ORDA Science Webinar Series:
Anderson Ranch Wetlands Hydrologic Characterization

USGS New Mexico Water Science Center

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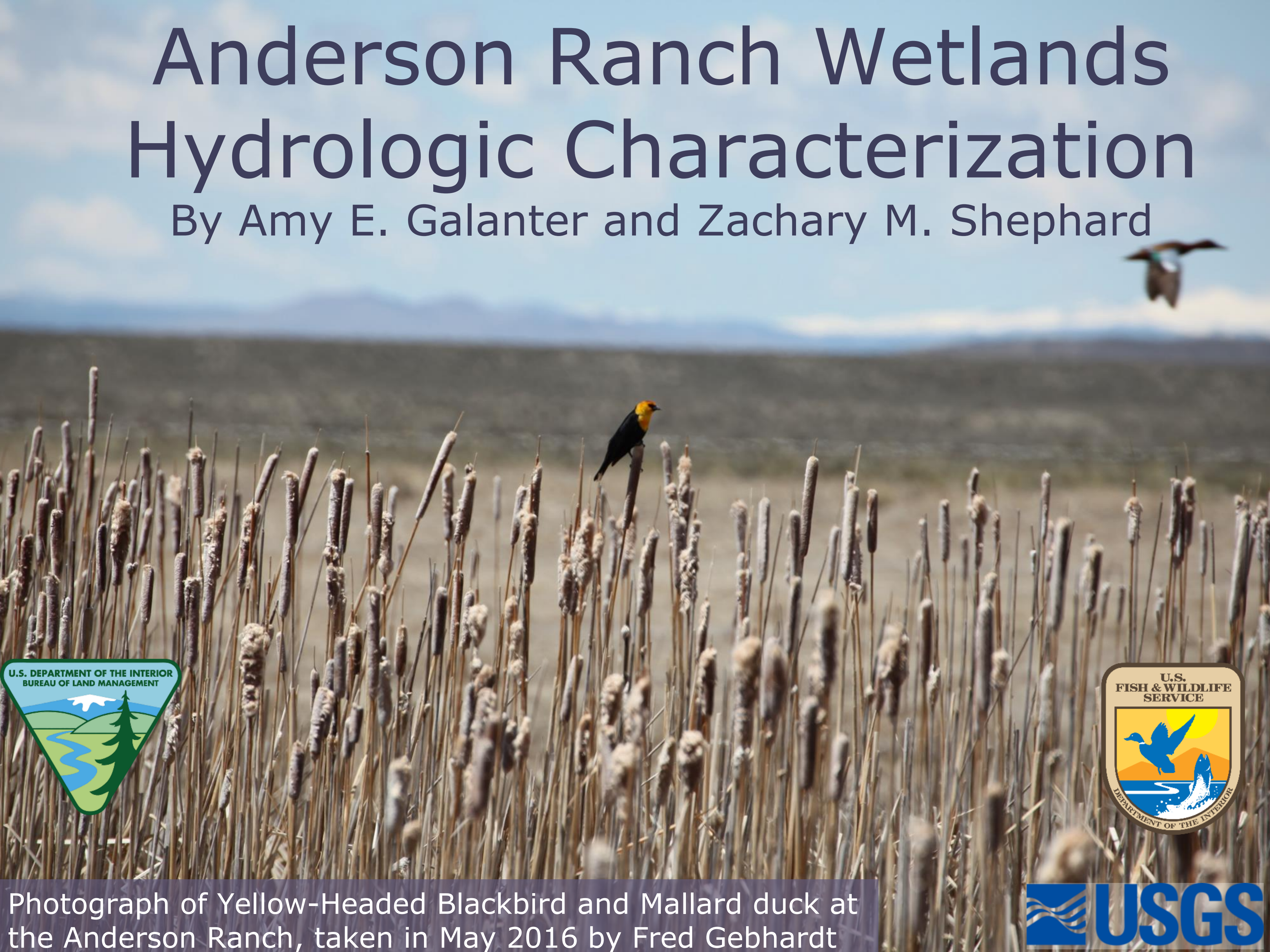
Anderson Ranch Wetlands Hydrologic Characterization

By Amy E. Galanter and Zachary M. Shephard



Photograph of Yellow-Headed Blackbird and Mallard duck at the Anderson Ranch, taken in May 2016 by Fred Gebhardt

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Open-File Report 2019-XXXX

U.S. Department of the Interior
U.S. Geological Survey

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Contents

Purpose and Scope

- The purpose of this Open-File Report is to communicate the results of the first phase of the project. This interim product can be used by BLM to determine the next steps of the project.

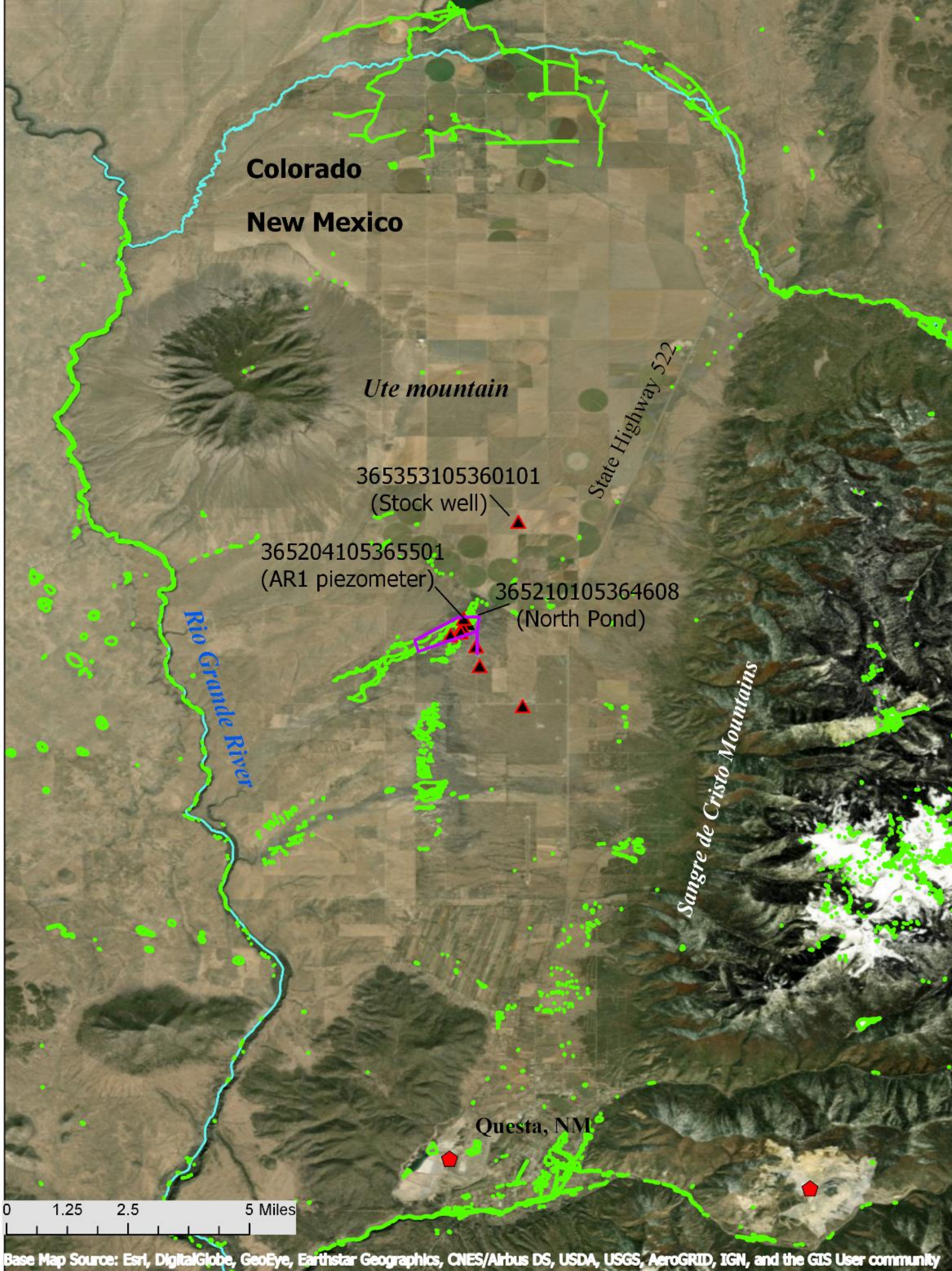
- The objective of this project is to provide a hydrologic characterization of the Anderson Ranch wetlands that will guide the best management strategy to maximize the trust resource values.

- This objective was met through literature review, data collection (groundwater-level data, aqueous chemical data, and a vegetation survey), and preliminary data analysis.

Long-term questions for BLM

- The purpose of this Open-File Report aligns with BLM’s long-term management questions regarding the Anderson Ranch wetlands, which include:
  - Assessing 50 to 100 year scenarios for the wetlands.
  - Determining the value of investment in this property.

Study Area



This figure shows the Anderson Ranch property (a 250-acre plot of land about 10 miles north of the Questa, NM) and the surrounding area.

Questa Mine sites

Anderson Ranch property

Data collection sites

Groundwater-level measurements

365204105365501 is continuous, all others are discrete

Aqueous Chemistry sampling site

Designated with USGS site id (short name)

Surface-water features

Rivers and creeks

National Wetlands Inventory Freshwater Features (USFWS, 2010)

Anderson Ranch Property Background

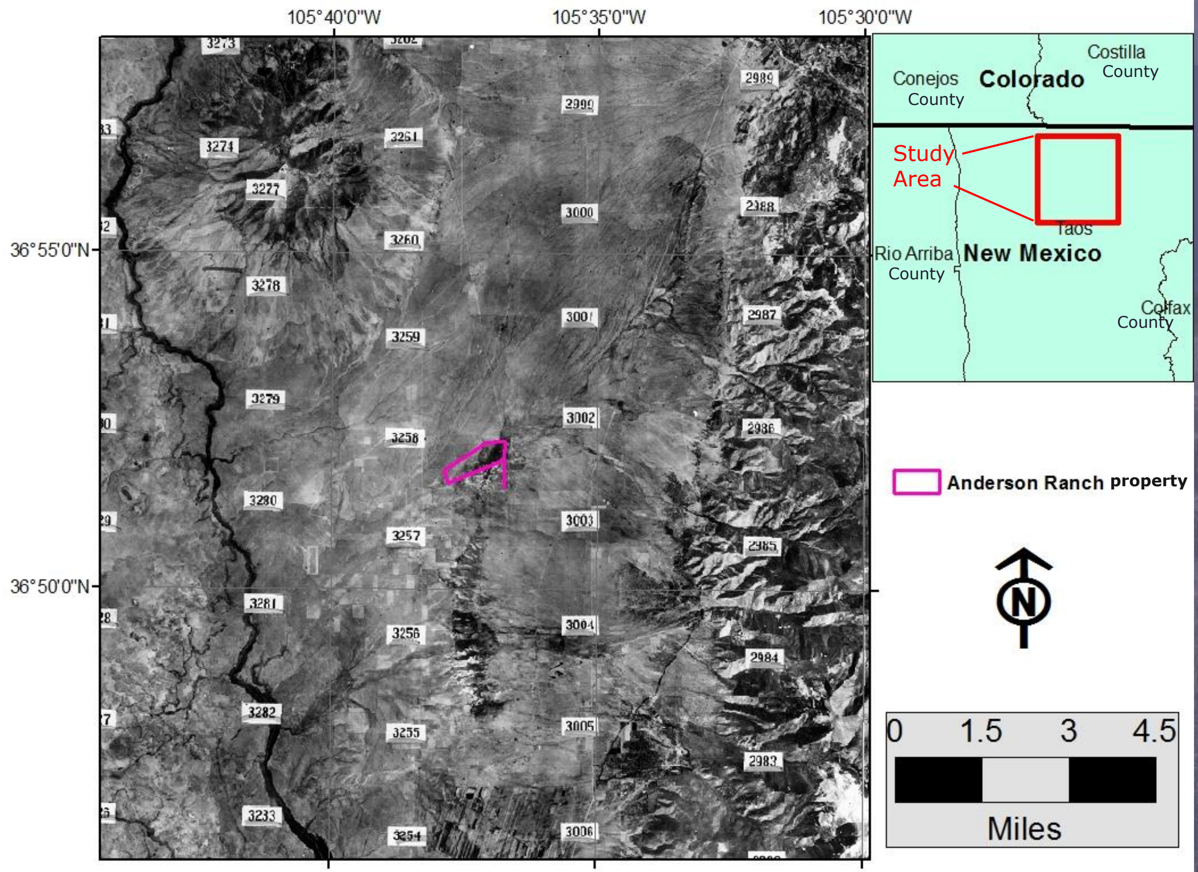
Photograph of Anderson Ranch property, from USGS archives for site number 365159105364801 (circa 1970s)

- <u>1955- 1964:</u> Property was used for irrigation (NM OSE, 2019).
- <u>1964:</u> Molycorp, Inc. (owned and operated the Questa mine) filed for a water right transfer (NM OSE, 2019).
- <u>2002-2017:</u> Natural Resource Damage Assessment was conducted (U.S. DOI and others, 2018).
- <u>2018:</u> Property was officially transferred to BLM (U.S. DOI and others, 2018).

Wetlands in New Mexico

- Wetland landscapes are rare in New Mexico, and wetland habitat has shrunk in the last 200 years (Fretwell and others, 1996).
- Wetlands provide unique habitat for diverse ecosystems and many organisms, notably migratory waterfowl and wading birds (Fretwell and others, 1996;U.S. EPA, 2017).
- Wetlands serve important functions for watersheds, with potential for water-quality improvement and carbon storage (U.S. EPA, 2017).
- Connectivity between wetlands can affect resilience of wetlands and populations that depend upon the wetlands for habitat (Uden and others, 2014).
- National Wetlands Inventory (USFWS, 2010) shows connectivity of freshwater wetlands features in the study area.

Past Indicators of Wetlands

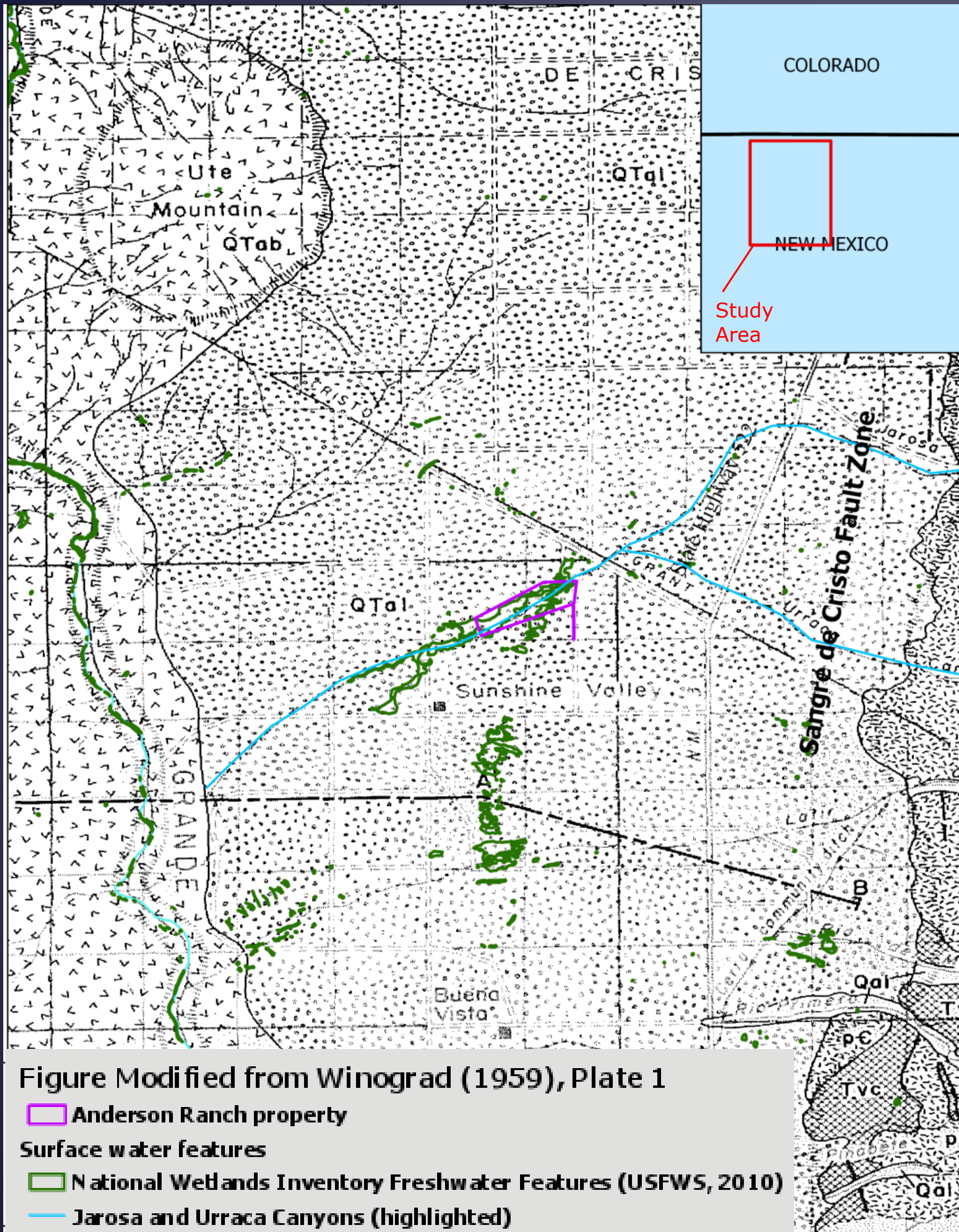


1935 aerial photo (Soil Conservation Service, 2008)

Historical imagery suggests that the Anderson Ranch wetlands have existed at least since 1935.

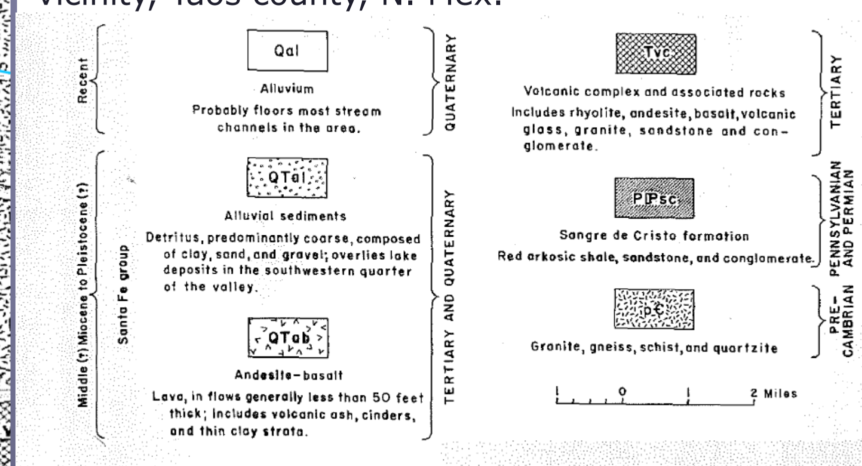
- Within the Anderson Ranch property, there is no volcanic outcropping at the land surface. The dark color from the 1935 image within the property boundary aligns with the National Wetlands Inventory (USFWS, 2010). Therefore, the darker color within and near the current wetlands extent is assumed to indicate the presence of wetlands in 1935.

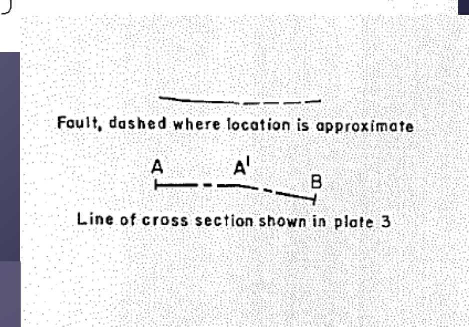
Literature Review: Winograd (1959)

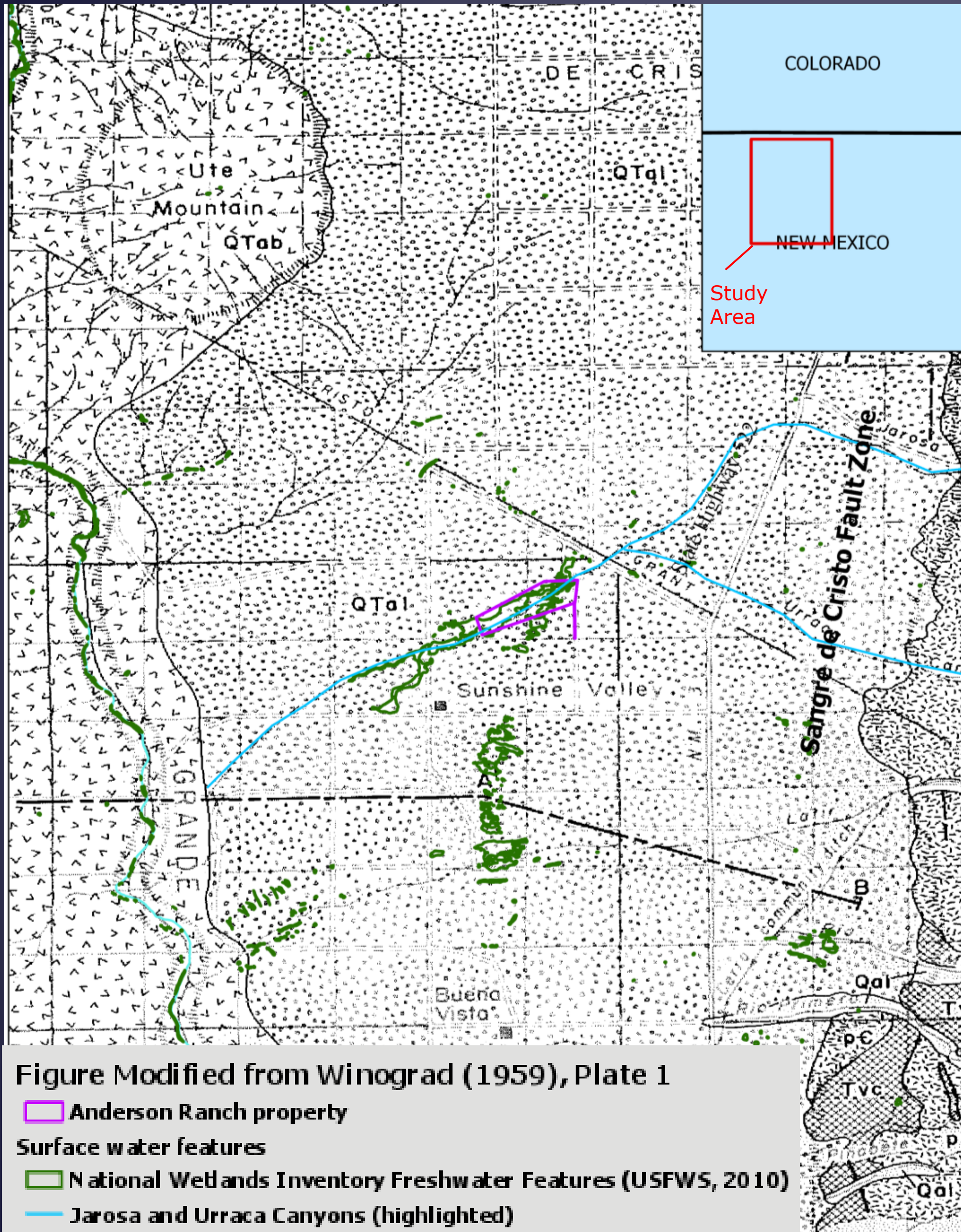


Relevant findings from this study are summarized on the following slide.

Explanation from Winograd (1959) plate 1.- generalized geologic map of sunshine valley and vicinity, Taos county, N. Mex.



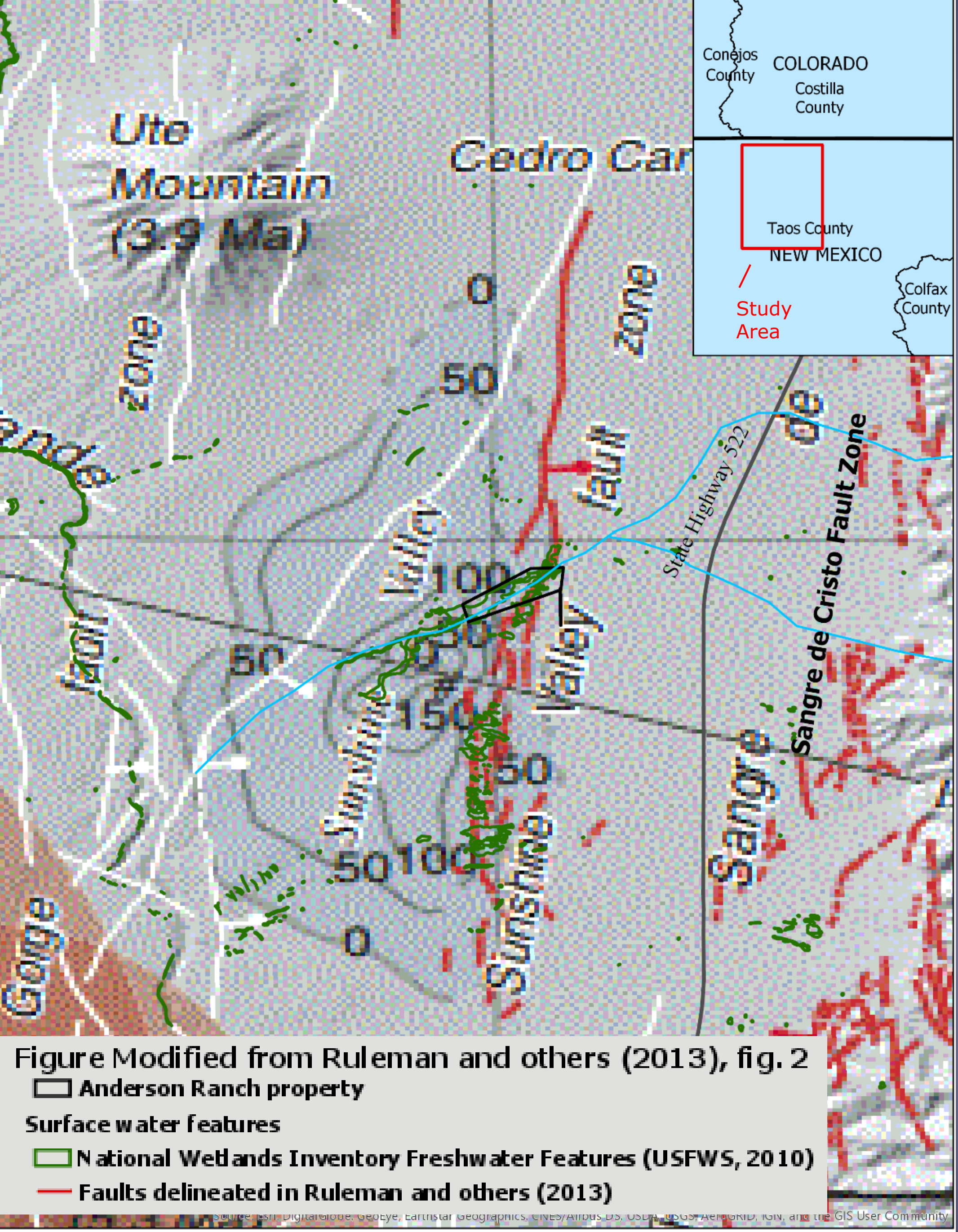




Literature Review

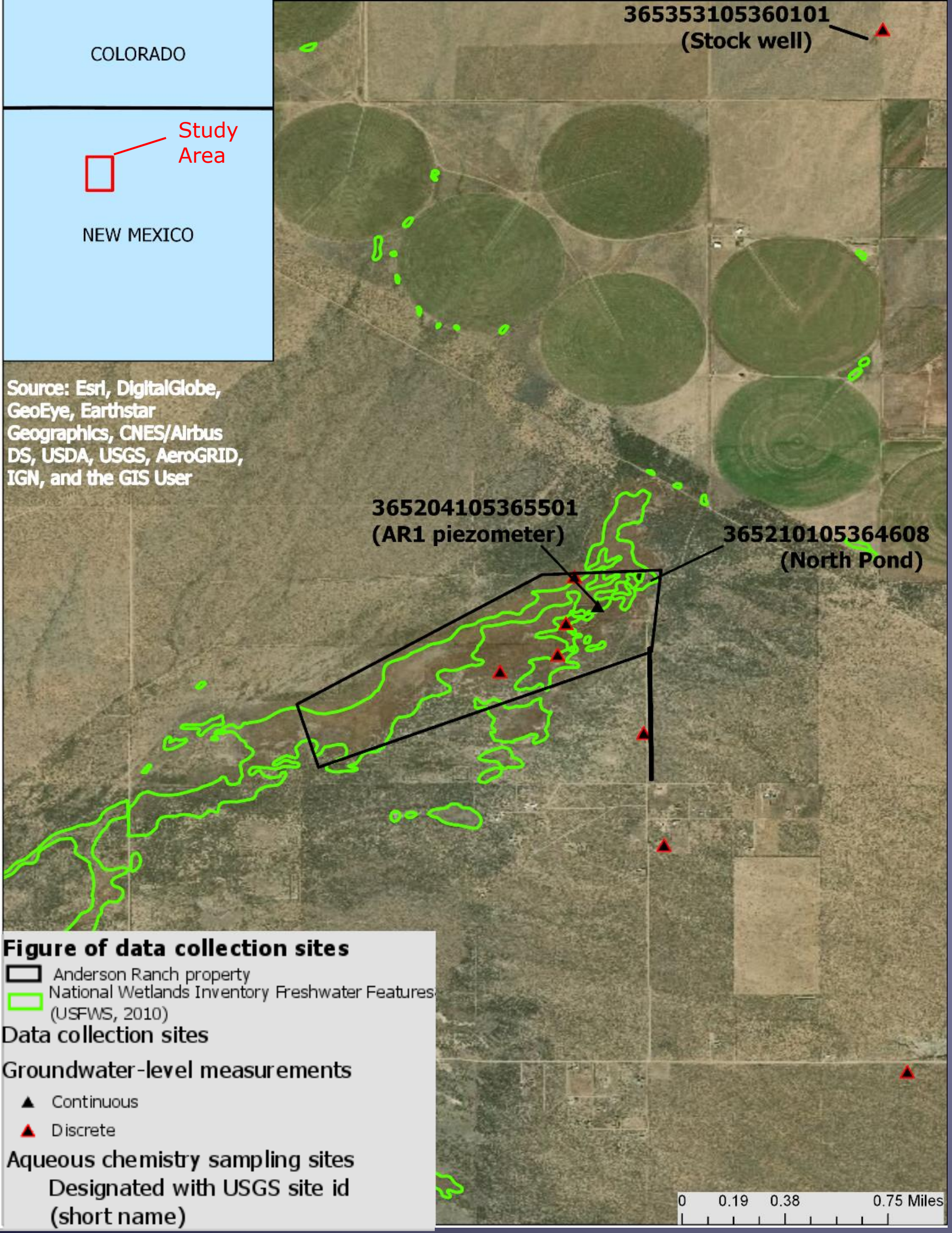
Winograd (1959)- findings shown in this figure as well as within the report.

- Sunshine Valley, the valley between the Sangre de Cristo Mountains on the east and the Rio Grande on the west, is a piedmont alluvial plain and contains alluvial sediments interbedded with lava as well as lacustrine sediments.
- Groundwater underlying the Sunshine Valley discharges to the Rio Grande.
- Groundwater is recharged from perennial streams, arroyo flood flows, direct infiltration, canals and irrigation infrastructure.
- Jarosa and Urraca canyons (highlighted in blue) converge north of the Anderson Ranch Wetlands.



Literature Review: Ruleman and others (2013)

Pliocene-early Pleistocene "Lake Sunshine" is shown by contours defining the thickness of lacustrine and interstratified fan deposits, which range from 0 to 150 ft.



Study Approach

<u>Groundwater Levels</u>

Assessed groundwater gradients and seasonal variability of groundwater levels.

<u>Aqueous Chemistry</u>

Assessed chemical composition of groundwater and surface water within and near the Anderson Ranch wetlands.

<u>Vegetation Survey</u>

Estimated coverage, frequency, occurrence of plant species during flowering season.

<u>Literature Review and Data Analysis</u>

This included a preliminary water budget analysis and elevation analysis.

*All groundwater-level data and aqueous chemistry data are available at https://waterdata.usgs.gov/nwis

*Aqueous chemistry data are also summarized in Appendix A

Groundwater-Level Data collection Sites

Photograph of Hydrologic Technician Fred Gebhardt installing a piezometer using a truck-mounted Geoprobe.

Table of groundwater-level measurement sites (locations of sites shown on slides 19 and 20)

Well type	USGS site identifier	Other name	Screen depth in feet below land surface	Total depth in feet	Measurement frequency
Piezometer	365204105365501	AR1	22 - 27	27	continuous (15 min)
Piezometer	365201105370101	AR2	22 - 27	27	discrete (quarterly)
Piezometer	365155105370301	AR3	17.5 - 22.5	22.5	discrete (quarterly)
Piezometer	365152105371301	AR4	16.6 - 21.6	21.6	discrete (quarterly)
Piezometer	365210105365901	AR5	14.55 - 19.6	19.6	discrete (quarterly)
Monitoring well	365035105360501	Cerro	135 - 240 275 - 330 460- 470	500	discrete (quarterly)
Agricultural well (no longer in use)	365148105364401	Old Ag Well	Unknown	187	discrete (quarterly)
Domestic well	365119105364201	Domestic	20-60	61	discrete (quarterly)
Stock well	365353105360101	Stock well	110-210	210	discrete (quarterly)

Geoprobe drilling refusals and driller's logs for other wells in the area indicate that there is a potential clay layer around 20 feet below land surface.

Aqueous Chemistry Sampling

Photograph of Hydrologic Technician Kate Wilkins using a Van Dorn sampler to collect a water sample at site 36521015364608

- ## Sites (locations shown on slide 3)

Surface water- (365210105364608)
Piezometer- (365204105365501)
Stock Well- (365353105360101)

- ## Constituents

Field parameters, nutrients, major ions, trace elements, isotopes

- ## Quality Control samples

Surface water and groundwater blank, groundwater replicate

Vegetation Survey (August, 2016)

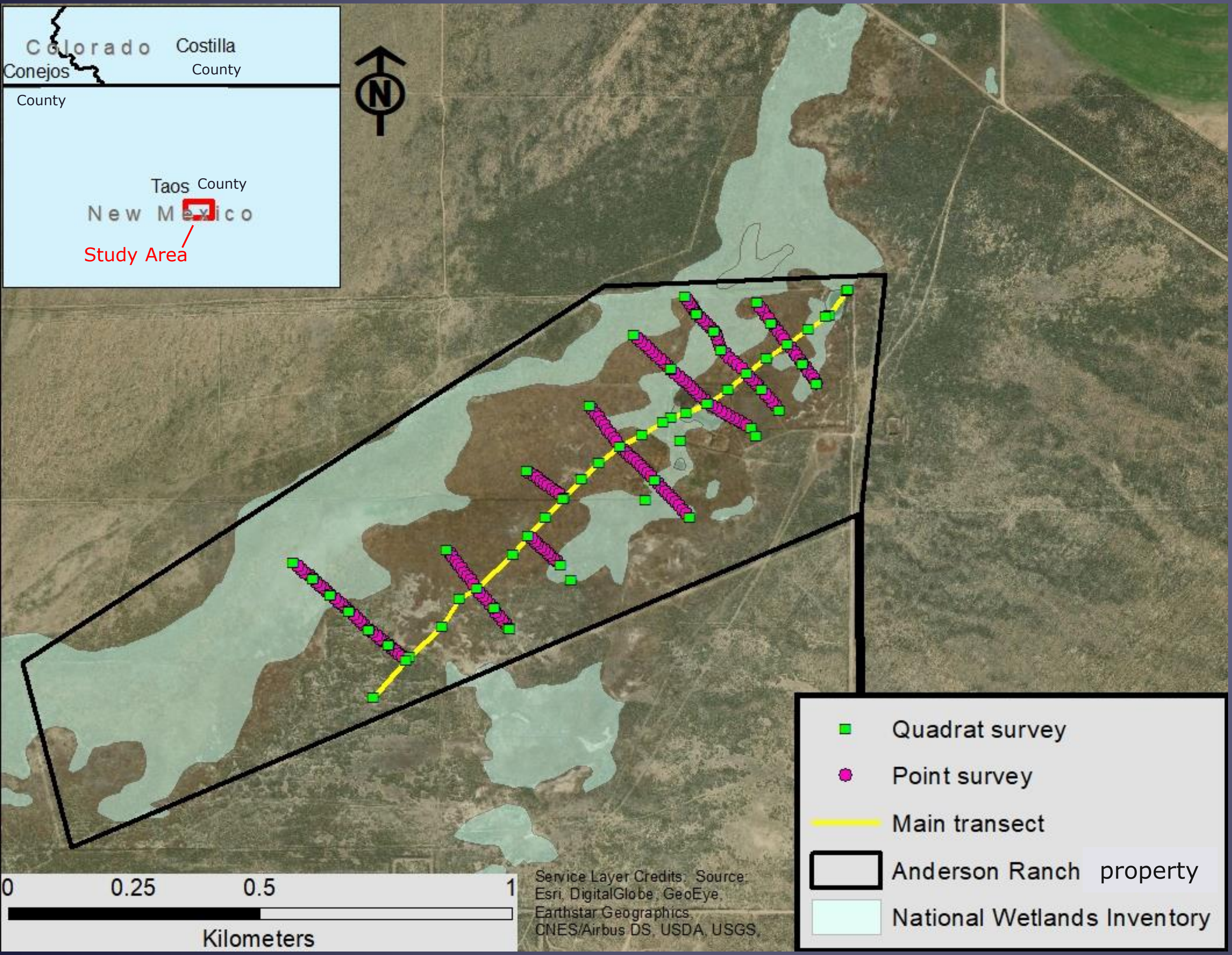
Photograph of USGS Botanist Joan Daniels and USGS Hydrologic Technician Alanna Jornigan identifying vegetation within a quadrat

To collect the baseline data of current characteristics and conditions of the wetland two methods were used*:

1. Quadrat (0.25 square meter sampling size) every 50 meters along a main transect and 9 perpendicular transects)
2. Point (a single point every 10 meters in between quadrats)

*For more information on the vegetation survey, please see Dong and others, (2018).

Vegetation Survey locations



This figure shows the locations of the quadrat survey locations, point survey locations, the Anderson Ranch property and the National Wetlands Inventory (USFWS, 2010).

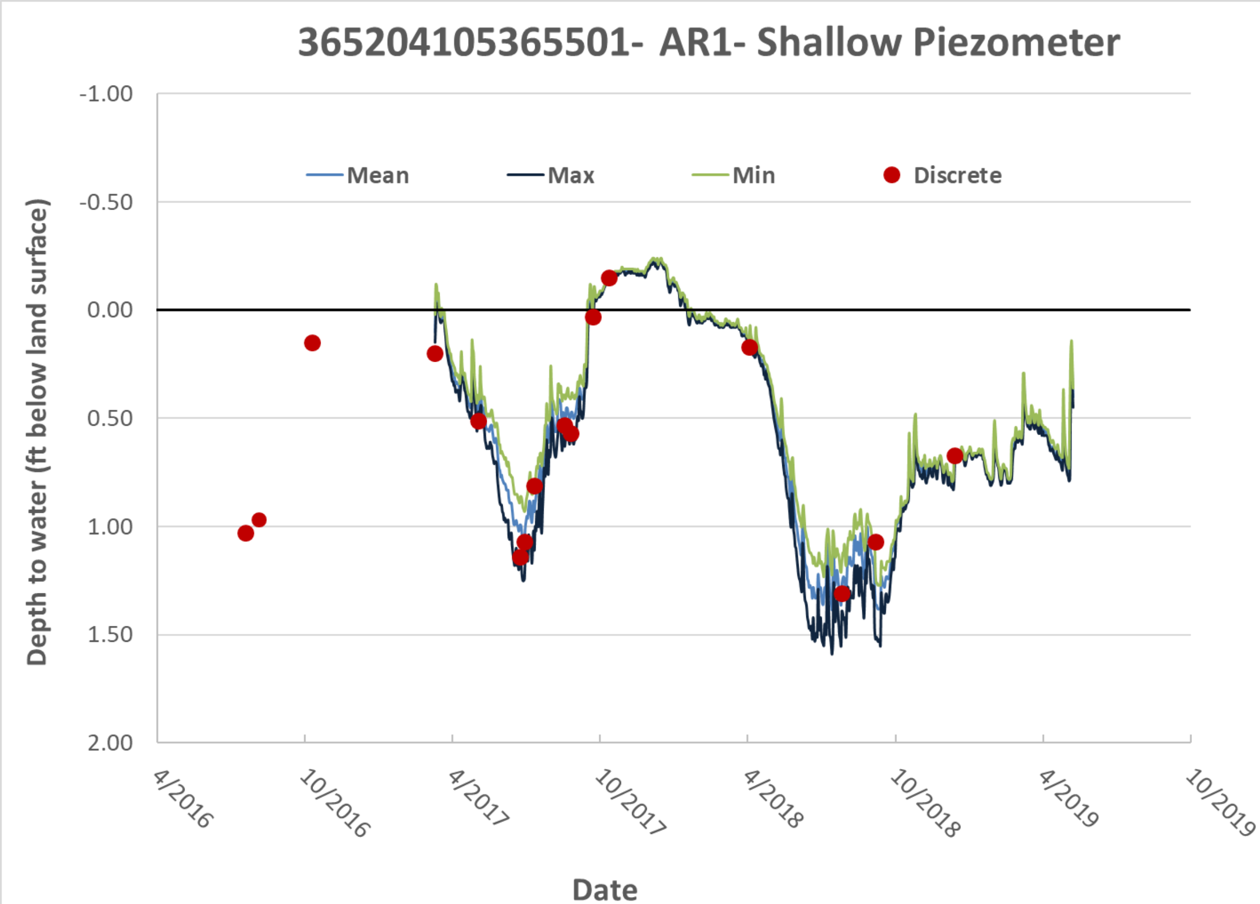
Vegetation Survey Classifications

Table of wetland indicator status, designation, and qualitative description, from Lichvar and others (2012). The wetland indicator status and designations were used in both quadrat and point surveys.

Indicator status	**Designation**	**Qualitative Description** (Lichvar and others (2012))
Obligate (OBL)	Hydrophyte	Almost always occur in wetland.
Facultative Wetland (FACW)	Hydrophyte	Usually occur in wetland, but may occur in nonwetland.
Facultative (FAC)	Hydrophyte	Occur in wetland and nonwetland.
Facultative Upland (FACU)	Nonhydrophyte	Usually occur in non-wetland, but may occur in wetland.
Upland (UPL)	Nonhydrophyte	Almost never occur in wetland.

For both quadrat and point survey methods, plant species were identified and wetland indicator status was determined.

Groundwater-level Data



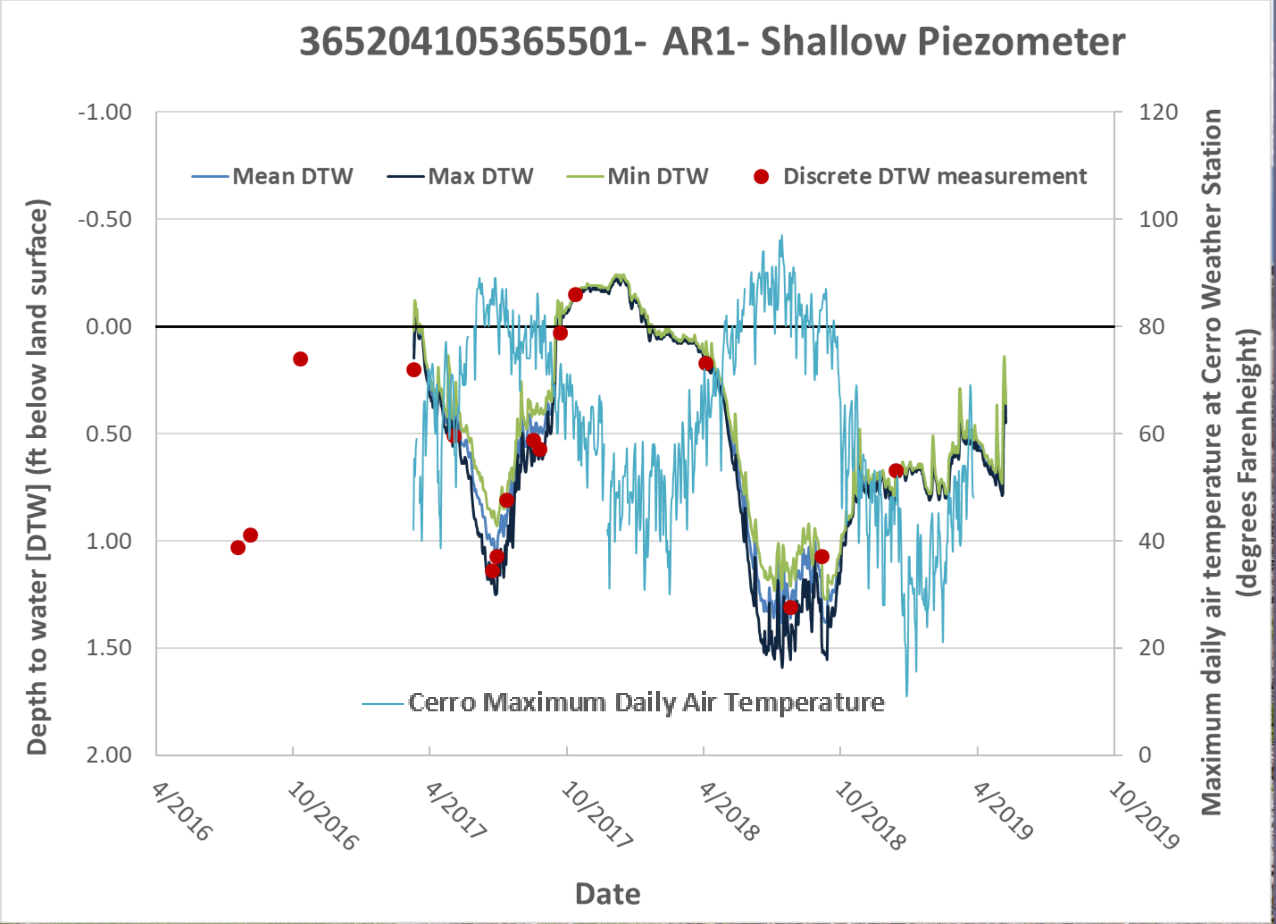
Interannual variation

Groundwater levels were higher in 2017 than they were for the corresponding dates in 2018.

- Winter 2017, groundwater levels are above land surface**, this is not the case in winter 2018.
- Summer 2018 groundwater levels are lower than summer 2017. Summer seasonal groundwater level remained lower for a longer duration.

*Tick marks on the horizontal axis are every 180 days to delineate rough estimate of seasons- Evapotranspiration and non Evapotranspiration seasons)
**Note that the negative depth-to-water values are water pressure above land surface. Groundwater levels above land surface mean that the pressure of the water within the piezometer causes the groundwater level within the piezometer to rise higher than the land surface. The piezometer allows the water to move above the land surface and the pressure originates from below the ground.

Groundwater-level and Temperature Data

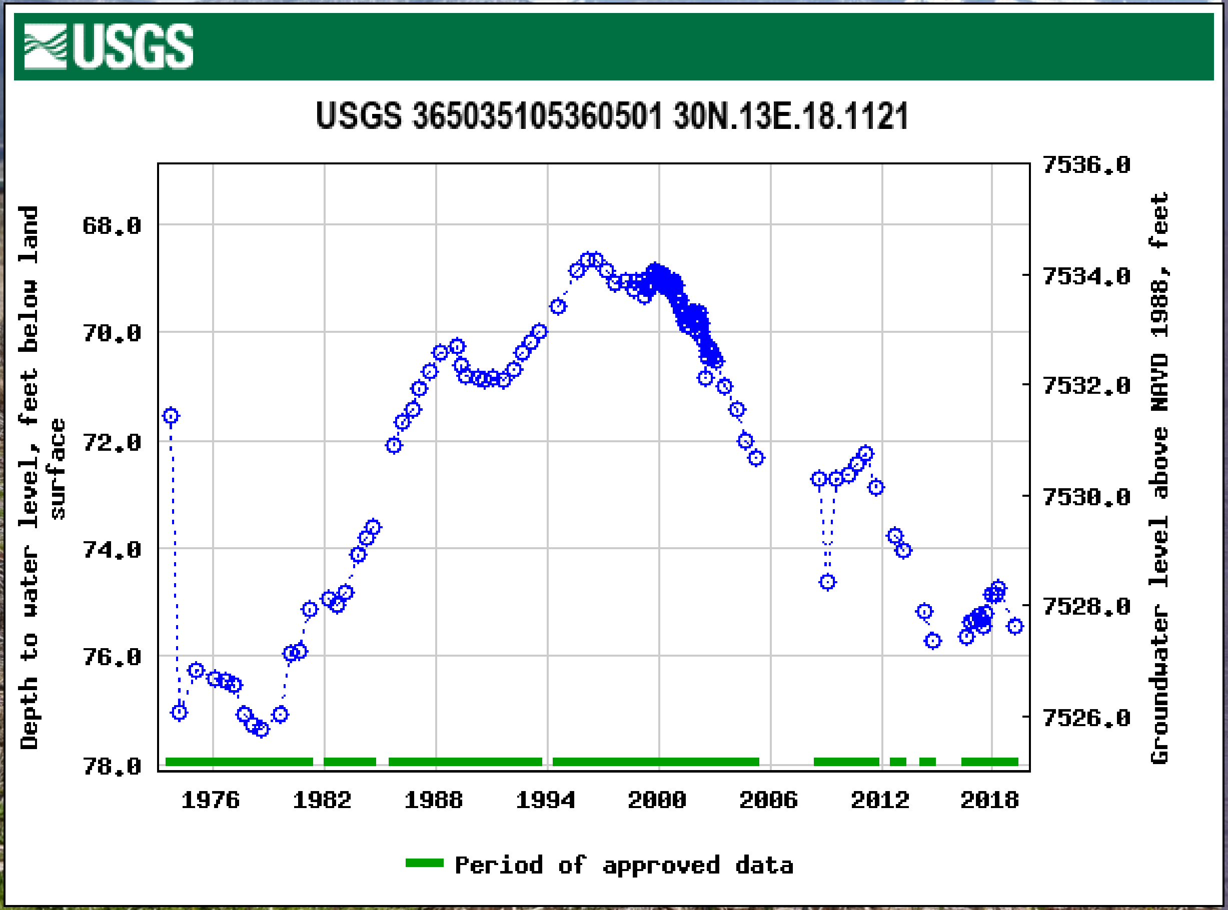


*Tick marks are every 180 days to delineate rough estimate of seasons- Evapotranspiration and non Evapotranspiration seasons)
**Note that the negative depth-to-water values are water pressure above land surface.

When compared with air temperature data from the nearby Cerro Weather Station (ACIS NOAA Regional Climate Centers, 2019):

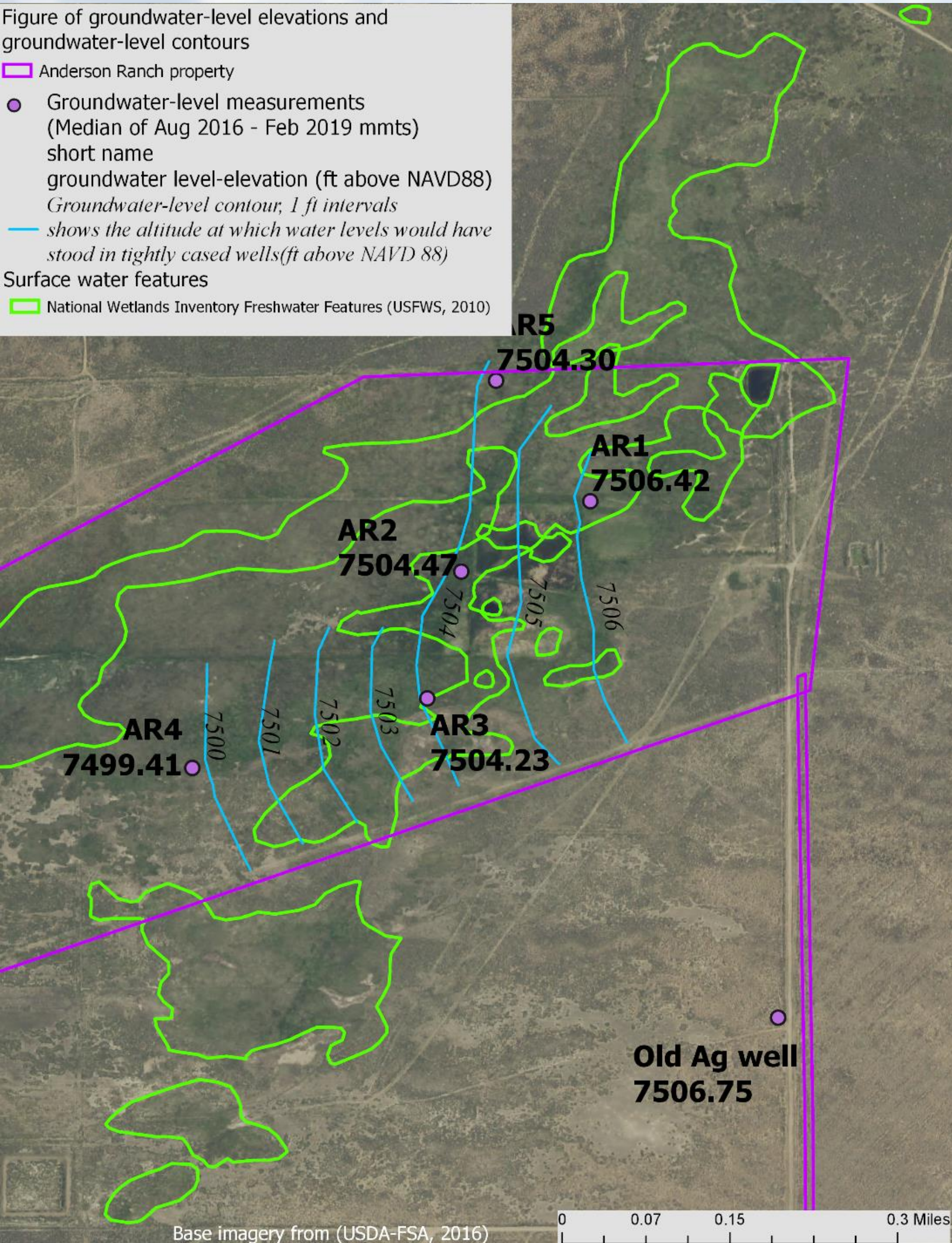
- Groundwater levels decline during warmer months and rise during cooler months.
- Daily groundwater-levels fluctuate more during warmer months, as indicated by the difference between the maximum (max) and minimum (min) temperatures.
- Continued data collection and further time-series analysis could yield a better understanding of the seasonality of groundwater levels.

Groundwater-level data at Cerro Monitoring Well

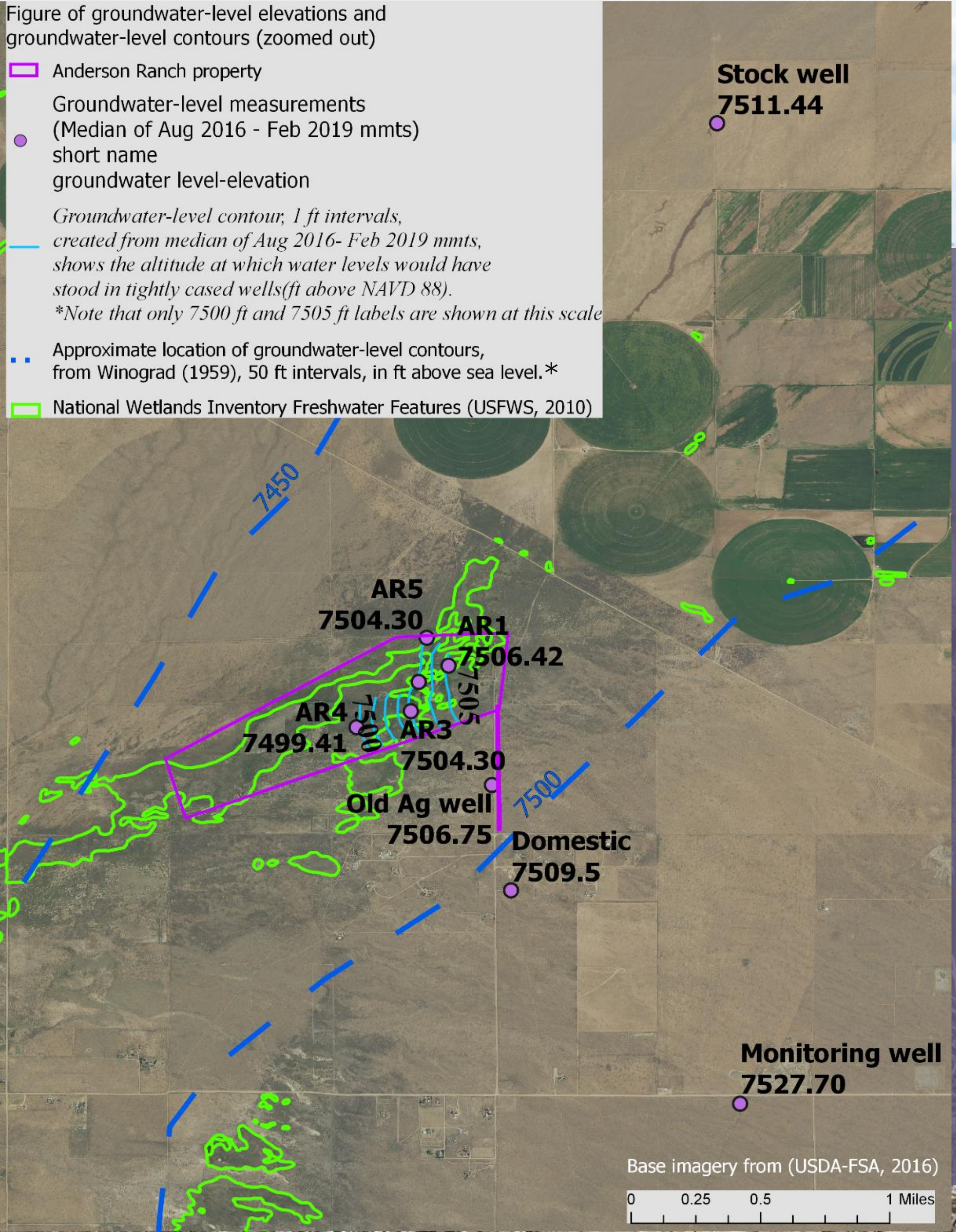


- 46-year period of record at deeper monitoring well shows an increasing trend in groundwater levels during the 1980-2000 period and a decreasing trend in groundwater levels during 2000–current period.
- Precipitation and climate data analysis along with groundwater-level data analysis could yield information about correlations between precipitation, climate, and groundwater levels.

Groundwater-level Contours



- Hydraulic gradient within wetland area is around 20 ft per mile.
- Groundwater flows from northeast to southwest
- Groundwater flow and gradient persist through winter and summer.
- Old agricultural well outside of wetlands area has a comparable water-level elevation, despite a deeper well depth and distance from wetlands.

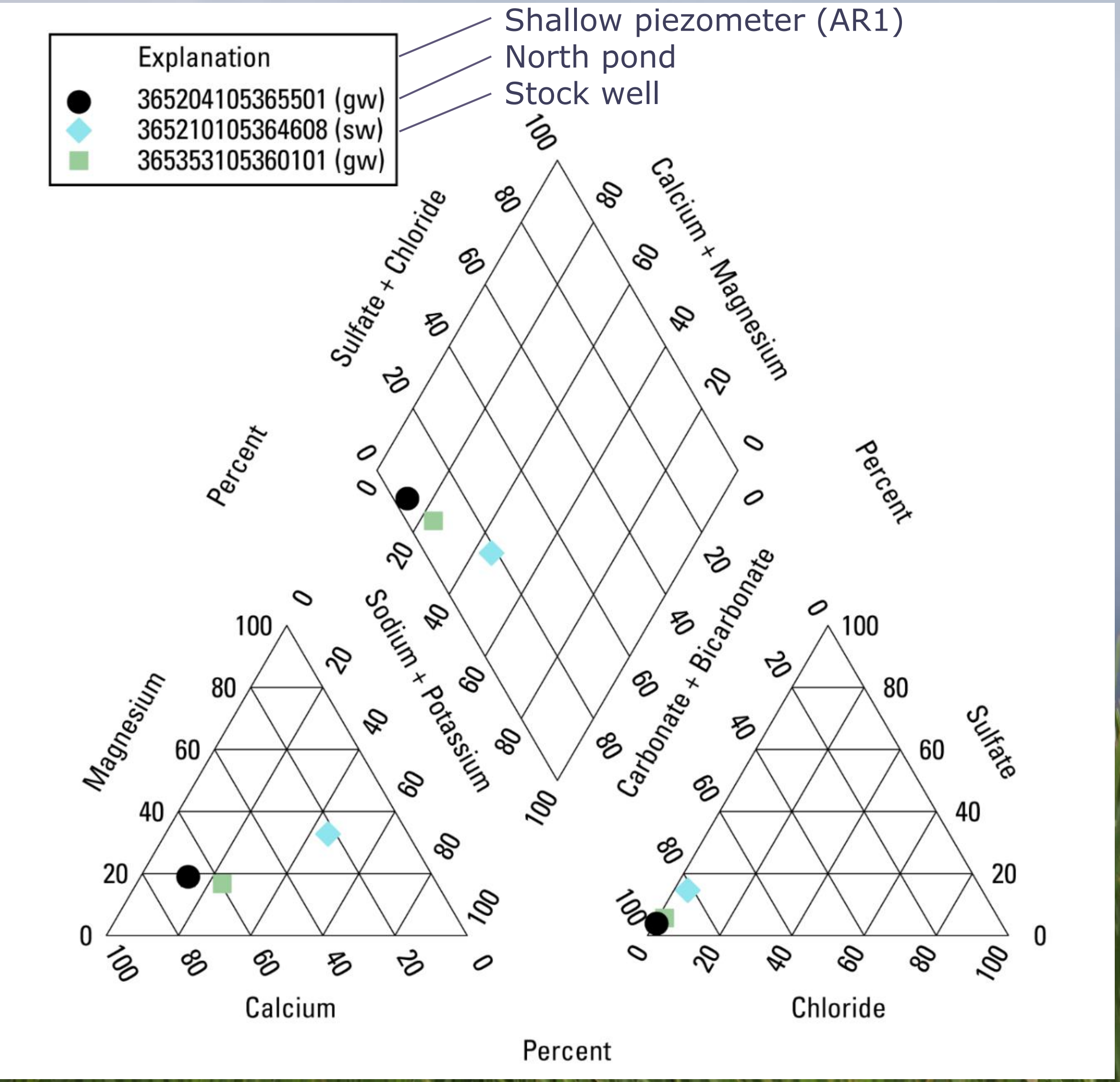


Groundwater-level Elevations

- The Anderson Ranch property is located between the groundwater-level contours of 7450 ft and 7500 ft shown in plate 2 of Winograd (1959).
- Current groundwater-level data do not show drastic changes in comparison to Winograd (1959) contours.

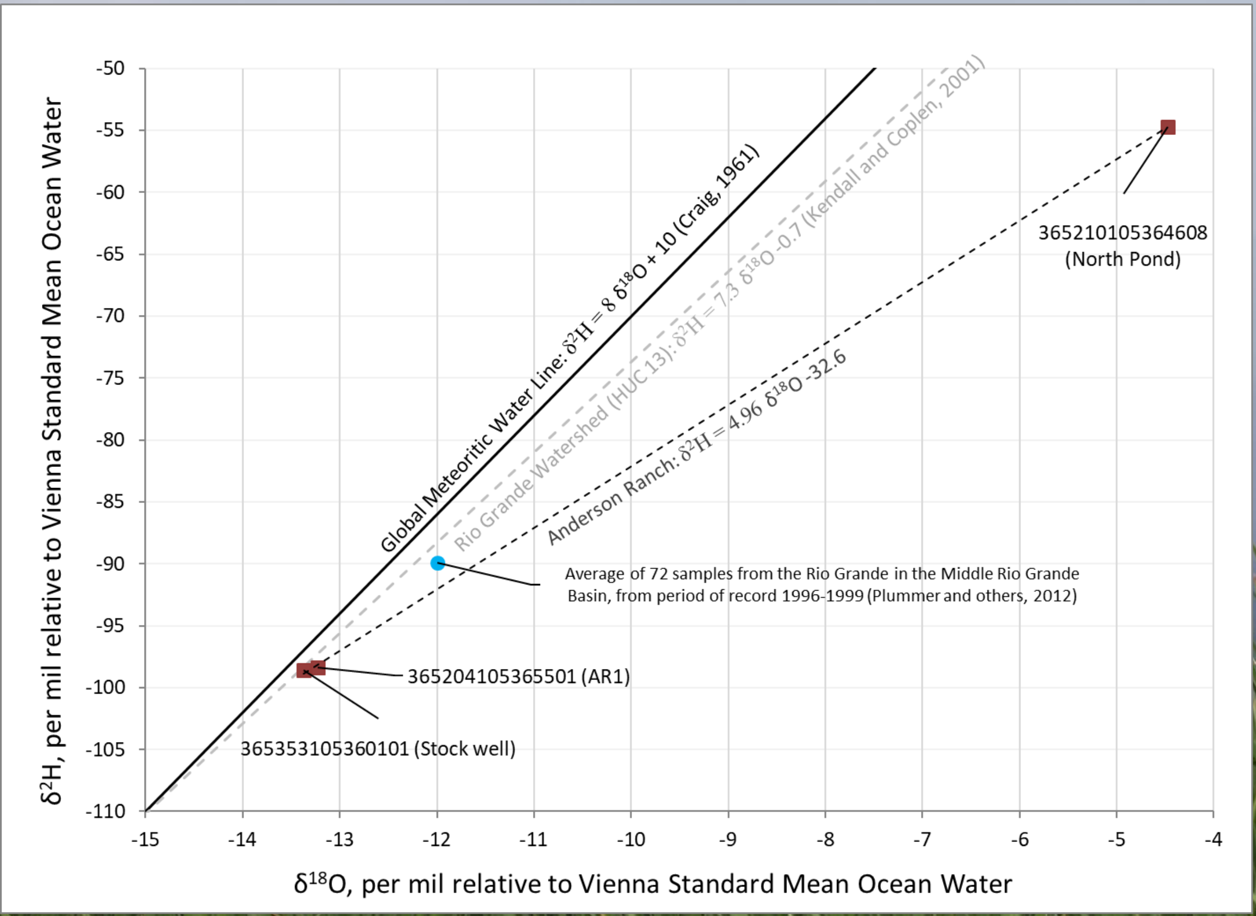
* As described in Winograd (1959), groundwater-level contours are of the upper surface of the zone of saturation within alluvial sediments; semi-perched in part and artesian pressure surface in part. Assumed to be referenced to NGVD 29, which is less than 6 ft lower elevation than NGVD 88 (NOAA, 2017).

Aqueous Chemistry: Major Ions



- A piper diagram is a trilinear diagram useful for illustrating the hydrochemical facies of a water sample (Hem, 1985).
- Based on major ion composition, both groundwater samples are calcium-bicarbonate water type and the surface-water sample is a mixed-cation bicarbonate type.
- Possible explanations for water-type difference at the surface-water site:
  - An evaporative signal at the surface-water site.
  - Cation exchange occurring within clay layers.

Aqueous Chemistry: Stable Isotopes



- The black dashed line connecting the Anderson Ranch sites is an estimated evaporative trend.
- The composition of the North Pond surface-water sample compared with the groundwater sample indicates evaporative fractionation.

Aqueous Chemistry: Nitrate, dissolved solids, and isotopes

Parameter	365210105364608	365204105365501	365353105360101
	North pond	AR1-Shallow Piezometer	Stock Well
Nitrate as N	< 0.040	3.39	1.34
δ* $^{15}N/^{14}N$ (Per mil)	NA	5.61	5.13
δ* $^{18}O/^{16}O$, Nitrate water filtered (Per mil) VSMOW**	NA	-2.25	-2.31
Dissolved solids dried at 180° Celsius (mg/L)	549	277	164
^{14}C Percent modern carbon, normalized	NA	112.6	98.92
Tritium (pCi/L)	NA	19.3	12.7

- Isotopes of Nitrate could be used to identify the source of nitrogen.
- Age-dating tracers ^{14}C and Tritium suggest recent recharge to shallow and deeper groundwater systems.

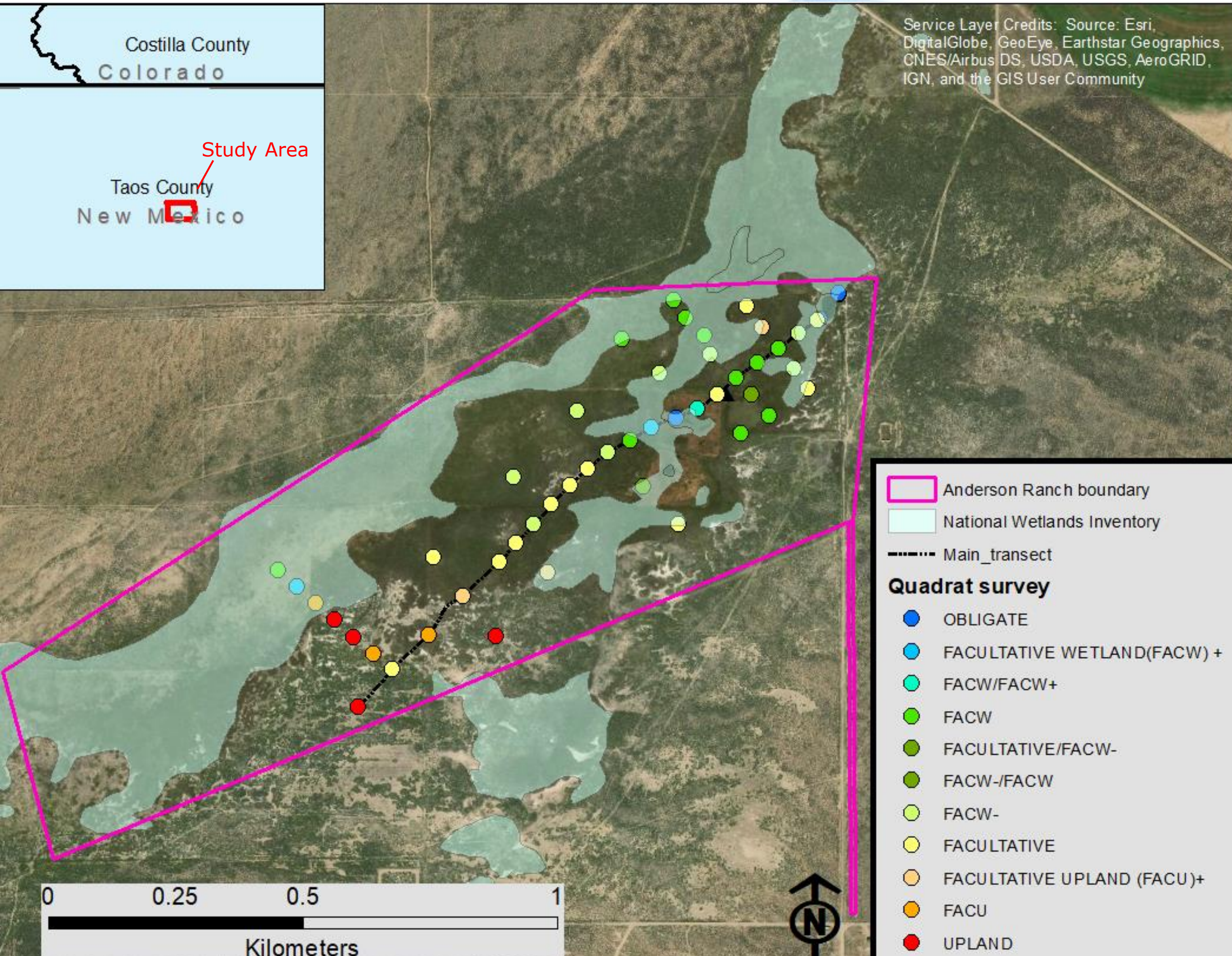
- Nitrate levels at AR1 are higher than the surface water and stock well nitrate levels, but still below the federal drinking water standard of 10 mg/L***
- Even low levels (greater than 2 mg/L) of Nitrate as Nitrogen have been found to affect aquatic organisms (Edwards and others, 2006; Edwards and Guillete, 2007).

*Please see the Appendix for an explanation of δ.
**Vienna Standard Mean Ocean Water
***2018 EPA Drinking water standard, maximum contaminant level (U.S. EPA, 2018).

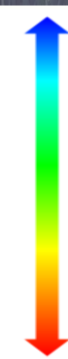
Aqueous Chemistry Summary

- Groundwater and surface water have similar ionic compositions and low dissolved solids.
  - Slightly higher dissolved solids and greater sodium and potassium concentrations in the surface water suggest additional processes affecting the surface water.
- Radiocarbon and tritium activity measured in groundwater samples indicate that most of the groundwater is composed of recent recharge.
- Groundwater samples plot on the Local Meteoric Water Line, while the stable isotope composition of the surface water suggests evaporative fractionation.
- There are slightly elevated nitrate levels at AR1 (365204105365501).

Vegetation Survey Results



- 30 species were identified.
- Coverage of hydrophytes, a plant growing in water or wet soil (Tiner, 1991), was significantly higher than the coverage of non-hydrophytes.



Commonly grow in wetlands

Almost never grow in wetlands

Water Budget

$$\Delta S = P - ET + SW_{in} - R + GW_{in} - GW_{out}$$

ΔS = change in storage

P = Precipitation

ET = Evapotranspiration

SW_{in} = Surface water inflows

R = Runoff (surface water outflows)

GW_{in} = Groundwater inflows

GW_{out} = Groundwater outflows

*all units are volumes $[Length^3]$

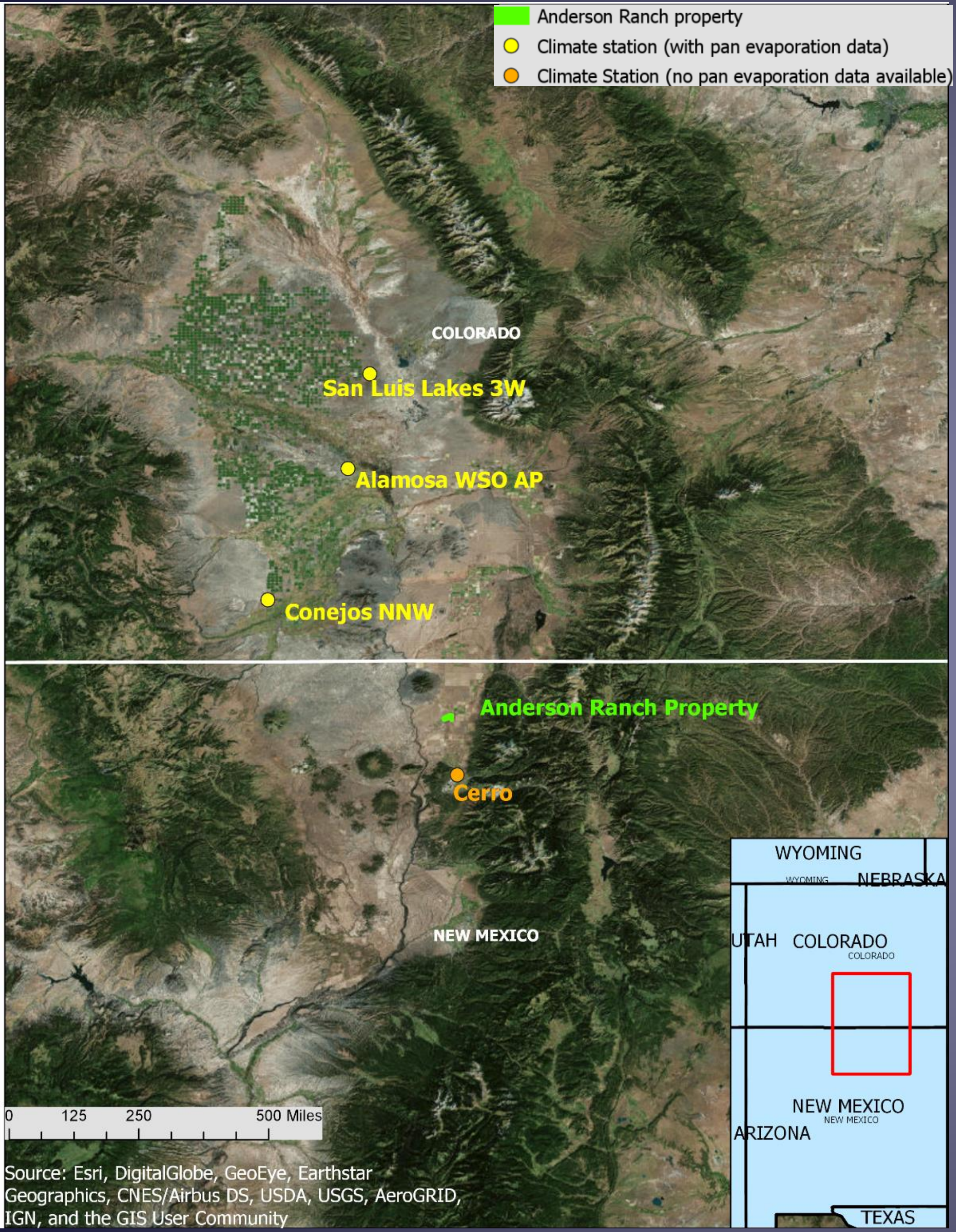
Assumptions made in this water budget

In order to estimate the Anderson Ranch wetland water budget in the absence of complete data, several assumptions were made:

1. The SW_{in} and R terms were assumed to be zero because there has been no observed surface flows into or out of the wetlands.

2. The GW_{in} and GW_{out} terms were assumed to be equal (due to lack of subsurface-flow information) and therefore the difference was assumed to equal zero.

Photograph of North Pond on the Anderson Ranch property, near site 365210105364608

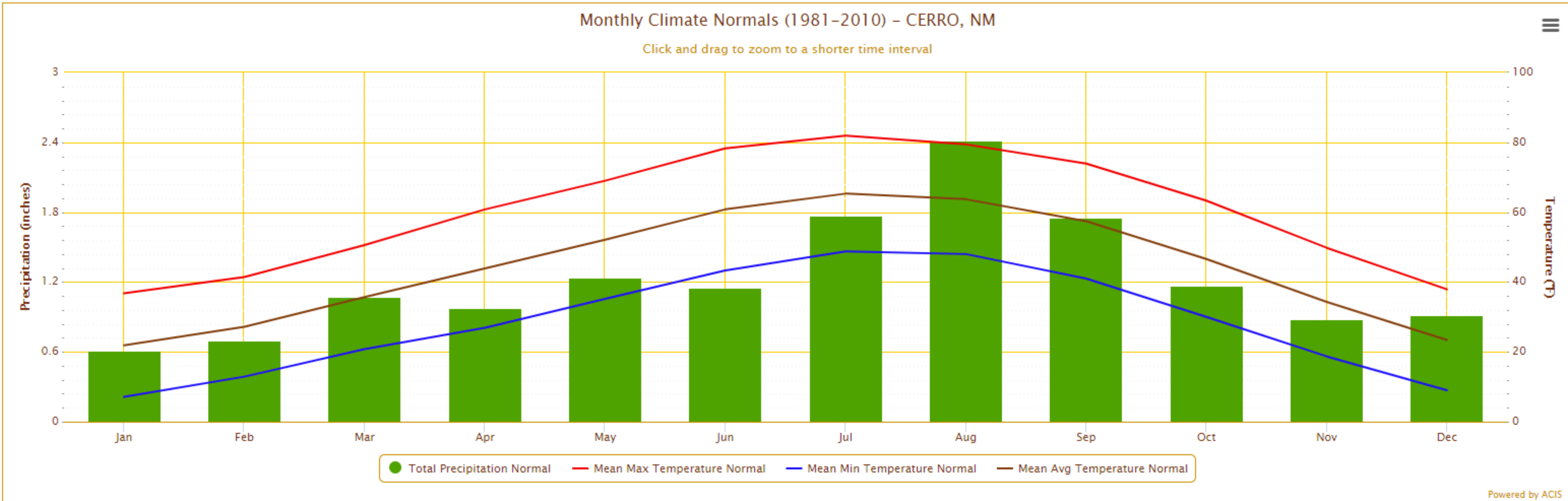


Data for a water budget

Nearby climate stations provide precipitation and pan evaporation data.

Precipitation

Station	Elevation (ft)	Period of record	Total Precipitation (inches)												
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
ALAMOSA WSO AP (station 050130)	7533	1948-2019	0.29	0.27	0.43	0.54	0.64	0.52	1.09	1.18	0.85	0.65	0.38	0.35	7.13
CONEJOS 3 NNW (station 051816)	7907	1945-1960	0.41	0.24	0.24	0.63	0.82	0.62	1.55	1.57	0.58	0.8	0.25	0.21	7.44
SAN LUIS LAKES 3W (station 057433)	7536	1946-1955	0.14	0.12	0.12	0.40	0.76	0.45	1.16	1.32	0.66	0.55	0.14	0.09	5.42
CERRO (station 291630)	7650	1910 -2019	0.57	0.57	0.79	0.91	1.14	0.87	1.92	1.98	1.45	1.15	0.63	0.72	11.89



Total precipitation at Cerro, Alamosa WSO AP, Conejos 3NNW and San Luis Lakes 3W climate stations and monthly climate normals at Cerro show the greatest precipitation is during the monsoon season (July – September).

Data from ACIS NOAA (2019)

Evapotranspiration (ET)

			Pan Evaporation (inches)												
Station	Elevation (ft)	Period of record	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
ALAMOSA WSO AP	7533	1948-2005	--	--	--	7.06	9.01	10.08	9.16	7.81	6.4	4.39	--	--	53.91
CONEJOS 3 NNW	7907	1948-1960	--	--	--	6.3	7.14	7.67	7.41	6.87	7.19	5.74	--	--	48.32
SAN LUIS LAKES 3W	7536	1948-1955	--	--	4.5	6.07	8.51	9.88	8.49	7.77	6.57	4.53	--	--	56.32

- Pan evaporation is measured using an above-ground Class A evaporation pan and adjusted for precipitation inputs. Due to effects of radiation and heat exchanges between water in the pan and the side walls of the pan, pan evaporation is an overestimate of evaporation from ponded surface water or wet soil, and an adjustment using a multiplication factor of 0.70 or 0.80 is suggested (WRRC, 2016).

- Differences between pan evaporation and ET depend on many factors, including vegetation type. ET can be estimated using the canopy crop coefficient (CCC) method which uses the evaporative demand of a region and the plant-species-specific crop coefficient (Drexler and others, 2004).

- Future work to determine appropriate crop coefficients could yield estimates of ET at the Anderson Ranch wetlands.

Water Budget-Preliminary Conclusions

1. Based on evaporation estimates from pan evaporation rates at nearby climate stations, evaporative (and likely ET) demand exceeds precipitation inputs.

2. Climate variability could result in higher temperatures (Chavarria and Gutzler, 2018) and increased evaporative demand, creating a larger outward flux.

3. Drought conditions could result in lower precipitation

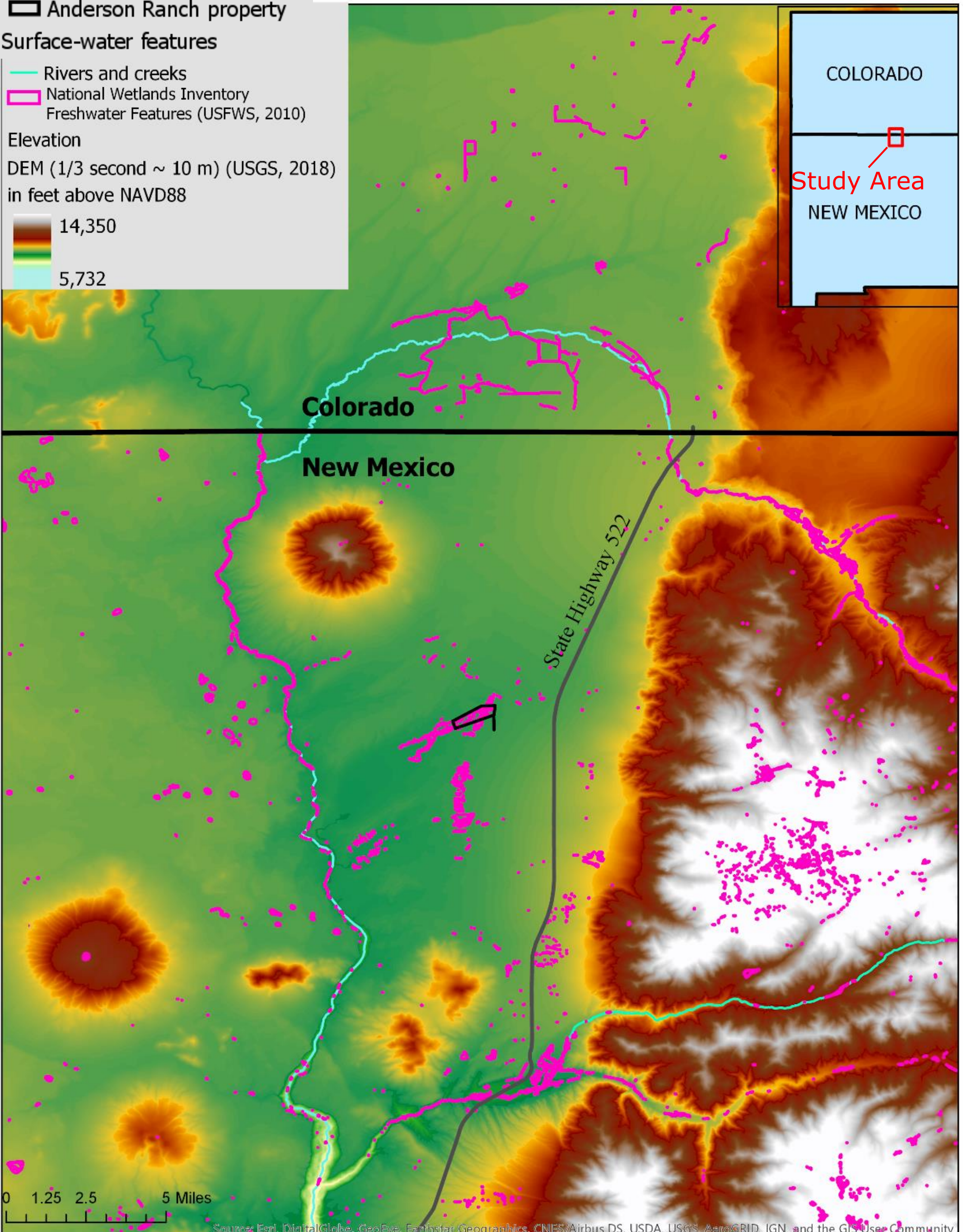
4. Increased groundwater pumping could result in decreases in subsurface inflows to the Anderson Ranch wetlands

Information required to complete a water budget analysis:

1. Subsurface inflows and outflows
   – Collect additional groundwater-level and surface water-level data
   – Build a groundwater-surface water model

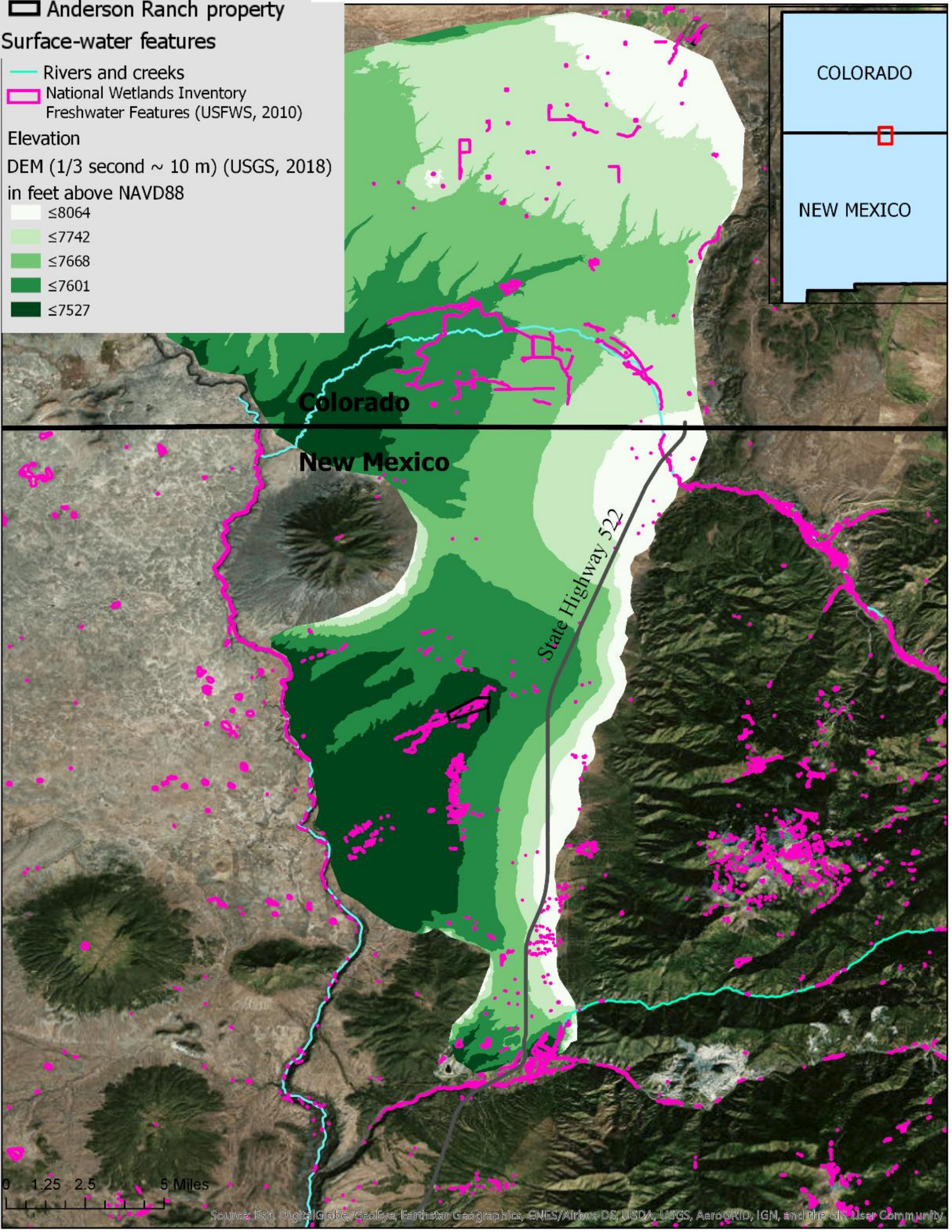
2. Historical and current extent of wetlands
   – Complete an analysis of historical wetland extent using Landsat imagery
   – Integrate results of vegetation survey with hydrologic characterization to determine the current extent of wetlands

3. Crop coefficients for wetland vegetation
   – Use results of vegetation survey and complete a literature review to determine appropriate crop coefficients



Elevation Analysis

The figure to the left shows that the Anderson Ranch property is located in a regional topographic low.



Elevation Analysis

Classifying lower elevations with smaller bins and natural jenks* illustrates that the Anderson Ranch property and the wetlands to the south are in a topographic low

*Natural jenks is an option in ArcGIS which clusters data based on data distribution.

Conclusions

1. Anderson Ranch wetlands are groundwater fed.
   - They are potentially the result of a regional topographic low as well as geologic features.
2. The Anderson Ranch wetlands appear to be connected to other nearby wetlands.
3. Surface water pond levels and groundwater-levels fluctuate seasonally
4. Hydraulic gradient in wetland area is from northeast to southwest
5. Current groundwater-level elevation within the Anderson Ranch Wetlands (~7500 ft) hasn't drastically changed since Winograd (1959) as evidenced by groundwater-level contours.
6. Water sourcing the wetlands is modern and potentially vulnerable to climate variability.
   - Deeper groundwater north of the wetlands (365353105360101, stock well) also has modern water.
7. Evapotranspiration a main driver of water demand

Future Work

To better understand the source of water to the wetlands

- Continue data collection and upgrade equipment to allow for real-time data collection (to provide data to cooperators and the public quickly and to prevent data loss due to equipment failures). Long-term data collection will allow for further trend analysis.
- Analyze temperature data at AR1 (365204105365501).
- Analyze climate data and groundwater-level data together.
- Conduct drone flights (NDVI*, infrared)
- Analyze data from other sources (including precipitation and groundwater-level data from the NMBMMR**, as well as data from published reports and other agencies).
- Complete the water budget.

To better understand historical and future scenarios

- Analyze Landsat and historical imagery.
- Analyze climate change scenarios (build a model).

To support the creation of a watchable wildlife station

- Build interactive data collection infrastructure.
- Conduct outreach efforts.

*Normalized difference vegetation index

**New Mexico Bureau of Geology & Mineral Resources

Thank You!

- Natural Resource Damage Assessment and Restoration Program
- Bureau of Land Management
- U.S. Fish and Wildlife Service
- The vegetation survey team: USGS employees Quan Dong, Joan Daniels, and Alanna Jornigan

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Appendix: Geochemical data for sites 365210105364608, 365204105365501, and 365353105360101

*These data are also available at https://waterdata.usgs.gov/nwis

Abbreviations	
NA	Not applicable
<	Less than
M	Presence verified but not quantified
E	Estimated

Units	
Deg C	Degrees Celsius
ft	Feet
MDT	Mountain Daylight Time
mmHg	Millimeters Mercury
mg/L	Milligrams per liter
µg/L	Micrograms per liter
µS/cm	Microsiemens per centimeter
NAD 83	North American Datum 1983
NAVD 88	North American Vertical Datum of 1988
NTRU	Nephelometric Turbidity Ratio Units
pCi/L	Picocuries per liter
VPDB	Vienna Pee Dee Belemnite
VSMOW	Vienna Standard Mean Ocean Water
δ	Delta, a measure of the ratio of stable isotopes within the sample. Delta is calculated from the ratio of the first stable isotope listed divided by the second stable isotope listed within the sample, divided by that same ratio within the standard, times 1000. Below is an example equation for δ18O. $$\left(\frac{\left(\frac{\delta^{18}O}{\delta^{16}O}\right)_{sample}}{\left(\frac{\delta^{18}O}{\delta^{16}O}\right)_{standard}} - 1\right) x\ 1000\ ‰$$
%	Percent
‰	Permil

Appendix (continued): Geochemical data for sites 365210105364608, 365204105365501, and 365353105360101

Parameter	365210105364608	365204105365501	365353105360101
Site Information			
Local identifier	30N.12E.01.1422	30N.12E.01.1414	31N.13E.30.114 (Projected)
Other name/description	North pond	AR1	Stock well
Latitude (Decimal degrees, NAD 83)	36.86958888	36.86783056	36.89818611
Longitude (Decimal degrees, NAD 83)	-105.6129889	-105.6153	-105.6002472
Well depth (ft below land surface)	NA	27	210
Screen depth (ft below land surface)	NA	22-27	110-210
Elevation (ft above NAVD 88)	7515	7506.98	7565
Field Parameters			
Sample date	10/24/2016	10/25/2016	10/25/2016
Sample time (MDT)	14:00	10:00	14:00
Average depth to water [2016-2019] (ft below land surface)	NA	0.51	53.5
Temperature (deg C)	10.5	9.7	11.9
Barometric Pressure (mm/Hg)	589	583	581
Specific Conductance, at 25 deg C (µS/cm)	864	582	257
Dissolved Oxygen (mg/L)	10.3	5.2	7.6
Dissolved Oxygen (% of saturation)	120	60	92
pH, field (standard units)	8.3	7.5	7.6
Air Temperature (deg C)	23.9	NA	NA
Turbidity (NTRU)	NA	1.6	6.3
Carbonate, inflection point titration (mg/L)	3.1	0.4	0.1
Bicarbonate, inflection point titration (mg/L)	369	335	126
Alkalinity (mg/L as $CaCO_3$)	308	276	104

Appendix (continued): Geochemical data for sites 365210105364608, 365204105365501, and 365353105360101

Parameter	365210105364608	365204105365501	365353105360101
Nutrients/Organics			
Total Nitrogen (mg/L)	< 1.0	3.5	< 1.4
Organic Nitrogen (mg/L)	< 0.97	< 0.07	< 0.07
Ammonia ($NH_3 + NH_4^+$) as N (mg/L)	< 0.01	< 0.01	< 0.01
Ammonia as NH_4^+ (mg/L)	< 0.013	< 0.013	< 0.013
Ammonia + Organic Nitrogen as N (mg/L)	0.97	0.07	< 0.07
Nitrite as N (mg/L)	< 0.001	< 0.001	< 0.001
Nitrate as N (mg/L)	< 0.040	3.39	1.34
Nitrate + Nitrite as N (mg/L)	< 0.040	3.39	1.34
Orthophosphate (mg/L)	< 0.012	0.05	0.084
Orthophosphate as P (mg/L)	< 0.004	0.016	0.028
Phosphorus (mg/L)	< 0.02	0.05	0.02
Organic Carbon, unfiltered (mg/L)	13.9	9.8	< 0.7
Organic Carbon, filtered (mg/L)	12.4	0.95	0.44
Major Ions			
Calcium (mg/L)	44.6	87.0	31.7
Magnesium (mg/L)	39.9	14.9	5.39
Sodium (mg/L)	98.8	20.0	13.6
Sodium, fraction of cations (% in equiv. of major cations)	43	13	22
Potassium (mg/L)	8.67	2.27	1.58
Chloride (mg/L)	25.3	2.50	3.94
Sulfate (mg/L)	131	31.8	16.0
Iodide (mg/L)	0.009	0.001	0.001
Bromide (mg/L)	E 0.431	0.066	0.069
Fluoride (mg/L)	0.66	0.17	0.32

Appendix (continued): Geochemical data for sites 365210105364608, 365204105365501, and 365353105360101

Parameter	365210105364608	365204105365501	365353105360101
Trace Elements			
Silica as SiO_2 (mg/L)	5.84	23.4	22.9
Arsenic (µg/L)	1.1	0.57	0.21
Barium (µg/L)	77.8	146	56.5
Boron (µg/L)	83	8.0	11
Iron (µg/L)	9.5	7.7	13.0
Manganese (µg/L)	2.87	2.51	1.19
Strontium (µg/L)	404	474	224
Aluminum (µg/L)	6.9	< 3.0	< 3.0
Lithium (µg/L)	31.6	9.20	3.04
Isotopes			
$\delta^{13}C$ (‰) VPDB	NA	-15.08	-11.82
^{14}C Percent modern carbon, normalized	NA	112.6	98.92
^{14}C Counting error 1σ percent modern carbon	NA	0.260	0.280
$\delta\ ^{2}H/^{1}H$ (‰) VSMOW	-54.70	-98.40	-98.60
$\delta\ ^{18}O/^{16}O$ (‰) VSMOW	-4.47	-13.23	-13.37
$\delta\ ^{15}N/^{14}N$ (‰)	NA	5.61	5.13
$\delta\ ^{18}O/^{16}O$, nitrate water filtered (‰)	NA	-2.25	-2.31
Tritium (pCi/L)	NA	19.3	12.7
Parameter	365210105364608	365204105365501	365353105360101
Other			
pH, lab (standard units)	8.3	7.9	7.8
Carbon Dioxide, unfiltered (mg/L)	2.7	18	5.4
Hardness, water, as $CaCO_3$ (mg/L)	276	279	NA
Hardness as HCO_3 (mg/L)	276	279	102
Dissolved solids dried (mg/L)	549	277	164
Dissolved solids sum (mg/L)	E 540	363	164