



Western Water & Land, Inc.

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June 28, 2016

Mr. Carlos Lujan
Environmental Protection Specialist
Northwest Region
State of Colorado
Oil and Gas Conservation Commission
796 Megan Avenue, Suite 201
Rifle, CO 81650

RE: Orphan Well Surface Characterization, De Beque, Colorado Area

Dear Mr. Lujan:

Western Water & Land, Inc. (WWL) has completed surface characterization of three orphan oil and gas well sites in the vicinity of De Beque, Colorado. Per your direction, WWL conducted water and soil quality sampling and analysis at these orphan well sites to support COGCC in their efforts to assess and prioritize plug and abandonment of orphan wells in the state.

The objective of the surface characterization was to assess the water quality of discharging water from the wells and soil quality of surface soils in the immediate vicinity. In addition, the potential extent of surface impact was determined based on visual observations. No subsurface characterization was conducted for this investigation.

The three wells assessed include:

- Buckeye-2: SE ¼, SE ¼, S21, T8S, R97W, 6PM
- Lloyd & Lowell-1: SW ¼, SE ¼, S29, T8S, R97W, 6PM
- Govt-Baker-1: SE ¼, SW ¼, S21, T8S, R97W, 6PM

This report has adopted the identifying names Buckeye-2, Lloyd & Lowell, and Govt-Baker for the investigated well sites. Figure 1 is a general location map for the assessed well sites. This report summarizes field sampling activities along with the quality control and soil chemistry results. See Figures 2, 3, and 4 for the sampled locations. Photographs of the sampling sites are shown in Attachment A. Field monitoring forms and notes are shown in Attachment B. An analytical summary is provided in Attachment C, and the laboratory report is in Attachment D.

FIELD INVESTIGATION

Field sampling was conducted on June 13th, 2016, and GPS delineation of impacted areas associated with each well was conducted on June 14, 2016. A total of six water samples and seven soil samples

were collected, including two water samples and two soil samples at each well site and one reference soil sample.

Water sampling at each well site included one sample immediately next to the well casing or emanation point and one sample located at some point downgradient. The downgradient sample location depended on the extent of surface flooding, the existence of a receiving surface water feature, and whether or not water depth was sufficient for sample collection. Discharge water from all three well sites was at least partially discharging to other nearby surface water features. Dark soil staining indicating the presence of hydrocarbons as well as a visible sheen and hydrocarbon odor were present at the Lloyd & Lowell and Govt-Baker well sites, including several tens of feet downgradient of the emanation points.

At the Buckeye-2 well site, the downgradient sample was collected at the furthest distance from the well head where water depth was sufficient. While an irrigation ditch was present at the downgradient extent of the Buckeye-2 well, the confluence area was indistinct (some mixing of well discharge and irrigation water) and therefore a sample was not collected here. The irrigation ditch was flowing between 5 and 10 cubic feet per second (cfs). See Figure 2 for a map of the sampling sites and interpreted area of impact for the Buckeye-2 well site.

The Lloyd & Lowell downgradient sample (Lloyd & Lowell-1) was collected at a point where ponded water downgradient of the well head was seeping into an adjacent irrigation ditch that was estimated to be flowing between 5 and 10 cfs. See Figure 3 for a map of the sampling sites and interpreted area of impact for the Lloyd & Lowell well site.

At the Govt-Baker well, the downgradient sample was collected approximately 300 feet from the well casing in a natural drainage that received the well discharge. The drainage was densely vegetated. WWL traced the drainage to the southwest toward Roan Creek. It was found that the drainage merged with a wetland and then formed at least one channel that flowed to the south subparallel to Roan Creek; the flow was estimated to be at least 0.5 cfs. The channel of Roan Creek was another 100 feet or more to the west; the creek was estimated to be flowing at 100 cfs or greater. See Figure 4 for a map of the sampling sites and interpreted area of impact for the Govt-Baker well site.

WWL conducted all water and soil sampling in accordance with industry-accepted practices and quality control procedures. Nitrile gloves were worn by sampling personnel. Water sampling methods consisted of direct (in-situ) filling of sample bottles at the sample locations. Sample bottles were filled so as not to lose preservatives. A total of 18 bottles were filled for each water sample.

Soil samples were collected as composite samples. Five subsamples were collected and mixed to form each soil sample. Each sample pit was excavated to a depth of approximately 6 inches and width of 6 to 8 inches. In cases where soil was compacted, a decontaminated steel shovel blade was used to break the surface crust. Decontaminated stainless steel scoops were used to collect each subsample which was placed into a stainless steel bowl. The soil material was thoroughly mixed into a composite sample and described before being transferred to soil sample containers. All samples were collected in new factory-cleaned glass jars for submittal to the analytical laboratory; 8 jars were used per sample. An additional volume of sample was collected in new Ziploc™ plastic bags for a temporary hand specimen to be used for soil description purposes and as laboratory back-up sample material. The samples were packed with ice for preservation and shipped via FedEx Ground® on the day of collection to the analytical laboratory, ALS Environmental [ALS] in Fort Collins, Colorado. Note that while photographs of soil sampling sites at the Lloyd & Lowell were taken, they did not upload properly and were lost.

The analytical schedule was designed to assess both analytes common to Table 910-1 of COGCC 900 Series Rules as well as compliance with CDPHE WQCC regulations for stream segment 12b of the Colorado River Basin which includes all tributaries and wetlands to the Colorado River from a point

immediately below the confluence of Parachute Creek to a point immediately below the confluence with Roan Creek, except for the specific listings in segments 14a, 14b, and 14c. In addition, Rule 609 analytes were applied to the list to assure complete consideration of potential oil and gas impacts. The analytical schedule is shown in Table 1.0.

QUALITY CONTROL SUMMARY

Due to time constraints, WWL did not conduct a Tier I quality control evaluation of the laboratory analytical data. However, WWL did calculate a cation-anion balance and total dissolved solids (TDS) ratio (based on measured and calculated TDS) from the results of each water sample. These results are as follows:

Sample ID	Cation-Anion Balance (%)	TDS Ratio
Buckeye 2-1	1.074	1.20
Buckeye 2-2	0.013	1.25
Lloyd & Lowell-1	2.928	1.26
Lloyd & Lowell-2	5.456	0.84
Govt-Baker-1	5.057	1.34
Govt-Baker-2	4.411	1.03

The calculated cation-anion balance are generally within or near the preferred range of $\pm 5\%$, whereas some of the calculated TDS ratios are slightly higher than the preferred range of 0.8 to 1.2.

ALS reported that the samples were received within the temperature criteria for proper preservation. One soil bottle had a small crack in cap, but no contamination was suspected. Three bottles indicated a pH > 2.0 , so HNO_3 was added. One bottle indicated a pH < 12.0 . Headspace was less than green pea in 4 VOAs, and a light dusting was observed in 10 bottles, with moderate sediment in 2 bottles.

ALS Laboratory assigned analytical results that were undetected with a “U” qualifier and a “J” qualifier to results that were detected above the method detection limit but below the reporting limit to indicate the result value is estimated.

Chromium

The laboratory reported some problems with the chromium analyses. Dissolved chromium III and VI were originally to be analyzed as dissolved species, however, ALS found the unusual occurrence where total (dissolved) chromium was not detected, whereas chromium IV was detected. It was suspected that there was some interference with the nondissolved fraction. After consideration, WWL directed ALS to report chromium as the total recoverable fraction. ALS provided the following explanatory text in an email:

“The total recoverable Cr that we ran was non-detect for all samples except sample Lloyd & Lowell-2 which came out at 0.07 ppm.

For the Lloyd & Lowell-2 sample the CrVI was a J flag hit at 0.0051 ppm. The technical manager said that indicates that for this sample the Cr is all CrIII.

For the other samples where the total recoverable Cr is non-detect but the CrVI were J flag detects or above RL detects that the CrVI results are due to an interference in the matrix. The samples do have sediment and even filtering for the CrVI wouldn’t filter out

other interferences that could develop some color that would interfere with the CrVI analysis.

Our recommendation is to not report CrIII for the samples except for the Lloyd & Lowell-2 sample can have the CrIII reported.”

ANALYTICAL RESULTS

Laboratory analysis was performed by ALS, in Fort Collins, Colorado in accordance with the analytes outlined in Table 1.0. The analytical results are summarized and compared to state standards in Attachment C; the data are qualified as indicated. The full laboratory analytical report is presented in Attachment D. Note that a dilution factor of 10 was common for metals analysis for all samples; this elevated the reporting limits for these constituents. For benzene, toluene, ethylbenzene, and total xylenes (BTEX), two analyses were conducted with different dilution factors of 1 and 5.

INTERPRETATION

A brief summary of analytical results and interpretation with an emphasis on state standards is presented below.

Water Results

This section of the report discusses water quality conditions at water samples collected at the well casing emanation point and at a sampling point downgradient of the well casing. However, it should be noted that water quality at downgradient locations may be influenced by other media and processes such as soils, vegetation, evaporation and microbial activity.

The analytical results for water samples showed several constituents that exceeded state domestic water supply standards. Note that the standard for aquatic life for several of the metals must be calculated using the hardness of the receiving water. The hardness for receiving waters (irrigation ditches and Roan Creek) is not known. The hardness of the waters can be estimated from other data, however, this was not conducted for this scope of work. The drinking water standard is of interest here as the water sources, Roan Creek and Colorado River, are designated for water supply use and may be potentially impacted by the orphan well discharge waters. A summary of selected water quality parameter results is provided below.

- Field pH measurements ranged from 7.72 to 8.13 s.u. for the 6 water sample sites associated with the orphan wells.
- Constituents that exceed the domestic water supply standard for at least one water sample at all three orphan well sites included barium and iron. Barium concentrations ranged from 1,200 to 41,000 µg /l; iron 360 to 110,000 µg /l.
- Chromium (total dissolved) was not detected in any water samples, but chromium VI was detected in the Buckeye 2-1 sample and the Govt-Baker-1 and Govt-Baker-2 samples, the latter two at concentrations of 66 and 210 µg /l, respectively, both of which are above state domestic water, agriculture, and aquatic life standards.
- Fluoride concentrations were above the state domestic water supply standard of 2 mg/l with the highest exceedance being 4.7 mg/l at the Buckeye 2-2 sample site. Fluoride was below the domestic water supply standard in the Govt-Baker well site samples.

- Manganese concentrations at both Govt-Baker well site samples (130 and 66 µg /l) exceeded the state domestic water supply standard of 50 µg/l.
- Sulfur species in the well discharge water is generally low with sulfate often reported at low concentrations or as not detected. Sulfide was not detected.
- Sodium and chloride concentrations are among the largest elemental concentrations in the well discharge; sodium ranges from 450 mg/l at the Lloyd & Lowell well to 4,700 mg/l at the Govt-Baker well, and chloride ranges from 50 mg/l at the Lloyd & Lowell well to 7,900 mg/l at the Govt-Baker well.
- Arsenic concentrations in the well discharge was mostly not detected or between the method detection limit and reporting limit, with the exception of a concentration of 20 µg/L for the Lloyd & Lowell-2 sample, which exceeded the drinking water and aquatic life standard of 0.2 to 10 µg/l.
- The chronic aquatic life standard for iron was exceeded at both Govt-Baker sample sites and the Lloyd & Lowell-2 sample site.
- TDS ranged from 1,100 mg/l for the Lloyd & Lowell-1 sample to 13,000 mg/l for the Govt-Baker-2 sample.

There were no detections of analyzed hydrocarbons at the Buckeye-2 well. However, total purgeable hydrocarbons (TPH) and total extractable hydrocarbons (TEH) (including gasoline range [GRO] and diesel range hydrocarbons[DRO]) were detected in the water discharging from the Lloyd & Lowell and Govt-Baker well head sites. In general, hydrocarbons were not detected at the downgradient sampling sites. TEH concentrations were the greatest at the Govt-Baker water sample at the well head with a concentration of 15 mg/l. TEH was detected at the Govt-Baker downgradient sampling site, but not at the Lloyd-Lowell downgradient sampling site. Benzene exceeded the drinking water standard of 2.3 to 5 µg/L at the Lloyd & Lowell-1 and Govt-Baker-1 wells with concentrations of 110 and 140 µg/l, respectively. These results also exceeded the state standards for water+fish and fish ingestion.

Calculated salt loading to the surface based on TDS and estimated discharge rates of 3, 10, and 5 gallons per minute at the Buckeye 2, Lloyd & Lowell, and Govt-Baker wells, respectively, is 112, 132, and 601 pounds per day for samples collected at the well head sites, respectively.

Soil Results

The COGCC Table 910-1 standards for soil were exceeded for a number of analytes including arsenic, boron, and total volatile and extractable petroleum hydrocarbons (TVEPH).

- Arsenic and boron concentrations in all soil samples including the reference soil sample exceeded the Table 910-1 standards of 0.39 mg/kg and 2 mg/kg, respectively. The arsenic concentrations in soils associated with the orphan wells sites ranged from -31% to +35% of the Soil Ref-1 sample. The two downgradient soil samples for the Lloyd & Lowell and Govt-Baker well sites exceeded the reference soil sample (Soil Ref-1) for boron by approximately two times.
- TPH and GRO were detected at only one soil sample, the downgradient soil sample for Govt-Baker well site (Govt-Baker-S2) at 4.8 and 7.5 mg/kg, respectively.

- TEH and DRO were detected in both soil samples at the Govt-Baker well site and the Lloyd & Lowell well site with exception of DRO at the Lloyd & Lowell well site soil sample (Lloyd & Lowell-S1).
- The Table 910-1 concentration limit for TVEPH of 500 mg/kg was exceeded at the Govt-Baker well.
- The well head soil sample (Govt-Baker-S1) and downgradient soil sample (Govt-Baker-S2) concentrations for TEH and DRO were 5,200 and 4,000 mg/kg, and 1,800 and 1,200 mg/kg, respectively.
- Also, of interest are the results for the downgradient soil sample at Lloyd & Lowell (Lloyd & Lowell-S2) for TEH and DRO; these results were 110 and 54 mg/kg, respectively, and were over ten times the concentrations for the soil sample near the well head (Lloyd & Lowell-S1).

In addition to the above discussed analytes, the soil results indicated that the sodium adsorption ratio (SAR), paste pH, and electrical conductivity (EC) of analyzed soils exceeded Table 910-1 standards. The reference soil sample collected, Soil Ref-1, was used to compare EC results for the well site soil samples.

- The SAR standard of 12 was exceeded in all well site soil samples, ranging from 18 to 120. The soil reference sample, Soil Ref-1 had a SAR result of 7.6. SAR was estimated for the Soil Ref-1 and Buckeye 2 –S2 sample because one or more of the analytes used in the calculation were not detected in the analysis.
- The paste pH standard of 6 to 9 s.u. was exceeded at the Buckeye 2-S1 and Lloyd & Lowell-S2 soil samples with results of 9.1 and 9.6 s.u., respectively. The Soil Ref-1 sample had a paste pH of 8.5 s.u.
- The EC standard of less than 4 mmhos/cm or 2x background was exceeded at 5 of the 6 well site soil samples ranging from 6 to 18 mmhos/cm. The Soil Ref-1 (background) result was 1.7 mmhos/cm. The Lloyd & Lowell-S1 sample had a EC of 2.6 mmhos/cm

SUMMARY AND CONCLUSIONS

At the request of COGCC, WWL conducted a field investigation of surface conditions at three orphan oil and gas wells near De Beque, Colorado. The orphan well sites Buckeye 2, Lloyd & Lowell and Govt-Baker were all discharging groundwater to the surface; gas bubbles and hydrocarbons, notably at the Lloyd & Lowell and Govt-Baker sites, were also present. Two water samples and two soil samples were collected at each well site; one of each sample type was collected at or very near the casing emanation point and at a downgradient location.

Concentrations and levels of several analytes and parameters exceeded COGCC Table 910-1 levels and CDPHE water quality standards. Analytical results indicate that the Buckeye 2 water and soil samples did not contain hydrocarbons. Whereas, hydrocarbon occurrence was present at both the Lloyd & Lowell and Govt-Baker well sites and most prevalent at the latter location. Hydrocarbon contamination may be present at some distance from the well casing emanation points. Other indicators of impact such as soil SAR and EC also indicate potential impact to areas downgradient of the well casing emanation

points. The potential exists for significant cumulative salt loading to waters of the state including Roan Creek and the Colorado River.

A general safety observation made by WWL during the field investigation was that each of the orphan well sites is not secured from incidental access. The well sites were generally inconspicuous in nature and would not readily be known to exist on the properties unless a person is standing a short distance away. The areas immediately next to the well sites are unsafe and present a hazard to wildlife, livestock and humans. The possibility exists that the emanating water and gas has undercut the existing bank and that the soil is thin and an underlying deep cavity of water is present. Even if this condition is not present, water depth could be significant making egress very difficult. It is recommended that the well casing sites where water and gas is emanating at the surface be fenced off until the wells are properly plugged and abandoned.

If you have any questions or concerns, please contact me at (970) 242-0170.

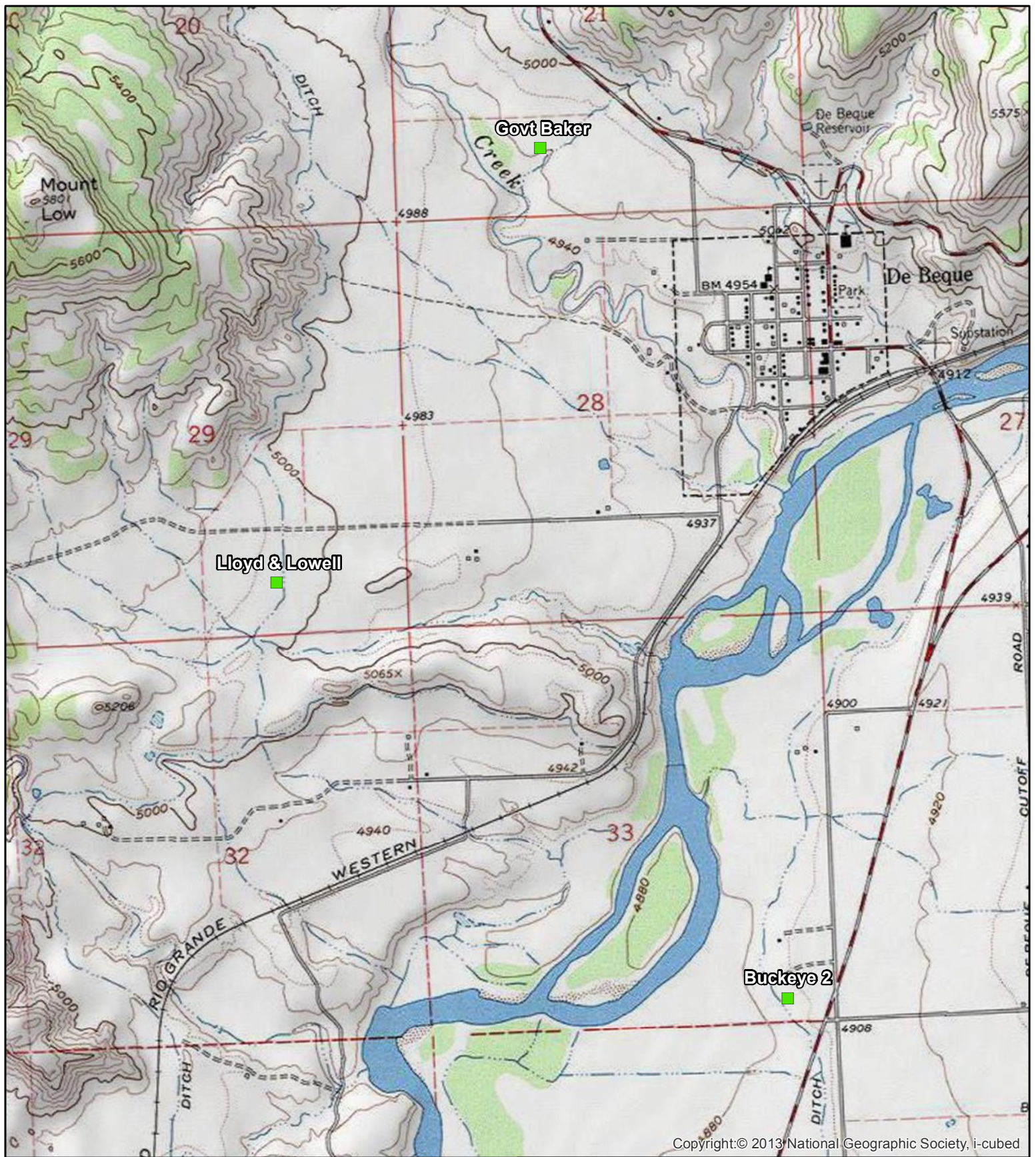
Sincerely,

A handwritten signature in black ink, appearing to read "Bruce D. Smith". The signature is fluid and cursive, with the first name "Bruce" being more legible than the last name "Smith".

Bruce D. Smith
Principal Hydrogeologist
WESTERN WATER & LAND, INC.

Attachments

Attachment A - Photographs
Attachment B - Field Monitoring Forms
Attachment C - Analytical Summary
Attachment D - Laboratory Report



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Legend

■ Ophan Wells

0 0.125 0.25 0.5 Miles
1:20,000

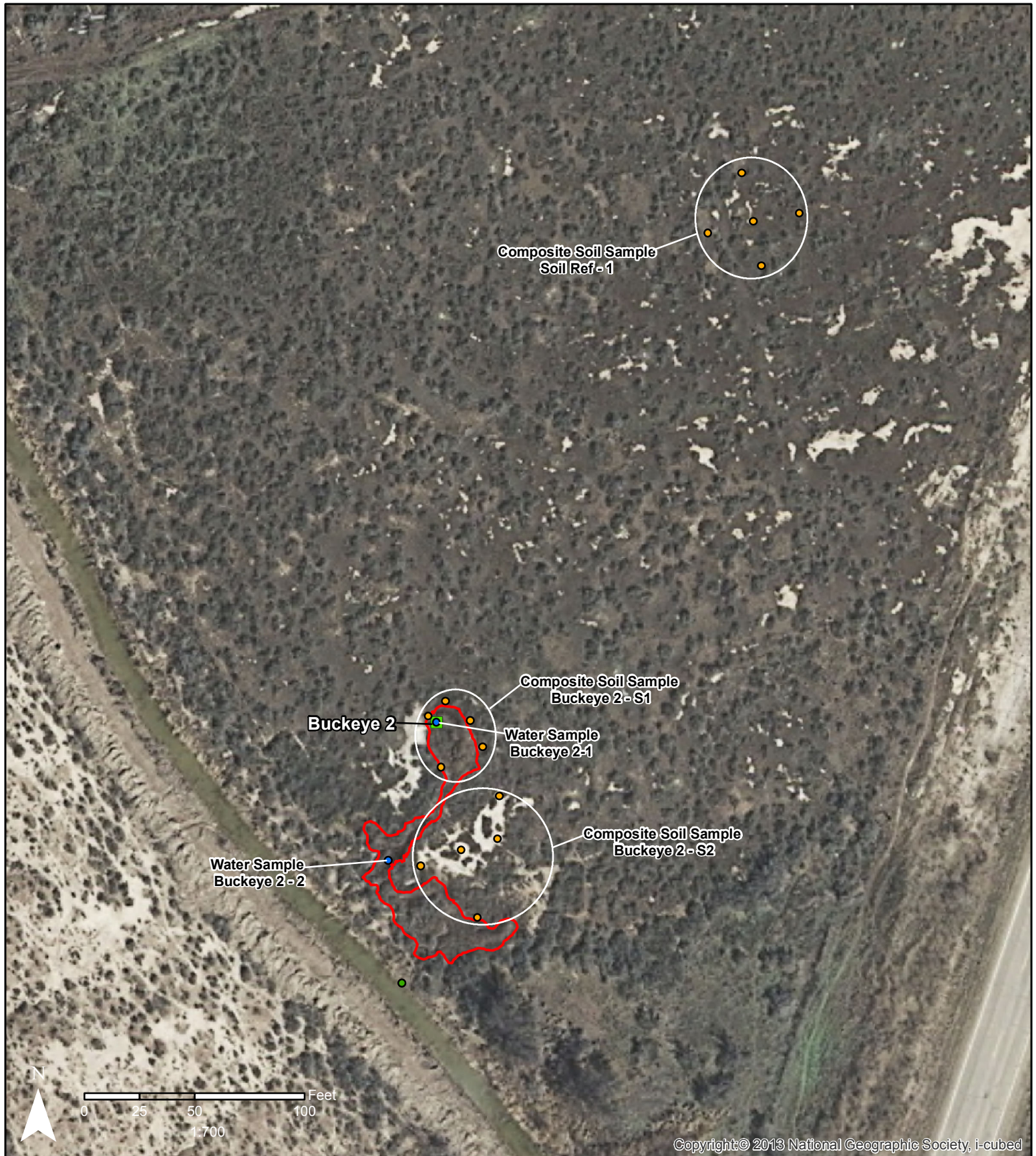


Figure 1: De Beque Orphan Well Locations

Mesa County, Colorado



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Legend

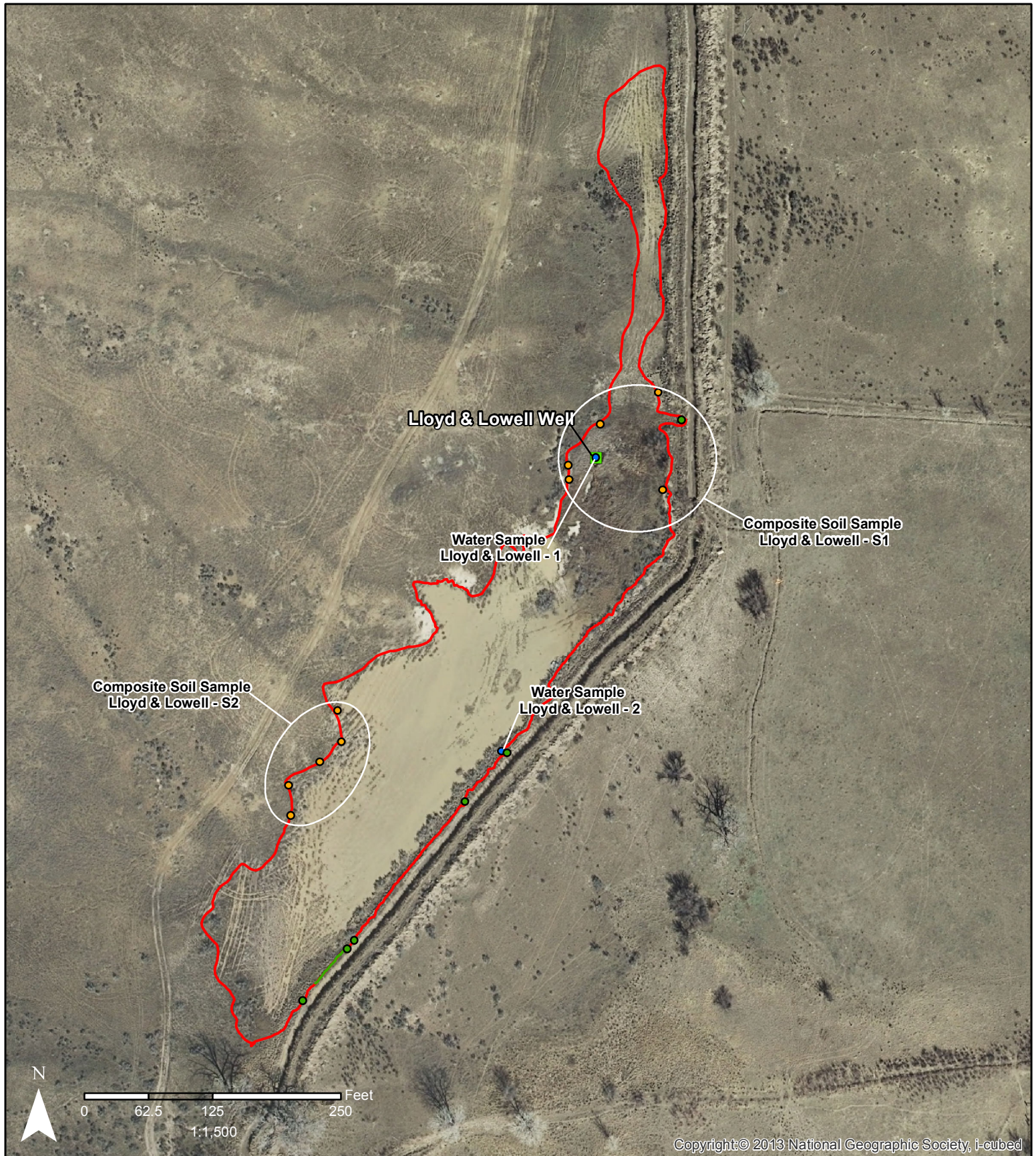
- Orphan Well
- Water Sample Locations
- Soil Sample Locations
- Water Enters Irrigation Ditch
- Approximate Area of Impact

Figure 2: Buckeye 2 Well

Mesa County, Colorado



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Legend

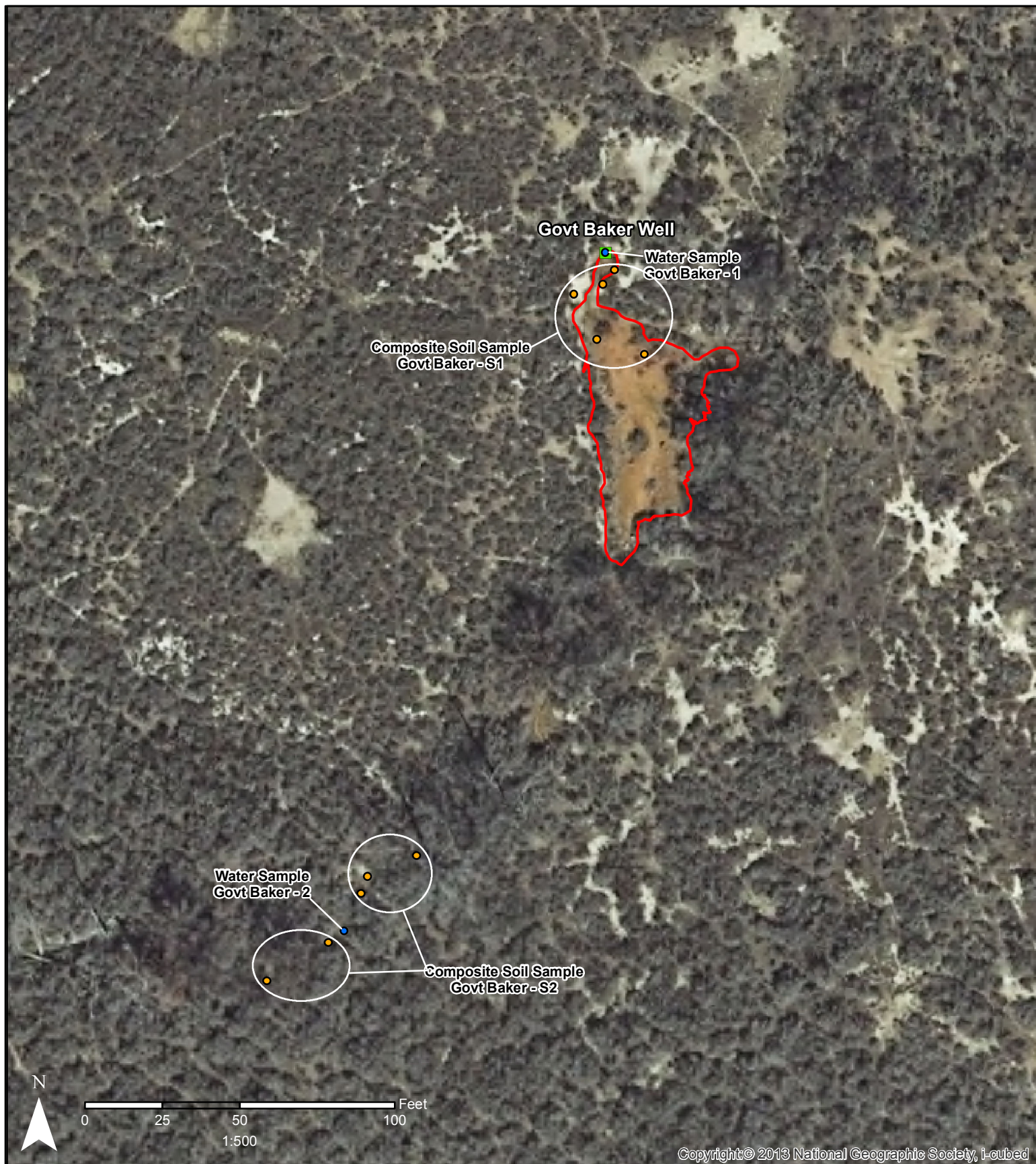
- Orphan Well
- Water Sample Locations
- Soil Sample Locations
- Water Enters Irrigation Ditch
- Approximate Area of Impact

Figure 3: Lloyd & Lowell Well

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- Orphan Well
- Water Sample Locations
- Soil Sample Locations
- Approximate Area of Impact

Figure 4: Govt Baker Well

Mesa County, Colorado



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Table 1. 0 COGCC De Beque, Colorado Orphan Well Surface Characterization Analytical Shedule

WATER SAMPLES (Modified from Rule 609, Table 910-1, and WQCC Standards)		SOIL SAMPLES (Modified Table 910-1)
ORGANIC COMPOUNDS	WQCC	ORGANIC COMPOUNDS
TPH (total purgable and extractable petroleum hydrocarbons)		TPH (total purgable and extractable petroleum hydrocarbons)
Benzene		Benzene
Ethylbenzene		Toluene
Toluene		Ethylbenzene
Xylenes		Xylenes (total)
Oil and grease		Acenaphthene
		Anthracene
		Benzo(a)anthracene
		Benzo(b)fluoranthene
		Benzo(k)fluoranthene
		Benzo(a)pyrene
		Chrysene
		Dibenzo(a,h)anthracene
		Fluoranthene
		Fluorene
		Indeno(1,2,3,c,d)pyrene
		Naphthalene
		Pyrene
		Oil and grease
METALS		METALS
Arsenic (trec)	X	Arsenic
Barium		Barium
Cadmium	X	Cadmium
Calcium		Calcium
Chromium III	X	Chromium (III)
Chromium VI	X	Chromium (IV)
Copper	X	Copper
Iron (trec)		Iron
Lead	X	Lead (inorganic)
Manganese		Manganese
Magnesium		Magnesium
Mercury (tot)	X	Mercury
Molybdenum (trec)	X	Nickel
Nickel	X	Potassium
Phosphorous, total		Selenium
Potassium		Silver
Selenium		Sodium
Silver	X	Zinc
Sodium		
Strontium		WET CHEMISTRY
WET CHEMISTRY		Boron
Alkalinity (total)		Bromide
Carbonate, total		Chloride
Bicarbonate, total		Electrical conductivity (EC)
Ammonia	X	Fluoride
Boron		Phosphorous
Bromide		Nitrate (as N)
Chloride		Nitrite (as N)
Cyanide (total)	X	Sulfate
Fluoride		pH
Nitrate (as N)		SAR
Nitrite (as N)		
pH		
Sulfate		
Sulfide	X	
Total dissolved solids (TDS)		
Total Suspended Solids (TSS)	Other	
EXPLANATION		
Non-bolded analytes are COGCC Rule 609 or Table 910-1 analytes		
Bold indicates analyte added to either Rule 609 or Table 910 analytes due to surface water standards (WQCC) or to allow more complete characterization.		