0.1		E300.0	11/01/04 17:07 / mli
Sulfate	ND	mg/L		1		E300.0	11/01/04 17:07 / mli
Calcium	25	mg/L		1		E200.7	11/10/04 13:09 / rlh
Magnesium	11	mg/L		1		E200.7	11/10/04 13:09 / rlh
Potassium	11	mg/L		1		E200.7	11/10/04 13:09 / rlh
Sodium	238	mg/L		1		E200.7	11/10/04 13:09 / rlh
MAJOR IONS - MILLIEQUIVALENTS							
Calcium, meq	1.26	meq/L		0.05		E200.7	11/10/04 13:09 / rlh
Magnesium, meq	0.91	meq/L		0.08		E200.7	11/10/04 13:09 / rlh
Sodium, meq	10.4	meq/L		0.04		E200.7	11/10/04 13:09 / rlh
METALS, DISSOLVED							
Boron	125	ug/L		100		E200.7	11/04/04 14:21 / rlh
Cadmium	ND	ug/L		0.1		E200.8	11/06/04 10:33 / jw
Chromium	ND	ug/L		1		E200.8	11/06/04 10:33 / jw
Copper	ND	ug/L		1		E200.8	11/06/04 10:33 / jw
Iron	ND	ug/L		30		E200.7	11/03/04 17:50 / rlh
Lead	ND	ug/L		2		E200.8	11/09/04 08:38 / jw
Manganese	37	ug/L		10		E200.7	11/04/04 14:21 / rlh
Mercury	ND	ug/L		0.06		E200.8	11/06/04 10:33 / jw
Nickel	14	ug/L		10		E200.8	11/06/04 10:33 / jw
Silver	ND	ug/L		3		E200.8	11/06/04 10:33 / jw
Zinc	ND	ug/L		10		E200.7	11/03/04 17:50 / rlh
METALS, TOTAL							
Barium	514	ug/L		100		E200.7	11/03/04 06:30 / rlh
METALS, TOTAL RECOVERABLE							
Aluminum	ND	ug/L		50		E200.7	11/03/04 06:26 / rlh
Antimony	ND	ug/L		5		E200.8	11/09/04 08:31 / jw
Arsenic	7.6	ug/L		0.1		E200.8	11/09/04 08:31 / jw
Beryllium	ND	ug/L		0.03		E200.8	11/06/04 10:06 / jw
Selenium	ND	ug/L		5		E200.8	11/09/04 08:31 / jw
Thallium	ND	ug/L		1		E200.8	11/09/04 08:31 / jw

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 1105 West First Street. * Gillette, WY 82716
Toll Free 866.686.7175 * 307.686.7175 * Fax 307.682.4625 * gillette@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Thomas Operating Co.
Project: Dugout Draw
Samp FRQ/Type:
Lab ID: G04100403-001
Client Sample ID: Thomas Oper HC 01WP-20-54-73
Location:

Report Date: 11/11/04
Collection Date: 10/28/04 11:00
DateReceived: 10/28/04
Sampled By: Robert Davis
Matrix: AQUEOUS

Analyses	Result	Units	Qualifiers	RL	QCL	Method	Analysis Date / By
NON-METALS							
Alkalinity, Total as CaCO3	659	mg/L		5		A2320 B	11/01/04 12:59 / mli
Conductivity @ 25 C	1200	umhos/cm		1		A2510 B	10/28/04 14:41 / daa
Cyanide, Total Automated	ND	ug/L		5		E335.3	11/01/04 13:04 / kp
Hardness as CaCO3	110	mg/L		10		A2340 B	11/11/04 09:30 / cw
pH	7.71	s.u.		0.01		A4500-H B	10/28/04 14:49 / daa
Phenolics, Total Recoverable	ND	ug/L		10		E420.2	11/04/04 09:46 / kp
Sodium Adsorption Ratio (SAR)	10	unitless		0.1		Calculation	11/11/04 09:31 / cw
Solids, Total Dissolved TDS @ 180 C	733	mg/L		20		A2540 C	11/01/04 11:18 / mli
Total Petroleum Hydrocarbons	ND	mg/L		1.0		SW1664A	11/03/04 11:32 / atd
DATA QUALITY							
A/C Balance	-2.98	%				A1030 E	11/11/04 09:28 / cw
Anions	13.6	meq/L		0.01		A1030 E	11/11/04 09:28 / cw
Cations	12.8	meq/L		0.01		A1030 E	11/11/04 09:28 / cw
RADIOCHEMICAL							
Radium 226	0.4	pCi/L		0.2		E903.0M	11/01/04 15:00 / df
Radium 226 precision (±)	0.2	pCi/L				E903.0M	11/01/04 15:00 / df

Chris Wilson
Chris Wilson
Project Manager

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Thomas Operating Co.
Project: Dugout Draw
Samp FRQ/Type:
Lab ID: G04100403-002
Client Sample ID: Thomas Oper State HC 15CC
Location:

Report Date: 11/11/04
Collection Date: 10/28/04 10:25
DateReceived: 10/28/04
Sampled By: Robert Davis
Matrix: AQUEOUS

Analyses	Result	Units	Qualifiers	RL	QCL	Method	Analysis Date / By
MAJOR IONS							
Bicarbonate as HCO3	1040	mg/L		5		A2320 B	11/01/04 13:06 / mli
Chloride	9	mg/L		1		E300.0	11/01/04 17:22 / mli
Fluoride	0.7	mg/L		0.1		E300.0	11/01/04 17:22 / mli
Sulfate	ND	mg/L		1		E300.0	11/01/04 17:22 / mli
Calcium	29	mg/L		1		E200.7	11/03/04 17:59 / rlh
Magnesium	18	mg/L		1		E200.7	11/03/04 17:59 / rlh
Potassium	14	mg/L		1		E200.7	11/04/04 14:29 / rlh
Sodium	293	mg/L		1		E200.7	11/04/04 14:29 / rlh
MAJOR IONS - MILLIEQUIVALENTS							
Calcium, meq	1.47	meq/L		0.05		E200.7	11/03/04 17:59 / rlh
Magnesium, meq	1.52	meq/L		0.08		E200.7	11/03/04 17:59 / rlh
Sodium, meq	12.8	meq/L		0.04		E200.7	11/04/04 14:29 / rlh
METALS, DISSOLVED							
Boron	108	ug/L		100		E200.7	11/04/04 14:29 / rlh
Cadmium	ND	ug/L		0.1		E200.8	11/06/04 10:47 / jw
Chromium	ND	ug/L		1		E200.8	11/06/04 10:47 / jw
Copper	ND	ug/L		1		E200.8	11/06/04 10:47 / jw
Iron	ND	ug/L		30		E200.7	11/03/04 17:59 / rlh
Lead	ND	ug/L		2		E200.8	11/06/04 10:47 / jw
Manganese	45	ug/L		10		E200.7	11/04/04 14:29 / rlh
Mercury	ND	ug/L		0.06		E200.8	11/06/04 10:47 / jw
Nickel	132	ug/L		10		E200.8	11/06/04 10:47 / jw
Silver	ND	ug/L		3		E200.8	11/06/04 10:47 / jw
Zinc	ND	ug/L		10		E200.7	11/03/04 17:59 / rlh
METALS, TOTAL							
Barium	889	ug/L		100		E200.7	11/03/04 06:38 / rlh
METALS, TOTAL RECOVERABLE							
Aluminum	ND	ug/L		50		E200.7	11/03/04 06:34 / rlh
Antimony	ND	ug/L		5		E200.8	11/06/04 10:40 / jw
Arsenic	ND	ug/L		0.1		E200.8	11/09/04 08:45 / jw
Beryllium	ND	ug/L		0.03		E200.8	11/06/04 10:40 / jw
Selenium	ND	ug/L		5		E200.8	11/06/04 10:40 / jw
Thallium	ND	ug/L		1		E200.8	11/06/04 10:40 / jw

Report Definitions:
RL - Analyte reporting limit.
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ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 1105 West First Street. * Gillette, WY 82716
Toll Free 866.686.7175 * 307.686.7175 * Fax 307.682.4625 * gillette@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Thomas Operating Co.
Project: Dugout Draw
Samp FRQ/Type:
Lab ID: G04100403-002
Client Sample ID: Thomas Oper State HC 15CC
Location:

Report Date: 11/11/04
Collection Date: 10/28/04 10:25
DateReceived: 10/28/04
Sampled By: Robert Davis
Matrix: AQUEOUS

Analyses	Result	Units	Qualifiers	RL	QCL	Method	Analysis Date / By
NON-METALS							
Alkalinity, Total as CaCO3	852	mg/L		5		A2320 B	11/01/04 13:06 / mli
Conductivity @ 25 C	1490	umhos/cm		1		A2510 B	10/28/04 14:42 / daa
Cyanide, Total Automated	ND	ug/L		5		E335.3	11/01/04 13:06 / kp
Hardness as CaCO3	150	mg/L		10		A2340 B	11/09/04 16:16 / cw
pH	7.89	s.u.		0.01		A4500-H B	10/28/04 14:50 / daa
Phenolics, Total Recoverable	ND	ug/L		10		E420.2	11/04/04 09:48 / kp
Sodium Adsorption Ratio (SAR)	10.4	unitless		0.1		Calculation	11/09/04 16:17 / cw
Solids, Total Dissolved TDS @ 180 C	916	mg/L		20		A2540 C	11/01/04 11:22 / mli
Total Petroleum Hydrocarbons	ND	mg/L		1.0		SW1664A	11/03/04 11:33 / atd
DATA QUALITY							
A/C Balance	-3.67	%				A1030 E	11/09/04 16:06 / cw
Anions	17.3	meq/L		0.01		A1030 E	11/09/04 16:06 / cw
Cations	16.1	meq/L		0.01		A1030 E	11/09/04 16:06 / cw
RADIOCHEMICAL							
Radium 226	0.6	pCi/L		0.2		E903.0M	11/01/04 15:00 / df
Radium 226 precision (±)	0.2	pCi/L				E903.0M	11/01/04 15:00 / df

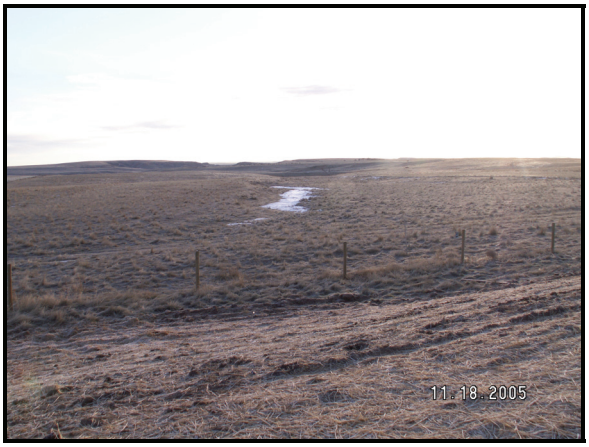
Chris Wilson
Chris Wilson
Project Manager

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

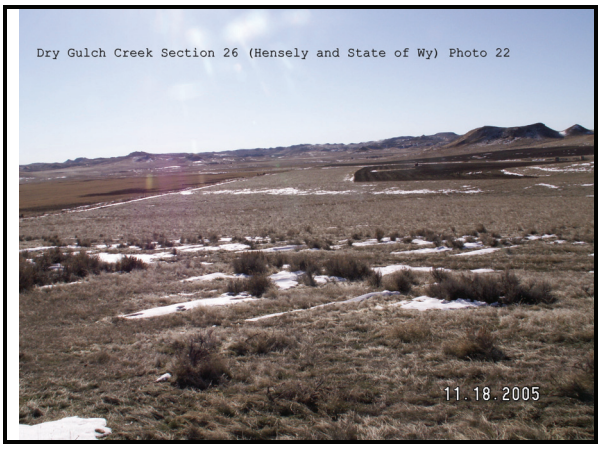
APPENDIX C

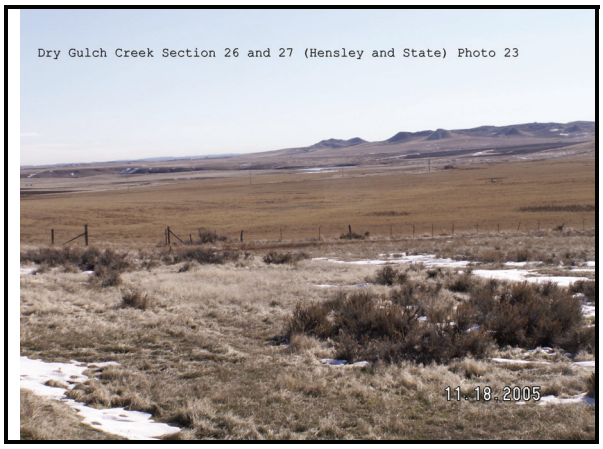
PHOTO DOCUMENTATION OF SOIL SAMPLING POINTS AND SITES INVESTIGATED BUT NOT SAMPLED

Picture Point BB-A



Picture Point BS-A





Picture Point CF-A

Sampling Point CK1-1

Sampling Point CK2-1

Sampling Point CK3-1

Sampling Point CK4-1

Sampling Point CK4-14

Sampling Point CK5-1

Sampling Point CK6-1

Sampling Point CK7-1

Picture Point DB-A

Sampling Point DM-1

Sampling Point DM-2

Picture Point DM-A

Picture Point DM-B

Picture Point DO-A

Picture Point DO-B

Picture Point DO-C

Picture Point DO-D

Picture Point DO-E

Picture Point DO-F

Sampling Point DT1-1

Sampling Point DT2-1

Sampling Point DT4-1

Sampling Point DT5-1

Sampling Point DT6-1

Picture Point DT-A

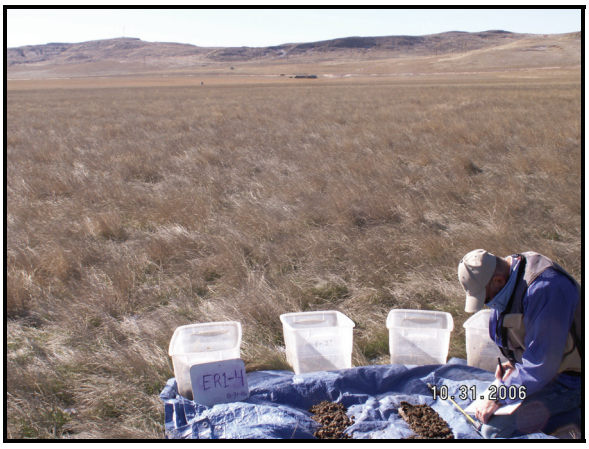
Picture Point DT-B

Sampling Point ER1-1

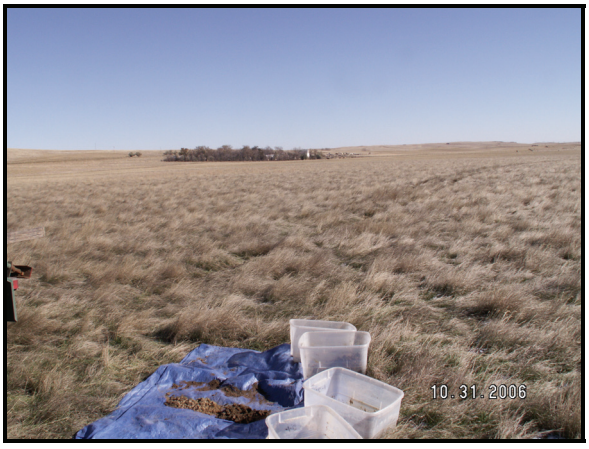
Sampling Point ER1-2

Sampling Point ER1-3

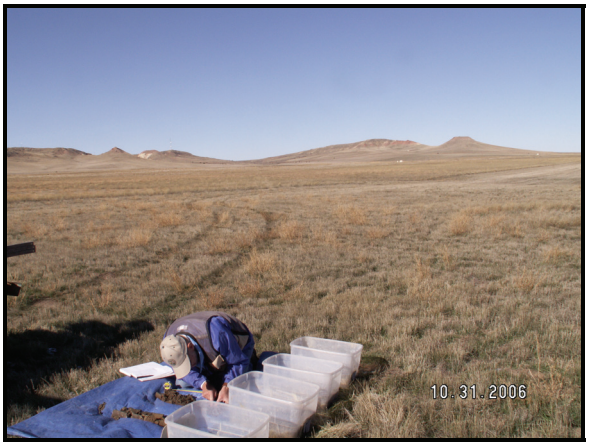
Sampling Point ER1-4



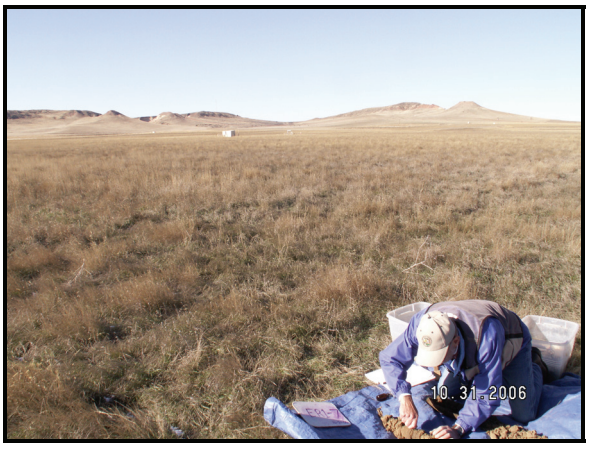
Sampling Point ER1-5



Sampling Point ER1-6



Sampling Point ER1-7



Picture Point FO-A

Picture Point FO-B

Picture Point FO-C

Sampling Point JW1-1

Picture Point JW-A

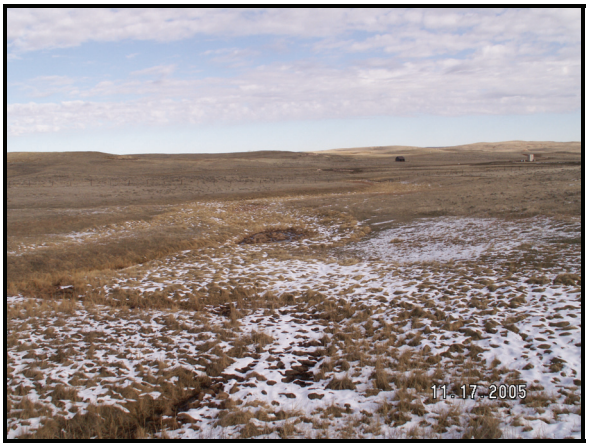
Picture Point JW-B

Picture Point JW-C

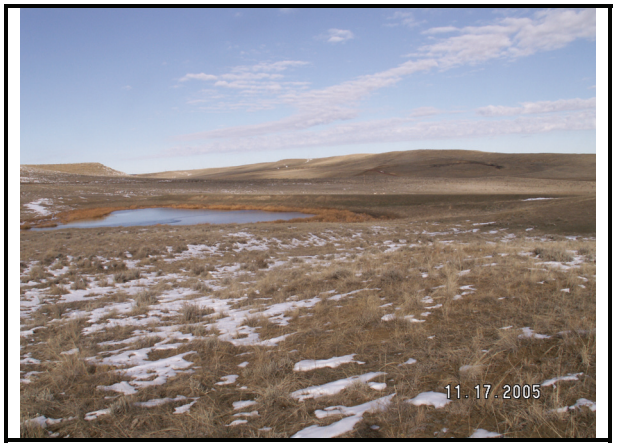
Picture Point LO-A

Picture Point LO-B

Picture Point LO-C



Picture Point LO-D



Picture Point LO-E

Sampling Point LP5-1

Sampling Point LP6-2

Sampling Point LP7-1

Sampling Point LP8-6

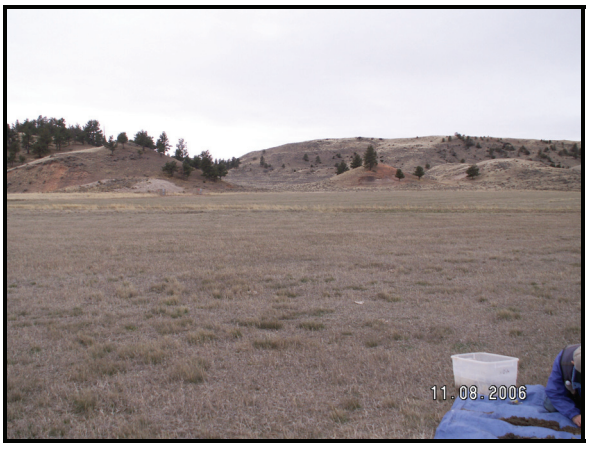
Sampling Point LS1-1

Sampling Point LS2-1

Sampling Point MP2-1

Sampling Point MP8-1

Sampling Point MP8-3



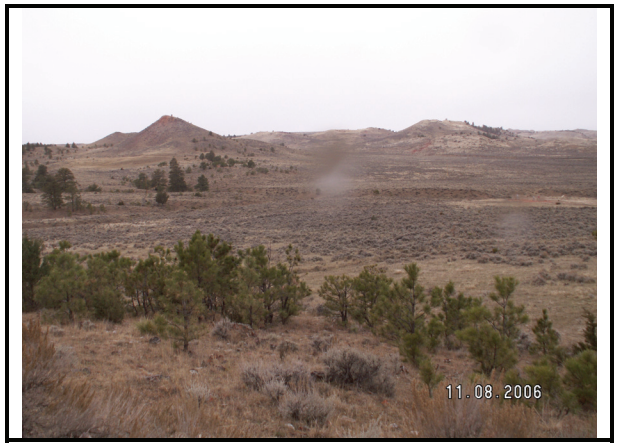
Sampling Point MP8-4

Sampling Point MP8-5

Sampling Point MP8-6

Sampling Point MP8-7

Picture Point MP-A



Picture Point MP-B

Picture Point MP-C

Picture Point OT-A

Picture Point OT-B

Picture Point OT-C

Picture Point OT-D

Picture Point OT-E

Picture Point OT-F

Picture Point OT-G

Picture Point OT-H

Picture Point OT-I

Sampling Point PP3-1

Sampling Point PP4-1

Sampling Point PP5-1

Sampling Point PP6-1

Sampling Point PP7-1

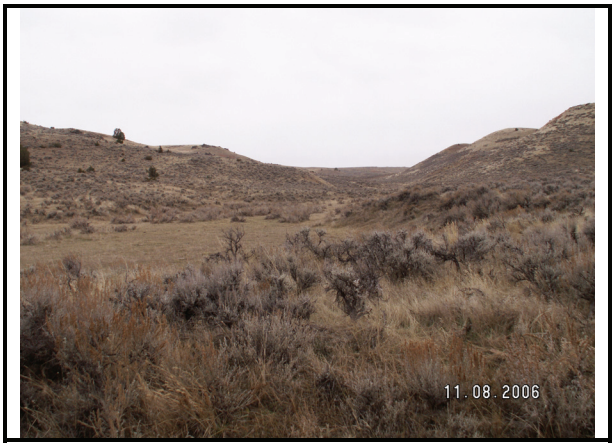
Sampling Point PP8-1

Sampling Point PP9-1

Sampling Point PP10-2

Picture Point PP-A

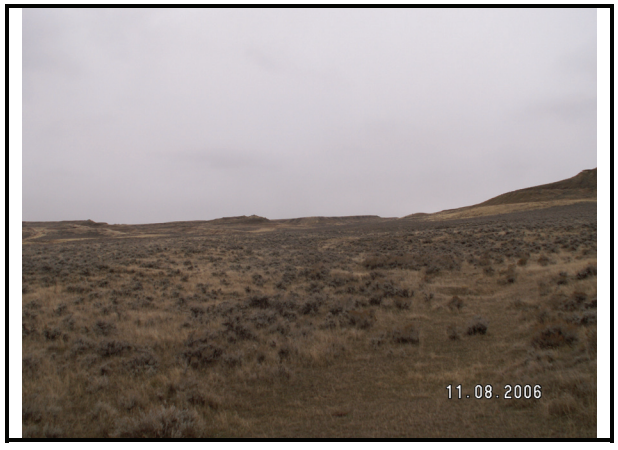
Picture Point PP-B

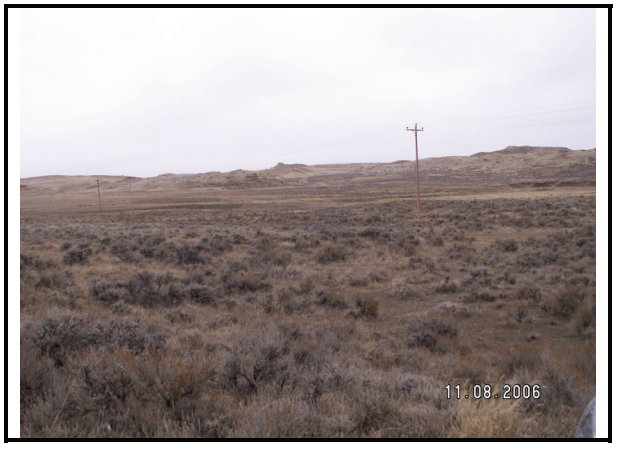


Picture Point PP-C

Picture Point PP-D

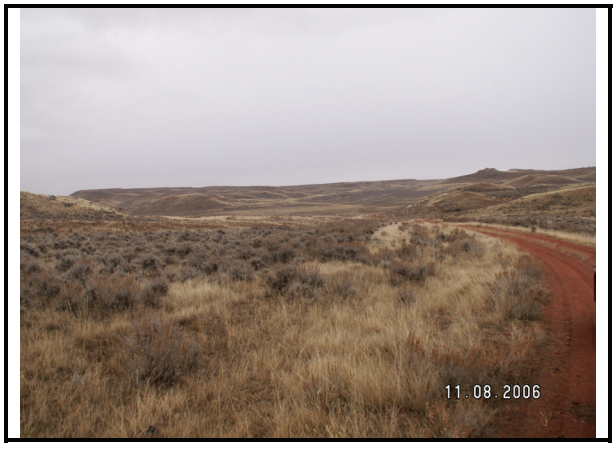
Picture Point PP-E





Picture Point PP-F

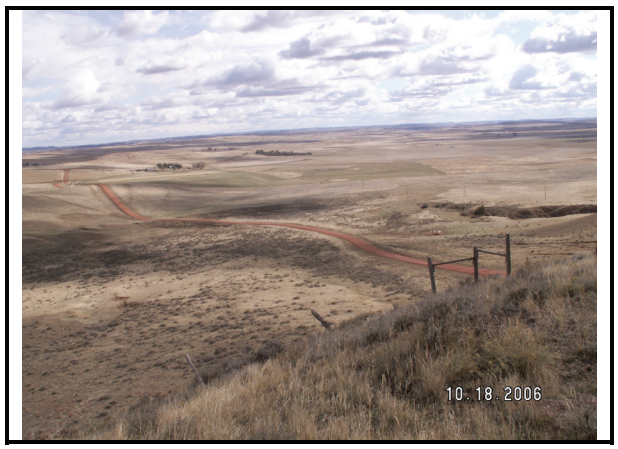
Picture Point PP-G



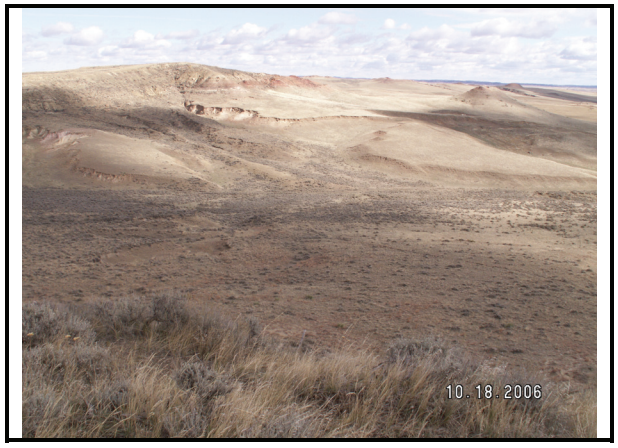
Picture Point PP-H

Picture Point PP-I

Picture Point RA-A



Picture Point RA-B



Picture Point RH-A

Picture Point RH-B

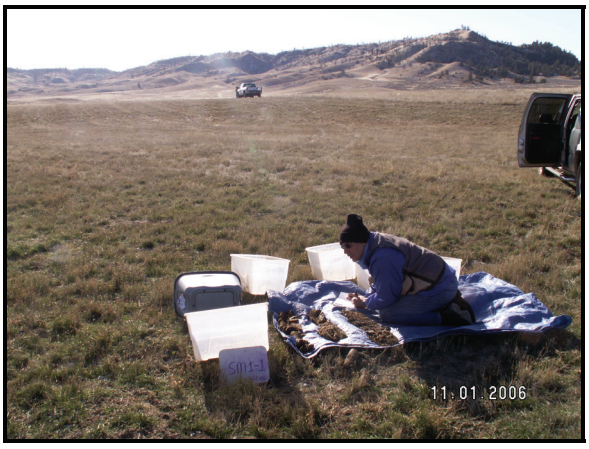
Picture Point RH-C

Picture Point RK-A

Picture Point RL-A

Picture Point RL-B

Sampling Point SM1-1



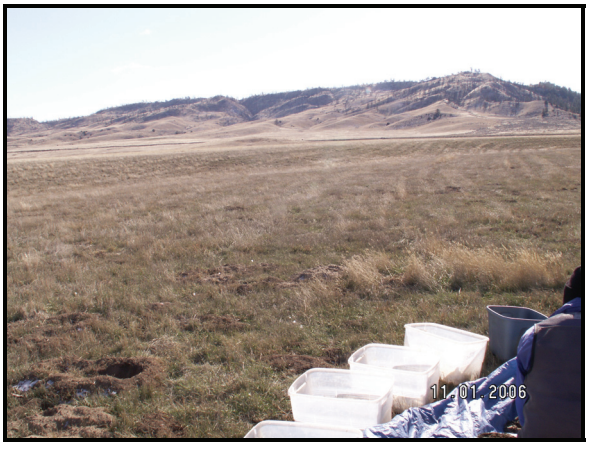
Sampling Point SM1-2

Sampling Point SM1-3

Sampling Point SM1-4

Sampling Point SM1-5

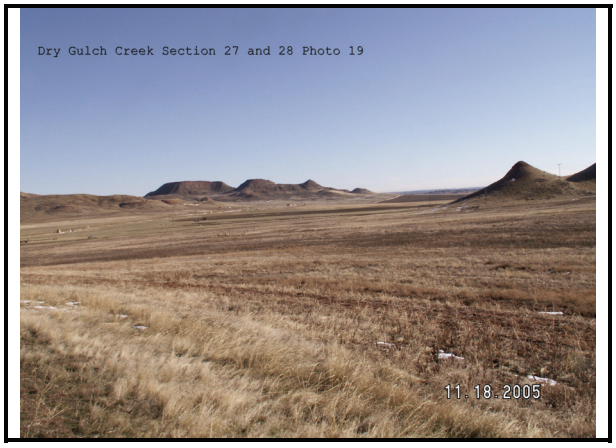
Sampling Point SM1-6



Sampling Point SM1-7

Sampling Point SM2-1

Picture Point SR-A



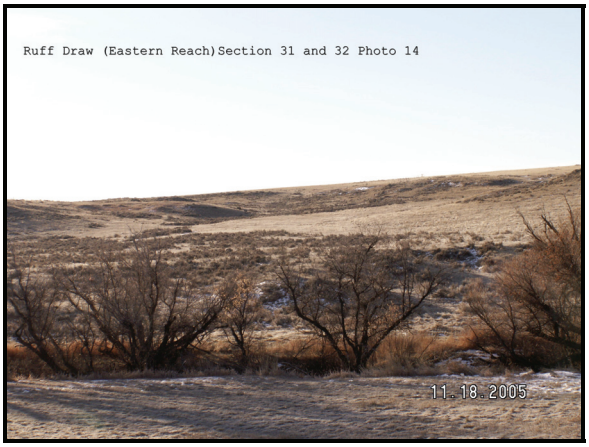
Picture Point SR-B

Picture Point SS-A

Picture Point STATE-A

Picture Point STATE-B

Picture Point STATE-C



APPENDIX D

ALLUVIAL GROUNDWATER QUALITY SAMPLE ANALYES

Inter·Mountain Laboratories, Inc.

1673 Terra Avenue
Sheridan, WY 82801

Sample Analysis Report

CLIENT: Western Water Consultants
P.O. Box 3042
Sheridan, WY 82801

Date Reported: 10/18/2006
Report ID: S0610021001

Work Order: S0610021
Project: Horse Creek
Collection Date: 10/1/2006 3:07 PM
Lab ID: S0610021-001
Date Received: 10/2/2006 8:00 AM
Client Sample ID: PP8-1
Sampler: TB
Matrix: Water

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	8.0	0.1		s.u.	10/04/2006 438 AT	EPA 150.1
Electrical Conductivity	5430	5		µmhos/cm	10/04/2006 438 AT	SM 2510B
Sodium Adsorption Ratio	5.7	0.1			10/09/2006 839 AT	Calculation
Cations						
Calcium	436	1		mg/L	10/05/2006 151 MH	EPA 200.7
Magnesium	359	1		mg/L	10/05/2006 151 MH	EPA 200.7
Sodium	664	1		mg/L	10/05/2006 151 MH	EPA 200.7
Cation/Anion-Milliequivalents						
Calcium	21.77	0.01		meq/L	10/09/2006 839 AT	SM 1030F
Magnesium	29.54	0.01		meq/L	10/09/2006 839 AT	SM 1030F
Sodium	28.89	0.01		meq/L	10/09/2006 839 AT	SM 1030F

These results apply only to the samples tested.

Qualifiers:

*	Value exceeds Maximum Contaminant Level	B	Analyte detected in the associated Method Blank
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit	S	Spike Recovery outside accepted recovery limits

Reviewed by: Wendy Owen
Wendy Owen, Project Manager

Inter·Mountain Laboratories, Inc.

1673 Terra Avenue
Sheridan, WY 82801

Sample Analysis Report

CLIENT: Western Water Consultants
P.O. Box 3042
Sheridan, WY 82801

Date Reported: 10/18/2006
Report ID: S0610145001

Work Order: S0610145
Project: Water Quality
Collection Date: 10/3/2006 1:34 PM
Lab ID: S0610145-001
Date Received: 10/5/2006 5:10 PM
Client Sample ID: MP5-1
Sampler:
Matrix: Water

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	7.7	0.1		s.u.	10/09/2006 1444 AT	EPA 150.1
Electrical Conductivity	5190	5		µmhos/cm	10/09/2006 1444 AT	SM 2510B
Sodium Adsorption Ratio	4.7	0.1			10/18/2006 1156 WO	Calculation
Cations						
Calcium	518	1		mg/L	10/09/2006 2216 RM	EPA 200.7
Magnesium	319	1		mg/L	10/09/2006 2216 RM	EPA 200.7
Sodium	557	1		mg/L	10/09/2006 2216 RM	EPA 200.7
Cation/Anion-Milliequivalents						
Calcium	25.83	0.01		meq/L	10/18/2006 1156 WO	SM 1030F
Magnesium	26.27	0.01		meq/L	10/18/2006 1156 WO	SM 1030F
Sodium	24.23	0.01		meq/L	10/18/2006 1156 WO	SM 1030F

These results apply only to the samples tested.

Qualifiers:

*	Value exceeds Maximum Contaminant Level	B	Analyte detected in the associated Method Blank
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit	S	Spike Recovery outside accepted recovery limits

Reviewed by: Wendy Owen
Wendy Owen, Project Manager

Inter·Mountain Laboratories, Inc.

1673 Terra Avenue
Sheridan, WY 82801

Sample Analysis Report

CLIENT: Western Water Consultants
P.O. Box 3042
Sheridan, WY 82801

Date Reported: 10/18/2006
Report ID: S0610145001

Work Order: S0610145
Project: Water Quality
Collection Date: 10/3/2006 9:00 AM
Lab ID: S0610145-002
Date Received: 10/5/2006 5:10 PM
Client Sample ID: MP1-3
Sampler:
Matrix: Water

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	7.9	0.1		s.u.	10/09/2006 1504 AT	EPA 150.1
Electrical Conductivity	5170	5		µmhos/cm	10/09/2006 1504 AT	SM 2510B
Sodium Adsorption Ratio	4.4	0.1			10/18/2006 1156 WO	Calculation
Cations						
Calcium	523	1		mg/L	10/09/2006 2220 RM	EPA 200.7
Magnesium	377	1		mg/L	10/09/2006 2220 RM	EPA 200.7
Sodium	544	1		mg/L	10/09/2006 2220 RM	EPA 200.7
Cation/Anion-Milliequivalents						
Calcium	26.11	0.01		meq/L	10/18/2006 1156 WO	SM 1030F
Magnesium	31.04	0.01		meq/L	10/18/2006 1156 WO	SM 1030F
Sodium	23.65	0.01		meq/L	10/18/2006 1156 WO	SM 1030F

These results apply only to the samples tested.

Qualifiers:

*	Value exceeds Maximum Contaminant Level	B	Analyte detected in the associated Method Blank
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit	S	Spike Recovery outside accepted recovery limits

Reviewed by: Wendy Owen
Wendy Owen, Project Manager

Inter·Mountain Laboratories, Inc.

1673 Terra Avenue
Sheridan, WY 82801

Sample Analysis Report

CLIENT: Western Water Consultants
P.O. Box 3042
Sheridan, WY 82801

Date Reported: 10/18/2006
Report ID: S0610145001

Work Order: S0610145
Project: Water Quality
Collection Date: 10/3/2006 8:48 AM
Lab ID: S0610145-003
Date Received: 10/5/2006 5:10 PM
Client Sample ID: MP1-1
Sampler:
Matrix: Water

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	7.9	0.1		s.u.	10/09/2006 1514 AT	EPA 150.1
Electrical Conductivity	6910	5		µmhos/cm	10/09/2006 1514 AT	SM 2510B
Sodium Adsorption Ratio	6.4	0.1			10/18/2006 1156 WO	Calculation
Cations						
Calcium	458	1		mg/L	10/09/2006 2223 RM	EPA 200.7
Magnesium	577	1		mg/L	10/09/2006 2223 RM	EPA 200.7
Sodium	867	1		mg/L	10/09/2006 2223 RM	EPA 200.7
Cation/Anion-Milliequivalents						
Calcium	22.85	0.01		meq/L	10/18/2006 1156 WO	SM 1030F
Magnesium	47.47	0.01		meq/L	10/18/2006 1156 WO	SM 1030F
Sodium	37.70	0.01		meq/L	10/18/2006 1156 WO	SM 1030F

These results apply only to the samples tested.

Qualifiers:

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E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit	S	Spike Recovery outside accepted recovery limits

Reviewed by: Wendy Owen
Wendy Owen, Project Manager

Inter·Mountain Laboratories, Inc.

1673 Terra Avenue
Sheridan, WY 82801

Sample Analysis Report

CLIENT: Western Water Consultants
P.O. Box 3042
Sheridan, WY 82801

Date Reported: 9/19/2006
Report ID: S0608601001

Work Order: S0608601
Project: PVES Terry Brown Horse Cr. Sec 20
Collection Date: 8/31/2006
Lab ID: S0608601-001
Date Received: 8/31/2006 2:40 PM
Client Sample ID: LP2-1
Sampler: TB
Matrix: Water

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	8.2	0.1		s.u.	09/01/2006 000 AT	EPA 150.1
Electrical Conductivity	3100	5		µmhos/cm	09/01/2006 000 AT	SM 2510B
Sodium Adsorption Ratio	6.7	0.1			09/19/2006 1045 WN	Calculation
Cations						
Calcium	90	1		mg/L	09/05/2006 1522 AB	EPA 200.7
Magnesium	145	1		mg/L	09/05/2006 1522 AB	EPA 200.7
Sodium	443	1		mg/L	09/05/2006 1522 AB	EPA 200.7
Cation/Anion-Milliequivalents						
Calcium	4.47	0.01		meq/L	09/19/2006 1045 WN	SM 1030F
Magnesium	11.95	0.01		meq/L	09/19/2006 1045 WN	SM 1030F
Sodium	19.27	0.01		meq/L	09/19/2006 1045 WN	SM 1030F

These results apply only to the samples tested.

Qualifiers:

*	Value exceeds Maximum Contaminant Level	B	Analyte detected in the associated Method Blank
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit	S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Project Manager

Inter·Mountain Laboratories, Inc.

1673 Terra Avenue
Sheridan, WY 82801

Sample Analysis Report

CLIENT: Western Water Consultants
P.O. Box 3042
Sheridan, WY 82801

Date Reported: 9/19/2006
Report ID: S0608601001

Work Order: S0608601
Project: PVES Terry Brown Horse Cr. Sec 20
Collection Date: 8/31/2006
Lab ID: S0608601-002
Date Received: 8/31/2006 2:40 PM
Client Sample ID: LP2-2
Sampler: TB
Matrix: Water

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	8.0	0.1		s.u.	09/01/2006 2120 AT	EPA 150.1
Electrical Conductivity	3210	5		µmhos/cm	09/01/2006 2120 AT	SM 2510B
Sodium Adsorption Ratio	5.0	0.1			09/19/2006 1045 WN	Calculation
Cations						
Calcium	182	1		mg/L	09/05/2006 1526 AB	EPA 200.7
Magnesium	181	1		mg/L	09/05/2006 1526 AB	EPA 200.7
Sodium	394	1		mg/L	09/05/2006 1526 AB	EPA 200.7
Cation/Anion-Milliequivalents						
Calcium	9.06	0.01		meq/L	09/19/2006 1045 WN	SM 1030F
Magnesium	14.88	0.01		meq/L	09/19/2006 1045 WN	SM 1030F
Sodium	17.15	0.01		meq/L	09/19/2006 1045 WN	SM 1030F

These results apply only to the samples tested.

Qualifiers:

*	Value exceeds Maximum Contaminant Level	B	Analyte detected in the associated Method Blank
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit	S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Project Manager

Inter·Mountain Laboratories, Inc.

1673 Terra Avenue
Sheridan, WY 82801

Sample Analysis Report

CLIENT: Western Water Consultants
P.O. Box 3042
Sheridan, WY 82801

Date Reported: 9/19/2006
Report ID: S0608601001

Work Order: S0608601
Project: PVES Terry Brown Horse Cr. Sec 20
Collection Date: 8/31/2006
Lab ID: S0608601-003
Date Received: 8/31/2006 2:40 PM
Client Sample ID: LP3-3
Sampler: TB
Matrix: Water

Analyses	Result	PQL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	8.4	0.1		s.u.	09/01/2006 000 AT	EPA 150.1
Electrical Conductivity	2930	5		µmhos/cm	09/01/2006 000 AT	SM 2510B
Sodium Adsorption Ratio	4.1	0.1			09/19/2006 1045 WN	Calculation
Cations						
Calcium	179	1		mg/L	09/05/2006 1529 AB	EPA 200.7
Magnesium	147	1		mg/L	09/05/2006 1529 AB	EPA 200.7
Sodium	306	1		mg/L	09/05/2006 1529 AB	EPA 200.7
Cation/Anion-Milliequivalents						
Calcium	8.93	0.01		meq/L	09/19/2006 1045 WN	SM 1030F
Magnesium	12.08	0.01		meq/L	09/19/2006 1045 WN	SM 1030F
Sodium	13.33	0.01		meq/L	09/19/2006 1045 WN	SM 1030F

These results apply only to the samples tested.

Qualifiers:

*	Value exceeds Maximum Contaminant Level	B	Analyte detected in the associated Method Blank
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit	S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Project Manager

APPENDIX E

VEGETATION LIST

VEGETATIVE LIST

COMMON NAME	SCIENTIFIC NAME
SHRUBS	
Native Perennial	
Silver Sagebrush	*Artemisia cana*
Fringed Sagebrush	*Artemisia frigida*
Winterfat	*Ceratoides lanata*
Skunkbrush Sumac	*Rhus trilobata*
HERB	
Native Perrennial	
Cloaked Bulrush	*Scirpus pallidus*
Threadleaf sedge	*Carex filifolia*
Equisetum	*Equisetum spp.*
Cattail	*Typha spp.*
TREES	
Native	
Boxelder	*Acer negundo*
FORBS	
Native Perennial	
Wavyleaf thistle	*Cirsium undulatum*
Wild Licorice	*Glycyrrhiza lepidota*
Curlycup gumweed	*Grindelia squarrosa*
Plains pricklypear	*Opuntia polyacantha*
Introduced Annual	
Kochia	*Kochia scoparia*
Field Pennycress	*Thlaspi arvense*
Russian Thistle	*Salsola iberica*
Introduced Perennial	
Alfalfa	*Medicago sativa*
Dandelion	*Taraxacum officinale*
NATIVE GRASSES	
Perennial	
Western Wheatgrass	*Agropyron smithii*
Foxtail Barley	*Hordeum jubatum*
Bluebunch Wheatgrass	*Agropyron spicatum*
Prairie Cordgrass	*Spartina pectinata*
Inland Saltgrass	*Distichlis spicata*

INTRODUCED GRASSES

Perennial

Crested Wheatgrass	*Agropyron cristatum*
Intermediate Wheatgrass	*Agropyron imtermedium*
Smooth Brome	*Bromus inermis*
Wheat	*Triticum spp.*

Annuals

Japanese Brome	*Bromus japonicus*

APPENDIX F

VEGETATION TRANSECT SUMMARIES, PHOTOS AND FIELD DOCUMENTATION

Date surveyed	Transect	Landowner	Location
9/11/2006	**W1**	**State of Wyoming**	**T54 R74 Sec. 35 SWNW**
Rt. Bnk	44.62005	105.73622	Transect width = 126'
Lft. Bnk.	44.62036	105.73628	10' sample intervals

Photos 001 - 002

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	14.29%	42.86% Annual
Field Pennycress	3	21.43%	
Russian Thistle	1	7.14%	
Intermediate Wheatgrass	1	7.14%	50.00% Perennial
Inland Saltgrass	1	7.14%	
Prairie Cordgrass	3	21.43%	
Western Wheatgrass	2	14.29%	
Soil	1	7.14%	
	Total Hits = 14	Sum = 100%	

Photo 001 Transect W1 Lft. Bnk.

Photo 002 Transect W1 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
9/11/2006	**W2**	**State of Wyoming**	**T54 R74 Sec. 35 NWNE**
Rt. Bnk	44.62241	105.72475	Transect width = 93'
Lft. Bnk.	44.62263	105.72469	10' sample intervals

Photos 003 - 004

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	3	30.00%	30.00% Annual
Prairie Cordgrass	4	40.00%	
Cloaked Bulrush	2	20.00%	70.00% Perennial
Western Wheatgrass	1	10.00%	
	Total Hits = 10	Sum = 100%	

Photo 003 Transect W2 Lft. Bnk.

Photo 004 Transect W2 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
9/11/2006	**W3**	**State of Wyoming**	**T54 R74 Sec. 35 NENE**
Rt. Bnk	44.62266	105.72009	Transect width = 182'
Lft. Bnk.	44.62297	105.71976	10' sample intervals

Photos 005 - 006

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	1	5.26%	68.42% Annual
Japanese Brome	12	63.16%	
Wavyleaf Thistle	1	5.26%	26.32% Perennial
Prairie Cordgrass	2	10.53%	
Silver Sagebrush	2	10.53%	
Bare Soil	1	5.26%	
	Total Hits = 19	Sum = 100%	

Photo 005 Transect W3 Lft. Bnk.

Photo 006 Transect W3 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
9/11/2006	**SS1**	**Steve Sorenson**	**T54 R74 Sec. 21 SWSE**
Rt. Bnk	44.64116	105.76462	Transect width = 134'
Lft. Bnk.	44.64130	105.76418	10' sample intervals

Photos 009 - 010

Individual Species	Hits	Percent Occurrence	Species Grouping
Kochia	1	6.67%	6.67% Annual
Wavyleaf thistle	1	6.67%	93.34% Perennial
Wheat	13	86.67%	
	Total Hits = 15	Sum = 100%	

Photo 009 Transect SS1 Lft. Bnk.

Photo 010 Transect SS1 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
9/11/2006	**DJ1**	**Don Joslyn**	**T54 R74 Sec. 27 NWSE**
Rt. Bnk	44.63163	105.74002	Transect width = 66'
Lft. Bnk.	44.63176	105.74786	10' sample intervals

Photos 007 - 008

Individual Species	Hits	Percent Occurrence	Species Grouping
Kochia	1	12.50%	62.50% Annual
Japanese Brome	3	37.50%	
Field Pennycress	1	12.50%	
Crested Wheatgrass	3	37.50%	37.50% Perennial
	Total Hits = 8	Sum = 100%	

Photo 007 Transect DJ1 Lft. Bnk.

Photo 008 Transect DJ1 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
10/16/2006	**DT1**	**Donna Tarver**	**T54 R74 Sec. 25 SWSW**
Rt. Bnk	44.62556	105.71191	Transect width = 179'
Lft. Bnk.	44.62557	105.71247	10' sample intervals

Photos 011 - 012

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	7	36.84%	47.37% Annual
Field Pennycress	2	10.53%	
Western Wheat Grass	3	15.79%	52.63% Perrennial
Silver Sagebrush	4	21.05%	
Prairie Cordgrass	2	10.53%	
Crested Wheat Grass	1	5.26%	
	Total Hits = 19	Sum = 100%	

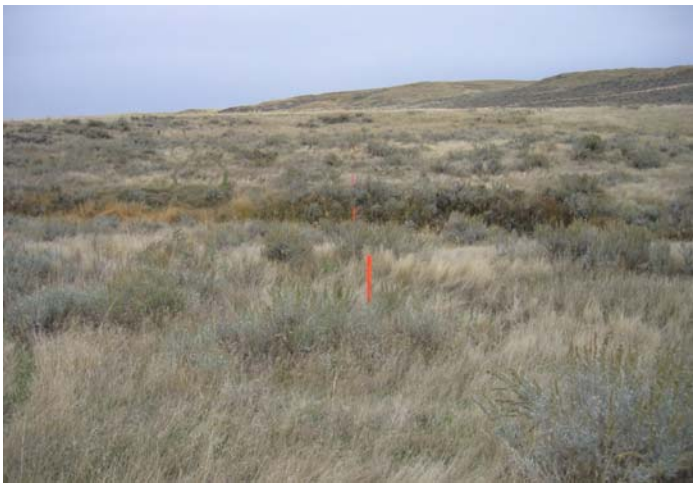

Photo 011 Transect DT1 Lft. Bnk.

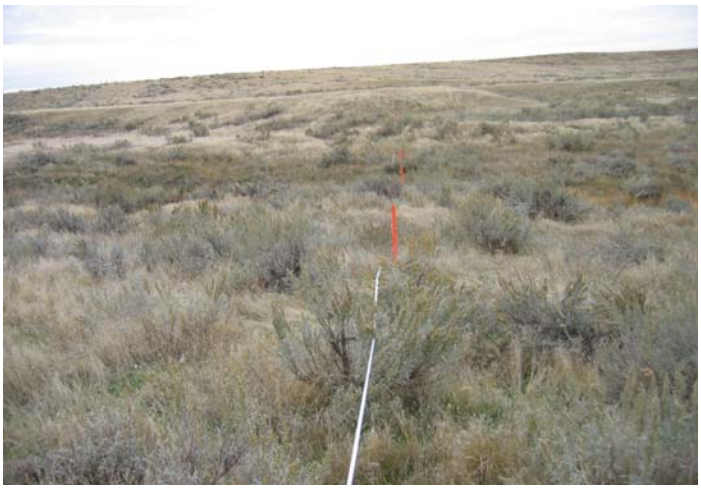

Photo 012 Transect DT1 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
10/16/2006	**DT2**	**Donna Tarver**	**T54 R74 Sec. 25 SWSW**
Rt. Bnk	44.62711	105.71095	Transect width = 247'
Lft. Bnk.	44.62717	105.71169	25' sample intervals

Photos 013 - 014

Individual Species	Hits	Percent Occurrence	Species Grouping
Kochia	1	9.09%	27.27% Annual
Japanese Brome	2	18.18%	
Smooth Brome	3	27.27%	63.63% Perrennial
Cloaked Bulrush	1	9.09%	
Dandelion	1	9.09%	
Silver Sagebrush	1	9.09%	
Prairie Cordgrass	1	9.09%	
Bare Soil	1	9.09%	
	Total Hits = 11	Sum = 100%	

Photo 013 Transect DT2 Lft. Bnk.

Photo 014 Transect DT2 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
9/7/2006	**DT3**	**Donna Tarver**	**T54 R73 Sec. 30 NENE**
Rt. Bnk	44.62878	105.68179	Transect width = 551'
Lft. Bnk.	44.62971	105.68365	25' sample intervals

Photos 015 - 016

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	4	17.39%	30.43% Annual
Kochia	3	13.04%	
Foxtail Barley	4	17.39%	21.74% Perrennial
Threadleaf Sedge	1	4.35%	
Bare Soil	11	47.83%	
	Total Hits = 23	Sum = 100%	

Photo 015 Transect DT3 Rt. Bnk.

Photo 016 Transect DT3 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
9/7/2006	**DT4**	**Donna Tarver**	**T54 R73 Sec. 29 NWSW**
Rt. Bnk	44.63113	105.67360	Transect width = 368'
Lft. Bnk.	44.63152	105.67448	25' sample intervals

Photos 017 - 018

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	4	25.00%	31.25% Annual
Kochia	1	6.25%	
Foxtail Barley	5	31.25%	56.25% Perrennial
Wavyleaf Thistle	1	6.25%	
Intermediate Wheatgrass	3	18.75%	
Bare Soil	2	12.50%	
	Total Hits = 16	Sum = 100%	

Photo 017 Transect DT4 Rt. Bnk.

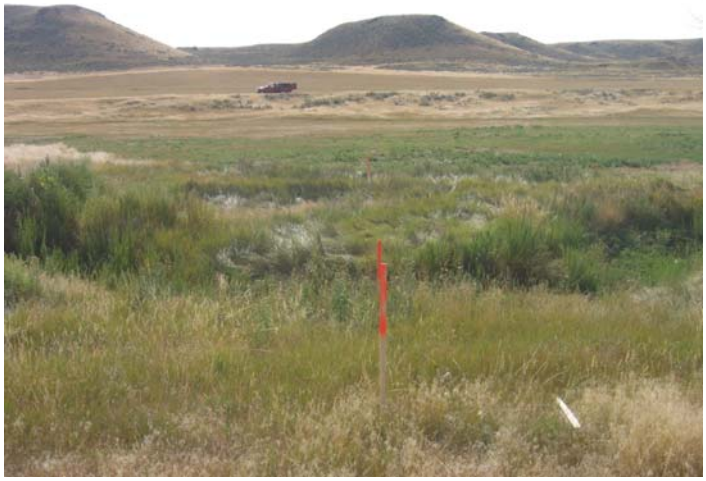

Photo 018 Transect DT4 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
9/7/2006	**DT5**	**Donna Tarver**	**T53 R73 Sec. 6 SWNE**
Rt. Bnk	44.60893	105.68566	Transect width = 259'
Lft. Bnk.	44.60915	105.68623	25' sample intervals

Photos 019 - 020

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	16.67%	16.67% Annual
Wild Licorice	1	8.33%	83.32% Perennial
Inland Saltgrass	3	25.00%	
Threadleaf Sedge	1	8.33%	
Wavy Leaf Thistle	1	8.33%	
Foxtail Barley	4	33.33%	
	Total Hits = 12	Sum = 100%	

Photo 019 Transect DT5 Rt. Bnk.

Photo 020 Transect DT5 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
9/7/2006	**DT6**	**Donna Tarver**	**T54 R73 Sec. 31 SWNE**
Rt. Bnk	44.62154	105.68191	Transect width = 75'
Lft. Bnk.	44.62165	105.68219	10' sample intervals

Photos 021-022

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	8	88.89%	88.89% Annual
Silver Sage	1	11.11%	11.11% Perennial
	Total Hits = 9	Sum = 100%	

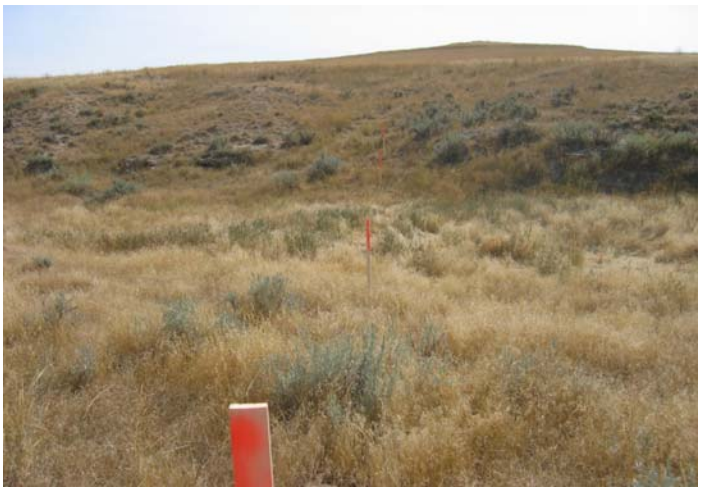

Photo 021 Transect DT6 Lft. Bnk.

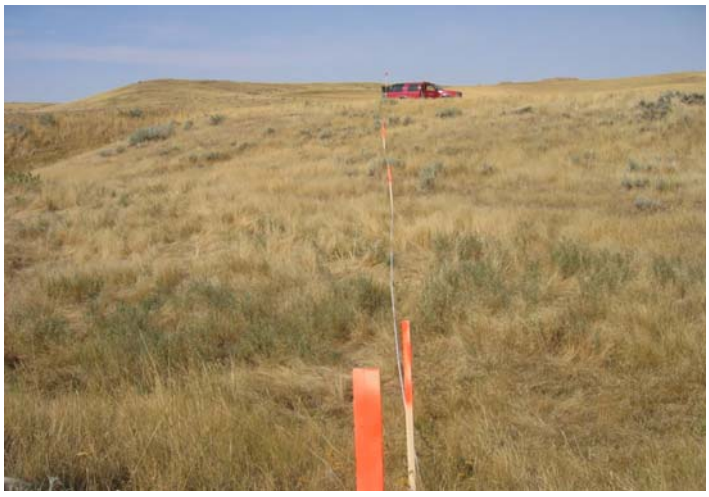

Photo 022 Transect DT6 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
9/7/2006	**DT7**	**Donna Tarver**	**T54 R73 Sec. 30 SWSE**
Rt. Bnk	44.62832	105.68484	Transect width = 148'
Lft. Bnk.	44.62877	105.68477	10' sample intervals

Photos 023 - 024

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	3	0.1875	43.75% Annual
Kochia	3	0.1875	
Field Pennycress	1	0.0625	
Foxtail Barley	4	0.25	50.00% Perennial
Crested wheatgrass	2	0.125	
Smooth Brome	1	0.0625	
Needle and Thread	1	0.0625	
Soil	1	0.0625	
	Total Hits = 16	Sum = 100%	

Photo 023 Transect DT7 Rt. Bnk.

Photo 024 Transect DT7 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
10/16/2006	**DT8**	**Donna Tarver**	**T54 R74 Sec. 25 SESE**
Rt. Bnk	44.63592	105.70135	Transect width = 122'
Lft. Bnk.	44.63597	105.70091	10' sample intervals

Photos 025 - 026

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	7	50.00%	50.0% Annual
Intermediate Wheatgrass	3	21.43%	50.0% Perrennial
Silver Sage	2	14.29%	
Dandelion	1	7.14%	
Foxtail Barley	1	7.14%	
	Total Hits = 16	Sum = 100%	

Photo 025 Transect DT8 Lft. Bnk.

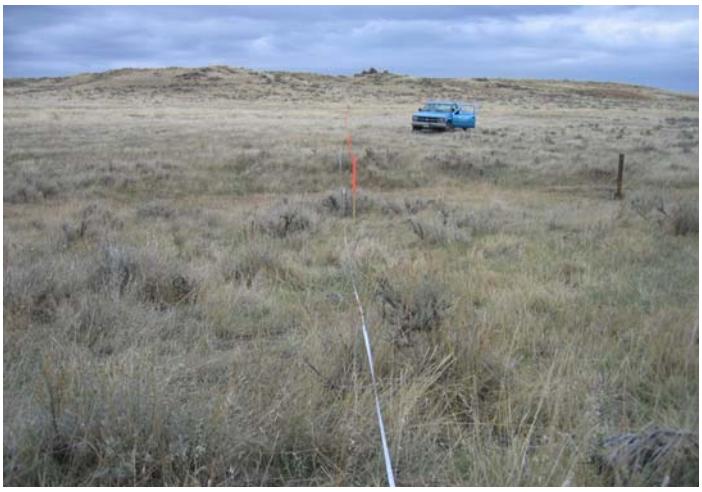

Photo 026 Transect DT8 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
11/15/2006	**DT9**	**Donna Tarver**	**T54 R73 Sec. 31 NENE**
Rt. Bnk	44.62268	105.67677	Transect width = 500 ft.
Lft. Bnk.	44.62265	105.67873	25' sample intervals

Photo 027

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	1	4.76%	4.76% Annual
Silver Sage	2	9.52%	80.95% Perennial
Intermediate wheatgrass	9	42.86%	
Fringed Sage	1	4.76%	
Crested wheatgrass	4	19.05%	
Alfalfa	1	4.76%	
Soil	3	14.29%	
	21	100.00%	

oto 027 Transect DT9 Rt. Bnk.

Date surveyed	Transect	Landowner
11/3/2006	**MP2**	**Marsha Pownell**
Rt. Bnk	44.69455	105.55367
Lft. Bnk.	44.69309	105.54816

Individual Species	Hits	Percent Occurrence
Japanese Brome	9	13.64%
Kochia	11	16.67%
Field Pennycress	2	3.03%
Crested Wheatgrass	21	31.82%
Inland Saltgrass	2	3.03%
Intermediate Wheatgrass	1	1.52%
Prairie Cordgrass	1	1.52%
Thistle	1	1.52%
Wheat	9	13.64%
Soil	9	13.64%
	66	100.00%

Location
T55 R72 Sec. 5 SWNW Transect width = 1625' 25' sample intervals

Photos 028 - 029

Species Grouping
33.33% Annual
53.03% Perennial

Photo 028 Transect MP2 Rt. Bnk.

Photo 029 Transect MP2 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
11/2/2006	**MP1**	**Marsha Pownell**	**T55 R72 Sec. 32 SESW**
Rt. Bnk	44.69995	105.54951	Transect width = 450'
Lft. Bnk.	44.70047	105.54822	25' sample intervals

Photos 030 - 031

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	11.11%	11.11% Annual
Smooth Brome	9	50.00%	88.89% Perennial
Prairie Cordgrass	3	16.67%	
Intermediate Wheatgrass	3	16.67%	
Western Wheatgrass	1	5.56%	
	18	100.00%	

Photo 030 Transect MP1 Rt. Bnk.

Photo 031 Transect MP1 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
11/2/2006	**MP3**	**Marsha Pownell**	**T55 R72 Sec. 30 SWNE**
Rt. Bnk	44.72235	105.56194	Transect width = 1775'
Lft. Bnk.	44.71872	105.56638	25' sample intervals

Photos 032 - 034

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	18	25.00%	25.00% Annual
Alfalfa	2	2.78%	72.22% Perennial
Crested Wheatgrass	20	27.78%	
Field Pennycress	3	4.17%	
Silver Sage	1	1.39%	
Smooth Brome	25	34.72%	
Wavyleaf thistle	1	1.39%	
Soil	2	2.78%	
	72	100.00%	

Photo 032 Transect MP3 Rt. Bnk.

Photo 034 Transect MP3 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
11/3/2006	**MP4**	**Marsha Pownell**	**T55 R72 Sec. 29 SWSW**
Rt. Bnk	44.71566	105.55325	Transect width = 1150'
Lft. Bnk.	44.71470	105.55750	25' sample intervals

Photos 035 - 036

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	23	48.94%	48.94% Annual
Alfalfa	9	19.15%	51.06% Perennial
Crested Wheatgrass	8	17.02%	
Curlycup gumweed	1	2.13%	
Field Pennycress	2	4.26%	
Intermediate Wheatgrass	2	4.26%	
Smooth Brome	1	2.13%	
Western Wheatgrass	1	2.13%	
	47	100.00%	

Photo 035 Transect MP4 Rt. Bnk.

Photo 036 Transect MP4 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
10/31/2006	**LO2**	**Leon Oedekoven**	
Rt. Bnk	44.74123	105.60965	Transect width = 875'
Lft. Bnk.	44.74343	105.60817	25' sample intervals

Photos 037 - 038

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	5.56%	5.56% Annual
Fringed Sage	1	2.78%	94.44% Perennial
Silver Sage	1	2.78%	
Foxtail Barley	5	13.89%	
Inland Saltgrass	6	16.67%	
Western Wheatgrass	12	33.33%	
Crested Wheatgrass	9	25.00%	
	36	100.00%	

Photo 037 Transect LO2 Lft. Bnk.

Photo 038 Transect LO2 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
10/31/2006	**W4**	**State of Wyoming**	
Rt. Bnk	44.74333	105.64657	Transect width = 275'
Lft. Bnk.	44.74407	105.64626	25' sample intervals

Photos 039 - 040

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	1	8.33%	8.33% Annual
Winterfat	1	8.33%	91.67% Perennial
Western Wheatgrass	6	50.00%	
Inland Saltgrass	2	16.67%	
Smooth Brome	1	8.33%	
Fringed Sage	1	8.33%	
	12	100.00%	

Photo 039 Transect W4 Lft. Bnk.

Photo 040 Transect W4 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
11/2/2006	**PP2**	**Paulette Parks**	**T55 R72 Sec. 33 SENE**
Rt. Bnk	44.70771	105.51619	Transect width = 1075'
Lft. Bnk.	44.70728	105.52045	25' sample intervals

Photos 041 - 042

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	5	11.36%	31.82% Annual
Field Pennycress	9	20.45%	
Smooth Brome	10	22.73%	68.18% Perennial
Prairie Cord Grass	5	11.36%	
Alfalfa	4	9.09%	
Crested Wheatgrass	10	22.73%	
Curlycup Gumweed	1	2.27%	
	44	100.00%	

Photo 041 Transect PP2 Lft. Bnk.

Photo 042 Transect PP2 Rt. Bnk

Date surveyed	Transect	Landowner	Location
11/2/2006	**PP1**	**Paulette Parks**	**T55 R72 Sec. 34 NWSE**
Rt. Bnk	44.70705	105.50533	Transect width = 1350'
Lft. Bnk.	44.70335	105.50388	25' sample intervals

Photos 043 - 044

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	2	3.64%	16.36% Annual
Japanese Brome	7	12.73%	
Alfalfa	1	1.82%	83.64% Perennial
Crested Wheatgrass	37	67.27%	
Prairie Cord Grass	3	5.45%	
Rush	1	1.82%	
Silver Sage	1	1.82%	
Smooth Brome	3	5.45%	
	55	100.00%	

Photo 043 Transect PP1 Rt. Bnk.

Photo 044 Transect PP1 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
11/1/2006	**SM1**	**Steve Mueller**	**T55 R72 Sec. 35 SENW**
Rt. Bnk	44.70536	105.49026	Transect width = 1950'
Lft. Bnk.	44.71080	105.49035	25' sample intervals

Photos 045 - 047

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	15	19.23%	32.05% Annual
Japanese Brome	9	11.54%	
Kochia	1	1.28%	
Alfalfa	2	2.56%	67.95% Perennial
Boxelder	1	1.28%	
Crested Wheatgrass	38	48.72%	
Western Wheatgrass	9	11.54%	
Silver Sage	1	1.28%	
Smooth Brome	1	1.28%	
Soil	1	1.28%	
	78	100.00%	

Photo 045 Transect SM1 Rt. Bnk.

Photo 047 Transect SM1 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
9/26/2006	**LP2**	**Loren Peyrot**	**T55 R72 Sec. 36 NWSW**
Rt. Bnk	44.70415	105.46957	Transect width = 960'
Lft. Bnk.	44.70609	105.47233	25' sample intervals

Photos 048 - 049

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	1	2.50%	5.00% Annual
Japanese Brome	1	2.50%	
Silver Sage	1	2.50%	95.00% Perennial
Smooth Brome	10	25.00%	
Prairie Cordgrass	2	5.00%	
Cloaked Bulrush	1	2.50%	
Western Wheatgrass	3	7.50%	
Intermediate Wheatgrass	9	22.50%	
Alfalfa	2	5.00%	
Wavyleaf Thistle	1	2.50%	
Equisetum	4	10.00%	
Cattails	5	12.50%	
	40	100.00%	

Photo 048 Transect LP2 Lft. Bnk.

Photo 049 Transect LP2 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
9/26/2006	**LP1**	**Loren Peyrot**	**T55 R72 Sec. 36 NESE**
Rt. Bnk	44.70379	105.45339	Transect width = 525'
Rt. Bnk.	44.70390	105.45586	25' sample intervals

Photos 050 - 051

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	4	17.39%	21.74% Annual
Field Pennycress	1	4.35%	
Smooth Brome	4	17.39%	78.26% Perennial
Kochia	3	13.04%	
Silver Sage	2	8.70%	
Prairie Cordgrass	5	21.74%	
Skunkbush Sumac	2	8.70%	
Inland Saltgrass	1	4.35%	
Crested Wheatgrass	1	4.35%	
	23	100.00%	

Photo 050 Transect LP1 Rt. Bnk.

Photo 051 Transect LP1 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
11/2/2006	**AK1**	**Adrienna Kretschman**	**T55 R71 Sec. 31 SESW**
Rt. Bnk	44.70240	105.44505	Transect width = 750'
Lft. Bnk.	44.70071	105.44643	25' sample intervals

Photos 052 - 053

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	13	41.94%	41.94% Annual
Smooth Brome	9	29.03%	58.06% Perennial
Crested Wheatgrass	1	3.23%	
Western Wheatgrass	1	3.23%	
Alfalfa	1	3.23%	
Wild Licorice	1	3.23%	
Prairie Cord Grass	1	3.23%	
Skunk Brush Sumac	1	3.23%	
Cattail	1	3.23%	
Silver Sagebrush	1	3.23%	
Rocky Mountain Juniper	1	3.23%	
	31	100.00%	

Photo 052 Transect AK1 Lft. Bnk.

Photo 053 Transect AK1 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
11/2/2006	**AK2**	**Adrienna Kretschman**	**T55 R71 Sec. 32 NESW**
Rt. Bnk	44.70608	105.42554	Transect width = 925'
Lft. Bnk.	44.70513	105.42252	25' sample intervals

Photos 054 - 055

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	10	26.32%	26.32% Annual
Cattail	12	31.58%	73.68% Perennial
Willow	6	15.79%	
Curlycup Gumweed	2	5.26%	
Crested Wheatgrass	5	13.16%	
Intermediate Wheatgrass	1	2.63%	
Thistle	1	2.63%	
Wild Licorice	1	2.63%	
	38	100.00%	

Photo 054 Transect AK2 Rt. Bnk.

Photo 055 Transect AK2 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
11/1/2006	**LS1**	**Larry Shippy**	**T55 R71 Sec. 28 SWSW**
Rt. Bnk	44.70625	105.41283	Transect width = 1000'
Lft. Bnk.	44.70889	105.41360	25' sample intervals

Photos 056 - 057

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	5	12.20%	29.27% Annual
Alfalfa	12	29.27%	82.93% Perennial
Crested Wheatgrass	10	24.39%	
Prairie Cordgrass	4	9.76%	
Wavyleaf thistle	4	9.76%	
Wild Licorice	2	4.88%	
Willow	2	4.88%	
Soil	2	4.88%	
	41	100.00%	

Photo 056 Transect LS1 Lft. Bnk.

Photo 057 Transect LS1 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
11/1/2006	**DM1**	**David Magnuson**	**T55 R71 Sec. 28 NESW**
Rt. Bnk	44.71955	105.40169	Transect width = 1000'
Lft. Bnk.	44.71861	105.40498	25' sample intervals

Photos 058 - 059

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	12	29.27%	29.27% Annual
Field Pennycress	1	2.44%	82.93% Perrennial
Western Wheatgrass	10	24.39%	
Smooth Brome	4	9.76%	
Alfalfa	7	17.07%	
Intermediate Wheatgrass	2	4.88%	
Rush	1	2.44%	
Silver Sage	2	4.88%	
Crested Wheatgrass	2	4.88%	
	41	100.00%	

Photo 058 Transect DM1 Lft. Bnk.

Photo 059 Transect DM1 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
10/31/2006	**ER1**	**Eric and Marie Rule**	**T54 R74 Sec. 2**
Rt. Bnk	44.69486	105.74144	Transect width = 2975'
Lft. Bnk.	44.70285	105.73589	25' sample intervals

Photos 060 - 064

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	1.67%	9.17% Annual
Field Pennycress	9	7.50%	
Crested Wheatgrass	87	72.50%	86.66% Perennial
Intermediate Wheatgrass	5	4.17%	
Smooth Brome	1	0.83%	
Fringed Sagebrush	3	2.50%	
Alfalfa	7	5.83%	
Western Wheatgrass	1	0.83%	
Soil	5	4.17%	
	Total Hits = 120	Sum = 100%	

Photo 060 Transect ER1 Lft. Bnk.

Photo 064 Transect ER1 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
10/31/2006	**JW1**	**James Wolff**	**T54 R74 Sec. 1**
Rt. Bnk	44.68817	105.71220	Transect width = 675'
Lft. Bnk.	44.68936	105.70908	25' sample intervals

Photos 065 - 066

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	3	10.71%	10.71% Annual
Intermediate Wheatgrass	1	3.57%	71.42% Perennial
Crested Wheatgrass	3	10.71%	
Winterfat	1	3.57%	
Blue Bunch Wheatgrass	1	3.57%	
Western Wheatgrass	7	25.00%	
Prairie Cordgrass	6	21.43%	
Foxtail Barley	1	3.57%	
Soil	5	17.86%	
	Total Hits = 28	Sum = 100%	

Photo 065 Transect JW1 Rt. Bnk.

Photo 066 Transect JW1 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
12/15/2006	**JW2**	**James Wolff**	**T54 R74 Sec. 2**
Rt. Bnk	44.69511	105.72433	Transect width = 925'
Lft. Bnk.	44.69688	105.72094	25' sample intervals

Photos 067 - 069

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	7	18.42%	18.42% Annual
Intermediate Wheatgrass	3	7.89%	
Foxtail Barley	5	13.16%	
Alfalfa	2	5.26%	81.57% Perennial
Western Wheatgrass	12	31.58%	
Inland Saltgrass	7	18.42%	
Soil	2	5.26%	
	Total Hits = 38	Sum = 100%	

Photo 067 Transect JW2 Lft. Bnk

Photo 069 Transect JW2 Rt. Bnk

Date surveyed	Transect	Landowner	Location
10/31/2006	**LO1**	**Leon Oedekoven**	**T55 R73**
Rt. Bnk	44.71191	105.63733	Transect width = 550'
Lft. Bnk.	44.71162	105.63501	25' sample intervals

Photos 070 - 071

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	8.33%	18.42% Annual
Western Wheatgrass	12	50.00%	
Inland Saltgrass	7	29.17%	81.57% Perennial
Wild Licorice	1	4.17%	
Wavyleaf thistle	1	4.17%	
Prickly Pear Cactus	1	4.17%	
	Total Hits = 24	Sum = 100%	

Photo 070 Transect LO1 Lft. Bnk.

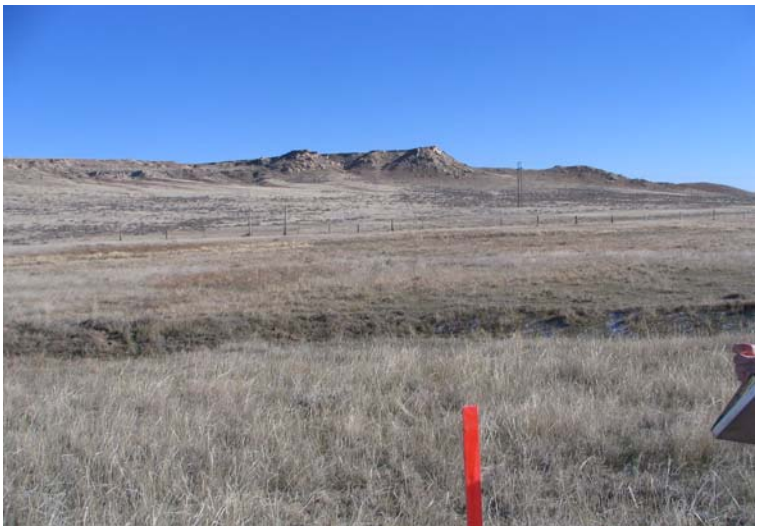

Photo 071 Transect LO1 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
12/15/2006	**MP5**	**Marsha Pownall**	**T55 R72 Sec. 21 NENW**
Rt. Bnk	44.71070	105.55045	Transect width = 600'
Lft. Bnk.	44.71179	105.54833	25' sample intervals

Photos 072 - 073

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	6	25.00%	42.86% Annual
Field Pennycress	7	29.17%	
Alfalfa	2	8.33%	50.00% Perennial
Smooth Brome	6	25.00%	
Soil	3	12.50%	
	Total Hits = 14	Sum = 100%	

Photo 072 Transect MP5 Lft. Bnk.

Photo 073 Transect MP5 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
12/15/2006	**MP6**	**Marsha Pownall**	**T55 R72 Sec. 30 NWNW**
Rt. Bnk	44.72414	105.57085	Transect width = 1375'
Lft. Bnk.	44.72610	105.56574	25' sample intervals

Photos 074 - 075

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	7	12.73%	12.73%
Curlycup Gumweed	1	1.82%	
Crested Wheatgrass	12	21.82%	
Smooth Brome	24	43.64%	
Intermediate Wheatgrass	1	1.82%	80.00%
Western Wheatgrass	1	1.82%	
Inland Saltgrass	3	5.45%	
Prairie Cordgrass	2	3.64%	
Soil	4	7.27%	
	Total Hits = 14	Sum = 100%	

Photo 074 Transect MP6 Lft. Bnk.

Photo 075 Transect MP6 Rt. Bnk.

Date surveyed	Transect	Landowner	Location
12/15/2006	**LK1**	**Lorraine King**	**T54 R72 Sec. 6**
Rt. Bnk	44.68975	105.55388	Transect width = 1050'
Lft. Bnk.	44.69179	105.55661	25' sample intervals

Photos 076 - 078

Individual Species	Hits	Percent Occurrence	Species Grouping
Smooth Brome	29	67.44%	86.05% Perennial
Crested Wheatgrass	4	9.30%	
Wild Licorice	5	4.65%	
Alfalfa	2	2.33%	
Prairie Cordgrass	1	2.33%	
Boxelder	1	2.33%	
Soil	1	11.63%	
	Total Hits = 43	Sum = 100%	

Photo 076 Transect LK1 Rt. Bnk.

Photo 078 Transect LK1 Lft. Bnk.

Date surveyed	Transect	Landowner	Location
9/11/2006	**W1**	**State of Wyoming**	**T54 R74 Sec. 35 SWNW**
Rt. Bnk	44.62005	105.73622	Transect width = 126'
Lft. Bnk.	44.62036	105.73628	10' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	126	Field Pennycress	Left Bank
Upland 2	116	Western Wheatgrass	Left Bank
Upland 3	106	Field Pennycress	Left Bank
Upland 4	96	Field Pennycress	Left Bank
Upland 5	86	Western Wheatgrass	Left Bank
Channel 1	76	Russian Thistle	
Channel 2	66	Japanese Brome	
Channel 3	56	Inland Saltgrass	
Channel 4	46	Prairie Cordgrass	
Channel 5	36	Prairie Cordgrass	
Channel 6	26	Bare soil	
Channel 7	16	Prairie Cordgrass	
Upland 5	6	Intermediate Wheatgrass	Right Bank
Upland 6	0	Japanese Brome	Right Bank
			Photos 001 - 002

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	14.29%	42.86% Annual
Field Pennycress	3	21.43%	
Russian Thistle	1	7.14%	
Intermediate Wheatgrass	1	7.14%	50.00% Perennial
Inland Saltgrass	1	7.14%	
Prairie Cordgrass	3	21.43%	
Western Wheatgrass	2	14.29%	
Soil	1	7.14%	
	Total Hits = 14	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/11/2006	**W 2**	**State of Wyoming**	**T54 R74 Sec. 35 NWNE**
Rt. Bnk	44.62241	105.72475	Transect width = 93'
Lft. Bnk.	44.62263	105.72469	10' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	93	Japanese Brome	Right Bank
Upland 2	83	Prairie Cordgrass	Right Bank
Channel 1	73	Cloaked Bulrush	
Channel 2	63	Cloaked Bulrush	
Channel 3	53	Prairie Cordgrass	
Channel 4	43	Prairie Cordgrass	
Channel 5	33	Prairie Cordgrass	
Upland 3	23	Western Wheatgrass	Left Bank
Upland 4	13	Japanese Brome	Left Bank
Upland 5	3	Japanese Brome	Left Bank
			Photos 003-004

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	3	30.00%	30% Annual
Prairie Cordgrass	4	40.00%	70.00% Perennial
Cloaked Bulrush	2	20.00%	
Western Wheatgrass	1	10.00%	
	Total Hits = 10	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/11/2006	**W3**	**State of Wyoming**	**T54 R74 Sec. 35 NENE**
Rt. Bnk	44.62266	105.72009	Transect width = 182'
Lft. Bnk.	44.62297	105.71976	10' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	182	Silver Sagebrush	Right Bank
Upland 2	172	Silver Sagebrush	Right Bank
Floodplain 1	162	Japanese Brome	
Floodplain 2	152	Japanese Brome	
Floodplain 3	142	Japanese Brome	
Floodplain 4	132	Japanese Brome	
Floodplain 5	122	Japanese Brome	
Floodplain 6	112	Japanese Brome	
Floodplain 7	102	Japanese Brome	
Channel 1	92	Wavyleaf Thistle	
Channel 2	82	Prairie Cordgrass	
Channel 3	72	Prairie Cordgrass	
Floodplain 8	62	Japanese Brome	
Floodplain 9	52	Japanese Brome	
Floodplain 10	42	Japanese Brome	
Upland 3	32	Japanese Brome	Left Bank
Upland 4	22	Field Penny Cress	Left Bank
Upland 5	12	Bare Soil	Left Bank
Upland 6	2	Japanese Brome	Left Bank
			Photos 005-006

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	1	5.26%	68.42% Annual
Japanese Brome	12	63.16%	
Wavyleaf Thistle	1	5.26%	26.32% Perennial
Prairie Cordgrass	2	10.53%	
Silver Sagebrush	2	10.53%	
Bare Soil	1	5.26%	
	Total Hits = 19	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/11/2006	**SS1**	**Steve Sorenson**	**T54 R74 Sec. 21 SWSE**
Rt. Bnk	44.64116	105.76462	Transect width = 134'
Lft. Bnk.	44.6413	105.76418	10' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 1	0	Wheat (Triticum spp.)	Wheat Field
Field 1	10	Wheat (Triticum spp.)	Wheat Field
Field 1	20	Kochia	Wheat Field
Field 1	30	Wheat (Triticum spp.)	Wheat Field
Field 1	40	Wheat (Triticum spp.)	Wheat Field
Field 1	50	Wheat (Triticum spp.)	Wheat Field
Field 1	60	Wheat (Triticum spp.)	Wheat Field
Field 1	70	Wheat (Triticum spp.)	Wheat Field
Field 1	80	Wheat (Triticum spp.)	Wheat Field
Field 1	90	Wheat (Triticum spp.)	Wheat Field
Field 1	100	Wheat (Triticum spp.)	Wheat Field
Field 1	110	Wheat (Triticum spp.)	Wheat Field
Field 1	120	Wavyleaf Thistle	Wheat Field
Field 1	130	Wheat (Triticum spp.)	Wheat Field
Field 1	134	Wheat (Triticum spp.)	Wheat Field
			Photos 009 - 010

Individual Species	Hits	Percent Occurrence	Species Grouping
Kochia	1	6.67%	6.67% Annual
Wavyleaf thistle	1	6.67%	93.345 Perennial
Wheat	13	86.67%	
	Total Hits = 15	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/11/2006	**DJ1**	**Don Joslyn**	**T54 R74 Sec. 27 NWSE**
Rt. Bnk	44.63163	105.74002	Transect width = 66'
Lft. Bnk.	44.63176	105.74786	10' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	66	Crested Wheatgrass	Right Bank
Upland 2	56	Crested Wheatgrass	Right Bank
Upland 3	46	Crested Wheatgrass	Right Bank
Channel 1	36	Kochia	
Channel 2	26	Japanese Brome	
Upland 4	16	Japanese Brome	Left Bank
Upland 5	6	Japanese Brome	Left Bank
Upland 6	0	Field Pennycress	Left Bank
			Photos 007 - 008

Individual Species	Hits	Percent Occurrence	Species Grouping
Kochia	1	12.50%	62.5% Annual
Japanese Brome	3	37.50%	
Field Pennycress	1	12.50%	
Crested Wheatgrass	3	37.50%	37.50% Perennial
	Total Hits = 8	Sum = 100%	

Date surveyed	Transect	Landowner	Location
10/16/2006	**DT1**	**Donna Tarver**	**T54 R74 Sec. 25 SWSW**
Rt. Bnk	44.62556	105.71191	Transect width = 179'
Lft. Bnk.	44.62557	105.71247	10' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	179	Western Wheat Grass	Right Bank
Upland 2	169	Silver Sagebrush	Right Bank
Upland 3	159	Japanese Brome	Right Bank
Floodplain 1	149	Japanese Brome	
Floodplain 2	139	Silver Sagebrush	
Floodplain 3	129	Field Penny Cress	
Floodplain 4	119	Silver Sagebrush	
Floodplain 5	109	Japanese Brome	
Channel 1	99	Prairie Cordgrass	
Channel 2	89	Prairie Cordgrass	
Channel 3	79	Western Wheat Grass	
Floodplain 6	69	Field Penny Cress	
Floodplain 7	59	Crested Wheat Grass	
Floodplain 8	49	Japanese Brome	
Floodplain 9	39	Silver Sagebrush	
Floodplain 10	29	Japanese Brome	
Upland 4	19	Japanese Brome	Left Bank
Upland 5	9	Japanese Brome	Left Bank
Upland 6	0	Western Wheat Grass	Left Bank
			Photos 011-012

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	7	36.84%	47.37% Annual
Field Pennycress	2	10.53%	
Western Wheat Grass	3	15.79%	52.63% Perennial
Silver Sagebrush	4	21.05%	
Prairie Cordgrass	2	10.53%	
Crested Wheat Grass	1	5.26%	
	Total Hits = 19	Sum = 100%	

Date surveyed	Transect	Landowner	Location
10/16/2006	**DT2**	**Donna Tarver**	**T54 R74 Sec. 25 SWSW**
Rt. Bnk	44.62711	105.71095	Transect width = 247'
Lft. Bnk.	44.62717	105.71169	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	247	Silver Sagebrush	Right Bank
Channel 1	222	Prairie Cordgrass	
Channel 2	197	Bare Soil	
Channel 3	172	Cloaked Bulrush	
Channel 4	147	Kochia	
Floodplain 1	122	Dandelion	
Floodplain 2	97	Japanese Brome	
Floodplain 3	72	Smooth Brome	
Floodplain 4	47	Smooth Brome	
Upland 2	22	Japanese Brome	Left Bank
Upland 3	0	Smooth Brome	Left Bank
			Photos 013-014

Individual Species	Hits	Percent Occurrence	Species Grouping
Kochia	1	9.09%	27.27% Annual
Japanese Brome	2	18.18%	
Smooth Brome	3	27.27%	63.63% Perennial
Cloaked Bulrush	1	9.09%	
Dandelion	1	9.09%	
Silver Sagebrush	1	9.09%	
Prairie Cordgrass	1	9.09%	
Bare Soil	1	9.09%	
	Total Hits = 11	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/7/2006	**DT3**	**Donna Tarver**	**T54 R73 Sec. 30 NENE**
Rt. Bnk	44.62878	105.68179	Transect width = 551'
Lft. Bnk.	44.62971	105.68365	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Japanese Brome	Right Bank
Upland 2	25	Japanese Brome	Right Bank
Floodplain 1	50	Kochia	
Floodplain 2	75	Foxtail Barley	
Floodplain 3	100	Kochia	
Floodplain 4	125	Foxtail Barley	
Floodplain 5	150	Foxtail Barley	
Floodplain 6	175	Foxtail Barley	
Floodplain 7	200	Bare Soil	
Channel 1	225	Threadleaf Sedge	
Floodplain 8	250	Bare Soil	
Floodplain 9	275	Bare Soil	
Floodplain 10	300	Bare Soil	
Floodplain 11	325	Bare Soil	
Floodplain 12	350	Bare Soil	
Floodplain 13	375	Bare Soil	
Floodplain 14	400	Bare Soil	
Floodplain 15	425	Bare Soil	
Floodplain 16	450	Bare Soil	
Floodplain 17	475	Bare Soil	
Upland 3	500	Kochia	Left Bank
Upland 4	525	Japanese Brome	Left Bank
Upland 5	550	Japanese Brome	Left Bank
			Photos 015-016

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	4	17.39%	30.43% Annual
Kochia	3	13.04%	
Foxtail Barley	4	17.39%	21.74% Perennial
Threadleaf Sedge	1	4.35%	
Bare Soil	11	47.83%	
	Total Hits = 23	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/7/2006	**DT4**	**Donna Tarver**	**T54 R73 Sec. 29 NWSW**
Rt. Bnk	44.63113	105.6736	Transect width = 368'
Lft. Bnk.	44.63152	105.67448	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Japanese Brome	Right Bank
Upland 2	25	Japanese Brome	Right Bank
Floodplain 1	50	Wavyleaf Thistle	
Floodplain 2	75	Foxtail Barley	hayed/grazed
Floodplain 3	100	Foxtail Barley	hayed/grazed
Floodplain 4	125	Foxtail Barley	hayed/grazed
Floodplain 5	150	Bare Soil	
Floodplain 6	175	Bare Soil	
Floodplain 7	200	Foxtail Barley	hayed/grazed
Floodplain 8	225	Foxtail Barley	hayed/grazed
Floodplain 9	250	Kochia	
Channel 1	275	Intermediate Wheatgrass	
Channel 2	300	Intermediate Wheatgrass	
Channel 3	325	Intermediate Wheatgrass	
Floodplain 9	350	Japanese Brome	Left Bank
Floodplain 10	375	Japanese Brome	Left Bank
			Photos 017-018

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	4	25.00%	31.25% Annual
Kochia	1	6.25%	
Foxtail Barley	5	31.25%	56.25% Perennial
Wavyleaf Thistle	1	6.25%	
Intermediate Wheatgrass	3	18.75%	
Bare Soil	2	12.50%	
	Total Hits = 16	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/7/2006	**DT5**	**Donna Tarver**	**T53 R73 Sec. 6 SWNE**
Rt. Bnk	44.60893	105.68566	Transect width = 259'
Lft. Bnk.	44.60915	105.68623	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Japanese Brome	Right Bank
Upland 2	25	Wild Licorice	Right Bank
Upland 3	50	Inland Saltgrass	
Channel 1	75	Inland Saltgrass	
Channel 2	100	Threadleaf Sedge	
Channel 3	125	Wavy Leaf Thistle	
Channel 4	150	Inland Saltgrass	
Channel 5	175	Foxtail Barley	
Channel 6	200	Foxtail Barley	
Upland 4	225	Foxtail Barley	Left Bank, heavily grazed
Upland 5	250	Japanese Brome	Left Bank
Upland 6	259	Foxtail Barley	Left Bank, heavily grazed
			Photos 009-010

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	16.67%	16.67% Annual
Wild Licorice	1	8.33%	
Inland Saltgrass	3	25.00%	
Threadleaf Sedge	1	8.33%	83.32% Perennial
Wavy Leaf Thistle	1	8.33%	
Foxtail Barley	4	33.33%	
	Total Hits = 12	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/7/2006	**DT6**	**Donna Tarver**	**T54 R73 Sec. 31 SWNE**
Rt. Bnk	44.62154	105.68191	Transect width = 75'
Lft. Bnk.	44.62165	105.68219	10' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Japanese Brome	Right Bank
Channel 1	10	Japanese Brome	Right Bank
Channel 2	20	Japanese Brome	
Channel 3	30	Japanese Brome	
Channel 4	40	Japanese Brome	
Upland 2	50	Japanese Brome	Left Bank
Upland 3	60	Silver Sage	Left Bank
Upland 3	70	Japanese Brome	Left Bank
Upland 4	75	Japanese Brome	Left Bank
			Photos 021-022

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	8	88.89%	88.89% Annual
Silver Sage	1	11.11%	11.11% Perennial
	Total Hits = 9	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/7/2006	**DT7**	**Donna Tarver**	**T54 R73 Sec. 30 SWSE**
Rt. Bnk	44.62832	105.68484	Transect width = 148'
Lft. Bnk.	44.62877	105.68477	10' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Needle and Thread	Right Bank
Upland 2	10	Japanese Brome	Right Bank
Upland 3	20	Japanese Brome	Right Bank
Upland 4	30	Foxtail Barley	Right Bank
Channel 1	40	Crested wheatgrass	
Channel 2	50	Smooth Brome	
Channel 3	60	Foxtail Barley	
Channel 4	70	Crested wheatgrass	
Channel 5	80	Kochia	
Channel 6	90	Foxtail Barley	
Channel 7	100	Kochia	
Channel 8	110	Foxtail Barley	
Upland 5	120	Kochia	Left Bank
Upland 6	130	Soil	Left Bank
Upland 7	140	Japanese Brome	Left Bank
Upland 8	148	Field Pennycress	Left Bank
			Photos 023 - 024

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	3	18.75%	43.75% Annual
Kochia	3	18.75%	
Field Pennycress	1	6.25%	
Foxtail Barley	4	25.00%	50.0% Perennial
Crested wheatgrass	2	12.50%	
Smooth Brome	1	6.25%	
Needle and Thread	1	6.25%	
Soil	1	6.25%	6.25% Soil
	Total Hits = 16	Sum = 100%	

Date surveyed	Transect	Landowner	Location
10/16/2006	**DT8**	**Donna Tarver**	**T54 R74 Sec. 25 SESE**
Rt. Bnk	44.63592	105.70135	Transect width = 122'
Lft. Bnk.	44.63597	105.70091	10' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	122	Japanese Brome	Right Bank
Upland 2	112	Japanese Brome	Right Bank
Upland 3	102	Intermediate Wheatgrass	Right Bank
Upland 4	92	Intermediate Wheatgrass	Right Bank
Channel 1	82	Silver Sage	
Channel 2	72	Dandelion	
Channel 3	62	Intermediate Wheatgrass	
Channel 4	52	Japanese Brome	
Upland 5	42	Silver Sage	Left Bank
Upland 6	32	Japanese Brome	Left Bank
Upland 7	22	Japanese Brome	Left Bank
Upland 8	12	Japanese Brome	Left Bank
Upland 9	2	Japanese Brome	Left Bank
Upland 10	0	Foxtail Barley	Left Bank
			Photos 025 - 026

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	7	50.00%	50.0% Annual
Intermediate Wheatgrass	3	21.43%	50.0% Perennial
Silver Sage	2	14.29%	
Dandelion	1	7.14%	
Foxtail Barley	1	7.14%	
	Total Hits = 16	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/15/2006	**DT9**	**Donna Tarver**	**T54 R73 Sec. 31 NENE**
Rt. Bnk	44.62268	105.67677	Transect width = 500 ft.
Lft. Bnk.	44.62265	105.67873	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
FP1	0	Intermediate wheatgrass	Left bank
FP2	25	Intermediate wheatgrass	
FP3	50	Sage	
Chann1	75	Soil	
Chann2	100	Fringed Sage	
Field 1	125	Crested wheatgrass	Hayed / Grazed
Field 2	150	Alfalfa	Hayed / Grazed
Field 3	175	Crested wheatgrass	Hayed / Grazed
Field 4	200	Crested wheatgrass	Hayed / Grazed
Field 5	225	Sage	Hayed / Grazed
Field 6	250	Intermediate wheatgrass	Hayed / Grazed
Field 7	275	Intermediate wheatgrass	Hayed / Grazed
Field 8	300	Intermediate wheatgrass	Hayed / Grazed
Field 9	325	Soil	Hayed / Grazed
Field 10	350	Intermediate wheatgrass	Hayed / Grazed
Field 11	375	Intermediate wheatgrass	Hayed / Grazed
Field 12	400	Intermediate wheatgrass	Hayed / Grazed
Field 13	425	Intermediate wheatgrass	Hayed / Grazed
Field 14	450	Soil	Hayed / Grazed
Field 15	475	Crested wheatgrass	Hayed / Grazed
Field 16	500	Japanese Brome	Hayed / Grazed Right Bank
			Photo 027

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	1	4.76%	4.76% Annual
Silver Sage	2	9.52%	80.95% Perennial
Intermediate wheatgrass	9	42.86%	
Fringed Sage	1	4.76%	
Crested wheatgrass	4	19.05%	
Alfalfa	1	4.76%	
Soil	3	14.29%	
	Total Hits = 21	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/3/2006	**MP2**	**Marsha Pownell**	**T55 R72 Sec. 5 SWNW**
Rt. Bnk	44.69455	105.55367	Transect width = 1625'
Lft. Bnk.	44.69309	105.54816	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Crested Wheatgrass	Right Bank
Upland 2	25	Crested Wheatgrass	
Upland 3	50	Japanese Brome	
Upland 4	75	Japanese Brome	
Field 1	100	Thistle	Hayed/Grazed
Field 2	125	Kochia	Hayed/Grazed
Field 3	150	Kochia	Hayed/Grazed
Field 4	175	Soil	Hayed/Grazed
Field 5	200	Soil	Hayed/Grazed
Field 6	225	Kochia	Hayed/Grazed
Field 7	250	Kochia	Hayed/Grazed
Field 8	275	Wheat	Hayed/Grazed
Field 9	300	Soil	Hayed/Grazed
Field 10	325	Japanese Brome	Hayed/Grazed
Field 11	350	Wheat	Hayed/Grazed
Field 12	375	Wheat	Hayed/Grazed
Field 13	400	Wheat	Hayed/Grazed
Field 14	425	Wheat	Hayed/Grazed
Field 15	450	Soil	Hayed/Grazed
Field 16	475	Kochia	Hayed/Grazed
Field 17	500	Wheat	Hayed/Grazed
Field 18	525	Wheat	Hayed/Grazed
Field 19	550	Kochia	Hayed/Grazed
Field 20	575	Soil	Hayed/Grazed
Field 21	600	Kochia	Hayed/Grazed
Field 22	625	Kochia	Hayed/Grazed
Field 23	650	Wheat	Hayed/Grazed
Field 24	675	Wheat	Hayed/Grazed
Field 25	700	Soil	Hayed/Grazed
Field 26	725	Soil	Hayed/Grazed
Field 27	750	Kochia	Hayed/Grazed
Field 28	775	Soil	Hayed/Grazed
Field 29	800	Kochia	Hayed/Grazed
Field 30	825	Soil	Hayed/Grazed
Field 31	850	Kochia	Hayed/Grazed
Channel 1	875	Prairie Cordgrass	Water in Channel 3ft wide by 1ft deep
Channel 2	900	Intermediate Wheatgrass	
Field 32	925	Crested Wheatgrass	
Field 33	950	Crested Wheatgrass	
Field 34	975	Crested Wheatgrass	
Field 35	1000	Crested Wheatgrass	
Field 36	1025	Crested Wheatgrass	Hayed/Grazed
Field 37	1050	Crested Wheatgrass	Hayed/Grazed
Field 38	1075	Crested Wheatgrass	Hayed/Grazed

Date surveyed	Transect	Landowner	Location
11/3/2006	**MP2**	**Marsha Pownell**	**T55 R72 Sec. 5 SWNW**
Rt. Bnk	44.69455	105.55367	Transect width = 1625'
Lft. Bnk.	44.69309	105.54816	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 39	1100	Crested Wheatgrass	Hayed/Grazed
Field 40	1125	Japanese Brome	Hayed/Grazed
Field 41	1150	Field Pennycress	Hayed/Grazed
Field 42	1175	Crested Wheatgrass	Hayed/Grazed
Field 43	1200	Crested Wheatgrass	Hayed/Grazed
Field 44	1225	Crested Wheatgrass	Hayed/Grazed
Field 45	1250	Crested Wheatgrass	Hayed/Grazed
Field 46	1275	Japanese Brome	Hayed/Grazed
Field 47	1300	Crested Wheatgrass	Hayed/Grazed
Field 48	1325	Crested Wheatgrass	Hayed/Grazed
Field 49	1350	Inland Saltbrush	Hayed/Grazed
Field 50	1375	Inland Saltbrush	Hayed/Grazed
Field 51	1400	Crested Wheatgrass	Hayed/Grazed
Field 52	1425	Field Pennycress	Hayed/Grazed
Field 53	1450	Japanese Brome	Hayed/Grazed
Field 54	1475	Japanese Brome	Hayed/Grazed
Field 55	1500	Crested Wheatgrass	
Field 56	1525	Crested Wheatgrass	
Field 57	1550	Crested Wheatgrass	
Field 58	1575	Crested Wheatgrass	
Field 59	1600	Japanese Brome	
Field 60	1625	Japanese Brome	Left Bank
			Photos 028 - 029

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	9	13.64%	
Kochia	11	16.67%	33.33% Annual
Field Pennycress	2	3.03%	
Crested Wheatgrass	21	31.82%	
Inland Saltgrass	2	3.03%	
Intermediate Wheatgrass	1	1.52%	53.03% Perennial
Prairie Cordgrass	1	1.52%	
Thistle	1	1.52%	
Wheat	9	13.64%	
Soil	9	13.64%	
	Total Hits = 66	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/2/2006	**MP1**	**Marsha Pownell**	**T55 R72 Sec. 32 SESW**
Rt. Bnk	44.69995	105.54951	Transect width = 450'
Lft. Bnk.	44.70047	105.54822	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Japanese Brome	Right Bank
Channel 1	25	Smooth Brome	
Channel 2	50	Smooth Brome	
Channel 3	75	Water	Water in channel 15ftx3ft, slight flow
Channel 4	100	Prairie Cordgrass	
Field 1	125	Smooth Brome	
Field 2	150	Smooth Brome	
Field 3	175	Smooth Brome	
Field 4	200	Smooth Brome	
Field 5	225	Smooth Brome	
Field 6	250	Smooth Brome	
Field 7	275	Smooth Brome	
Field 8	300	Intermediate Wheatgrass	
Field 9	325	Intermediate Wheatgrass	
Field 10	350	Western Wheatgrass	
Field 11	375	Prairie Cordgrass	
Field 12	400	Prairie Cordgrass	
Upland 2	425	Intermediate Wheatgrass	
Upland 3	450	Japanese Brome	Left Bank
			Photos 030 - 031

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	11.11%	11.11% Annual
Smooth Brome	9	50.00%	88.89% Perennial
Prairie Cordgrass	3	16.67%	
Intermediate Wheatgrass	3	16.67%	
Western Wheatgrass	1	5.56%	
	Total Hits = 18	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/2/2006	**MP3**	**Marsha Pownell**	**T55 R72 Sec. 30 SWNE**
Rt. Bnk	44.72235	105.56194	Transect width = 1775'
Lft. Bnk.	44.71872	105.56638	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Japanese Brome	Right Bank
Upland 2	25	Japanese Brome	
Upland 3	50	Silver Sage	
Upland 4	75	Japanese Brome	
Flood Plain 1	100	Smooth Brome	
Flood Plain 2	125	Smooth Brome	
Flood Plain 3	150	Smooth Brome	
Flood Plain 4	175	Smooth Brome	
Flood Plain 5	200	Smooth Brome	
Flood Plain 6	225	Smooth Brome	
Flood Plain 7	250	Smooth Brome	
Flood Plain 8	275	Smooth Brome	
Flood Plain 9	300	Smooth Brome	
Flood Plain 10	325	Smooth Brome	
Flood Plain 11	350	Smooth Brome	
Channel 1	375	Smooth Brome	
Channel 2	400	Smooth Brome	
Channel 3	425	Thistle	Water in Channel 3ft x 0.5ft; slight flow
Channel 4	450	Crested Wheatgrass	
Channel 5	475	Crested Wheatgrass	
Field 1	500	Field Pennycress	
Field 2	525	Crested Wheatgrass	
Field 3	550	Crested Wheatgrass	Hayed/Grazed
Field 4	575	Crested Wheatgrass	Hayed/Grazed
Field 5	600	Crested Wheatgrass	Hayed/Grazed
Field 6	625	Crested Wheatgrass	Hayed/Grazed
Field 7	650	Smooth Brome	Hayed/Grazed
Field 8	675	Crested Wheatgrass	Hayed/Grazed
Field 9	700	Smooth Brome	Hayed/Grazed
Field 10	725	Smooth Brome	Hayed/Grazed
Field 11	750	Crested Wheatgrass	Hayed/Grazed
Field 12	775	Crested Wheatgrass	
Field 13	800	Japanese Brome	
Field 14	825	Crested Wheatgrass	
Field 15	850	Crested Wheatgrass	
Field 16	875	Smooth Brome	
Field 17	900	Smooth Brome	
Field 18	925	Crested Wheatgrass	
Field 19	950	Alfalfa	
Field 20	975	Smooth Brome	
Field 21	1000	Smooth Brome	
Field 22	1025	Smooth Brome	
Field 23	1050	Japanese Brome	
Field 24	1075	Japanese Brome	

Date surveyed	Transect	Landowner	Location
11/2/2006	**MP3**	**Marsha Pownell**	**T55 R72 Sec. 30 SWNE**
Rt. Bnk	44.72235	105.56194	Transect width = 1775'
Lft. Bnk.	44.71872	105.56638	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 25	1100	Japanese Brome	
Field 26	1125	Smooth Brome	
Field 27	1150	Smooth Brome	
Field 28	1175	Smooth Brome	
Field 29	1200	Smooth Brome	
Field 30	1225	Japanese Brome	
Field 31	1250	Alfalfa	
Field 32	1275	Japanese Brome	
Field 33	1300	Field Pennycress	
Field 34	1325	Soil	
Field 35	1350	Field Pennycress	
Field 36	1375	Japanese Brome	
Field 37	1400	Crested Wheatgrass	
Field 38	1425	Soil	
Field 39	1450	Japanese Brome	
Field 40	1475	Japanese Brome	
Field 41	1500	Japanese Brome	
Field 42	1525	Japanese Brome	
Field 43	1550	Japanese Brome	
Field 44	1575	Crested Wheatgrass	
Field 45	1600	Crested Wheatgrass	
Field 46	1625	Crested Wheatgrass	
Field 47	1650	Crested Wheatgrass	
Field 48	1675	Japanese Brome	
Field 49	1700	Japanese Brome	
Field 50	1725	Japanese Brome	
Field 51	1750	Crested Wheatgrass	
Field 52	1775	Crested Wheatgrass	Left Bank
			Photos 032 - 034

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	18	25.00%	25.00% Annual
Alfalfa	2	2.78%	72.22% Perennial
Crested Wheatgrass	20	27.78%	
Field Pennycress	3	4.17%	
Silver Sage	1	1.39%	
Smooth Brome	25	34.72%	
Wavyleaf thistle	1	1.39%	
Soil	2	2.78%	
	Total Hits = 72	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/3/2006	**MP4**	**Marsha Pownell**	**T55 R72 Sec. 29 SWSW**
Rt. Bnk	44.71566	105.55325	Transect width = 1150'
Lft. Bnk.	44.7147	105.5575	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 1	0	Western Wheatgrass	Right Bank
Field 2	25	Japanese Brome	
Field 3	50	Intermediate Wheatgrass	
Field 4	75	Intermediate Wheatgrass	
Field 5	100	Japanese Brome	
Field 6	125	Crested Wheatgrass	
Field 7	150	Crested Wheatgrass	
Field 8	175	Field Pennycress	
Channel 1	200	Japanese Brome	
Channel 2	225	Japanese Brome	
Field 9	250	Japanese Brome	
Field 10	275	Crested Wheatgrass	
Field 11	300	Japanese Brome	
Field 12	325	Japanese Brome	
Field 13	350	Smooth Brome	
Field 14	375	Alfalfa	Crossed pipeline
Field 15	400	Japanese Brome	
Field 16	425	Japanese Brome	
Field 17	450	Alfalfa	
Field 18	475	Japanese Brome	
Channel 3	500	Japanese Brome	
Channel 4	525	Crested Wheatgrass	
Field 19	550	Crested Wheatgrass	
Field 20	575	Japanese Brome	Hayed/Grazed
Field 21	600	Japanese Brome	Hayed/Grazed
Field 22	625	Japanese Brome	Hayed/Grazed
Field 23	650	Japanese Brome	Hayed/Grazed
Field 24	675	Alfalfa	Hayed/Grazed
Field 25	700	Alfalfa	Hayed/Grazed
Field 26	725	Japanese Brome	Hayed/Grazed
Field 27	750	Japanese Brome	Hayed/Grazed; small irrigation ditch
Channel 5	775	Japanese Brome	Hayed/Grazed
Field 28	800	Alfalfa	Hayed/Grazed
Field 29	825	Field Pennycress	Hayed/Grazed
Field 30	850	Japanese Brome	Hayed/Grazed
Field 31	875	Japanese Brome	Hayed/Grazed
Field 32	900	Alfalfa	Hayed/Grazed
Field 33	925	Alfalfa	Hayed/Grazed
Field 34	950	Alfalfa	Hayed/Grazed
Channel 6	975	Crested Wheatgrass	Hayed/Grazed; small irrigation ditch
Field 35	1000	Crested Wheatgrass	Hayed/Grazed
Field 36	1025	Crested Wheatgrass	Hayed/Grazed
Field 37	1050	Japanese Brome	Hayed/Grazed
Field 38	1075	Japanese Brome	Hayed/Grazed

Date surveyed	Transect	Landowner	Location
11/3/2006	**MP4**	**Marsha Pownell**	**T55 R72 Sec. 29 SWSW**
Rt. Bnk	44.71566	105.55325	Transect width = 1150'
Lft. Bnk.	44.7147	105.5575	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 39	1100	Alfalfa	Hayed/Grazed
Field 40	1125	Japanese Brome	Hayed/Grazed
Field 41	1150	Curlycup gumweed	Left Bank
			Photos 035 - 036
			Diversion @ 44.71444 / 105.55640

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	23	48.94%	48.94% Annual
Alfalfa	9	19.15%	51.06% Perennial
Crested Wheatgrass	8	17.02%	
Curlycup gumweed	1	2.13%	
Field Pennycress	2	4.26%	
Intermediate Wheatgrass	2	4.26%	
Smooth Brome	1	2.13%	
Western Wheatgrass	1	2.13%	
	Total Hits = 47	Sum = 100%	

Date surveyed	Transect	Landowner	Location
10/31/2006	**LO2**	**Leon Oedekoven**	
Rt. Bnk	44.74123	105.60965	Transect width = 875'
Lft. Bnk.	44.74343	105.60817	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Fringed Sage	Left Bank
Upland 2	25	Silver Sage	
Channel 1	50	Foxtail Barley	
Channel 2	75	Foxtail Barley	
Channel 3	100	Foxtail Barley	
Channel 4	125	Foxtail Barley	
Floodplain 1	150	Inland Saltgrass	Heavily Grazed
Floodplain 2	175	Western Wheatgrass	Heavily Grazed
Floodplain 3	200	Inland Saltgrass	Heavily Grazed
Floodplain 4	225	Inland Saltgrass	Heavily Grazed
Floodplain 5	250	Inland Saltgrass	Heavily Grazed
Floodplain 6	275	Western Wheatgrass	Heavily Grazed
Floodplain 7	300	Inland Saltgrass	Heavily Grazed
Floodplain 8	325	Crested Wheatgrass	Heavily Grazed
Floodplain 9	350	Crested Wheatgrass	Heavily Grazed
Floodplain 10	375	Crested Wheatgrass	Heavily Grazed
Floodplain 11	400	Crested Wheatgrass	Heavily Grazed
Floodplain 12	425	Crested Wheatgrass	Heavily Grazed
Floodplain 13	450	Crested Wheatgrass	Heavily Grazed
Floodplain 14	475	Crested Wheatgrass	Heavily Grazed
Floodplain 15	500	Japanese Brome	Heavily Grazed
Floodplain 16	525	Crested Wheatgrass	Heavily Grazed
Floodplain 17	550	Japanese Brome	Heavily Grazed
Floodplain 18	575	Inland Saltgrass	Heavily Grazed
Floodplain 19	600	Western Wheatgrass	Heavily Grazed
Channel 5	625	Foxtail Barley	Heavily Grazed
Channel 6	650	Western Wheatgrass	Heavily Grazed
Floodplain 20	675	Western Wheatgrass	Heavily Grazed
Floodplain 21	700	Western Wheatgrass	Heavily Grazed
Floodplain 22	725	Western Wheatgrass	Heavily Grazed

Date surveyed	Transect	Landowner	Location
10/31/2006	**LO2**	**Leon Oedekoven**	
Rt. Bnk	44.74123	105.60965	Transect width = 875'
Lft. Bnk.	44.74343	105.60817	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Floodplain 23	750	Western Wheatgrass	Heavily Grazed
Floodplain 24	775	Crested Wheatgrass	Heavily Grazed
Floodplain 25	800	Western Wheatgrass	Heavily Grazed
Floodplain 26	825	Western Wheatgrass	Heavily Grazed
Floodplain 27	850	Western Wheatgrass	Heavily Grazed
Floodplain 28	875	Western Wheatgrass	Heavily Grazed - Right Bank
			Photos 037 - 038

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	5.56%	5.56% Annual
Fringed Sage	1	2.78%	94.44% Perennial
Silver Sage	1	2.78%	
Foxtail Barley	5	13.89%	
Inland Saltgrass	6	16.67%	
Western Wheatgrass	12	33.33%	
Crested Wheatgrass	9	25.00%	
	Total Hits = 36	Sum = 100%	

Date surveyed	Transect	Landowner	Location
10/31/2006	**W4**	**State of Wyoming**	
Rt. Bnk	44.74333	105.64657	Transect width = 275'
Lft. Bnk.	44.74407	105.64626	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Winterfat	
Upland 2	25	Western Wheatgrass	Left Bank
Floodplain 1	50	Inland Saltgrass	
Floodplain 2	75	Western Wheatgrass	
Floodplain 3	100	Inland Saltgrass	
Channel 1	125	Smooth Brome	
Floodplain 4	150	Fringed Sage	
Floodplain 5	175	Field Pennycress	
Upland 3	200	Western Wheatgrass	
Upland 4	225	Western Wheatgrass	
Upland 5	250	Western Wheatgrass	
Upland 6	275	Western Wheatgrass	
			Photos 039 - 040

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	1	8.33%	8.33% Annual
Winterfat	1	8.33%	91.67% Perennial
Western Wheatgrass	6	50.00%	
Inland Saltgrass	2	16.67%	
Smooth Brome	1	8.33%	
Fringed Sage	1	8.33%	
	Total Hits = 12	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/2/2006	**PP2**	**Paulette Parks**	**T55 R72 Sec. 33 SENE**
Rt. Bnk	44.70771	105.51619	Transect width = 1075'
Lft. Bnk.	44.70728	105.52045	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Smooth Brome	Left Bank
Channel 1	25	Prairie Cord Grass	
Channel 2	50	Prairie Cord Grass	
Channel 3	75	Prairie Cord Grass	
Field 1	100	Smooth Brome	
Field 2	125	Japanese Brome	
Field 3	150	Japanese Brome	
Field 4	175	Japanese Brome	
Field 5	200	Smooth Brome	Hayed
Field 6	225	Field Pennycress	Hayed
Field 7	250	Field Pennycress	Hayed
Field 8	275	Alfalfa	Hayed
Field 9	300	Crested Wheatgrass	Hayed
Field 10	325	Crested Wheatgrass	Hayed
Field 11	350	Field Pennycress	Hayed
Field 12	375	Crested Wheatgrass	Hayed
Field 13	400	Alfalfa	Hayed
Field 14	425	Field Pennycress	Hayed
Field 15	450	Alfalfa	Hayed
Field 16	475	Crested Wheatgrass	Hayed
Field 17	500	Curlycup Gumweed	Hayed
Field 18	525	Alfalfa	Hayed
Field 19	550	Crested Wheatgrass	Hayed
Field 20	575	Crested Wheatgrass	Hayed
Field 21	600	Field Pennycress	Hayed
Field 22	625	Crested Wheatgrass	Hayed
Field 23	650	Field Pennycress	Hayed
Field 24	675	Field Pennycress	Hayed
Field 25	700	Smooth Brome	Hayed
Field 26	725	Japanese Brome	Hayed
Field 27	750	Field Pennycress	Hayed
Field 28	775	Smooth Brome	
Field 29	800	Smooth Brome	
Field 30	825	Smooth Brome	
Field 31	850	Smooth Brome	
Field 32	875	Field Pennycress	
Field 33	900	Smooth Brome	
Field 34	925	Japanese Brome	
Field 35	950	Crested Wheatgrass	

Date surveyed	Transect	Landowner	Location
11/2/2006	**PP2**	**Paulette Parks**	**T55 R72 Sec. 33 SENE**
Rt. Bnk	44.70771	105.51619	Transect width = 1075'
Lft. Bnk.	44.70728	105.52045	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 36	975	Crested Wheatgrass	
Channel 4	1000	Prairie Cord Grass	
Channel 5	1025	Prairie Cord Grass	
Channel 6	1050	Crested Wheatgrass	
Upland 2	1075	Smooth Brome	Right Bank
			Photos 041 - 042
			Irrigation Structure @ 44.70822 / 105.51922

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	5	11.36%	31.82% Annual
Field Pennycress	9	20.45%	
Smooth Brome	10	22.73%	68.18% Perennial
Prairie Cord Grass	5	11.36%	
Alfalfa	4	9.09%	
Crested Wheatgrass	10	22.73%	
Curlycup Gumweed	1	2.27%	
	Total Hits = 44	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/2/2006	**PP1**	**Paulette Parks**	**T55 R72 Sec. 34 NWSE**
Rt. Bnk	44.70705	105.50533	Transect width = 1350'
Lft. Bnk.	44.70335	105.50388	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Crested Wheatgrass	Right Bank
Upland 2	25	Smooth Brome	
Channel 1	50	Prairie Cord Grass	
Channel 2	75	Prairie Cord Grass	
Channel 3	100	Smooth Brome	
Field 1	125	Crested Wheatgrass	Hayed
Field 2	150	Japanese Brome	Hayed
Field 3	175	Crested Wheatgrass	Hayed
Field 4	200	Crested Wheatgrass	Hayed
Field 5	225	Crested Wheatgrass	Hayed
Field 6	250	Crested Wheatgrass	Hayed
Field 7	275	Japanese Brome	Hayed
Field 8	300	Japanese Brome	Hayed
Field 9	325	Japanese Brome	Hayed
Field 10	350	Crested Wheatgrass	
Channel 4	375	Rush	
Channel 5	400	Prairie Cord Grass	
Field 11	425	Japanese Brome	
Field 12	450	Crested Wheatgrass	
Field 13	475	Crested Wheatgrass	
Field 14	500	Crested Wheatgrass	
Field 15	525	Crested Wheatgrass	
Field 16	550	Crested Wheatgrass	
Field 17	575	Crested Wheatgrass	
Field 18	600	Crested Wheatgrass	
Field 19	625	Crested Wheatgrass	
Field 20	650	Alfalfa	
Field 21	675	Crested Wheatgrass	
Field 22	700	Field Pennycress	
Field 23	725	Crested Wheatgrass	
Field 24	750	Crested Wheatgrass	
Field 25	775	Crested Wheatgrass	
Field 26	800	Crested Wheatgrass	
Field 27	825	Crested Wheatgrass	
Field 28	850	Crested Wheatgrass	
Field 29	875	Crested Wheatgrass	
Field 30	900	Crested Wheatgrass	
Field 31	925	Crested Wheatgrass	
Field 32	950	Crested Wheatgrass	
Field 33	975	Crested Wheatgrass	
Field 34	1000	Crested Wheatgrass	
Field 35	1025	Crested Wheatgrass	
Field 36	1050	Crested Wheatgrass	
Field 37	1075	Field Pennycress	

Date surveyed	Transect	Landowner	Location
11/2/2006	**PP1**	**Paulette Parks**	**T55 R72 Sec. 34 NWSE**
Rt. Bnk	44.70705	105.50533	Transect width = 1350'
Lft. Bnk.	44.70335	105.50388	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 38	1100	Crested Wheatgrass	
Field 39	1125	Crested Wheatgrass	
Field 40	1150	Crested Wheatgrass	
Field 41	1175	Smooth Brome	
Upland 3	1200	Silver Sage	
Upland 4	1225	Crested Wheatgrass	
Upland 5	1250	Crested Wheatgrass	
Upland 6	1275	Japanese Brome	
Upland 7	1300	Japanese Brome	
Upland 8	1325	Crested Wheatgrass	
Upland 9	1350	Crested Wheatgrass	Left Bank
			Photos 043 - 044

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	2	3.64%	16.36% Annual
Japanese Brome	7	12.73%	
Alfalfa	1	1.82%	83.64% Perennial
Crested Wheatgrass	37	67.27%	
Prairie Cord Grass	3	5.45%	
Rush	1	1.82%	
Silver Sage	1	1.82%	
Smooth Brome	3	5.45%	
	Total Hits = 55	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/1/2006	**SM1**	**Steve Mueller**	**T55 R72 Sec. 35 SENW**
Rt. Bnk	44.70536	105.49026	Transect width = 1950'
Lft. Bnk.	44.7108	105.49035	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 1	0	Japanese Brome	Right Bank
Field 2	25	Crested Wheatgrass	
Field 3	50	Crested Wheatgrass	
Field 4	75	Field Pennycress	
Field 5	100	Field Pennycress	
Field 6	125	Crested Wheatgrass	
Field 7	150	Western Wheatgrass	
Field 8	175	Western Wheatgrass	
Field 9	200	Crested Wheatgrass	
Field 10	225	Field Pennycress	
Field 11	250	Crested Wheatgrass	
Field 12	275	Field Pennycress	
Field 13	300	Crested Wheatgrass	
Field 14	325	Crested Wheatgrass	
Field 15	350	Japanese Brome	
Field 16	375	Japanese Brome	
Field 17	400	Japanese Brome	
Field 18	425	Field Pennycress	
Field 19	450	Crested Wheatgrass	
Field 20	475	Crested Wheatgrass	
Field 21	500	Crested Wheatgrass	
Field 22	525	Crested Wheatgrass	
Field 23	550	Crested Wheatgrass	
Field 24	575	Japanese Brome	
Field 25	600	Field Pennycress	
Field 26	625	Crested Wheatgrass	
Field 27	650	Crested Wheatgrass	
Field 28	675	Field Pennycress	Photo 46-Lat: 44.70736 Long: 105.49031
Field 29	700	Crested Wheatgrass	Hayed
Field 30	725	Crested Wheatgrass	Hayed
Field 31	750	Western Wheatgrass	Hayed
Field 32	775	Western Wheatgrass	Hayed
Field 33	800	Crested Wheatgrass	Hayed
Field 34	825	Alfalfa	Hayed
Field 35	850	Smooth Brome	Hayed
Field 36	875	Crested Wheatgrass	Hayed
Field 37	900	Field Pennycress	Hayed
Field 38	925	Crested Wheatgrass	Hayed
Field 39	950	Field Pennycress	Hayed
Field 40	975	Crested Wheatgrass	

Date surveyed	Transect	Landowner	Location
11/1/2006	**SM1**	**Steve Mueller**	**T55 R72 Sec. 35 SENW**
Rt. Bnk	44.70536	105.49026	Transect width = 1950'
Lft. Bnk.	44.7108	105.49035	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 41	1000	Crested Wheatgrass	
Field 42	1025	Crested Wheatgrass	
Field 43	1050	Crested Wheatgrass	
Field 44	1075	Field Pennycress	
Field 45	1100	Field Pennycress	
Field 46	1125	Field Pennycress	
Field 47	1150	Crested Wheatgrass	
Field 48	1175	Crested Wheatgrass	
Field 49	1200	Crested Wheatgrass	
Field 50	1225	Field Pennycress	
Field 51	1250	Crested Wheatgrass	
Field 52	1275	Crested Wheatgrass	
Field 53	1300	Western Wheatgrass	
Field 54	1325	Soil	
Field 55	1350	Crested Wheatgrass	
Field 56	1375	Crested Wheatgrass	
Field 57	1400	Crested Wheatgrass	
Field 58	1425	Field Pennycress	
Field 59	1450	Crested Wheatgrass	
Field 60	1475	Western Wheatgrass	
Field 61	1500	Crested Wheatgrass	
Field 62	1525	Japanese Brome	
Field 63	1550	Crested Wheatgrass	
Field 64	1575	Crested Wheatgrass	
Field 65	1600	Crested Wheatgrass	
Field 66	1625	Western Wheatgrass	
Field 67	1650	Crested Wheatgrass	
Field 68	1675	Western Wheatgrass	
Field 69	1700	Field Pennycress	
Field 70	1725	Alfalfa	
Field 71	1750	Crested Wheatgrass	
Field 72	1775	Japanese Brome	

Date surveyed	Transect	Landowner	Location
11/1/2006	**SM1**	**Steve Mueller**	**T55 R72 Sec. 35 SENW**
Rt. Bnk	44.70536	105.49026	Transect width = 1950'
Lft. Bnk.	44.7108	105.49035	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Channel 1	1800	Berry Bush	
Channel 2	1825	Japanese Brome	
Channel 3	1850	Kochia	
Channel 4	1875	Boxelder	
Channel 5	1900	Western Wheatgrass	
Upland 1	1925	Silver Sage	
Upland 2	1950	Japanese Brome	Left Bank
			Photos 045 - 047

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	15	19.23%	32.05% Annual
Japanese Brome	9	11.54%	
Kochia	1	1.28%	
Alfalfa	2	2.56%	67.95% Perennial
Boxelder	1	1.28%	
Crested Wheatgrass	38	48.72%	
Western Wheatgrass	9	11.54%	
Silver Sage	1	1.28%	
Smooth Brome	1	1.28%	
Soil	1	1.28%	
	Total Hits = 78	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/26/2006	**LP2**	**Loren Peyrot**	**T55 R72 Sec. 36 NWSW**
Rt. Bnk	44.70415	105.46957	Transect width = 960'
Lft. Bnk.	44.70609	105.47233	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Silver Sage	Left Bank
Upland 2	25	Smooth Brome	Left Bank
Upland 3	50	Smooth Brome	Left Bank
Channel 1	75	Prairie Cordgrass	
Channel 2	100	Cloaked Bulrush	
Floodplain 1	125	Western Wheatgrass	
Floodplain 2	150	Western Wheatgrass	
Floodplain 3	175	Intermediate Wheatgrass	
Floodplain 4	200	Equisetum	
Floodplain 5	225	Equisetum	
Floodplain 6	250	Equisetum	
Channel 3	275	Smooth Brome	
Channel 4	300	Cattails	
Floodplain 7	325	Smooth Brome	
Floodplain 8	350	Intermediate Wheatgrass	
Floodplain 9	375	Intermediate Wheatgrass	
Floodplain 10	400	Smooth Brome	
Floodplain 11	425	Intermediate Wheatgrass	
Floodplain 12	450	Equisetum	
Floodplain 13	475	Intermediate Wheatgrass	
Floodplain 14	500	Smooth Brome	
Floodplain 15	525	Intermediate Wheatgrass	
Floodplain 16	550	Smooth Brome	
Floodplain 17	575	Smooth Brome	
Floodplain 18	600	Smooth Brome	
Floodplain 19	625	Western Wheatgrass	
Floodplain 20	650	Intermediate Wheatgrass	
Floodplain 21	675	Alfalfa	
Floodplain 22	700	Intermediate Wheatgrass	
Floodplain 23	725	Smooth Brome	
Floodplain 24	750	Alfalfa	
Channel 5	775	Cattails	

Date surveyed	Transect	Landowner	Location
9/26/2006	**LP2**	**Loren Peyrot**	**T55 R72 Sec. 36 NWSW**
Rt. Bnk	44.70415	105.46957	Transect width = 960'
Lft. Bnk.	44.70609	105.47233	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Channel 6	800	Cattails	
Channel 7	825	Intermediate Wheatgrass	
Channel 8	850	Wavyleaf Thistle	
Channel 9	875	Prairie Cordgrass	
Channel 10	900	Cattails	
Channel 11	925	Cattails	
Upland 4	950	Field Pennycress	Right Bank
Upland 5	960	Japanese Brome	Right Bank
			Photos 048 - 049

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	1	2.50%	5.00% Annual
Japanese Brome	1	2.50%	
Silver Sage	1	2.50%	95.00% Perennial
Smooth Brome	10	25.00%	
Prairie Cordgrass	2	5.00%	
Cloaked Bulrush	1	2.50%	
Western Wheatgrass	3	7.50%	
Intermediate Wheatgrass	9	22.50%	
Alfalfa	2	5.00%	
Wavyleaf Thistle	1	2.50%	
Equisetum	4	10.00%	
Cattails	5	12.50%	
	Total Hits = 40	Sum = 100%	

Date surveyed	Transect	Landowner	Location
9/26/2006	**LP1**	**Loren Peyrot**	**T55 R72 Sec. 36 NESE**
Rt. Bnk	44.70379	105.45339	Transect width = 525'
Rt. Bnk.	44.7039	105.45586	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Smooth Brome	Right Bank
Upland 2	25	Kochia	Right Bank
Upland 3	50	Smooth Brome	Right Bank
Upland 4	75	Smooth Brome	Right Bank
Upland 5	100	Silver Sage	Right Bank
Channel 1	125	Prairie Cordgrass	
Channel 2	150	Prairie Cordgrass	
Floodplain 1	175	Japanese Brome	
Channel 3	200	Prairie Cordgrass	
Floodplain 2	225	Skunkbush Sumac	
Floodplain 3	250	Smooth Brome	
Floodplain 4	275	Kochia	
Floodplain 5	300	Kochia	
Floodplain 6	325	Skunkbush Sumac	
Floodplain 7	350	Inland Saltgrass	
Floodplain 8	375	Silver Sage	
Floodplain 9	400	Crested Wheatgrass	
Floodplain 10	425	Japanese Brome	
Channel 4	450	Prairie Cordgrass	
Channel 5	475	Prairie Cordgrass	
Channel 6	500	Japanese Brome	
Upland 6	525	Japanese Brome	Right Bank
Upland 7	550	Field Pennycress	Right Bank
			Photos 050 - 051

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	4	17.39%	21.74% Annual
Field Pennycress	1	4.35%	
Smooth Brome	4	17.39%	78.26% Perennial
Kochia	3	13.04%	
Silver Sage	2	8.70%	
Prairie Cordgrass	5	21.74%	
Skunkbush Sumac	2	8.70%	
Inland Saltgrass	1	4.35%	
Crested Wheatgrass	1	4.35%	
	Total Hits = 23	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/2/2006	**AK1**	**Adrienna Kretschman**	**T55 R71 Sec. 31 SESW**
Rt. Bnk	44.7024	105.44505	Transect width = 750'
Lft. Bnk.	44.70071	105.44643	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Japanese Brome	Right Bank
Field 1	25	Smooth Brome	
Field 2	50	Crested Wheatgrass	
Field 3	75	Western Wheatgrass	
Field 4	100	Japanese Brome	
Field 5	125	Japanese Brome	
Field 6	150	Alfalfa	
Field 7	175	Smooth Brome	
Field 8	200	Japanese Brome	
Field 9	225	Japanese Brome	
Field 10	250	Smooth Brome	
Field 11	275	Japanese Brome	
Field 12	300	Smooth Brome	
Field 13	325	Japanese Brome	
Field 14	350	Japanese Brome	
Field 15	375	Wild Licorice	
Field 16	400	Smooth Brome	
Field 17	425	Japanese Brome	
Field 18	450	Japanese Brome	
Field 19	475	Smooth Brome	
Field 20	500	Smooth Brome	
Field 21	525	Japanese Brome	
Field 22	550	Smooth Brome	
Channel 1	575	Smooth Brome	
Channel 2	600	Prairie Cord Grass	
Channel 3	625	Skunk Brush Sumac	
Channel 4	650	Cattail	
Channel 5	675	Japanese Brome	
Channel 6	700	Japanese Brome	
Channel 7	725	Silver Sagebrush	
Upland 2	750	Rocky Mountain Juniper	Left Bank
			Photos 052 - 053

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	13	41.94%	41.94% Annual
Smooth Brome	9	29.03%	58.06% Perennial
Crested Wheatgrass	1	3.23%	
Western Wheatgrass	1	3.23%	
Alfalfa	1	3.23%	
Wild Licorice	1	3.23%	
Prairie Cord Grass	1	3.23%	
Skunk Brush Sumac	1	3.23%	
Cattail	1	3.23%	
Silver Sagebrush	1	3.23%	
Rocky Mountain Juniper	1	3.23%	
	Total Hits = 31	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/2/2006	**AK2**	**Adrienna Kretschman**	**T55 R71 Sec. 32 NESW**
Rt. Bnk	44.70608	105.42554	Transect width = 925'
Lft. Bnk.	44.70513	105.42252	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Japanese Brome	Right Bank
Channel 1	25	Japanese Brome	
Channel 2	50	Cattail	
Channel 3	75	Cattail	
Channel 4	100	Cattail	
Channel 5	125	Cattail	
Channel 6	150	Cattail	
Field 1	175	Japanese Brome	
Field 2	200	Willow	
Field 3	225	Curlycup Gumweed	
Field 4	250	Japanese Brome	
Field 5	275	Crested Wheatgrass	
Field 6	300	Japanese Brome	
Field 7	325	Japanese Brome	
Field 8	350	Japanese Brome	
Field 9	375	Japanese Brome	
Field 10	400	Crested Wheatgrass	
Field 11	425	Crested Wheatgrass	
Field 12	450	Wild Licorice	
Field 13	475	Curlycup Gumweed	
Field 14	500	Japanese Brome	
Field 15	525	Crested Wheatgrass	
Field 16	550	Crested Wheatgrass	
Field 17	575	Intermediate Wheatgrass	
Channel 7	600	Japanese Brome	
Channel 8	625	Thistle	
Channel 9	650	Cattail	
Channel 10	675	Cattail	
Channel 11	700	Cattail	
Channel 12	725	Cattail	
Channel 13	750	Cattail	
Channel 14	775	Cattail	

Date surveyed	Transect	Landowner	Location
11/2/2006	**AK2**	**Adrienna Kretschman**	**T55 R71 Sec. 32 NESW**
Rt. Bnk	44.70608	105.42554	Transect width = 925'
Lft. Bnk.	44.70513	105.42252	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Channel 15	800	Cattail	
Channel 16	825	Boxelder	
Channel 17	850	Boxelder	
Channel 18	875	Boxelder	
Channel 19	900	Boxelder	
Upland 2	925	Boxelder	Left Bank
			Photos 054 - 055

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	10	26.32%	26.32% Annual
Cattail	12	31.58%	73.68% Perennial
Boxelder	6	15.79%	
Curlycup Gumweed	2	5.26%	
Crested Wheatgrass	5	13.16%	
Intermediate Wheatgrass	1	2.63%	
Thistle	1	2.63%	
Wild Licorice	1	2.63%	
	Total Hits = 38	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/1/2006	**LS1**	**Larry Shippy**	**T55 R71 Sec. 28 SWSW**
Rt. Bnk	44.70625	105.41283	Transect width = 1000'
Lft. Bnk.	44.70889	105.4136	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Channel 1	0	Willow	Left Bank
Channel 2	25	Soil	Mid-channel
Channel 3	50	Soil	
Channel 4	75	Willow	
Channel 5	100	Wavyleaf thistle	
Channel 6	125	Wavyleaf thistle	
Field 1	150	Japanese Brome	Grazed Field
Field 2	175	Crested Wheatgrass	Grazed Field
Field 3	200	Alfalfa	Grazed Field
Field 4	225	Alfalfa	Grazed Field
Field 5	250	Alfalfa	Grazed Field
Field 6	275	Alfalfa	Grazed Field
Field 7	300	Alfalfa	Grazed Field
Field 8	325	Wild Licorice	Grazed Field
Field 9	350	Alfalfa	Grazed Field
Field 10	375	Crested Wheatgrass	Grazed Field
Field 11	400	Crested Wheatgrass	Grazed Field
Field 12	425	Alfalfa	Grazed Field
Field 13	450	Alfalfa	Grazed Field
Field 14	475	Crested Wheatgrass	Grazed Field
Field 15	500	Japanese Brome	Grazed Field
Field 16	525	Crested Wheatgrass	Grazed Field - Lat:44.70751 Long:105.41320
Field 17	550	Japanese Brome	Grazed Field
Field 18	575	Alfalfa	Grazed Field
Field 19	600	Japanese Brome	Grazed Field
Field 20	625	Alfalfa	Grazed Field
Field 21	650	Crested Wheatgrass	Grazed Field
Field 22	675	Crested Wheatgrass	Grazed Field
Field 23	700	Crested Wheatgrass	Grazed Field
Field 24	725	Alfalfa	Grazed Field
Field 25	750	Crested Wheatgrass	Grazed Field
Field 26	775	Alfalfa	Grazed Field
Field 27	800	Japanese Brome	Grazed Field
Channel 7	825	Prairie Cordgrass	
Channel 8	850	Prairie Cordgrass	
Channel 9	875	Prairie Cordgrass	

Date surveyed	Transect	Landowner	Location
11/1/2006	**LS1**	**Larry Shippy**	**T55 R71 Sec. 28 SWSW**
Rt. Bnk	44.70625	105.41283	Transect width = 1000'
Lft. Bnk.	44.70889	105.4136	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Channel 10	900	Prairie Cordgrass	
Channel 11	925	Wavyleaf thistle	
Channel 12	950	Wavyleaf thistle	
Channel 13	975	Wild Licorice	
Upland 1	1000	Crested Wheatgrass	Right Bank
			Photos 056 - 057

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	5	12.20%	29.27% Annual
Alfalfa	12	29.27%	82.93% Perennial
Crested Wheatgrass	10	24.39%	
Prairie Cordgrass	4	9.76%	
Wavyleaf thistle	4	9.76%	
Wild Licorice	2	4.88%	
Willow	2	4.88%	
Soil	2	4.88%	
	Total Hits = 41	Sum = 100%	

Date surveyed	Transect	Landowner	Location
11/1/2006	**DM1**	**David Magnuson**	**T55 R71 Sec. 28 NESW**
Rt. Bnk	44.71955	105.40169	Transect width = 1000'
Lft. Bnk.	44.71861	105.40498	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 1	0	Japanese Brome	Left Bank - Hayed
Field 2	25	Japanese Brome	Hayed
Field 3	50	Western Wheatgrass	Hayed
Field 4	75	Smooth Brome	Hayed
Field 5	100	Western Wheatgrass	Hayed
Field 6	125	Alfalfa	Hayed
Field 7	150	Alfalfa	Hayed
Field 8	175	Alfalfa	Hayed
Field 9	200	Alfalfa	Hayed
Field 10	225	Western Wheatgrass	Hayed
Field 11	250	Western Wheatgrass	Hayed
Field 12	275	Alfalfa	Hayed
Field 13	300	Western Wheatgrass	Hayed
Field 14	325	Field Pennycress	Hayed
Field 15	350	Western Wheatgrass	Hayed
Field 16	375	Western Wheatgrass	Hayed
Field 17	400	Western Wheatgrass	Hayed
Field 18	425	Alfalfa	Hayed
Field 19	450	Alfalfa	Hayed
Field 20	475	Japanese Brome	Hayed
Field 21	500	Western Wheatgrass	
Field 22	525	Intermediate Wheatgrass	
Field 23	550	Intermediate Wheatgrass	
Field 24	575	Western Wheatgrass	Diversion Dam
Field 25	600	Crested Wheatgrass	
Field 26	625	Crested Wheatgrass	
Field 27	650	Japanese Brome	
Channel 1	675	Smooth Brome	
Channel 2	700	Smooth Brome	
Channel 3	725	Rush	
Channel 4	750	Smooth Brome	
Channel 5	775	Japanese Brome	
Upland 1	800	Japanese Brome	
Upland 2	825	Silver Sage	
Upland 3	850	Japanese Brome	

Date surveyed	Transect	Landowner	Location
11/1/2006	**DM1**	**David Magnuson**	**T55 R71 Sec. 28 NESW**
Rt. Bnk	44.71955	105.40169	Transect width = 1000'
Lft. Bnk.	44.71861	105.40498	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 4	875	Japanese Brome	
Upland 5	900	Japanese Brome	
Channel 6	925	Japanese Brome	
Channel 7	950	Japanese Brome	
Channel 8	975	Japanese Brome	
Upland 6	1000	Silver Sage	Right Bank
			Photos 058 - 059

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	12	29.27%	29.27% Annual
Field Pennycress	1	2.44%	82.93% Perennial
Western Wheatgrass	10	24.39%	
Smooth Brome	4	9.76%	
Alfalfa	7	17.07%	
Intermediate Wheatgrass	2	4.88%	
Rush	1	2.44%	
Silver Sage	2	4.88%	
Crested Wheatgrass	2	4.88%	
	Total Hits = 41	Sum = 100%	

Date surveyed	Transect	Landowner	Location
10/31/2006	**ER1**	**Eric and Marie Rule**	**T54 R74 Sec. 2**
Rt. Bnk	44.69486	105.74144	Transect width = 2975'
Lft. Bnk.	44.70285	105.73589	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Japanese Brome	Left Bank
Field 1	25	Crested Wheatgrass	
Field 2	50	Crested Wheatgrass	
Field 3	75	Crested Wheatgrass	
Field 4	100	Intermediate Wheatgrass	
Field 5	125	Crested Wheatgrass	
Field 6	150	Crested Wheatgrass	
Field 7	175	Intermediate Wheatgrass	
Field 8	200	Crested Wheatgrass	
Field 9	225	Japanese Brome	
Channel 1	250	Crested Wheatgrass	
Channel 2	275	Smooth Brome	
Channel 3	300	Crested Wheatgrass	
Field 10	325	Crested Wheatgrass	
Field 11	350	Crested Wheatgrass	
Field 12	375	Crested Wheatgrass	
Field 13	400	Crested Wheatgrass	
Field 14	425	Western Wheatgrass	
Field 15	450	Crested Wheatgrass	
Field 16	475	Field Pennycress	
Field 17	500	Crested Wheatgrass	
Field 18	525	Fringed Sagebrush	
Field 19	550	Crested Wheatgrass	
Field 20	575	Fringed Sagebrush	
Field 21	600	Crested Wheatgrass	
Field 22	625	Crested Wheatgrass	
Field 23	650	Fringed Sagebrush	
Field 24	675	Crested Wheatgrass	
Field 25	700	Crested Wheatgrass	
Field 26	725	Soil	Trail
Field 27	750	Crested Wheatgrass	
Field 28	775	Crested Wheatgrass	
Field 29	800	Crested Wheatgrass	
Field 30	825	Field Pennycress	
Field 31	850	Crested Wheatgrass	
Field 32	875	Crested Wheatgrass	
Field 33	900	Crested Wheatgrass	
Field 34	925	Crested Wheatgrass	
Field 35	950	Crested Wheatgrass	
Field 36	975	Crested Wheatgrass	
Field 37	1000	Crested Wheatgrass	
Field 38	1025	Crested Wheatgrass	
Field 39	1050	Field Pennycress	
Field 40	1075	Crested Wheatgrass	
Field 41	1100	Crested Wheatgrass	
Field 42	1125	Crested Wheatgrass	

Date surveyed	Transect	Landowner	Location
10/31/2006	**ER1**	**Eric and Marie Rule**	**T54 R74 Sec. 2**
Rt. Bnk	44.69486	105.74144	Transect width = 2975'
Lft. Bnk.	44.70285	105.73589	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 43	1150	Crested Wheatgrass	
Field 44	1175	Field Pennycress	Lat 44.69973 - Long 105.73800
Field 45	1200	Crested Wheatgrass	
Field 46	1225	Crested Wheatgrass	
Field 47	1250	Crested Wheatgrass	
Field 48	1275	Crested Wheatgrass	
Field 49	1300	Crested Wheatgrass	
Field 50	1325	Crested Wheatgrass	
Field 51	1350	Field Pennycress	
Field 52	1375	Crested Wheatgrass	
Field 53	1400	Crested Wheatgrass	
Field 54	1425	Crested Wheatgrass	
Field 55	1450	Crested Wheatgrass	
Field 56	1475	Intermediate Wheatgrass	
Field 57	1500	Intermediate Wheatgrass	
Field 58	1525	Crested Wheatgrass	
Field 59	1550	Crested Wheatgrass	
Field 60	1575	Crested Wheatgrass	
Field 61	1600	Crested Wheatgrass	
Field 62	1625	Crested Wheatgrass	
Field 63	1650	Crested Wheatgrass	
Field 64	1675	Intermediate Wheatgrass	
Field 65	1700	Crested Wheatgrass	
Field 66	1725	Crested Wheatgrass	
Field 67	1750	Crested Wheatgrass	
Field 68	1775	Crested Wheatgrass	
Field 69	1800	Crested Wheatgrass	
Field 70	1825	Crested Wheatgrass	
Field 71	1850	Crested Wheatgrass	
Field 72	1875	Crested Wheatgrass	
Field 73	1900	Crested Wheatgrass	
Field 74	1925	Field Pennycress	
Field 75	1950	Crested Wheatgrass	
Field 76	1975	Crested Wheatgrass	
Field 77	2000	Crested Wheatgrass	
Field 78	2025	Crested Wheatgrass	
Field 79	2050	Crested Wheatgrass	
Field 80	2075	Crested Wheatgrass	
Field 81	2100	Crested Wheatgrass	
Field 82	2125	Crested Wheatgrass	
Field 83	2150	Soil	Well Pad
Field 84	2175	Soil	Well Pad
Field 85	2200	Soil	Well Pad
Field 86	2225	Soil	Well Pad
Field 87	2250	Crested Wheatgrass	
Field 88	2275	Field Pennycress	

Date surveyed	Transect	Landowner	Location
10/31/2006	**ER1**	**Eric and Marie Rule**	**T54 R74 Sec. 2**
Rt. Bnk	44.69486	105.74144	Transect width = 2975'
Lft. Bnk.	44.70285	105.73589	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 89	2300	Field Pennycress	
Field 90	2325	Crested Wheatgrass	
Field 91	2350	Crested Wheatgrass	
Field 92	2375	Crested Wheatgrass	
Field 93	2400	Crested Wheatgrass	
Field 94	2425	Crested Wheatgrass	
Field 95	2450	Crested Wheatgrass	
Field 96	2475	Crested Wheatgrass	
Field 97	2500	Crested Wheatgrass	
Field 98	2525	Field Pennycress	
Field 99	2550	Crested Wheatgrass	
Field 100	2575	Crested Wheatgrass	
Field 101	2600	Alfalfa	
Field 102	2625	Alfalfa	
Field 103	2650	Crested Wheatgrass	
Field 104	2675	Crested Wheatgrass	
Field 105	2700	Alfalfa	
Field 106	2725	Crested Wheatgrass	
Field 107	2750	Crested Wheatgrass	
Field 108	2775	Alfalfa	
Field 109	2800	Crested Wheatgrass	
Field 110	2825	Crested Wheatgrass	
Field 111	2850	Alfalfa	
Field 112	2875	Alfalfa	
Field 113	2900	Crested Wheatgrass	
Field 114	2925	Alfalfa	
Field 115	2950	Crested Wheatgrass	
Field 116	2975	Crested Wheatgrass	Right Bank
			Photos 060 - 064

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	1.67%	9.17% Annual
Field Pennycress	9	7.50%	
Crested Wheatgrass	87	72.50%	86.66% Perennial
Intermediate Wheatgrass	5	4.17%	
Smooth Brome	1	0.83%	
Fringed Sagebrush	3	2.50%	
Alfalfa	7	5.83%	
Western Wheatgrass	1	0.83%	
Soil	5	4.17%	
	Total Hits = 120	Sum = 100%	

Date surveyed	Transect	Landowner	Location
10/31/2006	**JW1**	**James Wolff**	**T54 R74 Sec. 1**
Rt. Bnk	44.68817	105.7122	Transect width = 675'
Lft. Bnk.	44.68936	105.70908	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 1	25	Intermediate Wheatgrass	Right Bank
Field 2	50	Crested Wheatgrass	
Field 3	75	Soil	
Field 4	100	Crested Wheatgrass	
Field 5	125	Soil	
Field 6	150	Soil	
Field 7	175	Crested Wheatgrass	
Field 8	200	Soil	
Upland 1	225	Japanese Brome	
Upland 2	250	Winterfat	
Upland 3	275	Blue Bunch Wheatgrass	
Upland 4	300	Western Wheatgrass	
Channel 1	325	Prairie Cordgrass	
Channel 2	350	Prairie Cordgrass	
Channel 3	375	Prairie Cordgrass	
Channel 4	400	Prairie Cordgrass	
Flood Plain 1	425	Prairie Cordgrass	
Flood Plain 2	450	Western Wheatgrass	
Flood Plain 3	475	Prairie Cordgrass	
Flood Plain 4	500	Western Wheatgrass	
Flood Plain 5	525	Western Wheatgrass	
Flood Plain 6	550	Japanese Brome	
Flood Plain 7	575	Japanese Brome	
Channel 5	600	Foxtail Barley	
Channel 6	620	Western Wheatgrass	Heavily Grazed
Upland 5	625	Western Wheatgrass	Heavily Grazed
Upland 6	650	Western Wheatgrass	Heavily Grazed
Upland 7	675	Soil	Heavily Grazed - Left Bank
			Photos 065 - 066

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	3	10.71%	10.71% Annual
Intermediate Wheatgrass	1	3.57%	71.42% Perennial
Crested Wheatgrass	3	10.71%	
Winterfat	1	3.57%	
Blue Bunch Wheatgrass	1	3.57%	
Western Wheatgrass	7	25.00%	
Prairie Cordgrass	6	21.43%	
Foxtail Barley	1	3.57%	
Soil	5	17.86%	
	Total Hits = 28	Sum = 100%	

Date surveyed	Transect	Landowner	Location
12/15/2006	**JW2**	**James Wolff**	**T54 R74 Sec. 2**
Rt. Bnk	44.69511	105.72433	Transect width = 925'
Lft. Bnk.	44.69688	105.72094	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Upland 1	0	Intermediate Wheatgrass	Left Bank / Photo 067
Upland 2	25	Intermediate Wheatgrass	
Upland 3	50	Intermediate Wheatgrass	
Field 1	75	Foxtail Barley	
Field 2	100	Foxtail Barley	
Field 3	125	Alfalfa	
Field 4	150	Foxtail Barley	
Field 5	175	Alfalfa	
Field 6	200	Soil	
Field 7	225	Foxtail Barley	
Field 8	250	Foxtail Barley	
Field 9	275	Western Wheatgrass	
Field 10	300	Western Wheatgrass	
Field 11	325	Western Wheatgrass	
Field 12	350	Soil	
Field 13	375	Inland Saltgrass	
Field 14	400	Western Wheatgrass	
Field 15	425	Inland Saltgrass	
Field 16	450	Western Wheatgrass	Photo 068
Field 17	475	Western Wheatgrass	
Field 18	500	Inland Saltgrass	
Field 19	525	Western Wheatgrass	
Field 20	550	Western Wheatgrass	
Field 21	575	Western Wheatgrass	
Field 22	600	Western Wheatgrass	
Field 23	625	Western Wheatgrass	
Field 24	650	Western Wheatgrass	
Field 25	675	Inland Saltgrass	
Field 26	700	Japanese Brome	
Field 27	725	Japanese Brome	
Field 28	750	Japanese Brome	
Field 29	775	Japanese Brome	
Field 30	800	Inland Saltgrass	

Date surveyed	Transect	Landowner	Location
12/15/2006	**JW2**	**James Wolff**	**T54 R74 Sec. 2**
Rt. Bnk	44.69511	105.72433	Transect width = 925'
Lft. Bnk.	44.69688	105.72094	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 31	825	Japanese Brome	
Field 32	850	Inland Saltgrass	
Field 33	875	Japanese Brome	
Field 34	900	Japanese Brome	
Field 35	925	Inland Saltgrass	Right Bank / Photo 069

Photos 067 - 069

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	7	18.42%	18.42% Annual
Intermediate Wheatgrass	3	7.89%	81.57% Perennial
Foxtail Barley	5	13.16%	
Alfalfa	2	5.26%	
Western Wheatgrass	12	31.58%	
Inland Saltgrass	7	18.42%	
Soil	2	5.26%	
	Total Hits = 38	Sum = 100%	

Date surveyed	Transect	Landowner	Location
10/31/2006	**LO1**	**Leon Oedekoven**	**T55 R73**
Rt. Bnk	44.71191	105.63733	Transect width = 550'
Lft. Bnk.	44.71162	105.63501	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Floodplain 1	25	Western Wheatgrass	Left Bank
Floodplain 2	50	Western Wheatgrass	
Floodplain 3	75	Inland Saltgrass	
Floodplain 4	100	Inland Saltgrass	
Floodplain 5	125	Western Wheatgrass	
Floodplain 6	150	Western Wheatgrass	
Floodplain 7	175	Western Wheatgrass	
Floodplain 8	200	Inland Saltgrass	
Floodplain 9	225	Inland Saltgrass	
Floodplain 10	250	Western Wheatgrass	
Floodplain 11	275	Inland Saltgrass	
Channel 1	300	Japanese Brome	
Channel 2	312	Western Wheatgrass	
Floodplain 12	325	Western Wheatgrass	
Floodplain 13	350	Western Wheatgrass	
Floodplain 14	375	Inland Saltgrass	
Floodplain 15	400	Western Wheatgrass	
Floodplain 16	425	Wild Licorice	
Floodplain 17	450	Western Wheatgrass	
Floodplain 18	475	Inland Saltgrass	
Channel 3	500	Wavyleaf thistle	
Channel 4	512	Western Wheatgrass	
Upland 1	525	Japanese Brome	
Upland 2	550	Plains pricklypear	Right Bank
			Photos 070 - 071

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	2	8.33%	8.33% Annual
Western Wheatgrass	12	50.00%	91.67% Perennial
Inland Saltgrass	7	29.17%	
Wild Licorice	1	4.17%	
Wavyleaf thistle	1	4.17%	
Plains pricklypear	1	4.17%	
	Total Hits = 24	Sum = 100%	

Date surveyed	Transect	Landowner	Location
12/15/2006	**MP5**	**Marsha Pownall**	**T55 R72 Sec. 21 NENW**
Rt. Bnk	44.7107	105.55045	Transect width = 600'
Lft. Bnk.	44.71179	105.54833	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 1	0	Alfalfa	Left Bank
Field 2	25	Field Penny Cress	
Field 3	50	Alfalfa	
Field 4	75	Japanese Brome	
Field 5	100	Soil	
Field 6	125	Japanese Brome	
Field 7	150	Japanese Brome	
Field 8	175	Field Penny Cress	
Field 9	200	Field Penny Cress	
Field 10	225	Soil	
Field 11	250	Field Penny Cress	
Field 12	275	Field Penny Cress	
Field 13	300	Smooth Brome	
Field 14	325	Soil	
Field 15	350	Field Penny Cress	
Field 16	375	Field Penny Cress	
Field 17	400	Smooth Brome	
Field 18	425	Japanese Brome	
Field 19	450	Smooth Brome	
Field 20	475	Japanese Brome	
Field 21	500	Smooth Brome	
Field 22	525	Smooth Brome	
Upland 1	550	Smooth Brome	
Upland 2	575	Japanese Brome	Right Bank
			Photos 072 - 073

Individual Species	Hits	Percent Occurrence	Species Grouping
Japanese Brome	6	25.00%	42.86% Annual
Field Pennycress	7	29.17%	
Alfalfa	2	8.33%	50.00% Perennial
Smooth Brome	6	25.00%	
Soil	3	12.50%	
	Total Hits = 14	Sum = 100%	

Date surveyed	Transect	Landowner	Location
12/15/2006	**MP6**	**Marsha Pownall**	**T55 R72 Sec. 30 NWNW**
Rt. Bnk	44.72414	105.57085	Transect width = 1375'
Lft. Bnk.	44.7261	105.56574	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 1	0	Crested Wheatgrass	Right Bank
Field 2	25	Smooth Brome	Hayed/Grazed
Field 3	50	Intermediate Wheatgrass	Hayed/Grazed
Field 4	75	Smooth Brome	Hayed/Grazed
Field 5	100	Smooth Brome	Hayed/Grazed
Field 6	125	Smooth Brome	Hayed/Grazed
Field 7	150	Smooth Brome	Hayed/Grazed
Field 8	175	Smooth Brome	Hayed/Grazed
Field 9	200	Smooth Brome	Hayed/Grazed
Field 10	225	Smooth Brome	Hayed/Grazed
Field 11	250	Smooth Brome	Hayed/Grazed
Field 12	275	Smooth Brome	Hayed/Grazed
Field 13	300	Smooth Brome	Hayed/Grazed
Field 14	325	Smooth Brome	Hayed/Grazed
Field 15	350	Smooth Brome	Hayed/Grazed
Field 16	375	Smooth Brome	Hayed/Grazed
Field 17	400	Soil	Hayed/Grazed
Field 18	425	Field Pennycress	Hayed/Grazed
Field 19	450	Field Pennycress	Hayed/Grazed
Field 20	475	Smooth Brome	Hayed/Grazed
Field 21	500	Smooth Brome	Hayed/Grazed
Field 22	525	Smooth Brome	Hayed/Grazed
Field 23	550	Field Pennycress	Hayed/Grazed
Field 24	575	Soil	Hayed/Grazed
Field 25	600	Crested Wheatgrass	Hayed/Grazed
Field 26	625	Crested Wheatgrass	Hayed/Grazed
Field 27	650	Smooth Brome	Hayed/Grazed
Field 28	675	Crested Wheatgrass	Hayed/Grazed
Field 29	700	Inland Saltgrass	Hayed/Grazed
Field 30	725	Crested Wheatgrass	Hayed/Grazed
Field 31	750	Inland Saltgrass	Hayed/Grazed
Field 32	775	Crested Wheatgrass	Hayed/Grazed
Channel 1	800	Smooth Brome	
Field 33	825	Crested Wheatgrass	Hayed/Grazed
Field 34	850	Crested Wheatgrass	Hayed/Grazed
Field 35	875	Crested Wheatgrass	Hayed/Grazed
Field 36	900	Crested Wheatgrass	Hayed/Grazed
Field 37	925	Soil	Hayed/Grazed
Field 38	950	Soil	Hayed/Grazed
Field 39	975	Crested Wheatgrass	Hayed/Grazed
Field 40	1000	Field Pennycress	Hayed/Grazed
Field 41	1025	Field Pennycress	Hayed/Grazed
Field 42	1050	Crested Wheatgrass	Hayed/Grazed
Field 43	1075	Field Pennycress	Hayed/Grazed

Date surveyed	Transect	Landowner	Location
12/15/2006	**MP6**	**Marsha Pownall**	**T55 R72 Sec. 30 NWNW**
Rt. Bnk	44.72414	105.57085	Transect width = 1375'
Lft. Bnk.	44.7261	105.56574	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 44	1100	Smooth Brome	Hayed/Grazed
Floodplain 1	1125	Smooth Brome	
Floodplain 2	1150	Smooth Brome	
Floodplain 3	1175	Field Pennycress	
Floodplain 4	1200	Inland Saltgrass	
Floodplain 5	1225	Smooth Brome	
Floodplain 6	1250	Smooth Brome	
Channel 2	1275	Prairie Cordgrass	
Channel 3	1300	Prairie Cordgrass	
Floodplain 7	1325	Curlycup gumweed	
Upland 1	1350	Western Wheatgrass	Right Bank
			Photos 074 - 075

Individual Species	Hits	Percent Occurrence	Species Grouping
Field Pennycress	7	12.73%	12.73% Annual
Curlycup Gumweed	1	1.82%	
Crested Wheatgrass	12	21.82%	
Smooth Brome	24	43.64%	
Intermediate Wheatgrass	1	1.82%	80.00% Perennial
Western Wheatgrass	1	1.82%	
Inland Saltgrass	3	5.45%	
Prairie Cordgrass	2	3.64%	
Soil	4	7.27%	
	Total Hits = 14	Sum = 100%	

Date surveyed	Transect	Landowner	Location
12/15/2006	**LK1**	**Lorraine King**	**T54 R72 Sec. 6**
Rt. Bnk	44.68975	105.55388	Transect width = 1050'
Lft. Bnk.	44.69179	105.55661	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Field 1	0	Smooth Brome	Right Bank / Photo 076
Field 2	25	Smooth Brome	
Field 3	50	Smooth Brome	
Field 4	75	Crested Wheatgrass	
Field 5	100	Crested Wheatgrass	
Field 6	125	Crested Wheatgrass	
Field 7	150	Smooth Brome	Photo 077
Field 8	175	Smooth Brome	
Field 9	200	Smooth Brome	
Field 10	225	Smooth Brome	
Field 11	250	Smooth Brome	
Field 12	275	Smooth Brome	
Field 13	300	Smooth Brome	
Field 14	325	Smooth Brome	
Field 15	350	Soil	
Field 16	375	Soil	
Field 17	400	Smooth Brome	
Field 18	425	Smooth Brome	
channel 1	450	Wild Licorice	
channel 2	475	Wild Licorice	
Field 19	500	Smooth Brome	
Field 20	525	Smooth Brome	
Field 21	550	Smooth Brome	
Field 22	575	Smooth Brome	
Field 23	600	Smooth Brome	
Field 24	625	Smooth Brome	
Field 25	650	Smooth Brome	
Field 26	675	Smooth Brome	
Field 27	700	Alfalfa	
Field 28	725	Smooth Brome	
Field 29	750	Smooth Brome	
Field 30	775	Smooth Brome	
Field 31	800	Smooth Brome	
Field 32	825	Soil	
Field 33	850	Smooth Brome	
Field 34	875	Soil	

Date surveyed	Transect	Landowner	Location
12/15/2006	**LK1**	**Lorraine King**	**T54 R72 Sec. 6**
Rt. Bnk	44.68975	105.55388	Transect width = 1050'
Lft. Bnk.	44.69179	105.55661	25' sample intervals

AREA	DISTANCE	SPECIES	COMMENTS
Flood plain 1	900	Smooth Brome	
Flood plain 2	925	Smooth Brome	
Flood plain 3	950	Boxelder	
Channel 3	975	Smooth Brome	
Channel 4	1000	Prairie Cordgrass	
Flood plain 4	1025	Soil	
Upland 1	1050	Crested Wheatgrass	Left Bank / Photo 078
			Photos 076 - 078

Individual Species	Hits	Percent Occurrence	Species Grouping
Smooth Brome	29	67.44%	
Crested Wheatgrass	4	9.30%	
Wild Licorice	5	4.65%	86.05% Perennial
Alfalfa	2	2.33%	
Prairie Cordgrass	1	2.33%	
Boxelder	1	2.33%	
Soil	1	11.63%	
	Total Hits = 43	Sum = 100%	

APPENDIX G

SOIL PROFILE DESCRIPTIONS

Dave Magneson Ranch

DM1-1
Vegetation Summary – western wheatgrass, alfalfa (sparse)
Location - N 44º 42.729'; W 105º 24.780º

AB – 0-3 inches; sil; 2mgr (moderate medium granular);
Bw – 3 to 6 inches; cl; 2msbk (moderate medium subangular blocky)
Bk1 – 6 to 21 inches; cl, 2msbk; 3mswm (many medium soft white masses); st (strongly effervescent)
C1 – 21 to 42 inches; s; m; 2mswm; 2mr (moderate medium redox features); st
C2 – 42 to 46 inches; sc; m; 1mswm (few medium soft white masses); st
C3 – 46 to 52 inches; s; m; 2mswm; 2mr; st
C4 – 52 to 60 inches; cl; m (massive); 3mr; st
C5 – 60 to 72 inches; cl; m; 3mr; sl (slightly effervescent)

DM1-2
Vegetation Summary – western wheatgrass, alfalfa (sparse)
Location - N 44º 42.729'; W 105º 24.780º

AB – 0 to 2 inches; sil; 2msbk (moderate, medium subangular blocky)
C – 2 to 4 inches; ls; 2mthpl;
Bwb – 4 to 9 inches; cl; 2msbk; 3mr
Bkb – 9 to 12 inches; cl, 2msbk; 2mswm; 3mr; st (strongly effervescent)
C1 – 12 to 13 inches; grs; sg; 3fswm; 3mr; st
C2 – 13 to 24 inches; ls; m; 3mswmt (many medium soft white masses and threads); 3mr; ve
C3 – 24 to 30 inches; s; m; 3mswmt; 3mr; st
C4 – 30 to 60 inches; grs; sg;

DM1-3
Vegetation Summary – western wheatgrass, alfalfa (sparse)
Location - N 44º 43.065'; W 105º 24.357º

A – 0 to 2 inches; sil; 2mgr
C – 2 to 4 inches; ls; m; 3mr;
Bwb – 4 to 12 inches; cl; 2msbk; 3mr
Bk1 – 12 to 22 inches; cl, 2msbk; 3mswmt; 2fr; st
C1 – 12 to 24 inches; ls; m; 3fswmt; 3mr; st
C2 – 24 to 72 inches; grs (sand and scoria); sg

DM2-1
Vegetation Summary – western wheatgrass, alfalfa (sparse)
Location - N 44º 43.088'; W 105º 24.293º

A – 0 to 2 inches; cl; 2mgr
Bw – 2 to 4 inches; cl; 2msbk

C – 4 to 10 inches; ls; m;
Bwb – 10 to 20 inches; cl; 2msbk; 2mr
C1 – 20 to 32 inches; ls, m; 2fswm; 2fr; sl
C2 – 32 to 54 inches; cl; m; 2fswmt; 3mr; sl
C3 – 54 to 60 inches; cl; m; 2fswm; 3fr; sl
C4 – 60 to 72 inches; s, sg

Larry Shippy Ranch

LS1-1
Vegetation Summary –crested wheatgrass, alfalfa (sparse)
Location - N 44º 42.729'; W 105º 24.780º

AB – 0-3 inches; cl; 2mgr (moderate, medium granular) to 1msbk (weak, medium, subangular blocky).
Bw – 3 to 15 inches; cl; 2msbk
B1k1 – 15 to 24 inches; sil, 1msbk; 1mswm (few medium soft white masses); sl (slightly effervescent)
Bk2 – 30 to 36 inches; sl; 1msbk; sl
Bk3 – 36 to 42 inches; fsl; 1msbk; sl
Bk4 – 42 to 48 inches; sl; 1msbk; 3mswm (many medium soft white masses); sl
Ab – 48 to 52 inches; sil dark, 2msbk
Bkb – 52 to 56 inches; sl; 1msbk; sl
C1 – 56 to 60 inches; fsl; m (massive); 3mswm; ve (violently effervescent)
C2 – 60 to 72 inches; l; m

LS1-2
Vegetation Summary – crested wheatgrass, alfalfa (sparse)
Locations - N 44º 42.717'; W 105º 24.741'

AB – 0 to 6 inches; cl; 2mgr to 1msbk
Bw – 6 to 12 inches; cl; 2msbk
C1 – 12 to 20 inches; sil; 2mpl (moderate, medium, platy)
C2 – 20 to 24 inches; sil; 2msbk
C3 – 24 to 30 inches; sil; 2msbk
C4 – 30 to 48 inches; sl; 2msbk
Ab – 48 to 54 inches; l; 2msbk; 2mswm (common medium soft white masses); sl
Bkb – 54 to 60 inches; sil; 2msbk; 2fr (common fine redox features)
C – 60 to 72 inches; fsl; 1mswmt (few medium soft white masses and threads); 1fr (few fine redox features); sl

LS1-3
Vegetation Summary – canadian Thistle, crested wheatgrass, alfalfa (sparse)
Location - N 44º 42.713'; W 105º 24.822'

AB – 0 to 3 inches; l; 2mgr and 1msbk
Bw – 3 to 15 inches; cl; 2msbk

Bk – 15 to 30 inches; l; 2msbk; 1mswm; sl
Bk2 – 30 to 40 inches; fsl; 2msbk; st
Ab – 40 to 42 inches; l; 1msbk; sl
Bkb – 42 to 46 inches; l; 2msbk; 1mswm; sl
C – 46 to 60 inches; ls; m
C1 – 60 to 72 inches; ls; 1fr (few fine redox features); 1 scoria chips (few scoria chips)

LS2-1
Vegetation Summary - western wheatgrass, cheat grass, crested wheatgrass. Surface appears to be impacted with sodium (large cracks, hard at the surface)
Location - N 44º 42.691'; W 105º 24.885'

AB – 0 to .5 inches; cl; 2msbk; hard
Bn - .5 to 1 inch; cl; 2mcpr grading to 2msbk

LS2-2
Vegetation Summary - western wheatgrass, cheat grass, crested wheatgrass
Location – N 44º 42.672'; W 105º 24.922'

A – 0 to 1 inch; l; 1msbk
Bw – 1 to 6 inches; cl; 2msbk
C – 6+ inches; sl; 1msbk

LS3-1 (Not sampled - correlated to LS1)
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.556'; W 105º 24.864'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 6 inches; sl; 1msbk
C1 – 6 to 10 inches; ls; m
C2 – 10 to 12 inches; sl; 2mpl
C3 – 12 to 16 inches; sl; 1mpl; many scoria bits
C4 – 16 to 24 inches; sil; 2mpl
Bw – 24 to 25 inches; sil; 2msbk;
Bkb – 25 to 32 inches; sl; 2msbk; 1mswt; sl
C1 – 32 to 36 inches; sl; m; st
C2 – 36 to 48 inches; sil; m; 3mswt; st to ve

LS4-1 Not sampled – correlated to LS1
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.454'; W 105º 24.847'

AB – 0 to 1 inch; cl; 2mgr
Bw – 1 to 6 inches; cl; 2msbk

Bk1 – 6 to 15 inches; sil; 1msbk; sl
Bk2 – 15 to 21 inches; sl; 1msbk; sl
Bk3 – 21 to 28 inches; sil; 1msbk; sl
C1 – 28 to 36 inches; ls; m; sl
C2 – 36 to 44 inches; sil; m; 3mr (many medium redox features)
C3 – 44 to 72 inches; sil; m

LS5-1 Not sampled – correlated to LS1
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.347'; W 105º 24.977'

AB – 0 to 1 inch; l; 2mgr
Bw – 1 to 7 inches; cl; 2msbk
C1 – 7 to 12 inches; ls; m; 3f/mr (many fine to medium redox features)
C2 – 12 to 18 inches; sil; m
C3 – 18 to 30 inches; ls; m; sl
C4 – 30 to 57 inches; sil; m; sl
C5 – 57 to 72 inches; sil; m; st

LS6-1
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.327'; W 105º 25.169'

A – 0 to 3 inches; l; 2mgr
Bw – 3 to 12 inches; fsl; 3msbk
Bk – 12 to 18 inches; sil; 2msbk; 3mswmt; st
C1 – 18 to 24 inches; sil; m; 1mswmt; sl
C2 – 24 to 34 inches; sil; m; 3mswmt; st
C3 – 34 to 36 inches; s; m
C4 – 36 to 46 inches; sicl; m; 3mswmt; ve
C5 – 46 to 50 inches; s; m
C6 – 50 to 66 inches; m; 1mswmt; 2fr (common fine redox features); st
C7 – 66 to 67 inches; s; m
C8 – 67 to 72 inches; sicl; m; 1mswm; sl

LS6-2
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.282'; W 105º 25.171'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 7 inches; l; 1msbk
Bk1 – 7 to 12 inches; l; 1msbk; sl
Bk2 – 12 to 18 inches; fsl; 1msbk; 3fr; sl
Bk3 – 18 to 24 inches; sil; 1msbk; 3mswmt; st

C1 – 24 to 32 inches; sil; m; 1mswmt; st
C2 – 32 to 36 inches; sl; m; st
C3 – 36 to 48 inches; sil; m; 3mswmt; ve
C4 – 48 to 61 inches; cl; m; 3mswmt; 3mr; st
C5- 61 to 62 inches; s; m
C6 – 62 to 72 inches; cl; m; 2mswm; 3fr; st

LS6-3
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.324'; W 105º 25.215'

A – 0 to 1 inches; fsl; 2mgr
Bw – 1 to 9 inches; fsl; 1msbk
C1 – 9 to 12 inches; ls; m; vs (very slightly effervescent)
C2 – 12 to 18 inches; sil; m; 3swmt; st
C3 – 18 to 20 inches; sl; m; st
C4 – 20 to 36 inches; sil; m; st
C5 – 36 to 37 inches; sl; m; st
C6 – 37 to 48 inches; sil; m; 2mswmt; st
C7 – 48 to 57 inches; sil; m; 2mswm; st
C8 – 57 to 72 inches; Cl; m; 3mr; sl

LS6-4
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.393'; W 105º 25.203'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 8 inches; l; 2msbk
Bk1 – 8 to 12 inches; l; 2msbk; sl
Bk2 – 12 to 28 inches; fsl; 2msbk; sl
Bk3 – 28 to 33 inches; sl; 2msbk; sl
C3 – 33 to 48 inches; sil; m; sl
C4 – 48 to 60 inches; sl; m; 2mr
C5 – 60 to 63 inches; sl; m
C6 – 63 to 72 inches; cl; 2mr

LS6-5
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.460'; W 105º 25.213'
Appears this site could be sodium affected in the top horizons.

Bw – 0 to 7 inches; cl; 2msbk
Bk – 7 to 20 inches; cl; 2msbk; 3mswmt; st

C1 – 20 to 37 inches; sil; m; 3mswmt; st
C2 – 37 to 41 inches; ls; m; 2mr; sl
C3 – 41 to 54 inches; sil; m; 3fr; 3mswmt; st
C4 – 54 to 68 inches; cl; m; 20% redox features (gleying)
C5 – 68 to 72 inches; ls; m;

LS7-1
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.770'; W 105º 24.612'

Bw1 – 0 to 6 inches; cl; 2msbk
Bw2 – 6 to 12 inches; cl; 3msbk to 1cpr
Bk – 12 to 24 inches; sil; 2msbk; sl
C2 – 24 to 40 inches; sl; m; sl
C3 – 40 to 46 inches; ls; m; sl
C4 – 46 to 67 inches; sl; m; 1mr; sl
C5 – 67 to 72 inches; ls; m; st

LS7-2
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.865'; W 105º 24.448'

A – 0 to 2 inches; l; 2mgr
Bw1 – 2 to 12 inches; cl; 2msbk
Bw2 – 12 to 14 inches; sl; 1msbk
Bk – 14 to 26 inches; sl; 1msbk; st
C3 – 26 to 36 inches; sil; m; 3mswmt; ve
C4 – 36 to 40 inches; grsil; m; st
C5 – 40 to 44 inches; sl; m; st
C6 – 44 to 50 inches; sil; m; 3msfw; st
C7 – 50 to 60 inches; sl; m; st
C8 – 60 to 72 inches; cl; m; 2mswm; st

LS7-3
Vegetation Summary – alfalfa (sparse), crested wheatgrass, cheatgrass, smooth brome
Location - N 44º 42.779'; W 105º 24.479'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 12 inches; cl; 2msbk
Bk – 12 to 17 inches; l; 2msbk; sl
C1 – 17 to 37 inches; sl; m; 1mswm; st
C2 – 37 to 42 inches; sil; m; 3mswmt; ne
C3 – 42 to 48 inches; sl; m; st
C4 – 48 to 52 inches; sil m; 1mr; 3mswm; ve

C5 – 52 to 72 inches; sl; zones of 1mswm; st.

Carl Kretschman Ranch

CK1-1
Vegetation Summary – western wheat grass; crested wheatgrass
Location - N 44º 42.205'; W 105º 27.009'

A – 0 to 4 inches; sil; 2mgr
Bw – 4 to 9 inches; c1; 2msbk
Bk1 – 9 to 12 inches; cl; 2msbk; 3mswm; st
Bk2 – 12 to 36 inches; sl; 2msbk; 3mswm; st
BC – 36 to 48 inches; c1; 1msbk; 1mr; sl
C1 – 48 to 60 inches; cl; m; 1mr
C2 – 60 to 72 inches; fsc; m; 1mr; wet low end.

CK1-2
Vegetation Summary – western wheat grass; crested wheatgrass
Location - N 44º 42.192'; W 105º 26.973'

A – 0 to 3 inches; sil; 2mgr
Bw – 3 to 8 inches; c1; 2msbk
Bk – 8 to 22 inches; c1; 2msbk; 3mswm; st
C 22 to 25 inches; s; sg
Bkb – 25 to 30 inches; s1; 2msbk; 1mr; sl
C – 30 to 32 inches; s; m; 1mr
Bkb – 36 to 42 inches; sil; 2msbk; 1mr; sl
C1 – 42 to 48 inches; sil; m; 1mr; sl
C2 – 48 to 72 inches; c1; m; 1mr; sl

CK1-3
Vegetation Summary – western wheat grass; crested wheatgrass
Location - N 44º 42.155'; W 105º 26.921'

A – 0 to 2 inches; sil; 2mgr
Bw – 2 to 4 inches; c1; 2msbk
Bk1– 4 to 16 inches; c1; 2msbk; 3mswm; st
Bk2 – 16 to 43inches; sil; 2msbk; 3mswm; st
C1 – 43 to 60 inches; s; m; 2mr; st
C2 – 60 to 67 inches; sc; m; 2mr; sl
C3 – 67 to 69 inches; s; m; 2mr; sl
C4 – 69 to 72 inches; s1; m; 2mr; sl

CK2-1
Vegetation Summary – wheatgrass,
Location - N 44º 42.176'; W 105º 26.750'

A – 0 to 3 inches; c1; m (sodic?);
Bk1 – 3 to 12 inches; sicl; 2msbk (hard); 3mswm; st
Bk2 – 12 to 30 inches; sicl; 2msbk; 3mswm; st
Bk3 – 30 to 36 inches; sicl; 2msbk; 3mswm; 1mr; st
C1 – 36 to 46 inches; c; m; 2mr; sl
C2 – 46 to 48 inches; 1s; m 2mr; sl

CK2-2
Vegetation Summary - crested wheatgrass, western wheatgrass, alfalfa (tall)
Location - N 44º 42.212'; W 105º 26.742'

A – 0 to 4 inches; c1; m (hardpan – sodic?)
Bw – 4 to 12 inches; c1; 1msbk – m (hardpan – sodic)
Bk1 – 12 to 24 inches; cl; 2msbk; 2fswm; st
Bk2 – 24 to 48 inches; cl; 2msbk; 3fswm; st
BC – 48 to 55 inches; cl; 1msbk; 2fswm;1mr; st
C1 – 55 to 60 inches; s (layers) m; sl
C2 – 60 to 72 inches; gr; m

CK2-3
Vegetation Summary - crested wheatgrass, wheatgrass, weeds,
Location - N 44º 42.256'; W 105º 26.760'

A – 0 to 3 inches; cl; m (highly impacted – sodic)
Bw – 3 to 6 inches; c1; 2msbk (very hard; impacted);
Bk1 – 6 to 12 inches; c1; 2msbk (very hard impacted) 1mswm; st
Bk2 – 12 to 18 inches; cl; 2msbk (softer); 1mswm; st
Bk2 – 18 to 24 inches; c1; 2msbk; 3mswm; ve
Bk3 – 36 to 48 inches; c; 2msbk; 2mswm; st
C1 – 48 to 72 inches; c; m; 2mswm; 1mr; st

CK2-4
Vegetation Summary – western wheatgrass, alfalfa (sparse tall), crested wheatgrass
Location - N 44º 42.236'; W 105º 26.825'

A – 0 to 2 inches; cl; m (sodium impacted);
Bw – 2 to 4 inches; cl; 2msbk (sodium impacted);
Bk1 – 4 to 10 inches; cl; 2msbk; 3mswm; st
Bk2 – 10 to 15 inches; cl; 2msbk; 3mswm; st; color change
BC – 15 to 24 inches; cl; 1msbk; 3mswm; 2mr; st
C1 – 24 to 39 inches; sc; m; mswm (some layers); st
C2 – 39 to 48 inches; 1s (layers); m; 3mr; sl
C2 – 57 to 72 inches; s; m

CK2-5

Vegetation Summary – western wheatgrass, alfalfa (sparse tall), crested wheatgrass
Location - N 44º 42.184'; W 105º 26.830'

A – 0 to 2 inches; cl; 2mgr
Bw – 2 to 4 inches; c1; 1msbk (hard pan)
Bk1 – 4 to 12 inches; c1; 2msbk; 3mswm; st
Bk2 – 12 to 36 inches; c; 2msbk; 3mswm; ve
BC – 36 to 42 inches; c; 1msbk; 3mswm; ve
C1 – 42 to 53 inches; sc; m; 2mswm; ve
C2 – 53 to 55 inches; s; m; 2mr; st
C3 – 55 to 60 inches; c1; m; 2mr; sl
C4 – 60 to 64 inches; 1s; m; 1mr;
C5 – 64 to 66 inches; grs (scoria sand); sg
C6 – 66 to 72 inches; sc; m; 3mr

CK3-1
Vegetation Summary – western wheatgrass; alfalfa sparse, weeds
Location - N 44º 42.100'; W 105º 26.758'

A – 0 to 2 inches; sil; 2mgr
Bw – 2 to 6 inches; sil; 2msbk; iron stone – hard
Bk – 6 to 12 inches; sil; 2msbk; 1mswm; iron stone – hard; st
C – 12 to 13 inches; s; m; iron stone – hard
Bk(b) – 13 to 16 inches; cl; 2msbk; 1mswm; iron stone – hard; st
C – 16 to 24 inches; s; m; iron stone – hard; st
C – 24 to 36 inches; s; m; 1mswm; st
C – 36 to 48 inches; s; m; 2mr; st
C2 – 48 to 60 inches; 1s; m; 2mr; sl
C3 – 60 to 72 inches; c1; m; 2mr;

CK3-2
Vegetation Summary – western wheatgrass; alfalfa sparse, weeds
Location - N 44º 42.105'; W 105º 26.716'

A – 0 to 3 inches; sil; 1mgr
Bw – 3 to 5 inches; sil; 2msbk
Bk1 – 5 to 8 inches; sil; 2msbk; 1mswm; sl
Bk2 – 12 to 18 inches; s1; 2msbk; 2mswm; st
C – 18 to 30 inches; s; m; 2mswm; st
Bk(b) – 30 to 36 inches; c1; 2msbk; 1mswm; st
C – 36 to 47 inches; s; m; sl
Bk(b) – 47 to 48 inches; s1; 1msbk; 1mswm; sl
C – 48 to 68 inches; c1 (interbedded sand); m; 1mr; sl
C – 68 to 72 inches; s; m; 2mr

CK3-3

Vegetation Summary – western wheatgrass; alfalfa sparse, weeds
Location - N 44º 42.029'; W 105º 26.726'

A – 0 to 1 inch; sil; 2mgr
Bw – 1 to 10 inches; sil; 2msbk
Bk1 – 10 to 12 inches; sil; 2msbk; 3mswm; st
Bk2 – 12 to 28 inches; sil; 2msbk; 3mswm; 2mr; st
C1 – 28 to 36 inches; s (layered); m; 2mr; sl
C2 – 42 to 48 inches; s (layered); m; 3mswmt; st
C2 – 48 to 72 inches; grs (sand with scoria gravel); sg; sl

CK4-1
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location - N 44º 41.963'; W 105º 26.084'

Ap - 0 to 3 inches; sil; 2tnpl;
Bw – 3 to 16 inches; cl; 2msbk;
Bk1 – 16 to 36 inches; cl; 2msbk; sl
Bk2 – 36 to 48 inches; cl; 1msbk, sl
BC - 48 to 54 inches; cl; 1msbk; 1mswm; st
C1 – 54 to 66 inches; s; m; sl
C2 – 66 to 72 inches; s; m; 2mswm; st

CK4-2
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º42.003'; W105º26.195'

Ap - 0 to 3 inches; sil; 2tnpl;
Bw – 3 to 6 inches; cl; 2msbk; 2mr
Bk – 6 to 15 inches; cl; 2msbk; sl
BC – 15 to 18 inches; cl; 1msbk; sl
C – 18 to 24 inches; sl; m; sl;
C1 - 24 to 42 inches; sl; m; 2mswm; st
C2 – 42 to 48 inches; sl; m; sl
C3 – 48 to 60 inches; ls; m; 2mr; sl
C4 – 60 to 72 inches; s; m; 2mr

CK4-3
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º41.973'; W105º26.348'

Ap - 0 to 3 inches; sil; 2tnpl;
Bw1 – 3 to 5 inches; cl; 2msbk
Bw2 – 5 to 12 inches; cl; 2msbk; 2mr
Bk1 – 12 to 24 inches; cl; 2msbk; 1mr; sl
Bk2 – 24 to 42 inches; cl; 3msbk; 1mr; sl
C1 – 42 to 54 inches; cl; m; 1mr; sl

C2 – 54 to 60 inches; cl; m; 3mswm; 1mr; st
C3 – 60 to 66 inches; cl; m; 3 mswm; 2mr; st
C4 – 66 to 72 inches; sl; m; 2mr; sl

CK4-4
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location - N 44º 42.029'; W 105º 26.345'

Ap - 0 to 3 inches; sil; 2tnpl;
Bw1 – 3 to 6 inches; cl; 2msbk
Bw2 – 6 to 12 inches; l; 2msbk;
Bk – 12 to 16 inches; cl; 2msbk; sl
C – 16 to 24 inches; fsl; 2thpl; 1mswm; st
C1 - 24 to 36 inches; sl; m; 1mswm; st
C2 – 36 to 72 inches; sl; m; 1mswm; 1mr; st

CK4-5
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º42.099'; W105º26.375'

Ap - 0 to 3 inches; sil; 2tnpl;
Bw – 3 to 9 inches; cl; 2msbk
Bk1 – 9 to 19 inches; cl; 2msbk; 3mswm; st
BC – 16 to 24 inches; sl; 1msbk; sl
C1 - 24 to 36 inches; sl; 2thpl; 2mswm; st
C2 – 36 to 60 inches; sl; m; 1mswm; 1mr; st
C3 – 60 to 72 inches; ls; m; st

CK4-6
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º42.071'; W105º26.496'

Ap - 0 to 2 inches; sil; 2mgr; 2mr
Bw – 2 to 5 inches; sil; 2msbk; 2mr
Bk1 – 5 to 12 inches; sl; 2msbk; 3mswm; st
Bk2 – 12 to 24 inches; sl; 1msbkt; ve
C1 - 24 to 36 inches; s; sg (loose sand); 1mr; st
C2 – 36 to 60 inches; sl; m; 1mswm; 2mr; st
C3 – 60 to 72 inches; ls; grsg (scoria gravel); 2mr; st

CK4-7
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º41.997'; W105º26.456'

Ap - 0 to 4 inches; sil; 2mgr
Bw – 4 to 7 inches; sil; 2msbk
Bk1 – 7 to 12 inches; cl; 3msbk (hard); 3mswm; st

Bk2 – 12 to 44 inches; cl; 2msbk; 3mswm; st
C1 – 44 to 60 inches; cl; m; 3mswm; st
C2 – 60 to 66 inches; ls; m; 3 mswm; st
C3 – 66 to 72 inches; s; m; sl

CK4-8
Vegetation Summary – alfalfa (sparse), crested wheatgrass, Canadian thistle
Location – N44º41.918'; W105º26.145'

Ap - 0 to 3 inches; sil; m (hard – sodic)
Bw – 3 to 20 inches; cl; 3msbk; 1mr
Bk1 – 20 to 30 inches; cl; 3msbk; sl
C – 30 to 48 inches; s; m; st
Bk1b - 48 to 60 inches; cl; 1msbk; 3mswm; ve
Bk2b – 60 to 66 inches; cl; 2msbk; 3mswm; st
Bk3b – 66 to 72 inches; cl; 1msbk; 2mswm; 2mr; st

CK4-9
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º41.928'; W105º26.310'

Ap - 0 to 3 inches; cl; m (hard – sodic)
Bw – 3 to 9 inches; cl; 2msbk
Bk1 – 9 to 20 inches; cl; 3msbk; 3mswm; st
Bk2 – 20 to 64 inches; sicl; 2msbk; 3mswm; st
BC - 64 to 72 inches; scl; 1msbk; 3mswm; ve

CK4-10
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º41.928'; W105º26.310'

Ap - 0 to 5 inches; cl; m (hard – sodic)
Bw – 5 to 24 inches; cl; 2msbk
Bk1 – 24 to 36 inches; cl; 2msbk; 2mswm; st
Bk2 – 36 to 44 inches; cl; 2msbk; 3mswm; st
C - 44 to 72 inches; cl; m; 3mswm; ve

CK4-10
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º41.928'; W105º26.310'

Ap - 0 to 5 inches; cl; m (hard – sodic)
Bw – 5 to 24 inches; cl; 2msbk
Bk1 – 24 to 36 inches; cl; 2msbk; 2mswm; st
Bk2 – 36 to 44 inches; cl; 2msbk; 3mswm; st
C - 44 to 72 inches; cl; m; 3mswm; ve

CK4-11
Vegetation Summary – alfalfa (sparse), crested wheatgrass; cheat grass
Location – N44º41.914'; W105º26.275'

Ap - 0 to 5 inches; cl; 2mgr
Bk1 – 5 to 12 inches; cl; 3msbk; 3mswm; st
Bk2 – 12 to 24 inches; cl; 2msbk; 3mswm; st
BC – 24 to 38 inches; cl; 1msbk; 3mswm; ve
C - 38 to 72 inches; cl; m; 3mswm; 2mswm; ve

CK4-12
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º41.985'; W105º26.501'

Ap - 0 to 3 inches; cl; 2tnpl
Bw – 3 to 6 inches; cl; 3msbk (hard)
Bk1 – 6 to 15 inches; cl; 2msbk; 2mswm; st
Bk2 – 15 to 24 inches; cl; 1msbk; 2mswm; st
BC – 24 to 49 inches; cl; m; 3mswm; st
C1 – 49 to 60 inches; cl; m; 3 mswm; st
C2 – 60 to 70 inches; cl; m; st
C3 – 70 to 72 inches; scl; m; st

CK4-13
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º42.024'; W105º26.121'

Ap - 0 to 3 inches; sil; 2tnpl
Bw – 3 to 10 inches; cl; 2msbk
Bk1 – 10 to 16 inches; cl; 2msbk; 3mswm; st
BC – 16 to 22 inches; cl; 1msbk; 3mswm; st
C1 – 22 to 26 inches; s; sg; sl
C2 – 26 to 46 inches; ls; 3tnpl; 3mr; sl
C3 – 46 to 69 inches; s; m; 3mr; sl
C5 – 69 to 72 inches; scl; m; 3mr; st

CK4-14
Vegetation Summary – alfalfa (sparse), crested wheatgrass
Location – N44º42.191'; W105º26.419'

Ap - 0 to 4 inches; sil; 2tnpl
Bw – 4 to 7 inches; cl; 2msbk; 2mr
Bk1 – 7 to 16 inches; cl; 2msbk; 3mswm; st
C1 – 16 to 25 inches; s; m; 2mswm; 2mr; st
C2 – 25 to 30 inches; s; m; 2mr; sl
C2 – 30 to 36 inches; sl; m; 3mswm; 2mr; st
C3 – 36 to 48 inches; ls; m; 1mswm; 2mr; st

C4 – 48 to 60 inches; s; sg; sl
C5 – 60 to 66 inches; sl; m; 3mr; st
C6 – 60 to 72 inches; s; m; sl

Loren Peyrot Land

LP1-1
Vegetation Summary – alfalfa (sparse), wheatgrass
Location - N 44º 42.327'; W 105º 28.195'

A – 0 to 4 inches; sil; 2mgr
Bw – 4 to 10 inches; scl; 2msbk;
Bk1 – 12 to 22 inches; l; 2msbk; sl
Bk2 – 22 to 30 inches; grsl; 2msbk; sl
C1 – 30 to 38 inches; gr (scoria gravel); sg
C2 – 38 to 48 inches; l; m; sl
C3 – 48 to 60 inches; scl; m; sl
C4 – 60 to 72 inches; scl ; m; 3fr; wet

LP1-2
Vegetation Summary – alfalfa (sparse), wheatgrass
Location - N 44º 42.300'; W 105º 28.233'

Ap – 0 to 6 inches; sil; 2mgr
Bw1 – 6 to 9 inches; cl; 2msbk
Bw2 – 9 to 12 inches; sl; 2msbk
Bk1 – 12 to 18 inches; sil; 2msbk; sl
Bk2 – 18 to 24 inches; cl; 2msbk; sl
C1 – 24 to 36 inches; cl; 2msbk; st
C2 – 36 to 48 inches; cl; m; 2fr; sl
C3 – 48 to 60 inches; cl; m; 2fr; sl
C4 – 60 to 72 inches; cl; m; 3fr

LP1-3
Vegetation Summary – alfalfa (sparse), wheatgrass
Location - N 44º 42.290'; W 105º 28.253'

Ap – 0 to 6 inches; cl; 2mgr;
Bk1 – 6 to 12 inches; cl; 2msbk; 3mswm; st
Bk2 – 12 to 18 inches; cl; 1msbk; 3mswm; st
C1 – 18 to 24 inches; cl; m; sl
C1 – 24 to 36 inches; sicl; m; st
C2 – 36 to 48 inches; cl; m; st
C3 – 48 to 60 inches; sicl; m; 3mr; wet
C3 – 60 to 72 inches; sicl; m; 3mr; saturated

LP1-4

Vegetation Summary – alfalfa (sparse), wheatgrass
Location - N 44º 42.263'; W 105º 28.249'

Ap – 0 to 3 inches; sil; 2mgr;
Bw – 3 to 12 inches; sil; 2msbk;
Bk1 – 12 to 18 inches; sil; 2msbk; 2mswm; st
Bk2 – 18 to 24 inches; sl; 2msbk; 2mswm; st
Bk3 – 24 to 36 inches; sil; 2msbk; st
C1 – 36 to 48 inches; sl; m; sl; wet at 46 inches
C2 – 48 to 54 inches; cl; m; wet
C3 – 54 to 60 inches; ls; m; 2mr
C4 – 60 to 70 inches; sc; m; 2mr
C5 – 70 to 72 inches; scoria gravels; sg; saturated

LP-2-1
Vegetation Summary - snake weed; wheatgrass; sparse alfalfa
Location - N 44º 42.257'; W 105º 28.297'

Ap – 0 to 5 inches; sil; 2mgr;
Bk1 – 5 to 13 inches; cl; 2msbk; 2mswm; st
Bk2 – 13 to 24 inches; cl; 2msbk; st
C1 – 24 to 29 inches; sil; 2msbk; 2mr
C2 – 29 to 36 inches; sicl; m; 2mr
C3 – 36 to 48 inches; sicl; m; 2mr; saturated
C4 – 48 to 72 inches; sc; m; 2mr; saturated

LP-2-2
Vegetation Summary - milkweed; wheatgrass; alfalfa (sparse)
Location - N 44º 42.281'; W 105º 28.286'

Ap – 0 to 4 inches; sil; 2mgr
Bk1 – 4 to 12 inches; cl; 2msbk; sl
Bk2 – 12 to 18 inches; cl; 2msbk; sl
C1 – 18 to 24 inches; cl; m; 2mr
C2 – 24 to 30 inches; cl; m; 2mr (oxidation)
C3 – 30 to 48 inches; cl; m; 2mr (reduction and oxidation)
48 inches+ - saturated – No recovery

LP-2-3
Vegetation Summary - milkweed; wheatgrass; alfalfa (sparse)
Location - N 44º 42.311'; W 105º 28.299'

Ap – 0 to 3 inches; sil; 2mgr
Bk1 – 3 to 5 inches; cl; 3msbk; 2mswm; st
Bk2 – 3 to 12 inches; cl; 3msbk; 3mswm; ne
Bk3 – 12 to 24 inches; scl; 2msbk; st
C1 – 24 to 30 inches; cl (sandy zones); m; st

C2 – 30 to 36 inches; sicl; m; 2mr; sl
C3 – 36 to 48 inches; scl; m; 2mr; saturated;
C4 – 48 to ; s; sg; saturated; (48 inches+ -Saturated sand – no recovery; water table)

LP-3-1
Vegetation Summary - alfalfa (sparse); wheatgrass; smooth brome
Location - N 44º 42.340'; W 105º 28.253'

Ap – 0 to 5 inches; sil; 2mgr;
Bw – 5 to 8 inches; cl; 2msbk
Bk1 – 8 to 10 inches; cl; 2msbk; 3swm; st
Bk2 – 10 to 14 inches; cl; 2msbk; 2swm; st
C1 – 14 to 24 inches; sl (sandy zones); m; 1msbk; st
C2 – 24 to 36 inches; scl; m; st
C3 – 36 to 48 inches; scl; m; st
C4 – 48 to 72 inches; vfs; m; st; water table.

LP-3-2
Vegetation Summary - alfalfa (sparse); wheatgrass; sedges
Location - N 44º 42.368'; W 105º 28.312'

Ap – 0 to 4 inches; sil; 2mgr
Bw – 4 to 10 inches; cl; 2msbk
Bk – 10 to 19 inches; cl; 2msbk; 1mswm; st
C1 – 19 to 20 inches; cl; m; 2mswm; st; dark carbonate material
C2 – 20 to 36 inches; scl; m; st
C3 – 36 to 60 inches; s; m; water table

LP-3-3
Vegetation Summary - alfalfa (sparse); wheatgrass;
Location - N 44º 42.308'; W 105º 28.372'

Ap – 0 to 4 inches; sil; 2mgr
Bw – 4 to 10 inches; cl; 2msbk;
Bk1 – 10 to 15 inches; cl; 2msbk; 3mswm; st
Bk2 – 15 to 26 inches; cl; 2msbk; 1mswm; st
C1 – 26 to 29 inches; s; m
C2 – 29 to 36 inches; sicl; m; 2fr; sl
C2 – 36 to 48 inches; sicl; m; 2fr; dry
C3 – 48 to 60 inches; sicl; m; 3fr; wet
C4 – 60 to 72 inches; sc; m; wet

LP-3-4
Vegetation Summary - alfalfa (sparse); wheatgrass; snakeweed (sparse)
Location - N 44º 42.263'; W 105º 28.348'

Ap – 0 to 6 inches; sil; 2mgr
Bw – 6 to 10 inches; sil; 2msbk
Bk1 – 10 to 14 inches; sil; 2msbk; 3mswm; st
Bk2 – 14 to 40 inches; c1; 2msbk; st
Bk3 – 40 to 48 inches; cl; 2msbk; 3mswm; st
C1 – 48 to 60 inches; s1; m; st
C1 – 60 to 72 inches; s1; m; sl; very moist (68 to 72 inches)

LP3-5
Vegetation Summary – alfalfa (sparse), wheatgrass
Location - N 44º 42.222'; W 105º 28.384'

Ap – 0 to 5 inches; sil; 2mgr
Bw – 5 to 12 inches; sil; 2msbk
Bk1 – 12 to 18 inches; sil; 2msbk; sl
Bk2 – 18 to 24 inches; s1; 2mskb; sl
C1 – 24 to 36 inches; sil; m; st
C2 – 36 to 48 inches; s1; m; st
C3 – 48 to 60 inches; sc; m; 2mr; sl
C3 – 60 to 72 inches; sc; m; 2mr; very moist;

LP4 -1
Vegetation Summary - alfalfa (sparse); Koshia – weeds;
Location - N 44º 42.295'; W 105º 28.140'

Ap – 0 to 4 inches; cl; 2mgr
Bw – 4 to 12 inches; cl; 2msbk
Bk1 – 12 to 24 inches; cl; 2msbk; sl
Bk2 – 24 to 28 inches; cl; 2msbk; st
C1 – 28 to 32 inches; scoria gr; sg
C2 – 32 to 36 inches; cl; m; 3mswm; st
C2 – 36 to 45 inches; c; m; 3mswm; ve
C3 – 45 to 48 inches; grsl (sandy scoria); sg
C4 – 48 to 60 inches; s1; m; 2mr;
C5 – 60 to 72 inches; scoria gr; sg

LP4-2
Vegetation Summary – wheatgrass, koshia weeds
Location - N 44º 42.311'; W 105º 28.123'

Ap – 0 to 4 inches; sil; 2mgr
Bw1 - 4 to 6 inches; sil; massive hardpan;
Bw2 – 6 to 12 inches; cl; 2msbk
Bk1 – 12 to 20 inches; cl; 2msbk; 3mswm; st
Bk2 – 20 to 24 inches; sil; 2msbk; 1mswm; st
BC – 24 to 36 inches; cl; 2msbk; st
BC – 36 to 48 inches; c1; 2msbk; 2mr

C – 48 to 72 inches; cl; m; 2mr;

LP4-3
Vegetation Summary - alfalfa, wheatgrass, weeds, snake weed
Location - N 44º 42.270'; W 105º 28.081'

Ap – 1 to 3 inches; cl; 2msbk (hardpan -compact);
Bw – 3 to 10 inches; cl; 2msbk
Bk – 10 to 30 inches; cl; 2mskb; 2mswm; ve
BC – 30 to 36 inches; cl; 1msbk; 2mr; sl
C1 – 36 to 48 inches; scl; m; sl
C2 – 48 to 60 inches; scl; m; 2mr
C3 – 60 to 72 inches; sc; m; 2mr

LP5-1
Vegetation Summary - pasture grass, shrubs
Location - N 44º 42.286'; W 105º 27.255'

Ap – 0 to 5; sil; 2mgr
Bk1 – 5 to 12 inches; sil; 2msbk; 3mswm; st
Bk2 – 12 to 24 inches; s1; 2msbk; 2mswm; st
C1 – 24 to 36 inches; sl; m; 2mr; sl
C2 – 36 to 42 inches; s1; m; 2mr
C2 – 42 to 48 inches; s; m; saturated

LP5-2
Vegetation Summary - pasture grass, wheatgrass,
Location - N 44º 42.292'; W 105º 27.228'

A – 0 to 5 inches; sil; 2mgr
Bw – 5 to 13 inches; sil; 2msbk
Bk – 13 to 24 inches; cl; 2msbk; 1mswm; st
C1 – 24 to 36 inches; cl; m; 1mswm; st
C1 – 36 to 40 inches; s1; m; 1mswm; st
C2 – 40 to 48 inches; s; m; 1mr; sl

LP5-3
Vegetation Summary - pasture grass, wheatgrass,
Location - N 44º 42.317'; W 105º 27.251'

Ap – 0 to 3 inches; sil; m (hardpan with surface craking); very dark (om dispersion)
Bk1 – 3 to 5 inches; cl; 1msbk (hard); 1mswm; sl
Bk2 – 5 to 18 inches; c1; 2msbk; 3mswm; st
Bk3 – 18 to 24 inches; cl; 2msbk; 2mr; sl
C1– 24 to 36 inches; c1; m; 2mr
C2 – 36 to 48 inches; sc; m; 2mr; saturated

LP6-1
Vegetation Summary - pasture grass, wheatgrass,
Location – N44º42.230'; W105º27.280'

Ap – 0 to 4 inches: sil; 2mgr
Bk1 – 4 to 12 inches; sil; 2msbk; 1mswm; st
Bk2 – 12 to 24 inches; sil; 2msbk; 1mswm; st
C1 – 24 to 48 inches; grs; m; st

LP6-2
Vegetation Summary - pasture grass, wheatgrass,
Location – N44º42.203'; W105º27.276'

A – 0 to 5 inches; sil; 2mgr
Bw – 5 to 12 inches; sil; 2msbk
Bk– 12 to 16 inches; sil; 2msbk; 1mswm; st
C1 – 16 to 24 inches; s; m
C2 – 24 to 36 inches; grs (mixed scoria); m
C3 – 36 to 48 inches; s, sg

LP6-3
Vegetation Summary - pasture grass, wheatgrass,
Location – N44º42.182'; W105º27.268'

Ap – 0 to 3 inches; sil; 2mgr;
A – 3 to 5; sil; m (hardpan)
Bw – 5 to 18 inches; sil; 2msbk
Bk1 – 18 to 24 inches; sil; 2msbk; 1mswm; st
Bk2 – 24 to 29 inches; sil; 2msbk; 1mswm; st
C1 – 29 to 36 inches; s, m; st
C2 – 36 to 48 inches; s; m; 2mswm; st

LP7-1
Vegetation Summary - pasture grass, wheatgrass,
Location – N44º42.203'; W105º27.276'

A – 0 to 4 inches; sil; 2mgr
Bw – 4 to 7 inches; sil; 2msbk
Bk – 7 to 19 inches; sil; 2msbk; 1mswm; sl
C – 19 to 20 inches; grs (scoria sand layer); m
Bk(b) – 20 to 30 inches; cl; 2msbk; 2mswm; st
C – 30 to 44 inches; s; m
C – 44 to 48 inches; sc; m; 2mr

LP7-2
Vegetation Summary - pasture grass, wheatgrass,

Location – N44º42.305'; W105º27.385'

A – 0 to 2 inches; cl; 2mgr
Bw – 2 to 11 inches; cl; 2msbk
C – 11 to 12 inches; s; sg
A(b) – 12 to 13 inches; cl; 1msbk
Bw(b) – 13 to 18 inches; cl; 2msbk;
Bk(b) – 18 to 24 inches; c1; 2msbk; 1mswm; st
BC – 24 to 30 inches; c1; 1msbk; 2mswm; st
C1 – 24 to 36 inches; sc; m; 2mswm; st
C2 – 36 to 42 inches; s1; m; 1mswm; st
C3 – 42 to 48 inches; sc; m; 2mr; st

LP7-3
Vegetation Summary - pasture grass, wheatgrass,
Location – N 44º 42.260'; W 105º 27.366'

AB – 0 to 2 inches; cl; m (hard sodic?)
Bk1 – 2 to 8 inches; cl; 2msbk; 1mswm; sl
Bk2 – 8 to 24 inches; c1; 2msbk; 2mswm; sl
Bk3 – 24 to 30 inches; c1; 2msbk; 3mswm; st
C1 – 30 to 46 inches; c1; m; 2mswm; st
C2 – 46 to 48 inches; cl; m; 1mswm; 2mr; sl

LP8-1
Vegetation Summary – wheatgrass, wide leaf grass (wetland species)
Location – N44º42.367'; W105º27.736'

A – 0 to 2 inches; sil; 2mgr
Bk1 – 2 to 8 inches; c1; 2msbk; 1mswm; sl
Bk2 – 10 to 24 inches; c1; 2msbk; 1mswm; 2mr; sl
BC – 24 to 36 inches; c1; 1msbk; 1mswm; 3mr; sl
C1 – 36 to 42 inches; cl; m; 3mr; vs
C2 – 42 to 48 inches; sc; m; 3mr; vs

LP8-2
Vegetation Summary - shrubs (snowberry), weeds
Location - N 44º 42.391'; W 105º 27.718'

A – 0 to 3 inches; cl; 2mgr
Bw – 0 to 9 inches; cl; 2msbk; 1mr
Bk – 9 to 16 inches; cl; 2msbk; 3mswm; 1mr; st
C1 – 16 to 30 inches; sl; m; 3mr
C2 – 30 to 36 inches; s; m; 3mr
C4 – 36 to 48 inches; sc; m; 3mr

LP8-3

Vegetation Summary – reed grass
Location - N 44º 42.391'; W 105º 27.667'

A – 0 to 3 inches; cl; 2mgr
Bt – 3 to 6 inches; cl; 3msbk;
Bk1 – 6 to 11 inches; cl; 2msbk; 1msmw; sl
Bk2 – 11 to 21 inches; cl; 2msbk; 3mswm; 2mr; st
Bk3 – 21 to 24 inches; cl; 1msbk; 1mswm; 2mr; st
C – 24 to 28 inches; s; sg
Bk(b) – 28 to 32 inches; cl; 2msbk; 3mswm; 1mr; st
BC(b) – 32 to 36 inches; cl; 1msbk; 1mswm; 2mr; sl
C1 – 36 to 40 inches; grs (scoria and sand); sg
C2 – 40 to 48 inches; sc; m; 2mr; dry

LP8-4
Vegetation Summary – wheatgrass; smooth brome
Location - N 44º 42.380'; W 105º 27.644'

A – 0 to 4 inches; cl; 2mgr
Bw1 – 4 to 8 inches; cl; 2msbk
Bw2 – 8 to 16 inches; cl; 1msbk
C – 16 to 18 inches; grs (scoria and sand); sg
Bk(b) – 18 to 28 inches; cl; 2msbk; 1mswm; st
C1 – 28 to 44 inches; ls; m; st
C2 – 44 to 48 inches; sc; m; 2mr; sl

LP8-5
Vegetation Summary - snowberry, sagebrush, smooth brome, western wheatgrass
Location - N 44º 42.361'; W 105º 27.566'

A – 0 to 2 inches; sil; 2mgr
Bw – 2 to 9 inches; sil; 2msbk
Bk– 9 to 15 inches; c1; 2msbk; 1mswm; sl
C – 15 to 16 inches; s; sg
Bk(b) – 16 to 19 inches; c1; 2msbk; sl
C – 19 to 24 inches; grs (scoria and sand); sg
C – 24 to 40 inches; s; m
C – 40 to 48 inches; grs; sg; dry

LP8-6
Vegetation Summary – western wheatgrass; smooth brome
Location - N 44º 42.298'; W 105º 27.685'

Ap – 0 to 3 inches; sil; 2mgr (top inch – hard sodic);
Bw – 3 to 12 inches; c1; 2msbk
Bk – 12 to 21 inches; c1; 2msbk; 1mswm; sl
C1 – 21 to 24 inches; s1; m; sl

C2 – 24 to 36 inches; 1s; m; 1mr; sl
C3 – 36 to 48 inches; 1s; m; coal dep @ 46 inches; very wet at 46 inches

LP8-7
Vegetation Summary –
Location - N 44º 42.316'; W 105º 27.586'

A – 0 to 2 inches; sil; hard peds (sodic)
Bw – 2 to 6 inches; c1; 2msbk
Bk – 6 to 20 inches; c1; 2msbk; 3mswm; st
BC – 20 to 24 inches; c1; 1msbk; 3mswm; ve
C1 – 24 to 30 inches; c1; m; 3mswm; ve
C2 – 30 to 48 inches; c1; m; 2mr; wet to bottom

Stevan Mueller Ranch

SM1-1
Vegetation Summary - crested wheatgrass, alfalfa (sparse)
Location - N 44º 42.470'; W 105º 29.468'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 6 inches; l; 1msbk
Bk1 – 6 to 12 inches; cl; 1msbk; 2mswmt; sl
Bk2 – 12 to 18 inches; cl; 1msbk; 3mswmt; st
C1 -18 to 26 inches; l; m; 1mswm; st
C2 – 26 to 35 inches; l; m; 1mswmt; 2mr; ve
C3 – 35 to 43 inches; grs (scoria chips); m; 1mr; vs
C4 – 43 to 55 inches; sil; m; 2mr; sl
C5 – 55 to 72 inches; s; m;

SM1-2
Vegetation Summary - crested wheatgrass, alfalfa (sparse)
Location - N 44º 42.484'; W 105º 29.577'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 4 inches; l; 1msbk
Bk1 – 4 to 7 inches; l; 2msbk; st
Bk2 – 7 to 15 inches; l; 2msbk; 1mswm; st
Bk3 – 15 to 21 inches; l; 2msbk; 1mswm; sl
C1 – 21 to 40 inches; cl; m; 3mswmt; sl
C2 – 40 to 59 inches; fsl; m; st
C3 – 59 to 63 inches; fsl; 2mswm; st
C4 – 63 to 64 inches; s; m; 1mr; sl
C5 – 64 to 69 inches; sl; m; st
C6 – 69 to 72 inches; ls; m; 2mr; sl

SM1-3

Vegetation Summary - crested wheatgrass, alfalfa (sparse)
Location - N 44º 42.569'; W 105º 29.498'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 7 inches; l; 1msbk
Bk – 7 to 12 inches; l; 1msbk; 1mwsmt; st
C1 – 12 to 22 inches; l; m; st
C2 – 22 to 24 inches; ls; m; st
C3 – 24 to 29 inches; sl; m; st
C4 – 29 to 42 inches; ls; m; sl
C5 – 42 to 48 inches; sl; m; 2mswmt; 1mr: st
C6 – 48 to 61 inches; s; m; vs
C7 – 61 to 66 inches; sl; m; 1mr: st
C8 – 66 to 72 inches; ls; m; 1mswm; 1mr; sl

SM1-4
Vegetation Summary - crested wheatgrass, alfalfa (sparse)
Location - N 44º 42.575'; W 105º 29.365'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; l; 1msbk
Bk1 – 5 to 9 inches; l; 2msbk; 1mswmt; st
Bk2 – 9 to 16 inches; l; 2msbk; 3mswmt; ve
C1 – 16 to 36 inches; l; m; 1mswmt; ve
C2 – 36 to 47 inches; l; m; 2mswmt; ve
C3 – 47 to 60 inches; sl; m; 1mswmt; 1mr
C4 – 60 to 66 inches; ls; m; 1mswm; 1mr; sl
C5 – 66 to 72 inches; l; m; 2mswmt; 1mr; sl; some gypsum present

SM1-5
Vegetation Summary - crested wheatgrass, alfalfa (sparse)
Location - N 44º 42.485'; W 105º 29.350'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; l; 1msbk
Bk – 5 to 8 inches; l; 1msbk; st
C1 – 8 to 15 inches; grvsl; m; 1mswm; ve
C2 – 15 to 19 inches; ls; m; 1mfswm; ve
C3 – 19 to 24 inches; fsl; m; 2mswm; 2mr; ve
C4 – 24 to 29 inches; ls; m; 1mswm; sl
C5 – 29 to 54 inches; grsl; m; ve
C6 – 54 to 60 inches; sl; m; 3mr (oxidation/reduction); ve
C7 – 60 to 64 inches; ls; m; 2mr; vs
C8 – 64 to 72 inches; grs; m; vs

SM1-6
Vegetation Summary - crested wheatgrass, alfalfa (sparse)

Location - N 44º 42.487'; W 105º 29.239'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 8 inches; l; 1msbk
Bk1 – 8 to 15 inches; l; 2msbk; 1mswmt; st
Bk2 – 15 to 20 inches; l; 1msbk; 3mswmt; ve
C1 – 20 to 28 inches; cl; m; 3mswmt; ve
C2 – 28 to 36 inches; ls; m; 1mfswm; st
C3 – 36 to 48 inches; vgrs; m; 1mswm; ve
C4 – 48 to 70 inches; vgrs; m;
C5 – 70 to 72 inches; ls; m; 2mr

SM1-7
Vegetation Summary - crested wheatgrass, alfalfa (sparse)
Location - N 44º 42.430'; W 105º 29.068'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 8 inches; l; 1msbk
Bk1 – 8 to 10 inches; 1msbk; sl
Bk2 – 10 to 15 inches; l; 2msbk; e3; 3mswmt; ve
C1 – 15 to 26 inches; sil; m (some stratification); 2mswmt; ve
C2 – 26 to 34 inches; sil; m; 1mswmt; ve
C3 – 34 to 45 inches; vfsl; m; 1mswmt; 2mr; ve
C4 – 45 to 56 inches; s; m;
C5 – 56 to 60 inches; scl; m; se
C6 – 60 to 64 inches; s; sg;
C7 – 64 to 70 inches; cl; m; se
C8 – 70 to 72 inches; s; 2mr; saturated

SM2-1
Vegetation Summary - crested wheatgrass, alfalfa (sparse)
Location - N 44º 42.345'; W 105º 28.710'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 6 inches; l; 1msbk
Bk – 6 to 8 inches; l; 1msbk; sl
C1 – 8 to 15 inches; ls; m; sl
C2 – 15 to 24 inches; sil; m; 2mswmt; st
C3 – 24 to 40 inches; sil; m (some stratification); 1mswmt; 1mr; st
C4 – 40 to 48 inches; sil; m; 2mr; sl
C5 – 48 to 72 inches; sl; sl; saturated

Paulette Parks Ranch

PP1-1
Vegetation Summary – smooth brome, wheatgrass, alfalfa (sparse)
Location – N 44º 42.188'; W 105º 30.053'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 10 inches; l; 1msbk
Bk – 10 to 22 inches; 2msbk; st
C1 – 22 to 24 inches; ls; sg; sl
C2 – 24 to 32 inches; sil; m; 3mswmt; st
C3 – 32 to 40 inches; sl; m; st
C4 – 40 to 41 inches; ls; m; st
C5 – 41 to 47 inches; sl; m; st
C6 – 47 to 54 inches; sil; m; 3mswmt; st
C7 – 54 to 57 inches; sl; m; st; few scoria chips
C8 – 57 to 63 inches; cl; m; 3mswmt; st
C9 – 63 to 72 inches; gr (many scoria chips); sg

PP1-2
Vegetation Summary – smooth brome, wheatgrass, alfalfa (sparse)
Location – N 44º 42.160'; W 105º 30.099'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 12 inches; cl; 1msbk
Bk – 12 to 30 inches; cl; 2msbk; 1mswmt; 1mr; sl
C1 – 30 to 56 inches; sil; m; sl
C2 – 56 to 66 inches; sil; m; 3mswm; 3mr; st
C3 – 66 to 72 inches; vfsl; m; 2mr; sl

PP1 – 3
Vegetation Summary – smooth brome, wheatgrass, alfalfa (sparse)
Location – N 44º 42.163'; W 105º 30.171'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 8 inches; cl; 1msbk
Bk – 8 to 18 inches; cl; 2msbk; sl
C1 – 18 to 24 inches; sl; m; sl
C2 – 24 to 36 inches; sil; m; sl
C3 – 36 to 44 inches; sl; m; sl
C4 – 44 to 54 inches; sil; m; 3mswmt; 2mr; st
C5 – 45 to 60 inches; s, m; sl
C6 – 60 to 71 inches; cl; m; 3mswmt; 3mr; st
C7 – 71 to 72 inches; s; m; st

PP1 – 4
Vegetation Summary – smooth brome, wheatgrass, alfalfa (sparse)
Location – N 44º 42.197'; W 105º 30.126'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 8 inches; l; 2msbk

Bk – 8 to 18 inches; cl; 2msbk; sl
C1 – 18 to 32 inches; sil; m; sl
C2 – 32 to 40 inches; sil; m; sl
C3 – 40 to 41 inches; gr (scoria); sg
C4 – 41 to 47 inches; cl; m; sl
C5 – 47 to 72 inches; grs (intermixed with scoria; scoria rock at bottom); sg

PP1-5
Vegetation Summary – smooth brome, wheatgrass, alfalfa (sparse)
Location – N 44º 42.245'; W 105º 30.141'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 9 inches; l; 1msbk
Bk – 9 to 16 inches; sil; 3mskbk; sl
C – 16 to 72 inches; s; sg; sl

PP2-1
Vegetation Summary – crested wheatgrass, alfalfa (sparse)
Location – N 44º 42.281'; W 105º 30.206'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 7 inches; l; 1msbk
Bk – 7 to 18 inches; sil; 2msbk; sl
C1 – 18 to 36 inches; sil; m; sl
C2 – 36 to 37 inches; grs (some scoria); sg
C3 – 37 to 54 inches; sil; m; sl
C4 – 54 to 57 inches; sl; m; sl
C5 – 57 to 63 inches; sl; m; 1fswm; 1fr; st
C6 – 63 to 72 inches; grs (scoria gravel); sg

PP3-1:
Vegetation Summary – smooth brome, wheatgrass, alfalfa (sparse)
Location – N 44º 42.185'; W 105º 30.406'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 6 inches; cl; 1msbk
Bk – 6 to 18 inches; sil; 2msbk
C1 – 18 to 34 inches; sil; m; 3mswmt; 1mr; st
C2 – 34 to 40 inches; sl; m; st
C3 – 40 to 60 inches; sil; m; 2mswmt; 1mr; st
C4 – 60 to 64 inches; sl; m; st
C5 – 64 to 72 inches; cl; m; 2mr; st

PP4-1
Vegetation Summary –crested wheatgrass, alfalfa (sparse)
Location – N 44º 42.269'; W 105º 30.594'

A – 0 to 1 inch – l; 2mgr
Bw – 1 to 6 inches; cl; 1msbk
Bk1 – 6 to 12 inches; cl; 2msbk; sl
Bk2 – 12 to 18 inches; sil; 2msbk; sl
C1 – 18 to 32 inches; sil; m; sl
C2 – 32 to 40 inches; ls; m; sl
C3 – 40 to 61 inches; sil; m; sl
C4 – 61 to 72 inches; sil; m; 2mswm; 1mr; st

PP5-1
Vegetation Summary – crested wheatgrass, wheatgrass, alfalfa (sparse)
Location – N 44º 42.342'; W 105º 30.565'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 9 inches; l; 1msbk
Bk1 – 9 to 19 inches; l; 2msbk; sl
Bk2 – 19 to 28 inches; l; 2msbk; 3mswm; st
C1 – 28 to 34 inches; cl; m; 2mswmt; st
C2 – 34 to 42 inches; m; 3mswmt; st; dark color
C3 – 42 to 72 inches; cl; m; 3mswmt; st

PP5-2
Vegetation Summary – crested wheatgrass, wheatgrass, alfalfa (sparse)
Location – N 44º 42.365'; W 105º 30.753'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 9 inches; l; 1msbk
Bk – 9 to 18 inches; l; 2msbk; sl
C1 – 18 to 22 inches; fsl; m; sl
C2 – 22 to 32 inches; cl; m; 3mswmt; st
C3 – 32 to 34 inches; ls; m; st
C4 – 34 to 52 inches; sil; m; 3mswmt; ve
C5 – 52 to 62 inches; cl; m; 3mswmt; 3mr; st
C6 – 62 to 72 inches; scl; m; 3mswm; 3mr; st

PP6-1
Vegetation Summary – crested wheatgrass, wheatgrass, alfalfa (sparse)
Location – N 44º 42.451'; W 105º 30.080'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 6 inches; l; 1msbk
Bk – 6 to 14 inches; cl; 2msbk; sl
C1 – 14 to 20 inches; l; m; 3mswmt; st
C2 – 20 to 26 inches; sl; m: 3mswmt; ve
C3 – 26 to 38 inches; sl; m; 3mswmt; ve
C4 – 38 to 48 inches; sl; m; 3mswmt; st
C5 – 48 to 62 inches; sl; m; 1mswm; 2mr; sl

C6 – 62 to 72 inches; grcl; m; st; saturated

PP7-1
Vegetation Summary – crested wheatgrass, wheatgrass, alfalfa (sparse)
Location – N 44º 42.307'; W 105º 31.540'

A – 0 to 1 inch; l; 2mgr
Bw – 0 to 6 inches; l; 1msbk
Bk – 6 to 12 inches; l; 2msbk; 2mwsmt; st
C1 – 12 to 24 inches; fsl; m; st
C2 – 24 to 36 inches; sil; m; 1fmswmt; st
C3 – 36 to 40 inches; sl; m; 2mswm; st
C4 – 40 to 48 inches; cl; m; 2mswm; st
C5 – 48 to 60 inches; cl; m; 3mswm (calcite and gypsum); 2mr; sl
C6 – 60 to 72 inches; sicl; m; sl

PP8 – 1
Vegetation Summary – smooth brome, wheatgrass, alfalfa (sparse), crested wheatgrass; cheatgrass
Location – N 44º 42.390'; W 105º 31.426'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; l; 1msbk
Bk1 – 5 to 10 inches; l; 2msbk; sl
Bk2 – 10 to 14 inches; l; 2msbk; 3mswmt; st
C1 – 14 to 23 inches; l; m; 2mswmt; st
C2 – 23 to 24 inches; grs (scoria gravel); sg
C3 – 24 to 28 inches; l; m; 2mswmt; m; st
C4 – 28 to 30 inches; ls; m; sl
C5 – 30 to 60 inches; cl; m; 3mswmt (calcite and common gypsum threads); sl
C6 – 60 to 72 inches; cl (scoria in bottom); 3mr

PP9-1
Vegetation Summary – smooth brome, crested wheatgrass, alfalfa (sparse), cheat grass
Location – N 44º 42.386'; W 105º 31.799'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 6 inches; l; 2msbk
Bk1 – 6 to 12 inches; l; 2msbk; sl
Bk2 – 12 to 18 inches; l; 2msbk; 2mswm; st
C1 – 18 to 38 inches; sil; m; 3mswm; ve
C2 – 38 to 39 inches; ls; m; 2mswmt; ve
C3 – 39 to 44 inches; cl; m; 2mswm (calcite and few gyp nodules); st
C4 – 44 to 55 inches; cl; m; 2mswm; 2mr; sl
C5 – 55 to 72 inches; grs; sg

PP10-1
Vegetation Summary – intermediate wheatgrass, alfalfa (sparse); cheatgrass
Location – N 44º 42.306'; W 105º 31.620'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 6 inches; l; 1msbk
Bk – 6 to 14 inches; 2msbk; 2mswmt; st
C1 – 14 to 30 inches; sl; m; 2mswmt; st
C2 – 30 to 42 inches; sil; m; 2mswmt; ve
C3 – 42 to 49 inches; cl; m; 2mswmt; ve
C4 – 49 to 50 inches; sl; m; saturated
C5 – 50 to 60 inches; cl; m; 3mr;
C6 – 60 to 72 inches; sicl; m; 3 mswm (gypsum nodules); 3mr

PP10-2
Vegetation Summary – intermediate wheatgrass, alfalfa (sparse); cheatgrass
Location – N 44º 42.271'; W 105º 31.874'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; cl; 2msbk
Bk – 5 to 19 inches; l; 2msbk; 3mswmt; st
C1 – 19 to 24 inches; scl; m; 3mswmt;ve
C2 – 24 to 37 inches; cl; m; 2mswmt; st
C3 – 37 to 38 inches; ls; m; st
C4 – 38 to 48 inches; cl; m; 2mswmt; 3mr; st

PP10-3
Vegetation Summary – intermediate wheatgrass, alfalfa (sparse); cheatgrass
Location – N 44º 42.284'; W 105º 31.909'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; 1msbk
Bk1 – 5 to 12 inches; sil; 1msbk; 3mswmt; st
Bk2 – 12 to 18 inches; sil; 2msbk; 3mswmt; st
C1 – 18 to 24 inches; sil; m; 1mswmt; st
C2 – 24 to 28 inches; sil; m; 2vfswmt; ve
C3 – 28 to 40 inches; sil; m; 3vfswmt; ve
C4 – 40 to 48 inches; vfsl; m; 3vfswmt; ve

PP10-4
Vegetation Summary – intermediate wheatgrass, alfalfa (sparse); cheatgrass
Location – N 44º 42.304'; W 105º 31.953'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; sil; 1msbk
Bk1 – 5 to 10 inches; sil; 1msbk; 2mswmt; st
Bk2 – 10 to 18 inches; sil; 2msbk; 2mswm; st

C1 – 18 to 24 inches; cl; m; 3mswmt; 3mr; st
C2 – 24 to 36 inches; cl; m; 2mswmt; 2mr; st
C3 – 36 to 48 inches; sil; m; 3vfswmt; 1mr; st

PP10-5
Vegetation Summary – Intermediate wheatgrass, alfalfa (sparse); cheatgrass
Location – N 44º 42.326'; W 105º 31.916'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 4 inches; cl; 1msbk
Bk – 4 to 8 inches; cl; 2msbk; 2mswmt; st
C1 – 8 to 15 inches; sil; m; 3mswmt; ne
C2 – 15 to 32 inches; sil; m; 3mswmt; 1mr; st
C3 – 32 to 38 inches; sil; m; 3mswmt; 3mr; st
C4 – 38 to 46 inches; sil; m; 3mswmt; 3mr (strong oxidation and reduction); sl
C5 – 46 to 48 inches; vfsl; m; 3fswmt; 3mr; sl

PP10-6
Vegetation Summary – intermediate wheatgrass, alfalfa (sparse); cheatgrass
Location – N 44º 42.325'; W 105º 31.992'

A – 0 to 1 inch; l;2m gr
Bw – 1 to 6 inches; l; 1msbk
Bk – 6 to 15 inches; l;3 msbk; 2mswmt; st
C1 – 15 to 23 inches; sil; m; 3vfswmt; ne
C2 – 23 to 32 inches; cl; m; 2mswmt; 3vfr (redox feathers in root channels); st
C3 – 32 to 33 inches; vfsl; m; st
C4 – 33 to 41 inches; sil; m; 1mswmt; 2mr; st
C5 – 41 to 48 inches; vfsl; m; 2vfswmt; 3mr; st

PP10-7
Vegetation Summary – intermediate wheatgrass, alfalfa (sparse); cheatgrass
Location – N 44º 42.254'; W 105º 31.968'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; l; 1msbk
Bk1 – 5 to 12 inches; l; 2msbk; sl
Bk2 – 12 to 22 inches; l; 2msbk; 2mswmt; st
C1 – 22 to 24 inches; sil; m; 2mswmt; st
C2 – 24 to 36 inches; cl; m; 3mswmt; ve
C3 – 36 to 48 inches; sil; m; 3mswmt; 1mr; st

PP11-1
Vegetation Summary – intermediate wheatgrass, crested wheatgrass, alfalfa (sparse); cheatgrass
Location – N 44º 42.263'; W 105º 32.106'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 6 inches; l; 1msbk
Bk1 – 6 to 12 inches; l; 2msbk; 2mswmt; st
Bk2 – 12 to 18 inches; l; 1msbk; 2vfswm; ne
C1 – 18 to 30 inches; sil; m; 2mswmt; st
C2 – 30 to 34 inches; ls; m; st
C3 – 34 to 43 inches; vfsl; m; 3vfswm; st; some organic staining
C4 – 43 to 47 inches; ls; m; st
C5 – 47 to 54 inches; sil; m; 3vfswm; 1mr; st
C6 – 54 to 60 inches; sil; m; 3fswm; 1mr; st
C7 – 60 to 72 inches; sil; m; 2mswm; 2mr; st

Marsha Pownall Ranch

MP1-1
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 41.816'; W 105º 33.041'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 8 inches; l; 1msbk
Bk – 8 to 16 inches; l; 2msbk; 3mswmt; st
C1 – 16 to 22 inches; l; m; 2mswmt; st
C2 – 22 to 26 inches; fls; m; 2mswmt; st
C3 – 26 to 35 inches; sl; m; 3mswmt; 1mr; st
C4 – 35 to 48 inches; cl; m; 2mswmt; st
C5 – 48 to 50 inches; cl (scoria chips); m; 1mswm; st
C6 – 50 to 56 inches; cl; m; 1mswm; 1mr; st
C7 – 56 to 62 inches; sil; m; 2mr; sl
C8 – 62 to 68 inches; sl; m; 2mr (oxidation/reduction)
C9 – 68 to 72 inches; grcl; m; saturated

MP1-2
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 41.834'; W 105º 32.987'

A – 0 to 1 inch; l; 2mgr
Bk1 – 1 to 7 inches; l; 1msbk
Bk2 – 7 to 18 inches; l; 2msbk; 2mswmt; st
C1 – 18 to 27 inches; sl (stratified); m; 2mswmt; st
C2 – 27 to 30 inches; l (stratified); m; 2mswmt; st
C3 – 30 to 31 inches; ls; m: st
C4 – 31 to 40 inches; cl; m: 2mswmt; st
C5 – 40 to 41 inches; sil; m; st
C6 – 41 to 48 inches; cl; m; 3fswmt; 3mr (oxidation/reduction); sl
Went to 7 feet and couldn't get sample – saturated at 6 feet

MP1-3

Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 41.866'; W 105º 32.978'

A – 0 to 1 inch; l; 2mgr
Bk1 – 1 to 4 inches; l; 2msbk; sl
Bk2 – 4 to 14 inches; l; 2msbk; 3mswmt; st
Bk3 – 14 to 18 inches; l; 2msbk; 2mswmt; st
C1 – 18 to 28 inches; sil (stratified); m; 2mswmt; st
C2 – 28 to 29 inches; sl; m; 3fswm; st
C3 – 29 to 32 inches; sil; m; 2mswmt; st
C4 – 32 to 34 inches; sl; m; 3fswm; 2mr (redox features in root channels); st
C5 – 34 to 41 inches; sil; m; 2mswm; 3mr; sl
C6 – 41 to 48 inches; cl; m; 2mswm; 3mr; sl
C7 – 48 to 54 inches; sil; m; 2mswm; 3mr; sl
C8 – 54 to 72 inches; cl; m; 2vfswm; 3mr; sl; saturated at about 70 inches.

MP1-4
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 41.878'; W 105º 32.859'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; l; 1msbk
Bk1 – 5 to 10 inches; l; 1msbk; 1mswm; st
Bk2 – 10 to 22 inches; l; 1msbk; 3mswmt; 1mr; st
C1 – 22 to 30 inches; sl; m; 2mswmt; 2mr; st
C2 – 30 to 38 inches; sl; m; 3mswmt; 3mr (oxidation/reduction); st
C3 – 38 to 54 inches; sil; m; 1mswm; 3mr (oxidation/reduction; mottling)
Wet at 54 inches – couldn't recover samples

MP1-5
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 41.860'; W 105º 32.816'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; l; 1msbk
Bk – 5 to 14 inches; l; 1msbk; 3mswmt; st
C1 – 14 to 16 inches; sl; m; st
C2 – 16 to 26 inches; sil; m; 2mswmt; ve
C3 – 26 to 28 inches; sl; m; st
C4 – 28 to 54 inches; sil (stratified by lenses of sandy loam); m; 2mswmt; 3mr;sl
C5 – 54 to 60 inches; vfsl; m; 2fswm; sl
C6 – 60 to 66 inches; vfsl; m; 3mr (nodules and threads; redox features)
C7 – 66 to 72 inches; sil; m; 3mr (wet in this zone)

MP1-6
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 41.907'; W 105º 32.771'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; l; 1msbk
Bk – 5 to 12 inches; l; 2msbk; sl
C1 – 12 to 26 inches; sil; m; 3mswmt; st
C2 – 26 to 36 inches; sil; m; 2mswmt; 2mr; st
C3 – 36 to 45 inches; cl; m; 1mswmt; 2mr; st
C4 – 45 to 55 inches; cl; m; 2mswmt; 2mr; sl
C5 – 55 to 72 inches; cl; m; 3mr (oxidation/reduction; mottling)
Wet last 6 inches.

MP1-7
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 41.945'; W 105º 32.843'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 6 inches; l; 1msbk
Bk – 6 to 10 inches; l; 2msbk; 2mswmt; st
C1 – 10 to 20 inches; sil; m; 2mswmt; st
C2 – 20 to 22 inches; sl; m; 1mswm; st
C3 – 22 to 28 inches; sil; m; 2mswmt; st
C4 – 28 to 37 inches; sl; m; 1mswmt; 2mr; sl
C5 – 37 to 46 inches; sil; m; 2mswmt; 2mr; sl
C6 – 46 to 60 inches; sl; m; 2mr; sl

MP2-1
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 42.211'; W 105º 32.628'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 12 inches; l; 1msbk
Bk – 12 to 18 inches; l; 2msbk; 2mswmt; st
C1 – 18 to 22 inches; sl; m; 3mswmst
(correlated to MP1)

MP3-1
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 42.205'; W 105º 32.411'

A – 0 to 2 inches; l; 2mgr
Bk1 – 2 to 8 inches; sil; 2msbk; sl
Bk2 – 8 to 16 inches; sil; 2msbk; st
C1 – 16 to 24 inches; cl; m; 2mr; sl
(correlated to MP1)

MP4-1
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome

Location – N 44º 41.335’; W 105º 32.810’

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 7 inches; l; 1msbk
Bk – 7 to 14 inches; l; 1msbk; 2mswmt; st
C1 – 14 to 18 inches; l; m; 3mswmt; st
C2 – 18 to 27 inches; sil; m; 2mswmt; ve
C3 – 27+ inches; sl; m; 1mswmt; st
(correlated to MP1)

MP5-1
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 41.779’; W 105º 33.148’

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 5 inches; l; 1msbk
Bk – 5 to 12 inches; l; 2msbk; sl
C1 – 12 to 18 inches; cl; m; 1mswmt; st
C2 – 18 to 24 inches; cl; m; 2mswmt; st
C3 – 24 to 30 inches; cl; m; 3mswnt; 2mr; st
C4 – 30 to 48 inches; sil; m; 2mswmt; 2mr; st
C5 – 48 to 54 inches; sil; m; 2mswmt; 2mr; sl
C6 – 54 to 62 inches; sil; m; 1mswmt; 2mr; sl
C7 – 62 6o 72 inches; sil; m; 2mswmt; 3mr (oxidation/reduction); water table

MP6-1
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 41.657’; W 105º 33.105’

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 5 inches; l; 1msbk
Bk – 5 to 16 inches; l; 2msbk; 3mwsmt; st
C1 – 16 to 19 inches; l; m; 2mswmt; st
C2 – 19 to 30 inches; sl; m; 1mswmt; st
C3 – 30 to 36 inches; sil; m; 2mswmt; 2mr; sl
C4 – 36 to 48 inches; vfsl; m; 3mr; saturated
(correlated to MP1)

MP7-1
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 41.892’; W 105º 33.002’

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; l; 1msbk
Bk – 5 to 14 inches; l; 2msbk; 1mwsm; sl
C1 – 14 to 26 inches; l; m; 3mswmt; st
C2 – 26 to 28 inches; sl; m; st

C3 – 28 to 48 inches; sil; m (stratified in places); 2mswmt; 2mr; sl

MP9-1
Vegetation Summary – wheatgrass, alfalfa (sparse); smooth brome
Location – N 44º 42.562'; W 105º 32.825'

A - 0 to 1 inch; l; 2mgr
Bw1 – 1 to 4 inches; l; 1msbk
Bw2 – 4 to 9 inches; l; 2msbk
Bw3 – 9 to 23 inches; l; 2msbk (darker color)
Bk – 23 to 26 inches; l; 2msbk; sl
C1 – 26 to 43 inches; l; m; 1mswmt; st
C2 – 43 to 60 inches; l; m; 3mswmt; st
C3 – 60 to 72 inches; l; m; 3mswmt; 2mr; st

Donna Tarver Ranch

DT1-1
Vegetation Summary - western wheatgrass, smooth brome
Location - N 44º 37.903'; W 105º 40.383'

A – 0 to 1 inch; l; 2mgr
Bw1 – 1 to 20 inches; l; 2msbk
Bk1 – 20 to 24 inches; sil; 2msbk; sl
Bk2 – 24 to 28 inches; sl; 2msbk; 1mswm; st
C1 – 28 to 36 inches; sl; m; 1mswm; st
C2 – 36 to 44 inches; sil; m; 2mswmt; st
C3 – 44 to 48 inches; cl; m; 3mswmt; st

DT1-2
Vegetation Summary - western wheatgrass, smooth brome
Location - N 44º 37.873'; W 105º 40.451'

A – 0 to 1 inches; l; 2mgr
Bw – 1 to 12 inches; l; 1msbk
Bk1 – 12 to 20 inches; l; 2msbk; sl
Bk2 – 20 to 24 inches; l; 1msbk; sl
C1 – 24 to 30 inches; sl; m; 2fswm; st
C2 – 30 to 36 inches; s; sg; sl
C3 – 36 to 40 inches; sl; 2mswm; st
C4 – 40 to 48 inches; s; sg; sl

DT1-3
Vegetation Summary - western wheatgrass, smooth brome
Location - N 44º 37.844'; W 105º 40.536'

A – 0 to 1 inch; l; 2mgr

Bw – 1 to 7 inches; l; 1msbk
Bk – 7 to 16 inches; l; 1msbk; sl
C1 – 16 to 24 inches; sil; m; st
C2 – 24 to 32 inches; sl; m; 3mswm; st
C3 – 32 to 38 inches; ls; m; 1fswm; st
C4 – 38 to 48 inches; sil; m; 2mswm; st

DT2-1
Vegetation Summary - western wheatgrass, smooth brome
Location - N 44º 37.838'; W 105º 40.668'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 10 inches; l; 1msbk
Bk – 10 to 15 inches; l; 2msbk; sl
(correlated to DT1)

DT2-2
Vegetation Summary - western wheatgrass, smooth brome
Location - N 44º 37.782'; W 105º 40.745'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 6 inches; l; 1msbk
Bk1 – 6 to 13 inches; l; 1msbk; 1mswmt; st
Bk2 – 13 to 18 inches; l; 1msbk; 2mswmt; st
C1 – 18 to 24 inches; cl; m; st
C2 – 24 to 28 inches; sil; m; st
C3 – 28 to 38 inches; sil; m (sand zone between); 1mswm; st
C4 – 38 to 48 inches; sil; m; 1fswm; st

DT3-1
Vegetation Summary - western wheatgrass, smooth brome
Location - N 44º 37.738'; W 105º 40.944'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 7 inches; l; 1msbk
Bk1 – 7 to 11 inches; l; 2msbk; 1mcwm; st
Bk2 – 11 to 19 inches; l; 2msbk; 2mswmt; st
C1 – 19 to 28 inches; cl; m; 2mswmt; st
28 inches lense of sand
C2 – 28 to 40 inches; sil; m; 3mswmt; st
C3 – 40 to 48 inches; s; sg; saturated at bottom

DT4-1
Vegetation Summary - western wheatgrass, smooth brome
Location - N 44º 37.678'; W 105º 41.200'

A – 0 to 1 inch; l; 2mgr

Bw – 1 to 6 inches; l; 1msbk
Bk1 – 6 to 12 inches; cl; 2msbk; sl
Bk2 – 12 to 15 inches; cl; 2msbk; 3mswmt; st
C1 – 15 to 21 inches; cl; m; 3mswmt; st
C2 – 21 to 26 inches; ls; m; st
C3 – 26 to 37 inches; cl; m; 2mr; st
C4 – 37 to 47 inches; s; sg; sl
C5 – 47 to 48 inches; cl; m; 2mswm; 2mr; sl

DT5-1 Vegetation Summary - western wheatgrass, smooth brome
Location - N 44º 37.813'; W 105º 41.498'

A – 0 to 1 inch; l; 2mgr
Bk1 – 1 to 9 inches; cl; 1msbk
Bk2 – 9 to 12 inches; cl; 2msbk; sl
C1 – 12 to 14 inches; l; m; 3mswm; st
C2 – 14 to 24 inches; l; m; st
C3 – 24 to 36 inches; cl; m; 3mswmt; ve; deposition of coal
C4 – 36 to 37 inches; s; m; sg; sl
C5 – 37 to 39 inches; cl; m; 3mswmt; 2mr; st
C6 – 39 to 40 inches; ls; m; st
C7 – 40 to 48 inches; cl; m; 3mswmt;2mr; st

DT6-1
Vegetation Summary - western wheatgrass, smooth brome
Location - N 44º 37.813'; W 105º 40.713'

A – 0 to 1 inch; l; 2mgr
Bk – 1 to 6 inches; l; 2msbk; sl
C1 – 6 to 8 inches; sl; m; 1mswm; 2mr; sl
Bkb – 8 to 16 inches; l; 2msbk; 2mswm; sl
C2 – 16 to 24 inches; vfsl; m; 2mswm; st
C3 – 24 to 29 inches; ls; m; sl
C4 – 29 to 32 inches; s; sg; sl
C5 – 32 to 38 inches; sl; m; 2mswm; 2mr; st
C6 – 38 to 40 inches; s; sg; sl
C7 – 40 to 48 inches; scl; 2fswm; 2mr; sl

Hay Creek Watershed

James Wolff Ranch

JW1-1
Vegetation Summary - western wheatgrass, cheat grass; wild rye
Location - N 44º 41.729'; W 105º 43.337'

A – 0 to 2 inches; cl; 2mgr

Bw1 – 2 to 12 inches; c; 1msbk; 1mswmt; st
Bk1 – 12 to 30 inches; c; 1msbk; 1mswmt (few gypsum crystals); 1mr;; st
Couldn't pull sample from below 30 inches.

JW1-2
Vegetation Summary - western wheatgrass, cheat grass; wild rye
Location - N 44º 41.767'; W 105º 43.363'

A – 0 to 2 inches; cl; 2mgr
Bw1 – 2 to 9 inches; c; 1msbk
Bw2 – 9 to 18 inches; c; 1msbk; 2mswmt;
Bw3 – 18 to 28 inches; c; 1msbk; 2mswmt (many gypsum crystals)
Bw4 – 28 to 44 inches; c; 1msbk; 1vfcwmt (many gypsum crystals); 2mr
Bw5 – 44 to 48 inches; sic; 1msbk; 1fwsmt (few gypsum crystals); 3mr (oxidation/reduction)

JW1-3
Vegetation Summary - western wheatgrass, cheat grass; wild rye
Location - N 44º 41.814'; W 105º 43.441'

A – 0 to 5 inches; cl; 2mgr
Bw – 5 to 10 inches; c; 1msbk; cswm
Bw1 – 10 to 24 inches; c; 1msbk; 1fswm; pressure faced
Bw2 – 24 to 31 inches; c; 1msbk; 1fswm (many gypsum crystals)
Bw3 – 31 to 36 inches; c; 1msbk; 3mswm (many gypsum crystals)
Bw4 – 36 to 44 inches; 1msbk; 2mswm (few gypsum crystals); 1mr
Couldn't pull sample from below 44 inches.

JW1-4
Vegetation Summary - western wheatgrass, cheat grass; wild rye
Location - N 44º 41.872'; W 105º 43.466'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 8 inches; cl; 1msbk
Bk1 – 8 to 12 inches; cl; 1msbk; st
Bk2 – 12 to 18 inches; cl; 1msbk; 3mswm; st
Bk3 – 18 to 22 inches; c; 1msbk; 2mswm; vs (very slight effervescence)
Bk4 – 22 to 43 inches; cl; 1msbk; 1mswm; vs; few gypsum crystals
Couldn't pull sample from below 43 inches.

JW1-5
Vegetation Summary - western wheatgrass, cheat grass; wild rye
Location - N 44º 41.787'; W 105º 43.480'

A – 0 to 4 inches; l; 2mgr
Bw – 4 to 9 inches; c; 1msbk
Bw1 – 9 to 20 inches; c; 1msbk; 2mswm

Bw2 – 20 to 34 inches; c; 1msbk; 1fswm (many gypsum crystals)
Bw3 – 34 to 43 inches; c; 1msbk; 1fswm (vf gypsum crystals); 2mr
Couldn't pull sample from below 43 inches.

JW1-6
Vegetation Summary - western wheatgrass, cheat grass; wild rye
Location - N 44º 41.715'; W 105º 43.446'

A – 0 to 4 inches; l; 2mgr
Bw – 4 to 10 inches; cl; 1msbk
Bk1 – 8 to 10 inches; cl; 1msbk; 2mswmt; vs; few gypsum crystals
Bk2 – 10 to 39 inches; cl; 1msbk; 1vfswmt; vs; few gypsum crystals
C – 39 to 48 inches; c; m; vf gypsum crystals; 3mr

JW1-7
Vegetation Summary - western wheatgrass, cheat grass; wild rye
Location - N 44º 41.715'; W 105º 43.400'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 6 inches; cl; 1msbk
Bk1 – 6 to 11 inches; c; 1msbk; 1vfswmt; vs
Bk2 – 11 to 16 inches; c; 1msbk; 3mswmt; sl
C1 – 16 to 27 inches; cl; m; 1fswmt (few gypsum crystals)
C2 – 27 to 35 inches; cl; m; 3mswm (gypsum crystals)
C3 – 35 to 48 inches; cl; m; 1mswm (few gypsum crystals)

Eric Rule Ranch

ER1-1
Vegetation Summary – crested wheatgrass; western wheatgrass, cheatgrass
Location - N 44º 41.836'; W 105º 44.090'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 15 inches; cl; 1msbk
Bk – 15 to 18 inches; cl; 2msbk; 3mswm; sl
C1 – 18 to 38 inches; cl; m; 2mswm; sl
C2 – 38 to 48 inches; cl; m; 3mswm; many brown crystals

ER1-2
Vegetation Summary – crested wheatgrass; western wheatgrass, cheatgrass
Location - N 44º 41.779'; W 105º 43.995'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 8 inches; cl; 1msbk
Bk1 – 8 to 12 inches; cl; 1msbk; 1fswmt; vs
Bk2 – 12 to 18 inches; cl; 2msbk; 3mswmt; sl
Bk3 – 18 to 26 inches; cl; 1msbk; 3mswm; vs

C – 26 to 48 inches; sicl; m; many brown crystals

ER1-3
Vegetation Summary – crested wheatgrass; western wheatgrass, cheatgrass
Location - N 44º 41.957'; W 105º 44.008'

AB – 0 to 7 inches; l; 1msbk
Bt – 7 to 16 inches; cl; 3msbk
BC – 16 to 23 inches; cl; 1msbk
C1 – 23 to 32 inches; cl; m; 3mswm; sl
C2 – 32 to 48 inches; sicl; m; 3mswm; sl

ER1-4
Vegetation Summary – crested wheatgrass; western wheatgrass, cheatgrass
Dry soil profile
Location - N 44º 42.016'; W 105º 44.236'

A – 0 to 1 inch; l; 2mgr
Bw1 – 1 to 7 inches; cl; 1msbk
Bw2 – 7 to 14 inches; cl; 2msbk
Bk – 14 to 27 inches; c; 2msbk; 2mswm; sl
C1 – 27 to 38 inches; cl; m; sl
C2 – 38 to 48 inches; cl; m; 2mr; vs

ER1-5
Vegetation Summary – crested wheatgrass; western wheatgrass, cheatgrass
Location - N 44º 42.073'; W 105º 44.423'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 7 inches; l; 1msbk
Bw1 – 7 to 12 inches; l; 2msbk
C – 12 to 16 inches; sl; m
Bk1b – 16 to 22 inches; sl; 2msbk; ve
Bk2b – 22 to 38 inches; cl; 3msbk; 3mswm (on ped surface); ve
C – 38 to 48 inches; cl; m; ve

ER1-6
Vegetation Summary – crested wheatgrass; western wheatgrass, cheatgrass
Location - N 44º 41.785'; W 105º 44.556'

A – 0 to 2 inches; l; 2mgr
Bw1 – 2 to 7 inches; 1msbk
Bw2 – 7 to 12 inches; 2msbk
Bw3 – 12 to 18 inches; 2msbk
Bk – 18 to 24 inches; 2mbk; sl
C1 – 24 to 28 inches; cl; m; 3mswmt; st
C2 – 28 to 37 inches; m; scl; 2mswmt; sl

C3 – 37 to 48 inches; sil; m; 3mswmt; sl

ER1-7
Vegetation Summary – crested wheatgrass; western wheatgrass, cheatgrass
Location - N 44º 41.915'; W 105º 44.293'

A – 0 to 2 inches; l; 2mgr
Bw – 2 to 14 inches; l; 1msbk
Bk – 14 to 25 inches; l; 1msbk; sl
C2 – 25 to 29 inches; ls; m; sl
C3 – 29 to 36 inches; sl; m; st
C4 – 36 to 42 inches; cl; m; 2mswm; st
C5 – 42 to 48 inches; cl; m; 3mswm; st

Spring Creek Watershed

Marsha Pownall Ranch

MP2-1
Vegetation Summary – crested wheatgrass, smooth brome, alfalfa (sparse)
Location – N 44º 42.562'; W 105º 32.825'

A - 0 to 1 inch; l; 2mgr
Bw1 – 1 to 4 inches; l; 1msbk
Bw2 – 1 to 9 inches; l; 2msbk
Bw3 – 9 to 23 inches; l; 2msbk (darker color)
Bk – 23 to 26 inches; l; 2msbk; sl
C1 – 26 to 43 inches; l; m; 1mswmt; st
C2 – 43 to 60 inches; l; m; 3mswmt; ve
C3 – 60 to 72 inches; l; m; 3mswmt; 1mr; st

MP2-2
Vegetation Summary – crested wheatgrass, smooth brome, alfalfa (sparse)
Location – N 44º 42.645'; W 105º 32.949'

A - 0 to 2 inch; l; 2mgr
Bw1 – 2 to 6 inches; cl; 2msbk
Bk1 – 6 to 14 inches; cl; 2msbk; sl
Bk2 – 14 to 20 inches; cl; 2msbk; 2mswm; sl
C1 – 20 to 26 inches; cl; m; 2mswm; st
C2 – 26 to 36 inches; cl; m; 3mswm; st
C3 – 36 to 52 inches; l; m; 2mswm; st
C3 – 52 to 64 inches; l; m; 3mswm; st
C4 – 64 to 72 inches; sl; m; 3mswmt; 3fr; ve

MP2-3
Vegetation Summary – crested wheatgrass, smooth brome, alfalfa (sparse)

Location – N 44º 42.716’; W 105º 33.149’

A - 0 to 3 inch; sil; 2mgr
Bw1 – 3 to 8 inches; sil; 2msbk
Bk – 8 to 14 inches; sil; 2msbk; 3mswm; st
C1 – 14 to 21 inches; sl; m; 3mswmt; ve
C2 – 21 to 25 inches; sl; m; 2mswm; st
C3 – 25 to 28 inches; sl; m; 3mswmt; ve
C4 – 28 to 38 inches; l; m; 3mswmt; ve
C5 – 38 to 48 inches; cl; m; 3mswmt; ve
C6 – 48 to 61 inches; cl; m; 3mswm; st
C7 – 61 to 72 inches; c; m; 3mswm; 1fr; st

MP2-4
Vegetation Summary – crested wheatgrass, smooth brome, alfalfa (sparse)
Location – N 44º 42.815’; W 105º 33.215’

AB - 0 to 3 inch; sil; 2mgr to 2msbk
Bw1 – 3 to 9 inches; sil; 2msbk
Bk1 – 9 to 13 inches; l; 2msbk; 2mswm; sl
Bk2 – 13 to 21 inches; sl; 2msbk; 3mswmt; ve
C1 – 21 to 22 inches; ls; m; 3mswmt; st
C2 – 22 to 38 inches; l; m; 3mswmt; ve
C3 – 38 to 57 inches; sl; m; 2mswmt; st
C4 – 57 to 72 inches; l; m; 3mswmt; ve

MP2-5
Vegetation Summary – crested wheatgrass, smooth brome, alfalfa (sparse)
Location – N 44º 42.809’; W 105º 33.099’

AB - 0 to 3 inch; sil; 2mgr to 2msbk
Bw1 – 3 to 11 inches; sil; 2msbk
Bk1 – 11 to 18 inches; l; 2msbk; sl
Bk2 – 18 to 24 inches; l; 2msbk; 3mswmt; st
C1 – 24 to 37 inches; l; m; 3mswmt; st
C2 – 37 to 61 inches; l; m; 2mswmt; st
C3 – 61 to 66 inches; l; m; 3mswmt; st
C4 – 66 to 72 inches; l; m; 3mswmt; 2mr; st

MP2-6
Vegetation Summary – crested wheatgrass, smooth brome, alfalfa (sparse)
Location – N 44º 42.746’; W 105º 33.003’

A - 0 to 3 inch; sil; 2mgr
Bw1 – 3 to 9 inches; l; 2msbk
Bk1 – 9 to 18 inches; l; 1msbk; 2mswm; st
Bk2 – 18 to 30 inches; l; 2msbk; 2mswm; st

C1 – 30 to 36 inches; l; m; 2mswm; st
C2 – 36 to 42 inches; l; m; 3mswm; st
C3 – 42 to 66 inches; l; m; 3mswmt; st
C4 – 66 to 72 inches; sl; m; 3mswmt; 1mr; sl

MP2-7
Vegetation Summary – crested wheatgrass, smooth brome, alfalfa (sparse)
Location – N 44º 42.896'; W 105º 33.346'

A - 0 to 3 inches; sil; 2mgr
Bw1 – 3 to 9 inches; l; 2msbk
Bk1 – 9 to 18 inches; l; 2msbk; 2mswm; st
Bk2 – 18 to 30 inches; cl; 2msbk; 2mswm; st
C1 – 35 to 42 inches; l; m; 3mswm; 2mr; st
C2 – 42 to 48 inches; cl; m; 3mswmt; 3mr; st
C3 – 48 to 54 inches; sl; m; 2mswm; 3mr; sl
C4 – 54 to 68 inches; sl; m; 2mswm; 3mr; sl
C5 – 68 to 72 inches; cl; m; 2mswm; 3mr; sl

MP8-1
Vegetation Summary - crested wheatgrass, alfalfa, smooth brome
Location - N 44º 43.441'; W 105º 33.973'

A – 0 to 1 inch; l; 2mgr
Bw – 1 to 5 inches; l; 1msbk
Bk – 5 to 17 inches; l; 1msbk; 1mswm; sl
C1 – 17 to 29 inches; cl; m; 3mswmt; st
C2 – 29 to 39 inches; cl; m; 3mswmt; 1mr; st
C3 – 39 to 47 inches; c; m; 3mswm; 2mr; st
C4 – 47 to 54 inches; c; m; 2mswmt; 2mr; st
C5 – 54 to 72 inches; c; m; 2mr; st

MP8-2
Vegetation Summary - crested wheatgrass, alfalfa, smooth brome
Location - N 44º 43.578'; W 105º 34.119'

A – 0 to 1 inch; l; 2mgr
Bw1 – 1 to 5 inches; l; 1msbk
Bw2 – 5 to 8 inches; l; 2msbk
Bk1 – 8 to 14 inches; l; 2msbk; 1mswm; st
Bk2 – 14 to 22 inches; l; 2msbk; 2mswmt; st
C1 – 22 to 36 inches; cl; m; 3mswmt; ve
C2 – 36 to 54 inches; cl; m; 3mswmt; 1mr; ve
C3 – 54 to 72 inches; c; m; 2mswm; 2mr; st

MP8-3
Vegetation Summary - crested wheatgrass, alfalfa, smooth brome

Location - N 44º 43.629’; W 105º 34.268’

A – 0 to 1 inch; l; 2mgr
Bw1 – 1 to 5 inches; l; 1msbk
Bw2 – 5 to 14 inches; cl; 2msbk
C1 – 14 to 16 inches; l; m
Bwb – 16 to 24 inches; l; 2msbk
C2 – 24 to 36 inches; cl; m; 3mswm;
Bkb – 36 to 48 inches; cl; 3msbk; sl
C4 – 48 to 62 inches; cl; m; 3mswm; 2mr; st
C5 – 62 to 72 inches; l; m; 3mswm; 2mr; st

MP8-4
Vegetation Summary - crested wheatgrass, alfalfa, smooth brome
Location - N 44º 43.599’; W 105º 34.353’

A – 0 to 1 inch; l; 2mgr
Bw1 – 1 to 5 inches; l; 1msbk
Bw2 – 5 to 20 inches; cl; 2msbk
Bk – 20 to 30 inches; l; 1msbk; 1mswm; sl
C1 – 30 to 40 inches; cl; m; 2mswmt; st
C2 – 40 to 64 inches; c; m; 2mswmt; st
C3 – 64 to 72 inches; cl; m; 3mswmt; 1mr; st

MP8-5
Vegetation Summary - crested wheatgrass, alfalfa, smooth brome
Location – N 44º 43.513’; W 105º 34.230’

A – 0 to 3 inches; l; 2mgr
Bw – 3 to 7 inches; l; 1msbk
Bk1 – 7 to 12 inches; l; 1msbk; sl
Bk2 – 12 to 18 inches; l; 1msbk; 1mswm; sl
Bk3 – 18 to 28 inches; l; 1msbk; 3mswmt; st
C1 – 28 to 61 inches; m; l; 1mswm; st
C2 – 61 to 66 inches; m; cl; 1mswm; st
C3 – 66 to 72 inches; m; sl (few scoria chips); sl

MP8-6
Vegetation Summary - crested wheatgrass, alfalfa, smooth brome
Location – N 44º 43.391’; W 105º 34.107’

A – 0 to 3 inches; l; 2mgr
Bw1 – 3 to 6 inches; l; 1msbk
Bw2 – 6 to 15 inches; l; 2msbk
Bk – 15 to 26 inches; l; 1msbk; st
C1 – 26 to 46 inches; l; m; 3mswmt; ve
C2 – 46 to 54 inches; cl; m; 3mswmt;ve

C3 – 54 to 72 inches; cl; m; 1mswm; 2mr; st

MP8-7
Vegetation Summary - crested wheatgrass, alfalfa, smooth brome
Location - N 44º 43.348'; W 105º 33.944'

A – 0 to 1 inch; l; 2mgr
Bw1 – 1 to 3 inches; l; 1msbk; few scoria chips
Bw2 – 3 to 15 inches; l; 2msbk; few scoria chips
Bk – 15 to 20 inches; l; 1msbk; 1mswm; vs; few scoria chips
C1 – 20 to 26 inches; l; m; 3mswmt; ve; few scoria chips
C2 – 26 to 36 inches; l; m; 2mswmt; st
C3 – 36 to 39 inches; l; m; 1mswmt; st
C4 – 39 to 50 inches; l; m; 3m/cswmt (many moderate to coarse soft white masses and threads; ve
C5 – 50 to 56 inches; l; m; 3mswmt; ve
C6 – 56 to 64 inches; l; m; 1mswm; 2mr; st
C7 – 64 to 72 inches; cl; m; 1mswm; 2mr; sl

APPENDIX H

LABORATORY DATA SHEETS FOR THE SOILS ANALYSIS

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0608391001

Date: 1/4/2007

Work Order: S0608391

Project: Western Water Cons. Topsoil

Date Received: 8/22/2006

Lab ID	Sample ID	Depths Ft.	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR
S0608391-001	LP1	0-1	7.1	53.7	4.48	3.4	20.3	21.7	17.6	3.85
S0608391-002	LP1	1-2	8.3	47.2	13.7		19.0	107	101	12.7
S0608391-003	LP1	2-3	8.4	43.9	13.8		14.3	82.3	91.4	13.1
S0608391-004	LP1	3-4	8.3	39.0	11.2		17.3	69.2	84.1	12.8
S0608391-005	LP1	4-5	8.0	45.6	7.06		18.0	35.6	44.9	8.67
S0608391-006	LP1	5-6	7.8	42.7	6.53		20.0	34.0	38.3	7.36
S0608391-007	LP2	0-1	7.6	54.4	7.97	2.9	18.5	45.1	49.3	8.74
S0608391-008	LP2	1-2	8.0	42.0	6.79		17.5	33.5	44.3	8.77
S0608391-009	LP2	2-3	7.7	54.1	4.99		19.2	23.6	25.0	5.41
S0608391-010	LP2	3-4	7.5	48.4	4.06		20.0	19.3	15.6	3.52

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report
Western Water Consultants
P.O. Box 3042
Sheridan, WY 82801

Report ID: S0608391001
Date: 1/4/2007
Work Order: S0608391

Project: Western Water Cons. Topsoil
Date Received: 8/22/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0608391-001	LP1	0-1	24.0	50.0	26.0	Silty Loam
S0608391-002	LP1	1-2	53.0	24.0	23.0	Sandy Clay Loam
S0608391-003	LP1	2-3	42.0	40.0	18.0	Loam
S0608391-004	LP1	3-4	56.0	25.0	19.0	Sandy Loam
S0608391-005	LP1	4-5	45.0	33.0	22.0	Loam
S0608391-006	LP1	5-6	45.0	33.0	22.0	Loam
S0608391-007	LP2	0-1	37.0	38.0	25.0	Loam
S0608391-008	LP2	1-2	55.0	26.0	19.0	Sandy Loam
S0608391-009	LP2	2-3	32.0	41.0	27.0	Clay Loam
S0608391-010	LP2	3-4	35.0	38.0	27.0	Clay Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten
Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0608497001

Date: 1/4/2007

Work Order: S0608497

Project: Western Water Cons. Topsoil

Date Received: 8/27/2006

Lab ID	Sample ID	Depths Ft.	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR
S0608497-001	LP-7	0-1	6.8	54.3	5.28	4.3	20.3	23.1	25.0	5.38
S0608497-002	LP-7	1-2	8.1	54.8	11.5		16.6	66.1	75.3	11.7
S0608497-003	LP-7	2-3	8.4	51.5	11.1		16.9	53.8	80.2	13.5
S0608497-004	LP-7	3-4	8.0	40.3	7.02		17.3	31.1	41.6	8.45
S0608497-005	LP-8	0-1	7.2	56.6	4.87	3.7	18.5	24.8	18.7	4.02
S0608497-006	LP-8	1-2	7.9	49.8	7.47		17.9	37.2	44.0	8.39
S0608497-007	LP-8	2-3	7.9	43.1	6.45		18.2	27.9	35.3	7.35
S0608497-008	LP-8	3-4	7.9	40.9	5.12		15.6	21.1	25.5	5.95

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
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Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0608497001

Date: 1/4/2007

Work Order: S0608497

Project: Western Water Cons. Topsoil

Date Received: 8/27/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0608497-001	LP-7	0-1	39.0	34.0	27.0	Clay Loam
S0608497-002	LP-7	1-2	34.0	35.0	31.0	Clay Loam
S0608497-003	LP-7	2-3	49.0	24.0	27.0	Sandy Clay Loam
S0608497-004	LP-7	3-4	56.0	25.0	19.0	Sandy Loam
S0608497-005	LP-8	0-1	32.0	38.0	30.0	Clay Loam
S0608497-006	LP-8	1-2	44.0	29.0	27.0	Clay Loam
S0608497-007	LP-8	2-3	62.0	19.0	19.0	Sandy Loam
S0608497-008	LP-8	3-4	63.0	18.0	19.0	Sandy Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
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Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

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P.O. Box 3042
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Report ID: S0608498001

Date: 1/4/2007

Work Order: S0608498

Project: Western Water Cons. Topsoil

Date Received: 8/27/2006

Lab ID	Sample ID	Depths	pH	Saturation	Electrical Conductivity	Organic Matter	Calcium	Magnesium	Sodium	SAR
		Ft.	s.u.	%	dS/m	%	meq/L	meq/L	meq/L	
S0608498-001	LP-3	0-1	7.4	52.1	5.01	3.5	18.4	21.0	21.2	4.78
S0608498-002	LP-3	1-2	8.0	48.3	7.42		16.8	28.6	45.4	9.52
S0608498-003	LP-3	2-3	8.3	47.3	9.98		16.4	42.9	69.5	12.8
S0608498-004	LP-3	3-4	8.3	40.0	8.10		15.4	33.1	55.2	11.2
S0608498-005	LP-3	4-5	7.9	51.2	4.92		17.0	16.1	25.4	6.24
S0608498-006	LP-3	5-6	7.9	49.0	2.78		9.12	8.20	10.9	3.70
S0608498-007	LP-4	0-1	7.6	50.3	1.57	3.1	5.58	4.10	5.01	2.28
S0608498-008	LP-4	1-2	8.3	52.9	8.17		16.5	32.1	55.0	11.1
S0608498-009	LP-4	2-3	8.2	50.2	6.95		14.7	24.2	42.6	9.66
S0608498-010	LP-4	3-4	8.2	44.5	7.82		15.6	21.8	51.7	12.0
S0608498-011	LP-4	4-5	8.0	40.7	5.92		17.3	21.8	32.1	7.27
S0608498-012	LP-4	5-6	7.7	46.6	4.91		15.2	15.8	23.6	6.00
S0608498-013	LP-5	0-1	7.3	54.5	4.08	3.8	20.0	17.8	11.2	2.57
S0608498-014	LP-5	1-2	8.2	56.4	7.67		16.8	45.6	40.7	7.30
S0608498-015	LP-5	2-3	8.1	41.4	6.82		19.6	36.4	33.6	6.35
S0608498-016	LP-5	3-4	7.9	35.2	5.46		20.2	26.3	23.4	4.86
S0608498-017	LP-6	0-1	7.1	48.5	3.61	3.5	21.1	12.9	7.34	1.78
S0608498-018	LP-6	1-2	7.8	46.5	5.53		19.2	22.2	26.7	5.86
S0608498-019	LP-6	2-3	7.9	35.3	5.77		18.6	22.9	28.4	6.24
S0608498-020	LP-6	3-4	7.9	33.7	5.67		17.0	22.3	28.2	6.35

These results apply only to the samples tested.

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Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0608498001

Date: 1/4/2007

Work Order: S0608498

Project: Western Water Cons. Topsoil

Date Received: 8/27/2006

Lab ID	Sample ID	Depths	pH	Saturation	Electrical Conductivity	Organic Matter	Calcium	Magnesium	Sodium	SAR
		Ft.	s.u.	%	dS/m	%	meq/L	meq/L	meq/L	
S0608498-021	CK-1	0-1	7.5	50.4	4.85	3.3	20.0	26.3	13.8	2.87
S0608498-022	CK-1	1-2	8.4	44.2	11.7		17.5	72.6	79.0	11.8
S0608498-023	CK-1	2-3	8.3	46.2	9.65		15.5	53.4	58.6	9.98
S0608498-024	CK-1	3-4	8.2	43.2	7.64		17.9	38.6	43.3	8.14
S0608498-025	CK-1	4-5	8.0	50.3	5.01		17.6	23.7	22.7	5.01
S0608498-026	CK-1	5-6	7.9	50.4	4.68		18.3	22.3	19.2	4.27
S0608498-027	CK-2	0-1	7.1	74.6	3.91	3.0	20.4	17.3	14.3	3.30
S0608498-028	CK-2	1-2	7.9	66.3	5.92		16.8	22.2	32.2	7.30
S0608498-029	CK-2	2-3	7.9	71.2	5.15		15.0	17.0	28.3	7.07
S0608498-030	CK-2	3-4	7.9	72.8	4.88		15.8	16.0	25.4	6.37
S0608498-031	CK-2	4-5	7.8	48.4	4.09		17.4	15.7	16.8	4.14
S0608498-032	CK-2	5-6	7.8	41.5	3.47		17.7	13.1	11.6	2.96
S0608498-033	CK-3	0-1	7.5	56.4	4.09	5.4	20.6	20.4	8.73	1.93
S0608498-034	CK-3	1-2	8.2	42.3	8.55		18.5	41.2	51.2	9.38
S0608498-035	CK-3	2-3	8.1	37.3	9.17		16.6	46.2	54.9	9.79
S0608498-036	CK-3	3-4	8.1	35.2	7.59		19.4	35.7	44.3	8.45
S0608498-037	CK-3	4-5	8.1	40.5	6.04		15.5	26.5	31.6	6.91
S0608498-038	CK-3	5-6	8.0	43.3	5.08		16.9	24.3	25.2	5.55
S0608498-039	LP8 #7	3-4	7.9	73.6	7.90		20.2	25.0	45.7	9.61

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
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Karen Barten, Soil Lab Supervisor

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0608498001

Date: 1/4/2007

Work Order: S0608498

Project: Western Water Cons. Topsoil

Date Received: 8/27/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0608498-001	LP-3	0-1	39.0	32.0	29.0	Clay Loam
S0608498-002	LP-3	1-2	41.0	32.0	27.0	Clay Loam
S0608498-003	LP-3	2-3	46.0	30.0	24.0	Loam
S0608498-004	LP-3	3-4	50.0	27.0	23.0	Sandy Clay Loam
S0608498-005	LP-3	4-5	37.0	36.0	27.0	Clay Loam
S0608498-006	LP-3	5-6	42.0	31.0	27.0	Clay Loam
S0608498-007	LP-4	0-1	34.0	38.0	28.0	Clay Loam
S0608498-008	LP-4	1-2	38.0	34.0	28.0	Clay Loam
S0608498-009	LP-4	2-3	36.0	38.0	26.0	Loam
S0608498-010	LP-4	3-4	55.0	22.0	23.0	Sandy Clay Loam
S0608498-011	LP-4	4-5	55.0	26.0	19.0	Sandy Loam
S0608498-012	LP-4	5-6	56.0	21.0	23.0	Sandy Clay Loam
S0608498-013	LP-5	0-1	38.0	35.0	27.0	Clay Loam
S0608498-014	LP-5	1-2	24.0	40.0	36.0	Clay Loam
S0608498-015	LP-5	2-3	56.0	21.0	23.0	Sandy Clay Loam
S0608498-016	LP-5	3-4	68.0	15.0	17.0	Sandy Loam
S0608498-017	LP-6	0-1	44.0	31.0	25.0	Loam
S0608498-018	LP-6	1-2	44.0	29.0	27.0	Clay Loam
S0608498-019	LP-6	2-3	74.0	9.0	17.0	Sandy Loam
S0608498-020	LP-6	3-4	78.0	5.0	17.0	Sandy Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0608498001

Date: 1/4/2007

Work Order: S0608498

Project: Western Water Cons. Topsoil

Date Received: 8/27/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0608498-021	CK-1	0-1	44.0	28.0	28.0	Clay Loam
S0608498-022	CK-1	1-2	52.0	23.0	25.0	Sandy Clay Loam
S0608498-023	CK-1	2-3	43.0	27.0	30.0	Clay Loam
S0608498-024	CK-1	3-4	46.0	29.0	25.0	Loam
S0608498-025	CK-1	4-5	34.0	34.0	32.0	Clay Loam
S0608498-026	CK-1	5-6	35.0	34.0	31.0	Clay Loam
S0608498-027	CK-2	0-1	14.0	29.0	57.0	Silty Clay
S0608498-028	CK-2	1-2	22.0	30.0	48.0	Clay
S0608498-029	CK-2	2-3	22.0	29.0	49.0	Clay
S0608498-030	CK-2	3-4	13.0	30.0	57.0	Silty Clay
S0608498-031	CK-2	4-5	40.0	21.0	39.0	Clay Loam
S0608498-032	CK-2	5-6	57.0	8.0	35.0	Sandy Clay
S0608498-033	CK-3	0-1	50.0	25.0	25.0	Sandy Clay Loam
S0608498-034	CK-3	1-2	52.0	26.0	22.0	Sandy Clay Loam
S0608498-035	CK-3	2-3	60.0	21.0	19.0	Sandy Loam
S0608498-036	CK-3	3-4	70.0	13.0	17.0	Sandy Loam
S0608498-037	CK-3	4-5	50.0	29.0	21.0	Loam
S0608498-038	CK-3	5-6	51.0	22.0	27.0	Sandy Clay Loam
S0608498-039	LP8 #7	3-4	20.0	34.0	46.0	Clay

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
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Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0609002001

Date: 1/4/2007

Work Order: S0609002

Project: Section 20 Horse Cr.

Date Received: 9/1/2006

Lab ID	Sample ID	Depths	pH	Saturation	Electrical Conductivity	Organic Matter	Calcium	Magnesium	Sodium	SAR
		Ft.	s.u.	%	dS/m	%	meq/L	meq/L	meq/L	
S0609002-001	CK4-A	0-1	6.9	57.5	3.23	4.8	19.3	15.2	4.51	1.09
S0609002-002	CK4-A	1-2	8.1	40.8	8.61		17.0	49.0	54.8	9.55
S0609002-003	CK4-A	2-3	8.3	41.6	10.5		16.9	60.0	69.7	11.2
S0609002-004	CK4-A	3-4	8.2	41.9	7.37		16.8	37.9	42.7	8.17
S0609002-005	CK4-A	4-5	8.0	34.7	5.95		16.5	26.9	29.2	6.27
S0609002-006	CK4-A	5-6	8.1	36.8	6.03		17.0	30.6	31.5	6.45
S0609002-007	CK4-B	0-1	7.3	50.4	5.32	1.8	19.8	27.1	22.5	4.64
S0609002-008	CK4-B	1-2	7.7	51.4	11.2		18.6	74.9	68.7	10.1
S0609002-009	CK4-B	2-3	8.1	67.2	9.28		15.3	71.0	54.0	8.21
S0609002-010	CK4-B	3-4	8.0	65.2	9.55		16.4	69.4	57.9	8.84
S0609002-011	CK4-B	4-5	8.0	56.6	7.35		13.9	42.1	43.0	8.13
S0609002-012	CK4-B	5-6	8.0	55.7	8.39		16.3	47.9	48.3	8.52
S0609002-013	CK5	0-1	7.2	52.2	4.25	4.1	20.4	27.6	8.25	1.68
S0609002-014	CK5	1-2	8.0	45.6	6.93		16.6	49.0	30.8	5.37
S0609002-015	CK5	2-3	8.1	42.4	7.84		16.8	48.2	41.1	7.20
S0609002-016	CK5	3-4	8.1	45.3	8.08		16.0	57.2	44.0	7.28
S0609002-017	CK5	4-5	8.1	48.9	7.45		15.6	50.4	41.5	7.22
S0609002-018	CK5	5-6	8.0	46.8	6.10		14.7	37.6	31.2	6.10
S0609002-019	CK6	0-1	7.1	53.8	3.83	4.3	16.0	19.9	11.9	2.80
S0609002-020	CK6	1-2	8.2	43.4	8.98		16.4	49.4	59.8	10.4

These results apply only to the samples tested.

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Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0609002001

Date: 1/4/2007

Work Order: S0609002

Project: Section 20 Horse Cr.

Date Received: 9/1/2006

Lab ID	Sample ID	Depths Ft.	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR
S0609002-021	CK6	2-3	8.1	37.0	8.22		16.4	41.4	50.1	9.32
S0609002-022	CK6	3-4	8.2	35.3	7.70		18.3	39.3	44.9	8.36
S0609002-023	CK6	4-5	8.1	31.9	6.46		16.1	29.8	32.7	6.82
S0609002-024	CK6	5-6	7.7	31.5	5.70		16.4	26.1	27.9	6.04
S0609002-025	CK7	0-1	8.7	52.0	7.68	3.5	17.3	40.8	38.5	7.14
S0609002-026	CK7	1-2	8.6	51.0	15.7		15.5	111	112	14.1
S0609002-027	CK7	2-3	8.6	43.5	14.6		16.7	95.4	104	13.9
S0609002-028	CK7	3-4	8.3	38.8	7.85		16.8	43.6	45.5	8.28
S0609002-029	CK7	4-5	8.1	40.7	5.21		17.7	26.5	19.9	4.22
S0609002-030	CK7	5-6	8.0	36.7	4.85		18.0	23.8	16.6	3.63

These results apply only to the samples tested.

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Project: Section 20 Horse Cr.

Date Received: 9/1/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0609002-001	CK4-A	0-1	39.0	33.0	28.0	Clay Loam
S0609002-002	CK4-A	1-2	50.0	29.0	21.0	Loam
S0609002-003	CK4-A	2-3	53.0	31.0	16.0	Sandy Loam
S0609002-004	CK4-A	3-4	59.0	25.0	16.0	Sandy Loam
S0609002-005	CK4-A	4-5	68.0	18.0	14.0	Sandy Loam
S0609002-006	CK4-A	5-6	61.0	23.0	16.0	Sandy Loam
S0609002-007	CK4-B	0-1	30.0	35.0	35.0	Clay Loam
S0609002-008	CK4-B	1-2	21.0	43.0	36.0	Clay Loam
S0609002-009	CK4-B	2-3	22.0	35.0	43.0	Clay
S0609002-010	CK4-B	3-4	21.0	34.0	45.0	Clay
S0609002-011	CK4-B	4-5	20.0	35.0	45.0	Clay
S0609002-012	CK4-B	5-6	40.0	22.0	38.0	Clay Loam
S0609002-013	CK5	0-1	32.0	39.0	29.0	Clay Loam
S0609002-014	CK5	1-2	49.0	31.0	20.0	Loam
S0609002-015	CK5	2-3	47.0	34.0	19.0	Loam
S0609002-016	CK5	3-4	50.0	30.0	20.0	Loam
S0609002-017	CK5	4-5	35.0	41.0	24.0	Loam
S0609002-018	CK5	5-6	38.0	39.0	23.0	Loam
S0609002-019	CK6	0-1	30.0	39.0	31.0	Clay Loam
S0609002-020	CK6	1-2	42.0	38.0	20.0	Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0609002001

Date: 1/4/2007

Work Order: S0609002

Project: Section 20 Horse Cr.

Date Received: 9/1/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0609002-021	CK6	2-3	61.0	25.0	14.0	Sandy Loam
S0609002-022	CK6	3-4	67.0	18.0	15.0	Sandy Loam
S0609002-023	CK6	4-5	75.0	15.0	10.0	Sandy Loam
S0609002-024	CK6	5-6	77.0	13.0	10.0	Sandy Loam
S0609002-025	CK7	0-1	43.0	31.0	26.0	Loam
S0609002-026	CK7	1-2	40.0	35.0	25.0	Loam
S0609002-027	CK7	2-3	60.0	21.0	19.0	Sandy Loam
S0609002-028	CK7	3-4	68.0	15.0	17.0	Sandy Loam
S0609002-029	CK7	4-5	67.0	17.0	16.0	Sandy Loam
S0609002-030	CK7	5-6	51.0	22.0	27.0	Sandy Clay Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0610050001

Date: 1/4/2007

Work Order: S0610050

Project: Western Water Cons. Topsoil

Date Received: 10/3/2006

Lab ID	Sample ID	Depths Ft.	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR
S0610050-001	LS1	0-1	6.6	60.2	0.83	2.9	3.23	2.54	1.35	0.80
S0610050-002	LS1	1-2	7.6	52.8	0.71		2.42	1.28	2.14	1.57
S0610050-003	LS1	2-3	7.6	42.0	0.72		2.49	1.31	2.03	1.48
S0610050-004	LS1	3-4	7.7	42.7	0.70		2.47	1.12	1.95	1.46
S0610050-005	LS1	4-5	7.7	43.0	0.79		3.20	1.41	2.17	1.43
S0610050-006	LS1	5-6	7.8	39.6	0.86		3.41	1.65	2.10	1.32
S0610050-007	LS2	0-0.5	7.8	67.7	0.42	0.8	1.08	0.98	0.95	0.94
S0610050-008	LS2	0.5-1	6.4	58.9	0.35		0.87	0.66	0.80	0.92
S0610050-009	LS6	0-1	7.2	60.3	1.00	2.8	3.33	2.50	1.81	1.06
S0610050-010	LS6	1-2	8.0	51.7	6.97		17.7	24.6	38.4	8.35
S0610050-011	LS6	2-3	8.3	48.7	9.06		17.2	33.8	57.3	11.4
S0610050-012	LS6	3-4	8.3	48.8	8.48		16.3	30.2	51.0	10.6
S0610050-013	LS6	4-5	8.2	53.1	7.16		15.1	24.6	41.4	9.29
S0610050-014	LS6	5-6	8.1	53.4	6.38		15.6	20.3	34.6	8.17
S0610050-015	LS6-5	0-0.5	7.7	80.6	1.33	1.9	1.93	1.67	6.47	4.83
S0610050-016	LS6-5	0.5-1	7.7	64.9	6.14		19.1	19.2	34.8	7.95
S0610050-017	LS7-1&3	0-1	7.1	60.8	0.79	2.3	2.24	2.00	2.32	1.59
S0610050-018	PP1	0-1	7.3	64.6	0.66	2.8	2.64	2.19	0.61	0.39
S0610050-019	PP1	1-2	7.8	52.4	1.35		4.67	4.12	3.66	1.74
S0610050-020	PP1	2-3	8.0	52.6	5.63		17.3	25.7	24.3	5.25

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0610050001

Date: 1/4/2007

Work Order: S0610050

Project: Western Water Cons. Topsoil

Date Received: 10/3/2006

Lab ID	Sample ID	Depths Ft.	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR
S0610050-021	PP1	3-4	8.1	47.0	6.49		16.7	30.7	31.7	6.50
S0610050-022	PP1	4-5	8.0	45.5	5.25		17.7	21.3	21.0	4.75
S0610050-023	PP1	5-6	7.8	44.6	4.02		17.6	15.5	12.8	3.14

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0610050001

Date: 1/4/2007

Work Order: S0610050

Project: Western Water Cons. Topsoil

Date Received: 10/3/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0610050-001	LS1	0-1	20.0	49.0	31.0	Clay Loam
S0610050-002	LS1	1-2	21.0	49.0	30.0	Clay Loam
S0610050-003	LS1	2-3	51.0	29.0	20.0	Loam
S0610050-004	LS1	3-4	49.0	32.0	19.0	Loam
S0610050-005	LS1	4-5	50.0	32.0	18.0	Loam
S0610050-006	LS1	5-6	46.0	31.0	23.0	Loam
S0610050-007	LS2	0-0.5	12.0	34.0	54.0	Clay
S0610050-008	LS2	0.5-1	12.0	44.0	44.0	Silty Clay
S0610050-009	LS6	0-1	27.0	41.0	32.0	Clay Loam
S0610050-010	LS6	1-2	24.0	46.0	30.0	Clay Loam
S0610050-011	LS6	2-3	32.0	44.0	24.0	Loam
S0610050-012	LS6	3-4	31.0	43.0	26.0	Loam
S0610050-013	LS6	4-5	22.0	48.0	30.0	Clay Loam
S0610050-014	LS6	5-6	20.0	48.0	32.0	Clay Loam
S0610050-015	LS6-5	0-0.5	12.0	30.0	58.0	Silty Clay
S0610050-016	LS6-5	0.5-1	12.0	44.0	44.0	Silty Clay
S0610050-017	LS7-1&3	0-1	20.0	38.0	42.0	Clay
S0610050-018	PP1	0-1	19.0	50.0	31.0	Silty Clay Loam
S0610050-019	PP1	1-2	25.0	46.0	29.0	Clay Loam
S0610050-020	PP1	2-3	32.0	43.0	25.0	Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0610050001

Date: 1/4/2007

Work Order: S0610050

Project: Western Water Cons. Topsoil

Date Received: 10/3/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0610050-021	PP1	3-4	44.0	34.0	22.0	Loam
S0610050-022	PP1	4-5	51.0	28.0	21.0	Loam
S0610050-023	PP1	5-6	46.0	32.0	22.0	Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0610340001

Date: 1/4/2007

Work Order: S0610340

Project: Western Water Cons. Topsoil

Date Received: 10/20/2006

Lab ID	Sample ID	Depths Ft.	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR
S0610340-001	DM1-3	0-1	7.5	56.7	6.19	3.5	21.6	25.5	29.2	6.02
S0610340-002	DM1-3	1-2	8.2	49.8	9.90		19.2	43.3	68.2	12.2
S0610340-003	DM1-3	2-3	8.5	38.5	12.0		19.6	51.3	83.2	14.0
S0610340-004	DM1-3	3-4	8.4	36.9	10.5		18.7	49.2	69.6	11.9
S0610340-005	DM1-3	4-5	8.2	35.8	8.81		19.6	41.4	52.1	9.43
S0610340-006	DM1-3	5-6	8.2	35.8	8.35		19.4	36.9	50.2	9.46

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0610340001

Date: 1/4/2007

Work Order: S0610340

Project: Western Water Cons. Topsoil

Date Received: 10/20/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0610340-001	DM1-3	0-1	40.0	34.0	26.0	Loam
S0610340-002	DM1-3	1-2	42.0	33.0	25.0	Loam
S0610340-003	DM1-3	2-3	71.0	13.0	16.0	Sandy Loam
S0610340-004	DM1-3	3-4	78.0	10.0	12.0	Sandy Loam
S0610340-005	DM1-3	4-5	66.0	22.0	12.0	Sandy Loam
S0610340-006	DM1-3	5-6	70.0	19.0	11.0	Sandy Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0610433001

Date: 1/4/2007

Work Order: S0610433

Project: Western Water Cons. Topsoil

Date Received: 10/26/2006

Lab ID	Sample ID	Depths	pH	Saturation	Electrical Conductivity	Organic Matter	Calcium	Magnesium	Sodium	SAR
		Ft.	s.u.	%	dS/m	%	meq/L	meq/L	meq/L	
S0610433-001	MPI	0-1	7.6	68.1	7.83	3.7	18.9	51.7	36.0	6.05
S0610433-002	MPI	1-2	8.2	55.2	10.1		17.8	72.0	58.3	8.69
S0610433-003	MPI	2-3	8.1	57.8	8.45		18.7	62.3	45.1	7.08
S0610433-004	MPI	3-4	7.8	61.0	7.92		17.3	55.0	40.5	6.74
S0610433-005	MPI	4-5	7.8	51.3	6.42		18.3	36.3	28.3	5.42
S0610433-006	MPI	5-6	7.8	50.4	6.62		19.2	42.0	28.6	5.18
S0610433-007	DT1	0-1	7.4	64.9	0.87	3.7	3.15	1.86	1.26	0.80
S0610433-008	DT1	1-2	7.6	58.5	4.83		20.8	21.8	22.5	4.87
S0610433-009	DT1	2-3	7.9	41.2	6.10		18.6	31.4	31.3	6.25
S0610433-010	DT1	3-4	8.0	47.8	7.10		18.6	44.3	36.8	6.56
S0610433-011	PP10	0-1	7.8	64.8	7.04	3.0	16.5	42.8	33.3	6.11
S0610433-012	PP10	1-2	8.4	59.9	13.5		16.3	114	87.6	10.9
S0610433-013	PP10	2-3	8.3	60.7	13.7		17.2	115	90.8	11.2
S0610433-014	PP10	3-4	8.2	54.4	10.4		13.2	69.4	58.9	9.17

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0610433001

Date: 1/4/2007

Work Order: S0610433

Project: Western Water Cons. Topsoil

Date Received: 10/26/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0610433-001	MPI	0-1	24.0	38.0	38.0	Clay Loam
S0610433-002	MPI	1-2	18.0	49.0	33.0	Silty Clay Loam
S0610433-003	MPI	2-3	16.0	52.0	32.0	Silty Clay Loam
S0610433-004	MPI	3-4	17.0	47.0	36.0	Silty Clay Loam
S0610433-005	MPI	4-5	28.0	40.0	32.0	Clay Loam
S0610433-006	MPI	5-6	36.0	38.0	26.0	Loam
S0610433-007	DT1	0-1	24.0	41.0	35.0	Clay Loam
S0610433-008	DT1	1-2	18.0	48.0	34.0	Silty Clay Loam
S0610433-009	DT1	2-3	52.0	26.0	22.0	Sandy Clay Loam
S0610433-010	DT1	3-4	38.0	36.0	26.0	Loam
S0610433-011	PP10	0-1	14.0	50.0	36.0	Silty Clay Loam
S0610433-012	PP10	1-2	16.0	50.0	34.0	Silty Clay Loam
S0610433-013	PP10	2-3	20.0	44.0	36.0	Clay Loam
S0610433-014	PP10	3-4	28.0	44.0	28.0	Clay Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0610454002

Date: 1/4/2007

Work Order: S0610454

Project: Western Water Cons. Topsoil

Date Received: 10/27/2006

Lab ID	Sample ID	Depths	pH	Saturation	Electrical Conductivity	Organic Matter	Calcium	Magnesium	Sodium	SAR
		In.	s.u.	%	dS/m	%	meq/L	meq/L	meq/L	
S0610454-001	JW1	0-12	7.6	66.8	12.2	2.0	18.8	223	22.7	2.07
S0610454-002	JW1	12-24	8.0	72.5	16.8		17.9	383	40.0	2.83
S0610454-003	JW1	24-36	7.9	76.3	16.1		19.6	384	36.7	2.59
S0610454-004	JW1	36-48	7.8	77.8	17.1		19.4	425	37.6	2.52

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter-Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0610454002

Date: 1/4/2007

Work Order: S0610454

Project: Western Water Cons. Topsoil

Date Received: 10/27/2006

Lab ID	Sample ID	Depths In.	Sand %	Silt %	Clay %	Texture
S0610454-001	JW1	0-12	22.0	41.0	37.0	Clay Loam
S0610454-002	JW1	12-24	32.0	68.0	<0.1	Silty Loam
S0610454-003	JW1	24-36	28.0	72.0	<0.1	Silty Loam
S0610454-004	JW1	36-48	30.0	70.0	<0.1	Silty Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0611064002

Date: 1/4/2007

Work Order: S0611064

Project: Western Water Cons. Topsoil

Date Received: 11/3/2006

Lab ID	Sample ID	Depths	pH	Saturation	Electrical Conductivity	Organic Matter	Calcium	Magnesium	Sodium	SAR
		Ft.	s.u.	%	dS/m	%	meq/L	meq/L	meq/L	
S0611064-001	ER1	0-1	6.7	54.2	3.51	2.8	23.1	21.7	1.81	0.38
S0611064-002	ER1	1-2	7.6	61.2	6.09		20.0	60.0	11.6	1.84
S0611064-003	ER1	2-3	7.8	74.9	8.34		18.0	95.4	19.4	2.58
S0611064-004	ER1	3-4	7.8	76.8	8.77		17.4	104	18.6	2.40

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

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Soil Analysis Report

Western Water Consultants

P.O. Box 3042
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Report ID: S0611064002

Date: 1/4/2007

Work Order: S0611064

Project: Western Water Cons. Topsoil

Date Received: 11/3/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0611064-001	ER1	0-1	38.0	34.0	28.0	Clay Loam
S0611064-002	ER1	1-2	30.0	42.0	28.0	Clay Loam
S0611064-003	ER1	2-3	20.0	63.0	17.0	Silt Loam
S0611064-004	ER1	3-4	22.0	39.0	39.0	Clay Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

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Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0611067001

Date: 1/4/2007

Work Order: S0611067

Project: Western Water Cons. Topsoil

Date Received: 11/3/2006

Lab ID	Sample ID	Depths Ft.	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR
S0611067-001	SM1	0-1	7.5	55.1	4.77	3.7	17.4	15.8	11.7	2.86
S0611067-002	SM1	1-2	8.2	55.4	11.7		14.3	57.4	55.6	9.28
S0611067-003	SM1	2-3	8.2	44.0	11.0		16.1	50.9	47.5	8.21
S0611067-004	SM1	3-4	8.2	40.5	11.6		15.7	52.6	53.4	9.15
S0611067-005	SM1	4-5	8.1	39.3	9.23		15.3	37.3	43.4	8.46
S0611067-006	SM1	5-6	7.9	32.5	6.84		16.3	25.7	27.4	5.98
S0611067-007	SM1-2	2-3	8.3	71.0	14.3		14.7	73.9	70.6	10.6
S0611067-008	SM1-2	3-4	8.5	57.9	15.0		16.0	75.8	79.7	11.8
S0611067-009	SM1-4	2-3	8.5	50.4	15.4		18.0	67.9	79.5	12.1
S0611067-010	SM1-4	3-4	8.5	49.8	17.6		16.8	81.5	95.5	13.6
S0611067-011	SM1-7	2-3	8.4	61.2	16.1		16.9	77.1	77.6	11.3

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

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Soil Analysis Report

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Report ID: S0611067001

Date: 1/4/2007

Work Order: S0611067

Project: Western Water Cons. Topsoil

Date Received: 11/3/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0611067-001	SM1	0-1	30.0	46.0	24.0	Loam
S0611067-002	SM1	1-2	26.0	49.0	25.0	Loam
S0611067-003	SM1	2-3	58.0	30.0	12.0	Sandy Loam
S0611067-004	SM1	3-4	64.0	25.0	11.0	Sandy Loam
S0611067-005	SM1	4-5	61.0	28.0	11.0	Sandy Loam
S0611067-006	SM1	5-6	73.0	21.0	6.0	Sandy Loam
S0611067-007	SM1-2	2-3	10.0	82.0	8.0	Silt
S0611067-008	SM1-2	3-4	22.0	54.0	24.0	Silty Loam
S0611067-009	SM1-4	2-3	40.0	42.0	18.0	Loam
S0611067-010	SM1-4	3-4	35.0	46.0	19.0	Loam
S0611067-011	SM1-7	2-3	27.0	52.0	21.0	Silty Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

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Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0611353001

Date: 1/4/2007

Work Order: S0611353

Project: Western Water Cons. Topsoil

Date Received: 11/16/2006

Lab ID	Sample ID	Depths	pH	Saturation	Electrical Conductivity	Organic Matter	Calcium	Magnesium	Sodium	SAR
		Ft.	s.u.	%	dS/m	%	meq/L	meq/L	meq/L	
S0611353-001	MP8	0-1	7.1	57.8	0.88	2.9	3.58	3.31	1.15	0.62
S0611353-002	MP8	1-2	7.5	54.8	3.96		20.4	22.5	8.20	1.77
S0611353-003	MP8	2-3	7.8	54.5	6.71		20.0	43.4	24.3	4.31
S0611353-004	MP8	3-4	7.9	58.8	8.05		16.2	55.1	33.0	5.52
S0611353-005	MP8	4-5	7.9	62.2	9.01		17.9	67.6	41.1	6.29
S0611353-006	MP8	5-6	7.9	54.3	9.36		17.7	67.7	41.5	6.35

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

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Soil Analysis Report

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Report ID: S0611353001

Date: 1/4/2007

Work Order: S0611353

Project: Western Water Cons. Topsoil

Date Received: 11/16/2006

Lab ID	Sample ID	Depths Ft.	Sand %	Silt %	Clay %	Texture
S0611353-001	MP8	0-1	18.0	50.0	32.0	Silty Clay Loam
S0611353-002	MP8	1-2	14.0	49.0	37.0	Silty Clay Loam
S0611353-003	MP8	2-3	18.0	46.0	36.0	Silty Clay Loam
S0611353-004	MP8	3-4	10.0	46.0	44.0	Silty Clay
S0611353-005	MP8	4-5	10.0	50.0	40.0	Silty Clay
S0611353-006	MP8	5-6	24.0	44.0	32.0	Clay Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0612093001

Date: 1/4/2007

Work Order: S0612093

Project: Western Water Cons. Topsoil

Date Received: 12/6/2006

Lab ID	Sample ID	Depths FT.	pH s.u.	Saturation %	Electrical Conductivity dS/m	Organic Matter %	Calcium meq/L	Magnesium meq/L	Sodium meq/L	SAR
S0612093-001	MP2	0-1	7.4	54.3	2.07	2.7	14.1	10.9	2.48	0.70
S0612093-002	MP2	1-2	7.9	52.4	7.94		22.8	55.6	39.6	6.33
S0612093-003	MP2	2-3	8.0	55.8	11.4		23.3	85.1	55.8	7.59
S0612093-004	MP2	3-4	8.1	55.4	9.76		22.1	74.2	50.7	7.31
S0612093-005	MP2	4-5	8.0	55.4	8.20		21.8	57.9	40.5	6.41
S0612093-006	MP2	5-6	7.9	54.4	6.74		21.4	45.7	28.3	4.88

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

Inter·Mountain Laboratories, Inc.

Soil Analysis Report

Western Water Consultants

P.O. Box 3042
Sheridan, WY 82801

Report ID: S0612093001

Date: 1/4/2007

Work Order: S0612093

Project: Western Water Cons. Topsoil

Date Received: 12/6/2006

Lab ID	Sample ID	Depths FT.	Sand %	Silt %	Clay %	Texture
S0612093-001	MP2	0-1	28.0	45.0	27.0	Clay Loam
S0612093-002	MP2	1-2	20.0	47.0	33.0	Clay Loam
S0612093-003	MP2	2-3	22.0	46.0	32.0	Clay Loam
S0612093-004	MP2	3-4	24.0	45.0	31.0	Clay Loam
S0612093-005	MP2	4-5	26.0	45.0	29.0	Clay Loam
S0612093-006	MP2	5-6	22.0	42.0	36.0	Clay Loam

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Barten

Karen Barten, Soil Lab Supervisor

APPENDIX I

ADDITIONAL PHOTO POINTS (PERMITTED HORSE CREEK DIVERSION STRUCTURES AND UPPER SQUAW CREEK)

Diversion Structure

TPP-1U Lat: 44.71257 Long: 105.41251 Upstream View

Diversion Structure

TPP-1D Lat: 44.71257 Long: 105.41251 Downstream View

Diversion Structure

TPP-2U Lat: 44.70703 Long: 105.46115 Upstream View

Diversion Structure

TPP-2D Lat: 44.70703 Long: 105.46115 Downstream View

Diversion Structure

TPP-3U Lat: 44.70565 Long: 105.47346 Upstream View

Diversion Structure

TPP-3D Lat: 44.70565 Long: 105.47346 Downstream View

Diversion Structure

TPP-4U Lat: 44.70271 Long: 105.52865 Upstream View

Diversion Structure

TPP-4D Lat: 44.70271 Long: 105.52865 Downstream View

Diversion Structure

TPP-5U Lat: 44.70626 Long: 105.53287 Upstream View

Diversion Structure

TPP-5D Lat: 44.70626 Long: 105.53287 Downstream View

Diversion Structure

TPP-6U Lat: 44.71032 Long: 105.54620 Upstream View

Diversion Structure

TPP-6D Lat: 44.71032 Long: 105.54620 Downstream View

Diversion Structure

TPP-7U Lat: 44.72955 Long: 105.55385 Upstream View

Diversion Structure

TPP-7D Lat: 44.72955 Long: 105.55385 Downstream View

Diversion Structure

TPP-8U Lat: 44.72743 Long: 105.56537 Upstream View

Diversion Structure

TPP-8D Lat: 44.72743 Long: 105.56537 Downstream View

Diversion Structure

TPP-9U Lat: 44.68905 Long: 105.56454 Upstream View

Diversion Structure

TPP-9D Lat: 44.68905 Long: 105.56454 Downstream View

Squaw Creek

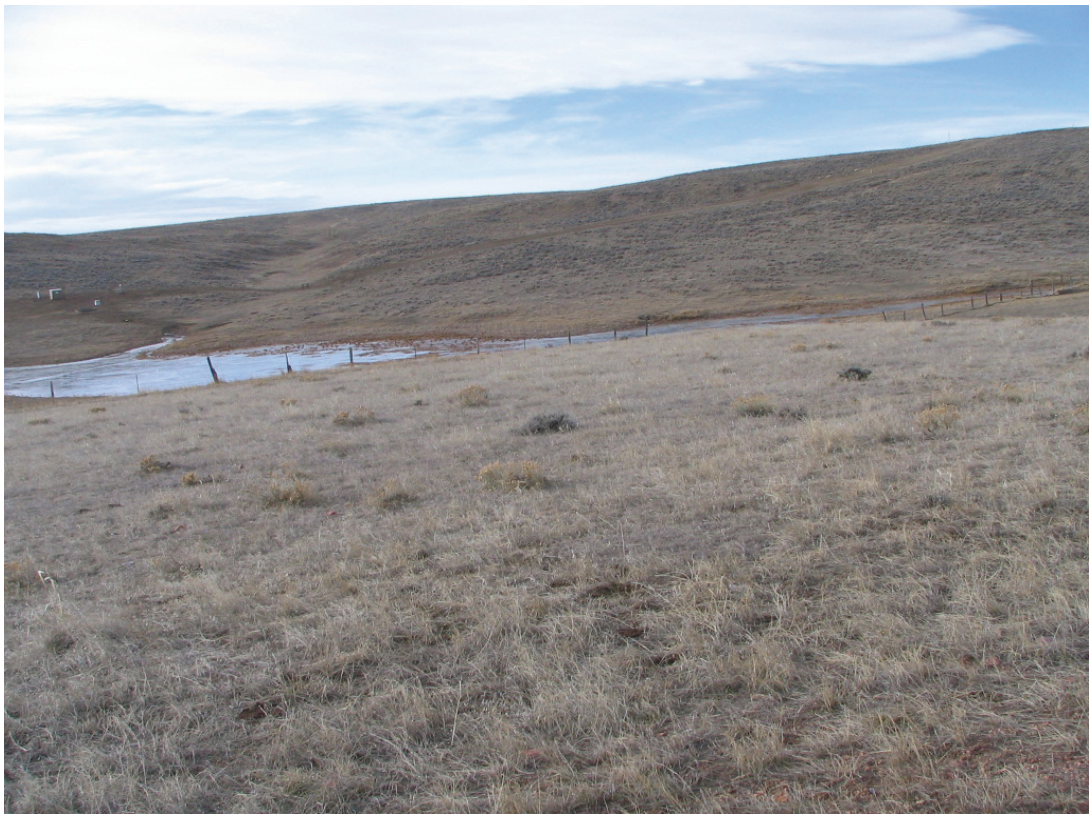
TPP-10 Lat: 44.71451 Long: 105.64761

Squaw Creek

TPP-11 Lat: 44.71858 Long: 105.65245

Squaw Creek

TPP-12 Lat: 44.72399 Long: 105.66493



Squaw Creek

TPP-13 Lat: 44.72389 Long: 105.67882

Squaw Creek

TPP-14 Lat: 44.72746 Long: 105.68951

Squaw Creek

TPP-15 Lat: 44.73059 Long: 105.70177

APPENDIX J

DOMINANT VEGETATIVE SPECIES, PERCENT OCCURRENCE AND THRESHOLD SOIL SALINITY TOLERANCES

Dominant Vegetative Species		Occurrence (%)	Threshold Soil Salinity Tolerance[a] (dS/m)
Common Name	**Scientific Name**		
Transect W1:			
Field Pennycress	*Thlaspi arvense*	21.43	7.5[c]
Prairie Cordgrass	*Spartina pectinata*	21.43	n/a
Japanese Brome	*Bromus japonicus*	14.29	8[d]
Western Wheatgrass	*Agropyron smithii*	14.29	6[b]
Transect W2:			
Prairie Cordgrass	*Spartina pectinata*	40.00	n/a
Japanese Brome	*Bromus japonicus*	30.00	n/a
Cloaked Bulrush	*Scirpus pallidus*	20.00	n/a
Western Wheatgrass	*Agropyron smithii*	10.00	6[b]
Transect W3:			
Japanese Brome	*Bromus japonicus*	63.16	8[d]
Prairie Cordgrass	*Spartina pectinata*	10.53	n/a
Silver Sagebrush	*Artemisia cana*	10.53	n/a
Field Pennycress	*Thlaspi arvense*	5.26	7.5[c]
Transect SS1:			
Wheat	*Triticum spp.*	86.67	7.5[b]
Wavyleaf thistle	*Cirsium undulatum*	6.67	n/a
Kochia	*Kochia scoparia*	6.67	moderate[b]
Transect DJ1:			
Japanese Brome	*Bromus japonicus*	37.50	8[d]
Crested Wheatgrass	*Agropyron cristatum*	37.50	7.5[c]
Kochia	*Kochia scoparia*	12.50	moderate[b]
Field Pennycress	*Thlaspi arvense*	12.50	7.5[c]
Transect DT1:			
Japanese Brome	*Bromus japonicus*	36.84	8[d]
Silver Sagebrush	*Artemisia cana*	21.05	n/a
Western Wheatgrass	*Agropyron smithii*	15.79	6[b]
Field Pennycress	*Thlaspi arvense*	10.53	7.5[c]
Transect DT2:			
Smooth Brome	*Bromus inermis*	27.27	10[b]
Japanese Brome	*Bromus japonicus*	18.18	8[d]
Kochia	*Kochia scoparia*	9.09	moderate[b]
Cloaked Bulrush	*Scirpus pallidus*	9.09	n/a
Transect DT3:			
Japanese Brome	*Bromus japonicus*	17.39	8[d]
Foxtail Barley	*Hordeum jubatum*	17.39	high[b]
Kochia	*Kochia scoparia*	13.04	moderate[b]
Threadleaf Sedge	*Carex filifolia*	4.35	n/a
Transect DT4:			
Foxtail Barley	*Hordeum jubatum*	31.25	high[b]
Japanese Brome	*Bromus japonicus*	25.00	8[d]
Intermediate Wheatgrass	*Agropyron intermedium*	18.75	6[b]
Kochia	*Kochia scoparia*	6.25	moderate[b]
Transect DT5:			
Foxtail Barley	*Hordeum jubatum*	33.33	high[b]
Inland Saltgrass	*Distichlis spicata*	25.00	very high[b]
Japanese Brome	*Bromus japonicus*	16.67	8[d]
Wild Licorice	*Glycyrrhiza lepidota*	8.33	n/a

Dominant Vegetative Species		Occurrence (%)	Threshold Soil Salinity Tolerance[a] (dS/m)
Common Name	**Scientific Name**		
Transect DT6:			
Japanese Brome	*Bromus japonicus*	88.89	8[d]
Silver Sagebrush	*Artemisia cana*	11.11	n/a
Transect DT7:			
Foxtail Barley	*Hordeum jubatum*	25.00	high[b]
Japanese Brome	*Bromus japonicus*	18.75	8[d]
Kochia	*Kochia scoparia*	18.75	moderate[b]
Crested Wheatgrass	*Agropyron cristatum*	12.50	7.5[c]
Transect DT8:			
Japanese Brome	*Bromus japonicus*	50.00	8[d]
Intermediate Wheatgrass	*Agropyron intermedium*	21.43	6[b]
Silver Sagebrush	*Artemisia cana*	14.29	n/a
Dandelion	*Taraxacum spp.*	7.14	n/a
Transect DT9:			
Intermediate Wheatgrass	*Agropyron intermedium*	42.86	6[b]
Crested Wheatgrass	*Agropyron cristatum*	19.05	7.5[c]
Silver Sagebrush	*Artemisia cana*	9.52	n/a
Japanese Brome	*Bromus japonicus*	4.76	8[d]
Transect MP2:			
Crested Wheatgrass	*Agropyron cristatum*	31.82	7.5[c]
Kochia	*Kochia scoparia*	16.67	moderate[b]
Japanese Brome	*Bromus japonicus*	13.64	8[d]
Wheat	*Triticum spp.*	13.64	7.5[b]
Transect MP1:			
Smooth Brome	*Bromus inermis*	50.00	10[b]
Prairie Cordgrass	*Spartina pectinata*	16.67	n/a
Intermediate Wheatgrass	*Agropyron intermedium*	16.67	6[b]
Japanese Brome	*Bromus japonicus*	11.11	8[d]
Transect MP3:			
Smooth Brome	*Bromus inermis*	34.72	10[b]
Crested Wheatgrass	*Agropyron cristatum*	27.78	7.5[c]
Japanese Brome	*Bromus japonicus*	25.00	8[d]
Field Pennycress	*Thlaspi arvense*	4.17	7.5[c]
Transect MP4:			
Japanese Brome	*Bromus japonicus*	48.94	8[d]
Alfalfa	*Medicago sativa*	19.15	7.5[b]
Crested Wheatgrass	*Agropyron cristatum*	17.02	7.5[c]
Field Pennycress	*Thlaspi arvense*	4.26	7.5[c]
Transect LO2:			
Western Wheatgrass	*Agropyron smithii*	33.33	6[b]
Crested Wheatgrass	*Agropyron cristatum*	25.00	7.5[c]
Inland Saltgrass	*Distichlis spicata*	16.67	very high[b]
Foxtail Barley	*Hordeum jubatum*	13.89	high[b]
Transect W4:			
Western Wheatgrass	*Agropyron smithii*	50.00	6[b]
Inland Saltgrass	*Distichlis spicata*	16.67	very high[b]
Smooth Brome	*Bromus inermis*	8.33	10[b]
Field Pennycress	*Thlaspi arvense*	8.33	n/a
Transect PP2:			

Dominant Vegetative Species		Occurrence (%)	Threshold Soil Salinity Tolerance[a] (dS/m)
Common Name	**Scientific Name**		
Crested Wheatgrass	*Agropyron cristatum*	22.73	7.5[c]
Smooth Brome	*Bromus inermis*	22.73	10[b]
Japanese Brome	*Bromus japonicus*	11.36	8[d]
Prairie Cordgrass	*Spartina pectinata*	11.36	n/a
Transect PP1:			
Crested Wheatgrass	*Agropyron cristatum*	67.27	7.5[c]
Japanese Brome	*Bromus japonicus*	12.73	8[d]
Prairie Cordgrass	*Spartina pectinata*	5.45	n/a
Smooth Brome	*Bromus inermis*	5.45	10[b]
Transect SM1:			
Crested Wheatgrass	*Agropyron cristatum*	48.72	7.5[c]
Field Pennycress	*Thlaspi arvense*	19.23	n/a
Japanese Brome	*Bromus japonicus*	11.54	8[d]
Alfalfa	*Medicago sativa*	2.56	7.5[b]
Transect LP2:			
Smooth Brome	*Bromus inermis*	25.00	10[b]
Intermediate Wheatgrass	*Agropyron intermedium*	22.50	6[b]
Cattails	*Typha spp.*	12.50	n/a
Equisetum	*Equisetum spp.*	10.00	n/a
Transect LP1:			
Prairie Cordgrass	*Spartina pectinata*	21.74	n/a
Smooth Brome	*Bromus inermis*	17.39	10[b]
Japanese Brome	*Bromus japonicus*	17.39	8[d]
Kochia	*Kochia scoparia*	13.04	moderate[b]
Transect AK1:			
Japanese Brome	*Bromus japonicus*	41.94	8[d]
Smooth Brome	*Bromus inermis*	29.03	10[b]
Crested Wheatgrass	*Agropyron cristatum*	3.23	7.5[c]
Western Wheatgrass	*Agropyron smithii*	3.23	6[b]
Transect AK2:			
Cattails	*Typha spp.*	31.58	n/a
Japanese Brome	*Bromus japonicus*	26.32	8[d]
Boxelder	*Acer negundo*	15.79	n/a
Crested Wheatgrass	*Agropyron cristatum*	13.16	7.5[c]
Transect LS1:			
Alfalfa	*Medicago sativa*	29.27	7.5[b]
Crested Wheatgrass	*Agropyron cristatum*	24.39	7.5[c]
Japanese Brome	*Bromus japonicus*	12.20	8[d]
Prairie Cordgrass	*Spartina pectinata*	9.76	n/a
Transect DM1:			
Japanese Brome	*Bromus japonicus*	29.27	8[d]
Western Wheatgrass	*Agropyron smithii*	24.39	6[b]
Alfalfa	*Medicago sativa*	17.07	7.5[b]
Intermediate Wheatgrass	*Agropyron intermedium*	4.88	6[b]
Transect ER1:			
Crested Wheatgrass	*Agropyron cristatum*	72.50	7.5[c]
Field Pennycress	*Thlaspi arvense*	7.50	n/a
Alfalfa	*Medicago sativa*	5.83	7.5[b]
Intermediate Wheatgrass	*Agropyron intermedium*	4.17	6[b]

Dominant Vegetative Species		Occurrence (%)	Threshold Soil Salinity Tolerance[a] (dS/m)
Common Name	**Scientific Name**		
Transect JW1:			
Western Wheatgrass	*Agropyron smithii*	25.00	6[b]
Prairie Cordgrass	*Spartina pectinata*	21.43	n/a
Crested Wheatgrass	*Agropyron cristatum*	10.71	7.5[c]
Japanese Brome	*Bromus japonicus*	10.71	8[d]
Transect JW2:			
Western Wheatgrass	*Agropyron smithii*	31.58	6[b]
Inland Saltgrass	*Distichlis spicata*	18.42	very high[b]
Japanese Brome	*Bromus japonicus*	18.42	8[d]
Foxtail Barley	*Hordeum jubatum*	13.16	high[b]
Transect LO1:			
Western Wheatgrass	*Agropyron smithii*	50.00	6[b]
Inland Saltgrass	*Distichlis spicata*	29.17	very high[b]
Japanese Brome	*Bromus japonicus*	8.33	8[d]
Wild Licorice	*Glycyrrhiza lepidota*	4.17	n/a
Transect MP5:			
Field Pennycress	*Thlaspi arvense*	29.17	n/a
Japanese Brome	*Bromus japonicus*	25.00	8[d]
Smooth Brome	*Bromus inermis*	25.00	10[b]
Alfalfa	*Medicago sativa*	8.33	7.5[b]
Transect MP6:			
Smooth Brome	*Bromus inermis*	43.64	10[b]
Crested Wheatgrass	*Agropyron cristatum*	21.82	7.5[c]
Field Pennycress	*Thlaspi arvense*	12.73	n/a
Inland Saltgrass	*Distichlis spicata*	5.45	n/a
Transect LK1:			
Smooth Brome	*Bromus inermis*	67.44	10[b]
Crested Wheatgrass	*Agropyron cristatum*	9.30	7.5[c]
Wild Licorice	*Glycyrrhiza lepidota*	4.65	n/a
Alfalfa	*Medicago sativa*	2.33	7.5[b]

[a] Threshold salinity tolerance levels are given in decisiemens per meter.

[b] Data obtained from Bridger Plant Materials Center (1996).

[c] Data obtained from USDA Agriculture Research Service website (2006).

[d] Data obtained from Alberta Food and Agriculture Department (2001).

n/a - Salt tolerance levels not available.

APPENDIX K

LITERATURE REVIEW – SALINE – SODIC SOILS

Title: Literature Review Sodic/Saline Materials

By Terry Brown, Ph.D.

2002

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Introduction

Excessive levels of salts impact extensive areas of soils throughout the world. The primary effects of these salts on soil quality are associated with saline and sodic conditions. Saline soil conditions are associated with excess salts usually consisting of chlorides (Cl^{-1}) and sulfates (SO_4^{-2}) of sodium (Na^{+1}), calcium (Ca^{+2}), and magnesium (Mg^{+2}) (Sumner et al., 1998a). Saline conditions often have a deleterious effect on plant growth because salts decrease the osmotic potential of soil water making it difficult for plants to extract water. Sodic conditions are associated with elevated levels of Na on the exchange complex often responsible for the development of the poor physical conditions in a soil. Thus the impacts of Na result in an inadequate balance between water and air regimes in the soil. This imbalance is caused by restricted water infiltration and transmission properties causing the soil to be too wet or dry for much of the time resulting in poor root development and plant growth. In addition, sodic soils often are difficult to cultivate and have low load bearing properties. Poor structural stability

promotes the sealing of soil pores and crust formation at the soil surface, resulting in soil erosion and pollution of surface water resources. An important aspect of sodic soil behavior is associated with the interaction between sodicity and salinity. A soil can be characterized with high exchangeable sodium percentages (ESP) and not develop instability of structure if the electrolyte levels in solution are above a threshold electrolyte concentration (TEC). As a result, a given ESP or sodium adsorption ratio (SAR) level means nothing relative to land management unless the salt levels of the system are understood.

Currently, the use of SAR or ESP levels for standards without adequate concern for electrical conductivity (EC), clay mineralogy, soil weathering and other important soil characteristics that determine now a soil will react or function under land use. This misconception has resulted in high reclamation costs that are more than likely unfounded. This issue will be addressed more thoroughly in a later section of this review.

Objectives

The objective of this work is to describe in some detail the chemistry of sodic/saline soil systems. The information will provide a basis for standards that can result in sound management plans leading to the successful use of CBNG produced water for beneficial purposes and the long-term stability of vegetation communities irrigated with sodic/saline water.

Chemistry of Sodic/Saline Materials

High levels of sodium often cause significant deterioration in the physical conditions of soils causing imbalances in the water and air regimes. The physical changes result from the flocculation and dispersion reactions impacted by the amount of Na that occupies cation exchange sites. The major factors responsible for these reactions include the type of soil colloid materials present and the charge distribution associated with the surfaces of these materials. The flocculation and dispersion reactions are governed by the

attractive and repulsive forces associated with the electron double layer resulting from the surface charge of soil colloids.

The basic theory of the diffuse double layer was developed separately by Gouy and Chapman and is now referred to as the Gouy-Chapman theory (DVLO) (Overbeek 1952). Bolt (1955) has shown that the Poisson-Boltzmann differential equation describes the exchange equilibrium of a Na-Ca illite in mixed solutions of NaCl and $CaCl_2$ and thereafter was referred to as the double-layer equation. The concept is based on the following. The permanent charge of clay minerals results from two types of charge at the surface: 1) permanent charge due to the replacement of higher valence cations in the mineral structure with lower valence cations resulting in a net negative charge; and 2) variable charge, which is caused by dissociation of mineral-edge hydroxyls. The electrical force acting on the cations present in solution is pulling them to the surface while the force of diffusion is pulling the cations away from the surface. The opposite interaction occurs for the anions. The anions are repulsed from the surface and approach the concentration of the bulk solution at an exponential rate. The net interaction between the attractive and repulsive forces allows the adsorbed ions to extend outward to a point where the forces are equal. This layer of cations and anions is labeled as the electronic diffuse double layer. The double layer is characterized by an excess of cations near the surface due to the attraction by the negatively charged surface and a deficit of anions close to the surface due to the repulsion by the negative charge associated with the surface. Therefore, the concentrations of cations and anions asymptotically approach the bulk solution concentrations with increasing distance from the surface.

The distribution of cations in the liquid phase of soils grades from high concentrations near the particle surface to lower concentrations in the bulk solution. It is convenient to think of the diffuse double layer as having a thickness, although the thickness cannot be precisely defined. As noted in various text books, the thickness of the double layers are small compared to the diameter of soil pores but are of the same magnitude of water film thicknesses in a dry soil (Bohn et al. 1979). The thickness of the diffuse double layer

decreases as the square root of the salt concentration of the bulk solution increases and directly with an increase in the valence of the exchangeable cations. The effect of increased salt concentration results from the reduction in cation diffusion from the surface to the bulk solution. Exchangeable Cations such as Na^{+1} with a large hydrated radius tend to promote the development of thick double layers while cations such as Ca^{+2} tend to promote a collapsed or thin double layer. The development of a thick diffuse double layer results in swelling especially with the expanding clay minerals. As the double layers associated with adjacent clay surfaces interact excess cations exist at the mid plane. The excess of cations at the midplane compared to the bulk solution results in an osmotic gradient, which causes water inbibition resulting in swelling and/or clay dispersion. Water inbibition continues until the osmotic potential at the midplane between clay particles equals the osmotic potential in the solution or until swelling is reduced by the lack of water. Swelling is most pronounced in soils containing large amounts of montmorillonite. The dispersion of clays results as the clay particles are pushed apart when the attractive forces holding the clay tactoids together are over come by repulsive forces causing the clay particles to fall apart or disperse.

The basic theory assumes that exchangeable cations exist as point charges, colloid surfaces are planar and infinite in extent, and surface charge is distributed uniformly over the entire colloid surface. These assumptions obviously do not describe the actual soil system. However, the theory seems to describe the system very well for soil colloids. Note that this system describes the pure colloid systems in aqueous solutions quite well, but probably does not come close to describing a real soil system that is not water saturated. This point of discussion will be addressed later in this review.

The Interactions between Salinity on Sodicity

The definition of a sodic soil in simple terms is a soil that has been adversely impacted physically by the presence of Na adsorbed to the cation exchange sites. The presence of Na in a soil promotes the slaking of aggregates and the dispersion of clay particles. At the same time, the impact of Na, as characterized by ESP or estimated by SAR, on the physical character of a soil is greatly dependent on the salinity of the soil. It is

impossible to estimate the impact of low or high SAR values on the physical state of a soil or spoil material without evaluating the EC or electrolyte concentration of the system (Shanmuganathan and Oades, 1983). Any attempt to set critical ESP or SAR values for land management would be arbitrary unless total cation concentration or EC is taken into consideration simultaneously (Sumner, et. al., 1998a). Research has shown that extremely high SAR values do not cause physical degradation of soil materials if the system also contains high levels of salts. This fact was first demonstrated by research done by Quirk and Schofield (1955). Their work showed that soil materials with an ESP of 40 maintained a stable permeability with an electrolyte concentration of about 30 mmol/L (about EC = 2.1 dS/m). McNeal and Coleman (1966) pointed out that typical arid land soils (having clay mineralogy dominated by 2:1 layer silicates with only moderate amount of montmorillonite) can tolerate ESP values of 15 or greater before serious reductions in hydraulic conductivity (K) occur, if the salt concentration of the percolating solution exceeds 3 mmol/L (0.2 dS/m). Gardner et al. (1959) came to the same conclusion dealing with unsaturated soils. Similar results were found by Amezketa and Aragues (1995) for calcareous soils from arid environments. These researchers also found that large reductions in K occurred in sand clay mixtures where steep concentration gradients developed between the micropores and macropores. They concluded that an "osmotic explosion" effect was responsible for the reduction in K. Although interesting, this finding was associated with an artificial system of sand mixed with clay and may not represent conditions occurring in soils.

Many studies have shown the relationship between clay mineralogy and the relationship between salinity and sodicity (Velasco-Molina, et al., 1971; Frenkel et al., 1978). In general, the research indicates that clay dispersion becomes very important for soil management decisions when electrolyte concentrations are low even at low SAR values. This was found for the 2:1 clay minerals and to a lesser degree in the 1:1 kaolinitic clays (Velasco-Molina, et al., 1971; Miller et al. 1990). Sumner et al. (1998a) provides a thorough discussion of the SAR/EC relationship in their publication titled "Sodic Soils: Distribution, Properties, Management, and Environmental Consequences."

As noted, the literature indicates that high sodium adsorption rations and/or low electrolyte concentrations can cause soil structural problems. However, we still do not have reliable criteria and standards for predicting a prior how these parameters quantitatively affect structural stability and K of soils (Rhoades, 1972). The mechanisms that cause these problems have been postulated to be: (1) swelling of soils; (2) clay dispersion and subsequent plugging of conducting pores by dispersed clay; and (3) failure or slaking of soil aggregates. However, many of the researchers have made diverging conclusions relative to the importance of these mechanisms. McNeal and Coleman (1966) and Jayawardane (1979) found that clay swelling was the dominant mechanism reducing K in sodic soils. Research by Rhoades and Ingvalson (1969), Frenkel et al. (1978), Pupisky and Shainberg (1979), Shainberg et al. (1981a) and Yousaf et al. (1987) showed that clay dispersion was the dominant mechanism responsible for the reduction in K. Other scientists such as Waldron and Constantin (1968; 1970) and Cass and Sumner (1982) concluded that the reduction in K was primarily related to the slaking of aggregates caused by internal swelling pressure or from shearing stresses.

As noted previously, the impact of sodicity on the physical properties of soils is dependent on the electrolyte concentration associated with the system. If salt is added to a dispersed clay in a suspension, the increased electrolyte concentration causes the clay particles to stick together forming flocs that settle. The minimum electrolyte concentration required to cause flocculation is referred to as the threshold electrolyte concentration (TEC) or flocculation value (FV). This value is dependent on counter-ion valency and clay type. The TEC values for a sodium-montmorillonite were shown to be about 12 mol/m^3 NaCl or 0.86 dS/m and 0.25 mol/m^3 $CaCl_2$ or 0.02 dS/m for calcium-montmorillonite (van Olphen, 1977). Corresponding values for sodium and calcium illites were found to be 40 mol/m^3 to 50 mol/m^3 NaCl and 0.25 mol/m^3, respectively (Arora and Coleman, 1979). These data show that a sodium montmorillonite can be maintained in a flocculated condition if the salt levels of the same ion (Na) are about 1 dS/m and sodium illites will tend to remain flocculated if salt levels with the same ion (Na) are about 3.6 dS/m. Sposito (1989) indicated through his discussion of the literature that a fully Na-saturated smectite suspension will flocculate if the electrolyte

concentration is > 8 mol/m^3 (0.6 dS/m) and a suspension of Na-illite will do the same if the electrolyte concentration reaches about 50 mol/m^3 (3.6 dS/m) His conclusion is that soil salinity tends to counteract the effect of exchangeable sodium on soil structure. The presence of divalent ions such as Ca would lower the TEC to lower salt concentrations.

Abu-Sharar et al. (1987) found some very interesting results with respect to aggregate slaking at various electrolyte concentrations. The stability of soil aggregates under various electrolyte/SAR combinations has provided some insight into the relationship between aggregate slaking and clay dispersion. SAR values of 0, 10, and 20 with corresponding electrolyte concentrations above 3.2, 15.9, and 19.4 mol/m^3 resulted in the slaking of aggregates as small as 5 μm with very little clay dispersion. Clay dispersion occurred only after electrolyte concentrations very reduced below these levels. They found that aggregate slaking preceded clay dispersion and that slaking occurred at electrolyte levels below the TEC. This finding is different from the previous findings that aggregates originated from the periphery of larger aggregates.

Goldberg and Forster (1990) found that the TEC for reference clays were much lower than those for soil clays indicating that studies evaluating reference clays to simulate the reactions expected in soils is not valid. Other factors such as organic matter content and the presence of Al- and Fe-oxide content may influence the dispersion of soil clays. Kaolinitic soils were also found to disperse under conditions of high ESP or SAR and low salt concentrations. However, such soils were usually impacted to a lesser degree as compared to the montmorillonitic and vermiculitic soils (Frenkel et al. 1978). Miller et al. (1990) found similar results for soils containing kaolinitic clays. This study showed that TEC for these highly weathered soils ranged from 1 to 8 mol/m^3 for Ca clays with SAR <1 and from 10 to 40 mol/m^3 for SAR 16.

The data show that if salinity is maintained at or above the TEC value for a specific material, the physical condition of the material will be maintained in a flocculated state no matter how high the SAR. The only caveat to this situation is that some materials that have high SAR and EC character can become dispersed at the surface if impacted with

water containing low levels of electrolytes from irrigation or rainfall. However, the dissolution of unstable minerals due to weathering often results in solution salt levels above the TEC and therefore swelling and/or dispersion are not experienced. This is especially true for the unstable minerals usually found in soils of the arid to sub arid regions of the country. In addition, mechanical forces resulting from raindrop impact, the flow of water at the surface or the use of farm equipment could cause clay dispersion. However, if measures are taken to eliminate these potential impacts to the system, the high SAR, low EC soil/spoil material will usually be maintained in good physical condition. One method of doing this is to treat the surface with an amendment such as gypsum. The application of gypsum at the surface would result in electrolyte concentrations from 5 to 15 mol Ca/m^3 would be sufficient to ensure flocculation of the soil clays, reducing dispersion-induced sealing and erosion. Another method of protecting the surface against the mechanical forces that can initiate slaking and dispersion is to cover such materials with topdressing material.

Misconceptions Associated with the Diagnosis of Sodicity Problems

An understanding of our current misconceptions relative to the diagnosis of problems associated with Na is easily found with a brief examination of the history of soil chemistry specifically with regard to sodic and saline interactions. As noted by Sumner et al. (1998a), several major issues have caused undo complexity to the understanding of the sodic/saline character of soils and other materials. One interesting observation is that in the United States and much of the rest of the world, a value of ESP > 15 was used as the level for separating sodic soils while in Australia and Asia a value of ESP > 6 was used as the separation value. This explains why North America has much less area determined to be sodic. Why did this discrepancy exist? Sumner et al. (1998a) have developed the argument that the quality of the water used during the experimentation is the most probable reason for the differences. Much of the early research done in the United States was accomplished at the U.S.D.A. Salinity Laboratory in Riverside California. The experiments were usually completed using tap water as the infiltrating solution. It happens that the tap water used in southern California contained relatively

high levels of electrolytes (varying from 4 to 10 mmol/L) while tap waters used in Australia and South Africa ranged from 0.4 to 0.7 mmol/L. Textural differences were also identified as having an impact on the separation level identified above, as the soils tested in the United States were generally sandy in texture as compared to those tested in Australia and Asia. In addition, weathering differences associated with the stability of the mineral fraction were also different between the soils found in California compared to those found in Australia. The arid soils studied in California were much more unstable than the more weathered soils studied in Australasia.

The major issue that has caused many misunderstandings in diagnosing sodic soils is the interaction between salinity and sodicity. The information promoted for use in the management of sodic soils by the USDA Salinity Laboratory during the 1960's and 1970's did not mention to any great extent interactions with salinity. The reason for this seemingly deletion was discussed by Sumner et al. (1998a) with regard to a personal communication these authors had with Dr. Bower the head of the Soil Salinity Laboratory at that time. Dr. Bower indicated the data collected by Quirk and Schofield that demonstrated the relationship between sodicity and salinity were associated with laboratory evaluations using disturbed samples. Under these conditions dispersion is often greater when compared to field samples. In addition, Dr. Bower indicated that the salt concentrations of the soil solution are too transient to use as a factor in a classification system for sodic soils. The relevancy of Dr. Bower's arguments does have justification. However, the use of ESP without consideration for the electrolyte levels found in the corresponding soil solutions has resulted in a great amount of confusion in the management of sodic soil conditions.

The discussion provided by Sumner et al. (1998a) addresses the fact that the USDA Soil Salinity Laboratory did not address this topic in their recommendations set forth during the late 1950's for the management of sodic soils even though they were well aware of it. In fact, the definition of sodic soils was published by Bower et al. (1958) without mention of electrolyte concentration in the definition. It was apparent at the time that people were well aware of the impact of salinity on the behavior of sodic conditions,

however apparently these scientists elected to down-play the relationships because of the apparent transient nature of salinity. Sumner et al. (1998a) noted that if the work of Quirk and Schofield (1955) had been adopted in the United States at that time, a much clearer understanding of sodicity would have resulted. Instead of using electrolyte concentration as an important component of the definition of sodic soils, Handbook 60 (Richards, 1954), which was published in 1954 and reprinted in 1969 without emphasizing the importance of salinity and its impact on sodicity, has been and continues to be used as an authority addressing salinity and sodicity issues. In more recent times, Hanson et al (2000??) have provided clarity to the issues dealing with salinity/sodicity relationships with a handbook that describes the relationships albeit for California conditions.

Model for Sodic Soil Behavior

Most research addressing soil sodicity has used a model evaluating the forces generated between colloidal clay minerals suspended in saturated systems to explain sodic soil behavior. Two major problems are apparent with this model. First, natural soils usually are complex heterogeneous aggregates made up of many clay types, silt and sand, intimately associated with inorganic and organic polymers. These aggregates do not resemble pure clay systems as was described by Abu-Sharar et al. (1987). In addition, the aggregates are not suspended in water. As a result, forces other than those that operate in saturated systems must be overcome during aggregate slaking and clay dispersion. Therefore, it is important to use a natural soil model that shows how sodicity and salinity impact the physical conditions of soil and/or spoil materials not suspended in aqueous solutions. The models described by Rengasamy and Sumner (1998) and Rengasamy and Olsson (1991) will be used to address this important concept. The fact is that aggregate slaking and clay dispersion decrease in an unsaturated system. This concept is further supported by the work of Russo and Bresler (1977) showing that unsaturated flow is not impacted compared to saturated flow at given soil ESP/EC levels. In other works, a soil will maintain more stability under unsaturated conditions than

saturated conditions. It happens that soils very rarely experience saturated conditions in the field environment.

The impact of ESP often estimated using SAR on the physical character of a soil is greatly dependent on the salinity of the soil. It is impossible to estimate the impact of low or high SAR values on the physical state of a soil or spoil material without knowing the EC or electrolyte concentration of the system (Shanmuganathan and Oades, 1983; Sumner et al., 1998a). Any attempt to set critical ESP or SAR values for land management would be arbitrary unless electrolyte levels are taken into consideration simultaneously (Sumner et al., 1998a). Research has shown that extremely high SAR values do not cause physical degradation of soil materials if the system also contains high levels of salts.

A system of classification based on soil behavior rather than on a threshold ESP or SAR level without consideration for electrolyte concentrations should be developed for land management purposes. As noted by Sumner et al. (1998a) it makes more sense to use the behavior of soils such as spontaneous and mechanical dispersibility as a basis for threshold limits rather than chemical composition of the soil. In fact, Rengasamy et al. (1991) described sodic soil behavior using dispersive potential in lieu of setting arbitrary limits of ESP (SAR) and EC. The definition of dispersive potential is the difference in osmotic pressures in the diffuse double layer between the critical flocculation concentration (CFC) of electrolyte and the existing soil solution concentration. This concept sounds good, however, a significant amount of work needs to be done to fully develop the concept to account for various field conditions including mechanical energy inputs.

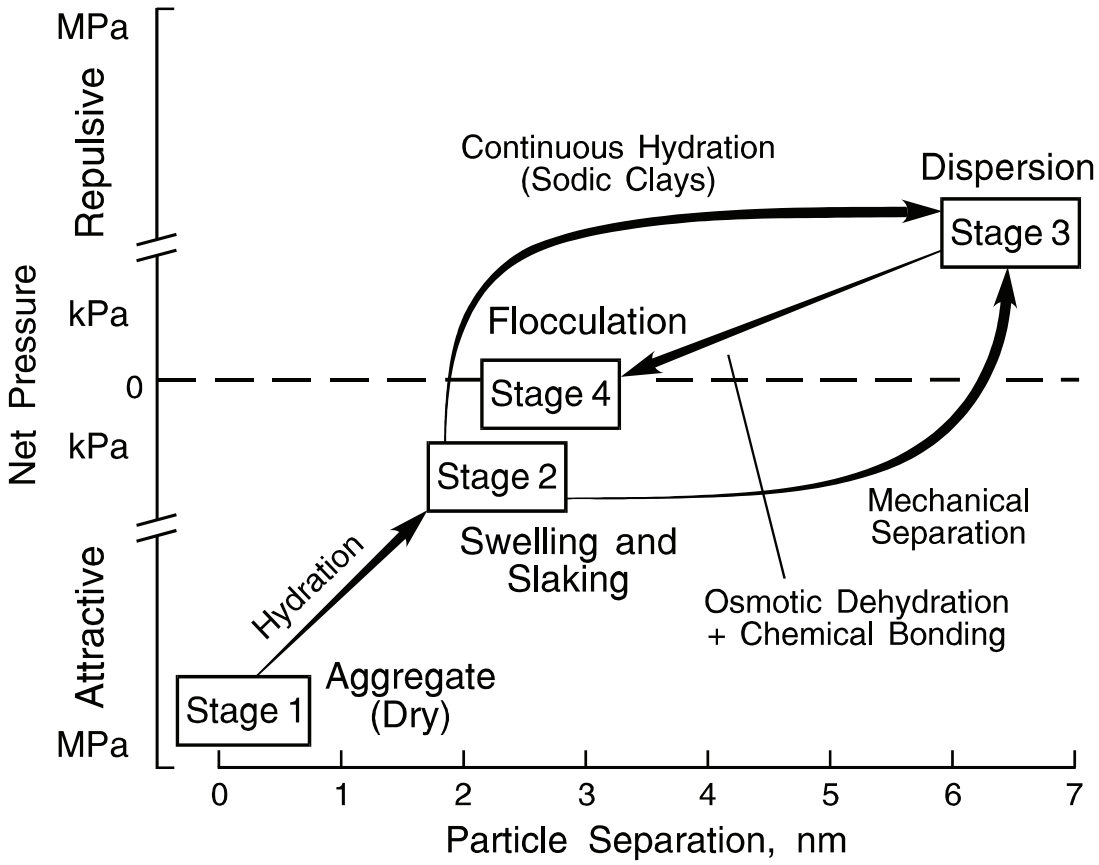
As noted in a previous section of this review, in the past, soil scientists have used a model involving electrical diffuse double layer theory to explain sodic soil behavior. This explanation was usually conducted using pure clay minerals in saturated systems. However, in natural systems, complex clay systems are bound together into aggregates with silt and sand particles by inorganic and organic compounds and are usually not

suspended in water. The slaking of aggregates and the dispersion of clays requires forces other than those that operate in colloidal clay suspensions. Rengasamy and Sumner (1998) have developed a model that describes the processes that take place during the wetting of a dry soil aggregate. Their model will be presented in this paper as a realistic approach describing the influences of sodicity and salinity on the physical nature of natural soil systems.

The model consists of four (4) stages as shown in Figure 1. Dry soil aggregates are held together by inorganic and organic compounds and associated bonds that produce very strong attractive forces. The forces involved include Lifshitz-van der Waals forces, ionic bonds, hydrogen bonds, hydrophobic interactions, and hard-soft acid-base reactions. As dry aggregates are wetted, solvation or hydration forces become important. The stability of aggregates, and hence the pore systems, depends upon attractive and repulsive forces resulting from intermolecular and electrostatic interactions between soil solution and soil particles (Rengasamy and Olsson, 1991). When an aggregate is placed in contact with water, the interactive forces lower the potential energy of water molecules; thus releasing energy for structural changes and as heat. Aggregate slaking, clay swelling, and clay dispersion are the major mechanisms that occur during these transformations.

Thus, as an aggregate is hydrated, the initial attractive forces between clay particles decrease. As hydration increases, the distance between particles increases. In general, if the clay particles are saturated with Ca or Mg, additional hydration does not increase the inter-particle distance beyond a few nanometers, resulting in a net force that is attractive and the aggregates are held together by hydrated cations. The swelling resulting from these reactions will occur even with high electrolyte concentrations. Slade and Quirk (1991) found that the change in separation to 1.5 nm is not affected by electrolyte solution (crystalline swelling) and that the separation from 1.5 to 1.9 nm is an osmotic process that includes electrolyte concentrations, charge density, and the location of the charge in the clay minerals. If the clays are saturated by monovalent cations such as Na, the clay particles are separated beyond 7 nm dependent on the ionic strength and the existence of soft-hard acid-base reactions. This results in clay dispersion shown as Stage

3 in Figure 1. Stage 3 can also be reached when a source of mechanical energy is applied to the clay domains that have undergone limited separation. Mechanical energy resulting



Source: P. Rengasamy and M.E. Sumner, 1998

Figure 1. Stages that take place during the wetting of a dry aggregate.

from raindrop impact and surface water flow can overcome the attractive forces causing the clay domains to separate or disperse. Once the system is completely dispersed, the electrostatic repulsive forces as predicted by the electrical double layer theory become important to the physical nature of the system. A dispersed clay system will become flocculated as the difference in the electrical potentials in the inner and outer solutions approach zero and as the clay particles approach each other. The repulsive pressure is balanced by osmotic pressure, and the van der Waals attractive forces become dominate. At this point, the clays become flocculated as identified in Figure 1 as Stage 4 of the model.

Parameters Associated with Sodic Behavior in Natural Soil Systems

The basic problem associated with sodic soils is the development of very poor physical conditions that result in imbalances between water and air regimes that greatly impact the development of vegetation. The imbalance in air and water regimes results from poor infiltration and transmission of water and air in the soil, which usually causes either wet or dry conditions for much of the time. In addition, the instability of soil structure often causes soil crusting, which results in erosion causing poor soil conditions and water pollution. The presence of relatively high levels of electrolytes will promote the maintenance of good physical conditions that maintain good plant growth. The impact of various conditions including electrolyte concentration, pH, water content, soil weathering and organic matter on the basic principals of the chemistry of sodicity will be briefly presented in this section.

Impact of Sodicity/Salinity on Hydraulic Conductivity (K) and Infiltration Rate

The impact of sodicity on the hydraulic properties of soils is dependent on the electrolyte concentration associated with the system (Malik et al., 1992; Lima et al., 1990; Mace and Amrhein, 2001; McNeal et al., 1968; Quirk and Shofield, 1955; Frenkel et al., 1978; Shainberg et al., 1981a; Abu-Sharar et al., 1987; Curtin et al., 1994a; Curtin et al., 1994b; Chiang et al., 1987). In general, the greater the SAR or ESP associated with a soil and the lower the EC, the greater for the potential for aggregate slaking, soil swelling and clay dispersion, which will reduce the K of a soil. As noted previously in this review (Section titled - The Interactions between Salinity on Sodicity), researchers have proposed different views on the primary mechanism responsible for the degradation of the physical structure of soils, which are responsible for changes in K. Sumner (1993) attributed the primary reduction in K to pore plugging due to aggregate slaking and clay dispersion. This author also suggested that clay swelling only impacted K at relatively high ESP values (ESP> 15%). However, high electrolyte concentrations either in the form of amendment applications to the surface or high salt levels of applied water would

reduce the impacts. The fact is that all three mechanisms occur in a soil system with varying impact from each dependent on the characteristics of the soil. Mace and Amrhein (2001) voiced this opinion in their study that showed substantial reduction in hydraulic conductivity with increasing SAR and decreasing EC. Results of their study using water with SAR values of 5 and 8 showed that the three mechanisms interact with each other. Clay swelling tends to reduce the size of the large pores enhancing the amount of pore clogging due to aggregate slaking and clay dispersion. The change in water holding capacity at –22 kPa suction was a good indication of the changes in pore geometry. As the electrolyte concentration of the water applied to the soils decreased the quantity of dispersed clay present in the leachate increased. This study demonstrated that both clay dispersion and clay swelling had major roles in the structural changes and the resulting decreasing K of the soil materials. The use of gypsum as an amendment was shown to reduce or eliminate clay dispersion due to the ionic strength effect. With subsequent leaching the EC of the solution in the soil materials decreased (less gypsum) and swelling again increased. The researchers found that the soils originally leached with the higher SAR water had the lowest HC values and the most internal swelling after reclamation, suggesting that pore plugging occurring initially resulted in a decreased HC that is largely not reversible. This reaction may be associated with the fact that about 23% of the exchangeable Na remained in the soil after reclamation using gypsum and H_2SO_4. This research effort demonstrates that irrigation water with SAR values of 5 and 8 result in both temporary and longterm reductions in K dependent on the electrolyte concentrations in the water/soil system.

Hydraulic conductivity (K) is less sensitive to sodic conditions as compared to infiltration rate (IR). The primary factor responsible for these differences is the influence of mechanical energy resulting from the impact of raindrops at the surface. This mechanical energy promotes the disintegration of aggregates and the dispersion of clays resulting in the formation of a structural crust. Crusts are formed as a result of the physical disintegration of aggregates, while compaction is caused by the impact of the water droplets and chemical dispersion of clays near the surface. Smectitic soils are very sensitive to reduced IR even at very low ESP levels (ESP<3). An important factor in the

degradation of IR is that rainfall contains very low levels of salts. Therefore, rainfall is responsible for leaching electrolytes from the surface, leaving the surface materials more susceptible to dispersion. K is much less susceptible to degradation, except at the surface, mainly because of the reduced impact of mechanical forces and the electrolyte levels that often occur (Shainberg et al., 1992). The mineral phase associated with arid land materials, usually readily weathers, providing electrolytes to the system, enhancing its ability to maintain structure.

This discussion supports the fact that suitable topdressing placed over sodic materials will alleviate the development of poor physical conditions in the sodic materials. The surface layer of material (topdressing) eliminates the mechanical energy input from raindrop impact and/or surface water flow on the sodic material and the low electrolyte rainwater that would promote aggregate slaking and clay dispersion. In addition, weathering of the surface layer and the underlying sodic materials result in increased electrolyte levels in solution. This prevents dispersion and the Ca^{+2} present in the solution therefore tends to self-remediate the sodic condition.

The Effect of Exchangeable Magnesium on the Physical Properties of Soils

Richards (1954) grouped Ca and Mg together as similar ions beneficial in developing and maintaining soil structure. However, evidence now exists that shows that Mg can cause the deterioration of soil structure under certain conditions. Studies have show that Na-Mg soils developed lower K characteristics than Na-Ca soils under similar conditions (McNeal et al., 1968). Research has also demonstrated that Mg can impact K through direct effects (specific effects) and through the ability of Mg^{+2} to cause higher exchangeable Na^{+1} levels to develop in the soils as compared to Ca^{+2} (Chi et al., 1977; Emerson and Chi, 1977).

Alperocitch et al. (1981) showed that well-weathered soils that do not contain $CaCO_3$, are impacted by the specific effect of Mg^{+2}. Reduction in K and enhanced clay dispersion resulted when Na/Mg soils were leached with distilled water (simulated rain water). The

theory behind this finding was that clays saturated with Mg^{+2} are chemically more stable and do not release electrolytes into solution. As a result, the lack of weathering products will allow the system to disperse more easily when leached with water that contains low concentrations of electrolytes. In the same study, exchangeable Mg^{+2} was found not to a specific effect on the K and clay dispersion in calcareous soils. In these soils, Mg^{+2} enhances the dissolution of $CaCO_3$ increasing the solution electrolyte concentrations preventing the dispersion of clays and the reduction of K.

Weathering

Dispersion is important in reducing the permeability of sodic soils, however, no adequate hypothesis is available that explains why some soils are more susceptible to clay dispersion than others when leached with distilled water. This is an important problem since the irrigation season is followed by the rainy season or snowmelt. Salt is usually built up in the soil during the irrigation season, thus the EC is high enough to prevent deterioration of the physical properties. However, when these soils are hit with rainwater or spring runoff, the salts are leached from the surface portion of the soil and the physical conditions at the surface are very susceptible to degradation.

The TEC of the Ca-montmorillonite clays has been reported by van Olphen (1977) to be 0.17 to 0.23 meq/L and that the TEC for Na-montmorillonite is 12 to 16 meq/L. Oster et al. (1980) found that the TEC of montmorillonitic clays saturated with mixtures of two cations increase rapidly with the initial increments of exchangeable Na to values of 3 and 6 meq/L for ESP values of 10 and 20, respectively. It is very apparent that soils capable of releasing salt through weathering processes at rates sufficient to maintain salt levels above the TEC values for specific clay materials should maintain their physical condition. These soils will not disperse and their hydraulic conductivity should not be affected significantly by rainfall or spring runoff. Rhoades et al. (1968) showed that arid land soils increased the levels of Ca and Mg by 3 to 5 meq/L and determined that the dissolution of plagioclase, feldspars, hornblende, and other common mafic minerals accounted for the release.

Oster and Shainberg (1979) in their evaluation of the dissolution of three arid zone soils observed that the release of Ca^{+2}, Mg^{+2} and K^{+1} from silicate minerals and the hydrolysis of exchangeable Na^{+1} and Ca^{+2} varied greatly. These researchers demonstrated that when salt-free soils were mixed with distilled water at a 1:5 ratio, the release of salts was fast enough to increase solution concentrations from 0.5 to 4.0 meq/L within 4 hours.

Shainberg et al. (1981a) showed that low salt concentrations (2 to 3 meq/L) in leaching water prevented clay dispersion and reductions in K for ESP values below 30. These observations lead to the idea that mineral dissolution is a major factor causing differences in susceptibility to sodic conditions when leached with low electrolyte water. These scientists hypothesized that sodic soils containing minerals that readily release soluble electrolytes such as $CaCO_3$ and minerals such as plagioclase, feldspars and hornblende will provide electrolytes levels high enough to prevent dispersion if leached with distilled water, which simulates rainfall and runoff. Shainberg et al. (1981b) showed that soils containing minerals that readily release soluble electrolytes will not disperse when leached with distilled water (simulated rainwater). This study was conducted using three soils; the Gila soil containing $CaCO_3$ with montmorillonite and mica, the Pachappa soil is a relatively unweathered soil containing montmorillonite and mica and a third, the Fallbrook soil, a soil characterized by increased weathering that contained montmorillonite and kaolinite clays. The salt release rates for these soils were initially greatest for the Gila soil. However, after about 100 hours the salt levels for the Gila and Pachappa soils were very similar. The levels of salts found in the Fallbrook were much lower since this soil had been weathered and was quite stable. The Fallbrook soil was found to be the most sensitive to sodicity impacts on clay dispersion and resulting impacts on K even though it contains sesquioxides and kaolinite in its clay fraction. The differences in capacity to release salts and to disperse are undoubtedly important relative to the formation of crusts under rainfall conditions. This is very important for materials that have moderate ESP levels that are able to maintain physical conditions through the soil profile but are susceptible to dispersion near the surface. Electrolytes resulting from weathering, especially soils in arid or semiarid environments, can maintain the physical

structure of the surface materials. Rhoades et al. (1968) found similar results studying arid soils treated with irrigation water characterized by SAR values varying from 5 to 20. The total salt content of the displaced soil solutions was much greater than the salt levels applied in the irrigation water. The effluent solutions contained from 3 to 5 meq/L higher salt levels than present in the irrigation water. Much of the increase in salt levels resulted from weathering of the soil materials, which released significant amounts of Ca and Mg and HCO_3^{-1} ions. The net effect of the weathering processes was a 30 to 90% reduction in the SAR of the soil solutions. SAR reductions were largest for the waters containing lower salt concentrations, but were significant for waters containing as much as 15 to 20 meq/L of salt. Evaluations of the mineral fraction of these soils showed that unstable Ca-silicates, Mg-silicates such as plagioclase, feldspars, hornblende along with some common mafic minerals in the various size fractions of the soil were the contributing components to the soil solutions. These researchers determined that the weathering phenomenon reduces the Na hazard and therefore should be considered in water quality evaluations. These findings imply that irrigation water containing relatively high levels of Na may be used successfully for irrigation of soils that have similar characteristics to those evaluated in this study.

In view of the above discussion concerning mineral weathering, Rhoades (1968) developed a modification to the Na hazard equation developed by Bower et al. (1963) for HCO_3^{-1} containing irrigation waters. This modification was based on the results of research that evaluated the impact that mineral weathering had on soils containing lime. The evaluation was complicated by the fact that the presence of Ca^{+2} and HCO_3^{-1} in solution would tend to precipitate at the same time mineral weathering is releasing Ca and Mg into the solution at relatively high rates. This study showed that the increases in Ca + Mg content produced by mineral weathering processes were greater than the decreases produced by lime precipitation processes. These data show that the evaluation of the Na hazard of HCO_3^{-1} containing irrigation water based on the assumption of $CaCO_3$ precipitation is inaccurate at least for soil water contents near saturation. It also demonstrates that mineral weathering must be considered in evaluating the Na hazard of irrigation waters in semiarid and arid soils.

Another important aspect of weathering is associated with the influence of CO_2 on the weathering of soils containing $CaCO_3$. The presence of CO_2 enhances the dissolution of $CaCO_3$ significantly (Nadler, et al., 1996). As a result, the development of a good plant cover on a soil containing calcite will result in significant levels of Ca in solution and on the exchange sites. Nadler et al. (1996) determined that solutions containing CO_2 will dissolve larger amounts of $CaCO_3$ as the contact time increases. As a result, topdressing materials overlying sodic spoil materials would be expected to provide significant levels of Ca to the soil solution, which could easily leach to lower levels in the profile reducing the ESP values of the impacted spoil materials.

Unsaturated Flow

As is apparent from the literature, most investigations concerning the effect of salts on the transport of water and solutes in soil have been described under steady-state saturated conditions. However, in field conditions the transport of solutes and water almost always occurs under unsaturated flow conditions. Information is limited on the impact of sodic/saline conditions on the hydraulic properties of soils however several very good studies have been completed. Russo and Bresler (1977) found that low soil water contents compensated for the negative effects of high ESP and low salt levels. This work was done in a laboratory study using the Gilat loam soil with various combinations of salt concentrations, compositions, and soil water contents. This study showed that maintaining the soil under unsaturated conditions allows a higher ratio of Na to Ca for any given EC without impacting the physical condition of the soil. These relationships are directly dependent on the degree of soil saturation. Since low water contents result in low repulsion forces, unsaturated systems would be expected to have higher attractive forces between clays and soil particles as compared to saturated systems. Rengasamy and Sumner (1998) indicated that spontaneous dispersion takes place when sodic clay is impacted with water of very low electrolyte concentration. However, soil water content below saturation results in limited swelling and incomplete separation of clay particles with the interparticle distance depending upon the water content. Therefore, aggregate

slaking and clay dispersion in unsaturated systems would be limited as compared to saturated systems for specific SAR/EC conditions. Russo and Bresler (1977) demonstrated this fact in their study evaluating K with regard to cationic ratio $(Na^{+1}/(Ca^{+2})^{1/2}$ (R), electrolyte concentrations (C), and volumetric water content (θ). This study showed that under specific combinations of these variables, the value of the cationic ratio can be estimated for a given K. For example, under saturated conditions with C = 0.02 N (approximate irrigation field soil) it is possible to maintain $K \geq 0.5$ cm/s as long as $R \leq 14$. Under the same conditions (C and K), but in unsaturated soils the corresponding value for R is 20. This study shows that water of poorer quality (higher sodicity) can be applied when unsaturated conditions are maintained during irrigation. However, soils impacted by increased Na levels and low salinity levels will be negatively affected whether under saturated or unsaturated conditions. In a similar study, Malik et al. (1992) found reductions in unsaturated flow when water containing high levels of Na was applied to montmorillonitic soil samples. The reductions in flow were attributed to changes in microstructure. These studies demonstrate that the negative effect of high SAR and low solution electrolyte levels decreases in unsaturated soils.

Menneer et al. (2001) showed that saturated and unsaturated K measurements associated with Na impacted soils did not change until a pressure head of –120 mm was applied. These results indicated that some structural deterioration in the soil matrix resulted, however, the macropore flow at high moisture contents in the field were sufficient to overcome the effects. Weinhold and Trooien (1998) found similar results in a study of several sulfatic soils located in the semiarid Northern Great Plains. Tension infiltrometers were used to compare infiltration rates at various applied tensions. Infiltration into fine textured soils was found to be greatly impacted

Crust Formation

Soil surface crusting has been discussed in the literature for a long time however, its serious consequences have not been fully appreciated. The influence of soil crusts on soils and eventually on vegetation and environment is of great importance. Processes

beginning with soil crust formation proceed to water and soil loss through erosion, followed by reduced plant cover and reduced yields. Other influences such as increased pressure from animal and human use intensify the impacts.

The susceptibility of soils to rainfall induced surface crusting is dependent on a combination of soil, physical, chemical and biological processes. The climate and soil conditions existing at a site will reflect the tendency for the formation of crusts. Flocculation and dispersion are important in determining the physical behavior of the colloidal fraction of soils and have a major bearing on the physical properties, which soils exhibit. There is strong evidence that dispersion of clay at the soil surface under the influence of impacting raindrops plays a major role in the formation of crusts. The formation of soil crusts begins with the breakdown of surface clods and aggregates by physical and chemical dispersive forces. The physical processes are controlled by the magnitude of the mechanical forces produced by water flow and rainfall impact and by air escaping from soil aggregates in relation to the internal resistance of the aggregates. The extent of chemical dispersion is determined by the chemistry of the pore water and the eroding or runoff water.

Soil crusting forms as a result of either structural deterioration as discussed previously or deposition of layers at the soil surface. Structural deterioration is usually associated with the impact of raindrops. The energy released from the impact of raindrops changes a structurally stable soil surface into a nonstructured reorientation of soil particles. Depositional crusts are formed by the deposition of particles on the surface from water. The formation of depositional crusts is also related to factors influencing soil erosion. The more soil erosion that occurs results in the formation of more extensive depositional crusting. Warrington et al. (1989) observed that erosion from an unstable and dispersive soil depended on water quality. This study showed that a soil treated with gypsum experienced twice the soil loss when the slope angle changed from 5 to 25% while the untreated control plot had a sevenfold increase in erosion when treated with distilled water as an approximation for rainfall for the 5 to 25% slope angle change. Soil dispersion has been implicated in reduced permeability and crusting of soils by a number

of researchers (Agassi et al., 1981; Kazman et al., 1983; Shainberg and Letey, 1984; Shainberg and Singer, 1986; Ben-Hur et al., 1985). The permeability of a soil to water depends on the exchangeable sodium percentage of the soil and on the salt concentration of the percolating solution. Permeability tends to decrease with increasing ESP and decreasing salt concentration (Quirk and Schofield, 1955, McNeal et al., 1968). Further more, soil K can be maintained at a high level as long as the EC of the infiltrating water is above a critical threshold level termed in this report the TEC (Quirk and Schofield, 1955). Work completed by Shainberg et al. (1981b) showed that relatively unweathered soils released high levels of electrolytes into solution due to mineral dissolution reducing clay dispersion and the resulting crust formation.

The Influence of pH on Sodicity

The role of pH on clay mineral dispersion is an area not often used to make management decisions relative to sodic soils. The flocculation behavior of clay mineral has been found to depend on pH (Arora and Coleman, 1979; Suarez et al., 1984; Swartzen-Allen and Matijevic, 1974). Swartzen-Allen and Matijevic (1974) found that the TEC for Na-montmorillonite in a $NaNO_3$ solution increased with pH from 1 meq/L at pH 3.8 to 10 meq/L at pH 10. These authors also found an increase in TEC of kaolinite from 2 meq/L at pH 4.1 to 40 meq/L at pH 10.1. Suarez et al. (1984) found that the K of soils containing predominantly kaolinite and montmorillonite decreased with changes in pH from 6 to 9. These authors suggested that the pH effect is due to the presence of variable charge associated with the clays and organic matter. Goldberg and Glaubig (1987) found that TEC's are much more pH dependent for kaolinitic clays compared to montmorillonites. These authors also showed that 50:50 mixtures of kaolinite with montmorillonite were not significantly impacted by kaolinite. The presence of kaolinite was expected to decreased the TEC. However, since the charge density of kaolinite per gram is much less that the montmorillonite it did not occur. This study also showed that small amounts of montmorillonite can disperse kaolinite. In addition, they found that small amounts of noncrystalline Al or Fe oxides improve the flocculation of clay systems.

This work also showed that Al oxide is more effective in promoting flocculation over a larger pH range compared to the Fe oxide .

The Relationships between Organic Matter and Physical Structure

The impact of Na on the nature of organic matter is an interesting and complex interaction. Sodicity influences plant production and the amount of organic matter available to influence the soil, and the loss of organic matter to mineralization, erosion and leaching. The amount of organic matter that a soil usually contains is directly dependent on the growth of plants occupying such soils. Sodic conditions usually have a direct impact on plant growth. The impact on sodium structure and nutrient availability has the greatest impact on productivity. Plant growth is limited by the high soil strengths, which directly impact seedling emergence and root penetration. However, organic matter present in the system will impact the physical condition of the soil materials.

The role of the various components of organic matter in the stabilization of soil structure varies with scales of structure. Macroaggregates are largely stabilized by plant roots, mycorrhizal hyphae and saprophytic fungal hyphae. These binding agents are transient in that these components are only present when plants are growing supplying fresh organic matter to the system continuously. At smaller scales, colloidal organomineral complexes are important in the stabilization of microaggregates with a variety of mechanisms that are more persistent in nature.

As noted previously, the bonding agents for the macroaggregates are usually transient in nature. The bonding mechanisms result from the decomposition of the light fraction and the influence that plant roots have on the rhizosphere. Living roots slough off plant cells and exude mucilages consisting of polysaccharides. Microorganisms and fauna colonize the area in the surrounding soil. These organisms metabolize the more readily decomposable materials and excrete various organic compounds and mucilages. The plant roots and complex organic materials, surrounded by microbial colonies and resulting mucilages become the core for stabile aggregation. As the readily

decomposable substrates are decomposed, the aggregates become less stable, and the clay particles become more easily detached. Finally, when the readily decomposable materials are decomposed, only the resistant organic materials with no inorganic particles attached are present.

The more persistent organic matter bonding agents are the polyanionic colloidal material referred to as humic substances. This material consists of plant remains and microbial materials that are persistent in soils due to their chemical recalcitrance and association with inorganic materials. The formation of the stable structure results from the interaction of these molecules with negatively charged inorganic colloids via cation bridges. These linkages are relatively persistent in the presence of polyvalent cations resulting a resistance to microbial decomposition, chemical extraction and physical disintegration. At the same time, humic materials can also result in a tendency to promote clay dispersion. These anionic materials can easily sorb to clay surfaces by attraction to the positive charged materials (usually oxides and clay edges). This results in a reduction of the point of zero charge (PZC) of the soil raising the TEC and the tendency for dispersion at a given pH. Also, anionic organics sorb to negatively charged inorganic colloids via cation bridges as noted previously. In this case, the high CEC associated with the organic matter enhances the stability of the soil structure. However, the high negative charge densities associated with the presence of anionic organic matter have a tendency to increase clay dispersion. Barzegar et al. (1997) showed a similar characteristic of soils when they measured clay dispersion with varying degrees of mechanical disturbance. The addition of organic matter to a soil in the form of pea straw after a 7-day incubation period had little or a negative effect on spontaneously dispersible clay but had a positive effect on mechanically dispersible clays. They attributed this difference to the organic matter having stabilizing and dispersing components and that the stabilizing components were susceptible to disturbance and the dispersive components were not. The dispersive components were possibly anionic materials that enhance dispersion by complexing polyvalent cations and increasing the negative charge on colloids. This study also evaluated the impact of adding organic matter on the development of soil aggregates in sodic materials. This study showed that the addition of

organic materials to sodic soils could be expected to improve their structural stability without prior treatment to remove sodium from the system. As usual they found that minimal disturbance after the application of organic matter further reduced the tendency for clay to disperse. Scanning electron microscopy showed that fungal hyphae were involved in the stabilization process forming aggregates no matter the clay type or the sodicity of the material.

Another study by Nelson et al. (1999) looked at the correlation between dispersibility and organic matter content. This study showed that the dispersibility of clay fractions was a function of the amount and type of organic matter, CEC, selectivity for cations and particle size. The less dispersive clay had smaller particle size and higher CEC than easily dispersed clay, which may indicate that high surface area and charge enhance interactions between particles decreasing dispersion. In general, easily dispersed clay also had less organic C compared to more stabile clays. The organic matter associated with easily dispersed clay contained a high proportion of amino acids and proteins while the more stable clays contained a high proportion of aliphatic materials in the topsoils and carbohydrate in the subsoil. These data suggest that the amino acid and proteins acted as dispersants and the aliphatic and carbohydrate organic materials acted as water stable glues holding the clays together. This work shows that the interactions between clay and organic matter have an important influence on clay dispersion in sodic and non-sodic soils.

Upward Sodium Migration

A major issue associated with mined land reclamation is whether or not sodium will migrate from a sodic spoil material into the overlying topsoil or topdressing material. A number of studies were undertaken in the Northern Great Plains (semiarid climate) during the 1970's using wedge plots to determine how much topsoil was needed over sodic materials to assure successful reclamation. These plots were also used by various researchers to assess the movement of Na from the spoil into the overlying topsoil material. Dollhopf et al. (1980) found no upward movement of Na in soils constructed 2

years prior with a sandy loam topsoil (70-cm in depth) overlying a spoil material characterized by kaolinitic clay mineralogy. These findings differ from those found in reconstructed soil profiles at sites in the northern Great Plains by Bailey (2001), which showed an accumulation of Na in the 15 cm of topdressing material directly above the spoil interface 16 years after soil profile construction. The constructed profiles consisted of 15 cm of a clay loam topsoil over either 0.55 m or 0.95 meters of subsoil above the sodic spoil material. These studies were associated with topsoil materials overlying spodic spoils containing smectitic clays. The researchers found that there tended to be less influence from upward Na migration in the 0.95 m subsoil profile compared to the 0.55 m subsoil profile. Similar findings were demonstrated by Merrill et al. (1983) using reconstructed profiles consisting of 30-cm of topsoil materials over sodic spoils (SAR = 25, EC = 3.3 dS/m) with about 30% smectitic clays (sandy clay loam texture) that had been reclaimed for 4 years. This study noted that the greatest upward migration of Na occurred during the first two years of the study. Barth and Martin (1984) found similar results in their study of wedge plots located in Wyoming, Montana and North Dakota where 152 cm of topsoil was placed over sodic spoil material. After 5 years, these sites showed Na migration from 7 to 14 cm into the topsoil overlying sodic spoil materials. These studies were all conducted where topsoil was placed over sodic spoil materials that were massive in structure and therefore represent similar conditons. The interesting result of these studies is that upward Na migration apparently reaches an "equilibrium" state of about 15 cm under the conditions studied. In addition, the upward diffusion of Na into the topsoil material is associated with an underlying spoil material that is characterized by a low saturated K, which promotes Na diffusion upward.

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APPENDIX L

RESULTS OF THE FAO-SES IRRIGATION SIMULATIONS FOR LAND ASSOCIATED WITH HORSE CREEK

Dave Magnuson Ranch – provided in the report.

Larry Shippy Ranch - Area LS6

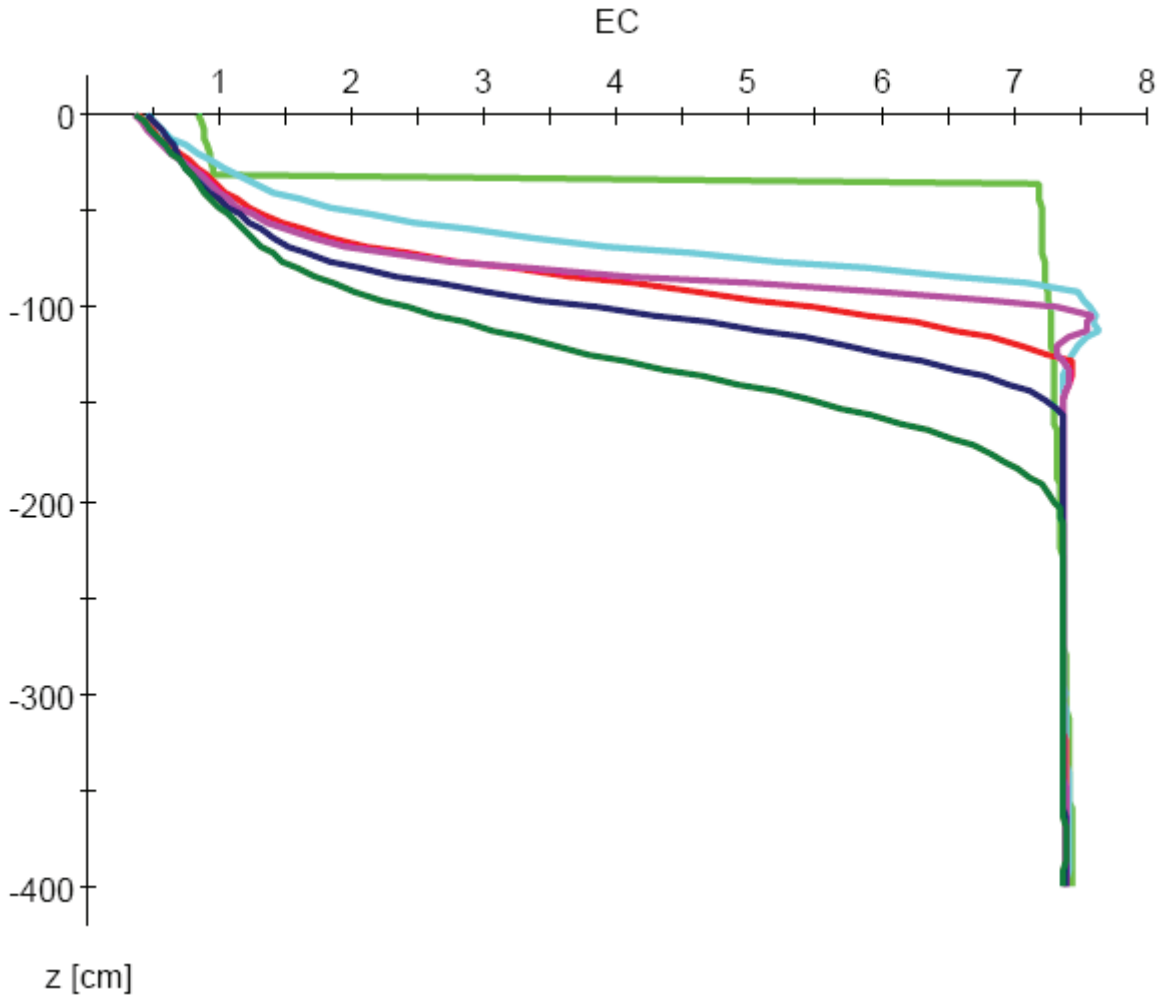


Figure 1. Salt concentrations (EC) by soil depth over the 5-year irrigation period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

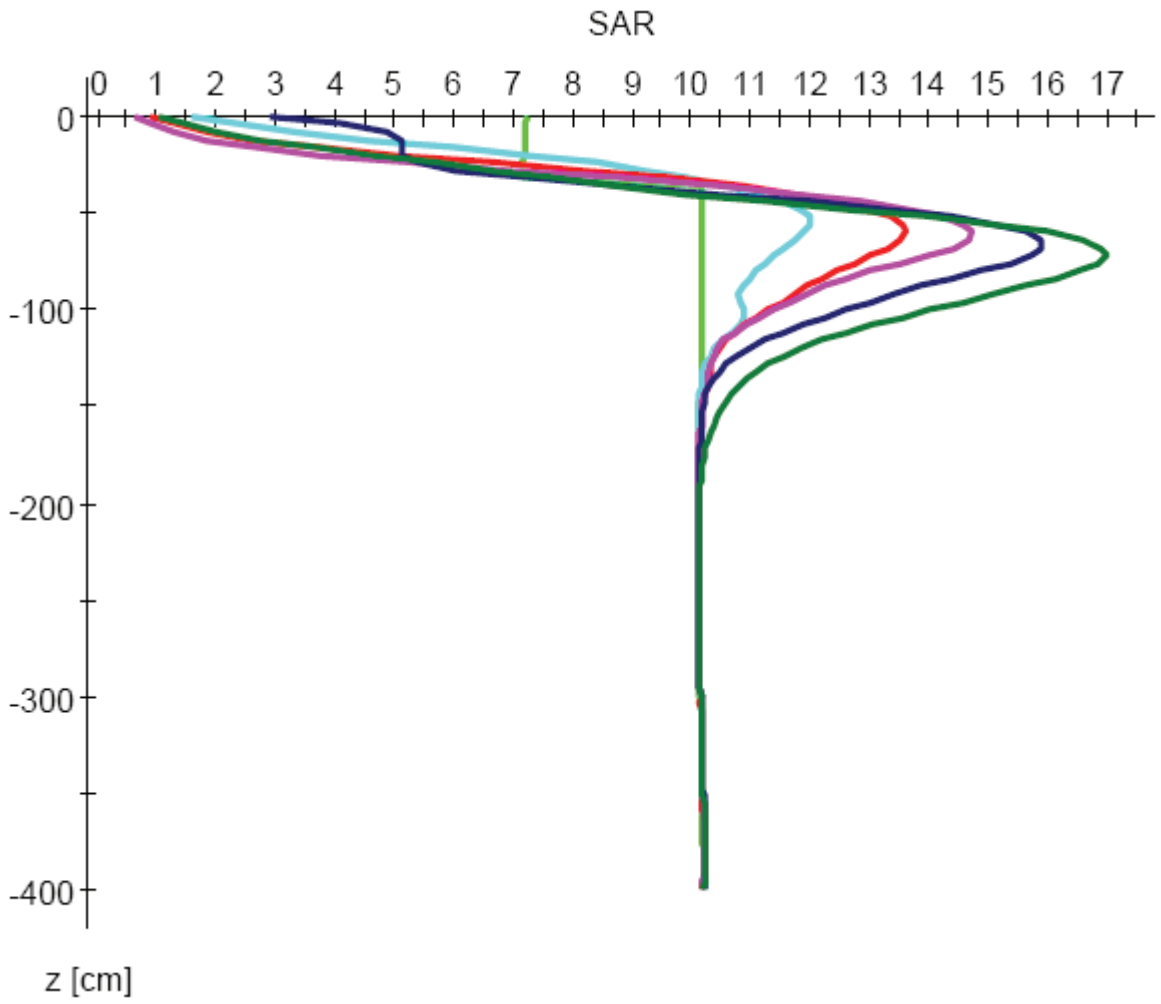


Figure 2. SAR by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

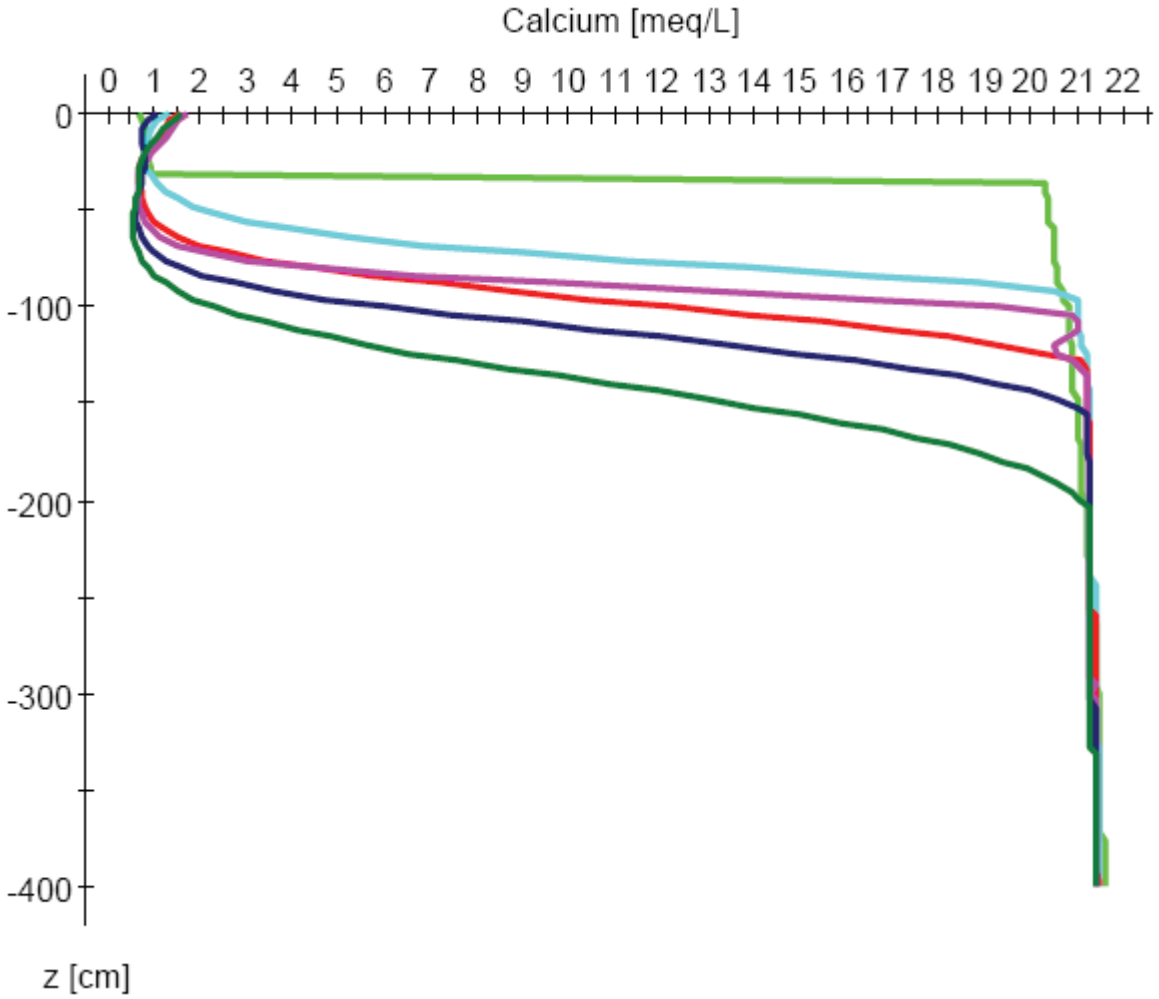


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

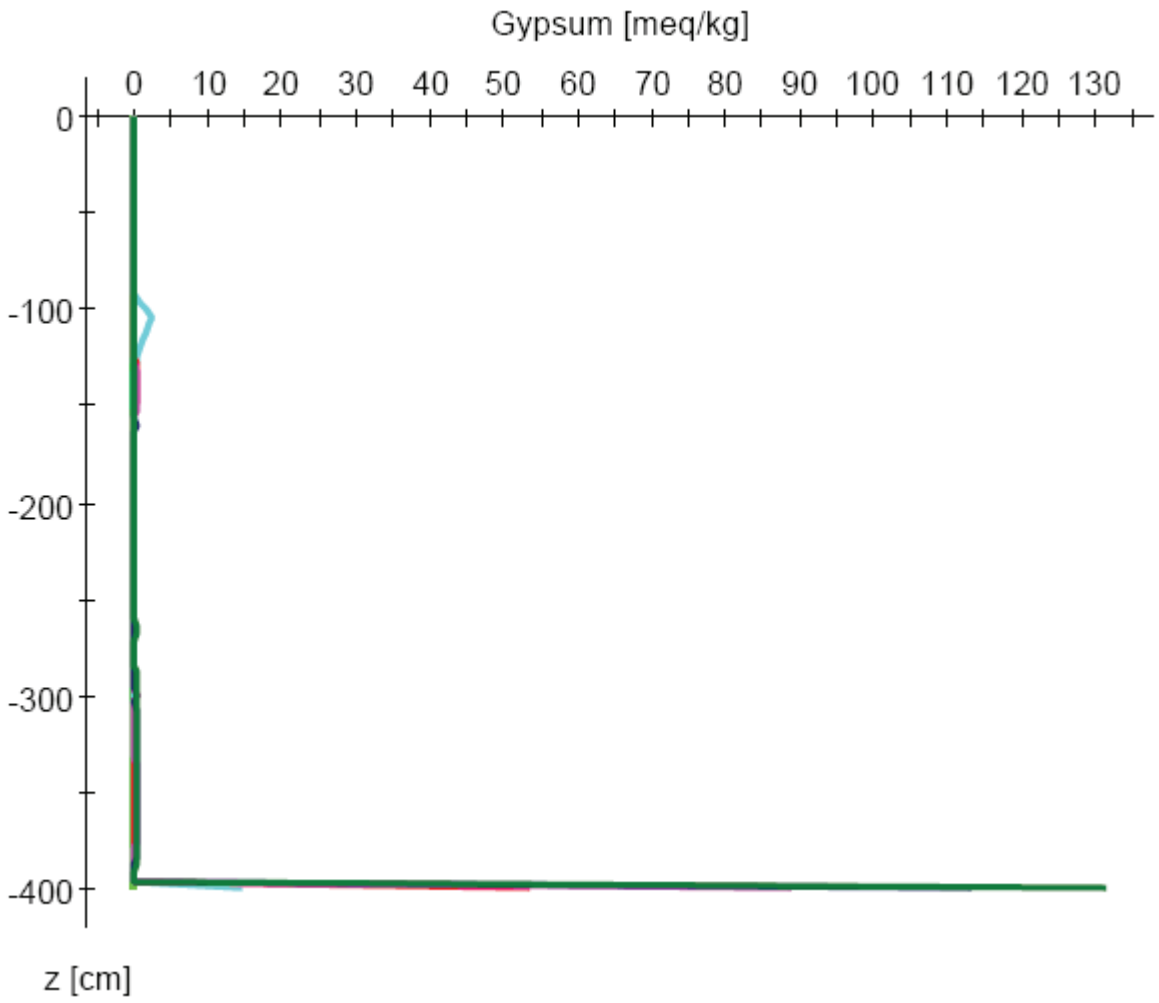


Figure 4. Gypsum levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

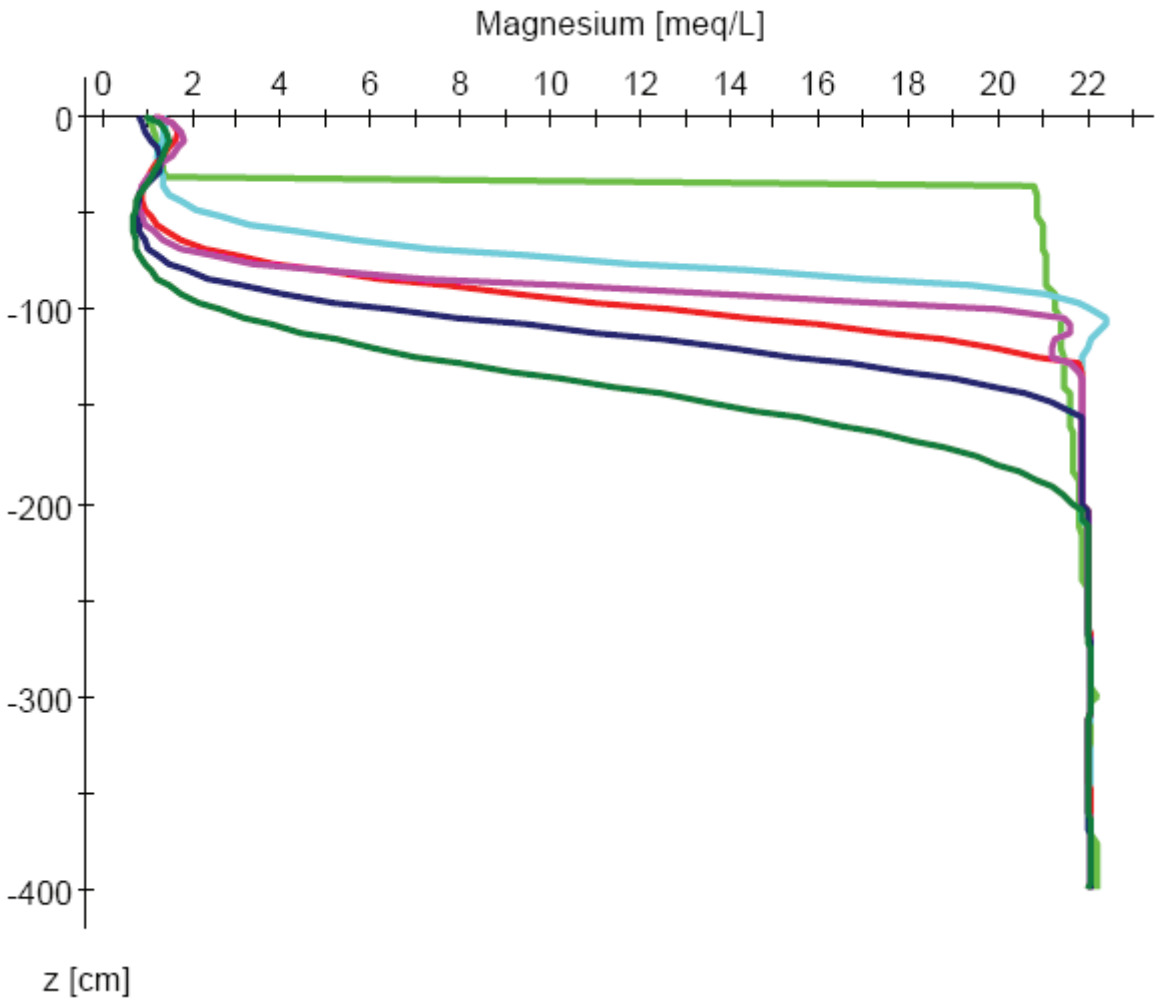


Figure 5. Solution magnesium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

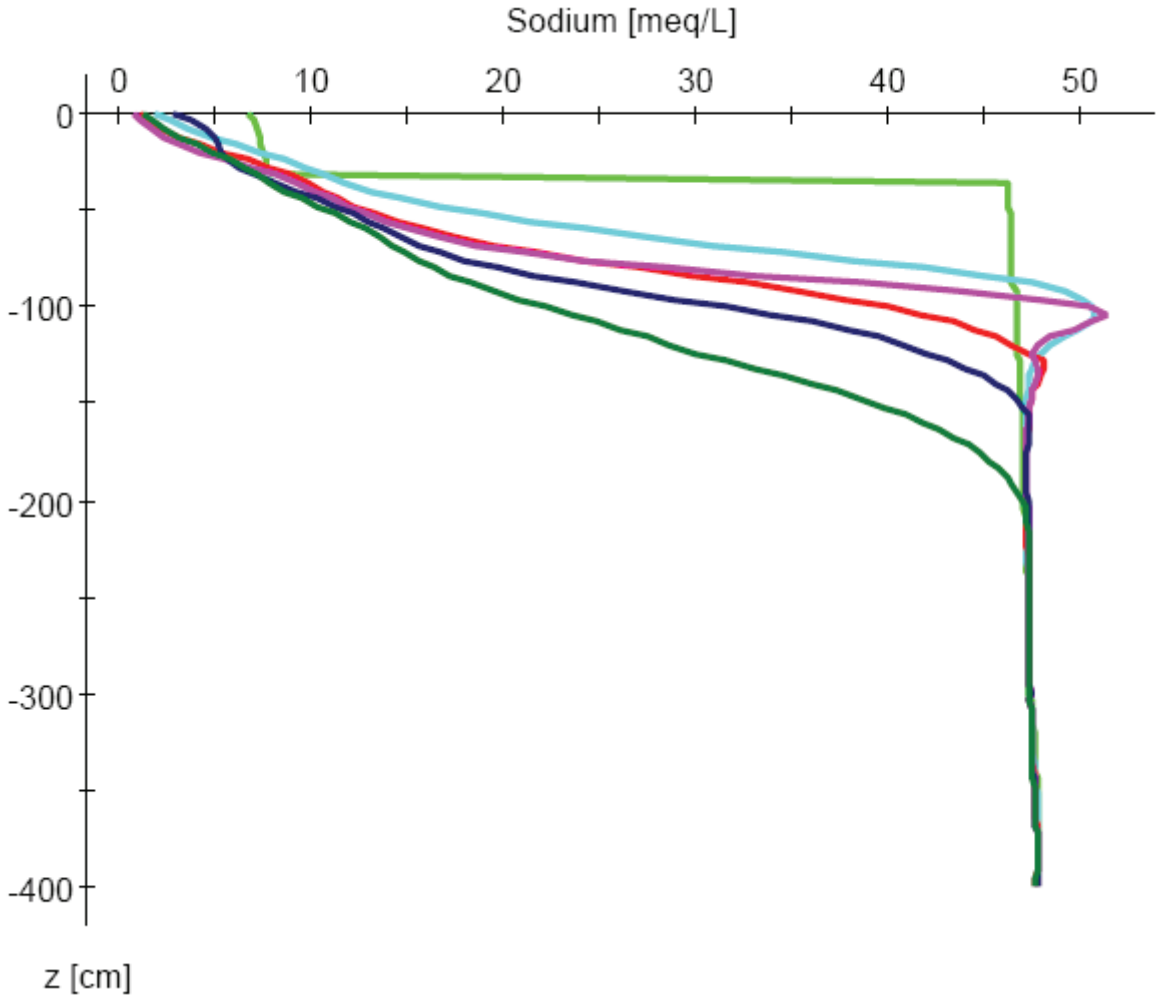


Figure 6. Solution sodium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

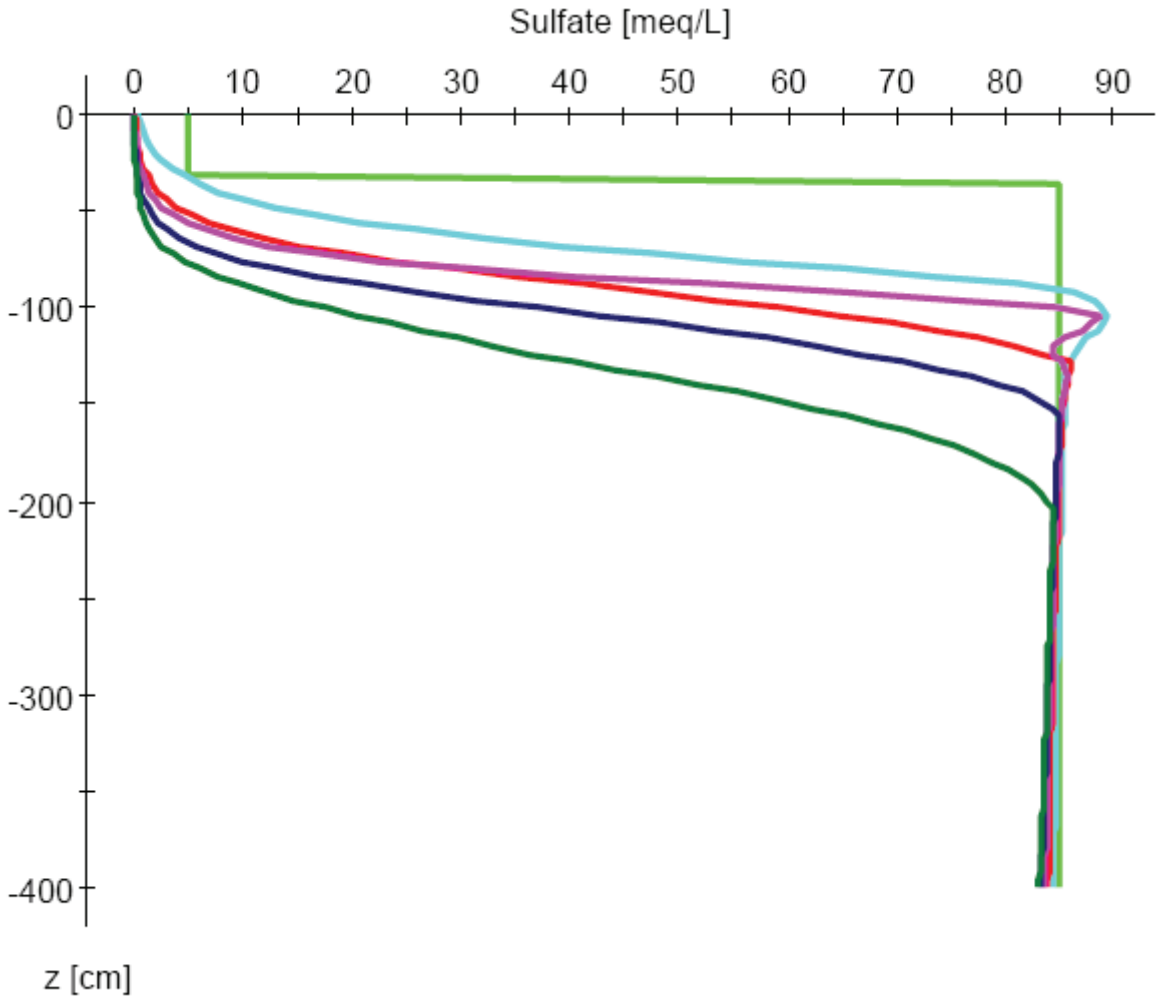


Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years

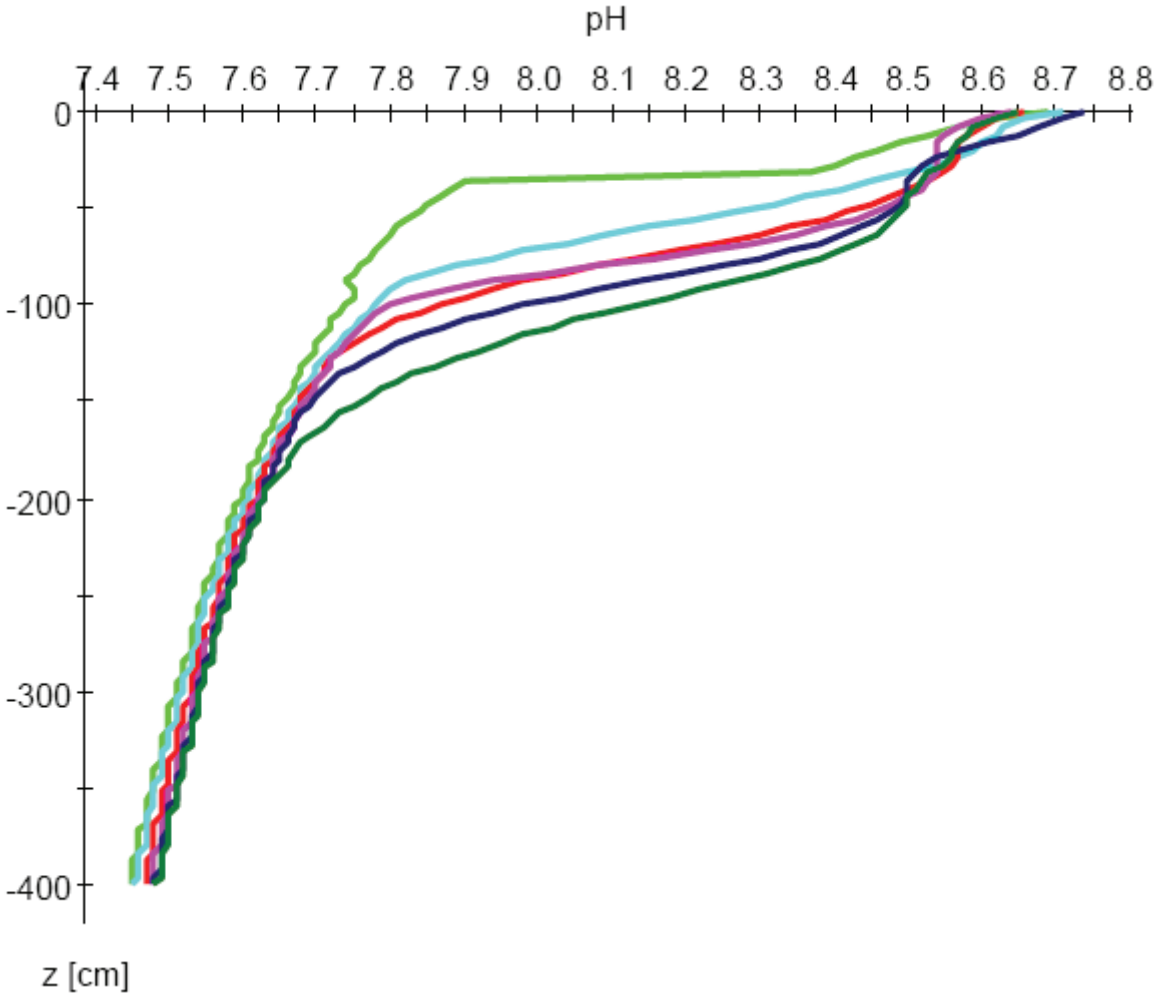


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

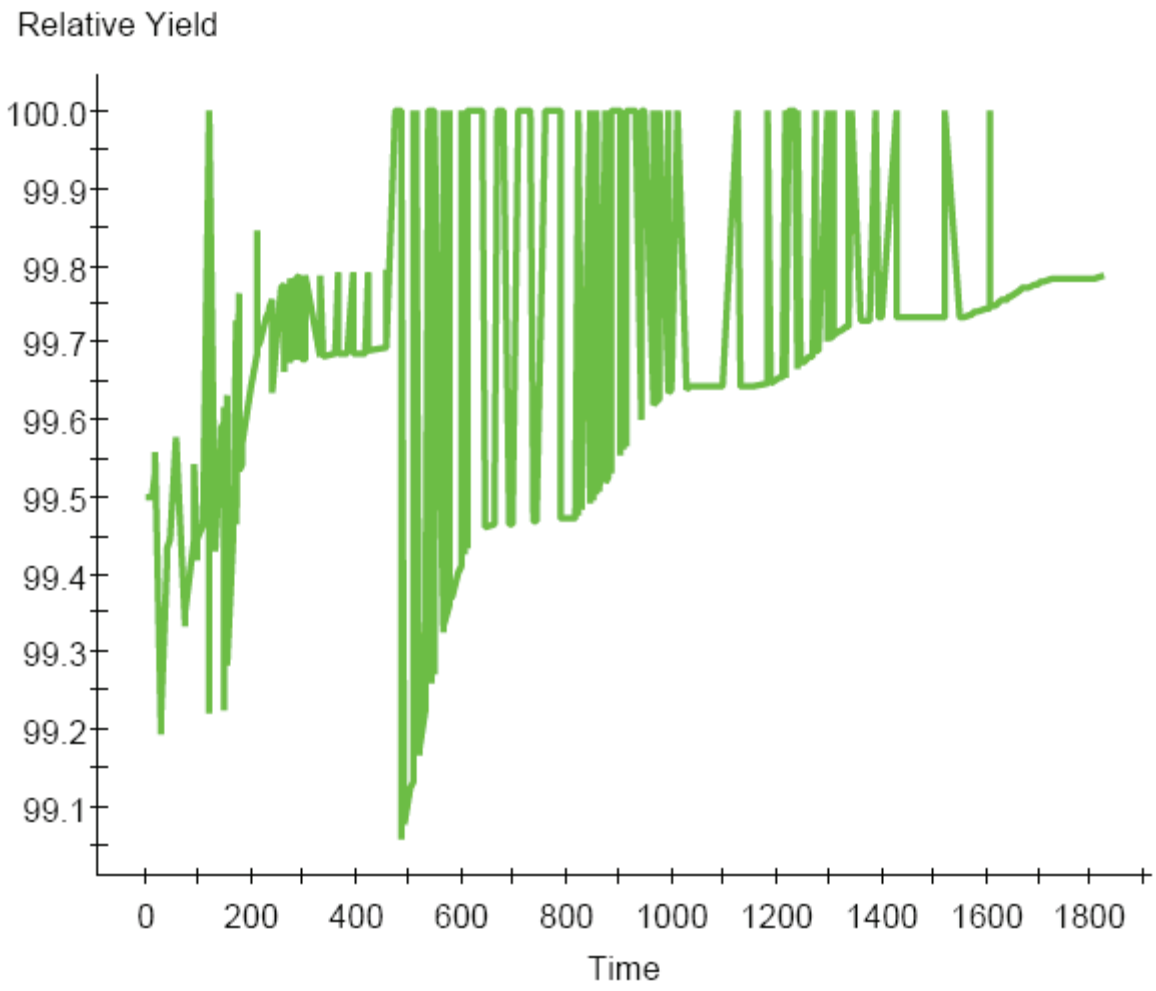


Figure 9. Relative crop yield over the 5-year simulation period.

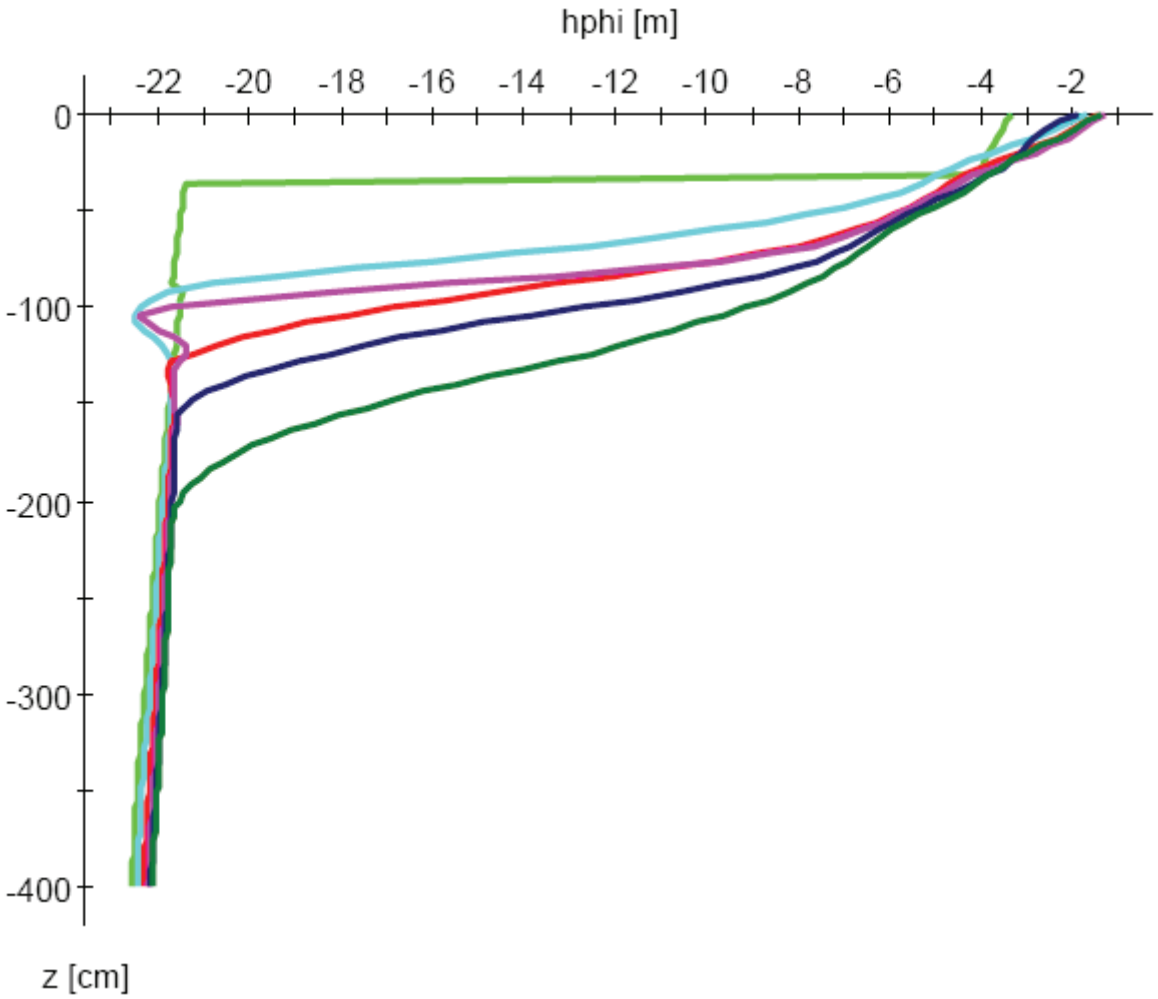


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

Carl Kretschman Ranch: Averaged soil conditions were used for all subirrigated sites sampled on the ranch for the physical and chemical input into the model.

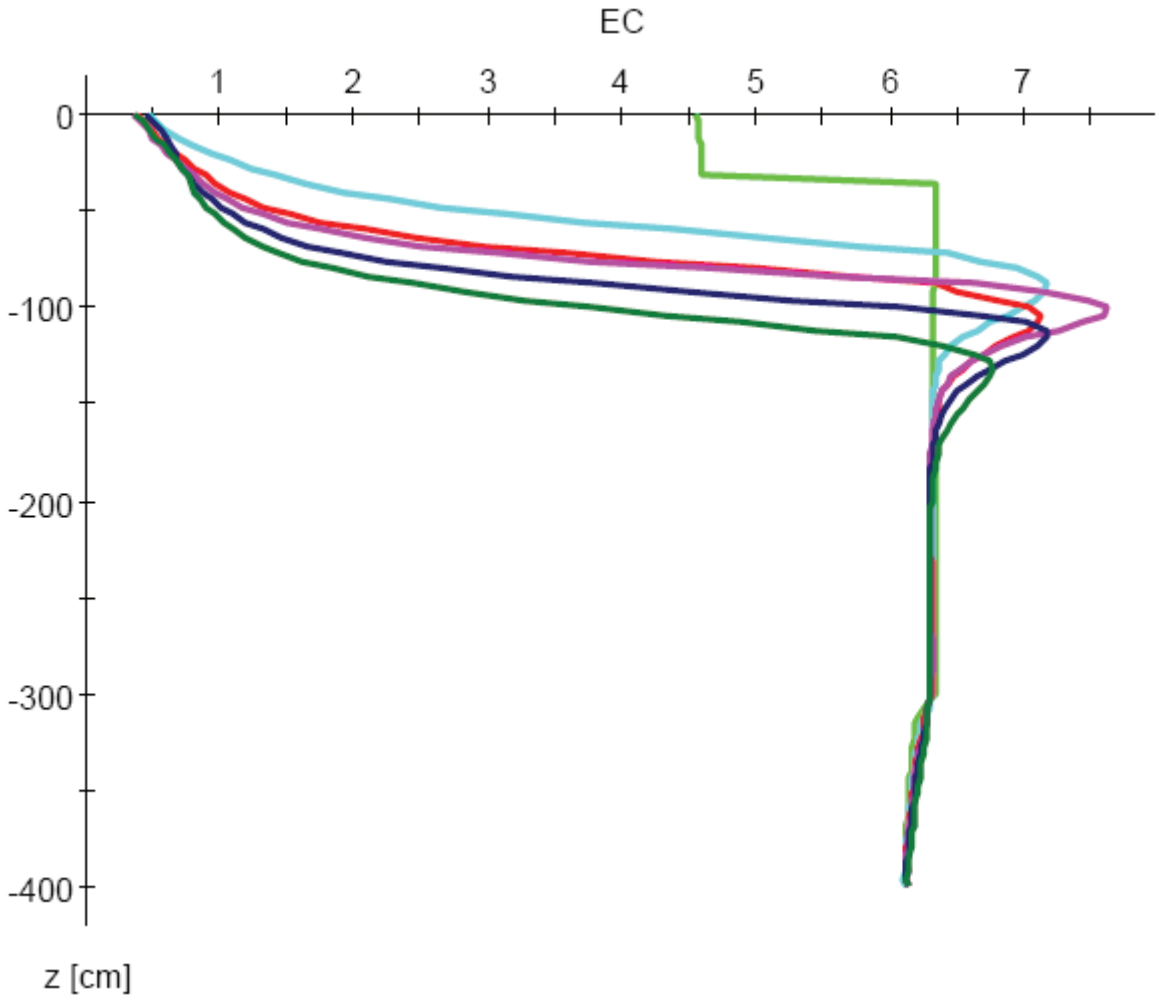


Figure 1. Salt concentrations (EC) by soil depth over the 5-year irrigation period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

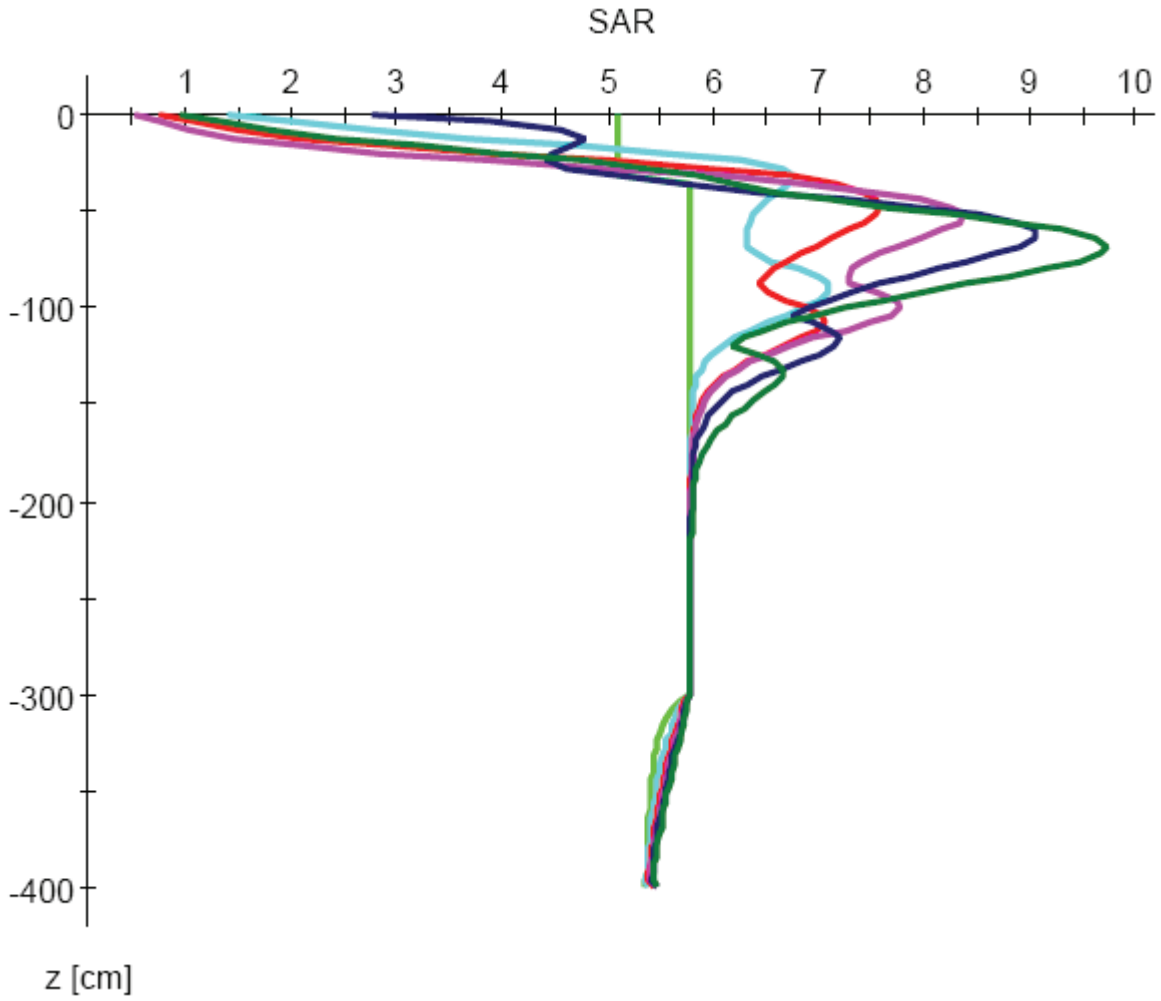


Figure 2. SAR by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

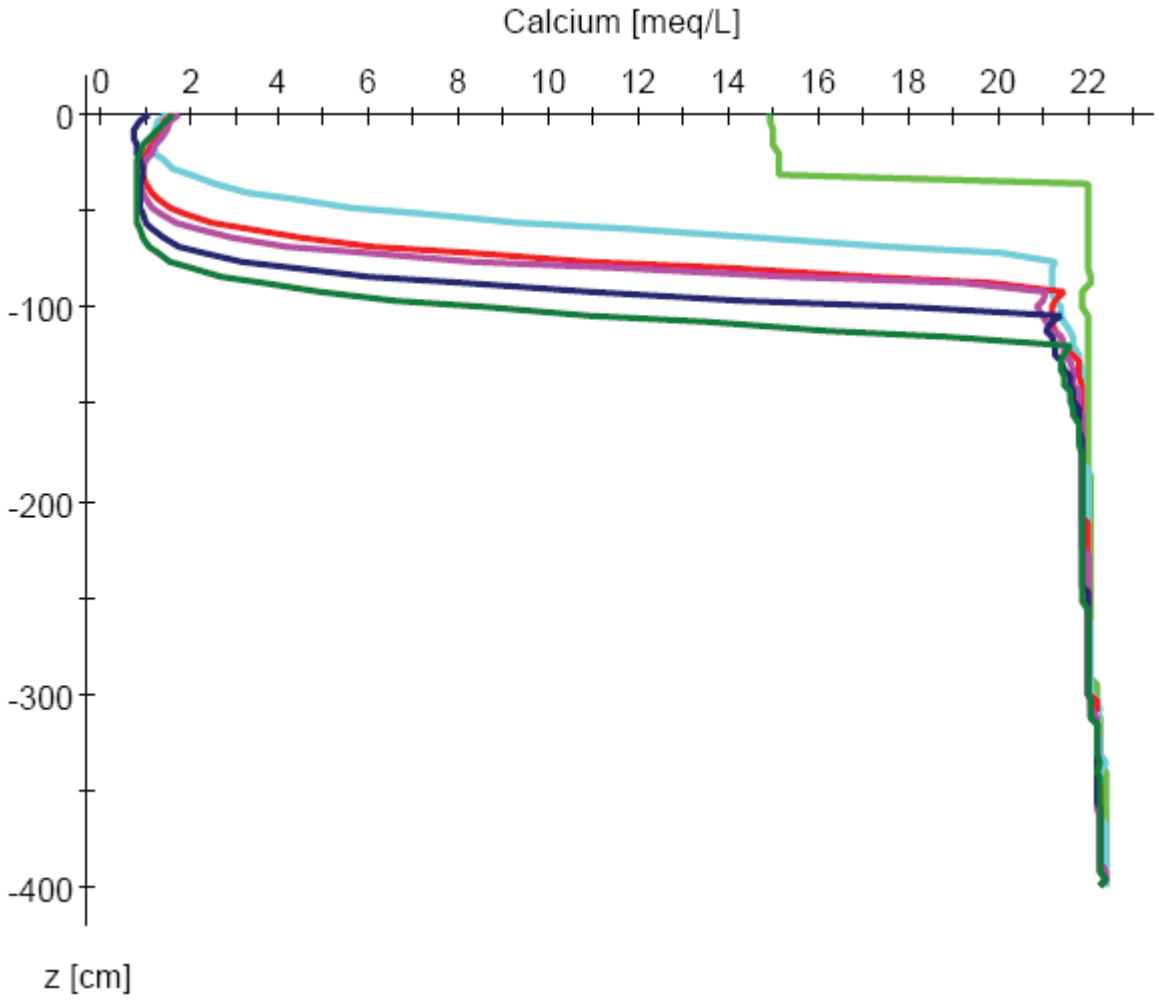


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

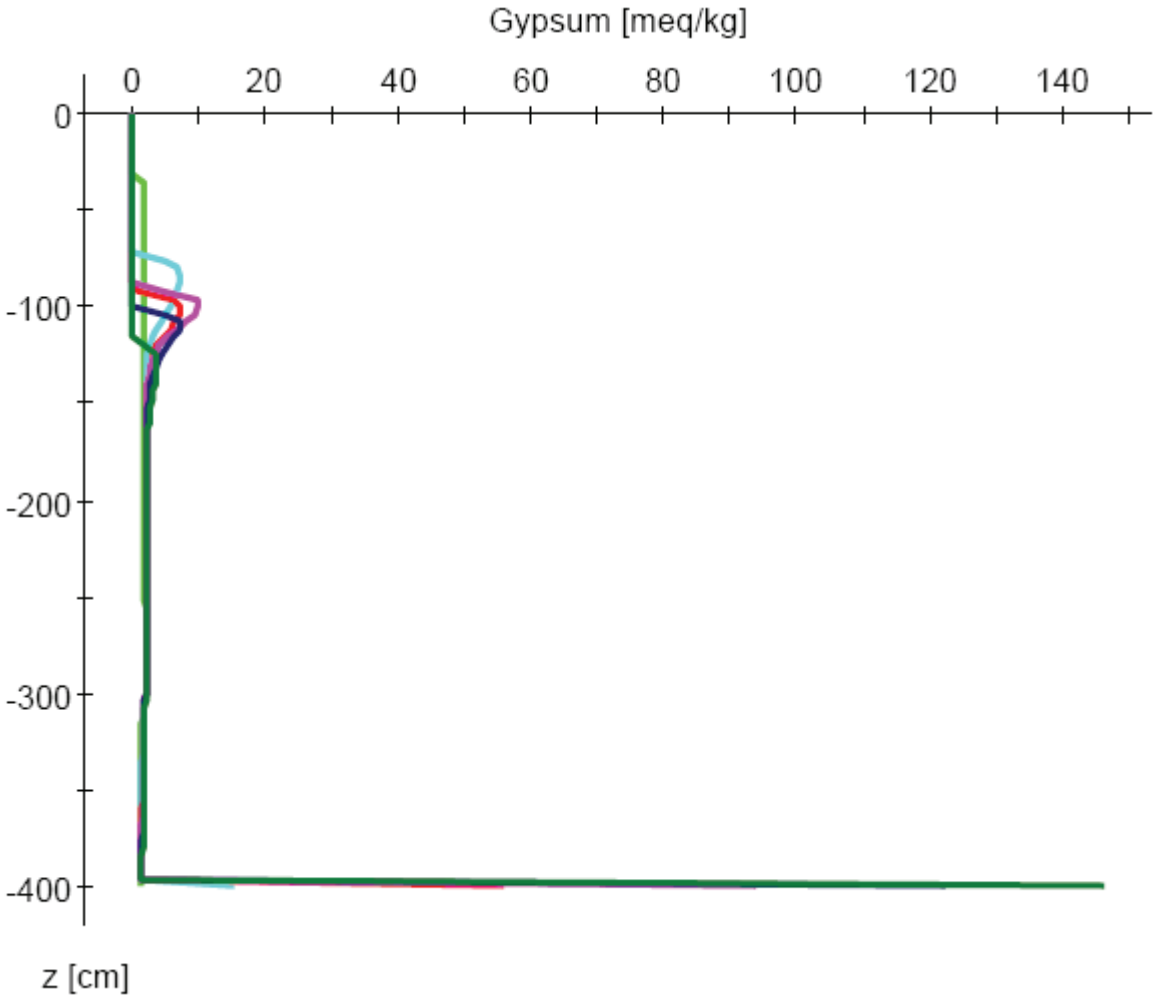


Figure 4. Gypsum levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

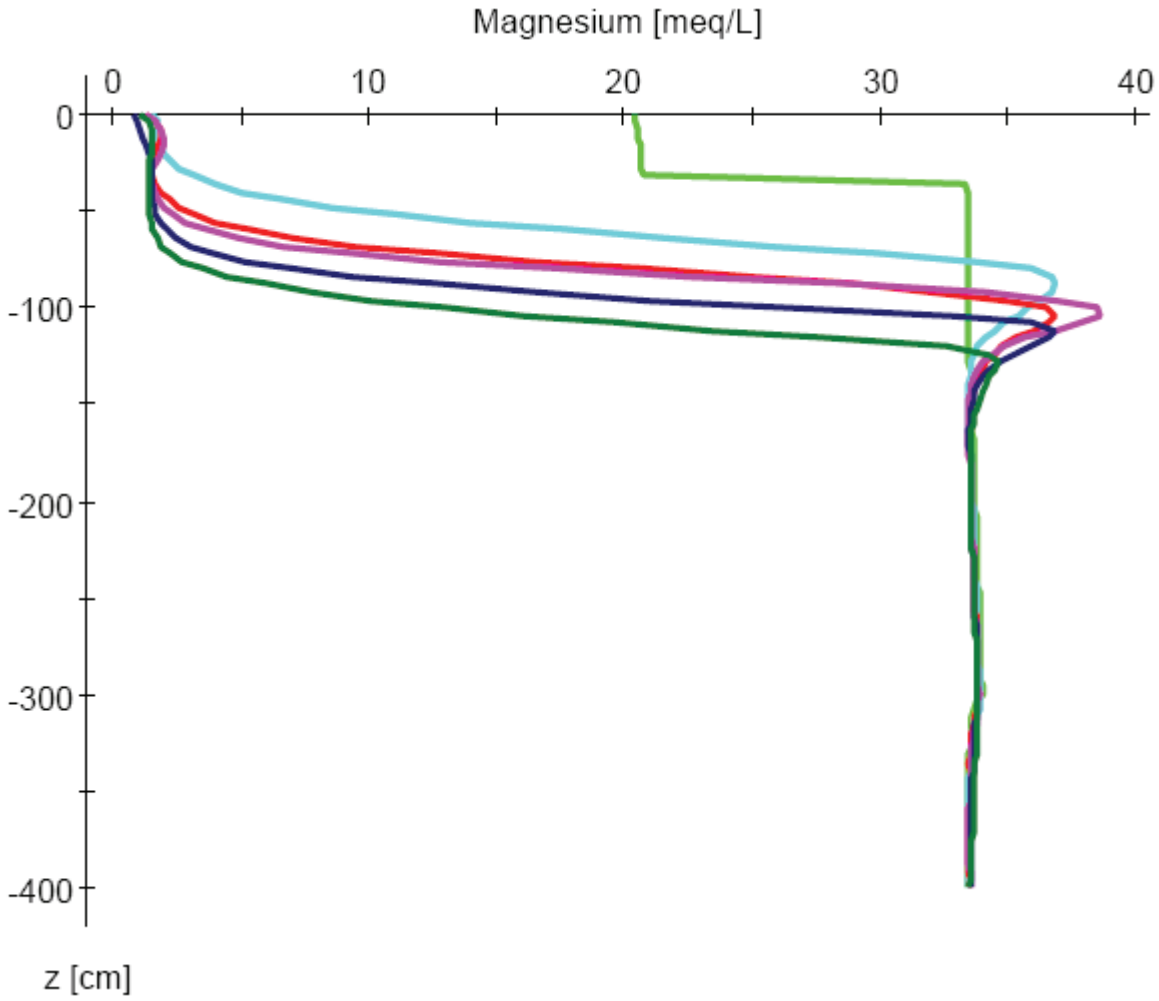


Figure 5. Solution magnesium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

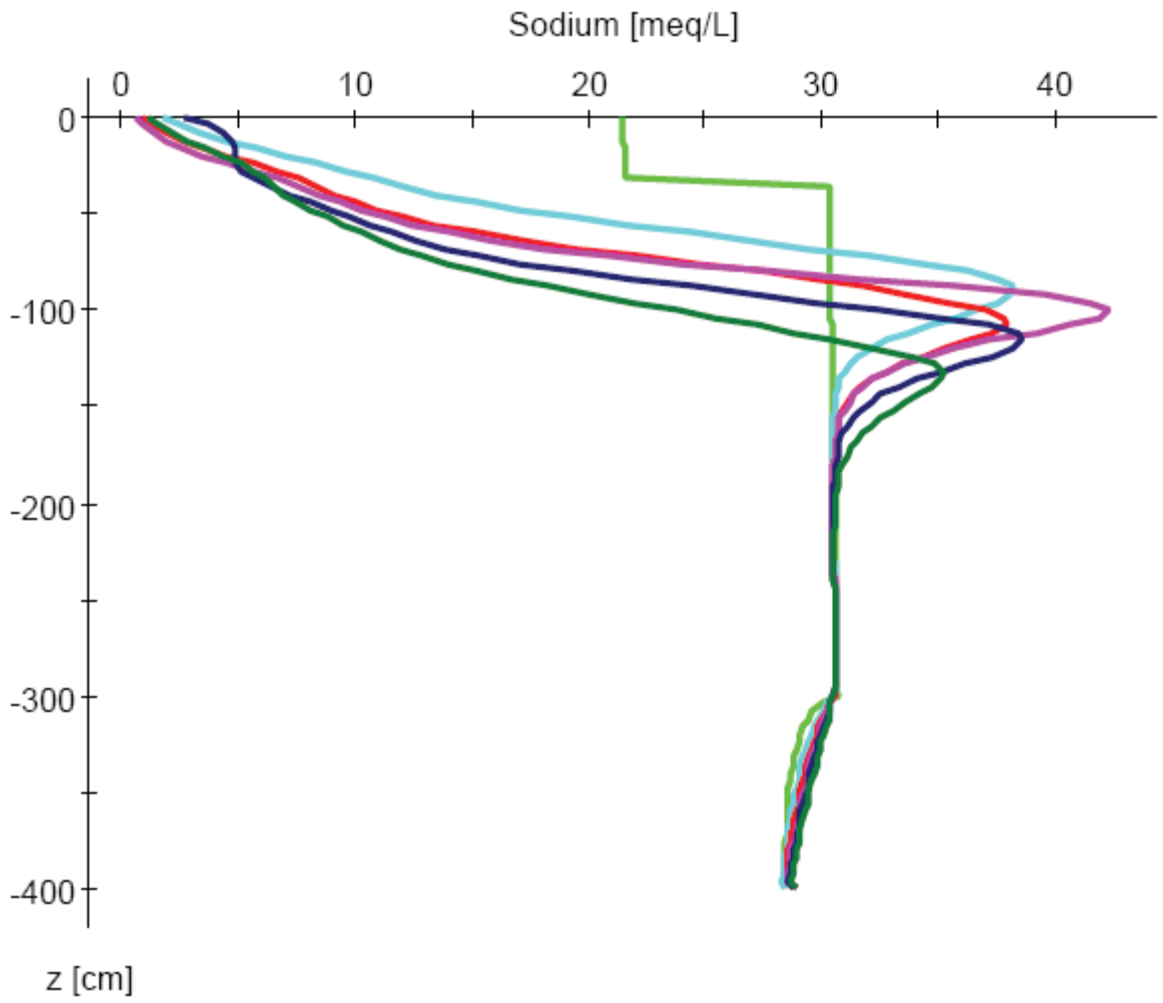


Figure 6. Solution sodium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

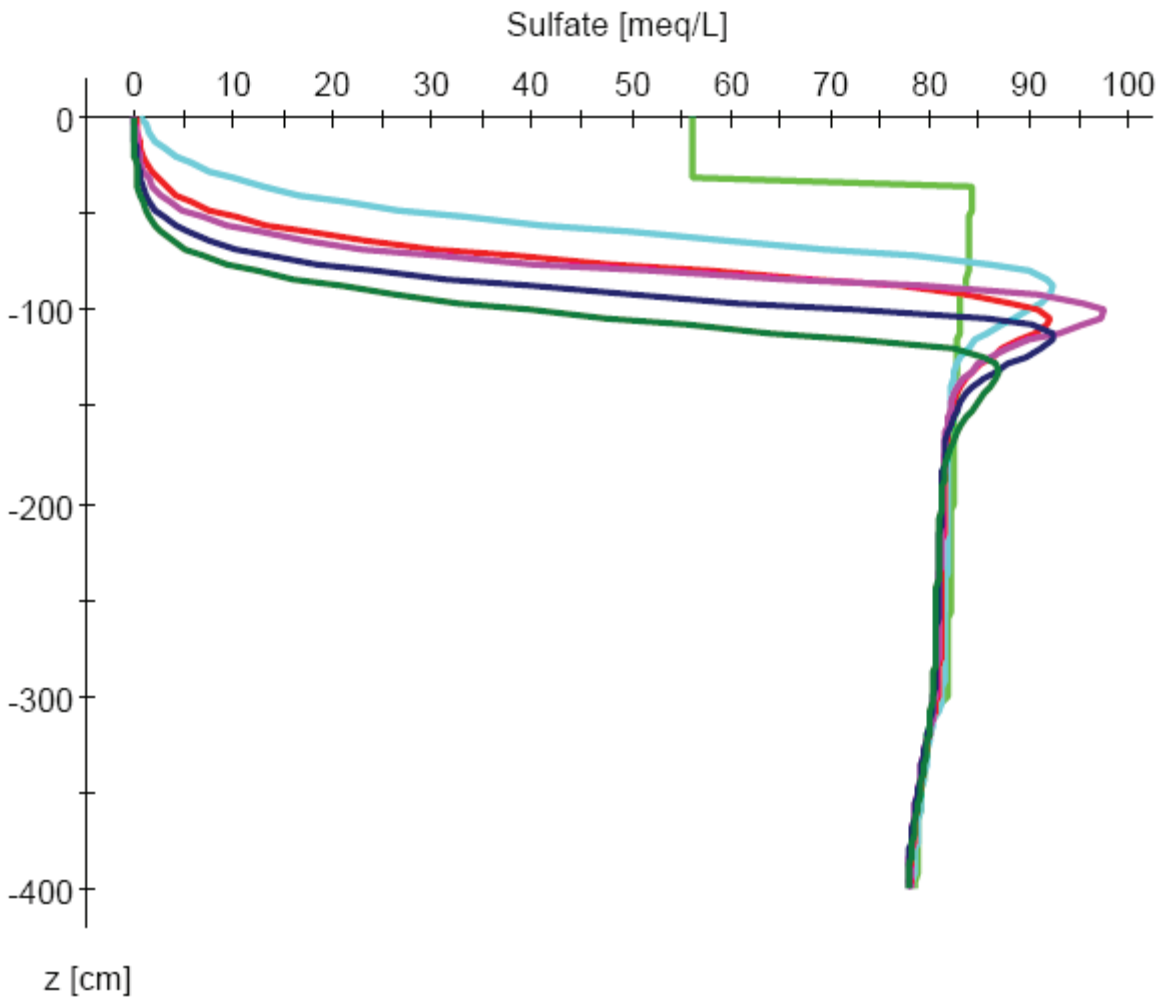


Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

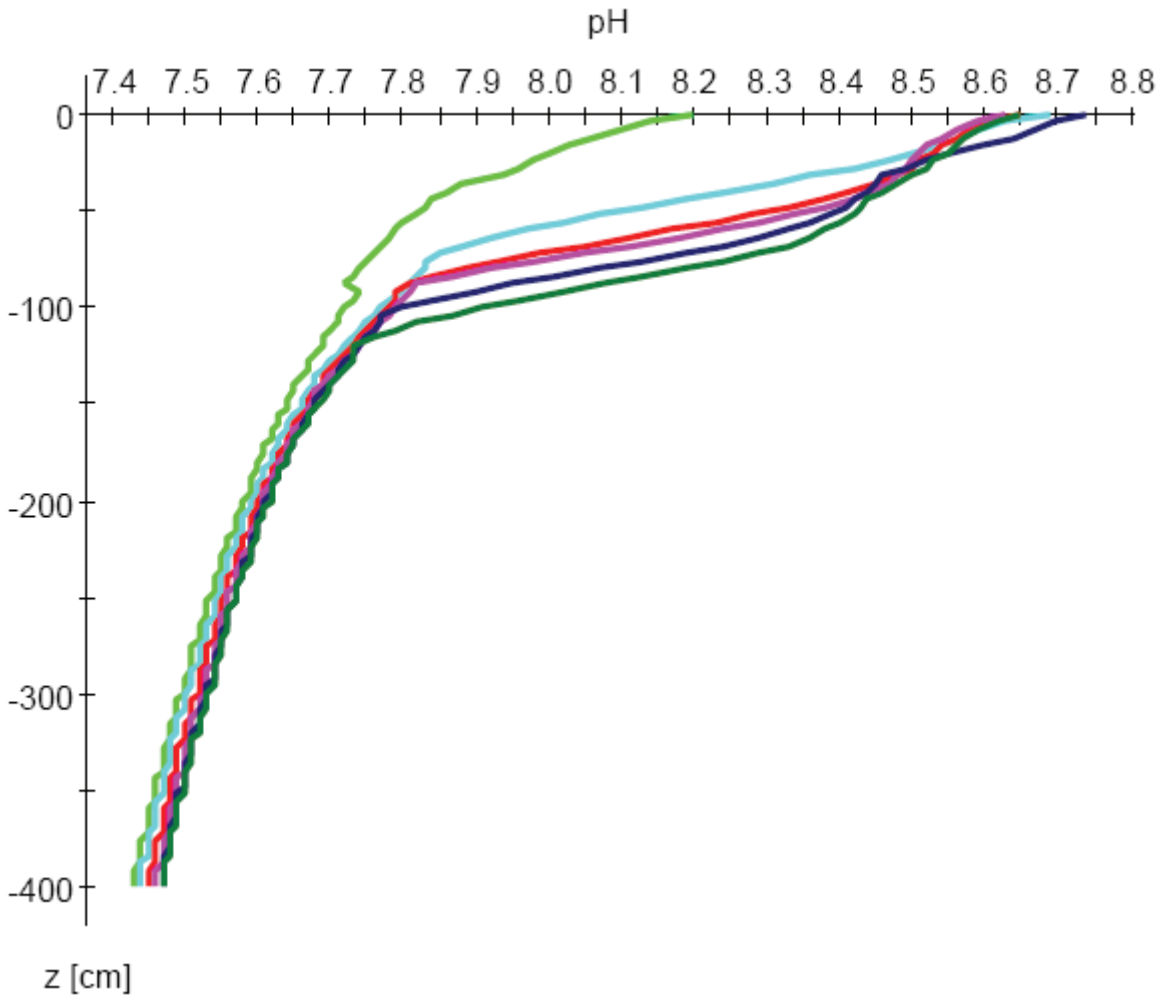


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

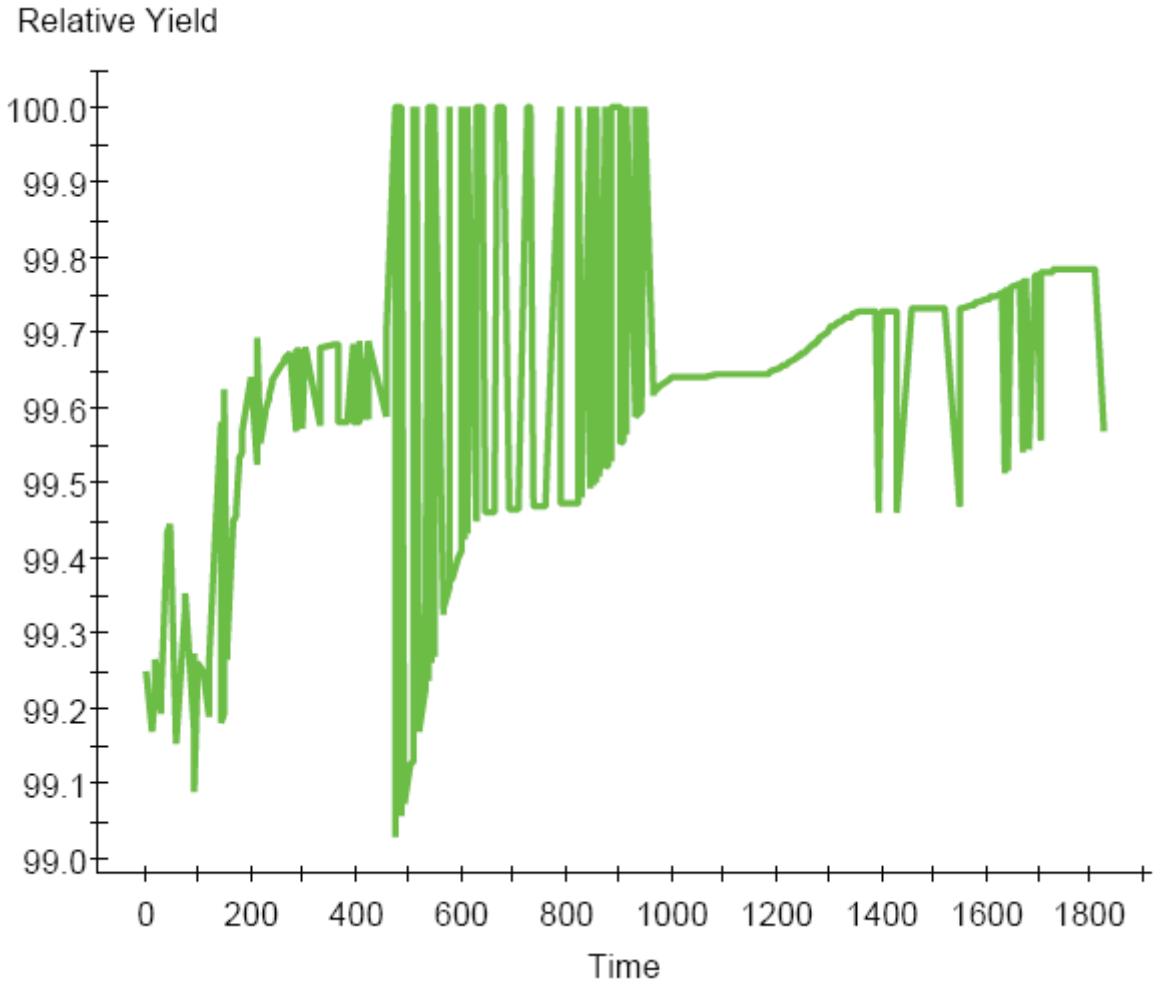


Figure 9. Relative crop yield over the 5-year simulation period.

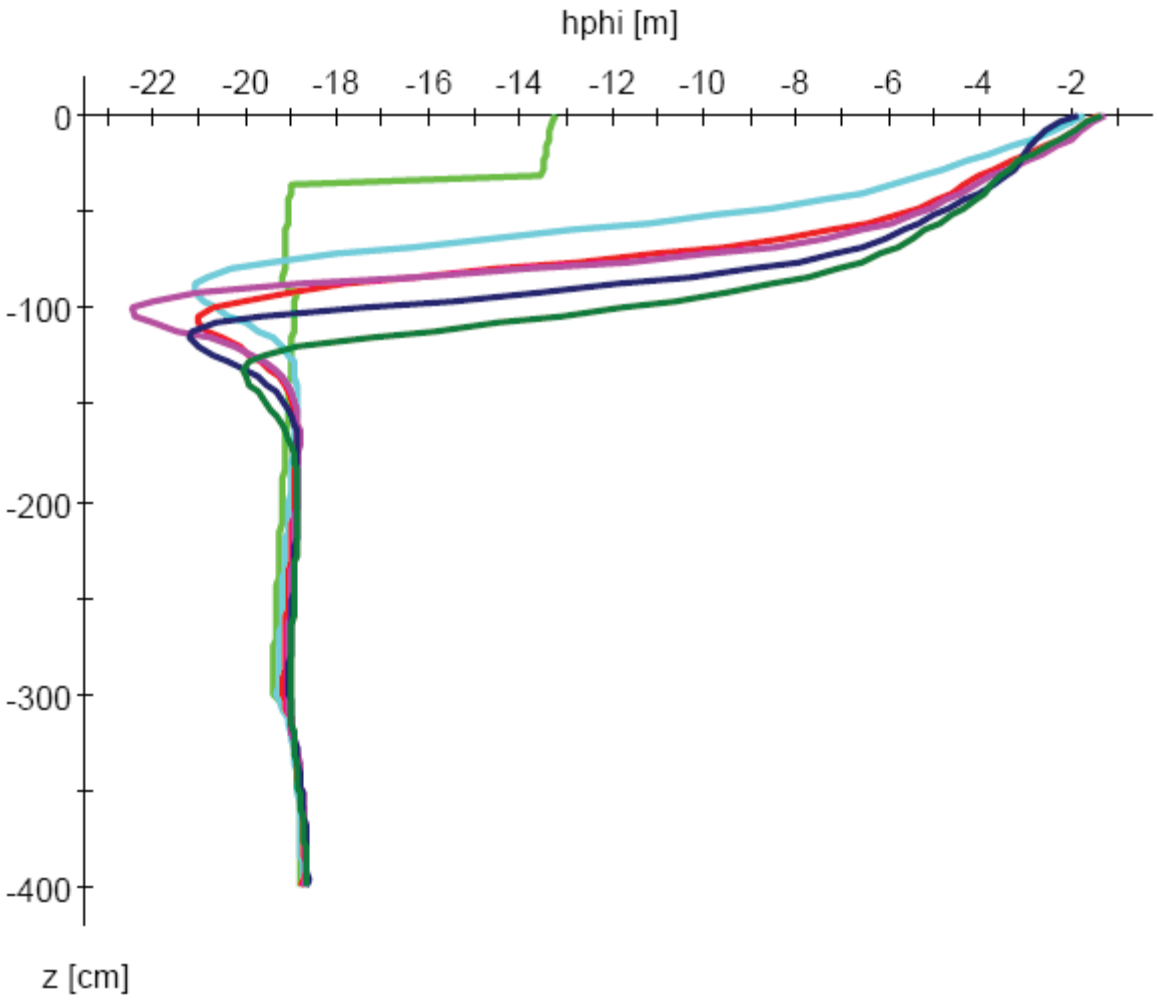


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

Loren Peyrot Ranch: Averaged soil conditions were used for all subirrigated sites sampled on the ranch for the physical and chemical input into the model.

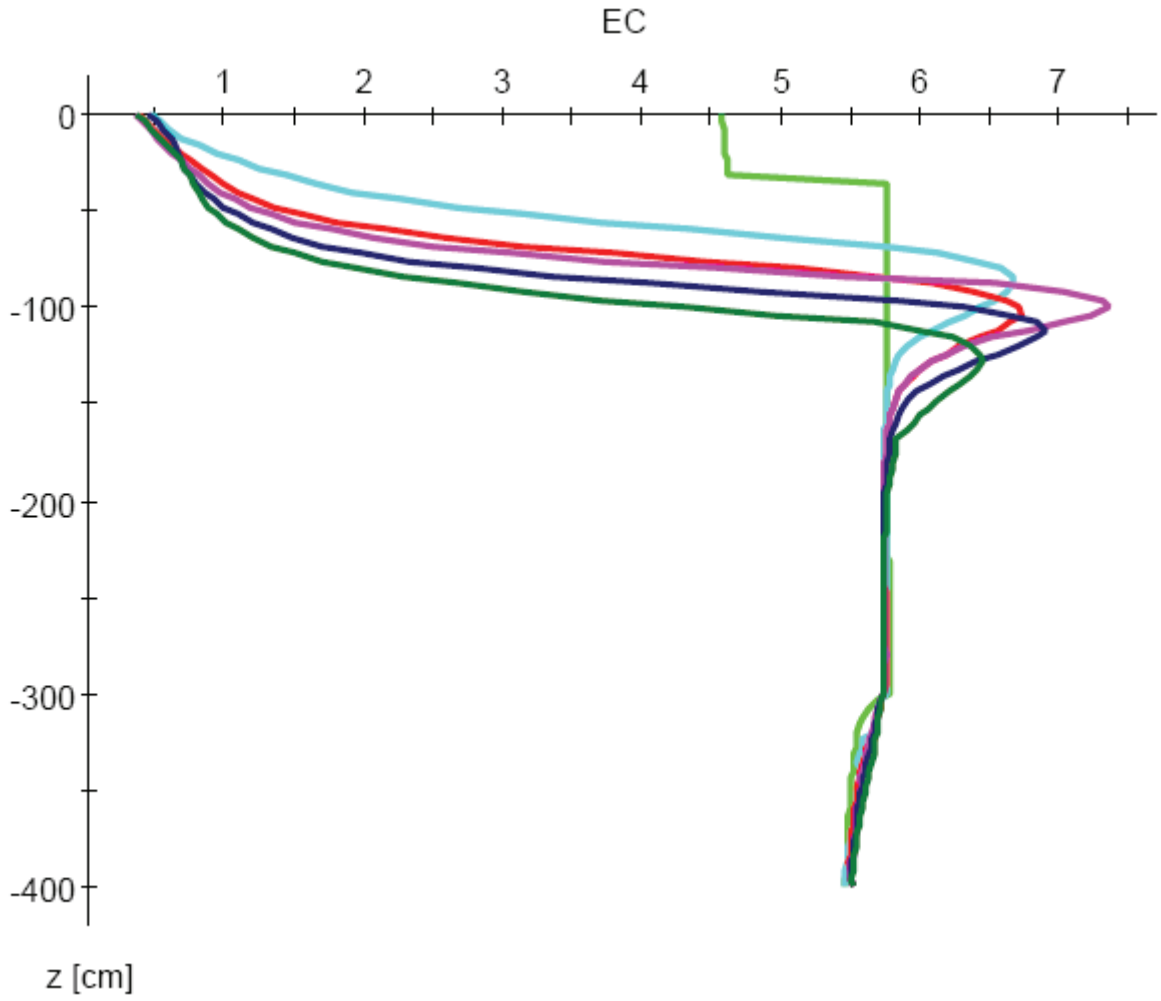


Figure 1. Salt concentrations (EC) by soil depth over the 5-year irrigation period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

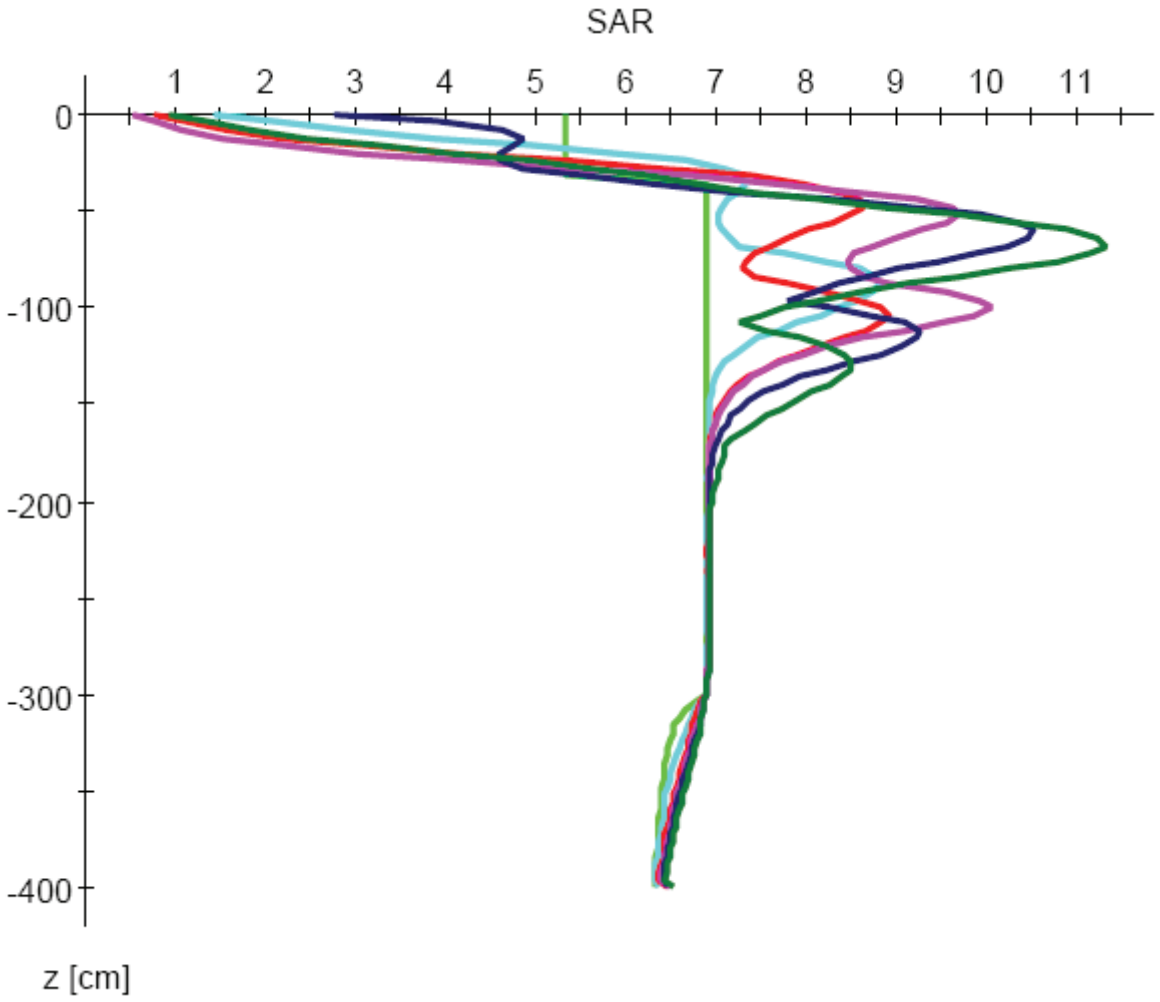


Figure 2. SAR by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

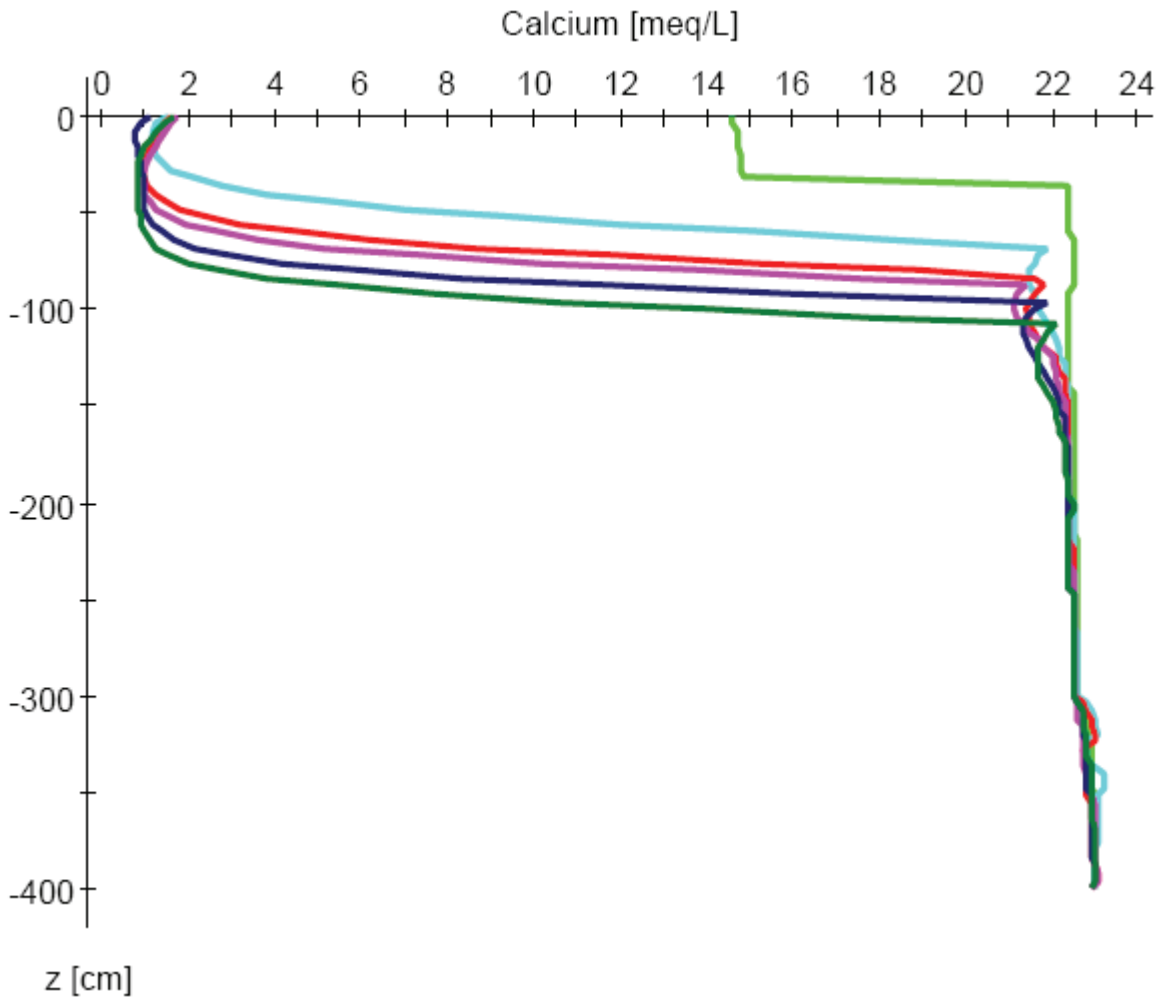


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

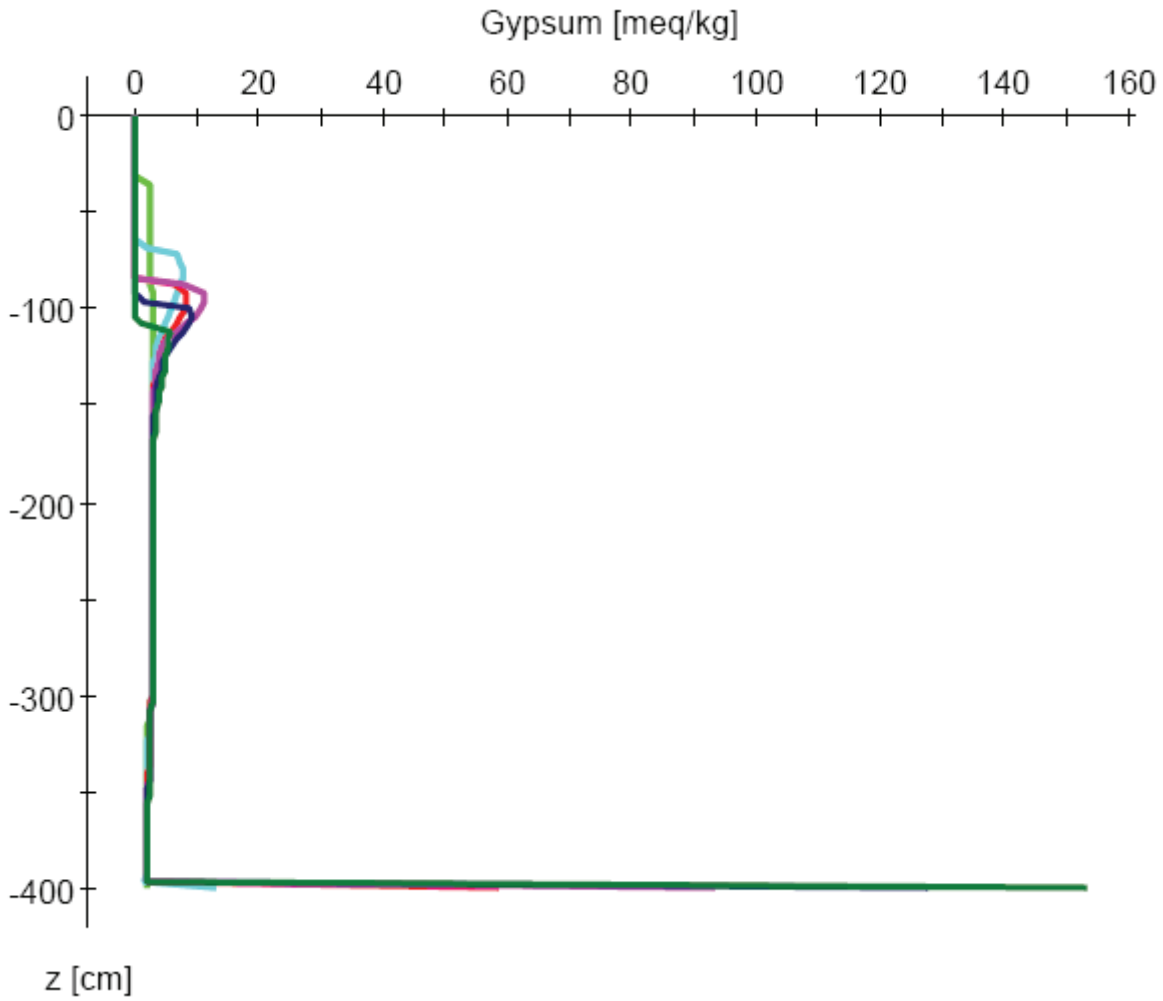


Figure 4. Gypsum levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

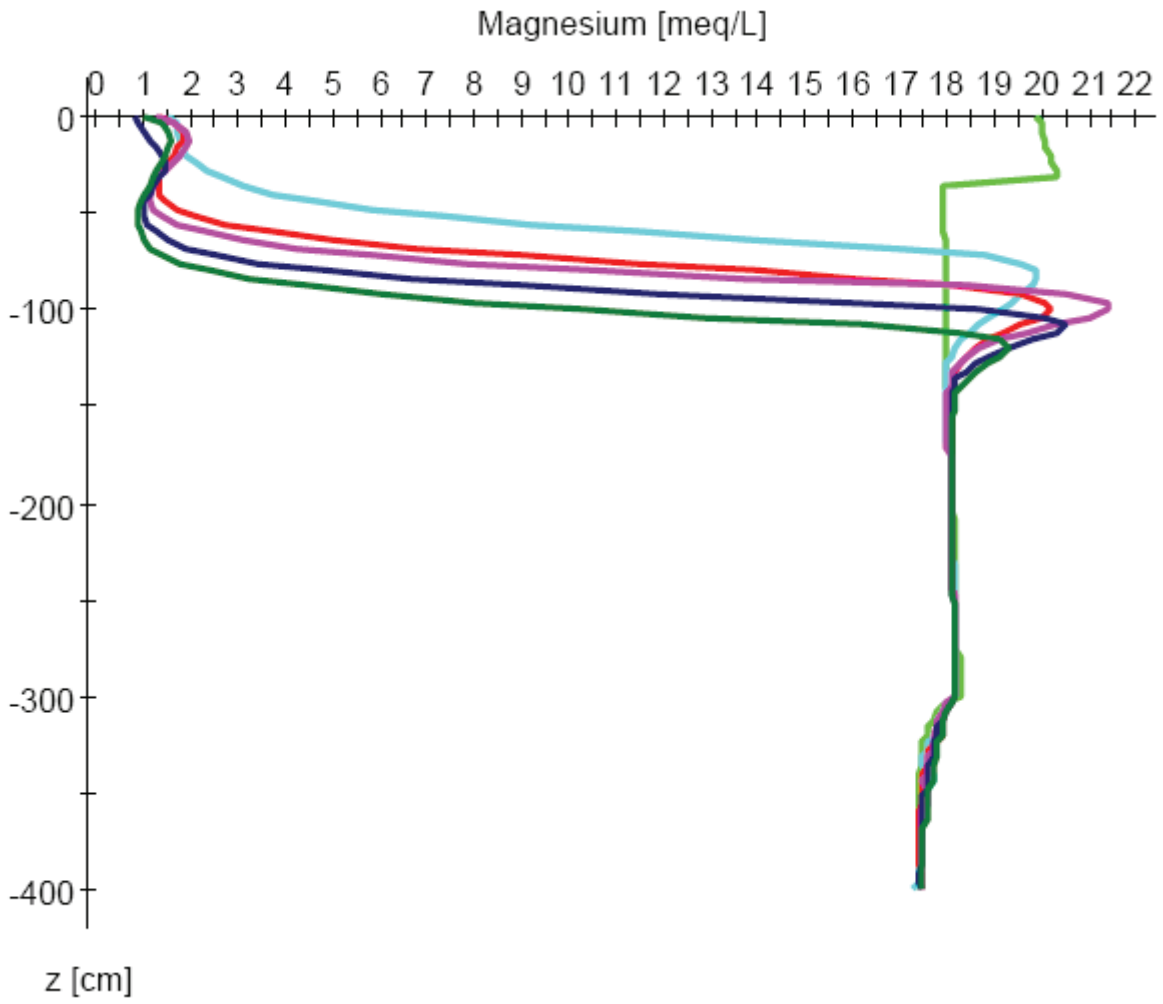


Figure 5. Solution magnesium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

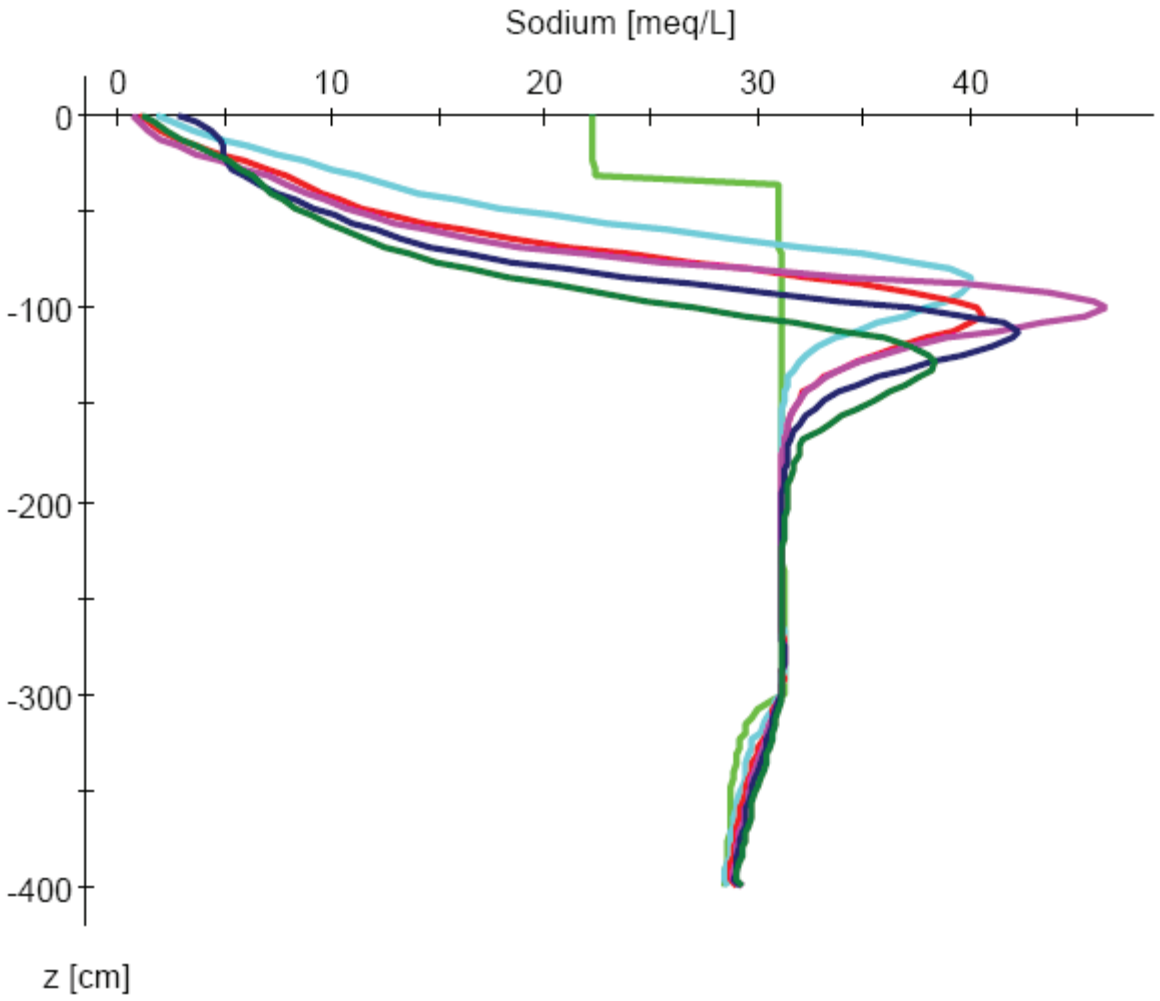


Figure 6. Solution sodium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

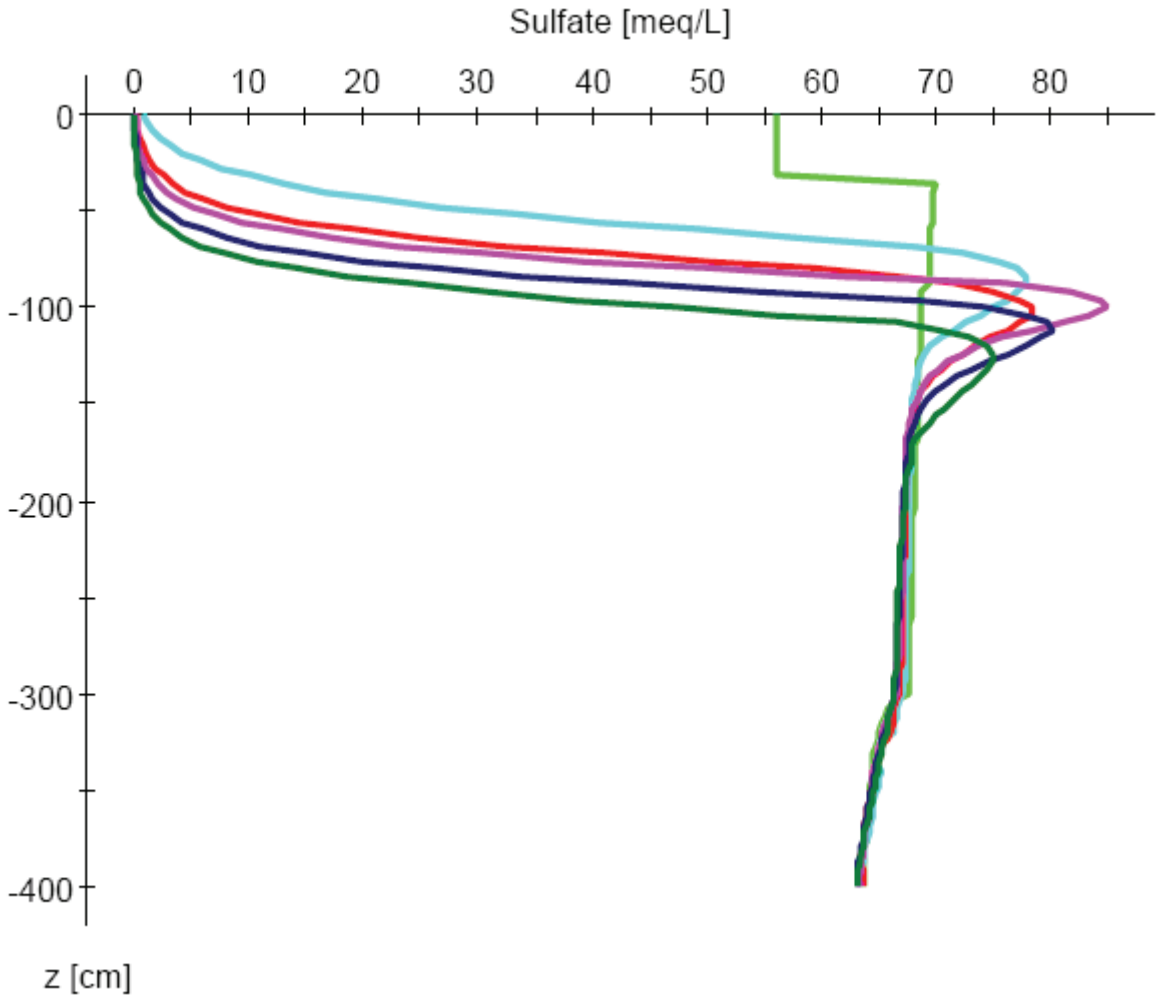


Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

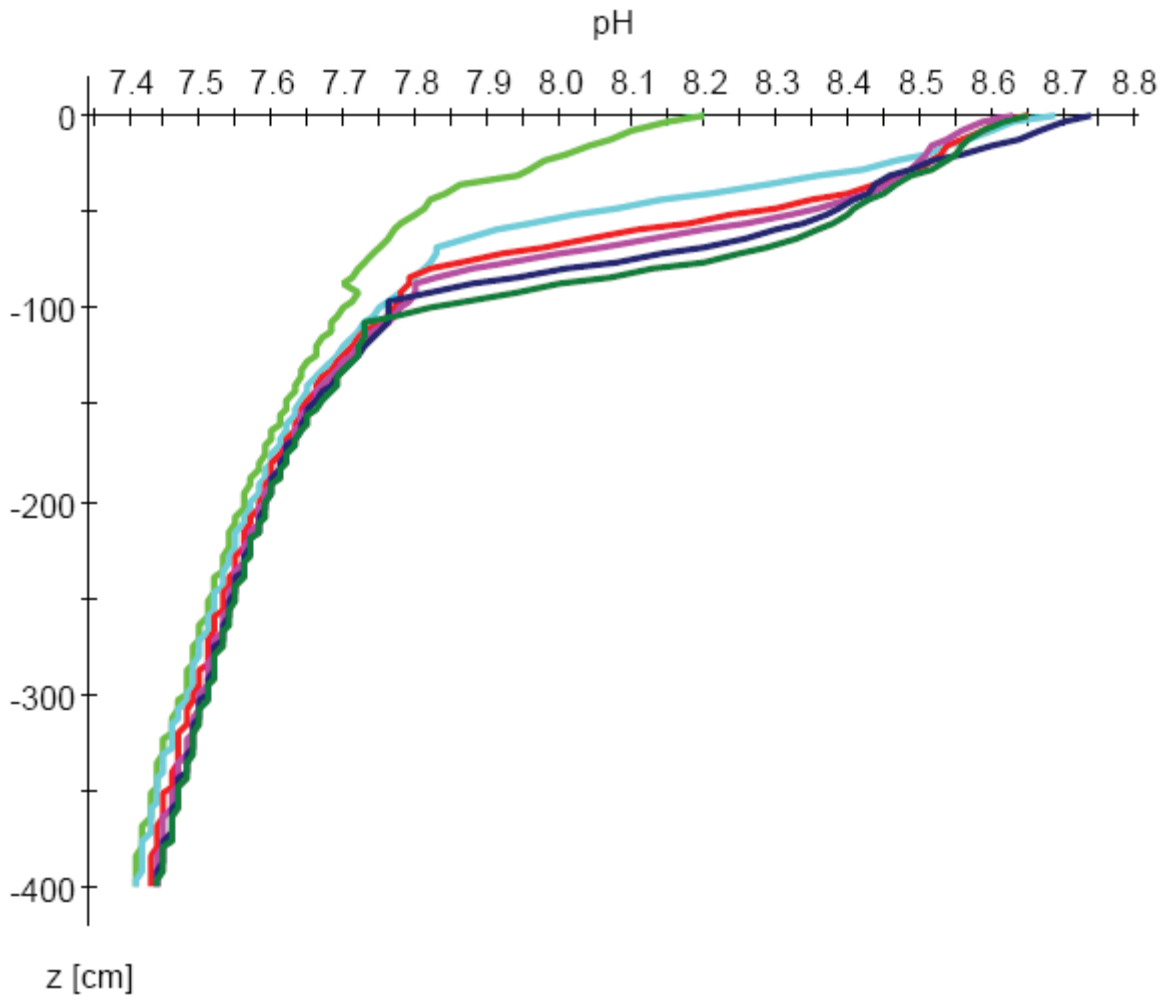


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

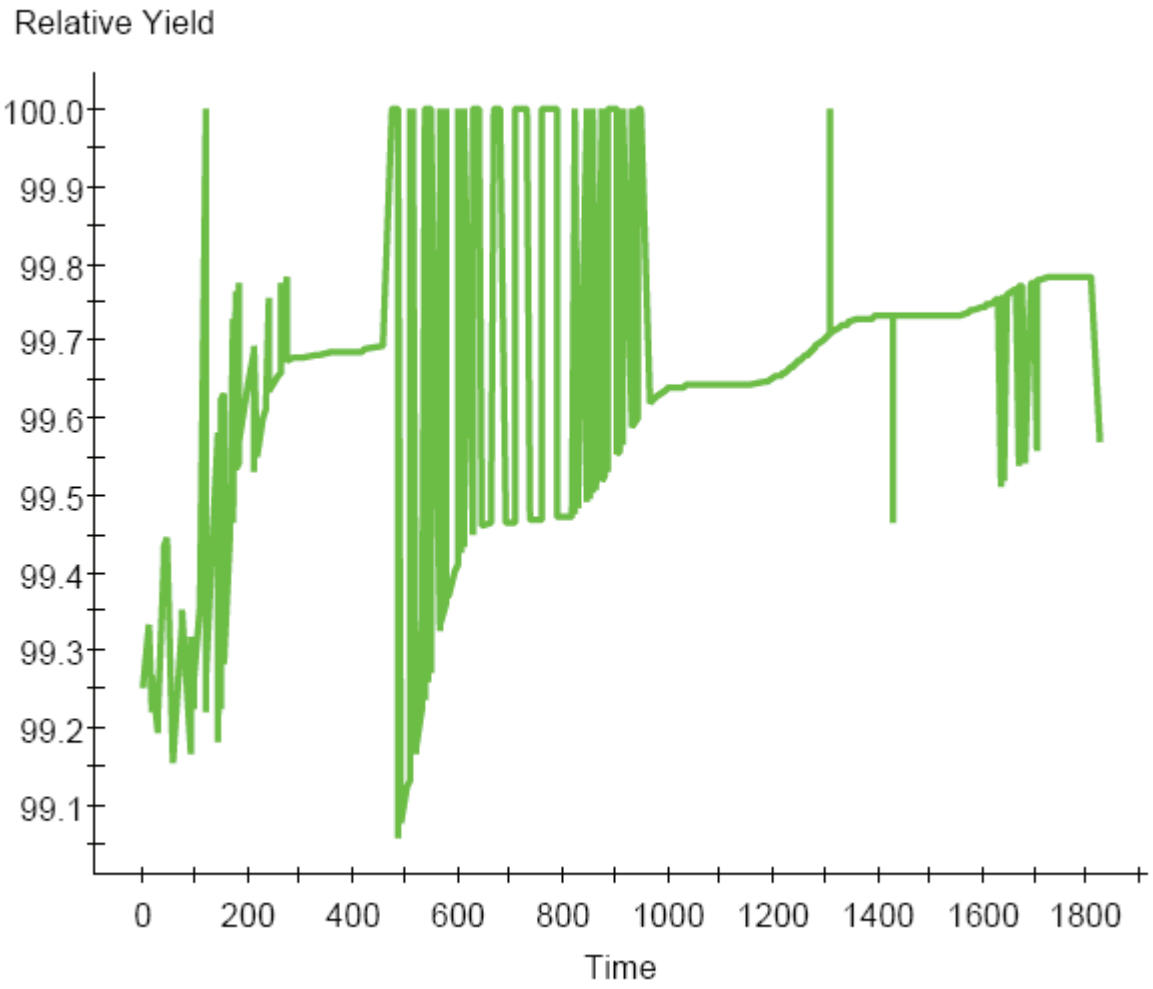


Figure 9. Relative crop yield over the 5-year simulation period.

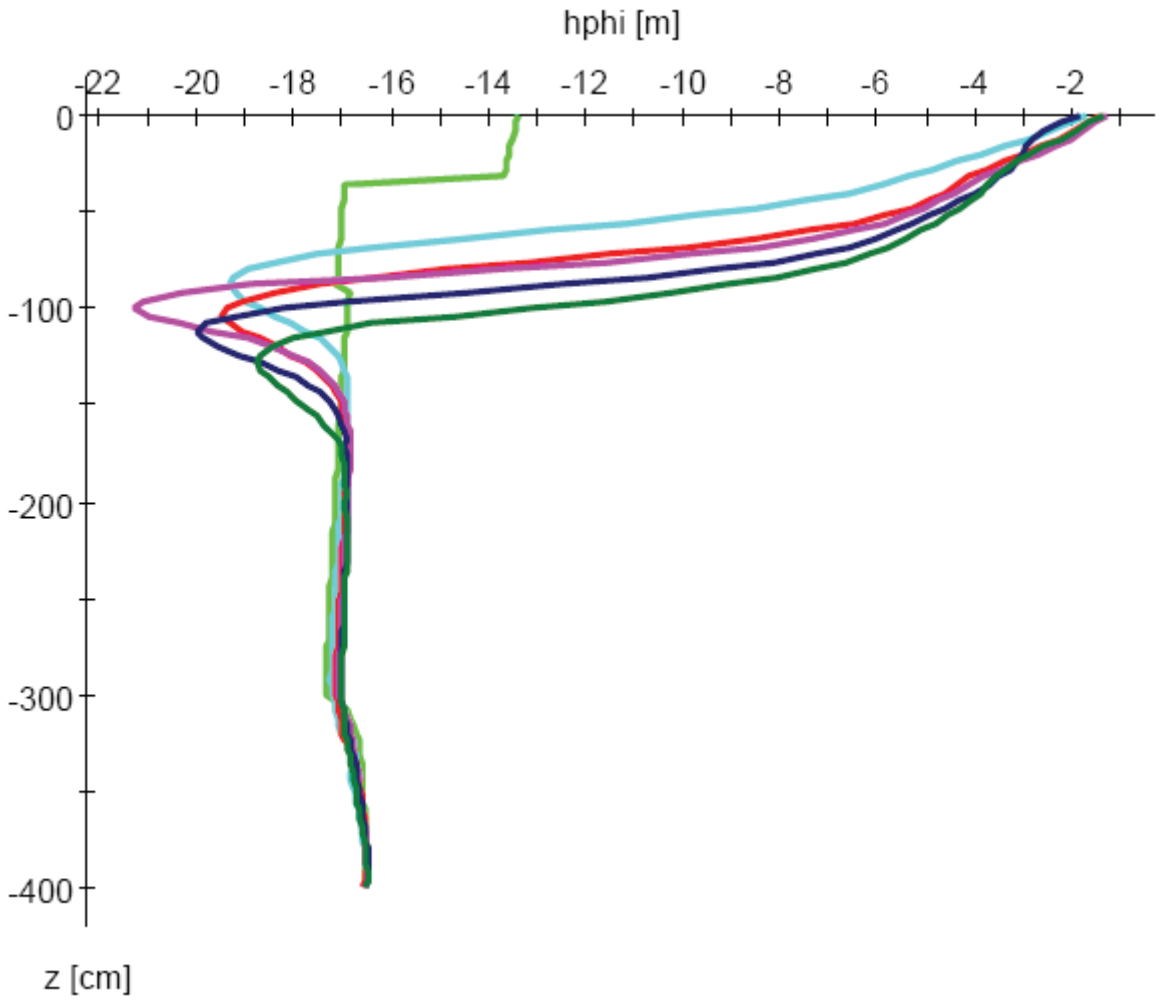


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

Stevan Mueller Ranch

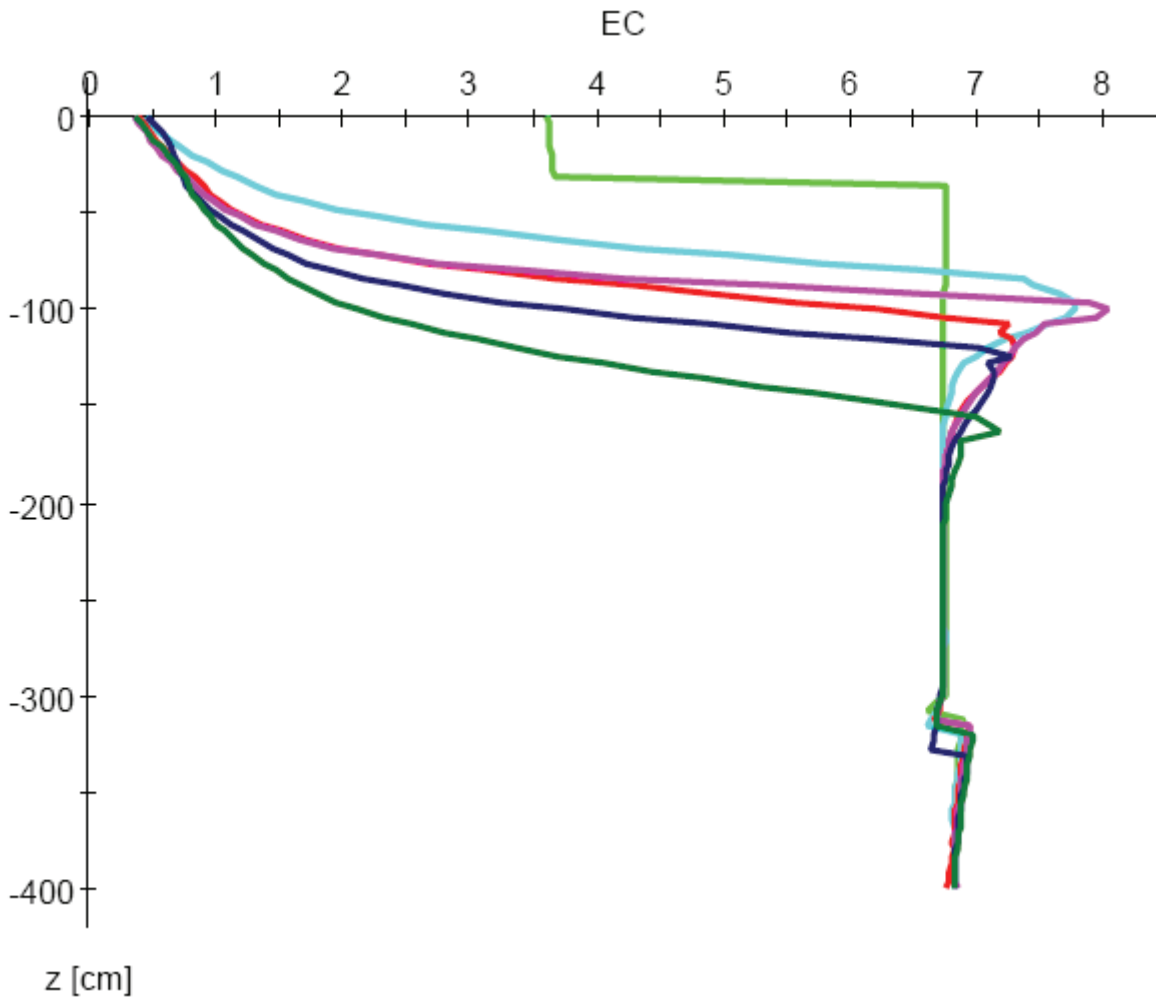


Figure 1. Salt concentrations (EC) by soil depth over the 5-year irrigation period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

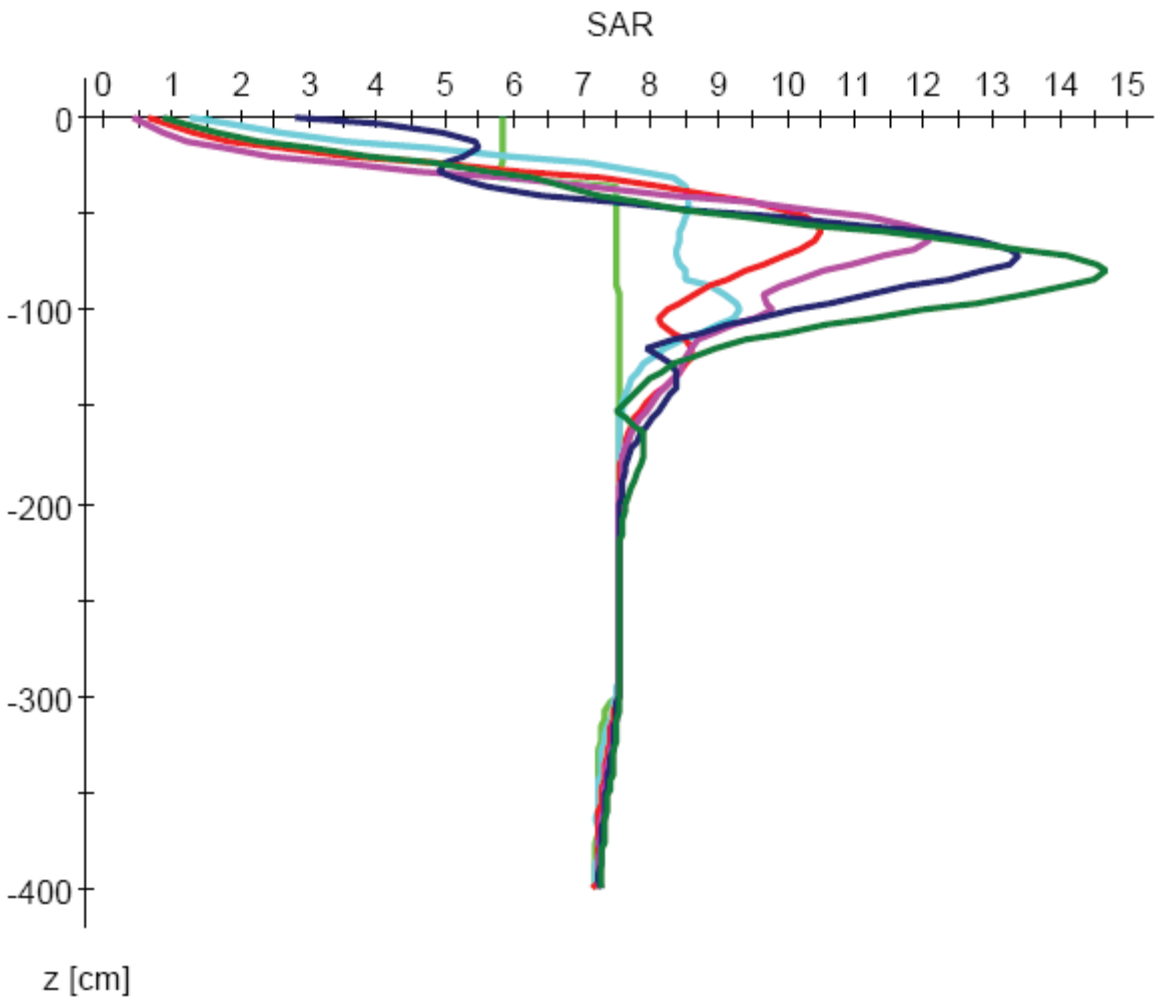


Figure 2. SAR by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

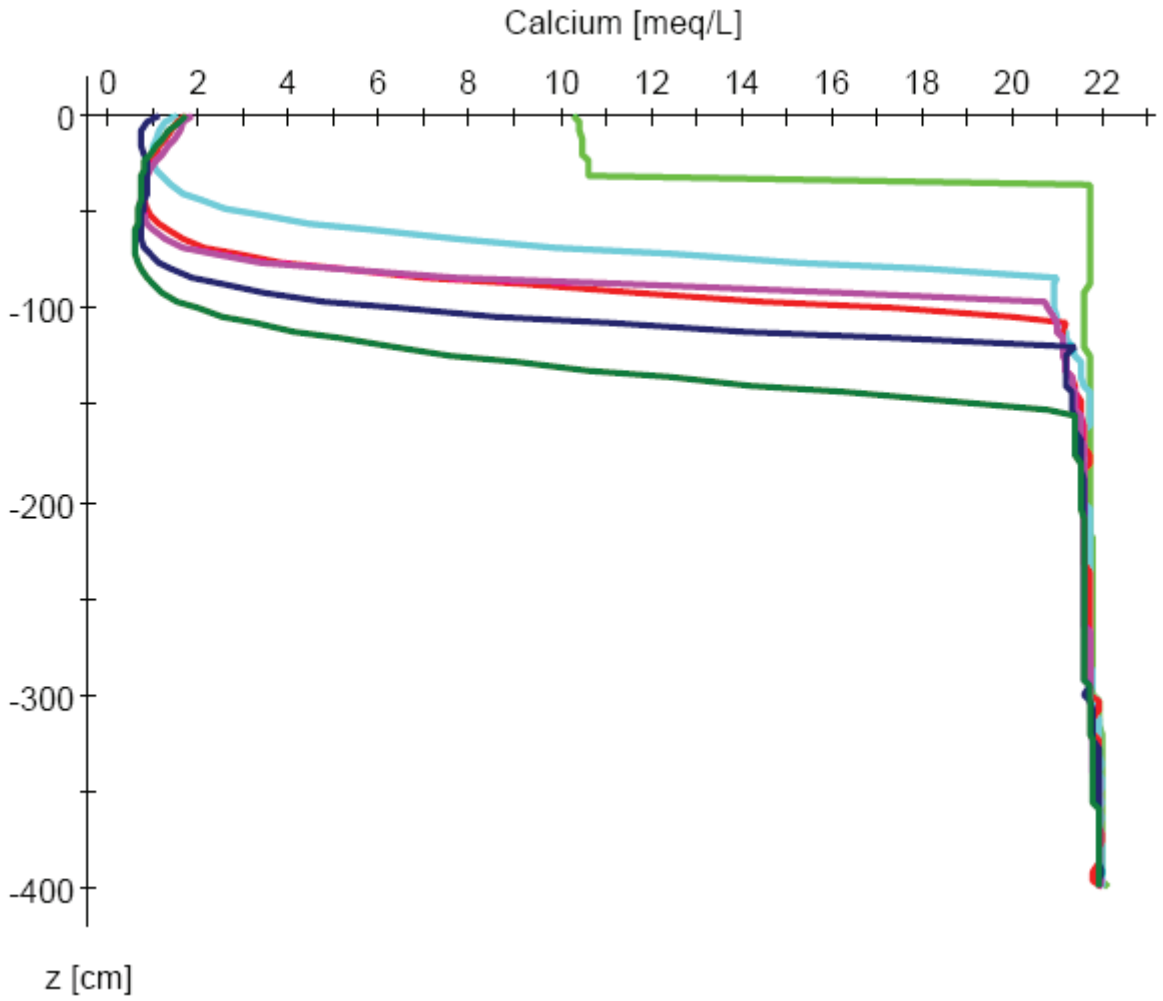


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

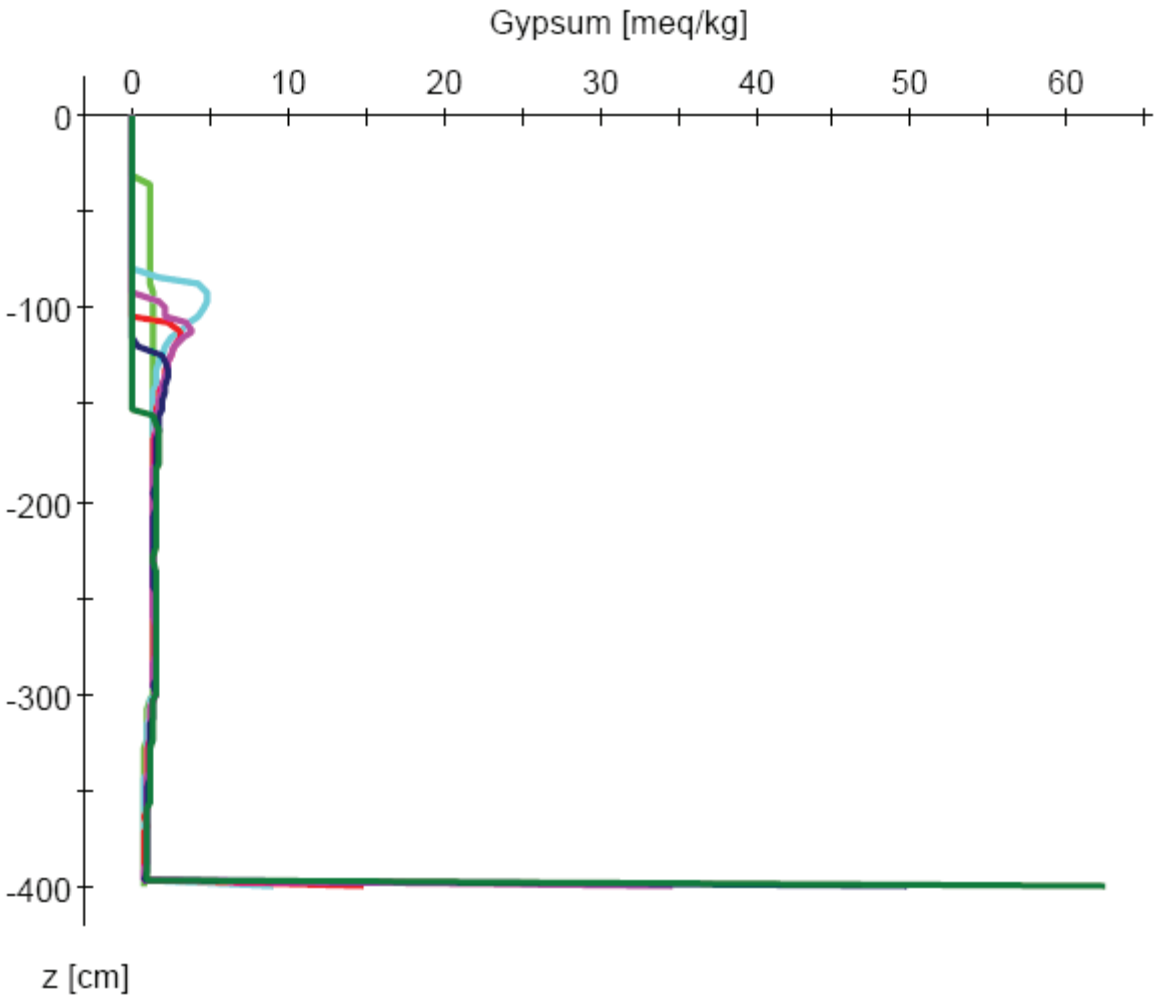


Figure 4. Gypsum levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

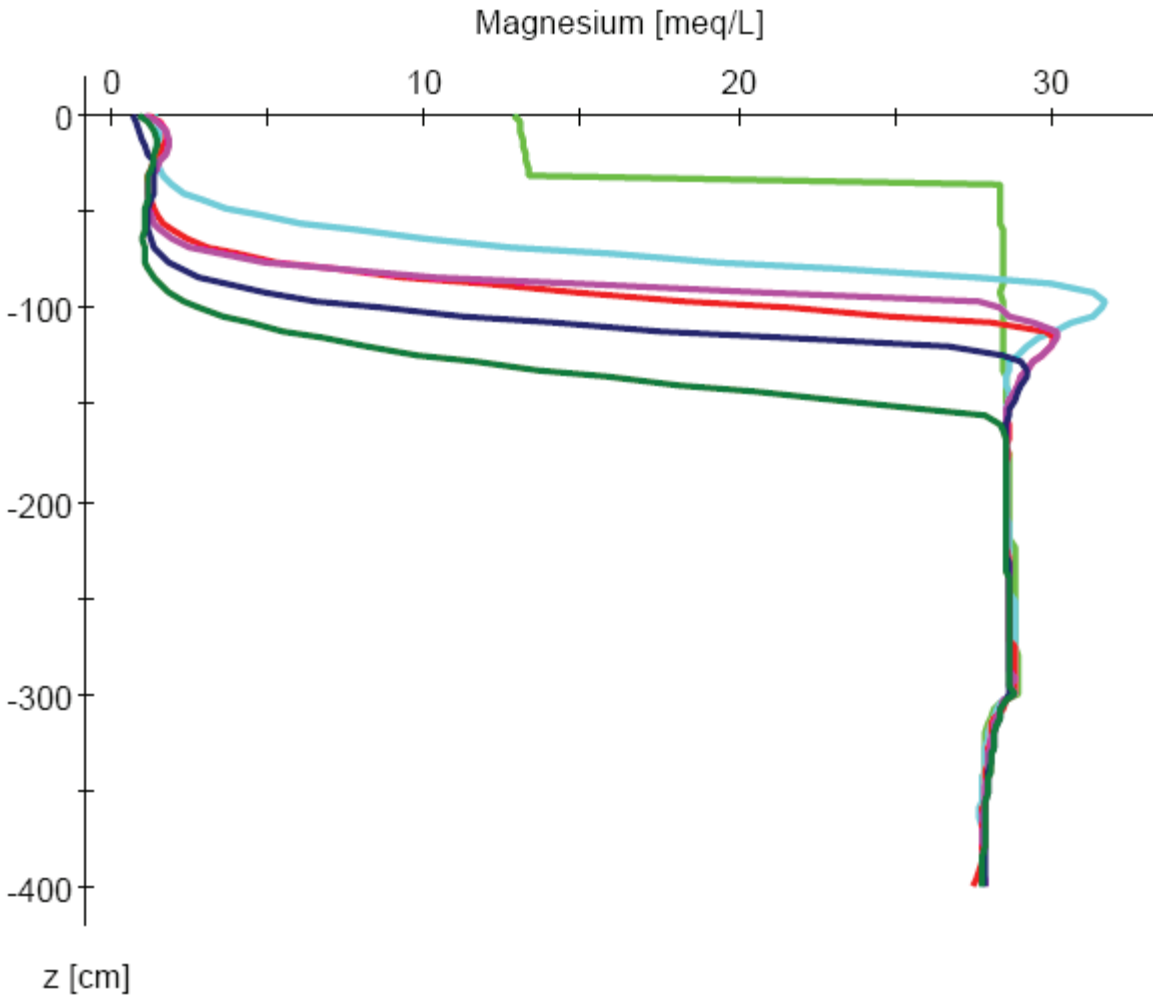


Figure 5. Solution magnesium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

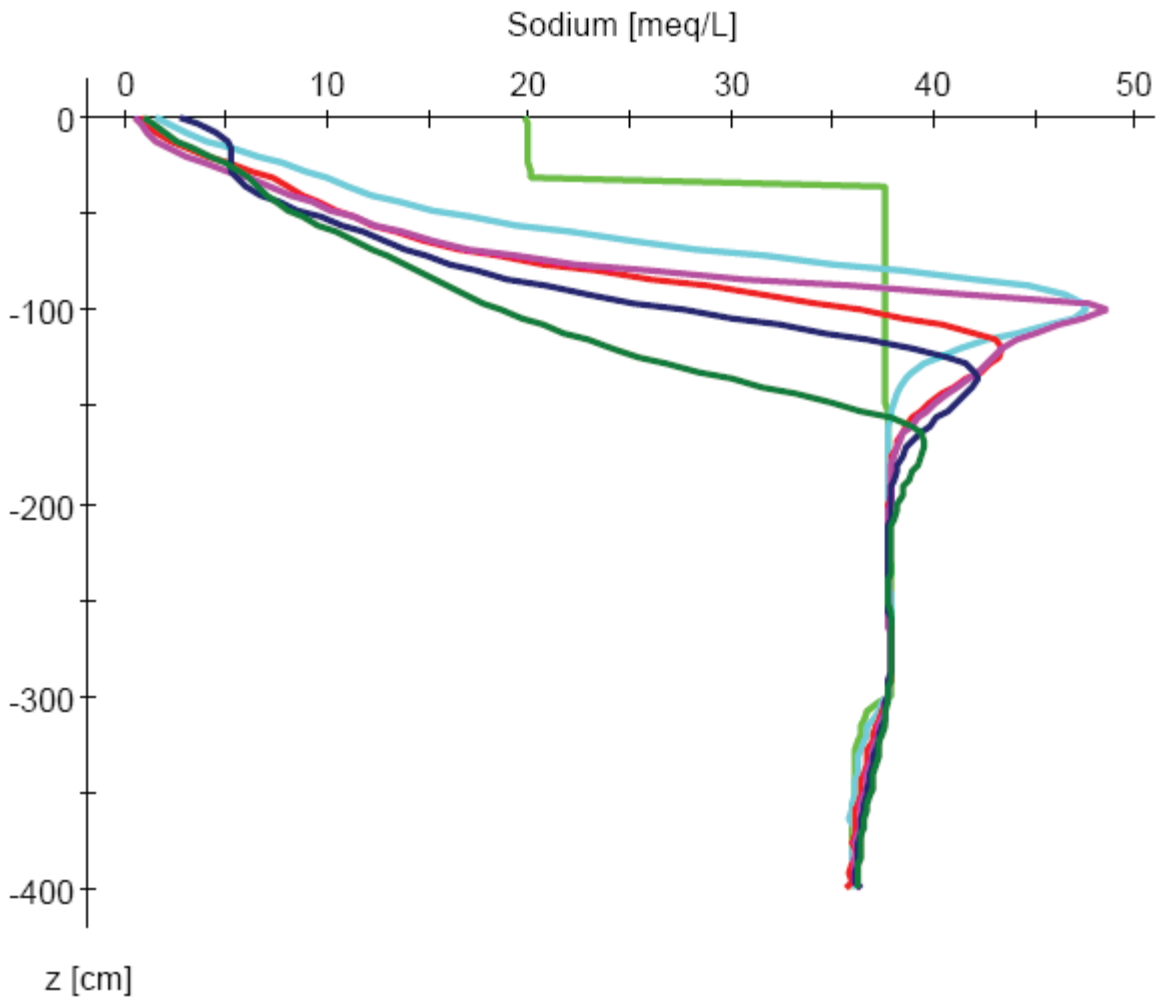


Figure 6. Solution sodium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

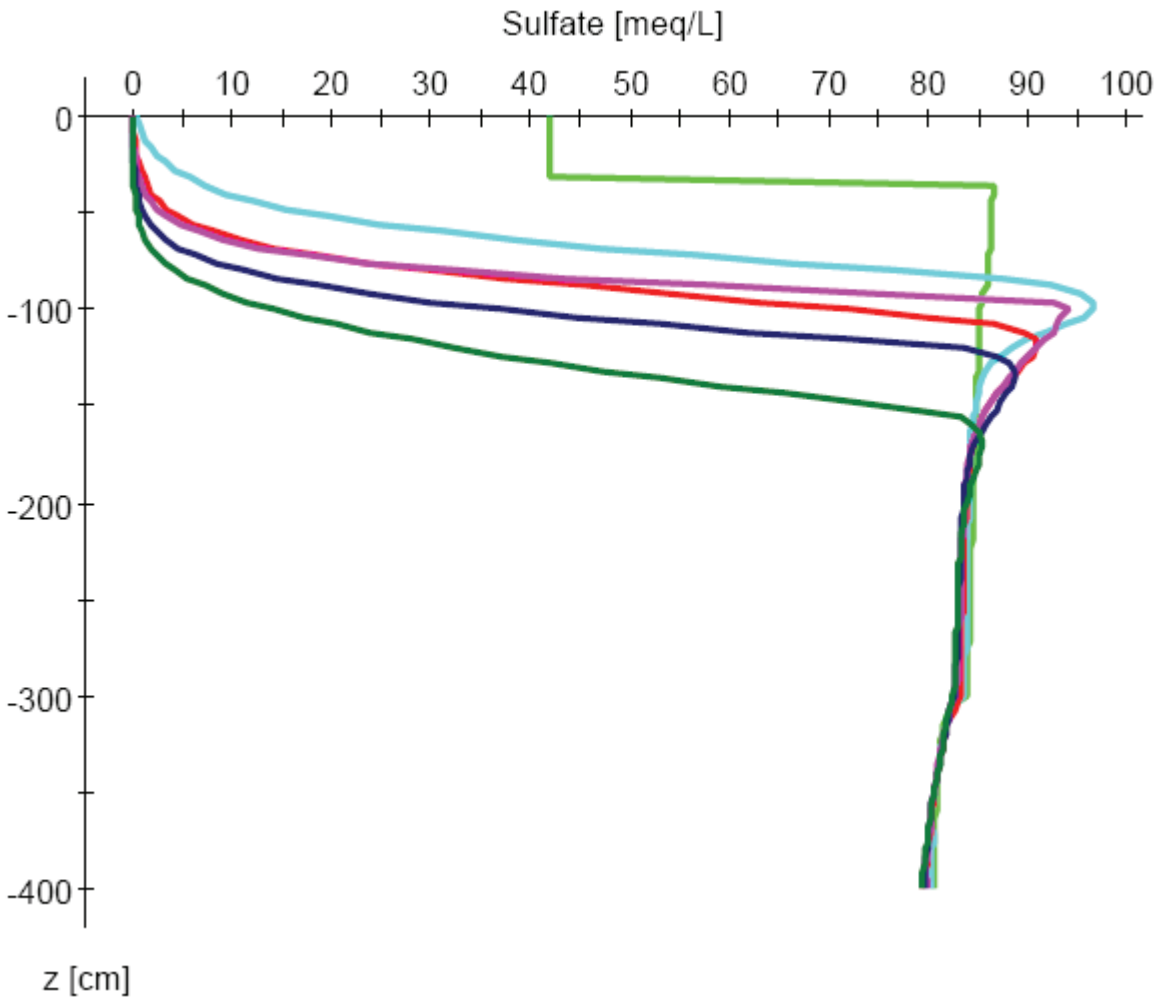


Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

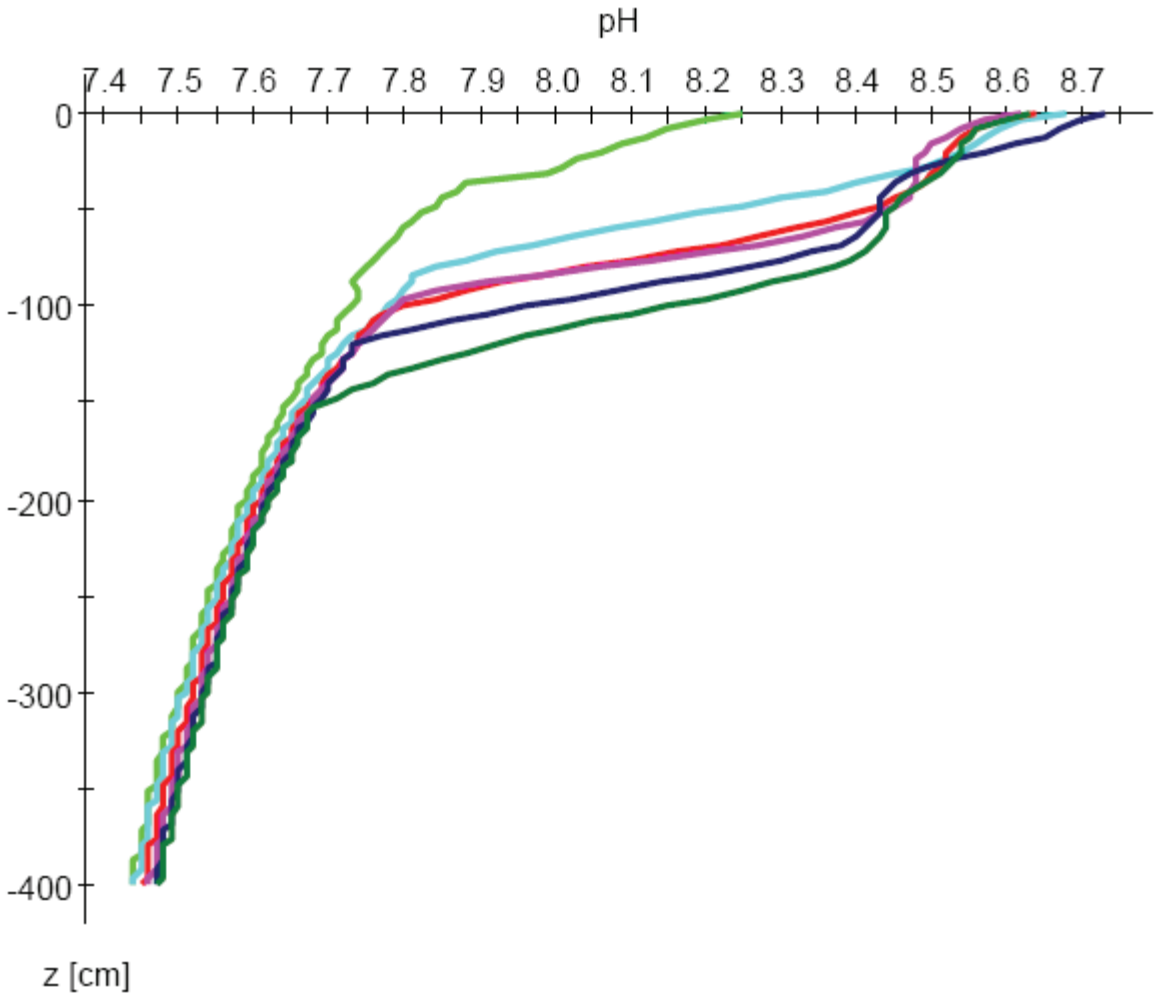


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

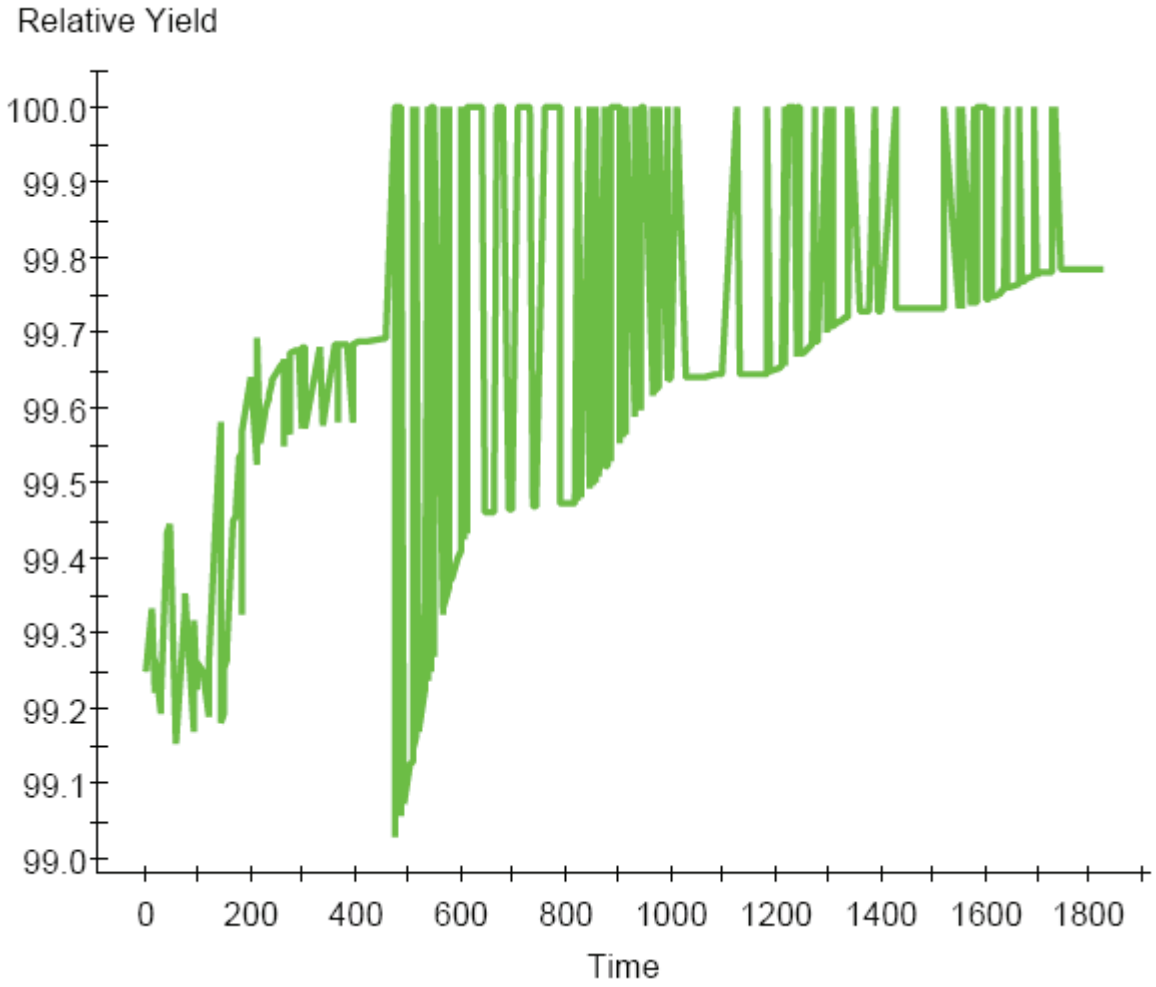


Figure 9. Relative crop yield over the 5-year simulation period.

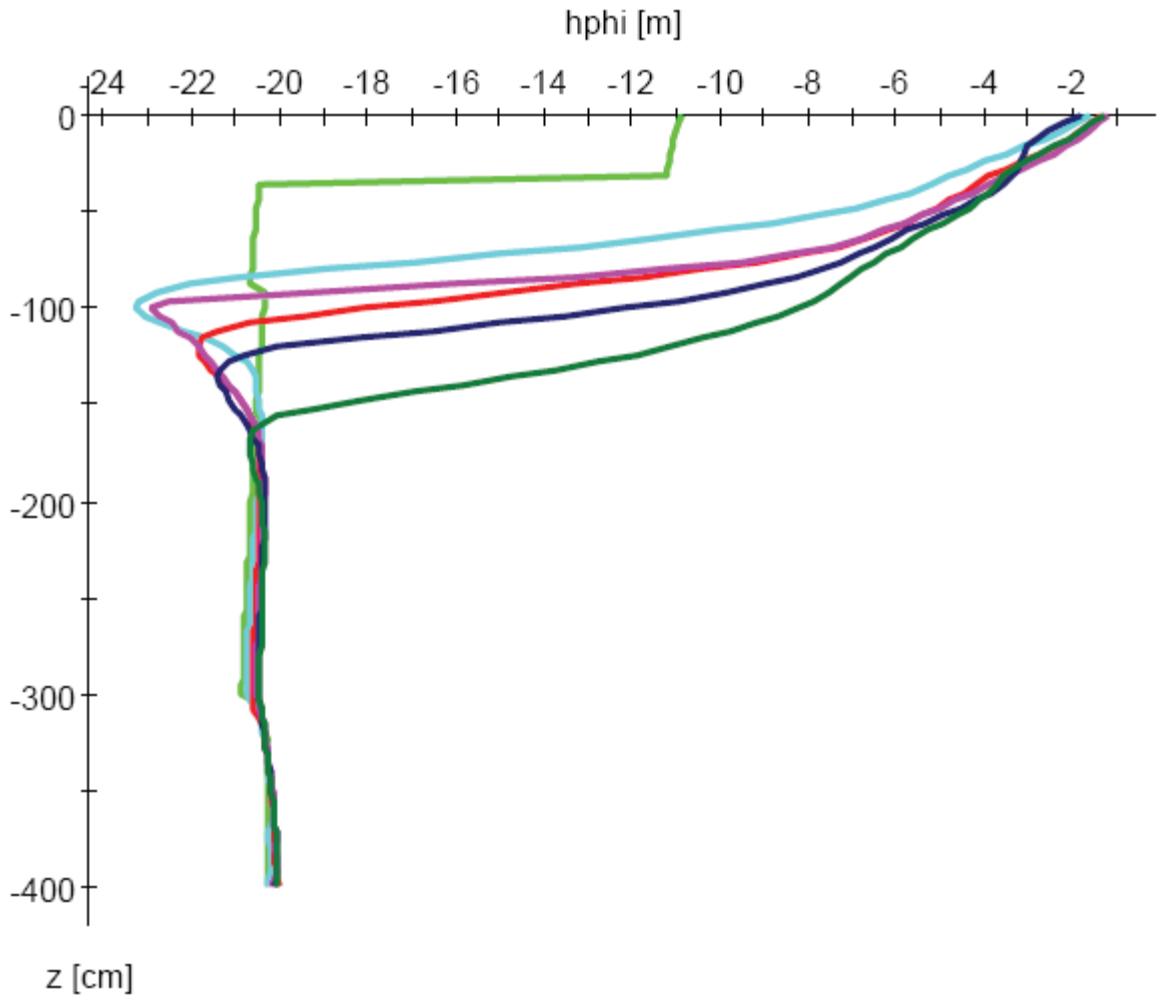


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

Paulette Parks - Site PP1.

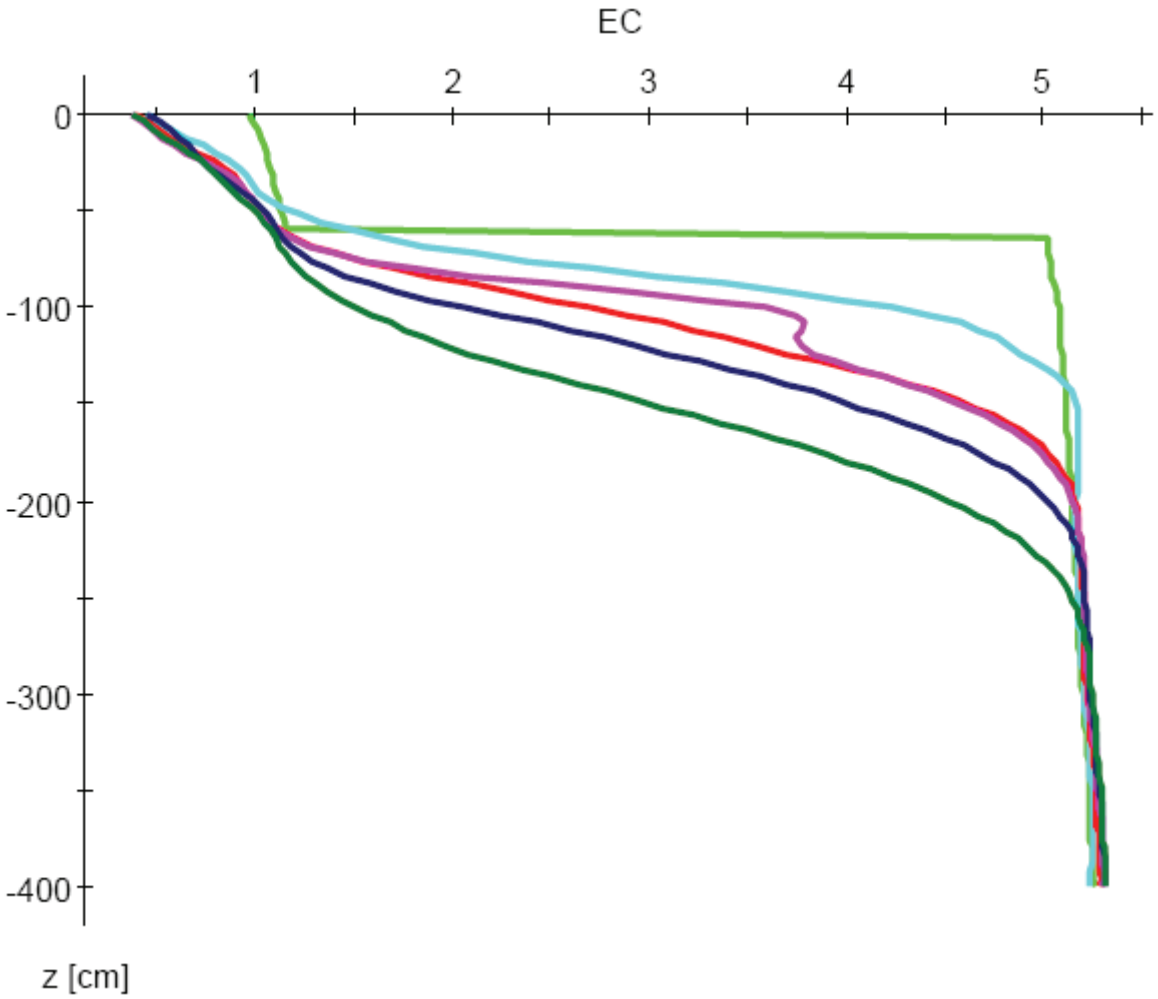


Figure 1. Salt concentrations (EC) by soil depth over the 5-year irrigation period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

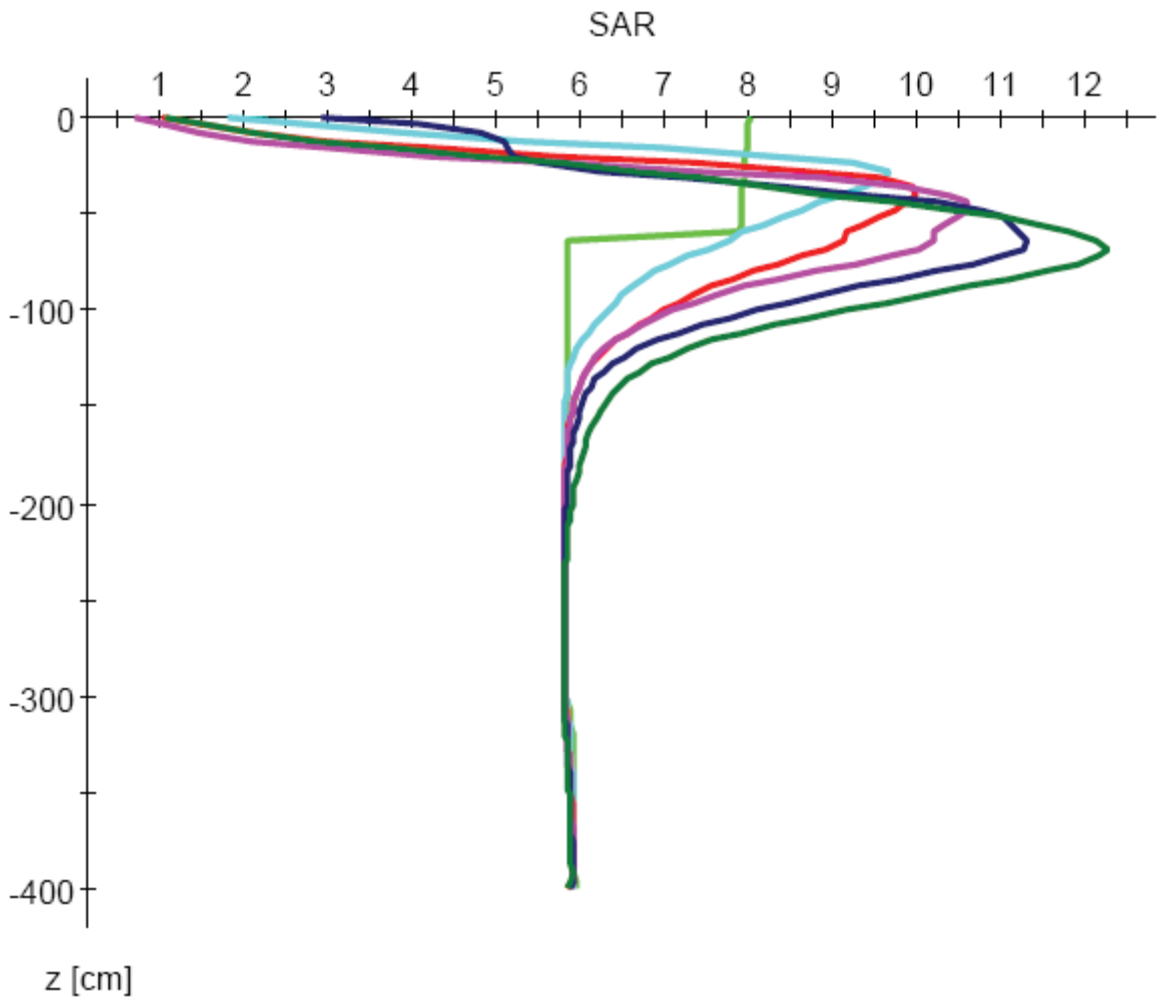


Figure 2. SAR by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

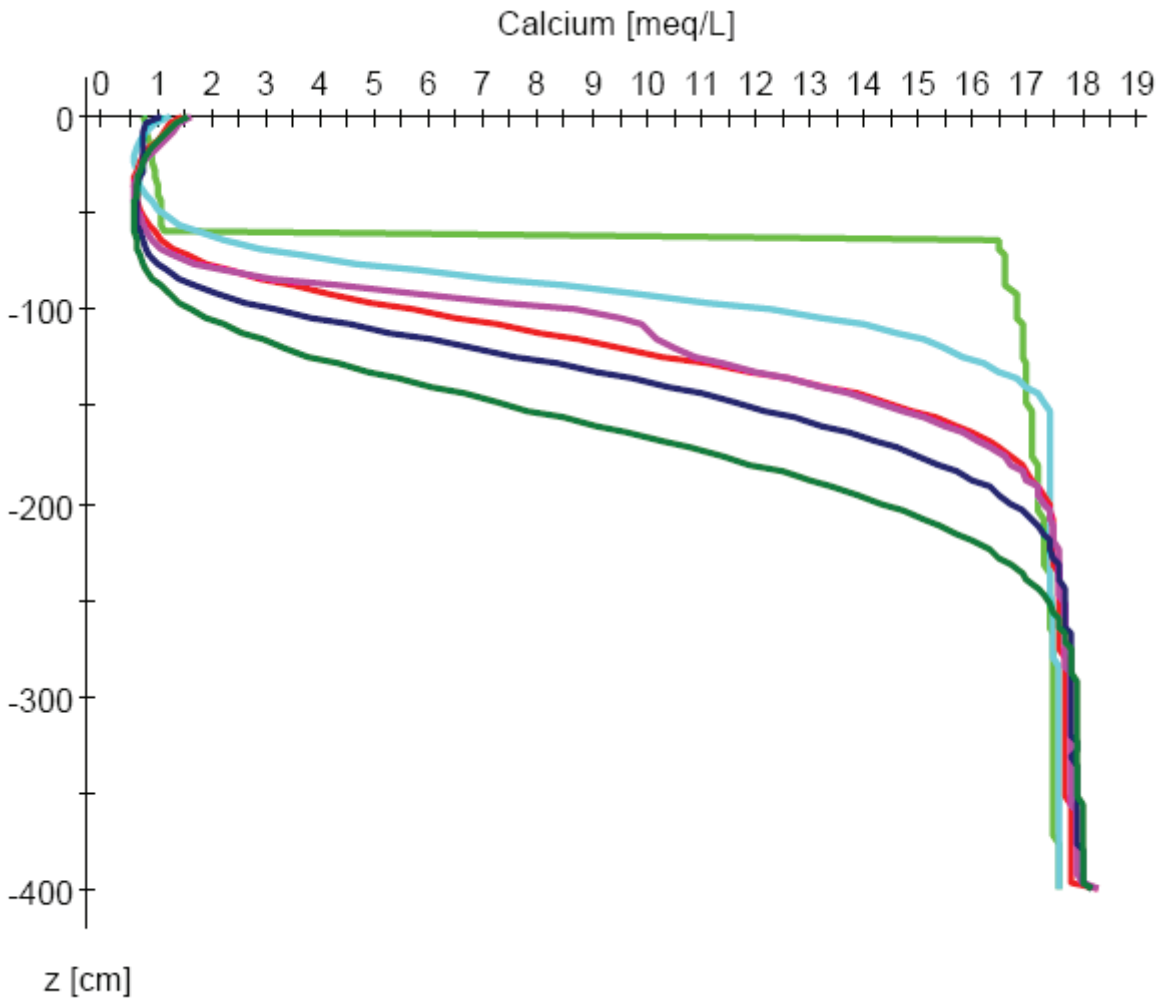


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

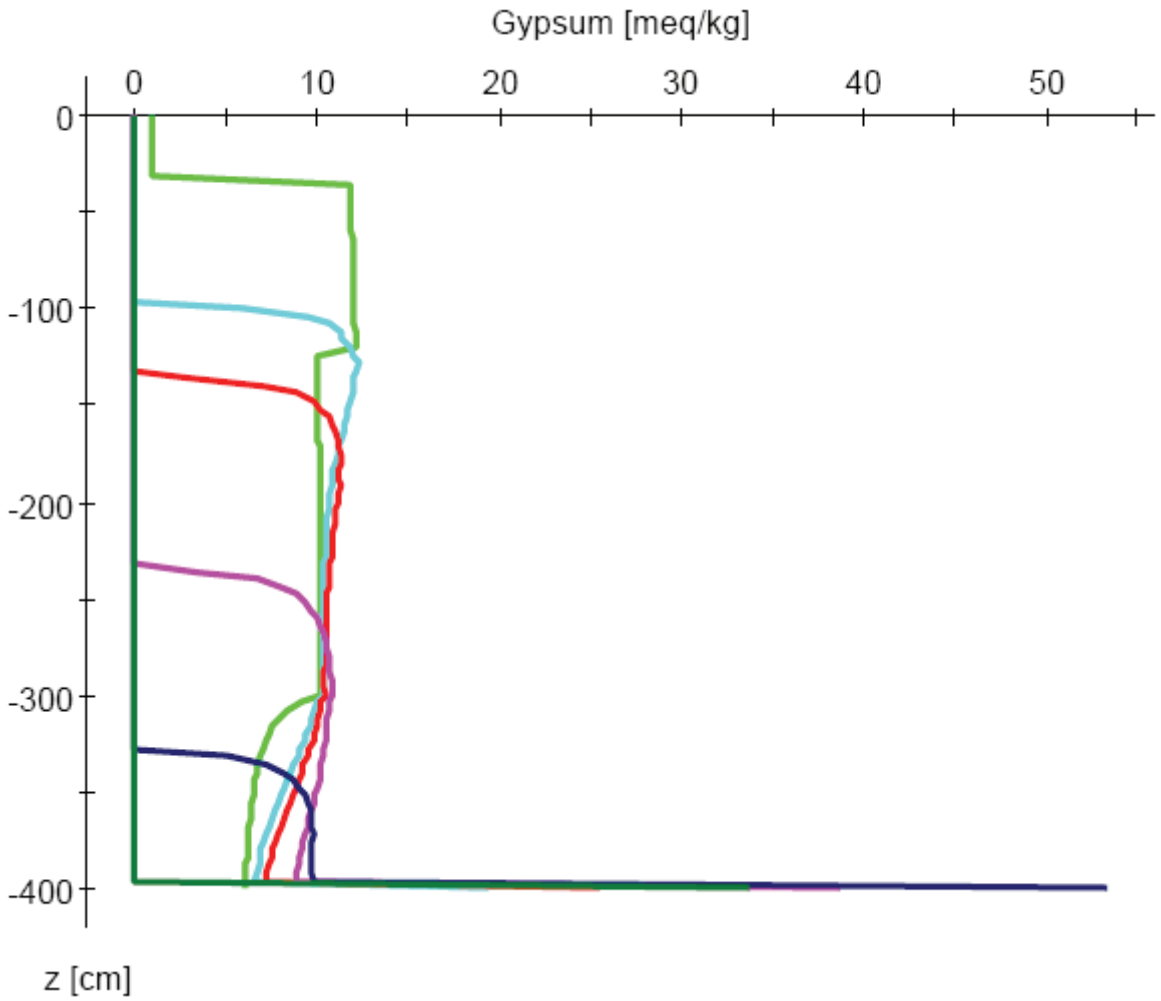


Figure 4. Gypsum levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

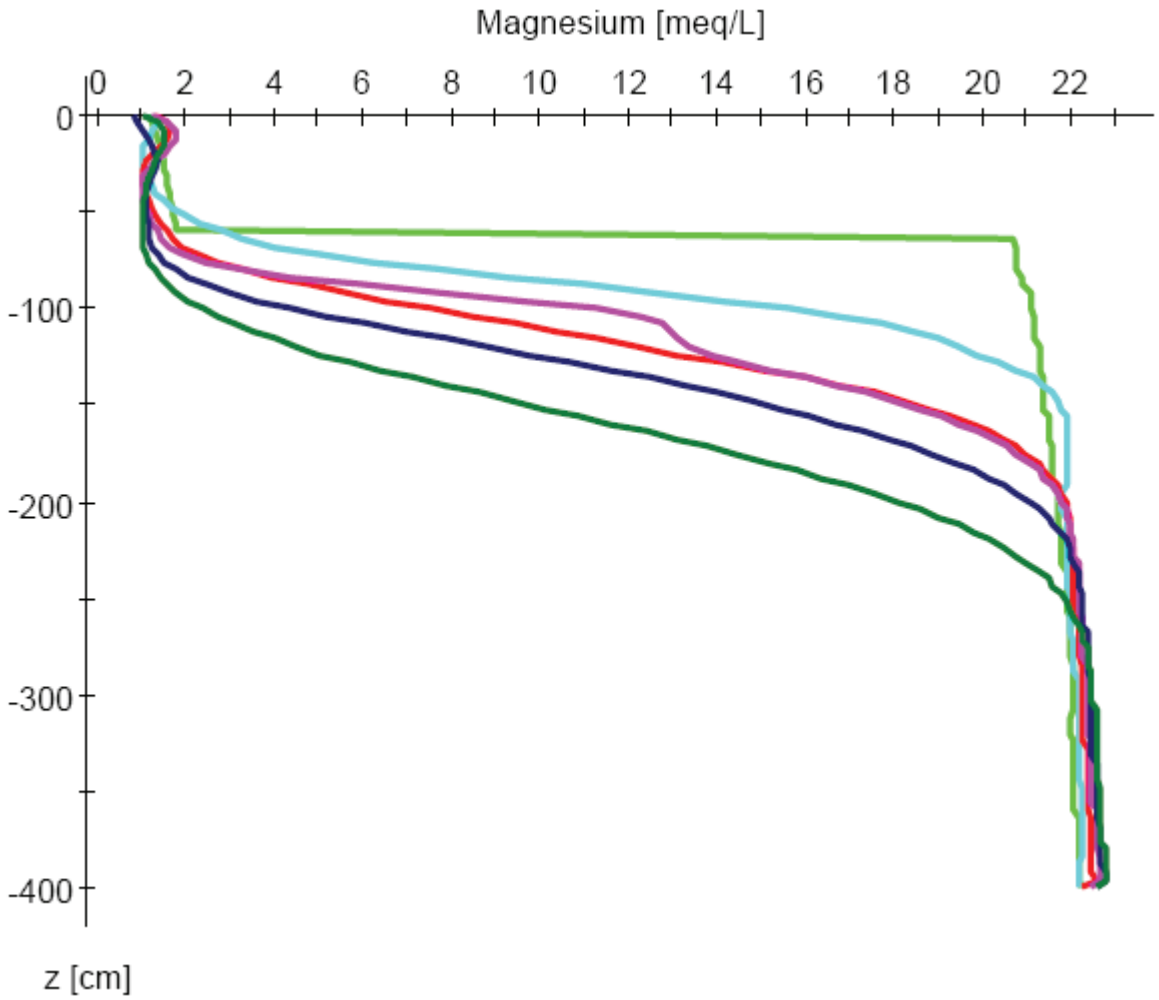
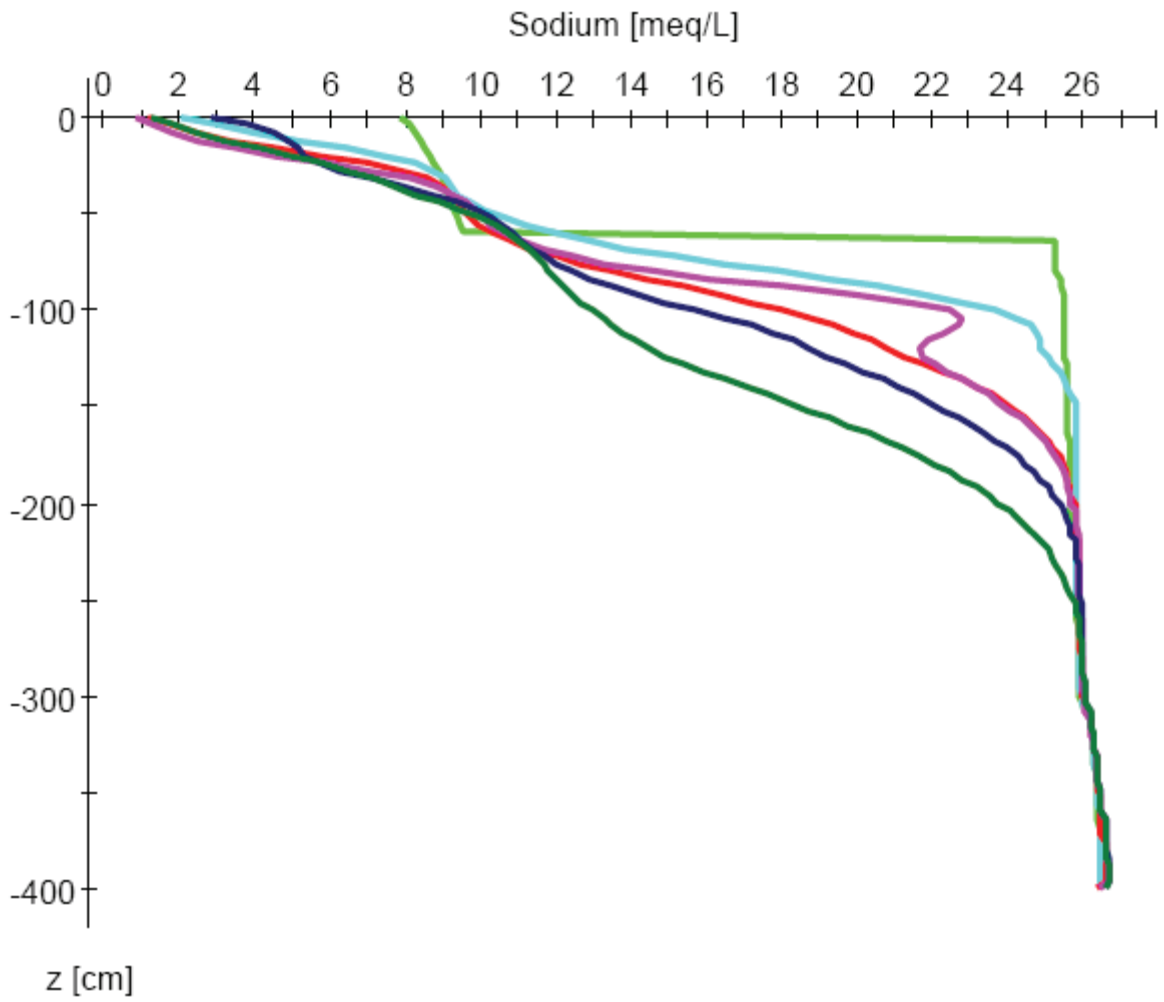


Figure 5. Solution magnesium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



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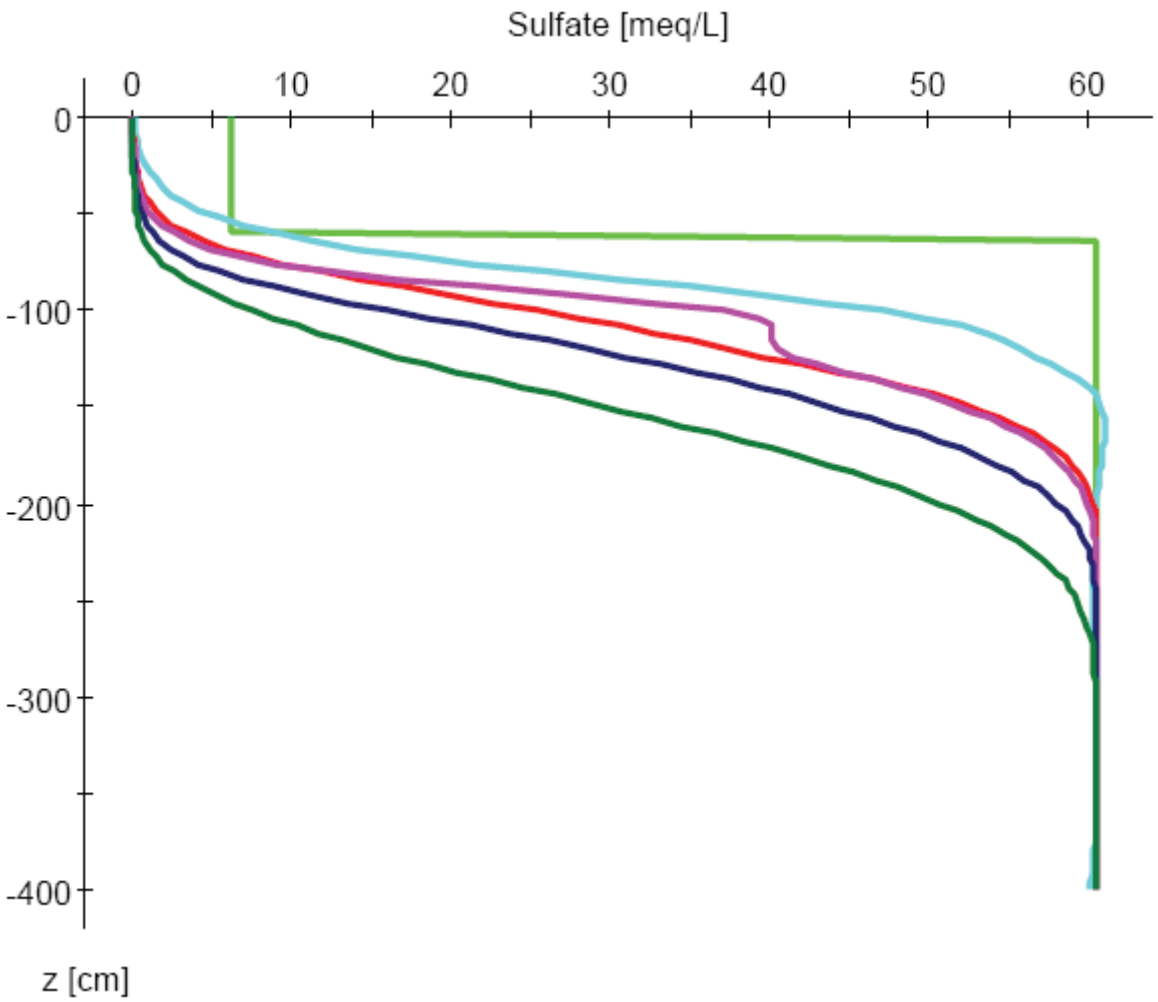


Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

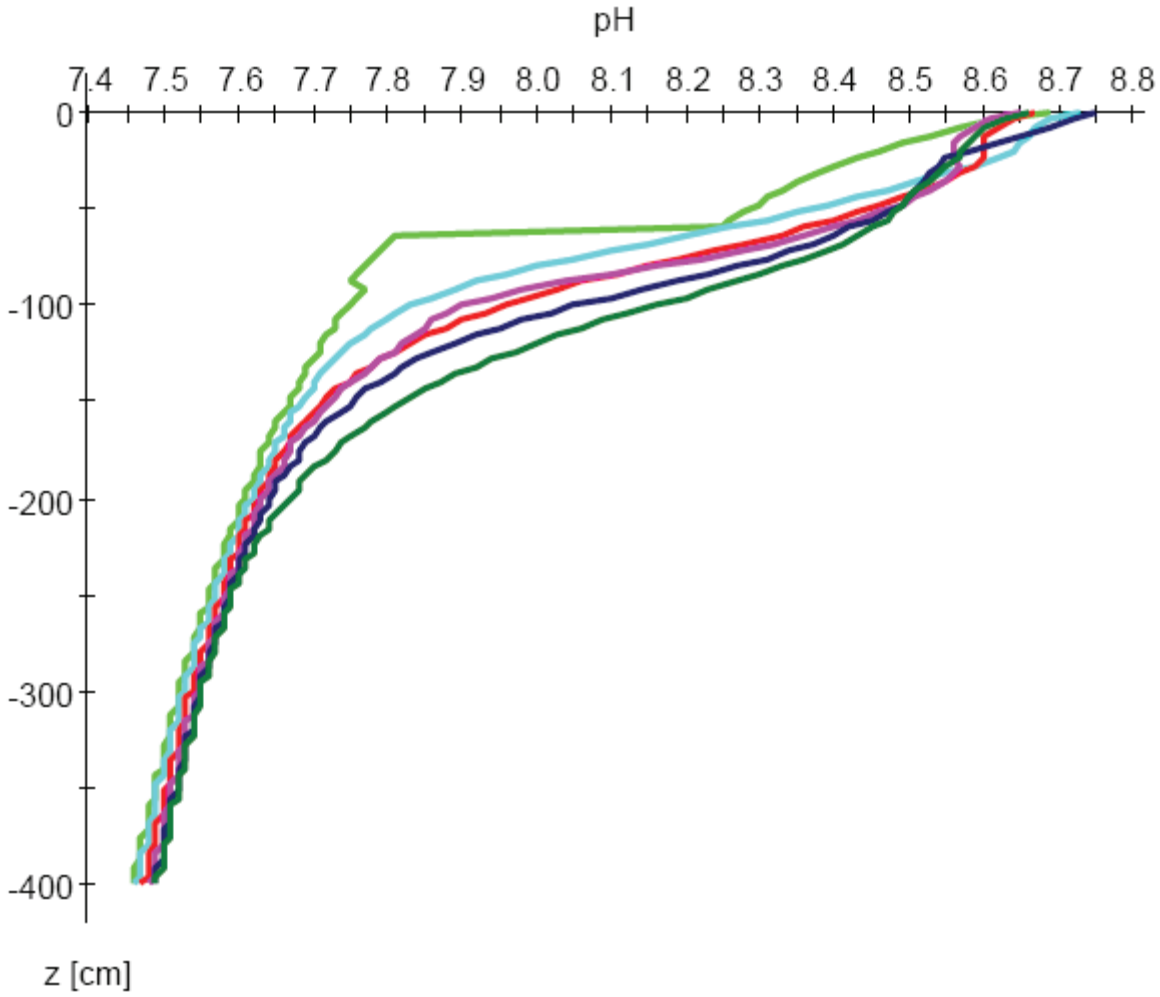


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

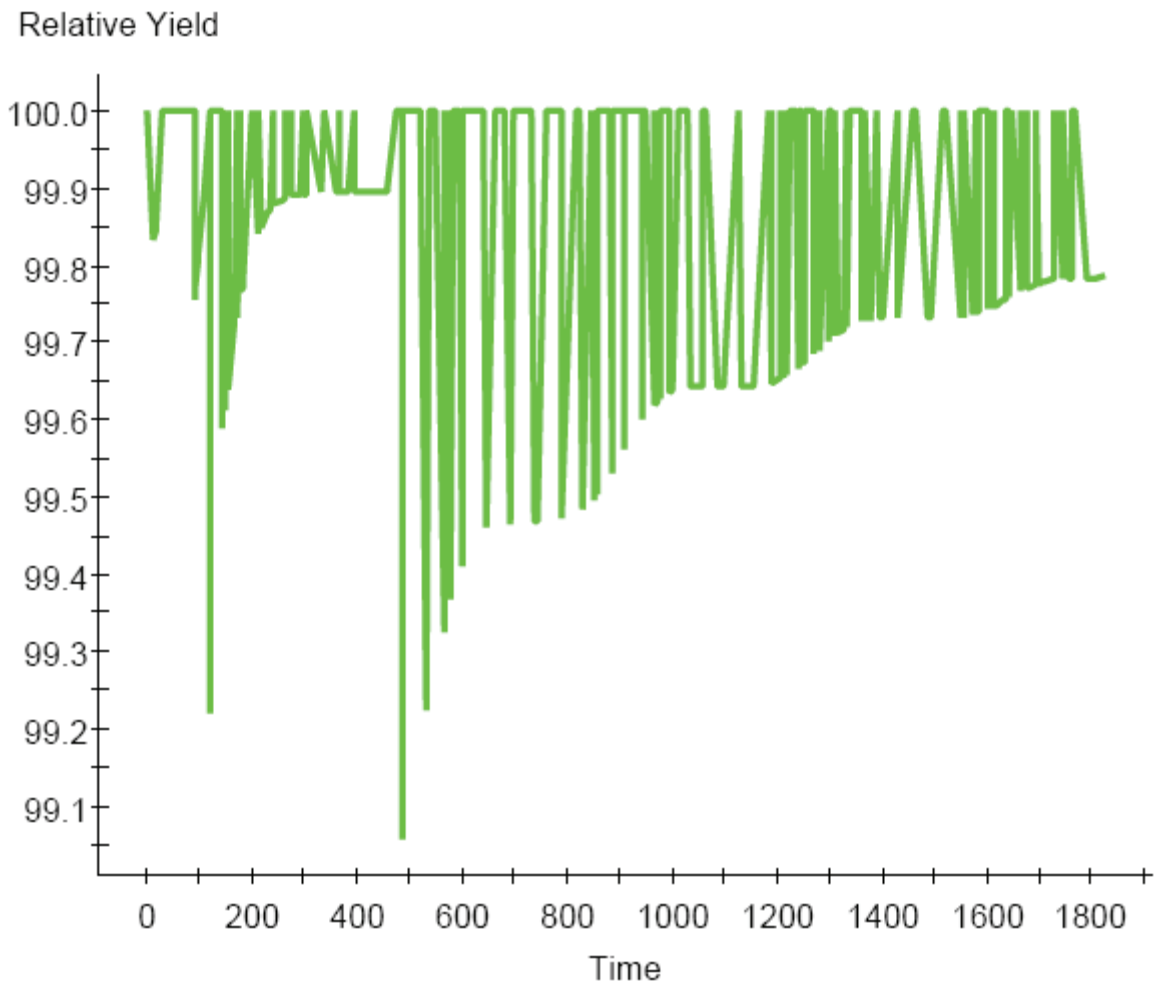


Figure 9. Relative crop yield over the 5-year simulation period.

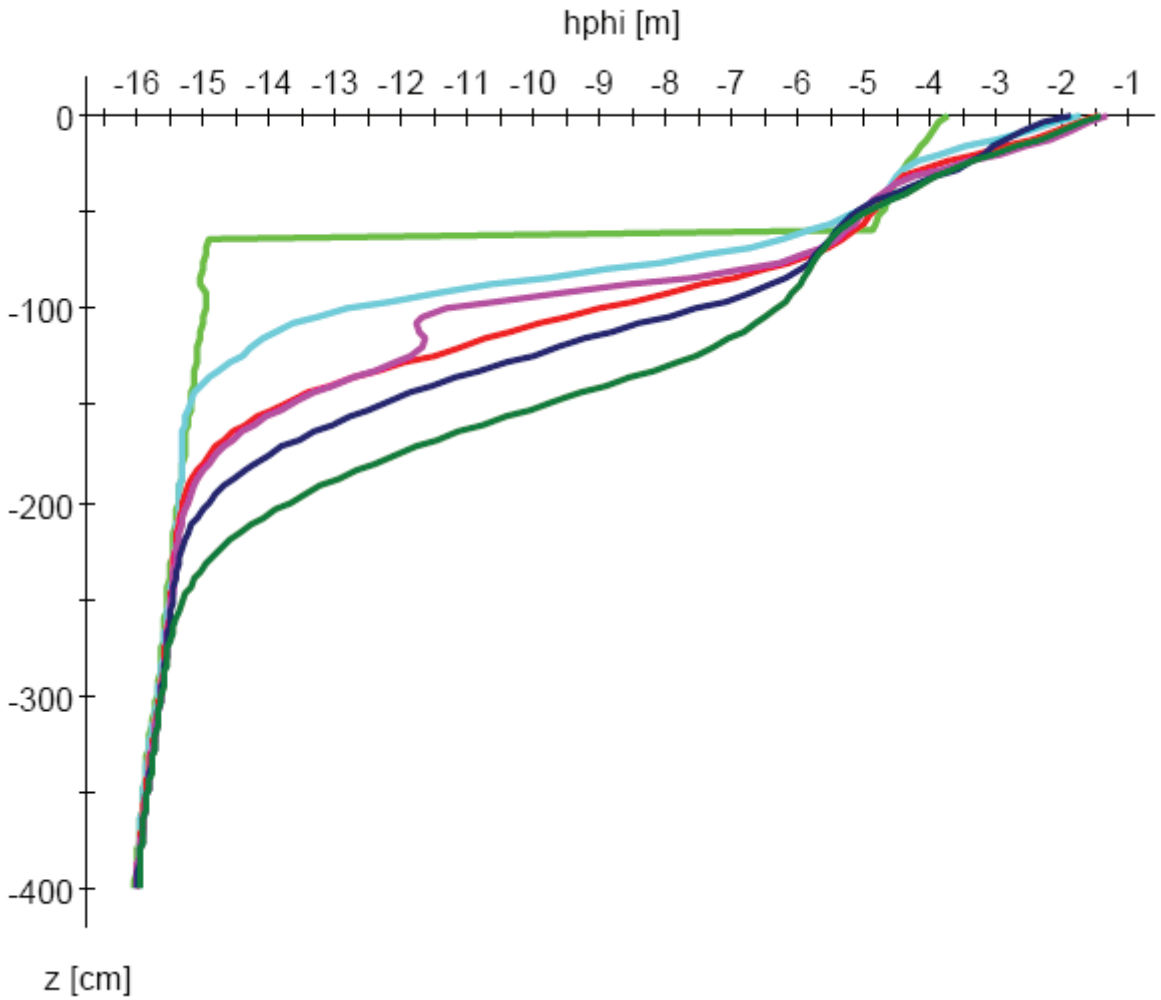


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

Paulette Parks Site PP10

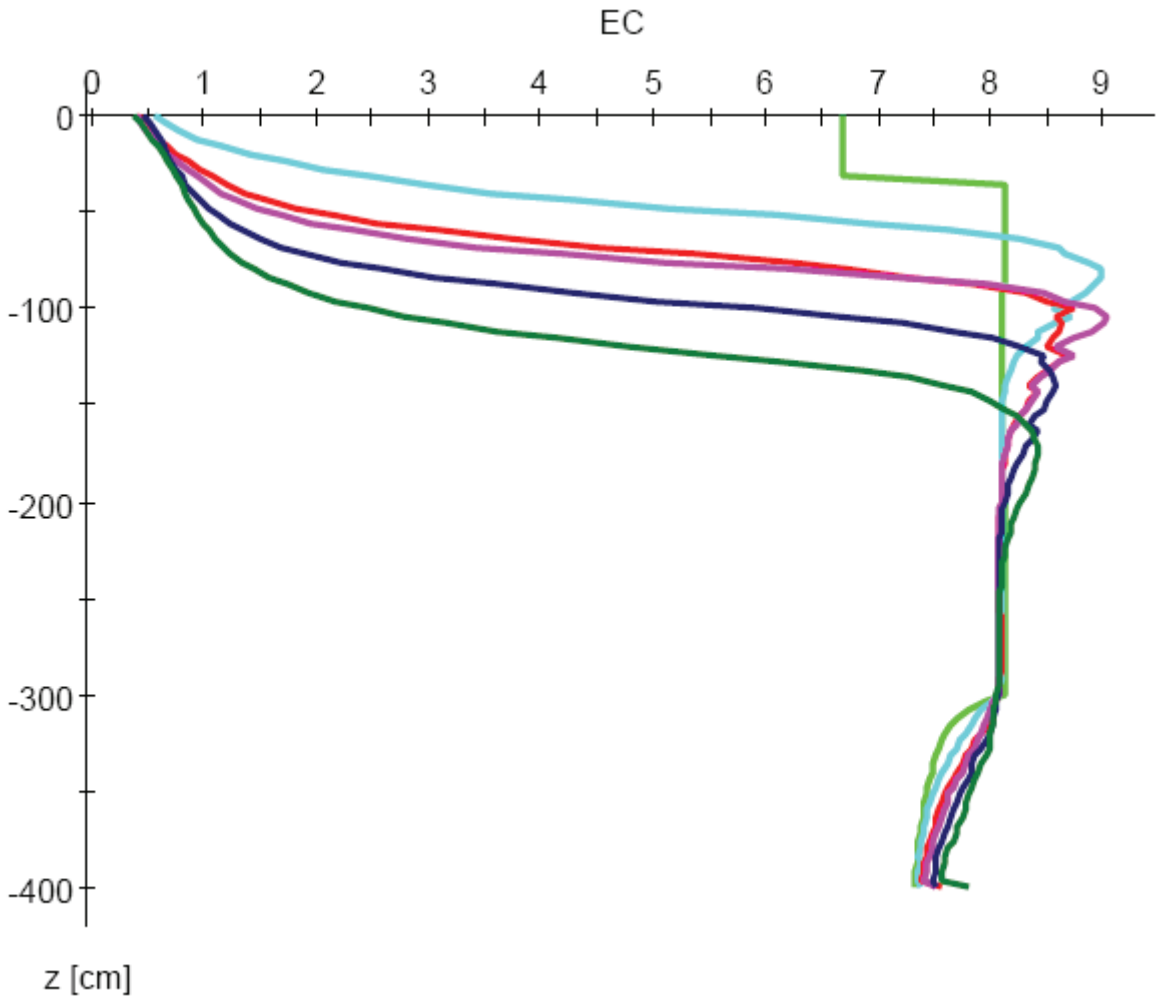


Figure 1. Salt concentrations (EC) by soil depth over the 5-year irrigation period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

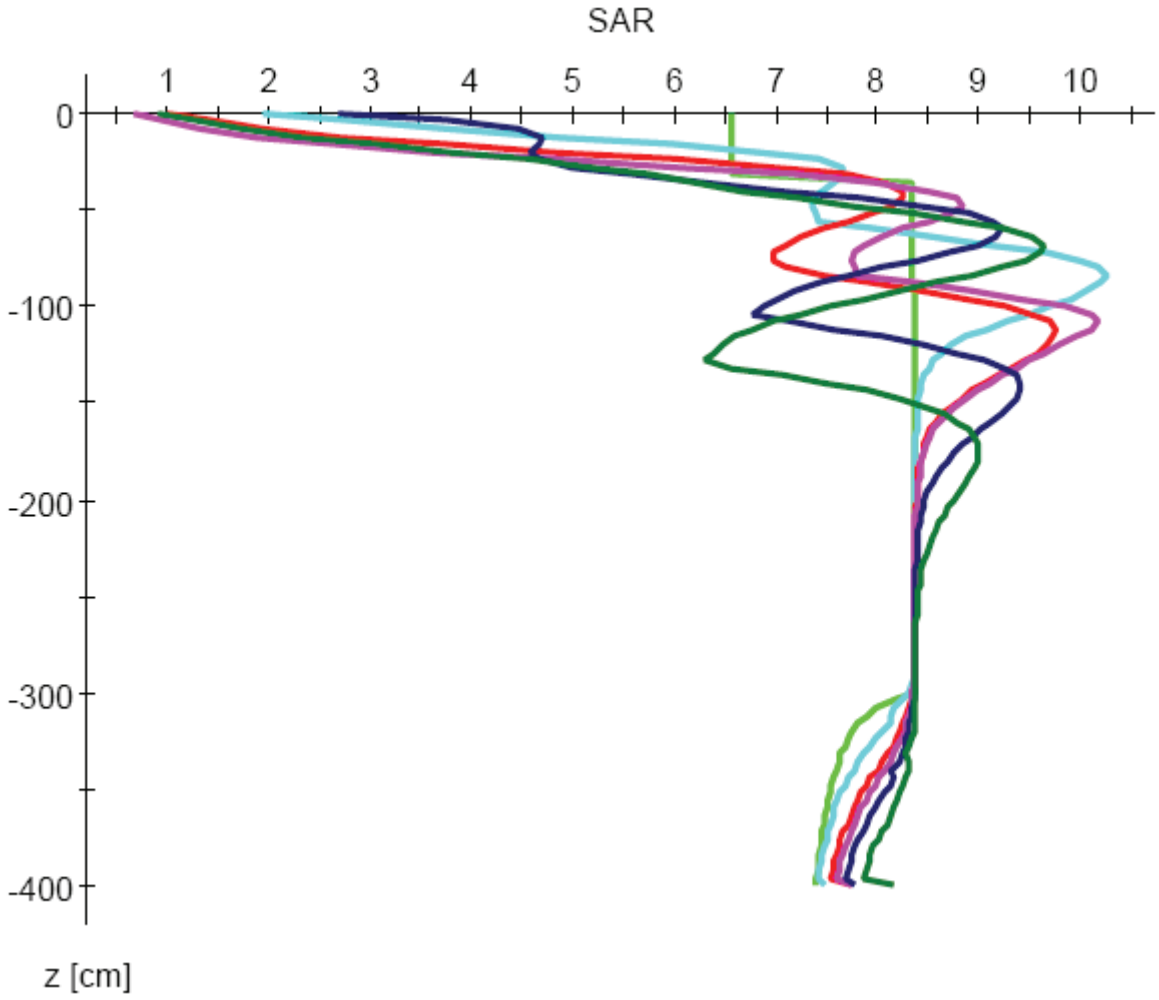


Figure 2. SAR by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

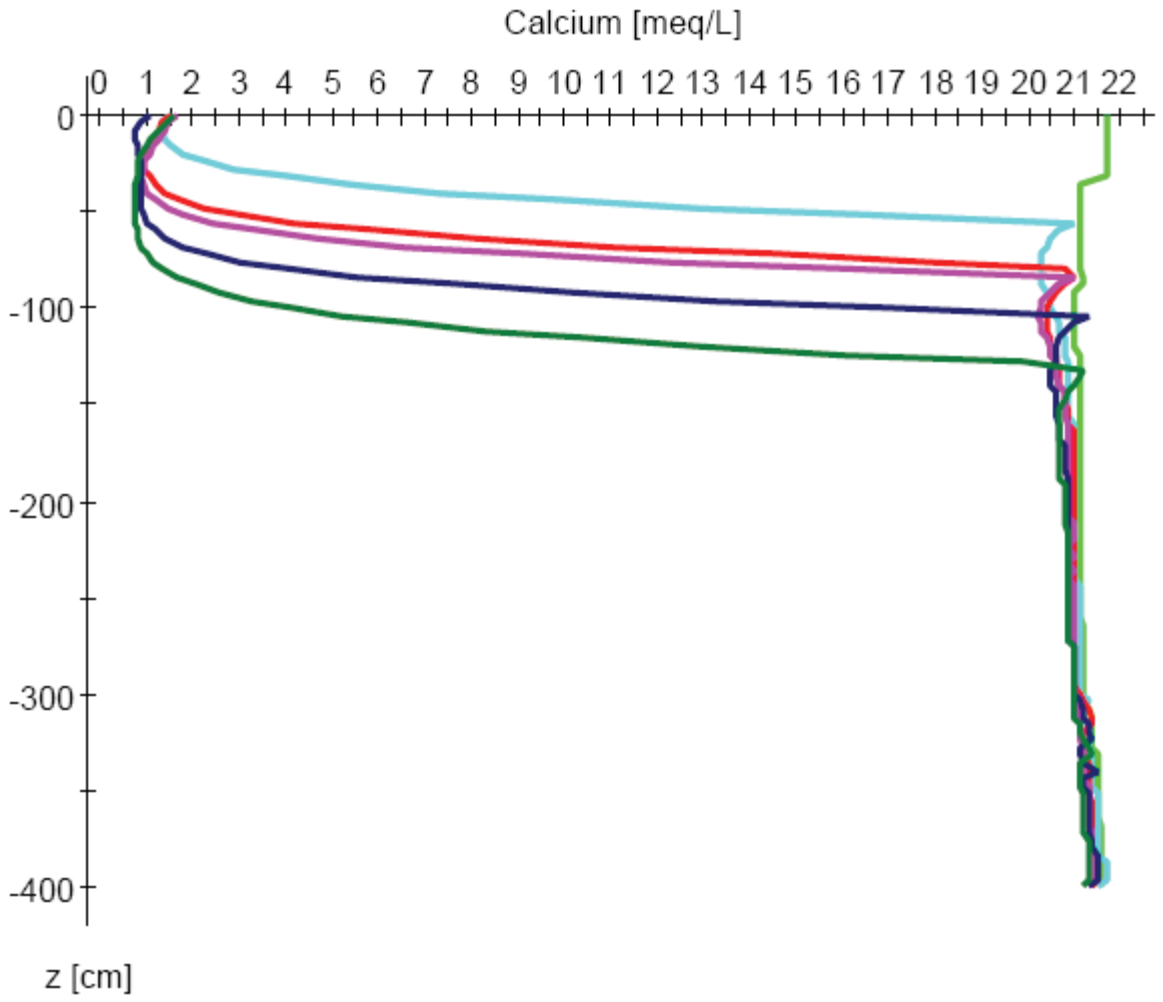


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

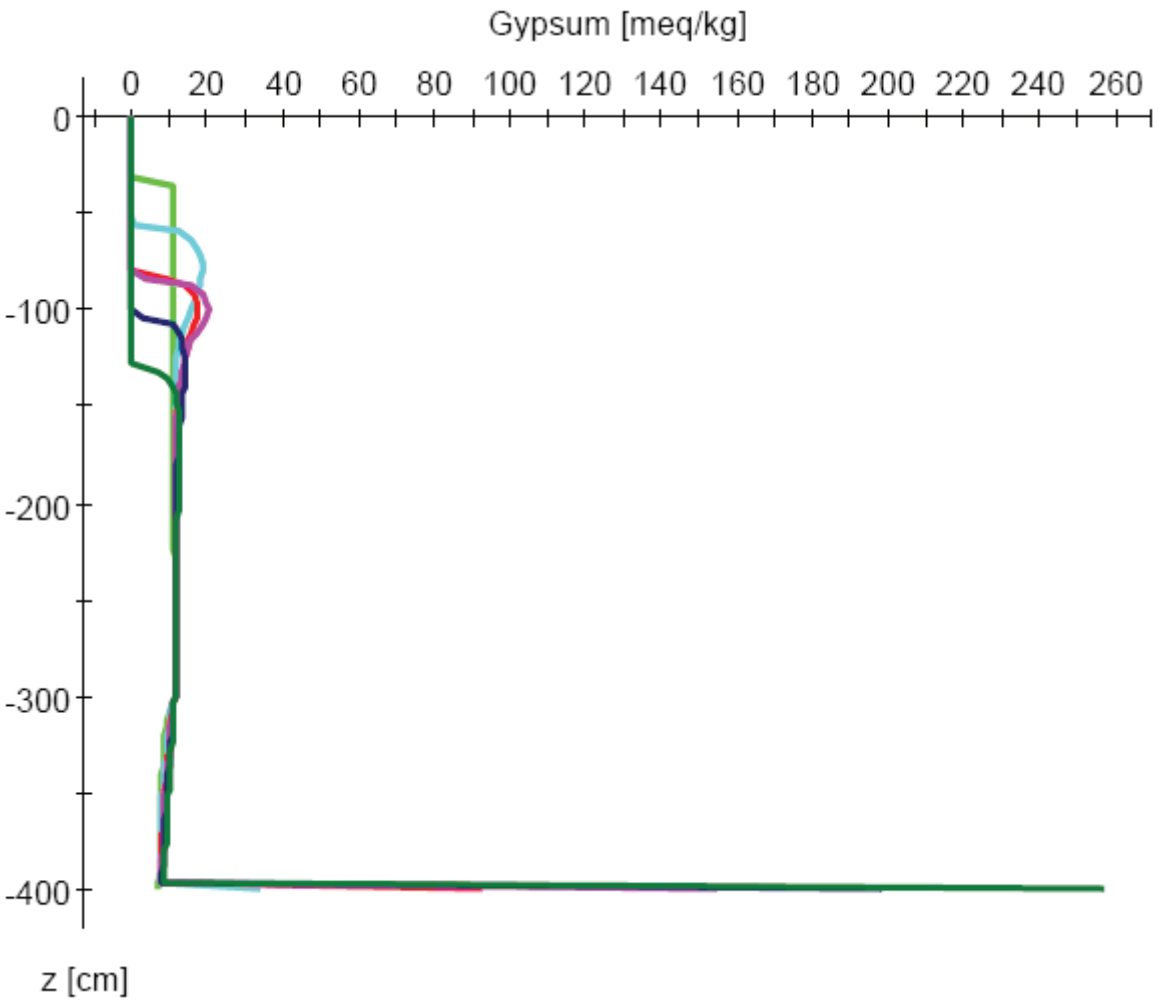


Figure 4. Gypsum levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

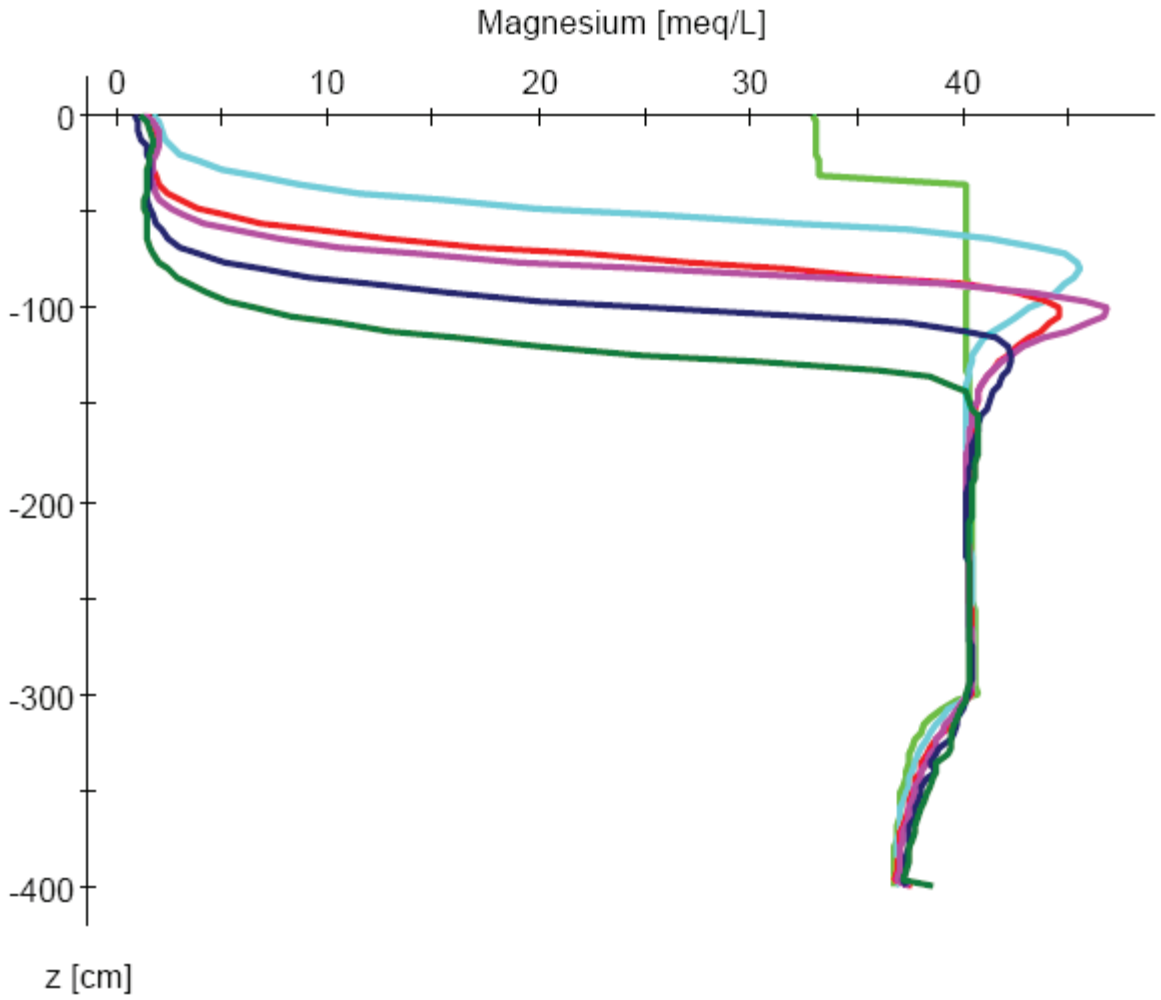
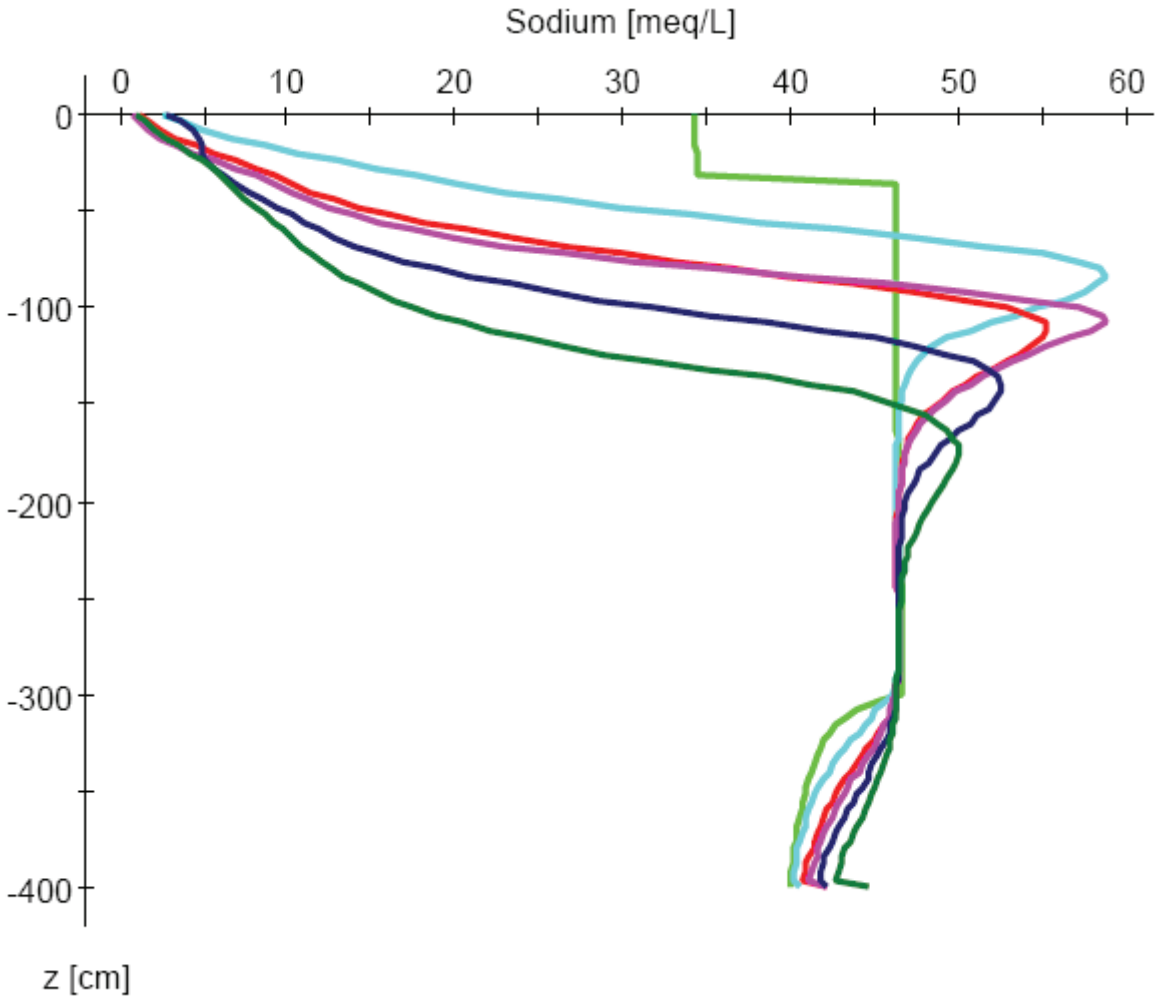


Figure 5. Solution magnesium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



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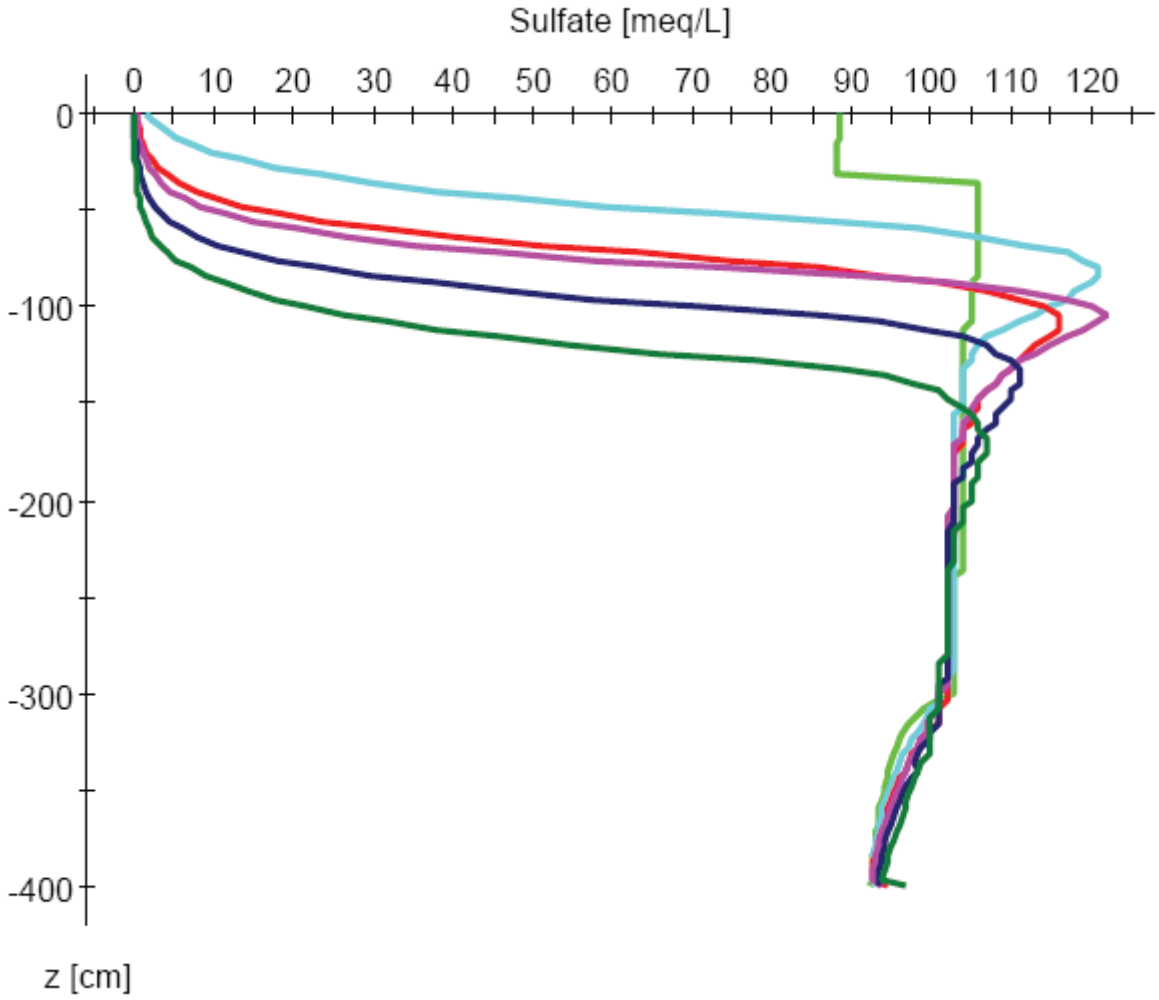


Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

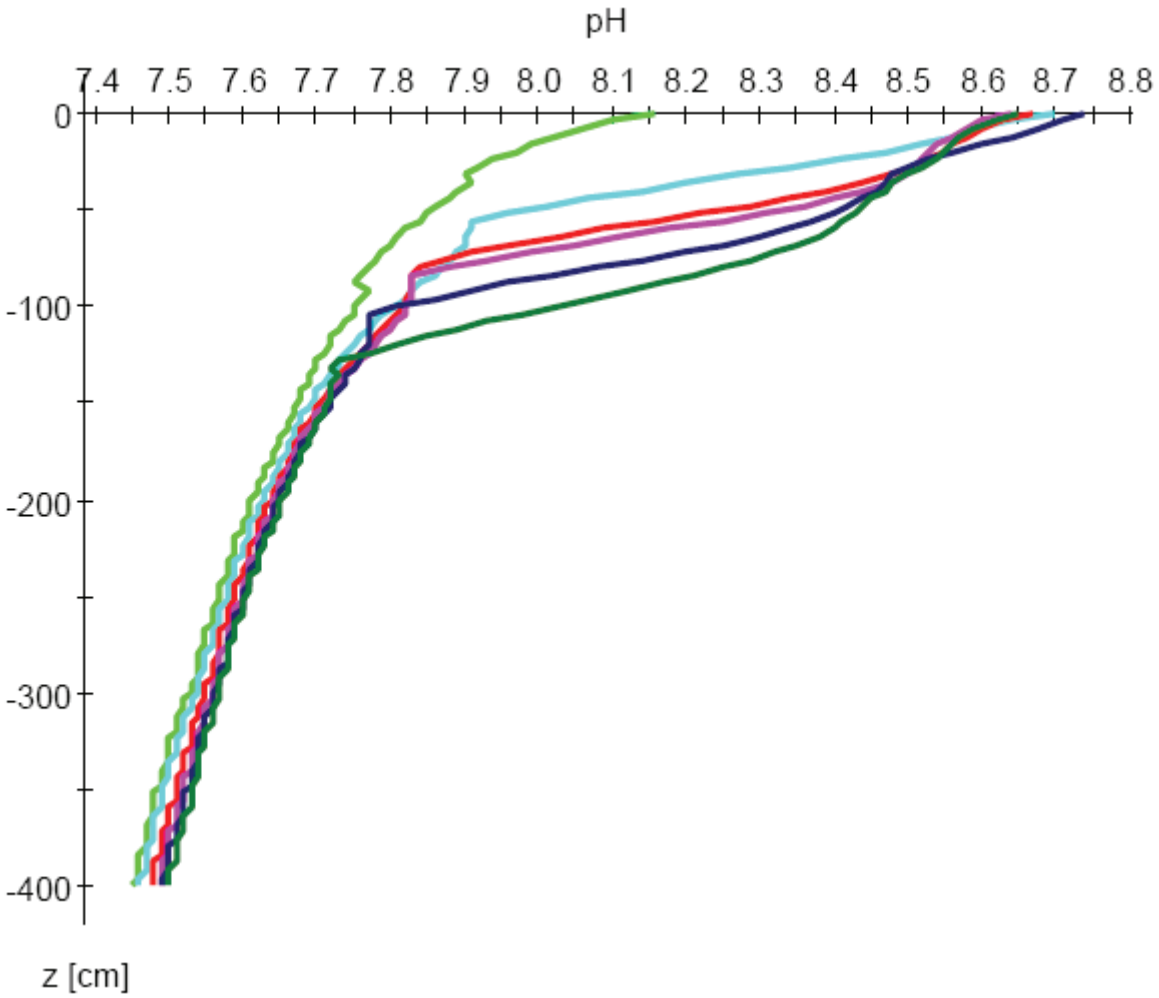


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

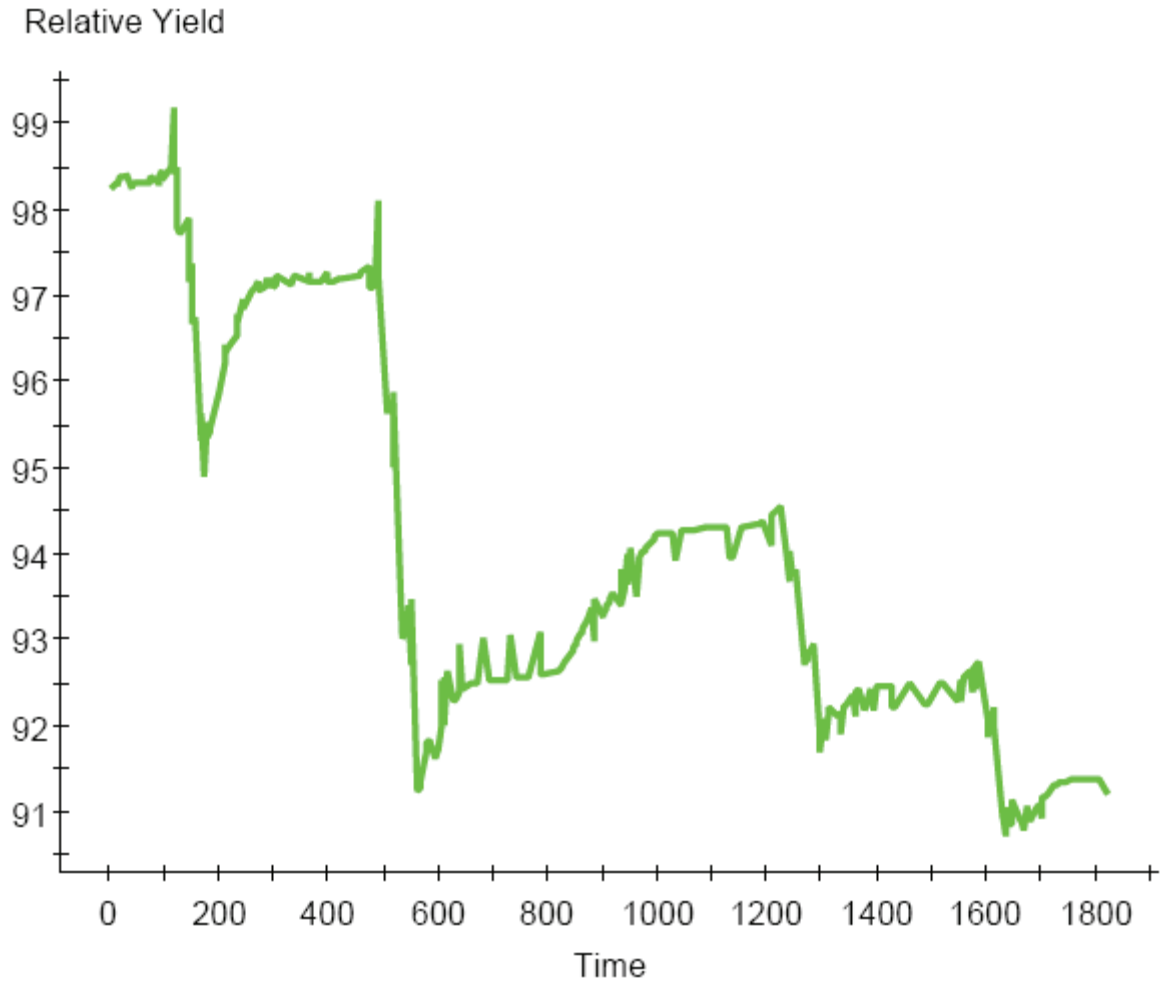


Figure 9. Relative crop yield over the 5-year simulation period.

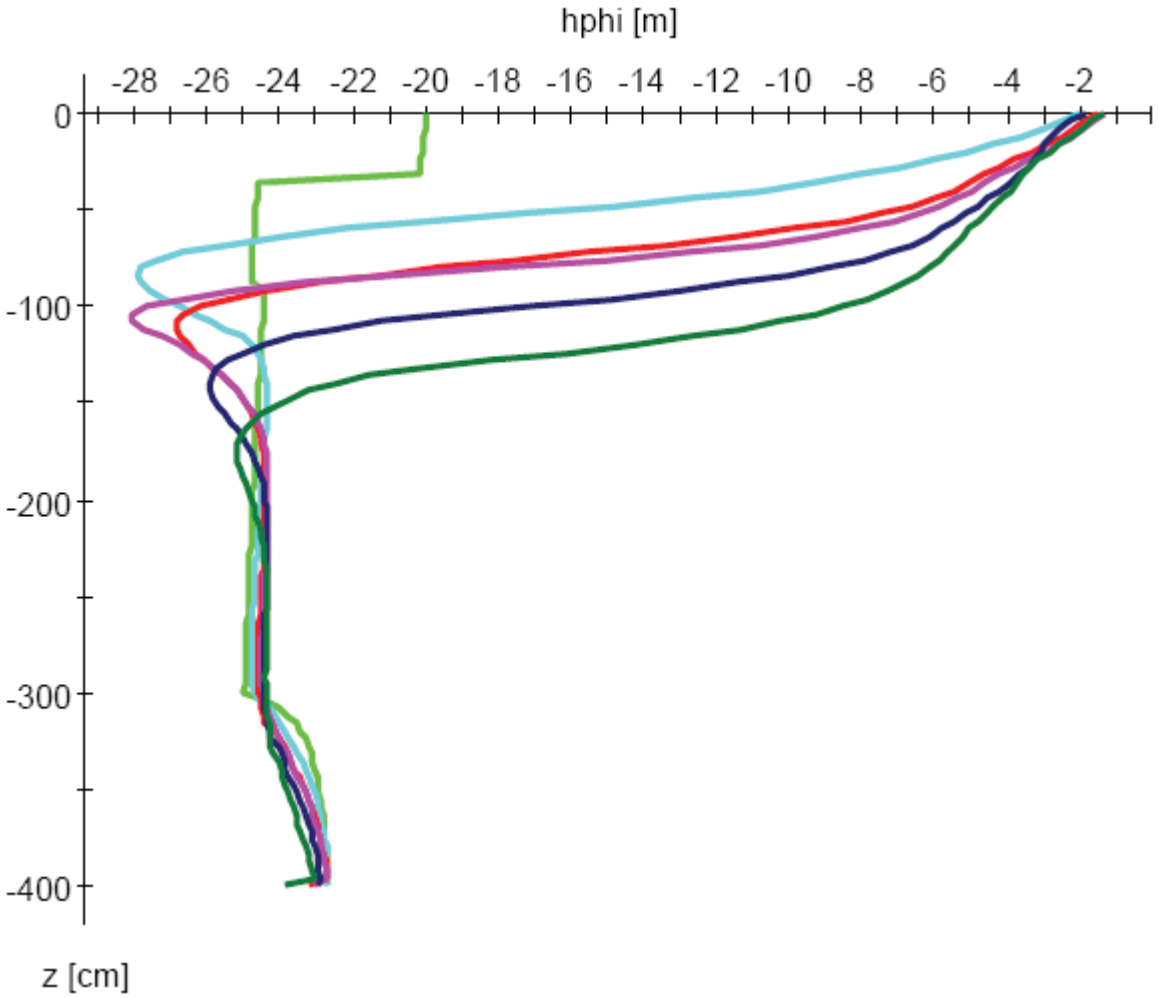
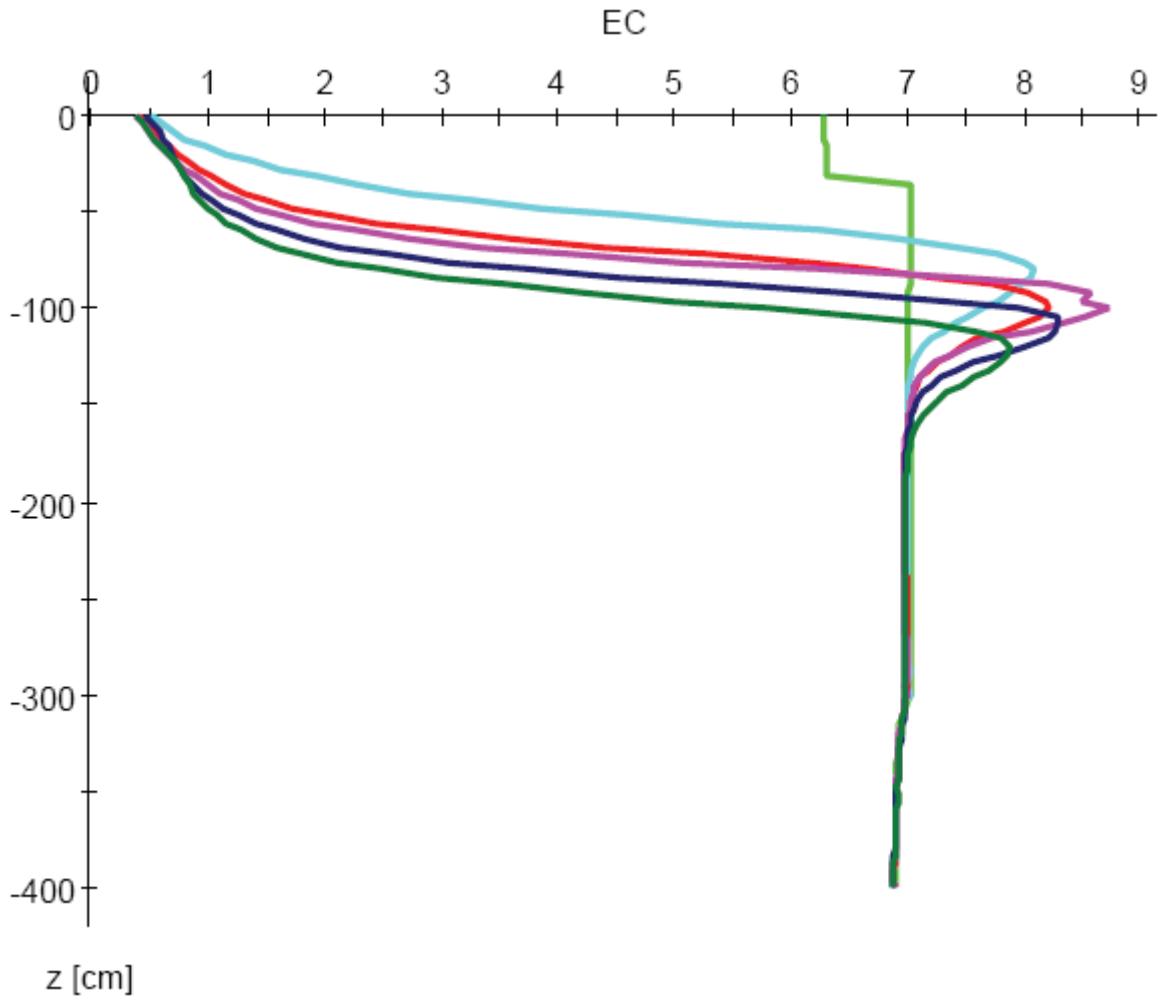


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

Marsha Pownall Ranch MP1



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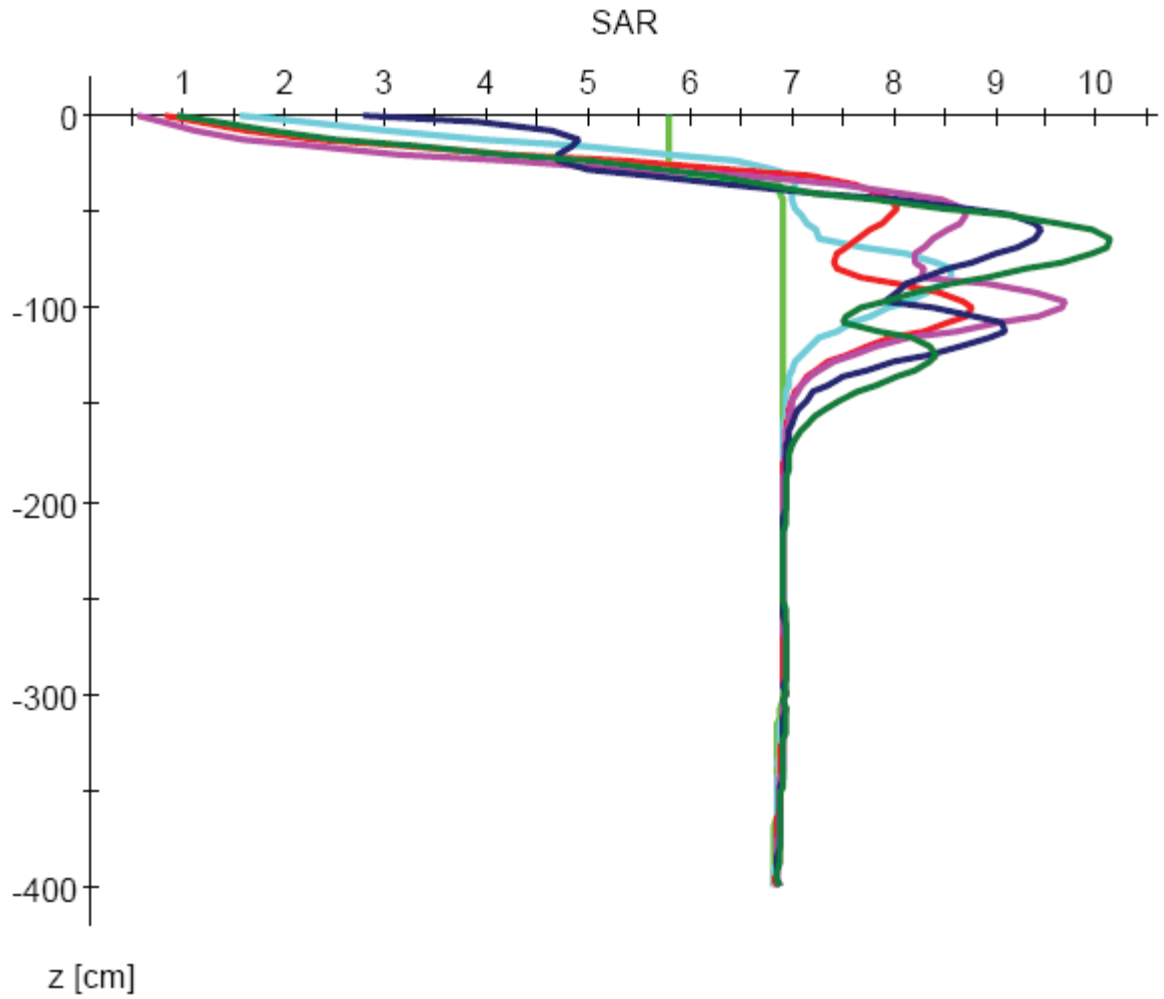

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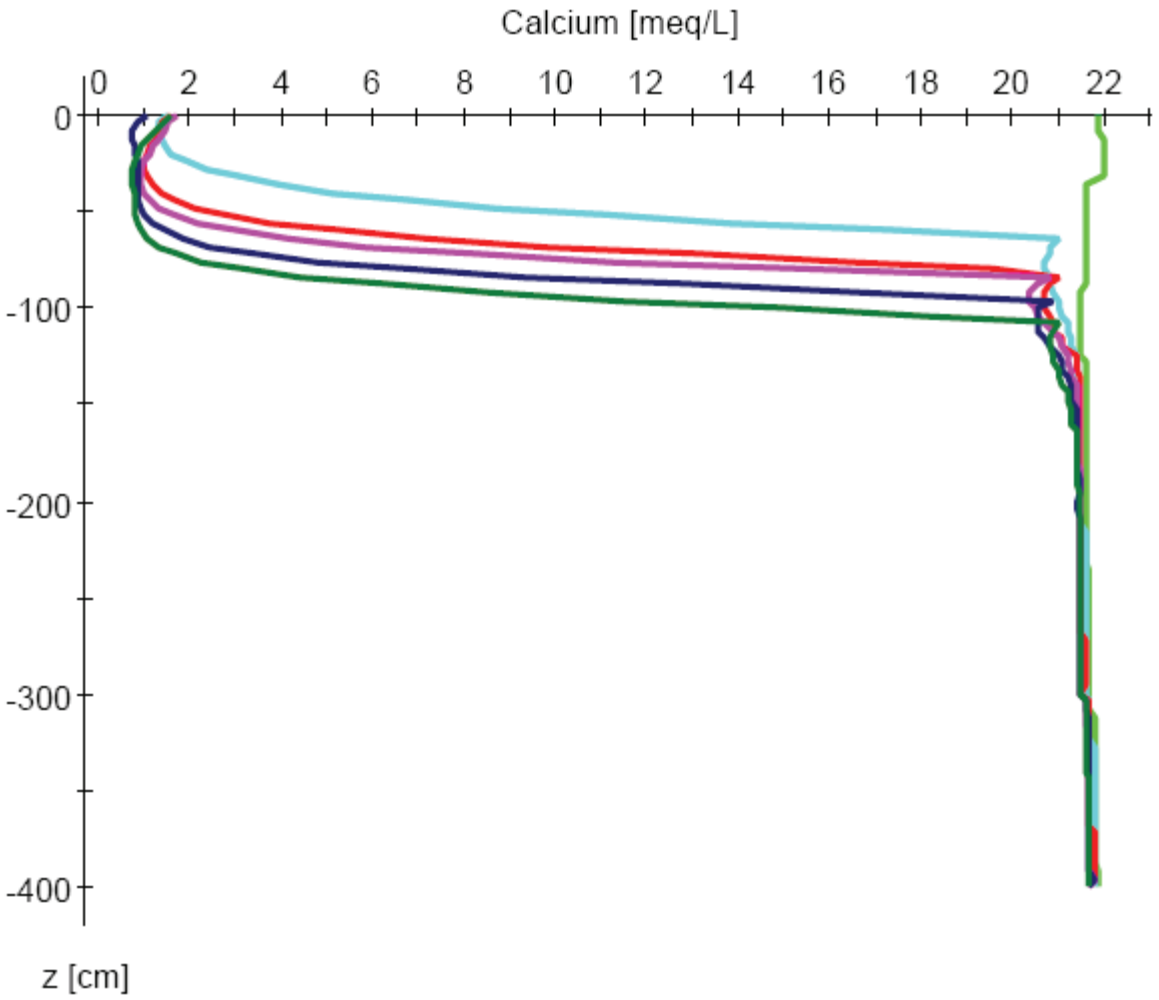
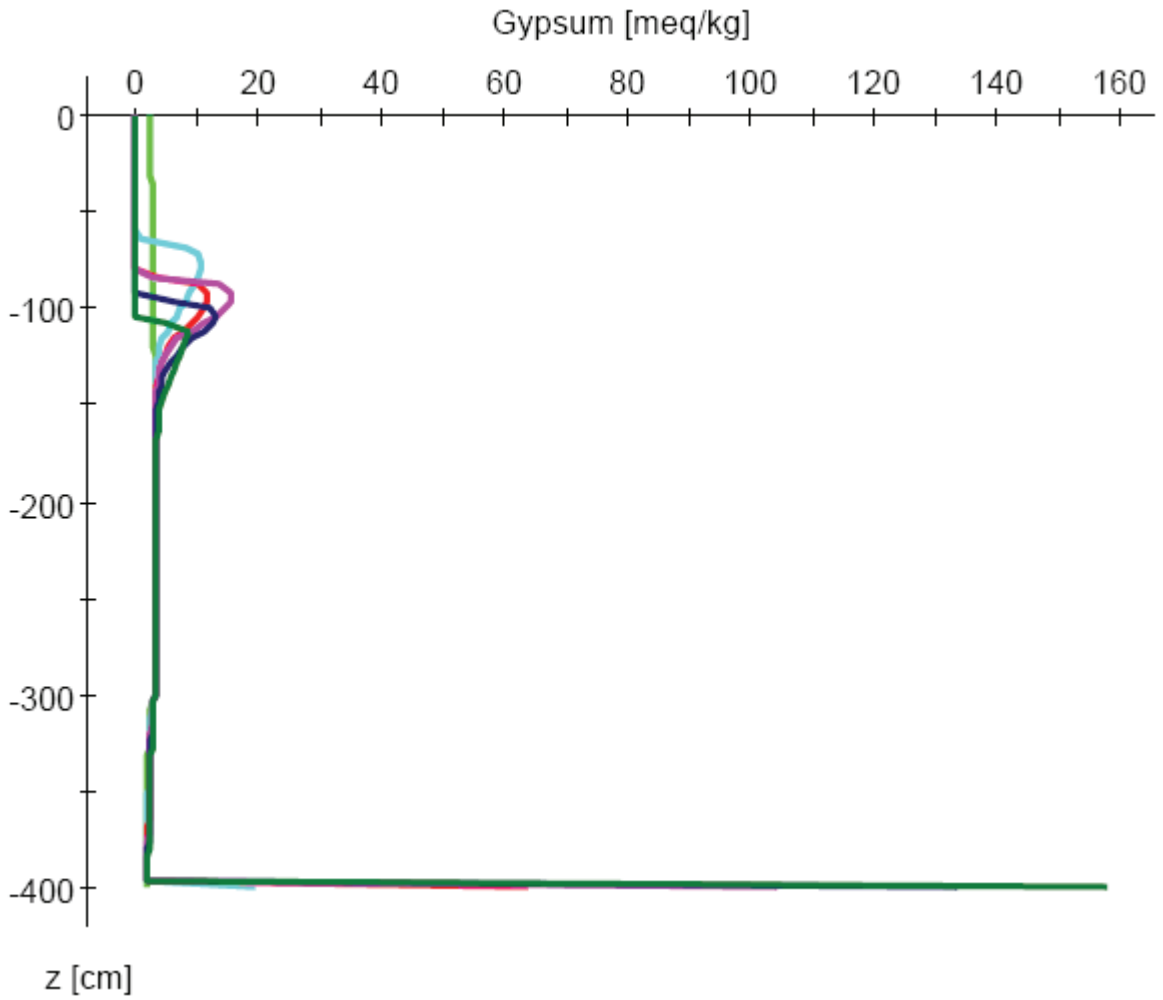


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



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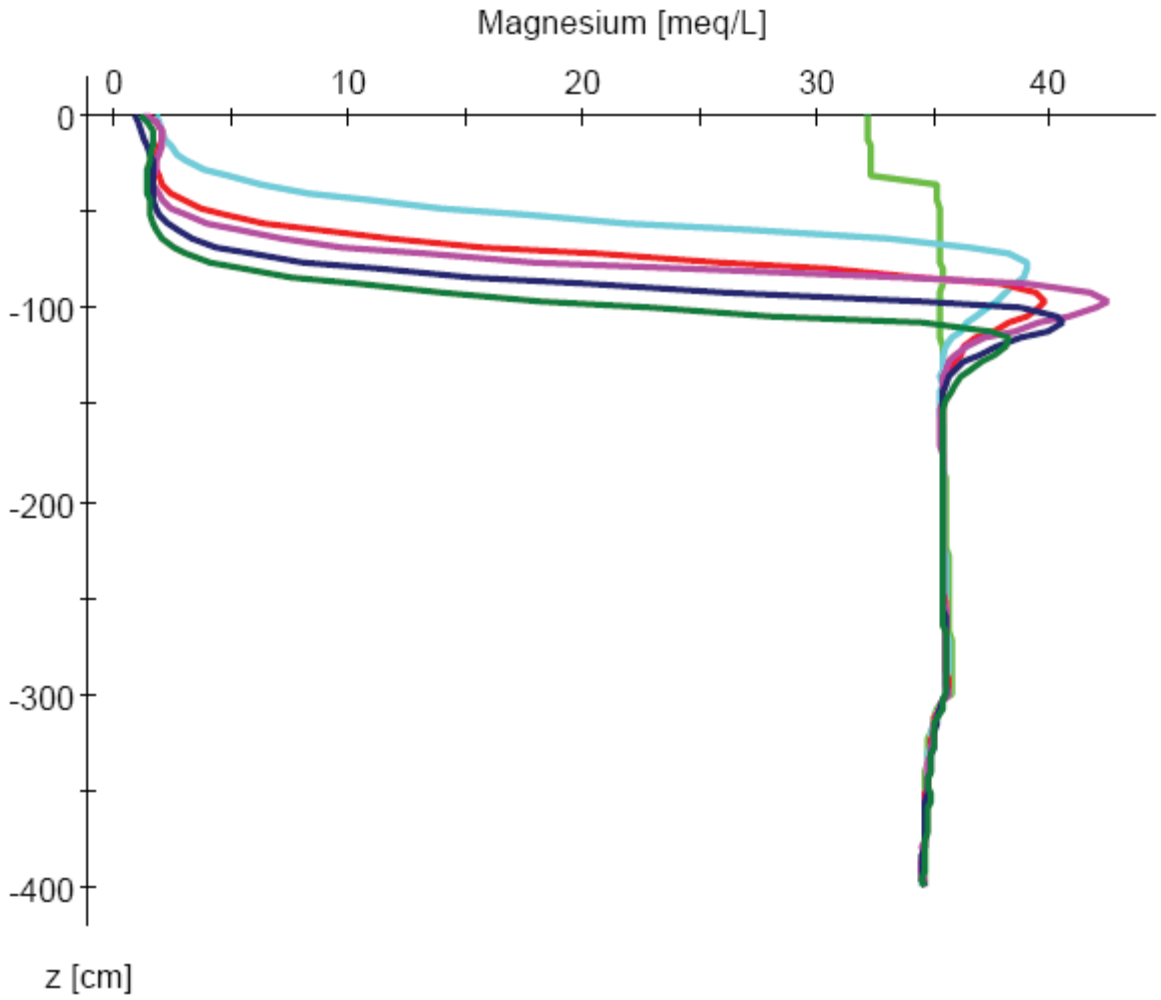
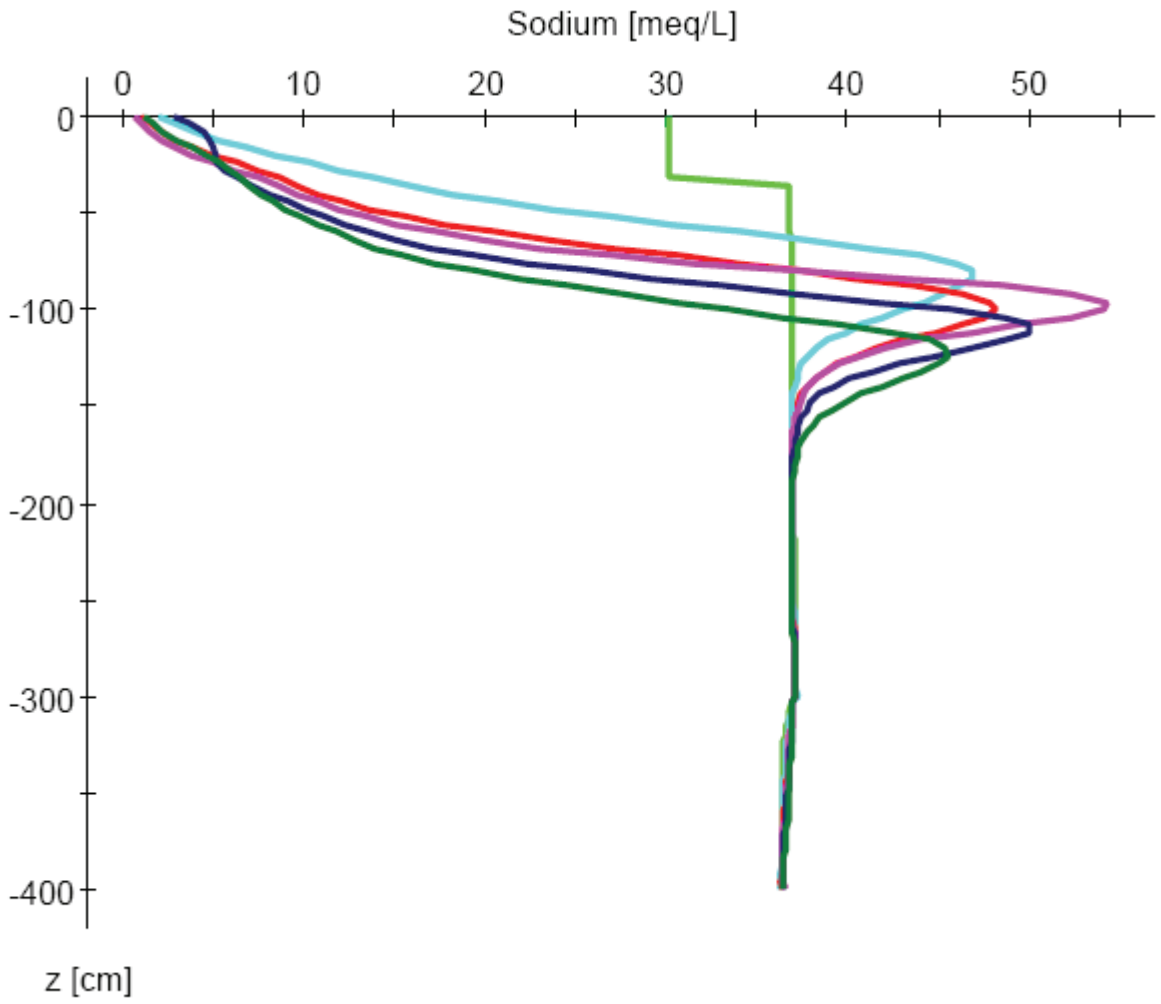


Figure 5. Solution magnesium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



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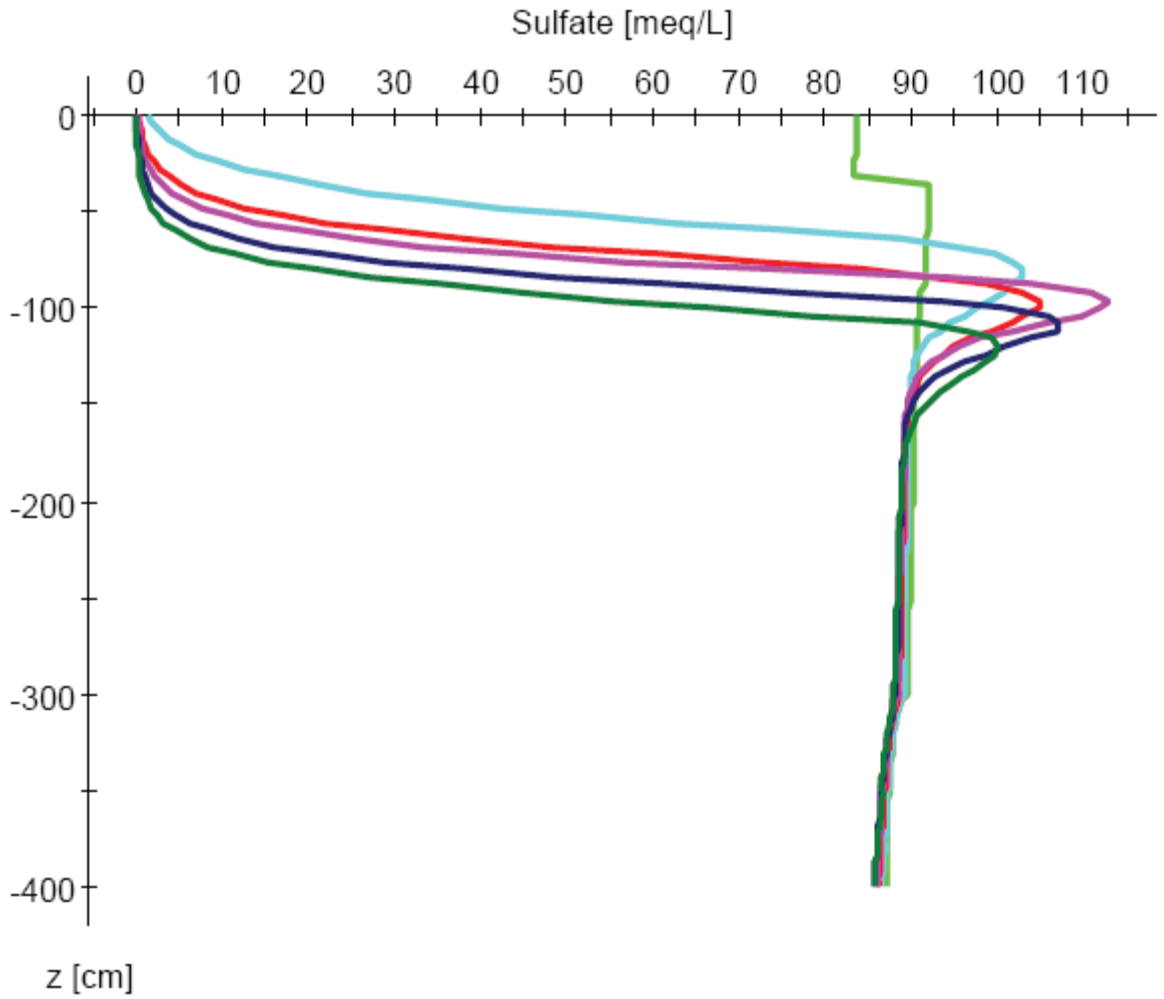

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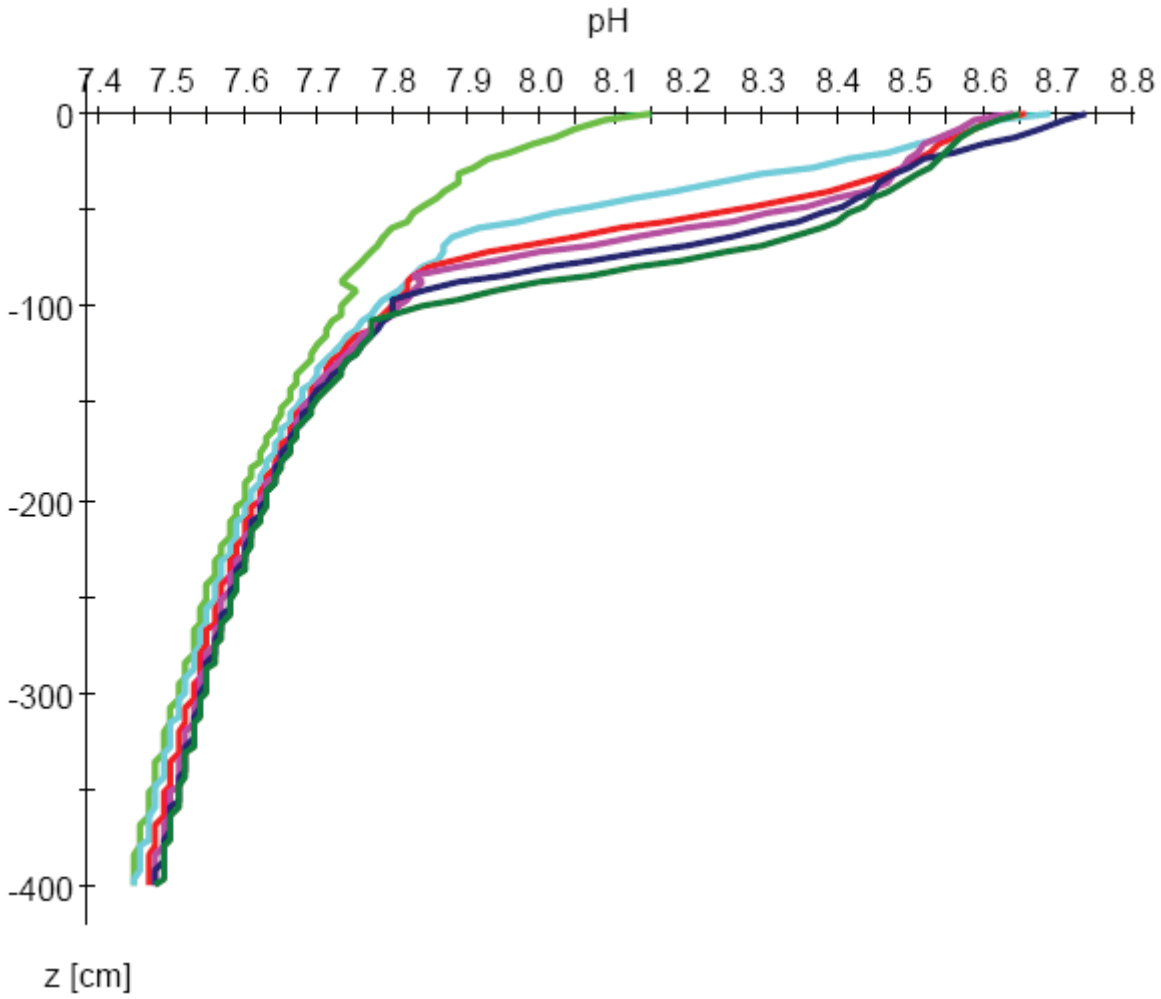
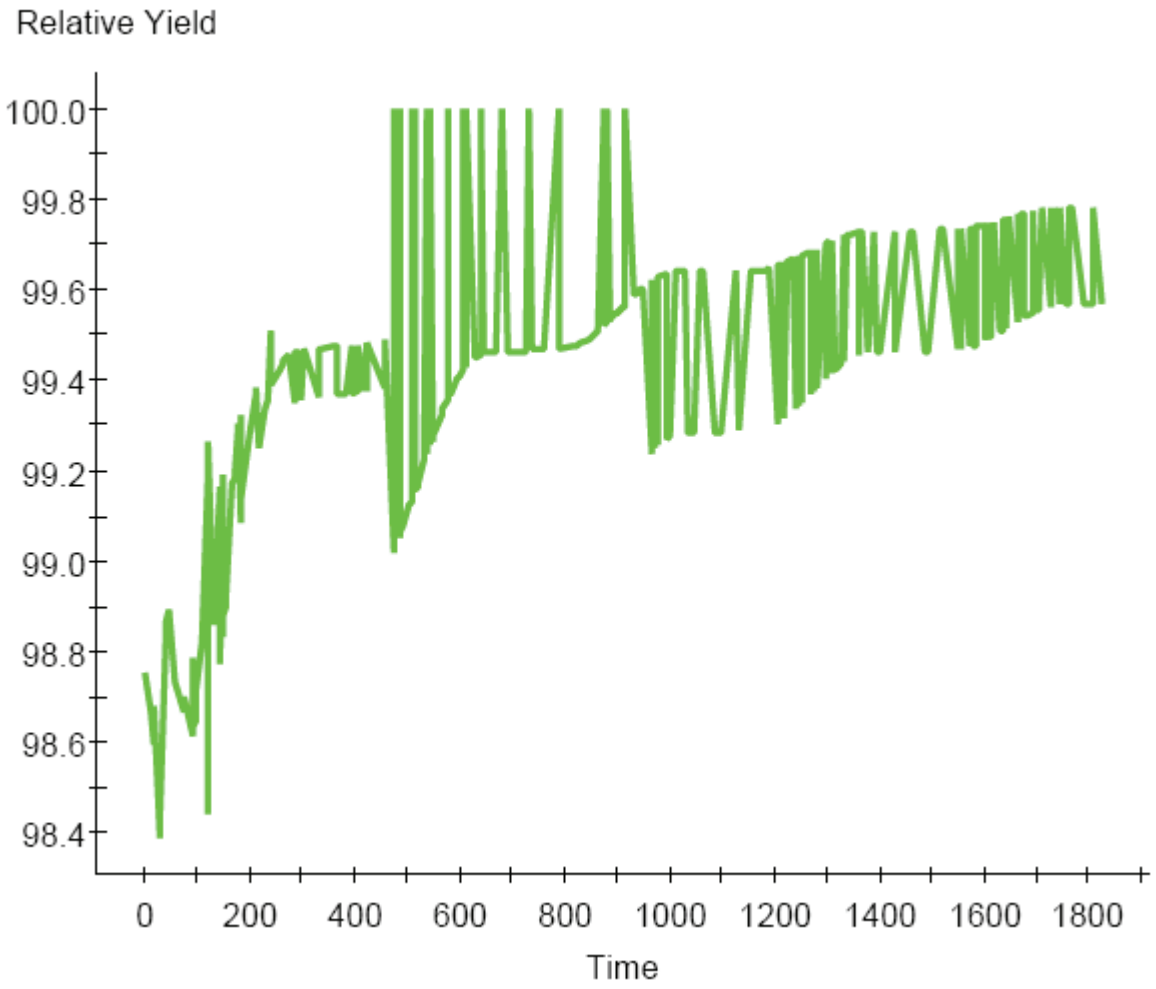


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



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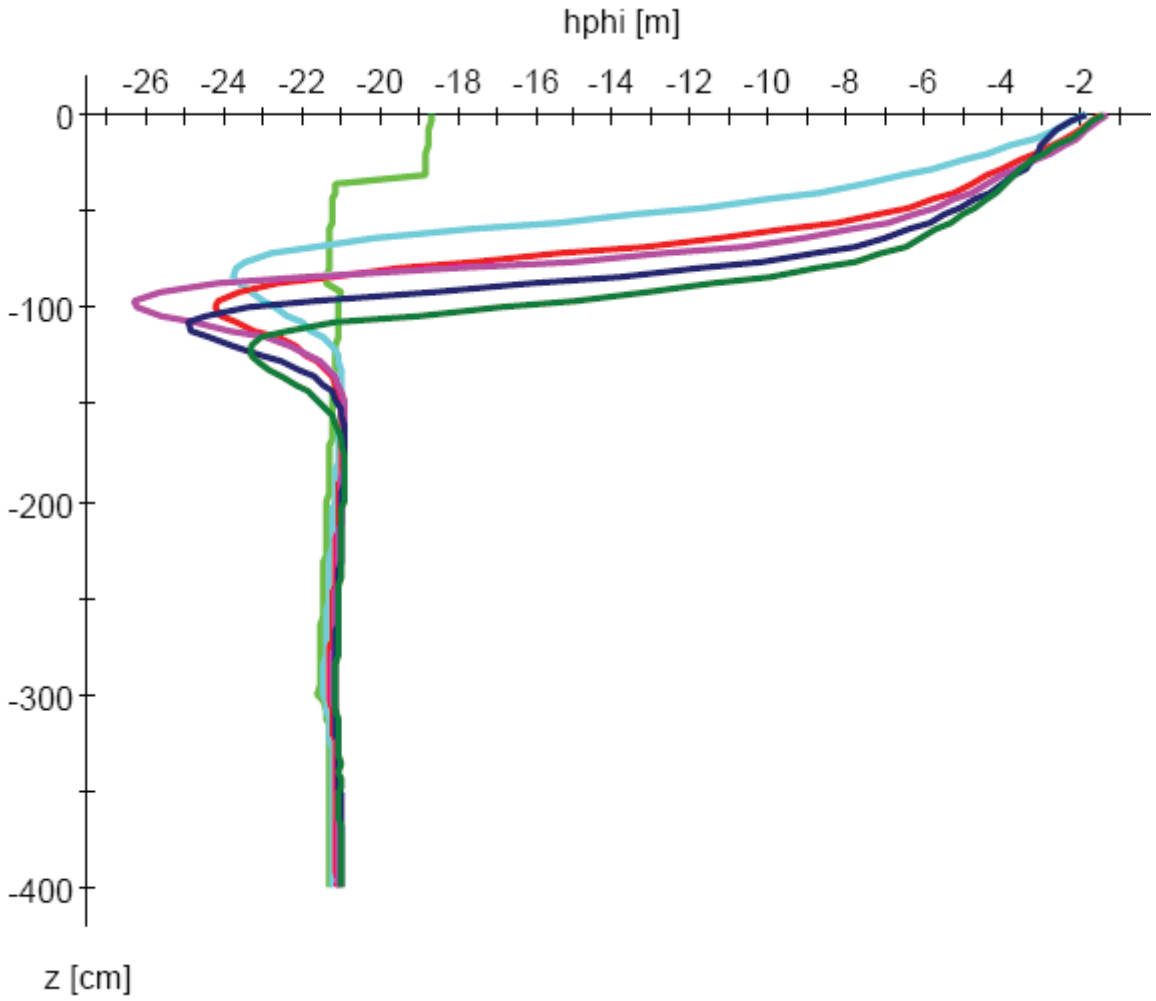
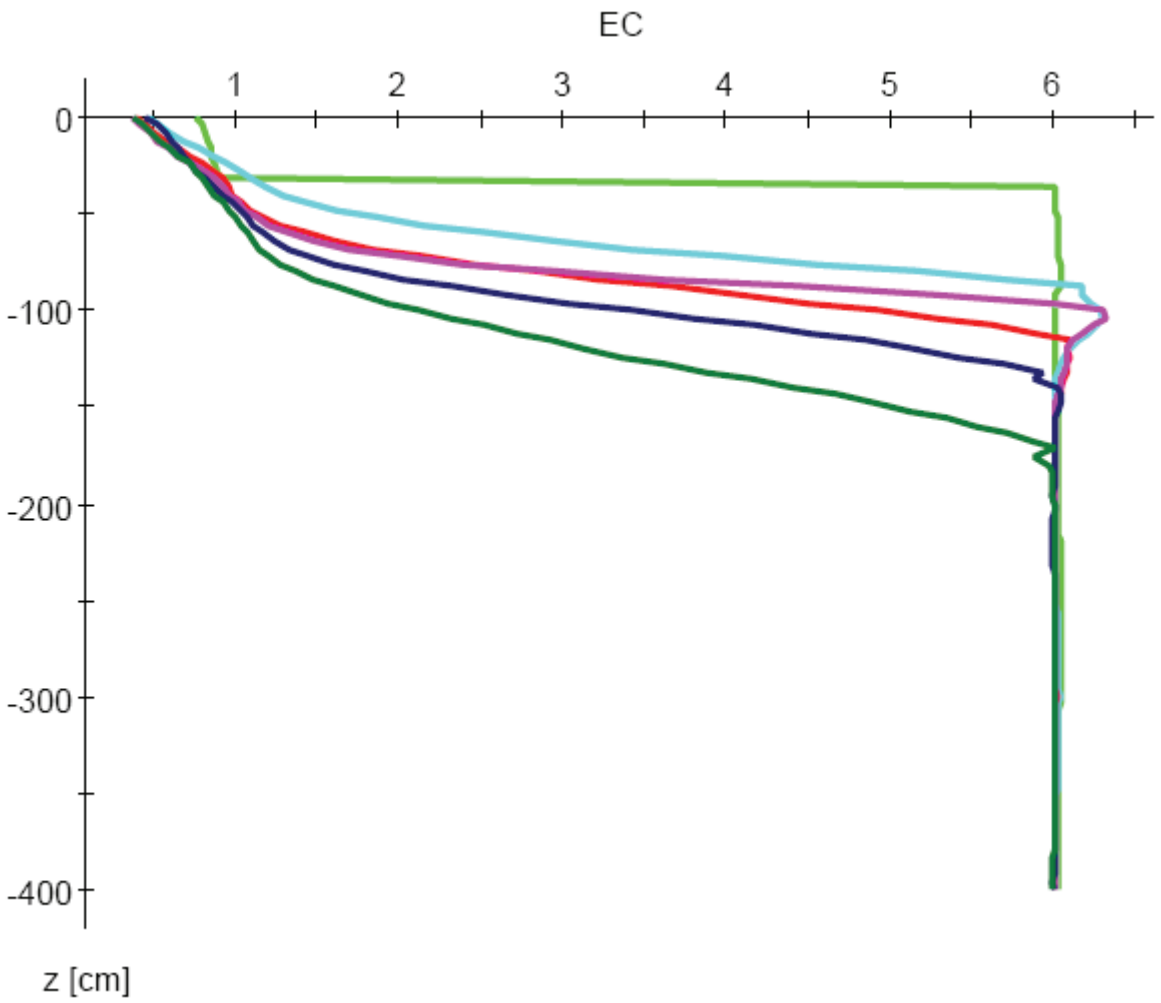


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

Donna Tarver Ranch



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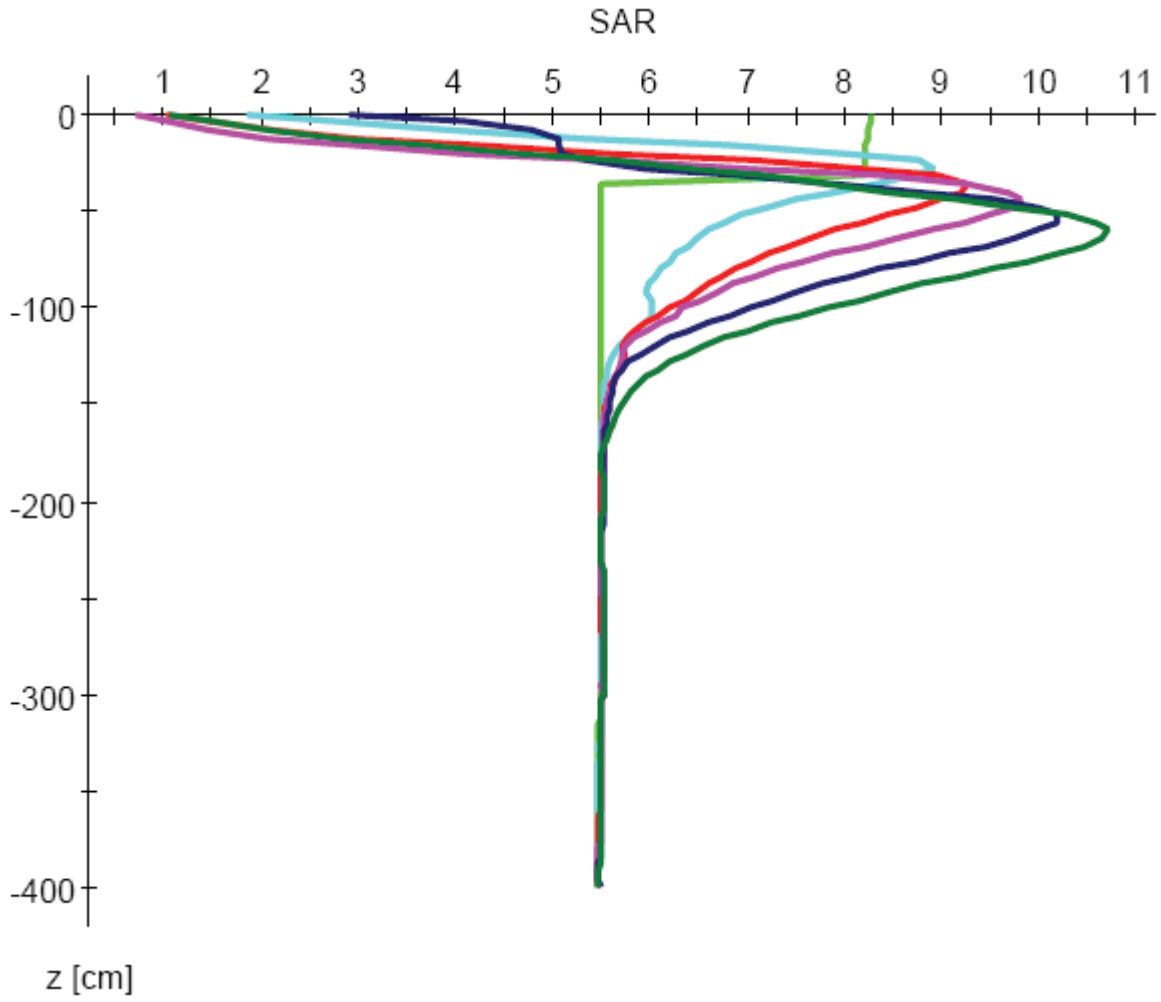

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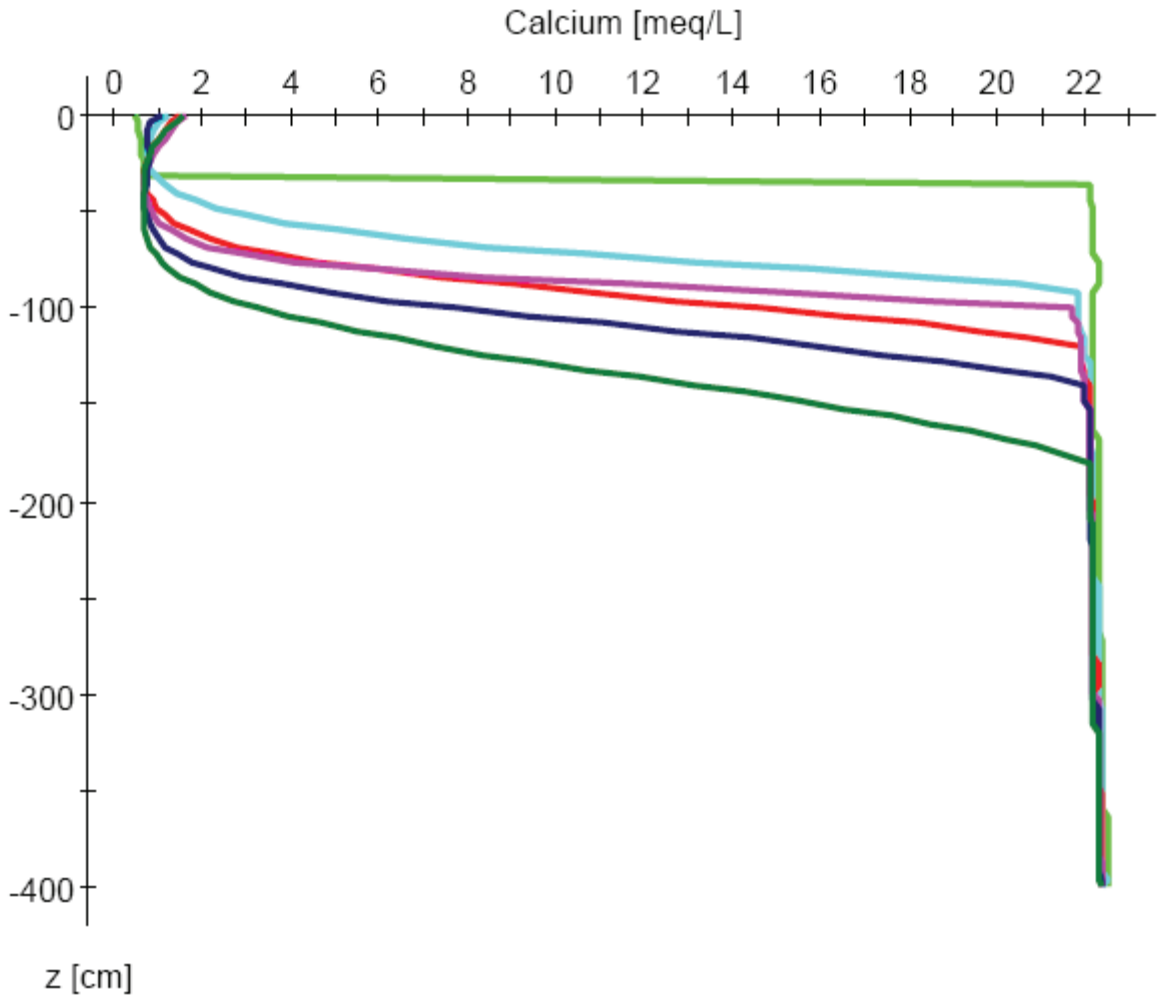

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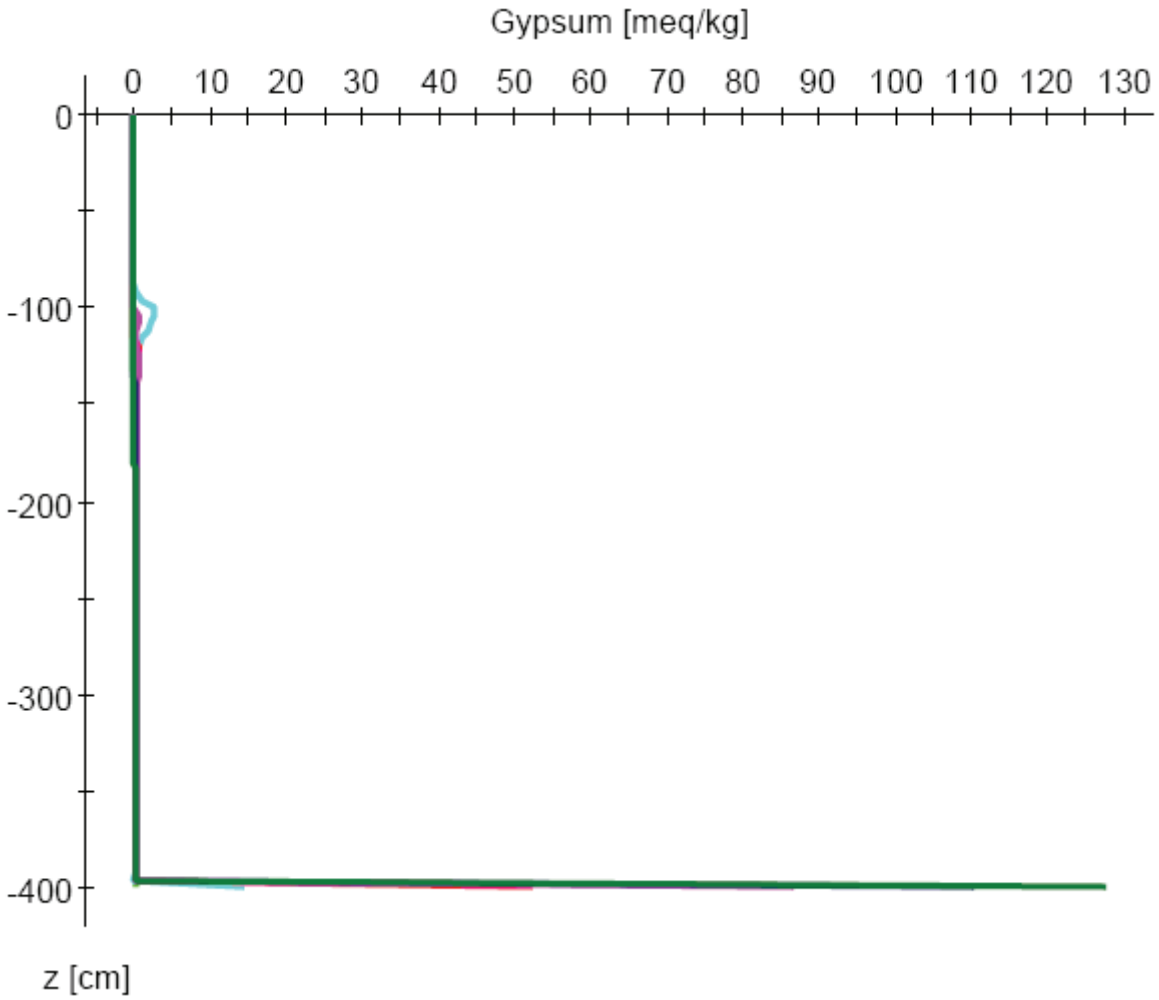

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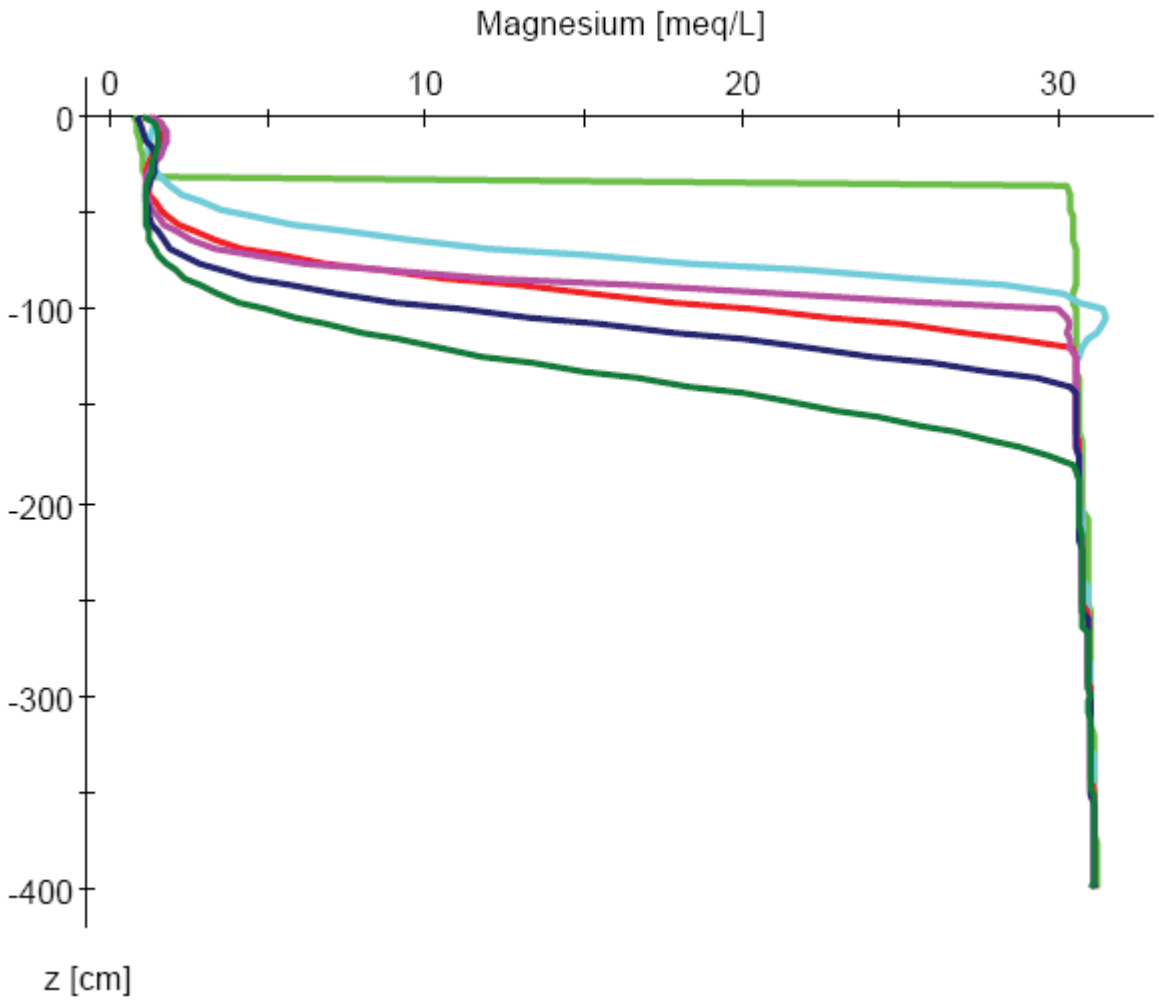

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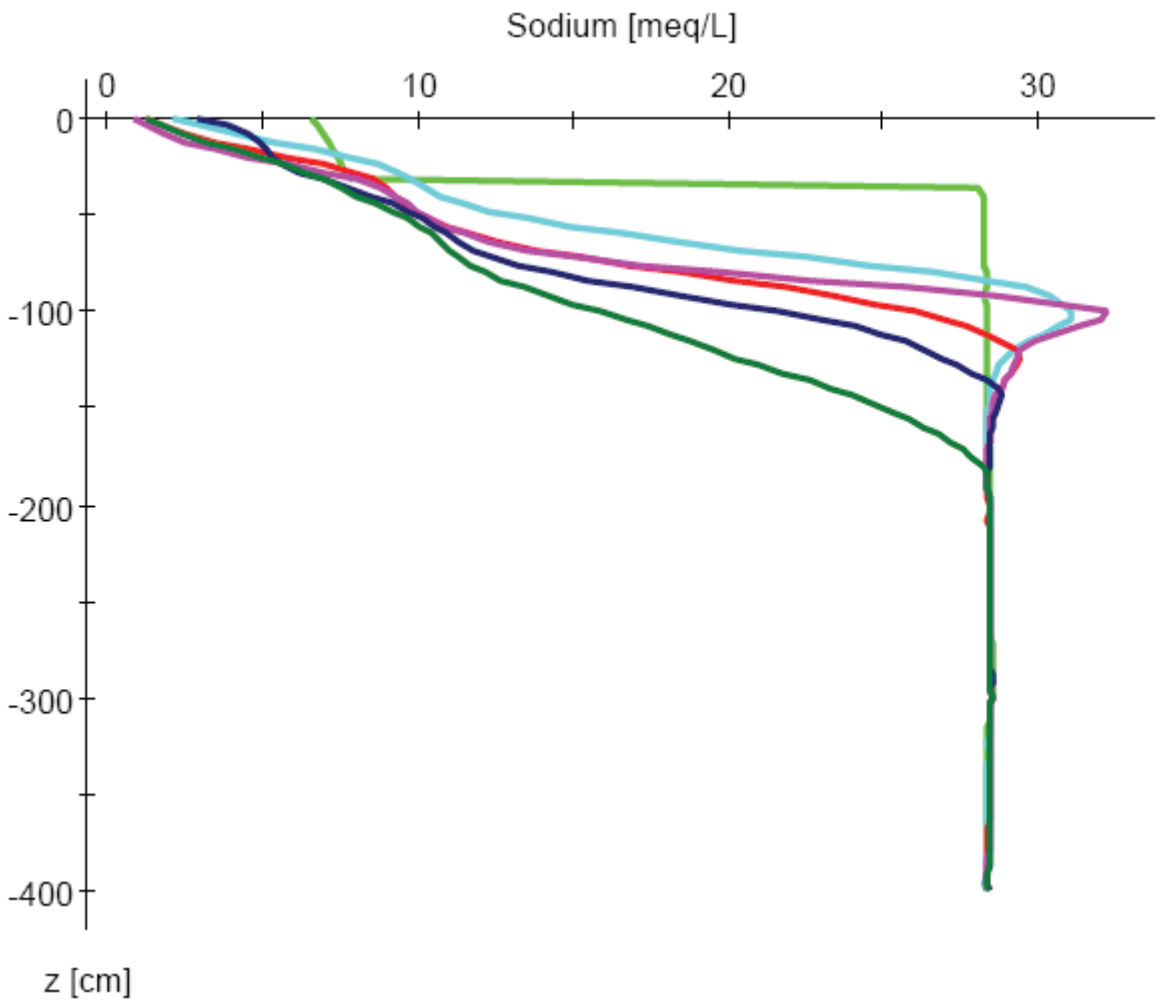


Figure 6. Solution sodium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

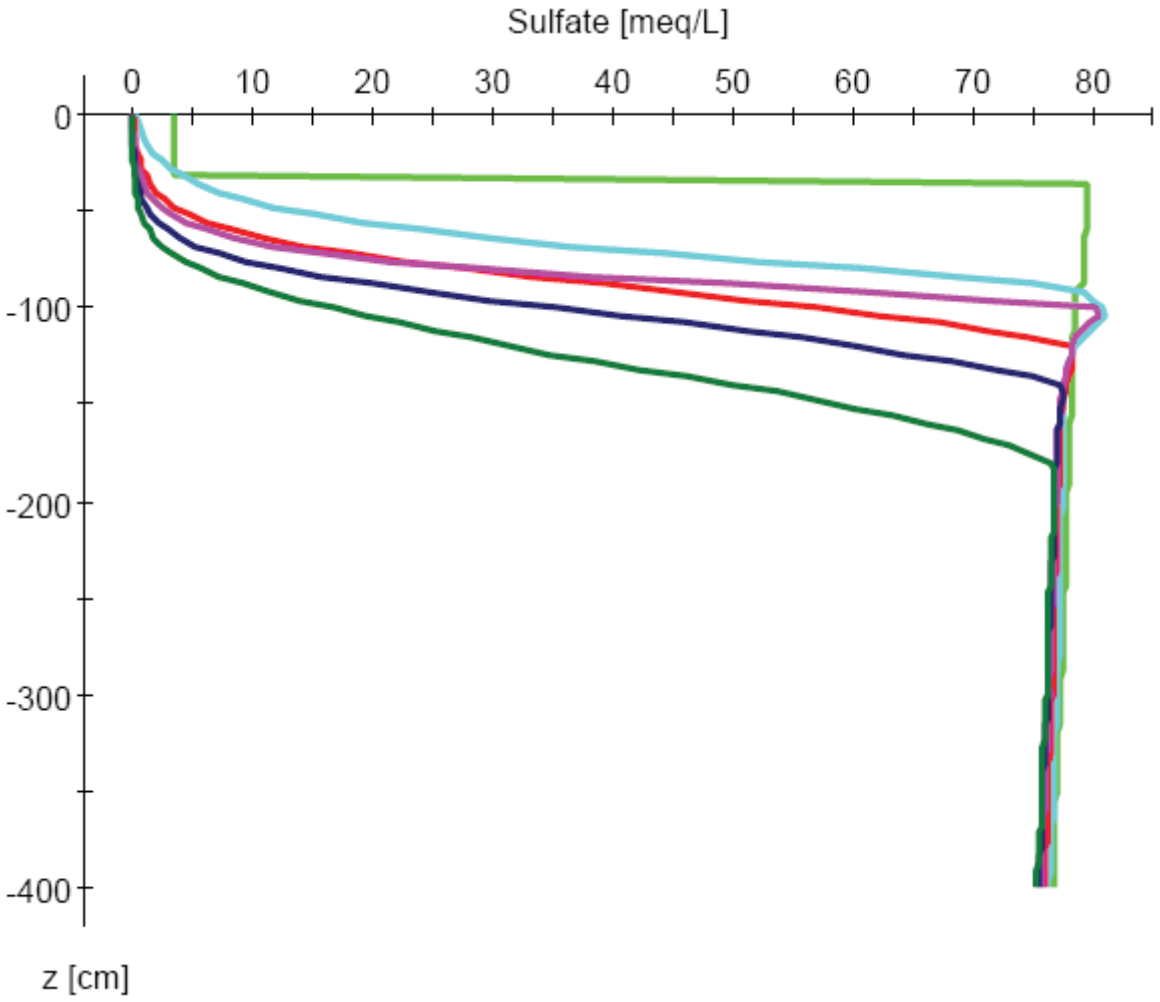


Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

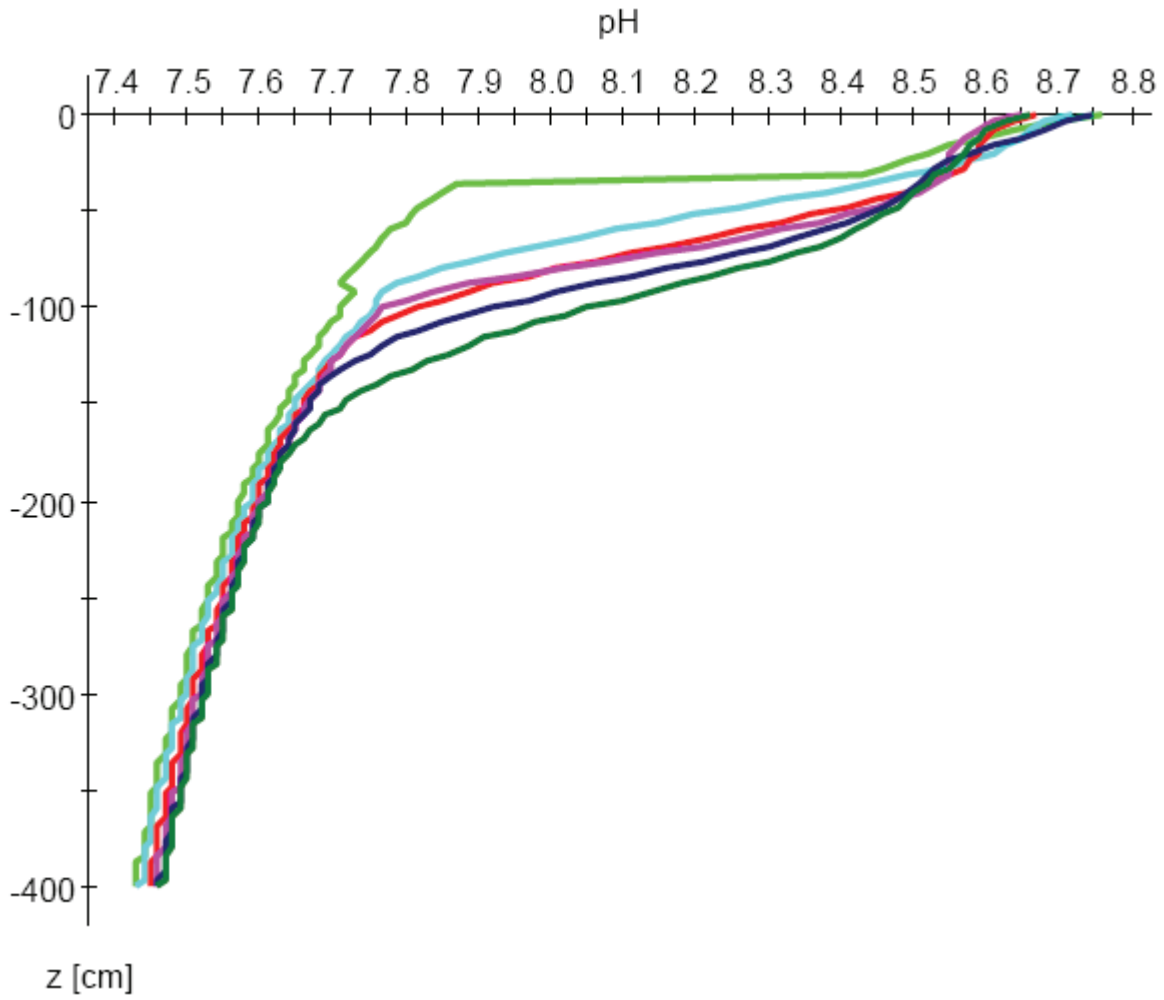


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

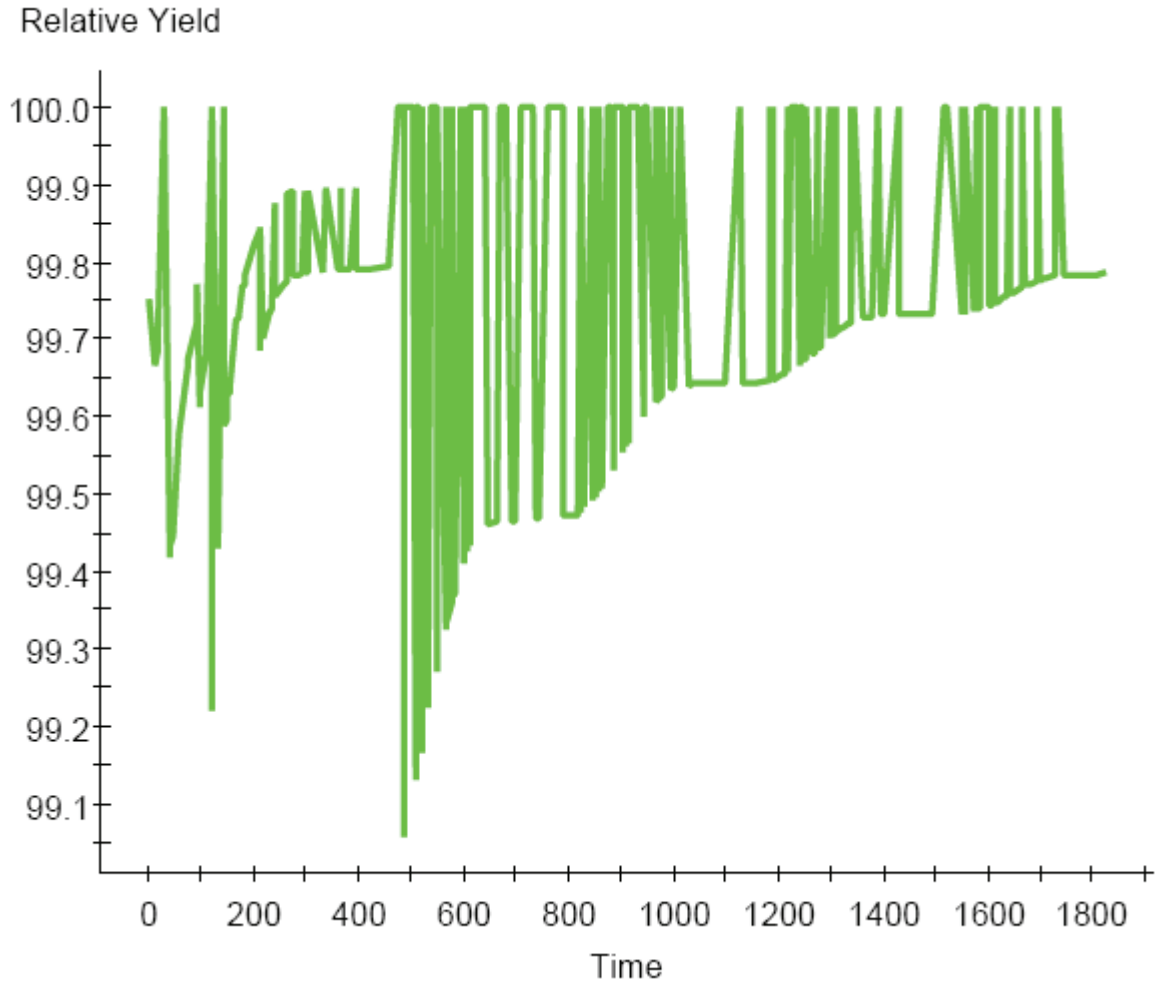


Figure 9. Relative crop yield over the 5-year simulation period.

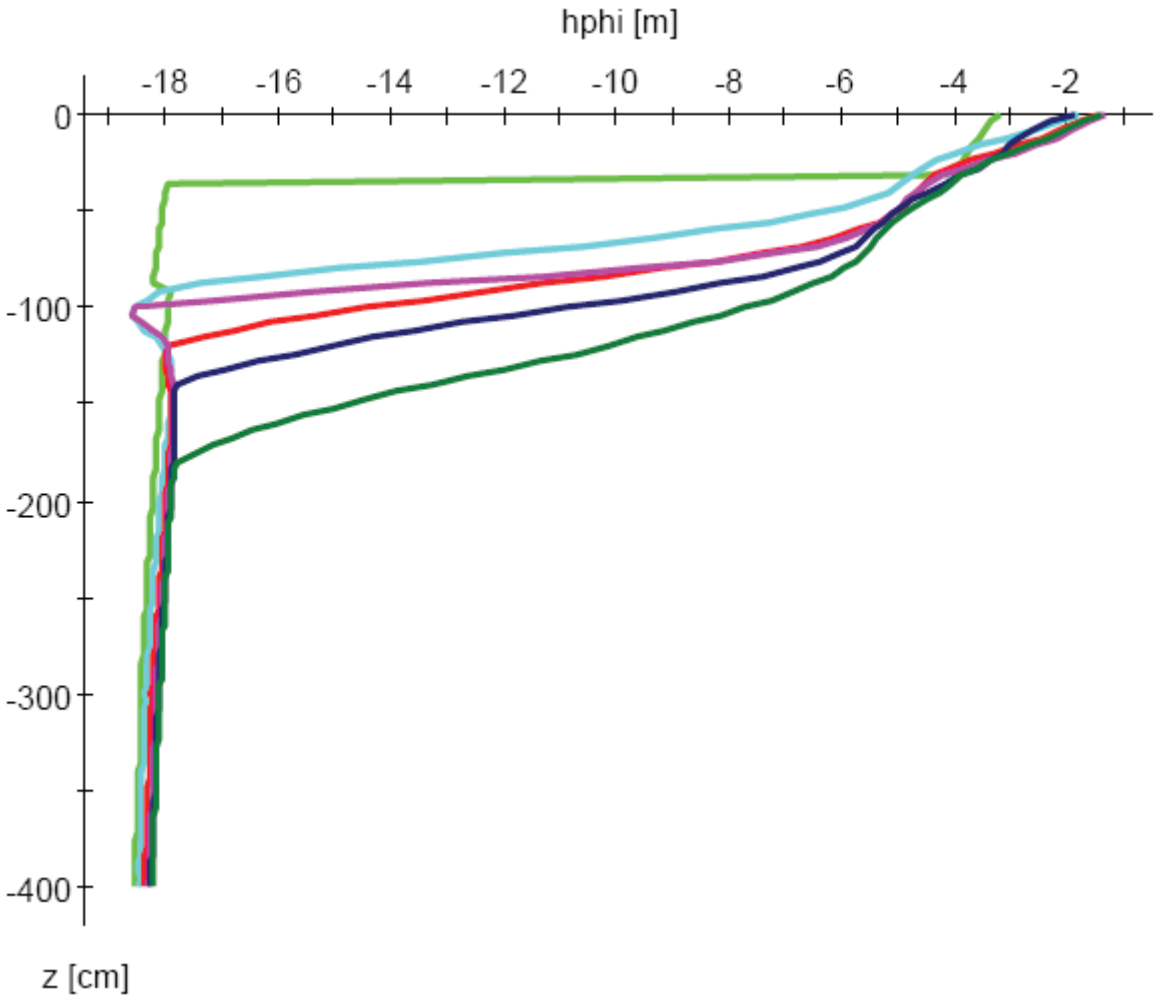


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

Marsha Pownall MP1 modified with SAR 25 CBNG produced water.

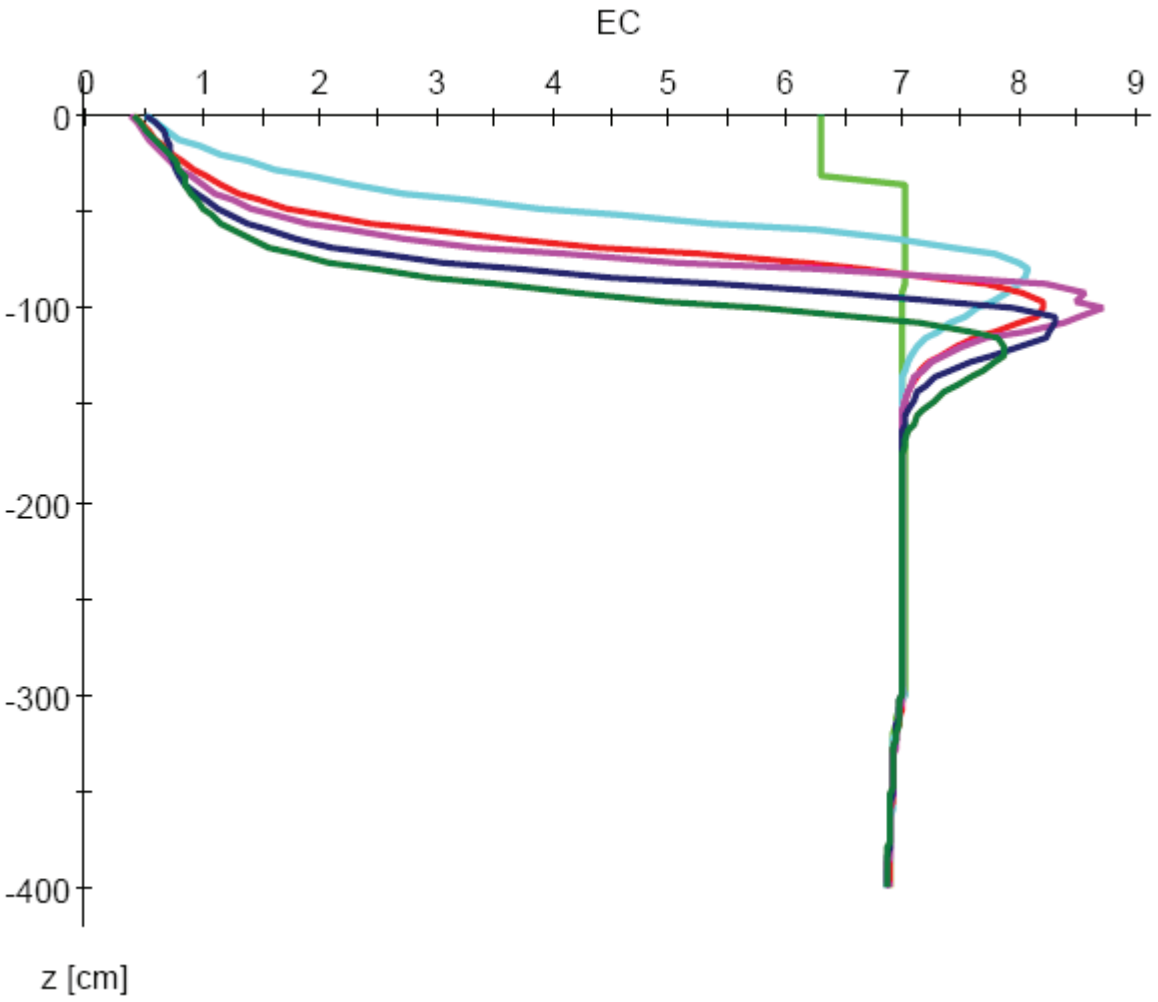


Figure 1. Salt concentrations (EC) by soil depth over the 5-year irrigation period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

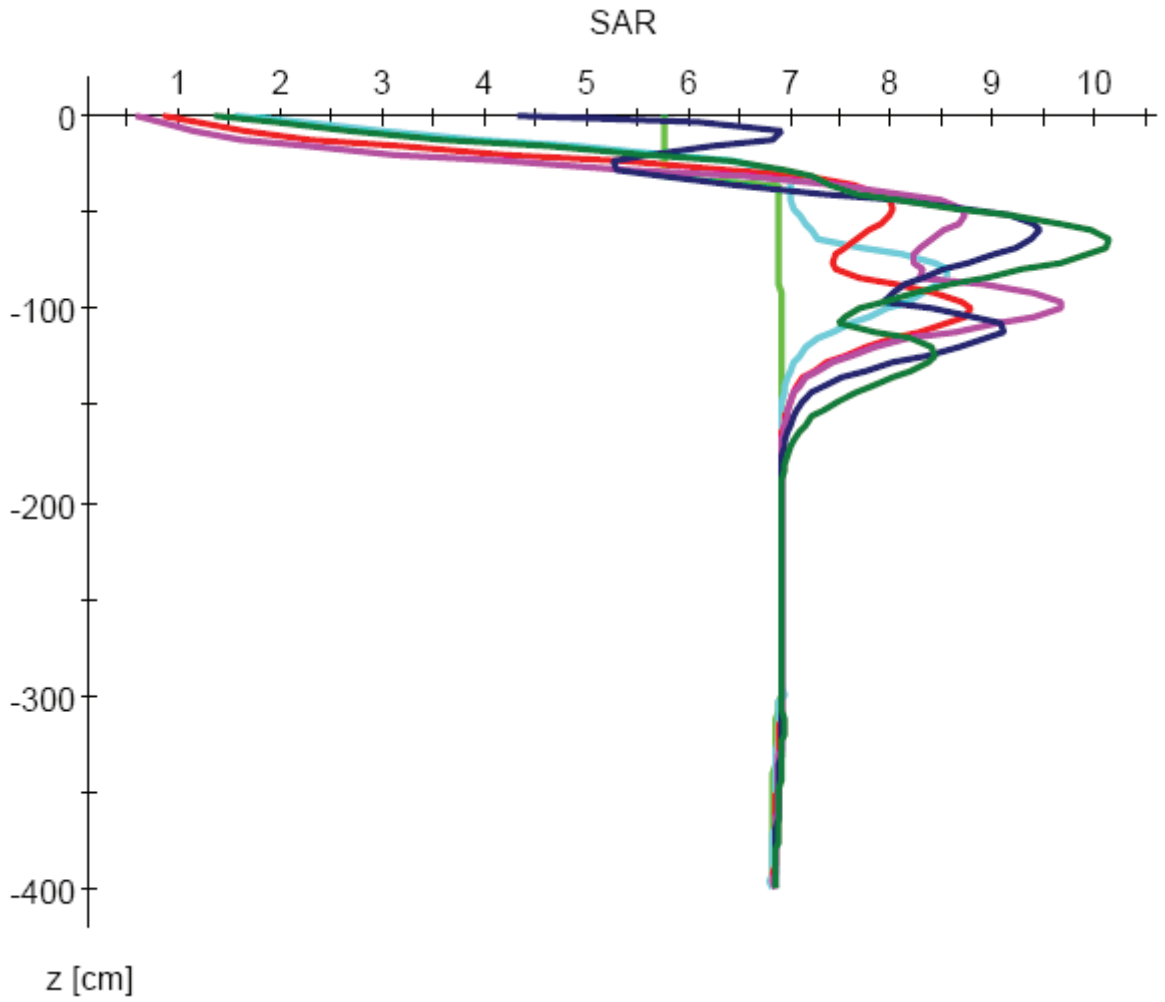


Figure 2. SAR by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

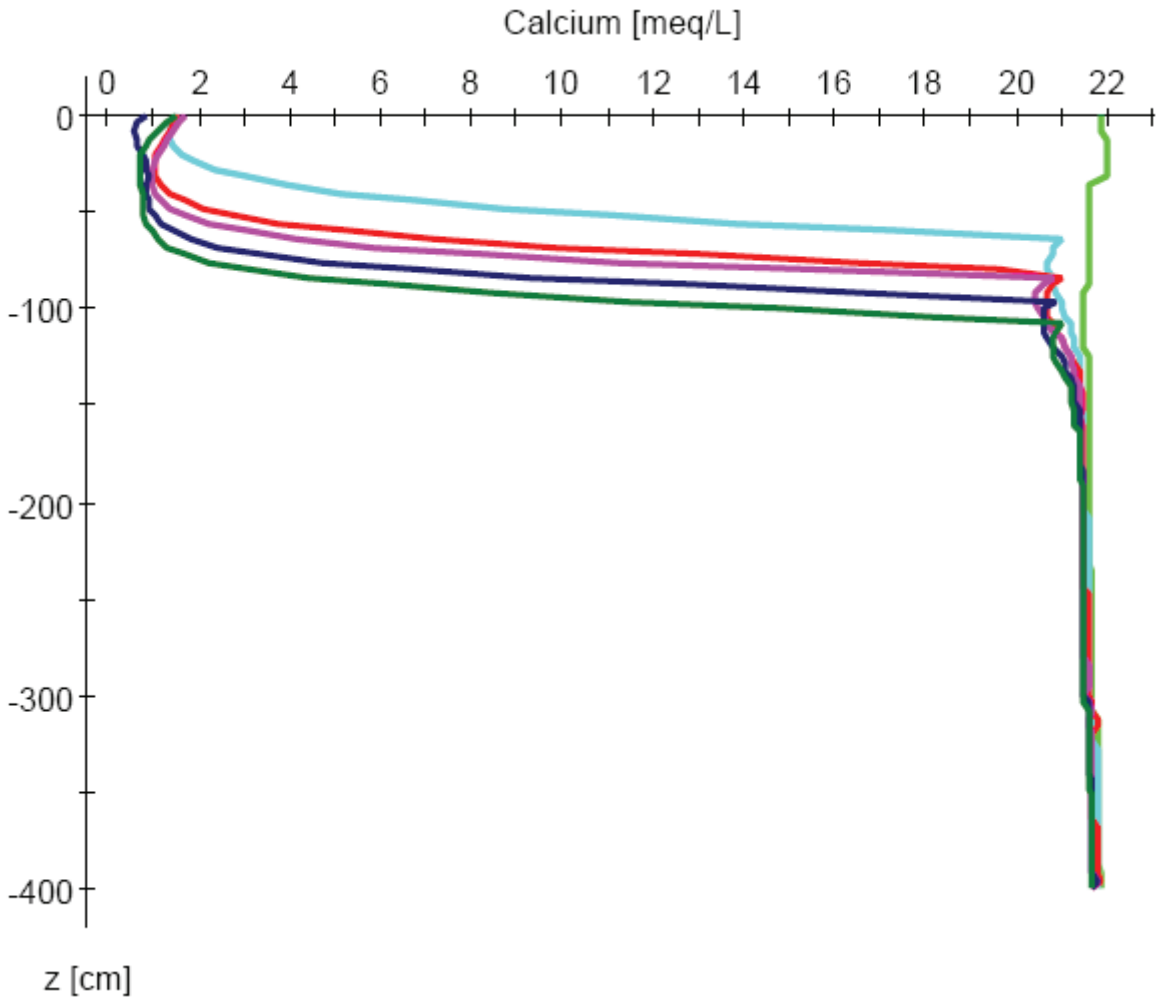


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

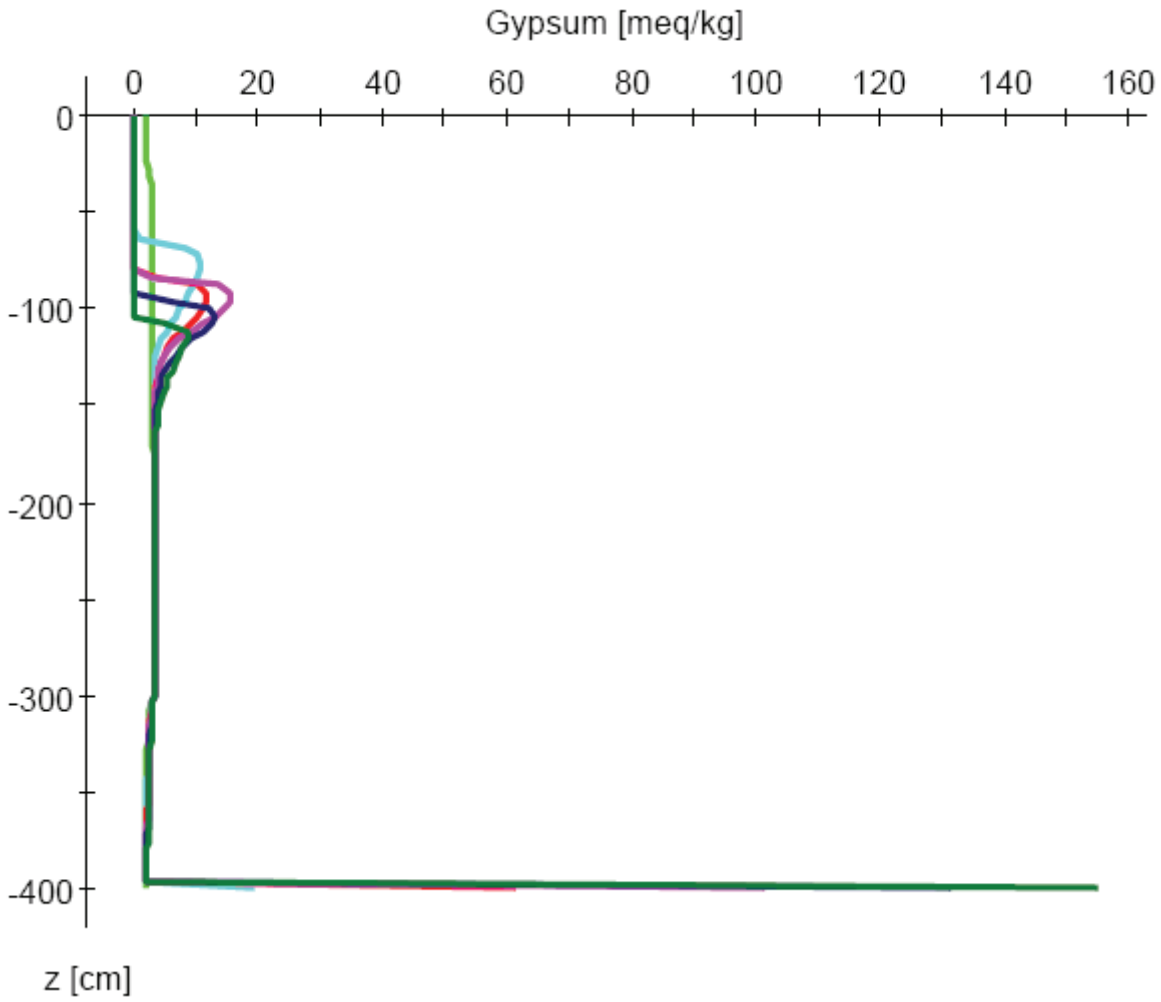


Figure 4. Gypsum levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

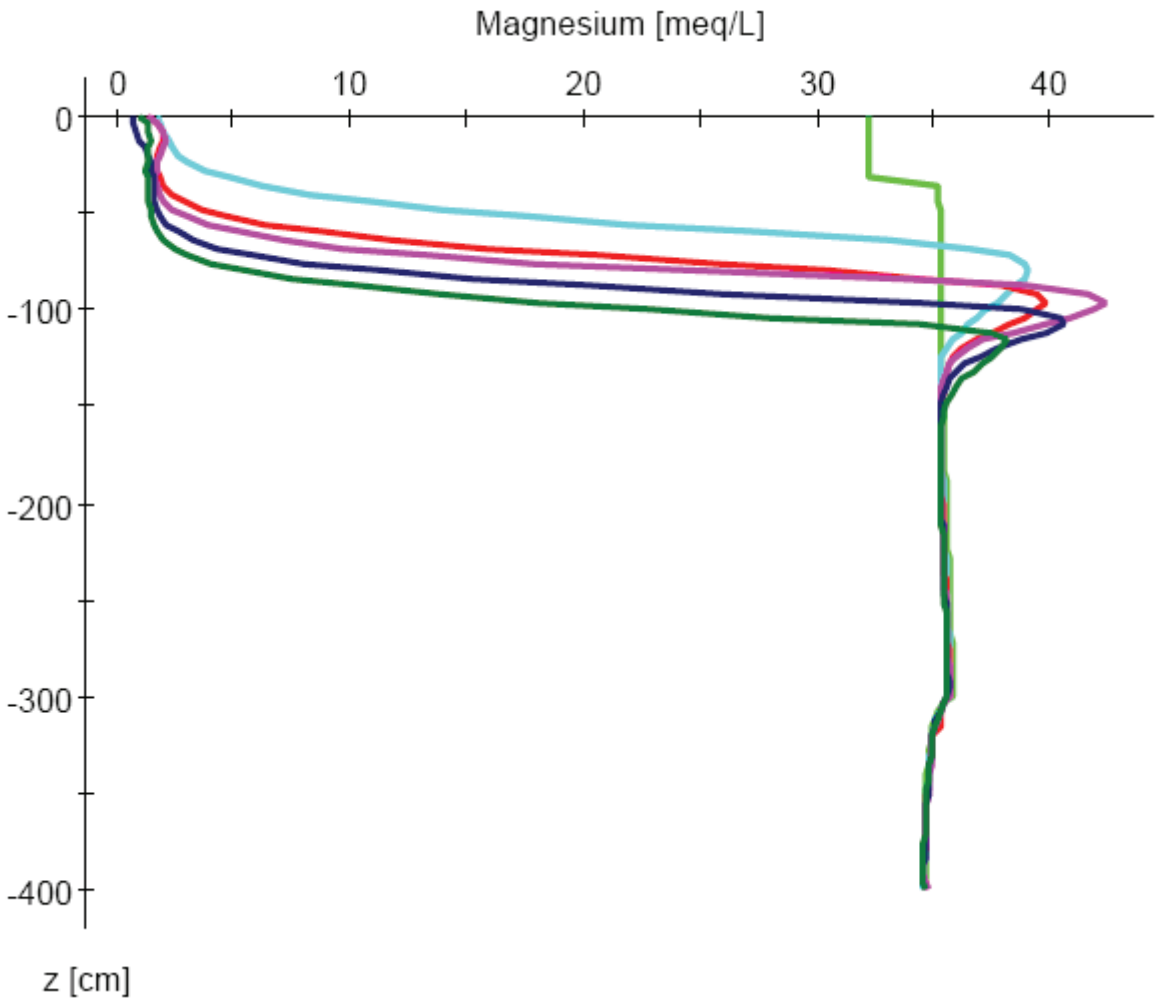
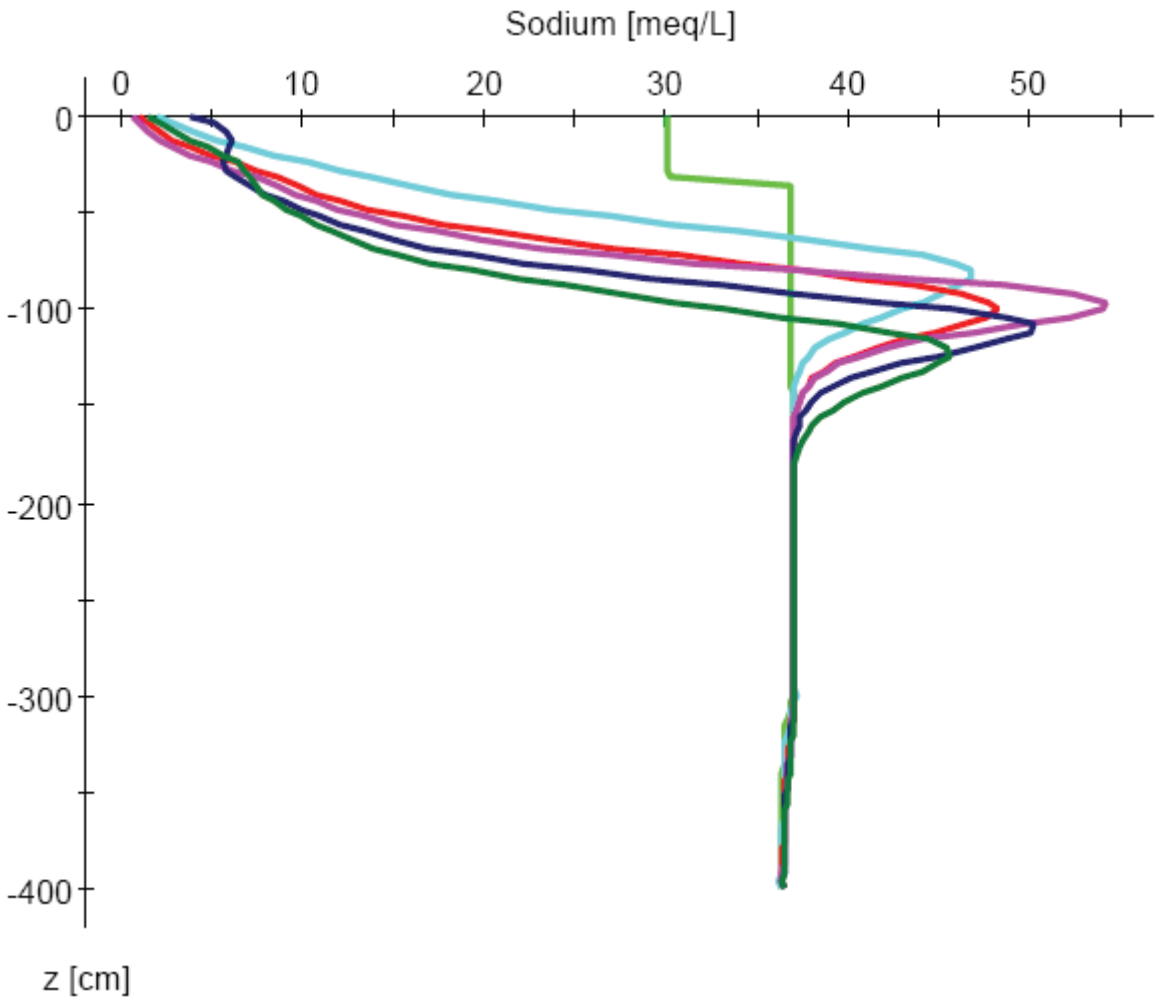


Figure 5. Solution magnesium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



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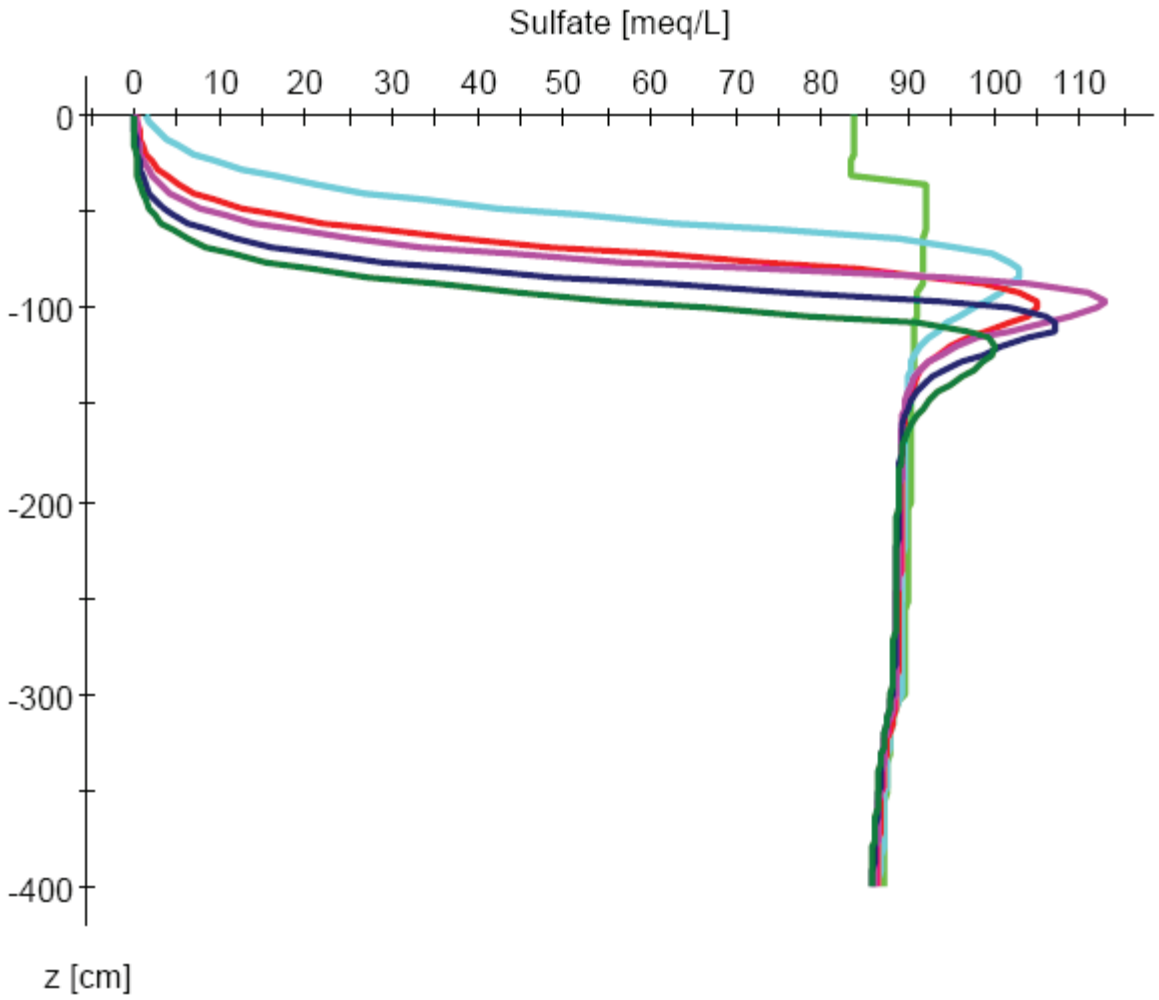


Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

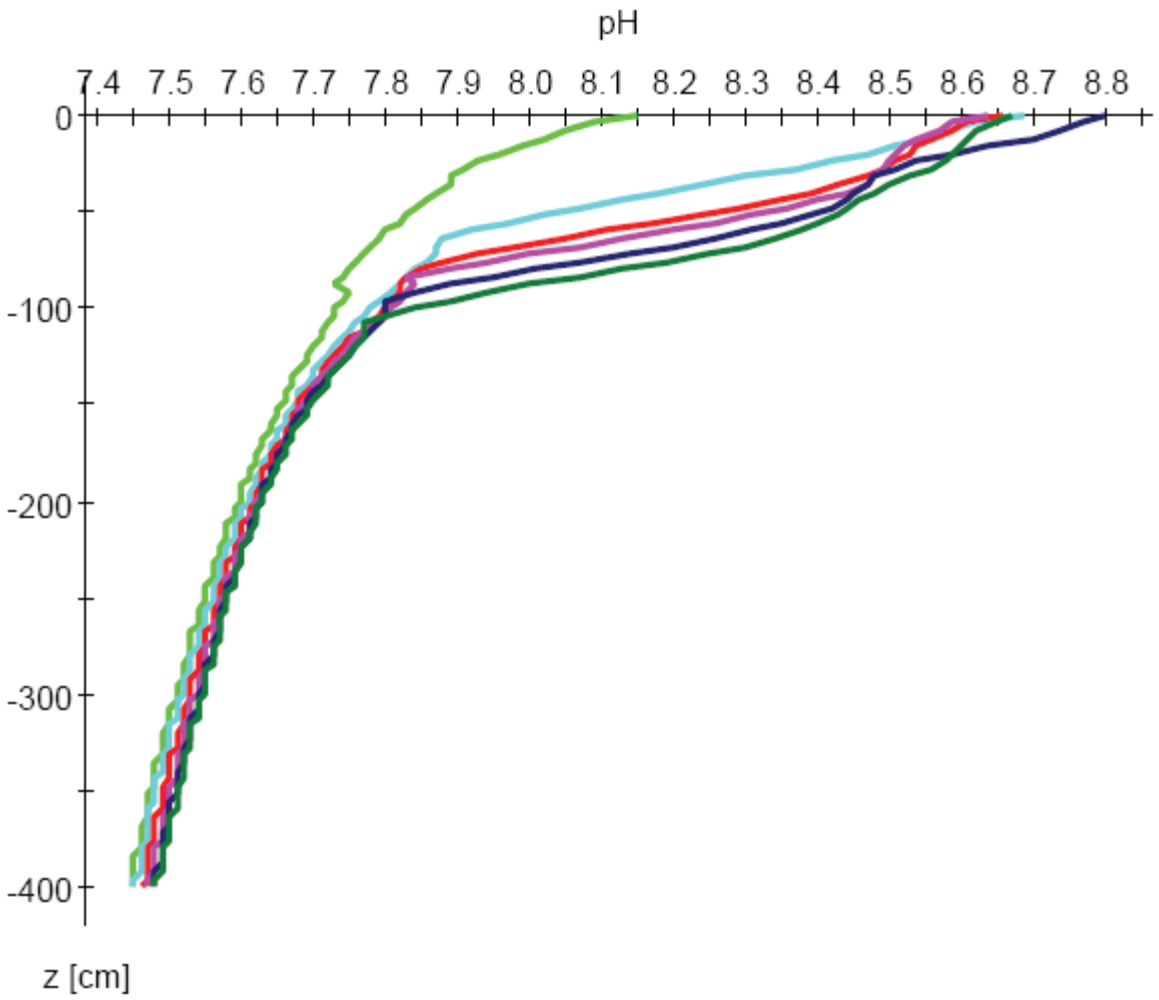


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

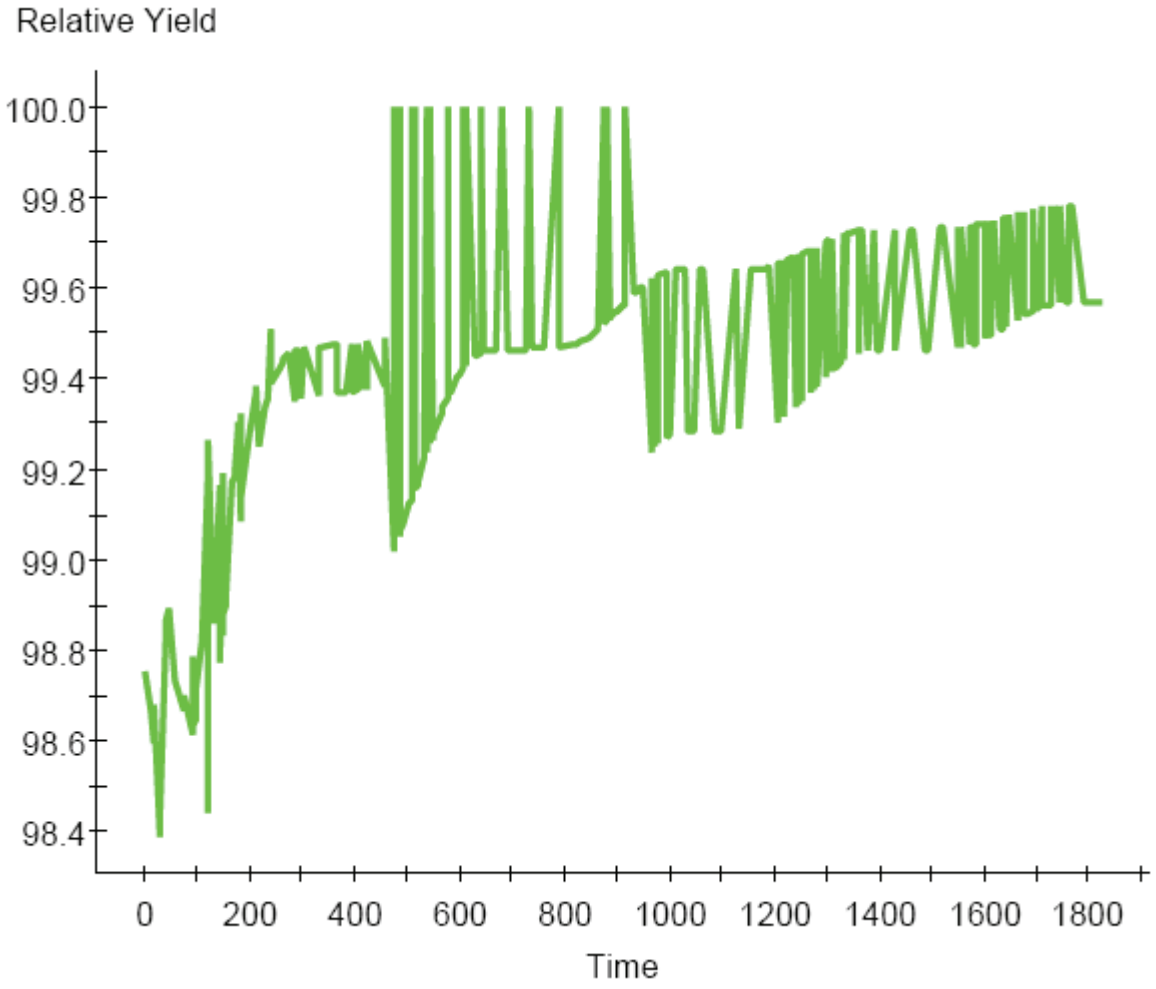


Figure 9. Relative crop yield over the 5-year simulation period.

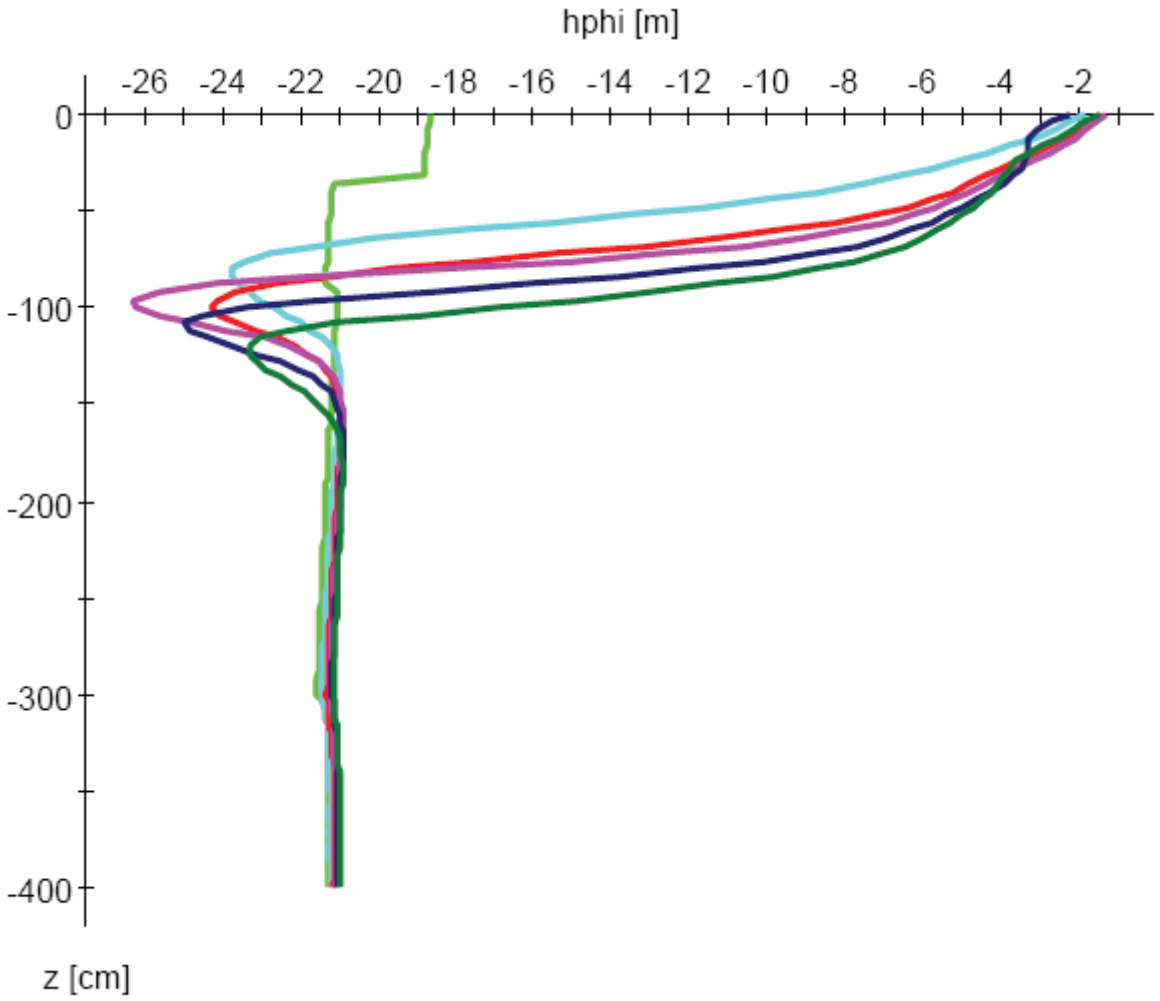


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

APPENDIX I – RESULTS OF THE FAO-SWS IRRIGATION SIMULATIONS FOR LANDS ASSOCIATED WITH HAY CREEK

James Wolff Ranch is presented in the report

Eric Rule Ranch

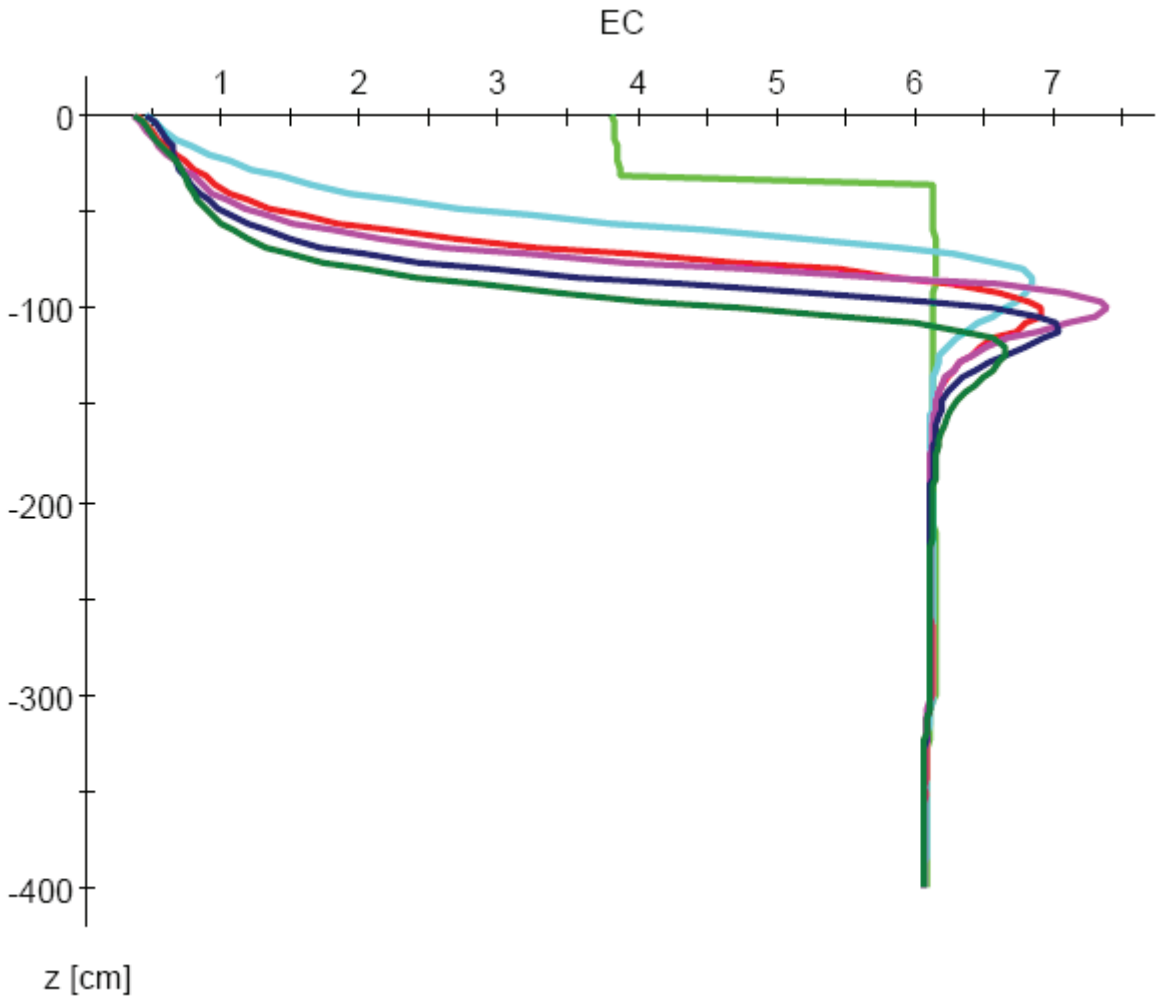


Figure 1. Salt concentrations (EC) by soil depth over the 5-year irrigation period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

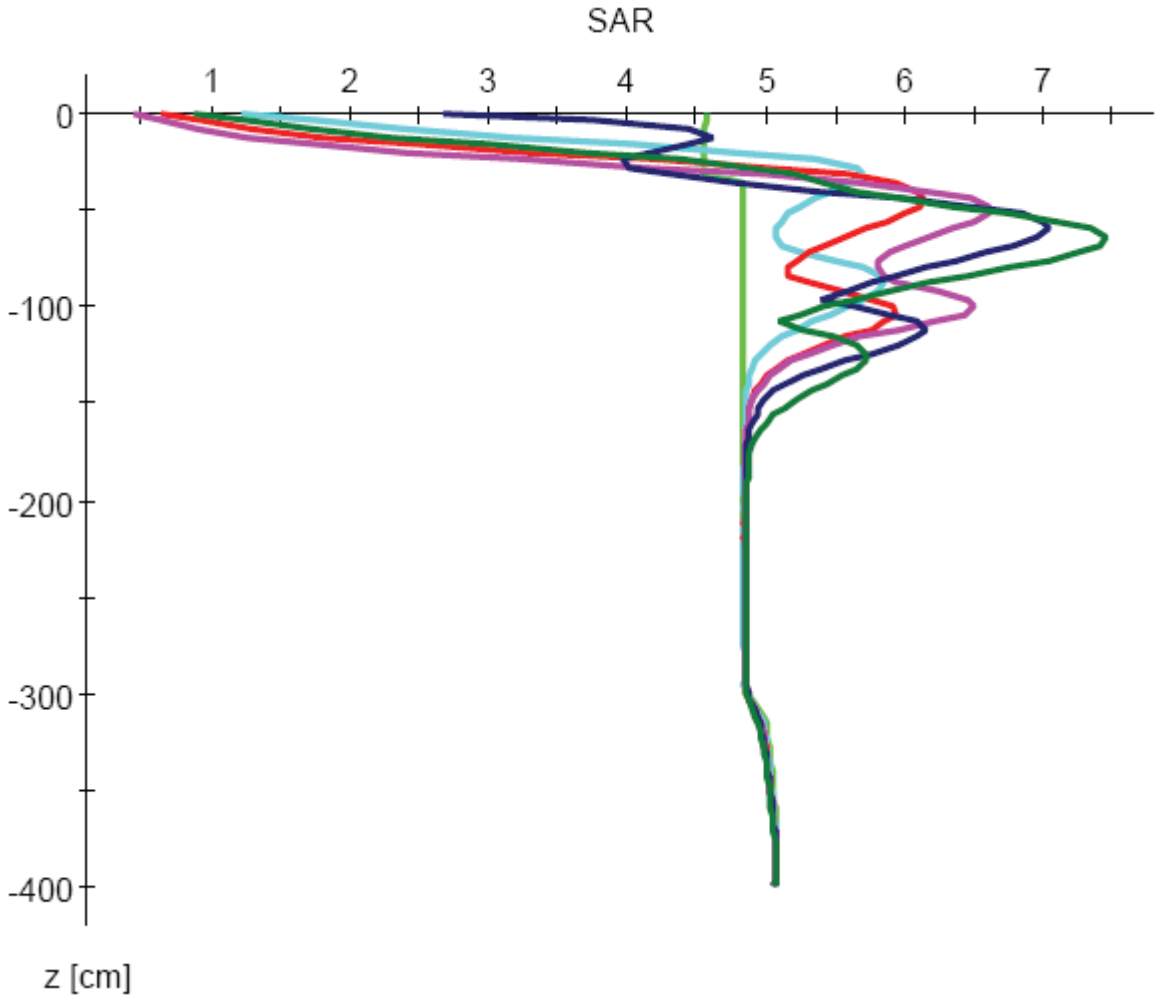


Figure 2. SAR by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

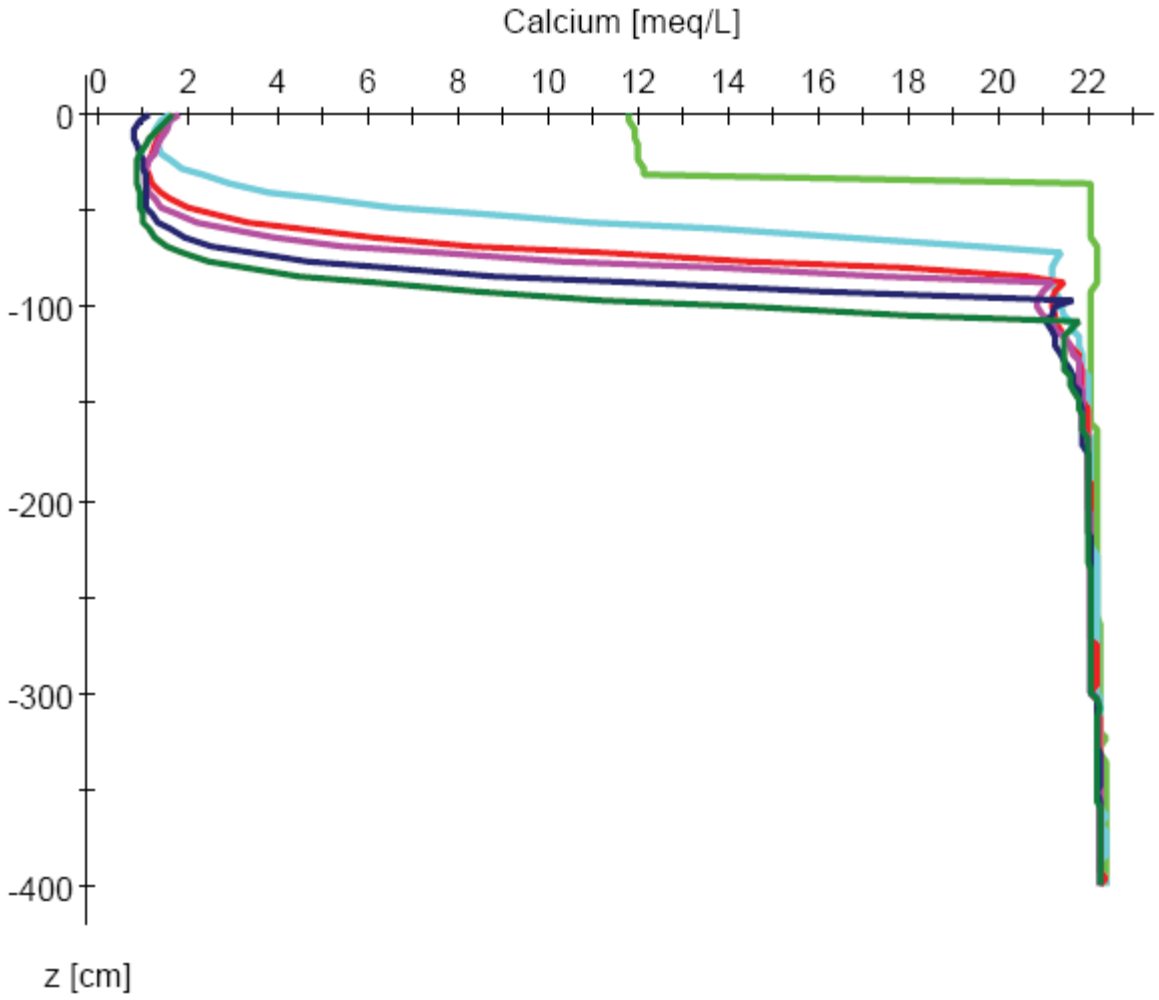


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

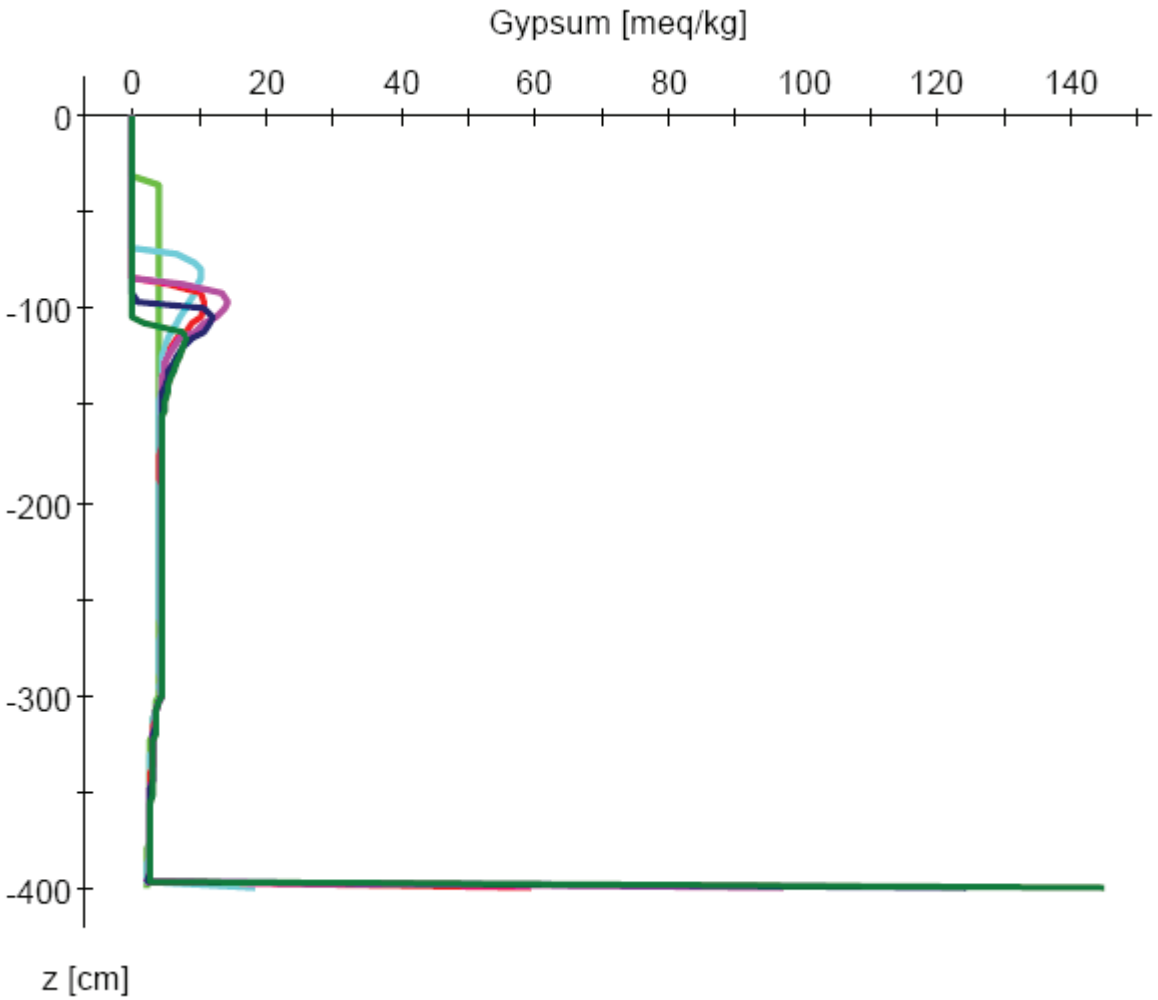


Figure 4. Gypsum levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

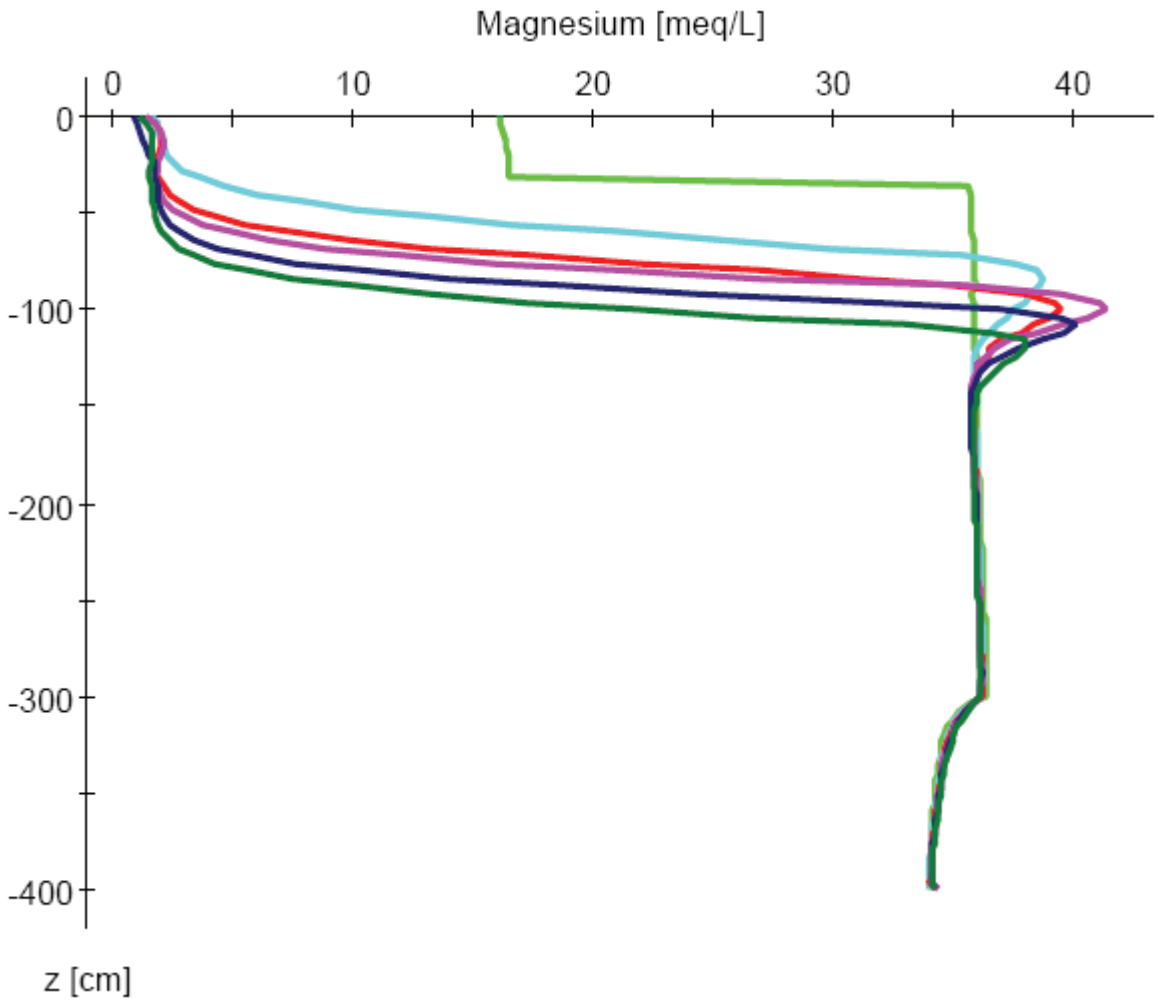
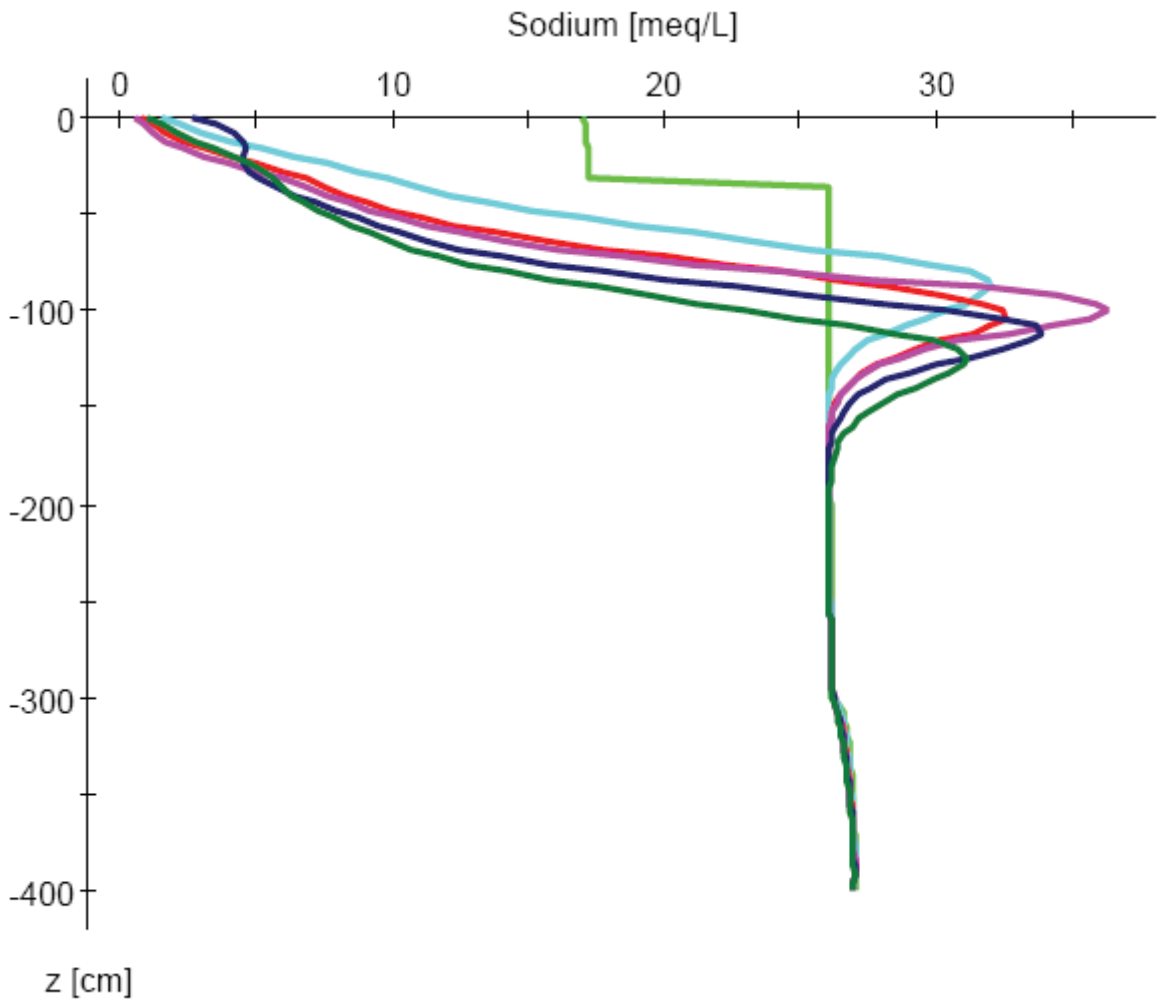


Figure 5. Solution magnesium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



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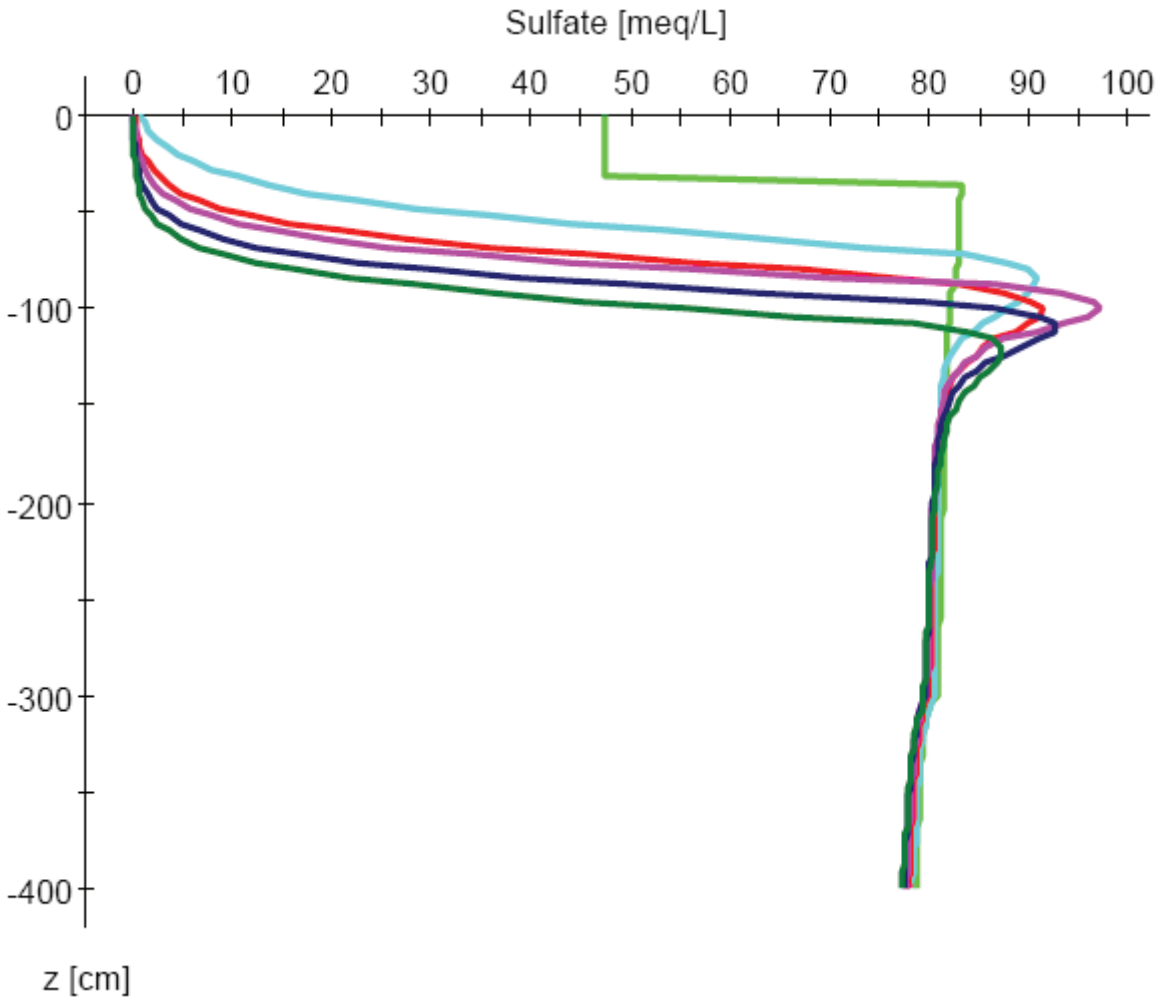


Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

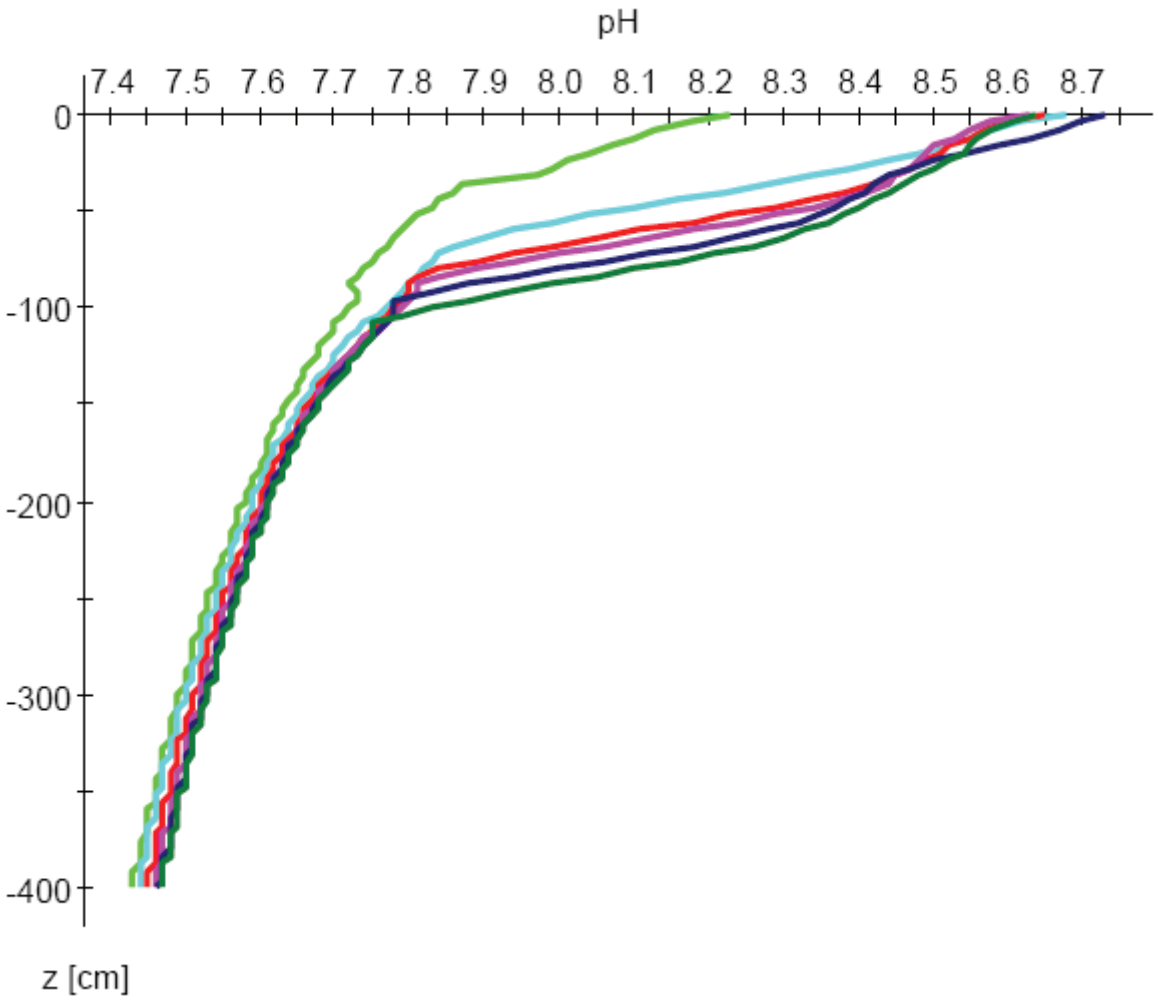


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

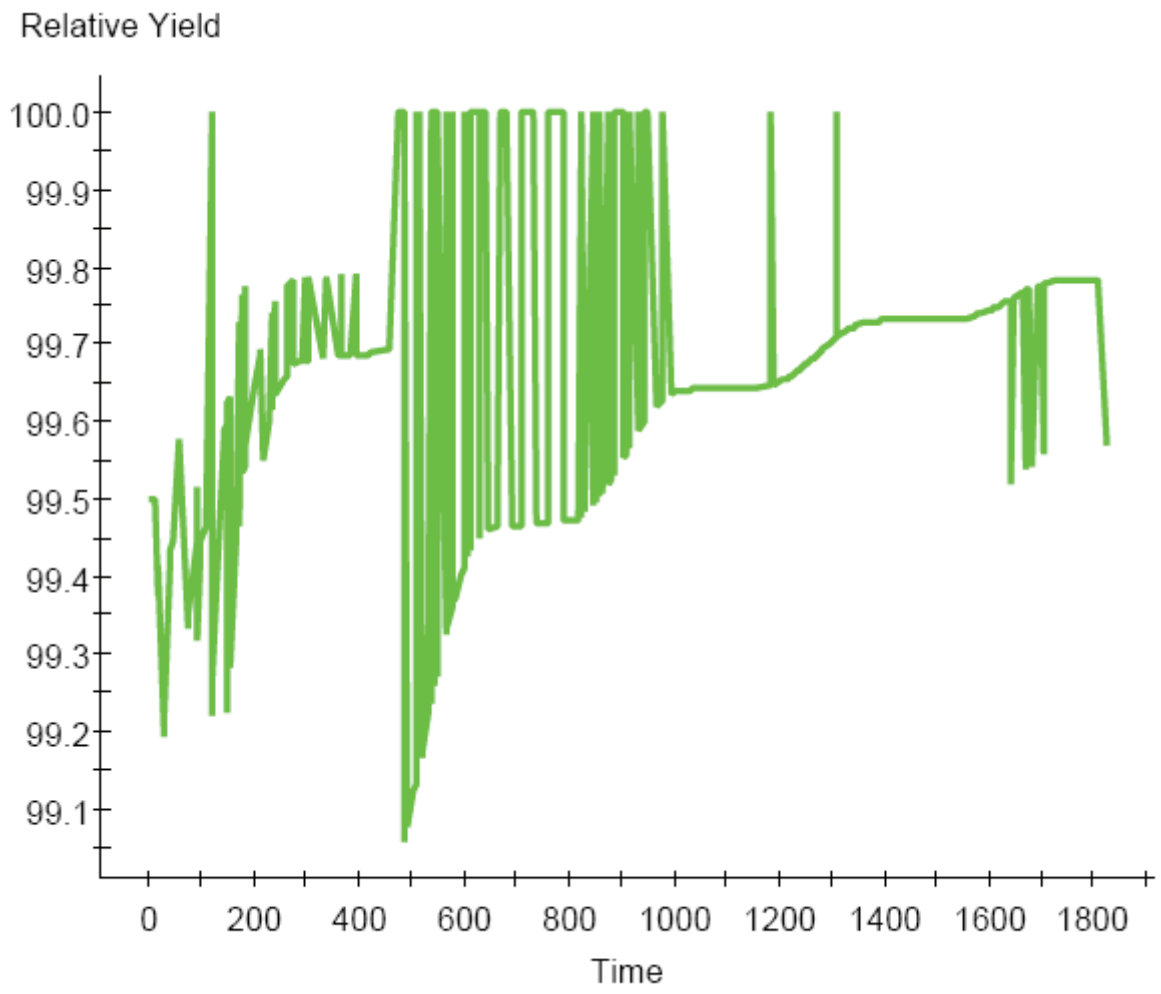


Figure 9. Relative crop yield over the 5-year simulation period.

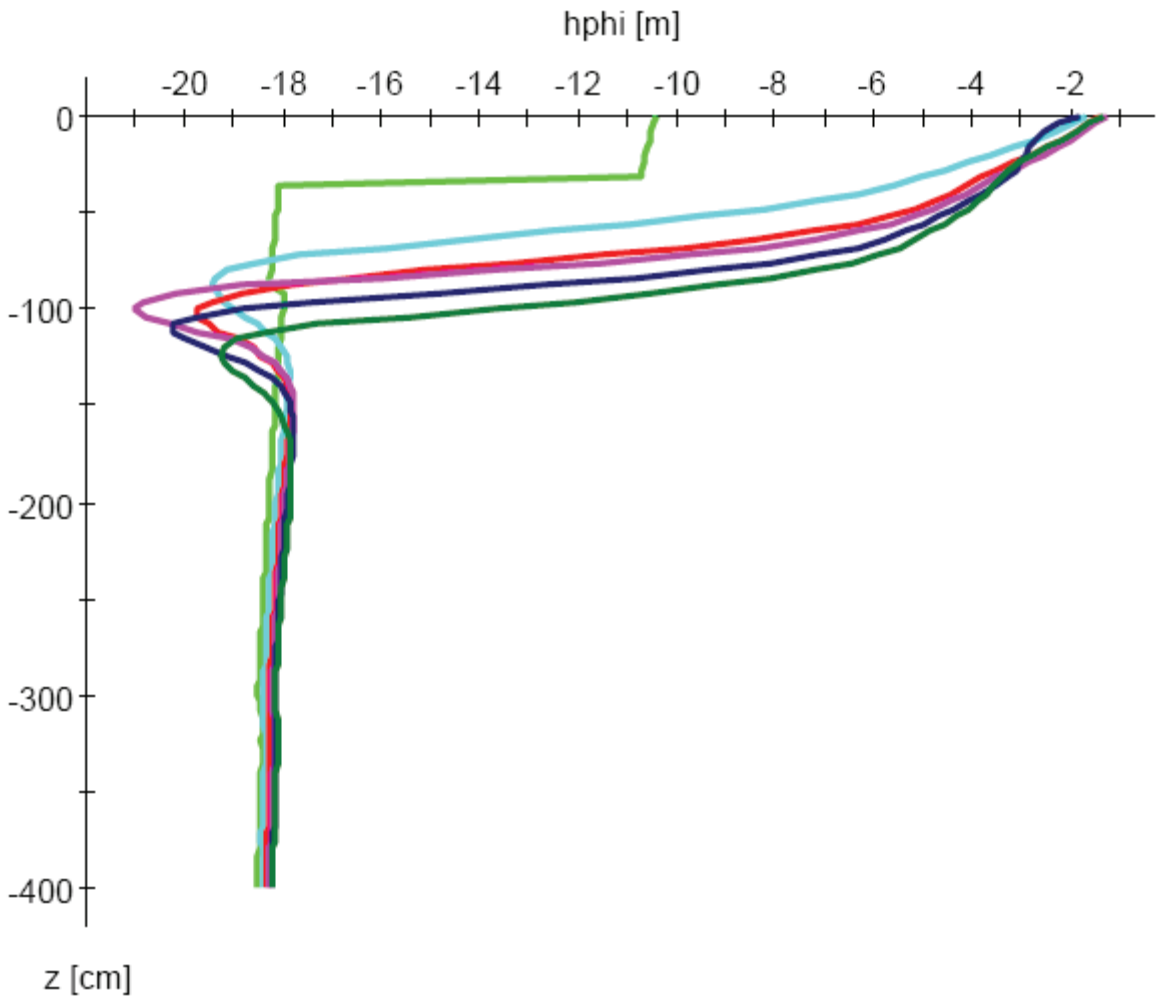


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

APPENDIX E – RESULTS OF THE FAO-SWS IRRIGATION SIMULATIONS FOR LANDS ASSOCIATED WITH SPRING CREEK

Marsha Pownall Ranch Subirrigated Area MP2

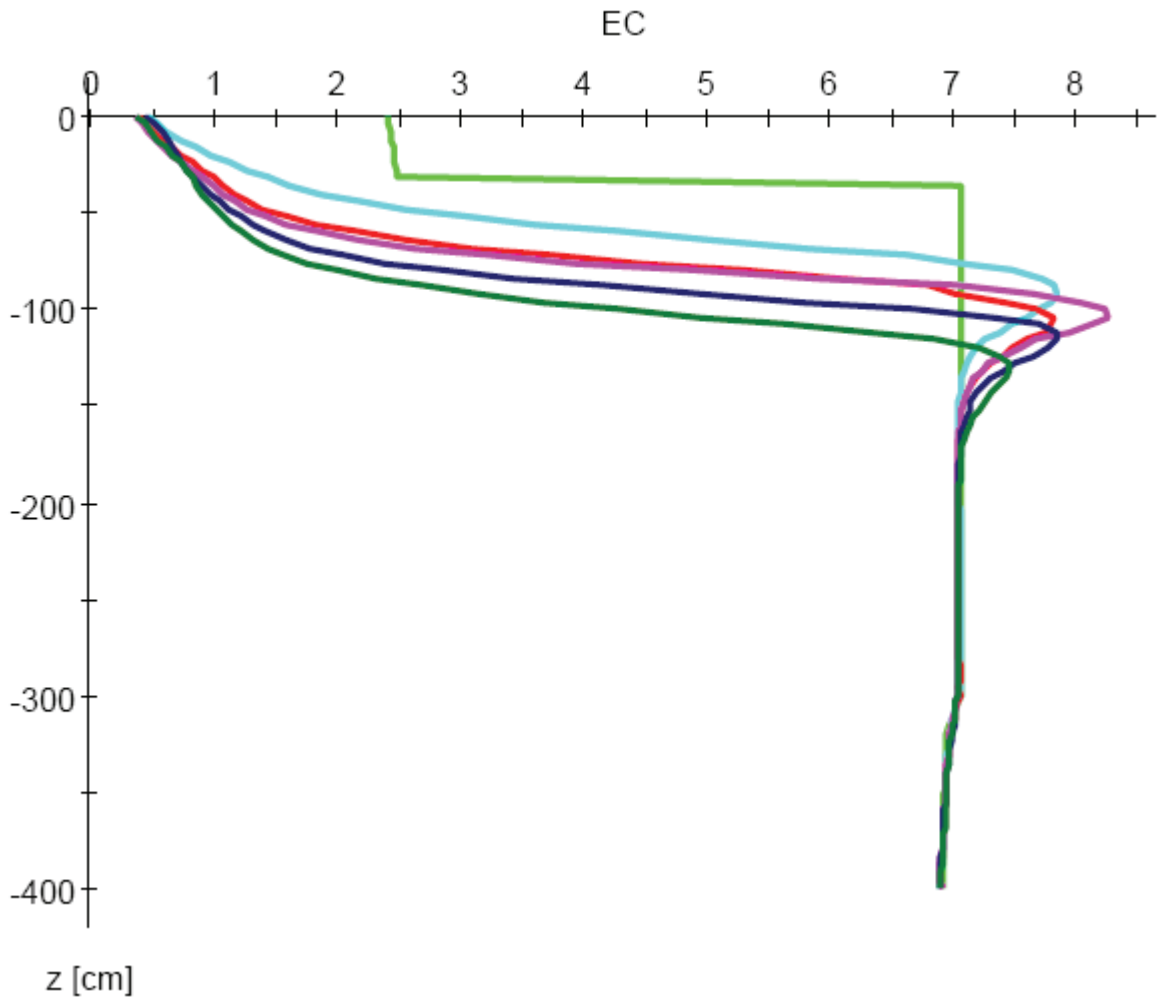


Figure 1. Salt concentrations (EC) by soil depth over the 5-year irrigation period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

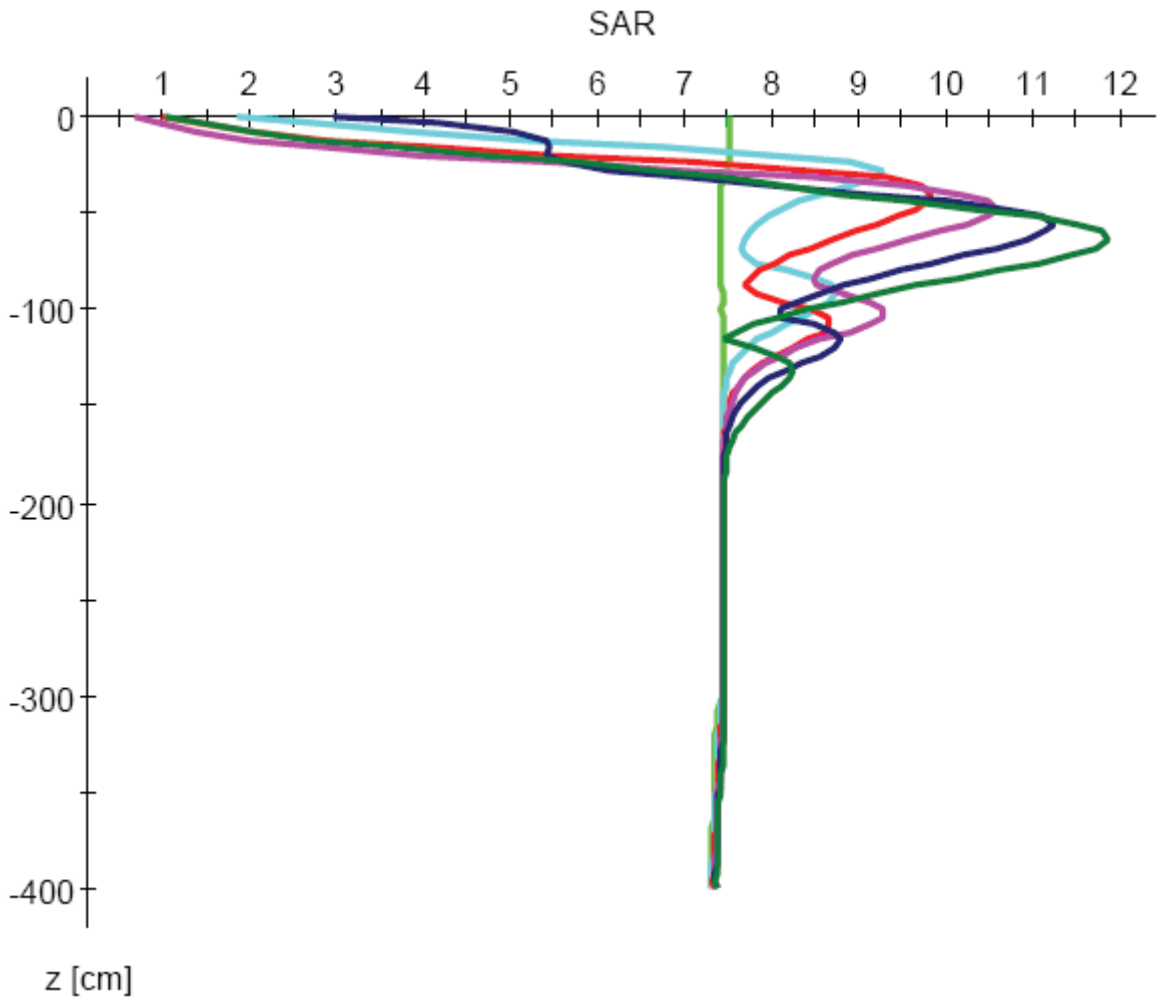


Figure 2. SAR by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

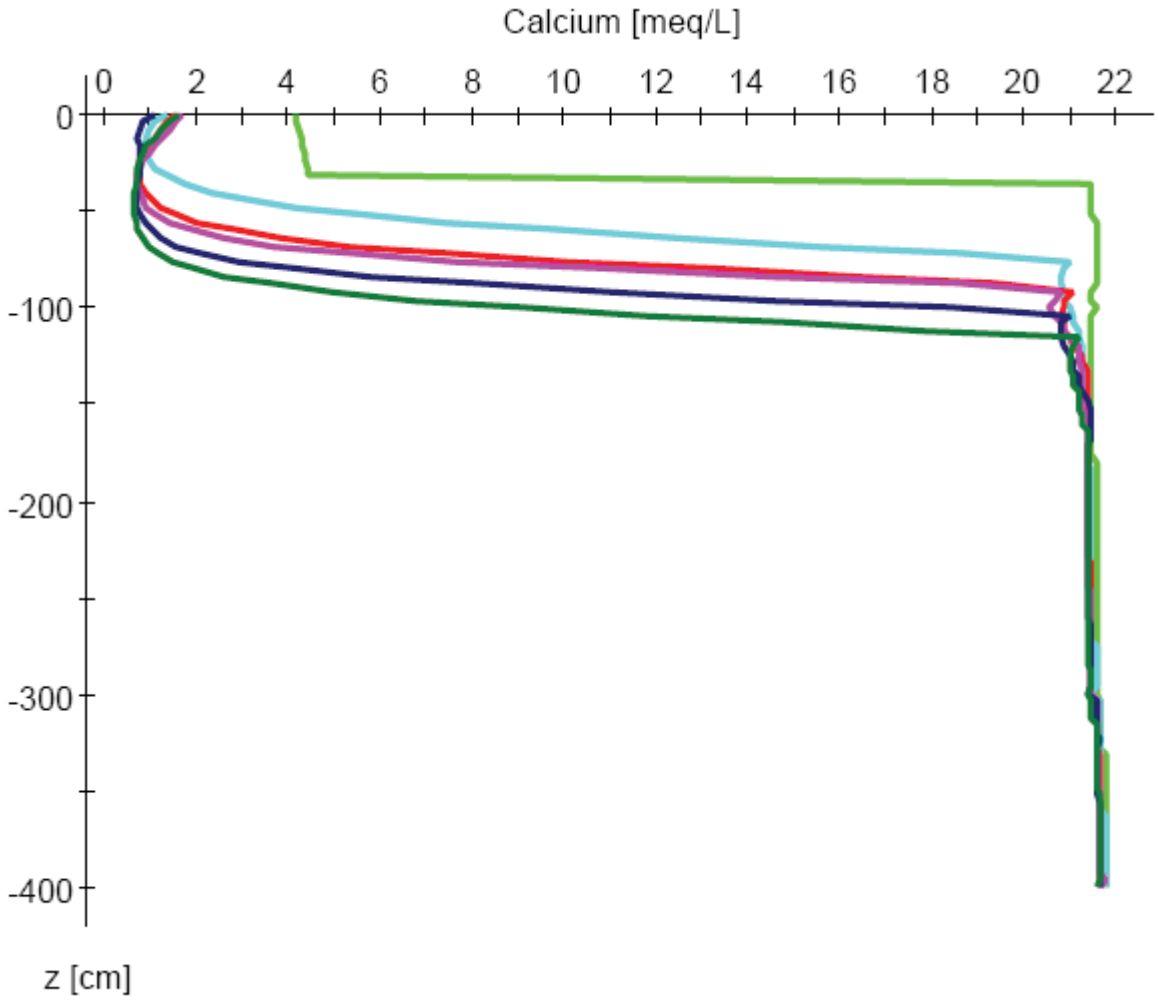


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

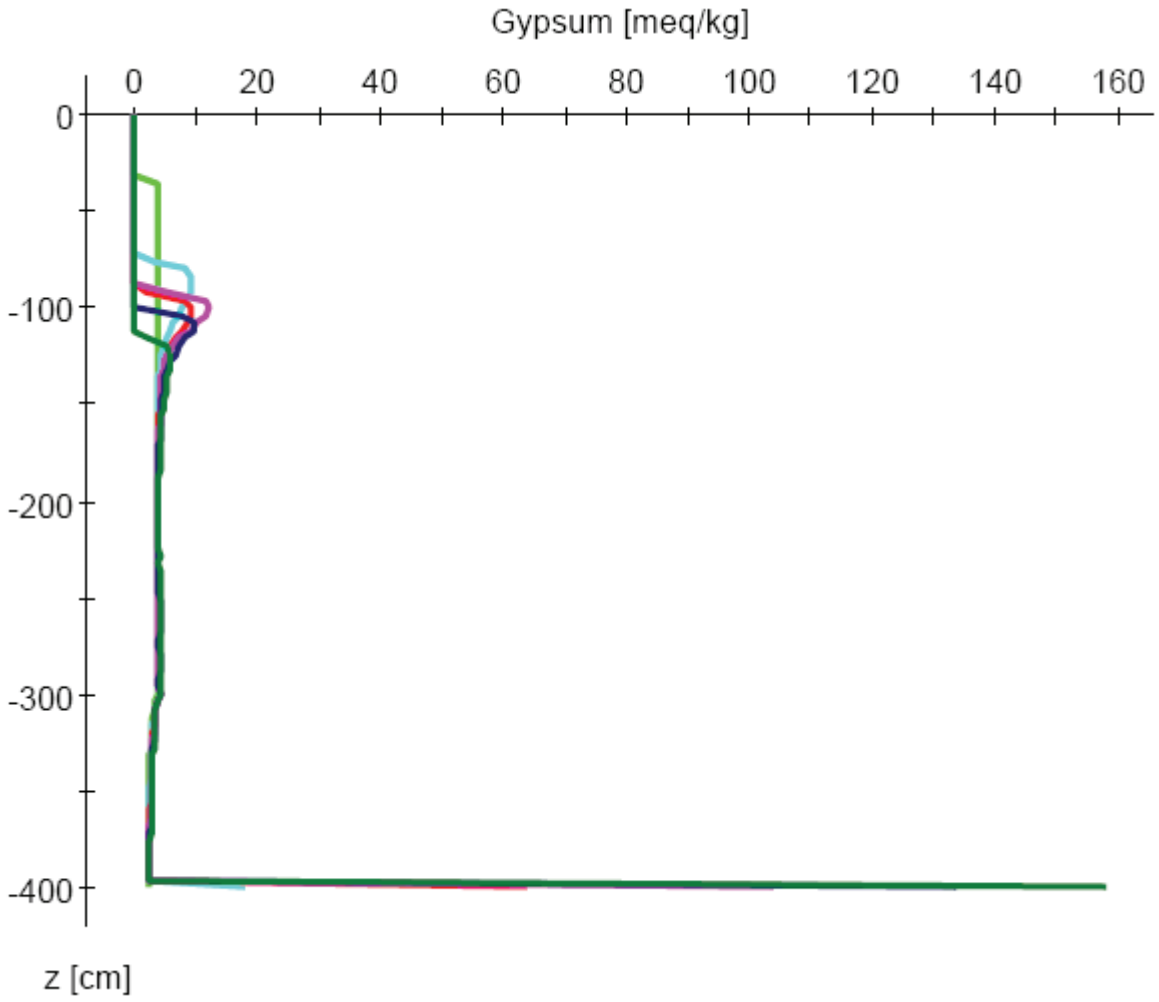


Figure 4. Gypsum levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

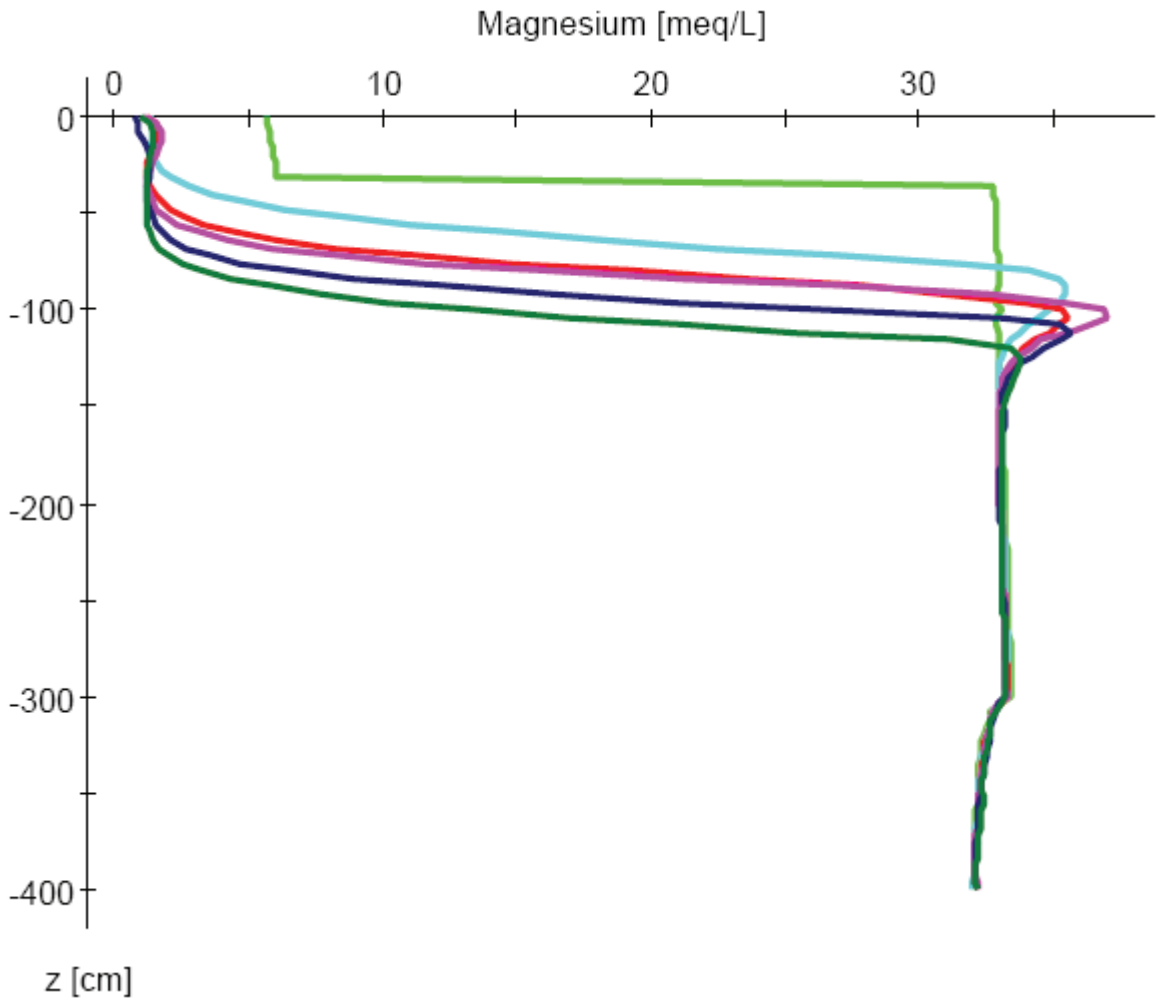
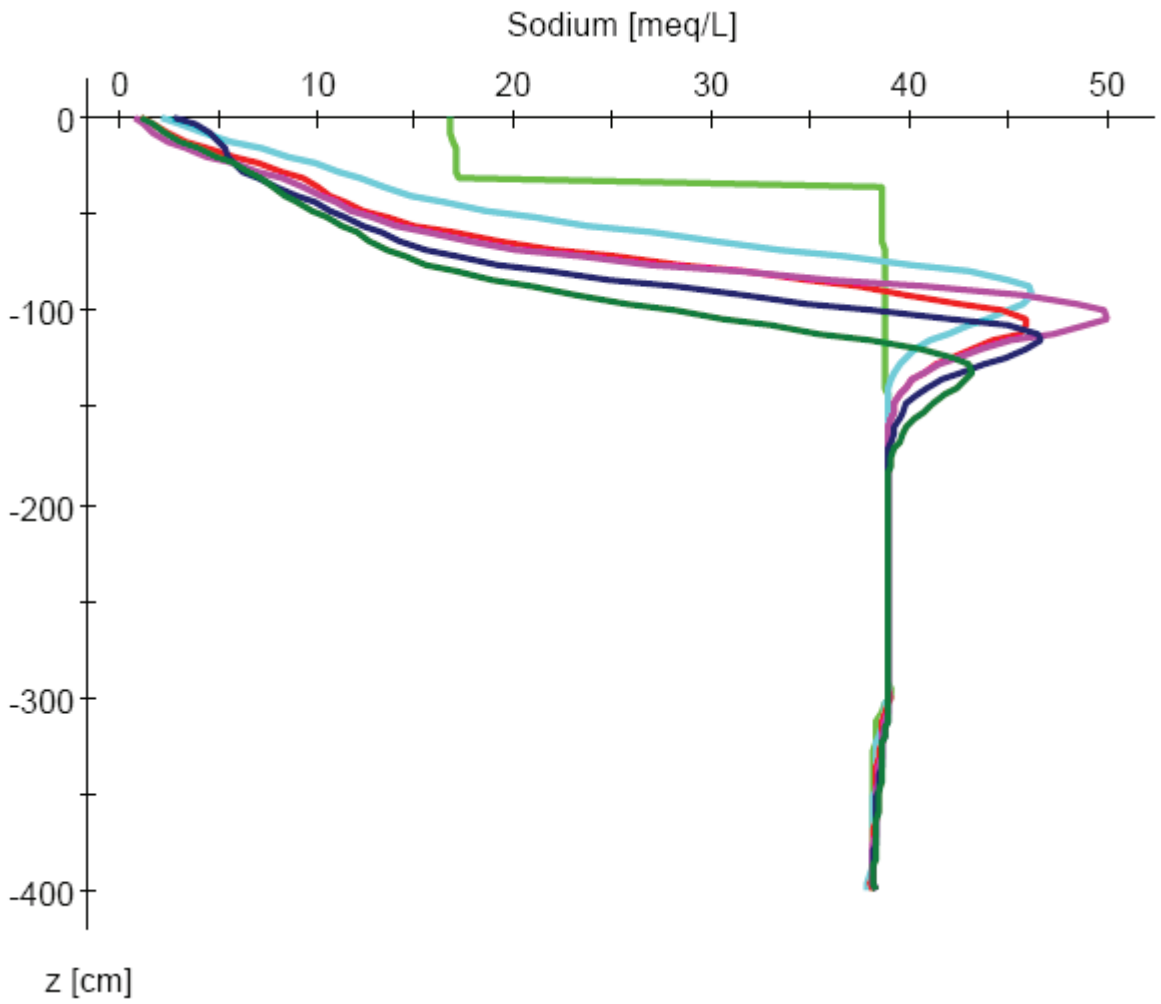


Figure 5. Solution magnesium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



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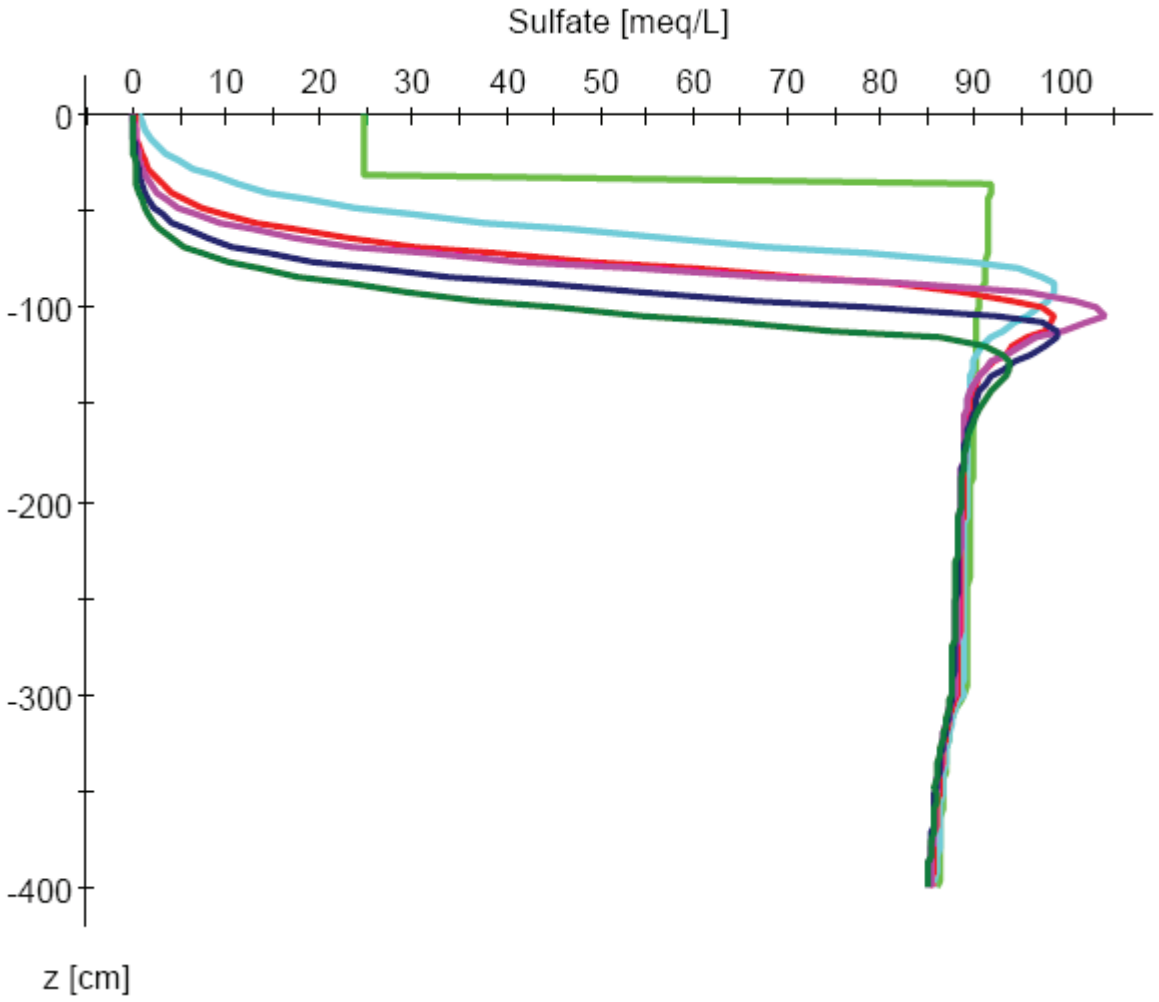


Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

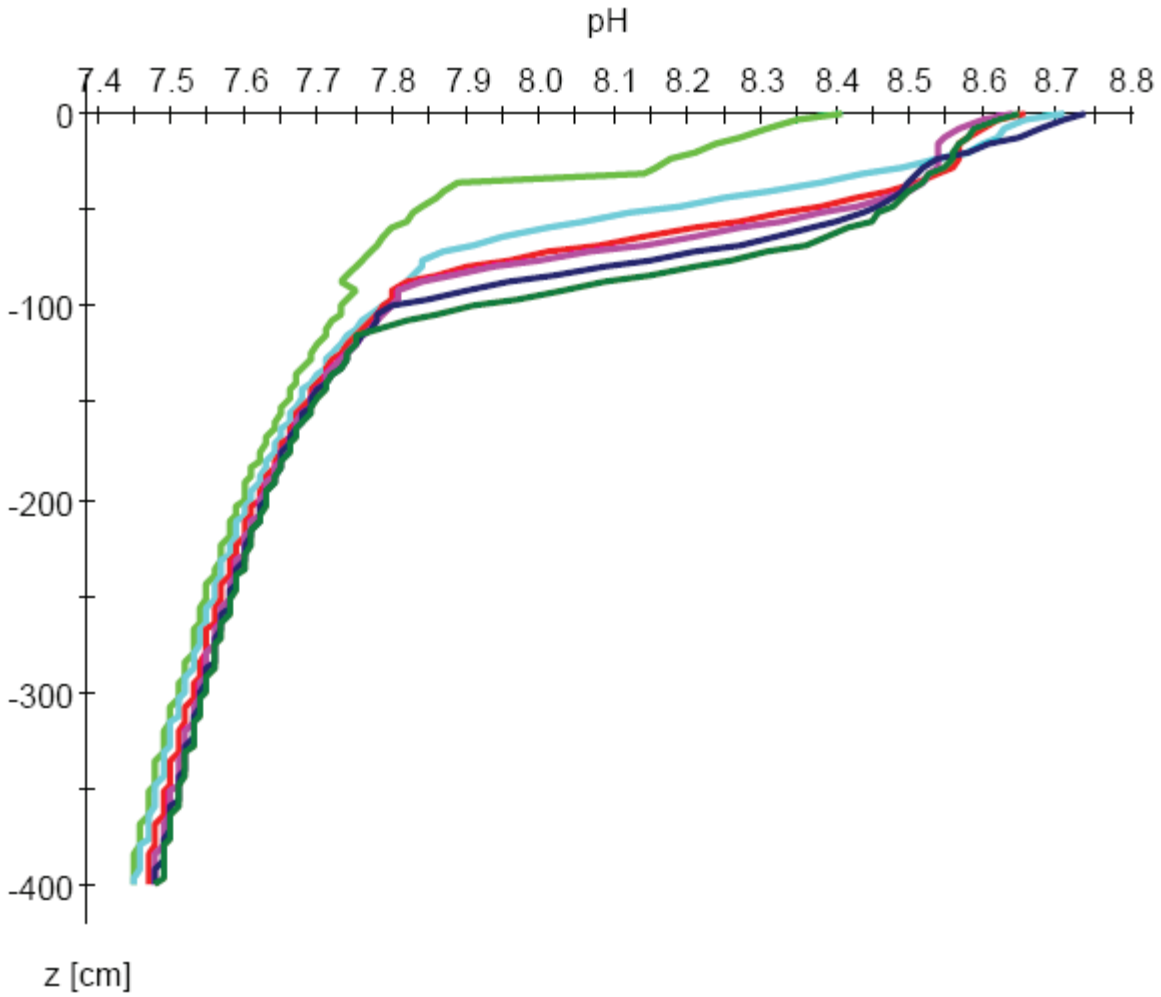


Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

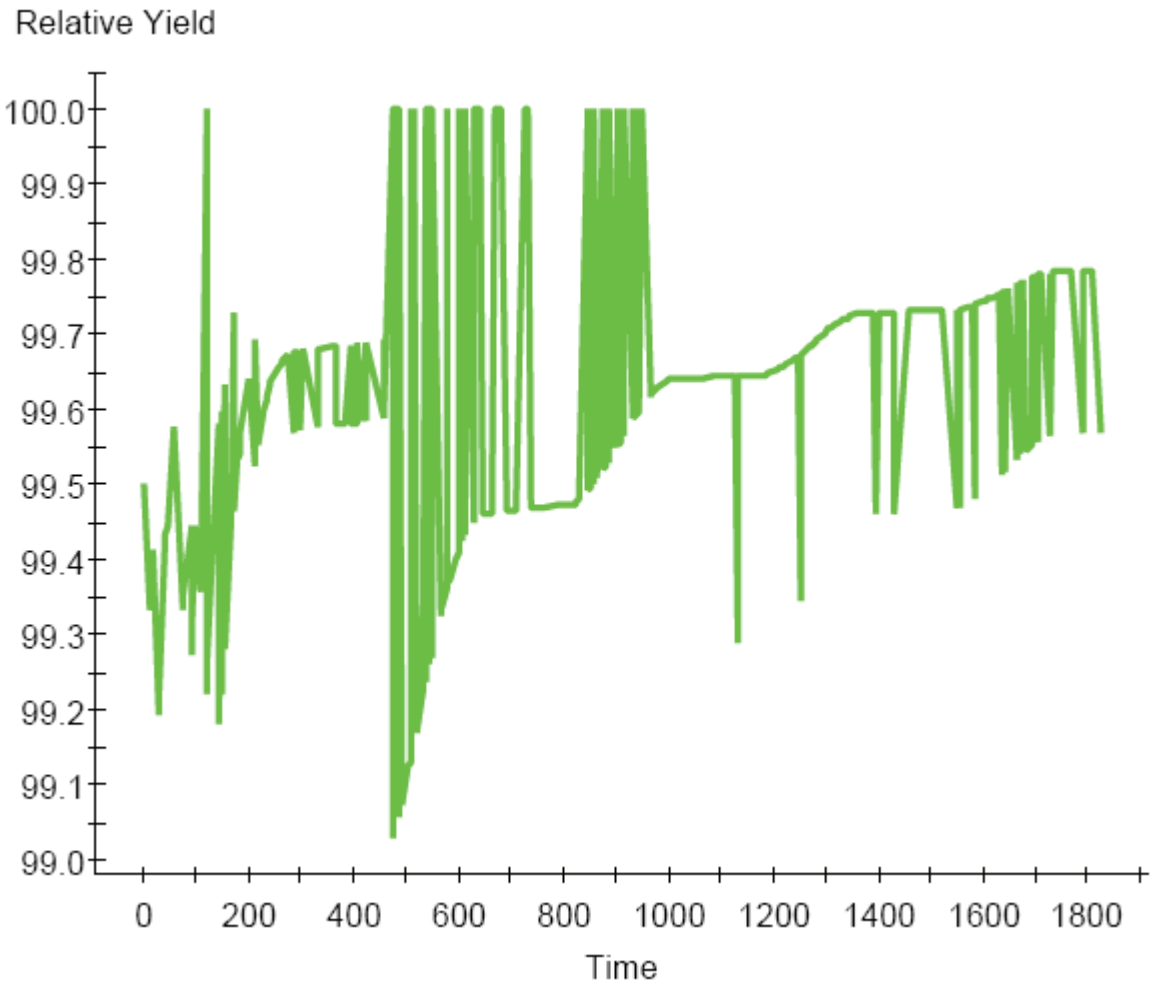


Figure 9. Relative crop yield over the 5-year simulation period.

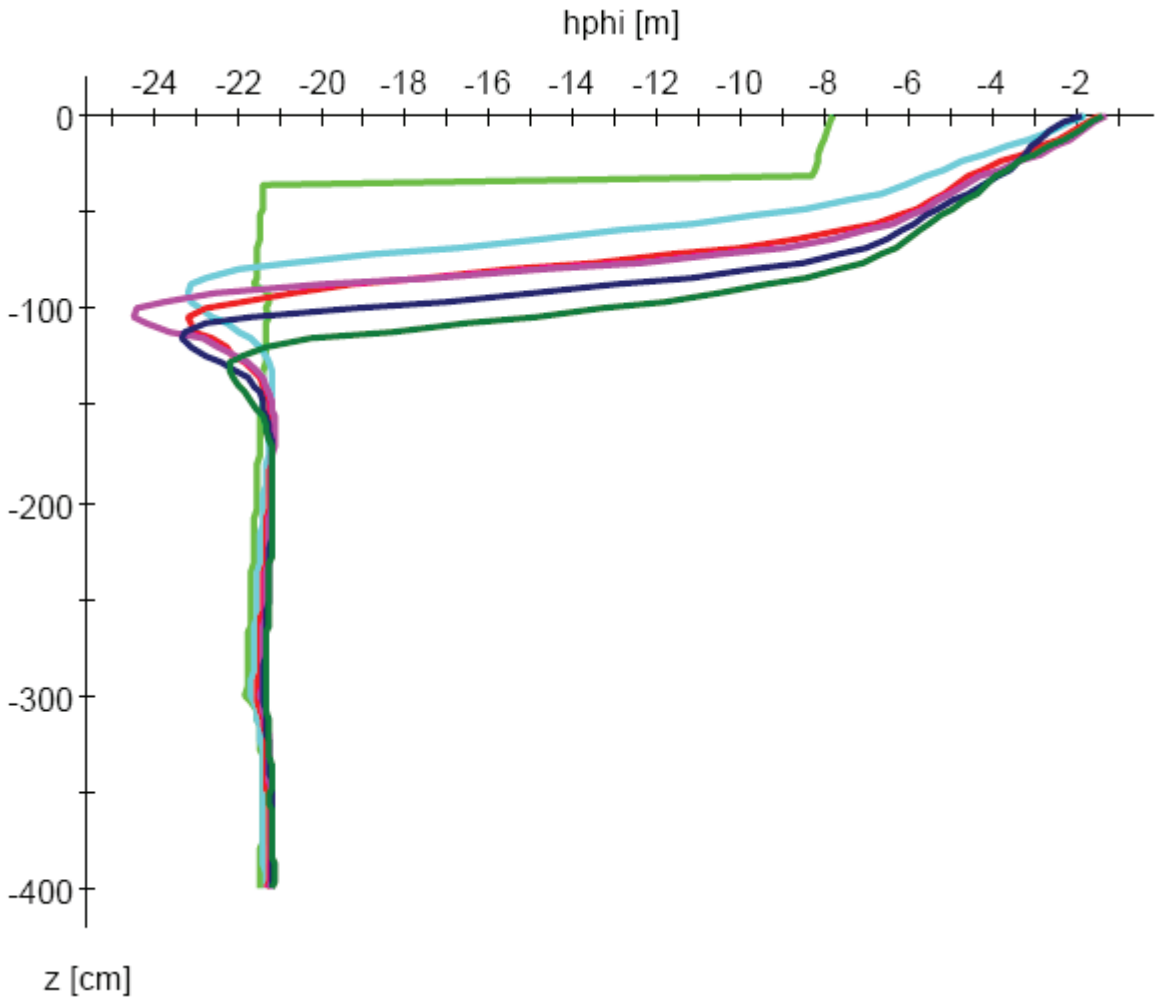


Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

Marsha Pownall Ranch Subirrigated Area MP8

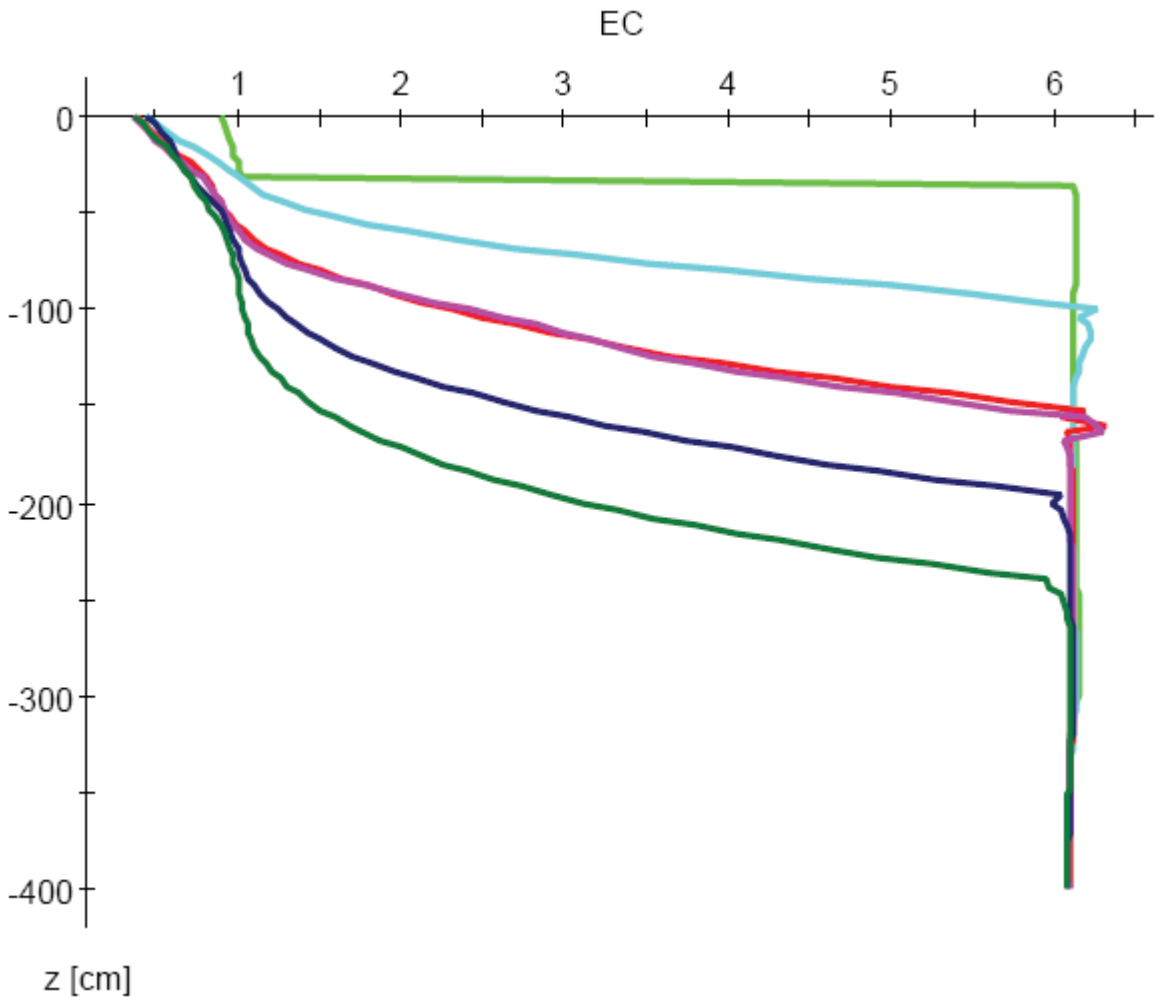


Figure 1. Salt concentrations (EC) by soil depth over the 5-year irrigation period (IP). (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

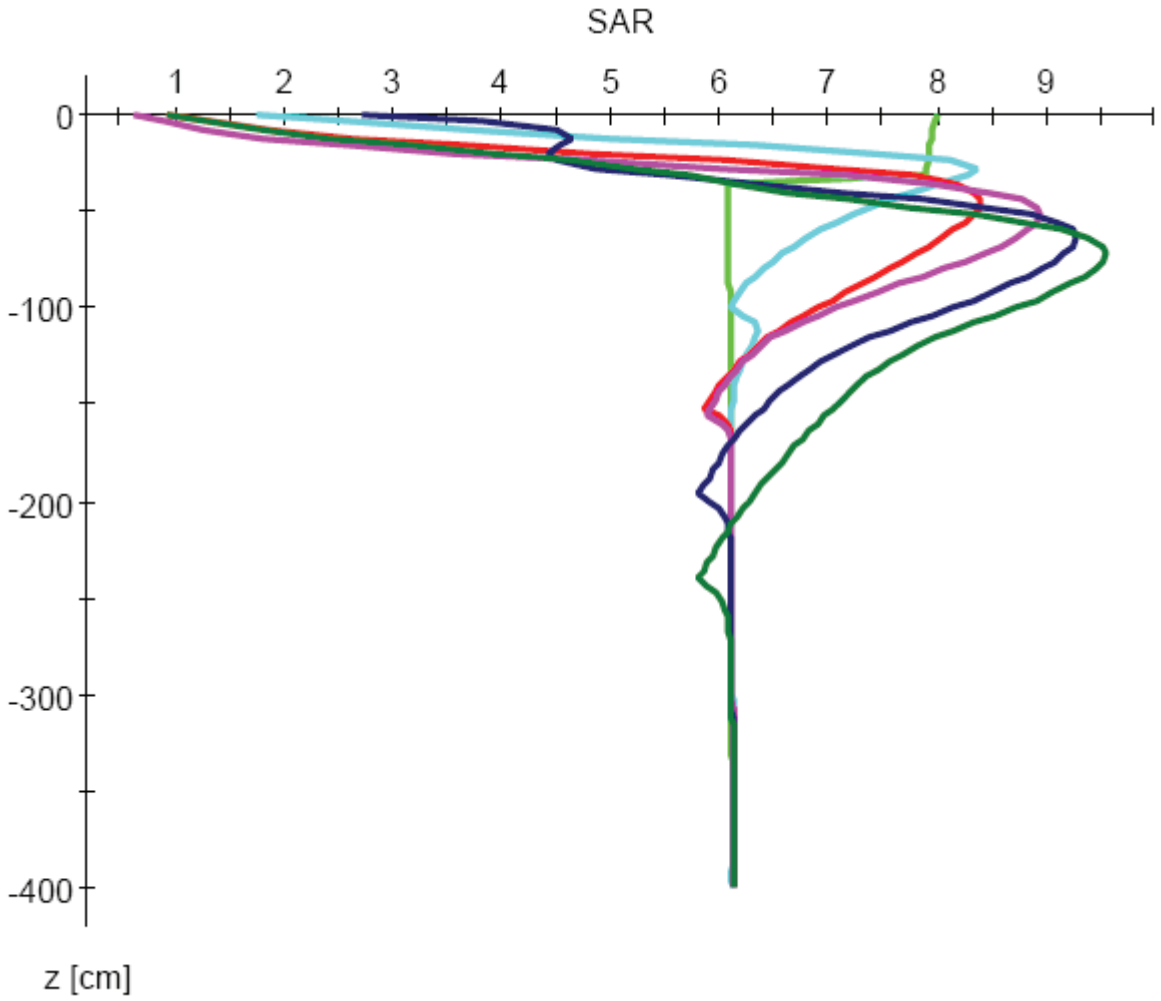


Figure 2. SAR by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

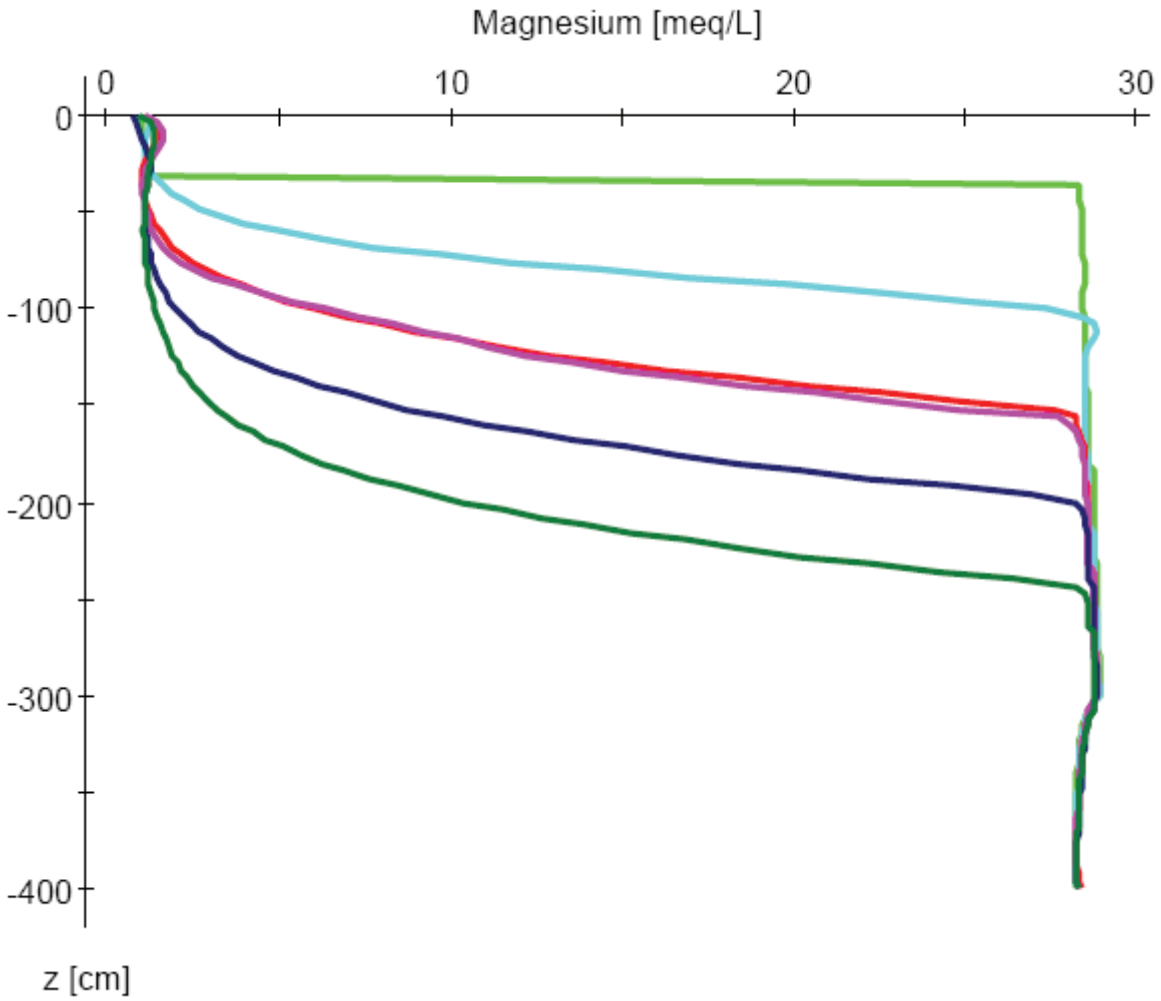


Figure 3. Solution calcium levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

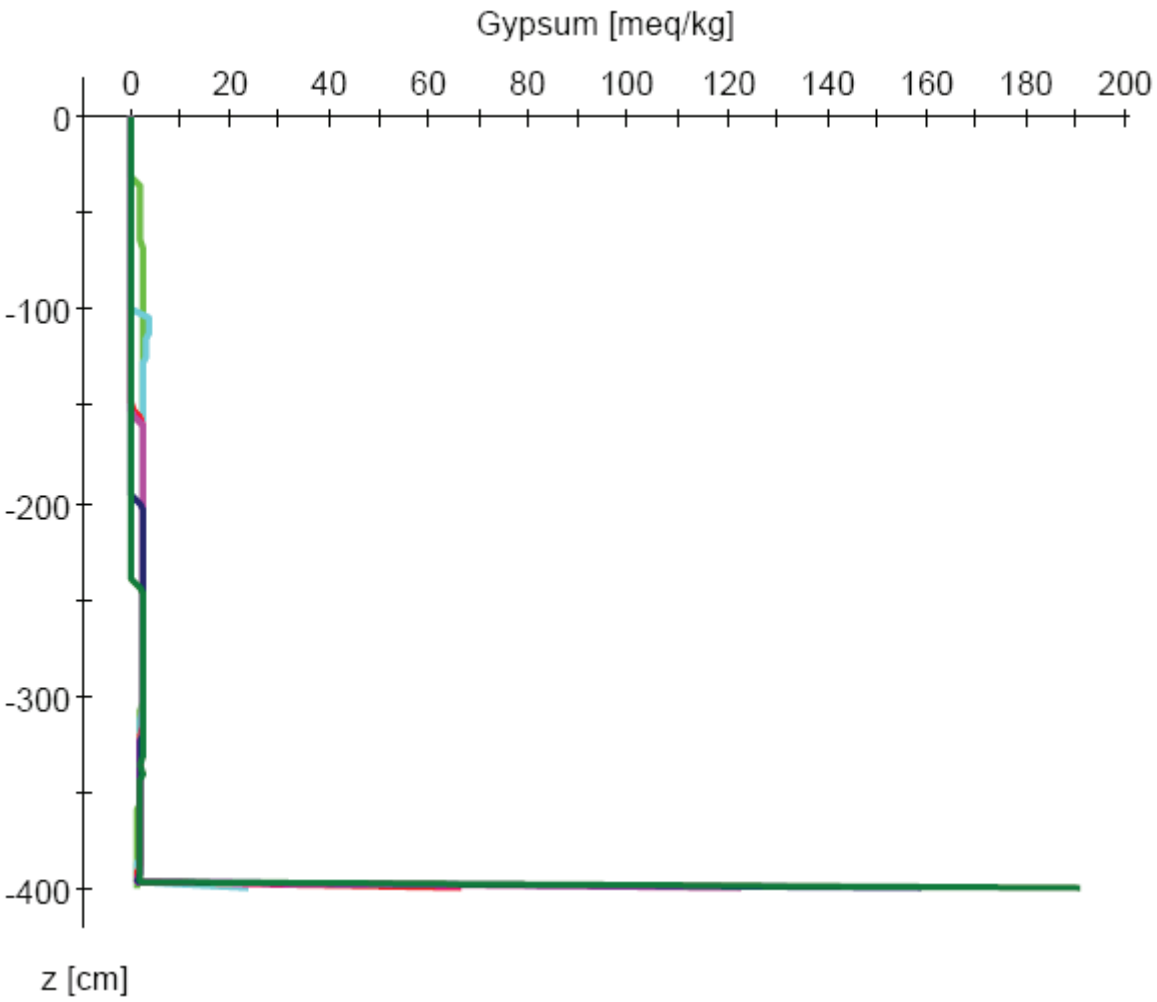
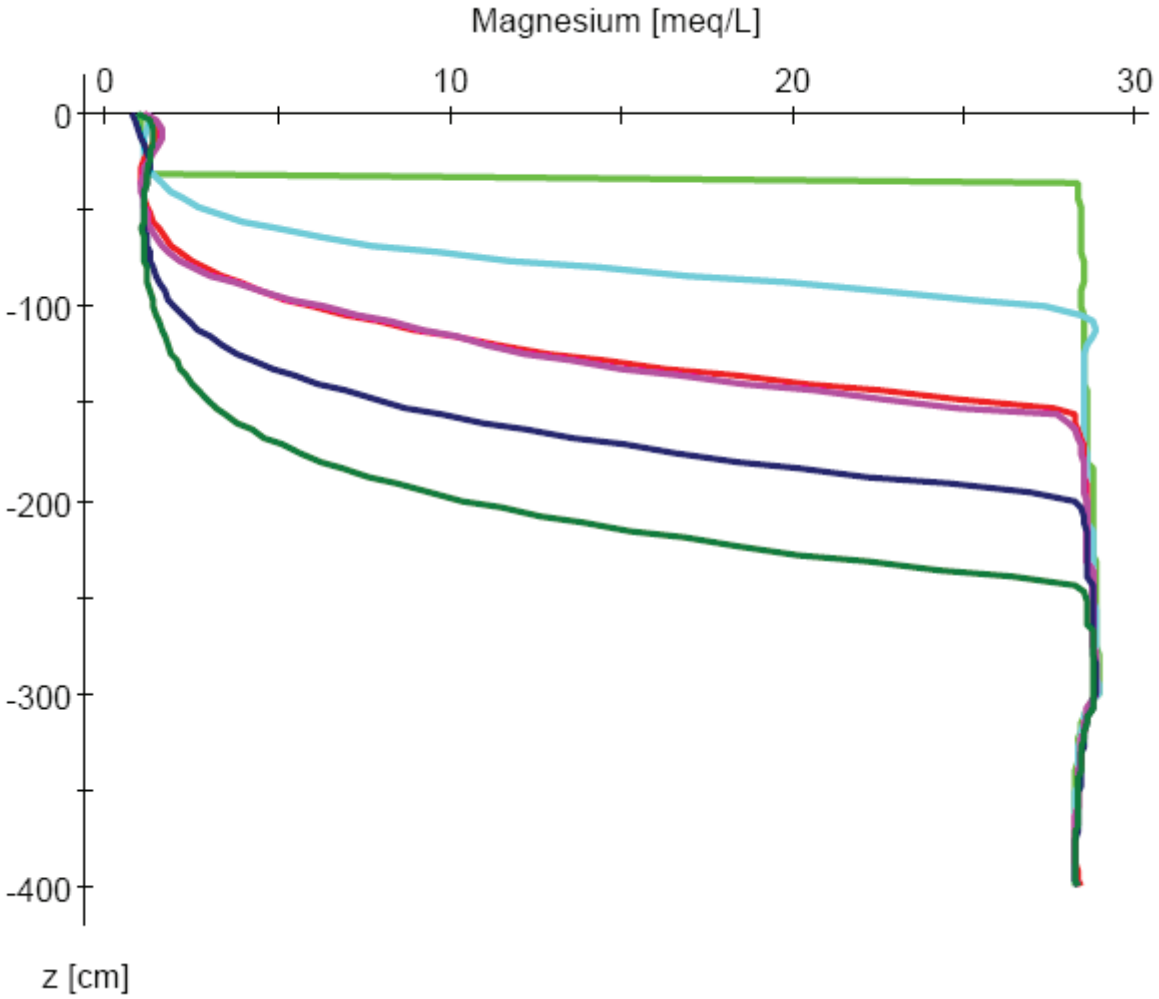


Figure 4. Gypsum levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)



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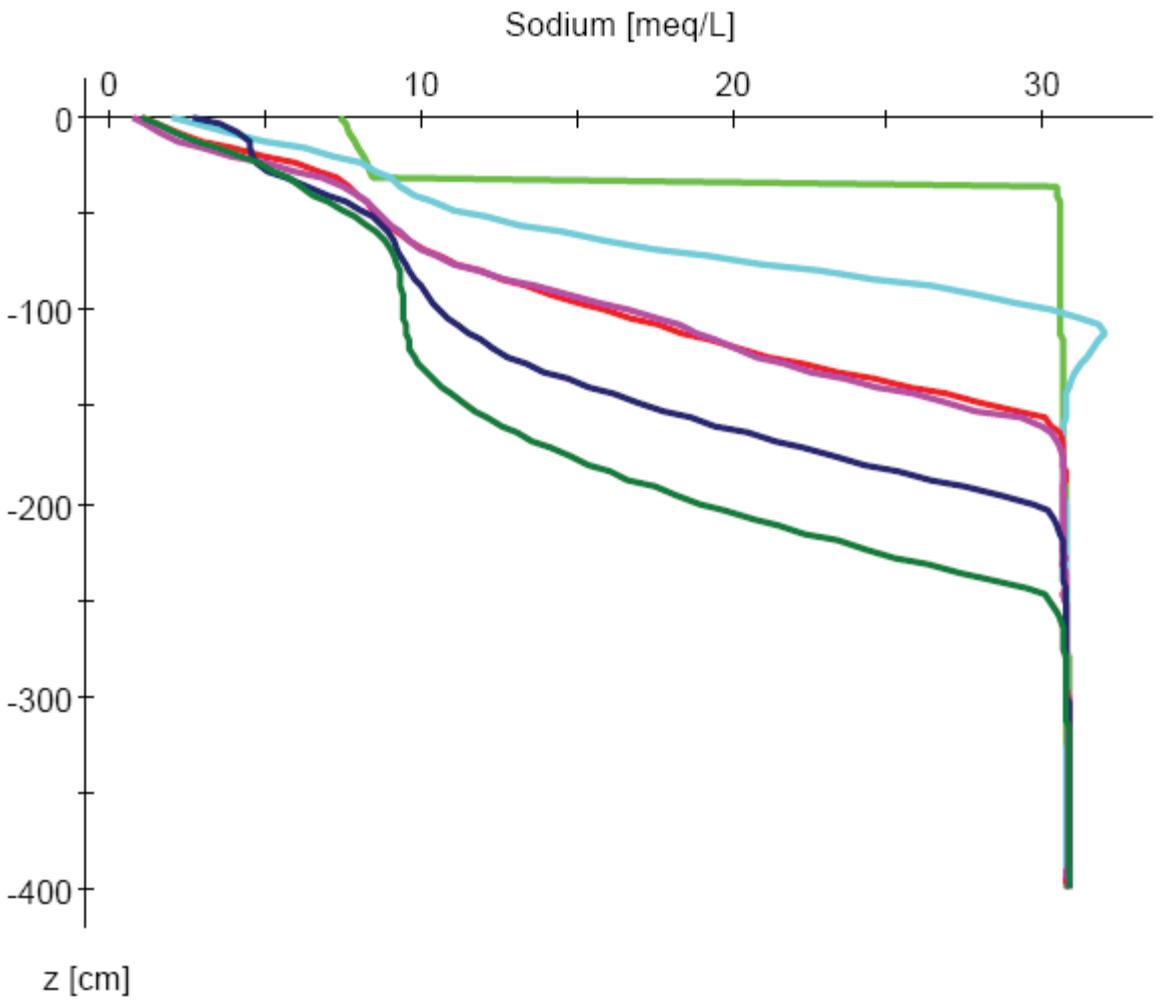

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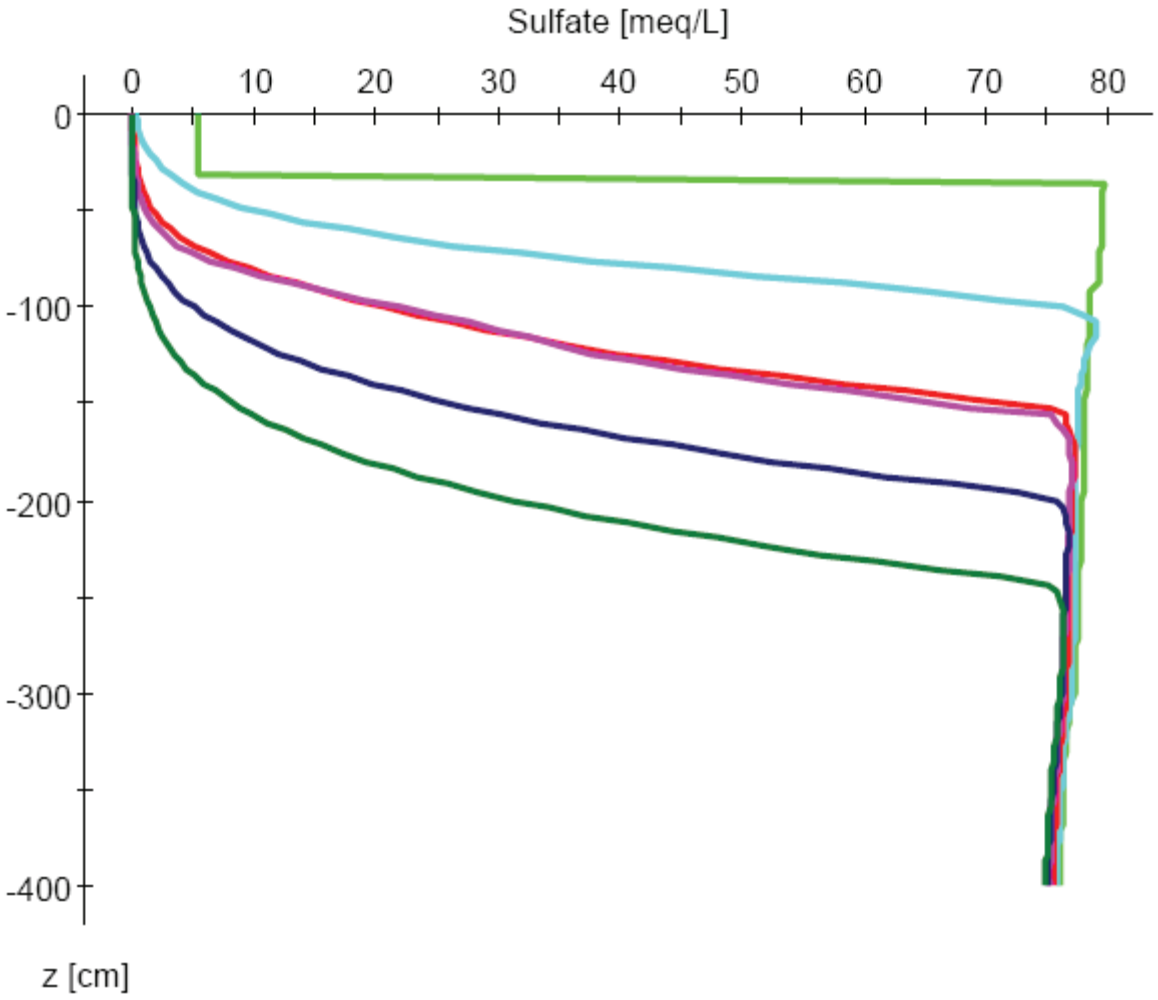

Figure 7. Solution sulfate levels by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

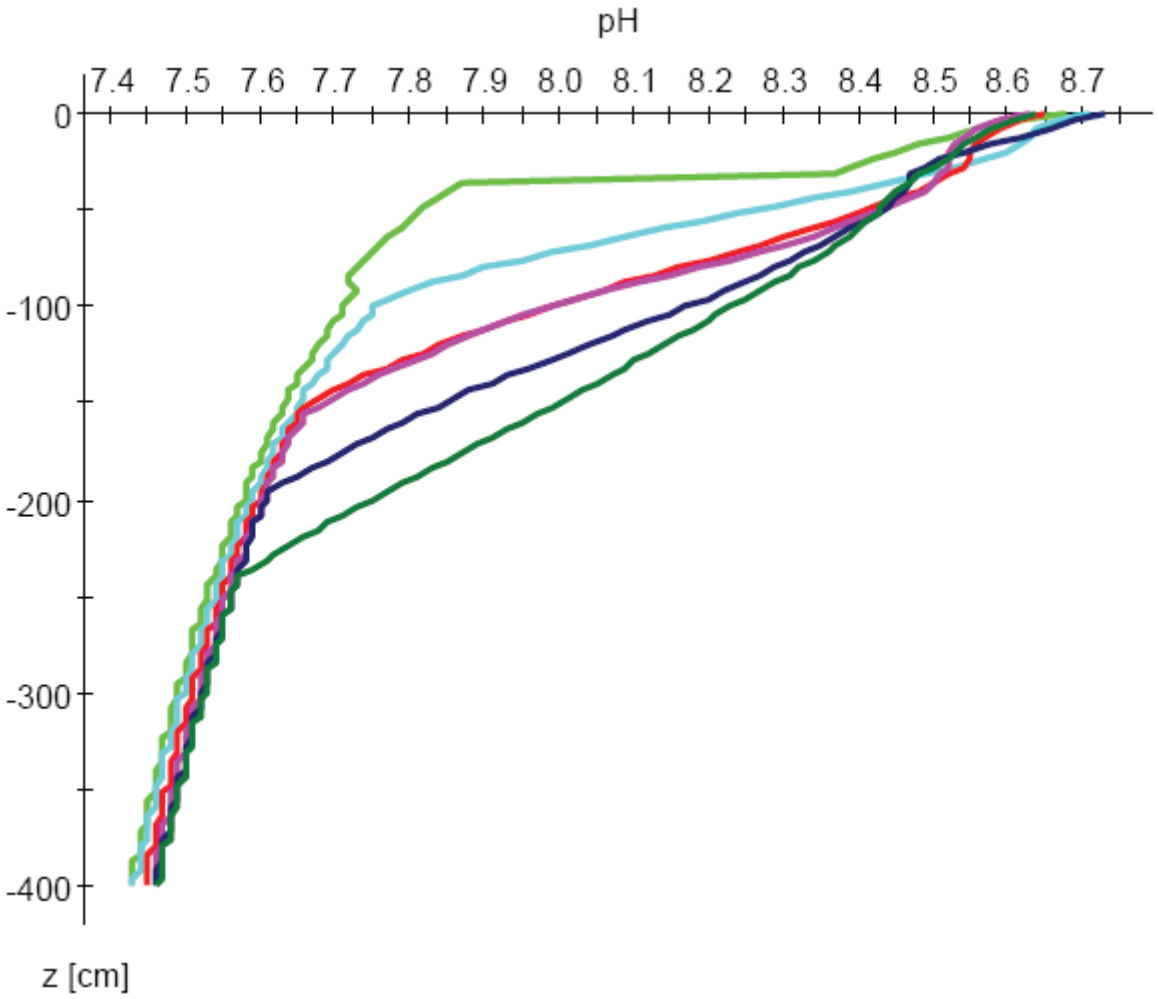

Figure 8. pH by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)

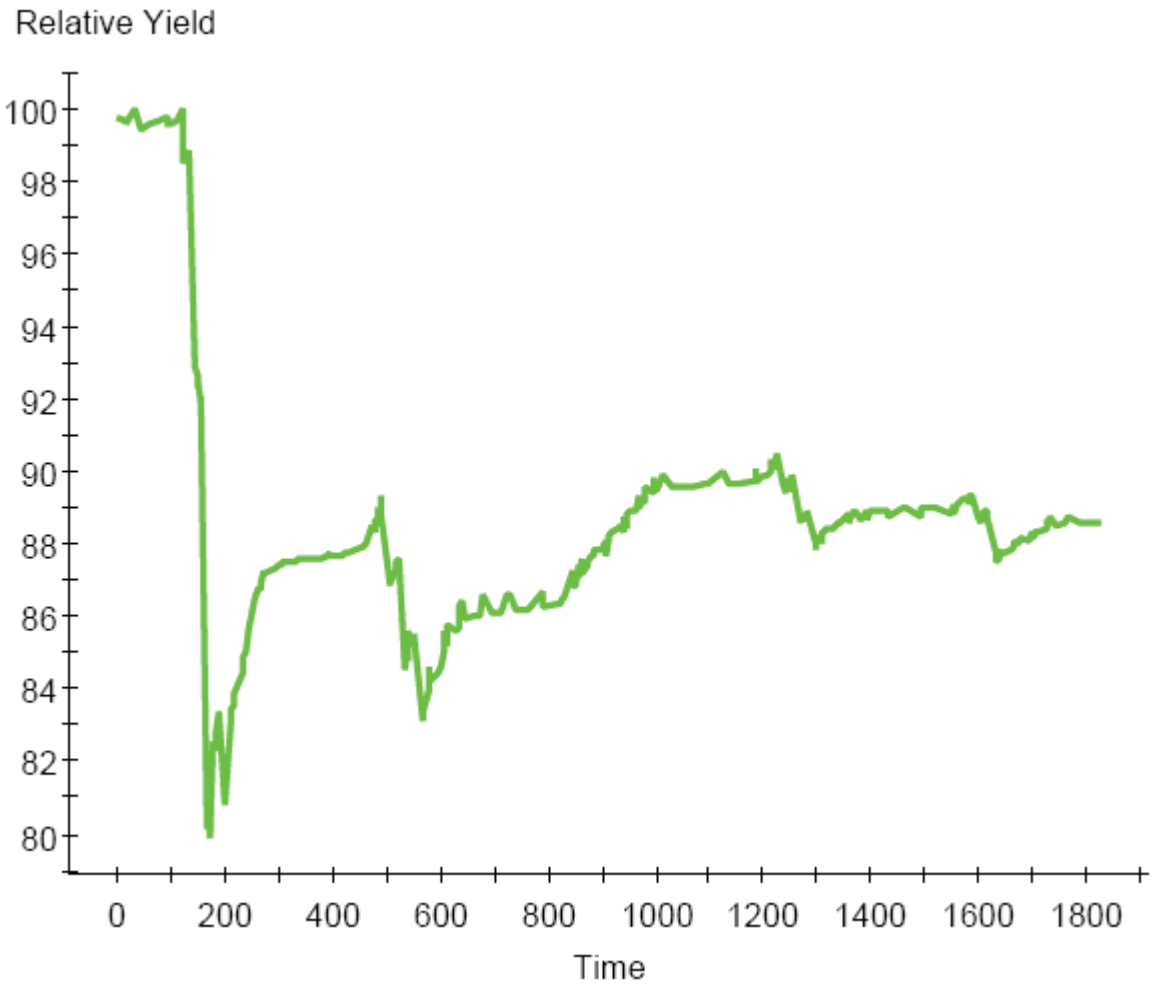

Figure 9. Relative crop yield over the 5-year simulation period.

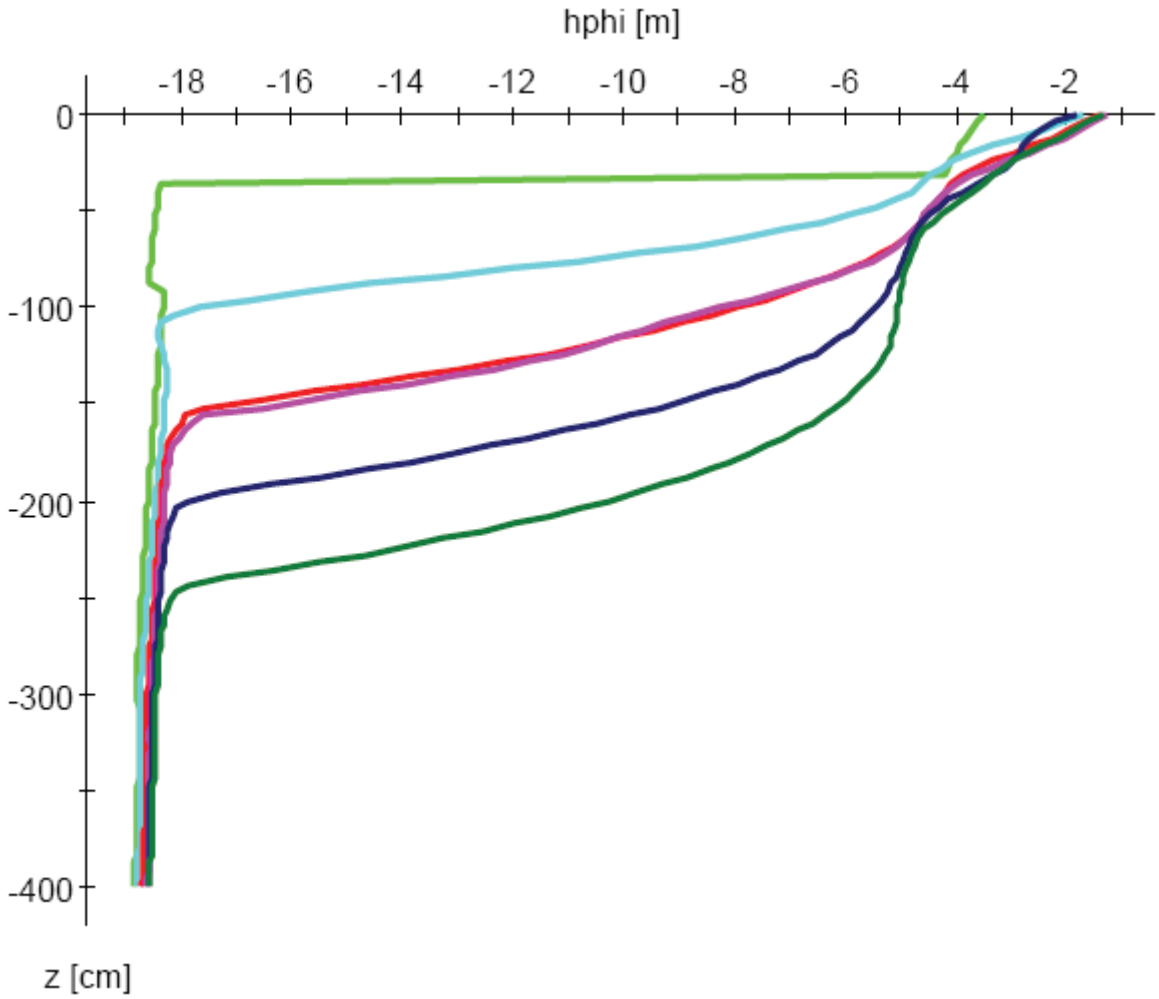

Figure 10. Osmotic Pressure Head by soil depth over the 5-year simulation period. (green – 0; turquoise – 1 year; red – 2 years; pink – 3 years; blue – 4 years; dark green – 5 years)