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Desalination and Water Purification Research and Development Program Report No 181

Using Halophyte Farming to Manage Inland Reverse Osmosis Concentrates

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
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Using Halophyte Farming to Manage Inland Reverse Osmosis Concentrates

Prepared for the Bureau of Reclamation Under Agreement No. R16AC00018, Including the work under R13AC80023

By

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Through
Desert Southwest Cooperative Ecosystem Study Unit

Bureau of Reclamation, Denver, Colorado and Brackish Groundwater National Desalination Research Facility, Alamogordo, NM

University of Arizona, Department of Soil, Water and Environmental Science

With
New Mexico State University (NMSU)

Texas A&M University – Kingsville (TAMUK)

U.S. Department of the Interior
Bureau of Reclamation
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Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Disclaimer

Acknowledgments

The Desalination and Water Purification Research and Development Program, Bureau of Reclamation, sponsored this research. Reclamation partners in both Denver and in Alamogordo, New Mexico provided on-going support through the DWPR program. We want to acknowledge John Walp and Miguel Arias- Paic, Grants Officer Technical Representatives (GOTR) on this project, for their guidance and technical support. Our project could not have been completed without the on-going collaboration with and support of Randy Shaw, Brackish Groundwater National Desalination Research (BGNDRF) Facility Manager, and the staff of BGNDRF: Steve Holling, Bobby Granados, and Dan Lucero.

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We dedicate our work to Martin R. Yoklic, the original Principal Investigator on this project, who led the team with visionary enthusiasm, professionalism and dedication before and after his retirement. See Section 4.1. Academic and Research Outcomes and Appendix 18 for further acknowledgements.

Acronyms and Abbreviations

ADF	acid detergent fiber
ALEC	Arizona Laboratory for Emerging Contaminants
BGNDRF	Brackish Groundwater National Desalination Research Facility
DAIC	Data Acquisition and Intelligent Control system
DM	dry matter
DWPR	Desalination and Water Purification Research and Development Program
EC	electrical conductivity
ECe	Electrical conductivity of a saturated soil extract
ETo	evapotranspiration
GOTR	Grants Officer Technical Representatives
ICP-MS	inductively coupled plasma mass spectroscopy
NMSU	New Mexico State University
NRC	Nuclear Regulatory Commission
Reclamation	Bureau of Reclamation
RO	reverse osmosis
SAR	sodium adsorption ratio
S&T	Science and Technology
TAMUK	Texas A&M University – Kingsville
TDN	total digestible nutrients
TDS	total dissolved solids
UA	University of Arizona
USFS	United States Forest Service
WEES	Water, Environmental, and Energy Solutions

Measurements

°C	degrees Celsius
°F	Fahrenheit ,
dS/m	deciSiemens per meter
g/L	grams per liter
kg/m^2	kilograms per square meter
m/yr	meters per year
mg/L	milligrams per liter
microS/cm	microSeimens per centimeter
MT/ha	metric tons per hectare
ppb	parts per billion
ppm	parts per million
µg/g	micrograms per gram

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Research Program

The research project, “Reverse Osmosis Concentrate Management through Halophyte Farming,” sponsored the Bureau of Reclamation’s (Reclamation) Desalination and Water Purification Research and Development Program (DWPR), builds upon the halophyte findings from the Marana project. This study includes two half- acre plots of halophytes irrigated with RO concentrate at the Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, New Mexico.

This project was designed to follow up on the results of a previous research program on the efficacy of growing halophytes for reverse osmosis (RO) concentrate management, conducted through Reclamation’s Science and Technology (S&T) program from 2006 through 2011 in Marana, Arizona (Holler 2010 and Yoklic et al. 2012).[1] Findings from these studies documented the technical feasibility and the environmental implications of using halophyte farming for RO concentrate management (Jordan et al. 2009 and Soliz et al. 2011) 3 and justified further investigation at the pilot scale.

This report contains the details of our project activities and results over the past two years and seven months, including the initial two-year pilot study, and the continuation funding. It is structured to report on Task deliverables for the 2013 - 2016 contract scopes. In the first year of the project, we focused on infrastructure planning and development in the BGNDRF agriculture area, and planting and establishing seedling through irrigation with RO concentrate of approximately 3,850 parts per million (ppm) total dissolved solids (TDS). In the second year and a portion of the third year, we implemented three irrigation regimes to bracket the expected evapotranspiration of 1,100 *Atriplex canescens* and *And Atriplex lentiformis* plants.

A summary of the primary experimental results is presented below.

[1] Reclamation’s Tucson Office, the University of Arizona, faculty from the Departments of Soil, Water and Environmental Science and Chemical and Environmental Engineering, the Northwest Water Partners (NWWP) (a consortium of water utilities in Northwest Tucson) and Tucson Water collaborated on this project.

Results

The soils at BGNDRF, located in the Tularosa Basin near White Sands National Monument, were formed from gypsiferous lake deposits and are naturally saline with and average soil Electrical Conductivity Extract (ECe) of 20 deciSiemens per meter (dS/m) (range: 3 - 43 dS/m) in the top 1.2 meters. The soils also contain 30 - 65% gypsum, calcite, plus dolomite minerals in the top 2.4 meters. The salinity of RO concentrate and local groundwater is composed of one-third gypsum plus dolomite and two-thirds Epsom plus table salts minerals. A significant portion of salt made up of slightly soluble gypsum and dolomite from the irrigation can precipitate in the soil matrix without changing the gypsic-dolomitic nature of the soil and the contributions of these two minerals to soil ECe (saturated paste) should be constant at about 3 dS/m. However, the remaining salts in the RO are more water-soluble and are expected to increase the soil water extract salinity ECe if no water drains below the root zone.

This study examined the viability of growing *Atriplex spp*. at the scale of an agricultural crop irrigated with RO concentrate, indicated the optimum irrigation rates for biomass production of *Atriplex canescens* and *Atriplex lentiformis*, and assessed the potential use of *Atriplex spp*. biomass in the animal feed industry.

Based on plant performance during the 20-month growing period of this pilot study, these plants indicate the potential to be viable agricultural crops in the Tularosa basin. A longer-term evaluation is needed to determine how *A. lentiformis* withstands temperature extremes of this region. Scaled-up production experiments can indicate the applicability of this treatment train to municipalities with existing or planned inland RO plants as well as brackish groundwater as a water source for future agricultural production and market potential. Future experiments will broaden the technology transfer applications of the research to include gardeners, farmers and agricultural-based communities with salt-effected groundwater as an irrigation source.

The study found that these halophyte plants, irrigated with RO concentrate, performed well through 20 months of age when they were last measured. Based on previous studies, *A. canescens*, native to the immediate Alamogordo, New Mexico site, was expected to perform well. However, in this study, *A. lentiformis*, while native to the southern portions of New Mexico (according to Granite Seed [2016], a commercial seed collection company), grew above its upper documented elevational range of 4,000 feet at Alamogordo's 4336 feet elevation. During this experiment, the low temperature recorded in Alamogordo was 14 degrees in December 2014, with the longest stretch at 12 nights below freezing in February 2016 (WeatherDB 2016). According to Colt Howland, a local rancher near Alamogordo, *A. canescens* on his ranch died back but recovered from temperatures below zero, based on extreme lows in the region during the winter of 2010/2011 (Howland 2016).

Salt bush *(Atriplex spp*.) can have a low energy concentration and high salt content, and thus does not fit well as a sole or major ingredient for livestock production in the United States. To evaluate using *A. canescens* and *A. lentiformis* biomass as a crop supplement in the animal feed industry, UA commissioned a detailed investigation under a subcontract agreement with Texas A&M – Kingsville (TAMUK), contributing to the evaluation by collecting crop harvest samples for chemical analysis. This study (McCuistion and Rivera 2016) evaluated the potential of *Atriplex spp*. for use as a commodity scale animal feed and forage crop supplement for the feed lot and dairy industries in the arid southwest (see Appendix 8). The literature review and the samples collected from halophyte farming in New Mexico show the potential for including *Atriplex spp*. in rations fed to feedlot and dairy cattle. A local rancher reported that his cattle rely on the *A. canescens* during the winter months when it is higher in protein than other vegetation. The next phase proposed for this study was to conduct trial feed studies, to quantify the benefits of including Atriplex spp. in cattle feed; also refer to 3.2 Additional Research Needed.

1. Introduction

Technic feasibility and costs for managing the inland reverse osmosis (RO) waste concentrate are barriers to desalination. Moreover, these concentrates can have impacts, including impacting local aquifers. Alternatives to manage these concentrates are needed. This study addresses reusing RO concentrate to irrigate halophytes (salt tolerant crops) to produce an agricultural crop.

This project was designed to build upon results of a previous research program on the efficacy of growing halophytes for reverse osmosis (RO) concentrate management, conducted through Reclamation's Science and Technology (S&T) program from 2006 through 2011 ($1.25 million program with a 3 to 1 match of USBR investment)[2] in Marana, Arizona. In this previous research program, *A. lentiformis* test plots were planted in September 2006 and monitored until October 2009.

Findings from these studies documented the technical feasibility and the environmental implications of using halophyte farming for RO concentrate management (Jordan et al. 2009 and Soliz et al. 2011) and justified further investigation at the pilot scale. These results included:

- Concentrate use was equal to that of a traditional evaporation pond per unit area
- Plant productivity was similar to conventional forage crops per unit area
- Soil salinity can be managed to maintain plant productivity while salt transport below the plants' root zone was minimized.

This pilot research program, "Reverse Osmosis Concentrate Management through Halophyte Farming," sponsored by Reclamation's Desalination and Water Purification Program (DWPR) was designed to:

- Develop field infrastructure planning and installation
- Propagate halophyte plants from seed
- Plant and establish seedlings

[2] Tucson Office, the University of Arizona, faculty from the Departments of Soil, Water and Environmental Science and Chemical and Environmental Engineering, the Northwest Water Partners (NWWP) (a consortium of water utilities in Northwest Tucson) and Tucson Water, collaborated on this project.

- Conduct irrigation experiment with RO concentrate
- Collect data on growth, tissue analysis, survival percentage, and wet and dry weights of plants when harvested
- Assess the potential use of biomass in the animal feed industry.

The project used the Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, New Mexico.

This report summarizes activities and outcomes related to the tasks in the current USBR/DECESU contract associated with the long-term research agenda (Figure 1). Tasks 1 - 4 focus on project planning, infrastructure design and installation, including collaboration with BGNDRF; Tasks 5 - 8 focus on data collection and analysis; and Task 9 includes project reporting, publications and public outreach. Note that the schedule does not include R13AC80023, which extended the schedule for six additional months for final data gathering, analysis and reporting.

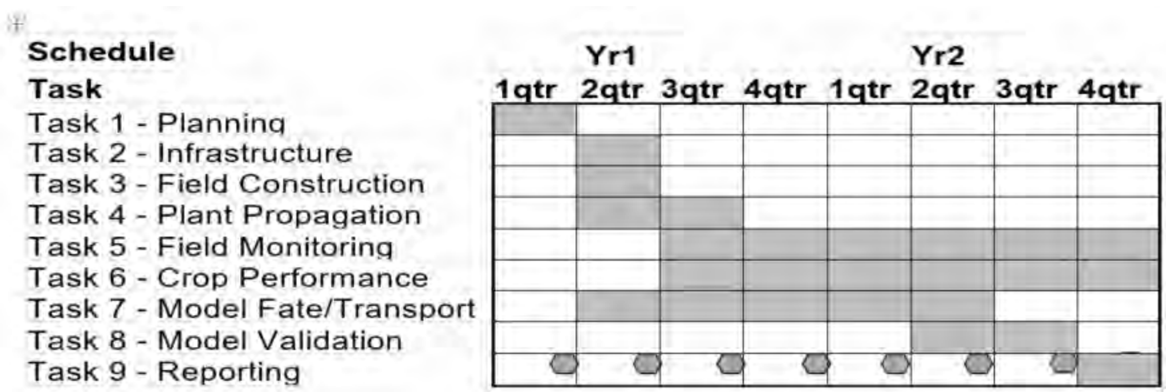


Figure 1.—Original Pilot Project Schedule

Task 1 – Planning. Plan the infrastructure BGNDRF to support a short-term and long-term research program.

Task 2 – Infrastructure. Construct a concentrate irrigation delivery system at the BGNDRF agriculture field site.

Task 3 – Field construction. Prepare the agriculture field and install research infrastructure.

Task 4 – Plant propagation. Propagate the *Atriplex lentiformis* and *Atriplex canescens* seedlings for field planting in a greenhouse.

Task 5 – Field monitoring. Plant and record data. Includes system maintenance, automated irrigation system, and data acquisition with the Data Acquisition and

Intelligent Control system (DAIC) and manual with neutron probe from soil moisture and validation of sensors, and field performance measures.

Task 6 – Crop performance. Monitor and analyze crop performance. Includes field production monitoring, nutrient content analysis, and evaluation of potential for use as a commodity crop supplement for dairy and feed lot industry and for landscape restoration and revegetation.

Task 7 – Model fate and transport. Develop and use a mass balance model addressing the fate and transport of all components applied to the field.

Task 8 – Model validation. Revise and refine the mass balance, fate/transport model based on research plot monitoring data.

Task 9 – Reporting. Includes quarterly and final reports, publication of results in peer reviewed journals and presentation of findings at technical and scientific meetings.

2. Contract Task Reports

2.1. Task 1 - Planning

Task 1 – Work with Bureau and BGNDRF management on field infrastructure planning that will support short and long-term research programs. Determine scale of initial research field site based on concentrate availability, near term research objectives and long-term goals. Use this to develop a plan and infrastructure design documents for the initial research project that can be easily expanded to support ongoing agriculture research goals.

2.1.1. Experiment Planning and Design

Martin Yoklic, Joanne Gallaher, and Bob Seaman (University of Arizona [UA]) travelled to BGNDRF in September 2013 and met with Randy Shaw, Steve Holland, and Bobby Granados for a project start-up meeting to kick off the project planning and facilitate a collaborative design for the agricultural area infrastructure and UA plots at BGNDRF. The group produced a conceptual layout of the UA field research and infrastructure in the designated BGNDRF Agricultural Area. The field layout included two half-acre plots with a subsurface drainage system (as required by the New Mexico Environment Department).

This experiment evaluates wild, native plants (*Atriplex spp*.) with potential as a new agricultural crop that could be produced using high salinity irrigation water and marketed as a supplement to the animal feed industry. The genus of *Atriplex* includes over 250 species (Olvera 2003) with halophytes found in continental interiors with saline and alkaline soils comprising the largest proportion of species (Osmond et al. 1980). Figure 2 shows the two varieties of *Atriplex spp.* used in the project.

A. lentiformis

A. canescens

Figure 2.—Salt bushes used in the project.

The project was initially proposed to be in Yuma, Arizona (elevation 141 feet) to expand on the success of the previous halophyte research in Marana, Arizona, using A. lentiformis. The project location was shifted to BGNDRF at Alamogordo, New Mexico (elevation 4,336 feet) which is higher in elevation than the reported natural distribution of A. lentiformis, which ranges from sea level to 4,000 feet (Meyer 2005 and Granite Seed 2016).

A. canescens was added to the experiment in case *A. lentiformis* did not perform well or survive the winter temperatures at the higher elevation in Alamogordo. *A. canescens* is a hardy, tap-rooted desert shrub that reaches over 10 feet tall (Barrow 1992) and has the largest distribution of all native woody plants in North America (Stutz 1979, Mozingo 1987, and Kartesz 1998). *A. canescens* also demonstrates extensive variation and hybridization among varieties, which can sometimes only be distinguished through chromosome analysis (Sanderson and Stutz 2001). The life span of individual *A. canescens* shrubs have been documented at over 100 years (Bowers 1995).

A. lentiformis occurs in riparian zones as well as desert scrub and grasslands (Meyer 2005). While *A. canescens* is the predominant range shrub in the Alamogordo area and is growing in undisturbed areas at BGNDRF, the United States Forest Service (USFS) plant database does not currently list *A. lentiformis* as being native to New Mexico (Meyer 2005). Granite Seed (2016), a commercial seed collection and supply company specializing in native plant seed collection in the western US, does show *A. lentiformis* growing across the central/southwestern portions of New Mexico, as well as in portions of California, Nevada, Utah, Arizona and Texas, from sea level to 4,000 feet.

Granite Seed (2016) describes *A. lentiformis* as the tallest of *Atriplex spp.*, growing up to 10 feet tall. The USFS describes its size as up to 11.5 feet tall and 24.5 feet wide (USDA 2004). Both *A. lentiformis* and *A. canescens* are C4 xerohalophytic shrubs—desert species of salt tolerant plants—and are important forage and rangeland shrubs in the southwestern United States (Watson and O'Leary 1993, Glenn and Brown 1998, Howard 2003, and Meyer 2005). *A. lentiformis* is considered an extreme halophyte, found on soils with 3 to 4% soluble salts in the top foot of soil (30,000 to 40,000 ppm TDS) (Osmond et al. 1980).

After considering the irrigation concentrate options of nanofiltration, reverse osmosis and/or using direct brackish well water, UA selected the option of using RO concentrate (estimated at 4,063 ppm TDS) produced with a blend of well 1 and 2 groundwater to be used on both plots. This decision was based on the water chemistry analysis including total TDS, the desire to demonstrate the use of RO concentrate in halophyte farming, and the ability to back up the system with a well water blend with similar TDS if needed, as two back-up irrigation sources are available at the site if the RO system were temporarily off line.

The UA project team developed the final research protocol for the field layout, which included the two *Atriplex* species irrigated with RO concentrate at three irrigation rates (see Figure 3).

Experimental design and irrigation regime

Seedlings were planted 3' on center (OC), to be thinned to 6' OC after 18 - 24 months
Irrigation applications were adjusted according to monthly ET rates as well as plant growth requirements from seedling establishment to maturity (refer to model)

Plant Species	Irrigation Treatment	Irrigation mg/L TDS	Dependent Variables
A. canescens	0.4 ETo	3800 - 4200	Plant yield; nutritional value of biomass; NaCl uptake in plant tissue; soil moisture profiles; drainage
A. canescens	0.8 ETo	"	"
A. canescens	1.2 ETo	"	"
A. lentiformis	0.4 ETo	"	"
A. lentiformis	0.8 ETo	"	"
A. lentiformis	1.2 ETo	"	"

Figure 3.—Experimental design and irrigation treatments.

2.1.2. Drainage System Design and Installation

The UA collaborated with BGNDRF on the design and installation of the required subsurface drainage system. UA completed the subsurface drainage system plans and details (see Appendix 1, Sheet 4), purchased six 4-feet diameter x 7-feet long culvert pipes for the drainage monitoring stations, the 4-inch drain pipe and gravel backfill, and assisted with the trencher rental costs.

BGNDRF completed the site grading, roadwork, electrical and plumbing, and installed the subsurface drainage system, including the drainage monitoring stations. UA installed the drainage collection buckets (Figure 4).

Figure 4.—UA drilling port access holes for monthly neutron probe measurements.

BGNDRF provided as-built dimensions of the Agriculture Area infrastructure, including underground utilities, access roads and berms, which the UA incorporated in an AutoCAD as-built plan. During the subsurface drainage trenching process, a buried debris field was discovered on Plot 1B and extending into the west side of Plot 2B. As a result, the UA research plots were shifted to Plots 2A and 2B. BGNDRF supplied an outline of the debris field (see Appendix 1, Sheet 2).

2.1.3. Operations and Maintenance

UA installed drainage collection buckets connected to the subsurface drains as part of the drainage monitoring stations. After sub-surface drainage installation, periodic field maintenance was required to refill and retamp fissure openings in the backfilled trench areas after discovering preferential drainage near trenched areas.

2.1.4. Data Collection and Analysis

Bob Seaman (UA) tested and recorded the drainage water electroconductivity (EC) during his monthly visits. Water occasionally drained into the collection buckets during storm events. Test results of the collected drainage water indicates that this water was not irrigation water that saturated the soil to reach the drainage pipes. Rather, the system collected some preferential drainage of rain water due to fissures in backfilled trenches on the site. The only exception was a higher EC of drainage water that reflected an irrigation leak near a soil fissure due to trenching and backfilling near the soil sensors.

2.2. Task 2 - Infrastructure

Task 2 – BGNDRF agriculture field site infrastructure Concentrate Irrigation Delivery System construction (power, water supply, filtration, storage, and control system) including interface with initial field research system requirement and Data Acquisition and Intelligent Control system (DAIC).

2.2.1. Design and Installation

BGNDRF installed two 5,000-gallon water tanks to store RO concentrate on the UA project and completed installation of the power, water supply, pressure tanks, pumps, filtration, storage, and control systems. BGNDRF also installed the DAIC shed, shipped from Tucson, near the tanks. Bob Seaman installed the grounding system on the DAIC shed and surge protection for the electrical supply to the UA plots.

2.2.2. Operations and Maintenance

The Concentrate Irrigation Delivery System infrastructure became operational in September 2015 in conjunction with the planting operations. The system performed well overall; however, there were some initial system failures as well as later leaks in the irrigation lines (see Task 5) that together resulted in some irregularities in irrigation applications over the two plots.

During the second week of operation, the tanks were emptied and the pump in the DAIC shed continued running for a time before BGNDRF staff discovered the problem. No harm was done to the pump motor, and the plants were not damaged, as the soil remained moist at the plants' root zones.

UA/BGNDRF collaborated on steps taken to avoid repeating this situation, including regular updates from UA to BGNDRF regarding adjustments in the irrigation rates. BGNDRF installed external gauges and viewing windows on the two 5,000-gallon tanks to enable a visual check of the water levels. UA, with assistance from BGNDRF and a field assistant, began more frequent monitoring of the flow meters on the drip irrigation system. These measurements were compared with the tank amounts to determine accuracy and to help detect leaks in the system.

In November 2014, BGNDRF staff discovered that a previous, slow leak inside the DAIC shed was worsening, and UA contracted with a local plumber for the repair. A second minor leak at the pump housing (also in the DAIC shed) appeared to have self-sealed.

2.3. Task 3 - Field Construction

Task 3 – Agriculture field preparation, installation of research infrastructure including data acquisition ports, irrigation sub systems and DAIC monitoring and control interface.

2.3.1. Design and Installation

UA developed the initial data acquisition protocol and prepared a plan for 68 Acclima SDI-12 Soil Moisture Transducers sensors, sensor wiring, and neutron probe data access port locations. In consultation with New Mexico State University (NMSU), UA also determined the need for a soil infiltration test, to be conducted by NMSU (subconsultant on the project).

UA conducted lab tests on the TDR Sensors (Acclima SDI-12 Soil Moisture Transducers) including connecting them to the Campbell Scientific Data logger; monitoring their measurements and data transmission; and programming, addressing, and labeling the 68 sensors. The sensors were then installed in the field following the Data Port Layout Plan, which included eight port holes (12 inches wide by 5 feet deep) per half-acre plot, plus one additional port hole at the edge of Plot 2B. Each port hole had four sensors buried at 1-foot vertical increments. Wiring for the sensors was connected in junction boxes and then buried in trenches to the DAIC shed, where they were hooked up to the Data logger. The sensors were hard wired to the data logger and multiplexer, which were initially located in the DAIC shed. After troubleshooting and identifying irregularities with the sensor data, the initial data logger was relocated to the south plot and a second data logger was installed in the north plot. The sensors began downloading data to the data loggers upon completing the final reconfigurations in April 2015.

UA drilled a total of 38 neutron probe port holes on Plots 2A and 2B per the data port layout plan, plus two additional off-site control holes located near sites of earlier soil testing at Trenches 2 and 8 for a total of 40 port holes (see Appendix 1, As-Built Plans, Sheet 6). The two control holes were not influenced by irrigation. Additional soil was collected during the drilling process at the two perimeter holes for future soil sampling as needed. The data collected from these sites was used in calibrating the neutron probe readings to the site soil at BGNDRF (see Task 8).

Jeff Sandstrom conducted a neutron probe use and transport training session for Joanne Gallaher, Bob Seaman, and Ryan Furcini at UA during the summer of 2015 (Figure 5). David Schoep, Radiation Safety Officer, NMSU, conducted a second Neutron Probe safety training session at BGNDRF in December 2015. BGNDRF personnel (Randy Smith, Steve Holland, Bobby Granados, and Dan Lucero) and UA personnel (Joanne Gallaher and Bob Seaman) attended the training and received completed training certificates. After the safety training, Bob Seaman, UA Research Technician, conducted the field use portion of the training at the UA plots.

Figure 5.— Neutron probe training.

Due to the high fees associated with the out-of-state use of the UA neutron probe at BGNDRF, the UA probe license was transferred from Dr. Ed Glenn (UA) to Dr. Manoj Shukla (NMSU) under a reciprocity agreement. Under this agreement, the probe was stored at BGNDRF for use on the project. The reciprocity agreement was facilitated by Jeff Sandstrom, UA Radiation Safety Technician, Dave Schoep, Radiation Safety Manager, NMSU and Randy Shaw, BGNDRF. This initial BGNDRF use/storage agreement was approved by the Nuclear Regulatory Commission (NRC) in August 2014 and the permanent license was issued December 2015. The NRC license was obtained by NMSU because the BGNDRF is a Bureau of Reclamation facility which is under exclusive Federal jurisdiction. NMSU now holds the NRC Radioactive Material License (License # 30-35283-01) to allow for the unlimited use and storage of the CPN 503DR Soil Moisture gauge at BGNDRF. The NRC Material License expires December 2025.

2.3.2. Data Collection and Analysis

UA contracted with Amir Gonzalez, a Post Doctoral student working under Dr. Manoj Shukla (NMSU), to conduct a series of soil infiltrometer tests on the UA plots. The first series of tests were conducted in August and September 2014, prior to planting and irrigation, so that changes in infiltration can be monitored over time. (See Appendix 1, Sheet 8 and Appendix 2).

UA recorded the initial set of neutron probe readings prior to initiating irrigation as a control to show changes in measurements after irrigation is initiated. Monthly neutron probe readings were collected from September 2014 through April 2015 with the exception of one month when the probe was down due to maintenance, and one month when the probe had to be transported to Las Cruces, New Mexico, due to licensing restrictions.

UA conducted laboratory experiments at UA to corroborate sensor readings with soil tests from the plots. These experiments indicate that the soil salinity measurements accurately reflect the application of concentrate, as long as the soil remains wet. Also, soil temperature and moisture readings are accurate in all soil conditions.

See Task 8 for additional soil test results as well as soil sensor and neutron probe data collection and analysis.

2.4. Task 4 - Plant Propagation

Task 4 – Greenhouse propagation of *Atriplex lentiformis* and *Atriplex canescens* seedlings for field planting. The initial estimate of seedlings needed was 1,200 - 1,600 (based on 20 rows of 60 plants each per acre).

2.4.1. Seedling Selection and Growth

Two species of Atriplex, *A. lentiformis* and *A. canescens*, were selected for this study (see Task 1). The UA contracted with Dr. Daniel Manuchia, a grower in Las Cruces, New Mexico, experienced in seed collection and production of *Atriplex spp*. for the New Mexico Department of Transportation, to grow 1,600 seedlings (800 each of *Atriplex canescens* and *Atriplex lentiformis*). The UA team initially collected *A. canescens* seed from sources in Tularosa, north of Alamogordo, and near the White Sands National Monument west of Alamogordo.

Because the elevation at BGNDRF (4300 feet) is higher than the normal range of *A. lentiformis*, the UA contacted the NCRS plant Material Center in Tucson to see if seeds collected from wild plants at the upper range of the plant were available. Consequently, seed for *A. lentiformis* was donated to the project through "Seeds of Success," a multi-agency partnership administered by the Bureau of Land Management. Through this donation, *A. lentiformis* seed from the Carson City, Nevada, collection team was shipped from the USFS, Bend Seed Extractory in Bend, Oregon for use on the project. The seed was collected from stands of *A. lentiformis* growing at the higher elevations of its natural range.

Germination of the *A. lentiformis* (the cleaned seed was processed by the USFS Bend Seed Extractory) was very successful; however, germination of the *A. canescens* collected by the UA in New Mexico was poor. In total, the grower had 1,190 *A. lentiformis* seedlings and 84 *A. canescens* seedlings. Due to the poor germination results of the *A. canescens,* the grower collected and grew additional *A. canescens* from the West Mesa Sand Dune near Las Cruces (500 seedlings); Jornada Range (20 seedlings); and brackish salt flat east of El Paso (50 seedlings).

The total number of seedlings needed for the project was reduced to 1, to accommodate aisle widths and the final layout of the irrigation and subsurface drainage systems. Due to an error in protocol in the grower's greenhouse (related to a medical emergency), a portion of the *A. lentiformis* seedlings grown for the project were lost. Fortunately, the grower had enough replacement *A. lentiformis* and extra *A. canescens* to fulfill the total planting goal. However, the *A. canescens* from the miscellaneous seed sources were planted in the *A. lentiformis* rows due to the shortage of *A. lentiformis.*

2.4.2. Replacement

In Spring 2014, 148 *A. lentiformis* and 102 *A. canescens* were used to replace those lost over winter (see Task 5). The grower provided these replacement seedlings, as well as additional seedlings for the UA *Atriplex spp*. greenhouse experiment (see Task 8). The grower also maintained about 400 *A. lentiformis* seedlings left over after the replacement planting for later use on the project.

2.5. Task 5 - Field Monitoring

Task 5 – Planting, system maintenance, automated irrigation system, and data acquisition with DAIC and manual with neutron probe from soil moisture and validation of sensors, and field performance measures.

This section addresses the automated irrigation system, planting and associated field performance measures; data acquisition associated with the neutron probe and soil sensors are addressed in Task 8.

2.5.1. Irrigation and Planting Installation, Operations and Maintenance

2.5.1.1. Irrigation System Installation

2.5.1.1.1. Evapotranspiration (ET) Analysis and Irrigation Settings

Ed Glenn (UA) used the Blaney-Criddle equation process to determine the evapotranspiration rate for Alamogordo, New Mexico, used on this project. The Blaney-Criddle formula was originally developed based on air temperature, soil moisture and humidity of farmers' crops in the Roswell-Artesia area of New Mexico (Blaney et al. 1942, Blaney et al. 1950, and Sammis et al. 2011). The formula has been revised over time (Sammis et al. 2011) but continues to rely on weather data to predict the evapotranspiration of a reference crop (usually grass or alfalfa) (Glenn, personal communication, March 2016).

The average annual temperature in Alamogordo, New Mexico is 62.6 degrees Fahrenheit (°F), with the average winter temperature at 49.2 °F and the average summer temperature at 77.8 °F. The highest seasonal precipitation in New Mexico occurs during the summer months following the monsoon pattern of the southwestern US (Guido 2013) (see Appendix 3). The average annual precipitation in Alamogordo, New Mexico is 11.52 inches. Figure 6 shows the average monthly temperatures and Figure 7 shows the monthly precipitation in Alamogordo during the study period (WeatherDB 2016).

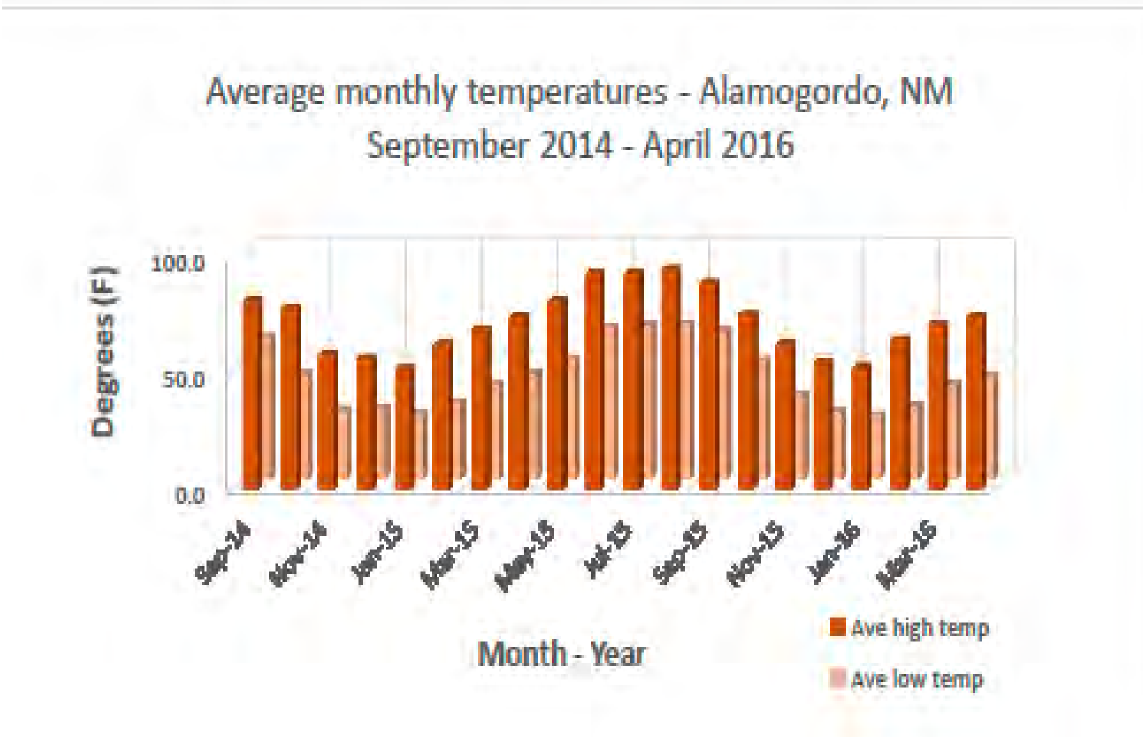


Figure 6.—Alamogordo, New Mexico, average monthly temperatures during the study period (September 2014 - April 2016).

Figure 7.—Alamogordo, New Mexico, average monthly precipitation during the study period (September 2014 – April 2016).

The actual precipitation for 2015 was 14.6 inches, which is around 3 inches over the average annual precipitation (WeatherDB 2016).

Table 1 provides a chart with the Alamogordo reference evapotranspiration (ETo) calculated by Dr. Glenn using the Blaney-Criddle method.

The irrigation treatments in this experiment were designed to deliver 0.4, 0.8 and 1.2 times the reference evapotranspiration (ETo) on a regular basis, and are referred to as 0.4ET, 0.8 ET and 1.2 ET.

Table 1. Almagordo Reference Evapotranspiration

Month	Max 0C	Min 0C	PPT	PPT	Mean 0C	Mean daily %	Eto	Eto	1.0ETo	1.2ETo	0.80ETo	1.0ETo
			(mm/day)	(mm/mo)		Ann Daylt Hrs.	(mm/day)	(mm/mo	(lt/m^2/day)	(lt/m^2/d	(lt/m^2/d	(m^3/m^2/mo)
1	13.67	-1.50	0.57	17.53	6.08	0.24	2.54	78.67	2.54	3.05	2.03	0.08
2	16.28	0.61	0.43	12.16	8.44	0.25	2.97	83.19	2.97	3.57	2.38	0.08
3	20.00	3.56	0.40	12.45	11.78	0.27	3.62	112.31	3.62	4.35	2.90	0.11
4	25.06	7.61	0.31	9.35	16.33	0.29	4.50	134.97	4.50	5.40	3.60	0.14
5	30.17	12.33	0.43	13.21	21.25	0.31	5.51	170.82	5.51	6.61	4.41	0.17
6	34.94	17.22	0.70	20.90	26.08	0.32	6.40	191.99	6.40	7.68	5.12	0.19
7	34.72	19.00	1.57	48.53	26.86	0.32	6.41	198.78	6.41	7.69	5.13	0.20
8	33.33	18.11	1.66	51.33	25.72	0.30	5.95	184.44	5.95	7.14	4.76	0.18
9	30.50	14.67	1.28	38.36	22.58	0.28	5.15	154.46	5.15	6.18	4.12	0.15
10	25.11	8.56	0.91	28.20	16.83	0.26	4.01	124.45	4.01	4.82	3.21	0.12
11	18.50	2.17	0.47	14.02	10.33	0.24	3.00	89.91	3.00	3.60	2.40	0.09
12	13.89	-1.61	0.90	27.95	6.14	0.23	2.44	75.50	2.44	2.92	1.95	0.08
Mean annual	24.68	8.39	0.80	24.50	16.50	0.27	4.38	133.29	4.37	5.25	3.50	0.13
Annual total			292.00	294.00				1,599.00	1,597.00	1,916.00	1,277.00	1.60
											liters/y	m^3/m^2/yr
Total A-S	1.035	m^3/m^2/A - S										

2.5.1.1.2. Irrigation Model

UA developed an irrigation model used to calculate the irrigation settings for the three irrigation treatments and to develop total RO concentrate projections throughout the project (Bresdin 2015). The model uses an interactive calculator to predict irrigation requirements based on user inputs. Figure 8 shows an example of the irrigation model output for May, indicating the irrigation applications for the three ETo rates (see Appendix 4 - Irrigation Model).

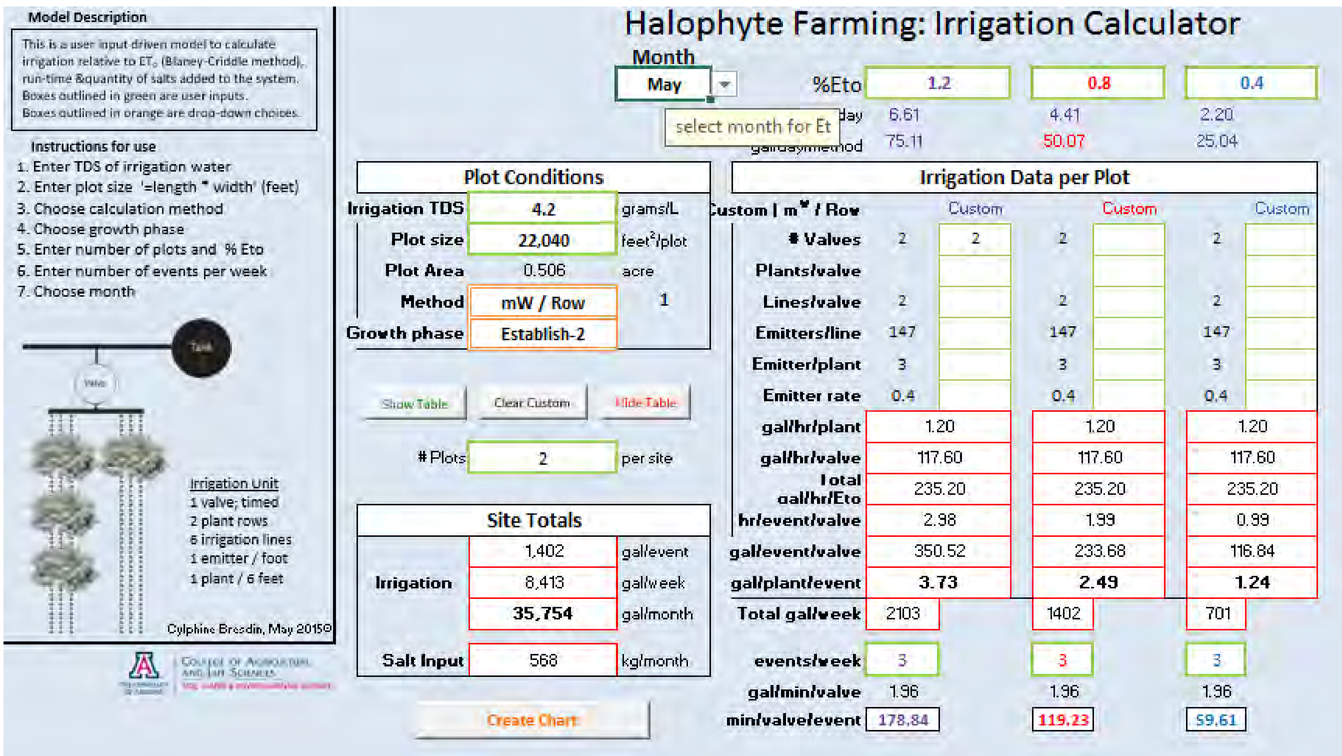


Figure 8.—Example of irrigation model output for May.

The irrigation model was used to calculate both actual irrigation applied and projected irrigation to estimate the amount of concentrate needed as the plants increased in size (Figure 9).

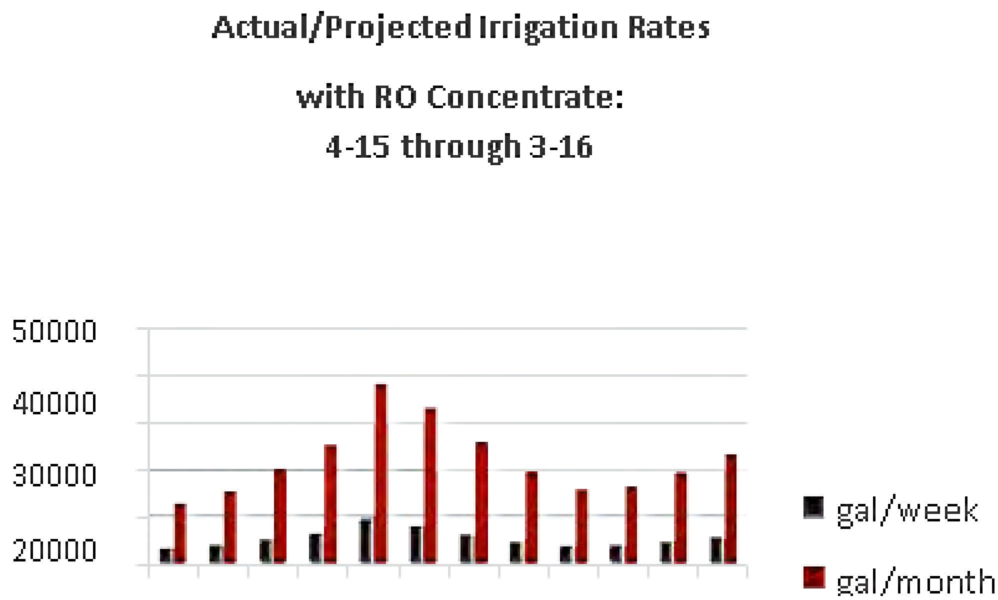


Figure 9.—Actual and projected irrigation rates from April 2015 to March 2016: actual rates are shown for April and May 2015; projected rates are shown for June 2015 – March 2016.

2.5.1.2. Irrigation Field Installation

UA designed the planting and irrigation system based on conceptual plans produced at the 2013 BGNDRF meeting, and prepared final bid documents. (See Appendix 1.) Based on previous problems with drip emitter plugging in the Marana study, drip tape was selected for the irrigation system. Through consultation with a regional agricultural irrigation specialist, an agricultural grade drip tape with non-pressure compensating emitters was selected for the project, to demonstrate typical agricultural crop irrigation systems in the southwestern United States. The Streamline drip tape, manufactured by Netafim USA, was installed on grade to facilitate monitoring and replacing sections of tape damaged by equipment, animals or plugging.

After holding a mandatory Pre-Bid meeting at BGNDRF in April 2014, UA received bids in May. The planting and irrigation installation was awarded to High Desert Native Plants for $17,400. The project schedule was revised to reflect an approximate 3-week delay due to a shortage of bidders and contract negotiation, which moved the planting to September 2014. The irrigation system was installed and tested in September 2014 before planting.

During irrigation installation, additional scattered and buried household debris was encountered at various locations on the two plots (2A and 2B). Although both plots drained from the northeast to the southwest, the field conditions also included uneven grades with various low spots resulting in the periodic pooling of irrigation water and precipitation.

2.5.1.3. Irrigation Operations and Maintenance

The irrigation was initially set based on the seedling establishment. After initially watering two days per week, UA adjusted the irrigation system to one day per week as the temperatures decreased and plant growth slowed during the winter months. Irrigation was turned off intermittently during periods of rain. The seedlings adjusted to the BGNDRF soil and RO concentrate and began to put on new growth shortly after planting. Following an establishment period for the replanted seedlings, UA adjusted the monthly irrigation rates according to the ET values. See Appendix 17.

UA installed a wireless range extender module in the DAIC so that the irrigation controller system could be programmed, accessed, and monitored remotely, using the BGNDRF wireless system. However, the original irrigation controllers periodically failed because of a weak wireless signal at the DAIC shed. UA replaced these controllers with manually-controlled units that had been tested on previous research projects. These controllers do not offer the remote reading/adjustment ability of the previous models, but they operated continually throughout the remainder of the project.

During the winter 2014 mortality inventory for replacement, UA identified the primary causes of mortality as:

- Problems with one valve at the start of irrigation (serving 2 rows of *A. lentiformis*)

- Some seedling planting issues in the North field (which was documented and brought to the attention of the contractor)

- Rabbit damage – more prominent in the North field; and normal winter seedling mortality.

A leak detection/response protocol was developed and tested prior to ramping up the irrigation system in the spring of 2015. UA, with assistance from a field assistant, recorded weekly water meter readings which were initially used to help identify irrigation leaks. Later in the project, the field assistant began conducting a weekly 10-minute/line leak test to make more timely repairs.

During spring of 2015, additional drip tape leaks required regular maintenance. It appeared that the leaks were related to damage by rabbits observed on the two plots. After unsuccessful attempts to catch rabbits with a live animal trap, UA contracted with High Desert Native Plants to install a rabbit-proof fence around the UA plots, using partially buried silt fence material. Follow up fence maintenance was required, as high winds at BGNDRF (as well as a microburst storm) resulted in broken wood fence posts. Both BGNDRF and UA personnel provided temporary repairs until the fence contractor was able to reinforce the original wood fence posts with steel posts.

Higher than average seasonal precipitation resulted in significant weed growth on the UA plots. In June 2015, UA hired a local landscape maintenance contractor for weed removal on the two plots. UA also replaced all the patched Streamline drip tape with new drip tape during the weeding process. Over the summer of 2015, additional pin point drip tape leaks appeared to be caused by insects and UV damage; these leaks tapered off during the fall and winter of 2015. The Streamline drip tape was replaced with Netafim Uniram Heavywall drip line, with pressure-compensating emitters, in May 2016.

These irrigation leaks over the course of the project on the two plots resulted in variations in the overall irrigation water applied. Additionally, the uneven grade over the two plots combined with the non-pressure compensating irrigation emitters resulted in varied amounts of irrigation applied within the row pairs, including some water ponding in low spots.

2.5.2. Planting

2.5.2.1. Experimental Field Plants

A total of 1,117 seedlings were planted in September 2014 with 494 *A. lentiformis* and 623 *A. canescens* planted. In April 2015, we completed the replacement of 225 plants: 148 *A. lentiformis* and 102 *A. canescens*. Some plants that were previously included in the mortality count produced new shoots during late March/early April, reducing our overall winter mortality to approximately 20 percent. Irrigation was adjusted according to the ETo settings after seedling establishment. See Appendix 1 for as-built plans.

The *A. canescens* seedlings were grown from seed collected from various sources by Dr. Manuchia in his greenhouse operation in Las Cruces, New Mexico (see Task 4). Most of the *A. canescens* seedlings (484 out of 623) planted in September 2014 were grown from seed collected near Las Cruces by Dr. Manuchia, with the source described as “West Mesa Sand Dunes.” Other *A. canescens* seed was collected by Dr. Gallaher and Dr. Manuchia from sites near Tularosa, White Sands National Monument, El Paso, and the Jornada range resulting in 139 seedlings. These 139 seedlings were planted in specific rows so that they could be monitored separately from the other *A. canescens.*

Dr. Glenn, UA, identified the *A. canescens* seedlings as *Atriplex canescens* var. occidentalis, with the exception of a handful of seedlings identified as *A. polycarpa*, another common variety of *Atriplex* in the desert southwest. The native *A. canescens* growing at BGNDRF were also identified *Atriplex canescens* var. occidentalis.

During the summer of 2015, UA began observing that plants in the *A. lentiformis* rows at BGNDRF were varying in height, growth habit and overall appearance. We began taking plant cuttings to Dr. Glenn, our team’s halophyte specialist, for positive plant species identification. After the plants seeded, Dr. Glenn was able to examine complete, fully seeded shrub specimens from BGNDRF along with the side-by-side photos of the plants in the field (Figure 10). By early October, the seeding samples developed to the extent that Dr. Glenn was able to identify a difference in the seed cover of the plants under a scope. He identified the other species as *Atriplex argentea.*

Figure 10.—*A. argentea* (left and foreground) and *A. lentiformis* (right, from second row)

Both *A. argentea* and *A. lentiformis* have triangular leaves and small, flat seeds. The original seed was provided to us in two containers by the USDA Seed Bank, hand collected at higher elevation areas of native *A. lentiformis*. The fruits were harvested from the wild, and apparently the harvesters picked and mixed seeds from the two species, which can grow together, in one of the two provided seed containers. During the summer of 2015, the *A. argentea* plants stopped growing at about 80 centimeters tall, then produced lots of seeds, (as it grows as an annual/perennial) whereas the authentic *A. lentiformis* kept growing into a much larger plant. While the fruits are different, it took examination through a lens to tell them apart.

Since *A. argentea* is categorized as an annual/perennial and is not suitable for our long-term study, UA made the decision to replace the plants, and they were likely already beginning to die. The grower, Dr. Manuchia, had 400 additional *A. lentiformis* seedlings that were left over from the earlier replacement plantings and were available for use on the project. The *A. argentea* plants were removed and replaced with *A. lentiformis* seedlings in October and November 2016. At this time, the miscellaneous *A. canescens* previously planted in the *A. lentiformis* rows were also replaced with *A. lentiformis* seedlings. As of November 2015, the *A. lentiformis* rows contain only *A. lentiformis* with the exception of a few *A. argentea* that were left in place for observation, located at the end of plant rows where they would eventually have been removed due to thinning.

Because of the large number of replacements made in the *A. lentiformis* rows, UA began tracking the ages of the individual *A. lentiformis* plants for data analysis purposes. These plants are identified in three age groups as of April 2016:

- 19-month-old plants from the original planting (September 2014 - April 2016)

- 12-month-old plants from the winter mortality replacement (April 2015 - April 2016)

- 6-month-old plants from replacing *A. argentea* and miscellaneous *A. canescens* (October/November 2015 - April 2016.

The final biomass measurements were collected in May 2016 when the harvested plants were 20 months old. The *A. canescens* plants replaced in April 2015 due to winter mortality were not individually tracked. (See As-Built Planting Age Chart, Appendix 6).

2.5.2.2. Control Plants

The purpose of the control plants is to provide growth measurements and nutrient analysis of non-irrigated plants as compared to RO-irrigated plants, as negative controls for the irrigation. The comparison of irrigated versus non-irrigated plants during experimental analysis is one result that will indicate how *Atriplex spp*. respond to RO-irrigation in the native soil and atmospheric conditions at BGNDRF. Eight *A. canescens* and eight *A lentiformis* seedlings were planted in April 2015 outside of the perimeter rabbit fence enclosure of each plot as control plants. These plants were hand watered as needed to attain successful establishment. They were then weaned from supplemental watering during summer 2015 precipitation.

2.5.2.3. Photos of Plant Growth and Field Conditions Over Time

Figure 11 through Figure 14 are photos of the plants at BGNDRF over time. Appendix 19 for additional plant photos.

Figure 11.—Plants planted in September 2014.

Figure 12.—Seedlings at north UA plot, June 2015.

Figure 13.—Plants on the north plot looking south – April 2016.

Figure 14.—Plants on the north plot looking northeast – April 2016.

2.5.2.4. Irrigation and Plant Data Acquisition/Analysis

2.5.2.4.1. Water Meter Readings – Based on 3 ET Treatments

Irrigation began at the time of planting. The south field planting was completed on September 17, 2014; the north field planting was delayed until September 24 due to rain. Figure 15 is a chart showing the total irrigation applied to each row-pair of plants by Valve in both the North and South fields. The Expected Gallons value is based on the gallons per minute and number of minutes set at the controller. Meter Value indicates the actual amount measured by the flow meters at each valve.

Total irrigation applied 9/15/14 through 4/21/16							
	North Plot						
Valve	**1**	**2**	**3**	**4**	**5**	**6**	Total
IrrigationTreatment	**1.2**	**0.8**	**1.2**	**0.8**	**0.4**	**1.2**	Gallons
Expected Gallons	53466	40635	53466	40635	27833	53466	269502
Meter Value	45891	30832	43655	33668	19467	47131	220644
in Cubic Meters	173.717	116.713	165.252	127.445	73.691	178.410	835.229
Total Salt kgs	667	448	635	490	283	685	3208
				Total irrigation on North plot in Acre-feet			**0.68**
	South Plot						
Valve	**1**	**2**	**3**	**4**	**5**	**6**	Total
Treatment	**0.4**	**0.4**	**1.2**	**0.8**	**0.8**	**0.4**	Gallons
Expected Gallons	27833	27833	53466	40635	40635	27833	218236
Meter Value	18527	15737	40780	30279	28405	18564	152292
in Cubic Meters	70.132	59.572	154.370	114.618	107.526	70.272	576.490
Total Salt kgs	269	229	593	440	413	270	2214
				Total irrigation on South plot in Acre-feet			**0.47**
				Total field irrigation in Acre-feet			**1.14**
				Total salt applied in Kgs			**5423**

Figure 15.—Total irrigation per valve.

The actual irrigation amount applied was lower than the expected value due to several factors, such as initial controller problems due to a poor wireless signal in the field (these controllers were replaced), and cancelations of scheduled irrigation periods due to maintenance, rain, and muddy field conditions. Based on the calculations above, the average of the actual ET values for the irrigation water applied was 0.26ET; 0.61ET, and 1.0ET compared to the planned ET values of 0.4ET, 0.8ET, and 1.2ET. We believe the largest factor to the actual irrigation being lower than the expected irrigation is the higher than normal precipitation during the project, which resulted in irrigation suspensions due to muddy field conditions. Overall, the plants performed well and did not appear stressed, with the exception of some plants in the 0.4ET rows, which showed some signs of stress during the summer of 2015. The total irrigation water applied to the two half-acre plots is the equivalent of 13.73 inches over the 19-month period of collected irrigation data.

2.5.2.4.2. Irrigation EC Data Analysis

UA took measurements of the electrical conductivity (EC) of the RO concentrate irrigation water as delivered to the plots by BGNDRF. The average TDS of the RO concentrate in PPM for the measurement period was 3,841 mg/L (Table 2).

Table 2. RO Concentrate EC Measurements

Date	microS/cm	Temperature (°C)
5/15/2015	3690	20
7/24/2015	4534	30
8/21/2015	4534	30.3
9/25/2015	4692	24
10/25/2015	4560	
1/20/2015	4280	12.7
2/24/2015	4455	
3/15/2015	4485	17.3
4/21/2015	4508	24
Average EC (microS/cm)	4415	
Average EC (dS/m)	4.4	
TDS (mg/L)	38413.8	
TDS (g/L)		
microS/cm = microSeimens per centimeter °C = degrees Celsius mg/L = milligrams per liter g/L = grams per liter		

2.5.2.5. Yield Model

The shrubs selected for this experiment can become large in wild settings without supplemental irrigation as *A. Canescens*, with heights up to 10 feet tall and *A. lentiformis*, with heights up to 14’ tall have been documented in the wild (Howard 2003 and USDA 2004). Natural regrowth on *A. canescens* has been documented after cattle grazing (Price et al. 1989), indicating that mature shrubs can be harvested multiple times per year.

During the Marana study, crop yield from *A. lentiformis* was a maximum of 24.4 metric tons per hectare (MT/ha) when irrigated with RO concentrate of 3,000 mg/L at an irrigation rate of 1.0 ETo (approximately 2 meters per year [m/yr]) after three years of growth (Yoklic 2011). An earlier study indicated that, in an agronomic setting, the annual productivity of *A. lentiformis* may reach or exceed 10 MT/ha with biannual harvests (Watson and O’Leary 1993).

UA developed an interactive model to predict crop yield of *A. lentiformis* (Figure 16) and *A. canescens* (Figure 17) with field conditions in Alamogordo (Bresdin

2015). The model is based on prior experiments conducted on *A. lentiformis* in Marana (Jordan et al. 2009 and Soliz et al. 2011).

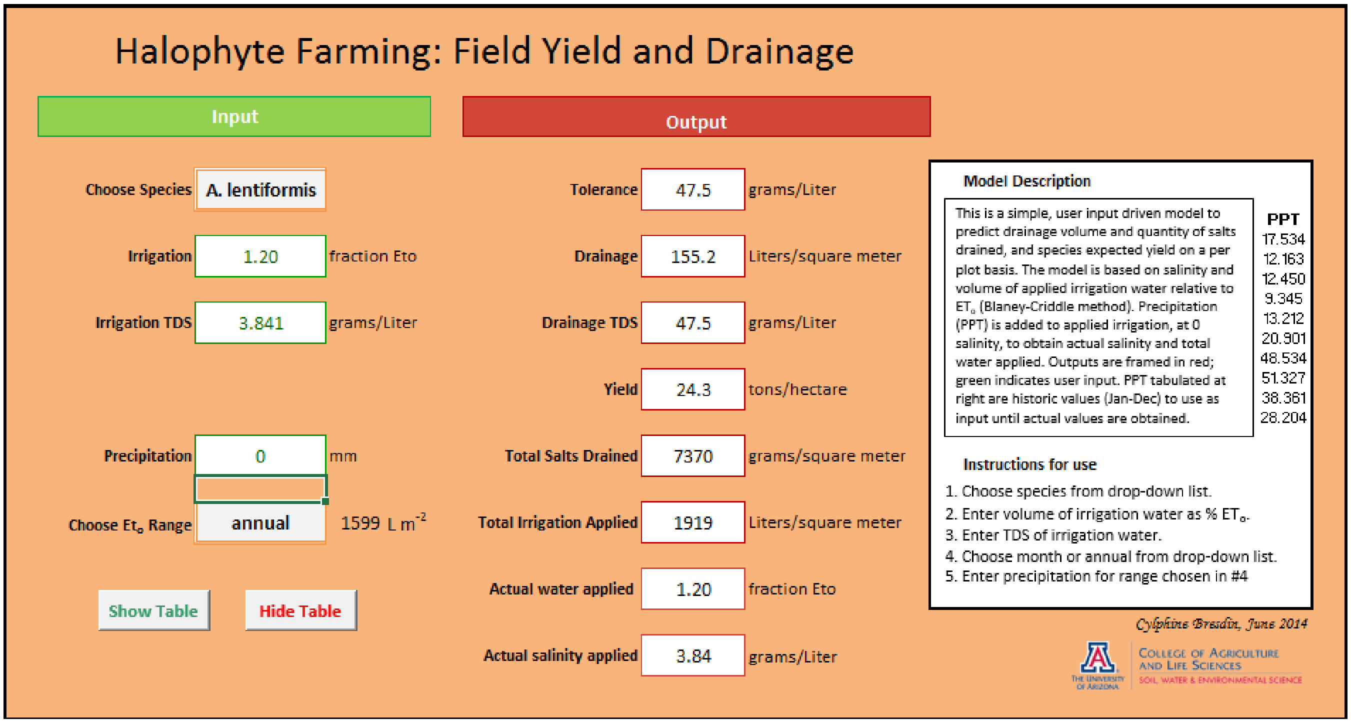


Figure 16.—Yield Model Projections for *A. lentiformis.*

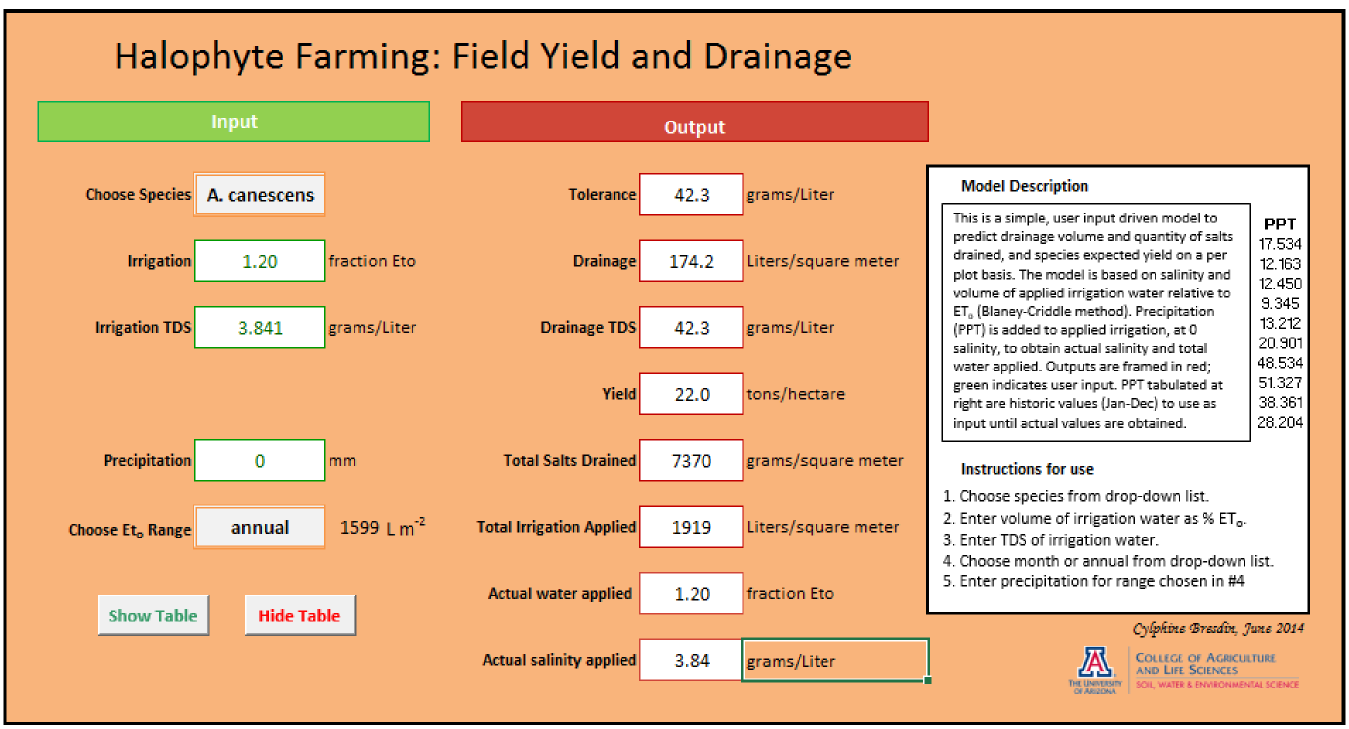


Figure 17.—Yield Model Projections for *A. canescens.*

Sample yield model projections as shown in these figures indicate yields of 24.3 MT/ha for *A. lentiformis* and 22.0 MT/ha for *A. canescens* (see Appendix 4 - Yield Model). The following section summarizes the biomass measurements from the Alamogordo plants up to 20 months old and follows with yield projections based on these results.

2.5.2.6. Biomass Measurements

Plant yield and biomass production measurements were taken to measure the overall productivity of the plants irrigated with RO concentrate and to determine the biomass with the optimal nutritional components for potential use in the animal feed industry. Plant measurement data will help determine the recommended irrigation rate to produce the maximum volume and highest quality of biomass of both species of *Atriplex.* Plant yield and biomass production were measured in three ways:

- Monthly measurements of the height and width of designated measurement plants across the three irrigation rates
- Measurement of blocks of plants of both species within the three irrigation rates
- Recording the total weight of harvested plants within the three irrigation rates

Of the 1,117 total *Atriplex spp.* seedlings planted at BGNDRF in September 2014, a total of 96 plants (48 per half-acre plot) were randomly selected for monthly plant growth measurements and are referred to as designated measurement plants (see Appendix 5 for this selection protocol). Plant measurements began in April 2015 after seedling establishment. Following is a summary of plant measurement data collected from April 2015 through April 2016.

2.5.2.6.1. Atriplex canescens

Two of the *A. canescens* measurement plants (#66 and #90) were flagged as a separate species by Bob Seaman (UA) and were assumed to be *A. polycarpa;* these plants as well as the measurement plants that were replaced due to winter mortality in April 2015 and plants that were later identified as *A. argentea* were removed from the measurement plant database.

A minimum of 12 *A. canescens* measurement plants per irrigation treatment were included in the monthly measurement plant data analysis. The following charts show the averages of the monthly height and width measurements of the measurement plants for each irrigation rate. Plant volume was calculated from the height and width measurements using an ellipsoid formula (Figure 18 - Figure 20). These plants were 19 months old at the time of the last measurement in April 2016.

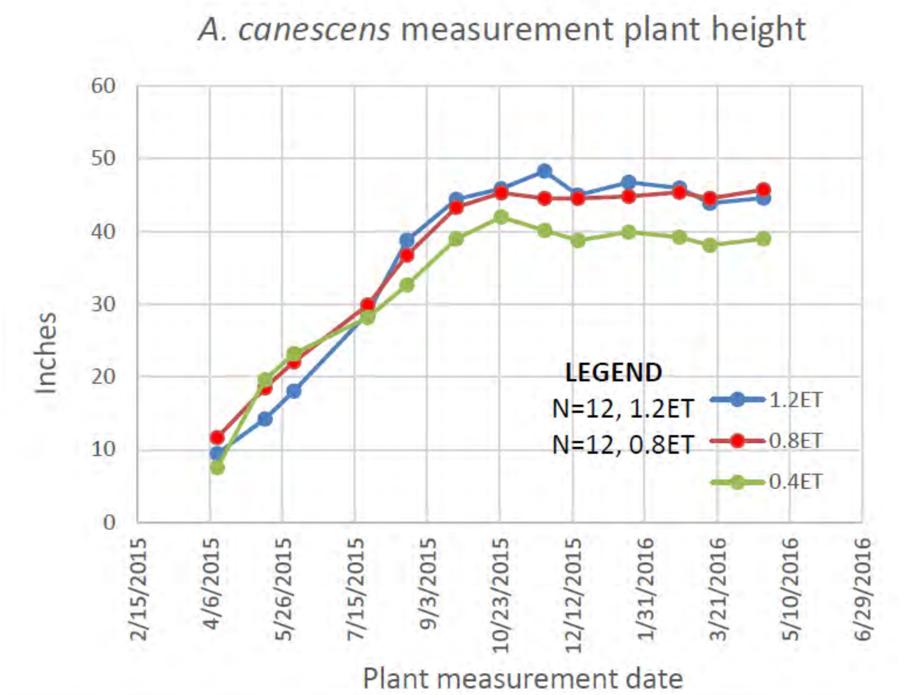


Figure 18.—Average plant heights for designated *Atriplex canescens* measurement plants per irrigation treatment.

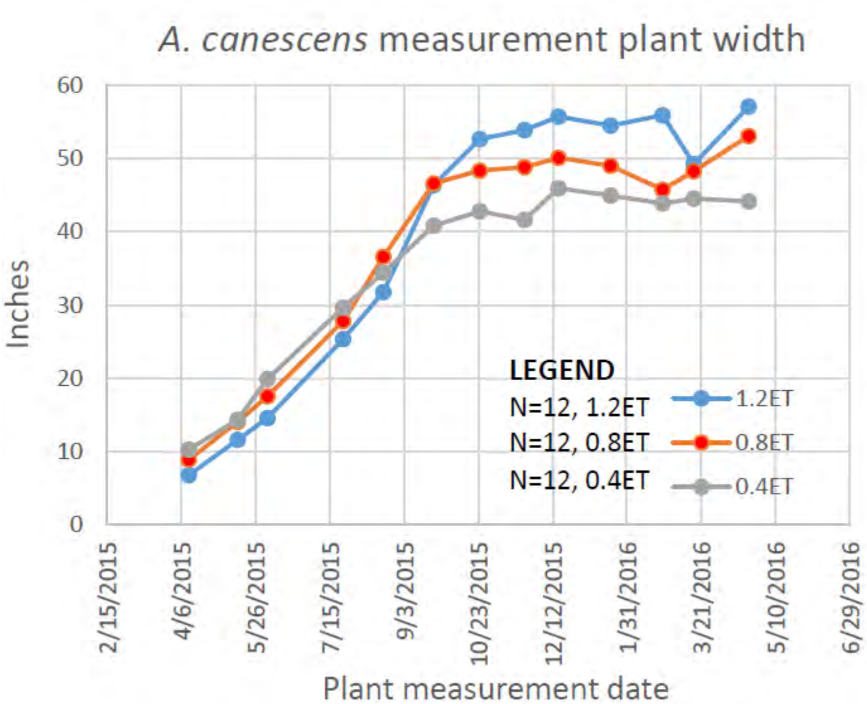


Figure 19.—Average plant widths for designated *Atriplex canescens* measurement plants per irrigation treatment.

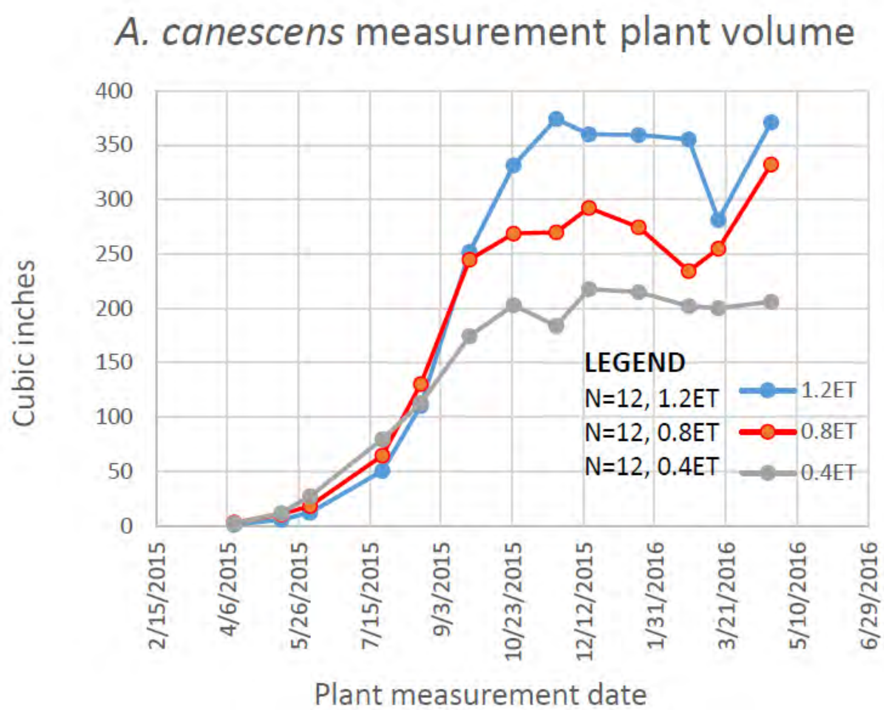


Figure 20.—Average plant volumes for designated *Atriplex canescens* measurement plants per irrigation treatment.

Measurement Inconsistencies

Larger *A. canescens* can become top heavy and can tend to tip over. For this reason, height and width measurements alone may not be consistent from month to month as these measurements can change dramatically if the plant has tipped over. Because of this, the plant volume calculations are likely the most representative of the plant biomass production of the measurement plants.

North and South Field Plant Measurements at 0.8 ET irrigation Rate

Due to the randomization of the irrigation treatments on the two plots, only the 0.8ET irrigation treatment appears in both the North and South plots—there is no 1.2ET *A. canescens* treatment in the South plot and no 0.4ET *A. canescens* treatment in the North plot. The average height, width, and volume of seven measurement plants in the South plot and five measurement plants in the North plot at the 0.8ET irrigation treatment are compared in Figure 21 through Figure 23

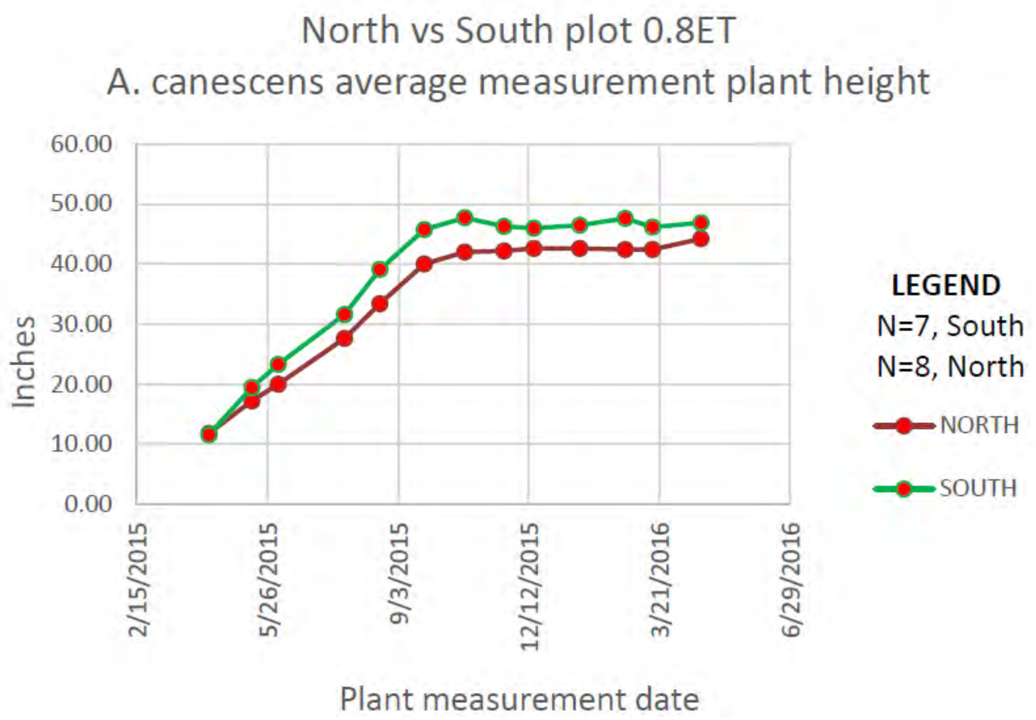


Figure 21.—Height measurements for *Atriplex canescens* measurement plants April 2015 – April 2016.

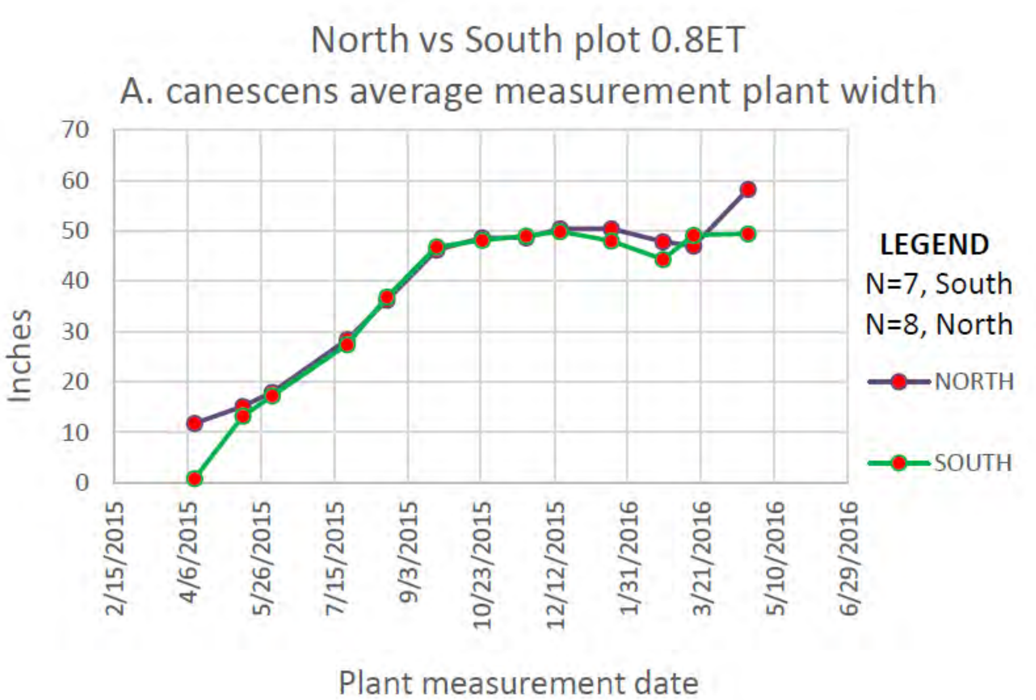


Figure 22.—Width measurements for *Atriplex canescens* measurement plants April 2015 – April 2016.

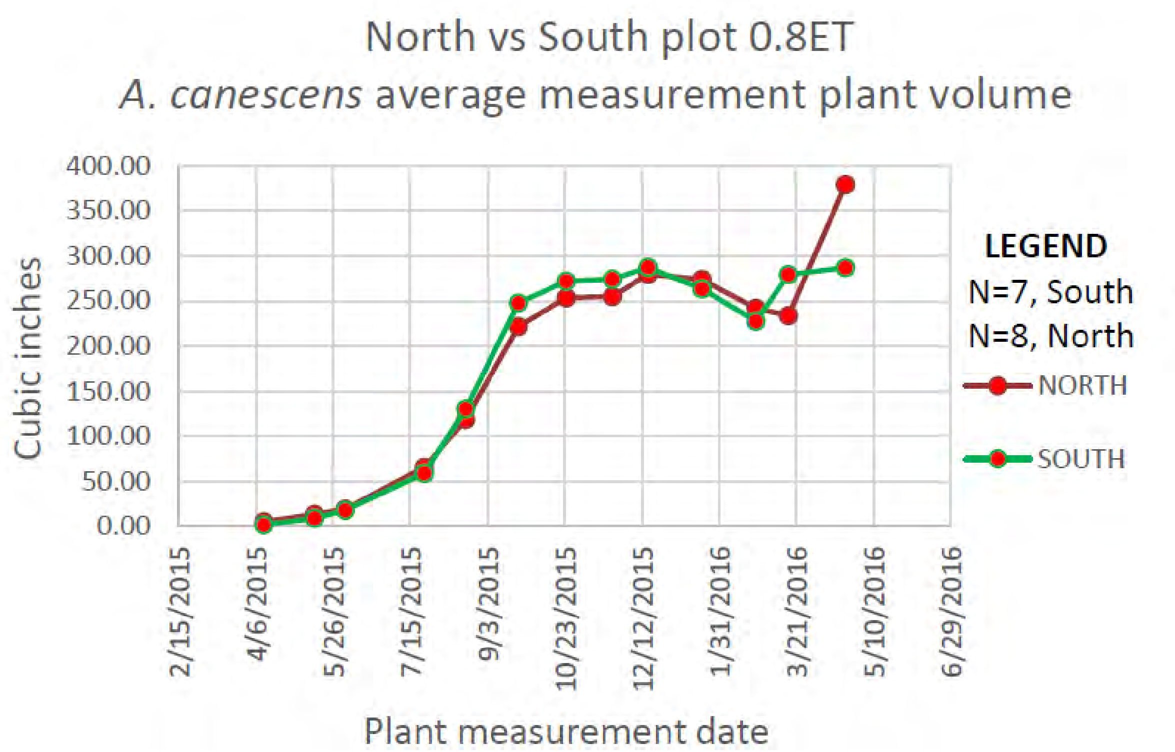


Figure 23.—Volume measurements for *Atriplex canescens* measurement plants April 2015 - April 2016.

The above charts indicate that, although field conditions varied between the North and South plots, the overall growth trends of the *A. canescens* measurement plants were comparable.

2.5.2.6.2. Atriplex lentiformis

Due to the initial shortage of *A. lentiformis* seedlings and the large number of *A. argentea* plants later replaced in the *A. lentiformis* plant rows, a reduced number of *A. lentiformis* plants remain from the original planting in September 2014. Of these original plants, only five were designated *A. lentiformis* measurement plants.

Although these measurement plants do include representatives from each irrigation rate, the results are not statistically relevant. Below is a chart showing growth of these 5 plant height measurements from April 2015 – April 2016 (Figure 24).

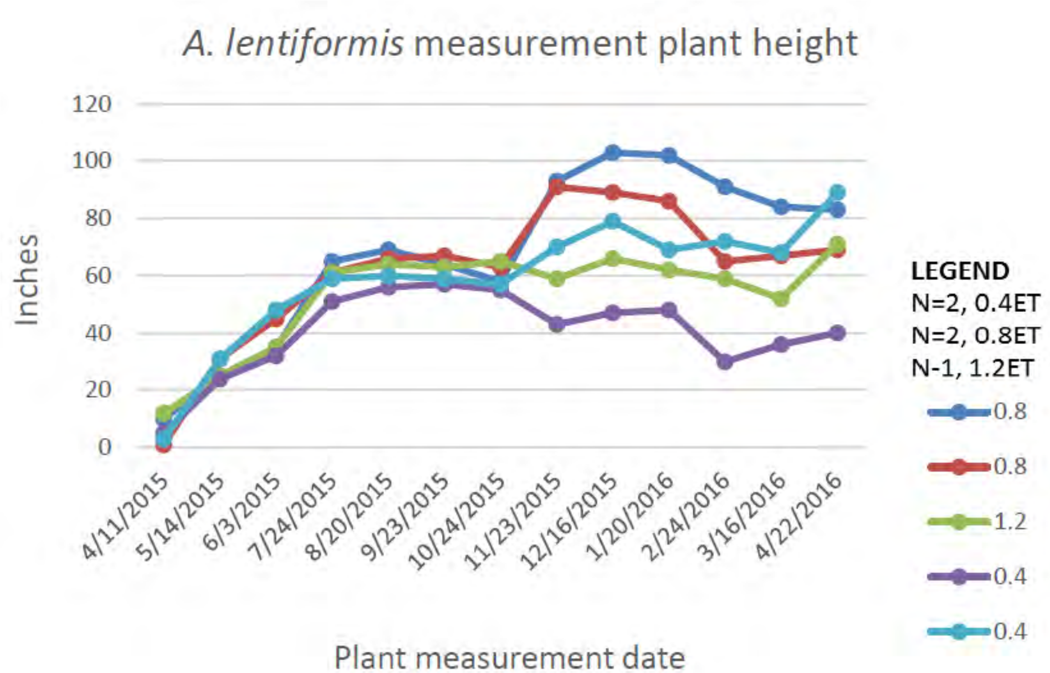


Figure 24.—Height measurements for five designated *Atriplex lentiformis* measurement plants, April 2015 - April 2016.

2.5.2.6.3. Biomass Measurements by Blocks of Plants

In addition to data collected on the designated measurement plants, UA collected plant biomass data in blocks of *A. canescens* and *A. lentiformis* in both fields in March 2016.[3] During this process, randomly selected blocks of same-aged plants within the three irrigation regimes were measured for comparative volume measurements. Shrubs within the blocks were measured individually and the entire block length, width, and height was also measured for this protocol. (See Appendix 7.)

The volume measurements in Figure 25 are based on average volume per plant within the total block measurement. Only one block per treatment is available for *A. lentiformis* in this age group, and there are no blocks of *A. canescens* in this age group.

[3] An as-built planting plan was created to track the ages of the *A. lentiformis* plants in both plots. These include plants replaced due to winter mortality in April 2015, and miscellaneous *A. canescens* and *A. argentea* plants in the *A. lentiformis* rows replaced in October and November 2015. *A. canescens* plants replaced in April 2015 due to winter mortality were not individually tracked.

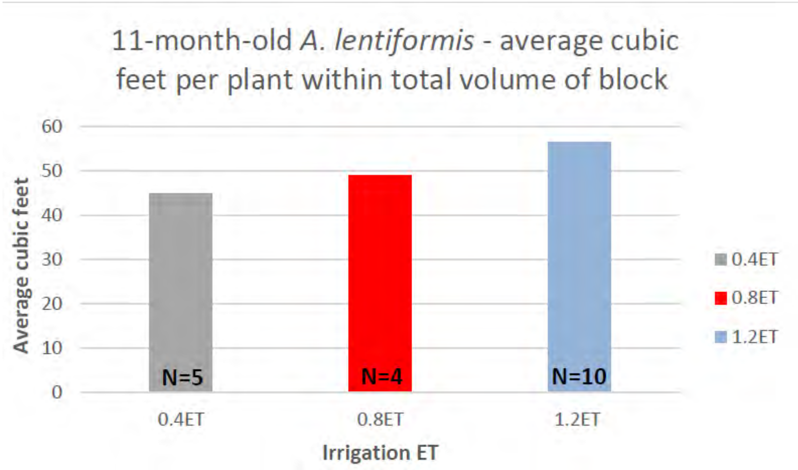


Figure 25.—Average cubic feet per plant measurements for 11-month-old *Atriplex lentiformis.*

Figure 26 and Figure 27 show volume measurements based on the individual plant measurements within the blocks; these measurements would include the volume of overlapping plants. The A. *canescens* volumes are based on 4 blocks per irrigation treatment, with 37 plants per block. The *A. lentiformis* volumes are based on two blocks of the 0.4 treatment, 3 blocks of the 0.8 treatment and two blocks of the 1.2 treatment with varying numbers of plants per block as indicated.

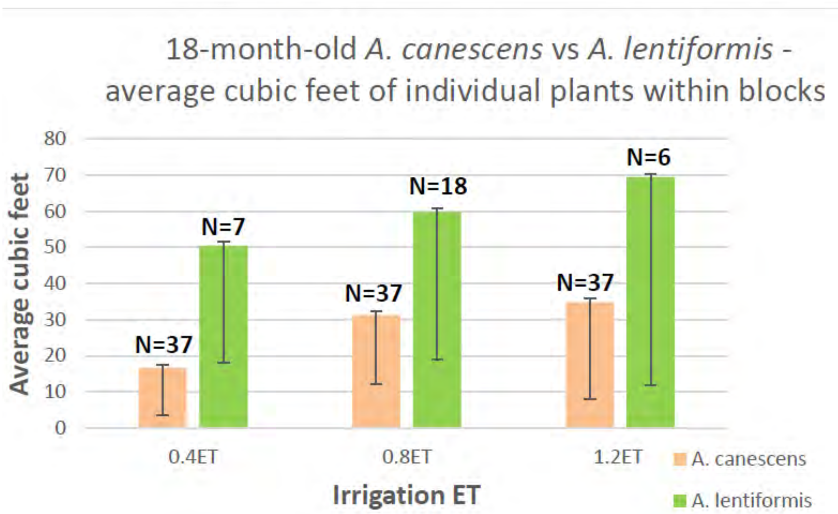


Figure 26.—Average cubic feet of individual plants within blocks for 18-month-old *Atriplex lentiformis*

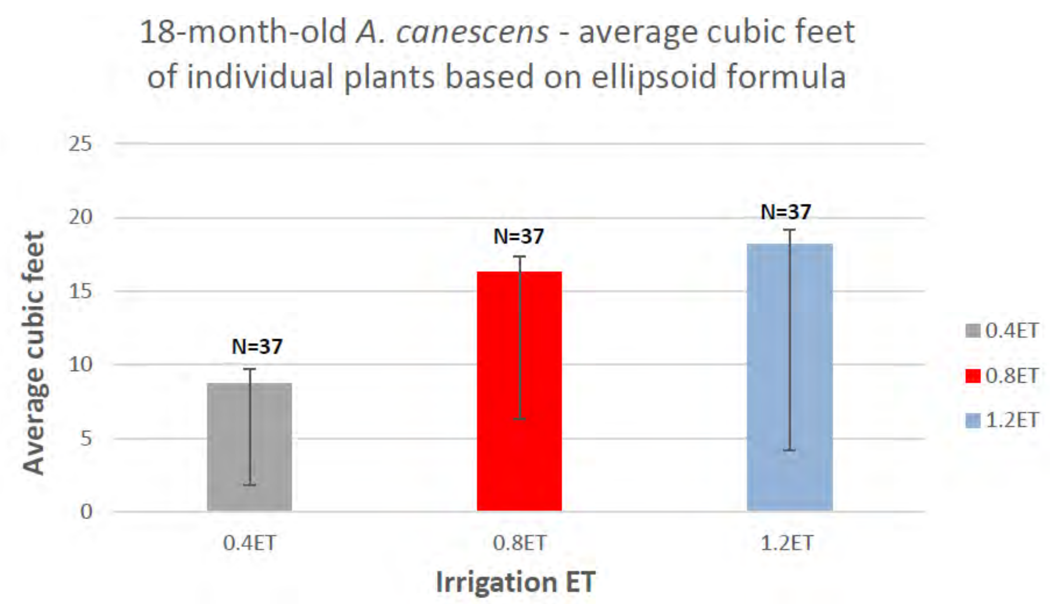


Figure 27.—Average cubic feet of individual plants based on the ellipsoid formula for 18-month- old *Atriplex lentiformis*

The above volumes are based on ellipsoid calculations of individual plants in 4 blocks per treatment. This calculation may better represent the natural growth habit and shape of *A. canescens* shrubs.

2.5.2.6.4. Biomass Measurements by Wet Weight

In May 2016, UA collected additional biomass data by harvesting and weighing entire *A. canescens* and *A. lentiformis* plants in both plots. During this process, 10 randomly selected plants from the original planting in September 2014 located within the three irrigation regimes were measured for comparative biomass (wet) weights (Figure 28). The total sample size was 10 (plants) x 3 (0.4, 0.8, 1.2 irrigation treatments) x 2 (species) = 60 total samples (see Appendix 7 for this protocol).

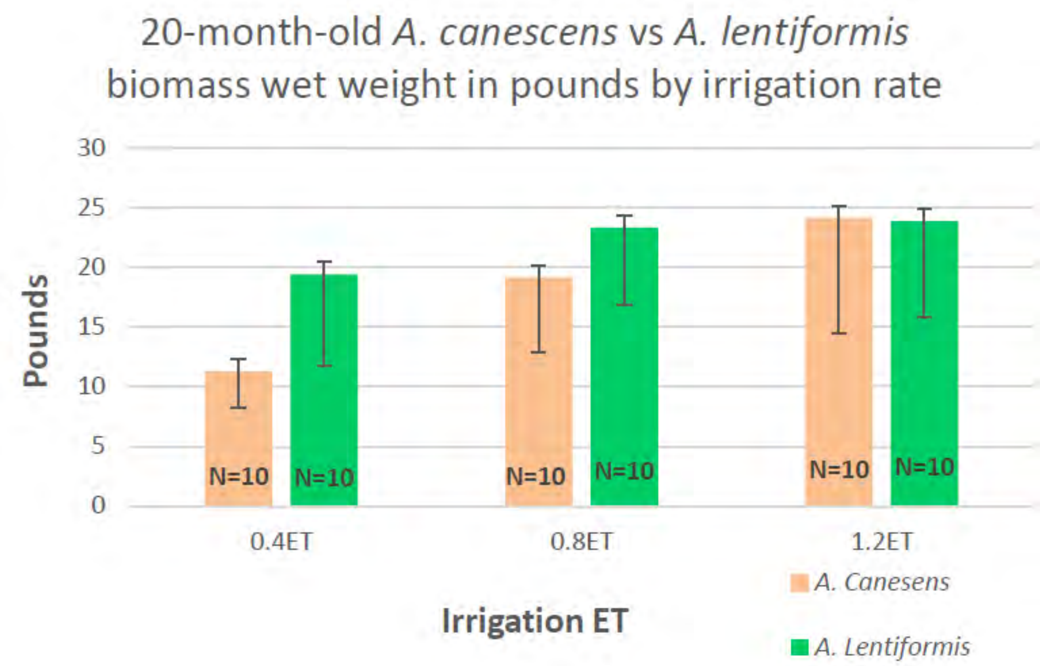


Figure 28.—Biomass wet weight in pounds of *A. canescens* and *A. lentiformis* with three irrigation treatments.

Of the three biomass data collection methods, only the final measurement by plant weights contained sufficient samples for comparing yields of *A. canescens* and *A. lentiformis* plants. Although the results contain high variability among the samples, the growth trends suggest that the 1.2ET irrigation treatment produces the most total biomass for *A. canescens* and the 0.8ET and 1.2ET irrigation rates are producing similar biomass for *A. lentiformis.*

2.5.2.6.5. Biomass Measurements Converted to Dry Matter

Biomass yield for animal feed is measured in dry matter (DM), which is air dried or oven dried to remove most of the moisture content for nutrient rationing. The May harvest samples were oven dried at 60 °C and arrived at Litchfield Analytics for nutrient analysis with an average measured moisture content of 4%. The *A. lentiformis* samples contained more moisture and produced less DM biomass per unit than the *A. canescens* (see Figure 29).

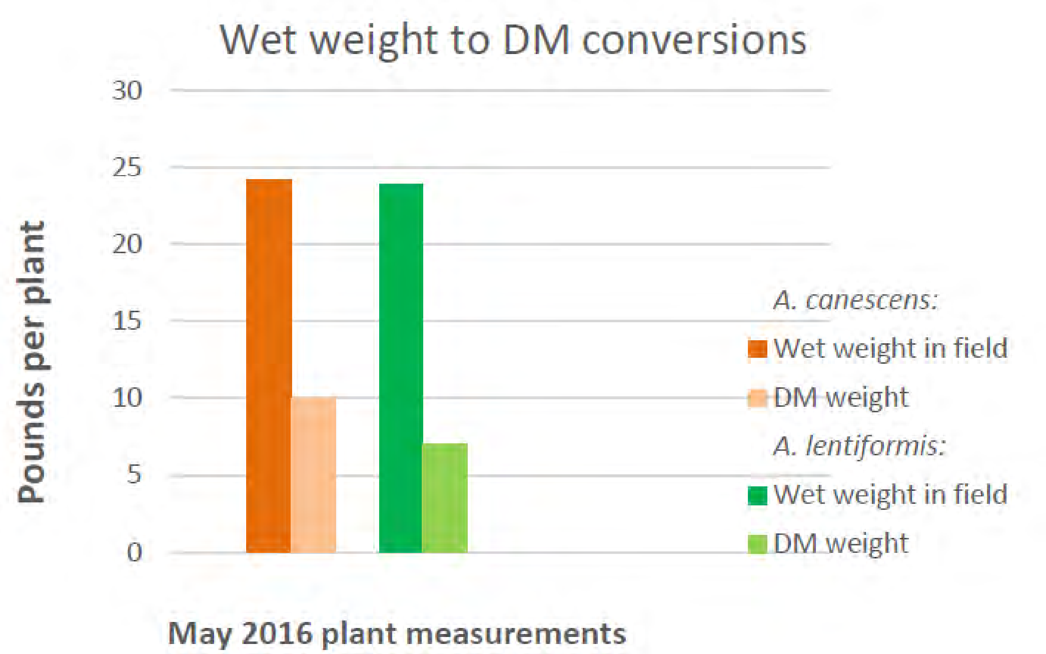


Figure 29.—Wet weight to DM weight in pounds per plant.

2.5.2.6.6. Yield Comparisons to the Marana Study

Different locations and field conditions make it challenging to directly compare yield production between the Alamogordo study and the earlier Marana study However, some level of comparison is possible. These comparisons need to take into account that the Marana study evaluated *A. lentiformis* plant production under different climate, soil, and irrigation treatments and with different plant spacing and densities. The Alamogordo project provided tighter plant row spacing with aisles between planting rows for harvesting equipment access and the Marana study did not include any access aisles. The studies also measured yields at different plant ages and periods of growth in the field.

To compare Alamogordo DM yield production to the earlier Marana study, it is necessary to convert the production to an annual basis. However, this can be misleading as the length of the growing seasons is not necessarily proportional. Differences in overall tonnage among studies could also reflect variations in the percent of moisture content in the samples (air dried compared to oven dried). The following chart shows the annualized *A. lentiformis* yield in kilograms per square meter (kg/m^2) of the three studies with differing months of plant yield production: Marana at 13 months; Alamogordo at 20 months; and Marana at 28.5 months (Figure 30).

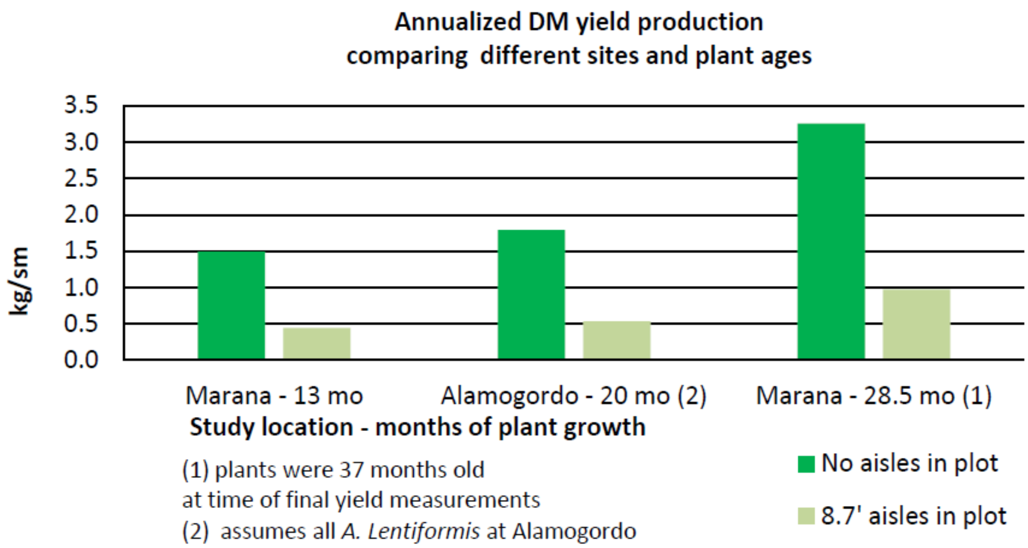


Figure 30.—Annualized DM yield production.

Figure 31 shows that, even though the Alamogordo, New Mexico site was at a higher elevation with cooler average temperatures, the overall yields fall within the range of the Marana, Arizona yields. It is important to note that the Marana, study yield measurements for 28.5 months of growth measure much older plants than the 20-month-old and 13-month-old plants of the other yield measurements. Previous studies have indicated that *A. lentiformis* becomes increasingly woody with age and number of harvests (Watson and O'Leary 1993), and the above yields likely reflect this increase.

Yield projections - Dry matter (DM) weight			
Alamogordo and Marana	kg/m^2 no aisles	MT/ha no aisles	MT/ha w/aisles
1 harvest biennually - cut entire plant (estimated)			
Alamogordo study			
20 month yield as measured	3.0	29.9	9.0
24 months - projected 20% increased yield	3.6	35.9	10.8
Marana study			
Annual yield estimated at 15 - 22 MT/ha*			
24 month yield - projected (low end)	3.0	30.0	9.0
24 month yield - projected (high end)	4.4	44.0	13.2
	* (Soliz et al. 2011)		

Note: assumes all A. lentiformis plants at Alamogordo and Alamogordo plants at 24 months have additional 20% yield; Marana plants are projected to double plant yield in the second year

Figure 31.—Yield projections comparing Alamogordo and Marana.

Sustainable yields for both species in the Alamogordo study can be projected based on the above DM weights and harvest samples with estimates of the plants' regrowth after harvest and annual harvest regimes. For example, based on the above DM yields of the 1.2ET treatment and assuming biennial harvests beginning with 20-month-old plants, the total annual *A. canescens* crop yield is estimated at 3.17 metric tons/ha, and *A. lentiformis* crop yield is estimated at 2.21 metric tons/ha DM (96% moisture). This calculation assumes that harvests would begin at 20 months with two harvests/year of 50% of plants harvested, with full recovery of biomass between harvests. The first year would include a one-time additional yield of 5.37 metric tons/ha by thinning every other plant (Table 3).

Table 3. Yield Projections for Sustainable Harvest—Alamogordo

Yield projections: Dry matter (DM) weight Alamogordo - sustainable harvest		**MT/ha**	**k/m^2**
2 harvests per year - sustainable - 50% of biomass harvested (estimated):			
1/2 acre	*A. canescens*	3.21	0.32
1/2 acre	*A. lentiformis*	2.19	0.22
1 acre	Both species	5.39	0.54

Note: assumes plants are 50% harvested twice a year, beginning at 20 months. Assumes 564 plants/acre with 8.7' aisles for harvesting equipment access; plants at 6' centers. Initial harvest would increase yield by an additional 5.37 metric tons/ha with thinning.

Further research is needed to determine the best management practices for harvesting *A. canescens* and *A. lentiformis.* Additional field experimentation is recommended for further research (see Section 3.2. Additional Research Needed). These studies need to include: an animal feed market study, the types of equipment, methods and optimal schedule for harvest; and preparation and transporting the crop to market.

2.6. Task 6 - Crop Performance

Task 6 – Crop performance, field production monitoring, nutrient content analysis, and evaluation of potential for use as a commodity crop supplement for dairy and feed lot industry and for landscape restoration and revegetation.

To evaluate using *A. canescens* and *A. lentiformis* biomass as a crop supplement in the animal feed industry, UA commissioned a detailed investigation under a subcontract agreement with Texas A&M – Kingsville (TAMUK), contributing to the evaluation by collecting crop harvest samples for chemical analysis.

An initial meeting between UA and TAMUK was held at BGNDRF on June 19, 2014. Joanne Gallaher, Bob Seaman, and Ryan Furcini attended from the UA, and Kim McCuistion, along with four students, attended from TAMUK. Martin

Yoklic (UA) also participated via speaker phone. During this meeting, we reviewed the background and scope of the project, as well as the focus of the study and deliverable to be produced by TAMUK.

2.6.1. Nutritional Laboratory Testing of Harvest Samples

Based on input from Dr. Ed Glenn, UA, and Dr. Kim McCuistion, TAMUK, a standard Proximate Analysis lab test for nutritional content including protein, fiber, fat, digestible energy and ash (mineral) content as well as individual cations and anions (sodium, potassium and magnesium); and supplemented with tests for chloride and sulfur was selected as the chemical analysis. This analysis was conducted by Litchfield Analysis, Litchfield, Michigan. UA developed a protocol for collecting harvest samples from five plants per species per irrigation treatment, oven drying the samples and shipping them to the lab. (See Appendix 9).

UA collected harvest samples in July and September 2015 and again in March and April 2016. The samples were bagged and dried at the UA soils lab and sent to Litchfield Analytics for analysis. These test results were provided to Dr. Kim McCuistion, Texas A&M – Kingsville and an evaluation is included in McCuistion and Rivera 2016).

2.6.2. TAMUK Report (McCuistion and Rivera 2016)

The TAMUK report, McCuistion and Rivera 2016, "*Atriplex* as a Potential Feedstuff in Beef and Dairy Production in the Southwestern United States," reviews the literature on the uses of *Atriplex spp*. for animal feed and evaluates the potential of *Atriplex spp*. for use as a commodity scale animal feed and forage crop supplement for the feedlot and dairy industry in the arid southwest. See Appendix 8 for this report.

The literature review and the samples collected from halophyte farming in New Mexico show the potential for *Atriplex spp*. inclusion in rations fed to feedlot and dairy cattle. Because *Atriplex spp*. can have a low energy concentration and high salt content, it does not fit well as a sole or major ingredient for livestock production in the United States. The results of this study support RO concentrate as a source of irrigation water to grow *Atriplex spp*. for animal feed.

Forages presently used in cattle rations (such as alfalfa, corn and sorghum silages) are not able to grow under irrigation water with such high salt concentrations, although some species of alfalfa are more salt tolerant than standard alfalfa. For future use in the cattle industries of the Southwest, additional research is needed. Areas to consider for future work include an animal feeding trial, large-scale harvesting methods, transportation, feed processing, and feed storage.

2.6.3. Nutritional Quality of ETo Samples

In addition to biomass production and yield projections, the nutritional values of *A. canescens* and *A. lentiformis* were analyzed by irrigation treatment for consideration in the recommendation of the optimal irrigation rate for each species. The average percentages of crude protein, acid detergent fiber (ADF), total digestible nutrients (TDN), ash, sodium, sodium chloride, potassium, and the sodium:potassium ratio was compared for both species at the three irrigation levels.

There is no apparent trend to suggest a significant difference in nutrient quality based on the three irrigation rates in these samples.

2.6.4. Heavy Metals Laboratory Testing

Based on input from Dr. Janick Artiola, UA, a subset of the harvest samples was also tested for heavy metals at the Arizona Laboratory for Emerging Contaminants (ALEC), University of Arizona.

Two sets of composite oven-dried ground plant samples were sent to the UA-ALEC laboratory for elemental analysis. Forty-six elements were measured in these four sets of plant tissues (two *A. canescens* and two *A. lentiformis*) using microwave acid digests and inductively coupled plasma mass spectroscopy (ICP-MS). The results are reported in Appendix 11 in micrograms/gram (parts per billin [ppb]) of dry plant tissue.

The two *A. canescens* plant tissue sample composites had similar concentrations of all elements except for Na. One sample was about 3 times lower than expected. Laboratory QC check confirmed the Na data level as reported initially. This unexpectedly resulted in a low Na:K ratio (0.22) for this halophyte species. Whereas, the *A. lentiformis* tissue samples had Na:K ratio of 1.7 suggesting a strong competition of Na for K uptake. If the Na:K ratio for *A. canescens* holds true, it indicates that this halophyte is better adapted to saline conditions *than A. lentiformis*. Note also the that ratio of Na:K in the irrigation water (RO concentrate) used in this study was about 200:1.

Since calcium and strontium and potassium and rubidium have similar chemical properties, each pair competes for plant uptake. The plant uptake ratios vary, depending on the soil solution composition of each of these four elements. According to the literature, the plant tissue levels of strontium and rubidium are within the range of other observed plant values.

A review of the literature on the elemental composition and metal uptake by halophytes indicates that these plants tend to accumulate more salts with increasing salinity and wet conditions. Thus, halophytes that grow in marshes, wetlands, and coastal areas tend to accumulate more salts and metals that dryland halophytes.

Plant tissue data on halophytes and other common plants including grasses, grains and shrubs, on metal concentrations found in the literature indicate that the two halophyte species did not accumulate "abnormal" or unusually high concentrations of any of the following elements: sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), boron (B), silicon (Si), phosphorus (P), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nitrogen (Ni), copper (Cu), nickel (Ni), arsenic (As), (selenium) Se, molybdenum (Mo), titanium (Ti), cadmium (Cd), tin (Sn), strontium (Sr), rubidium (Rb), zirconium (Zr), cesium (Cs), barium (Ba), gallium (Ga), mercury (Hg), thallium (Tl), silver (Ag), lead (Pb), and uranium (U). Typical levels found in plants for the remaining elements (rhenium [Re], tungsten [W], tantalum [Ta], antimony [Sb], indium [In], niobium [Nb], germanium [Ge]) were not readily available in the literature. However, all levels of these seven elements were very low or below quantifiable detection limits (0.15 to <0.01 micrograms per gram [μg/g]) in dry plant tissue.

In summary, elemental analysis of four composite plant tissue samples of the *Atriplex canescens* and *Atriplex lentiformis* gathered at the end of this two-year field experiment, grown under the soil and water conditions previously described, indicate the plant tissue composition was within a "normal" range for the 46 elements tested including salts (halophyte plants). Specifically, the levels of commonly tested and potentially toxic elements such as arsenic (As), lead (Pb), cadmium (Cd), uranium (U), nickel (Ni), iron (Fe), aluminum (Al), copper (Cu), zinc (Zn), molybdenum (Mo), and manganese (Mn) were within the range of those found in other halophytes and agricultural plants.

2.6.5. Interview with Colt Howland

In May 2016, UA interviewed a local rancher, Colt Howland, and toured his ranch located west of Alamogordo. See Appendix 12 for this interview. The ranch in over 38,000 acres and was originally homesteaded in the 1950s. At the time of the interview, the herd totaled around 300 head, reduced from a maximum of 480 allowed by permit, due to drought and range conditions. The range vegetation is primarily *Atriplex canescens* (known locally as common name of Chamize), mixed with three native grasses: Bush Muhly (*Muhlenbergia porteri*), Alkali sacaton (*Sporobolus airoides*), and Black grama (*Bouteloua eriopoda Torr.).* [Common names of *Atriplex canescens* include Fourwing Saltbush, Chamize, Chamiso, Chamiza, and Shadscale]. The ranch also contains pockets of Honey mesquite (*Prosopis glandulosa Torr*)., creosote (*Larrea tridentata*), and Salt cedar (*Tamarix spp.*); these species were introduced in the late 1900s by the railroad. Salt cedar is a non-native, invasive species. The woody plants (mesquite, creosote, and salt cedar) are increasing. The cattle rely on the *A. canescens* during the winter months when it is higher in protein than other vegetation. *A. canescens* periodically dies back but recovers from temperatures below zero, based on extreme lows in the region during the winter of 2010/2011.

2.7. Task 7 - Model Fate/Transport

Task 7 – Mass balance model addressing the fate and transport of all components applied to the field. The initial model to be constructed based on experimental plan, field site conditions, water source and chemistry, irrigation rate, soil type, climate and extrapolating finding from previous research to estimate field performance and map subsurface moisture and salinity migration.

As part of this study, a greenhouse experiment was conducted at the Environmental Research Lab, University of Arizona, to determine the maximum saline tolerance and wilt-point of three species of *Atriplex; A. lentiformis, A. canescens* and *A. linearis,* when grown in soil from BGNDRF and irrigated with the RO concentrate from BGNDRF. Results show that *A. lentiformis* consumes a greater percentage of irrigation and has a higher salinity tolerance than *A. canescens*. When we consider the relationship of maximum tolerance, ability to overcome osmotic potential and increase in volume consumption to decreasing irrigation salinity, we can make predictions of field outcomes. Increasing irrigation salinity will increase the drainage fraction because it adds more salts to the soil-water mix, which will increase osmotic potential of the soil-water and will reach maximum tolerance sooner than it will with lower salinity irrigation water. This is also the scenario when irrigation salinity remains the same, but higher volume of water is used, assuming deficit irrigation. Therefore, we can expect longer growth times with lower irrigation volumes and more growth with less drainage from *A. lentiformis* than from *A. canescens* in BGNDRF soil. See Appendix 13.

Three related models are included as deliverables with this project: the Irrigation Model, the Yield Model, and an NaCl model. See Appendix 14.

2.8. Task 8 - Model Validation

Task 8 – Revision/refinement of Mass balance, fate/transport model based on research plot monitoring data including soil moisture and salinity at depth, plant productivity including usable biomass (animal feed), chaff (leaf drop), and total carbon storage. Characteristics of soil and below the root zone.

2.8.1. Soil Chemistry and Characteristics

To address the sustainability of the soil for halophyte irrigation with RO concentrate at BGNDRF, Dr. Artiola determined the need for additional soil tests at the perimeter of our site and near Trench 2. To collect additional soil core samples, Bob Seaman (UA) fabricated a custom coring attachment for the UA drill rig. In October 2015, Bob, with assistance from Amir Gonzalez, NMSU, collected 36 soil core samples from four locations to a depth of 8 feet, using the UA drill rig with the custom corer attachment.

UA entered into a subconsultant agreement with Dr. Manoj Shukla, NMSU, to conduct specified soil chemistry lab tests on BGNDRF site soil. Dr. Manoj Shukla, NMSU, coordinated the lab testing of these samples plus an additional sample of BGNDRF soil that we are using for lab tests at UA. These samples were tested for salinity, sodium adsorption ratio (SAR), and pH, with the BGNDRF site soil used for lab tests also tested for anions, cations and Sulphur.

Dr. Artiola, UA, produced the “Halophyte Soil Sustainability Evaluation” report, which includes a detailed analysis of the soil conditions and tests on the project. See Appendix 14. Following are excerpts and Summary conclusions from his report. Figure 32a (below, left) shows a soil profile distribution (%) of three of the four major minerals common in this soil: gypsum, dolomite, and calcite minerals. Calcite is a very insoluble mineral that predominates in the top 3 feet, whereas, gypsum—which is more soluble than calcite—increases with depth, becoming predominant below five feet. These mineral composition trends are common in Alamogordo soils and confirm the highly calcareous and gypsic nature of the BGNDRF soils.

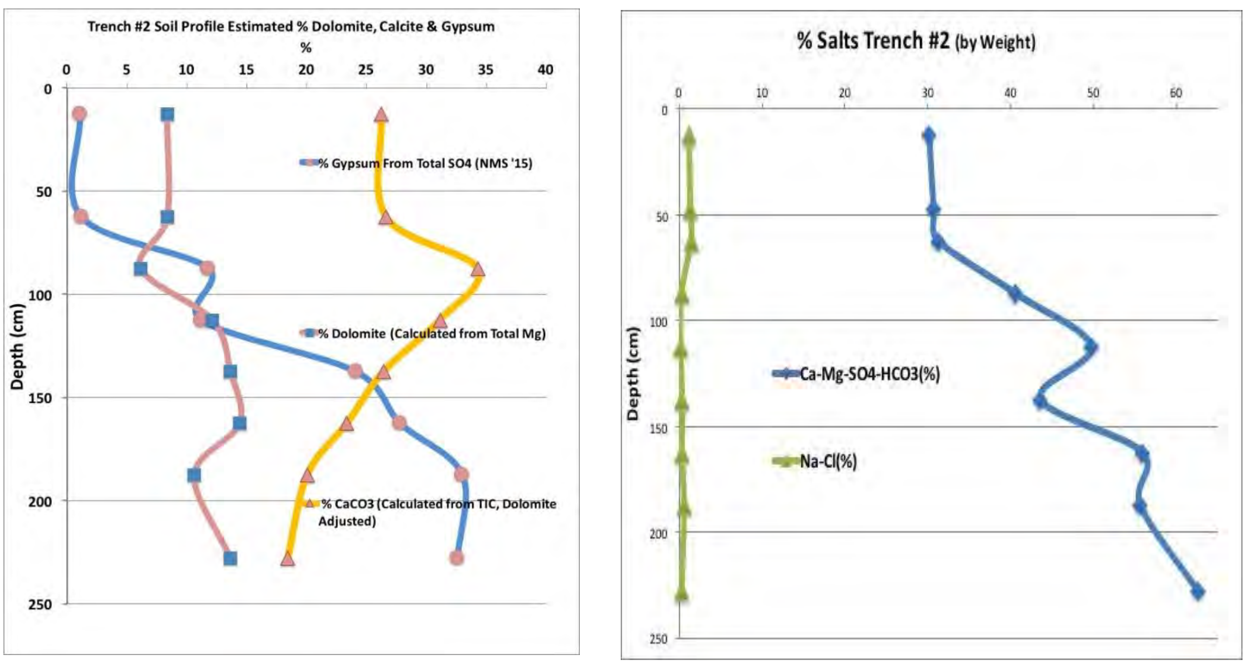


Figure 32.—Soil profile distributions.

Figure 32b contrasts the total amount of the three minerals from Figure 32a with sodium chloride, which is also present in the soil. This extremely soluble mineral, which controls soil EC when it rises to about about 3 to 4 dS/m (in soil water extracts), is present in comparatively low concentrations but uneven (~0.05-1.5%) in the soil profile. The soil salinity was not measured at the end of this project as any increases in soil salinity would be difficult to quantify without collecting and analyzing hundreds of samples for several reasons:

- The study was short (two years) and less than 10% of the total soluble salts known to be initially present in the soil were added through irrigation

- The research used of three levels of water applications using drip irrigation, which typically produces highly stratified spatial distribution of soluble salts in soils

- The irrigation treatments were randomized with significant differences in salts applications across the fields.

2.8.2. Summary of Results

The RO concentrate used to irrigate the UA halophyte research plots is classified as a saline water with a TDS of an average of 3,841 mg/L, and its chemical composition is similar to the soils at the site. The RO concentrate contains gypsum, dolomite, and magnesium sulfate (about 78% by mass) and table salt (about 22% by mass). Therefore, given that the soils, the site, and the RO concentrate have similar chemistries, the RO concentrate will not change the nature of the existing soils or pose a significant threat to the existing brackish groundwater quality below the site in the short term.

The UA halophyte research plots in the Alamogordo, NM BGNDF Research Facility, are located within a one-acre area with soils, previously undisturbed (except for areas located within a former landfill), that are heavy-textured ranging from clay loams to clays, containing a large fraction (about 30-65% by mass) of minerals such as gypsum, dolomite, and calcite, as well as much smaller (about 1%) but significant amounts of table salt. In their native state, these soils are classified as saline with ECe averaging 20 dS/m (top 4feet.) with a range of about 3 - 43 dS/m. The soils at the site that can be described as strongly saline are above a potentially water restrictive calcite accumulation layer located about 4 feet (90 – 120 centimeters) deep. Below this layer, the salinity is moderate with very high concentrations of gypsum and other minerals.

The water infiltration of the soils at the site are moderately slow to very rapid, and this is not expected to change significantly with RO concentrate irrigation in the short term. This is because of the similar ion compositions between the soil and the irrigation water. In addition, the SAR of the RO concentrate is 7.8, classified of unrestricted (given that its EC is 5.2 dS/m). Whereas the soils (in their natural condition) are strongly saline with SAR values ranging between 1 and 21 in the top 4 feet.

Laboratory studies showed that the Acclima sensors installed at the site can provide precise continuous soil moisture data down to 4 feet, but they are no substitute for the more extensive network of neutron probe access tubes located within the UA research plots designed to measure soil moisture to a depth of 9 feet. These probes can act as an early warning system to detect relative increases in salt accumulation in the soils at the site as their responses are positively correlated to changes in soil salinity particularly at or near soil water saturation (field capacity) conditions, but they are no substitute for ECe measurements from soil samples.

Soils at site contain about 14,000 MT/ha at 0 to 2.5 meters deep of salts including: sulfate, calcium, sodium, chloride and carbonate. According to a site-specific irrigation model estimate of the salt input when plants reach maturity, the soil at the site will receive about 26 MT/ha of salts annually, which could double the amount of soluble salts now present at the site in about 13 years if no salts leach below 9 feet (2.5 meters) or are taken up by plants. Greenhouse studies have determined that the threshold salinities of the halophytes now being grown at the UA research plots are about 3.5 times higher than the average soil salinity at the site. Thus, it should take more than a decade to reach average soil salinities close to the halophyte tolerances determined in the greenhouse studies. A balance between applied irrigation water volume, maximum tolerable soil salinity, minimum acceptable plant yields, and drainage water quality/volume will have to be determined based on economic and environmental considerations.

Soil moisture data collected monthly in 2015 from 39 neutron access tubes located in and around the UA research plots indicate that the soil profile is drier above and below an existing calcite zone of accumulation (layer) located 3 and 4 feet below the surface. Under the present irrigation regime this layer may be slowing or retaining water sufficiently to preclude significant amounts of water and therefore salts from moving below the monitored depth of 9 feet. An annual soil drying trend can be observed at several soil depths, suggesting that presently there is an irrigation deficit (water applied < plant water demand). The BGNDRF groundwater is not expected to be impacted in the near future using present irrigation management practices.

2.9. Task 9 – Reporting

Task 9 – Quarterly and final reports, publication of results in peer reviewed journals and presentation of findings at technical and scientific meetings.

Technology transfer and public outreach related to this project to date includes the publication of a Research Update in March 2014, participation at the USAID-sponsored Desal Prize at BGNDRF in April 2015, and two poster session presentations in March and April 2016 at the University of Arizona.

The UA Research Update, published in March 2014, was distributed at BGNDRF and the Department of Soil, Water and Environmental Science, University of Arizona, and was also available on the UA SWES department website for download. See Appendix 15.

UA participated in the public tours during the Desal Prize competition at BGNDRF in April 2015. UA installed signs to identify our project and made Research Update brochures available for distribution (Figure 33).

Figure 33.—Dr. Joanne Gallaher, UA, discussing the UA halophyte farming project with a group during the public tour during the Desal Prize competition at BGNDRF.

A poster entitled "Halophyte Farming for the Management of Desalination Waste Concentrates and Brackish Waters" (Wardell et al., 2016) was presented at the Arizona Water Resources Research Center (WRRC) 2016 Annual Conference "#AZwaterfuture: Tech, Talk and Tradeoffs", March 21, 2016, and the UA Arid Lands Poster Session: Cross-disciplinary Symposium on Arid Environments Research, April 27, 2016. See Appendix 16.

2.10. Project Management

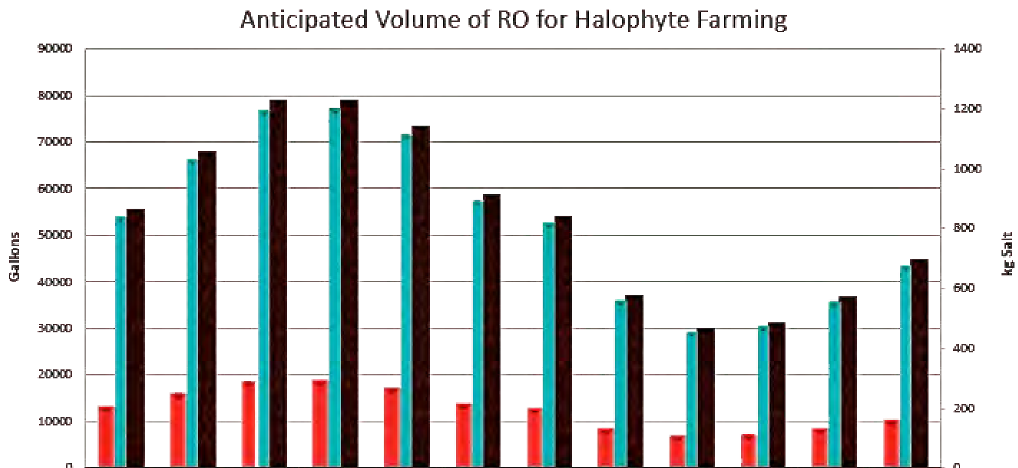
The initial Cooperative Agreement, dated September 2013, included a scope and budget based on a two-year effort. We received a second Cooperative Agreement to extend the project funding for an additional 6 months, dated January 2016, largely due to the setback of receiving incorrect seed that resulted in a large-scale replacement planting. This funding extension allowed additional growth on the plants so that UA could complete data collection and analysis during the spring of 2016. A subsequent proposal for a new Reclamation DWPR program to extend the current research was not awarded, but the review comments suggest that we reapply.

3. Recommendations and Additional Research Needed

This research involves a complex system based on the development, production and commercial acceptance of a new agricultural crop.

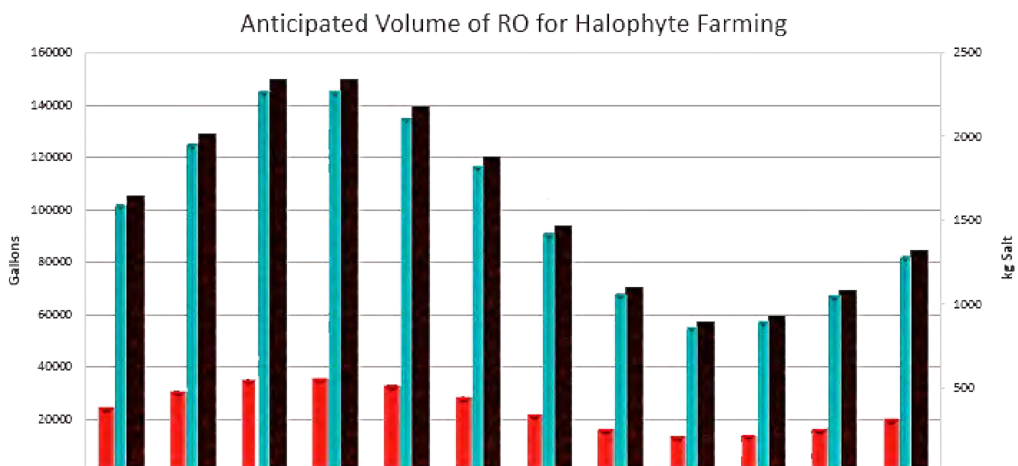
3.1. Irrigation Recommendations for Continuing the Project

Figure 34 and Figure 35 are projections for irrigation demands during the following year as the plants continue to grow and in 2017 after the plants reach maturity. These projections are based on the irrigation adjustment to 1.2 ETo on all plant rows, based on maximum biomass production.



	April	May	June	July	August	September	October	November	December	January	February	March
gal/week	13035	15966	18542	18579	17239	13823	12727	8684	7056	7353	8609	10497
gal/month	55400	67855	78805	78961	73266	58747	54092	36906	29990	31248	36587	44612
kg salt	838.851	1027.433	1193.230	1195.598	1109.362	889.523	819.036	558.811	454.097	473.153	553.982	675.496

Figure 34.—Irrigation projection from April 2016 – March 2017 with a projected adjustment to1.2 ETo for all plant rows in May 2016.



	April	May	June	July	August	September	October	November	December	January	February	March
gal/week	24727	30285	35173	35242	32700	28298	22065	16472	13385	13947	16330	19911
gal/month	105088	128713	149483	149780	138976	120266	93775	70006	56887	59275	69401	84623
kg salt	1591.203	1948.922	2263.420	2267.912	2104.332	1821.028	1419.912	1060.000	861.369	897.516	1050.840	1281.337

Figure 35.—Irrigation projection from April 2017 – March 2018 with an adjustment to 1.2 ETo for all plant showing volumes for plants at maturity.

We see a scaled-up production of *Atriplex spp*. irrigated with RO concentrate as a next step in furthering this line of research. Collaborating with the existing El Paso, Texas. RO plant and the planned Alamogordo, New Mexico, RO plant are two possible locations. To explore an interest in future collaborations based on the results of this on-going research project, Dr. Gallaher met with Bob Johnson, Project Manager, City of Alamogordo, regarding Alamogordo's plans for a municipal RO plant. Additional follow-up is needed.

3.2. Additional Research Needed

The production of *Atriplex spp*. as an agricultural crop irrigated with brackish groundwater also needs to be scaled up and studied to develop Best Management Practices for production, harvest, shipping and processing of the crop as a component of the animal feed industry.

Since brackish groundwater from BGNDRF was used to produce RO concentrate, their chemical compositions are similar (each containing a similar mix of cations and anions such as sodium, calcium sulfate, chloride and other trace contaminants) and the RO concentrate can serve as a 'proxy' for the use of brackish groundwater in halophyte crop production. Our study determined that these crops are viable in the Tularosa basin. Scaled-up production experiments will indicate the applicability of this treatment train to municipalities with existing or planned inland RO plants as well as brackish groundwater as a water source for future agricultural production and market potential. Future experiments will broaden the technology transfer applications of the research to include gardeners, farmers and agricultural-based communities with salt-effected groundwater as an irrigation source.

The study of the market potential for the *Atriplex* biomass, including its commercial acceptance in the animal feed industry, is another important component of furthering this research. This should address:

- Evaluate the sustainability and production potential of Atriplex sp. as a new agricultural crop using RO concentrate for irrigation in the Tularosa Basin
    - Evaluate the Atriplex plants' growth/health through maturity
    - Measure halophyte growth and biomass production
    - Evaluate soil sustainability and aquifer protection
    - Evaluate *Atriplex spp*. for phytostablization and rangeland revegetation

- Gain commercial use and acceptance of the halophyte biomass in the animal feed industry
    - With mature shrubs, conduct simulated harvests, nutrient value analyses, and digestibility evaluations
    - Based on the simulated harvest results, develop Best Harvest Practices for *Atriplex spp.*
    - Conduct economic/market analysis to identify market potential at the commodity feed scale, including potential niche markets in the personal and health care industry
    - Conduct preliminary feed lot trials to test rate of gain on cattle fed with a feed mix including Atriplex biomass vs conventional feed mix; based on results of preliminary feed lot trials, biomass testing, digestibility evaluations and outreach efforts, determine most cost-effective steps needed for commercial acceptance in Year 2, to include additional feed lot trials and collaborations with the local agricultural community and cattle growers
- Community and industry outreach

4. References

4.1. Academic and Research Outcomes

University student support and involvement included the services of three UA graduate students and an NMSU undergraduate student on the project:

Cylphine Bresdin, a UA Ph.D. graduate student worked under the direction of Dr. Ed Glenn (Co- PI on the project), Department of Soil, Water and Environmental Science, to produce the mass balance model and assist with other aspects of the project. This position was partially funded by UA Water, Environmental and Energy Solutions program (WEES) as UA matching funds for this research project.

Ryan Furcini, a UA master's degree student, assisted with the DAIC system data logger programming, soil sensor calibration and testing, neutron probe ports and other site installations.

Katia Gedrath-Smith, a UA master's degree student, assisted with AutoCAD bid document plans and production of a Research Update.

Reece Broughton, an NMSU–Alamogordo undergraduate student in Applied Science in Electronics Technology and Science, assisted with weekly irrigation meter readings, data organization and analysis, and installation of the soil sensors.

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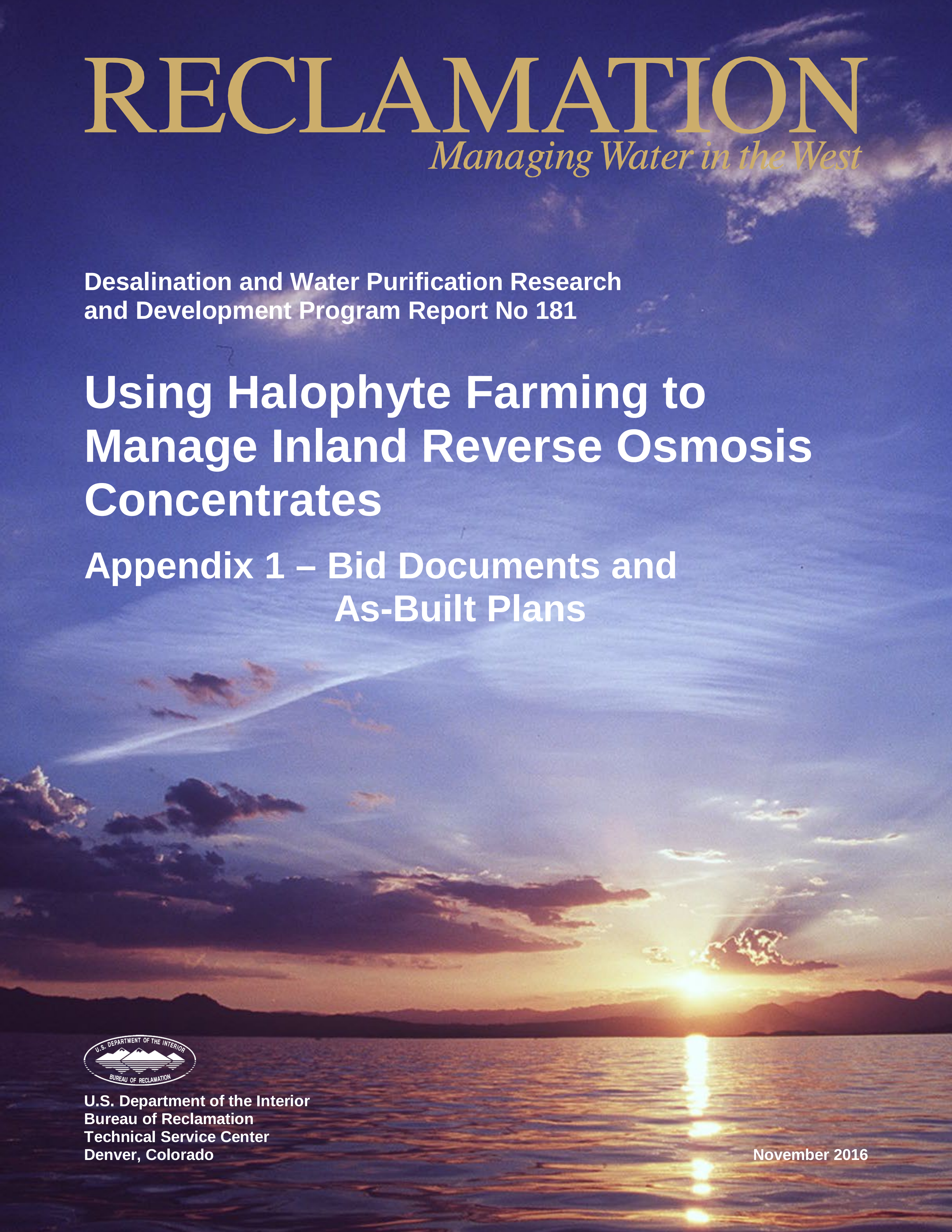


RECLAMATION

Managing Water in the West

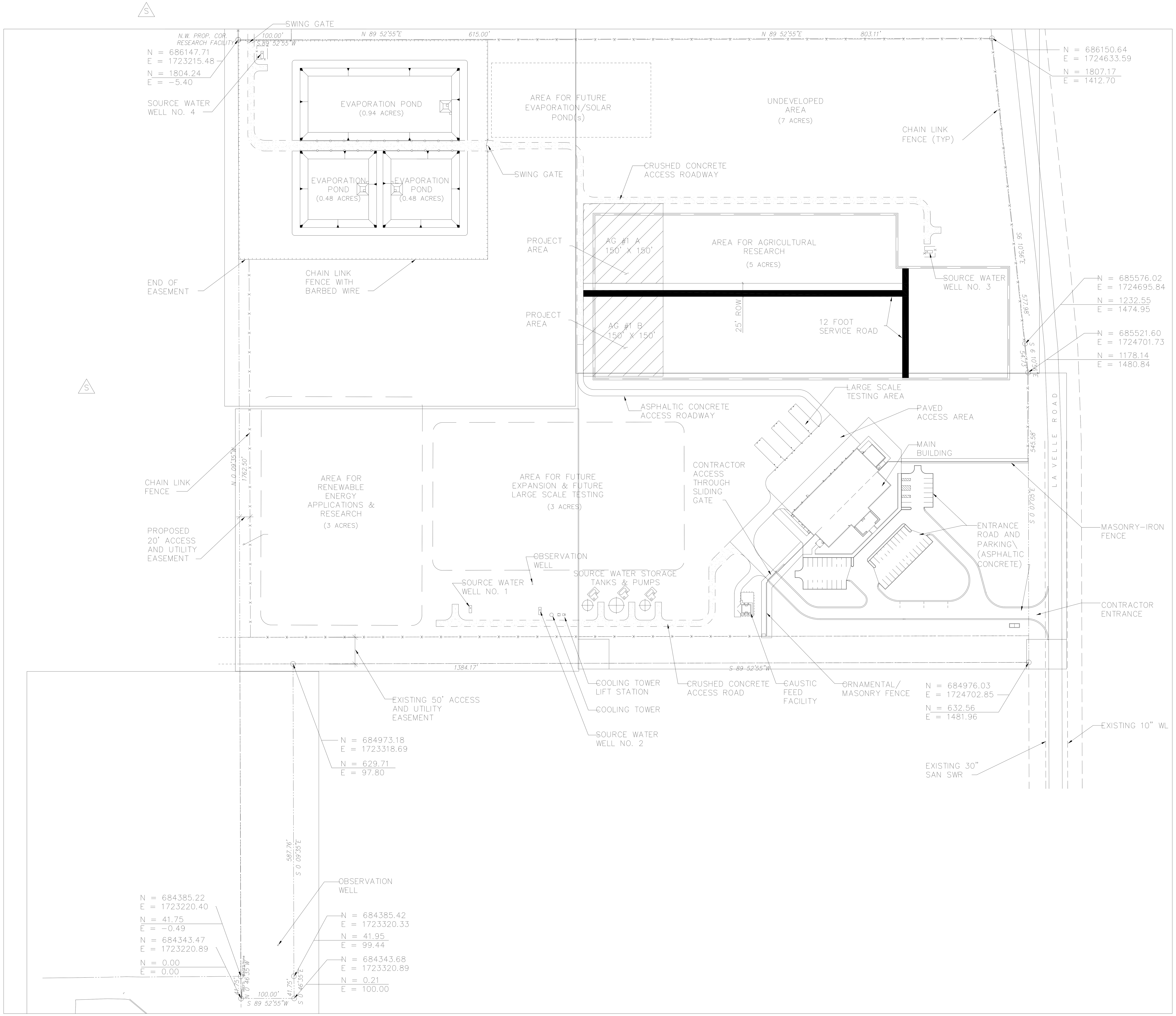
Desalination and Water Purification Research and Development Program Report No 181

Using Halophyte Farming to Manage Inland Reverse Osmosis Concentrates

Appendix 1 – Bid Documents and As-Built Plans

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2016



NOTE:

1. THE COORDINATES SHOWN AND NOTED ON THESE DRAWINGS ARE BASED ON A FACILITY COORDINATE SYSTEM DEVELOPED BY SETTING THE FAR SOUTHWEST CORNER OF THE PROPERTY TO 0.00, 0.00.

2. BENCH MARK:
HORIZONTAL – NEW MEXICO STATE PLANE COORDINATE SYSTEM, NAD83NM CENTRAL ZONE.

3" ALUMINUM CAP ON AN 18" REBAR SET IN CONCRETE, MARKED "COA 1996 A–28"

FROM THE INTERSECTION OF US 70 AND LA VELLE ROAD, PROCEED NORTH ON LA VELLE TO THE RAILROAD TRACKS. CONTINUE PAST THE TRACKS APPROXIMATELY 0.40 MILES TO THE EARTHEN DIKE. THE POINT IS LOCATED 250 FEET WEST OF LA VELLE ROAD AND 45 FEET SOUTH OF THE DIKE.

X = 1724533.52

Y = 684109.12

ELEVATION = 4272.25

LATITUDE = 32°52' 49.27021"N

LONGITUDE = 105°58' 33.57286"W

SCALE FACTOR: 0.9999010

COMBINED FACTOR: 0.999703709

GAMMA = 0"8'55.53"

VISIBLE STATION = NONE

3. VERTICAL – NGVD29
BENCHMARK IS SET IN THE TOP OF A CONCRETE POST WHICH PROJECTS 0.1 FEET ABOVE GROUND MARKED "ALAMOGORDO 4333.676 1932".

THE BENCHMARK IS LOCATED 122 FT NORTHEAST AT A SEMICIRCULAR PARK, 56.5 FT NORTH OF THE CENTERLINE OF TENTH STREET, 6.5 FEET NORTH OF THE NORTH EDGE OF A SIDEWALK, 26 FEET SOUTHEAST OF A 15–INCH CEDAR TREE, 3 FEET NORTH OF A CHAIN FENCE.

TBM: 1/2" REBAR NE PROPERTY CORNER

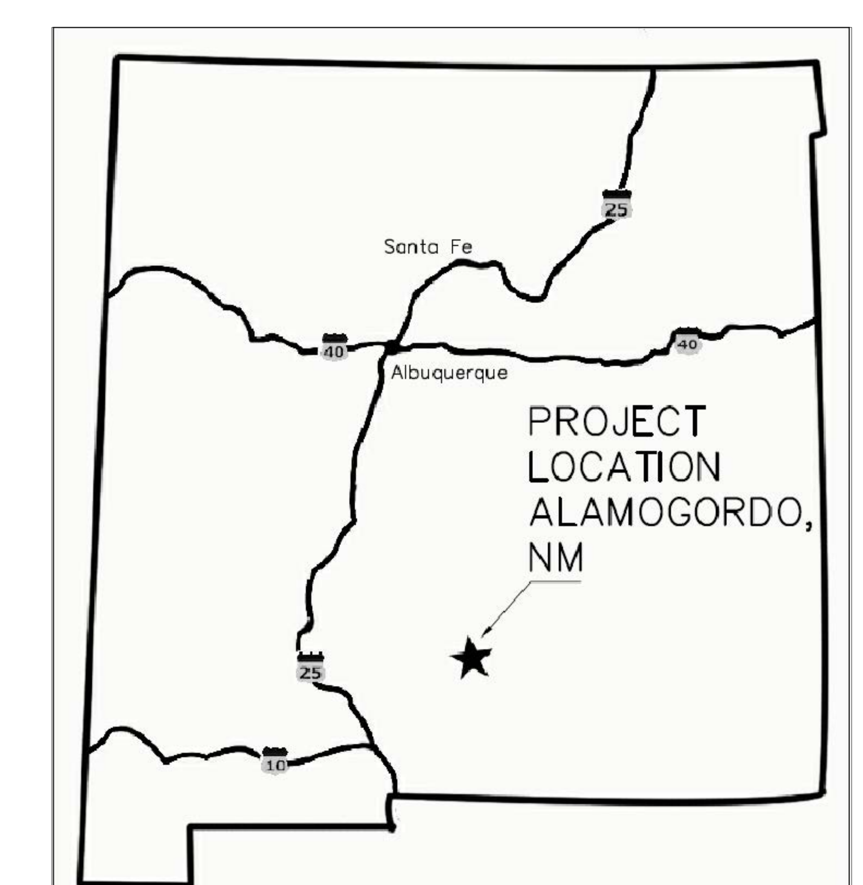
N: 686150.64

E: 1724633.59

1"x1"x8" OAK HUB SE PROPERTY CORNER

N: 684976.03

E: 1724702.85



NEW MEXICO

REVISIONS

NO.	BY	DATE	REMARKS

BUREAU OF RECLAMATION

As–Built No Changes | WILLIAM BELLER
As–Built With Changes

DES. ______
DWN. ______
CKD. ______

U.S. DEPARTMENT OF THE INTERIOR · BUREAU OF RECLAMATION

Brackish Groundwater National Desalination Research Facility
Alamogordo, NM

University of Arizona
Reverse Osmosis Concentrate Management Through Halophyte Farming

AS–BUILT PLANS– PROJECT LOCATION
SCALE: 1"=100'

DATE November 1, 2016

SHEET 1 OF 8

CAD REF. NO. ______

REVISIONS			
NO.	BY	DATE	REMARKS

BUREAU OF RECLAMATION

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As-Built With Changes

U.S. DEPARTMENT OF THE INTERIOR — BUREAU OF RECLAMATION

Brackish Groundwater National Desalination Research Facility
Alamogordo, NM

University of Arizona
Reverse Osmosis Concentrate Management Through Halophyte Farming

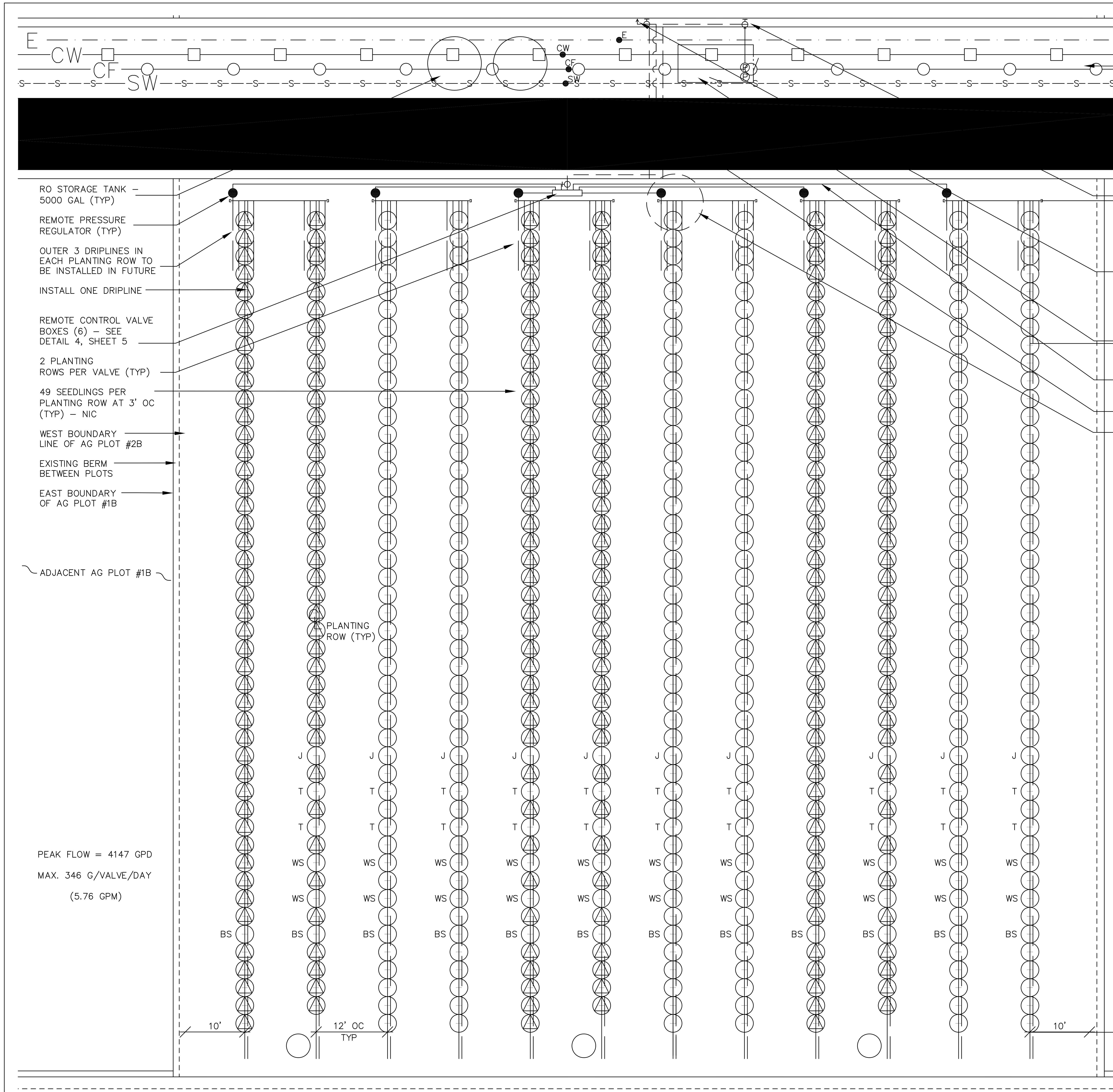
AS-BUILT PLANS– AGRICULTURAL RESEARCH AREA – EXISTING INFRASTRUCTURE

0 15' 30' 60'

DATE NOVEMBER 1, 2016

SHEET 2 OF 8

CAD REF. NO.

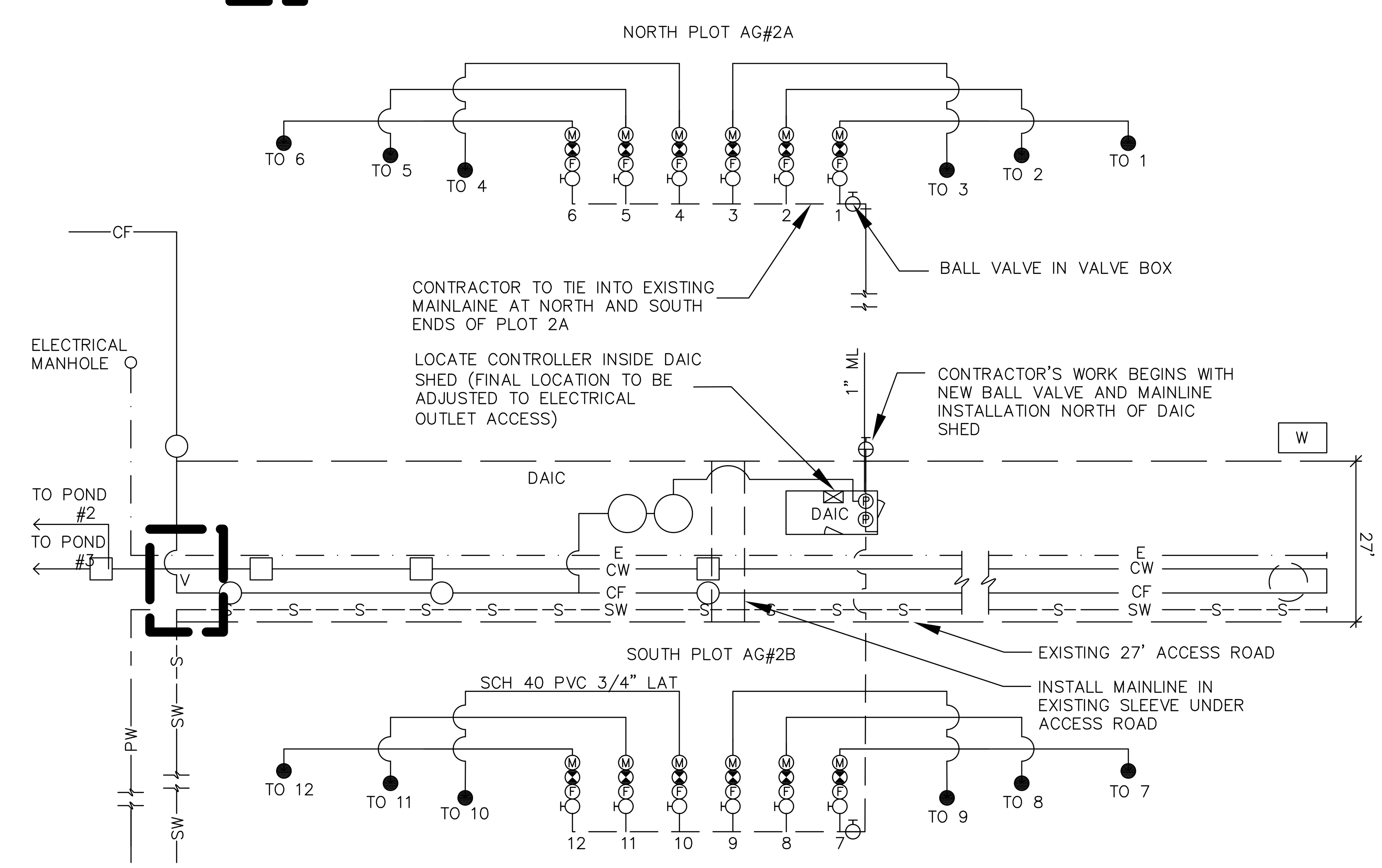


NOTES:
1. DO NOT DISTURB SUBSURFACE DRAINAGE SYSTEM – SEE AS-BUILT INFORMATION ON SHEET 4
2. SOUTH PLOT (#2B) SHOWN – REPEAT IRRIGATION SYSTEM ON NORTH PLOT (#2A) – SEE IRRIGATION SCHEMATIC – DETAIL 1, THIS SHEET
3. CONTRACTOR TO TIE INTO EXISTING MAINLINE IN NORTH FIELD TRENCH, APPROXIMATELY 2'-6" DEEP
4. CONTRACTOR SHALL INSTALL NEW IRRIGATION MAINLINE (AND CONNECT TO EXISTING IRRIGATION MAINLINE LOCATED IN NORTH PLOT (2A) TRENCH, AS INDICATED ON THE PLANS AND MARKED IN THE FIELD) AND ASSOCIATED IRRIGATION EQUIPMENT AS SHOWN ON THE PLANS.
5. ALL OTHER REQUIRED IRRIGATION SYSTEM EQUIPMENT SHALL BE PROVIDED BY THE CONTRACTOR EXCEPT THE POLY DRIPLINE SYSTEM COMPONENTS, WHICH SHALL BE PROVIDED BY THE OWNER.
6. IRRIGATION PLANS ARE SCHEMATIC. ALL EQUIPMENT IS TO BE STAKED IN THE FIELD PRIOR TO TRENCHING FOR APPROVAL BY THE OWNER'S REPRESENTATIVE
7. ALL IRRIGATION EQUIPMENT IS TO BE PRESSURE TESTED, ANY LEAKS REPAIRED, AND EQUIPMENT SHALL BE FUNCTIONAL AND IN WORKING ORDER. CONTRACTOR TO COORDINATE A SITE INSPECTION AND RECEIVE THE APPROVAL OF THE OWNER'S REPRESENTATIVE PRIOR TO BACKFILLING THE TRENCHES.
8. CONTRACTOR TO PROVIDE CONTROLLER PROGRAM COPIES TO THE OWNER'S REPRESENTATIVE UPON PROJECT COMPLETION.

SYMBOL	EXISTING INFRASTRUCTURE
— E —	ELECTRICAL
— CW —	CONCENTRATE WASTE
— CF —	CONCENTRATE FEED – MAIN IRRIGATION SOURCE WATER
—S— SW —S—	WELL WATER – BACK UP IRRIGATION SOURCE WATER
— PW —	POTABLE WATER
○	5000 GAL TANK
Ⓟ	PRESSURIZATION SYSTEM – TANK/PUMP
	EXISTING MAINLINE BALL VALVE
	FUTURE 5000 GAL TANK
W	EXISTING WELL #3
DAIC	DATA ACQUISITION AND INTELLIGENCE CONTROL SYSTEM SHED
V	UTILITY VAULT

SYMBOL	NEW IRRIGATION SYSTEM
	CONTROLLER – SEE SPECS
	EXISTING MAINLINE
	NEW MAINLINE – SCH 40 PVC – 1"
	NEW LATERAL LINE – SCH 40 PVC – ¾"
Ⓜ	FLOW METER
	MAINLINE BALL VALVE
	BALL VALVE
	REMOTE CONTROL VALVE
Ⓕ	FILTER
●	REMOTE PRESSURE RGULATOR
	UTIILITY STUB-OUTS

SYMBOL	PLANT SPECIES
	ATRIPLEX CONESCENS – FUTURE (NIC)
	ATRIPLEX LENTIFORMIS – FUTURE (NIC)



1 IRRIGATION SCHEMATIC
SCALE:NTS

NO.	BY	DATE	REMARKS

REVISIONS

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As-Built With Changes

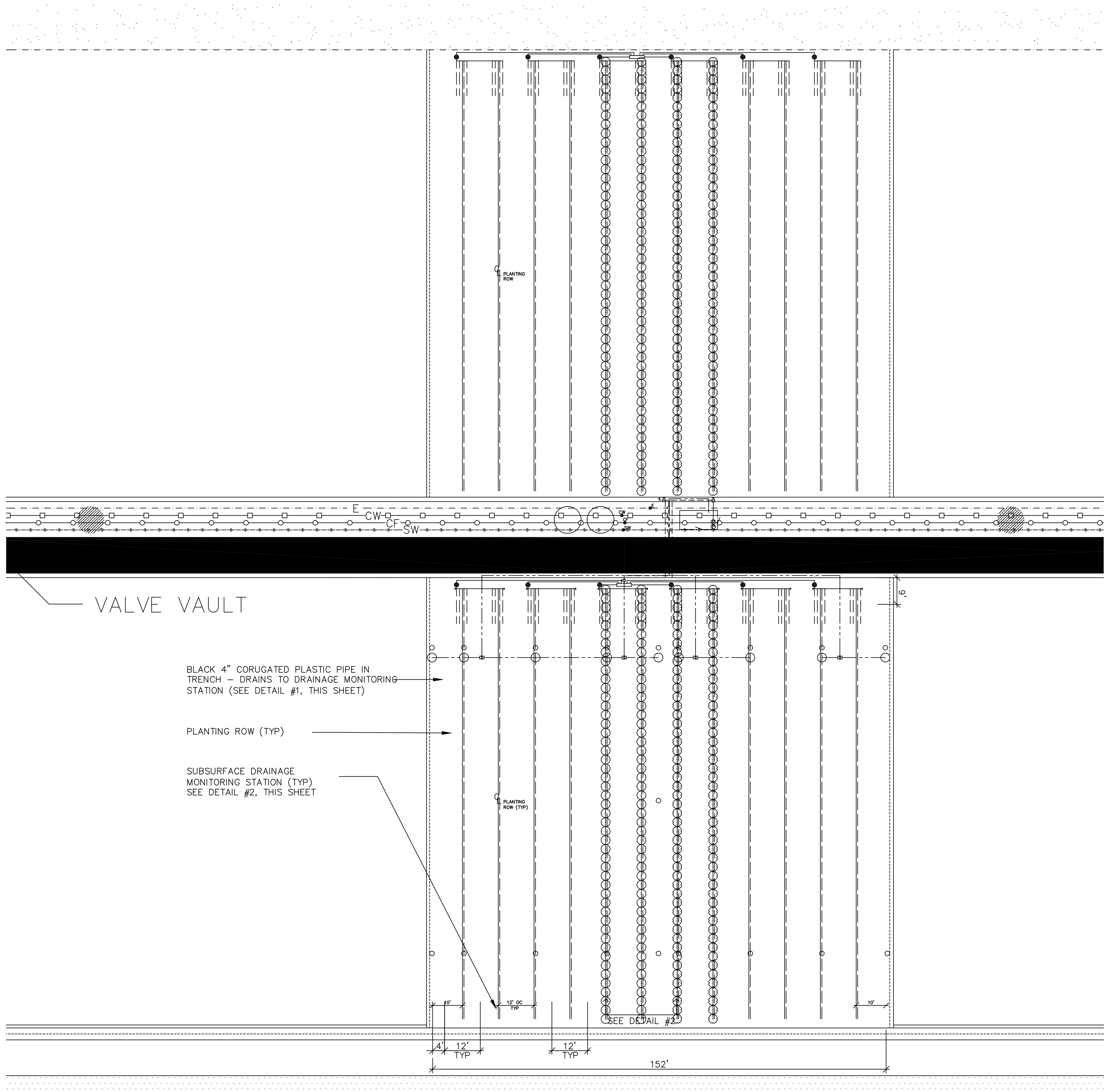
Brackish Groundwater National Desalination Research Facility
Alamogordo, NM

University of Arizona
Reverse Osmosis Concentrate Management Through Halophyte Farming

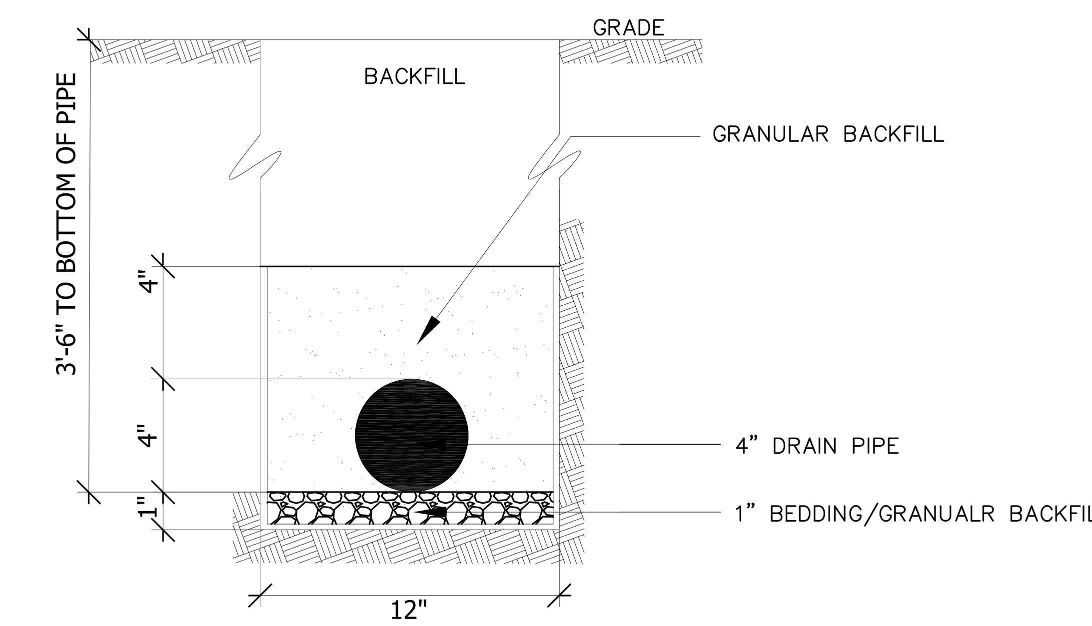
AS-BUILT PLAN- IRRIGATION LAYOUT: AG #2B (AG #1B SIMILAR)

0 5' 10' 20'

DATE NOVEMBER 1, 2016
SHEET 3 OF 8
CAD REF. NO.

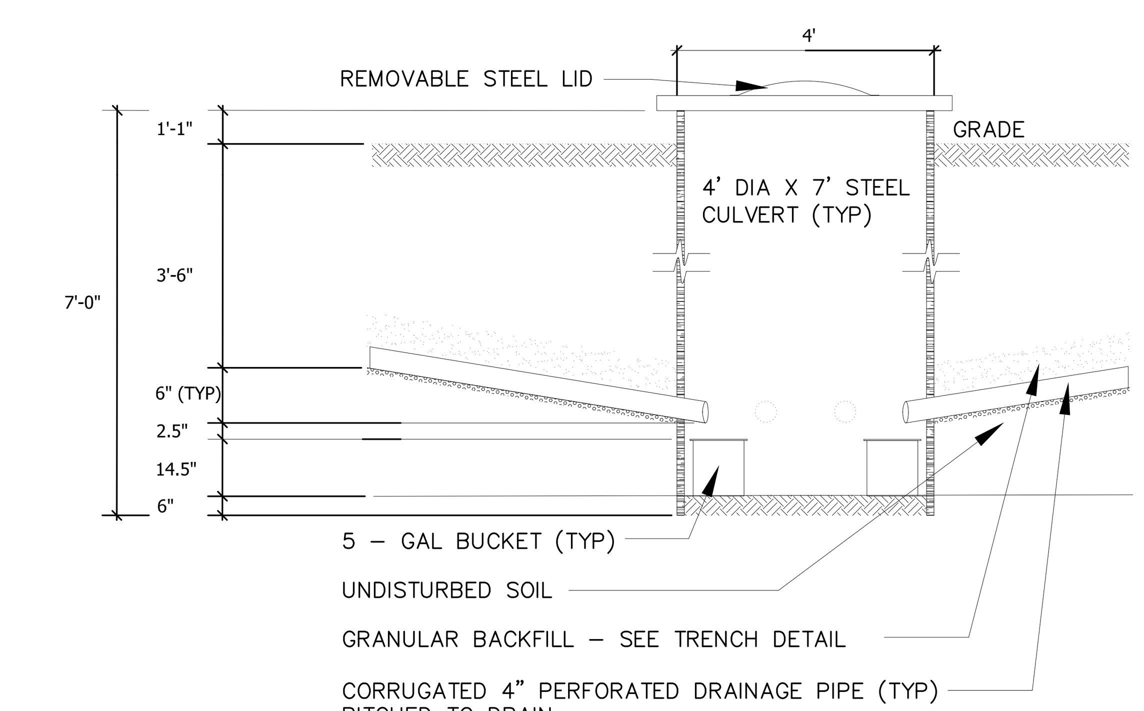


NOTE: MAINTAIN SET GRADE FROM SURFACE TO BOTTOM OF TRENCH; CLEAN TRENCH AND LAY PIPE ON 1" GRAVEL BED SO PIPE DRAINS AT CONSTANT SLOPE TO OUTLET



1 DRAINAGE TRENCH

SCALE:NTS



2 SUBSURFACE DRAINAGE MONITORING STATION

SCALE:NTS

REVISIONS			
NO.	BY	DATE	REMARKS
BUREAU OF RECLAMATION			
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As-Built With Changes			

Brackish Groundwater National Desalination Research Facility Alamogordo, NM

University of Arizona Reverse Osmosis Concentrate Management Through Halophyte Farming

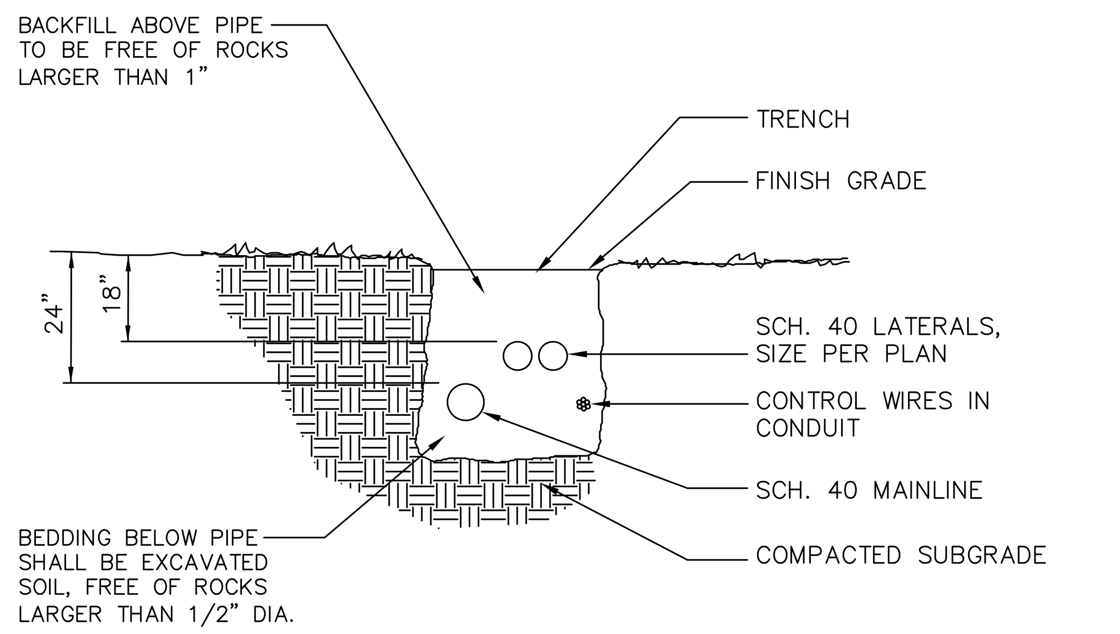
AS–BUILT PLAN– SUBSURFACE DRAINAGE SYSTEM

0 10' 20' 40'

DATE NOVEMBER 1, 2016

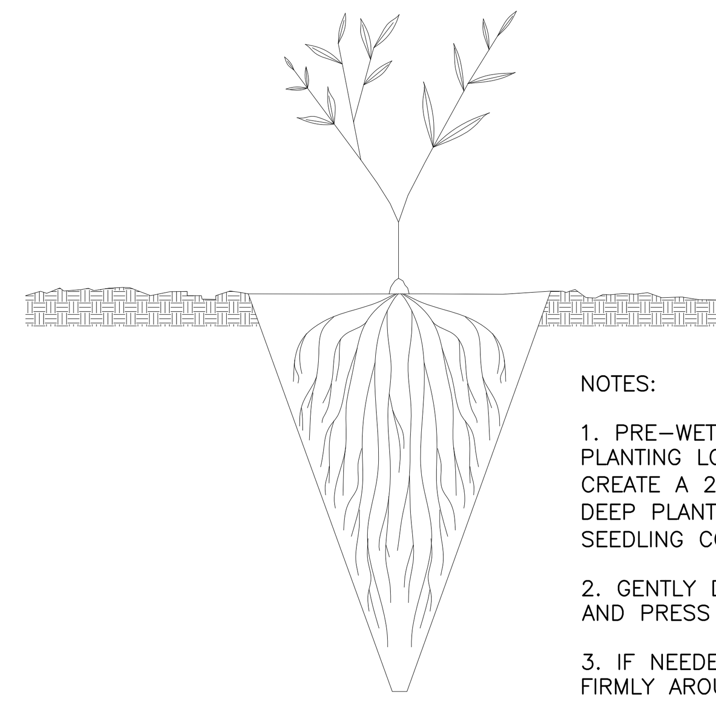
SHEET 4 OF 8

CAD REF. NO.



NOTE:
ALL MAINLINES TO BE INSTALLED IN ACCORDANCE W/ MANUFACTURER'S SPECIFICATIONS.

1 IRRIGATION TRENCHING
SCALE:NTS



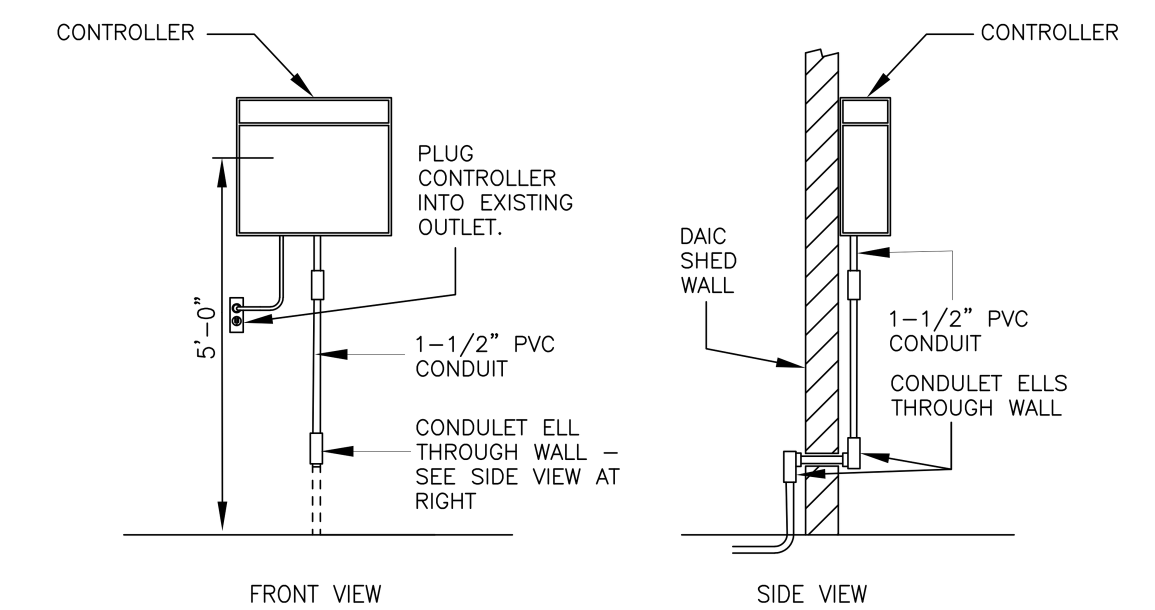
NOTES:

1. PRE-WET GROUND AROUND SEEDLING PLANTING LOCATION. USING A DIGGING BAR, CREATE A 2 1/2" (DIAMETER) BY 6" (OR 12") DEEP PLANTING HOLE (SLIGHTLY LARGER THAN SEEDLING CONTAINER)
2. GENTLY DISLODGE SEEDLING FROM CONTAINER AND PRESS INTO HOLE
3. IF NEEDED, USE BAR TO CLOSE HOLE FIRMLY AROUND ROOTS WITH SEEDLING IN A VERTICAL POSITION. SEEDLINGS SHALL BE WATERED IMMEDIATELY AFTER PLANTING

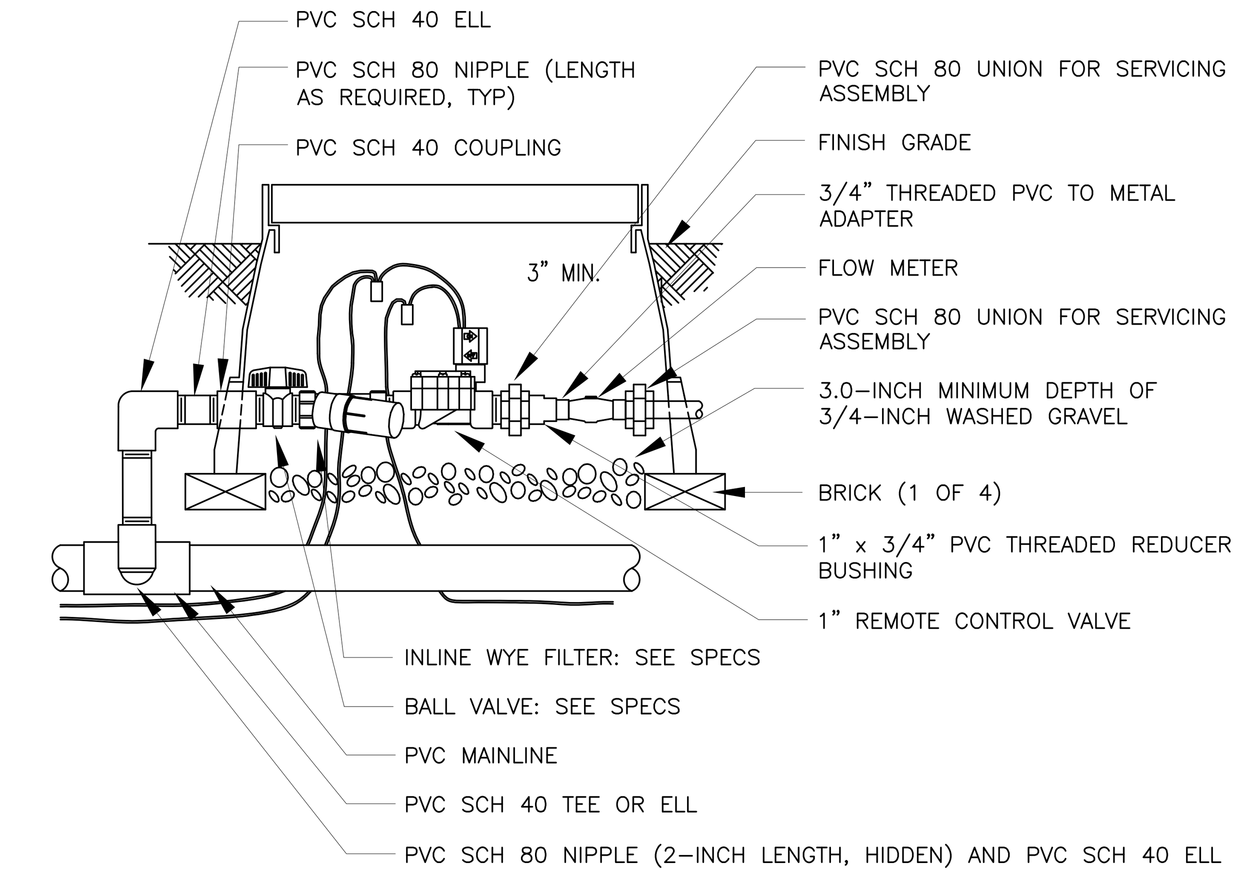
2 PLANTING DETAIL - NIC
SCALE:NTS

NOTES:

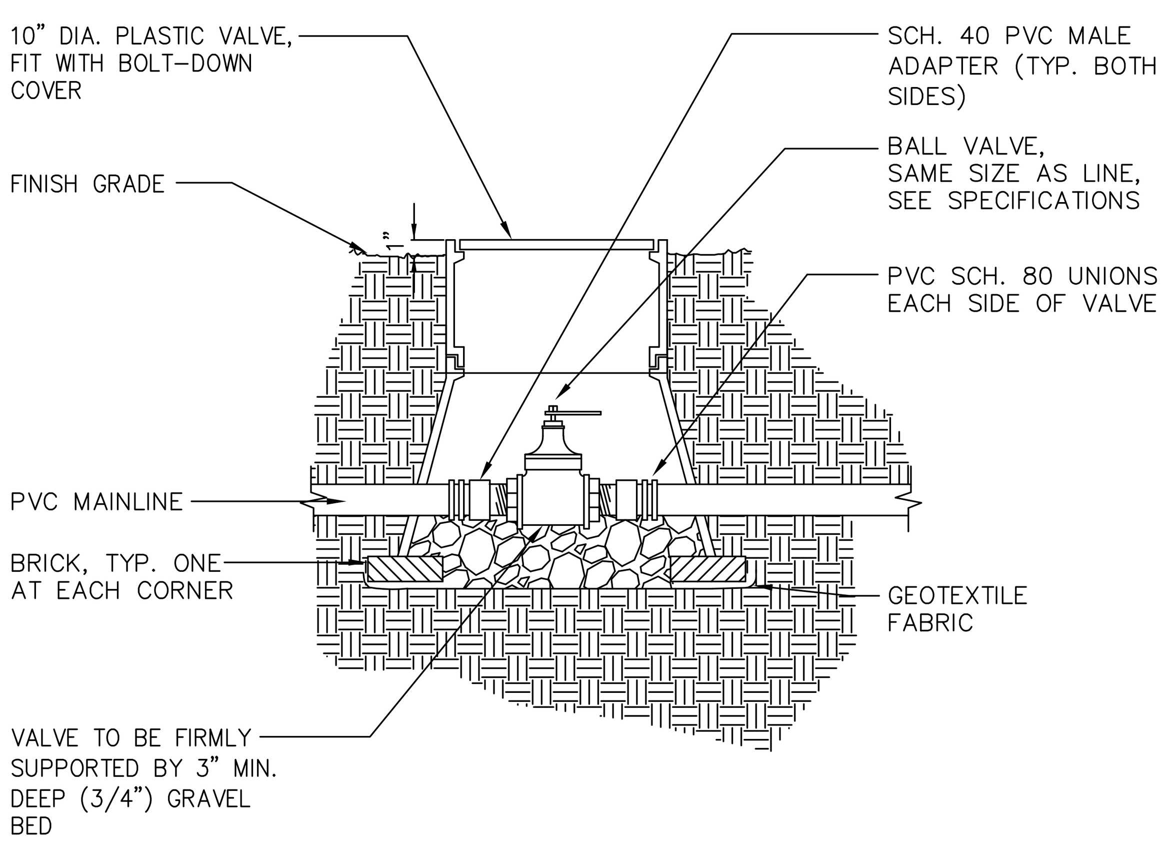
1. FINAL CONTROLLER LOCATION INSIDE DAIC SHED, NEAR ELECTRICAL OUTLET
2. SEE SPECS FOR CONTROLLER INFORMATION.
3. PLUG CONTROLLER INTO A GFCI OUTLET 120 VAC POWER SUPPLY



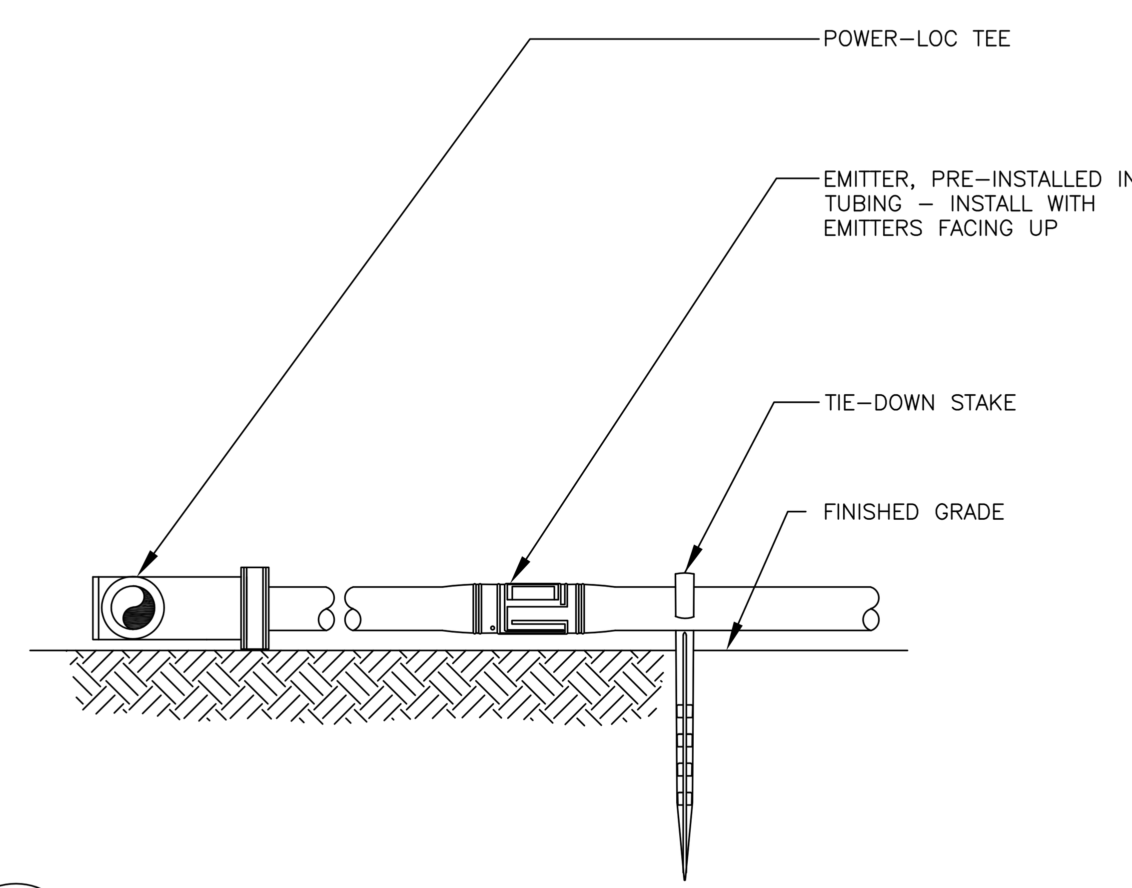
3 WALL MOUNTED CONTROLLER
SCALE:NTS



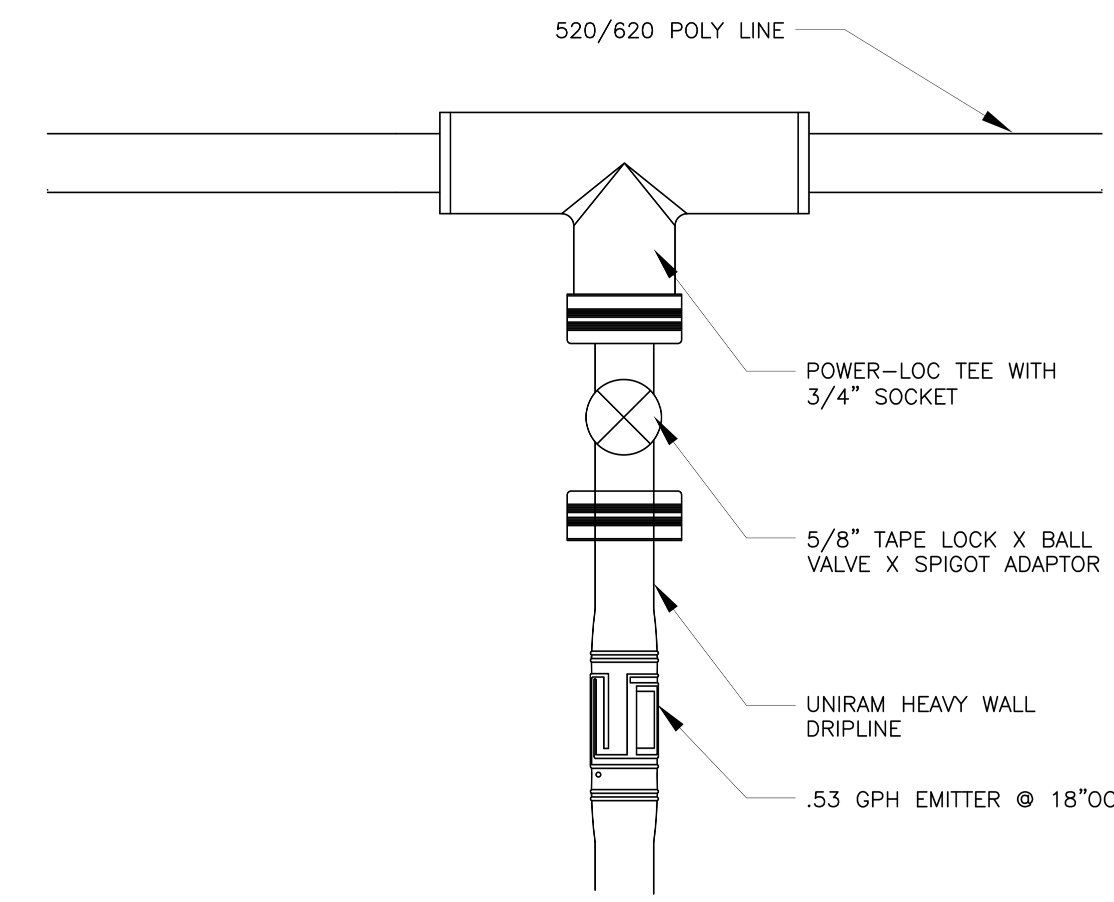
4 VALVE BOX
SCALE:NTS



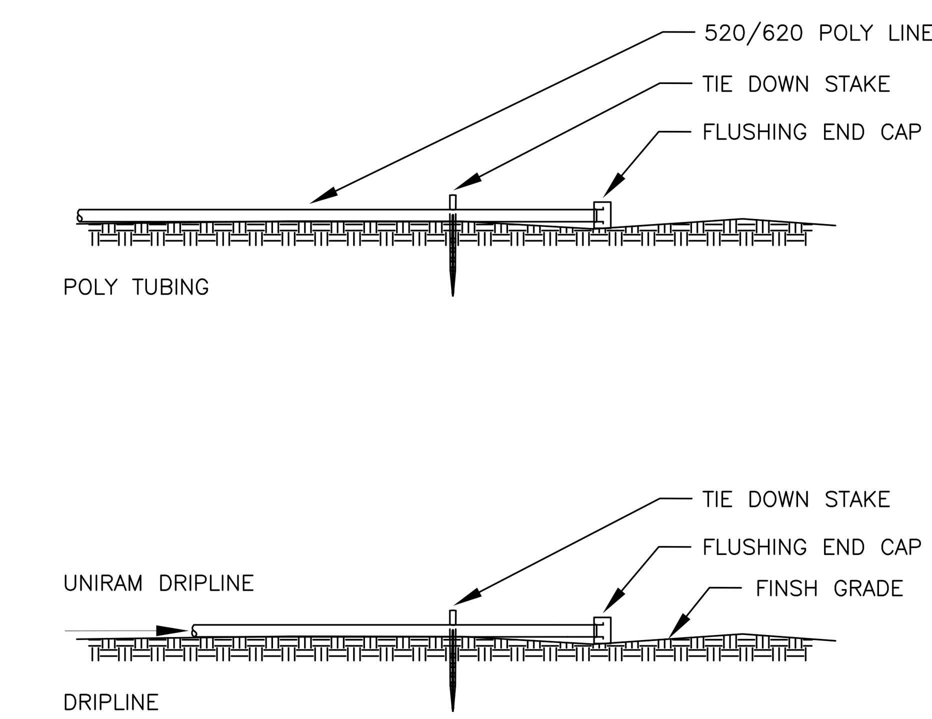
5 MAIN LINE BALL VALVE DETAIL
SCALE:NTS



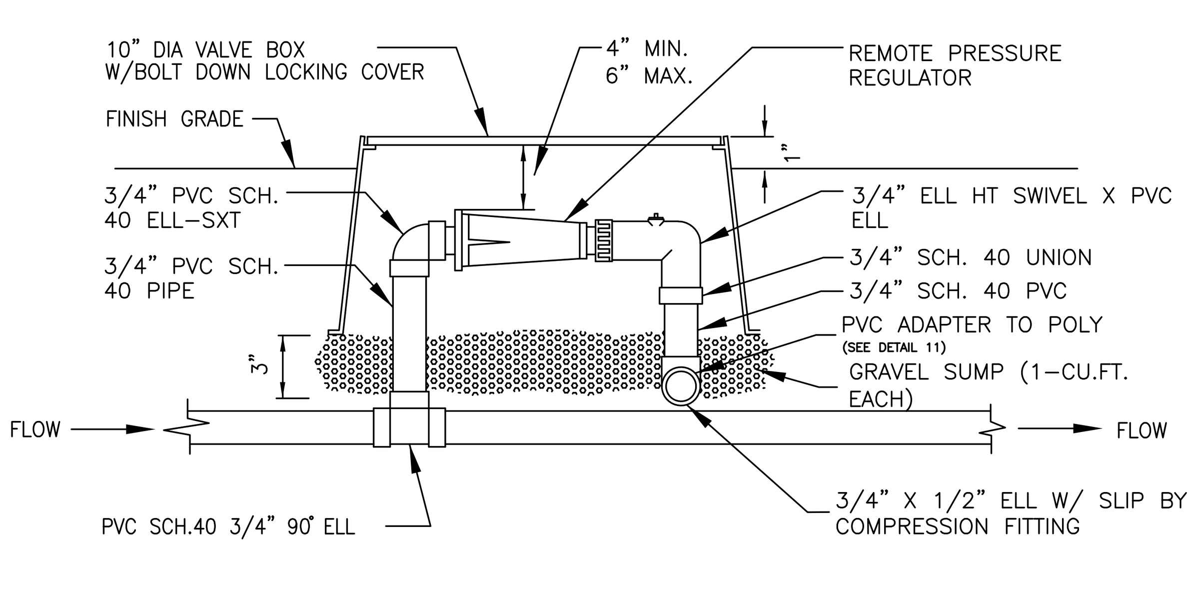
6 DRIPLINE INSTALLATION DETAIL
SCALE:NTS



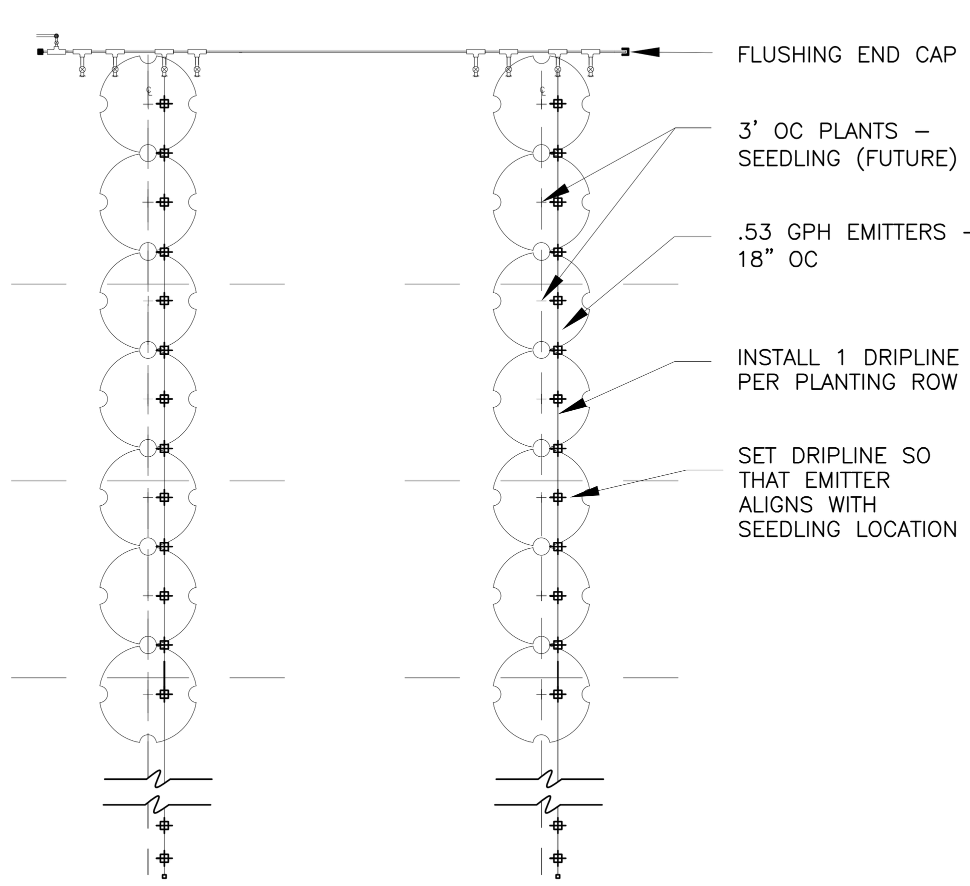
7 LANDSCAPE DRIPLINE LAYOUT
SCALE: NTS



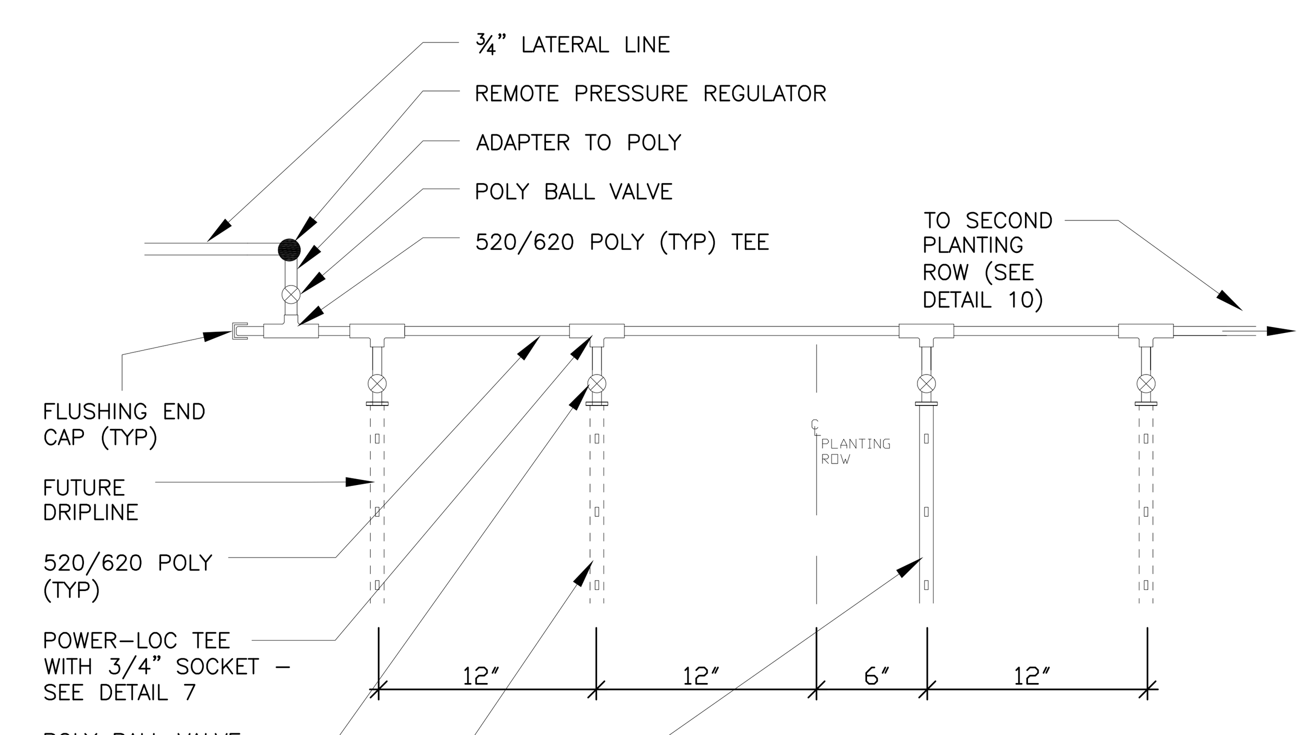
8 FLUSHING ENDCAP DETAIL
SCALE:NTS



9 REMOTE PRESSURE REGULATOR
SCALE:NTS



10 TYPICAL DRIPLINE LAYOUT - 2 PLANTING ROWS PER VALVE
SCALE:NTS



NOTE:
ALL POLY CONNECTION PARTS AND DRIPLINE TO BE PROVIDED BY OWNER

11 TYPICAL DRIPLINE LAYOUT - PLANTING ROW
SCALE:NTS

NO.	BY	DATE	REMARKS

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DES. ______
DWN. ______
CKD. ______

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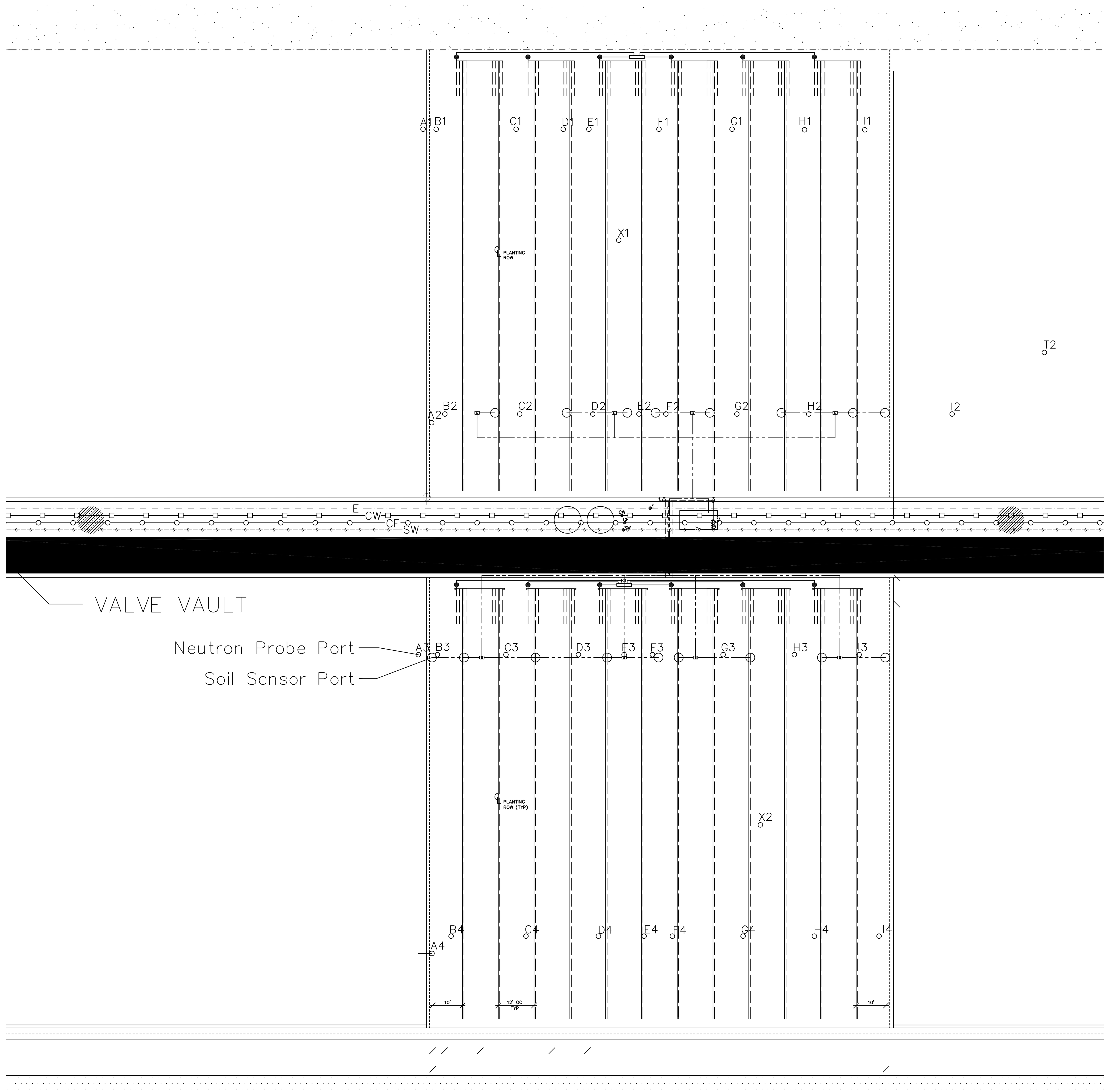
Reverse Osmosis Concentrate Management Through Halophyte Farming

AS-BUILT PLAN-IRRIGATION DETAILS

DATE NOVEMBER 1, 2016

SHEET 5 OF 8

CAD REF. NO. ______



NORTH FIELD			SOUTH FIELD		
NP PORT location measurments in feet relative to each other					
PORT	X	Y		X	Y
A2	0	0	A4	0	0
B2	4.4	2.9	B4	6.4	5.8
C2	29.5	2.9	C4	31.5	5.8
D2	54	2.9	D4	55.8	5.8
E2	69.5	2.9	E4	71.1	5.8
F2	78.5	2.9	F4	80.6	5.8
G2	102.3	2.9	G4	104.3	5.8
H2	126.4	2.9	H4	128.2	5.8
I2	147.5	2.9	I4	149.9	5.8
T2	205.4	23.53			
X1	62.7	61.2	X2	110.1	43.1
A1	-2.9	98.4	A3	-4.6	100.2
B1	4.4	98.4	B3	6.4	100.2
C1	31.2	98.4	C3	29.4	100.2
D1	47	98.4	D3	53.7	100.2
E1	55.6	98.4	E3	69	100.2
F1	79.1	98.4	F3	78.5	100.2
G1	103.6	98.4	G3	102.2	100.5
H1	127.9	98.2	H3	126.1	100.5
I1	148.1	98.2	I3	147.8	100.5
Note: Y measurments are approximate and not tied to any markers					
Measuremnts made with 100' tape on March 15, 2016 by LW and JA					

Instructions: North and south fields are measured separately. The Southwest probe in each field is used as the point of reference (0,0). So the X values are in feet to the east of (0,0) and Y is north of (0,0).

REVISIONS			
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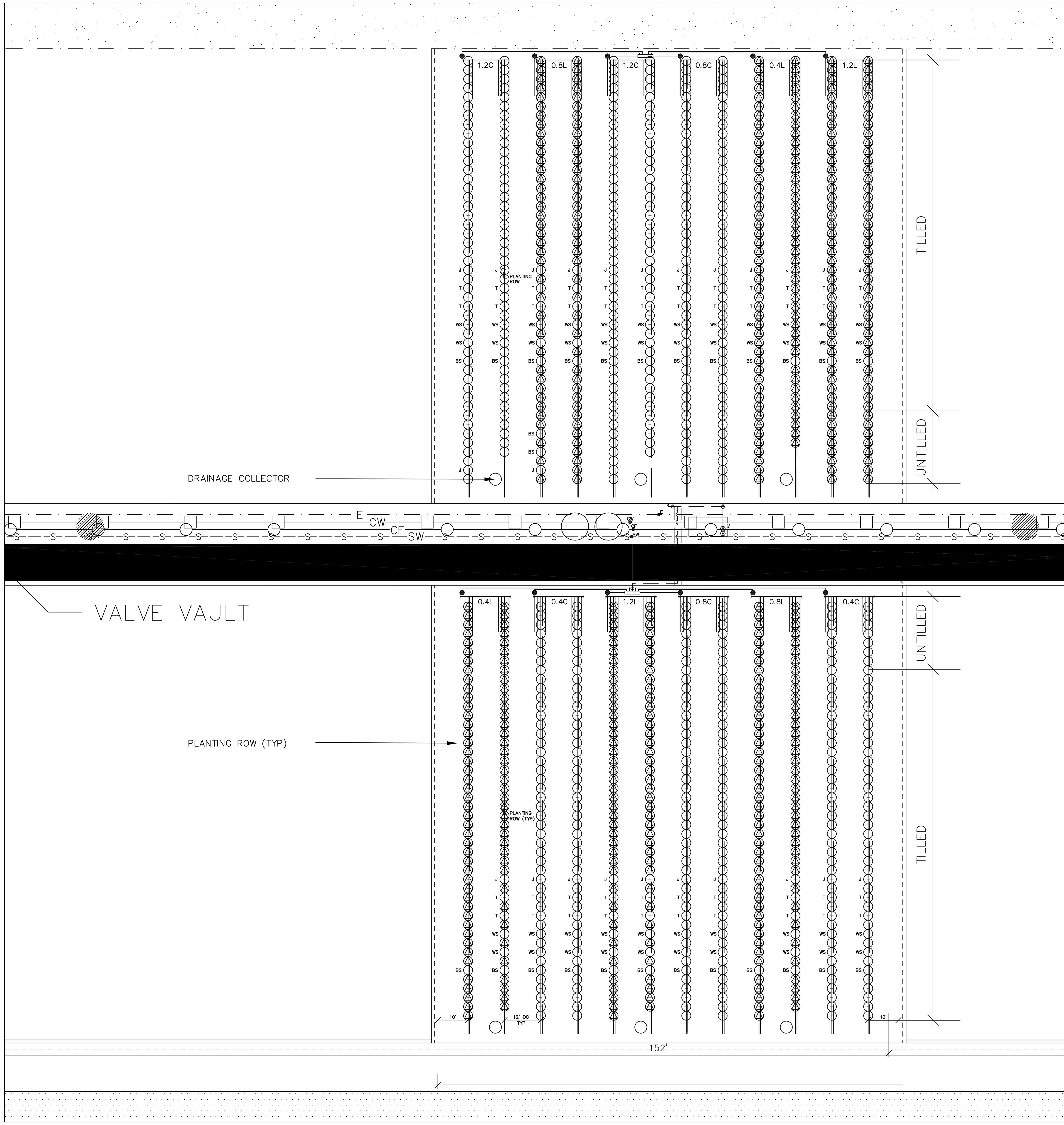
AS-BUILT
PLAN-NEUTRON PROBE PORTS AND SOIL SENSOR LOCATIONS

N
0 10' 20' 40'

DATE NOVEMBER 1, 2016

SHEET 6 OF 8

CAD REF. NO.



Seedling layout - from north to south in each row
September 4 2014

N field

	1.2 ET - C x	1.2 ET - C x	0.8 ET - L x	0.8 ET - L x	1.2 ET - C x	1.2 ET - C x	0.8 ET - C x	0.8 ET - C x	0.4 ET - L x	0.4 ET - L x	1.2 ET - L x	1.2 ET - L x	TOT lent	cans	
A lentiformis	0	0	38	41	0	0	0	0	41	38	41	41	240		
A canescens WMSD	40	37	0	0	41	38	41	41	0	0	0	0		238	
A canescens T	2	2	2	2	2	2	2	2	2	2	2	2		24	
A canescens WS	2	2	2	2	2	2	2	2	2	2	2	2		24	
A canescens BSF	1	2	3	1	1	1	1	1	1	1	1	1		15	
A canescens J	2	1	2	1	1	1	1	1	1	1	1	1		14	
	47	44	47	47	47	44	47	47	47	44	47	47	240	315	555 total N field

S field

	0.4 ET - L x	0.4 ET - L x	0.4 ET - C x	0.4 ET - C x	1.2 ET - L x	1.2 ET - L x	0.8 ET - C x	0.8 ET - C x	0.8 ET - L x	0.8 ET - L x	0.4 ET - C x	0.4 ET - C x			
A lentiformis	46	40	0	0	41	40	0	0	46	41	0	0	254		
A canescens WMSD	0	0	41	41	0	0	41	41	0	0	41	41		246	
A canescens T	0	2	2	2	2	2	2	2	0	2	2	2		20	
A canescens WS	0	2	2	2	2	2	2	2	0	2	2	2		20	
A canescens BSF	1	1	1	1	1	1	1	1	1	1	1	1		12	
A canescens J	0	1	1	1	1	1	1	1	0	1	1	1		10	
	47	46	47	47	47	46	47	47	47	47	47	47	254	308	562 total S field
													494 L		623 C
															1117 total planted
															1117

KEY:

1.2 ET - C — 1.2 ET rate - Atriplex canescens
0.8 ET - L — 0.8 ET rate - Atriplex lentiformis

KEY

= A. Lentiformis
= A. Canescens West Mesa Sands Dunes
T = A. Canescens Tularosa
WS = A. Canescens White Sands
BS = A. Canescens Brackish Salt Flat
J = A. Canescens Jornada

NOTE: SEE AS-BUILT PLANTING AGE CHART, APP. 6 FOR UPDATED REPLACEMENT PLANTINGS

REVISIONS

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Reverse Osmosis Concentrate Management Through Halophyte Farming

AS-BUILT PLAN—PLANTING PLAN

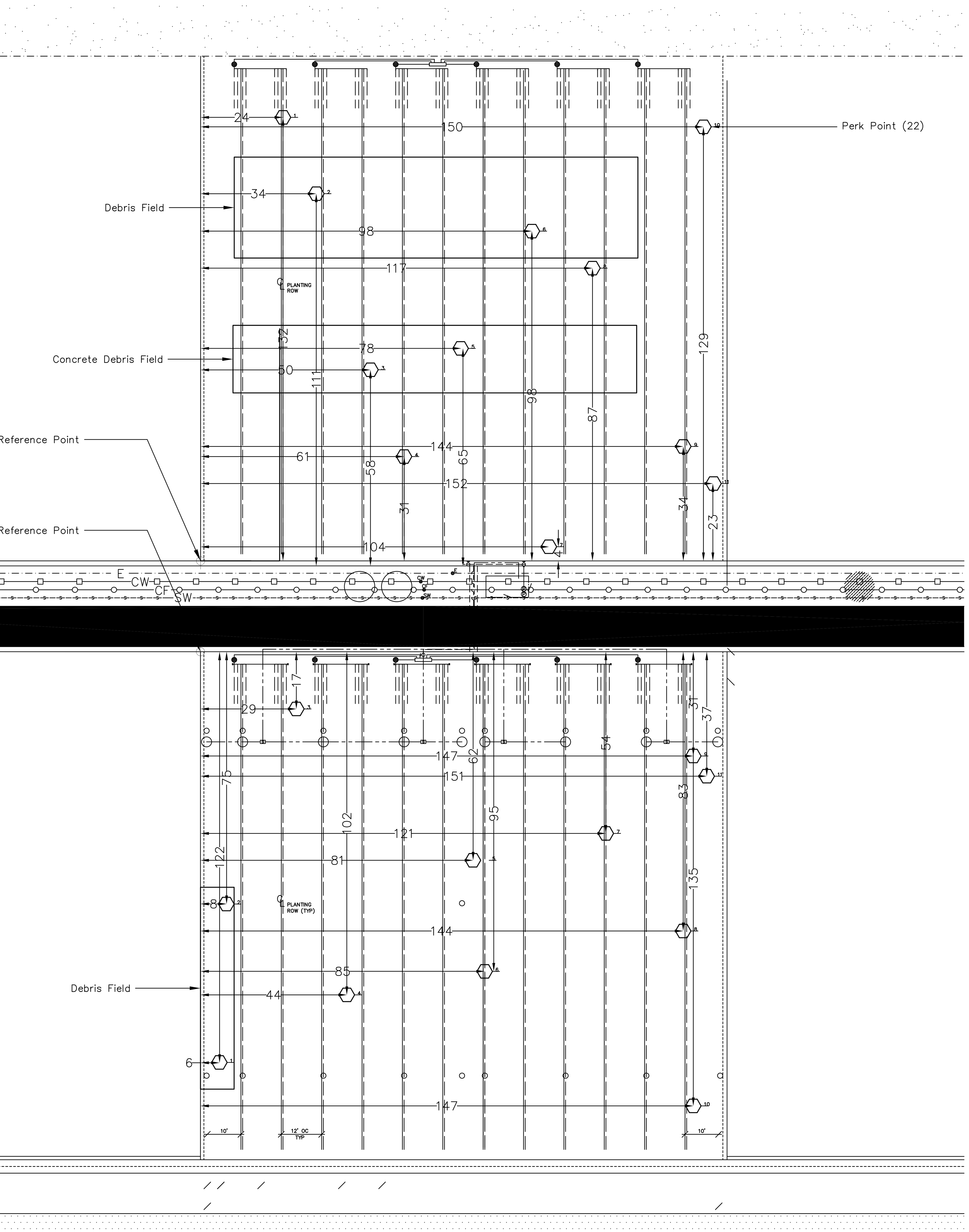
0 10' 20' 40'

DATE NOVEMBER 1, 2016
SHEET 7 OF 8
CAD REF. NO.

Perk Point Location Table

North Site

Hole #	East (ft)	North (ft)
1	24	132
2	34	111
3	50	58
4	61	31
5	78	65
6	98	98
7	104	4
8	117	87
9	144	34
10	150	129
11	152	23



Perk Point Location Table

South Site

Hole #	East (ft)	South (ft)
1	6	122
2	8	75
3	29	17
4	44	102
5	81	62
6	85	95
7	121	54
8	144	83
9	147	31
10	147	135
11	151	151

REVISIONS

NO.	BY	DATE	REMARKS

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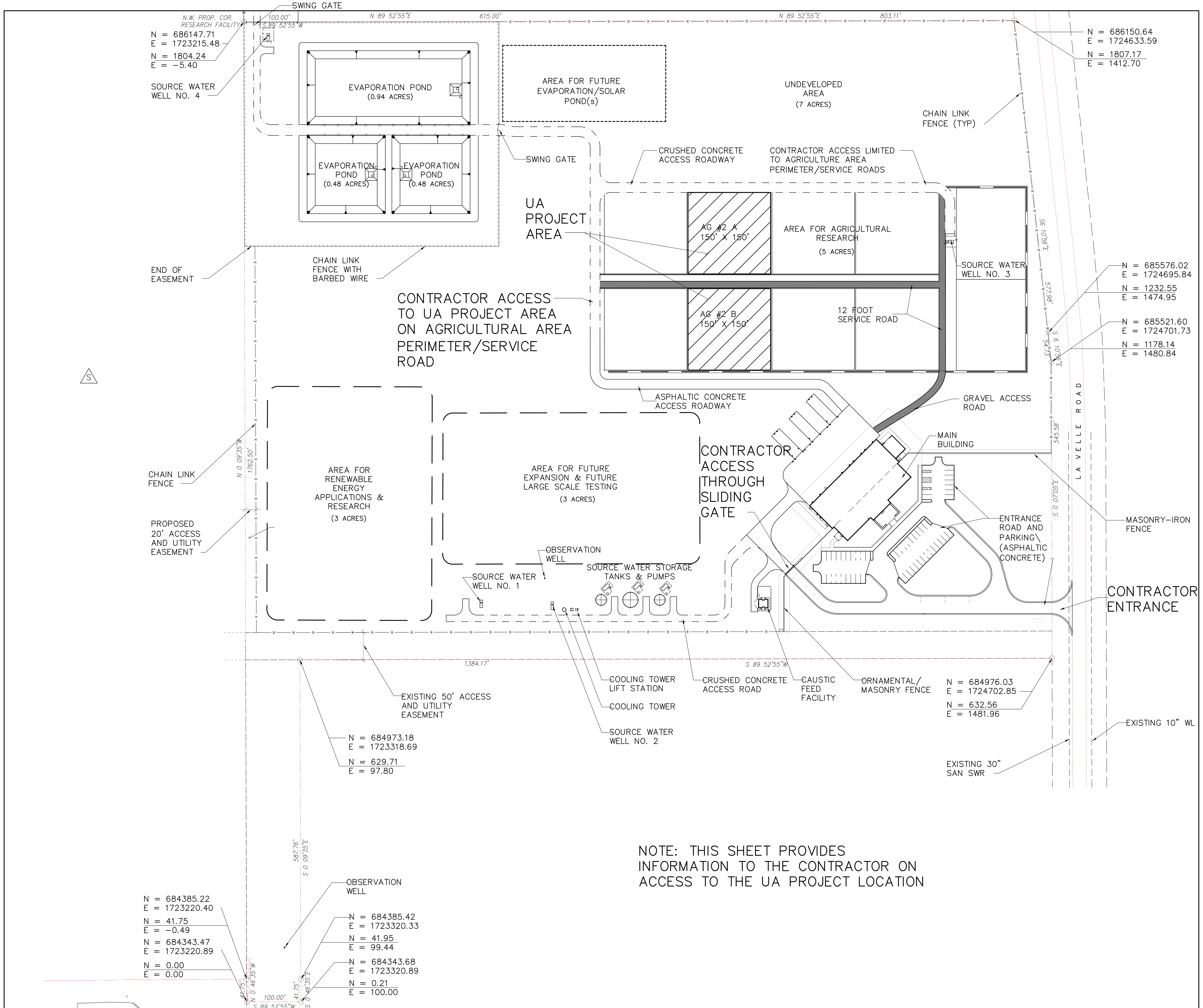
AS-BUILT PLAN—
SOIL INFILTROMETER POINT LOCATION

0 10' 20' 40'

DATE NOVEMBER 1, 2016

SHEET 8 OF 8

CAD REF. NO.



SURVEY NOTES:

1. THE COORDINATES SHOWN AND NOTED ON THESE DRAWINGS ARE BASED ON A FACILITY COORDINATE SYSTEM DEVELOPED BY SETTING THE FAR SOUTHWEST CORNER OF THE PROPERTY TO 0.00, 0.00.

2. BENCH MARK:
HORIZONTAL – NEW MEXICO STATE PLANE COORDINATE SYSTEM, NAD83NM CENTRAL ZONE.

3" ALUMINUM CAP ON AN 18" REBAR SET IN CONCRETE, MARKED "COA 1996 A-28"

FROM THE INTERSECTION OF US 70 AND LA VELLE ROAD, PROCEED NORTH ON LA VELLE TO THE RAILROAD TRACKS. CONTINUE PAST THE TRACKS APPROXIMATELY 0.40 MILES TO THE EARTHEN DIKE. THE POINT IS LOCATED 250 FEET WEST OF LA VELLE ROAD AND 45 FEET SOUTH OF THE DIKE.

X = 1724533.52

Y = 684109.12

ELEVATION = 4272.25

LATITUDE = 32°52' 49.27021"N

LONGITUDE = 105°58' 33.57286"W

SCALE FACTOR: 0.9999010

COMBINED FACTOR: 0.999703709

GAMMA = 0°8'55.53"

VISIBLE STATION = NONE

VERTICAL – NGVD29
BENCHMARK IS SET IN THE TOP OF A CONCRETE POST WHICH PROJECTS 0.1 FEET ABOVE GROUND MARKED "ALAMOGORDO 4333.676 1932".

THE BENCHMARK IS LOCATED 122 FT NORTHEAST AT A SEMICIRCULAR PARK, 56.5 FT NORTH OF THE CENTERLINE OF TENTH STREET, 6.5 FEET NORTH OF THE NORTH EDGE OF A SIDEWALK, 26 FEET SOUTHEAST OF A 15-INCH CEDAR TREE, 3 FEET NORTH OF A CHAIN FENCE.

TBM: 1/2" REBAR NE PROPERTY CORNER

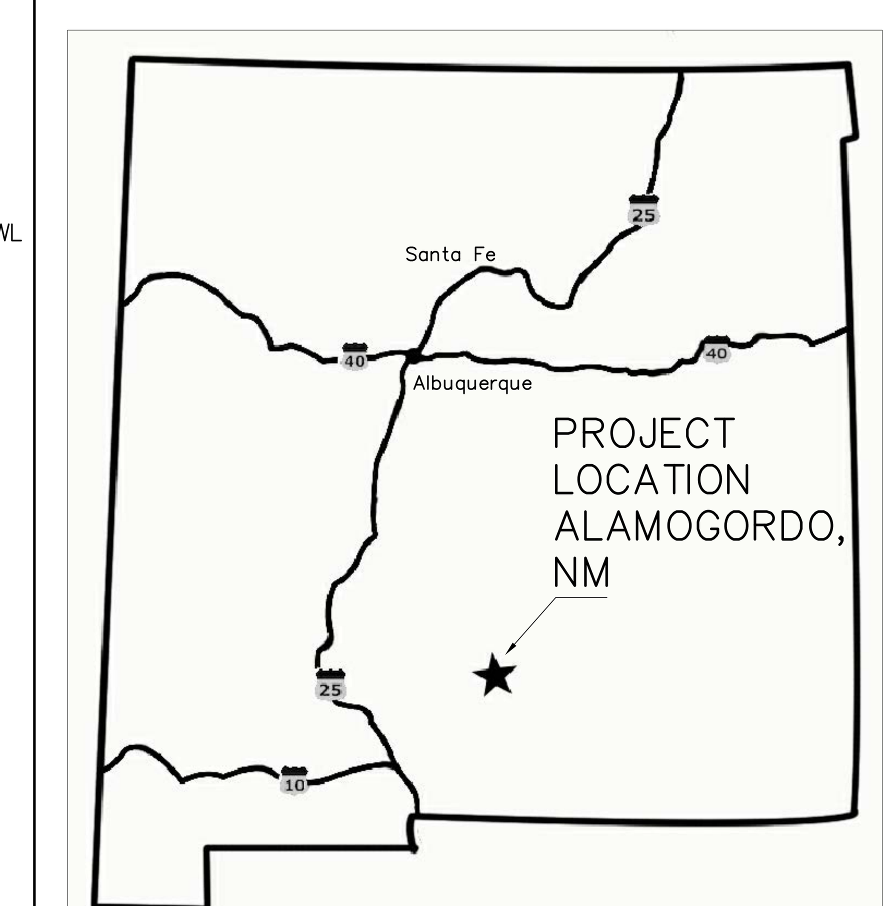
N: 686150.64

E: 1724633.59

1"x1"x8" OAK HUB SE PROPERTY CORNER

N: 684976.03

E: 1724702.85



NEW MEXICO

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Reverse Osmosis Concentrate Management Through Halophyte Farming

Project Location

0 50' 100' 200'

DATE APRIL 7, 2014

SHEET 1 OF 5

CAD REF. NO.

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AGRICULTURAL RESEARCH AREA – EXISTING INFRASTRUCTURE

0 15' 30' 60'

DATE APRIL 7, 2014

SHEET 2 OF 5

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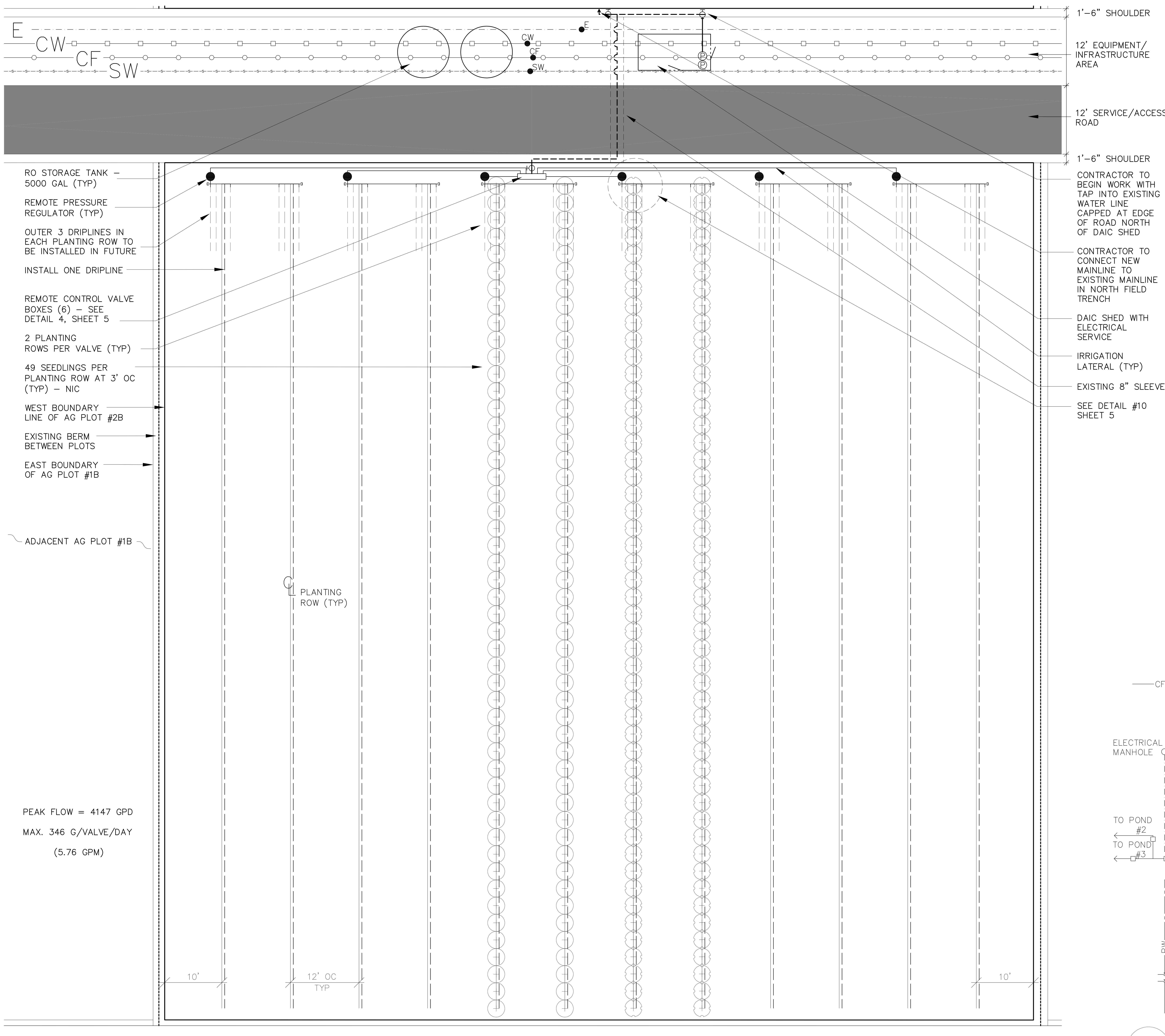


PEAK FLOW = 4147 GPD

MAX. 346 G/VALVE/DAY

(5.76 GPM)

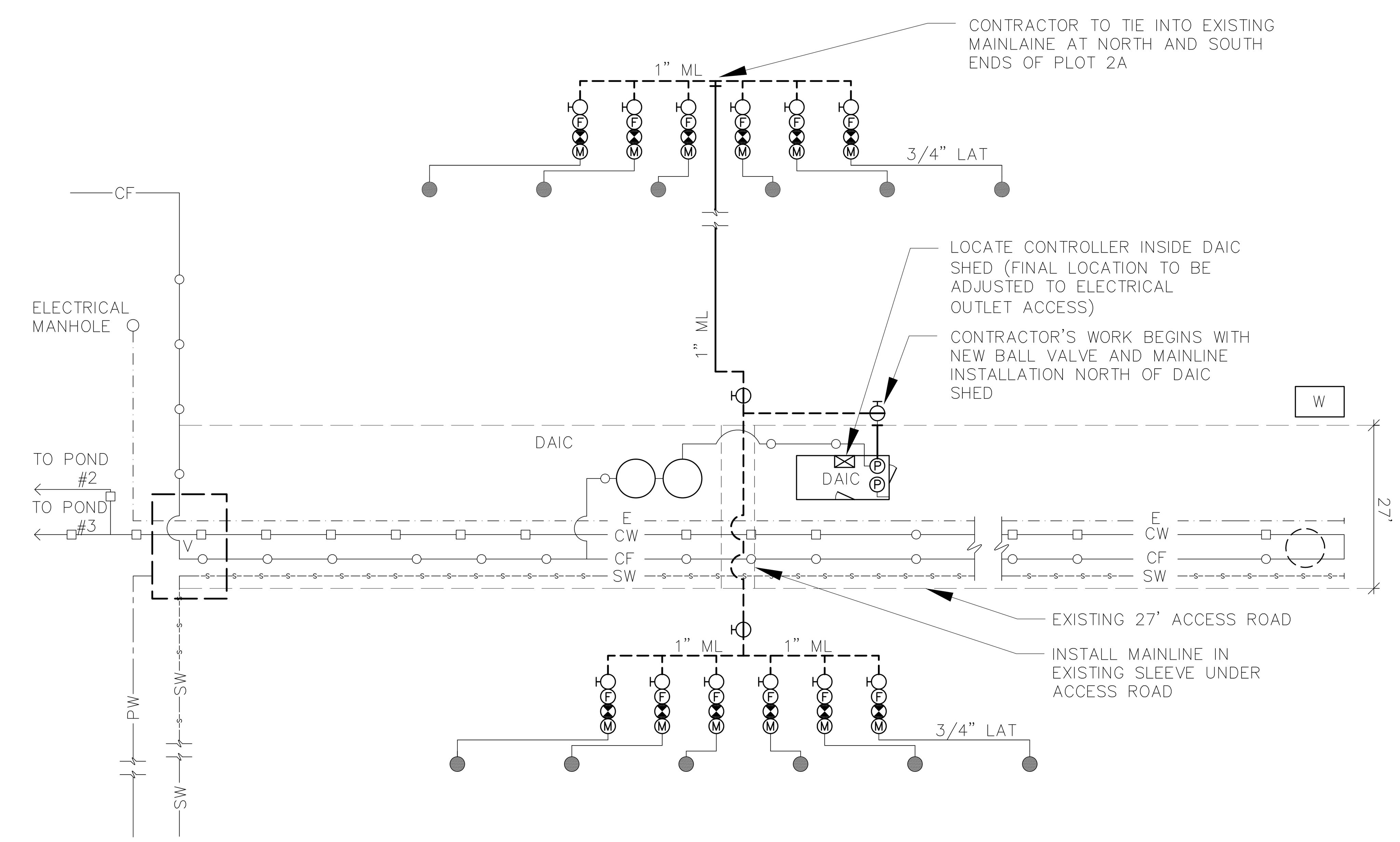
NOTES:

1. DO NOT DISTURB SUBSURFACE DRAINAGE SYSTEM – SEE AS –BUILT INFORMATION ON SHEET 4
2. SOUTH PLOT (#2B) SHOWN – REPEAT IRRIGATION SYSTEM ON NORTH PLOT (#2A) – SEE IRRIGATION SCHEMATIC – DETAIL 1, THIS SHEET
3. CONTRACTOR TO TIE INTO EXISTING MAINLINE IN NORTH FIELD TRENCH, APPROXIMATELY 2'–6" DEEP
4. CONTRACTOR SHALL INSTALL NEW IRRIGATION MAINLINE (AND CONNECT TO EXISTING IRRIGATION MAINLINE LOCATED IN NORTH PLOT (2A) TRENCH, AS INDICATED ON THE PLANS AND MARKED IN THE FIELD) AND ASSOCIATED IRRIGATION EQUIPMENT AS SHOWN ON THE PLANS.
5. ALL OTHER REQUIRED IRRIGATION SYSTEM EQUIPMENT SHALL BE PROVIDED BY THE CONTRACTOR EXCEPT THE POLY DRIPLINE SYSTEM COMPONENTS, WHICH SHALL BE PROVIDED BY THE OWNER.
6. IRRIGATION PLANS ARE SCHEMATIC. ALL EQUIPMENT IS TO BE STAKED IN THE FIELD PRIOR TO TRENCHING FOR APPROVAL BY THE OWNER'S REPRESENTATIVE
7. ALL IRRIGATION EQUIPMENT IS TO BE PRESSURE TESTED, ANY LEAKS REPAIRED, AND EQUIPMENT SHALL BE FUNCTIONAL AND IN WORKING ORDER. CONTRACTOR TO COORDINATE A SITE INSPECTION AND RECEIVE THE APPROVAL OF THE OWNER'S REPRESENTATIVE PRIOR TO BACKFILLING THE TRENCHES.
8. CONTRACTOR TO PROVIDE CONTROLLER PROGRAM COPIES TO THE OWNER'S REPRESENTATIVE UPON PROJECT COMPLETION.

SYMBOL	EXISTING INFRASTRUCTURE
– – – E – – –	ELECTRICAL
–□– CW –□–	CONCENTRATE WASTE
–○– CF –○–	CONCENTRATE FEED – MAIN IRRIGATION SOURCE WATER
–+–+– SW –+–+–	WELL WATER – BACK UP IRRIGATION SOURCE WATER
– · – PW – · –	POTABLE WATER
○	5000 GAL TANK
Ⓟ	PRESSURIZATION SYSTEM – TANK/PUMP
	EXISTING MAINLINE BALL VALVE
dashed circle	FUTURE 5000 GAL TANK
W	EXISTING WELL #3
DAIC	DATA ACQUISITION AND INTELLIGENCE CONTROL SYSTEM SHED
V	UTILITY VAULT

SYMBOL	NEW IRRIGATION SYSTEM
⊠	CONTROLLER – SEE SPECS
———	EXISTING MAINLINE
– – – –	NEW MAINLINE – SCH 40 PVC – 1"
———	NEW LATERAL LINE – SCH 40 PVC – ¾"
Ⓜ	FLOW METER
	MAINLINE BALL VALVE
	BALL VALVE
	REMOTE CONTROL VALVE
Ⓕ	FILTER
●	REMOTE PRESSURE RGULATOR
•	UTILITY STUB–OUTS

SYMBOL	PLANT SPECIES
⊕	ATRIPLEX CONESCENS – FUTURE (NIC)
⊕	ATRIPLEX LENTIFORMIS – FUTURE (NIC)



1 IRRIGATION SCHEMATIC

SCALE:NTS

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University of Arizona Reverse Osmosis Concentrate Management Through Halophyte Farming

IRRIGATION LAYOUT: AG #2B (AG #1B SIMILAR)

0 5' 10' 20'

DATE APRIL 7, 2014

SHEET 3 OF 5

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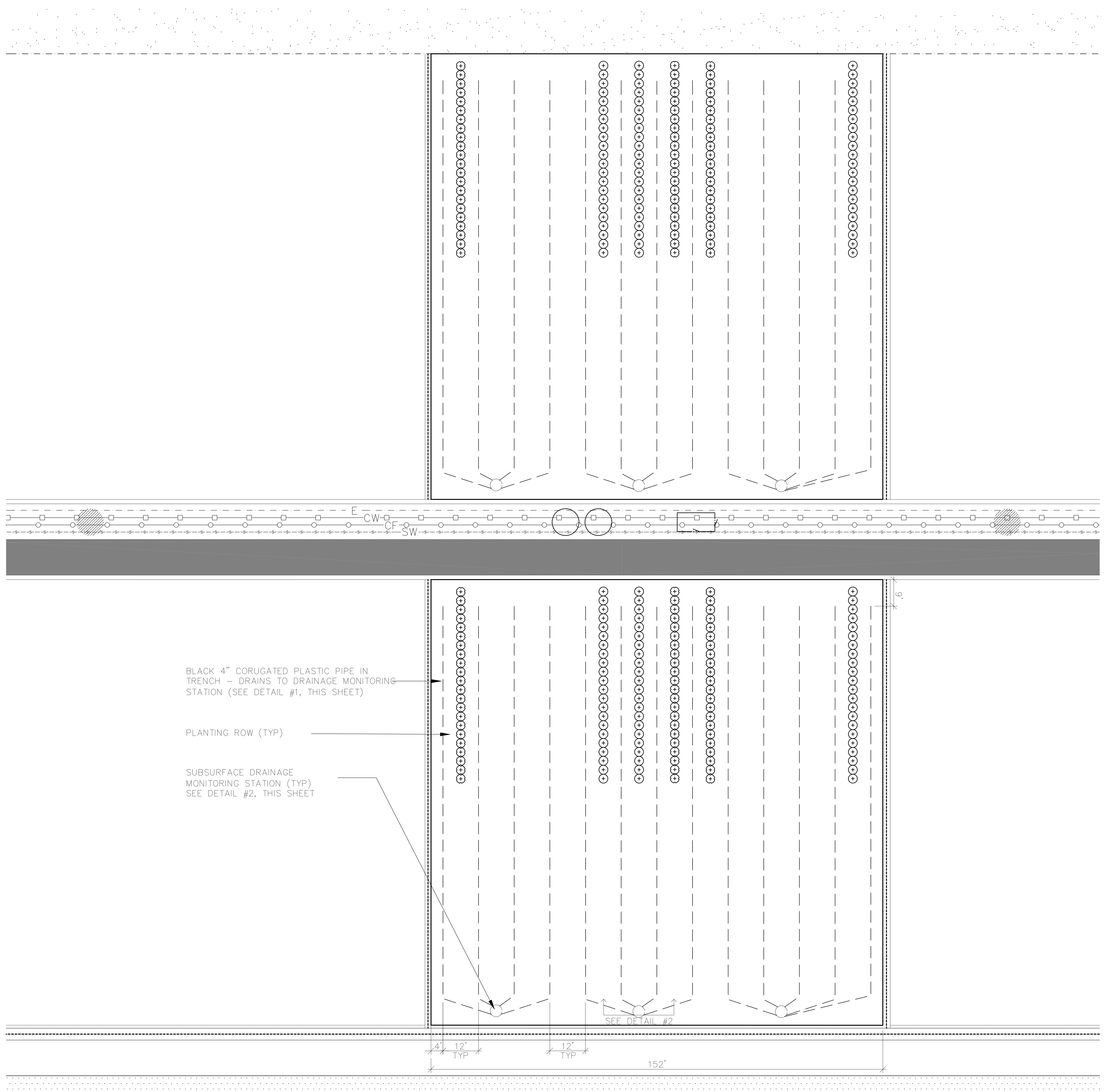
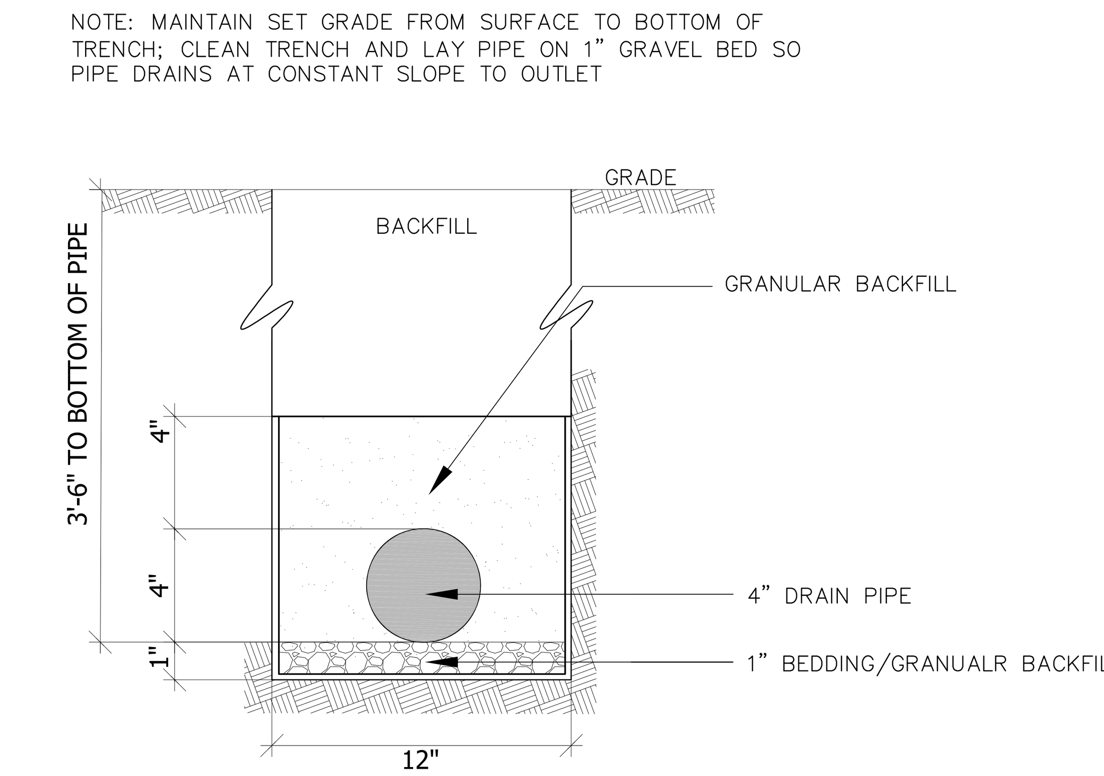
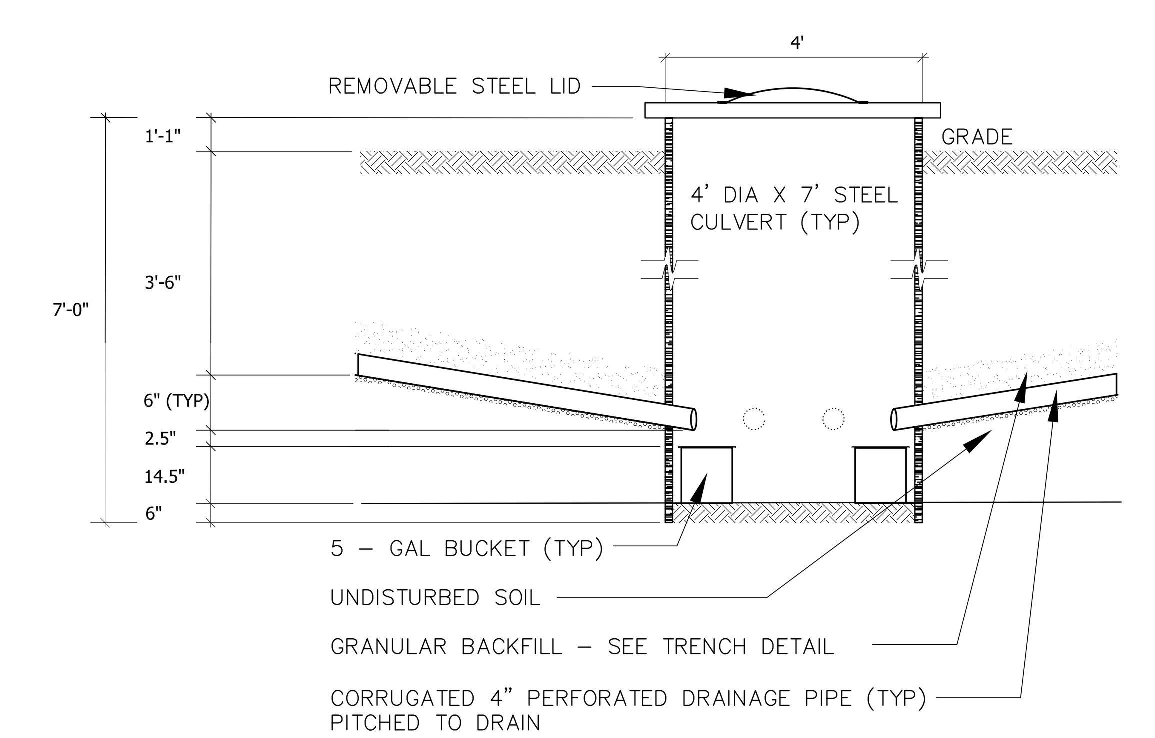




1 DRAINAGE TRENCH
SCALE:NTS



2 SUBSURFACE DRAINAGE MONITORING STATION
SCALE:NTS

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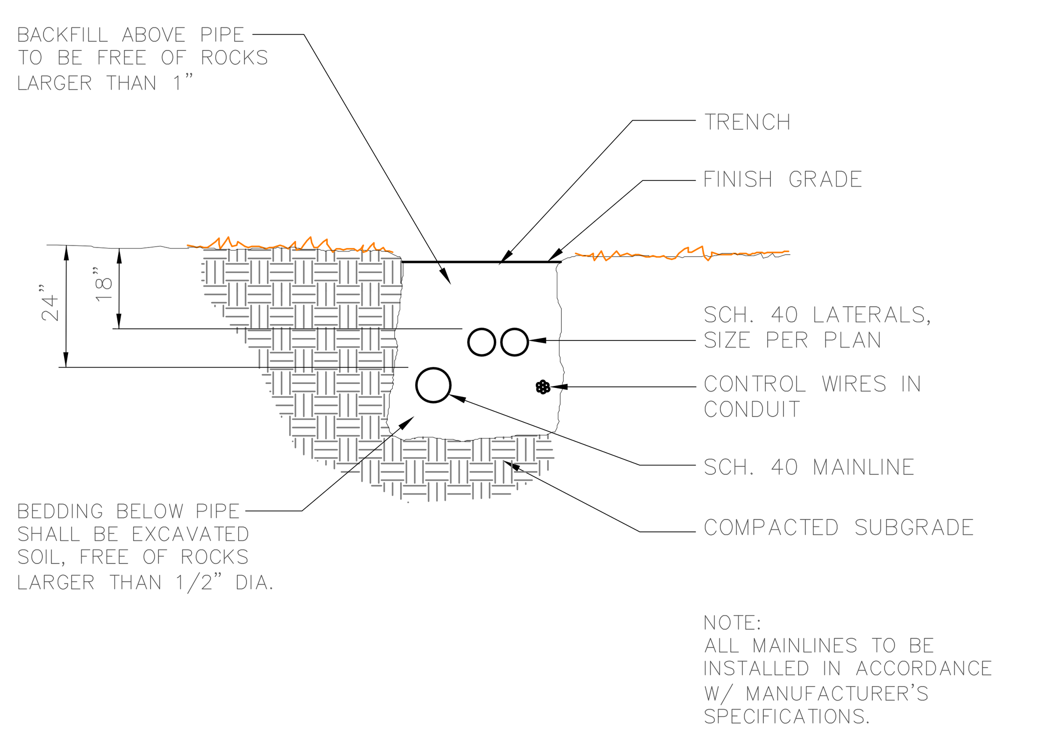
Reverse Osmosis Concentrate Management Through Halophyte Farming

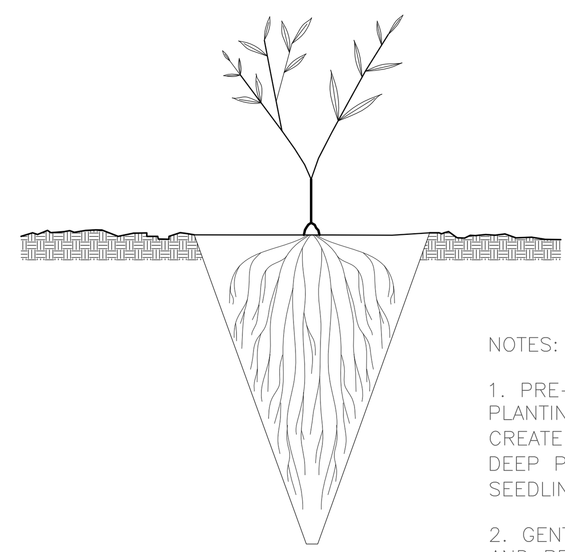
SUBSURFACE DRAINAGE AS–BUILT
(FOR INFORMATION ONLY)

N
0 10' 20' 40'

DATE APRIL 7, 2014
SHEET 4 OF 5
CAD REF. NO.



1 IRRIGATION TRENCHING
SCALE:NTS



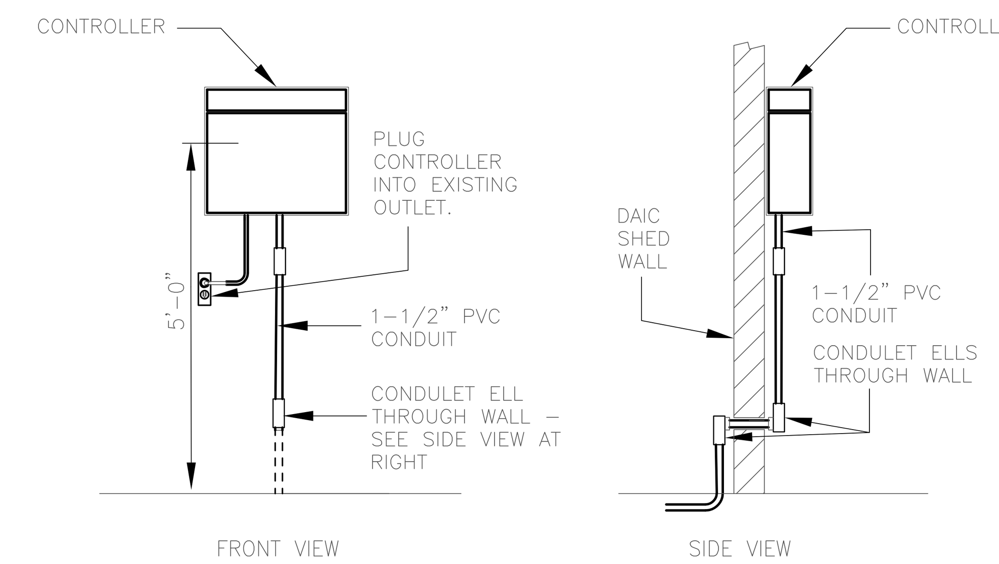
NOTES:

1. PRE-WET GROUND AROUND SEEDLING PLANTING LOCATION. USING A DIGGING BAR, CREATE A 2 1/2" (DIAMETER) BY 6" (OR 12") DEEP PLANTING HOLE (SLIGHTLY LARGER THAN SEEDLING CONTAINER)
2. GENTLY DISLODGE SEEDLING FROM CONTAINER AND PRESS INTO HOLE
3. IF NEEDED, USE BAR TO CLOSE HOLE FIRMLY AROUND ROOTS WITH SEEDLING IN A VERTICAL POSITION. SEEDLINGS SHALL BE WATERED IMMEDIATELY AFTER PLANTING

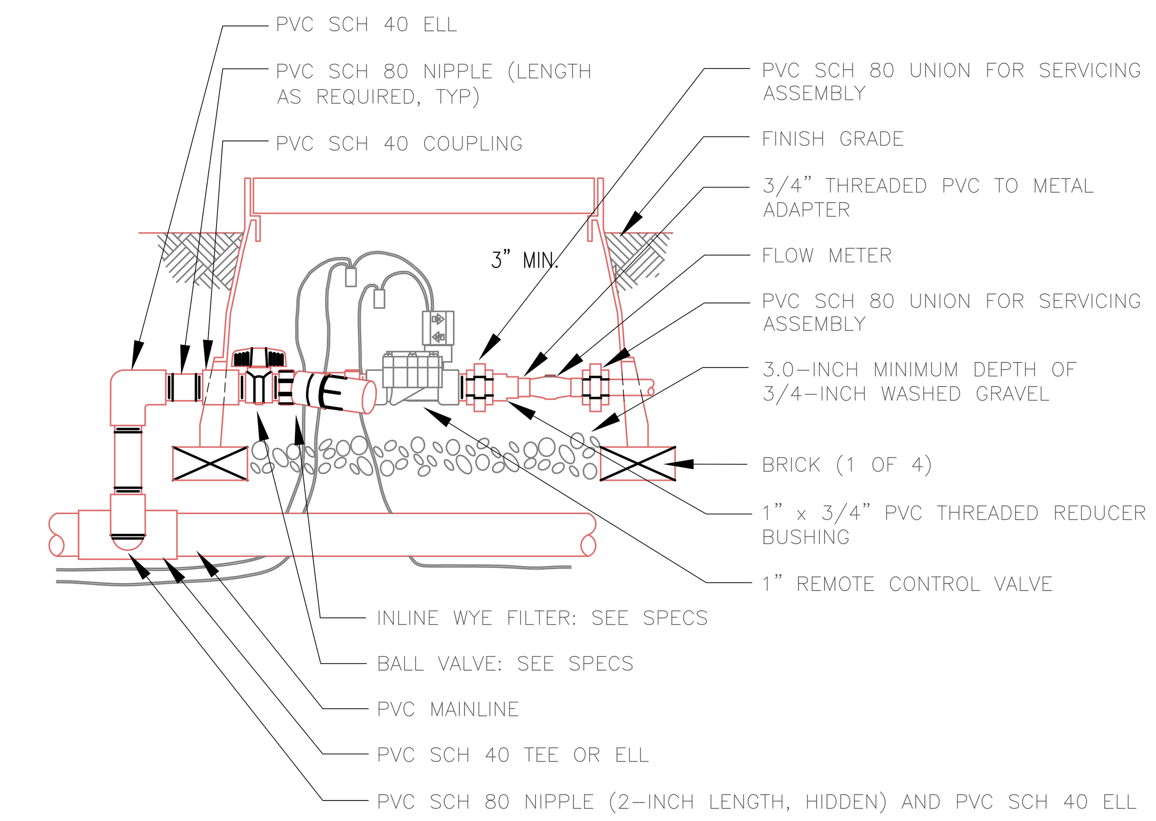
2 PLANTING DETAIL - NIC
SCALE:NTS

NOTES:

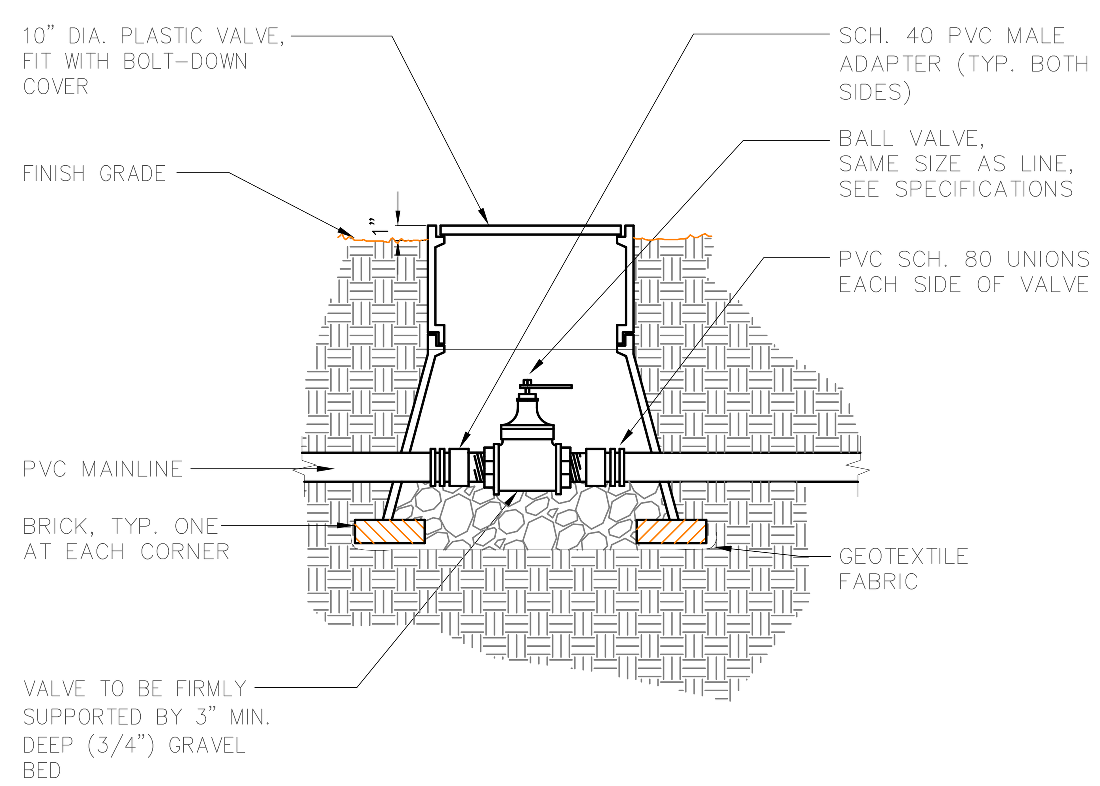
1. FINAL CONTROLLER LOCATION INSIDE DAIC SHED, NEAR ELECTRICAL OUTLET
2. SEE SPECS FOR CONTROLLER INFORMATION.
3. PLUG CONTROLLER INTO A GFCI OUTLET 120 VAC POWER SUPPLY



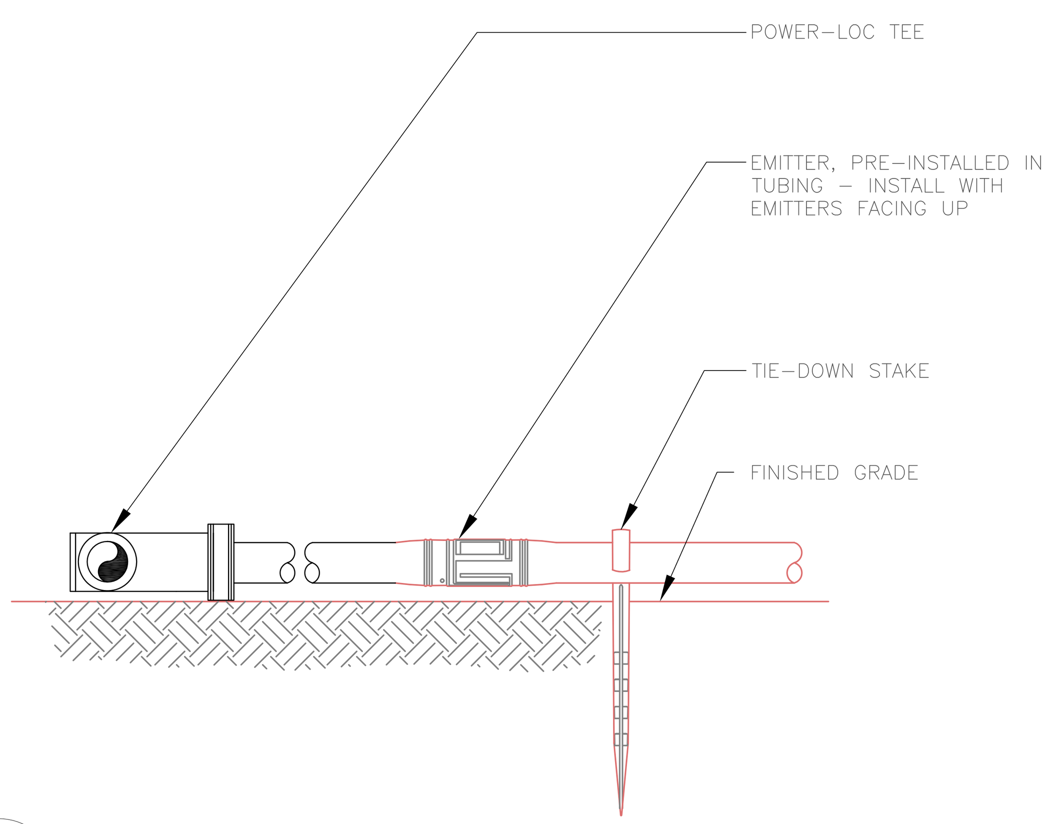
3 WALL MOUNTED CONTROLLER
SCALE:NTS



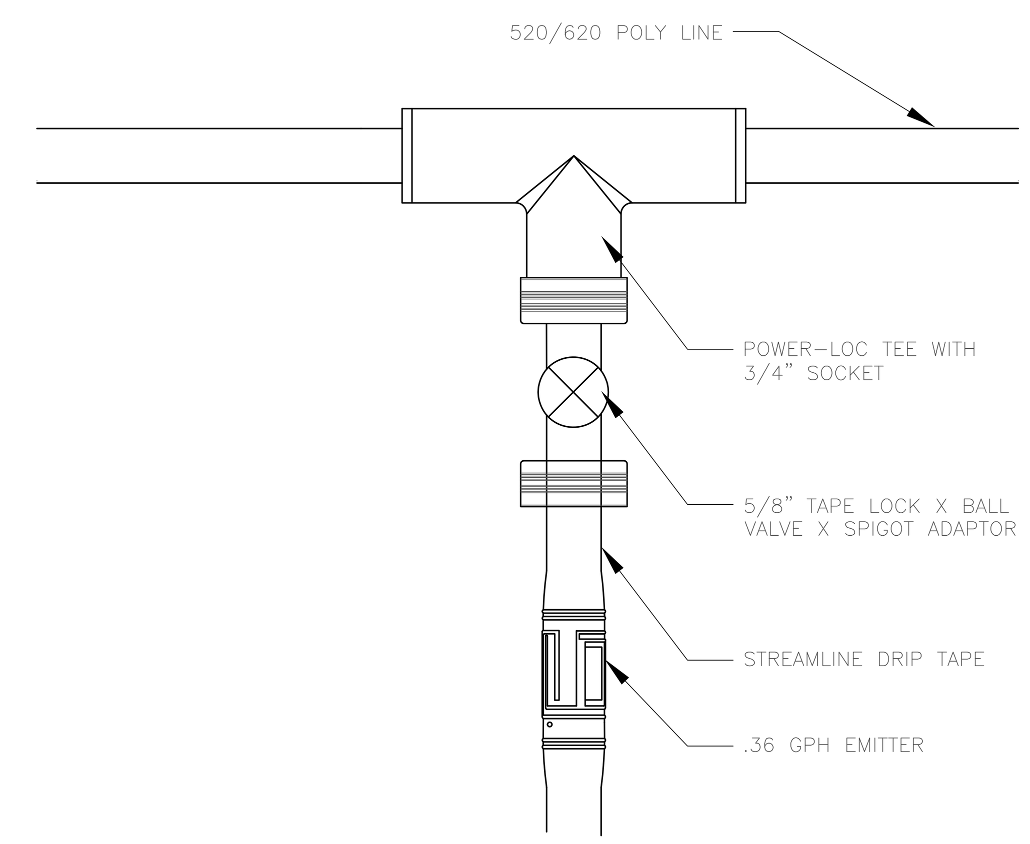
4 VALVE BOX
SCALE:NTS



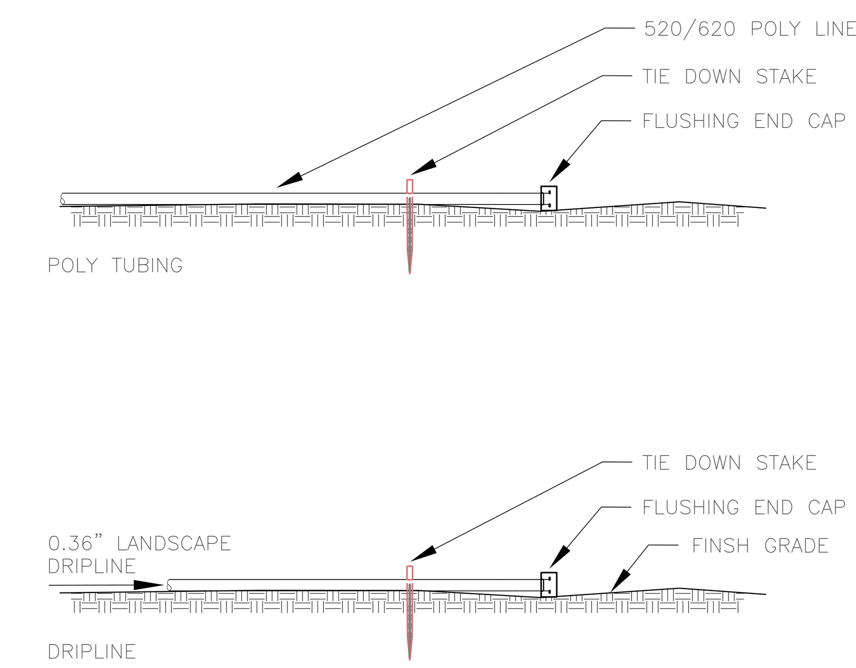
5 MAIN LINE BALL VALVE DETAIL
SCALE:NTS



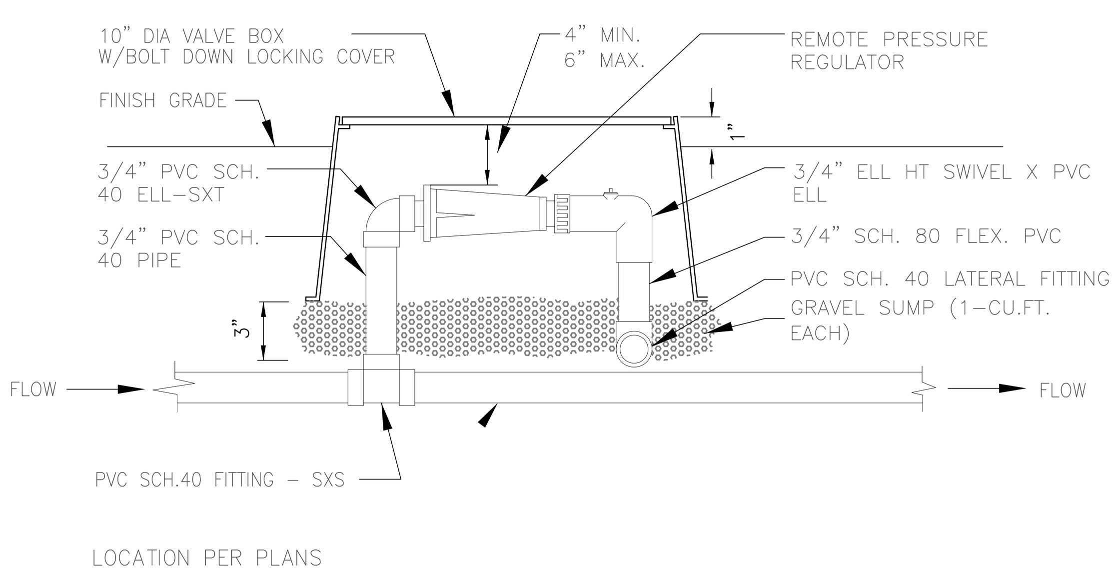
6 DRIPLINE INSTALLATION DETAIL
SCALE:NTS



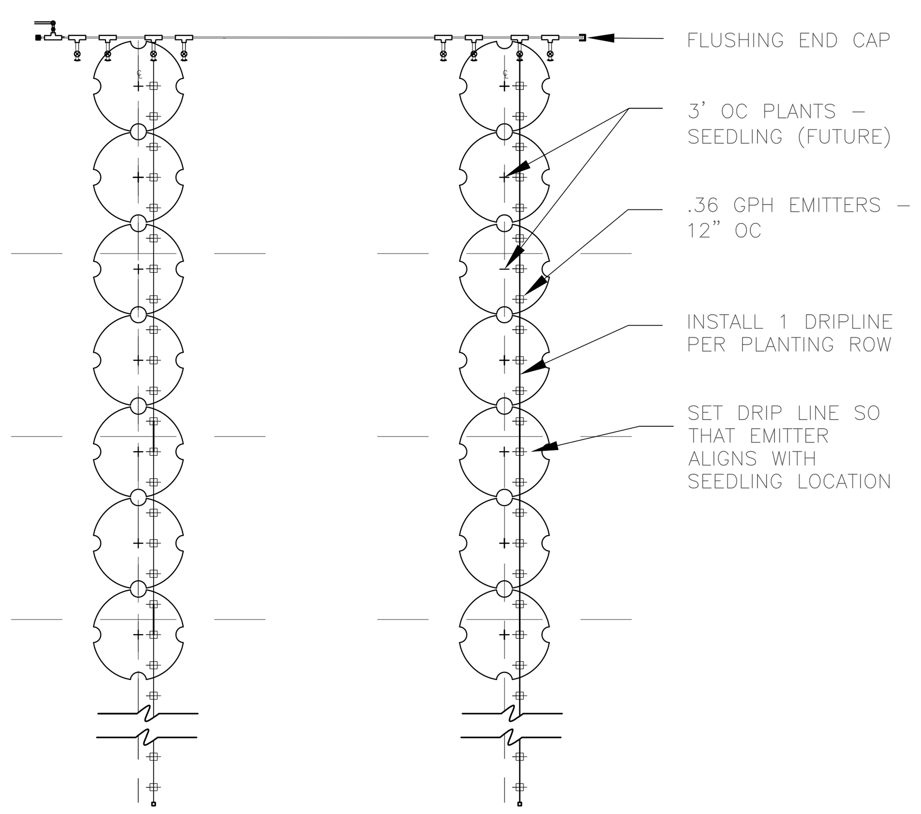
7 LANDSCAPE DRIPLINE LAYOUT
SCALE: NTS



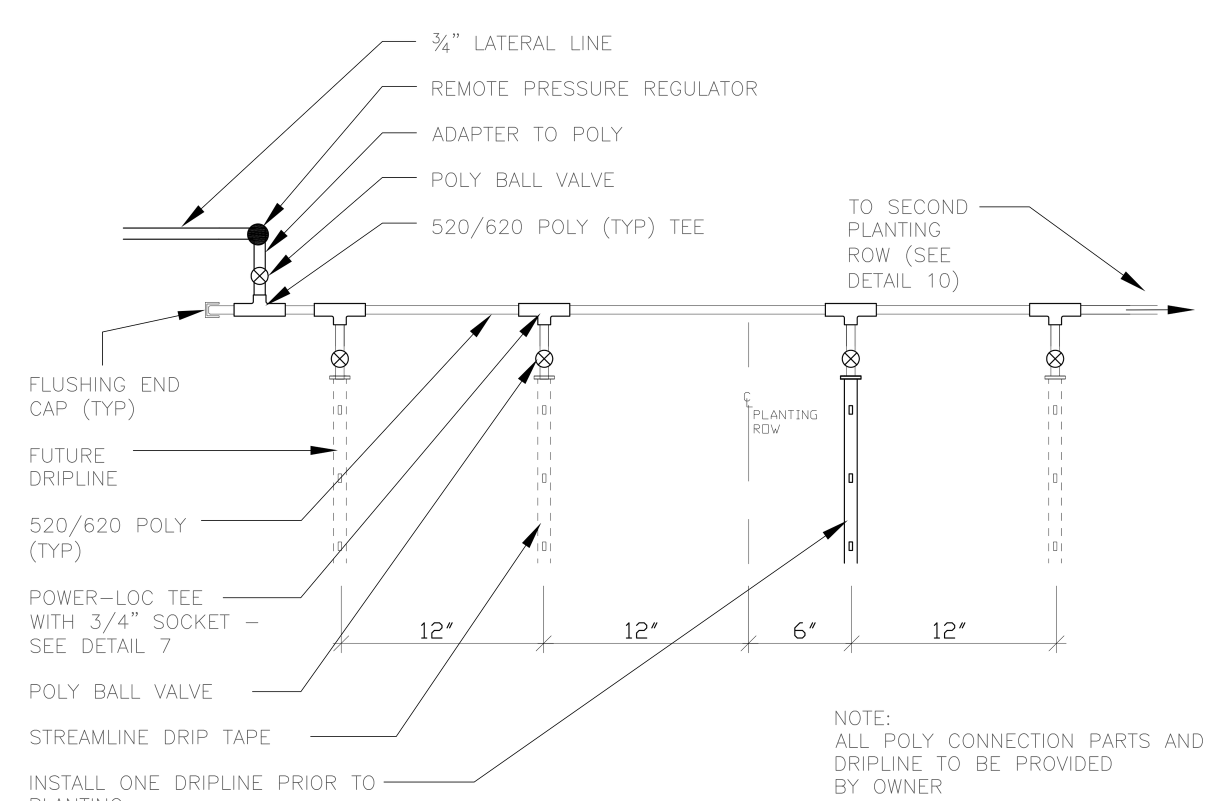
8 FLUSHING ENDCAP DETAIL
SCALE:NTS



9 REMOTE PRESSURE REGULATOR
SCALE:NTS



10 TYPICAL DRIPLINE LAYOUT - 2 PLANTING ROWS PER VALVE
SCALE:NTS



11 TYPICAL DRIPLINE LAYOUT - PLANTING ROW
SCALE:NTS

REVISIONS			
NO.	BY	DATE	REMARKS

BUREAU OF RECLAMATION
As-Built No Changes — WILLIAM BELLER
As-Built With Changes

DES. ____
DWN ____
CKD ____

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Irrigation Details

DATE APRIL 7, 2014
SHEET 5 OF 5
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UA HALOPHYTE FARMING IRRIGATION
CONTRACT SPECIFICATIONS
April 7, 2014

SECTION 1 - IRRIGATION SYSTEM

Part 1. GENERAL

1.01 DESCRIPTION OF WORK:

Furnish all work and material, appliances, tools, equipment, facilities, transportation, and services necessary for, and incidental to, performing all operations in connection with the installation of the automatic dripline irrigation system, as shown on drawings and/or specified herein, including connections to materials already installed at the project site as described below and materials to be supplied by the Owner as specified herein. When the term "Contractor" is used in this section, it shall refer to the irrigation contractor; when the term “Owner” is used, it shall refer to the University of Arizona. When the term BGNDRF is used, it shall refer to the U.S. Bureau of Reclamation Brackish Groundwater National Desalination Research Facility in Alamogordo, NM, the project location.

Phase 1 shall include the installation of main lines, lateral lines, main line ball valves, filters, flow gauges, electric remote control valves, controller, remote pressure regulators, and all associated components. A section of main line and irrigation wiring has been preinstalled in an existing trench in the north Ag Area (Plot # 2A) as indicated on the plans. Phase 1 includes the Contractor connecting to this existing section of main line and irrigation wiring to complete the Phase 1 system. All other materials required for Phase 1 shall be supplied by the Contractor.

Phase 2 shall include the installation of ½” poly tubing, flush end caps, dripline, tees, poly ball valves, and associated components. All materials required for Phase II shall be supplied by the Owner and installed by the Contractor. Planting is not included in this project.

1.02 APPLICABLE STANDARDS:

ASTM D2241 - Poly (Vinyl Chloride) (PVC) Plastic Pipe (SDR-PR)

D2464 - Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Threaded, Schedule 80

D2466 - Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Threaded, Schedule 40

D2564 - Solvent cements for Poly (Vinyl Chloride) (PVC) Plastic Pipe and Fittings

D2855 - Making Solvent - Cemented Joints with Poly (Vinyl Chloride) (PVC) Pipe and Fittings

1.03 GUARANTEE AND MAINTENANCE

A. The Contractor shall guarantee materials and workmanship for six months after provisional acceptance including repair and replacement of defective materials and workmanship as outlined in Section 3.13.

B. Provisional acceptance shall be given by the Owner's Representative when the Contractor has demonstrated the irrigation is complete, fully operational, and in conformance with the plans and specifications; has approved Record Drawings as specified in Section 1.09; provided a Controller Chart as specified in Section 1.10; provided Operating and Maintenance Manuals as specified in Section 1.11; and provided a checklist as specified in Section 1.12. Provisional acceptance marks the beginning of the maintenance period. Final acceptance shall not be given until after the final observation at the end of the maintenance period.

C. Contractor shall coordinate all guarantee work with BGNDRF and the Owner’s Representative (see Section 3.13).

1.04 SUBSTITUTION OF MATERIALS

This irrigation system has been designed around the irrigation components herein stated and as shown on the plans. Any changes of brand name, trade name, trademarked, patented articles, or any other substitutions will be allowed only by written order signed by the Owner's Representative. The Owner is under no obligation to accept materials other than as specified. If a bidder wishes for a substitute item to receive consideration as an "approved equal", the bidder and each item must meet all of the following requirements without exceptions.

An item, to be considered a substitute, must meet the same specifications of materials, fabrication or construction, dimension or size, shape, finish, performance standards, warranty or guarantee, and any other pertinent and salient features of quality, as indicated in manufacturer's specifications for original specified item.

Equipment or material installed or furnished without prior approval of the Owner's Representative as herein specified, may be rejected and the Contractor required to remove such materials at their own expense.

1.05 CODES/PERMITS AND CONTRACTOR REQUIREMENTS

All work under this contract shall comply with the provisions of these specifications, as illustrated on the accompanying drawings, or as directed by the Owner's Representative, and shall satisfy all applicable local codes, ordinances, or regulations of the governing bodies and all authorities having jurisdiction over this project.

Installation of equipment and material shall be done in accordance with the requirements of the National Electric Code, County Plumbing Codes and standard plumbing procedures. The drawings and these specifications are intended to comply with all the necessary rules and regulations; however, some discrepancies may occur. Where such discrepancies occur, the Contractor shall immediately notify the Owner's Representative in writing of the discrepancies and apply for an interpretation.

The installation of the irrigation system shall be made by an individual or firm bonded and licensed under the State of New Mexico Registrar of Contractors, and with demonstrated experience within Otero or Doña Ana County of at least three projects of comparable size and complexity to this project unless otherwise approved by the Owner's Representative. Contractor shall also carry required amounts of general liability insurance and workers compensation.

The Contractor shall attend a mandatory Prebid Meeting at BGNDRF, 500 Lavelle Road, Alamogordo, NM 88301 – time and date to be announced.

1.06 CONTRACTOR'S SUPERINTENDENT

A. The Contractor's superintendent shall be satisfactory to the Owner's Representative.
B. The Contractor's superintendent shall not be changed, except with the consent of the Owner's Representative.
C. The Contractor's superintendent shall be authorized to represent the Contractor.

1.07 SITE ACCESS, SCHEDULE AND NOTIFICATION OF OWNER'S REPRESENTATIVE AND BGNDRF PERSONNEL

Prior to project start-up, the Contractor and their workers shall attend a 1-hour BGNDRF safety and site orientation meeting. The Contractor shall notify the Owner's Representative and BGNDRF personnel of their planned work schedule at this meeting, and coordinate with BGNDRF for site access procedures. Contractor activities at BGNDRF shall be limited to the Ag Area and the Ag Area access/service roads.

Should the Contractor work periodically on the job, the BGNDRF shall have the right to require the Contractor to give a 24-hour notice of each and every day or partial day that they intend to work on the project. The Contractor shall perform no work unless the Owner's Representative and BGNDRF personnel have been properly notified. Failure to notify the Owner's Representative may require the Contractor to redo, uncover pipe, expose for inspection, etc., all that the Owner's Representative was unable to inspect. The Owner's Representative and

BGNDRF personnel shall have free access to the work whenever it is in preparation or progress and proper facilities, for such access and inspection.

1.08 EXISTING UTILITIES - LOCATION AND ELEVATIONS

Locations and elevations of various utilities included with the scope of this work have been obtained from the most reliable sources available and should serve as a general guide without guarantee to accuracy. The Contractor shall examine the site and verify to their own satisfaction the locations and elevations of all utilities and availability of utilities and services required. The Contractor shall inform themselves as to their relation to the work and the submission of bids shall be deemed as evidence thereof. The Contractor shall be responsible for marking the utility locations on the ground as needed before and during construction in order to insure avoidance. The Contractor shall repair at his own expense, and to the satisfaction of BGNDRF, for damage to any utility shown or not shown on the plans.

Should utilities not shown on the plans be found during excavations, Contractor shall promptly notify Owner's Representative for instructions as to further action.

Contractor shall make necessary adjustments in the layout as may be required to connect to existing stubouts, should any such stubouts not be located as shown and as may be required to work around existing work, at no increase in cost to the Owner. All such work will be recorded on record drawings by the Owner's Representative, to be reviewed and approved for accuracy by the Contractor prior to final acceptance.

1.09 RECORD DRAWINGS:

A. Note any changes made to Contract Drawings during installation and provide this information to the Owner's Representative for final documentation. Coordinate with Owner's Representative in the documentation and preparation of dimensioned locations and depths by providing as-built locations for each of the following:

1. Irrigation pressure main line and lateral line routing
2. Pressure Regulators
3. Ball Valves
4. Remote Control Valves
5. Filters
6. Flow meters
7. Control wire routing
8. Sleeves
9. Control wire junction boxes, if needed
10. Poly tubing
11. Valve boxes and other related items.

B. These plans will record all changes made from the Contract Drawings.

C. Contractor shall review, sign and date final record drawings prepared by the Owner's Representative as an accurate representation of the final irrigation system installed.

1.10 CONTROLLER CHART

A. Provide two controller charts for the automatic controller installed, showing the operating times and schedules for each program.

1.11 OPERATING AND MAINTENANCE MANUALS:

A. Provide two individually bound manuals detailing operating and maintenance requirements for irrigation system.

B. Manuals shall be delivered to the Owner's Representative after the systems are fully operational, and prior to provisional acceptance.

C. Provide descriptions of all installed materials and systems in sufficient detail to permit maintenance personnel to understand, operate and maintain the equipment.

D. Provide the following in each manual:

1. Index sheet, stating Irrigation Contractor's name, address, telephone number and name of person to contact.
2. Duration of guarantee period.
3. Equipment list providing the following for each item:
    a. Manufacturer's name
    b. Make and model number
    c. Name and address of local manufacturer's representative
    d. Spare parts list in detail
    e. Detailed operating and maintenance instructions of major equipment

1.12 CHECKLIST

A. Provide a signed and dated checklist and deliver to the Owner's Representative prior to final acceptance of the work.

B. Use the following format:

1. Plumbing permits: if none required, so note.
2. Material approvals: approved by and date
3. Pressure line tests: by whom and date
4. Record drawings: received/approved by and date
5. Controller charts: received by and date
6. Operation and maintenance manuals: received by and date.

7. Manufacturer's warranties: received by and date.
8. Written guarantee period: received by and date.

1.13 ELECTRIC POWER

Electric power to operate the controller is existing at the controller location, inside the DAIC shed. Service wiring to the controller cabinet, switch and outlet shall be furnished by the irrigation contractor, including bringing the wiring through the wall of the shed at the direction of the Owner’s Representative or BGNDRF personnel.

1.14 WATER SERVICE

Water service for this project will be provided by BGNDRF including all water necessary for testing and flushing the system.

1.15 TOOLS TO BE FURNISHED

A. Supply as part of this contract the following tools:

   1. Two keys for the automatic controller
   2. Four valve box keys or wrenches

B. The above-mentioned tools shall be turned over to BGNDRF upon provisional acceptance and before final inspection.

1.16 SLEEVES AND ELECTRICAL CONDUITS

Contractor shall use existing sleeves at the project location unless otherwise approved by the Owner’s Representative.

1.17 PROGRESS MEETINGS

Contractor shall attend all progress meetings/conference calls as requested by the Owner's Representative during installation (minimum of one per week).

Part 2. PRODUCTS

2.01 GENERAL

All materials furnished by the Contractor shall be new. This irrigation system has been designed around the irrigation components herein stated and as shown on plan. Any changes of brand name, trade name, trademarked, patented articles, or any other substitutions will be allowed only by written order as outlined in Section 1.04. Phase 1 irrigation system components to be provided by the Contractor are described below in Sections 2.02 – 2.10. Phase 2 irrigation system components to be provided by the Owner are described in Section 2.11.

2.02 PVC PRESSURE MAINLINE AND LATERAL LINE PIPE FITTINGS

A. Pressure mainline and lateral line piping shall be PVC Schedule 40, size as shown on the plans, and shall include sizes, shapes and fittings as required.

B. Pipe shall be made from NSF approved type I, Grade I PVC compound conforming to ASTM specification D 2241. Piping shall be SDR solvent weld.

C. PVC solvent-weld fittings shall be Schedule 80, Type I NSF approved conforming to ASTM test procedure D2464 and shall be as manufactured by Spears, Lasco or Dura.

D. Solvent cement and primer for PVC solvent-weld pipe and fittings shall be Weld-on 705 and Weld-on Purple Primer, or approved equal. Manufacturer's installation requirements shall be strictly adhered to.

E. All PVC pipe shall bear the following markings:

1. Manufacturer's name
2. Nominal pipe size
3. Schedule or class
4. Pressure rating in psi
5. National Sanitation Foundation (NSF) approval.
6. Date of extrusion

F. All fittings shall bear the manufacturer's name or trademark, material designation, size, applicable IPS schedule and NSF seal of approval.

G. Any pipe that has evidence of discoloring due to ultraviolet degradation shall be rejected.

2.03 MAIN LINE BALL VALVES

Main line ball valves shall be 1” Spears True Union 2000 Standard ball valve, installed per manufacturer’s installation detail.

2.04 PRESSURE REGULATOR

Pressure regulators shall be Senniger’s Low Flow Pressure Regulator (0.1 – 8.0 gpm), PRL-12-3/4”, preset to 12 PSI.

http://www.senninger.com/senninger-products/pressure-regulators/prl-%E2%80%93-pressure-regulator-low-flow/

2.05 FILTER

Filters shall be Amiad 1" Compact Plastic Filter with 130 mesh stainless steel element.

http://www.amiad.com/filters/PL101_2.asp?filterNum=PL101

2.06 FLOW METER

Flow meter shall be EKM ¾" Water Meter – Stainless Steel Pulse Output Water Meter, Model SPWM-075.

http://www.ekmmetering.com/ekm-metering-products/water-meters/stainless-steel-pulse-output-water-meter-spwm-075.html

2.07 CONTROL WIRING

A. Connections between the automatic controller and the electric control valves shall be made with 18DD 7500 #18 copper wire AWG-UF 600 volt 7-strand sprinkler system wire. Circuit wires shall be direct bury single strand #18 as manufactured by A.E.F. or equal. Install in accordance with valve manufacturer's specifications and wire chart. Common wire size shall be less #14.

B. Wiring shall occupy the same trench and shall be installed along the same route as pressure supply or lateral lines whenever possible. All wiring shall be installed in Schedule 40 PVC conduit.

C. An expansion curl shall be provided within three feet of each wire connection. Expansion curl shall be of sufficient length at each splice connection at each electric control, so that in case of repair the valve bonnet may be brought to the surface without disconnection of the control wires. Control wire shall be installed loosely in conduit and conduit shall be snaked to allow for thermal expansion and contraction.

D. Field splices between the automatic controller and electrical control valves will not be allowed without prior approval of the Owner's Representative. All approved splices shall occur in a valve box or junction box.

E. Three "spare" wires (minimum) shall be run from the controller to the furthest valve location in each direction. Wires shall be multi-strand #18 as manufactured by A.E.F. or equal and marked in an approved manner.

F. All wire connectors shall have a two-piece PVC housing which, when filled with resin epoxy and pressed together, forms a permanent, one-piece, moisture-proof wire splice. All connectors shall be UL listed, rated 600 volt, for PVC insulated wire. No wire splices shall be buried. All wire connectors shall be Rainbird ST-03 Black/PT-S5 or approved equal.

2.08 ELECTRIC CONTROLLER

Electric irrigation controller shall be Signature EZConnect 8250 Series with a station expansion module.

2.09 ELECTRIC REMOTE CONTROL VALVES

Electric remote control valves shall be Netafim 1", 2-Way Series 80 Valves, Item Number 71640-007406, Model Number 61ET1GH2, located as shown on the drawings. A Spears True Union ball valve shall be installed where shown on the plans for each valve.

2.10 VALVE BOXES

A box shall be provided for all Phase 1 valves. Valve boxes shall be made of high-strength, plastic suitable for turf irrigation purposes. Boxes shall be suitable in size and configuration for the operability and adjustment of the valve. Extension sections will be used as appropriate to the depth of piping. The openings in the sides and bottoms of the valve boxes shall be sealed with geotextile fabric.

A. Electric Valves - Boxes for electric valves shall be Ametek Jumbo series with bolt down cover. Only one electric valve per box will be permitted. The drip filter, PVC ball valve and flow gauge shall be installed in the same valve box as the remote control valve in locations as shown on the plans.

B. Remote Pressure Regulator - Boxes for the pressure regulators shall be 10" Ametek or approved equal.

C. Mainline Ball Valve – Boxes for the mainline ball valves shall be 10" Ametek or approved equal.

2.11 DRIPLINE SYSTEM COMPONENTS (SUPPLIED BY OWNER AND INSTALLED BY CONTRACTOR)

A. PVC to poly adaptor – ¾" MPT x 620 compression fittings.

B. Netafim poly tubing – 520/620 poly riser tubing.

C. Antelco poly insert shut-off valves.

D. 600 Series Compression Tees.

E. Series 50 Power-Loc Tees with ¾" socket – PL-50-SSPIT.

F. 5/8” Tape-Loc x Ball Valve x ¾” spigot adaptors.

G. Streamline drip tape, 8 mil, with .36 gph emitters at 12” oc.

H. 5/8” tape end caps.

I. 600 Series flush end caps.

J. Soil staples – TL 65.

Part 3. EXECUTION

3.01 INSTALLATION

A. GENERAL

1. Contractor Responsibility: The Contractor shall not willfully install the irrigation system as shown on the drawings when it is obvious in the field that obstructions, grade differences or discrepancies in equipment usage, area dimensions or static water pressure exist that might not have been considered in the design. Such obstructions or differences shall be brought to the attention of the Owner's Representative. In the event this notification is not performed, the Contractor shall assume full responsibility for any revision necessary.

2. All material and equipment shall be delivered to the job site in unbroken cartons or other packaging to demonstrate that such material is new and of a quality and grade in keeping with the intent of these specifications.

B. Site Conditions:

1. The irrigation plans are schematic and all scaled dimensions are approximate. The Contractor shall check and verify all size dimensions and receive Owner's Representative approval prior to proceeding with work under this Section.

2. Exercise extreme care in excavating and working near existing utilities and drainage structures. Contractor shall be responsible for damage to utilities/drainage structures which are caused by their operation or neglect. Check existing utilities/drainage structure drawings and review the locations with BGNDRF personnel to confirm existing infrastructure locations prior to beginning work.

3. Coordinate installation of irrigation materials, including pipe, so there shall be no interference with utilities, drainage structures or

other construction. Avoid trampling and the use of vehicles/heavy equipment in future seedling planting locations.

4. The Contractor shall carefully check all site conditions to ensure that they may safely proceed before starting work on the irrigation system.

3.02 PREPARATION

A. Physical Layout:

1. Prior to installation, the Contractor shall locate the existing section of irrigation mainline/controller wire in the north plot; stake out all new pressure supply line, poly line, dripline, remote control valve, mainline ball valve and remote pressure regulator locations, and confirm the location of the controller.

2. All layout shall be approved by Owner's Representative prior to installation. Prior approval shall be obtained for remote control valves, controller, mainline/lateral trenching, mainline ball valves and pressure regulator locations.

B. Water Supply:

1. Irrigation system shall be connected to water supply points or connection at approximate locations as indicated on the drawings. Contractor is responsible for minor changes caused by actual site conditions.

3.03 EXCAVATION AND BACKFILL

A. Trenching: Dig trenches straight and support pipe continuously on bottom of trench. Lay pipe to an even grade. Trenching excavation shall follow layout indicated on drawings and as noted. If the bottom of a pipe trench excavation is found to consist of rock, or any other material that, by reason of its hardness, cannot be excavated to give a uniform bearing surface, said rock or other material shall be removed for at least three (3) inches below the specified trench depth, and be refilled to specified trench depth with sand or bedding material thoroughly tamped into place.

B. Burial of Pipe: Burial of pipe shall be as follows:

Main Line	24" minimum coverage
PVC Laterals	18" minimum coverage
Irrigation Wire Conduit	18" minimum coverage

C. Backfilling:

1. Bedding materials for all pipes shall be placed at a depth of 2” below pipe and shall contain no foreign matter larger than 1/2" in size.
2. The trenches shall not be backfilled until all required tests are performed. Trenches shall be carefully backfilled in 6" lifts with the excavated materials approved for backfilling, consisting of earth, loam, sandy clay, sand, or other approved materials, free from clods of earth or stones larger than one inch (1") in diameter. Backfill shall be mechanically compacted as needed to a dry density equal to adjacent undisturbed soil. Backfill will conform to adjacent grades without dips, sunken areas, humps or other surface irregularities. Backfilling shall not be performed while trenches or backfill material is in a wet or muddy condition.

3. If settlement occurs and subsequent adjustments in pipe, valves, or other installed equipment are necessary, the Contractor shall make all required adjustments without cost to the Owner.

3.04 Assemblies

A. Routing of irrigation lines as indicated on the drawings is diagrammatic. Install lines and various assemblies to conform to the details shown in drawings and in accordance with the manufacturer's recommendations.

B. Install all assemblies specified herein in accordance with respective detail. In absence of detail drawings or specifications pertaining to specific items required to complete work, perform such work in accordance with best standard practice with prior approval of Owner's Representative.

C. PVC pipe and fittings shall be thoroughly cleaned of dirt, dust and moisture before installation. Installation and solvent-welding methods shall be recommended by the pipe and fitting manufacturer. Primer shall be used on all solvent weld joints. No solvent weld joint shall be submitted to water pressure until curing for 24 hours minimum.

D. On PVC to metal connections, the Contractor shall work the metal connections first. Teflon paste or approved equal shall be used on all threaded PVC to PVC joints, and on all threaded PVC to metal joints. Light wrench pressure is all that is required. Where threaded PVC connections are required, use threaded PVC adapters into which the pipe may be welded. Teflon tape shall not be accepted. Use only male plastic in female metal fittings to adapt. Male plastic nipples or adapters in female plastic fittings are not permitted unless a special reinforced reducer bushing (such as produced by Spears or equal) is approved in advance by the Owner’s Representative.

3.05 PVC PIPE INSTALLATION

A. Piping shall be snaked in the trench to allow for thermal expansion and contraction.

B. After all curing of solvent weld joint and after having received the approval of the Owner's Representative, the mainline shall be filled. Extreme care will be taken to slowly fill the piping while releasing entrapped air at the ends of the main line.

C. All irrigation lines shall have a minimum clearance of four inches from each other, and a minimum clearance of six inches from lines of other trades. Parallel lines shall not be installed directly over one another.

D. Manufacturing's installation recommendations shall be strictly adhered to.

3.06 POLYETHYLENE PIPE INSTALLATION

A. Cut tubing square and clean.

B. On compression fittings with internal barb, walk or "wiggle" the poly tubing into the fitting. Twisting and turning could result in damage to the tubing. Insert tubing into fitting a minimum of 1/2".

C. For lubrication, use manufacturer's recommended lubricant. Soaps, oils, detergents, or other wetting agents must not be used as a method of making insertion easier.

D. The minimum bend radius is 20 diameters of the tubing.

F. Snake and tubing to allow for thermal expansion and contraction.

G. Flush caps shall be installed at the end of all lateral/branch poly lines and driplines or where shown on the plans. Caps shall be installed as detailed on plans.

H. Flush lines completely and prior to installation of dripline.

I. Stabilize dripline with soil staples as approved by Owner’s Representative.

3.07 FLUSHING OF SYSTEM

A. Before the dripline has has been installed, the control valves shall be opened with the dripline ball valves closed, and a full head of water shall be used to flush out the system.

B. Dripline shall be installed only after flushing of the system has been accomplished to the complete satisfaction of the Owner's Representative.

3.08 AUTOMATIC CONTROLLER

Install automatic controller as per manufacturer's instructions. Remote control valves shall be connected to controller in numerical sequence as shown on the drawings and approved by the Owner’s Representative.

3.09 HIGH VOLTAGE WIRING FOR AUTOMATIC CONTROLLER

A. An electrical outlet shall be provided for the Contractor’s use inside the DAIC shed for the controller.

B. All electrical work shall conform to local codes, ordinances, and governing authorities having jurisdiction.

3.10 REMOTE CONTROL VALVES

Install remote control valves where shown on drawings and details. Install each remote control valve in a separate valve box in locations approved by the Owner’s Representative. All electric control valves shall be tagged with permanent tags and markings indicating valve number and controller station. The openings in the sides and bottoms of the valve boxes shall be sealed with geotextile fabric.

3.11 CONTROL WIRE INSTALLATION

All control wire less than 500 feet in length shall be continuous without splices or joints from the controller to the valves. Connections to the electric valves shall be made within 18 inches of the valve using connectors specified in Paragraph 2.07, unless otherwise approved by the Owner's Representative in writing.

All wiring shall be installed in Schedule 40 Grey PVC conduit. Minimum size shall be 1¼” for new conduit. All conduit shall terminate in a valve box. All bends and turns shall use long sweep ells. Maximum number of bends shall be as limited by N.E.C. and pull boxes shall be provided where required.

All control wires shall be installed at least 18 inches deep. Contractor shall obtain the Owner's Representative's approval for wire routing when installed in separate trench. Control wires may be installed in a common trench with piping; however, wires must be installed a minimum of 3 inches below or to one side of piping.

3.12 FIELD QUALITY CONTROL AND SYSTEM TESTING

A. Adjustment of the system:

1. Owner's Representative to approve all dripline locations and reserves the right to request Contractor to make minor adjustments to dripline placement at no cost to the Owner.
2. All parts of the irrigation system and associated equipment shall be adjusted to function properly and shall be turned over to the Owner in operating condition.

B. Testing of Irrigation System:

1. The Contractor shall request the presence of the Owner's Representative at least 48 hours in advance of testing.
2. Test all pressure lines under hydrostatic pressure at the high end of the system pressure pump (approximately 50 psi), located at the DAIC shed, to demonstrate that the system is water tight.
3. Pipe sections shall be center loaded and all couplings shall be exposed. Before testing, the line shall have been filled with water for at least four (4) hours and provisions made for thoroughly bleeding the line of air. Sustain pressure with no more than a 2 psi loss in lines for not less than 6 hours.
4. All hydrostatic tests shall be made only in the presence of Owner's Representative and/or BGNDRF personnel. No pipe shall be backfilled until it has been inspected, tested and approved by the Owner’s Representative.
5. The pressure pump at the water supply source may be used for the pressure test; Contractor shall provide all other test equipment.

C. The Phase I and 2 irrigation systems shall be installed and pressure tested no later than June 2, 2014. The Owner’s Representative will grant provisional acceptance after Phase 1 and 2 irrigation has been installed, tested and completed in conformance with the contract documents. The Contractor shall make every effort to achieve provisional acceptance no later than June 6, 2014.

3.13 WORK DURING GUARANTEE PERIOD

A. After provisional acceptance, Contractor shall be responsible for the repair and replacement of defective materials or workmanship through the guarantee period.

B. If a problem is observed, Contractor shall respond to Owner’s Representative within 24 hours of the request.

C. Following the guarantee period, the Owner shall grant final job acceptance after the Contractor has field-verified all work and system components are complete, fully operational, and in conformance with the contract documents.

3.14 CLEANUP

Cleanup shall be made as each portion of work progresses. Refuse and excess soil materials shall be removed from the site, and any damage sustained to existing conditions at the Ag Area and the Ag Area service/access roads shall be repaired to the original conditions acceptable to the Owner's Representative and BGNDRF personnel.

3.15 OBSERVATION Prior to Acceptance

The Contractor shall operate each station for the Owner's Representative at the time of inspection for provisional acceptance and at the time of inspection for final acceptance. Any items deemed not acceptable due to defective materials and workmanship shall be reworked to the complete satisfaction of the Owner's Representative.

The Contractor shall show evidence to the Owner's Representative that the Owner has received all accessories, charts, record drawings, and equipment as required before final observation can occur.

3.16 OBSERVATION SCHEDULE

A. Contractor shall be responsible for notifying the Owner's Representative/ BGNDRF in advance for the following observations according to the time indicated:

   1. Pre-job conference - 7 days
   2. Pressure supply line installation and testing - 48 hours
   3. Automatic controller installation - 48 hours
   4. Control wire installation - 48 hours
   5. Dripline system installation and testing – 48 hours
   6. Provisional and final observation - 7 days

B. When the inspections have been conducted by other than the Owner's Representative, show evidence of when and by whom these inspections were made.

END OF SECTION

RECLAMATION

Managing Water in the West

Desalination and Water Purification Research and Development Program Report No 181

Using Halophyte Farming to Manage Inland Reverse Osmosis Concentrates

Appendix 2 – NMSU Soil Infiltration Report

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2016

Soil Hydraulic Conductivity using Tension Infiltrometer at BGNDRF

PREPARED FOR

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Test-site: Brackish Groundwater National Desalination Research Facility, Alamogordo, NM

Introduction

Soil water transport in the vadose zone depends on the soil hydraulic properties. Among different soil hydrological properties, the saturated hydraulic conductivity is reported to have the greatest statistical variability (Biggar and Nielsen, 1976). Soil hydraulic conductivity is influenced by the number, volume, diameter, continuity, and connectivity of the macropores (Shukla, 2011). Macropores are channels with large pore radius (usually > 0.05 cm; Luxmoore, 1981) and contribute to rapid water flow through the soil matrix. Several researchers have emphasized the advantage of estimating the porosity of actively conducting macropores, rather than the total porosity, using tension infiltrometers (Beven and Germann, 1981). A tension infiltrometer is a simple device, requires a lesser volume of water than double ring infiltrometers, and can determine in-situ saturated hydraulic conductivity (K_s) and unsaturated hydraulic conductivity ($K(\psi)$) (Dasgupta et al., 2006; Adhikari et al., 2012). Saturated hydraulic conductivity is one of the most important parameters for soil-water-plant interactions, water and solute movement and retention through the soil profile. It is a critically important parameter for estimation of various other soil hydrological parameters necessary for modeling flow through the naturally unsaturated vadose zone (Deb and Shukla, 2012).

Theory

Infiltration is the entry of water from the soil surface into the soil and becomes soil water. The infiltration capacity of the soil can be determined using an infiltrometer. The exponential model of Gardner (1958) was used to calculate the $K(\psi)$ for each tension using tension infiltrometer data (Shukla, 2014):

$$K(\psi) = K_S \exp(\alpha\psi) \qquad (1)$$

where $K(\psi)$ ($L\ T^{-1}$) is the unsaturated hydraulic conductivity for a given tension ψ (L), K_s ($L\ T^{-1}$) is the field saturated hydraulic conductivity, and α (L^{-1}) is the sorptive number. Wooding's (1968) equation (eq. 2) was used to calculate hydraulic conductivity from steady-state infiltration rate:

$$Q(\psi) = \pi r^2 K(\psi)\left[1 + \frac{4}{\pi r \alpha}\right] \qquad (2)$$

where Q ($L^3\ T^{-1}$) is the steady-state infiltration rate, and r (L) is the radius of the disk (10 cm). Since Eq 2 has two unknown variables, $K(\psi)$ and α, two steady-state fluxes at different tensions are required. The limitations of equation 2 include the assumptions of homogeneous soil profile and uniform moisture content. The $K(\psi)$ was estimated in the middle of an interval between two applied tensions (ψ_1 and ψ_2), assuming α to be constant over this interval (Reynolds and Elrick 1991):

$$\alpha = \frac{\ln[Q(\psi_2)/Q(\psi_1)]}{\psi_2 - \psi_1} \qquad (3)$$

An infiltrometer is comprised of a bubble tower (the shorter with 1 inch inner diameter tube), water reservoir tower (the longer with 2 inches outer diameter tube) and a disk. A specific tension is set by adjusting the elevation of the air entry tube inside the bubble tower to control the water flow from the water reservoir tower to the disc in contact with the soil. This report was prepared on behalf of University of Arizona to describe the infiltration tests conducted at the

Brackish Groundwater National Desalination Research Facility (BGNDRF), Alamogordo, NM and document the generated data.

Infiltration tests

All infiltration tests were performed from August 28 to September 5, 2014 using a tension infiltrometer of 20 cm disk diameter (Soil Measurement Systems, Tucson, AZ; **Fig. 1**) at the BGNDRF site in Alamogordo, NM. On August 28, a total of 22 locations were identified in two fields known as north and south fields with a total area of about 1,906.37 m^2 (20,520 ft^2). The identified locations were marked with marking whiskers and labeled using a black sharpie marker and duct tape on August 28. Locations in the south and north fields were labeled as S-1 through S-11 and N-1 through N-11, respectively.

Fig. 1. Infiltrometer installed for infiltration tests at the Brackish Groundwater National Desalination Research Facility, Alamogordo, NM on August 28, 2014

Infiltration tests were conducted in the south field from August 28 to September 3, 2014. During this period, weather was sunny, soil was dry, and surface crusting was observed at some locations while soil disturbance by a backhoe loader was observed at some other locations especially along the southern edge of the field. On August 29, the backhoe loader was seen to be operational along the southern edges of both fields.

Soil at each location was prepared before conducting the infiltration tests by removing approximately 2 cm from the soil surface to level the surface on which sand will be placed. This also eliminated the soil crust that could alter the infiltration rate. A layer of sand with a diameter of 20 cm was placed on the prepared soil surface to facilitate good contact between the infiltrometer disk and the soil. Infiltrometer was placed on a leveled soil surface to ensure that the tension at the infiltration disk is the same as the one set with the air entry tube in the bubble tower.

Most of the day of August 28 was spent on the identification of the locations and infiltration tests were performed only in location S-3. The date and number of locations where infiltration tests were completed are shown in **Table 1**. GPS readings were recorded at each location (**Table 2**) and soil samples were collected at the end of the infiltration tests to determine saturated soil water content (**Table 3** and **Table 4**) in the laboratory. The recorded tension infiltrometer data was used to calculate $K(\psi)$, K_s, and α for each sampling location of the south field (**Table 3**).

Table 1. Infiltration tests completed at different locations from August 28 through September 5, 2014 in south (S) and north (N) fields.

Date	Infiltration tests completed at each location
28-Aug-14	S-3
29-Aug-14	S-1 and S-2
2-Sep-14	S-4, S-5, S-6 and S-7
3-Sep-14	S-8, S-9, S-10 and S-11
4-Sep-14	N-1, N-2, N-3, N-4 and N-5
5-Sep-14	N-6, N-7, N-8, N-9, N-10 and N-11

Table 2. GPS coordinates of locations of interest in the south and north fields of the Brackish Groundwater National Desalination Research Facility, Alamogordo, NM

Count	Location	ID-Location	N-Latitude	W-Longitute	Accuracy of GPS
1	South Field	S-1	32^o 53.055'	105^o 58.658'	± 9 Ft
2	South Field	S-2	32^o 53.066'	105^o 58.658'	± 10 Ft
3	South Field	S-3	32^o 53.077'	105^o 58.651'	± 9 Ft
4	South Field	S-4	32^o 53.063'	105^o 58.650'	± 9 Ft
5	South Field	S-5	32^o 53.070'	105^o 58.643'	± 9 Ft
6	South Field	S-6	32^o 53.065'	105^o 58.640'	± 9 Ft
7	South Field	S-7	32^o 53.071'	105^o 58.629'	± 9 Ft
8	South Field	S-8	32^o 53.065'	105^o 58.629'	± 9 Ft
9	South Field	S-9	32^o 53.073'	105^o 58.628'	± 9 Ft
10	South Field	S-10	32^o 53.057'	105^o 58.629'	± 9 Ft
11	South Field	S-11	32^o 53.074'	105^o 58.626'	± 9 Ft
12	North Field	N-1	32^o 53.106'	105^o 58.652'	± 9 Ft

13	North Field	N-2	32° 53.103'	105° 58.651'	± 9 Ft
14	North Field	N-3	32° 53.094'	105° 58.647'	± 9 Ft
15	North Field	N-4	32° 53.086'	105° 58.647'	± 9 Ft
16	North Field	N-5	32° 53.093'	105° 58.643'	± 9 Ft
17	North Field	N-6	32° 53.097'	105° 58.640'	± 9 Ft
18	North Field	N-7	32° 53.083'	105° 58.639'	± 9 Ft
19	North Field	N-8	32° 53.097'	105° 58.636'	± 9 Ft
20	North Field	N-9	32° 53.086'	105° 58.629'	± 9 Ft
21	North Field	N-10	32° 53.103'	105° 58.629'	± 9 Ft
22	North Field	N-11	32° 53.085'	105° 58.629'	± 9 Ft

Table 3. Unsaturated hydraulic conductivity ($K(\psi)$), saturated hydraulic conductivity (K_s), sorptive number (α) and gravimetric soil moisture content (w) values of locations of interest in the south field of the Brackish Groundwater National Desalination Research Facility, Alamogordo, NM

Sample	$K(\psi)$ (cm/h) at -20 cm	$K(\psi)$ (cm/h) at -10 cm	$K(\psi)$ (cm/h) at -5 cm	$K(0) = K_s$ (cm/h)	α (cm^{-1})	w (%)
S-1-A	0.6806	4.2445	10.5994	24.5168	0.1830	17.78
S-1-B	0.3975	5.2338	18.9905	68.9059	0.0673	30.66
S-2-A	0.1546	0.8877	2.1269	5.0963	0.1748	21.76
S-2-B	0.0709	1.7717	8.8549	44.2568	0.3218	34.36
S-3-A	0.0253	0.2399	0.7388	2.2756	0.2250	24.78
S-3-B	0.1698	0.4745	0.7933	1.3263	0.1028	23.31
S-4-A	0.0856	0.4841	1.1515	2.7387	0.1733	28.63
S-4-B	0.0824	0.4038	0.8937	1.9782	0.1589	19.31
S-5-A	0.1183	0.5891	1.3145	2.9335	0.1605	27.77
S-5-B	0.1224	0.7582	1.8869	4.6961	0.1824	23.08
S-6-A	0.1971	0.5419	0.8984	1.4895	0.1011	19.41
S-6-B	0.0827	0.4109	0.9158	2.0409	0.1603	10.46
S-7-A	0.2144	1.0527	2.3325	5.1683	0.1591	28.88
S-7-B	0.2732	1.3813	3.1060	6.9841	0.1621	25.19
S-8-A	0.0908	0.6733	1.8335	4.9930	0.2004	14.71
S-8-B	0.0858	0.4895	1.1694	2.7936	0.1742	27.44
S-9-A	0.5001	6.9301	25.7967	96.0260*	0.2629	26.43
S-9-B	0.2908	3.1852	10.5421	34.8916	0.2394	29.62
S-10-A	0.1497	0.5467	1.0447	1.9964	0.1295	20.60
S-10-B	0.0903	0.6511	1.7483	4.6948	0.1976	20.33
S-11-A	0.0883	0.5723	1.4569	3.7089	0.1869	20.31
S-11-B	0.2402	0.6795	1.1428	1.9220	0.1040	27.81

Infiltration tests were conducted under tensions of -20, -10, -5 and 0 cm in that order at each location. Tension values below -20 cm were not used to prevent air entry from the layer of sand into the nylon mesh membrane of the infiltration disk.

On September 4, infiltration tests were performed at five (5) locations in the north field (**Table 4**). Most of the soil disturbance by a backhoe loader was observed along the southern edge of the field. On September 5, the weather was cloudy in the morning and sunny the rest of the day. The soil in the north field was moist and a puddle of approximately 3 feet in diameter was formed in the southeastern corner of the field as result of a precipitation event that took place early morning on September 5 (**Appendix 1**).

Table 4. Unsaturated hydraulic conductivity (K(ψ)), saturated hydraulic conductivity (K_s), sorptive number (α) and gravimetric soil moisture content (w) values of locations of interest in the North field of the Brackish Groundwater National Desalination Research Facility, Alamogordo, NM

Sample	K(ψ) (cm/h) at -20 cm	K(ψ) (cm/h) at -15 cm	K(ψ) (cm/h) at -10 cm	K(ψ) (cm/h) at -5 cm	K(ψ) (cm/h) at -2 cm	K(0) =K_s (cm/h)	α (cm^{-1})	w (%)
N-1-A	0.0874		0.5418	1.3488		3.3575	0.1824	13.38
N-1-B	0.0931		0.7896	2.3002		6.7003	0.2138	20.43
N-2-A	0.1475		0.5179	0.9705		1.8187	0.1256	19.03
N-2-B	0.5144		5.0232	15.6977		49.0556	0.2279	21.02
N-3-A	0.4478		3.1024	8.1660		21.4940	0.1936	17.28
N-3-B	0.0803		0.3589	0.7590		1.6050	0.1498	17.99
N-4-A	0.6148		3.8886	9.7794		24.5939	0.1844	23.16
N-4-B	0.2063		0.6189	1.0719		1.8566	0.1099	22.35
N-5-A	0.2635		0.8704	1.5819		2.8749	0.1195	15.64
N-5-B	0.2047		3.4449	14.1336		57.9864	0.2823	16.68
N-6-A			0.4226	1.3565	2.7308	4.3540	0.2332	23.08
N-6-B		0.2272	1.8029	14.3099		113.5778*	0.4143	28.04
N-7-A		0.0907	0.2461	0.6680		1.8134	0.1997	26.46
N-7-B		0.3067	0.7228	1.7032		4.0136	0.1714	23.18
N-8-A		0.1643	0.3618	0.7963		1.7530	0.1578	16.36
N-8-B		0.2416	1.0471	4.5385		19.6715	0.2933	19.59
N-9-A		0.1415	0.6980	3.4429		16.9820	0.3192	25.96
N-9-B		0.1886	0.8671	3.9871		18.3335	0.3051	21.43
N-10-A		0.2246	1.6196	11.6793		84.2220*	0.3951	19.90
N-10-B		0.2296	0.3430	0.5123		0.7653	0.0803	20.01
N-11-A		0.1846	1.6955	15.5738		143.0526*	0.4435	30.59
N-11-B		0.1416	1.1006	8.5535		66.4715	0.4101	23.08

Precipitation of 1.5 inches on September 5 increased the soil moisture content, therefore, infiltration test could not be conducted at -20 cm tension (**Table 4**). Infiltration tests at location N-6 were conducted using two tension increments. The first infiltration test was performed with tensions of -10, -5, -2 and 0 cm. The second test was performed with tensions of -15, -10, -5 and 0 cm and latter increments were chosen for the remaining tests. Since the values of K(ψ) were similar for the tests at N-5, test was not repeated at -15 cm tension. The infiltration tests were conducted at the remaining six locations on September 6 (**Table 1**). The K(ψ), K_s and soil gravimetric moisture content values for each of the locations from the north fields are shown in **Table 4**. Some of the K_s values (marked with an *) in Tables 3 and 4 are not the true K_s values because some lateral movement of water on the soil surface was observed at 0 cm tension.

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Appendix 1. On September 5, 2014 the soil at the Brackish Groundwater National Desalination Research Facility, Alamogordo, NM was moist after a precipitation event.

RECLAMATION
Managing Water in the West

Desalination and Water Purification Research and Development Program Report No 181

Using Halophyte Farming to Manage Inland Reverse Osmosis Concentrates

Appendix 3 – Alamogordo, NM Weather

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2016

Average Weather For Alamogordo, New Mexico, USA

Location

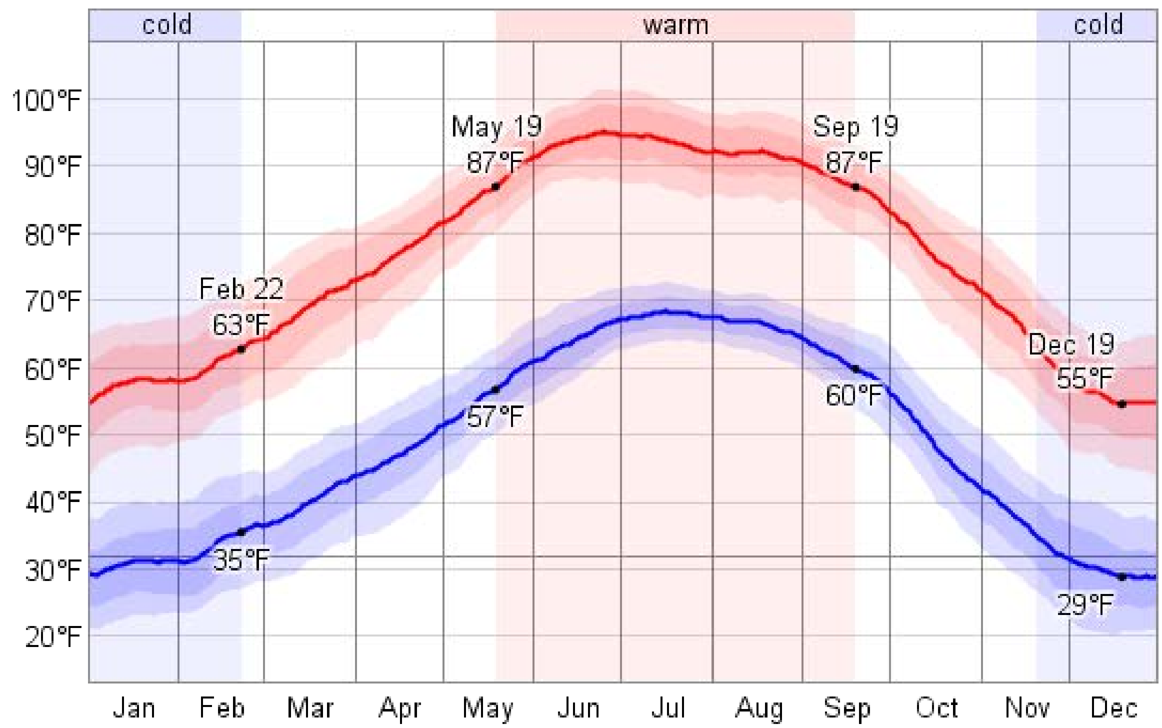
This report describes the typical weather at the Alamogordo-White Sands Regional Airport (Alamogordo, New Mexico, United States) weather station over the course of an average year. It is based on the historical records from 1997 to 2012. Earlier records are either unavailable or unreliable.

Alamogordo, New Mexico has a cold semi-arid steppe climate. The area within 25 miles of this station is covered by shrublands (59%), forests (31%), and grasslands (10%).

Temperature

Over the course of a year, the temperature typically varies from 29°F to 95°F and is rarely below 20°F or above 101°F.

Daily High and Low Temperature

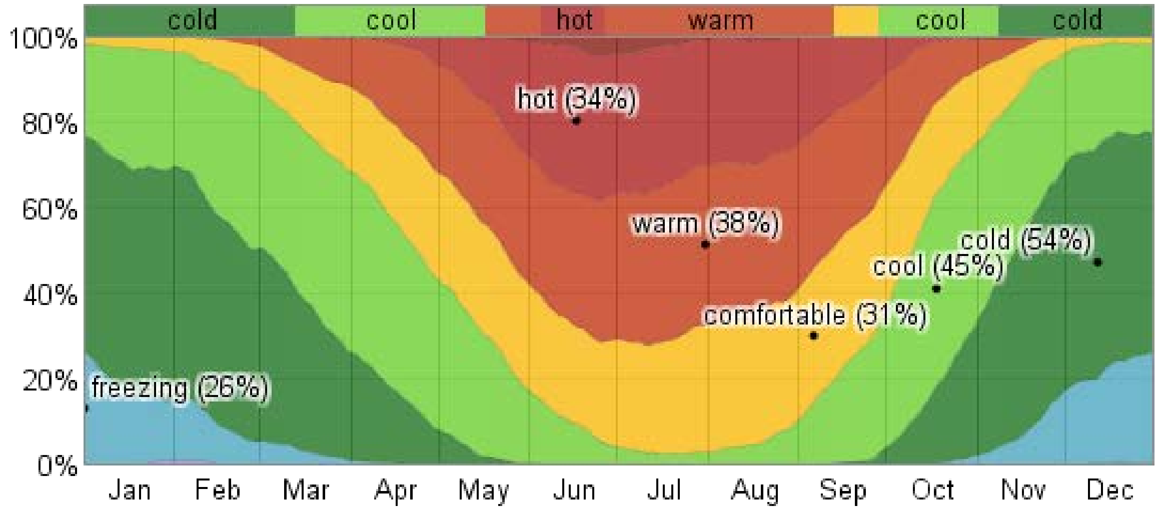


The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

The warm season lasts from May 19 to September 19 with an average daily high temperature above 87°F. The hottest day of the year is June 25, with an average high of 95°F and low of 66°F.

The cold season lasts from November 20 to February 22 with an average daily high temperature below 63°F. The coldest day of the year is December 28, with an average low of 29°F and high of 55°F.

Fraction of Time Spent in Various Temperature Bands

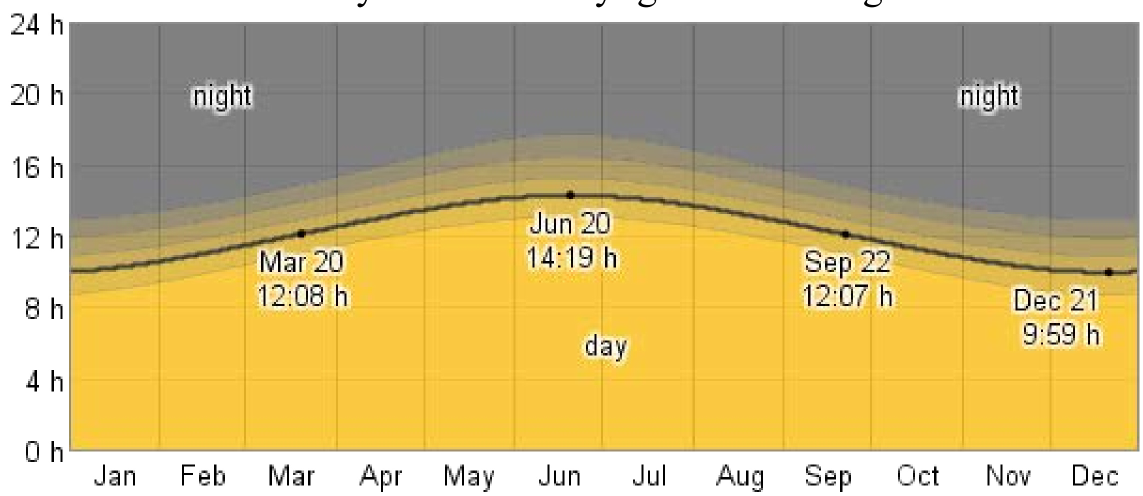


The average fraction of time spent in various temperature bands: frigid (below 15°F), freezing (15°F to 32°F), cold (32°F to 50°F), cool (50°F to 65°F), comfortable (65°F to 75°F), warm (75°F to 85°F), hot (85°F to 100°F) and sweltering (above 100°F).

Sun

The length of the day varies significantly over the course of the year. The shortest day is December 21 with 9:59 hours of daylight; the longest day is June 20 with 14:19 hours of daylight.

Daily Hours of Daylight and Twilight

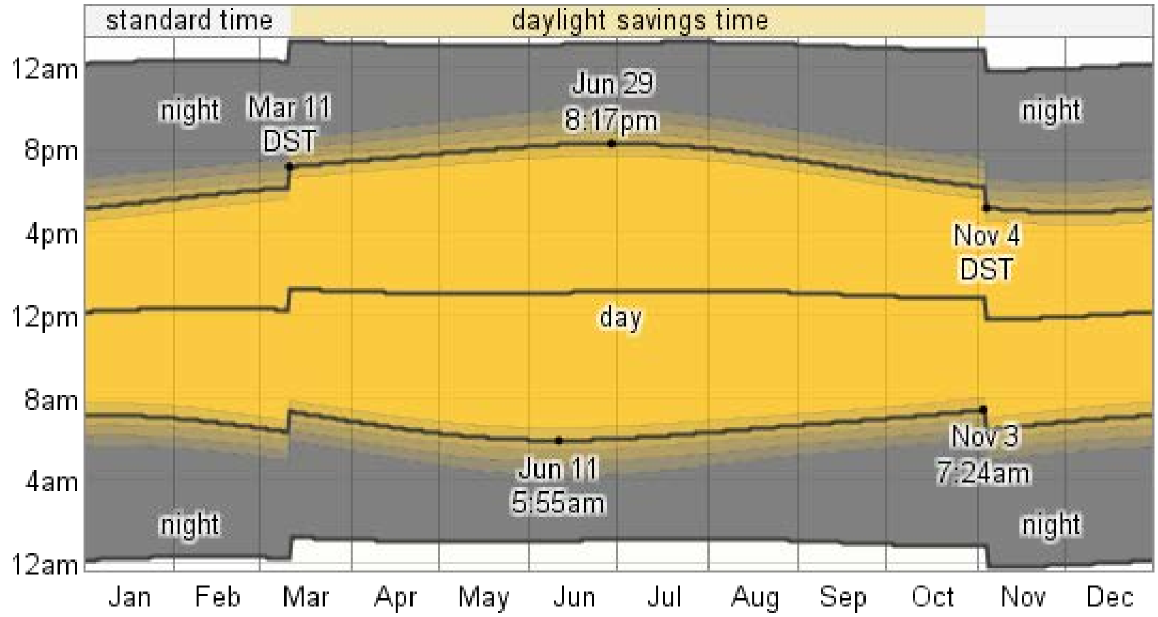


The number of hours during which the Sun is visible (black line), with various degrees of daylight, twilight, and night, indicated by the color bands. From bottom (most yellow) to top (most gray): full daylight, solar twilight (Sun is visible but less than 6Â° from the horizon), civil twilight (Sun is not visible but is less than 6Â° below the horizon), nautical twilight (Sun is between 6Â° and 12Â° below the horizon), astronomical twilight (Sun is between 12Â° and 18Â° below the horizon), and full night.

The earliest sunrise is at 5:55am on June 11 and the latest sunset is at 8:17pm on June 29. The latest sunrise is at 7:24am on November 3 and the earliest sunset is at 4:57pm on December 4.

Daylight savings time (DST) is observed in this location during 2012, starting in the spring on March 11 and ending in the fall on November 4.

Daily Sunrise & Sunset with Twilight and Daylight Savings Time

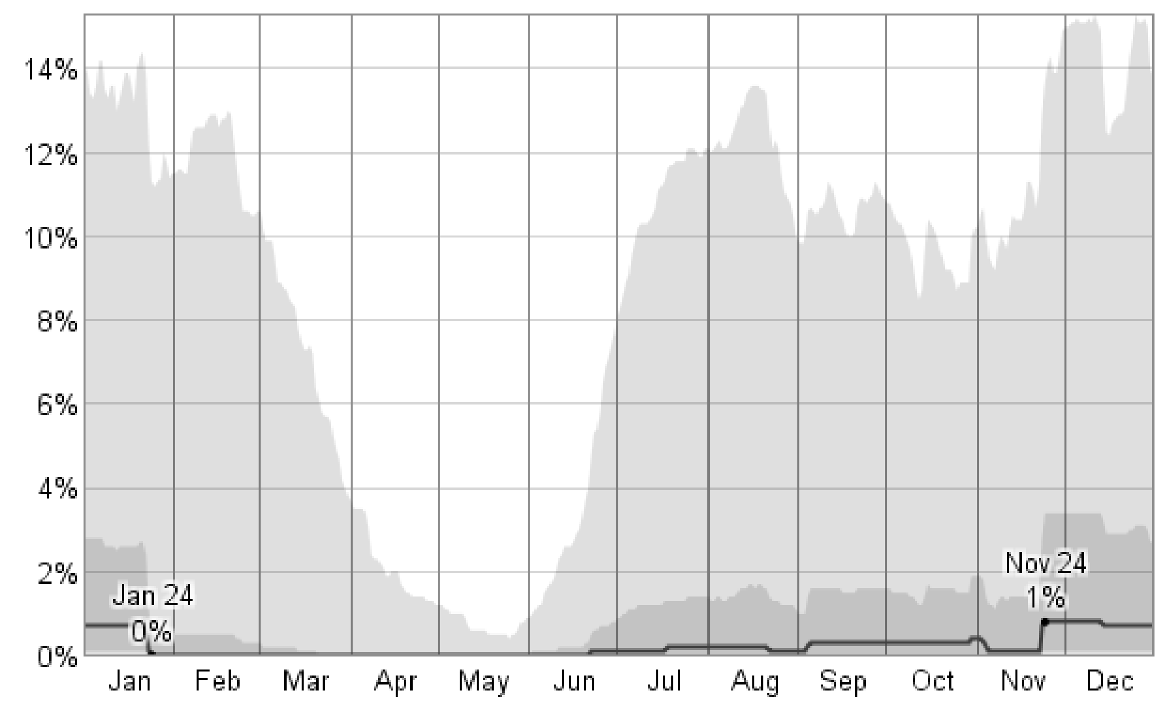


The solar day over the course of the year 2012 . From bottom to top, the black lines are the previous solar midnight, sunrise, solar noon, sunset, and the next solar midnight. The day, twilights (solar, civil, nautical, and astronomical), and night are indicated by the color bands from yellow to gray. The transitions to and from daylight savings time are indicated by the "DST" labels.

Clouds

The median cloud cover is 0% (clear) and does not vary substantially over the course of the year.

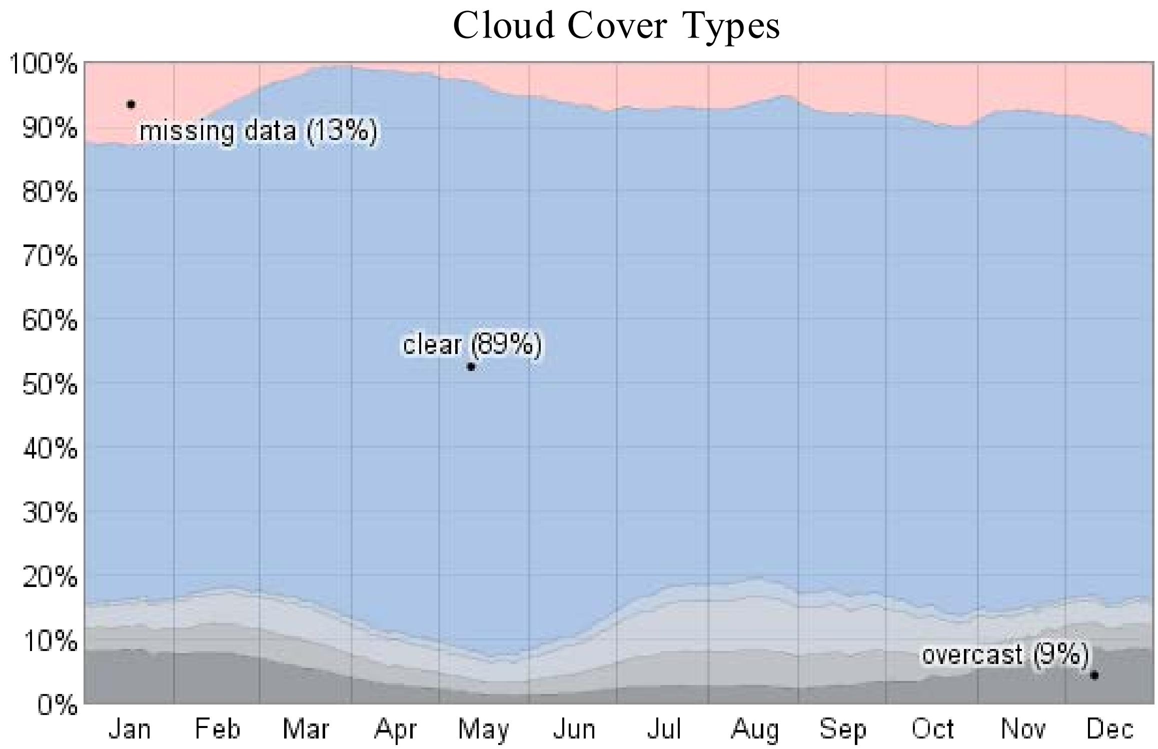
Median Cloud Cover



The median daily cloud cover (black line) with percentile bands (inner band from 40th to 60th percentile, outer band from 25th to 75th percentile).

On January 24, the clearest day of the year, the sky is clear, mostly clear, or partly cloudy 77% of the time, and overcast or mostly cloudy 11% of the time.

On November 24, the cloudiest day of the year, the sky is overcast, mostly cloudy, or partly cloudy 15% of the time, and clear or mostly clear 77% of the time.

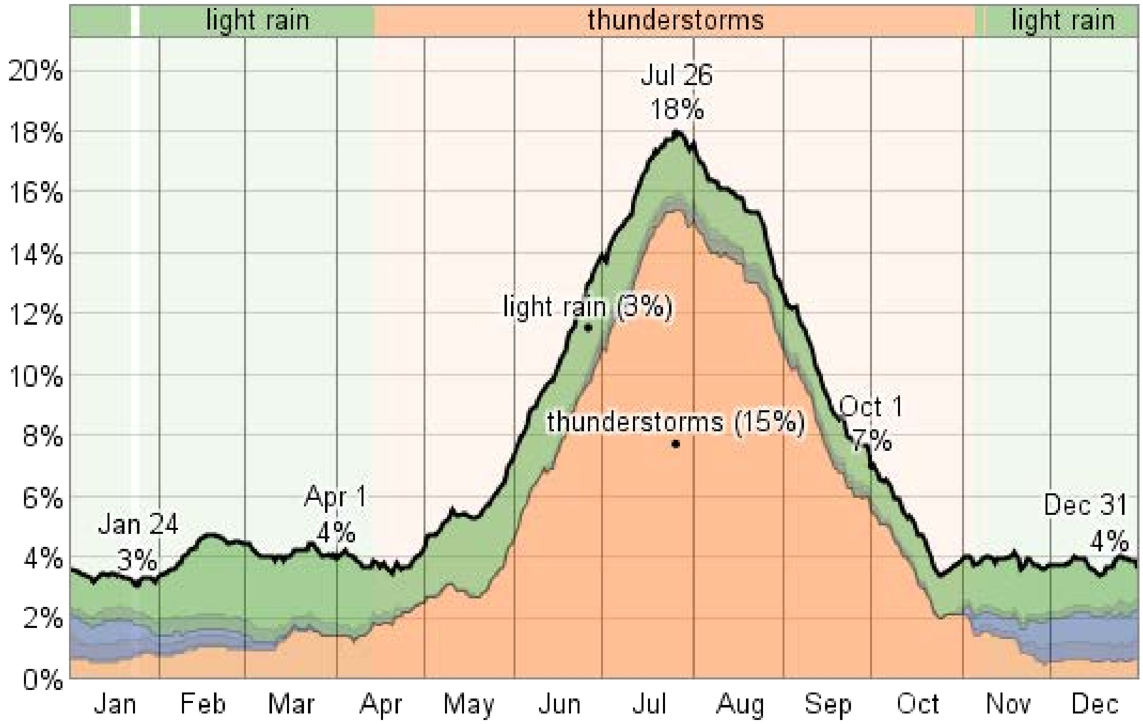


The fraction of time spent in each of the five sky cover categories. From top (most blue) to bottom (most gray), the categories are clear, mostly clear, partly cloudy, mostly cloudy, and overcast. Pink indicates missing data. Outside of the United States clear skies are often reported ambiguously, leading them to be lumped in with the missing data.

Precipitation

The probability that precipitation will be observed at this location varies throughout the year. Precipitation is most likely around July 26, occurring in 18% of days. Precipitation is least likely around January 24, occurring in 3% of days.

Probability of Precipitation at Some Point in the Day



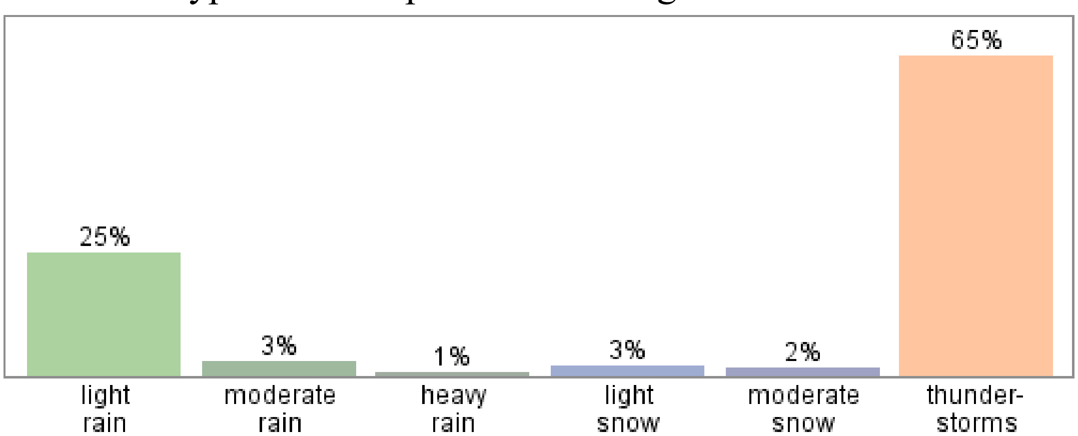
The fraction of days in which various types of precipitation are observed. If more than one type of precipitation is reported in a given day, the more severe precipitation is counted. For example, if light rain is observed in the same day as a thunderstorm, that day counts towards the thunderstorm totals. The order of severity is from the top down in this graph, with the most severe at the bottom.

Over the entire year, the most common forms of precipitation are thunderstorms and light rain.

Thunderstorms are the most severe precipitation observed during 65% of those days with precipitation. They are most likely around July 26, when it is observed during 15% of all days.

Light rain is the most severe precipitation observed during 25% of those days with precipitation. It is most likely around June 26, when it is observed during 3% of all days.

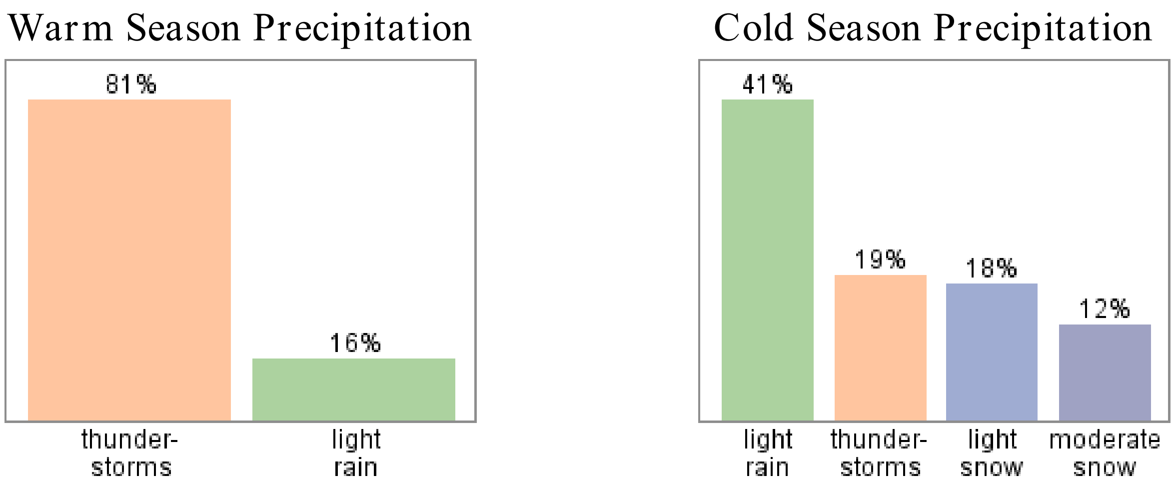
Types of Precipitation Throughout the Year



Relative frequency of various types of precipitation over the course of a typical year.

During the warm season, which lasts from May 19 to September 19, there is a 13% average chance that precipitation will be observed at some point during a given day. When precipitation does occur it is most often in the form of thunderstorms (81% of days with precipitation have at worst thunderstorms) and light rain (16%).

During the cold season, which lasts from November 20 to February 22, there is a 4% average chance that precipitation will be observed at some point during a given day. When precipitation does occur it is most often in the form of light rain (41% of days with precipitation have at worst light rain), thunderstorms (19%), light snow (18%), and moderate snow (12%).



Relative frequency of various types of precipitation during the warm and cold seasons respectively.

Snow

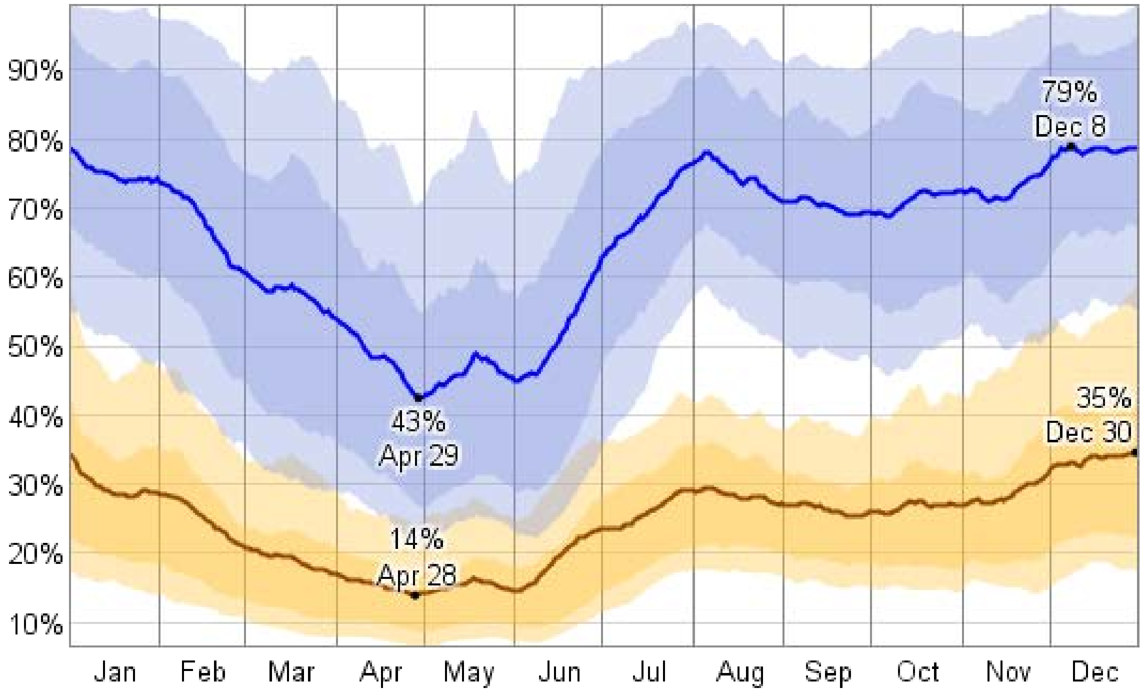
Either snow is exceptionally unlikely to fall at any time during the year at this location or this station does not reliably report precipitation types.

Humidity

The relative humidity typically ranges from 14% (very dry) to 79% (humid) over the course of the year, rarely dropping below 7% (very dry) and reaching as high as 99% (very humid).

The air is driest around April 28, at which time the relative humidity drops below 16% (dry) three days out of four; it is most humid around December 8, exceeding 67% (mildly humid) three days out of four.

Relative Humidity



The average daily high (blue) and low (brown) relative humidity with percentile bands (inner bands from 25th to 75th percentile, outer bands from 10th to 90th percentile).

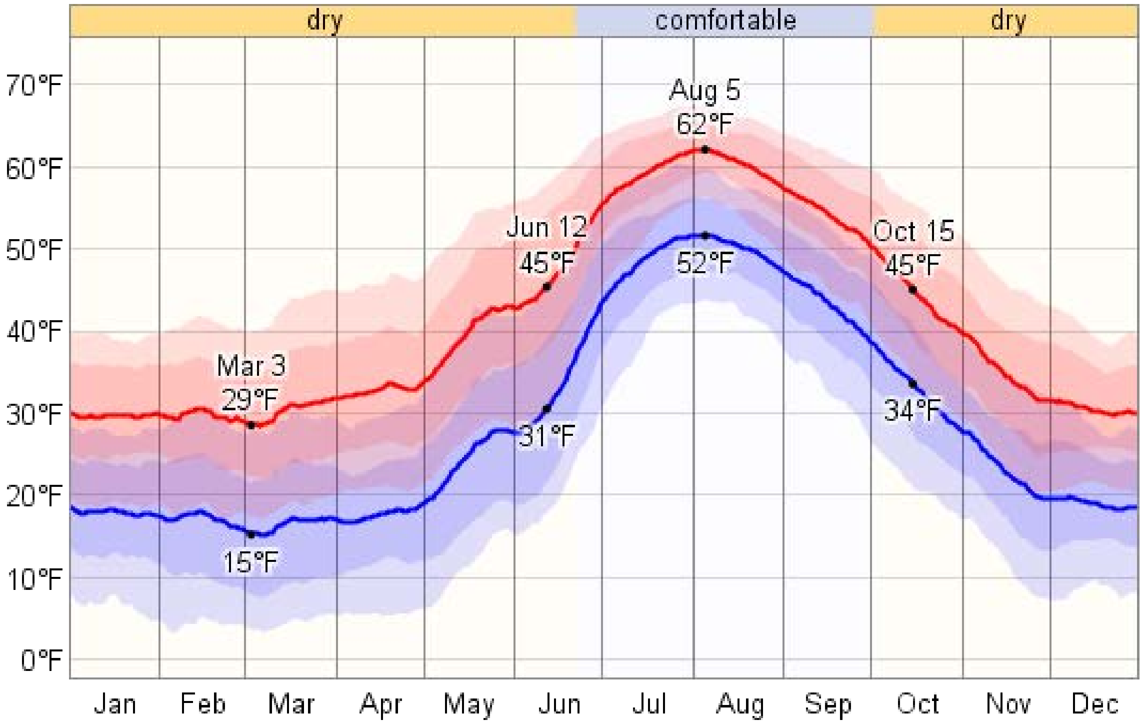
Dew Point

Dew point is often a better measure of how comfortable a person will find the weather than relative humidity because it more directly relates to whether perspiration will evaporate from the skin, thereby cooling the body. Lower dew points feel drier and higher dew points feel more humid.

Over the course of a year, the dew point typically varies from 15°F (dry) to 62°F (mildy humid) and is rarely below 3°F (dry) or above 67°F (muggy).

The time of the year between June 22 and October 2 is the most comfortable, with dew points that are neither too dry nor too muggy.

Dew Point



The daily average low (blue) and high (red) dew point with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

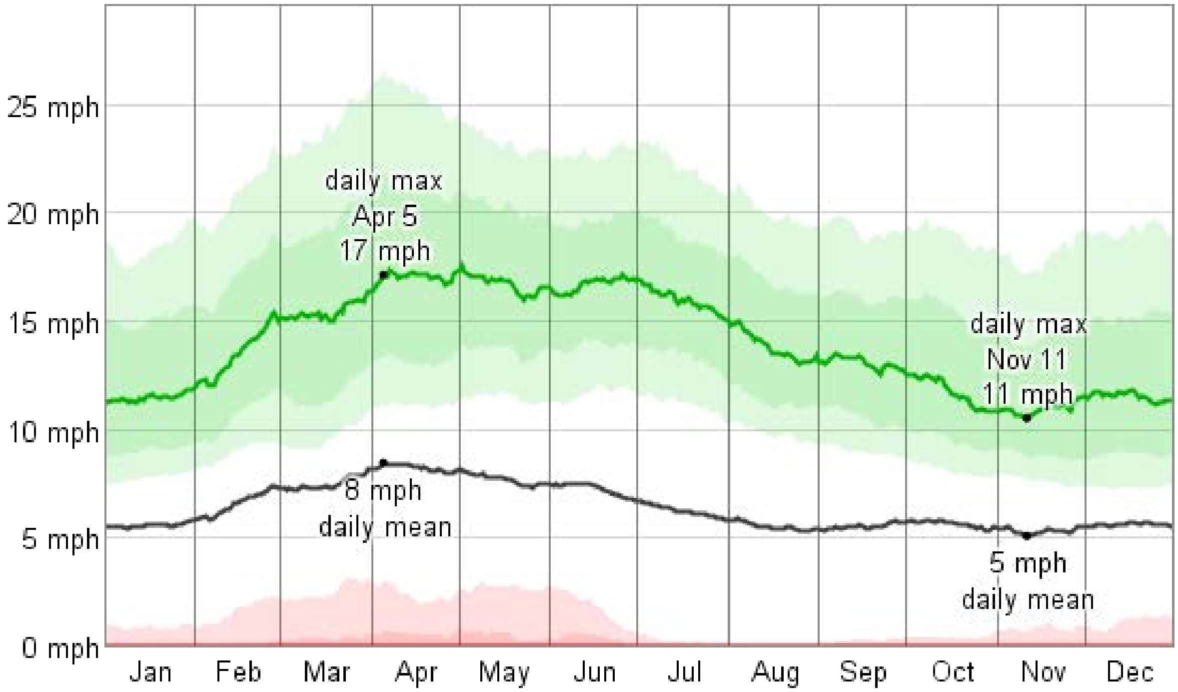
Wind

Over the course of the year typical wind speeds vary from 0 mph to 18 mph (calm to moderate breeze), rarely exceeding 27 mph (strong breeze).

The highest average wind speed of 8 mph (gentle breeze) occurs around April 5, at which time the average daily maximum wind speed is 17 mph (moderate breeze).

The lowest average wind speed of 5 mph (light breeze) occurs around November 11, at which time the average daily maximum wind speed is 11 mph (gentle breeze).

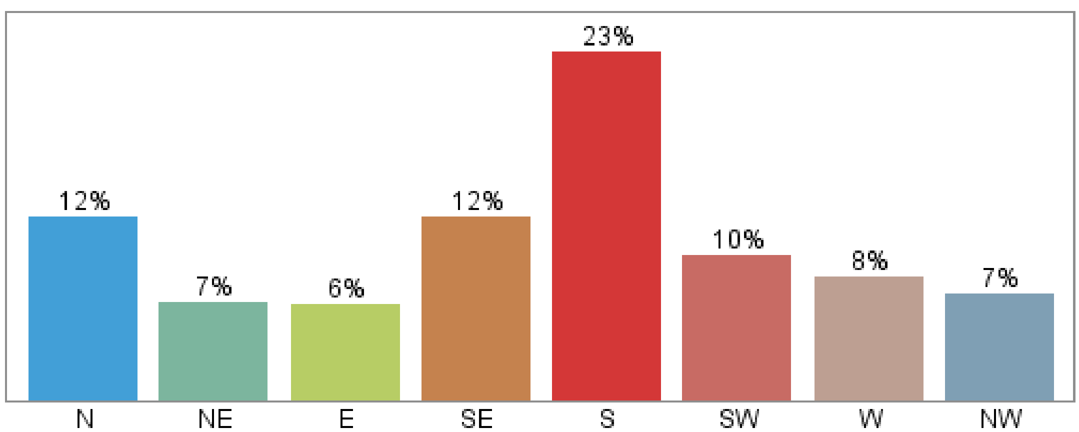
Wind Speed



The average daily minimum (red), maximum (green), and average (black) wind speed with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

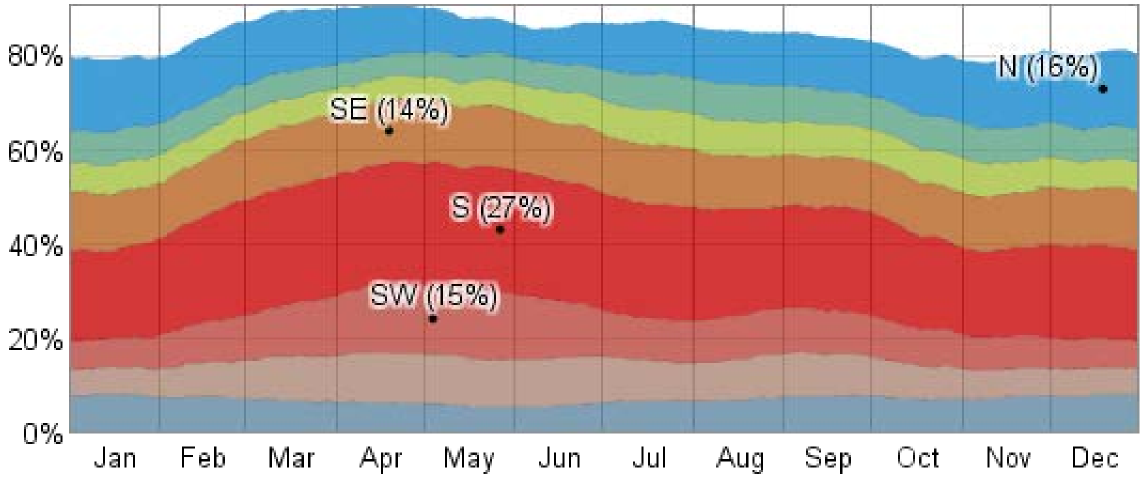
The wind is most often out of the south (23% of the time), north (12% of the time), and south east (12% of the time).

Wind Directions Over the Entire Year

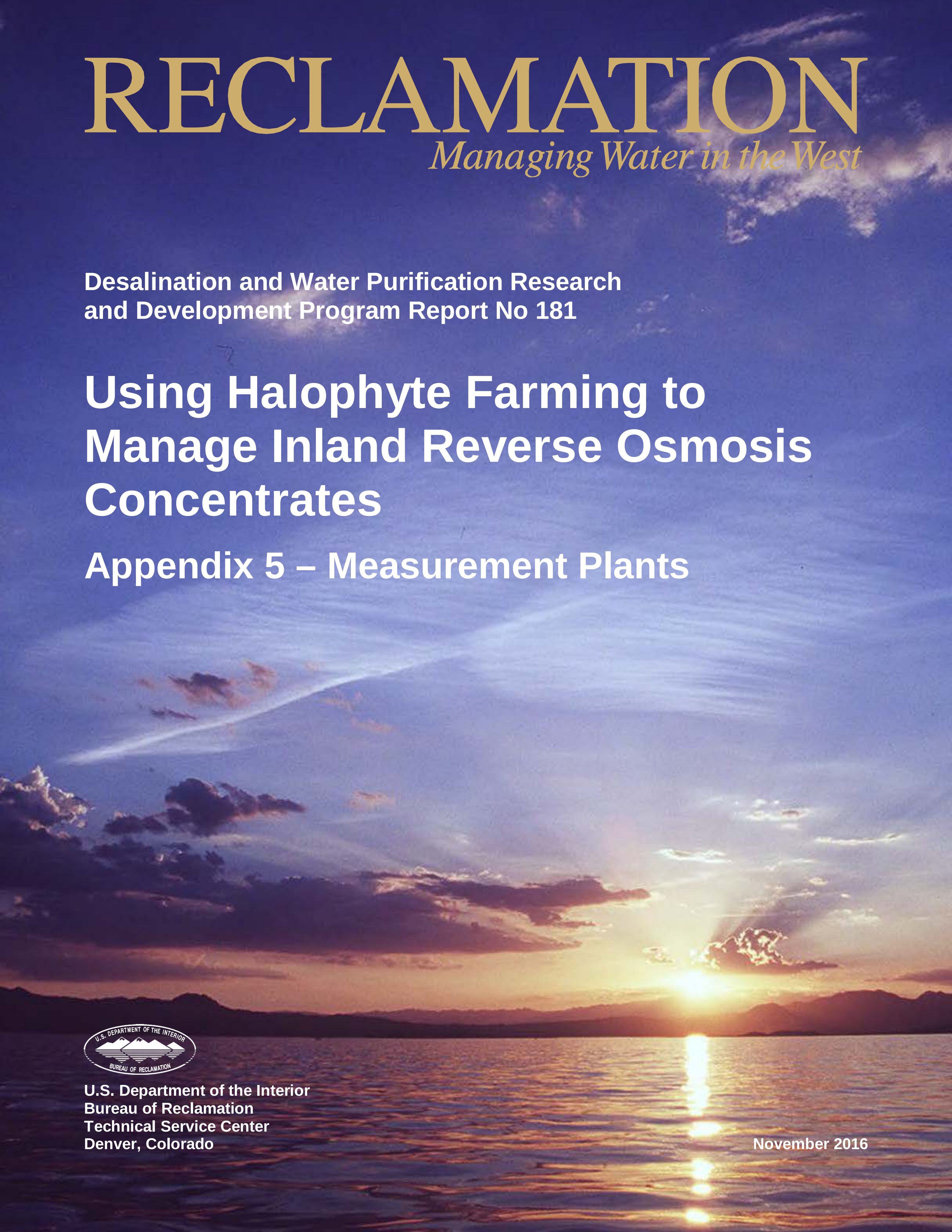


The fraction of time spent with the wind blowing from the various directions over the entire year. Values do not sum to 100% because the wind direction is undefined when the wind speed is zero.

Fraction of Time Spent with Various Wind Directions



The fraction of time spent with the wind blowing from the various directions on a daily basis. Stacked values do not always sum to 100% because the wind direction is undefined when the wind speed is zero.



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Managing Water in the West

Desalination and Water Purification Research and Development Program Report No 181

Using Halophyte Farming to Manage Inland Reverse Osmosis Concentrates

Appendix 5 – Measurement Plants

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Denver, Colorado

November 2016

Appendix 5

Measurement Plants - Methods and Procedures

Tracking plant growth: At the start of establishment stage prior to initiation of experimental irrigation regime, 48 individual plants out of a total of 550 plants per 0.517 acre plot were selected and tagged with a numbered field flag. This was about 10% of plants at establishment and would increase to about 20% of plants at maturity due to thinning prior to the plants reaching maturity.

Plant selection was made based upon total coverage and equal spread throughout the plot. Four plants out of a total of 47 plants per drip line were systematically selected; every tenth plant was selected, alternating distribution from the south to north for even numbered lines and north to south for odd numbered lines (figures N, S). Counts always begin from south and proceed to north. Since newly transplanted replacements were not established they were disregarded in the selection process. If the tenth plant was a new transplant, the next established plant along the tape line was selected and counting by ten resumed. *Atriplex canescens* seedlings grown from various seed sources were included.

Measurements- A measuring stick was held horizontal on the north side of the plant at its widest height. To avoid field calculation errors, eastern (E) and western (W) numbers correlating to plant expanse were noted and added to an excel spreadsheet as '=W-E'. That excel column was copied and only values were pasted into the width column. Plant height was measured from ground surface to upper height of plant. All units are in inches due to readability of the measuring stick. A profile photo was then taken from the south.

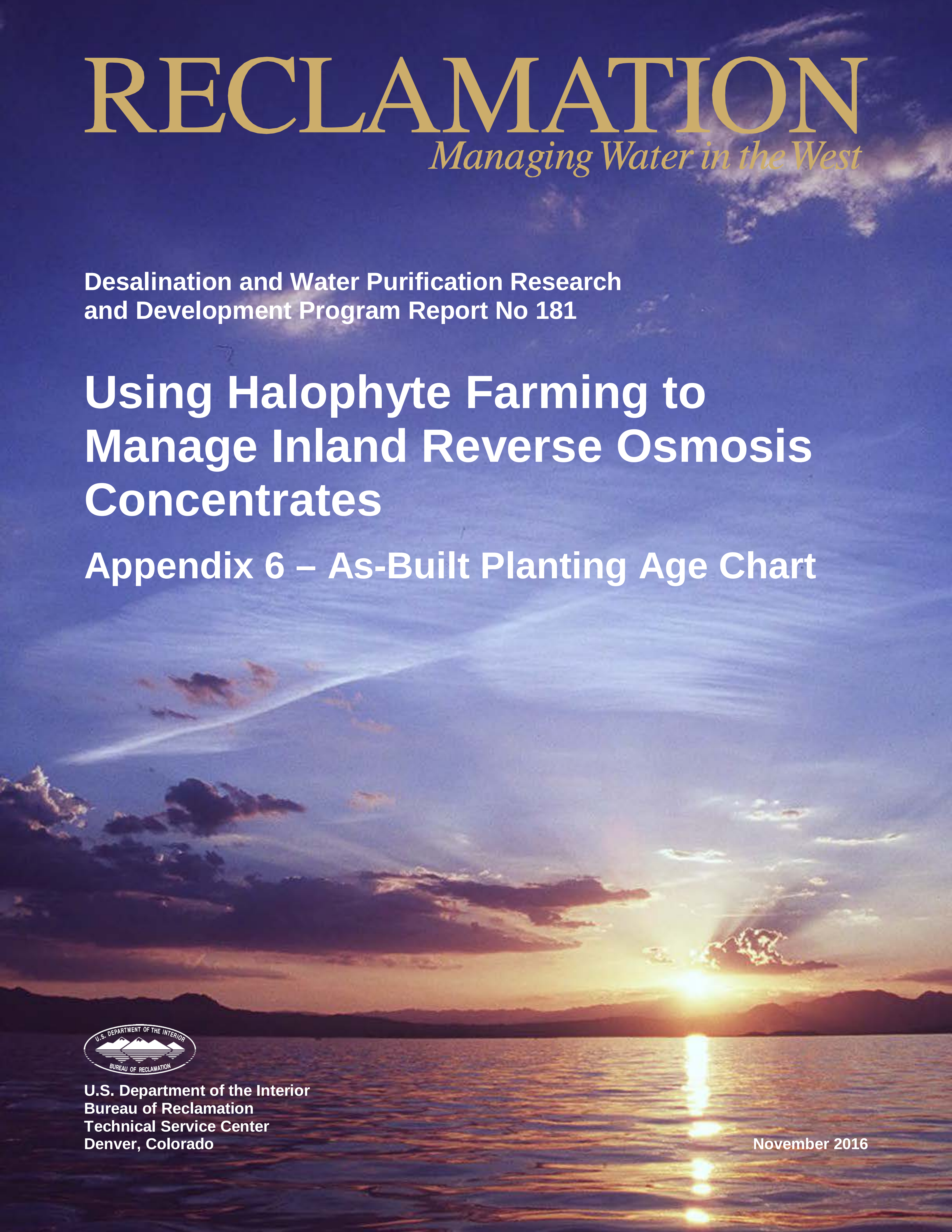
N

Valve		N1		N2		N3		N4		N5		N6	
%Eto		1.2		0.8		1.2		0.8		0.4		1.2	
Species		Canescens		Lentiformis		Canescens		Canescens		Lentiformis		Lentiformis	
Line		A	B	A	B	A	B	A	B	A	B	A	B
Tracking #		93 -- 96	89 -- 92	84 -- 88	81 -- 84	77 --8 0	73 -- 76	69 -- 72	65 -- 68	61 -- 64	57 -- 60	53 -- 56	49 -- 52
Place in	47												
Row	46			88								56	
	45	96											
	44												
	43							72					
	42					80							
	41									64			
	40				84								
	39												
	38						76		68				
	37		92										
	36			87									
	35										60		
	34					79		71					52
	33											55	
	32												
	31	95											
	30									63			
	29			86									
	28						75						
	27				83				67				
	26												
	25		91								59		
	24					78							
	23							70				54	51
	22									62			
	21	94											
	20												
	19			85									
	18												
	17												
	16												
	15		90		82							53	
	14						74		66				
	13										58		50
	12												
	11									61			
	10	93				77							
	9							69					
	8												
	7												
	6												
	5		89										
	4												
	3						73				57		
	2												
	1				81				65				49

N

Valve	S1		S2		S3		S4		S5		S6	
%Eto	0.4		0.4		1.2		0.8		0.8		0.4	
Species	Lentiformis		Canescens		Lentiformis		Canescens		Lentiformis		Canescens	
Line	A	B	A	B	A	B	A	B	A	B	A	B
Tracking #	45 -- 48	41 -- 44	37 -- 40	33 -- 36	29 -- 32	25 -- 28	21 -- 24	17 -- 20	13 -- 16	9 -- 12	5 -- 8	1 -- 4

Place in Row												
47	48		40									
46									16			
45					32						8	
44							24					
43												
42												
41												
40		44								12		
39												
38												
37				36		28						
36									15		7	
35	47											
34			39									
33							23	20				
32												
31												
30					31							4
29		43										
28										11		
27												
26				35		27			14		6	
25												
24	46											
23			38				22					
22								19				
21												
20					30							3
19												
18		42										
17												
16									13			
15						26				10	5	
14												
13	45			34								
12								18				
11			37									
10							21					2
9					29							
8												
7												
6												
5										9		
4						25						
3		41										
2								17				
1				33								1



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Appendix 6 – As-Built Planting Age Chart

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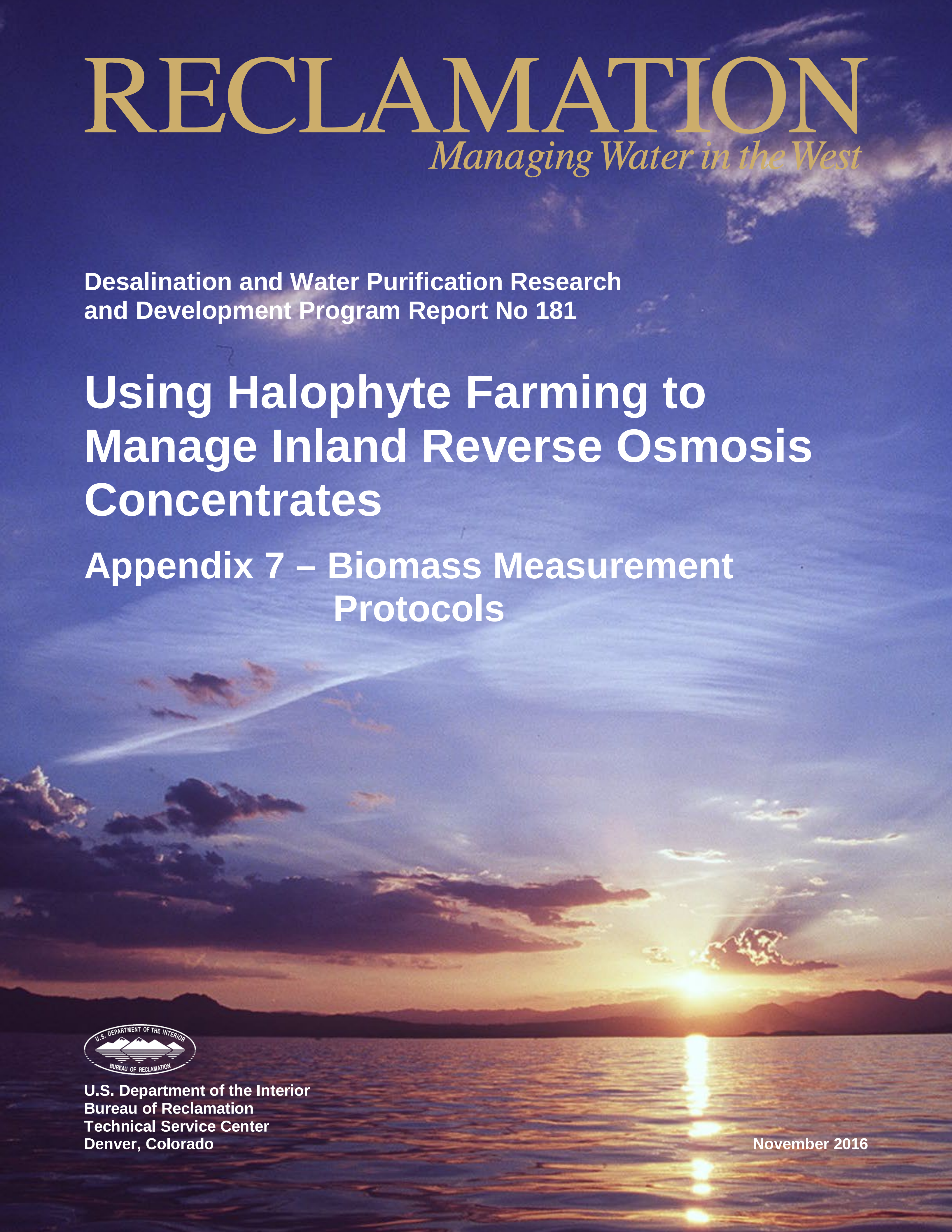
Valve	S1		S2		S3		S4		S5		S6	
%Eto	0.4		0.4		1.2		0.8		0.8		0.4	
Species	Lentiformis		Canescens		Lentiformis		Canescens		Lentiformis		Canescens	
Line	A	B	A	B	A	B	A	B	A	B	A	B
Tracking #	45 -- 48	41 -- 44	37 -- 40	33 -- 36	29 -- 32	25 -- 28	21 -- 24	17 -- 20	13 -- 16	9 -- 12	5 -- 8	1 -- 4
47	L 48	L	40		valve	boxes						
46	L	L			L (Note 1)	L	CAN (Note 2)		L 16	L		
45	L	L			32 L	L	24		L	L	8	
44	A	L			L	L			L	L		
43	A	O			L	A			L	L		
42	A	O			L	A			L	L	7	
41	A	44 L			L	L	box, gauge		L	L		
40	L	L			L	L			L	L 12		
39	L	L			L	L			A	A		
38	A	O			O	O 28			O	O		
37	A	O		36	O	A			N 15	O		
36	O	O			s7 N	O			A	A		
35	47 N	N	39		A	O			A	A		
34	O	N			A	O			O	A		
33	O	O			A	A			A	O		
32	O	O			A	O	23	20	O	O		
31	O	CANESCENS			A	O			N	A		4
30	O	O			31 O	A			N	O		
29	O	43 N			N	O			O	N		
28	O	O			A	O			N	11, O		
27	O	O			O	N 27			O14	A		
26	O	O		35	O	A			A	A		
25	O	O			O	A			O	N	6	
24	46 N	O	38		O	A			N	A		
23	O	O			O	O	22		N	O		
22	O	O			O	N		19	N	O		
21	O	O			O	N			O	O		3
20	O	O			30, O	A			O	O		
19	O	N			O	N			A	O		
18	O	N 42			O	N			O	O		
17	O	O			O	O			O	N		
16	A	N			N	N			N 13	N		
15	O	O			O	N 26			A	N 10	5	
14	O	N			O	O		T	O	O		
13	45 N	O		34	O	O			O	Bs2 N (ck)		
12	O	N			N	CAN(Note 3)			O	A		
11	O	O	37		O	O		T, 18	O	N		2
10	O	N	WS		A	N	21		O	O		
9	O	O			N 29	A			O	N		
8	O	N			N	N			O	O		
7	O	O			O	O			O	N		
6	N	N		BSF	O	N			O	O		
5	A	O			O	O			O	N 9		
4	O	O			O	N 25			O	O		
3	L	N 41			O	N			O	A		
2	L	ARG			O	O		17	O	ARG		1
1	L	ARG		33	O				O	ARG		
	1	2	3	4	5	6	7	8	9	10	11	12



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Appendix 7 – Biomass Measurement Protocols

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November 2016

Biomass plant measurements – March 2016

Block measurements

In March 2016, hedges in all irrigation ETo applications of varying lengths were randomly selected, marked and measured (length, width, height). Then each plant within the hedge was measured (length, width, height). This data was entered into an excel spreadsheet and calculated as 1) volume of the hedge (similar to the volume of a box), 2) the average plant volume within the hedge, and 3) the average of the individually measured plant volumes using an ellipsoid formula.

Conclusions: *A. lentiformis* volumes are difficult to measure, especially individual plants, as many of them had overlapping branches. Many of the *A. canescens* plants were not mature enough to form full hedges and therefore the hedge measurements should overestimate the plant volume. The ellipsoid formula may be more accurate for individual *A. canescens* plants at this age.

Biomass weight measurements

In March 2016, individual A. canescens and A. lentiformis plants that were planted in September 2014 were randomly selected and tagged for removal and biomass measurement by weight. Ten plants of each species were selected in rows representing all three of the irrigation ETo applications, across the two plots. The plants were cut at ground level, and placed in a large plastic barrel. The gross (wet) weight was recorded in the field, and the weight of the barrel was then subtracted. A total of

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Appendix 8 – Texas A&M University Report: *Atriplex* as a Potential Feedstuff in Beef and Dairy Production in the Southwestern United States

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2016

Atriplex as a Potential Feedstuff in Beef and Dairy Production in the Southwestern United States

November 8, 2016

A Report Submitted by

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Introduction

Atriplex species are a family of salt tolerant plants commonly known as halophytes that have developed mechanisms to manage salts in irrigation water (Flowers et al., 1977). Some Halophytes are native to desert regions around the world. Halophytes can be irrigated with water containing a high salt content, such as the waste concentrate resulting from the reverse osmosis (RO) process. Other crops commonly grown for livestock feed forage, such as alfalfa hay, corn and sorghum silages, do not grow well when irrigated with reverse osmosis (RO) concentrate (Masters, 2007).

Two species of *Atriplex* native to the arid southwest region are being evaluated and reported on in this study, namely: *A. lentiformis* and *A. canescens*. The investigators hope to better characterize the nutritive value of *Atriplex* when grown with RO concentrate and determine the plants' potential as replacement forage for use in animal feed rations. As a component of this research project, an intensive review of the literature was collected from previous studies to examine the nutrient content of *Atriplex* species and their potential as livestock feed and included in this report.

At the Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, NM, the water used in the RO process comes from brackish water; it is water with a higher salinity than fresh water but a lower salinity than seawater. The RO process forces high salinity water through a permeable membrane. This permeable membrane blocks certain particles from passing through the membrane, depending on pore size. The result is that fresh water recovered can be used for multiple purposes; however, what does not pass through the permeable membrane is considered wastewater or concentrate and has a high salt concentration. The wastewater from RO is not usually used for crop irrigation because presently used forages are not able to utilize water with such a high salt content.

The Dairy and Feedlot Industry in the Southwestern U.S.

Most dairies and feedlots in Arizona and New Mexico are considered Concentrated Animal Feeding Operations (CAFO). An operation is designated as a large CAFO if it confines at least 700 dairy cows or 1,000 beef cattle for more than 45 days (EPA, 2012). In AZ, dairies contain an average of 1,500-2,000 head (Arizona Experience, 2012) and feedlots contain an average of 49-50 thousand head (Ward, 2001). New Mexico's dairies average 2,100 head (Dairy Producers of New Mexico, 2015) and feedlots average 17,500 head (Ward, 2001).

Cattle Inventory

According to the National Agricultural Statistic Service (NASS, 2014), Arizona's cattle inventory is 447,000 which includes dairy and feedlot cattle. New Mexico's cattle inventory was 323,000 in 2014. New Mexico last reported its feedlot cattle population at 45,000 in 2012. The cattle inventory in this region has the potential to affect demand for crops that are fed to the cattle. Expected dry matter intake will vary for cattle in different stages of growth in the feedlot (Table 1) or different stages of milk production at the dairy (Table 2 and 3).

Feeding Practices

When animals are confined for production, all feed is provided in the form of a Total Mixed Ration (TMR). Each TMR is formulated by a consulting nutritionist to meet the animal's nutrient requirements based on stage of production. All animals require six basic types of nutrients: protein, carbohydrates, fats, vitamins, minerals, and water. These are provided through a variety of feedstuffs that are combined to meet the animal's nutrient requirements in a cost efficient manner through formulation of a least-cost ration. Common feedstuffs for this region include alfalfa hay, corn silage, sorghum silage, corn grain, sorghum grain and distiller's grain.

An example of nutrient requirements for a dry dairy cow, lactating dairy cow, growing steer (660 lbs) and finishing steer (960 lbs) can be found in Tables 4 and 5. These stages of production were included so a range in nutrient requirements for dairy cattle (Table 4) and feedlot cattle (Table 5) could be evaluated. Energy (TDN (total digestible nutrients), ME (metabolized energy), and NE (net energy), Crude Protein (CP), Ca and P are major components that the nutritionist will evaluate when formulating a ration.

Roughage in Cattle Diets

Ruminant animals, by definition, have the unique capability to digest fiber, such as cellulose, hemicellulose, and lignin. Roughages are feeds high in fiber. Dairy cattle require large amounts of roughage in their diet, whereas feedlot animals do not. High producing dairy cows require a minimum of 40% roughage in their diet on a dry matter (DM) basis (Wheeler, 1996). On the other hand, according to a survey of feedlots by a consulting nutritionist (Galyean and Gleghorns, 2001), feedlot rations contained 4.5 to 13.5% roughage on a DM basis. Typical roughages that meet the needs of both dairies and feedlots include hay, corn and sorghum silage. According to NASS (2014), annual hay production in Arizona totaled 2,410,000 tons, corn silage totaled 1,334,000 tons, and sorghum silage totaled 391,000 tons. New Mexico roughage production included an annual hay production at 1,198,000 tons, corn silage at 1,898,000 tons, and sorghum silage at 429,000 tons. When the total number of cattle in the region is combined with their potential feed intake, it is clear that there is demand for cost-efficient feedstuffs that meet animal nutrient requirements.

Roughage is an important component of the diet for both beef and dairy cattle, but for different reasons. Feedlot cattle require roughage because it helps dilute the TMR to prevent acidosis and founder. Acidosis is caused by a pH change in the rumen falling below 5.5. The normal pH of a grazing animal is 6.8 to 7.0. Acidosis is associated with feeding highly fermentable starches and sugars (grain) and the overproduction of acids in the rumen which can cause founder, affecting the hooves causing damage and discomfort. Founder also known as laminitis, is the inflammation of the lamina, the soft tissue that separates the hoof wall from the boney structure of the foot.

Roughages also increase rumination which has many positive benefits, such as increased digestion through particle size reduction (aiding microbial attachment) and increased saliva flow through regurgitation and mastication. Saliva flow due to mastication can serve as a buffer in the rumen, preventing acidosis and stabilizing the pH. The reason why nutritionists limit roughage inclusion in the TMR is because high roughage levels will decrease feed and energy intake. For example, in beef cattle the goal is to increase body weight quickly and efficiently. Due to forage being bulky, it limits cattle from consuming the optimal amount of feed. That is why beef cattle diets consist of more grains because they are more energy dense and can maximize weight gains more efficiently than roughages.

Dairy cattle require more roughage in the diet compared to feedlot animals because higher roughage levels will improve rumen fermentation and positively impact milk fat composition (Linn, 2015). Linn (2015) reported that a correctly balanced total mixed ration (TMR) can increase milk production 2.2-5.5 lbs per cow per day. Roughage intake is based on forage quality, cow size, and grain level. Milking cows can consume 2.1-5.6% of body weight daily, depending on cow body weight and milk yield (Table 2). Mertens (2009) suggested that

100% roughage rations do not maximize productivity, profitability or efficiency. Dairy ration formulation are usually based on roughage: concentrate ratio between 40:60 with lower quality forage and can be up to 60:40 with higher quality forage for high producing dairy cattle (Mertens, 2009). More roughage can be fed to cows in late lactation or at low production levels.

Roughages also contain carbohydrates, a major source of energy, which makes up 60-70% of a dairy cow's diet. Carbohydrate nutrition influences the composition of milk as precursors for lactose, fat and protein. In order for a high producing dairy cow to meet its high energy demands and maintain proper milk composition, diets containing high quality forages are necessary, usually at the expense of fiber intake. As previously stated, high concentrated diets for high yielding dairy cows need an adequate amount of fiber in order to stimulate rumination and saliva production, and to maintain milk fat percentage (Zebeli et al., 2006).

***Atriplex* as a Potential Feedstuff in Beef and Dairy Production**

This literature review focused on the nutritive value of two specific halophytes, *A. lentiformis* and *A. canescens*. Both *A. lentiformis* and *A. canescens* were planted at BGNDRF in Alamogordo, NM as part of the "Reserve Osmosis Concentrate Management through Halophyte Farming" project which is funded by the United States Bureau of Reclamation. These species were selected because they are native to the region, have adequate growth potential, and acceptable nutritive value for livestock feed.

Atriplex spp. is classified as a halophyte, or salt tolerant plant. Halophytes are found throughout the world in desert regions and along seashores. The indigenous halophytes found in the desert regions of the world have historically been grazed by nomadic sheep and goat herds. Animal production is poor when the diet is comprised of 100% halophyte shrubs (El Shaer, 2010); however, *Atriplex* spp. has nutritive aspects that make it a suitable feedstuff to include in a TMR but the salt content of the forage will limit its use in rations, with particular emphasis on the high chlorine (Cl) content. *Atriplex* spp. typically has a high crude protein (CP) and low fiber content.

Legumes and grasses are not considered salt tolerant forages because they thrive only with irrigation at lower salt concentrations (<9.6 g/L) and produce 5-10 tons of usable dry matter (DM) per hectare per year when high quality water availability is abundant. When salt concentration in the soil and water increases, production levels of legumes and grasses that are not salt tolerant decrease (Masters, 2007). Masters (2007) compares this finding to *A. lentiformis* that can thrive in higher salt concentrations in irrigation (40 g/L) and produce over 10 tons of DM (dry matter) per hectare. Given that most RO waste concentrate has a salt content ranging from 2-40 g/L, *Atriplex* species are ideal candidates for irrigation with RO waste concentrate. However, even at these high salinities, there are a range of halophytic grasses and shrubs from the *Chemopodiaceae* family that will produce between 0.5 and 5 tons of edible DM per hectare per year (Masters, 2007). It is important to recognize that plant dry matter production is a function of the interaction between the plant genotype and the environment it is grown under (climate/soil/plant/animal combination).

Atriplex grows well in soil with high salt concentrations, but has the potential to provide a large amount of salt to ruminants through salts held in plant tissue. High concentrations of salt can depress feed intake and in extreme conditions may cause health problems. Salt tolerant plants also may contain high levels of anti-quality components, such as oxalates, tannins, and nitrates. Oxalate poisoning most often occurs when unadapted sheep or cattle are allowed to graze large amounts of plants with a high amount of oxalate. Ruminants, in general, tolerate relatively more oxalate in their diet than other animals because they are able to detoxify oxalate in the rumen; thereby preventing the absorption of the soluble oxalates (Knight and Walter, 2003).

Ruminants can consume nitrates through feed. Under normal conditions, nitrates get converted to nitrite, and then to ammonia by microbes in the rumen. Ammonia is then absorbed from the rumen into the blood and passed in the urine as urea. Nitrate poisoning occurs when nitrite levels exceed normal concentrations which reduce the ability of the microbes to convert it to ammonia. Nitrates and nitrites are then absorbed through the rumen wall into the blood stream. Nitrite binds to hemoglobin which can then be converted to methemoglobin. Hemoglobin's role is to transport oxygen to body tissues, but when converted to methemoglobin, this is no longer possible. The animal then suffers from oxygen starvation (Yaremico, 2009). Tannins bind and precipitate feed proteins. Tannin levels above 5% can become a serious anti-nutritional factor (reduced N retention) in plant materials fed to ruminants (McLeod, 1974; Waghorn and Shelton, 1995).

Davis (1981) showed the relationship between oxalate, tannins, crude fiber and crude protein in *Atriplex* spp. at six weeks, six months and nine months of growth (Table 6). When the *Atriplex* plants are in the vegetative stage (after germination and prior to flowering), crude protein (CP) is the highest. As harvest time approaches, oxalates and crude fiber increases. Davis (1981) stated that the mean crude fiber level of all supplements at the August harvest date was less then alfalfa hay but the December fiber content mean was higher than alfalfa.

Plants growing in saline environments also contain compounds beneficial to animals such as Vitamin E and betaine (Masters, 2007). Vitamin E levels are usually high in fresh pasture and may have positive impacts on the immune system (Blezinger, 2001). Betaine, naturally found in plants and an oxidative product of choline, is converted to acetate in the rumen, which may be used for milk fat synthesis. A study using 18 Holstein cows was conducted with different levels of betaine in the diet to determine the effect on milk yield. Peterson et al. (2012) concluded that overall 100 g/d of dietary betaine increased milk yield compared to lower betaine levels.

Nutritive Value of Atriplex

To meet roughage requirements, cattle in dairies and feedlots are typically consuming hay, corn or sorghum silage in their daily diets. Incorporating *Atriplex* spp. into the TMR of cattle may meet the animal's nutrient requirements in a cost efficient manner through formulation on a least-cost ration basis. According to Kahlil et al. (1986), *Atriplex* leaf protein has an amino acid profile that would complement many cereal grain proteins. The leaves had 13% CP, the seeds had 17% CP, and the stem had 3.5% CP at the Marana Project Site at Marana, Arizona where *A. lentiformis* was grown using RO concentrate (Soliz et al., 2011). The stem plant fraction had more crude fiber, ADF (acid detergent fiber) and NDF (neutral detergent fiber), making it more difficult to digest compared to the leaves.

Protein Content

Crude protein (CP) plays an important role in ruminant nutrition. On average, CP needs to be above 8% DM, or above 1% nitrogen (N), to keep the microbial population stable and properly functioning in the rumen (Salem and Nefzaoui, 2004). When CP decreases below the basal level, it will reduce voluntary feed intake. In general, *Atriplex* spp. are considered to be a good source of CP with values ranging from 9 to24% CP (Guevara et al., 2006; Norman et al., 2008). The protein in *Atriplex* leaves comes from the large amount of nitrogen found in the plant. According to Masters et al. (2007) and Le Houerou (1991), *Atriplex* has 1.5-3.6% N (9.4-22.5%

CP) and 40-50% of that is non-protein nitrogen, which can be converted by the microbes into microbial protein. *A. lentiformis* and *A. canescens* are significantly higher in CP compared to the presently used forages in dairies and feedlots, such as corn and sorghum silages (Table 7).

Energy Content

Metabolizable energy (ME) is defined as the amount of energy available after the loss of energy in feces, urine and combustible gasses. *Atriplex* spp. is low in ME, which is the reason it cannot be a sole ingredient in high producing cattle diets. Khalil et al. (1986) reported in Saudi Arabia that *A. canescens* had ME as high as 2.8 Mcal/kg and *A. lentiformis* at 2.6 Mcal/kg; however, that was the energy value of the leaves only. In contrast, in an experiment involving the entire plant; *A. lentiformis* grown with drainage water (low salt concentration 12 g/L) had ME levels as low as 1.2 Mcal/kg (Diaz et al., 2013; Table 8). Even though there are animals in nomadic situations that can solely survive on *Atriplex*, the goal of dairies and feedlots is to exceed maintenance of the animal and produce either a large quantity of milk or gain a specific amount of weight. Metabolized energy is important to increase cattle production (milk/weight gain) and make non-protein nitrogen into microbial protein. Without high levels of energy, the protein does not get converted completely and the animal will miss opportunities to capitalize on protein metabolism and utilization. It would be wise to use *Atriplex* in a TMR where other added ingredients can compensate for lower level of energy in Atriplex.

Mineral Content

Mineral requirements for cattle are categorized as either macrominerals or microminerals. Macrominerals are required in larger quantities (g/day or mg/day) than microminerals (ppm/day). Minerals that play an important role in cattle production include sodium, sulfur, potassium, calcium, phosphorus, and magnesium. The microminerals are iron, zinc, copper, cobalt, selenium, iodine, and manganese. Studies that report mineral composition of *Atriplex* spp. have found that mineral content in leaves meet or exceed beef or dairy cattle requirements.

The ash component is the result of incinerating the feed to remove organic matter (CP, fat, carbohydrate, etc.); thus, the inorganic component remains which is often composed of minerals. According to Soliz (2011), *Atriplex* spp. ash values range from 9 to 34% DM, with a majority of it being salt, although the plant is also high in other minerals. *A. canescens* regrowth forage provided the best combinations of low ash and Na/K ratio (Watson and O'Leary, 1993). Halophytes are known to thrive in salty environments; as a result, high salt content within the plant should be expected. As stated by Khalil et al. (1986), the level of Na was extremely low (0.21%) in *A. canescens* compared to the other species (2.4 to 5.6%) simply showing that *A. canescens* stores less salt than other *Atriplex* spp.

When daily intake of salt is above normal for cattle, it may cause several problems. The maximum tolerable level for salt is approximately 3% of dietary DM for dairy cattle. If salt is overconsumed, it may cause reduced feed intake and thus, decrease milk production and growth (Weiss, 2010). Drinking water with 0.25% salt can cause significant reductions in milk yields (NRC, 2005). Although production may be reduced, salt toxicity is not typically an issue in cattle because of their high tolerance of salt (Berger and Rasby, 2011). Ingested salt by ruminants is almost completely absorbed causing an increase in the blood NaCl levels, which must be eliminated via urine (Cardon et al., 1951). If drinking water is lacking, urine will not be produced and salt in the blood will not decrease; this could become toxic and is sometimes fatal.

Salt toxicity can be an issue when salt is present in the drinking water for cattle; the addition of a high salt ration may lead to health issues. Symptoms of acute toxicity include salivation, increased thirst, vomiting, abnormal discomfort, diarrhea, blindness, seizures, and possible paralysis (Thompson, 2012). Even low levels of salt in drinking water can result in reduced feed and water intake, decreased cattle growth, digestive disturbances, and diarrhea (Parish and Rhinehart, 2008). Salt can be absorbed from the intestinal tract and into the blood stream to be filtered through the kidneys and excreted as urine. Raymond (2011) stated that salt is used frequently as a way to regulate feed intake. High salt levels will reduce intake of highly palatable feed and thus, should be a consideration when including halophytes in a ration. Although salt toxicity does not occur frequently, an adequate supply of easily accessible fresh drinking water will reduce the risk of toxicity.

The National Research Council (2005) stated that beef cattle can tolerate up to 8% NaCl (salt) on a DM basis. *A. lentiformis* had greater sodium and less potassium than *A. canescens* based on several studies (Khalil et al., 1986; Meyer, 2005; Sameni and Solelmani., 2011, Soliz, 2011; Mellado et al., 2012; Diaz et al., 2013; Table 9). Due to A. lentiformis having a higher salt content means that less salt resides in the soil compared to soils where A. canescens is grown.

Atriplex Use in Cattle Rations

The use of alternative feeds in livestock production can provide producers with both cost advantages and a reduction in inventory constraints. More recent concerns in the southwest region have focused on water availability and acreage to provide quality forages, as well as adequate inventory of forage being grown for agriculture. According to a dairy nutritionist (William Miller, Ph.D.; Dairy CSI,), *Atriplex* spp. appears to have some desirable characteristics for use in livestock production. With a CP content of approximately 12%, this would allow *Atriplex* spp. to be utilized to replace a portion of the forage protein in the diet of lactating cows without an expected production loss. The concern a nutritionist would have with *Atriplex* as a forage source is the high amount of Cl. In a lactation diet, Cl should be limited to 0.2% of DM and thus will limit the maximum amount of *Atriplex* spp. in the diet (Wheeler 1996). An example lactation ration is provided in Figure 1. A similar lactation ration that has replaced a portion of the corn silage and alfalfa hay with *Atriplex* is shown in Figure 2. *Atriplex* was included at a rate of 4.99 lbs on a dry matter basis of a daily meal, which would be a reasonable amount for cost effective forage with the characteristics of *Atriplex* spp. to replace other more costly forages.

According to Dr. Miller, the economics of *Atriplex* inclusion could provide a substantial savings over current diet ingredients. Using a couple of constraints in the diet formulation of dairy cattle suggests a maximum price for *Atriplex* spp. would be approximately $126/ton at 91% DM when used with *Atriplex* spp included in the ration. The amount of *Atriplex* spp. utilized in this diet would begin to decrease when the price exceeds $80/ton, but remains in the diet until the previously mentioned figure of $126/ton. Dr. Miller used a cost of $65/ton based on the protein market on 1/16/15. The differential from $65 to $125 could be an area to provide *Atriplex* spp. to alternative markets when processed through grinding and/or pelleting.

Current Work at Brackish Groundwater National Desalination Facility

A pilot research project was initiated in September, 2014 to validate the viability of farming halophytes using RO concentrate as a source of irrigation water as an economical alternative to the evaporation ponds, deep well injection, and other more costly approaches to concentrate management. In addition, a portion of this research study focused on the nutritive value of the halophyte forage and its viability as a forage supplement in ruminant diets.

Material and Methods

Seeds of *A. lentiformis* and *A. canescens* were sown in the greenhouse using suitable soil. They were irrigated with potable water until they were grown to about 8-10 inches tall. Approximately 1,100 seedlings were then transferred to the BGNDRF agricultural research area where they were transplanted in a designated 1-acre area assigned to the University of Arizona. The area was subdivided into two half-acre plots, with 12 planting rows and 6 irrigation valves per plot. After the seedlings were established, the plants were irrigated with three different irrigation regimes, depending on potential evapo-transpiration rate (ET): 1.2 ET, 0.8 ET, and 0.4 ET. To date, two harvest samples of the *Atriplex* species have been collected and analyzed: the first on July 15, 2015 and the second on September 24, 2015 and consisted of either having no seeds, seeds, male flowers, green or red stems. Harvested forage samples were labeled with an N or S depicting the location of the sample in the North or South ½-acre plot. The first number is the irrigation valve number (numbered from 1-6 from west to east). The second number corresponds to the evapotranspiration rate: 1 is 1.2 ET, 2 is 0.8 ET, and 3 is 0.4 ET in the July sample labels; the September sample labels included 0.4, 0.8 and 1.2 for ET rates. The last letter or other label is associated with the plant species; *lentiformis* (EBL in the July sample labels; L in the September sample labels), *canescens* (C), and *argentea* (ELL in the July sample labels and P in the September sample labels). The L label in the July samples includes a mix of *A. lentiformis* and *A. argentea*, as the July samples were collected before *A. argentea* had been identified as a separate species.

While collecting samples in July 2015 in the south portion of the field, a dichotomy was noticed. Samples from a smaller-leafed plant that was flowering were collected and identified as *A. polycarpa*. At the September 2015 harvest sample collection, another *Atriplex* species was discovered and identified as *A. argentea*. Each harvest sample is a random composite of a minimum of cuttings to range between 100-150 grams of wet weight per sample; however, discrete samples were collected from *A. lentiformis* and *A. argentea* in the second set of samples.

Results and Discussion

Results from the July and September harvest samples are found in Tables 10 and 11, respectively. *A. canescens* CP averaged 14.3% in July and decreased to 13.9% in September. Other components that decreased in the two-month span for this species were ADF, Ca, Mg and the microminerals. The components that increased were ash, Na, K, and Cl.

A. lentiformis had an increase in average CP from 14.2 to 15.0% between the July and September harvest sample dates. The other nutritional components that slightly increased were ash and Na. Nutritional components that decreased for *A. lentiformis* over that time period were ADF, Cl, as well as the microminerals. Note that the July samples also contained plant tissue samples from *A. argentea* as previously noted.

Based on results from the literature, nutritional composition of the *Atriplex* species from this study are similar to those reported by other authors (Tables 7, 9, and 12). The CP values of the forage species did remain relatively stable between the harvest sample times. Over the growing season, forages have a high CP and low fiber (NDF/ADF/lignin) content during the vegetative stage, but declines in quality as the plant matures, having lower CP and higher fiber content. Davis (1981) reported a decrease in CP and an increase in fiber for *A. lentiformis* and *A. canescens* between August and December harvest dates. A study conducted by Mellado et al. (2012) in northern Mexico with *A. canescens* reported higher CP in the summer (17.2%) than the fall (14.6%), and lower ADF in the summer (18.8%) compared to the fall (20.6%), which shows a more typical decline in nutritive value over the growing season. Results from the fall samples at BGNDRF suggest that forage quality stayed relatively high and stable over the sampling periods, with CP and ADF values being comparable to alfalfa hay.

The ash content is higher for these *Atriplex* species, especially *A. lentiformis*, compared to alfalfa; this can be attributed to the higher Na, K, Mg, and Cl levels when compared to alfalfa. In the Mellado et al. (2012) study, Na and K was evaluated during the spring, summer and fall and according to his results, Na did not differ and K had a slight decrease in the summer and fall compared to spring.

In the September harvest, another *Atriplex* species was later identified as *A. argentea*. This species is native to the central region and west coast of the U. S. and Canada. *A. argentea* has a significant lower crude protein concentration compared to the other species. This species also has a larger concentration of ADF, Mg, Cl, Fe, Zn, and Cu and the lowest concentration of P compared to the other species.

Future Work

While *Atriplex* farming under varying levels of RO concentrate irrigation do provide important information about agronomic and nutritive values, there are numerous questions which still need to be answered if *Atriplex* is to become competitive with other feed forages in the region. Additional topics of interest include: harvesting methods (date/maturity, plant portion, fertilization and technique); transportation options from production site to the end-user; storage (bale, bunker, or bag); processing (grinding/ pelleting); and animal feeding performance trials. Increasing information on these topics will enable end-users to make educated decisions when deciding to utilize *Atriplex* in livestock feeds.

Although several studies have published nutritive value information about *Atriplex* species, none of the literature reviewed provided information/recommendations on large-scale use of the product. To collect the forage samples, authors reported using hand-clipping techniques which met the needs of the study (Tiedermann et al., 1984; Watson, 1990; Swingle et al., 1996; Mellado et al., 2012; Peterson et al., 2012; Diaz et al., 2013), but do not translate well if *Atriplex* is going to be produced and mechanically harvested in a traditional cropping system for animal feed.

Several articles reported *Atriplex* biomass production under various grazing conditions (including soil salinity and water qualities) and harvesting parameters, which may be useful to consider when determining harvesting recommendations (Watson, 1990; Gupta and Arya, 1995; Diaz et al. 2013). *Atriplex* species can be harvested and/or utilized in many ways such as biomass for energy, particle board, or animal feed production (Diaz et al., 2013). For the purpose of animal feed production, selecting the vegetative parts of the plant will result in capturing a higher nutrient density. In the Watson (1990) study, which focused on animal feed production, plants were clipped at different stages while recording cut heights and yield. The first harvest yielded more than the second harvest. *A. canescens* 1st clipping was 11-14 cm of the upper portion of the plant and yielded 172-186 g/plant. The 2nd clipping was 8-10 cm of the upper portion of the plant and yielded 124-131 g/plant. *A. lentiformis* 1st clipping was 20 cm and yielded 340 g/plant. Compared to *A. canescens,* it was noted that *A. lentiformis* was seeded directly rather than transplanted. It is not clear if the decline in yield was due to environmental effect on the plant, including soil and water salinity, or because the woodier and greater portion of the plant was excluded (Diaz et al., 2013). Thus, if the goal of an operation is to have multiple clippings within the same season, producers should expect to have lower yields after the first clipping.

Conclusion

The literature review was created in Kingsville, TX as a subcontracted project apart of the larger projected conducted at BGNDRF at Alamogordo, NM. The literature review and the samples collected from halophyte farming in New Mexico show the potential for *Atriplex* inclusion in rations fed to feedlot and dairy cattle. *Atriplex* spp. can have a low energy concentration and high salt content, it does not fit well as a sole or major ingredient for livestock production in the United States. It appears that RO concentrate is able to serve as a source of irrigation water to grow *Atriplex* spp. for feed. Forages presently used in cattle rations (such as alfalfa, corn and sorghum silages) are not able to grow under irrigation water with such high salt concentrations. For future use in the cattle industries of the Southwest, additional research is needed. Areas to consider for future work include an animal feeding trial, large-scale planting and harvesting methods, transportation, feed processing, and feed storage.

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Table 1. Expected dry matter intake (DMI) of cattle in a feedlot.

Weight of cattle and type of ration fed	Expected DMI, % of body weight
550 lbs, grower ration[1]	2.8
700 lbs grower ration	2.6
850 lbs finisher ration[2]	2.4
1,000 lbs finisher ration	2.2

Source: Robinson, 2000.

[1] Complete ration for the growing stage of cattle to rapidly increase weight

[2] Complete high energy ration designed to put weight on quickly and efficiently

Table 2. Dry matter intake (DMI) by cows in mid and late lactation (% of body weight and lbs per day).

Milk Yield (lbs)	Cow Body Weight[1] (lbs)					
	990		1210		1430	
	% DMI	lbs of feed consumed on a DM basis	% DMI	lbs of feed consumed on a DM basis	% DMI	lbs of feed consumed on a DM basis
22	2.6	25.7	2.3	27.8	2.1	30.0
44	3.4	33.7	3.0	36.3	2.8	40.0
66	4.2	41.6	3.7	44.8	3.4	48.6
88	5.0	49.5	4.3	52.0	3.8	54.3
110	5.6	55.4	5.0	60.5	4.4	62.9

Source: Wheeler, 1996.

[1]Cows in mid to late-gestation increase in milk yield, not all cows produce the same milk yield. This table shows three different cow weights and their corresponding milk yield, ranging from 22 lbs to 110 lbs.

Table 3. Nutrient requirements for dry cows at 1,600 lbs

			Diet Nutrient Density			
	ADG (lb/day)	DMI (lb/day)	NE_L (Mcal/lb)	CP (%DM)	Ca (%DM)	P (%DM)
240 days pregnant[1]						
	1.5	31.7	0.44	9.9	0.44	0.22
279 days pregnant						
	1.5	22.2	0.65	12.4	0.48	0.26

Source: NRC, 2001.

[1]As cattle go from 240-279 days pregnant there will be an increase in nutrient intake to accommodate the mother's health and the rapidly growing offspring. 'Dry' refers to a non-lactating cow.

Table 4. Combined requirements for maintenance and milk production at various levels for cows of two different weights producing 3.5% milk fat.

Daily Nutrient Requirements					
Milk lbs	CP (lb)	NEL (Mcal)	TDN (lb)	Ca (lb)	P (lb)
Small Breed, 1000 lbs[1]					
30	3.35	17.2	16.7	0.131	0.083
40	4.14	20.3	19.7	0.161	0.101
50	4.93	23.4	22.7	0.191	0.119
60	5.72	26.5	25.7	0.221	0.137
70	6.51	29.6	28.7	0.251	0.155
80	7.30	32.7	31.7	0.281	0.173
Large Breed, 1400 lbs					
60	6.11	28.7	27.9	0.237	0.148
70	6.90	31.8	30.9	0.267	0.166
80	7.69	34.9	33.9	0.297	0.184
90	8.48	38.0	36.9	0.327	0.202
100	9.27	41.2	40.8	0.360	0.230
110	10.06	44.2	42.9	0.390	0.240

Source: NRC, 2001.

[1]Smaller breeds of cattle produce less milk due to the mother's and calf's size compared to a larger breed cow producing a larger calf.

Table 5. Nutrient requirements of growing yearling steers finishing at 1,200 lbs

			Diet Nutrient Density					
Body Wt.[1] (lbs)	ADG (lb)	DMI (lb/day)	TDN (%DM)	NE_m (Mcal/lb)	NEg (Mcal/lb)	CP (%DM)	Ca (%DM)	P (%DM)
660	2.00	18.4	60	0.61	0.35	10.2	0.34	0.19
	3.78	17.0	80	0.90	0.61	15.8	0.61	0.29
960	2.00	24.4	60	0.61	0.35	8.10	0.27	0.15
	3.78	22.5	80	0.90	0.61	11.3	0.41	0.22

NE_m : Net Energy for maintenance, NE_g : Net Energy for growth
Source: NRC, 2000 and 2001.
[1] As ADG increases in different body weights of cattle, so does the nutrients within the diet to maximize growth.

Table 6. Toxicity and nutrient comparison at different stages of production of the *Atriplex* species.

	Nutrients								
	Oxalates, %DM`			Tannin, %DM		Crude Fiber, %DM		Crude Protein, %DM	
Atriplex Species	6 wk old seedlings	6 mo	9 mo	6 mo	9 mo	6 mo	9 mo	6 mo	9 mo
A. canescens	9.4	3.0	1.9	6.4	7.9	14.9	31.8	11.6	7.0
A. lentiformis	8.3	3.9	3.5	5.0	3.5	13.9	19.5	11.3	6.3

Source: Davis, 1981.

Table 7. Nutrient content of *Atriplex* species in comparison to present feedstuffs on a dry matter basis.

Plant/section	CP %	Fiber%	ADF%	NDF%	Ash%	Notes	Author/Location
A.lentiformis							
whole	-	-	-	-	31.6	-	Goodin and Mckell,1970/ Australia
whole	8.9-22.4	-	-	-	11.9-18.7	-	Welch, 1978/ Utah and Oregon
whole	13.9	11.3	-	-	-	Aug harvest	Davis, 1981/ Washington
whole	19.5	6.3	-	-	-	Dec harvest	Davis, 1981/ Washington
leaves	21.9	8.0	18.5	-	22.0	-	Khalil et al., 1986/ Saudi Arabia
leaves	11.2	-	-	-	15.2	-	Gupta and Arya., 1993/ India*
stems	6.0	-	-	-	3.20	-	Gupta et al., 1993/ India*
whole	17.7	30.3	-	-	16.6	-	Meyer, 2005/ Utah
whole	12.1	-	-	-	-	-	Sameni and Solelmani, 2006/ Southern Iran
whole	16	-	-	-	-	-	Bauder et al., 2008/ Montana and Wyoming
stems	3.01	42.5	53.0	-	8.5	-	Soliz, 2011/Arizona
leaves	12.8	-	15.8	-	28.2	-	Soliz, 2011/Arizona
fruits	17.0	-	16.4	-	17.8	-	Soliz, 2011/Arizona
whole	12	-	-	42.6	-	-	Diaz et al., 2013/ California**
whole	12.8	-	-	53.2	-	-	Diaz et al., 2013/ California**
whole	-	-	-	-	21.1	-	Diaz et al., 2013/ California**
whole	-	-	-	-	18.7	-	Diaz et al., 2013/ California**
whole	16.1	-	29.0	49.5	20.6	-	Diaz et al., 2013/ California**
A. canescens							
whole	11.6	-	14.9	-	-	Aug harvest	Davis, 1981/ Washington
whole	7.0	-	31.8	-	-	Dec harvest	Davis, 1981/ Washington
leaves	19.4	-	-	-	-	-	Tiedermann et al., 1984/ Utah
leaves	17.4	9.0	14.1	-	18.5	-	Khalil et al., 1986/ Saudi Arabia
whole	18.4	-	17.9	32.3	34.6	-	Watson, 1990/ California***
whole	14.4	-	30.9	47.8	16.6	-	Watson, 1990/ California***
whole	14.2	18.3	28.7	34.5	19.6	-	Shaer, 2010/ Egypt
whole	17.2	-	18.8	36.4	17.8	Summer	Mellado et al., 2012/ Northern Mexico
whole	14.6	-	20.6	41.1	16.8	Fall	Mellado et al., 2012/ Northern Mexico
Alfalfa Hay	14.1	-	31.2	39.6	10.0		NRC, 2000
Sorghum Silage	10.8	-	40.7	63.3	10.9		NRC, 2000
Corn Silage	8.8	-	28.1	45	4.3		NRC, 2000

*7.68-10.88 g/L soil salinity; **18.3 g/L soil salinity; ***6.4-8.32 g/L water salinity

Table 8. Energy obtained from different *Atriplex* spp. compared to non-halopyte forages.

Species	DE, Mcal/Kg	ME, Mcal/Kg	Author/Location
A. canescens			
leaves	3.36	2.76	Khalil et al., 1986/ Saudi Arabia
A.lentiformis			
leaves	3.22	2.64	Khalil et al., 1986/ Saudi Arabia
whole	-	2.00	Soliz, 2011/ Arizona
whole	-	1.20	Diaz et al., 2013/ California
whole	-	1.20	Diaz et al., 2013/ California
Alfalfa Hay	2.73	2.08	NRC, 2000
Sorghum silage	2.41	1.79	NRC, 2000
Corn Silage	2.99	2.33	NRC, 2000

Table 9. Macromineral element content of *Atriplex* spp. in comparison to presently used feedstuffs on a dry matter basis.

Plant	Ca, %	P, %	Na, %	K, %	Mg, %	Cl, %	Citation/ location
A. lentiformis							
leaves	1.12	0.28	4.91	2.76	0.79	-	Khalil et al., 1986/ Saudi Arabia
leaves	1.79	0.13	10.2	1.17	0.92	-	Gupta and Arya, 1995/ India*
stems	0.61	0.16	0.61	0.55	0.17	-	Gupta and Arya, 1995/ India
whole	0.34	0.13	6.23	2.88	0.27	8.89	Sameni and Solelmani 2006/ Southern Iran
stems	1.58	0.04	0.95	1.09	0.34	-	Soliz, 2011/ Arizona
leaves	2.27	0.14	5.75	3.32	1.44	-	Soliz, 2011/ Arizona
fruits	2.03	0.24	5.46	3.69	1.06	-	Soliz, 2011/ Arizona
whole	1.25	-	4.92	-	0.47	4.18	Diaz et al., 2013/ California**
whole	1.04	-	4.59	-	0.42	4.19	Diaz et al., 2013/ California**
A. canescens							
leaves	1.31	0.19	0.21	6.06	0.72	-	Khalil et al., 1986/ Saudi Arabia
Alfalfa hay	1.19	0.24	0.07	1.56	0.30	-	NRC, 2001
Sorghum silage	0.64	0.24	0.03	2.57	0.31	-	NRC, 2001
Corn silage	0.28	0.26	0.01	1.20	0.17	-	NRC, 2001

*7.68-10.88 g/L salinity in soil

**18.3 g/L soil salinity

Table 10. Nutrient composition of *A. canescens*, *A. lentiformis* and *A. polycarpa* collected at BGNDRF on July 15, 2015.

	CP%	ADF%	Ash%	Ca%	P%	Na%	K%	Mg%	Cl%	S%	Fe ppm	Mn ppm	Zn ppm	Cu ppm	Treatment
A. canescens															
N11C	15.96	51.64	18.64	1.48	0.19	1.32	5.59	0.79	3.82	0.54	242	88	69	22	1.2 ET
N31C	13.88	26.31	13.86	1.18	0.15	1.68	4.00	0.83	3.30	0.45	356	73	98	21	1.2 ET
N42C	12.04	34.87	11.76	1.24	0.11	0.29	4.66	1.04	1.63	0.32	443	108	44	23	0.8 ET
S23C	14.86	26.65	13.57	1.17	0.16	0.22	4.78	0.65	2.58	0.47	236	70	37	21	0.4 ET
S42C	15.98	25.03	13.02	1.53	0.14	0.43	4.18	0.92	2.77	0.39	164	41	34	22	0.8 ET
S63C	12.97	32.27	11.48	0.91	0.19	0.14	0.56	4.42	2.70	0.40	123	23	39	17	0.4 ET
Average	14.28	32.80	13.72	1.25	0.16	0.68	3.96	1.44	2.80	0.43	261	67	54	21	-
A. lentiformis															
N22L	12.12	27.71	20.99	0.85	0.16	3.64	3.13	0.78	7.52	0.33	376	57	56	19	0.8 ET
N53L	14.85	24.44	21.85	1.00	0.19	3.76	3.81	0.84	8.44	0.47	409	48	60	19	0.4 ET
N61L	12.83	24.20	22.65	1.01	0.14	3.57	3.60	0.84	7.99	0.37	342	51	61	19	1.2 ET
S13L	14.84	24.23	22.12	1.55	0.21	2.75	4.52	1.02	7.71	0.44	395	100	71	23	0.4 ET
S31L	12.27	28.29	19.26	1.05	0.13	3.45	3.40	0.99	7.49	0.29	234	44	35	21	1.2 ET
S52L	15.32	26.31	19.94	0.99	0.20	3.38	3.19	0.86	8.05	0.39	221	46	45	21	0.8 ET
EBL	16.87	25.99	18.09	1.02	0.25	3.53	3.51	0.74	6.41	0.37	135	36	50	22	-
Average	14.16	25.88	20.70	1.07	0.18	3.44	3.59	0.87	7.66	0.38	302	55	54	21	
A.polycarpa															
ELL	12.54	30.75	19.95	0.92	0.14	2.86	3.84	1.06	8.94	0.30	309	37	28	23	-

Table 11. Nutrient composition of *A. canescens*, *A. lentiformis* and *A. polycarpa* collected at the BGNDRF on September 24, 2015

	CP%	ADF%	Ash%	Ca%	P%	Na%	K%	Mg%	Cl%	S%	Fe ppm	Mn ppm	Zn ppm	Cu ppm	Treatment
A. canescens															
N11C	13.88	24.71	16.65	1.24	0.18	1.52	4.41	0.64	2.78	0.45	139	61	44	18	1.2ET
N31C	14.62	26.38	13.61	0.68	0.22	0.54	4.48	0.68	2.05	0.34	88	44	65	19	1.2ET
N42C	14.49	26.75	13.17	0.76	0.21	0.39	4.74	0.71	2.19	0.36	108	48	74	19	0.8ET
S23C	13.49	26.37	13.15	1.18	0.12	0.15	4.29	0.77	2.13	0.34	141	37	35	18	0.4ET
S42C	14.08	25.58	13.77	1.21	0.17	0.36	4.87	0.77	2.12	0.32	113	38	29	21	0.8ET
S63C	16.80	23.01	14.60	0.96	0.16	0.59	4.36	0.66	3.20	0.45	205	39	21	19	0.4ET
SC	10.19	27.72	21.10	1.41	0.11	2.91	4.01	0.60	8.00	0.53	482	44	22	14	-
Average	13.94	25.79	15.15	1.06	0.17	0.92	4.45	0.69	3.21	0.40	182	44	41	18	-
A. lentiformis															
N22L	15.82	23.32	19.27	0.93	0.28	3.79	3.22	0.78	5.56	0.32	118	31	63	17	0.8ET
N53L	16.90	22.36	21.92	0.96	0.17	3.99	3.29	0.84	6.73	0.30	217	48	63	17	0.4ET
N61L	16.72	22.41	21.24	0.98	0.16	3.80	3.20	0.83	6.47	0.28	138	44	57	17	1.2ET
S13L	16.68	21.09	20.10	0.98	0.17	3.10	3.55	0.79	6.90	0.32	253	30	54	16	0.4ET
S31L	12.08	24.12	21.11	1.19	0.16	3.43	3.67	0.87	6.97	0.31	371	42	36	16	1.2ET
S52L	14.75	22.74	21.00	1.18	0.17	3.72	3.29	0.91	6.26	0.32	281	43	51	19	0.8ET
SL	11.88	18.10	22.04	0.93	0.14	3.60	4.16	0.79	6.21	0.36	189	29	35	15	-
Average	14.98	22.02	20.95	1.02	0.18	3.63	3.48	0.83	6.44	0.32	224	38	51	17	-
A.argentea															
N22P	10.99	31.20	19.97	0.93	0.16	3.37	3.32	0.97	6.50	0.41	748	54	69	21	0.8ET
N53P	12.82	30.36	20.89	0.99	0.13	3.18	3.33	1.07	7.46	0.42	804	50	58	19	0.4ET
N61P	11.26	27.94	19.05	0.90	0.11	2.73	3.06	0.94	6.55	0.34	571	53	40	17	1.2ET
S13P	11.84	30.85	20.48	1.17	0.12	2.77	3.15	1.01	7.13	0.46	870	66	50	21	0.4ET
S31P	10.24	31.28	18.85	1.21	0.13	2.84	3.45	1.15	5.94	0.35	775	50	36	20	1.2ET
S52P	11.02	29.58	19.06	0.89	0.10	2.68	3.21	1.00	6.87	0.38	612	46	31	18	0.8ET
SP	10.32	25.47	26.92	1.24	0.14	3.68	4.41	1.11	9.84	0.56	1068	63	35	21	-
Average	11.21	29.53	20.75	1.05	0.13	3.04	3.42	1.04	7.18	0.42	778	55	46	20	-

Table 12. Micromineral element content of *Atriplex* spp. in comparison to presently used feedstuffs on a dry matter basis.

Plant	Fe ppm	Mn ppm	Zn ppm	Cu ppm	Citation/ Location
A. lentiformis					
leaves	250	75	59	26	Khalil et al. 1986/ Saudi Arabia
whole	167	64.2	27.9	12.5	Sameni and Solelmai, 2006/ Southern Iran
stems	141	35	22	8	Soliz, 2011/ Arizona
leaves	204	194	46	11	Soliz, 2011/ Arizona
fruits	235	137	58	20	Soliz, 2011/ Arizona
A. canescens					
leaves	370	84	59	20	Khalil et al., 1986/ Saudi Arabia
Alfalfa hay	286	35	24	9	NRC, 2000
Sorghum silage	990	79	33	11	NRC, 2000
Corn silage	104	36	24	6	NRC, 2000

Figure 1. Example lactation ration which does not include *Atriplex*.

Ration Analysis DALEX CONNECT Bill Miller, PhD

Deerfield Dairy

Prepared On: January 16, 2015

Milk Cow Diet - Ingredient Detail

Ingredient Name	Ingredient DM Pct	AF lb	DM lb	% of DM	Ration lb/ton AF	Ingredient AF $/ton
Corn Silage - Corner	40.900	27.000	11.043	20.641	523.203	55.000
Alfalfa Silage Deerfield	34.000	25.000	8.500	15.888	484.447	65.000
Corn Grain - Ground - Fine	88.000	15.064	13.256	24.777	291.900	170.000
Corn Distillers - Wet	35.600	12.000	4.272	7.985	232.535	58.000
Whey - Acid	22.000	8.000	1.760	3.290	155.023	32.000
Cottonseed - Whole - Fuzzy	92.000	4.800	4.416	8.254	93.014	275.000
Amino Plus	88.000	3.534	3.110	5.813	68.484	469.000
Soybean Hulls	91.000	3.163	2.878	5.380	61.286	138.000
Alfalfa Hay Deerfield	89.300	3.000	2.679	5.007	58.134	255.000
Deerfield KS Lact Mineral	96.120	1.650	1.586	2.964	31.974	810.000
Total		103.210	53.500		2,000.000	

Costs($/Formula)

Ingredient Cost (AsFed)	6.069

Milk Cow Diet - Nutrient Amount

DM Intake		53.500	AF Intake	103.210
Dry Matter	%	51.836		

Milk Cow Diet - Nutrient Analysis (DM%)

Moisture	%	46.500	Phosphorus	%	0.354
Roughage Dry Matter	%	41.536	Zinc	ppm	92.447
Concentrate Dry Matter	%	58.464	Copper	ppm	17.262
ADF	%	21.247	Magnesium	%	0.237
NDF	%	30.634	Potassium	%	1.675
Protein	%	17.686	Biotin	ppm	0.019
Ruminally Degradable Protein (%CP)	%	52.792	Cobalt	ppm	0.305
Ruminally Undegradable Protein (%CP)	%	47.208	Selenium	ppm	0.216
Fat	%	5.113	Iodine	ppm	0.840
ChoB1 Starch (%DM) / CPM	%	24.988	Monensin	g/ton	12.797
ChoA2 Sugar (%DM) / CPM	%	5.217	Vitamin A	IU/lb	2,157.040
Net Energy Lactation / NRC01	Mcal/cwt	73.642	Vitamin D	IU/lb	312.482
Calcium	%	0.929	Vitamin E	IU/lb	14.171

Figure 2. Example lactation ration which includes *Atriplex*.

Ration Analysis | DALEX CONNECT | Bill Miller, PhD

Deerfield Dairy

Prepared On: January 16, 2015

Milk Cow Diet - Ingredient Detail

Ingredient Name	Ingredient DM Pct	AF lb	DM lb	% of DM	Ration lb/ton AF	Ingredient AF $/ton
Corn Silage - Corner	40.900	24.000	9.816	18.348	510.831	55.000
Corn Grain - Ground - Fine	88.000	15.583	13.713	25.631	331.672	170.000
Alfalfa Silage Deerfield	34.000	12.817	4.358	8.146	272.812	65.000
Corn Distillers - Wet	35.600	12.000	4.272	7.985	255.415	58.000
Whey - Acid	22.000	8.000	1.760	3.290	170.277	32.000
Atriplex spp.	91.000	5.485	4.992	9.330	116.756	65.000
Cottonseed - Whole - Fuzzy	92.000	4.800	4.416	8.254	102.166	275.000
Amino Plus	88.000	4.129	3.634	6.792	87.885	469.000
Alfalfa Hay Deerfield	89.300	3.000	2.679	5.007	63.854	255.000
Soybean Hulls	91.000	2.500	2.275	4.252	53.212	138.000
Deerfield KS Lact Mineral	96.120	1.650	1.586	2.964	35.120	810.000
Total		93.965	53.500		2,000.000	

Costs($/Formula)

Ingredient Cost (AsFed)	5.907

Milk Cow Diet - Nutrient Amount

DM Intake		53.500	AF Intake	93.965
Dry Matter	%	56.936		

Milk Cow Diet - Nutrient Analysis (DM%)

Moisture	%	46.500	Phosphorus	%	0.330
Roughage Dry Matter	%	31.501	Zinc	ppm	91.693
Concentrate Dry Matter	%	68.499	Copper	ppm	17.040
ADF	%	20.170	Magnesium	%	0.209
NDF	%	29.984	Potassium	%	1.479
Protein	%	17.400	Biotin	ppm	0.020
Ruminally Degradable Protein (%CP)	%	47.358	Cobalt	ppm	0.253
Ruminally Undegradable Protein (%CP)	%	52.642	Selenium	ppm	0.200
Fat	%	4.872	Iodine	ppm	0.828
ChoB1 Starch (%DM) / CPM	%	25.000	Monensin	g/ton	12.797
ChoA2 Sugar (%DM) / CPM	%	5.130	Vitamin A	IU/lb	2,157.040
Net Energy Lactation / NRC01	Mcal/cwt	66.767	Vitamin D	IU/lb	312.482
Calcium	%	0.770	Vitamin E	IU/lb	14.171

Appendix A.

The following abbreviations may have been used without definition in this report. Chemical symbols were used when referencing specific elements.

Item	Term
ADF	acid detergent fiber (assumed sequential)
ADG	average daily gain
cal	calorie
CP	crude protein
DM	dry matter
DMI	dry matter intake
NDF	neutral detergent fiber
NE	net energy
NE_g	net energy for gain
NE_l	net energy for lactation
NE_m	net energy for maintenance
NRC	National Research Council
TDN	total digestible nutrients

RECLAMATION
Managing Water in the West

Desalination and Water Purification Research and Development Program Report No 181

Using Halophyte Farming to Manage Inland Reverse Osmosis Concentrates

Appendix 9 – Harvest Sampling Protocol

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2016

Harvest Sampling Protocol

Harvest samples were collected from plants growing in both UA plots at BGNDRF, in July and September, 2015, and April and May, 2016. Samples were collected from each row-pair of plantings from each irrigation treatments, according to the following protocol:

Cut branches around 6" in length from a minimum of 8 - 12 plants on the same irrigation valve. The samples should be around 130 grams, and a minimum of 100 grams. This will fill the paper bag (sandwich size) to around 2/3 full.

Chop up the material coarsely to place in bag.

Label each bag as follows:

For the 12 samples from each irrigation valve:

N or S for north or south plot

0.4, 0.8 or 1.2 for irrigation treatment

C - canescens or L - lentiformis

Record the wet weight minus the bag weight of each bag.

Samples were transported to the UA campus and oven dried at 50 - 60 degrees C for a minimum of 24 hours prior to shipping to Litchfield Lab.

RECLAMATION

Managing Water in the West

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Appendix 10 – Litchfield Analysis Lab Results and Protocols

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2016

7/27/2015
Derived Field Notes
SEAMAN

Plant samples taken 7/23/15 at the halophyte plots at BGNDRF, Alamogordo, NM.

Sample Labels:

N11C	**N22L**	**N31C**	**N42C**	**N53L**	**N61L**
S13L	**S23C**	**S31L**	**S42C**	**S52L**	**S63C**

Extra Samples:

EBL	**ELL**

Description of Sample Labels:

Samples were taken from each set of plantings, which is coordinated with each of the 12 irrigation valves. The letters **N** corresponds with the North field while **S** signifies that the sample was taken from the South field. The first number is the irrigation valve number. The second number relates to the treatment: **1** is the 1.2 et treatment, **2** is the 0.8 et treatment, and **3** is the 0.4 et irrigation treatment. Finally, the letter **L** is a *lentiformis* planting, while **C** is a *canescens* planting.

The extra samples are from the South field *lentiformis* treatments. Here we see a dichotomy in plants. On the North end of the field the *lentiformis* plants are large with big leaves. These plants have grown in a similar fashion to the *lentiformis* of the Marana experiment. However, as we look South, the plants abruptly change to what looks like a stunted version of *lentiformis.* The leaves of these plants are smaller versions of a *lentiformis* leaf shape. However, they are not the same color hue, these leaves are a whiter shade of green. So I took a composite sample of each plant type.

I think that there has been a planting error. And I think that the smaller plant is a different species all together. Additionally, all the April replacement *lentiformis* plantings appear to be what I know to as *lentiformis*. I can rule out all other explanations: the soil type does not change, and these plants have not been subjected to as many irrigation irregularities as have other treatments. Therefore, I think it is important to include a discrete sample for these different plants. **EBL** is the sample of the large plants, while **ELL** is the sample of the small plants.

Each sample is a random composite of a minimum of cuttings from five plants or as many plant cuttings it took to exceed 100 grams of wet weight per sample. The extra samples are a composite of each discrete phenotype in the South *lentiformis* plots.

Litchfield Analytical Services
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Litchfield, MI 49252

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 68,105 **Date Processed:** 08/12/15
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 08/10/15
Grower ID: BGNDRF Alamogordo NM
Sample ID: EBL **Cust#:** A928

University of Arizona - SWES
P.O. Box 210038
1177 E. 4th Street
Tucson AZ 85721-0038
Attn: Joanne Gallagher

Phone: 520-370-9060
Fax:
Email: joanneg@email.arizona.edu

Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	5.80	0.00
DM (Dry Matter) %	WetChem	94.20	100.00
CP (Crude Protein) %	WetChem	15.89	16.87
ADF (Acid Detergent Fiber) %	WetChem	24.48	25.99
CF (Crude Fiber) %	{Calc}	19.58	20.79
Crude Carbohydrates %	{Calc}	40.65	43.15
Digestible Carbohydrates %	{Calc}	32.11	34.09
Fat %	Ether Ext.	1.04	1.10
Total Digestible Nutrients (TDN) %	{Calc}	54.85	58.22
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.56	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.54	0.57
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.25	0.27
Effective Net Energy (ENE) %	{Calc}	44.92	47.69
Digestible Energy DE (Mcal / lb)	{Calc}	1.10	1.16
Metabolizable Energy (Kcal / lb)	{Calc}	901	956
Ash %	WetChem	17.04	18.09
Phosphorus (P) %	WetChem	0.24	0.25
Calcium (Ca) %	WetChem	0.97	1.02
Potassium (K) %	WetChem	3.31	3.51
Magnesium (Mg) %	WetChem	0.69	0.74
Sodium (Na) %	WetChem	3.32	3.53
Sulfur (S) %	WetChem	0.35	0.37
Chloride (Cl) %	WetChem	6.04	6.41
Salt Calculated from Chloride (NaCl) %	{Calc}	9.96	10.57
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	167.91	178.25
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	300.43	318.93
Copper (Cu) ppm	WetChem	21	22
Iron (Fe) ppm	WetChem	127	135
Zinc (Zn) ppm	WetChem	47	50
Manganese (Mn) ppm	WetChem	34	36

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 68,106 ***Date Processed:*** 08/12/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 08/10/15
Grower ID: BGNDRF Alamogordo NM
Sample ID: ELL ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	5.25	0.00
DM (Dry Matter) %	WetChem	94.75	100.00
CP (Crude Protein) %	WetChem	11.88	12.54
ADF (Acid Detergent Fiber) %	WetChem	29.14	30.75
CF (Crude Fiber) %	{Calc}	23.31	24.60
Crude Carbohydrates %	{Calc}	39.82	42.02
Digestible Carbohydrates %	{Calc}	31.46	33.20
Fat %	Ether Ext.	0.84	0.89
Total Digestible Nutrients (TDN) %	{Calc}	52.89	55.82
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.54	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.50	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.22	0.23
Effective Net Energy (ENE) %	{Calc}	42.91	45.29
Digestible Energy DE (Mcal / lb)	{Calc}	1.06	1.12
Metabolizable Energy (Kcal / lb)	{Calc}	868	917
Ash %	WetChem	18.90	19.95
Phosphorus (P) %	WetChem	0.13	0.14
Calcium (Ca) %	WetChem	0.87	0.92
Potassium (K) %	WetChem	3.64	3.84
Magnesium (Mg) %	WetChem	1.00	1.06
Sodium (Na) %	WetChem	2.71	2.86
Sulfur (S) %	WetChem	0.29	0.30
Chloride (Cl) %	WetChem	8.47	8.94
Salt Calculated from Chloride (NaCl) %	{Calc}	13.96	14.74
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-208.77	-220.34
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	-67.80	-71.56
Copper (Cu) ppm	WetChem	21	23
Iron (Fe) ppm	WetChem	293	309
Zinc (Zn) ppm	WetChem	26	28
Manganese (Mn) ppm	WetChem	35	37

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 68,107 ***Date Processed:*** 08/12/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 08/10/15
Grower ID: BGNDRF Alamogordo NM
Sample ID: N11C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	5.25	0.00
DM (Dry Matter) %	WetChem	94.75	100.00
CP (Crude Protein) %	WetChem	15.12	15.96
ADF (Acid Detergent Fiber) %	WetChem	48.93	51.64
CF (Crude Fiber) %	{Calc}	39.14	41.31
Crude Carbohydrates %	{Calc}	21.79	22.99
Digestible Carbohydrates %	{Calc}	17.21	18.16
Fat %	Ether Ext.	1.04	1.10
Total Digestible Nutrients (TDN) %	{Calc}	49.18	51.90
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.50	0.52
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.45	0.47
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.15	0.16
Effective Net Energy (ENE) %	{Calc}	39.20	41.38
Digestible Energy DE (Mcal / lb)	{Calc}	0.98	1.04
Metabolizable Energy (Kcal / lb)	{Calc}	808	852
Ash %	WetChem	17.66	18.64
Phosphorus (P) %	WetChem	0.18	0.19
Calcium (Ca) %	WetChem	1.41	1.48
Potassium (K) %	WetChem	5.30	5.59
Magnesium (Mg) %	WetChem	0.75	0.79
Sodium (Na) %	WetChem	1.25	1.32
Sulfur (S) %	WetChem	0.52	0.54
Chloride (Cl) %	WetChem	3.62	3.82
Salt Calculated from Chloride (NaCl) %	{Calc}	5.97	6.30
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	252.27	266.24
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	444.76	469.40
Copper (Cu) ppm	WetChem	21	22
Iron (Fe) ppm	WetChem	229	242
Zinc (Zn) ppm	WetChem	65	69
Manganese (Mn) ppm	WetChem	84	88

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 68,108 ***Date Processed:*** 08/12/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 08/10/15
Grower ID: BGNDRF Alamogordo NM
Sample ID: N22L ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.70	0.00
DM (Dry Matter) %	WetChem	95.30	100.00
CP (Crude Protein) %	WetChem	11.55	12.12
ADF (Acid Detergent Fiber) %	WetChem	26.41	27.71
CF (Crude Fiber) %	{Calc}	21.13	22.17
Crude Carbohydrates %	{Calc}	41.53	43.58
Digestible Carbohydrates %	{Calc}	32.81	34.42
Fat %	Ether Ext.	1.10	1.15
Total Digestible Nutrients (TDN) %	{Calc}	53.32	55.95
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.54	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.51	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.22	0.23
Effective Net Energy (ENE) %	{Calc}	43.29	45.43
Digestible Energy DE (Mcal / lb)	{Calc}	1.07	1.12
Metabolizable Energy (Kcal / lb)	{Calc}	876	919
Ash %	WetChem	20.00	20.99
Phosphorus (P) %	WetChem	0.15	0.16
Calcium (Ca) %	WetChem	0.81	0.85
Potassium (K) %	WetChem	2.98	3.13
Magnesium (Mg) %	WetChem	0.74	0.78
Sodium (Na) %	WetChem	3.47	3.64
Sulfur (S) %	WetChem	0.32	0.33
Chloride (Cl) %	WetChem	7.17	7.52
Salt Calculated from Chloride (NaCl) %	{Calc}	11.82	12.40
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	24.65	25.86
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	153.41	160.98
Copper (Cu) ppm	WetChem	18	19
Iron (Fe) ppm	WetChem	359	376
Zinc (Zn) ppm	WetChem	53	56
Manganese (Mn) ppm	WetChem	54	57

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	68,109	***Date Processed:***	08/12/15
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	08/10/15
Grower ID:	BGNDRF Alamogordo NM		
Sample ID:	N31C	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	5.10	0.00
DM (Dry Matter) %	WetChem	94.90	100.00
CP (Crude Protein) %	WetChem	13.17	13.88
ADF (Acid Detergent Fiber) %	WetChem	24.97	26.31
CF (Crude Fiber) %	{Calc}	19.98	21.05
Crude Carbohydrates %	{Calc}	47.57	50.13
Digestible Carbohydrates %	{Calc}	37.58	39.60
Fat %	Ether Ext.	1.04	1.09
Total Digestible Nutrients (TDN) %	{Calc}	58.57	61.72
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.60	0.63
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.59	0.62
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.31	0.33
Effective Net Energy (ENE) %	{Calc}	48.58	51.19
Digestible Energy DE (Mcal / lb)	{Calc}	1.17	1.23
Metabolizable Energy (Kcal / lb)	{Calc}	962	1,013
Ash %	WetChem	13.15	13.86
Phosphorus (P) %	WetChem	0.14	0.15
Calcium (Ca) %	WetChem	1.12	1.18
Potassium (K) %	WetChem	3.80	4.00
Magnesium (Mg) %	WetChem	0.79	0.83
Sodium (Na) %	WetChem	1.60	1.68
Sulfur (S) %	WetChem	0.43	0.45
Chloride (Cl) %	WetChem	3.13	3.30
Salt Calculated from Chloride (NaCl) %	{Calc}	5.16	5.44
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	234.10	246.68
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	402.99	424.64
Copper (Cu) ppm	WetChem	20	21
Iron (Fe) ppm	WetChem	338	356
Zinc (Zn) ppm	WetChem	93	98
Manganese (Mn) ppm	WetChem	70	73

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	68,110		***Date Processed:***	08/12/15
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	08/10/15
Grower ID:	BGNDRF Alamogordo NM			
Sample ID:	N42C		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	5.10	0.00
DM (Dry Matter) %	WetChem	94.90	100.00
CP (Crude Protein) %	WetChem	11.43	12.04
ADF (Acid Detergent Fiber) %	WetChem	33.09	34.87
CF (Crude Fiber) %	{Calc}	26.47	27.89
Crude Carbohydrates %	{Calc}	44.94	47.35
Digestible Carbohydrates %	{Calc}	35.50	37.41
Fat %	Ether Ext.	0.90	0.95
Total Digestible Nutrients (TDN) %	{Calc}	58.29	61.42
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.60	0.63
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.59	0.62
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.30	0.32
Effective Net Energy (ENE) %	{Calc}	48.30	50.90
Digestible Energy DE (Mcal / lb)	{Calc}	1.17	1.23
Metabolizable Energy (Kcal / lb)	{Calc}	957	1,009
Ash %	WetChem	11.16	11.76
Phosphorus (P) %	WetChem	0.10	0.11
Calcium (Ca) %	WetChem	1.18	1.24
Potassium (K) %	WetChem	4.43	4.66
Magnesium (Mg) %	WetChem	0.99	1.04
Sodium (Na) %	WetChem	0.28	0.29
Sulfur (S) %	WetChem	0.31	0.32
Chloride (Cl) %	WetChem	1.54	1.63
Salt Calculated from Chloride (NaCl) %	{Calc}	2.54	2.68
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	284.06	299.32
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	441.61	465.34
Copper (Cu) ppm	WetChem	22	23
Iron (Fe) ppm	WetChem	421	443
Zinc (Zn) ppm	WetChem	42	44
Manganese (Mn) ppm	WetChem	103	108

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	68,111		***Date Processed:***	08/12/15
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	08/10/15
Grower ID:	BGNDRF Alamogordo NM			
Sample ID:	N53L		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	5.30	0.00
DM (Dry Matter) %	WetChem	94.70	100.00
CP (Crude Protein) %	WetChem	14.06	14.85
ADF (Acid Detergent Fiber) %	WetChem	23.14	24.44
CF (Crude Fiber) %	{Calc}	18.51	19.55
Crude Carbohydrates %	{Calc}	40.52	42.79
Digestible Carbohydrates %	{Calc}	32.01	33.80
Fat %	Ether Ext.	0.92	0.97
Total Digestible Nutrients (TDN) %	{Calc}	52.72	55.67
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.54	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.50	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.22	0.23
Effective Net Energy (ENE) %	{Calc}	42.75	45.14
Digestible Energy DE (Mcal / lb)	{Calc}	1.05	1.11
Metabolizable Energy (Kcal / lb)	{Calc}	866	914
Ash %	WetChem	20.69	21.85
Phosphorus (P) %	WetChem	0.18	0.19
Calcium (Ca) %	WetChem	0.95	1.00
Potassium (K) %	WetChem	3.61	3.81
Magnesium (Mg) %	WetChem	0.79	0.84
Sodium (Na) %	WetChem	3.56	3.76
Sulfur (S) %	WetChem	0.44	0.47
Chloride (Cl) %	WetChem	7.99	8.44
Salt Calculated from Chloride (NaCl) %	{Calc}	13.17	13.91
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-26.42	-27.90
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	136.49	144.13
Copper (Cu) ppm	WetChem	18	19
Iron (Fe) ppm	WetChem	388	409
Zinc (Zn) ppm	WetChem	57	60
Manganese (Mn) ppm	WetChem	46	48

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Sample Number:	68,112	***Date Processed:***	08/12/15
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	08/10/15
Grower ID:	BGNDRF Alamogordo NM		
Sample ID:	S13L	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	5.00	0.00
DM (Dry Matter) %	WetChem	95.00	100.00
CP (Crude Protein) %	WetChem	14.10	14.84
ADF (Acid Detergent Fiber) %	WetChem	23.02	24.23
CF (Crude Fiber) %	{Calc}	18.42	19.39
Crude Carbohydrates %	{Calc}	40.63	42.77
Digestible Carbohydrates %	{Calc}	32.10	33.79
Fat %	Ether Ext.	0.84	0.88
Total Digestible Nutrients (TDN) %	{Calc}	52.66	55.43
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.53	0.56
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.50	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.21	0.22
Effective Net Energy (ENE) %	{Calc}	42.66	44.91
Digestible Energy DE (Mcal / lb)	{Calc}	1.05	1.11
Metabolizable Energy (Kcal / lb)	{Calc}	865	910
Ash %	WetChem	21.01	22.12
Phosphorus (P) %	WetChem	0.20	0.21
Calcium (Ca) %	WetChem	1.47	1.55
Potassium (K) %	WetChem	4.29	4.52
Magnesium (Mg) %	WetChem	0.97	1.02
Sodium (Na) %	WetChem	2.61	2.75
Sulfur (S) %	WetChem	0.42	0.44
Chloride (Cl) %	WetChem	7.32	7.71
Salt Calculated from Chloride (NaCl) %	{Calc}	12.07	12.70
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-43.43	-45.71
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	141.23	148.67
Copper (Cu) ppm	WetChem	21	23
Iron (Fe) ppm	WetChem	376	395
Zinc (Zn) ppm	WetChem	67	71
Manganese (Mn) ppm	WetChem	95	100

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	68,113		***Date Processed:***	08/12/15
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	08/10/15
Grower ID:	BGNDRF Alamogordo NM			
Sample ID:	S23C		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.80	0.00
DM (Dry Matter) %	WetChem	95.20	100.00
CP (Crude Protein) %	WetChem	14.15	14.86
ADF (Acid Detergent Fiber) %	WetChem	25.37	26.65
CF (Crude Fiber) %	{Calc}	20.30	21.32
Crude Carbohydrates %	{Calc}	46.42	48.76
Digestible Carbohydrates %	{Calc}	36.67	38.52
Fat %	Ether Ext.	1.41	1.48
Total Digestible Nutrients (TDN) %	{Calc}	59.12	62.10
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.61	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.60	0.63
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.32	0.33
Effective Net Energy (ENE) %	{Calc}	49.10	51.58
Digestible Energy DE (Mcal / lb)	{Calc}	1.18	1.24
Metabolizable Energy (Kcal / lb)	{Calc}	971	1,020
Ash %	WetChem	12.92	13.57
Phosphorus (P) %	WetChem	0.16	0.16
Calcium (Ca) %	WetChem	1.12	1.17
Potassium (K) %	WetChem	4.55	4.78
Magnesium (Mg) %	WetChem	0.62	0.65
Sodium (Na) %	WetChem	0.21	0.22
Sulfur (S) %	WetChem	0.45	0.47
Chloride (Cl) %	WetChem	2.46	2.58
Salt Calculated from Chloride (NaCl) %	{Calc}	4.06	4.26
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	128.14	134.60
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	289.68	304.29
Copper (Cu) ppm	WetChem	20	21
Iron (Fe) ppm	WetChem	225	236
Zinc (Zn) ppm	WetChem	35	37
Manganese (Mn) ppm	WetChem	66	70

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 68,114 ***Date Processed:*** 08/12/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 08/10/15
Grower ID: BGNDRF Alamogordo NM
Sample ID: S31L ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	5.15	0.00
DM (Dry Matter) %	WetChem	94.85	100.00
CP (Crude Protein) %	WetChem	11.64	12.27
ADF (Acid Detergent Fiber) %	WetChem	26.83	28.29
CF (Crude Fiber) %	{Calc}	21.46	22.63
Crude Carbohydrates %	{Calc}	42.04	44.32
Digestible Carbohydrates %	{Calc}	33.21	35.01
Fat %	Ether Ext.	1.44	1.52
Total Digestible Nutrients (TDN) %	{Calc}	54.51	57.46
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.56	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.53	0.56
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.24	0.26
Effective Net Energy (ENE) %	{Calc}	44.52	46.94
Digestible Energy DE (Mcal / lb)	{Calc}	1.09	1.15
Metabolizable Energy (Kcal / lb)	{Calc}	895	944
Ash %	WetChem	18.27	19.26
Phosphorus (P) %	WetChem	0.13	0.13
Calcium (Ca) %	WetChem	1.00	1.05
Potassium (K) %	WetChem	3.22	3.40
Magnesium (Mg) %	WetChem	0.94	0.99
Sodium (Na) %	WetChem	3.27	3.45
Sulfur (S) %	WetChem	0.28	0.29
Chloride (Cl) %	WetChem	7.10	7.49
Salt Calculated from Chloride (NaCl) %	{Calc}	11.70	12.34
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	32.75	34.53
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	172.16	181.51
Copper (Cu) ppm	WetChem	20	21
Iron (Fe) ppm	WetChem	222	234
Zinc (Zn) ppm	WetChem	33	35
Manganese (Mn) ppm	WetChem	41	44

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 68,115 **Date Processed:** 08/12/15
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 08/10/15
Grower ID: BGNDRF Alamogordo NM
Sample ID: S42C **Cust#:** A928

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Proximate Feed Analysis Report	*Method*	As Received	Dry Basis
Moisture %	{Calc}	5.40	0.00
DM (Dry Matter) %	WetChem	94.60	100.00
CP (Crude Protein) %	WetChem	15.12	15.98
ADF (Acid Detergent Fiber) %	WetChem	23.68	25.03
CF (Crude Fiber) %	{Calc}	18.94	20.03
Crude Carbohydrates %	{Calc}	47.01	49.69
Digestible Carbohydrates %	{Calc}	37.14	39.26
Fat %	Ether Ext.	1.21	1.27
Total Digestible Nutrients (TDN) %	{Calc}	59.27	62.65
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.61	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.60	0.64
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.32	0.34
Effective Net Energy (ENE) %	{Calc}	49.31	52.12
Digestible Energy DE (Mcal / lb)	{Calc}	1.19	1.25
Metabolizable Energy (Kcal / lb)	{Calc}	973	1,029
Ash %	WetChem	12.32	13.02
Phosphorus (P) %	WetChem	0.13	0.14
Calcium (Ca) %	WetChem	1.45	1.53
Potassium (K) %	WetChem	3.95	4.18
Magnesium (Mg) %	WetChem	0.87	0.92
Sodium (Na) %	WetChem	0.41	0.43
Sulfur (S) %	WetChem	0.37	0.39
Chloride (Cl) %	WetChem	2.62	2.77
Salt Calculated from Chloride (NaCl) %	{Calc}	4.32	4.57
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	99.90	105.60
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	271.02	286.49
Copper (Cu) ppm	WetChem	21	22
Iron (Fe) ppm	WetChem	155	164
Zinc (Zn) ppm	WetChem	32	34
Manganese (Mn) ppm	WetChem	39	41

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	68,116	***Date Processed:***	08/12/15
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	08/10/15
Grower ID:	BGNDRF Alamogordo NM		
Sample ID:	S52L	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	5.30	0.00
DM (Dry Matter) %	WetChem	94.70	100.00
CP (Crude Protein) %	WetChem	14.51	15.32
ADF (Acid Detergent Fiber) %	WetChem	24.92	26.31
CF (Crude Fiber) %	{Calc}	19.94	21.05
Crude Carbohydrates %	{Calc}	40.40	42.67
Digestible Carbohydrates %	{Calc}	31.92	33.71
Fat %	Ether Ext.	0.97	1.02
Total Digestible Nutrients (TDN) %	{Calc}	53.74	56.75
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.55	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.52	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.23	0.25
Effective Net Energy (ENE) %	{Calc}	43.77	46.22
Digestible Energy DE (Mcal / lb)	{Calc}	1.07	1.13
Metabolizable Energy (Kcal / lb)	{Calc}	882	932
Ash %	WetChem	18.88	19.94
Phosphorus (P) %	WetChem	0.19	0.20
Calcium (Ca) %	WetChem	0.94	0.99
Potassium (K) %	WetChem	3.02	3.19
Magnesium (Mg) %	WetChem	0.81	0.86
Sodium (Na) %	WetChem	3.20	3.38
Sulfur (S) %	WetChem	0.37	0.39
Chloride (Cl) %	WetChem	7.62	8.05
Salt Calculated from Chloride (NaCl) %	{Calc}	12.56	13.26
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-98.27	-103.77
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	48.69	51.41
Copper (Cu) ppm	WetChem	20	21
Iron (Fe) ppm	WetChem	209	221
Zinc (Zn) ppm	WetChem	43	45
Manganese (Mn) ppm	WetChem	43	46

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	68,117		**Date Processed:**	08/12/15
Sample Type:	*F67*	Ruminant Feed > 10% CF	**Date Received:**	08/10/15
Grower ID:	BGNDRF Alamogordo NM			
Sample ID:	N61L		**Cust#:**	A928

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Proximate Feed Analysis Report	*Method*	As Received	Dry Basis
Moisture %	{Calc}	5.05	0.00
DM (Dry Matter) %	WetChem	94.95	100.00
CP (Crude Protein) %	WetChem	12.18	12.83
ADF (Acid Detergent Fiber) %	WetChem	22.98	24.20
CF (Crude Fiber) %	{Calc}	18.38	19.36
Crude Carbohydrates %	{Calc}	41.75	43.97
Digestible Carbohydrates %	{Calc}	32.98	34.74
Fat %	Ether Ext.	1.13	1.18
Total Digestible Nutrients (TDN) %	{Calc}	52.62	55.42
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.53	0.56
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.50	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.21	0.22
Effective Net Energy (ENE) %	{Calc}	42.63	44.89
Digestible Energy DE (Mcal / lb)	{Calc}	1.05	1.11
Metabolizable Energy (Kcal / lb)	{Calc}	864	910
Ash %	WetChem	21.51	22.65
Phosphorus (P) %	WetChem	0.14	0.14
Calcium (Ca) %	WetChem	0.96	1.01
Potassium (K) %	WetChem	3.42	3.60
Magnesium (Mg) %	WetChem	0.80	0.84
Sodium (Na) %	WetChem	3.39	3.57
Sulfur (S) %	WetChem	0.35	0.37
Chloride (Cl) %	WetChem	7.59	7.99
Salt Calculated from Chloride (NaCl) %	{Calc}	12.51	13.18
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-5.86	-6.17
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	140.69	148.17
Copper (Cu) ppm	WetChem	18	19
Iron (Fe) ppm	WetChem	325	342
Zinc (Zn) ppm	WetChem	58	61
Manganese (Mn) ppm	WetChem	48	51

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 68,118 ***Date Processed:*** 08/12/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 08/10/15
Grower ID: BGNDRF Alamogordo NM
Sample ID: S63C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	5.15	0.00
DM (Dry Matter) %	WetChem	94.85	100.00
CP (Crude Protein) %	WetChem	12.30	12.97
ADF (Acid Detergent Fiber) %	WetChem	30.61	32.27
CF (Crude Fiber) %	{Calc}	24.49	25.82
Crude Carbohydrates %	{Calc}	46.24	48.75
Digestible Carbohydrates %	{Calc}	36.53	38.51
Fat %	Ether Ext.	0.93	0.98
Total Digestible Nutrients (TDN) %	{Calc}	58.99	62.20
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.61	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.60	0.63
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.32	0.33
Effective Net Energy (ENE) %	{Calc}	49.01	51.67
Digestible Energy DE (Mcal / lb)	{Calc}	1.18	1.24
Metabolizable Energy (Kcal / lb)	{Calc}	969	1,021
Ash %	WetChem	10.89	11.48
Phosphorus (P) %	WetChem	0.18	0.19
Calcium (Ca) %	WetChem	0.86	0.91
Potassium (K) %	WetChem	4.19	4.42
Magnesium (Mg) %	WetChem	0.53	0.56
Sodium (Na) %	WetChem	0.14	0.14
Sulfur (S) %	WetChem	0.38	0.40
Chloride (Cl) %	WetChem	2.56	2.70
Salt Calculated from Chloride (NaCl) %	{Calc}	4.22	4.45
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	79.59	83.91
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	209.83	221.22
Copper (Cu) ppm	WetChem	17	17
Iron (Fe) ppm	WetChem	116	123
Zinc (Zn) ppm	WetChem	22	23
Manganese (Mn) ppm	WetChem	37	39

BGNDRF Alamogordo
September Plant Sample
9/24/2015 Collection Date
10/5/2015 Dry Weight
SEAMAN

Sample	Wet Weight	Bag Weight	Wet Weight - Bag Weight	Dry Weight + Bag Weight	Dry Weight- Bag Weight	Wet Weight- Dry Weight	% change	Notes
SP	162	10	152	51	41	111	73.0	Immature seed
SL	161	11	150	52	41	109	72.7	Immature seed
SC	142	10	132	48	38	94	71.2	Immature seed
N1 1.2 C	154	10	144	55	45	99	68.8	NS
N3 !.2 C	127	10	117	48	38	79	67.5	NS Rst
N6 1.2 L	157	10	147	51	41	106	72.1	NS MF Gst
N6 1.2 P	140	10	130	64	54	76	58.5	WS MF
S3 1.2 L	153	10	143	48	38	105	73.4	WS MF
S3 1.2 P	140	10	130	66	56	74	56.9	WS MF
N2 0.8 L	149	11	138	49	38	100	72.5	Gst MF NS
N2 0.8 P	142	10	132	56	46	86	65.2	WS
N4 0.8 C	155	10	145	56	46	99	68.3	NS
S5 0.8 L	142	10	132	49	39	93	70.5	WS
S5 0.8 P	148	10	138	63	53	85	61.6	WS
S4 0.8 C	117	11	106	46	35	71	67.0	NS
N5 0.4 L	146	10	136	48	38	98	72.1	NS MF
N5 0.4 P	117	10	107	47	37	70	65.4	WS
S1 0.4 L	144	11	133	53	42	91	68.4	WS
S1 0.4 P	134	11	123	53	42	81	65.9	WS
S2 0.4 C	122	10	112	50	40	72	64.3	NS
S6 0.4 C	109	10	99	43	33	66	66.7	NS

881

Notes :

NS	No Seed
WS	With Seed
MF	Male Flowers
Rst	Red Stems
Gst	Green Stems

Quantities of seed or flowers in samples were not quantified.
This is merely a presence or absence observation.

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	71,318	***Date Processed:***	11/13/15
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	11/04/15
Grower ID:	Terminal 10cm Branches/Leaves		
Sample ID:	S3 1.2L	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.50	0.00
DM (Dry Matter) %	WetChem	92.50	100.00
CP (Crude Protein) %	WetChem	11.17	12.08
ADF (Acid Detergent Fiber) %	WetChem	22.31	24.12
CF (Crude Fiber) %	{Calc}	17.85	19.30
Crude Carbohydrates %	{Calc}	42.84	46.32
Digestible Carbohydrates %	{Calc}	33.85	36.59
Fat %	Ether Ext.	1.11	1.20
Total Digestible Nutrients (TDN) %	{Calc}	52.47	56.73
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.53	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.50	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.23	0.25
Effective Net Energy (ENE) %	{Calc}	42.71	46.17
Digestible Energy DE (Mcal / lb)	{Calc}	1.05	1.13
Metabolizable Energy (Kcal / lb)	{Calc}	862	931
Ash %	WetChem	19.53	21.11
Phosphorus (P) %	WetChem	0.15	0.16
Calcium (Ca) %	WetChem	1.11	1.19
Potassium (K) %	WetChem	3.40	3.67
Magnesium (Mg) %	WetChem	0.80	0.87
Sodium (Na) %	WetChem	3.17	3.43
Sulfur (S) %	WetChem	0.29	0.31
Chloride (Cl) %	WetChem	6.45	6.97
Salt Calculated from Chloride (NaCl) %	{Calc}	10.63	11.49
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	112.87	122.02
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	249.23	269.44
Copper (Cu) ppm	WetChem	15	16
Iron (Fe) ppm	WetChem	343	371
Zinc (Zn) ppm	WetChem	34	36
Manganese (Mn) ppm	WetChem	39	42

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	71,319	***Date Processed:***	11/13/15
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	11/04/15
Grower ID:	Terminal 10cm Branches/Leaves		
Sample ID:	S3 1.2P	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.45	0.00
DM (Dry Matter) %	WetChem	92.55	100.00
CP (Crude Protein) %	WetChem	9.48	10.24
ADF (Acid Detergent Fiber) %	WetChem	28.95	31.28
CF (Crude Fiber) %	{Calc}	23.16	25.02
Crude Carbohydrates %	{Calc}	41.95	45.33
Digestible Carbohydrates %	{Calc}	33.14	35.81
Fat %	Ether Ext.	0.51	0.55
Total Digestible Nutrients (TDN) %	{Calc}	52.27	56.47
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.53	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.50	0.54
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.22	0.24
Effective Net Energy (ENE) %	{Calc}	42.49	45.91
Digestible Energy DE (Mcal / lb)	{Calc}	1.05	1.13
Metabolizable Energy (Kcal / lb)	{Calc}	858	927
Ash %	WetChem	17.45	18.85
Phosphorus (P) %	WetChem	0.12	0.13
Calcium (Ca) %	WetChem	1.12	1.21
Potassium (K) %	WetChem	3.20	3.45
Magnesium (Mg) %	WetChem	1.07	1.15
Sodium (Na) %	WetChem	2.62	2.84
Sulfur (S) %	WetChem	0.33	0.35
Chloride (Cl) %	WetChem	5.50	5.94
Salt Calculated from Chloride (NaCl) %	{Calc}	9.07	9.80
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	93.17	100.67
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	255.40	275.96
Copper (Cu) ppm	WetChem	19	20
Iron (Fe) ppm	WetChem	717	775
Zinc (Zn) ppm	WetChem	33	36
Manganese (Mn) ppm	WetChem	46	50

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	71,320	***Date Processed:***	11/13/15
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	11/04/15
Grower ID:	Terminal 10cm Branches/Leaves		
Sample ID:	N2 0.8L	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.40	0.00
DM (Dry Matter) %	WetChem	92.60	100.00
CP (Crude Protein) %	WetChem	14.65	15.82
ADF (Acid Detergent Fiber) %	WetChem	21.59	23.32
CF (Crude Fiber) %	{Calc}	17.27	18.65
Crude Carbohydrates %	{Calc}	41.97	45.33
Digestible Carbohydrates %	{Calc}	33.16	35.81
Fat %	Ether Ext.	0.87	0.93
Total Digestible Nutrients (TDN) %	{Calc}	53.58	57.86
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.55	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.52	0.56
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.24	0.26
Effective Net Energy (ENE) %	{Calc}	43.80	47.30
Digestible Energy DE (Mcal / lb)	{Calc}	1.07	1.16
Metabolizable Energy (Kcal / lb)	{Calc}	880	950
Ash %	WetChem	17.84	19.27
Phosphorus (P) %	WetChem	0.26	0.28
Calcium (Ca) %	WetChem	0.86	0.93
Potassium (K) %	WetChem	2.98	3.22
Magnesium (Mg) %	WetChem	0.73	0.78
Sodium (Na) %	WetChem	3.51	3.79
Sulfur (S) %	WetChem	0.30	0.32
Chloride (Cl) %	WetChem	5.15	5.56
Salt Calculated from Chloride (NaCl) %	{Calc}	8.49	9.17
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	295.71	319.34
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	413.50	446.54
Copper (Cu) ppm	WetChem	16	17
Iron (Fe) ppm	WetChem	109	118
Zinc (Zn) ppm	WetChem	59	63
Manganese (Mn) ppm	WetChem	28	31

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,321 ***Date Processed:*** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: N2 0.8P ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	6.90	0.00
DM (Dry Matter) %	WetChem	93.10	100.00
CP (Crude Protein) %	WetChem	10.23	10.99
ADF (Acid Detergent Fiber) %	WetChem	29.05	31.20
CF (Crude Fiber) %	{Calc}	23.24	24.96
Crude Carbohydrates %	{Calc}	40.39	43.38
Digestible Carbohydrates %	{Calc}	31.90	34.27
Fat %	Ether Ext.	0.66	0.70
Total Digestible Nutrients (TDN) %	{Calc}	51.83	55.68
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.53	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.49	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.21	0.23
Effective Net Energy (ENE) %	{Calc}	42.01	45.13
Digestible Energy DE (Mcal / lb)	{Calc}	1.04	1.11
Metabolizable Energy (Kcal / lb)	{Calc}	851	914
Ash %	WetChem	18.59	19.97
Phosphorus (P) %	WetChem	0.15	0.16
Calcium (Ca) %	WetChem	0.86	0.93
Potassium (K) %	WetChem	3.09	3.32
Magnesium (Mg) %	WetChem	0.90	0.97
Sodium (Na) %	WetChem	3.13	3.37
Sulfur (S) %	WetChem	0.38	0.41
Chloride (Cl) %	WetChem	6.05	6.50
Salt Calculated from Chloride (NaCl) %	{Calc}	9.97	10.71
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	94.88	101.91
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	249.77	268.28
Copper (Cu) ppm	WetChem	19	21
Iron (Fe) ppm	WetChem	696	748
Zinc (Zn) ppm	WetChem	64	69
Manganese (Mn) ppm	WetChem	51	54

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,322 **Date Processed:** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: N4 0.8C **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.60	0.00
DM (Dry Matter) %	WetChem	92.40	100.00
CP (Crude Protein) %	WetChem	13.39	14.49
ADF (Acid Detergent Fiber) %	WetChem	24.72	26.75
CF (Crude Fiber) %	{Calc}	19.78	21.40
Crude Carbohydrates %	{Calc}	46.01	49.79
Digestible Carbohydrates %	{Calc}	36.35	39.34
Fat %	Ether Ext.	1.06	1.14
Total Digestible Nutrients (TDN) %	{Calc}	57.43	62.15
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.59	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.58	0.63
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.31	0.33
Effective Net Energy (ENE) %	{Calc}	47.67	51.59
Digestible Energy DE (Mcal / lb)	{Calc}	1.15	1.24
Metabolizable Energy (Kcal / lb)	{Calc}	943	1,021
Ash %	WetChem	12.17	13.17
Phosphorus (P) %	WetChem	0.20	0.21
Calcium (Ca) %	WetChem	0.71	0.76
Potassium (K) %	WetChem	4.38	4.74
Magnesium (Mg) %	WetChem	0.66	0.71
Sodium (Na) %	WetChem	0.36	0.39
Sulfur (S) %	WetChem	0.34	0.36
Chloride (Cl) %	WetChem	2.02	2.19
Salt Calculated from Chloride (NaCl) %	{Calc}	3.33	3.60
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	226.66	245.30
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	348.17	376.81
Copper (Cu) ppm	WetChem	17	19
Iron (Fe) ppm	WetChem	100	108
Zinc (Zn) ppm	WetChem	68	74
Manganese (Mn) ppm	WetChem	44	48

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,323 ***Date Processed:*** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: S5 0.8L ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	8.00	0.00
DM (Dry Matter) %	WetChem	92.00	100.00
CP (Crude Protein) %	WetChem	13.57	14.75
ADF (Acid Detergent Fiber) %	WetChem	20.92	22.74
CF (Crude Fiber) %	{Calc}	16.74	18.19
Crude Carbohydrates %	{Calc}	41.26	44.85
Digestible Carbohydrates %	{Calc}	32.60	35.43
Fat %	Ether Ext.	1.11	1.21
Total Digestible Nutrients (TDN) %	{Calc}	52.37	56.93
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.53	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.50	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.23	0.25
Effective Net Energy (ENE) %	{Calc}	42.65	46.36
Digestible Energy DE (Mcal / lb)	{Calc}	1.05	1.14
Metabolizable Energy (Kcal / lb)	{Calc}	860	935
Ash %	WetChem	19.32	21.00
Phosphorus (P) %	WetChem	0.16	0.17
Calcium (Ca) %	WetChem	1.09	1.18
Potassium (K) %	WetChem	3.03	3.29
Magnesium (Mg) %	WetChem	0.84	0.91
Sodium (Na) %	WetChem	3.43	3.72
Sulfur (S) %	WetChem	0.29	0.32
Chloride (Cl) %	WetChem	5.76	6.26
Salt Calculated from Chloride (NaCl) %	{Calc}	9.50	10.32
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	207.00	225.00
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	344.86	374.85
Copper (Cu) ppm	WetChem	18	19
Iron (Fe) ppm	WetChem	259	281
Zinc (Zn) ppm	WetChem	47	51
Manganese (Mn) ppm	WetChem	40	43

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,324 ***Date Processed:*** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: S5 0.8P ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.77	0.00
DM (Dry Matter) %	WetChem	92.23	100.00
CP (Crude Protein) %	WetChem	10.16	11.02
ADF (Acid Detergent Fiber) %	WetChem	27.28	29.58
CF (Crude Fiber) %	{Calc}	21.82	23.66
Crude Carbohydrates %	{Calc}	41.84	45.37
Digestible Carbohydrates %	{Calc}	33.05	35.84
Fat %	Ether Ext.	0.83	0.89
Total Digestible Nutrients (TDN) %	{Calc}	52.50	56.92
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.53	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.51	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.23	0.25
Effective Net Energy (ENE) %	{Calc}	42.75	46.36
Digestible Energy DE (Mcal / lb)	{Calc}	1.05	1.14
Metabolizable Energy (Kcal / lb)	{Calc}	862	935
Ash %	WetChem	17.58	19.06
Phosphorus (P) %	WetChem	0.09	0.10
Calcium (Ca) %	WetChem	0.82	0.89
Potassium (K) %	WetChem	2.96	3.21
Magnesium (Mg) %	WetChem	0.92	1.00
Sodium (Na) %	WetChem	2.47	2.68
Sulfur (S) %	WetChem	0.36	0.38
Chloride (Cl) %	WetChem	6.34	6.87
Salt Calculated from Chloride (NaCl) %	{Calc}	10.45	11.33
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-80.49	-87.27
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	72.15	78.23
Copper (Cu) ppm	WetChem	17	18
Iron (Fe) ppm	WetChem	564	612
Zinc (Zn) ppm	WetChem	28	31
Manganese (Mn) ppm	WetChem	42	46

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,325 **Date Processed:** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: SP **Cust#:** A928

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Proximate Feed Analysis Report	*Method*	As Received	Dry Basis
Moisture %	{Calc}	7.72	0.00
DM (Dry Matter) %	WetChem	92.28	100.00
CP (Crude Protein) %	WetChem	9.52	10.32
ADF (Acid Detergent Fiber) %	WetChem	23.50	25.47
CF (Crude Fiber) %	{Calc}	18.80	20.37
Crude Carbohydrates %	{Calc}	37.68	40.83
Digestible Carbohydrates %	{Calc}	29.77	32.26
Fat %	Ether Ext.	1.44	1.56
Total Digestible Nutrients (TDN) %	{Calc}	48.23	52.26
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.49	0.53
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.44	0.48
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.15	0.17
Effective Net Energy (ENE) %	{Calc}	38.48	41.70
Digestible Energy DE (Mcal / lb)	{Calc}	0.96	1.05
Metabolizable Energy (Kcal / lb)	{Calc}	792	858
Ash %	WetChem	24.84	26.92
Phosphorus (P) %	WetChem	0.13	0.14
Calcium (Ca) %	WetChem	1.15	1.24
Potassium (K) %	WetChem	4.07	4.41
Magnesium (Mg) %	WetChem	1.02	1.11
Sodium (Na) %	WetChem	3.40	3.68
Sulfur (S) %	WetChem	0.52	0.56
Chloride (Cl) %	WetChem	9.08	9.84
Salt Calculated from Chloride (NaCl) %	{Calc}	14.97	16.22
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-166.10	-180.00
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	37.29	40.41
Copper (Cu) ppm	WetChem	19	21
Iron (Fe) ppm	WetChem	986	1,068
Zinc (Zn) ppm	WetChem	32	35
Manganese (Mn) ppm	WetChem	58	63

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,326 ***Date Processed:*** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: SL ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.57	0.00
DM (Dry Matter) %	WetChem	92.43	100.00
CP (Crude Protein) %	WetChem	10.98	11.88
ADF (Acid Detergent Fiber) %	WetChem	16.73	18.10
CF (Crude Fiber) %	{Calc}	13.38	14.48
Crude Carbohydrates %	{Calc}	45.99	49.75
Digestible Carbohydrates %	{Calc}	36.33	39.30
Fat %	Ether Ext.	1.71	1.85
Total Digestible Nutrients (TDN) %	{Calc}	53.55	57.93
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.55	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.52	0.56
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.25	0.27
Effective Net Energy (ENE) %	{Calc}	43.79	47.37
Digestible Energy DE (Mcal / lb)	{Calc}	1.07	1.16
Metabolizable Energy (Kcal / lb)	{Calc}	879	951
Ash %	WetChem	20.37	22.04
Phosphorus (P) %	WetChem	0.13	0.14
Calcium (Ca) %	WetChem	0.86	0.93
Potassium (K) %	WetChem	3.85	4.16
Magnesium (Mg) %	WetChem	0.73	0.79
Sodium (Na) %	WetChem	3.33	3.60
Sulfur (S) %	WetChem	0.33	0.36
Chloride (Cl) %	WetChem	5.74	6.21
Salt Calculated from Chloride (NaCl) %	{Calc}	9.46	10.24
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	275.55	298.11
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	409.91	443.48
Copper (Cu) ppm	WetChem	14	15
Iron (Fe) ppm	WetChem	175	189
Zinc (Zn) ppm	WetChem	33	35
Manganese (Mn) ppm	WetChem	26	29

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,327 ***Date Processed:*** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: SC ***Cust#:*** A928

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Proximate Feed Analysis Report	*Method*	As Received	Dry Basis
Moisture %	{Calc}	6.59	0.00
DM (Dry Matter) %	WetChem	93.41	100.00
CP (Crude Protein) %	WetChem	9.52	10.19
ADF (Acid Detergent Fiber) %	WetChem	25.89	27.72
CF (Crude Fiber) %	{Calc}	20.71	22.17
Crude Carbohydrates %	{Calc}	42.27	45.26
Digestible Carbohydrates %	{Calc}	33.40	35.75
Fat %	Ether Ext.	1.20	1.28
Total Digestible Nutrients (TDN) %	{Calc}	52.42	56.12
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.53	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.50	0.54
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.22	0.24
Effective Net Energy (ENE) %	{Calc}	42.57	45.57
Digestible Energy DE (Mcal / lb)	{Calc}	1.05	1.12
Metabolizable Energy (Kcal / lb)	{Calc}	861	921
Ash %	WetChem	19.71	21.10
Phosphorus (P) %	WetChem	0.11	0.11
Calcium (Ca) %	WetChem	1.32	1.41
Potassium (K) %	WetChem	3.74	4.01
Magnesium (Mg) %	WetChem	0.56	0.60
Sodium (Na) %	WetChem	2.72	2.91
Sulfur (S) %	WetChem	0.50	0.53
Chloride (Cl) %	WetChem	7.47	8.00
Salt Calculated from Chloride (NaCl) %	{Calc}	12.31	13.18
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-126.06	-134.95
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	54.14	57.96
Copper (Cu) ppm	WetChem	13	14
Iron (Fe) ppm	WetChem	450	482
Zinc (Zn) ppm	WetChem	20	22
Manganese (Mn) ppm	WetChem	41	44

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,328 **Date Processed:** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: N1 1.2C **Cust#:** A928

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Proximate Feed Analysis Report	*Method*	As Received	Dry Basis
Moisture %	{Calc}	7.14	0.00
DM (Dry Matter) %	WetChem	92.86	100.00
CP (Crude Protein) %	WetChem	12.89	13.88
ADF (Acid Detergent Fiber) %	WetChem	22.95	24.71
CF (Crude Fiber) %	{Calc}	18.36	19.77
Crude Carbohydrates %	{Calc}	45.25	48.73
Digestible Carbohydrates %	{Calc}	35.75	38.50
Fat %	Ether Ext.	0.90	0.97
Total Digestible Nutrients (TDN) %	{Calc}	55.52	59.79
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.57	0.61
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.55	0.59
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.27	0.30
Effective Net Energy (ENE) %	{Calc}	45.72	49.23
Digestible Energy DE (Mcal / lb)	{Calc}	1.11	1.20
Metabolizable Energy (Kcal / lb)	{Calc}	912	982
Ash %	WetChem	15.46	16.65
Phosphorus (P) %	WetChem	0.16	0.18
Calcium (Ca) %	WetChem	1.15	1.24
Potassium (K) %	WetChem	4.10	4.41
Magnesium (Mg) %	WetChem	0.59	0.64
Sodium (Na) %	WetChem	1.41	1.52
Sulfur (S) %	WetChem	0.42	0.45
Chloride (Cl) %	WetChem	2.58	2.78
Salt Calculated from Chloride (NaCl) %	{Calc}	4.25	4.58
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	305.05	328.51
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	459.61	494.95
Copper (Cu) ppm	WetChem	16	18
Iron (Fe) ppm	WetChem	129	139
Zinc (Zn) ppm	WetChem	40	44
Manganese (Mn) ppm	WetChem	56	61

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,329 **Date Processed:** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: N3 1.2C **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.50	0.00
DM (Dry Matter) %	WetChem	92.50	100.00
CP (Crude Protein) %	WetChem	13.52	14.62
ADF (Acid Detergent Fiber) %	WetChem	24.40	26.38
CF (Crude Fiber) %	{Calc}	19.52	21.10
Crude Carbohydrates %	{Calc}	45.98	49.71
Digestible Carbohydrates %	{Calc}	36.33	39.27
Fat %	Ether Ext.	0.89	0.96
Total Digestible Nutrients (TDN) %	{Calc}	57.10	61.73
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.59	0.63
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.57	0.62
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.30	0.33
Effective Net Energy (ENE) %	{Calc}	47.33	51.17
Digestible Energy DE (Mcal / lb)	{Calc}	1.14	1.23
Metabolizable Energy (Kcal / lb)	{Calc}	938	1,014
Ash %	WetChem	12.59	13.61
Phosphorus (P) %	WetChem	0.20	0.22
Calcium (Ca) %	WetChem	0.63	0.68
Potassium (K) %	WetChem	4.14	4.48
Magnesium (Mg) %	WetChem	0.63	0.68
Sodium (Na) %	WetChem	0.50	0.54
Sulfur (S) %	WetChem	0.31	0.34
Chloride (Cl) %	WetChem	1.90	2.05
Salt Calculated from Chloride (NaCl) %	{Calc}	3.13	3.39
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	249.02	269.21
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	360.54	389.77
Copper (Cu) ppm	WetChem	18	19
Iron (Fe) ppm	WetChem	82	88
Zinc (Zn) ppm	WetChem	60	65
Manganese (Mn) ppm	WetChem	40	44

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,330
Date Processed: 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF
Date Received: 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: N6 1.2L
Cust#: A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.69	0.00
DM (Dry Matter) %	WetChem	92.31	100.00
CP (Crude Protein) %	WetChem	15.43	16.72
ADF (Acid Detergent Fiber) %	WetChem	20.69	22.41
CF (Crude Fiber) %	{Calc}	16.55	17.93
Crude Carbohydrates %	{Calc}	39.77	43.09
Digestible Carbohydrates %	{Calc}	31.42	34.04
Fat %	Ether Ext.	0.95	1.02
Total Digestible Nutrients (TDN) %	{Calc}	52.16	56.51
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.53	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.50	0.54
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.22	0.24
Effective Net Energy (ENE) %	{Calc}	42.41	45.94
Digestible Energy DE (Mcal / lb)	{Calc}	1.04	1.13
Metabolizable Energy (Kcal / lb)	{Calc}	856	928
Ash %	WetChem	19.61	21.24
Phosphorus (P) %	WetChem	0.15	0.16
Calcium (Ca) %	WetChem	0.91	0.98
Potassium (K) %	WetChem	2.95	3.20
Magnesium (Mg) %	WetChem	0.77	0.83
Sodium (Na) %	WetChem	3.51	3.80
Sulfur (S) %	WetChem	0.26	0.28
Chloride (Cl) %	WetChem	5.97	6.47
Salt Calculated from Chloride (NaCl) %	{Calc}	9.84	10.66
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	199.06	215.64
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	319.63	346.26
Copper (Cu) ppm	WetChem	16	17
Iron (Fe) ppm	WetChem	127	138
Zinc (Zn) ppm	WetChem	53	57
Manganese (Mn) ppm	WetChem	41	44

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,331 ***Date Processed:*** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: N6 1.2P ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	6.83	0.00
DM (Dry Matter) %	WetChem	93.17	100.00
CP (Crude Protein) %	WetChem	10.49	11.26
ADF (Acid Detergent Fiber) %	WetChem	26.03	27.94
CF (Crude Fiber) %	{Calc}	20.82	22.35
Crude Carbohydrates %	{Calc}	43.39	46.57
Digestible Carbohydrates %	{Calc}	34.27	36.79
Fat %	Ether Ext.	0.72	0.77
Total Digestible Nutrients (TDN) %	{Calc}	53.29	57.19
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.54	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.51	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.24	0.25
Effective Net Energy (ENE) %	{Calc}	43.46	46.64
Digestible Energy DE (Mcal / lb)	{Calc}	1.07	1.14
Metabolizable Energy (Kcal / lb)	{Calc}	875	939
Ash %	WetChem	17.75	19.05
Phosphorus (P) %	WetChem	0.10	0.11
Calcium (Ca) %	WetChem	0.84	0.90
Potassium (K) %	WetChem	2.85	3.06
Magnesium (Mg) %	WetChem	0.88	0.94
Sodium (Na) %	WetChem	2.54	2.73
Sulfur (S) %	WetChem	0.31	0.34
Chloride (Cl) %	WetChem	6.10	6.55
Salt Calculated from Chloride (NaCl) %	{Calc}	10.06	10.79
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-37.03	-39.74
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	104.17	111.81
Copper (Cu) ppm	WetChem	16	17
Iron (Fe) ppm	WetChem	532	571
Zinc (Zn) ppm	WetChem	37	40
Manganese (Mn) ppm	WetChem	49	53

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,332 ***Date Processed:*** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: S4 0.8C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.41	0.00
DM (Dry Matter) %	WetChem	92.59	100.00
CP (Crude Protein) %	WetChem	13.04	14.08
ADF (Acid Detergent Fiber) %	WetChem	23.68	25.58
CF (Crude Fiber) %	{Calc}	18.94	20.46
Crude Carbohydrates %	{Calc}	47.07	50.84
Digestible Carbohydrates %	{Calc}	37.19	40.16
Fat %	Ether Ext.	0.79	0.85
Total Digestible Nutrients (TDN) %	{Calc}	57.17	61.75
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.59	0.63
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.58	0.62
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.30	0.33
Effective Net Energy (ENE) %	{Calc}	47.39	51.19
Digestible Energy DE (Mcal / lb)	{Calc}	1.14	1.23
Metabolizable Energy (Kcal / lb)	{Calc}	939	1,014
Ash %	WetChem	12.75	13.77
Phosphorus (P) %	WetChem	0.16	0.17
Calcium (Ca) %	WetChem	1.12	1.21
Potassium (K) %	WetChem	4.51	4.87
Magnesium (Mg) %	WetChem	0.72	0.77
Sodium (Na) %	WetChem	0.33	0.36
Sulfur (S) %	WetChem	0.29	0.32
Chloride (Cl) %	WetChem	1.96	2.12
Salt Calculated from Chloride (NaCl) %	{Calc}	3.23	3.49
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	255.72	276.18
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	387.72	418.75
Copper (Cu) ppm	WetChem	19	21
Iron (Fe) ppm	WetChem	105	113
Zinc (Zn) ppm	WetChem	27	29
Manganese (Mn) ppm	WetChem	36	38

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	71,333	***Date Processed:***	11/13/15
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	11/04/15
Grower ID:	Terminal 10cm Branches/Leaves		
Sample ID:	N5 0.4L	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.56	0.00
DM (Dry Matter) %	WetChem	92.44	100.00
CP (Crude Protein) %	WetChem	15.62	16.90
ADF (Acid Detergent Fiber) %	WetChem	20.67	22.36
CF (Crude Fiber) %	{Calc}	16.54	17.89
Crude Carbohydrates %	{Calc}	39.35	42.57
Digestible Carbohydrates %	{Calc}	31.09	33.63
Fat %	Ether Ext.	0.68	0.73
Total Digestible Nutrients (TDN) %	{Calc}	51.52	55.74
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.52	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.49	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.21	0.23
Effective Net Energy (ENE) %	{Calc}	41.76	45.18
Digestible Energy DE (Mcal / lb)	{Calc}	1.03	1.11
Metabolizable Energy (Kcal / lb)	{Calc}	846	915
Ash %	WetChem	20.26	21.92
Phosphorus (P) %	WetChem	0.16	0.17
Calcium (Ca) %	WetChem	0.89	0.96
Potassium (K) %	WetChem	3.04	3.29
Magnesium (Mg) %	WetChem	0.78	0.84
Sodium (Na) %	WetChem	3.69	3.99
Sulfur (S) %	WetChem	0.28	0.30
Chloride (Cl) %	WetChem	6.22	6.73
Salt Calculated from Chloride (NaCl) %	{Calc}	10.25	11.09
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	206.23	223.10
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	330.34	357.36
Copper (Cu) ppm	WetChem	16	17
Iron (Fe) ppm	WetChem	200	217
Zinc (Zn) ppm	WetChem	59	63
Manganese (Mn) ppm	WetChem	44	48

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,334 ***Date Processed:*** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: N5 0.4P ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.52	0.00
DM (Dry Matter) %	WetChem	92.48	100.00
CP (Crude Protein) %	WetChem	11.86	12.82
ADF (Acid Detergent Fiber) %	WetChem	28.08	30.36
CF (Crude Fiber) %	{Calc}	22.46	24.29
Crude Carbohydrates %	{Calc}	37.61	40.66
Digestible Carbohydrates %	{Calc}	29.71	32.12
Fat %	Ether Ext.	1.23	1.33
Total Digestible Nutrients (TDN) %	{Calc}	51.33	55.50
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.52	0.56
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.49	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.21	0.22
Effective Net Energy (ENE) %	{Calc}	41.56	44.94
Digestible Energy DE (Mcal / lb)	{Calc}	1.03	1.11
Metabolizable Energy (Kcal / lb)	{Calc}	843	911
Ash %	WetChem	19.32	20.89
Phosphorus (P) %	WetChem	0.12	0.13
Calcium (Ca) %	WetChem	0.91	0.99
Potassium (K) %	WetChem	3.08	3.33
Magnesium (Mg) %	WetChem	0.99	1.07
Sodium (Na) %	WetChem	2.94	3.18
Sulfur (S) %	WetChem	0.39	0.42
Chloride (Cl) %	WetChem	6.90	7.46
Salt Calculated from Chloride (NaCl) %	{Calc}	11.37	12.30
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-56.85	-61.47
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	108.59	117.42
Copper (Cu) ppm	WetChem	18	19
Iron (Fe) ppm	WetChem	744	804
Zinc (Zn) ppm	WetChem	53	58
Manganese (Mn) ppm	WetChem	47	50

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	71,335		***Date Processed:***	11/13/15
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	11/04/15
Grower ID:	Terminal 10cm Branches/Leaves			
Sample ID:	S1 0.4L		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	8.11	0.00
DM (Dry Matter) %	WetChem	91.89	100.00
CP (Crude Protein) %	WetChem	15.33	16.68
ADF (Acid Detergent Fiber) %	WetChem	19.38	21.09
CF (Crude Fiber) %	{Calc}	15.50	16.87
Crude Carbohydrates %	{Calc}	40.97	44.58
Digestible Carbohydrates %	{Calc}	32.36	35.22
Fat %	Ether Ext.	1.62	1.76
Total Digestible Nutrients (TDN) %	{Calc}	53.59	58.32
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.55	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.52	0.57
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.25	0.27
Effective Net Energy (ENE) %	{Calc}	43.88	47.75
Digestible Energy DE (Mcal / lb)	{Calc}	1.07	1.17
Metabolizable Energy (Kcal / lb)	{Calc}	880	958
Ash %	WetChem	18.47	20.10
Phosphorus (P) %	WetChem	0.16	0.17
Calcium (Ca) %	WetChem	0.90	0.98
Potassium (K) %	WetChem	3.26	3.55
Magnesium (Mg) %	WetChem	0.73	0.79
Sodium (Na) %	WetChem	2.85	3.10
Sulfur (S) %	WetChem	0.29	0.32
Chloride (Cl) %	WetChem	6.34	6.90
Salt Calculated from Chloride (NaCl) %	{Calc}	10.45	11.37
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	46.80	50.93
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	171.68	186.83
Copper (Cu) ppm	WetChem	15	16
Iron (Fe) ppm	WetChem	233	253
Zinc (Zn) ppm	WetChem	49	54
Manganese (Mn) ppm	WetChem	28	30

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,336 ***Date Processed:*** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: S1 0.4P ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.23	0.00
DM (Dry Matter) %	WetChem	92.77	100.00
CP (Crude Protein) %	WetChem	10.98	11.84
ADF (Acid Detergent Fiber) %	WetChem	28.62	30.85
CF (Crude Fiber) %	{Calc}	22.90	24.68
Crude Carbohydrates %	{Calc}	38.74	41.76
Digestible Carbohydrates %	{Calc}	30.60	32.99
Fat %	Ether Ext.	1.16	1.25
Total Digestible Nutrients (TDN) %	{Calc}	51.69	55.72
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.53	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.49	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.21	0.23
Effective Net Energy (ENE) %	{Calc}	41.90	45.17
Digestible Energy DE (Mcal / lb)	{Calc}	1.03	1.11
Metabolizable Energy (Kcal / lb)	{Calc}	849	915
Ash %	WetChem	19.00	20.48
Phosphorus (P) %	WetChem	0.11	0.12
Calcium (Ca) %	WetChem	1.08	1.17
Potassium (K) %	WetChem	2.92	3.15
Magnesium (Mg) %	WetChem	0.94	1.01
Sodium (Na) %	WetChem	2.57	2.77
Sulfur (S) %	WetChem	0.43	0.46
Chloride (Cl) %	WetChem	6.61	7.13
Salt Calculated from Chloride (NaCl) %	{Calc}	10.90	11.75
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-119.83	-129.17
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	56.94	61.38
Copper (Cu) ppm	WetChem	19	21
Iron (Fe) ppm	WetChem	807	870
Zinc (Zn) ppm	WetChem	47	50
Manganese (Mn) ppm	WetChem	61	66

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,337 **Date Processed:** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: S2 0.4C **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.61	0.00
DM (Dry Matter) %	WetChem	92.39	100.00
CP (Crude Protein) %	WetChem	12.46	13.49
ADF (Acid Detergent Fiber) %	WetChem	24.36	26.37
CF (Crude Fiber) %	{Calc}	19.49	21.09
Crude Carbohydrates %	{Calc}	46.83	50.69
Digestible Carbohydrates %	{Calc}	37.00	40.04
Fat %	Ether Ext.	1.46	1.58
Total Digestible Nutrients (TDN) %	{Calc}	57.92	62.69
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.59	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.59	0.64
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.31	0.34
Effective Net Energy (ENE) %	{Calc}	48.16	52.13
Digestible Energy DE (Mcal / lb)	{Calc}	1.16	1.25
Metabolizable Energy (Kcal / lb)	{Calc}	951	1,029
Ash %	WetChem	12.15	13.15
Phosphorus (P) %	WetChem	0.11	0.12
Calcium (Ca) %	WetChem	1.09	1.18
Potassium (K) %	WetChem	3.96	4.29
Magnesium (Mg) %	WetChem	0.71	0.77
Sodium (Na) %	WetChem	0.14	0.15
Sulfur (S) %	WetChem	0.32	0.34
Chloride (Cl) %	WetChem	1.97	2.13
Salt Calculated from Chloride (NaCl) %	{Calc}	3.25	3.51
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	145.95	157.97
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	285.97	309.52
Copper (Cu) ppm	WetChem	16	18
Iron (Fe) ppm	WetChem	130	141
Zinc (Zn) ppm	WetChem	32	35
Manganese (Mn) ppm	WetChem	34	37

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 71,338 ***Date Processed:*** 11/13/15
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 11/04/15
Grower ID: Terminal 10cm Branches/Leaves
Sample ID: S6 0.4C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	7.92	0.00
DM (Dry Matter) %	WetChem	92.08	100.00
CP (Crude Protein) %	WetChem	15.47	16.80
ADF (Acid Detergent Fiber) %	WetChem	21.19	23.01
CF (Crude Fiber) %	{Calc}	16.95	18.41
Crude Carbohydrates %	{Calc}	44.89	48.75
Digestible Carbohydrates %	{Calc}	35.46	38.51
Fat %	Ether Ext.	1.33	1.44
Total Digestible Nutrients (TDN) %	{Calc}	57.05	61.95
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.59	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.58	0.62
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.30	0.33
Effective Net Energy (ENE) %	{Calc}	47.32	51.39
Digestible Energy DE (Mcal / lb)	{Calc}	1.14	1.24
Metabolizable Energy (Kcal / lb)	{Calc}	937	1,017
Ash %	WetChem	13.44	14.60
Phosphorus (P) %	WetChem	0.15	0.16
Calcium (Ca) %	WetChem	0.88	0.96
Potassium (K) %	WetChem	4.01	4.36
Magnesium (Mg) %	WetChem	0.60	0.66
Sodium (Na) %	WetChem	0.54	0.59
Sulfur (S) %	WetChem	0.42	0.45
Chloride (Cl) %	WetChem	2.95	3.20
Salt Calculated from Chloride (NaCl) %	{Calc}	4.86	5.28
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	77.99	84.70
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	224.05	243.32
Copper (Cu) ppm	WetChem	18	19
Iron (Fe) ppm	WetChem	189	205
Zinc (Zn) ppm	WetChem	20	21
Manganese (Mn) ppm	WetChem	36	39

BGNDRF Alamogordo
April Plant Sample
4/21/16 Collection Date
4/27/16 plants placed in oven @ 60° C
SEAMAN

Sample	Wet Weight	Bag Weight	Wet Weight - Bag Weight	Dry Weight + Bag Weight	Dry Weight- Bag Weight	Wet Weight- Dry Weight	% change	Notes
N1 1.2 C	133	10	123					
N! 1.2 CD	130	10	120					
N3 1.2 C	138	10	128					
N3 1.2 CS	136	10	126					
N6 1.2 L	117	10	107					
N6 1.2 LD	128	10	118					
S3 1.2 L	124	10	114					
S3 1.2 LS	130	10	120					
N2 0.8 L	134	10	124					
N4 0.8 C	130	10	120					
S5 0.8 L	132	10	122					
S4 0.8 C	134	10	124					
N5 0.4 L	136	10	126					
S1 0.4 L	134	10	124					
S2 0.4 C	135	10	125					
S6 0.4 C	136	10	126					
EBL	133	10	123					
Cont. L	137	10	127					
Cont. C	NA	10	[redacted]					
Nat. BGNDRF	137	10	127					
Nat. Howland	Na	10	[redacted]					

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,036 ***Date Processed:*** 05/06/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/03/16
Grower ID: BGNDRF
Sample ID: N1 1.2C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.94	0.00
DM (Dry Matter) %	WetChem	96.06	100.00
CP (Crude Protein) %	WetChem	14.63	15.23
ADF (Acid Detergent Fiber) %	WetChem	18.80	19.57
CF (Crude Fiber) %	{Calc}	15.04	15.66
Crude Carbohydrates %	{Calc}	48.38	50.36
Digestible Carbohydrates %	{Calc}	38.22	39.78
Fat %	Ether Ext.	1.49	1.55
Total Digestible Nutrients (TDN) %	{Calc}	58.50	60.90
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.60	0.62
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.58	0.61
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.30	0.31
Effective Net Energy (ENE) %	{Calc}	48.39	50.38
Digestible Energy DE (Mcal / lb)	{Calc}	1.17	1.22
Metabolizable Energy (Kcal / lb)	{Calc}	961	1,000
Ash %	WetChem	16.53	17.21
Phosphorus (P) %	WetChem	0.23	0.24
Calcium (Ca) %	WetChem	0.91	0.94
Potassium (K) %	WetChem	3.89	4.05
Magnesium (Mg) %	WetChem	0.58	0.60
Sodium (Na) %	WetChem	1.46	1.52
Sulfur (S) %	WetChem	0.77	0.81
Chloride (Cl) %	WetChem	2.62	2.73
Salt Calculated from Chloride (NaCl) %	{Calc}	4.32	4.50
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	184.59	192.16
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	404.88	421.48
Copper (Cu) ppm	WetChem	13	13
Iron (Fe) ppm	WetChem	146	152
Zinc (Zn) ppm	WetChem	102	107
Manganese (Mn) ppm	WetChem	97	101

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,037 **Date Processed:** 05/06/16
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 05/03/16
Grower ID: BGNDRF
Sample ID: N1 1.2 CD **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.43	0.00
DM (Dry Matter) %	WetChem	96.57	100.00
CP (Crude Protein) %	WetChem	17.57	18.19
ADF (Acid Detergent Fiber) %	WetChem	18.75	19.42
CF (Crude Fiber) %	{Calc}	15.00	15.53
Crude Carbohydrates %	{Calc}	45.26	46.86
Digestible Carbohydrates %	{Calc}	35.75	37.02
Fat %	Ether Ext.	1.43	1.48
Total Digestible Nutrients (TDN) %	{Calc}	58.00	60.06
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.59	0.61
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.58	0.60
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.29	0.30
Effective Net Energy (ENE) %	{Calc}	47.85	49.55
Digestible Energy DE (Mcal / lb)	{Calc}	1.16	1.20
Metabolizable Energy (Kcal / lb)	{Calc}	952	986
Ash %	WetChem	17.32	17.94
Phosphorus (P) %	WetChem	0.23	0.23
Calcium (Ca) %	WetChem	0.83	0.86
Potassium (K) %	WetChem	4.57	4.73
Magnesium (Mg) %	WetChem	0.49	0.51
Sodium (Na) %	WetChem	1.42	1.47
Sulfur (S) %	WetChem	0.62	0.65
Chloride (Cl) %	WetChem	3.40	3.52
Salt Calculated from Chloride (NaCl) %	{Calc}	5.60	5.80
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	199.87	206.97
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	379.30	392.77
Copper (Cu) ppm	WetChem	6	6
Iron (Fe) ppm	WetChem	115	119
Zinc (Zn) ppm	WetChem	54	56
Manganese (Mn) ppm	WetChem	67	69

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,038		***Date Processed:***	05/06/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/03/16
Grower ID:	BGNDRF			
Sample ID:	N3 1.2 C		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.41	0.00
DM (Dry Matter) %	WetChem	96.59	100.00
CP (Crude Protein) %	WetChem	16.60	17.19
ADF (Acid Detergent Fiber) %	WetChem	18.60	19.26
CF (Crude Fiber) %	{Calc}	14.88	15.41
Crude Carbohydrates %	{Calc}	49.35	51.09
Digestible Carbohydrates %	{Calc}	38.99	40.36
Fat %	Ether Ext.	1.37	1.42
Total Digestible Nutrients (TDN) %	{Calc}	60.40	62.53
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.62	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.61	0.63
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.33	0.34
Effective Net Energy (ENE) %	{Calc}	50.25	52.02
Digestible Energy DE (Mcal / lb)	{Calc}	1.21	1.25
Metabolizable Energy (Kcal / lb)	{Calc}	992	1,027
Ash %	WetChem	14.39	14.90
Phosphorus (P) %	WetChem	0.21	0.21
Calcium (Ca) %	WetChem	0.94	0.97
Potassium (K) %	WetChem	4.29	4.44
Magnesium (Mg) %	WetChem	0.59	0.61
Sodium (Na) %	WetChem	0.30	0.31
Sulfur (S) %	WetChem	0.68	0.70
Chloride (Cl) %	WetChem	2.03	2.10
Salt Calculated from Chloride (NaCl) %	{Calc}	3.35	3.46
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	104.26	107.94
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	306.88	317.72
Copper (Cu) ppm	WetChem	10	11
Iron (Fe) ppm	WetChem	133	138
Zinc (Zn) ppm	WetChem	74	77
Manganese (Mn) ppm	WetChem	93	96

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,039		***Date Processed:***	05/06/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/03/16
Grower ID:	BGNDRF			
Sample ID:	N3 1.2 CSB		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.39	0.00
DM (Dry Matter) %	WetChem	96.61	100.00
CP (Crude Protein) %	WetChem	16.92	17.51
ADF (Acid Detergent Fiber) %	WetChem	19.41	20.09
CF (Crude Fiber) %	{Calc}	15.53	16.07
Crude Carbohydrates %	{Calc}	48.49	50.19
Digestible Carbohydrates %	{Calc}	38.30	39.65
Fat %	Ether Ext.	1.60	1.65
Total Digestible Nutrients (TDN) %	{Calc}	60.63	62.76
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.62	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.61	0.64
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.33	0.34
Effective Net Energy (ENE) %	{Calc}	50.47	52.25
Digestible Energy DE (Mcal / lb)	{Calc}	1.21	1.26
Metabolizable Energy (Kcal / lb)	{Calc}	996	1,030
Ash %	WetChem	14.08	14.57
Phosphorus (P) %	WetChem	0.20	0.21
Calcium (Ca) %	WetChem	0.96	1.00
Potassium (K) %	WetChem	4.35	4.50
Magnesium (Mg) %	WetChem	0.60	0.62
Sodium (Na) %	WetChem	0.33	0.35
Sulfur (S) %	WetChem	0.71	0.73
Chloride (Cl) %	WetChem	2.04	2.11
Salt Calculated from Chloride (NaCl) %	{Calc}	3.36	3.48
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	109.85	113.70
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	320.77	332.03
Copper (Cu) ppm	WetChem	12	12
Iron (Fe) ppm	WetChem	112	116
Zinc (Zn) ppm	WetChem	62	65
Manganese (Mn) ppm	WetChem	101	105

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,040		***Date Processed:***	05/06/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/03/16
Grower ID:	BGNDRF			
Sample ID:	N6 1.2 L		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.37	0.00
DM (Dry Matter) %	WetChem	96.63	100.00
CP (Crude Protein) %	WetChem	21.68	22.44
ADF (Acid Detergent Fiber) %	WetChem	14.97	15.49
CF (Crude Fiber) %	{Calc}	11.98	12.39
Crude Carbohydrates %	{Calc}	39.25	40.62
Digestible Carbohydrates %	{Calc}	31.01	32.09
Fat %	Ether Ext.	1.53	1.58
Total Digestible Nutrients (TDN) %	{Calc}	54.84	56.75
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.56	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.53	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.24	0.25
Effective Net Energy (ENE) %	{Calc}	44.68	46.24
Digestible Energy DE (Mcal / lb)	{Calc}	1.10	1.13
Metabolizable Energy (Kcal / lb)	{Calc}	900	932
Ash %	WetChem	22.19	22.96
Phosphorus (P) %	WetChem	0.24	0.25
Calcium (Ca) %	WetChem	0.84	0.87
Potassium (K) %	WetChem	4.26	4.41
Magnesium (Mg) %	WetChem	0.65	0.67
Sodium (Na) %	WetChem	3.55	3.67
Sulfur (S) %	WetChem	0.38	0.39
Chloride (Cl) %	WetChem	6.68	6.91
Salt Calculated from Chloride (NaCl) %	{Calc}	11.01	11.40
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	232.64	240.75
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	364.34	377.04
Copper (Cu) ppm	WetChem	9	10
Iron (Fe) ppm	WetChem	85	87
Zinc (Zn) ppm	WetChem	52	54
Manganese (Mn) ppm	WetChem	66	68

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,041		**Date Processed:**	05/06/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	**Date Received:**	05/03/16
Grower ID:	BGNDRF			
Sample ID:	N6 1.2 LD		**Cust#:**	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.39	0.00
DM (Dry Matter) %	WetChem	96.61	100.00
CP (Crude Protein) %	WetChem	20.99	21.73
ADF (Acid Detergent Fiber) %	WetChem	14.46	14.97
CF (Crude Fiber) %	{Calc}	11.57	11.97
Crude Carbohydrates %	{Calc}	40.75	42.18
Digestible Carbohydrates %	{Calc}	32.19	33.32
Fat %	Ether Ext.	1.51	1.56
Total Digestible Nutrients (TDN) %	{Calc}	55.28	57.22
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.56	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.53	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.25	0.25
Effective Net Energy (ENE) %	{Calc}	45.13	46.71
Digestible Energy DE (Mcal / lb)	{Calc}	1.11	1.14
Metabolizable Energy (Kcal / lb)	{Calc}	908	940
Ash %	WetChem	21.80	22.56
Phosphorus (P) %	WetChem	0.25	0.26
Calcium (Ca) %	WetChem	0.80	0.82
Potassium (K) %	WetChem	3.84	3.97
Magnesium (Mg) %	WetChem	0.61	0.63
Sodium (Na) %	WetChem	3.58	3.71
Sulfur (S) %	WetChem	0.36	0.37
Chloride (Cl) %	WetChem	6.35	6.57
Salt Calculated from Chloride (NaCl) %	{Calc}	10.47	10.84
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	239.28	247.67
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	362.07	374.77
Copper (Cu) ppm	WetChem	11	12
Iron (Fe) ppm	WetChem	81	83
Zinc (Zn) ppm	WetChem	51	53
Manganese (Mn) ppm	WetChem	81	84

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,042		***Date Processed:***	05/06/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/03/16
Grower ID:	BGNDRF			
Sample ID:	S3 1.2 LS		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	2.97	0.00
DM (Dry Matter) %	WetChem	97.03	100.00
CP (Crude Protein) %	WetChem	16.87	17.39
ADF (Acid Detergent Fiber) %	WetChem	16.12	16.61
CF (Crude Fiber) %	{Calc}	12.90	13.29
Crude Carbohydrates %	{Calc}	44.20	45.56
Digestible Carbohydrates %	{Calc}	34.92	35.99
Fat %	Ether Ext.	1.14	1.17
Total Digestible Nutrients (TDN) %	{Calc}	55.17	56.86
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.56	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.53	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.24	0.25
Effective Net Energy (ENE) %	{Calc}	44.97	46.35
Digestible Energy DE (Mcal / lb)	{Calc}	1.10	1.14
Metabolizable Energy (Kcal / lb)	{Calc}	906	934
Ash %	WetChem	21.92	22.59
Phosphorus (P) %	WetChem	0.21	0.21
Calcium (Ca) %	WetChem	0.97	1.00
Potassium (K) %	WetChem	3.77	3.89
Magnesium (Mg) %	WetChem	0.69	0.71
Sodium (Na) %	WetChem	3.54	3.65
Sulfur (S) %	WetChem	0.37	0.38
Chloride (Cl) %	WetChem	6.86	7.07
Salt Calculated from Chloride (NaCl) %	{Calc}	11.31	11.65
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	154.54	159.27
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	293.05	302.02
Copper (Cu) ppm	WetChem	8	8
Iron (Fe) ppm	WetChem	121	125
Zinc (Zn) ppm	WetChem	47	49
Manganese (Mn) ppm	WetChem	54	56

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,043 ***Date Processed:*** 05/06/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/03/16
Grower ID: BGNDRF
Sample ID: S3 1.2 LSB ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.75	0.00
DM (Dry Matter) %	WetChem	96.25	100.00
CP (Crude Protein) %	WetChem	17.22	17.89
ADF (Acid Detergent Fiber) %	WetChem	15.19	15.78
CF (Crude Fiber) %	{Calc}	12.15	12.63
Crude Carbohydrates %	{Calc}	43.57	45.27
Digestible Carbohydrates %	{Calc}	34.42	35.76
Fat %	Ether Ext.	1.18	1.22
Total Digestible Nutrients (TDN) %	{Calc}	54.60	56.73
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.56	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.52	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.24	0.25
Effective Net Energy (ENE) %	{Calc}	44.48	46.21
Digestible Energy DE (Mcal / lb)	{Calc}	1.09	1.13
Metabolizable Energy (Kcal / lb)	{Calc}	897	931
Ash %	WetChem	22.13	22.99
Phosphorus (P) %	WetChem	0.26	0.26
Calcium (Ca) %	WetChem	1.05	1.09
Potassium (K) %	WetChem	4.43	4.60
Magnesium (Mg) %	WetChem	0.74	0.77
Sodium (Na) %	WetChem	3.67	3.81
Sulfur (S) %	WetChem	0.36	0.37
Chloride (Cl) %	WetChem	6.85	7.12
Salt Calculated from Chloride (NaCl) %	{Calc}	11.29	11.73
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	261.13	271.31
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	398.98	414.53
Copper (Cu) ppm	WetChem	8	9
Iron (Fe) ppm	WetChem	119	124
Zinc (Zn) ppm	WetChem	53	55
Manganese (Mn) ppm	WetChem	61	64

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,044		***Date Processed:***	05/06/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/03/16
Grower ID:	BGNDRF			
Sample ID:	N2 0.8 L		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.05	0.00
DM (Dry Matter) %	WetChem	96.95	100.00
CP (Crude Protein) %	WetChem	18.80	19.39
ADF (Acid Detergent Fiber) %	WetChem	14.64	15.10
CF (Crude Fiber) %	{Calc}	11.71	12.08
Crude Carbohydrates %	{Calc}	42.61	43.95
Digestible Carbohydrates %	{Calc}	33.66	34.72
Fat %	Ether Ext.	0.94	0.97
Total Digestible Nutrients (TDN) %	{Calc}	54.37	56.08
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.55	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.52	0.54
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.23	0.23
Effective Net Energy (ENE) %	{Calc}	44.18	45.57
Digestible Energy DE (Mcal / lb)	{Calc}	1.09	1.12
Metabolizable Energy (Kcal / lb)	{Calc}	893	921
Ash %	WetChem	22.89	23.61
Phosphorus (P) %	WetChem	0.27	0.28
Calcium (Ca) %	WetChem	1.05	1.09
Potassium (K) %	WetChem	4.23	4.36
Magnesium (Mg) %	WetChem	0.68	0.70
Sodium (Na) %	WetChem	4.17	4.30
Sulfur (S) %	WetChem	0.37	0.38
Chloride (Cl) %	WetChem	7.02	7.24
Salt Calculated from Chloride (NaCl) %	{Calc}	11.57	11.94
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	311.46	321.26
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	447.46	461.54
Copper (Cu) ppm	WetChem	10	11
Iron (Fe) ppm	WetChem	120	123
Zinc (Zn) ppm	WetChem	70	72
Manganese (Mn) ppm	WetChem	73	76

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,045 ***Date Processed:*** 05/06/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/03/16
Grower ID: BGNDRF
Sample ID: N4 0.8 C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.40	0.00
DM (Dry Matter) %	WetChem	96.60	100.00
CP (Crude Protein) %	WetChem	13.74	14.22
ADF (Acid Detergent Fiber) %	WetChem	19.61	20.30
CF (Crude Fiber) %	{Calc}	15.69	16.24
Crude Carbohydrates %	{Calc}	51.57	53.38
Digestible Carbohydrates %	{Calc}	40.74	42.17
Fat %	Ether Ext.	1.44	1.49
Total Digestible Nutrients (TDN) %	{Calc}	60.63	62.76
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.62	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.61	0.64
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.33	0.34
Effective Net Energy (ENE) %	{Calc}	50.48	52.25
Digestible Energy DE (Mcal / lb)	{Calc}	1.21	1.26
Metabolizable Energy (Kcal / lb)	{Calc}	996	1,031
Ash %	WetChem	14.17	14.67
Phosphorus (P) %	WetChem	0.18	0.19
Calcium (Ca) %	WetChem	0.93	0.97
Potassium (K) %	WetChem	4.95	5.12
Magnesium (Mg) %	WetChem	0.60	0.62
Sodium (Na) %	WetChem	0.33	0.34
Sulfur (S) %	WetChem	0.51	0.53
Chloride (Cl) %	WetChem	1.94	2.01
Salt Calculated from Chloride (NaCl) %	{Calc}	3.20	3.31
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	246.91	255.60
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	413.89	428.46
Copper (Cu) ppm	WetChem	9	9
Iron (Fe) ppm	WetChem	139	144
Zinc (Zn) ppm	WetChem	81	83
Manganese (Mn) ppm	WetChem	92	95

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,046	**Date Processed:**	05/06/16
Sample Type:	*F67* Ruminant Feed > 10% CF	**Date Received:**	05/03/16
Grower ID:	BGNDRF		
Sample ID:	S5 0.8 L	**Cust#:**	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	2.80	0.00
DM (Dry Matter) %	WetChem	97.20	100.00
CP (Crude Protein) %	WetChem	14.77	15.20
ADF (Acid Detergent Fiber) %	WetChem	19.97	20.55
CF (Crude Fiber) %	{Calc}	15.98	16.44
Crude Carbohydrates %	{Calc}	43.86	45.13
Digestible Carbohydrates %	{Calc}	34.65	35.65
Fat %	Ether Ext.	1.10	1.13
Total Digestible Nutrients (TDN) %	{Calc}	54.88	56.47
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.56	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.53	0.54
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.23	0.24
Effective Net Energy (ENE) %	{Calc}	44.67	45.96
Digestible Energy DE (Mcal / lb)	{Calc}	1.10	1.13
Metabolizable Energy (Kcal / lb)	{Calc}	901	927
Ash %	WetChem	21.49	22.11
Phosphorus (P) %	WetChem	0.20	0.20
Calcium (Ca) %	WetChem	1.00	1.03
Potassium (K) %	WetChem	3.85	3.96
Magnesium (Mg) %	WetChem	0.69	0.71
Sodium (Na) %	WetChem	3.93	4.04
Sulfur (S) %	WetChem	0.34	0.35
Chloride (Cl) %	WetChem	6.48	6.67
Salt Calculated from Chloride (NaCl) %	{Calc}	10.68	10.99
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	295.97	304.50
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	430.79	443.20
Copper (Cu) ppm	WetChem	7	7
Iron (Fe) ppm	WetChem	171	176
Zinc (Zn) ppm	WetChem	50	52
Manganese (Mn) ppm	WetChem	44	46

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,047		***Date Processed:***	05/06/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/03/16
Grower ID:	BGNDRF			
Sample ID:	S4 0.8 C		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.65	0.00
DM (Dry Matter) %	WetChem	96.35	100.00
CP (Crude Protein) %	WetChem	13.89	14.42
ADF (Acid Detergent Fiber) %	WetChem	20.19	20.95
CF (Crude Fiber) %	{Calc}	16.15	16.76
Crude Carbohydrates %	{Calc}	51.08	53.02
Digestible Carbohydrates %	{Calc}	40.36	41.88
Fat %	Ether Ext.	0.88	0.91
Total Digestible Nutrients (TDN) %	{Calc}	59.69	61.95
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.61	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.60	0.62
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.32	0.33
Effective Net Energy (ENE) %	{Calc}	49.56	51.44
Digestible Energy DE (Mcal / lb)	{Calc}	1.19	1.24
Metabolizable Energy (Kcal / lb)	{Calc}	980	1,017
Ash %	WetChem	14.35	14.89
Phosphorus (P) %	WetChem	0.16	0.17
Calcium (Ca) %	WetChem	1.07	1.11
Potassium (K) %	WetChem	3.94	4.09
Magnesium (Mg) %	WetChem	0.56	0.59
Sodium (Na) %	WetChem	0.93	0.97
Sulfur (S) %	WetChem	0.50	0.52
Chloride (Cl) %	WetChem	2.77	2.87
Salt Calculated from Chloride (NaCl) %	{Calc}	4.57	4.74
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	146.53	152.08
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	314.24	326.15
Copper (Cu) ppm	WetChem	8	8
Iron (Fe) ppm	WetChem	161	167
Zinc (Zn) ppm	WetChem	41	42
Manganese (Mn) ppm	WetChem	71	74

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,048 | **Date Processed:** 05/06/16
Sample Type: *F67* Ruminant Feed > 10% CF | **Date Received:** 05/03/16
Grower ID: BGNDRF
Sample ID: N5 0.4 L | **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.75	0.00
DM (Dry Matter) %	WetChem	96.25	100.00
CP (Crude Protein) %	WetChem	17.11	17.78
ADF (Acid Detergent Fiber) %	WetChem	16.26	16.89
CF (Crude Fiber) %	{Calc}	13.01	13.51
Crude Carbohydrates %	{Calc}	43.32	45.00
Digestible Carbohydrates %	{Calc}	34.22	35.55
Fat %	Ether Ext.	1.40	1.45
Total Digestible Nutrients (TDN) %	{Calc}	55.10	57.25
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.56	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.53	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.24	0.25
Effective Net Energy (ENE) %	{Calc}	44.98	46.73
Digestible Energy DE (Mcal / lb)	{Calc}	1.10	1.14
Metabolizable Energy (Kcal / lb)	{Calc}	905	940
Ash %	WetChem	21.42	22.25
Phosphorus (P) %	WetChem	0.27	0.28
Calcium (Ca) %	WetChem	0.81	0.84
Potassium (K) %	WetChem	3.89	4.04
Magnesium (Mg) %	WetChem	0.67	0.69
Sodium (Na) %	WetChem	4.30	4.46
Sulfur (S) %	WetChem	0.37	0.38
Chloride (Cl) %	WetChem	6.66	6.92
Salt Calculated from Chloride (NaCl) %	{Calc}	10.98	11.41
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	342.80	356.16
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	470.53	488.87
Copper (Cu) ppm	WetChem	7	7
Iron (Fe) ppm	WetChem	142	147
Zinc (Zn) ppm	WetChem	86	89
Manganese (Mn) ppm	WetChem	49	51

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,049		***Date Processed:***	05/06/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/03/16
Grower ID:	BGNDRF			
Sample ID:	S1 0.4 L		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.65	0.00
DM (Dry Matter) %	WetChem	96.35	100.00
CP (Crude Protein) %	WetChem	18.38	19.08
ADF (Acid Detergent Fiber) %	WetChem	15.73	16.33
CF (Crude Fiber) %	{Calc}	12.58	13.06
Crude Carbohydrates %	{Calc}	41.83	43.42
Digestible Carbohydrates %	{Calc}	33.05	34.30
Fat %	Ether Ext.	1.58	1.63
Total Digestible Nutrients (TDN) %	{Calc}	54.90	56.98
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.56	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.53	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.24	0.25
Effective Net Energy (ENE) %	{Calc}	44.77	46.47
Digestible Energy DE (Mcal / lb)	{Calc}	1.10	1.14
Metabolizable Energy (Kcal / lb)	{Calc}	902	936
Ash %	WetChem	21.98	22.81
Phosphorus (P) %	WetChem	0.21	0.22
Calcium (Ca) %	WetChem	1.06	1.10
Potassium (K) %	WetChem	3.97	4.12
Magnesium (Mg) %	WetChem	0.75	0.77
Sodium (Na) %	WetChem	3.79	3.93
Sulfur (S) %	WetChem	0.33	0.34
Chloride (Cl) %	WetChem	6.01	6.24
Salt Calculated from Chloride (NaCl) %	{Calc}	9.91	10.28
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	346.72	359.86
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	482.67	500.95
Copper (Cu) ppm	WetChem	8	8
Iron (Fe) ppm	WetChem	170	176
Zinc (Zn) ppm	WetChem	71	73
Manganese (Mn) ppm	WetChem	61	63

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,050 ***Date Processed:*** 05/06/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/03/16
Grower ID: BGNDRF
Sample ID: S2 0.4 C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.60	0.00
DM (Dry Matter) %	WetChem	96.40	100.00
CP (Crude Protein) %	WetChem	11.57	12.00
ADF (Acid Detergent Fiber) %	WetChem	20.94	21.72
CF (Crude Fiber) %	{Calc}	16.75	17.38
Crude Carbohydrates %	{Calc}	51.49	53.41
Digestible Carbohydrates %	{Calc}	40.68	42.19
Fat %	Ether Ext.	1.47	1.52
Total Digestible Nutrients (TDN) %	{Calc}	59.61	61.84
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.61	0.63
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.60	0.62
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.32	0.33
Effective Net Energy (ENE) %	{Calc}	49.48	51.33
Digestible Energy DE (Mcal / lb)	{Calc}	1.19	1.24
Metabolizable Energy (Kcal / lb)	{Calc}	979	1,015
Ash %	WetChem	15.12	15.68
Phosphorus (P) %	WetChem	0.13	0.13
Calcium (Ca) %	WetChem	1.10	1.14
Potassium (K) %	WetChem	4.33	4.49
Magnesium (Mg) %	WetChem	0.70	0.72
Sodium (Na) %	WetChem	1.03	1.07
Sulfur (S) %	WetChem	0.50	0.51
Chloride (Cl) %	WetChem	2.80	2.90
Salt Calculated from Chloride (NaCl) %	{Calc}	4.62	4.79
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	207.21	214.94
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	386.02	400.43
Copper (Cu) ppm	WetChem	6	6
Iron (Fe) ppm	WetChem	179	186
Zinc (Zn) ppm	WetChem	38	39
Manganese (Mn) ppm	WetChem	92	95

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,051 | **Date Processed:** 05/06/16
Sample Type: *F67* Ruminant Feed > 10% CF | **Date Received:** 05/03/16
Grower ID: BGNDRF
Sample ID: S6 0.4 C | **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.70	0.00
DM (Dry Matter) %	WetChem	96.30	100.00
CP (Crude Protein) %	WetChem	12.33	12.80
ADF (Acid Detergent Fiber) %	WetChem	20.34	21.12
CF (Crude Fiber) %	{Calc}	16.27	16.90
Crude Carbohydrates %	{Calc}	51.86	53.85
Digestible Carbohydrates %	{Calc}	40.97	42.54
Fat %	Ether Ext.	1.42	1.47
Total Digestible Nutrients (TDN) %	{Calc}	60.13	62.44
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.62	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.61	0.63
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.32	0.34
Effective Net Energy (ENE) %	{Calc}	50.00	51.92
Digestible Energy DE (Mcal / lb)	{Calc}	1.20	1.25
Metabolizable Energy (Kcal / lb)	{Calc}	987	1,025
Ash %	WetChem	14.42	14.97
Phosphorus (P) %	WetChem	0.13	0.13
Calcium (Ca) %	WetChem	0.86	0.90
Potassium (K) %	WetChem	4.66	4.84
Magnesium (Mg) %	WetChem	0.60	0.62
Sodium (Na) %	WetChem	0.50	0.52
Sulfur (S) %	WetChem	0.49	0.51
Chloride (Cl) %	WetChem	2.35	2.44
Salt Calculated from Chloride (NaCl) %	{Calc}	3.87	4.02
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	200.47	208.18
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	363.59	377.56
Copper (Cu) ppm	WetChem	7	7
Iron (Fe) ppm	WetChem	151	157
Zinc (Zn) ppm	WetChem	33	34
Manganese (Mn) ppm	WetChem	68	71

Litchfield Analytical Services
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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,052 ***Date Processed:*** 05/06/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/03/16
Grower ID: BGNDRF
Sample ID: EBL ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.00	0.00
DM (Dry Matter) %	WetChem	97.00	100.00
CP (Crude Protein) %	WetChem	17.11	17.64
ADF (Acid Detergent Fiber) %	WetChem	18.37	18.94
CF (Crude Fiber) %	{Calc}	14.70	15.15
Crude Carbohydrates %	{Calc}	42.97	44.30
Digestible Carbohydrates %	{Calc}	33.95	35.00
Fat %	Ether Ext.	1.32	1.36
Total Digestible Nutrients (TDN) %	{Calc}	55.55	57.27
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.57	0.58
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.54	0.55
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.25	0.25
Effective Net Energy (ENE) %	{Calc}	45.36	46.76
Digestible Energy DE (Mcal / lb)	{Calc}	1.11	1.15
Metabolizable Energy (Kcal / lb)	{Calc}	912	940
Ash %	WetChem	20.90	21.55
Phosphorus (P) %	WetChem	0.24	0.24
Calcium (Ca) %	WetChem	1.00	1.03
Potassium (K) %	WetChem	4.09	4.21
Magnesium (Mg) %	WetChem	0.64	0.66
Sodium (Na) %	WetChem	3.68	3.80
Sulfur (S) %	WetChem	0.32	0.33
Chloride (Cl) %	WetChem	7.34	7.57
Salt Calculated from Chloride (NaCl) %	{Calc}	12.10	12.47
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	171.58	176.89
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	294.96	304.08
Copper (Cu) ppm	WetChem	9	9
Iron (Fe) ppm	WetChem	78	81
Zinc (Zn) ppm	WetChem	54	56
Manganese (Mn) ppm	WetChem	48	49

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,053 **Date Processed:** 05/06/16
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 05/03/16
Grower ID: BGNDRF
Sample ID: CONT L **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.45	0.00
DM (Dry Matter) %	WetChem	96.55	100.00
CP (Crude Protein) %	WetChem	16.51	17.10
ADF (Acid Detergent Fiber) %	WetChem	17.38	18.00
CF (Crude Fiber) %	{Calc}	13.90	14.40
Crude Carbohydrates %	{Calc}	42.18	43.69
Digestible Carbohydrates %	{Calc}	33.32	34.51
Fat %	Ether Ext.	1.39	1.43
Total Digestible Nutrients (TDN) %	{Calc}	54.21	56.15
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.55	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.52	0.54
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.23	0.24
Effective Net Energy (ENE) %	{Calc}	44.06	45.63
Digestible Energy DE (Mcal / lb)	{Calc}	1.08	1.12
Metabolizable Energy (Kcal / lb)	{Calc}	890	922
Ash %	WetChem	22.57	23.38
Phosphorus (P) %	WetChem	0.22	0.22
Calcium (Ca) %	WetChem	1.10	1.14
Potassium (K) %	WetChem	4.05	4.19
Magnesium (Mg) %	WetChem	0.81	0.84
Sodium (Na) %	WetChem	4.03	4.17
Sulfur (S) %	WetChem	0.33	0.34
Chloride (Cl) %	WetChem	7.36	7.62
Salt Calculated from Chloride (NaCl) %	{Calc}	12.13	12.57
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	228.53	236.70
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	369.70	382.91
Copper (Cu) ppm	WetChem	9	9
Iron (Fe) ppm	WetChem	150	155
Zinc (Zn) ppm	WetChem	55	57
Manganese (Mn) ppm	WetChem	55	57

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,054	**Date Processed:**	05/06/16
Sample Type:	F67 Ruminant Feed > 10% CF	**Date Received:**	05/03/16
Grower ID:	BGNDRF		
Sample ID:	NAT BGNDRF	**Cust#:**	A928

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Proximate Feed Analysis Report	Method	As Received	Dry Basis
Moisture %	{Calc}	3.35	0.00
DM (Dry Matter) %	WetChem	96.65	100.00
CP (Crude Protein) %	WetChem	12.29	12.72
ADF (Acid Detergent Fiber) %	WetChem	24.64	25.49
CF (Crude Fiber) %	{Calc}	19.71	20.40
Crude Carbohydrates %	{Calc}	46.70	48.32
Digestible Carbohydrates %	{Calc}	36.89	38.17
Fat %	Ether Ext.	1.23	1.27
Total Digestible Nutrients (TDN) %	{Calc}	57.44	59.43
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.59	0.61
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.57	0.59
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.28	0.29
Effective Net Energy (ENE) %	{Calc}	47.28	48.92
Digestible Energy DE (Mcal / lb)	{Calc}	1.15	1.19
Metabolizable Energy (Kcal / lb)	{Calc}	943	976
Ash %	WetChem	16.72	17.30
Phosphorus (P) %	WetChem	0.13	0.13
Calcium (Ca) %	WetChem	1.59	1.64
Potassium (K) %	WetChem	2.37	2.45
Magnesium (Mg) %	WetChem	0.69	0.71
Sodium (Na) %	WetChem	2.40	2.49
Sulfur (S) %	WetChem	0.52	0.53
Chloride (Cl) %	WetChem	3.57	3.69
Salt Calculated from Chloride (NaCl) %	{Calc}	5.88	6.09
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	146.05	151.11
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	345.34	357.31
Copper (Cu) ppm	WetChem	3	3
Iron (Fe) ppm	WetChem	220	227
Zinc (Zn) ppm	WetChem	38	40
Manganese (Mn) ppm	WetChem	91	94

BGNDRF Alamogordo
May 2016 Plant Sample
5/17/2016 Collection Date
ARTIOLA, DAVIS and GALLAHER

Litchfield Label	Sample	Wet Weight	Bag Weight	Wet Weight - Bag Weight	Dry Weight + Bag Weight	Dry Weight- Bag Weight	Wet Weight- Dry Weight	% change	Notes
75592	S1 0.4 L	180	7	173	58	51	122	70.5	
75593	S3 1.2 L	194	7	187	58	51	136	72.7	
75594	S5 0.8 L	209	7	202	66	59	143	70.8	
75595	S2 0.4 C	137	7	130	64	57	73	56.2	
75596	S4 0.8 C	161	7	154	73	66	88	57.1	
75597	S6 0.4 C	151	7	144	69	62	82	56.9	
75598	N1 1.2 C	152	7	145	59	52	93	64.1	
75599	N3 1.2 C	138	7	131	60	53	78	59.5	
75600	N4 0.8 C	154	7	147	70	63	84	57.1	
75601	N2 0.8 L	166	7	159	53	46	113	71.1	
75602	N5 0.4 L	172	7	165	59	52	113	68.5	
75603	N6 1.2 L	169	7	162	54	47	115	71.0	
75604	CONT C	115	7	108	47	40	68	63.0	Control plant, Atriplex canescens
75605	NAT HOW	100	7	93	77	70	23	24.7	Native Atriplex canescens from Howland Ranch

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,592 **Date Processed:** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 05/31/16
Grower ID: BGNDRF
Sample ID: S1 0.4 L **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.25	0.00
DM (Dry Matter) %	WetChem	95.75	100.00
CP (Crude Protein) %	WetChem	14.97	15.63
ADF (Acid Detergent Fiber) %	WetChem	20.43	21.34
CF (Crude Fiber) %	{Calc}	16.34	17.07
Crude Carbohydrates %	{Calc}	44.26	46.23
Digestible Carbohydrates %	{Calc}	34.97	36.52
Fat %	Ether Ext.	1.12	1.16
Total Digestible Nutrients (TDN) %	{Calc}	55.55	58.01
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.57	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.54	0.57
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.26	0.27
Effective Net Energy (ENE) %	{Calc}	45.48	47.49
Digestible Energy DE (Mcal / lb)	{Calc}	1.11	1.16
Metabolizable Energy (Kcal / lb)	{Calc}	912	953
Ash %	WetChem	19.06	19.91
Phosphorus (P) %	WetChem	0.19	0.20
Calcium (Ca) %	WetChem	1.07	1.11
Potassium (K) %	WetChem	3.54	3.70
Magnesium (Mg) %	WetChem	0.65	0.68
Sodium (Na) %	WetChem	3.39	3.54
Sulfur (S) %	WetChem	0.30	0.31
Chloride (Cl) %	WetChem	6.40	6.68
Salt Calculated from Chloride (NaCl) %	{Calc}	10.55	11.02
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	175.72	183.52
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	301.86	315.26
Copper (Cu) ppm	WetChem	9	10
Iron (Fe) ppm	WetChem	118	123
Zinc (Zn) ppm	WetChem	49	51
Manganese (Mn) ppm	WetChem	31	32

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,592 ***Date Processed:*** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/31/16
Grower ID: BGNDRF
Sample ID: S1 0.4 L ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.25	0.00
DM (Dry Matter) %	WetChem	95.75	100.00
CP (Crude Protein) %	WetChem	14.97	15.63
ADF (Acid Detergent Fiber) %	WetChem	20.43	21.34
CF (Crude Fiber) %	{Calc}	16.34	17.07
Crude Carbohydrates %	{Calc}	44.26	46.23
Digestible Carbohydrates %	{Calc}	34.97	36.52
Fat %	Ether Ext.	1.12	1.16
Total Digestible Nutrients (TDN) %	{Calc}	55.55	58.01
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.57	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.54	0.57
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.26	0.27
Effective Net Energy (ENE) %	{Calc}	45.48	47.49
Digestible Energy DE (Mcal / lb)	{Calc}	1.11	1.16
Metabolizable Energy (Kcal / lb)	{Calc}	912	953
Ash %	WetChem	19.06	19.91
Phosphorus (P) %	WetChem	0.19	0.20
Calcium (Ca) %	WetChem	1.07	1.11
Potassium (K) %	WetChem	3.54	3.70
Magnesium (Mg) %	WetChem	0.65	0.68
Sodium (Na) %	WetChem	3.39	3.54
Sulfur (S) %	WetChem	0.30	0.31
Chloride (Cl) %	WetChem	6.40	6.68
Salt Calculated from Chloride (NaCl) %	{Calc}	10.55	11.02
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	175.72	183.52
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	301.86	315.26
Copper (Cu) ppm	WetChem	9	10
Iron (Fe) ppm	WetChem	118	123
Zinc (Zn) ppm	WetChem	49	51
Manganese (Mn) ppm	WetChem	31	32

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,593 **Date Processed:** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 05/31/16
Grower ID: BGNDRF
Sample ID: S3 1.2 L **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.45	0.00
DM (Dry Matter) %	WetChem	95.55	100.00
CP (Crude Protein) %	WetChem	14.73	15.42
ADF (Acid Detergent Fiber) %	WetChem	20.62	21.58
CF (Crude Fiber) %	{Calc}	16.50	17.26
Crude Carbohydrates %	{Calc}	44.32	46.39
Digestible Carbohydrates %	{Calc}	35.02	36.65
Fat %	Ether Ext.	1.10	1.15
Total Digestible Nutrients (TDN) %	{Calc}	55.48	58.06
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.57	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.54	0.57
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.26	0.27
Effective Net Energy (ENE) %	{Calc}	45.43	47.54
Digestible Energy DE (Mcal / lb)	{Calc}	1.11	1.16
Metabolizable Energy (Kcal / lb)	{Calc}	911	953
Ash %	WetChem	18.90	19.78
Phosphorus (P) %	WetChem	0.24	0.25
Calcium (Ca) %	WetChem	1.18	1.24
Potassium (K) %	WetChem	1.05	1.09
Magnesium (Mg) %	WetChem	0.75	0.79
Sodium (Na) %	WetChem	3.26	3.41
Sulfur (S) %	WetChem	0.30	0.32
Chloride (Cl) %	WetChem	6.49	6.79
Salt Calculated from Chloride (NaCl) %	{Calc}	10.70	11.20
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-151.55	-158.60
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	-19.53	-20.44
Copper (Cu) ppm	WetChem	8	9
Iron (Fe) ppm	WetChem	109	114
Zinc (Zn) ppm	WetChem	39	41
Manganese (Mn) ppm	WetChem	45	47

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,593 ***Date Processed:*** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/31/16
Grower ID: BGNDRF
Sample ID: S3 1.2 L ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.45	0.00
DM (Dry Matter) %	WetChem	95.55	100.00
CP (Crude Protein) %	WetChem	14.73	15.42
ADF (Acid Detergent Fiber) %	WetChem	20.62	21.58
CF (Crude Fiber) %	{Calc}	16.50	17.26
Crude Carbohydrates %	{Calc}	44.32	46.39
Digestible Carbohydrates %	{Calc}	35.02	36.65
Fat %	Ether Ext.	1.10	1.15
Total Digestible Nutrients (TDN) %	{Calc}	55.48	58.06
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.57	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.54	0.57
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.26	0.27
Effective Net Energy (ENE) %	{Calc}	45.43	47.54
Digestible Energy DE (Mcal / lb)	{Calc}	1.11	1.16
Metabolizable Energy (Kcal / lb)	{Calc}	911	953
Ash %	WetChem	18.90	19.78
Phosphorus (P) %	WetChem	0.24	0.25
Calcium (Ca) %	WetChem	1.18	1.24
Potassium (K) %	WetChem	1.05	1.09
Magnesium (Mg) %	WetChem	0.75	0.79
Sodium (Na) %	WetChem	3.26	3.41
Sulfur (S) %	WetChem	0.30	0.32
Chloride (Cl) %	WetChem	6.49	6.79
Salt Calculated from Chloride (NaCl) %	{Calc}	10.70	11.20
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	-151.55	-158.60
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	-19.53	-20.44
Copper (Cu) ppm	WetChem	8	9
Iron (Fe) ppm	WetChem	109	114
Zinc (Zn) ppm	WetChem	39	41
Manganese (Mn) ppm	WetChem	45	47

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,594		***Date Processed:***	06/01/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF			
Sample ID:	S5 0.8 L		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.05	0.00
DM (Dry Matter) %	WetChem	95.95	100.00
CP (Crude Protein) %	WetChem	16.06	16.74
ADF (Acid Detergent Fiber) %	WetChem	21.70	22.62
CF (Crude Fiber) %	{Calc}	17.36	18.09
Crude Carbohydrates %	{Calc}	40.81	42.53
Digestible Carbohydrates %	{Calc}	32.24	33.60
Fat %	Ether Ext.	1.13	1.17
Total Digestible Nutrients (TDN) %	{Calc}	54.12	56.40
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.55	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.52	0.54
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.23	0.24
Effective Net Energy (ENE) %	{Calc}	44.02	45.88
Digestible Energy DE (Mcal / lb)	{Calc}	1.08	1.13
Metabolizable Energy (Kcal / lb)	{Calc}	889	926
Ash %	WetChem	20.60	21.47
Phosphorus (P) %	WetChem	0.22	0.23
Calcium (Ca) %	WetChem	1.08	1.13
Potassium (K) %	WetChem	4.05	4.23
Magnesium (Mg) %	WetChem	0.84	0.87
Sodium (Na) %	WetChem	4.16	4.33
Sulfur (S) %	WetChem	0.31	0.33
Chloride (Cl) %	WetChem	7.13	7.43
Salt Calculated from Chloride (NaCl) %	{Calc}	11.75	12.25
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	290.80	303.08
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	427.93	445.99
Copper (Cu) ppm	WetChem	10	10
Iron (Fe) ppm	WetChem	135	141
Zinc (Zn) ppm	WetChem	44	45
Manganese (Mn) ppm	WetChem	49	51

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,594
Sample Type: *F67* Ruminant Feed > 10% CF
Grower ID: BGNDRF
Sample ID: S5 0.8 L

Date Processed: 06/01/16
Date Received: 05/31/16
Cust#: A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.05	0.00
DM (Dry Matter) %	WetChem	95.95	100.00
CP (Crude Protein) %	WetChem	16.06	16.74
ADF (Acid Detergent Fiber) %	WetChem	21.70	22.62
CF (Crude Fiber) %	{Calc}	17.36	18.09
Crude Carbohydrates %	{Calc}	40.81	42.53
Digestible Carbohydrates %	{Calc}	32.24	33.60
Fat %	Ether Ext.	1.13	1.17
Total Digestible Nutrients (TDN) %	{Calc}	54.12	56.40
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.55	0.57
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.52	0.54
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.23	0.24
Effective Net Energy (ENE) %	{Calc}	44.02	45.88
Digestible Energy DE (Mcal / lb)	{Calc}	1.08	1.13
Metabolizable Energy (Kcal / lb)	{Calc}	889	926
Ash %	WetChem	20.60	21.47
Phosphorus (P) %	WetChem	0.22	0.23
Calcium (Ca) %	WetChem	1.08	1.13
Potassium (K) %	WetChem	4.05	4.23
Magnesium (Mg) %	WetChem	0.84	0.87
Sodium (Na) %	WetChem	4.16	4.33
Sulfur (S) %	WetChem	0.31	0.33
Chloride (Cl) %	WetChem	7.13	7.43
Salt Calculated from Chloride (NaCl) %	{Calc}	11.75	12.25
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	290.80	303.08
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	427.93	445.99
Copper (Cu) ppm	WetChem	10	10
Iron (Fe) ppm	WetChem	135	141
Zinc (Zn) ppm	WetChem	44	45
Manganese (Mn) ppm	WetChem	49	51

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,595 ***Date Processed:*** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/31/16
Grower ID: BGNDRF
Sample ID: S2 0.4 C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.05	0.00
DM (Dry Matter) %	WetChem	95.95	100.00
CP (Crude Protein) %	WetChem	11.68	12.17
ADF (Acid Detergent Fiber) %	WetChem	22.32	23.26
CF (Crude Fiber) %	{Calc}	17.86	18.61
Crude Carbohydrates %	{Calc}	51.63	53.81
Digestible Carbohydrates %	{Calc}	40.79	42.51
Fat %	Ether Ext.	1.37	1.43
Total Digestible Nutrients (TDN) %	{Calc}	60.20	62.74
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.62	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.61	0.64
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.33	0.34
Effective Net Energy (ENE) %	{Calc}	50.11	52.22
Digestible Energy DE (Mcal / lb)	{Calc}	1.20	1.25
Metabolizable Energy (Kcal / lb)	{Calc}	988	1,030
Ash %	WetChem	13.41	13.98
Phosphorus (P) %	WetChem	0.13	0.13
Calcium (Ca) %	WetChem	1.13	1.18
Potassium (K) %	WetChem	4.50	4.69
Magnesium (Mg) %	WetChem	0.63	0.66
Sodium (Na) %	WetChem	0.52	0.54
Sulfur (S) %	WetChem	0.45	0.47
Chloride (Cl) %	WetChem	2.26	2.36
Salt Calculated from Chloride (NaCl) %	{Calc}	3.73	3.88
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	207.12	215.86
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	374.27	390.07
Copper (Cu) ppm	WetChem	7	8
Iron (Fe) ppm	WetChem	184	192
Zinc (Zn) ppm	WetChem	31	32
Manganese (Mn) ppm	WetChem	55	58

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,595		***Date Processed:***	06/01/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF			
Sample ID:	S2 0.4 C		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.05	0.00
DM (Dry Matter) %	WetChem	95.95	100.00
CP (Crude Protein) %	WetChem	11.68	12.17
ADF (Acid Detergent Fiber) %	WetChem	22.32	23.26
CF (Crude Fiber) %	{Calc}	17.86	18.61
Crude Carbohydrates %	{Calc}	51.63	53.81
Digestible Carbohydrates %	{Calc}	40.79	42.51
Fat %	Ether Ext.	1.37	1.43
Total Digestible Nutrients (TDN) %	{Calc}	60.20	62.74
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.62	0.64
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.61	0.64
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.33	0.34
Effective Net Energy (ENE) %	{Calc}	50.11	52.22
Digestible Energy DE (Mcal / lb)	{Calc}	1.20	1.25
Metabolizable Energy (Kcal / lb)	{Calc}	988	1,030
Ash %	WetChem	13.41	13.98
Phosphorus (P) %	WetChem	0.13	0.13
Calcium (Ca) %	WetChem	1.13	1.18
Potassium (K) %	WetChem	4.50	4.69
Magnesium (Mg) %	WetChem	0.63	0.66
Sodium (Na) %	WetChem	0.52	0.54
Sulfur (S) %	WetChem	0.45	0.47
Chloride (Cl) %	WetChem	2.26	2.36
Salt Calculated from Chloride (NaCl) %	{Calc}	3.73	3.88
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	207.12	215.86
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	374.27	390.07
Copper (Cu) ppm	WetChem	7	8
Iron (Fe) ppm	WetChem	184	192
Zinc (Zn) ppm	WetChem	31	32
Manganese (Mn) ppm	WetChem	55	58

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,596 **Date Processed:** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 05/31/16
Grower ID: BGNDRF
Sample ID: S4 0.8 C **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.00	0.00
DM (Dry Matter) %	WetChem	96.00	100.00
CP (Crude Protein) %	WetChem	11.42	11.90
ADF (Acid Detergent Fiber) %	WetChem	23.96	24.96
CF (Crude Fiber) %	{Calc}	19.17	19.97
Crude Carbohydrates %	{Calc}	52.96	55.17
Digestible Carbohydrates %	{Calc}	41.84	43.58
Fat %	Ether Ext.	1.05	1.09
Total Digestible Nutrients (TDN) %	{Calc}	61.21	63.76
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.63	0.65
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.34	0.36
Effective Net Energy (ENE) %	{Calc}	51.11	53.24
Digestible Energy DE (Mcal / lb)	{Calc}	1.22	1.28
Metabolizable Energy (Kcal / lb)	{Calc}	1,005	1,047
Ash %	WetChem	11.40	11.88
Phosphorus (P) %	WetChem	0.15	0.16
Calcium (Ca) %	WetChem	1.03	1.07
Potassium (K) %	WetChem	4.05	4.22
Magnesium (Mg) %	WetChem	0.48	0.50
Sodium (Na) %	WetChem	0.34	0.35
Sulfur (S) %	WetChem	0.45	0.46
Chloride (Cl) %	WetChem	2.24	2.33
Salt Calculated from Chloride (NaCl) %	{Calc}	3.69	3.85
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	124.04	129.20
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	275.25	286.72
Copper (Cu) ppm	WetChem	9	10
Iron (Fe) ppm	WetChem	150	156
Zinc (Zn) ppm	WetChem	29	30
Manganese (Mn) ppm	WetChem	55	58

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,596
Sample Type: *F67* Ruminant Feed > 10% CF
Grower ID: BGNDRF
Sample ID: S4 0.8 C

Date Processed: 06/01/16
Date Received: 05/31/16
Cust#: A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.00	0.00
DM (Dry Matter) %	WetChem	96.00	100.00
CP (Crude Protein) %	WetChem	11.42	11.90
ADF (Acid Detergent Fiber) %	WetChem	23.96	24.96
CF (Crude Fiber) %	{Calc}	19.17	19.97
Crude Carbohydrates %	{Calc}	52.96	55.17
Digestible Carbohydrates %	{Calc}	41.84	43.58
Fat %	Ether Ext.	1.05	1.09
Total Digestible Nutrients (TDN) %	{Calc}	61.21	63.76
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.63	0.65
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.34	0.36
Effective Net Energy (ENE) %	{Calc}	51.11	53.24
Digestible Energy DE (Mcal / lb)	{Calc}	1.22	1.28
Metabolizable Energy (Kcal / lb)	{Calc}	1,005	1,047
Ash %	WetChem	11.40	11.88
Phosphorus (P) %	WetChem	0.15	0.16
Calcium (Ca) %	WetChem	1.03	1.07
Potassium (K) %	WetChem	4.05	4.22
Magnesium (Mg) %	WetChem	0.48	0.50
Sodium (Na) %	WetChem	0.34	0.35
Sulfur (S) %	WetChem	0.45	0.46
Chloride (Cl) %	WetChem	2.24	2.33
Salt Calculated from Chloride (NaCl) %	{Calc}	3.69	3.85
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	124.04	129.20
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	275.25	286.72
Copper (Cu) ppm	WetChem	9	10
Iron (Fe) ppm	WetChem	150	156
Zinc (Zn) ppm	WetChem	29	30
Manganese (Mn) ppm	WetChem	55	58

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,597	***Date Processed:***	06/01/16
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF		
Sample ID:	S6 0.4 C	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.80	0.00
DM (Dry Matter) %	WetChem	96.20	100.00
CP (Crude Protein) %	WetChem	11.38	11.83
ADF (Acid Detergent Fiber) %	WetChem	21.83	22.69
CF (Crude Fiber) %	{Calc}	17.46	18.15
Crude Carbohydrates %	{Calc}	54.23	56.37
Digestible Carbohydrates %	{Calc}	42.84	44.53
Fat %	Ether Ext.	1.10	1.14
Total Digestible Nutrients (TDN) %	{Calc}	61.41	63.83
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.63	0.65
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.34	0.36
Effective Net Energy (ENE) %	{Calc}	51.29	53.32
Digestible Energy DE (Mcal / lb)	{Calc}	1.23	1.28
Metabolizable Energy (Kcal / lb)	{Calc}	1,008	1,048
Ash %	WetChem	12.03	12.51
Phosphorus (P) %	WetChem	0.13	0.13
Calcium (Ca) %	WetChem	0.71	0.74
Potassium (K) %	WetChem	4.15	4.31
Magnesium (Mg) %	WetChem	0.43	0.45
Sodium (Na) %	WetChem	0.21	0.21
Sulfur (S) %	WetChem	0.47	0.49
Chloride (Cl) %	WetChem	2.54	2.64
Salt Calculated from Chloride (NaCl) %	{Calc}	4.19	4.35
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	63.55	66.06
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	208.79	217.04
Copper (Cu) ppm	WetChem	7	7
Iron (Fe) ppm	WetChem	177	184
Zinc (Zn) ppm	WetChem	24	24
Manganese (Mn) ppm	WetChem	49	51

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,597		***Date Processed:***	06/01/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF			
Sample ID:	S6 0.4 C		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.80	0.00
DM (Dry Matter) %	WetChem	96.20	100.00
CP (Crude Protein) %	WetChem	11.38	11.83
ADF (Acid Detergent Fiber) %	WetChem	21.83	22.69
CF (Crude Fiber) %	{Calc}	17.46	18.15
Crude Carbohydrates %	{Calc}	54.23	56.37
Digestible Carbohydrates %	{Calc}	42.84	44.53
Fat %	Ether Ext.	1.10	1.14
Total Digestible Nutrients (TDN) %	{Calc}	61.41	63.83
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.63	0.65
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.34	0.36
Effective Net Energy (ENE) %	{Calc}	51.29	53.32
Digestible Energy DE (Mcal / lb)	{Calc}	1.23	1.28
Metabolizable Energy (Kcal / lb)	{Calc}	1,008	1,048
Ash %	WetChem	12.03	12.51
Phosphorus (P) %	WetChem	0.13	0.13
Calcium (Ca) %	WetChem	0.71	0.74
Potassium (K) %	WetChem	4.15	4.31
Magnesium (Mg) %	WetChem	0.43	0.45
Sodium (Na) %	WetChem	0.21	0.21
Sulfur (S) %	WetChem	0.47	0.49
Chloride (Cl) %	WetChem	2.54	2.64
Salt Calculated from Chloride (NaCl) %	{Calc}	4.19	4.35
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	63.55	66.06
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	208.79	217.04
Copper (Cu) ppm	WetChem	7	7
Iron (Fe) ppm	WetChem	177	184
Zinc (Zn) ppm	WetChem	24	24
Manganese (Mn) ppm	WetChem	49	51

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,598 **Date Processed:** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF **Date Received:** 05/31/16
Grower ID: BGNDRF
Sample ID: N1 1.2 C **Cust#:** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.40	0.00
DM (Dry Matter) %	WetChem	95.60	100.00
CP (Crude Protein) %	WetChem	14.44	15.10
ADF (Acid Detergent Fiber) %	WetChem	22.90	23.95
CF (Crude Fiber) %	{Calc}	18.32	19.16
Crude Carbohydrates %	{Calc}	47.60	49.79
Digestible Carbohydrates %	{Calc}	37.60	39.33
Fat %	Ether Ext.	0.95	0.99
Total Digestible Nutrients (TDN) %	{Calc}	58.53	61.23
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.60	0.63
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.59	0.61
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.30	0.32
Effective Net Energy (ENE) %	{Calc}	48.48	50.71
Digestible Energy DE (Mcal / lb)	{Calc}	1.17	1.22
Metabolizable Energy (Kcal / lb)	{Calc}	961	1,005
Ash %	WetChem	14.29	14.95
Phosphorus (P) %	WetChem	0.19	0.19
Calcium (Ca) %	WetChem	1.16	1.21
Potassium (K) %	WetChem	4.43	4.64
Magnesium (Mg) %	WetChem	0.48	0.50
Sodium (Na) %	WetChem	0.87	0.91
Sulfur (S) %	WetChem	0.82	0.86
Chloride (Cl) %	WetChem	2.97	3.11
Salt Calculated from Chloride (NaCl) %	{Calc}	4.90	5.12
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	73.74	77.14
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	310.68	324.98
Copper (Cu) ppm	WetChem	10	10
Iron (Fe) ppm	WetChem	138	144
Zinc (Zn) ppm	WetChem	52	54
Manganese (Mn) ppm	WetChem	97	102

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,598
Sample Type: *F67* Ruminant Feed > 10% CF
Grower ID: BGNDRF
Sample ID: N1 1.2 C

Date Processed: 06/01/16
Date Received: 05/31/16
Cust#: A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.40	0.00
DM (Dry Matter) %	WetChem	95.60	100.00
CP (Crude Protein) %	WetChem	14.44	15.10
ADF (Acid Detergent Fiber) %	WetChem	22.90	23.95
CF (Crude Fiber) %	{Calc}	18.32	19.16
Crude Carbohydrates %	{Calc}	47.60	49.79
Digestible Carbohydrates %	{Calc}	37.60	39.33
Fat %	Ether Ext.	0.95	0.99
Total Digestible Nutrients (TDN) %	{Calc}	58.53	61.23
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.60	0.63
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.59	0.61
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.30	0.32
Effective Net Energy (ENE) %	{Calc}	48.48	50.71
Digestible Energy DE (Mcal / lb)	{Calc}	1.17	1.22
Metabolizable Energy (Kcal / lb)	{Calc}	961	1,005
Ash %	WetChem	14.29	14.95
Phosphorus (P) %	WetChem	0.19	0.19
Calcium (Ca) %	WetChem	1.16	1.21
Potassium (K) %	WetChem	4.43	4.64
Magnesium (Mg) %	WetChem	0.48	0.50
Sodium (Na) %	WetChem	0.87	0.91
Sulfur (S) %	WetChem	0.82	0.86
Chloride (Cl) %	WetChem	2.97	3.11
Salt Calculated from Chloride (NaCl) %	{Calc}	4.90	5.12
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	73.74	77.14
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	310.68	324.98
Copper (Cu) ppm	WetChem	10	10
Iron (Fe) ppm	WetChem	138	144
Zinc (Zn) ppm	WetChem	52	54
Manganese (Mn) ppm	WetChem	97	102

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,599	***Date Processed:***	06/01/16
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF		
Sample ID:	N3 1.2 C	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.70	0.00
DM (Dry Matter) %	WetChem	95.30	100.00
CP (Crude Protein) %	WetChem	11.17	11.72
ADF (Acid Detergent Fiber) %	WetChem	24.62	25.83
CF (Crude Fiber) %	{Calc}	19.70	20.67
Crude Carbohydrates %	{Calc}	52.59	55.18
Digestible Carbohydrates %	{Calc}	41.55	43.59
Fat %	Ether Ext.	1.16	1.21
Total Digestible Nutrients (TDN) %	{Calc}	61.17	64.19
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.34	0.36
Effective Net Energy (ENE) %	{Calc}	51.14	53.66
Digestible Energy DE (Mcal / lb)	{Calc}	1.22	1.28
Metabolizable Energy (Kcal / lb)	{Calc}	1,004	1,054
Ash %	WetChem	10.69	11.22
Phosphorus (P) %	WetChem	0.16	0.16
Calcium (Ca) %	WetChem	0.86	0.90
Potassium (K) %	WetChem	3.94	4.14
Magnesium (Mg) %	WetChem	0.42	0.44
Sodium (Na) %	WetChem	0.28	0.29
Sulfur (S) %	WetChem	0.55	0.58
Chloride (Cl) %	WetChem	2.26	2.37
Salt Calculated from Chloride (NaCl) %	{Calc}	3.73	3.91
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	67.39	70.71
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	231.93	243.36
Copper (Cu) ppm	WetChem	8	8
Iron (Fe) ppm	WetChem	113	118
Zinc (Zn) ppm	WetChem	59	62
Manganese (Mn) ppm	WetChem	73	77

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,599 ***Date Processed:*** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/31/16
Grower ID: BGNDRF
Sample ID: N3 1.2 C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.70	0.00
DM (Dry Matter) %	WetChem	95.30	100.00
CP (Crude Protein) %	WetChem	11.17	11.72
ADF (Acid Detergent Fiber) %	WetChem	24.62	25.83
CF (Crude Fiber) %	{Calc}	19.70	20.67
Crude Carbohydrates %	{Calc}	52.59	55.18
Digestible Carbohydrates %	{Calc}	41.55	43.59
Fat %	Ether Ext.	1.16	1.21
Total Digestible Nutrients (TDN) %	{Calc}	61.17	64.19
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.34	0.36
Effective Net Energy (ENE) %	{Calc}	51.14	53.66
Digestible Energy DE (Mcal / lb)	{Calc}	1.22	1.28
Metabolizable Energy (Kcal / lb)	{Calc}	1,004	1,054
Ash %	WetChem	10.69	11.22
Phosphorus (P) %	WetChem	0.16	0.16
Calcium (Ca) %	WetChem	0.86	0.90
Potassium (K) %	WetChem	3.94	4.14
Magnesium (Mg) %	WetChem	0.42	0.44
Sodium (Na) %	WetChem	0.28	0.29
Sulfur (S) %	WetChem	0.55	0.58
Chloride (Cl) %	WetChem	2.26	2.37
Salt Calculated from Chloride (NaCl) %	{Calc}	3.73	3.91
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	67.39	70.71
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	231.93	243.36
Copper (Cu) ppm	WetChem	8	8
Iron (Fe) ppm	WetChem	113	118
Zinc (Zn) ppm	WetChem	59	62
Manganese (Mn) ppm	WetChem	73	77

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,600 ***Date Processed:*** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/31/16
Grower ID: BGNDRF
Sample ID: N4 0.8 C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.60	0.00
DM (Dry Matter) %	WetChem	95.40	100.00
CP (Crude Protein) %	WetChem	11.38	11.93
ADF (Acid Detergent Fiber) %	WetChem	23.19	24.31
CF (Crude Fiber) %	{Calc}	18.55	19.45
Crude Carbohydrates %	{Calc}	53.05	55.61
Digestible Carbohydrates %	{Calc}	41.91	43.93
Fat %	Ether Ext.	1.19	1.25
Total Digestible Nutrients (TDN) %	{Calc}	61.16	64.11
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.34	0.36
Effective Net Energy (ENE) %	{Calc}	51.13	53.59
Digestible Energy DE (Mcal / lb)	{Calc}	1.22	1.28
Metabolizable Energy (Kcal / lb)	{Calc}	1,004	1,053
Ash %	WetChem	11.23	11.77
Phosphorus (P) %	WetChem	0.15	0.16
Calcium (Ca) %	WetChem	0.85	0.89
Potassium (K) %	WetChem	4.30	4.51
Magnesium (Mg) %	WetChem	0.51	0.53
Sodium (Na) %	WetChem	0.10	0.11
Sulfur (S) %	WetChem	0.47	0.49
Chloride (Cl) %	WetChem	1.77	1.86
Salt Calculated from Chloride (NaCl) %	{Calc}	2.92	3.06
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	159.25	166.93
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	311.65	326.67
Copper (Cu) ppm	WetChem	9	10
Iron (Fe) ppm	WetChem	109	114
Zinc (Zn) ppm	WetChem	60	63
Manganese (Mn) ppm	WetChem	57	59

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,600	***Date Processed:***	06/01/16
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF		
Sample ID:	N4 0.8 C	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.60	0.00
DM (Dry Matter) %	WetChem	95.40	100.00
CP (Crude Protein) %	WetChem	11.38	11.93
ADF (Acid Detergent Fiber) %	WetChem	23.19	24.31
CF (Crude Fiber) %	{Calc}	18.55	19.45
Crude Carbohydrates %	{Calc}	53.05	55.61
Digestible Carbohydrates %	{Calc}	41.91	43.93
Fat %	Ether Ext.	1.19	1.25
Total Digestible Nutrients (TDN) %	{Calc}	61.16	64.11
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.63	0.66
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.34	0.36
Effective Net Energy (ENE) %	{Calc}	51.13	53.59
Digestible Energy DE (Mcal / lb)	{Calc}	1.22	1.28
Metabolizable Energy (Kcal / lb)	{Calc}	1,004	1,053
Ash %	WetChem	11.23	11.77
Phosphorus (P) %	WetChem	0.15	0.16
Calcium (Ca) %	WetChem	0.85	0.89
Potassium (K) %	WetChem	4.30	4.51
Magnesium (Mg) %	WetChem	0.51	0.53
Sodium (Na) %	WetChem	0.10	0.11
Sulfur (S) %	WetChem	0.47	0.49
Chloride (Cl) %	WetChem	1.77	1.86
Salt Calculated from Chloride (NaCl) %	{Calc}	2.92	3.06
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	159.25	166.93
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	311.65	326.67
Copper (Cu) ppm	WetChem	9	10
Iron (Fe) ppm	WetChem	109	114
Zinc (Zn) ppm	WetChem	60	63
Manganese (Mn) ppm	WetChem	57	59

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,601		***Date Processed:***	06/01/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF			
Sample ID:	N2 0.8 L		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.25	0.00
DM (Dry Matter) %	WetChem	95.75	100.00
CP (Crude Protein) %	WetChem	17.04	17.80
ADF (Acid Detergent Fiber) %	WetChem	18.14	18.95
CF (Crude Fiber) %	{Calc}	14.51	15.16
Crude Carbohydrates %	{Calc}	44.79	46.78
Digestible Carbohydrates %	{Calc}	35.39	36.96
Fat %	Ether Ext.	1.03	1.07
Total Digestible Nutrients (TDN) %	{Calc}	56.38	58.88
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.58	0.60
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.55	0.58
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.27	0.28
Effective Net Energy (ENE) %	{Calc}	46.31	48.36
Digestible Energy DE (Mcal / lb)	{Calc}	1.13	1.18
Metabolizable Energy (Kcal / lb)	{Calc}	926	967
Ash %	WetChem	18.38	19.20
Phosphorus (P) %	WetChem	0.23	0.24
Calcium (Ca) %	WetChem	0.86	0.90
Potassium (K) %	WetChem	3.75	3.91
Magnesium (Mg) %	WetChem	0.61	0.64
Sodium (Na) %	WetChem	3.35	3.50
Sulfur (S) %	WetChem	0.31	0.33
Chloride (Cl) %	WetChem	7.09	7.40
Salt Calculated from Chloride (NaCl) %	{Calc}	11.69	12.21
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	100.20	104.64
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	216.94	226.56
Copper (Cu) ppm	WetChem	10	10
Iron (Fe) ppm	WetChem	96	101
Zinc (Zn) ppm	WetChem	49	51
Manganese (Mn) ppm	WetChem	48	50

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,601 ***Date Processed:*** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/31/16
Grower ID: BGNDRF
Sample ID: N2 0.8 L ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.25	0.00
DM (Dry Matter) %	WetChem	95.75	100.00
CP (Crude Protein) %	WetChem	17.04	17.80
ADF (Acid Detergent Fiber) %	WetChem	18.14	18.95
CF (Crude Fiber) %	{Calc}	14.51	15.16
Crude Carbohydrates %	{Calc}	44.79	46.78
Digestible Carbohydrates %	{Calc}	35.39	36.96
Fat %	Ether Ext.	1.03	1.07
Total Digestible Nutrients (TDN) %	{Calc}	56.38	58.88
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.58	0.60
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.55	0.58
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.27	0.28
Effective Net Energy (ENE) %	{Calc}	46.31	48.36
Digestible Energy DE (Mcal / lb)	{Calc}	1.13	1.18
Metabolizable Energy (Kcal / lb)	{Calc}	926	967
Ash %	WetChem	18.38	19.20
Phosphorus (P) %	WetChem	0.23	0.24
Calcium (Ca) %	WetChem	0.86	0.90
Potassium (K) %	WetChem	3.75	3.91
Magnesium (Mg) %	WetChem	0.61	0.64
Sodium (Na) %	WetChem	3.35	3.50
Sulfur (S) %	WetChem	0.31	0.33
Chloride (Cl) %	WetChem	7.09	7.40
Salt Calculated from Chloride (NaCl) %	{Calc}	11.69	12.21
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	100.20	104.64
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	216.94	226.56
Copper (Cu) ppm	WetChem	10	10
Iron (Fe) ppm	WetChem	96	101
Zinc (Zn) ppm	WetChem	49	51
Manganese (Mn) ppm	WetChem	48	50

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,602	***Date Processed:***	06/01/16
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF		
Sample ID:	N5 0.4 L	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.90	0.00
DM (Dry Matter) %	WetChem	96.10	100.00
CP (Crude Protein) %	WetChem	19.52	20.31
ADF (Acid Detergent Fiber) %	WetChem	18.23	18.97
CF (Crude Fiber) %	{Calc}	14.58	15.18
Crude Carbohydrates %	{Calc}	42.10	43.80
Digestible Carbohydrates %	{Calc}	33.26	34.61
Fat %	Ether Ext.	1.22	1.27
Total Digestible Nutrients (TDN) %	{Calc}	56.36	58.64
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.58	0.60
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.55	0.57
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.27	0.28
Effective Net Energy (ENE) %	{Calc}	46.25	48.13
Digestible Energy DE (Mcal / lb)	{Calc}	1.13	1.17
Metabolizable Energy (Kcal / lb)	{Calc}	925	963
Ash %	WetChem	18.68	19.44
Phosphorus (P) %	WetChem	0.19	0.20
Calcium (Ca) %	WetChem	0.83	0.87
Potassium (K) %	WetChem	3.27	3.40
Magnesium (Mg) %	WetChem	0.64	0.67
Sodium (Na) %	WetChem	4.08	4.24
Sulfur (S) %	WetChem	0.33	0.35
Chloride (Cl) %	WetChem	6.65	6.92
Salt Calculated from Chloride (NaCl) %	{Calc}	10.96	11.41
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	238.66	248.34
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	363.24	377.98
Copper (Cu) ppm	WetChem	6	6
Iron (Fe) ppm	WetChem	120	125
Zinc (Zn) ppm	WetChem	58	60
Manganese (Mn) ppm	WetChem	35	37

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,602		***Date Processed:***	06/01/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF			
Sample ID:	N5 0.4 L		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.90	0.00
DM (Dry Matter) %	WetChem	96.10	100.00
CP (Crude Protein) %	WetChem	19.52	20.31
ADF (Acid Detergent Fiber) %	WetChem	18.23	18.97
CF (Crude Fiber) %	{Calc}	14.58	15.18
Crude Carbohydrates %	{Calc}	42.10	43.80
Digestible Carbohydrates %	{Calc}	33.26	34.61
Fat %	Ether Ext.	1.22	1.27
Total Digestible Nutrients (TDN) %	{Calc}	56.36	58.64
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.58	0.60
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.55	0.57
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.27	0.28
Effective Net Energy (ENE) %	{Calc}	46.25	48.13
Digestible Energy DE (Mcal / lb)	{Calc}	1.13	1.17
Metabolizable Energy (Kcal / lb)	{Calc}	925	963
Ash %	WetChem	18.68	19.44
Phosphorus (P) %	WetChem	0.19	0.20
Calcium (Ca) %	WetChem	0.83	0.87
Potassium (K) %	WetChem	3.27	3.40
Magnesium (Mg) %	WetChem	0.64	0.67
Sodium (Na) %	WetChem	4.08	4.24
Sulfur (S) %	WetChem	0.33	0.35
Chloride (Cl) %	WetChem	6.65	6.92
Salt Calculated from Chloride (NaCl) %	{Calc}	10.96	11.41
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	238.66	248.34
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	363.24	377.98
Copper (Cu) ppm	WetChem	6	6
Iron (Fe) ppm	WetChem	120	125
Zinc (Zn) ppm	WetChem	58	60
Manganese (Mn) ppm	WetChem	35	37

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,603		***Date Processed:***	06/01/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF			
Sample ID:	N6 1.2 L		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.85	0.00
DM (Dry Matter) %	WetChem	96.15	100.00
CP (Crude Protein) %	WetChem	16.06	16.70
ADF (Acid Detergent Fiber) %	WetChem	23.51	24.45
CF (Crude Fiber) %	{Calc}	18.81	19.56
Crude Carbohydrates %	{Calc}	41.44	43.10
Digestible Carbohydrates %	{Calc}	32.74	34.05
Fat %	Ether Ext.	1.23	1.28
Total Digestible Nutrients (TDN) %	{Calc}	55.51	57.73
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.57	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.54	0.56
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.25	0.26
Effective Net Energy (ENE) %	{Calc}	45.40	47.22
Digestible Energy DE (Mcal / lb)	{Calc}	1.11	1.15
Metabolizable Energy (Kcal / lb)	{Calc}	911	948
Ash %	WetChem	18.61	19.36
Phosphorus (P) %	WetChem	0.18	0.19
Calcium (Ca) %	WetChem	0.94	0.98
Potassium (K) %	WetChem	3.85	4.01
Magnesium (Mg) %	WetChem	0.48	0.50
Sodium (Na) %	WetChem	3.10	3.22
Sulfur (S) %	WetChem	0.28	0.29
Chloride (Cl) %	WetChem	6.85	7.12
Salt Calculated from Chloride (NaCl) %	{Calc}	11.29	11.74
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	102.83	106.95
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	210.92	219.36
Copper (Cu) ppm	WetChem	9	10
Iron (Fe) ppm	WetChem	85	88
Zinc (Zn) ppm	WetChem	40	42
Manganese (Mn) ppm	WetChem	45	47

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,603 ***Date Processed:*** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/31/16
Grower ID: BGNDRF
Sample ID: N6 1.2 L ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.85	0.00
DM (Dry Matter) %	WetChem	96.15	100.00
CP (Crude Protein) %	WetChem	16.06	16.70
ADF (Acid Detergent Fiber) %	WetChem	23.51	24.45
CF (Crude Fiber) %	{Calc}	18.81	19.56
Crude Carbohydrates %	{Calc}	41.44	43.10
Digestible Carbohydrates %	{Calc}	32.74	34.05
Fat %	Ether Ext.	1.23	1.28
Total Digestible Nutrients (TDN) %	{Calc}	55.51	57.73
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.57	0.59
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.54	0.56
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.25	0.26
Effective Net Energy (ENE) %	{Calc}	45.40	47.22
Digestible Energy DE (Mcal / lb)	{Calc}	1.11	1.15
Metabolizable Energy (Kcal / lb)	{Calc}	911	948
Ash %	WetChem	18.61	19.36
Phosphorus (P) %	WetChem	0.18	0.19
Calcium (Ca) %	WetChem	0.94	0.98
Potassium (K) %	WetChem	3.85	4.01
Magnesium (Mg) %	WetChem	0.48	0.50
Sodium (Na) %	WetChem	3.10	3.22
Sulfur (S) %	WetChem	0.28	0.29
Chloride (Cl) %	WetChem	6.85	7.12
Salt Calculated from Chloride (NaCl) %	{Calc}	11.29	11.74
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	102.83	106.95
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	210.92	219.36
Copper (Cu) ppm	WetChem	9	10
Iron (Fe) ppm	WetChem	85	88
Zinc (Zn) ppm	WetChem	40	42
Manganese (Mn) ppm	WetChem	45	47

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,604		***Date Processed:***	06/01/16
Sample Type:	*F67*	Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF			
Sample ID:	CONT C		***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.55	0.00
DM (Dry Matter) %	WetChem	95.45	100.00
CP (Crude Protein) %	WetChem	11.77	12.33
ADF (Acid Detergent Fiber) %	WetChem	22.64	23.72
CF (Crude Fiber) %	{Calc}	18.11	18.98
Crude Carbohydrates %	{Calc}	46.82	49.05
Digestible Carbohydrates %	{Calc}	36.99	38.75
Fat %	Ether Ext.	1.05	1.10
Total Digestible Nutrients (TDN) %	{Calc}	56.08	58.75
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.57	0.60
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.55	0.58
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.27	0.28
Effective Net Energy (ENE) %	{Calc}	46.03	48.23
Digestible Energy DE (Mcal / lb)	{Calc}	1.12	1.17
Metabolizable Energy (Kcal / lb)	{Calc}	921	965
Ash %	WetChem	17.70	18.54
Phosphorus (P) %	WetChem	0.13	0.14
Calcium (Ca) %	WetChem	1.54	1.61
Potassium (K) %	WetChem	4.50	4.71
Magnesium (Mg) %	WetChem	0.76	0.80
Sodium (Na) %	WetChem	0.77	0.81
Sulfur (S) %	WetChem	0.69	0.72
Chloride (Cl) %	WetChem	3.49	3.66
Salt Calculated from Chloride (NaCl) %	{Calc}	5.75	6.03
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	31.69	33.20
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	272.95	285.96
Copper (Cu) ppm	WetChem	6	7
Iron (Fe) ppm	WetChem	603	632
Zinc (Zn) ppm	WetChem	28	29
Manganese (Mn) ppm	WetChem	89	94

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,604 ***Date Processed:*** 06/01/16
Sample Type: *F67* Ruminant Feed > 10% CF ***Date Received:*** 05/31/16
Grower ID: BGNDRF
Sample ID: CONT C ***Cust#:*** A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	4.55	0.00
DM (Dry Matter) %	WetChem	95.45	100.00
CP (Crude Protein) %	WetChem	11.77	12.33
ADF (Acid Detergent Fiber) %	WetChem	22.64	23.72
CF (Crude Fiber) %	{Calc}	18.11	18.98
Crude Carbohydrates %	{Calc}	46.82	49.05
Digestible Carbohydrates %	{Calc}	36.99	38.75
Fat %	Ether Ext.	1.05	1.10
Total Digestible Nutrients (TDN) %	{Calc}	56.08	58.75
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.57	0.60
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.55	0.58
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.27	0.28
Effective Net Energy (ENE) %	{Calc}	46.03	48.23
Digestible Energy DE (Mcal / lb)	{Calc}	1.12	1.17
Metabolizable Energy (Kcal / lb)	{Calc}	921	965
Ash %	WetChem	17.70	18.54
Phosphorus (P) %	WetChem	0.13	0.14
Calcium (Ca) %	WetChem	1.54	1.61
Potassium (K) %	WetChem	4.50	4.71
Magnesium (Mg) %	WetChem	0.76	0.80
Sodium (Na) %	WetChem	0.77	0.81
Sulfur (S) %	WetChem	0.69	0.72
Chloride (Cl) %	WetChem	3.49	3.66
Salt Calculated from Chloride (NaCl) %	{Calc}	5.75	6.03
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	31.69	33.20
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	272.95	285.96
Copper (Cu) ppm	WetChem	6	7
Iron (Fe) ppm	WetChem	603	632
Zinc (Zn) ppm	WetChem	28	29
Manganese (Mn) ppm	WetChem	89	94

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number:	75,605	***Date Processed:***	06/01/16
Sample Type:	*F67* Ruminant Feed > 10% CF	***Date Received:***	05/31/16
Grower ID:	BGNDRF		
Sample ID:	NAT HOW C	***Cust#:***	A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.75	0.00
DM (Dry Matter) %	WetChem	96.25	100.00
CP (Crude Protein) %	WetChem	9.26	9.62
ADF (Acid Detergent Fiber) %	WetChem	27.83	28.91
CF (Crude Fiber) %	{Calc}	22.26	23.13
Crude Carbohydrates %	{Calc}	43.88	45.59
Digestible Carbohydrates %	{Calc}	34.66	36.01
Fat %	Ether Ext.	0.67	0.70
Total Digestible Nutrients (TDN) %	{Calc}	53.44	55.52
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.54	0.56
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.51	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.22	0.23
Effective Net Energy (ENE) %	{Calc}	43.32	45.01
Digestible Energy DE (Mcal / lb)	{Calc}	1.07	1.11
Metabolizable Energy (Kcal / lb)	{Calc}	877	912
Ash %	WetChem	20.18	20.97
Phosphorus (P) %	WetChem	0.06	0.06
Calcium (Ca) %	WetChem	2.94	3.05
Potassium (K) %	WetChem	1.16	1.21
Magnesium (Mg) %	WetChem	0.95	0.98
Sodium (Na) %	WetChem	2.89	3.00
Sulfur (S) %	WetChem	0.52	0.54
Chloride (Cl) %	WetChem	3.22	3.35
Salt Calculated from Chloride (NaCl) %	{Calc}	5.31	5.51
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	146.28	151.98
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	412.31	428.37
Copper (Cu) ppm	WetChem	3	3
Iron (Fe) ppm	WetChem	379	394
Zinc (Zn) ppm	WetChem	13	14
Manganese (Mn) ppm	WetChem	67	69

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Feeds Forages Mycotoxins Soils Plant Tissues Manure Fertilizers Lime Water

Sample Number: 75,605
Sample Type: *F67* Ruminant Feed > 10% CF
Grower ID: BGNDRF
Sample ID: NAT HOW C

Date Processed: 06/01/16
Date Received: 05/31/16
Cust#: A928

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Proximate Feed Analysis Report	***Method***	**As Received**	**Dry Basis**
Moisture %	{Calc}	3.75	0.00
DM (Dry Matter) %	WetChem	96.25	100.00
CP (Crude Protein) %	WetChem	9.26	9.62
ADF (Acid Detergent Fiber) %	WetChem	27.83	28.91
CF (Crude Fiber) %	{Calc}	22.26	23.13
Crude Carbohydrates %	{Calc}	43.88	45.59
Digestible Carbohydrates %	{Calc}	34.66	36.01
Fat %	Ether Ext.	0.67	0.70
Total Digestible Nutrients (TDN) %	{Calc}	53.44	55.52
Net Energy for Lactation NEL (Mcal / lb)	{Calc}	0.54	0.56
Net Energy for Maintenance NEM (Mcal / lb)	{Calc}	0.51	0.53
Net Energy for Gain NEG (Mcal / lb)	{Calc}	0.22	0.23
Effective Net Energy (ENE) %	{Calc}	43.32	45.01
Digestible Energy DE (Mcal / lb)	{Calc}	1.07	1.11
Metabolizable Energy (Kcal / lb)	{Calc}	877	912
Ash %	WetChem	20.18	20.97
Phosphorus (P) %	WetChem	0.06	0.06
Calcium (Ca) %	WetChem	2.94	3.05
Potassium (K) %	WetChem	1.16	1.21
Magnesium (Mg) %	WetChem	0.95	0.98
Sodium (Na) %	WetChem	2.89	3.00
Sulfur (S) %	WetChem	0.52	0.54
Chloride (Cl) %	WetChem	3.22	3.35
Salt Calculated from Chloride (NaCl) %	{Calc}	5.31	5.51
Dietary Cation Anion Diff. (DCAD-4) meq / lb	{Calc}	146.28	151.98
Dietary Cation Anion Diff. (DCAD-7) meq / lb	{Calc}	412.31	428.37
Copper (Cu) ppm	WetChem	3	3
Iron (Fe) ppm	WetChem	379	394
Zinc (Zn) ppm	WetChem	13	14
Manganese (Mn) ppm	WetChem	67	69

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Feed & Forage Analysis Definitions

Proximate Analysis: A chemical scheme for evaluating feedstuffs, in which a feed is partitioned into the six fractions: 1) Moisture; 2) Total (Crude) Protein; 3) Fat; 4) Ash; 5) Crude Fiber; and 6) Nitrogen-Free Extract (NFE).

Inductively Coupled Plasma Discharge (ICP): The leading spectrochemical excitation source for atomic emission spectroscopy and ion source for inorganic mass spectrometry.

Near Infrared Reflective (NIR): NIR analysis is a non-destructive analytical technique for fast evaluation of the chemical composition and associated feeding value attributes of forages. Each major feed component exhibits unique absorption and reflectance characteristic patterns when near infrared energy is applied. These patterns are compared with standard NIR patterns stored in the computer's memory. NIR reports Moisture, Soluble Protein, Crude Protein, ADF, NDF, Heat Damaged Protein, Lignin, and Starch. From these, DM, Insoluble Protein, TDN, NEL, NEG, NEM, and ME can be calculated. It provides accurate results, fast turnaround time, reliability, and low cost.

E.L.I.S.A: Enzyme Linked ImmunoSorbant Assay

Relative Feed Value (RFV): A measure of a forage's feeding value compared to standards of full-bloom alfalfa-grass mixtures expressed as a percentage. A high RFV reflects high quality, high intake, high digestibility, and good animal performance. As an example, high producing dairy cows require forages with RFVs above 118.

Grass & Leg RFV =	(DMI * DDM) / 1.29
Legume RFV =	(DMI * DDM) / 1.29
Grass RFV =	(DMI * DDM) / 1.29

Dry Matter Intake (DMI):

Grass & Leg DRYMI =	120 / NDF
Legume DRYMI =	120 / NDF
Grass DRYMI =	120 / NDF

Digestible Dry Matter (DDM): Is the estimated digestibility of the feed based on the ADF concentration.

Grass & Leg DDM =	88.90 – (0.779 * ADF)
Legume DDM =	88.90 – (0.779 * ADF)

MOISTURE

Air Dry: This refers to feed that is dried by means of natural air movement, usually in the open. It may either be an actual or an assumed dry matter content; the later is approximately 90%. Most feeds are fed in an air-dry state.

As Fed: This refers to feed as normally fed to animals. It may range from 0 - 100% dry matter.

Moisture: The amount of water in the sample.

Dry Matter Basis: A method of expressing the level of a nutrient contained in a feed on the basis that the material contains no water.

Dry Matter (DM): That part of a feed which is not water. It is computed by determining the percentage of water and subtracting the water content from 100%.

DM% = (100% – Moisture%)

Anhydrous: The same as dry matter. What is left after the water is taken out.

Anhydrous% = (100% – Moisture%)

PROTEIN

Crude Protein (CP): The total amount of protein present, including true protein and non-protein nitrogen. Crude protein is determined by finding the nitrogen content and multiplying the result by 6.25. The nitrogen content of proteins averages about 16% (100 / 16 = 6.25).

Heat Damaged Protein: Heat Damaged Protein is the same value expressed as Acid Detergent Insoluble Nitrogen (ADIN), Acid Detergent Fiber Crude Protein (ADFCP), Acid Detergent Insoluble Crude Protein (AD-ICP), Indigestible ADF Crude Protein (IADFCP), or as "Unavailable Protein." It is an indication of the amount of heating that took place after harvest. Research suggests that a feedstuff is not truly heat damaged unless the protein contained in the Acid Detergent Fiber is both greater than 1% of the dry matter and greater than 10% of the total protein content of the feed. These "normalized" ADF Protein results are due to residual analysis error, intrinsic protein characteristics of the feed, and other reasons. Thus, those feeds which contain less than 1% ADF Protein or less than 10% of the crude protein in the ADF fraction should generally not be considered heat damaged.

Forages IADFCP = (.7 * ADFCP) Concentrates IADFCP = (.4 * ADFCP)

Acid Detergent Insoluble Nitrogen (ADIN): See Heat Damaged Protein.

Acid Detergent Insoluble Crude Protein (AD-ICP): See Heat Damaged Protein.

Acid Detergent Fiber Crude Protein (ADFCP): See Heat Damaged Protein.

Indigestible ADF Crude Protein (IADFCP): See Heat Damaged Protein.

Neutral Detergent Fiber Crude Protein (NDFCP): NDF Protein is the measured protein residue remaining in the NDF after analysis. This resultant is used in a calculation to determine the protein free NDF content of the feed. The NDF Protein should always be greater that or equal to the ADF Protein content.

Adjusted Crude Protein (Adjusted CP): The adjusted Crude Protein is calculated utilizing the Acid Detergent Fiber Crude Protein (ADFCP) value, but corrected for "normalized" ADF Protein results. Research suggests that a feedstuff is not truly heat damaged unless the protein contained in the Acid Detergent Fiber is both greater than 1% of the dry matter and greater than 10% of the total protein content of the feed. These "normalized" ADF Protein results are due to residual analysis error, intrinsic protein characteristics of the feed, and other reasons. Therefore, feeds which contain less than 1% ADF Protein or less than 10% of the crude protein in the ADF fraction will reflect an Adjusted CP value that will not differ from the Crude Protein value. This value should be utilized when feed programming on a crude protein basis for ruminants.

Corn Silage Adjusted CP =	IF((1.16 * CP) – (1.6 * ADF CP) < CP, (1.16 * CP) – (1.6 * ADF CP), 1 * CP))
Grass & Leg Adjusted CP =	IF((1.16 * CP) – (1.6 * ADF CP) < CP, (1.16 * CP) – (1.6 * ADF CP), 1 * CP))
Grass Adjusted CP =	IF((1.16 * CP) – (1.6 * ADF CP) < CP, (1.16 * CP) – (1.6 * ADF CP), 1 * CP))
Legume Adjusted CP =	IF((1.16 * CP) – (1.6 * ADF CP) < CP, (1.16 * CP) – (1.6 * ADF CP), 1 * CP))

Available Protein (AP): Available Protein is calculated by subtracting the ADF Protein (also expressed as Heat Damaged Protein, IADFCP, ADFCP, ADIN, ADFCP, AD-ICP, or as Unavailable Protein) from the Crude Protein. This value, however is not corrected for "normalized" ADF Protein resultants. Available Protein is used to calculate the Adjusted Crude Protein. It will only vary from crude protein if the heat damaged protein is high.

Corn Silage AP =	(CP – Heat Damaged Protein)
Grass & Leg AP =	(CP – Heat Damaged Protein)
Grass AP =	(CP – Heat Damaged Protein)
Legumes AP =	(CP – Heat Damaged Protein)

Soluble Protein (SP): Soluble protein is the actual protein percent of the dry matter which consists of the non-protein nitrogen (NPN) and rapidly degraded true protein content of the feed.

Corn Silage SP =	CP – Insoluble Protein
Grass & Leg SP =	CP – Insoluble Protein
Legume SP =	CP – Insoluble Protein
Grass SP =	CP – Insoluble Protein
Ear Corn SP =	CP – Insoluble Protein
Shelled Corn SP =	CP – Insoluble Protein

Protein Solubility: Protein solubility is the percentage of the crude protein which is soluble protein. Balancing for protein solubility is important to prevent excessive rumen blow-off of NPN as Blood Urea Nitrogen (BUN). Likewise, by balancing for minimum protein solubility you help assure against a deficiency of available nitrogen for microbial population growth. A level of 30% protein solubility (when formulating with NRC crude protein requirements) seems adequate for high producing dairy cows. It is important to remember that protein types and carbohydrate degradation should be considered when formulating rations. *Proceedings 1987 Winter Dairy Management School, Cornell University, Pg. 113-120.*

Corn Silage Protein Solubility =	(Soluble Protein / CP) * 100
Grass & Leg Protein Solubility =	(Soluble Protein / CP) * 100
Legume Protein Solubility =	(Soluble Protein / CP) * 100
Grass Protein Solubility =	(Soluble Protein / CP) * 100

Degraded Protein: The protein degradation test is still experimental and under refinement by university research. However, a calculated estimate can be made from protein solubility for forages. The equation for Protein Degradability % = Solubility % + (0.5*(100-Solubility%)). This equation works with relative accuracy for all forage types, but should not be used for grains, commodity feeds, or total mixed rations. It needs to be remembered that this value is influenced by length of cut, rate of passage, moisture content, forage to concentrate ratio of total diet, system of feeding, and pH of rumen, etc. It is recommended that the above reference proceeding be viewed for estimates of protein degradability of grains and commodity feed products. A calculated protein degradability of 60 – 62% is recommended in the diet of a high producing dairy cow.

Digestible Protein (est): An estimation of the amount of the crude protein that is available for digestion by the animal.

FIBER

Crude Fiber (CF): The amount of hard-to-digest carbohydrates. Most fiber is made up of cellulose and lignin. Crude fiber is the residue that remains after boiling a feed in a weak acid, and then in a weak alkali, in an attempt to imitate the process that occurs in the digestive tract. This procedure is based on the supposition that carbohydrates which are readily dissolved also will be readily digested by animals, and that those not soluble under such conditions are not readily digested. Unfortunately, the treatment dissolves much of the lignin, a non-digestible component. Hence, crude fiber is only an approximation of the indigestible material in feedstuffs. Nevertheless, it is a rough indicator of the energy value of feeds.

Corn Silage CF =	0.80 * ADF
Grass & Leg CF =	0.80 * ADF
Legume CF =	0.80 * ADF
Grass CF =	0.80 * ADF
Ear Corn CF =	0.80 * ADF
Shelled Corn CF =	0.80 * ADF

Acid Detergent Fiber (ADF): ADF is the most accurate determinant of forage digestible dry matter and digestible energy. It is the amount of fiber that is indigestible. The lower the ADF value, the more digestible it is expected to be. The ADF value is used in calculating energy content of forages. ADF differs from Neutral Detergent Fiber (NDF) in that NDF contains most of the feed hemicellulose and a limited amount of protein, not present in ADF.

ADF extraction involves boiling a 1.0-gram sample of air-dry material in a specially prepared acid detergent solution for 1 hour, then filtering. The insolubles, or residue, make up what is known as ADF and consist primarily of cellulose, lignin, heat-damaged proteins, and variable amounts of silica.

Cell Wall (CW): See Neutral Detergent Fiber (NDF).

Neutral Detergent Fiber (NDF): This is the insoluble fraction resulting from boiling a feed sample in a neutral detergent solution. It contains cellulose, hemicellulose, silica, some protein (heat damaged), and lignin. Cell wall (CW), or NDF, components are of low digestibility and entirely dependent on the microorganisms of the digestive tract for any digestion that they undergo; hence, they are essentially undigested by non-ruminants. NDF is closely related to feed intake. This fraction of a forage affects the volume it will occupy in the digestive tract, a principal factor limiting the amount of feed consumed. Animals fed such forages are often unable to consume enough feed to produce weight gains or milk economically. An animal will eat more feed with a low NDF value compared to feed with higher amounts of NDF. NDF will almost always be higher than ADF.

The soluble fraction – the cell contents – consists of sugars, starch, fructosans, pectin, protein, non-protein nitrogen, lipids, water, soluble minerals, and vitamins. This portion is highly digestible (about 98%) by both ruminants and non-ruminants.

NDF (Protein Free) (NDFPF): This value represents the protein free NDF content of the feed. It is calculated using both the ADF and NDF Protein resultants. Many high fiber protein feeds and heat damaged forages contain appreciable amounts of protein in the NDF fraction. Thus, using the raw NDF value without correcting for this residue protein overestimates the true NDF content of the feedstuff. Also, because the OSU Energy Equation requires ash free lignin determination, the lignin, ADF, and NDF are adjusted downward for the level of lignin insoluble ash (LIA) contained in the feed. This makes the fiber analysis results as accurate and unbiased as possible. The NDF (Protein Free) value is the recommended value of choice to be used in ration balancing in place of standard NDF results. A minimum of 28% of the ration dry matter as NDF (Protein Free) coming from forages (of adequate length to stimulate cudd chewing) should be included in the ration dry matter. *1989 NRC Nutrient Requirements of Dairy Cattle.*

NDFPF = NDF - NDFCP + IADFCP

Available NDF (Protein Free): The available NDF (Protein Free) value represents that NDF which is available for digestion in the ruminant. It is calculated using a complex equation utilizing the lignin content of the feedstuff and the intrinsic interactions it has on the digestibility of the protein free NDF. The higher the protein free Available NDF content of the feed, generally the more acetic acid will be produced from its fermentation in the rumen. However, this is highly dependent on the particle size of the feedstuff (as fed), as well as the other feedstuffs in the total ration. A minimum of 14% of the ration dry matter is recommended. However, ration levels of 16 to 18% would be more advantageous as long as minimum NSC (38%) and minimum forage NDF (Protein Free) are maintained in the ration of a high producing dairy cow.

Available NDFPF = .75*(NDFPF - L) * (1-((L / NDFPF)^.667))

Cellulose: Celulose is, by far, the most abundant polysaccharide in nature – composing close to 50% of the total organic carbon. It is a straight-chain polymer that is extremely resistant to acid and alkaline hydrolysis. Non-ruminant animals lack the necessary enzymes to cleave the linkages of glucose molecules in cellulose. Hence, they are poor users of fibrous plants. The microorganisms in the rumen of ruminants contain the enzyme celulase; hence, ruminants can effectively utilize feeds that are high in cellulose.

Lignin: Lignin is a major component of the cell wall of certain plant materials, such as wood, hulls, straws, and over-ripe hays. This fraction is essentially indigestible by all animals and is the substance that limits the availability of cellulose carbohydrates in the plant cell wall to rumen bacteria.

The acid detergent fiber (ADF) procedure is used as a preparatory step in determining the lignin of a forage sample. Hemicellulose is solubilized during this procedure, while the lignocellulose fraction of the feed remains insoluble. Cellulose is then separated from lignin by the addition of sulfuric acid. Only lignin and acid-insoluble ash remains upon completion of this step. This residue is then ashed, and the difference of the weights before and after ashing yields the amount of lignin present in the feed.

ENERGY

Calorie: The amount of energy as heat required to raise the temperature of 1 gram of water 1 degree Celsius.

Kilocalorie (kcal): The amount of energy as heat required to raise the temperature of 1 kilogram of water 1 degree Celsius, equivalent to 1,000 calories.

Megacalorie (Mcal): Equivalent to 1,000 kilocalories or 1,000,000 calories. Also, referred to as a *therm*, but the term megacalorie is preferred.

British Thermal Unit (Btu): The amount of energy as heat required to raise 1 pound of water 1 degree Fahrenheit, equivalent to 252 calories. This term is seldom used in animal nutrition.

Joule (J): A proposed international unit for expressing mechanical chemical, or electrical energy, as well as the concept of heat. In the future, energy requirements and feed values may be expressed by this unit. (4.184J = 1 calorie)

Hay Equivalent (HE): This is the energy equivalent of 1 ton of hay, which, on the average, contains 800 Mcal of net energy. With an Animal Unit Month (AUM) being equivalent to 320 Mcal of net energy, 2.5 AUM are required to furnish the same amount of energy as 1 ton of hay.

Total Digestible Nutrients (TDN): A measurement of the energy value of a feedstuff, TDN has been the standard method of expressing the energy value of feeds for many years. However, the usefulness of TDN is limited and presently is used mostly in formulating maintenance rations for beef cows. The following disadvantages are inherent in the TDN system: 1) Only digestive losses are considered – it does not take into account other important losses, such as those in urine, gases, and increased heat production; 2) There is a poor relationship between crude fiber and NFE digestibility in certain feeds; and 3) It overestimates roughages in relation to concentrates when animals are fed for high rates of production due to the higher heat loss per pound of TDN in high-fiber feeds.

Penn State Energy Equations

Corn Silage TDN =	31.4 + (53.1 * NEL)
Grass & Leg TDN =	4.898 + (89.796 * NEL)
Legume TDN =	31.4 + (53.1 * NEL)
Grass TDN =	31.4 + (53.1 * NEL)
Ear Corn TDN =	99.72 - (1.927 * ADF)
Shelled Corn TDN =	99.22 – (1.535 * ADF)

OSU Energy Equations

Forage TDN =	(CP * 38^(-0.012 * ADIN)) + (0.98 * (100-NDFCP - CP -Ash - EE)) + (0.94 * (EE - 1) * 2.8) + (0.75 * (NDFCP - L) * (1 - (L / NDFCP^0.667))) - 7
Concentrate TDN =	(CP * (1 - 0.004 * ADIN)) + (0.98 * (100- NDFCP - CP -Ash - EE)) + (0.94 * (EE - 1) * 2.8) + (0.75 * (NDFCP - L) * (1 - (L / NDFCP^0.667))) - 7

Total Digestible Nutrients for Horses (TDNHORSE):

Grass & Leg TDNHORSE =	(DE / 0.02)
Legume TDNHORSE =	(DE / 0.02)
Grass TDNHORSE =	(DE / 0.02)
Shelled Corn TDNHORSE =	(DE / 0.02)

Metabolizable Energy (ME): Metabolizable energy represents that portion of the gross energy that is not lost in the feces, urine, and gas (mainly methane) expressed as Kcal/lb. It does not take into account the energy lost as heat, commonly called heat increment. As a result, it overevaluates roughages compared with concentrates, as does TDN and DE. ME is used primarily to evaluate the energy concentration in swine and poultry rations. ME is considered to be the most accurate evaluation of the energy of feedstuffs for the scientific formulation of poultry feeds.

Corn Silage ME =	0.01642 * TDN
Grass & Leg ME =	0.01642 * TDN
Legume ME =	0.01642 * TDN
Grass ME =	0.01642 * TDN
Ear Corn ME =	0.01642 * TDN
Shelled Corn ME =	0.01642 * TDN

Gross Energy (GE): Gross energy represents the total combustible energy in a feedstuff. It does not differ greatly between feeds, except for those high in fat. For example, 1 pound of corncobs contains about the same amount of GE as 1 pound of shelled corn. Therefore, GE does little to describe the useful energy in feeds for finishing animals.

Net Energy (NE): Net energy represents the energy fraction in a feed that is left after the fecal, urinary, gas, and heat losses are deducted from the Gross Energy (GE). Because of its greater accuracy, net energy is being used increasingly in ration formulations, especially in computerized formulations for large operations. However, NE is difficult to determine.

Two systems of net energy evaluation are presently used: 1) net energy for maintenance (NEM) and net energy for gain (NEG), and 2) net energy for lactation (NEL).

Net Energy Lactation (NEL): A calculated value that nutritionists and dairy producers can use to evaluate or predict performance of rations fed to lactating ruminants.

Corn Silage NEL =	1.044 – (0.0124 * ADF)
Grass & Leg NEL =	1.044 – (0.0119 * ADF)
Legume NEL =	1.044 – (0.0119 * ADF)
Grass NEL =	1.085 – (0.0124 * ADF)
Ear Corn NEL =	1.036 – (0.0203 * ADF)
Shelled Corn NEL =	0.9050 – (0.0026 * ADF)

Net Energy Maintenance (NEM): Value calculated as a tool for nutritionists and producers to evaluate or predict performance of rations fed to non-lactating ruminants.

Corn Silage NEM = -0.508 + (1.37 *ME1) – (0.3042 *ME2) + (0.051 *ME3)

Grass & Leg NEM = -0.508 + (1.37 *ME1) – (0.3042 *ME2) + (0.051 *ME3)

Legume NEM = -0.508 + (1.37 *ME1) – (0.3042 *ME2) + (0.051 *ME3)

Grass NEM = -0.508 + (1.37 *ME1) – (0.3042 *ME2) + (0.051 *ME3)

Ear Corn NEM = -0.508 + (1.37 *ME1) – (0.3042 *ME2) + (0.051 *ME3)

Shell Corn NEM = -0.508 + (1.37 * ME1) – (0.3042 *ME2) + (0.051 *ME3)

Net Energy Gain (NEG): Value calculated as a tool for nutritionists and producers to evaluate or predict performance of rations fed to non-lactating ruminants.

Crn Silage NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Grass & Leg NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Legume NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Grass NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Ear Corn NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Shell Corn NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Digestible Energy (DE): Digestible Energy is that portion of the gross energy in a feed that is not excreted in the feces. It is roughly comparable to TDN. For most animals, DE is relatively easy to determine. With poultry, however, true digestibility is very difficult to measure because undigested residues and urinary wastes are excreted together.

Grass & Leg DE = (1.91 – (0.05 * ADF)) + (0.0151 * CP) + (0.00051 * ADF * ADF)

Legume DE = (1.91 – (0.05 * ADF)) + (0.0151 * CP) + (0.00051 * ADF * ADF)

Grass DE = (1.91 – (0.05 * ADF)) + (0.0151 * CP) + (0.00051 * ADF * ADF)

Coefficient of Digestibility: The percentage value of a food nutrient that is absorbed. For example, if a food contains 10 grams of nitrogen and it is found that 9.5 grams are absorbed, the digestibility is 95%.

Digestible Dry Matter (DDM): Is the estimated digestibility of the feed based on the ADF concentration.

FAT

Fat: Lipids (fat and fat-like substances), like carbohydrates, contain the 3 elements – carbon, hydrogen, and oxygen. Fats are soluble in such organic solvents as ether, chloroform, and benzene. As livestock feeds, fats function much like carbohydrates in that they serve as a source of heat and energy and for the formation of fat. Because of the larger proportion of carbon and hydrogen, however, fats liberate more heat than carbohydrates when digested, furnishing on oxidation approximately 2.25 times as much heat or energy per pound as do the carbohydrates. A smaller quantity of fat is required, therefore, to serve the same function.

Volatile Fatty Acids (VFA): Commonly used in reference to acetic, propionic, and butyric acids found especially in rumen contents and / or silage.

Crude Fat (EE): Material that is extracted from moisture-free feeds by ether. It consists largely of fats and oils with small amounts of waxes, resins, and coloring matter. In calculating the energy value of a feed, the fat is considered to have 2.25 times as much energy as either nitrogen-free extract or protein.

Nitrogen-Free Extract (NFE): The more readily digested carbohydrates (calculated rather than measured chemically) consisting principally of sugars, starches, pentoses, and non-nitrogenous organic acids. The percentage is determined by subtracting the sum of the percentages of moisture, crude protein, crude fat, crude fiber and ash from 100.

NFE = 100% - Moisture% - CP% - EE% - CF% - Ash%

Available Carbohydrate: This is the sum of the available NDF (Protein Free) and the available NSC. (The NSC is estimated to be 98% available.) The Available Carbohydrate value represents the maximum theoretical total carbohydrate available for digestion in the ruminant. Normal value ranges for high-producing cows would be 50 – 60% of the ration dry matter.

Non-Structural Carbohydrate (NSC): The NSC level of a feedstuff is an estimate of the starch and sugar content of the feed. It is calculated by difference after subtracting the crude protein, ash, fat, and protein free neutral detergent fiber from the feed dry matter. NSC, by calculation difference, also contains pectin, beta-glucans, and other substances. These substances have a similar digestibility to starch, but yield different fermentation products in the rumen. Practical applied nutrition suggests a NSC level of 38 – 42% of the ration dry matter of high producing dairy cows. *Journal of Dairy Science, Volume 74, Pg. 3583-3644.*

Shell Corn NEG = DM - CP - Ash - Fat - NDFPF - IADFCP

Non-Fiber Carbohydrates (NFC):

Corn Silage NFC = (92 – CP – NDF)

Grass & Leg NFC = IF((85 – CP – NDF) < 5, 5, IF(NDF < 43, 85 - CP – NDF, 87 – CP – NDF))

Legume NFC = IF((87 – CP – NDF) < 5, 5, IF(NDF < 43, 87 - CP – NDF, 89 – CP – NDF))

Grass NFC = IF((84 – CP – NDF) < 5, 5, IF(NDF < 45, 84 - CP – NDF, 86 – CP – NDF))

Ear Corn NFC = (94 – CP – NDF)

Shelled Corn NFC = (94 – CP – NDF)

Starch: Most glucose is stored in plants in the form of starch, of which there are two types: 1) amylose, a straight-chained structure of repeating glucose molecules; and 2) amylopectin, a highly branched compound. When either type of starch is hydrolyzed, dextrins are formed.

ASH

Ash: The mineral matter of a feed. The inorganic elements of animals and plants, determined by burning off the organic matter and weighing the residue.

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Plant Nutrients & Their Functions

Nitrogen (N)

Plant Uptake of N: NO_3^- NH_4^+

Functions of Nitrogen

- Directly involved with chlorophyll production.
- Key building block for proteins and enzymes.
- Promotes cell division.
- Causes darker green plants and rapid growth.
- Boosts plant protein levels.

Nitrogen Deficiency Symptoms

- Young, spindles, stunted plants.
- Reduced growth.
- Yellowing of plants starting with older leaves.

Phosphorus (P)

Plant Uptake of P: $H_2PO_4^-$ HPO_5^-

Functions of Phosphorus

- Promotes rapid root development from seeds planted early in cold, moist soils.
- Insures vigorous seedling growth early.
- Promotes seed formation and reproduction.
- Improves water use efficiency.
- Improves uniformity of crop maturity and quality.

Phosphorus Deficiency Symptoms

- Stunted or reduced growth.
- Purpling of leaves especially with young plants
- Delayed maturity.

Potassium (K)

Plant Uptake of K: K^+

Functions of Potassium

- Controls plant respiration.
- Improves stalk quality and reduces plant lodging.
- Builds disease resistance.
- Helps open and close leaf pores (stomates) more efficiently to control pater loss during drought.
- Promotes rapid and efficient conversion of nitrogen into protein.
- Helps regulate many enzyme reactions and other plant functions.

Potassium Deficiency Symptoms

- Firing of tips and margins of lower leaves.
- White spots and yellowing of edges of lower leaves.
- Leaf tips are scorched.
- Plant lodging.

Calcium (Ca)

Plant Uptake of Ca: Ca^{++}

Functions of Calcium

- Cell wall formation for strong cells.
- Translocation of sugrars.
- Root hair formation (feeder roots).
- Neutralized poisons produced in the plant.
- Encourages fruit and seed production.
- Improves general plant vigor and stiffnes of straw.

Calcium Deficiency Symptoms

- Dark green vein in mid-rib of leaf, with yellowish green areas between.
- Leaves have wrinkled appearance and may defoliate.
- Dying back of border of plants.
- Poorly developed root hair.
- Blossom end rot of tomatoes.
- Young leaves and terminal bud become hooked in appearance and die back at the tips and along the margin.

Magnesium (Mg)

Plant Uptake of Mg: Mg^{++}

Functions of Magnesium

- Essential for chlorophyll formation.
- Seed formation.
- Helps regulate the uptake of other plant nutrients.
- Acts as a carrier of phosphorus in the plant.
- Promotes formation of oils and fats.

Magnesium Deficiency Symptoms

- General loss of green color starting at the bottom older leaves and later moves up the plant.
- Veins of leaf remain green with loss of color between the veins.
- Leaves curve upward along the margins.
- Plants have weak stalks with long branch roots.

Sulfur (S)

Plant Uptake of S: SO_4^{--}

Functions of Sulfur

- Necessary for protein formation.
- Helps maintain dark green color.
- Promotes nodule formation on legumes.
- Stimulates seed production.
- Encourages more vigorous plant growth.

Sulfur Deficiency Symptoms

- Deficiency occurs in new growth only.
- Stems turn yellow, while leaves turn a very bright yellow, with even lighter veins.

Boron (B) *Plant Uptake of B:* H_3B0_3-

Functions of Boron

- Aids in nodule and seed formation in legumes.
- Aids in calcium uptake and sugar transfer.
- Aids in terminal bud formation.

Boron Deficiency Symptoms

- More generally deficient in high pH soils.
- Dry rot of sugar beets.
- Yellow top of alfalfa.
- Lack of seed formation on one side of ear of corn.

Chloride (Cl) *Plant Uptake of Cl:* Cl-

Functions of Chloride

- Aids in photosynthesis.
- Controls waer use efficiency in plants.
- Aids in crop maturity.
- Helps with disease control.
- Aids in sugar translocation.

Chloride Deficiency Symptoms

- Deficiency symptoms on row crops are not common.
- Chloride deficient small grains show a higher incidence of moisture stress, greater incidence of root, stem, and leaf diseases, and reduced yields.

Copper (Cu) *Plant Uptake of Cu:* Cu++

Functions of Copper

- Essential for intercellular metabolism and it acts as an oxidizer in the plant processes.

Copper Deficiency Symptoms

- Die back in extreme cases.
- Little or no fruit.
- S shaped tips with coarse leaves.
- Deficiency shows on new growth first.
- Generally associated with high organic soils (muck) especially those with a high pH.

Iron (Fe) *Plant Uptake of Fe:* Fe++

Functions of Iron

- Needed for chlorophyll synthesis, plant metabolism, and oxidation.
- Functions as a catalyst in chlorophyll formation.

Iron Deficiency Symptoms

- Deficiencies occur on alkaline or high pH soils due to insolubility of the iron and on acid soils due to the extreme solubility and resultant leaching of iron.
- Tall, slender plants with few leaves.
- Pale green, then yellow, then white between the veins. (Generally new leaves with light green band along the leaf margins.)
- Die back in the case of advanced deficiency.
- Short, much branched root system.

Manganese (Mn) *Plant Uptake of Mn:* Mn++

Functions of Manganese

- Aids in oxidation and respiration processes of the plant.
- Accelerates seed germination and plant maturity with resultant crop yield and quality.
- Increases the availability of calcium, magnesium, and phosphorus.
- Aids in the synthesis of chlorophyll.
- Functions in photosynthesis.

Manganese Deficiency Symptoms

- Occurs on new growth first.
- Fading between veins changing to medium yellow with dark mid-rib.
- Does not affect size of leaf nor texture, only color.
- More deficient on soils with a high pH, either due to natural calcareous content or due to over-liming.

Molybdenum (Mo) *Plant Uptake of Mo:* MoO_4--

Functions of Molybdenum

- Aids in protein synthesis.
- Essential for legume nitrogen fixation.
- Helps enzyme systems.
- Aids in nitrogen metabolism.

Molybdenum Deficiency Symptoms

- Similar to nitrogen deficiency symptoms because plants cannot utilize nitrate nitrogen without adequate supplies of molybdenum.

Zinc (Zn) *Plant Uptake of Zn:* Zn++

Functions of Zinc

- Controls use of other elements in plants.
- Needed for growth hormone, seed and grain production.
- Influences protein synthesis rate of maturing of seed, and stalks, height or length of plants.

Zinc Deficiency Symptoms

- More deficient with high soil pH.
- White area between the veins (chlorosis).
- Small sharp pointed leaves.
- Undersized leaf is a definite characteristic of zinc deficiency.
- In corn, white buds form.

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Dietary Cation-Anion Difference (DCAD)

Dietary Cation-Anion Difference (DCAD), is a way to help balance the electrical charges of the cations and anions in the diet. These electrical charges affect blood buffering capacity and acidity in a cow's blood. The following DCAD equations are used by Litchfield Analytical Services:

DCAD-7 (meq / lb) = (1.00 * %Na * 197.72) + (1.00 * %K * 116.25) + (0.15 * %Ca * 226.82) + (0.15 * %Mg * 373.93) - (1.00 * %Cl * 128.21) - (0.20 * %S * 283.52) - (0.30 * %P * 264.15)

DCAD-4 (meq / lb) = (%Na * 197.72) + (%K * 116.25) - (%Cl * 128.21) - (%S * 283.52)

Conversions: (meq / kg) = (meq / lb) * 2.2 (meq / 100g) = (meq / lb) * 0.22

High-producing dairy cows tend to have a high level of acid buildup in their blood, in large part due to a corresponding increase in feed intake and absorption of acids produced in the rumen as well as the metabolic production of acids as feed is transformed into milk.. Under modern feeding practices, cows do not generate as much salivary bicarbonate (the major blood buffer) since they do not "chew the cud" as much as they did when they were fed only pasture or hay. This, along with the high metabolic rate, results in depleted blood buffer levels so cows cannot neutralize all of the acids they produce.

The optimum DCAD level should be based on the cow's milking status. For just-fresh cows and lactating cows, producers should achieve a highly positive DCAD level, between +159 and +204 meq / lb of total ration dry matter or TRDM (equivalent to +35 to +45 meq / 100g of TRDM or +350 to +450 meq / kg of TRDM). This level helps improve feed intake and milk production without affecting milk fat and protein percentages. Higher DCAD levels are especially effective during heat-stress conditions, when cows naturally reduce feed intake and have further problems with low blood bicarbonate and rumen acidosis.

For dry cows three weeks from calving, a negative DCAD is desirable. This increases blood calcium levels prior to freshening. Lowering the DCAD level to –36 to –55 meq / lb of TRDM (equivalent to –8 to –12 meq / 100g of TRDM or –80 to –120 meq / kg of TRDM) helps increase blood calcium, preventing milk fever, reducing udder edema, and leading to fewer retained placentas and displaced abomasums.

To lower DCAD, add the appropriate anionic salts. Magnesium is recommended as the first addition because it appears to be the most palatable, and because it can be used to meet the cow's requirement for magnesium. Formulate to 0.4% dietary magnesium in the TRDM. Add calcium sulfate or ammonium sulfate next to achieve 0.4% dietary sulfur in the TRDM. Then, add chloride sources (ammonium, calcium, or magnesium chloride) to bring the DCAD down to to –36 to –55 meq / lb of TRDM (equivalent to –8 to –12 meq / 100g of TRDM or –80 to –120 meq / kg of TRDM). Check the dietary non-protein nitrogen and degradable protein. Reduce the use of ammonium salts if NPN is greater than 0.5% of TRDM (more than 3.1% of crude protein from NPN in the TRDM) or degradable protein is greater than 70% of the total crude protein. If it is possible to lower DCAD to –45 to –68 meq / lb (equivalent to –10 to –15 meq / 100g or –100 to –150 meq / kg), add calcium to achieve calcium 1.5% to 1.8% dietary Ca in the TRDM. In field reports where problems were encountered with the feeding of negative DCAD diets, many were due to inadequate dietary calcium.

To raise DCAD through good nutrition, add supplemental sodium, potassium or both to the ration, without additional sulfates or chlorides. During hot summer months, it is clear cows respond positively to a combination of sodium and potassium. Heat-stressed cows lose potassium through sweat and milk, often making them deficient. Three studies at Texas A&M University showed that each 0.1 percentage increase in potassium led to almost one pound per day more milk. Nutritionists continue to find the best ways to raise DCAD levels. Dr. Elliot Block, Manager of Animal Research for the ARM & HAMMER Animal Nutrition Group, conducted research at McGill University that showed balancing DCAD with combination of potassium and sodium achieved the optimal dry matter intake and milk production.

Potassium is present in milk in greater quantities than even calcium. Therefore, to maintain high milk production, dairy cows need dietary potassium to avoid deficiencies. Potassium also appears to play an important role in insulin production, protein metabolism and in controlling the cows' "cell pumping ." Yet high-producing cows lose potassium through the normal everyday functions of milking and sweating. Replenish potassium levels without adding chlorides or sulfates that can negatively impact a ration's DCAD balance.

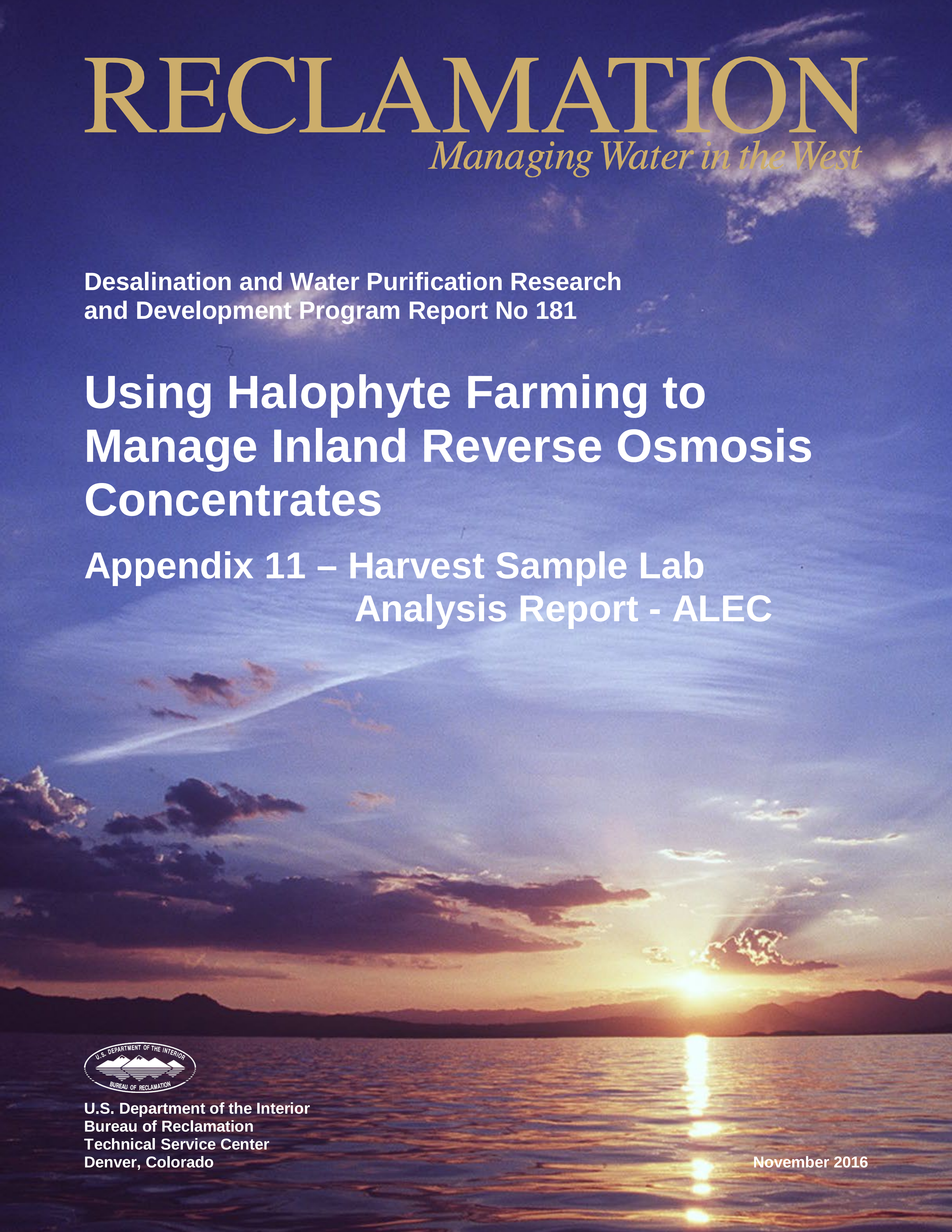
If the buffer being fed is sodium bicarbonate, or sodium sesquicarbonate, it does help increase the DCAD level. You can determine the amount of impact the buffer will have on DCAD by checking the minimum sodium guarantee, as not all buffers carry the same guarantee. In addition, it is vital that overall nutrient requirements provide the proper balance of both potassium and sodium. It is also important to supplement magnesium in rations when feeding extra potassium, and subsequently, to monitor potassium fertility levels on farms.

A pre-fresh ration should be an intermediate step between a high fiber, low energy dry cow diet to a low fiber, high energy lactating diet. The diet should transition the rumen to prepare rumen microbes for the changing diet, while providing key nutrients to avoid metabolic disorders common at calving. This step is important to maintaining cow health and enhancing productivity in early lactation. Provide the cow with essential nutrients rumen microbes need to produce microbial protein efficiently. This creates an optimal rumen environment that enhances dry matter intake and feed efficiency, preparing pre-fresh cows for early lactation diets. A palatable source of chlorides creates a negative DCAD that helps prevent costly metabolic disorders. Metabolic disorders, especially milk fever, can dramatically reduce productivity and profitability in early lactation cows. This has a multiplier effect throughout lactation, with lower peak production and decreased total milk throughout the lactation. Research at Cornell University indicates the one case of milk fever alone can cost over $180 per cow. Add the costs of the added effects of milk fever, including displaced abomasum, retained placenta, ketosis and other metabolic disorders, and the impact on your profitability can be enormous.
Recent multi-herd evaluations from Idaho and Minnesota have shown that the ultimate effect of these transition disorders is that many more cows are leaving the dairy early in lactation. When these cows are culled so early they give little or no profit back to the dairy and they are becoming increasingly more expensive to replace.

References:

"Prevention of Milk Fever by Application of the Dietary Cation-Anion Balance Concept", W.K. Sanchez & R. Blauwiekel, University of Idaho, Moscow ID, Washington State University, Pullman WA, Bulletin EB1783, April 2001.

"Use of Acidifying Diets for Prevention of Milk Fever in Dairy Cattle", G. Oetzel DVM, University of Wisconsin-Madison, Madison, WI, 1997.



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Appendix 11 – Harvest Sample Lab Analysis Report - ALEC

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2016

June 2016

Biomass sampling for the Arizona Laboratory for Emerging Contaminants (ALEC) Lab, UA:

Samples were collected from two sets of dry matter (DM) materials (0% moisture) as returned to the UA from Litchfield Lab, collected in September 2015 and April 2016. The samples represent materials from plants on all 1.2 ETo irrigation treatments - two row pairs of *A. lentiformis* and two row pairs of *A. canescens*. The samples were composited into 4 samples of 2 grams each, with 2 samples for each species. The ALEC lab ran duplicate tests of a randomly selected sample.

See Summary report in Excel spreadsheet, App 11.

ALEC - Arizona Laboratory for Emerging Contaminants

Southwest Hazardous Waste Program - Hazard Identification Core (HIC)

		7 Li	9 Be	11 B	23 Na	24 Mg	27 Al
ALEC Log#	Sample ID	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
Digests 4842	N1	1.30	0.00	35.89	13599	5297	169
Digests 4843	N3	0.78	0.01	34.28	3696	5506	120
Digests 4844	N6	1.98	0.01	30.94	37150	7327	118
Digests 4845	S3	2.91	0.02	36.84	30074	6544	255
Digests 4846	S3	2.85	0.01	37.51	27745	6022	206

Analyst: MKA
Job: 4842-4846
Date: 7/15/2016

Please use the following statement when acknowledging this work:

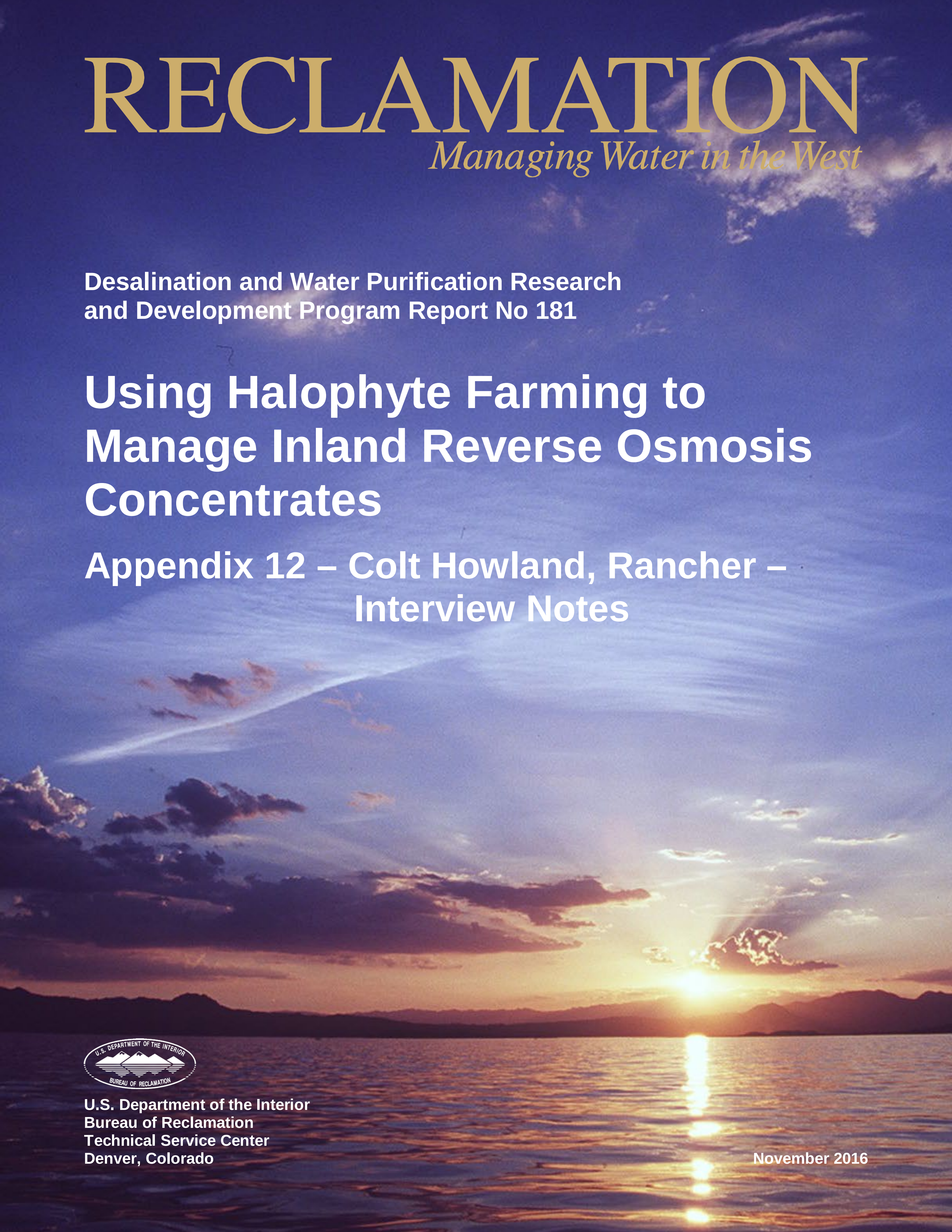
The analyses for ______ were performed by the Arizona Laboratory for Emerging Contaminants (ALEC) at the University of Arizona, Tucson, AZ

28 Si	31 P	39 K	44 Ca	49 Ti	51 V	52 Cr	55 Mn	56 Fe	59 Co
ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
248	2087	38216	8555	3.84	0.26	2.99	91.83	155	0.34
245	2343	39559	6040	3.04	0.20	3.68	76.09	126	0.41
203	2305	36248	8469	2.12	0.18	3.73	54.00	124	0.25
258	1794	31051	9667	4.11	0.40	3.95	48.76	227	0.26
235	1979	28296	10391	3.53	0.33	3.79	50.33	202	0.24

60 Ni	63 Cu	66 Zn	69 Ga	72 Ge	75 As	78 Se	85 Rb	88 Sr	90 Zr
ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
5.14	13.32	89.03	0.10	0.01	0.08	0.13	6.51	127.91	0.17
5.22	11.25	67.09	0.09	0.01	0.06	0.00	8.83	94.16	0.14
4.31	8.69	48.91	0.09	0.01	0.06	0.13	7.19	94.94	0.11
5.08	8.58	40.93	0.13	0.02	0.08	0.07	6.46	131.86	0.23
4.59	8.66	43.24	0.13	0.02	0.07	0.28	6.58	129.50	0.25

93 Nb	95 Mo	107 Ag	111 Cd	115 In	118 Sn	121 Sb	133 Cs	181 Ta	182 W
ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
0.09	1.42	0.04	0.28	0.01	0.03	0.01	0.03	0.03	0.01
0.06	1.06	0.03	0.19	0.00	0.03	0.01	0.02	0.02	0.03
0.07	0.53	0.01	0.05	0.01	0.04	0.01	0.02	0.03	0.04
0.14	0.57	0.01	0.03	0.00	0.07	0.01	0.03	0.07	0.16
0.20	0.56	0.01	0.03	0.00	0.04	0.01	0.03	0.14	0.12

185 Re	137 Ba	205 Tl	Hg 202	208 Pb	209 Bi	238 U
ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
0.13	3.25	0.02	0.036	0.26	0.01	0.01
0.17	2.09	0.01	0.023	0.14	0.00	0.00
0.20	1.81	0.01	0.023	0.14	0.01	0.00
0.14	3.88	0.01	0.040	0.35	0.00	0.01
0.14	3.49	0.01	0.030	0.22	0.00	0.00



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Appendix 12 – Colt Howland, Rancher – Interview Notes

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2016

Interview with Colt Howland, Rancher – May 17, 2016

PO Box 2761
Alamogordo, NM 88311
June 23, 2016

Attending: Joanne Gallaher and Janick Artiola, UA; Randy Shaw, BGNDRF, and Sarah Davis (project volunteer), Tucson, AZ

1) Describe your ranch operation – history, total size in sections/acres, grazing permits, etc.

Please document the total grazing area – total sections/acres in BLM versus private land, and the differences in range management, irrigation, etc.

Settlement in the area began in the 1800s; the house on the ranch was built in 1901 as part of the Circle Cross Ranch (it was split up by the Homestead Act).

The original property was homesteaded in the 1950s, and included land north and south of Highway 70.

Total ranch is– 38,400 acres, mostly grazing permits on BLM/State Trust Land; 7,000 acres of private land; Most of the ranch (60 sections) is south of highway 70; it also includes 8 sections north of highway 70; this area is mostly private land. Total State Trust Land is 12,500 acres; it is checkerboard and treated as BLM land.

The ranch was formerly 2 ranches now ran as 1 ranch, leased from the Sally Walker LLC. The east half is the HW Allotment (HW stands for Howland Walker), the west half is the White Sands Allotment, 5 miles east of the house. The property line of another property (four miles west of the house) became the White Sands Missile Range.

Number of head – 300 now, maximum allowed by permit is 480. The herd is reduced due to drought and range conditions. The herd is a 50 – 50 mix of heifers and steers, including club calves, show cattle and steers.

The BLM land is fenced. BLM officials and law enforcement have direct access to check range conditions and patrol the area.

The ranch has an artesian spring with brackish water located on a hill at the high point on the ranch, near the ranch house. The hill was formed naturally over thousands of years. The spring drains in a small creek to a ¼ acre pond that is 4 ½' deep with less salinity. The soil in the higher area near the pond is around 80% Gypsum. The soil improves to the east.

Wildlife in the area include oryx (introduced by the NM Game and Fish Department), coyote and fox.

2) What are the native/nonnative species at the ranch that the cattle graze?

What is the % of A. canescens? All native?

The range vegetation is primarily *Atriplex canescens* (known locally as common name of Chamize), mixed with three native grasses: Bush Muhly (*Muhlenbergia porteri*), Alkali sacaton (*Sporobolus airoides)*, and Black grama (*Bouteloua eriopoda* Torr.). [Common names of *Atriplex canescens* include Fourwing Saltbush, Chamize, Chamiso, Chamiza, and Shadscale]. The ranch also contains pockets of

Honey mesquite (*Prosopis glandulosa* Torr)., creosote (*Larrea tridentata*), and Salt cedar (*Tamarix spp*.); these species were introduced in the late 1900s by the railroad. Salt cedar is a non-native, invasive species. The woody plants (mesquite, creosote and salt cedar) are increasing. Cows do not like creosote.

Cattle have always grazed the Chamize. It takes one rainy season after grazing for the plants to recover.

The largest invasive species problem is African Rue (*Peganum harmala*), a noxious weed that kills a cow within 3 days of consumption. It's tap root can reach 30' and it spreads quickly in disturbed soil through seed distribution by birds, water and vehicle tires along roadways. Roundup is not effective (see attached publication). It is found on the ranch near roads and other disturbed areas.

Pickleweed (*Salicornia sp*), grows near the homestead near the artesian spring and pond. Cattle avoid it. Salicornia also grows in dry lake beds in the area.

4) How is the Atriplex managed? How old are the plants? Any revegetation by seed? If so, where, how much?

No information on the age of plants – Chamize is native to the range. Chamize is all natural reseeding – BLM does not allow seeding on their land.

Additional information is available from NMSU Range Improvement Task Force. Planted drought-resistant hybrid Sudan (Tru-Dan) with a tractor mounted seed spreader on worn out farm land as an annual that was grazed, or disked in for nitrogen.

Does Chamize become woodier over the years? If not, why not? (Watson's experience in the San Joaquin Valley in California, showed that the Atriplex got woodier after each cutting).

The Chamize becomes greener over the years, not woodier. The top of the Chamize breaks off when dry.

During severe drought, Chamize was grazed down to stubs; the plants are now largest in areas where it was grazed the hardest.

Livestock likes new, full growth. During the winter, Chamize holds protein where grasses lose protein.

5) Do you need to irrigate any fields? What is the quality of the irrigation/ground water?

Areas near the wells are flood irrigated.

Wells near Highway 54 are 180 to 200' deep; other wells are 40 – 60' deep. The ranch has 18' of elevation change. Wells north of the Highway 70 produce 400 gpd. The ranch has 44 miles of water line. Waterlines are checked every other day.

The well near highway 54 serves cattle drinkers and the house, runs from 6 pm to 4 am. In summer, the well produces 20 – 30 gallons per day (?)

When the cattle drink less, the quality of meat is not as good. 'USDA Prime' refers to the % fat/marbling.

Well water and drinkers are tested for iron; wants to maintain low iron as it bonds with copper.

Texaco drilled test wells, found a geyser; this is now on the missile range.

6) What parts of the Atriplex are preferred by cattle?

The order of preference is:

Winter – Chamize is preferred, when it is high in protein (compared to other species)
Winter feed is over 50% Chamize (need to confirm)
Fall – Chamize seeds
Spring/Summer – grasses

7) Do you cut any of the Atriplex or is it only grazed?

It is only grazed.

8) What lab tests do you conduct?

Hi-Pro Feeds, Friona Mill, Friona, TX, provides range supplements based on forage samples and fecal profiling tests by GAN Lab (Grazing land Animal Nutrition Lab), Temple, TX (affiliated with Texas A&M University).

What is the mix of species sent for analysis?

Forage samples are taken annually during a different season each year. The samples are random composite samples of what the cattle graze. Fecal tests are conducted six times per year using a laser spectrometer.

Can you give us data on the range cube product and supplements that you use? How are these distributed?

The range cube includes alfalfa. Supplements are based on the nutrition and fecal test results.

Do you use any fertilizers?

No fertilizers are used; BLM does not allow seeding, fertilizer or irrigation.

9) Do you auction most of your cattle? Provide information on the quality of meat.

There are two herds: 1) older cows, and 2) heifers and younger cows up to two-years old that are bred back. The 20 bulls spend 3 – 4 months with the cows and the rest of the year they are separated on 600 acres. East half – past the fence – moved cows there in November. The soil changes in this area, and is more loamy. There is prickly pear and yucca in this area, and the vegetation overall is thicker.

Approximately ½ of heifers are sold annually.

Quality of the meat is good, lean.

10) What feed lot do you use and when do you send cattle there? Also how many? What is the feed lot ration?

Only steers and non-breeders (older cows) are sent to a feed lot (through a feed lot buyer), where the cattle weight is increased from 500 or 600 pounds to around 1200 pounds. There are no commercial feed lots in NM.

11) Please document the Atriplex survival during extreme cold snaps and periods of drought vs other species.

Temperatures reached in the -20's in 2010. The Chamize recovered, where mesquite and creosote still has not come back in some areas.

There are three rain gauges on the ranch (the airport always indicates higher amounts).

Ranch precipitation:

2010 = < 1"
2011 = 0
2012 = < 1"
2013 = < 3"
2014 = > 8"
2015 = > 7"
2016 = dry so far – Jan .7"; April .2"

12) Is Alfalfa grown in this area? Was it grown earlier and then decreased due to increased salinity over time? Do you foresee a shift out of Alfalfa to other crops due to increased salinity of groundwater?

Some alfalfa in grown in the Tularosa area, using canal fed pivot irrigation. The area lost a few of the smaller growers, up to 40 acres, as there is less water available now.

13) Describe your need for a small RO plant for your operation.

The planned RO plant is to treat the brackish water for the cattle drinkers.

What are plans for the waste concentrate from the small RO plant that you are planning?

Worried about planting *Atriplex lentiformis* (growing at BGNDRF) as it is not found growing in the immediate area (although it is in NM).

14) Do you collect/sell Atriplex seed – and if so, what is the market? Granite seed, others? Do your neighbors collect/sell seed?

Colt does not collect seed on his ranch. Some native seed is collected on Otero Mesa, a proposed conservation area managed by the BLM.

15) Would he be interested in collaborative research on his *Atriplex* and perhaps see other varieties for comparison?

Colt is President of the Otero County Cattle Growers Association, with 140 members, and Secretary of the Otero County Farm Bureau.

There are 120 livestock growers in Otero County.

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Appendix 13 – UA Greenhouse Experiment

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2016

BGNDRF Halophyte Farming Greenhouse Studies

Cylphine Bresdin and Ed Glenn,

original: January 2016 | revised: February 2016

Atriplex lentiformis and *Atriplex canescens* have been studied in both greenhouse and field. Determination of salinity tolerance and field yield of biomass have been determined for *A. lentiformis* grown in native sand-loam soil. Tolerance has been reported to be 43.7 g L-1 TDS and maximum yield at 24.1 t ha^{-1} (Ed Glenn). Less is known about *A. canescens* and *A. linearis*. Although, *A. linearis* is not an experimental species included in the Halophyte Farming project, it does have potential for future studies because it has a high salt tolerance (Ed Glenn).

Soil at the Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, New Mexico is a heavy clay-loam high in sulfate with a mean EC of 23.6 mS, mean SAR of 12.79 and mean hydraulic conductivity (Ks) of 1.46 cm hr^{-1}[information derived from soil report, March 2014 (mbleiwei)]. Growth response of Atriplex spp. in the site soil with the experimental water [reference Concentrate Summary excel book, January 2014 (Valerie Batista-Garcia) and June 2014 (Michelle Chapman)]was an unknown. In order to gain insight into the maximum saline tolerance and wilt point of *Atriplex spp*. in site soil with experimental RO irrigation, greenhouse studies were conducted at the Environmental Research Lab (ERL) in Tucson. Maximum tolerance is necessary to predict field yield so it is a required variable in the yield model. Wilt point is a required input variable to understand and predict plant-water-soil relationships. It will inform us of the minimum water the species can tolerate in the site soil.

Purpose

To determine maximum saline tolerance and wilt-point of three species of *Atriplex: lentiformis, canescens* and *linearis* when grown in soil and irrigation from BGNDRF.

Materials

Substrate: Dry soil from the upper 100 cm was collected from the BGNDRF field site and pulverized; processed through a hammer mill to obtain a granularity similar to course cornmeal. Sand was local construction sand.

Irrigation: Test irrigation waters were: Reverse osmosis reject from BGNDRF processing (RO), RO plus 3 g L^{-1}, 10 g L^{-1}, or 20 g L^{-1} extra coarse salt (Water Tech, Tucson, AZ).

Pots: Two liter plastic pots (15 D x 9.5 H (cm)) were used for the preliminary test and four liter plastic pots (15 D x 18 H (cm)) were used for the repeat experiment.

Plants: *Atriplex linearis* fruits were collected from the grounds of the Environmental Research Lab (ERL, Tucson, AZ) and germinated in the greenhouse. Seeding substrate was a 3:1 mix of sand and soil with an overhead spray of city water three times a day. Plants were seeded in trays in September 2014 and were approximately six centimeters high when transplanted on April 17, 2015.*A.canescens* and *A. lentiformis* that had been seeded in seeding cones (4 D x 21 H (cm) were obtained from the grower (Daniel Manuchia, Las Cruces, New Mexico) March, 2015 and maintained under paddy irrigation with city water in the ERL greenhouse and ranged from 5-27 cm when transplanted on April 17, 2015 and June 15-16, 2015 for the tolerance repeat.

Methods

Preliminary Tolerance Experiment: Two liter pots were lined with a six inch square of newsprint and filled with either pulverized BGNDRF soil or sand. Plants were removed from the cone and potting soil was teased away from the roots which were then encircled to fit into the pot and buried in the dry soil. Soil was moistened with 350 mL RO and another 350 mL RO was added after initial aliquot had absorbed. Two days later (April 19, 2015), 350 mL RO was added to each pot. Drainage was collected and pooled per species per test irrigationthenpooled volume and g/L were measured to obtain start conditions. Plant height was also measured. Test irrigations began on April 22, 2015 when 200 mL was added to each pot. 100 mL was added on a weekly basis to bisect and supplement weekly test irrigations that started on April 26, 2015. Plant height, drainage volume and g/L were measured following a three hour absorption period after irrigation with 300 mL for BGNDRF soil and 450 mL for sand. The preliminary experiment was terminated on May 24, 2015.Dead plants were removed, surface cracks were filled and healed then substrate was flushed of salts and kept moist by sitting in drainage from a regular spray of city water. A thin layer of sand was laid on the surface of surviving plants and plants were kept moist with a daily spray of city water. Controls for the preliminary experiment were unplanted 2 liter pots that received the same irrigation regime as the test plants.

Repeat Tolerance Experiment: *A. linearis* was not included in the repeat experiment because there was 100% death in the original set-up. Remaining plants from the original March, 2015 cones that had been kept paddy style on city water were used for the repeat experiment. One gallon pots were lined with a six inch square of trace paper, a thin layer of sand was added to secure the liner followed by a thin layer of fresh dry pulverized BGNDRF soil. Plants were removed from cones and situated upright into prepared one gallon pots and secured with wet, washed soil remaining from the preliminary experiment to about 1/3 pot depth. A layer of dry non-pulverized BGNDRF soil was added, moistened and topped with another layer of washed BGNDRF soil to bring substrate surface to the base of the plant. Water was added, the surface was smoothed and allowed to drain then a thin layer of sand was applied to the moist surface (figure 1).

Transplantation took place over two days, June 15-16, 2015. To allow plants to establish, cracks were repaired on a daily basis by rubbing the surface followed by irrigation with 100 mL of city water until test waters were started on August 2, 2015. Thereafter, test water was used in place of city water for daily irrigation (100 mL). Plants were given enough water every seventh day to generate a drainage fraction that was collected, measured and a sample was transferred into a 50 mL polypropylene conical screw cap tube and saved for analysis of TDS as g L^{-1} and pH. Plant height was measured on a weekly basis at the time of drainage collection. Controls for the repeat experiment were surviving plants from the preliminary experiment that remained on city water irrigation. Table 1 shows experimental design.

Figure 1. Steps in transplantation of *Atriplex spp*. seedlings into 4 L pots with BGNDRF soil. The measure is 15.2 cm (6 in).

Table 1. Number of repeats per test irrigation in 4 L pots with BGNDRF soil as described in methods is shown in the table. Values in () are actual g L^{-1} of applied irrigation.

	RO (3.3)	RO + 3 g L^{-1} (6.8)	RO + 10 g L^{-1} (15.5)	RO + 20 g L^{-1} (28.5)
A. lentiformis	5	5	5	5
A. canescens	5	5	5	5

Wilt-point Experiment: Pots were set-up as in the preliminary tolerance experiment with the exception that newsprint liners were not used. Soil or sand was put into a plastic bag (4 gallon, Great White) lining the pot and dry initial weight was taken. Plants were transplanted into the bag on April 19, 2015, 400 mL test irrigation water was added and the bag was twisted and tucked closed then height and weight was taken and continued to be measured on a weekly basis until plant death occurred as indicated by a third week of no height increase. At this point weight continued to be taken for all plants until experiment termination on June 7, 2015. The bags of pots with dead plants were then left open in the hot greenhouse to dry the soil. Plants that appeared to be alive at experiment termination were left alone and periodically monitored until they died and the soil was dry. When plants and soil were dry, pots were weighed one final time. Controls for the wilt point experiment were unplanted pots that received the same test irrigation as the experimental plants.

Analysis

Salinity and pH: Every week collected samples were processed; g L^{-1} recorded with a Traceable conductivity probe and pH measured with a plastic 0-14 strip (LabRat Supplies).

Wilt-point: After soil was dry (August 9, 2015), pots were weighed and the difference between weight of pot at plant death and dry weight was noted. Water content was calculated by weight difference.

Results

Tolerance: The preliminary experiment was not analyzed due to low survival in both control sand and BGNDRF soil when plants were transplanted into 2 L pots. Two A. canescens and three A. lentiformis survived in BGNDRF soil and survivors ranged the test salinities. This indicates that death was due to mechanical conditions of transplantation not experimental tests. It was noted that *A. lentiformis* root structure was more fibrous and matted than *A. canescens*. The five survivors where used as irrigation water controls, input city tap water was 0.5 g L^{-1}. Drainage from control *A. lentiformis* was 1.0 g L^{-1} and 1.2 g L^{-1} from *A. canescens*. All plants survived transplantation and duration of the repeat experiment (Table 1). Four of the *A. canescens* plants were noted to have larger leaves and tended toward a prone profile (identified with bold font in the tolerance workbook) and were treated as *A. canescens* in the analysis.

Analysis of variance (ANOVA) [refer to BGNDRF_Tolerance-workbook, sheet: ANOVA] of drainage salinity indicates that there is no significance within groups ($P>0.05$) with two exceptions, *A. lentiformis* irrigated with RO and RO+15 g L^{-1} (Table 2). However, if acceptable level of P is decreased to 0.01, then differences within all groups is not significant, hence, the use of 0.01 for P. Degrees of freedom (d*f*) within groups is 4, n = 5. There is significance in the difference of drainage salinity between test irrigations for both *A. lentiformis* and *A. canescens*, $P<0.01$, $df = 3$, n = 140. The difference in salinity of drainage between *A. lentiformis* and *A. canescens*is significant, $P=0.002$, $df = 1$, n = 280.

Table 2. Tabulation of P values for drainage salinity (TDS) g L^{-1}.

	Within test	Between tests	Between species
A. lentiformis	P>0.01	P<0.01	P=0.002
A. canescens	P>0.01	P<0.01	

There was a distinct pattern in drainage salinity (Figure 2) with a large increase between week one and two and thereafter the salinity leveled out within test groups. Mean salinity for each test irrigation group from week two to seven was used to calculate mean salinity of drainage from each test group. As irrigation salinity (gram of NaCl) increased, drainage salinity (TDS) increased. Salinity of drainage from *A. canescens* was lower than *A. lentiformis* for all test irrigations: 71% (RO), 73% (RO+3), 82% (RO+10), 89% (RO+20).Percentages were calculated by using mean g L^{-1}*A. canescens* as numerator and *A. lentiformis* as denominator.

There was a distinct pattern in percentage of irrigation drained and hence, irrigation retained in the pot (Figure 3). As irrigation salinity increases, volume drained increases leading to lower volume retained in the pot. The effect is more dramatic with *A. lentiformis* which presents drainage with higher salinity. Similar to drainage salinity, volume retained by species tend toward equality at high irrigation salinities: 64% (RO and RO+3), 71% (RO+10), 79% (RO+20). Percent volume retained was calculated as, volume added minus volume drained which was then divided by volume added: $(V_{in} - V_{out}) / V_{in}$.

Growth was measured in height over time for each irrigation test (Figure 4). Plant growth was slower in *A. canescens* than *A. lentiformis* under experimental conditions, the curve is flat. For *A. canescens* it is the 3.3 g/L that appears to be an anomaly at weeks five and seven and may be due to measurement error. There was a prone contaminate species in the test group. Figure 4 suggests a pattern of growth, measured as height not area or volume, in response to irrigation salinity over time. With low saline irrigation water it takes longer for the soil-water to reach the species maximum tolerance, hence, the growth curve is steeper and increase in growth is maintained longer, until that maximum is reached. The intermediate salinity, 6.9 g/L, appears to be what the plant prefers until maximum salinity of soil-water is reached and this is sooner than it is with the low salinity of 3.3 g/L. The 15.5 g/L group of *A. lentiformis* has a smaller average plant height but the curves of the two highest salinities, 15.5 g/L and 28.5 g/L are similar.

Wilt-point: Time of wilt is defined as data point when height remained unchanged for three consecutive measurements with survival slightly longer for *A. lentiformis* than *A. canescens* [refer to BGNDRF_Wilt-workbook]. Weight data was converted from pound.ounce to ounce then to gram for all tests. Since specific gravity of water is 1 g mL^{-1}, gram equals mL of water. Volume of water not consumed was calculated by subtracting original dry weight (S) from wilt-point weight (W) for each test then averaged per test. Since soil volume was 2 L, mean volume not consumed was divided by 2 to obtain mean mL water remaining per L soil [(S - W)/2] and then values were plotted (Figure 5[c1]). [JA2]Water remaining indicates soil moisture content where the species can no longer overcome the osmotic potential created in BGNDRF soil with the test irrigation waters (Table 1). No statistical analysis was done on the wilt data.

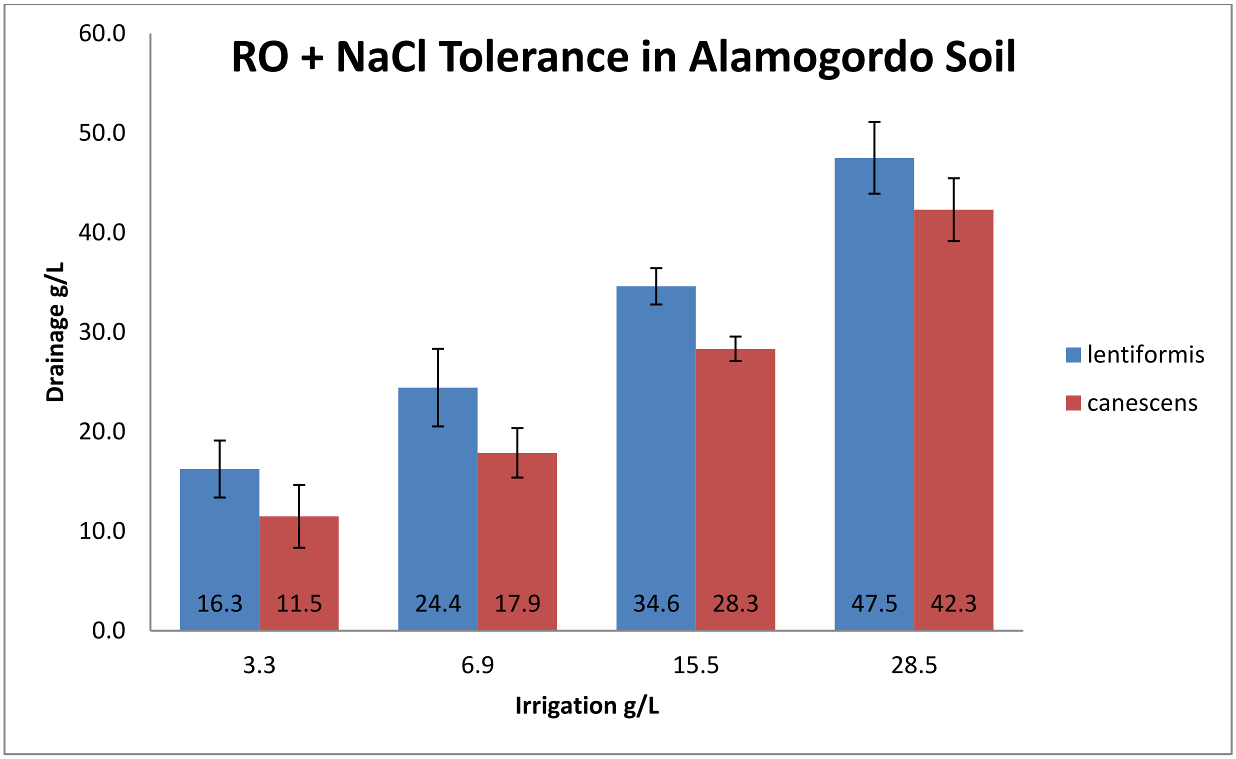


Figure 2. Comparison of mean drainage salinity from week two to seven (values in bars) for each species and irrigation test (X axis). Error bars are +/- 1 standard deviation.

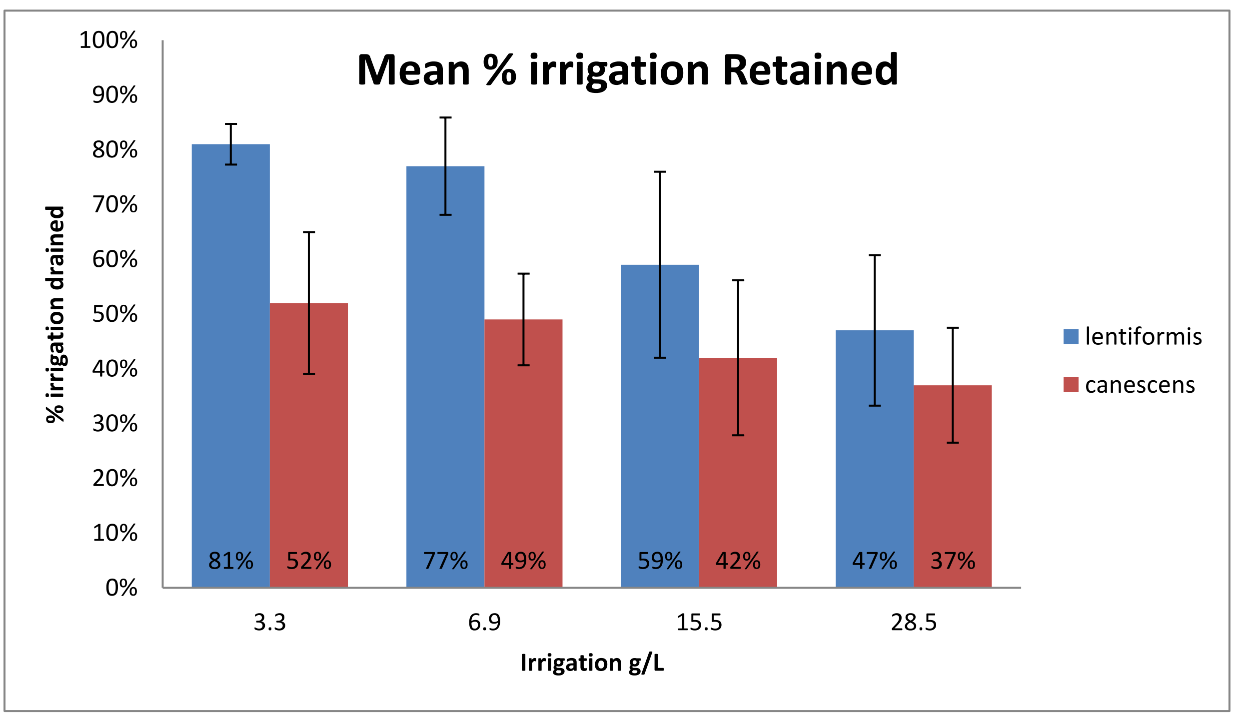


Figure 3. Comparison of mean percent of irrigation volume retained indicates volume replaced which is volume used from week two to seven (values in bars) for each species and irrigation test. Error bars are +/- 1 standard deviation.

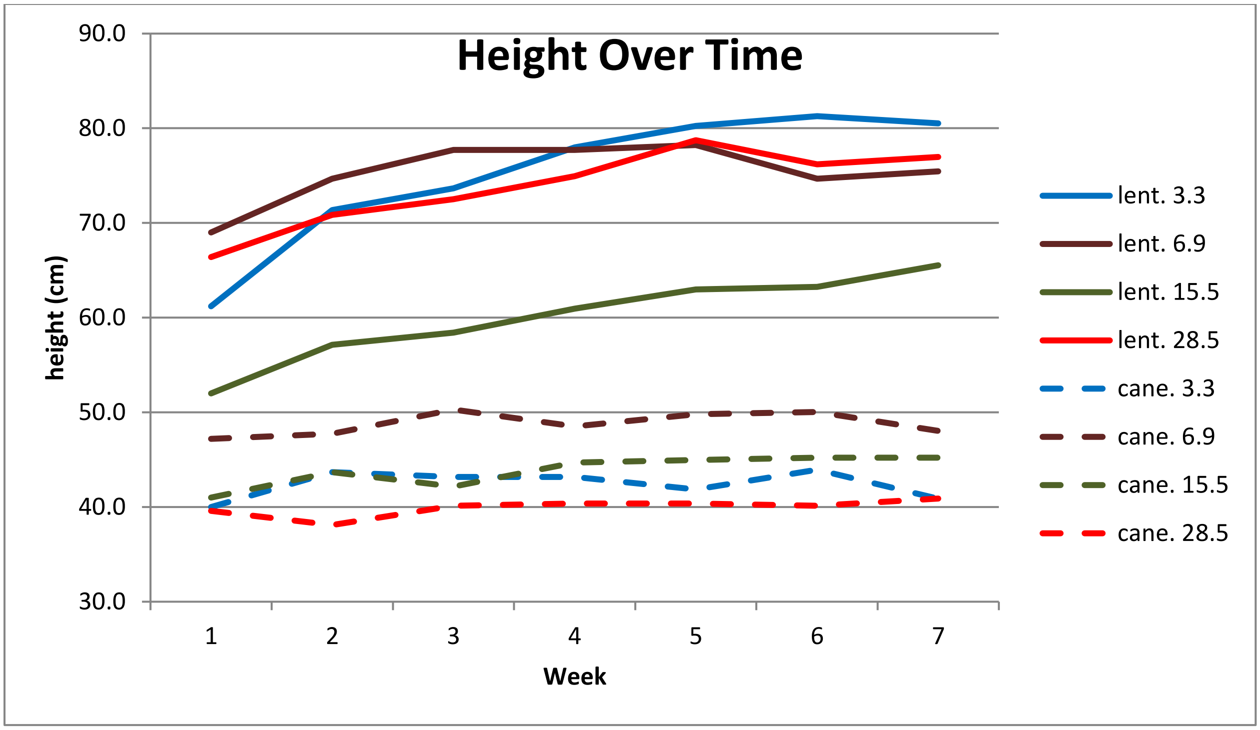
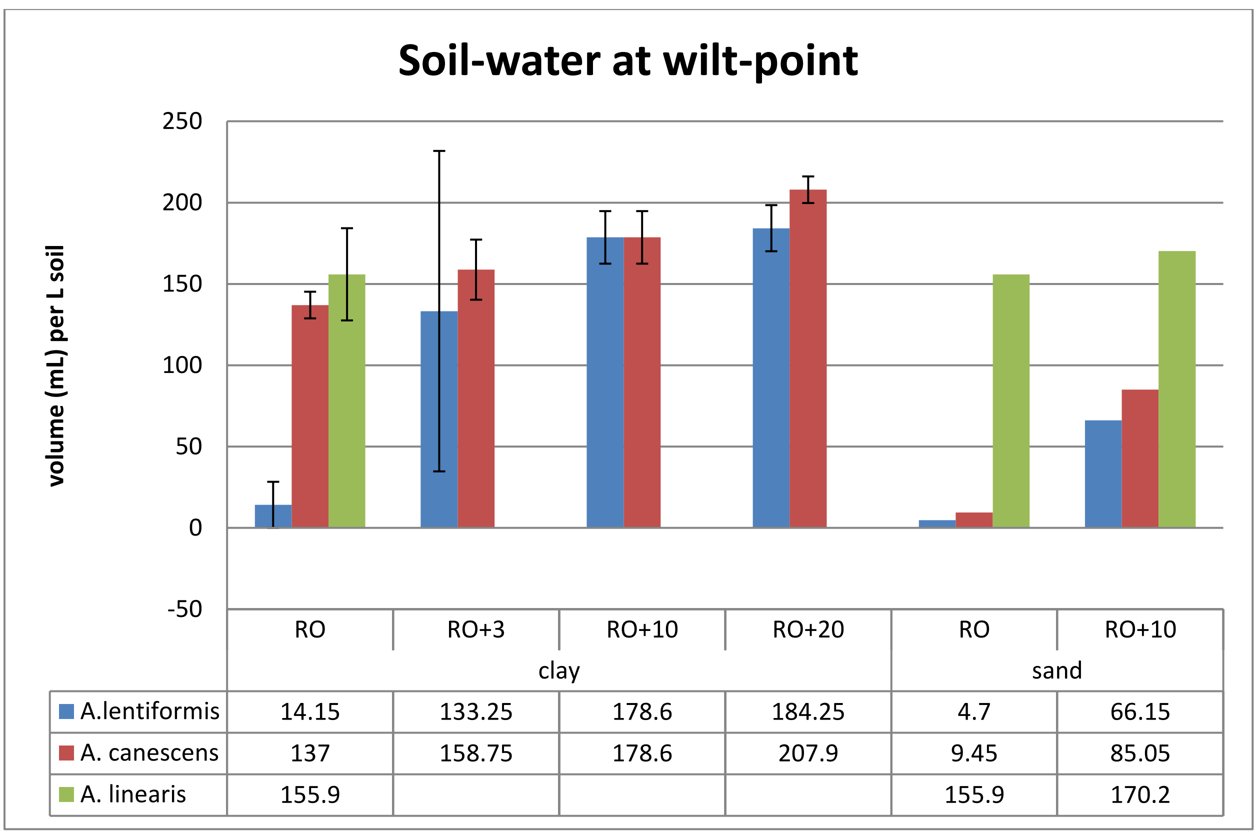


Figure 4. Growth rate of each species for each irrigation salinity in the tolerance study.



	clay				sand	
	RO	RO+3	RO+10	RO+20	RO	RO+10
A.lentiformis	14.15	133.25	178.6	184.25	4.7	66.15
A. canescens	137	158.75	178.6	207.9	9.45	85.05
A. linearis	155.9				155.9	170.2

Figure 5. Volume of soil-water at wilt-point; lower volume indicates higher plant consumption and ability to pull against an osmotic/matrix potential. Error bars are +/- 1 standard deviation.

Discussion

Tolerance: Differences of drainage salinities within groups is what is expected for random sampling ($P>0.05$). This is a good result because it suggests that the experiment resembles what would take place in a field setting. The significance of the difference between groups, both irrigation salinities and species, indicates that differences are true and we have a valid experiment. Maximum salinity (gram NaCl) tolerance of *A. lentiformis* in soil from the BGNDRF field site can be taken as 47.5 g L^{-1} (TDS) and for *A. canescens* it is 42.3 g L^{-1}. The value for A. lentiformis is within range of predicted, 47.3 g L^{-1}. The value for *A. canescens* is greater than the 22 g L^{-1} expected (personal communication with Dr. Ed Glenn). This could be due to the clay structure of the soil being able to bind NaCl provided in the irrigation water, thus removing it from plant available soil-water and with each irrigation event the sodium is exchanged.

Soil EC was not a directly tested variable. We cannot determine EC for optimal plant growth from this in vitro experiment. Field data should elucidate maximum yield. Maximum yield was not investigated, just tolerance. Species maximum tolerance value is where the plant self equilibrates charge potential of the soil-water. It is the maximum potential of soil-water that the species can pull against to extract soil water to keep itself alive, hence, maximum tolerance. A synonym could be tensile strength, where one knows the maximum amount of force (stretch) applied before breakage.

Retention volume pattern shows that at lower irrigation salinity more water is retained. Thus the plant has consumed a greater quantity of water with irrigation of lower salinity. This is reasonable when we consider that the plant is in osmotic competition with the soil for water and that the higher the salinity of irrigation, the faster the osmotic tension increases and inhibits plant uptake so more volume would drain at higher irrigation salinities. Water extraction above the sum of evaporation and drainage is a sign of life, not necessarily health and growth. Field data is required for analysis of yield optimums. The 3.3 g/L curve for A. lentiformis suggests that lower salinity produces faster and sustained growth when soil-water salinity is less saline but it provides no indication that lower salinity supports greater yield over time.

As with the A. lentiformis, A. canescens plant height seems to be merging over time and it is expected that plant height might equalize for all irrigation salinities as soil-water for each test reaches maximum tolerance. This was a short-term experiment, seven weeks. At six weeks we start to see evidence of a merging of plant height. If the experiment had continued, we likely would have eventually seen equal plant height and drainage salinity for all irrigation salinities for both species. This is reasonable when we consider the irrigation salinity-uptake relationship in the soil matrix. We can expect longer growth times with lower irrigation volumes and more growth with less drainage from *A. lentiformis* than *A. canescens* in BGNDRF soil.

Wilt-point: Figure 5 shows that at lower irrigation salinity, *A. lentiformis* and *A. canescens* can extract more water from the soil than at higher irrigation salinity. Both species can extract more water from control sand than BGNDRF soil and *A. lentiformis* has a slightly longer survival time. These results are expected. Results show that *A. lentiformis* consumes more volume which indicates that it can withstand a higher soil-water/matrix potential than *A. canescens*, confirming the higher maximum tolerance of *A. lentiformis*. *A. linearis* showed poor performance in both sand and BGNDRF soil.

Conclusions

Results show that *A. lentiformis* consumes a greater percentage of irrigation and has a higher salinity tolerance than *A. canescens*. When we consider the relationship of maximum tolerance, ability to overcome osmotic potential and increase in volume consumption to decreasing irrigation salinity, we can make predictions of field outcomes; increasing irrigation salinity will increase drainage fraction because it adds more salts to the soil-water which will increase osmotic potential and soil-water will reach maximum tolerance sooner than it will with lower salinity irrigation water. This is the scenario when irrigation salinity remains the same but higher volume is used, assuming deficit irrigation. The leaching requirement is defined as the volume of irrigation water needed in excess of the evapotranspiration rate in order to maintain the field capacity soil-water at the salinity that allows maximum yield. This value is dependent on maximum soil-water tolerance, soil salinity for maximum yield and irrigation salinity. This study provides information on the maximum soil-water salinity tolerance for *A. lentiformis* and *A. canescens* in BGNDRF soil.

RECLAMATION

Managing Water in the West

Desalination and Water Purification Research
and Development Program Report No 181

Using Halophyte Farming to Manage Inland Reverse Osmosis Concentrates

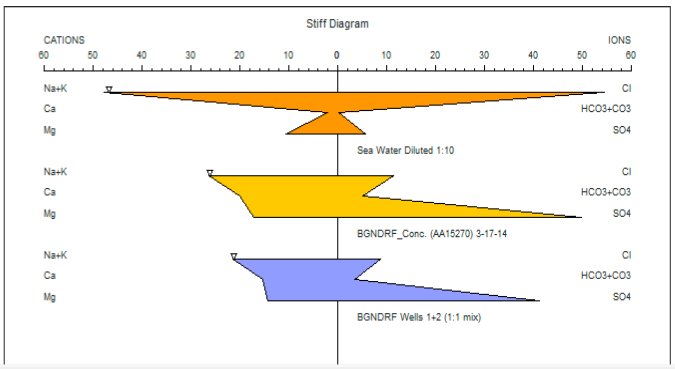
Appendix 14 – BGNDRF Soil Sustainability Report

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2016

RO Concentrate Composition

This section discusses the RO concentrate water quality and its potential impact to soil chemistry and salinity. The RO concentrate used to irrigate the BNGDRF UA Halophyte Research Plots produced from local (Alamogordo) groundwater contains the following minerals and ions: gypsum, dolomite, Epsom salt (*~78% by mass*) (*ions: Ca^{++}, Mg^{++}, HCO_3^-, $SO_4^=$*) and table salt (*~22% by mass*, with *ions: Na^+ and Cl^-*) (see Fig. 1). Therefore, unlike seawater, the RO concentrate salinity is dominated by sulfate, calcium, and magnesium ions; not sodium and chloride ions.



	Sample	Color	Na	K	Cl	Ca	HCO3	CO3	Mg	SO4
1	Sea Water Diluted 1:10		1076	39.9	1935	41.1	14.2	0	129	271
2	BGNDRF_Conc. (AA15270) 3-17-14		603	5.7	404	400	310	0	208	2396
3	BGNDRF Wells 1+2 (1:1 mix)		489	4	311	305	214	0	173	1982
4										
5										
6										

Figure 1. Stiff Diagrams of RO Concentrate and GW.

According to the equilibrium water chemistry model MINEQL+, gypsum and dolomite minerals dominate the chemistry of the RO concentrate. These two minerals are at or near saturation and super saturated with gypsum and dolomite, respectively. Therefore, a significant portion the salts from RO concentrate in the BGNDRF site's gypsic-dolomitic soil (*see section below*) will precipitate in the soil matrix. When the RO concentrate enters the soil environment, gypsum ions remain in solution up to a maximum water solubility of ~*2.4 grams/Liter (g/L)*; whereas dolomite will readily precipitate due to its very low solubility *(~0.08 g/*L). It is the presence of these two types of minerals in the irrigation water that will likely dominate the soil solution salinity even though other more soluble salts are present in the RO concentrate; including magnesium sulfate[1] (*solubility ~400 g/L*) and sodium chloride (*solubility ~380 g/L*). Once dolomite and gypsum precipitate out of the soil solution *(~35% of the total salts*), the remaining salts *(~65%)* of the RO concentrate are expected to increase the soil the soil salinity as measured by the soil saturated paste electrical conductivity method (EC_e).

In spite of the RO concentrate brackish salinity (*TDS ~4,390 mg/L*), the presence of significant amounts of divalent ions like Ca^{++} and Mg^{++} makes this water very hard with a favorable Sodium Absorption Ratio (SAR_{adj} = 7.8) that does not restrict its use for soil irrigation (FAO 1985). It is also important to note that the RO concentrate electrical conductivity (*EC=5.2dS/m*) is relatively low compared to its TDS. Thus, when TDS is divided by EC, the resulting conversion factor is 870, which is much higher than the 640 default conversion factor commonly used for most natural and saline waters dominated by sodium and chloride ions. For example, the EC of water with 10,000 mg/L NaCl is ~17 dS/m and the EC of water with 10,000 mg/L of $MgSO_4$ is ~8 dS/m (Ag. Handbook No. 60). This implies that $MgSO_4$ dominated waters have much lower electrical

[1] Besides Epsom salt ($MgSO_4.7H_2O$) other slightly less soluble or slow to dissolve minerals may be formed in the soil environment in the presence of K, Mg, SO_4 such as Langbeinite (~240g/L), very slow to dissolve in water once formed.

conductivities and therefore ~1/3 lower osmotic potential (pressure) than waters with equivalent amounts of NaCl. Consequently, plants grown with brackish water dominated by $MgSO_4$ ions experience less water stress than plants grown with brackish waters dominated by NaCl ions.

Note: The literature on field and laboratory research on halophyte plants often fails to adequately quantify the nature of the brackish or saline water used and report the salinity levels of the water only in terms of EC or the TDS of the irrigation water and the soil extract EC_e. Salt-induced plant water stress is not only related to water salinity levels but also to the nature of the ions found in the water and soils.

BGNDR Agricultural Area Soil Characterization-Evaluation

This section is based on data from the following sources:

- USDA Soil Survey data
- Soil data from the original BGNDRF soil characterization report of soil samples collected from Trenches #1-7 (USBOR, 201)
- Detailed characterization of Trench #2
- Field infiltration data (NMSU 2014)
- Additional analysis of Trench #2 soil samples (NMSU 3-2015)
- Soil cores near the UA research plots and analyzed by NMSU laboratory (NMSU-9-2015).

Soil Properties and Classification

According to the Otero Area, NM Soil survey (USDA-SCS-FS), the BGNDRF UA Agricultural Research Area *(~5.5 acres*), located in Alamogordo, Otero County, is in or surrounded by soils classified as very fine sand loams to silty loams with varying amounts of calcium carbonate (*up to 30%)* and gypsum (*up to 55%).* The parent materials of these soils are alluvium and/or aolian gypsiferous, sandstone, or shale deposits with up to 3% slopes. The USDA soil survey also indicates that restrictive features (layers) and groundwater are >80 inches deep. The soil salinities can be moderate to strongly saline (8-16 dS/m) and the soils' ability to infiltrate water, measured as saturated hydraulic conductivity (K_{sat}), are classified as moderately high to very high (*0.20-6 inches/hour*). Following a detailed evaluation of the soil minerals and particle size distributions discussed below, the BGNDRF research plots are located in an area with a soil unit named: **AbB-Alamogordo very fine sandy loam, 0-3 percent slopes**.

Based on the preceding description, the rainfall and temperature range of this area, and the mineral composition of the soil profile described below; this soil may be classified as a *Calcic Gypsiorthid* or *Calcigypsid* according to the old and new (after 1975) USDA Soil Classification Systems, respectively, with *Aridic* soil moisture and *Hyperthermic* temperature regimes. Note that in the Continental US gypsiferous soils only occur in Alamogordo region of New Mexico. Worldwide these soils are also uncommon, most countries having ~0.1% similar to the US and China being the exception with ~18%.

Soil Topography

The 2013 Analysis of Soil from the BGNDRF Agricultural Research Area (USBOR, 2014) presents soil data collected from seven trenches in 1-foot intervals, some excavated to a depth of 8 feet. Figure 2 presents an elevation contour plot with soil sampling locations. The figure text offers a more detailed description. The elevation contour lines indicate that prior to grading the site surface was gently sloping *(<3% slope*) from the NE to the SW direction.

Note: It is assumed that trench elevations were measured before the site was graded and the Ag Research area berms and access roads were built.

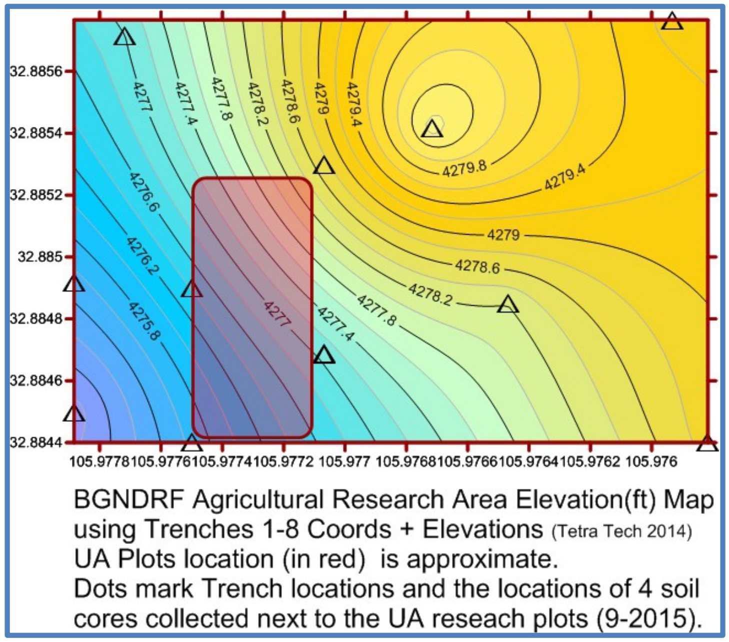


Figure 2. BGNDRF Agricultural Research site elevation changes.

Soil Texture and Infiltration Rates

The physical analysis of soil samples from the seven trenches showed that in general, the soils at this site are heavier (*more clay size particles*) in texture than anticipated from the Soil Survey; ranging from silt loam to clay soils. However, the K_{sat} values from undisturbed soil cores collected in Trenches 1-7 showed values in the range of 0.8-12 inches/hour; in the range of those reported in the Otero Soil survey (USDA-SCS-FS).

Prior to halophyte planting a series of random surface soil infiltration measurements (22 sites) using a tension infiltrometer were taken (NMSU 2014) inside the North and South UA research plots (*area ~1 acre*) located within the red area shown in Fig. 2. The field K_{sat} data values ranged from 0.3-25 inches/hour suggesting a higher spatial variability in K_{sat} values than those observed in the trench soil core data collected from the entire BGNDRF Agricultural Research Area (~5.5 acres). The soil K_{sat} values obtained from these field tests classify the soils as moderately slow to very rapid using the NRCS-BLM soil permeability scale.

Soil Water Holding Capacity

Laboratory soil moisture retention data (NMSU 2014) was collected from 29 undisturbed soil cores taken from Trenches 1-5 to a depth of ~4 ft. The data indicate these soils hold significant amounts of water even at high tensions considered "extreme dry soil conditions". The soil core moisture release data shown from Trench 2 in Fig. 3 is typical of values observed in other soil cores. Average values for all the cores show that the fully saturated soils hold ~47% water (volume/volume), at field capacity (*1/3 bar*) ~30%, at 1 to 3 bars ~21%, and at permanent wilting point (*15 bars*) ~18%. A wilting point water content of 15-20% is typical of clay soils and soils that contain high amounts of gypsum and other hydrated minerals. Note that when plants (common agricultural crops) are at permanent wilting point they may not recover their turgidity upon wetting and die. However, halophyte plants are typically more adapted to high salinity and water stress conditions. Some halophytes grown in saline conditions can sustain water tensions far above 15 bars and survive and grow, such as species of *Tamarix* (*34 bars*) and *Artrocnemum* (*45 bars*) (Waisel and Pollak 1969). Note that the water holding capacity test uses gravimetric moisture (*from oven dried samples @105^{o}C*) measurements and soil field bulk density to determine volumetric water contents.

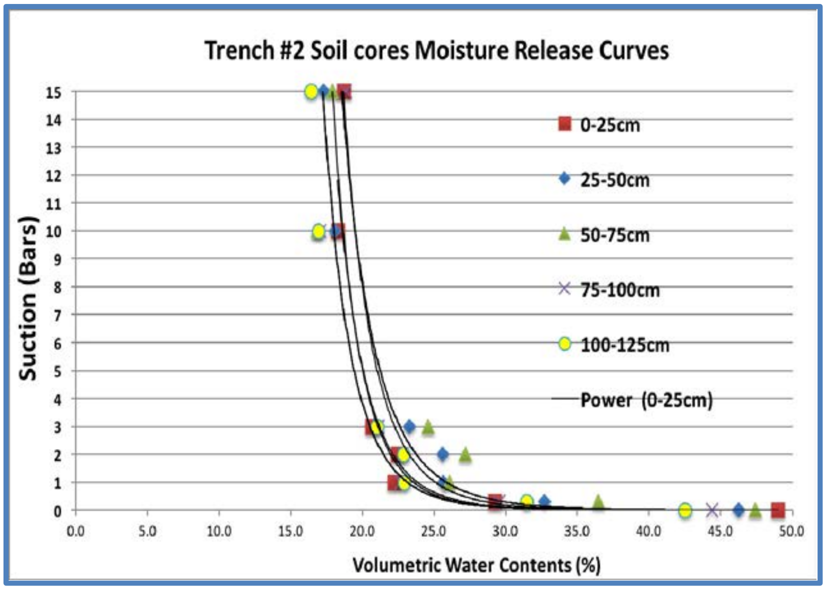


Figure 3. Soil moisture release curves, Trench #2 soil cores.

Since not all of the soils at the site are clay soils (see Fig. 4), it is reasonable to assume that the soil samples high in gypsum (*gypsum has 21% crystalline water that escapes at temperatures above 100^{o}C but not at soil suction tensions up to 15 bars*) also have a significant water content contribution to the water remaining in these soils, even when subjected to 15 bars of tension. Research using hydrogen and oxygen stable isotopes (Palacio et al., 2014) suggests that the crystallized water forms of gypsum in gypsiferous soils is available to plants and may be a significant source of moisture during periods of high water stress. However, is it not known

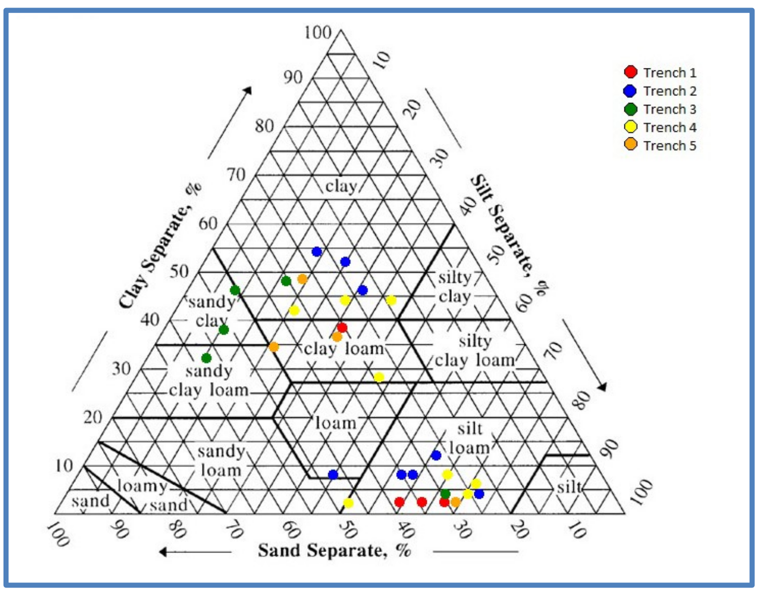


Figure 4. Soil cores from trenches 1-5 textural classification data (NMSU 2014).

whether soil gypsum crystalline water may be plant available under both very dry and highly saline soil conditions.

Soil Chemical Analyses

A complete chemical analysis of the soil samples collected from Trench 2 located in the lower center of the BGNDRF Agricultural Research Area next to the UA research plots indicates that the soil in and around the research plots are gypsiferous with significant amounts of three minerals: gypsum, calcite, and dolomite. Together the mass of these three minerals range between 30 and 65% (see Fig.5). In addition, the soil also contains ~0.3-1.4% table salt in the same profile (*not shown in Fig. 5*). This figure also shows the presence of a zone of calcite accumulation at 90cm (~*3 ft.*), which was also observed in other trenches at 75cm to 120cm in depth (USBOR, 2014). However, the zone of calcium carbonate accumulation is not sufficiently dense or cemented to stop water infiltration. Nonetheless, neutron probe moisture data (see section below) indicates that this layer may restrict water infiltration sufficiently to increase the water content significantly above this layer. Soil

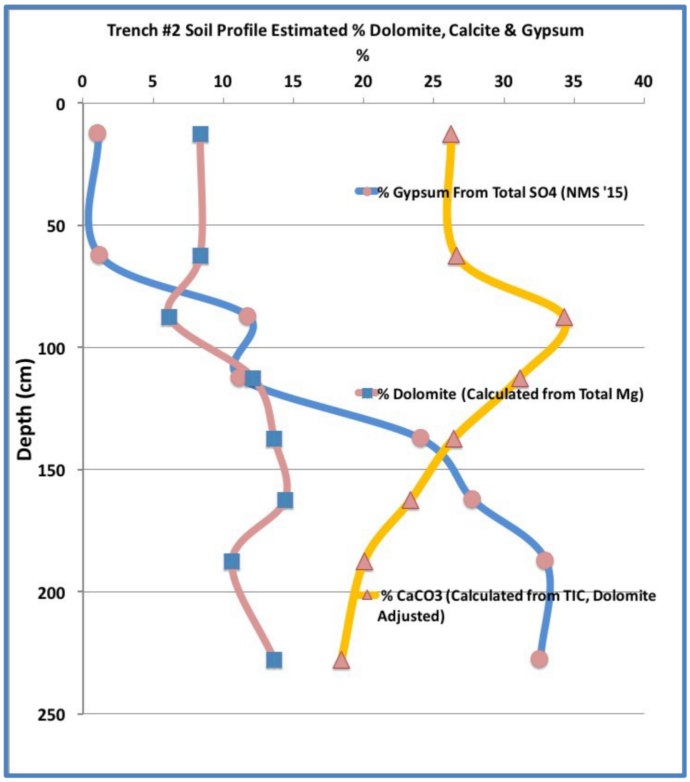


Figure 5. Gypsum, calcite and dolomite content (%) in Trench 2 soil cores.

analysis (*data not shown from USBOR, 2014*) also

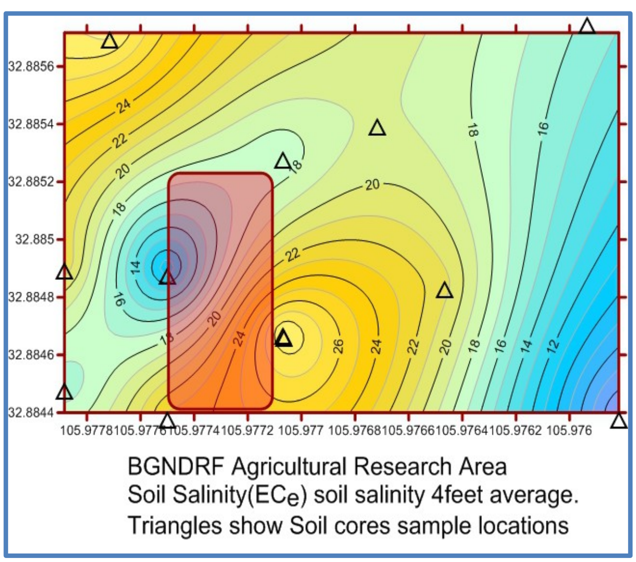


Figure 6. Average soil salinity (as ECext dS/m) 0-100cm depth.

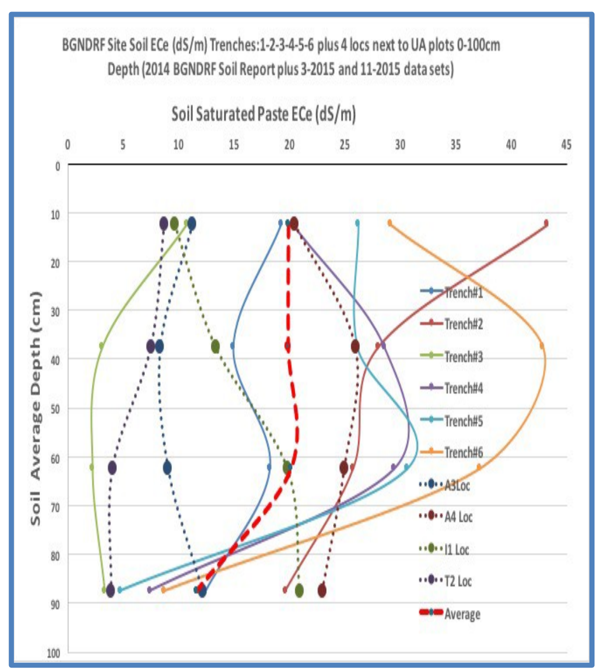


Figure 3. Soil salinity profiles of Trenches 1-6 and four soil cores sets of samples collected 0-100cm depth.

indicates that the background concentrations of sodium were significantly higher in soil samples collected above the calcium carbonate layer than below.

Soil Salinity

Prior to the start of the UA halophyte research project, soil saturated paste extracts salinity data (as EC_e) was collected from seven locations within the BGNDRF Agricultural Research Area and at 4 locations adjacent to the UA research plots (Fig. 6). This salinity contour map shows that the average soil salinity contour lines within the top 4 feet of the soil is strongly saline, ranging from 10-28 dS/m with an overall (site) average of 20 dS/m in the top two feet (Fig. 7). Therefore, these soils contain significant amounts of soluble salts in their natural state, which are spatially highly variable at relative short distances (Fig. 7). For example, the individual soil core data values of the 12 sampling locations collected to a depth of 4 feet show a range of EC_e from 3 to 43 dS/m. To date, soil core samples have not been collected within the UA research plots to prevent disturbing the ongoing halophyte experiment.

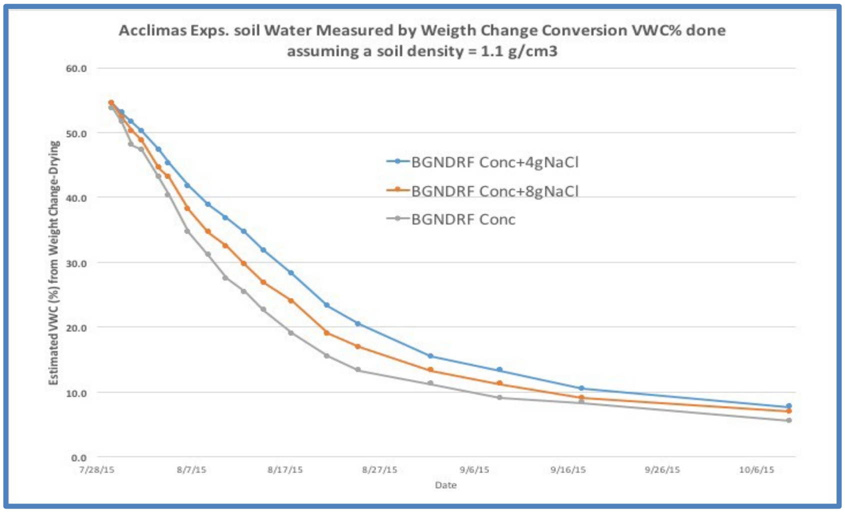


Figure 8. VWC% estimated using soil weight changes over time.

Soil Moisture Content

Two rows of Acclima TDT Sensors (15) were installed within 20 feet of the access road in the north and south UA research plots at every foot to a depth of 4 ft. to measure soil moisture content and soil salinity changes prior to the start of the experiments. According to the manufacturer, Acclima sensors TDT measure soil permissivity and convert it to volumetric soil water content "independently" of soil salinity. However, the behavior of these sensors under highly salinity conditions was not fully understood. (*Note: soil VWC% is also being measured at the UA-research plots using a neutron probe, discussed below*). Therefore, laboratory studies were conducted to test the behavior of these sensors under simulated field conditions and at different moisture and salinity conditions. Three sets of Acclima probes were buried between two 3-inch layers of BGNDRF soil and subjected to different moisture and salinity conditions. Data from the Acclima digital probes was collected with the aid of a Campbell Scientific 23X datalogger. Figures

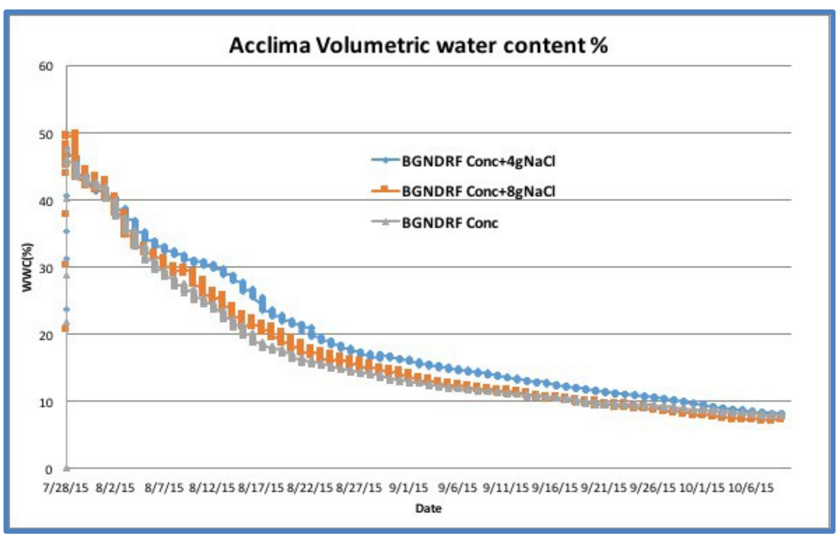


Figure 9. VWC% measured using Acclima Sensors.

8 and 9 show the behavior of the Acclima probes during a wet-dry cycle following soil flushing with 6 liters of water with the following salinities: 5.8, 8.0 and 4.1; blue, red and gray curves, respectively.

Figure 8 shows the change in VWC% as the BGNDR soil dried for a period of 3 months under laboratory conditions (22-25°C). Note that excess water was passed through the soils to rinse other soluble salts present and to "equilibrate" the soil with the three different water salinities. Although the soils inside each bucket dried at somewhat different rates, the drying trends are closely paralleled. Figure 9 shows the Acclima probes recorded data from each bucket. Other studies suggest that Acclima probes need to be calibrated for each soil condition. Our data indicates that the Acclima probes can measure soil moisture to within 3-5% moisture change independently of the soil salinity (*See soil salinity measurement next paragraph)*. Figure 10 shows combined correlation of the data shown in Figs. 8 & 9. The expanding nature of the soil produced large soil density changes during the experiments which could not be recorded. Thus, a soil bulk density of 1.1 g/cm^3 was used to convert gravimetric water content changes to volumetric water contents as shown in Fig. 8. Note that the high R^2 of 0.997 and the slope is less than one. This is because the VWC% measured by weight used a fixed soil bulk density that resulted in an overestimation of the VWC% at the beginning of the experiment and an underestimation that tilted the slope of the line.

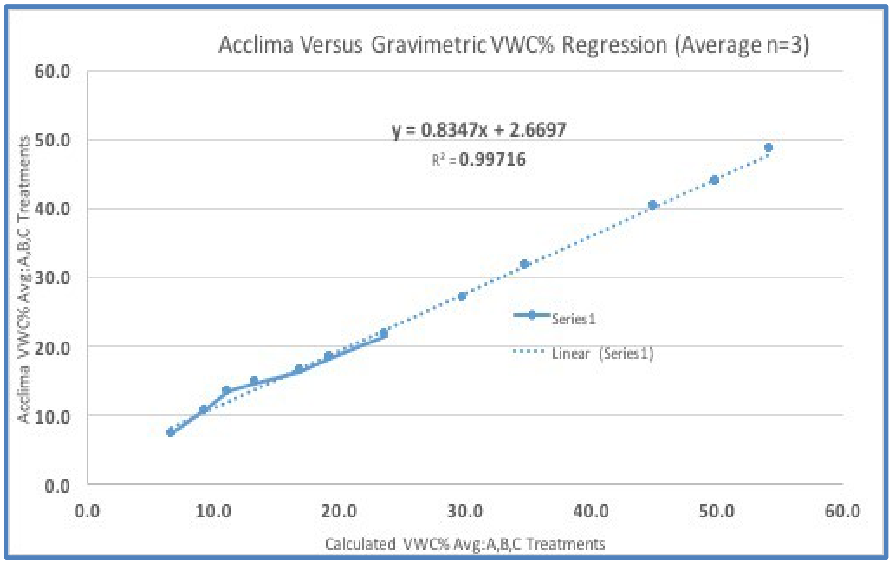


Figure 10. VWC% Correlation between Acclima sensor and Gravimetric measurements. Avg: Treatments-A,B,C.

The Acclima TDT probes also measure soil salinity as EC. However, the sensor EC data cannot be readily converted to soil EC_e since this is usually measured at a constant soil moisture content and is depended on the varying solubilities of soil minerals. Figure 11 shows the Acclima soil salinity measured concomitantly with the soil moisture contents shown in Fig. 9. It can be seen that the Acclima probe initially (*under near soil water saturation conditions*) recorded EC values close to the expected soil salinities: the highest EC being in the BGNDRF concentrate spiked with NaCl, 8.0 dS/m and the lowest, 4.1 dS/m. The separation between the soil leached with saline water became less obvious as the soils dried (Fig. 11). Furthermore, all Acclima probes showed that soil EC decreases with soil water content, which is not possible since salt content tends to stay the same or accumulate in soils as they dry. Therefore, this probe cannot reliably be used to measure or estimate EC_e (saturated soil paste EC) under field conditions. However, Acclima TDT probes may be used to estimate[2] initial soil EC immediately following irrigation when soils are at or near water saturated conditions, and only relative changes in EC as the soil dries. The probes consistently recorded the lowest soil salinity in BGNDRF concentrate water without NaCl and higher salinities in soils with BNGDRF concentrate spiked with 4 g/L and 8 g/L NaCl, respectively, as the three soils dried. Thus, this probe may be able to provide estimates of “relative” changes in soil salinity over time.

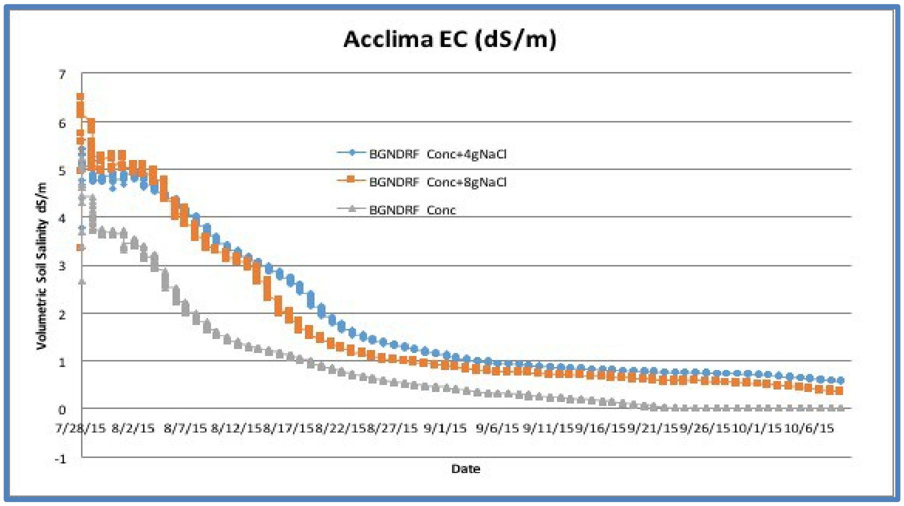


Figure 11. Soil EC measured using Acclima probes.

Since Acclima probes are set to record VWC% and salinity every hour they can provide an early warning if large soil salinity changes occurring during the halophyte field experiment without the need of collecting and analyzing soil cores. However, their EC range and soil zone of influence are limited[2].

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[2] According to the manufacturer the Acclima probe may not measure soil EC values above 9 dS/m. Our laboratory studies suggest that this threshold me be variable ranging between 6.5 and 8. According to the manufacturer Acclima sensors can only detect moisture/salinity changes within a 0.5 to 1inch radius along the metal probes.

Salt Balance

Estimates of the total amounts of salts in the soils at the site were calculated using an extensive soil core data set from Trench 2. Figure 6 shows the amounts of three minerals, common in the soils at the site, calculated using additional analysis of inorganic carbon, chloride, and sulfate ions not included in the USBOR (2014) report. Figure 6 does not include the mass of table salt in the soil profile. However, Fig. 12, shows the estimated masses of two groups of ions present in gypsum, calcite, and dolomite, and then in table salt. Note that a $\log_{10}$ X-axis scale was used to highlight the different masses between the first and second group. When integrated to a depth of 9 ft., the soils of Trench #2 contain ~14,000 Metric tons/hectare (MT/ha) of the first group of ions and about 220 MT/ha of NaCl.

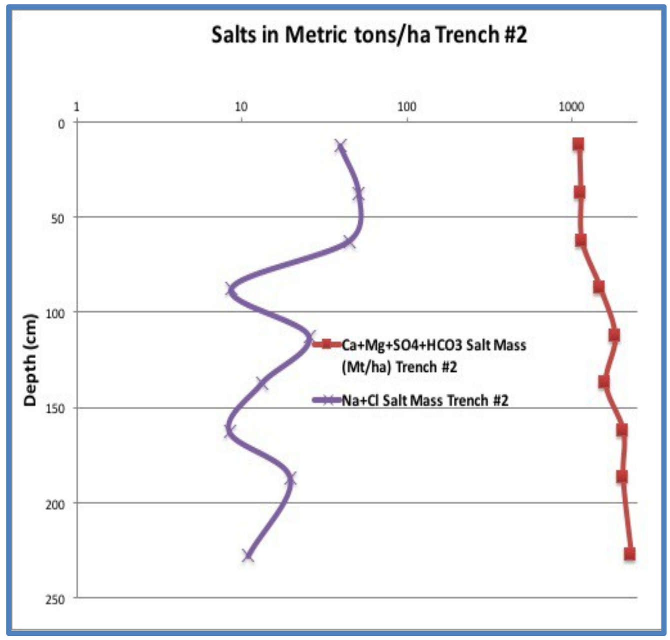

Figure 12. Mass of salts 0-8ft depth Trench 2.

According to our irrigation model calculations, at maturity, the irrigation of the halophyte plants with RO concentrate will add about 26[3] Metric tons/hectare of salts annually to the soils at the site. Using the total mass of salts shown in Fig. 12 and assuming that salts will not leach below 9 ft. (2.5 meters), it may take about 13 years to double the amount soluble salts like NaCl + $MgSO_4$ in the soils and potentially doubling the soil EC_e. Significant amounts of gypsum and dolomite minerals will also be added (~9 MT/ha) but these will precipitate out of solution without changing the soil salinity significantly. However, it cannot be known exactly how these salt additions will affect the soil water extract salinity measured as EC_e since there may be other mineral phases that form, precipitate, and re-dissolve as the soils wets and dries that were not taken into account when calculating the masses of minerals shown in Fig. 6. Given the large spatial variability in the salt content of the soils at the site described earlier (see Figs. 5 & 6) it is difficult to anticipate any adverse effects to the halophyte plants growing in the research plots, since plants will be

[3] This value is similar to the actual 2015 year water application rates.

continuously drip irrigated with RO concentrate that will maintain the salinity within the root zone at levels that will be lower than the average EC measured at the site (see Fig. 7).

Green house studies recently completed using BGNDRF soil and the two *Atriplex* species; *A. lentiformis* and *A. canescens* indicate that the maximum soil-water salinity tolerances of these halophyte plants are 48,000 mg/L and 42,000 mg/L, respectively (Bresdin & Glenn 2016). Since these experiments were conducted using RO concentrate spiked with 3-20 g/L of NaCl, the two soil salinity tolerances are equivalent to soil EC_e values of 75 dS/m and 66 dS/m, respectively. These values are ~3.5 times greater than the average soil salinity measured at the site (see Soil Salinity section), which prior to the beginning of the experiment averaged about 20 dS/m and ranged 3-43 dS/m in the top 4 ft. However, the greenhouse results show that plants will grow more at low irrigation water salinities as they are able to use more water (less osmotic pressure) than at higher water salinities. Thus, under a fixed irrigation regime, as irrigation water salinity increases so will drainage water volume and its EC. Low irrigation salinity water (high plant water intake) will lead to faster accumulation of salts and will also require more irrigation (excess) water to prevent excessive salt accumulation in the soil. This progressive salt accumulation could be managed with periodic applications of excess water to temporarily increase the drainage water volume to flush salts below the root zone.

In conclusion, the initial soil salinity (average) at the site may double in 13 years to 40 dS/m with the present RO concentrate salinity and irrigation regime (*and observed soil profile movement, see next section*). This projected increase is still far below the maximum soil salinity tolerance of the *Atripex* plants being grown at BGNDRF. Green house studies indicate that the two *Atriplex* species are very salt tolerant but their water use and growth rates are inversely related and are dependent on irrigation water salinity. If the RO concentrate salinity remains constant, the rate of salt accumulation in the soil profile will depend on the irrigation regime, which will have to be selected to balance plant yield (growth) and salt leaching below to root zone.

Neutron Probe Calibration

A soil site-specific neutron probe calibration using soil samples from the UA research plots at BGNDRF was conducted. To this end, four soil cores sets of samples were collected at one-foot intervals to a depth of 6 feet at four locations adjacent to four neutron probe access tubes. Sealed soil samples were taken to the laboratory for gravimetric moisture content determinations after oven-drying at 105^oC and neutron probe counts were measured near the time of sampling. Soil volume water content (VWC%) versus neutron probe counts showed a large variability and very low R^2 for one of the four sets of soils. The following regression equation

$$VWC\% = 0.1966 \times counts + 0.0361 \qquad (r^2=0.56)$$

was obtained using the remaining three sets of soil cores. The low correlation factor can be explained by the fact that the soil properties at the site, especially mineral composition are spatially highly variable (see Fig. 5) and inter-layer soil mixing occurred during the difficult coring process. This equation was modified using the gypsum content measured in the soil cores from Trench 2 (see Fig. 5) and a correction factor that incorporated soil gypsum (%) was added to the calculated WVC% equation shown above. This correction factor *(–0.1004 x gypsum (%) – 0.0034*) was derived from research on gypsic soils by Arsland & Razouk (1994), which show that neutron probe counts are significantly affected by the presence of gypsum in soils.

Soil Water Content-2015 Field Data

The VWC% has been monitored since the start of the halophyte planting in November 2014 using an extensive network (39 sites) of 9-ft deep access tubes (Fig. 13). The figure shows the approximate irrigation lines locations and contour lines showing an example in time of the moisture distribution at the site at a depth 8-9 feet. The VWC% range is 5-25%, that is inclusive of all range of values recorded monthly by the neutron probe during 2015. Figure 14 shows the contour lines of VWC% at three depths: 0.5, 2.5 and 3.5 feet, from January to December 2015. We can observe that in general, the moisture content is higher at 3.5 than 2.5 feet for all months of the year, particularly during months of high plant demand and higher irrigation rates; May through August. Figure 15 contrasts the soil moisture contents of the plots at 4.5, 6.5 and 8.5 feet of depth and here the trend is reversed; that is, the soils are much dryer at 8.5 feet than at 4.5 feet depth. This suggest that the irrigation water is not moving below the 3.5 to 4.5-foot depth, probably part due to the presence of an enriched layer of calcite present in the soils that slows down the water

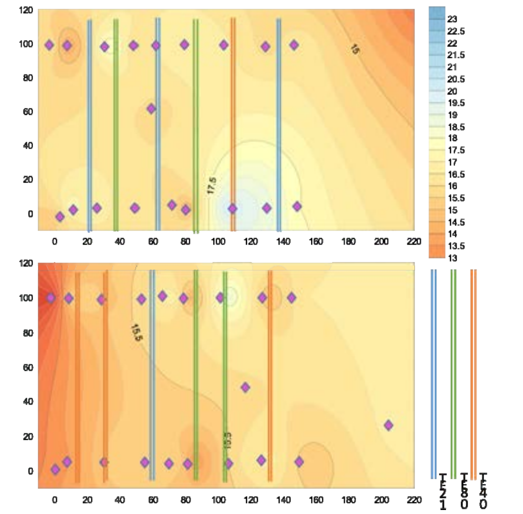

Figure 13. Contour plots at 8-9ft depth of the %VWC for both North and South fields in March 2015 with approximate locations of the irrigation lines that are color-coded for the three different irrigation rates and pink diamonds approximately locating the neutron probe ports.

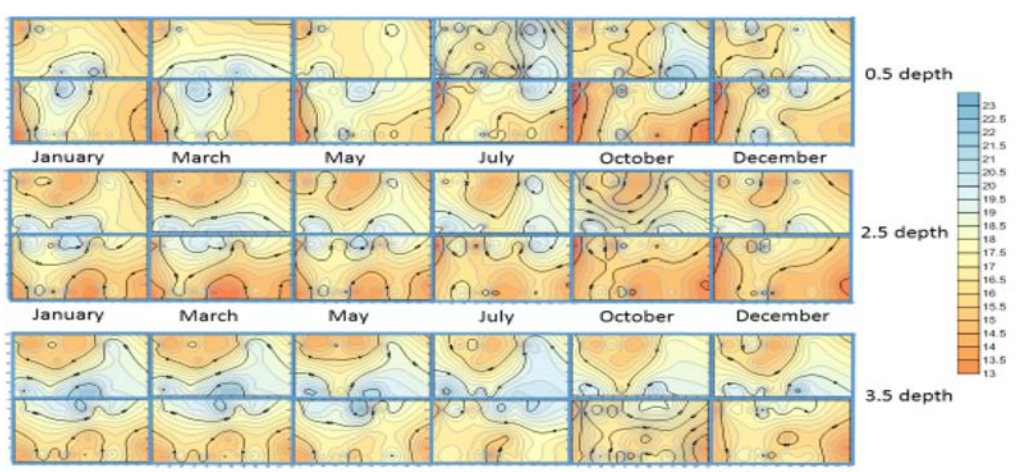

Figure 14. Contour plots of VWC% in 2015 comparing depths at 0.5, 2.5 and 3.5 feet.

movement as previously discussed. We can also observe that in general the soil profile became drier at all depths during the January to December 2015 months. This may be due to the fact that prior to planting in the summer of 2014 the plots were flooded with up to 4 inches of water to facilitate weed removal and to reduce surface roughness. However, this amount of water would have wetted the soil profile only to up to a depth of about 3 feet in a typical clay soil. Overall, the observed vertical changes and temporal trends in VWC% in the soil profile indicate that no significant amounts of water moved below the 3.5-foot depth in 2015.

In general, the soil profile is moderately wet at a depth of 3.5, dryer at 4.5 feet, and extremely dry at 8.5 ft. since most VWC% values shown in Figs. 14 and 15 range between 12 and 20%. Therefore, this indicates that the water is being held at tensions that range ~3 bars (*blue contour areas*) to >15 bars (*brown contour areas*), using Fig.4 soil moisture release curves as reference.

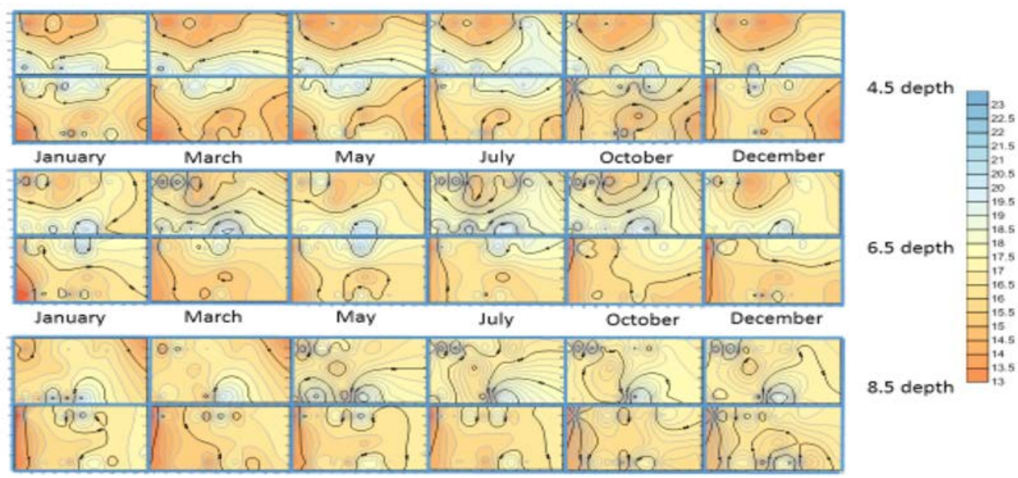

Figure 15. Contour plots of VWC% in 2015 comparing depths at 4.5, 6.5 and 8.5 feet.

Figure 13 shows the three drip irrigation treatments presently being used at the site to determine optimum halophyte plants water requirements as measured by a reference evapotranspiration (ET_o). To this end, at the start of the research, three irrigation regimes were selected based on a halophyte plant ET_o previously determined from halophyte field experiments in Marana, AZ (Glenn et al., 2014?); these being 0.4, 0.8 and 1.2 ET_o. Therefore, during 2015, the halophyte plants growing at the UA research plots received an average of 0.8 ET_0 of their estimated water requirements. If the initial (base) ET_0 used in this field research was correct, then is reasonable to conclude that on average all of the RO concentrate water applied in 2015 could have been used by the plants' ET demands. Since the average ET_o used is 0.8 not 1.0, this could also explain the temporal drying trend of the soil at the site. Note also that the three irrigation water treatments were randomized (see Fig. 12). These uneven water applications coupled with the spatially variable soil textural changes discussed previously, may be reflected in the varying and uneven soil moisture content distributions shown in Figs. 14 and 15.

In conclusion, monthly neutron probe measurements collected to a depth of 9 ft. do not show any evidence of soil moisture conditions in the plots that would indicate gravitational water (*water held at or less than 1 bar tension*) is present below 9 feet, precluding water or salt migration below this depth. However, soil profile VWC% distributions may change as plants grow and an optimum plant and site-specific ET_o is selected that could increase irrigation requirements to maintain optimum halophyte yields.

Soil Channeling

Water can drain through soils bypassing the soil matrix (micro and macro pore) when large cracks, fractures or cavities exist in the soil that can facilitate the rapid movement of water. In most soils the slow application of water (irrigation or rainfall) results in the progressive saturation of micro pores first and then macro pores that eventually saturate the entire soil matrix. Eventually, water movement reaches a steady state as soil erosion through macro pores stabilizes and cracks close. However, soil channeling can occur when water is applied quickly to a dry soil (flooding). Preferential flow can continue and increase through any existing large pores, cracks or cavities that continue to erode rather than close. Note that the poorly structured, fine textured gypsiferous nature of the soil at the site, see **Soil Properties and Classification** section, makes it prone to erosion and channeling. In addition, the significant trenching activities that took place during the installation of the drain pipes and sensor cables also contributed to the formation of subsurface cavities.

Surface sink holes that indicate soil channeling were observed at several plot locations during periods of unintended soil flooding (monsoon season). This resulted in the collection of large volumes of water from some drain lines installed as the site 4 feet below the surface. From September 2015 to June 2016 soil "drainage" water was collected from 2 to 4 of the 26 drain lines following each of four monsoon flooding events, see Figure 16. The salinity of the drain water ranged from 0.11 to 4.5 dS/m with an average and standard deviation of 1.9 ($\pm$1.21) dS/m. The EC of the drain water never exceeded that of the irrigation water, this being 5.2 dS/m. This indicates that the drain water from the drainage pipes installed at 4 feet did not collect any excess irrigation water since irrigation drainage water salinity must be equal to or (more likely) exceed irrigation water salinity. This is evidence that any water collected at the culverts was from rainfall flood events that caused soil surface failure (and subsurface channeling) often observed after flood events as shown in Figure 17.

Figure 16. Culvert drain buckets following a flood event. Note full to near empty buckets.

Figure 17. Soil surface failure showing deep channeling following a flood event.

Summary

- The RO concentrate used to irrigate the UA halophyte research plots is classified as a saline water with a TDS of 4,400 mg/L and its chemical composition is <u>similar to the soils</u> at the site. The RO concentrate contains gypsum, dolomite, and magnesium sulfate (~*78% by mass)* and table salt *(~22% (by mass*). Therefore, given that the soils and the site and the RO concentrate have similar chemistries, in the short term the RO concentrate will not change the nature of the existing soils or pose a significant threat to the existing brackish groundwater quality below the site.

- The UA halophyte research plots in the Alamogordo, NM BGNDF Research Facility, are located within a one-acre area with soils, previously undisturbed (*except for areas located within a former landfill*), that are heavy-textured ranging from clay loams to clays, containing a large fraction *(~30-65% by mass*) of minerals such as gypsum, dolomite, calcite, and much smaller (~1%) but significant amounts of table salt. In their native state these soils are classified as saline with EC_e averaging 20 dS/m (top 4ft.) with a range ~3-43 dS/m. The soils at the site can be described as being strongly saline are above a potentially water restrictive calcite accumulation layer located around 4ft. (90-120cm) depth. Below this layer the salinity is moderate with very high concentrations of gypsum and other minerals.

- The water infiltration of the soils at the site are moderately slow to very rapid and this is not expected to change significantly with RO concentrate irrigation in the short term. This is because of the similarities in ion compositions between the soil and the irrigation water. In Addition, the SAR of the RO concentrate is 7.8, classified of unrestricted (<u>*given that its EC is 5.2 dS/m*</u>). Whereas the soils (*in their natural condition*) are strongly saline with SAR values ranging between 1 and 21 in the top 4 ft.

- Laboratory studies showed that the Acclima sensors installed at the site can provide precise continuous soil moisture data down to 4 ft. but they are no substitute for the more extensive network of neutron probe access tubes located within the UA research plots designed to measure soil moisture to a depth of 9 ft. These probes can act as an early warning system to detect relative increases in salt accumulation in the soils at the site as their responses are positively correlated to changes in soil salinity particularly at or near soil saturation (field capacity) conditions, but they are no substitute for EC_e measurements from soil samples.

- Soils at site contain ~14,000 MT/ha at 0-2.5m depth of salts including: sulfate, calcium, sodium, chloride and carbonate. Using a site-specific irrigation model estimate salt input when plants reach maturity the soil at the site will receive ~26 MT/ha of salts annually, which could double the amount of <u>soluble</u> salts now present at the site in about 13 years if no salts leach below 9 ft. (2.5m). Greenhouse studies have determined the threshold salinities of the halophytes now being grown at the UA research plots and these are ~3.5 times higher than the average soil salinity at the site. Thus, it should take more than a decade to reach average soil salinities close to the halophyte tolerances determined in the greenhouse studies. A balance between irrigation water volume, maximum soil salinity, minimum plant yields, and drainage water quality/volume will have to be determined based on economic and environmental considerations.

- Soil moisture data collected monthly in 2015 from 39 neutron access tubes located in and around the UA research plots indicate that the soil profile is drier above and below an existing calcite zone of accumulation (layer) located 3 and 4 feet below the surface. Under the present irrigation regime this layer may be slowing or retaining water sufficiently to preclude significant amounts of water and therefore salts from moving below the monitored depth of 9 feet. A soil drying trend can be observed January to December at several soil depths, suggesting that presently there is an irrigation deficit (*water applied* < *plant water demand*). The BGNDRF groundwater is not expected to be impacted in the near future using present irrigation management practices.

- Soil channeling was observed at several plot locations during periods of unintended soil flooding (monsoon season) resulting in the sporadic collection of water from some drain lines 4 feet below the surface. This was attributed to the nature of the local soil and extensive trenching during construction.

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RECLAMATION

Managing Water in the West

Desalination and Water Purification Research and Development Program Report No 181

Using Halophyte Farming to Manage Inland Reverse Osmosis Concentrates

Appendix 15 – UA Research Update

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

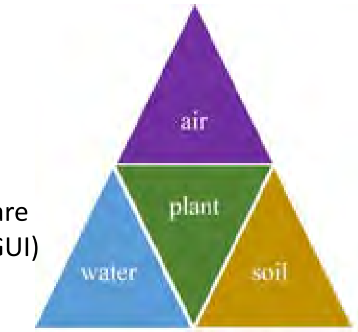
November 2016

Model

In terms of dynamics

- Mathematical construct of relationship algorithms
  - Simple: one system aspect in equation form
  - Complex: multiple aspects in network form
    - Spreadsheet(s) or other coding software
    - Package with graphic user interface (GUI)
- Algorithms based on site specific parameters
  - Calibrated with data from negative control
- Algorithm variables based on user input of values
  - Validated by collected field data

Dynamic mass balance predictive model, developed by Cylphine Bresdine, graduate student, under the supervision of Dr. Ed Glenn, University of Arizona



$$(\emptyset + \varphi)^n = \sum_{k=0}^{n} \binom{n}{k} \emptyset^k \varphi^{n-k}$$

Ø = hydrualic head
ρ = osmotic potential

Groundwater Protection:

One component of this study is to protect local groundwater aquifers from infiltration of the RO waste concentrate due to the surface application as irrigation. A subsurface drainage system with drainage monitoring stations was installed to intercept excess irrigation. In addition, soil moisture throughout the planting area will be monitored using two techniques: a neutron hydroprobe, with measurements to a depth of 10', and digital soil moisture sensors, with measurements to a depth of 4'.

Bob Seaman, Research Technician (left) and Ryan Furcini, graduate student (right), University of Arizona, drilling data port holes for neutron hydroprobe readings

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US Bureau of Reclamation, Desalination and Water Purification Research and Development Program (DWPR)

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March 2015

University of Arizona

Research Update

Reverse Osmosis Concentrate Management through Halophyte Farming

- A Pilot Project sponsored by the Bureau of Reclamation
- Agreement No. R13AC80023; 10-1-13 through 9-30-15

Introduction

Increasing Water Shortages in the Arid Southwest

Population growth in arid regions of the world is resulting in increasing demands for potable water. Expanded agricultural production and increased aridity due to climate change will accelerate the shortage of freshwater supplies in the Southwestern US. While some aquifers are naturally saline, groundwater in many arid areas is becoming increasingly higher in salinity due to the agricultural irrigation practice known as 'leaching'. Under this practice, a surplus of irrigation water is applied to push salts in the soil downward rather than accumulating in the crop root zone. Groundwater that is higher in salinity is limited for use as a source of drinking water, and can also result in reduced agricultural productivity when used for irrigation.

Municipalities in the southwestern US are increasingly turning to inland Reverse Osmosis (RO) as a means of reducing the groundwater salinity to meet potable water demands. RO processing results in a high salinity waste concentrate stream, and options for concentrate disposal is limited in inland locations. Up to a third of the total cost of inland RO facilities involves the environmental permitting, management and disposal of the waste concentrate produced during the desalination process (Ahmed et al. 2001; Elsaid et al. 2012). Affordable and sustainable concentrate management strategies are needed for desalination to be a viable means of providing potable water for municipalities in the future.

This pilot research project, sponsored by the US Bureau of Reclamation's Desalination and Water Purification Research and Development Program, evaluates the cost effectiveness and technological efficacy of using RO waste concentrate to grow and irrigate halophytes (salt-tolerant shrubs) as an alternative to conventional concentrate management and disposal options. Two species of *Atriplex* – a shrub native to the arid Southwest – were selected for evaluation. An additional component of the research examines the potential market for the biomass of *Atriplex sp.* to evaluate long-term halophyte production as an agro-economic crop.

Project location: Brackish Groundwater National Desalination Research Facility Alamogordo, NM
Photo credit: New Mexico State University

What is a halophyte?

Halophytes are salt-tolerant plants that have developed mechanisms in their roots, shoots and leaf cells to filter, sequester, and/or discharge salts, allowing them to thrive naturally in salt-affected soils. They also grow well when irrigated with brackish water (see Table 1). Two halophytes native to arid areas of the southwestern US are being evaluated in this experiment: *Atriplex canescens* (Fourwing Saltbush) and *Atriplex lentiformis* (Big Saltbush). Mature *Atriplex canescens* are growing near the Agricultural Area at BGNDRF.

Atriplex canscens (Four wing salt-bush) in full seed production

Atriplex lentiformis (Big saltbush)
Photo credits: Mountain States Nursery

Joanne Gallaher (UA), Taylor Morrell and Kim McCuistion (Texas A&M – Kingsville) with an existing *Atriplex canescens* at BGNDRF

Planting *Atriplex* sp. seedlings at BGNDRF

How is water salinity measured?

Salinity in groundwater relates to the amount of dissolved minerals (solids) it contains. Dissolved solids vary in both make-up (e.g. calcium, magnesium, sodium, carbonate, chloride, sulfate, and nitrate) and in concentration levels. These constituents are often expressed as Total Dissolved Solids (TDS) in milligrams per liter (mg/L) or parts per million (ppm). Generally, water that is higher in salinity than drinking water but lower than seawater is referred to as *brackish water*.

TABLE 1

Water classification	TDS range in PPM (or mg/L)	(TDS in percentage)
Fresh water	1-1,000*	.0001% to 0.1%
Brackish water	1,000-10,000	0.1% to 1.0%
Saline water	10,000-35,000**	1% to3.5%
Brine	>35,000	3.5%+

* The EPA recommendation for drinking water is a maximum of 500 mg/L TDS.
** Sea water is approximately 35,000 ppm TDS

Reverse Osmosis

Reverse Osmosis (RO) is a membrane-based process developed to treat brackish and saline water so that it can be used as a source of drinking water. RO processing, which is being used on this experiment, operates by applying sufficient pressure on the feedwater (salty) side of the membrane to force only water molecules through the membrane to the fresh water side, thus reversing the osmotic process. RO membranes permit very little passage of dissolved salts so that the RO finished water TDS is much lower than the feedwater TDS.

RO is performed at different recovery rates, with the percent recovered describing the desalted permeate. For example, an 80% RO recovery rate produces 80% 'good' water, and 20% 'waste' concentrate. The waste concentrate generated during the RO process at BGNDRF is collected and used as irrigation water for this concentrate management experiment. The typical TDS of the waste concentrate produced through RO processing of brackish water ranges from 2,000 to 40,000 mg/L – see Table 2 (AWWA 2007). The waste concentrate used on this experiment is approximately 4,060 TDS, using a 30% RO recovery rate. Note that this is a lower recovery rate than standard, as in this situation, the goal was to maximize the volume of concentrate rather than the volume of permeate.

Project Location: Brackish Groundwater National Desalination Research Facility, 500 Lavelle Road, Alamogordo, NM 88310

Several municipalities in the southwestern US have installed inland RO facilities, including Gila Bend, Arizona and El Paso, Texas. A new RO facility is also being planned for Alamogordo, NM. Because of the high cost and environmental impacts of conventional concentrate management, alternative management options are needed. This project is evaluating halophyte farming as a lower cost alternative to manage RO waste concentrate with reduced environmental impacts.

Feed Water and RO Concentrate

Brackish groundwater in the Tularosa Basin, New Mexico

The Tularosa Basin of southern New Mexico is a hydrologically closed basin with groundwater generally increasing in salinity from the outer edges, where fresh water infiltrates at mountain fronts, to brine water at interior evaporative discharge areas (see Table 1 for salinity terminology) (Fryberger 2001; Huff 2004). The City of Alamogordo, at the eastern edge of the Tularosa Basin, has a history of fresh surface water availability through discharge from the Sacramento Mountains. Surface water supplies have historically been supplemented with groundwater; however, periods of severe drought have reduced surface water reliability. Increased groundwater pumping over time has resulted in water quality decline throughout the region. Desalination of brackish groundwater in the basin can help protect surface water quality by capturing the poorer quality water before it migrates and mixes with the fresher water (Zhuing et al., 2001; Livingston and Finch 1997).

The feed water used for this experiment is a brackish blend of two well sources at BGNDRF, with a TDS of approximately 3,450 ppm. The RO waste concentrate produced for irrigation has a slightly higher TDS of 4,063ppm (RO recovery rate of 30%). Due to the similar range of TDS, this halophyte farming research will have applicability to both brackish groundwater and RO concentrate as an irrigation source.

Alamogordo, New Mexico – within the Tularosa Basin (*Huff 2004*)

TABLE 2 - Typical quality of waste concentrate produced by RO plants

Parameter	Surface Water	Fresh Groundwater	Brackish Groundwater	Seawater
Feed water TDS	200-400	400-500	500-10,000	30,000-40,000
Water recovery, % of source water	80-90%	80-90%	65-85%	40-60%
Concentrate quantity, % of source water	10-20%	10-20%	15-35%	40-60%
Concentrate TDS, mg/L (at example recovery rate)	1,330 – 2,660 (85%)	2,660 – 3,330 (85%)	2,000 – 40,000 (75%)	60,000 – 80,000 (50%)

Source: American Water Works Association; Reverse Osmosis and Nanofiltration, AWWA Manual M46, Second Edition; 2007

Project Description

This pilot project includes validating the viability of the halophyte farming for concentrate management as a lower cost alternative to concentrate management, with little environmental impact.

This research builds upon the findings of a previous experiment supported by the USBR Science and Technology Program, located in Marana, Arizona indicating:
i) concentrate use was equal to that of a traditional evaporation pond per unit area,
ii) halophyte productivity was similar to conventional forage crops per unit area, and
iii) soil salinity could be managed to maintain plant productivity while salt transport below the root zone of the plant was minimized.

In the current pilot project, two halophytes, *Atriplex canescens* and *Atriplex lentiformis* were planted on a 1 acre plot at BGNDRF in September, 2014 and are being irrigated with RO concentrate. After the seedling establishment phase, three irrigation rates will be implemented, based on the evapotranspiration rate of the plants at the site. Plant productivity, soil moisture and the fate of salts will be measured throughout the experiment.

Reverse Osmosis processing unit at BGNDRF

RO Desalination Plant, El Paso, TX – the world's largest inland desalination plant
Photo credit: www.water-technology.net

Goals:

- demonstrate the reduced cost and lower environmental impact of desalination concentrate management through halophyte farming
- develop a forage crop that can thrive in a warmer climate using RO concentrate or brackish water sources for irrigation
- connect communities' need for RO with their traditional agricultural base in the region
- develop a model to predict the field performance of halophytes irrigated with RO concentrate – including biomass yield and fate of salts – which will be applicable to future project sites

Research objectives:

- grow halophytes with RO concentrate to produce biomass equal or greater than conventional forage crops
- determine optimum plant productivity to maximum RO concentrate use
- determine market potential and economic viability of substituting a percentage of halophyte biomass as a commodity food in the dairy/livestock feedlot industries
- identify the potential savings of fresh water in offsetting fresh water use crops (e.g. alfalfa) in the dairy/livestock feed industries
- demonstrate ground water protection at the halophyte farm
- analyze soil productivity to evaluate long-term halophyte crop production potential

Findings from this research will indicate the role of halophyte farming for concentrate management as a part of regional water resource climate adaptation management strategies, with applicability to arid and semi-arid regions of the world.

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Appendix 16 – Halophyte Farming Poster

U.S. Department of the Interior
Bureau of Reclamation
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Denver, Colorado

November 2016

HALOPHYTE FARMING FOR THE MANAGEMENT OF DESALINATION WASTE CONCENTRATES AND BRACKISH WATERS

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INTRODUCTION

The demand for inland reverse osmosis facilities (RO) is growing due to increased water demand and anthropogenic degradation of aquifers. Inland RO facilities have limited options for the disposal and management of the waste concentrate generated. Affordable and sustainable concentrate management strategies are needed for desalination to be a viable means of providing potable water in the future.

The goal of this pilot scale project is to evaluate the viability of halophyte (salt tolerant) farming as a means of RO waste concentrate management that is sustainable and cost effective. Two halophyte species native to the southwest were selected: Atriplex *lentiformis* and Atriplex *canescens*. Both are known to grow well in brackish water and also have potential as an agro-economic crop in the cattle feed industry.

EXPERIMENTAL

The two research plots with over 1,100 plants contain rows of A. *lentiformis* and A. *canescens* irrigated at rates of 0.4, 0.8 and 1.2 times a calculated evapotranspiration rate (ET) that is adjusted monthly. The average total dissolved solids concentration of the irrigation water is 4,000 mg/L.

Monthly monitoring includes plant growth measurements and neutron probe measurements via a network of access holes to a depth of 9 ft. Automated recorded data of soil moisture and salinity changes is done using arrays of Time Domain Transmissomer soil sensors.

Plant biomass is analyzed for properties that contribute to energy content and digestibility in animal feed, including moisture, crude ash, crude protein, fats, crude fiber and salt content.

Soil will be analyzed to determine changes in salinity infiltration rates using soil cores and field infiltration measurements.

FIELD SITE

The project is located on two adjacent half-acre plots at the Brackish Groundwater National Desalination Research Facility in Alamogordo, NM which also supplies the RO waste concentrate for irrigation. At an elevation of approximately 4,300 ft, the climate is semi-arid with precipitation averagine 11 inches annually. The high gypsum soil is typical for the location in the Tularosa Basin of south central New Mexico.

Figure 1. Photograph is looking north across the northern ½ acre plot. On the map of New Mexico, the oval encircles the Tularosa Basin of south central New Mexico. The approximate location of Alamogordo is also indicated.

ACKNOWLEDGEMENTS

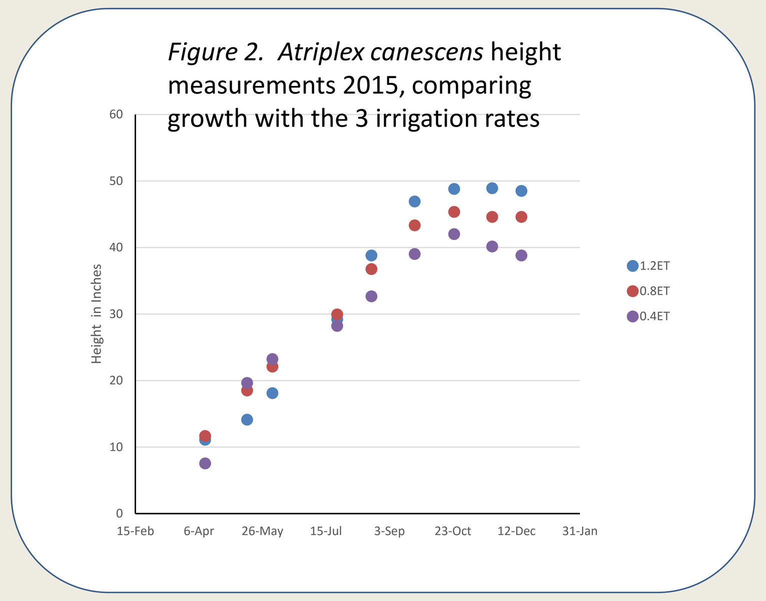
Kim McCuistion, Texas A&M University-Kingsville; Manoj Shukla and Amir González-Delgado, New Mexico State University; Netafim Irrigation; and Randy Shaw, Brackish Groundwater National Desalination Research Facility.

Sponsor: Bureau of Reclamation, Agreement No. R13AC80023.
For more information: Joanne Gallaher, joanneg@email.arizona.edu

PRELIMINARY RESULTS

During the early growth phase, impact from the different irrigation rates appear negligible (Fig. 2). Late September, 2015, the A. *canescens* reached peak height and exhibit a noticeable difference based on their irrigation regime with the higher watering rates resulting in taller plants.

Figure 2. Atriplex canescens height measurements 2015, comparing growth with the 3 irrigation rates

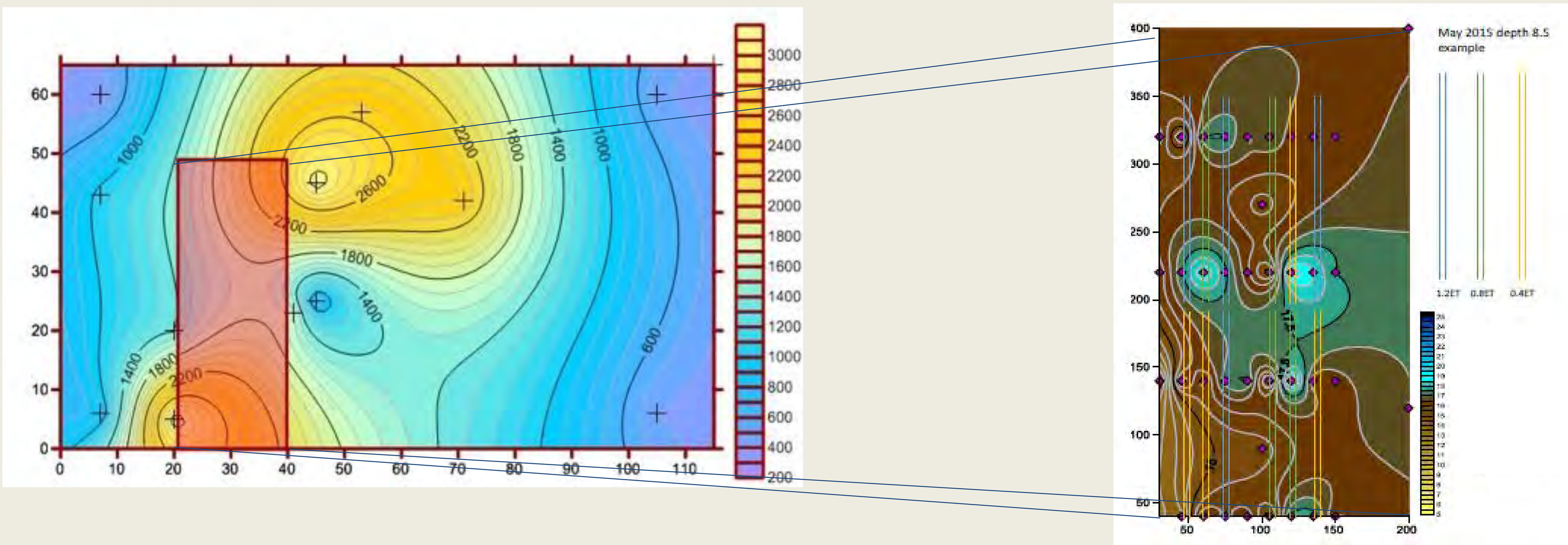


In Figure 3, the table shows averages of some of the nutritional values for the two halophyte species. Most notable is the higher salt concentration for the A. *lentiformis*, averaging 10.68% NaCl on a dry weight basis.

SPECIES	% Crude Protein	% Crude Fiber	% Crude Carbohydrates	% Total Digestible Nutrients	% Salt (NaCl)
A. *canescens*	14.56	20.37	48.75	61.68	3.98
A. *lentiformis*	15.49	18.14	44.46	57.02	10.68

Figure 3. Averages of analytical results from sample harvest collected in September 2015.

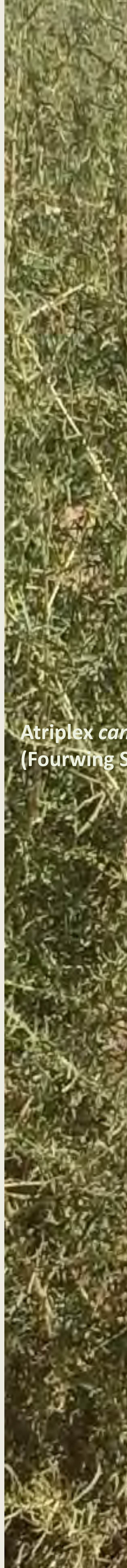
Figure 4. Left is a salinity contour map for the top 4 ft. The red block indicates the location of both research plots and symbols are the soil core locations. The plot on the right is a soil moisture diagram combining the two research plots. The colored lines correlate to the different irrigation lines with color-coded watering rates.



This salinity contour map (Fig. 4) for the top four feet shows the soils contain significant amounts of soluble salts that are spatially variable at relative short distances. Additional sampling will be conducted near the end of the project to determine whether salt content has increased significantly in the study plots due to brackish water irrigation. Soil moisture is also being monitored to determine any downward migration. Results to date indicate that irrigation water is not migrating past a carbonate accumulation zone located at approximately 4 ft depth.

CONCLUSIONS

Preliminary results support the efficacy of halophytes for RO concentrate management. Additionally, results suggests that halophyte crop production is applicable to the local agricultural community in areas with brackish groundwater. The next phase of research, as the plants reach maturity, will be to evaluate the cost effectiveness and sustainability of halophyte farming for RO waste concentrate management at a larger scale; evaluate the sustainability and production potential of *Atriplex sp.* as a new agricultural crop; determine the market potential for *Atriplex* biomass at the commodity feed scale; and to gain commercial use and acceptance of the halophyte biomass in the animal feed industry.



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Appendix 17 – Irrigation Settings

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Denver, Colorado

November 2016

4/25/2016

Total Irrigation at BGNDRF

September 2014 through April 22 2015

SEAMAN

Gallaher - 11/28/2016

	IRRIGATION SETTINGS			**Weeks at**	**Irrigation**	**Total minutes of irrigation per setting**		
		Minutes of irrigation		**irrigation rate**	**events**			
Date	**1.2**	**0.8**	**0.4**			**1.2**	**0.8**	**0.4**
9/15/2014	75	75	75	35	105	7875	7875	7875
5/15/2015	122	81	41	10	30	3660	2430	1230
7/23/2015	208	139	69	4	12	2496	1668	828
8/20/2015	193	129	64	5	15	2895	1935	960
9/24/2015	167	111	56	4	12	2004	1332	672
10/24/2015	127	85	42	8	24	3048	2040	1008
12/17/2015	97	65	33	10	30	2910	1950	990
2/25/2015	118	78	39	3	9	1062	702	351
3/17/2015	146	97	49	5	15	2190	1455	735
4/21/2016	179	119	60					

NOTES:

1) The south field was planted on 9/17/14. The north field planting was delayed until the 24th due to rain. After manual irrigation settings and experimentation with the timers, irrigation using the above settings on both fields began on 9/25/14.
2) There were problems with the initial irrigation controllers due to the lack of a reliable wireless signal in the DAIC shed; these controllers were replaced with manual models.
3) Scheduled irrigation periods were suspended due to maintenance and rain on an as-needed basis.
4) Expected Gallons calculations were based on the set irrigation schedules and do not take suspensions due to maintenance activities or weather conditions into account.
5) Meter Value = actual water applied.

The total water applied over the 19 months of irrigation

Total Gallons 9/15/14 through 4/21/16 (19 months of irrigation)

	North Plot						
Valve	**1**	**2**	**3**	**4**	**5**	**6**	Total
IrrigationTreatment	**1.2**	**0.8**	**1.2**	**0.8**	**0.4**	**1.2**	Gallons
Expected Gallons	53466	40635	53466	40635	27833	53466	269502
Meter Value	45891	30832	43655	33668	19467	47131	220644
in Cubic Meters	173.717	116.713	165.252	127.445	73.691	178.410	835.229
Total Salt kgs	667	448	635	490	283	685	3208
				Total irrigation on North plot in Acre-feet			**0.68**
	South Plot						
Valve	**1**	**2**	**3**	**4**	**5**	**6**	Total
Treatment	**0.4**	**0.4**	**1.2**	**0.8**	**0.8**	**0.4**	Gallons
Expected Gallons	27833	27833	53466	40635	40635	27833	218236
Meter Value	18527	15737	40780	30279	28405	18564	152292
in Cubic Meters	70.132	59.572	154.370	114.618	107.526	70.272	576.490
Total Salt kgs	269	229	593	440	413	270	2214
				Total irrigation on South plot in Acre-feet			**0.47**
				Total field irrigation in Acre-feet			**1.14**
				Total field irrigation in inches			**13.73**
				Total salt applied in Kgs			**5423**

Actual irrigation applied at 1.2 ETo (4 irrigation valves) over 19 months in gallons	Irrigation total if all 12 valves were 1.2 ETo in gallons	Multiply by 2 (because field is 50% canopy cover) for max irr in gallons	Maximum irrigation in acre-feet	Maximum irrigation at 1.2 ETo in inches	Annualize 19 months of plant growth to maximum annual irrigation rate 0.631578947 in inches
177457	532371	1064743	3.27	39.21	24.76

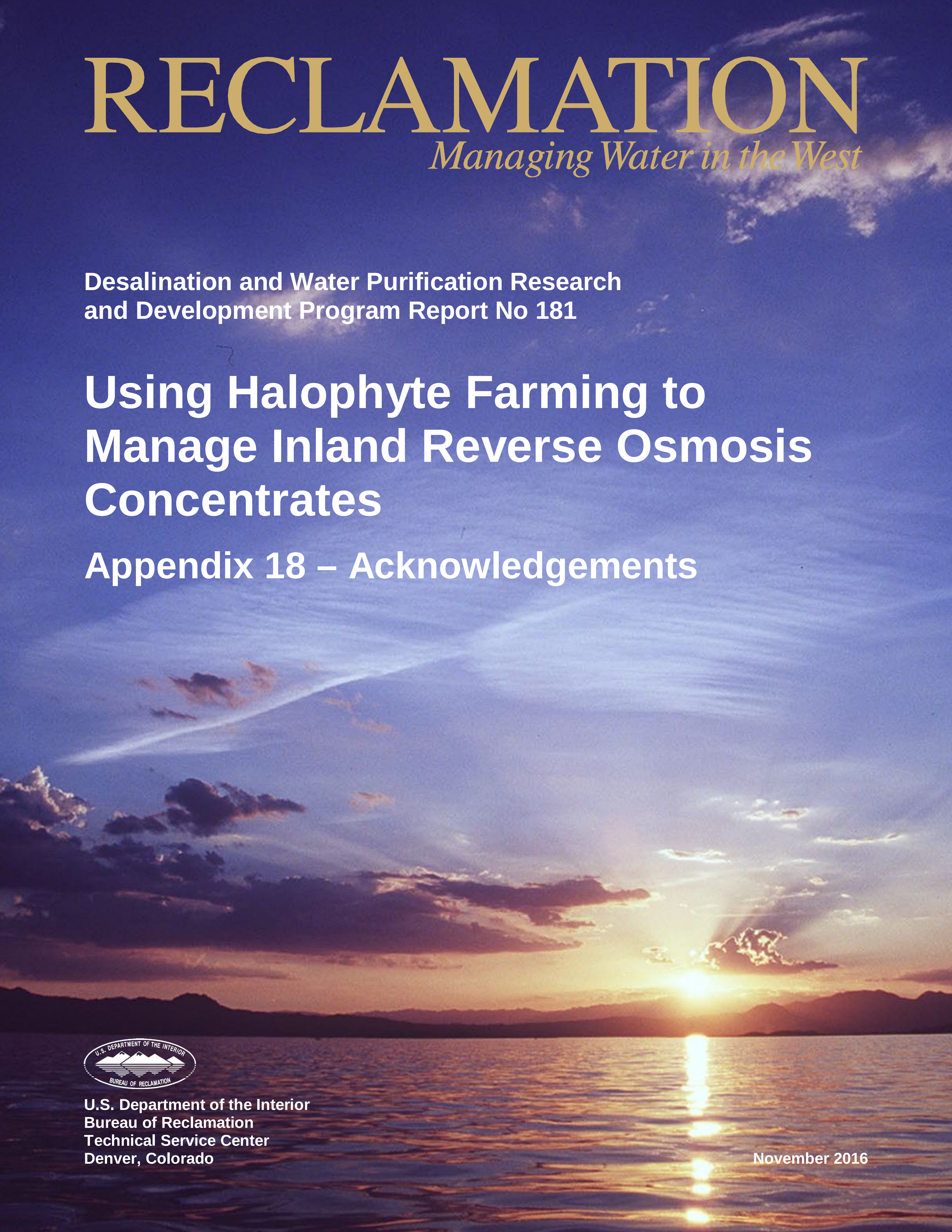
Conversion c	**1.2**		**0.8**	**0.4**		
Total Minute	28140		21387	14649		
Total Expecte	53466		40635	27833		
1 cubic foot =	**7.48052**	**Gallons**	**1 cubic Mete**	**264.172**	**Gallons**	
Actual Meter Readings in Cubic Feet						
North Plot	**1**	**2**	**3**	**4**	**5**	**6**
4/22/2016	6134.75	4121.68	5835.81	4500.69	2602.39	6300.49
Actual Meter Readings in Cubic Feet						
South Plot	**1**	**2**	**3**	**4**	**5**	**6**
4/22/2016	2476.7	2103.75	5451.52	4047.69	3797.25	2481.63
1 acre-foot =		325851.429 gallons	acre-foot			
Total applied - North plot		220644		0.68		
Total applied - South plot		152292		0.47		
Site total irrigation applied		372936		1.14		

EXPECTED ET	**0.4**	**0.8**	**1.2**
% of expecte	0.67	0.76	0.86
	0.57	0.83	0.82
	0.67	0.75	0.88
	0.70	0.70	0.76
AVE	0.65	0.76	0.83
ACTUAL ETo	**0.26**	**0.61**	**1.00**

Irigation Water Conductivity
4/25/2015
SEAMAN
BGNDRF

Date	microS/cm	temp °C
5/15/2015	3690	20.0
7/24/2015	4534	30.0
8/21/2015	4534	30.3
9/25/2015	4692	24.7
10/25/2015	4560	
1/20/2016	4280	12.7
2/24/2016	4455	
3/15/2016	4485	17.3
4/21/2016	4508	24.0

Average	4415.3					
mg/L TDS	3841		TDS mg/L	Aproximate	microS/cm X	0.87
g/L TDS	3.84					



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Appendix 18 – Acknowledgements

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Denver, Colorado

November 2016

Appendix 18 - Acknowledgements

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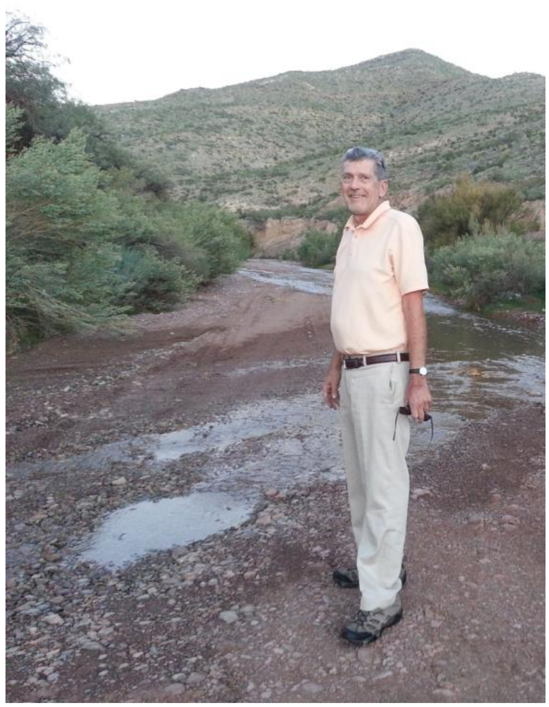
We dedicate our work to Martin Yoklic, the original Principal Investigator on this project, who led the team with visionary enthusiasm, professionalism and dedication before and after his retirement.



Martin R. Yoklic, Research Scientist, University of Arizona
(1949 – 2014)