Technical Memorandum

Date: February 20, 2020

To: Collette Anderson, P.E., Great West Engineering

From: David Donohue, HydroSolutions Inc

Subject: **Hydrogeologic Investigation and Proposed Public Water Supply Well Site, Clancy Water and Sewer District, Jefferson County, Montana**

1.0 Introduction and Objectives

HydroSolutions Inc (HydroSolutions), under contract to Great West Engineering (GWE), evaluated potential locations for a new public water supply (PWS) well for the Clancy Water and Sewer District (District). The criteria used to investigate and evaluate potential sites to install a test well (or wells) and verify a dependable PWS well site included the following:

- Presence of existing water quality data supporting the potential for good quality water,
- Favorable screened interval at approximate depth of at least 100 feet below ground surface (bgs), preferably in a confined to semi-confined aquifer,
- Location where a high yield aquifer may be available to produce up to 150 gallons per minute (gpm), and
- Located away from sources of known groundwater contamination and from potential threats to source water, able to meet sanitary setback distances to provide source water protection.

The purpose of this phase of work was to complete an initial hydrogeologic investigation to support the development of a new groundwater source for a PWS for the District. This hydrogeologic investigation provides the basis for locating and developing centralized public water supply wells to serve the District and its residents. The hydrogeologic investigation considered water quality and water quantity objectives described in the Clancy Water System Improvements Preliminary Engineering Report (PER), updated June 2018 (Great West Engineering 2018). The PER identified primarily water quality parameters of concern including nitrates and uranium, and a minimum required production rate of 143 gpm. Additionally, the

PER identified a preferred water supply site at the Clancy School, though this hydrogeologic study was not limited to this site alone.

Tasks completed as part of this evaluation included:

- Completed literature review of existing publicly available reports and studies on hydrogeology, well logs, and water quality,
- Reviewed unpublished data and information that was available from governmental agencies and officials including Jefferson County, Montana Department of Natural Resources and Conservation (DNRC), U.S. Geological Survey (USGS), Montana Bureau of Mines and Geology (MBMG), and Montana Department of Environmental Quality (DEQ),
- Identified potentially favorable geologic and structural features and lithology for test well sites to meet water quality and water quantity objectives, and
- Provided recommendations and estimated costs to drill a test well.

2.0 Background

A description of the area geology, hydrogeology, and potential groundwater sources are described below.

2.1 Geology and Hydrogeology

The area in and around Clancy and the District is located near the northern margin of the Boulder Batholith, a large igneous intrusion, and dominated by quartz monzonite (Becraft 1953). The batholithic rocks intruded pre-batholithic volcanic rocks, remnants of a large dominantly fine-grained andesitic roof pendant. Both the quartz monzonite and volcanic rocks have been intruded by silica-rich aplite exposed in outcrops around the area (Lewis 1998). Northeast-trending steeply dipping faults cut through the intrusives and resulted in brecciated and silicified zones identified by oxidized outcrops (Becraft 1953). Unsilicified faults are common but often difficult to trace any great distance. In some locations, thin layers of Quaternary alluvial and colluvial material are present near Clancy Creek, Lump Gulch, and Prickly Pear Creek and overlie shallow bedrock.

Geologic maps reviewed for the area do not identify fractures or faults in the vicinity of Clancy (Lewis 1998, Becraft 1953). However, the general northeast-southwest trace of Lump Gulch and Clancy Creek on aerial photographs reviewed in Google Earth may indicate a major joint or fracture system associated with the intrusive bedrock and provide a potential conduit for groundwater flow. Lineaments or fractures in the bedrock aquifer may be significant in controlling groundwater flow, water quality, and yield. Potential joint structures in the area are shown on Figure 1. Although theoretical, these structures may influence groundwater flow and associated high yield wells and are a primary exploration target. As is the case in other locations in Montana, wells in fractured bedrock settings have and can produce high yields.

2.2 Groundwater Source

Groundwater sources in the area include a shallow aquifer and a deeper bedrock aquifer system. Based on data reviewed from the Montana Bureau of Mines and Geology (MBMG) Groundwater Information Center (GWIC), depth to shallow groundwater varies across the District from 5 to 20 feet bgs near Clancy. Shallow groundwater flow is estimated to be to the northeast toward Prickly Pear Creek (Strozewski, Nagisetty and Bullock 2018). Deeper groundwater found in the bedrock aquifer would generally move through fractures and lineaments at depths greater than 40 to 50 feet bgs (Montana Bureau of Mines and Geology n.d.), as is the case for the Clancy School and Red Cliff Estates wells. The source of water for the Clancy School and Red Cliff Estates wells is fractured bedrock, as is the case for most wells completed at depths greater than 40 to 50 feet in the area (Montana Bureau of Mines and Geology n.d.).

Recharge to the shallow alluvial and deeper bedrock aquifers is likely from precipitation and snowmelt, irrigation water, leakage from losing stream reaches, and subsurface flow from bedrock. Amount of recharge to the aquifers will depend on seasonal and yearly precipitation amounts and irrigation practices.

2.3 Clancy Area PWS Wells

Several PWS wells are located in Clancy and within the District boundary. Information on lithology, water quality, and water quantity were obtained from publicly available records and used to evaluate potential test well locations. These include Clancy Elementary School, Single Tree Saloon (aka Chubbys), and the Legal Tender. In addition, the Red Cliff Estates PWS wells are just north of the Clancy School well and adjacent to Clancy Creek. General information on these PWS wells is provided below in Tables 1 and 2.

In 2011, a 24-hour pumping test was completed on Red Cliff Estates Well #6 to collect data to support a new water right application. The well was pumped at 102 gpm and recorded 6.27 feet of drawdown. The pumping rate was limited by the pump size able to be placed in the 6-inch diameter well casing. A larger diameter casing would accommodate a larger horsepower pump capable of producing a higher volume of water. However, the result of this test indicates the potential for higher yield wells in this area adjacent to Clancy Creek.

Table 1. Clancy PWS wells within the District boundary

Source Name	Clancy School	Single Tree Saloon (Chubbys)	Legal Tender
Location (Latitude and Longitude)	46.4656 -111.9909	46.4647 -111.9859	46.46836726895 -111.983686359
MBMG GWIC Number	138380	140200	58606
Water Right Number	084679	C087934-00	C043373-00
Date completed	July 30, 1993	October 27, 1993	February 28, 1982
Total Depth (feet bgs)	220	180	160
Well Casing Diameter (inches)	8	6 to 34 feet 4 from 10 to 180 feet	4
Perforated or Screened Interval (feet bgs)	180 to 220 Perforated	120 to 180 Perforated	90 to 160 Perforated
Static Water Level (feet bgs)	8	18	10
Depth to top of Granite (feet bgs)	39	27	20
Pumping Water Level (feet bgs)	195 (Pumping test)	177 (Air test)	150 (Air test)
Drawdown (feet)	66 after 10 hours	175 after 2 hours	No data
Yield (gpm)	200	20	20

Notes:

MBMG GWIC Montana Bureau of Mines and Geology, Ground Water Information Center
bgs below ground surface
gpm gallons per minute

Table 2. Red Cliff Estates PWS wells.

Source Name	Red Cliffs Estate (Well #5)	Red Cliffs Estate Well #2 (previous Well #6)
Location (Latitude and Longitude)	46.4663983157 -111.9892426945	46.46619 -111.99055
MBMG GWIC Number	195743	248988
Water Right Number	41I 30116524	41I 30068548
Date completed	April 12, 2002	April 29, 2003
Total Depth (feet bgs)	140	150
Well Casing Diameter (inches)	6 to 56 feet 4 from 40 to 140feet	6 to 41 feet 4 from 30 to 150 feet
Perforated or Screened Interval (feet bgs)	60 to 140 Perforated	40 to 150 Perforated
Static Water Level (feet bgs)	3.92	6.17
Depth to top of Granite (feet bgs)	30	32
Pumping Water Level (feet bgs)	93 (Pumping test)	No data
Drawdown (feet)	No data (after 9 hours)	No data (after 9 hours)
Yield (gpm)	120	80

Notes:

MBMG GWIC Montana Bureau of Mines and Geology, Ground Water Information Center
bgs below ground surface
gpm gallons per minute

3.0 Methods

The general methods completed in this investigation include compilation, review, and analysis of existing publications, reports, and data relating to the groundwater water quality (specifically uranium, nitrate-nitrite, and fluoride), hydrologic setting, and groundwater well pumping capacities in the District area. Work consisted of a “desktop study,” and no new data were collected. Data analysis methods are summarized in corresponding result sections below. References and citations are noted within the text and at the end of this document.

Water quality data were reviewed using the available data sources listed below:

- Water quality for the Clancy area were downloaded from MBMG GWIC online database and reviewed
- Water quality data from the USGS radionuclides study were evaluated for select wells within the District boundary (Caldwell, Nimick and DeVaney 2014)
- Source water delineation and assessment reports (SWDAR) prepared by DEQ for Clancy school, Single Tree (Chubbys), and Legal Tender PWS systems were reviewed.
- Wells completed in the bedrock aquifer were selected.

In addition, a meeting with the Clancy School Board was attended by Collette Anderson of GWE and David Donohue of HydroSolutions on January 30, 2020 to explain the preliminary proposed plan for a new PWS well site and address questions. A walk around school property was also completed to identify possible well locations on Clancy School property. Other potential locations near Clancy were also evaluated during the site visit.

The hydrogeology around Clancy was discussed with the following professional scientists who have direct experience in southern Lewis and Clark and northern Jefferson Counties:

- Rod Caldwell, U.S. Geological Survey
- James Swierc, Lewis and Clark County Water Quality Protection District
- Megan Bullock, Jefferson County Sanitarian

4.0 Results

Limited water quality and lithologic data are available from wells located around the Clancy area. Subsurface conditions are variable and limited data provides a challenge to locating a public water supply well that will meet water quality, water quantity, and the other criteria set forth in the project objectives.

As part of this hydrogeologic evaluation, uranium, nitrate, and fluoride occurrence and water quality data were reviewed. These analytes have been found to be a concern in the Clancy groundwater.

4.1 Uranium Occurrence

Granitic rocks, such as Boulder Batholith quartz monzonites and aplite units found in the Clancy area, are known sources of naturally occurring uranium. Data collected from a study completed by the US. Geological Survey indicate that, in general, predicting the occurrence of elevated radionuclide concentrations in groundwater demonstrated a high degree of uncertainty (Caldwell, Nimick and DeVaney 2014). The study found that wells completed in the Boulder Batholith or similar geologic units were more likely to produce groundwater with elevated radionuclides. However, concentrations varied in groundwater samples from wells completed in the same geologic unit and in close proximity to one another (less than 1,000 feet apart) (Caldwell, Nimick and DeVaney 2014). As noted in the study, the occurrence and mobility of radionuclides in groundwater are controlled by the presence of source radionuclides in the aquifer materials; hydrogeologic characteristics of the aquifers; and chemical and physical processes (precipitation, adsorption, and ion exchange) that occur as water flows through and interacts with the aquifer matrix. Differences in the hydrogeologic setting of the flow system in aquifers can affect residence time, water/rock volumetric ratio, and the surface area of the rock per volume of water, all of which affect radionuclide occurrence in groundwater (Caldwell, Nimick and DeVaney 2014). In some cases, groundwater samples from wells in close proximity to each other sometimes produce water with different chemistry, likely because of different residence times and mineralogy, and varying geochemical conditions (such as pH, dissolved oxygen, and temperature) encountered along their individual flow paths (Caldwell, Nimick and DeVaney 2014).

A preliminary review of uranium concentration evaluated from the US Geological Survey study (Caldwell, Nimick and DeVaney 2014) compared to well depth specifically for the Clancy area is shown on Figure 2. Results indicate most reported concentration for uranium were below US EPA MCL of 30 micrograms per liter (µg/L). The majority of these groundwater samples were collected from wells completed in the Boulder Batholith units. Although no samples were collected from the Clancy School well and analyzed for uranium, low concentrations of associated radionuclides were reported in a sample collected in 2013 (Montana DEQ 2020).

4.2 Nitrate-nitrate

Elevated nitrate-nitrite concentrations have been found in shallow groundwater associated with septic system and animal contamination (Strozewski, Nagisetty and Bullock 2018). Elevated levels of nitrate [greater than 2 milligrams per liter (mg/L)] was measured in 47 percent of 28 representative drinking water wells. The US EPA MCL of 10 mg/L for nitrates was exceeded in 18 percent of 28 representative drinking water well samples as part of this study. Samples from several deep wells were reported to contain elevated nitrate-nitrite concentrations. The reason for the occurrence of nitrates-nitrites in a few deep well samples is unknown but may be related to well completion and perforation depth (Bullock 2020). In some other cases, failed well completion and surface seals or casing breaks may be contributing factors to shallow contamination moving into deeper groundwater. A source of nitrate-nitrite contamination that is upgradient of Clancy may also be present and contributing to groundwater contamination at depth.

A review of recent nitrate results from the three PWS wells in Clancy sampled at the end of 2019 ranged from 0.963 to 2.06 milligrams per liter (mg/L). A sample collected in March 2019 from the Red Cliffs Estates PWS wells reported a concentration of 0.38 mg/L. These results are below the EPA MCL of 10 mg/L.

4.3 Fluoride

Igneous geologic environments such as the Boulder Batholith have rocks with fluoride bearing minerals like apatite, fluorite, biotite, and hornblende. As these rocks weather, infiltration of precipitation through these weathered rocks increases fluoride concentrations in groundwater. Similar to controlling factors increasing concentrations of uranium described above, the occurrence and mobility of fluoride in groundwater are controlled by the concentration of weathered minerals, hydrogeologic characteristics of the aquifers, and chemical and physical processes that occur as water flows through and interacts with the aquifer matrix.

Since limited fluoride data are available, the distribution of fluoride concentrations is uncertain in the Clancy area. Fluoride has been noted in bedrock wells located just north of Clancy Creek drilled in an attempt to locate an acceptable water supply source for Red Cliffs Estate. However, concentrations exceeded EPA MCL for fluoride of 4 mg/L at several locations. Acceptable fluoride concentration was reported from the current location of the Red Cliff wells located adjacent to Clancy Creek. A water sample collected on October 29, 2019 from the Clancy School well reported a fluoride concentration of 0.343 mg/L, well below US EPA MCL.

4.4 Selected High Yield Wells

The distribution of wells with pumping rates greater than 50 gpm and completion depths to 400 feet bgs in the area around Clancy is shown on Figure 3. The map was developed using GIS and geospatial data from readily available sources, including GWIC data for wells located in an area within ½ mile of the District boundary. (Note well locations identified from GWIC data should be considered very approximate and may not be accurate. Often locations are at centroid of reported legal descriptions - Township, Range, Section).

As with water quality data for the area, limited data exists to comprehensively evaluate high yield well locations with a high level of certainty. Aquifer transmissivities will vary extensively when dominated by the amount of fracture flow in the bedrock, type of well construction, well efficiency, or inaccurately reported driller's data. High yield wells are found closer to Clancy Creek as demonstrated by the PWS wells at Clancy School and Red Cliffs Estate. This suggest that increased fractures may be present along possible lineament systems and allow for greater groundwater flow and yields.

5.0 Conclusions and Recommendations

Potential suitable locations for a new PWS well to supply the District have been identified. The locations have been proposed based on evaluation of 1) existing water quality, 2) approximate well completion depths of at least 100 feet bgs, 3) potential location for a high yield aquifer, and 4) located away from sources of known groundwater contamination.

For the most part, the locations agree with those locations identified in the PER (Great West Engineering 2018). Although there is a level of uncertainty to locate a high-yield fracture in a bedrock aquifer, data indicate that there are suitable sites to drill a test well.

Based on review of available water quality and hydrogeologic data, and consideration of the criteria used to define water quantity and quality search parameters, several locations are proposed. It appears that locations adjacent to and near the lower end of Clancy Creek are suitable for a test well. In addition, a similar hydrogeologic situation associated with fracture flow is possible near the downstream end of Lump Gulch, as well as along Prickly Pear Creek. It is my opinion that joints or structural fractures controlled the placement and orientation of the drainages and lend themselves to potential fracture flow conditions.

Well location A on Clancy School property is located near PWS wells that provide good information on the water quality and quantity at aquifer target depths. Both the Clancy school well and the Red Cliff Estates wells provide acceptable water quality and quantity results which would be estimated to be found at the proposed A location. Proposed areas for test well locations are shown on Figure 3.

The potential well site located on the State Land south of the District appears less certain to produce a high yield well. Very limited data were available to assess this location. The location does not include any obvious lineaments suggesting fracture flow environments. However, there are some small drainages oriented east west at the northern boundary of State Land which may be exploration targets.

Based on the results of this hydrogeologic investigation, the following recommendations are proposed:

1. The well location A on Clancy School property adjacent to Clancy Creek is preferred for an initial test well. An agreeable location was identified just west of the current daycare building during the site visit.
2. The location B west of Prickly Pear Creek and just north of Clancy Creek should be considered as an alternative site. Proximity to flood plain area should be considered.
3. The locations on State Land just south of the District have potential but have limited data to support or contradict the locations. Future land use for the area should be considered.
4. Proceed with planning and preparation of bid specifications for the Clancy school property well
5. Prior to drilling a test well, verify easements and land use agreement
6. If test well drilling provides unfavorable results at Locations A and B, consider the use of focused shallow surface geophysical methods, like shallow seismic refraction, direct current resistivity, or seismoelectrical technique to assist in locating fractures which may be capable of high yields and can be used to help further define test well locations.
7. Evaluate water rights considerations (need for change application, adverse effect analysis) once target completion depth and well location are selected.

6.0 Test Well Drilling Planning Costs

Costs to drill a test well and complete a pumping test vary per location, geology, steel casing and screen costs, driller bids, and other factors. Once a test well site is selected, HydroSolutions will solicit bids from area drillers, evaluate bids, and recommend a driller to the District. Based on our recent experience with similar water resource exploration projects, estimated subcontractor driller costs to drill a test well using air rotary drilling method in alluvial and bedrock aquifers and complete a 24-hour pumping test are summarized below:

Drilling Method	Drilling cost per foot	Estimated Cost for Drilling – 200-foot depth	Aquifer Testing Cost	Total Estimated Cost
Air Rotary	$70 to $100	$14,000 to $20,000	$1,500 to $8,500	$20,000 to $30,000

Bibliography

Alden, W.C. 1953. *Physiography and Glacial Geology of Western Montana and Adjacent Areas.* U.S. Geological SurveyProfessional Paper 231.

Becraft, George E. 1953. *Preliminary Report on the Clancy Creek Area, Jefferson City Quadrangle, Jefferson County, Montana.* Trace Elements Investigations Report 257, U.S. Geological Survey.

Bullock, Megan, interview by David Donohue. 2020. *Jefferson County Sanitarian* (February 19).

Caldwell, R.R., D.A. Nimick, and R.M. DeVaney. 2014. *Occurrence and hydrogeochemistry of radiochemical constituents in groundwater of Jefferson County and surrounding areas, southwestern Montana, 2007 through 2010.* Investigations Report 2013-5235., U.S. Geological Survey.

Great West Engineering. 2018. "Clancy Water & Sewer District, 2018 Preliminary Engineering Report, Water System Improvements."

Kendy, Eloise, and Ruth E. Tresch. 1996. *Geographic, Geologic, and Hydrologic Summaries of Intermontane Basins of the Northern Rocky Mountains, Montana.* U.S. Geological Survey, Water-Resources Investigations Report 96-4025.

Lewis, Reed S. 1998. *Geologic Map of the Butte 1 Degree x 2 Degree Quandrangle, South-Western Montana.* Open File No. 363, Montana Bureau of Mines and Geology.

Montana Bureau of Mines and Geology. n.d. *Groundwater Information Center (GWIC).* http://mbmggwic.mtech.edu/.

Montana DEQ. 2004b. "Source Water Delineation and Assessment Report for Chubbys Bar and Grill (PWSID MT0001400)."

Montana DEQ. 2004a. "Source Water Delineation and Assessment Report for Clancy Elementary School District #01 (PWSID MT0001397)."

Montana DEQ. 2004c. "Source Water Delineation and Assessment Report for Legal Tender Retaurant and Bar (PWSID MT0002866)."

Montana DEQ, Drinking Water Watch. 2020. *Drinking Water Watch, Public Water Supply http://sdwisdww.mt.gov:8080/DWW/Help/html_Public_Water_Supply_Sytems_Search_Paramaters.htm.*

Strozewski, Matt, Raja Nagisetty, and Megan Bullock. 2018. *Clancy Drinking Water Wells Water Quality.* Montana Tech of the University of Montana.

FIGURES

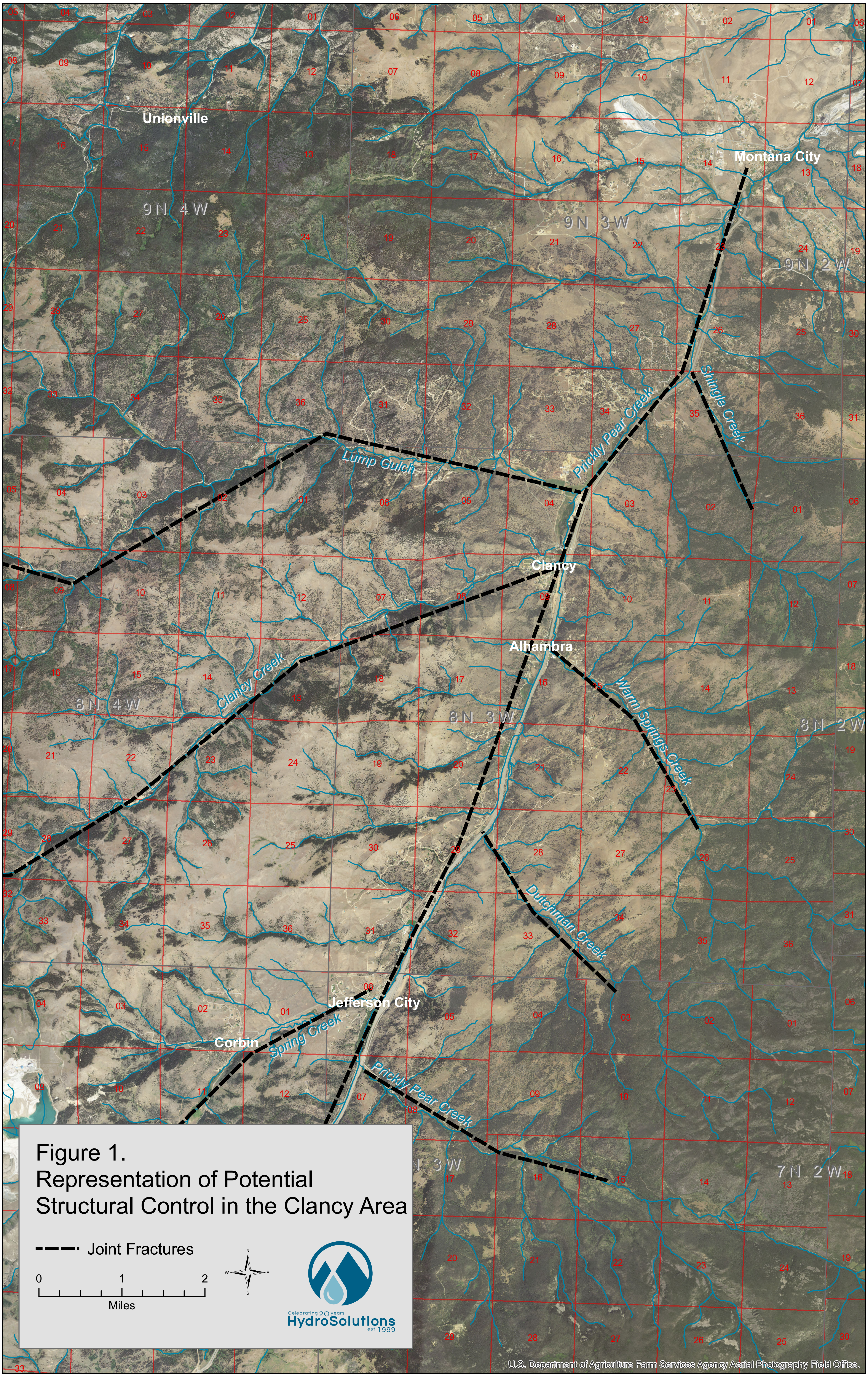


Figure 1.
Representation of Potential Structural Control in the Clancy Area

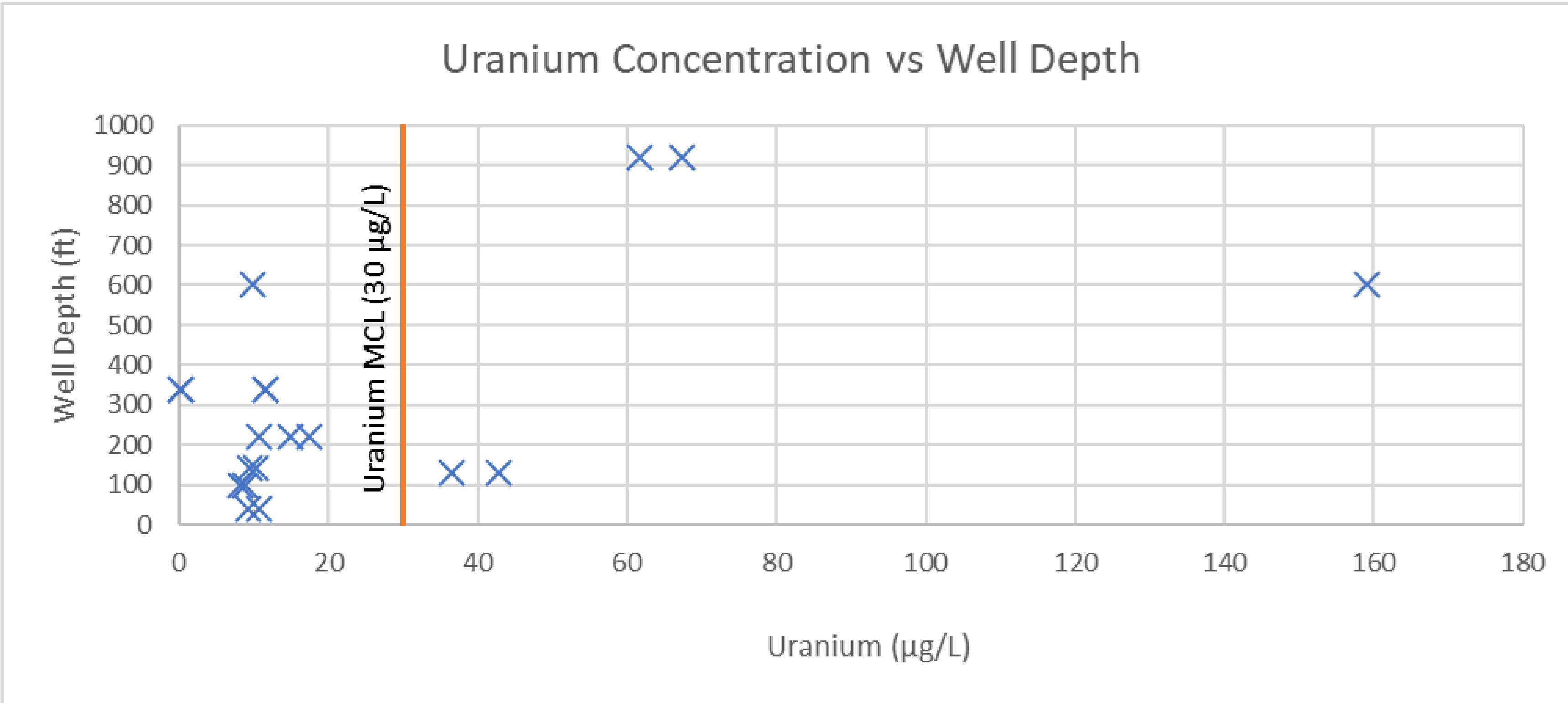
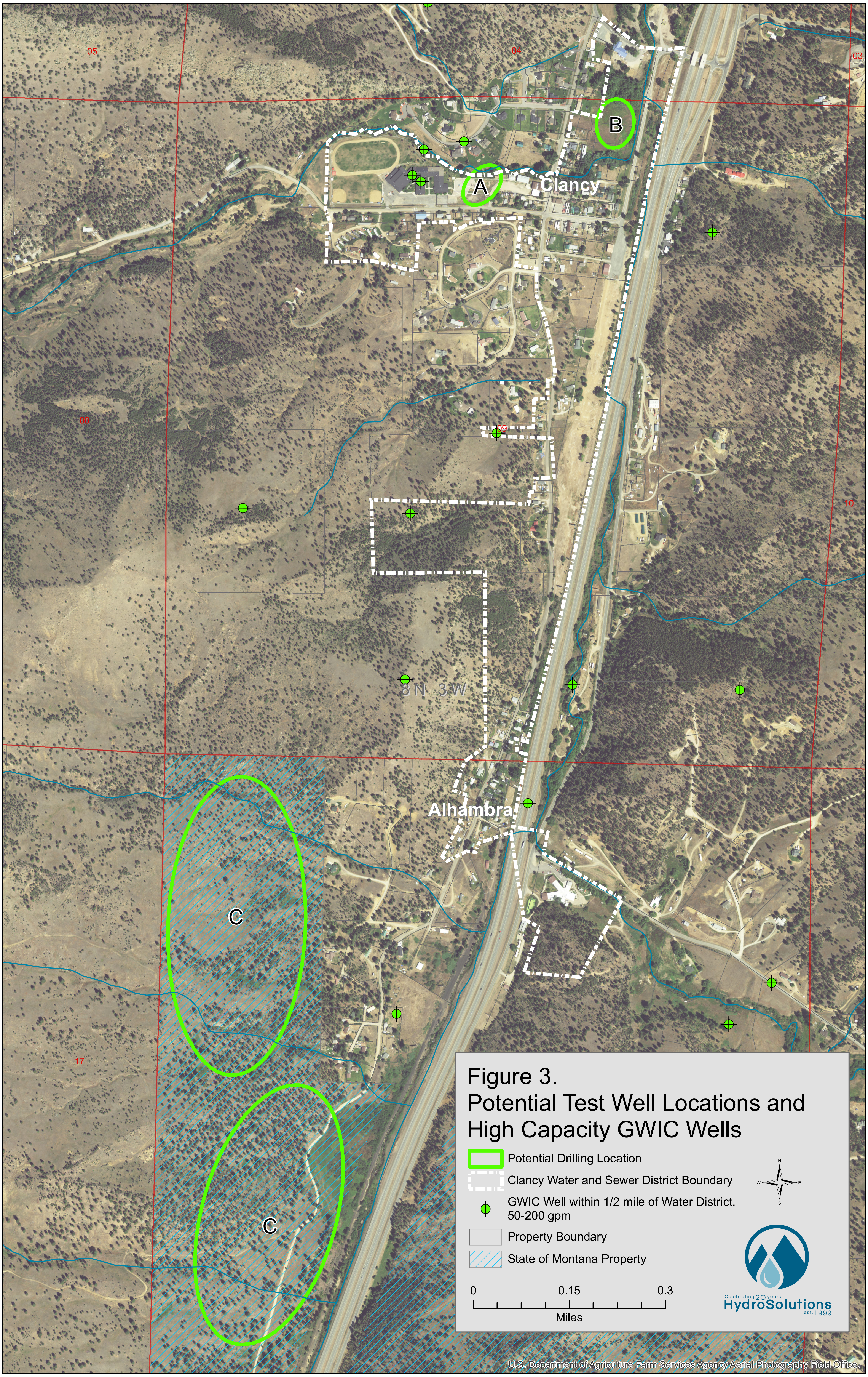


Figure 2. Uranium concentration versus well depth, Township 8 North, Range 3 West, Clancy, Montana

MCL Maximum Contaminant Level
X Laboratory result
µg/L microgram per liter


Clancy
Alhambra
A
B
C
C
3 N 3 W
Figure 3.
Potential Test Well Locations and
High Capacity GWIC Wells
Potential Drilling Location
Clancy Water and Sewer District Boundary
GWIC Well within 1/2 mile of Water District,
50-200 gpm
Property Boundary
State of Montana Property
0
0.15
0.3
Miles
Celebrating 20 years
HydroSolutions
est. 1999
U.S. Department of Agriculture Farm Services Agency Aerial Photography Field Office