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Sensitive Area Determination Assessment Report

CM Production, LLC
Cliff Field – Rice Lease Produced Water Pits
Section 33, T12N, R54W, 6th P.M.
Garfield County, Colorado

Prepared for

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1.0 INTRODUCTION

CM Production, LLC (CM Production) contracted Olsson Associates Inc. (Olsson) to prepare a sensitive area determination of the Cliff Field – Rice Lease Produced Water Pits located in Logan County, Colorado. This work was performed at the request of the Colorado Oil and Gas Conservation Commission (COGCC) environmental staff in response to an unsatisfactory inspection of the Rice Lease that was conducted in January 2014. The Rice Lease pits are identified in the COGCC online global information systems (GIS) database as facility #100570, 100572, and 116281 and are located in Section 33, Township 12 North, Range 54 West, of the Sixth Principal Meridian. Figure 1 presents the General Site Location of the Rice Lease, and Figure 2 shows the Rice Lease Site Map with the location of the produced water pits.

1.1 Sensitive Area Definition

According to the definition provided in the COGCC 100 Series Rules:

A Sensitive Area is an area vulnerable to potential significant adverse groundwater impacts due to factors such as the presence of shallow groundwater or pathways for communication with deeper groundwater; proximity to surface water, including lakes, rivers, perennial or intermittent streams, creeks, irrigation canals, and wetlands. Additionally, areas classified for domestic use by the Water Quality Control Commission, local (water supply) wellhead protection areas, areas within 1/8 mile of a domestic water well, areas within 1/4 mile of a public water supply well, ground water basins designated by the Colorado Ground Water Commission, and surface water supply areas are sensitive areas.

1.2 Sensitive Area Determination (Rule 901)

The COGCC 900 Series rules and regulations establish the permitting, construction, operating, and closure requirements for pits, methods of exploration and production (E&P) waste management, procedures for spill/release response and reporting, and sampling and analysis for remediation activities. The 900 Series rules are applicable only to E&P waste as defined in § 34-60-103(4.5), C.R.S, and other solid waste where the Colorado Department of Public Health and Environment has allowed remediation oversight by the COGCC.

According to the COGCC Rule 901.e *a sensitive area determination is to be performed when the operator or Director has data that indicate an impact or threat of impact to ground water or surface water, the Director may require the operator to make a sensitive area determination and that determination shall be subject to the Director's approval. The sensitive area determination shall be made using appropriate geologic and hydrogeologic data to evaluate the potential for impact to ground water and surface water, such as appropriate percolation tests that demonstrate that seepage will not reach underlying ground water or waters of the State and impact current or future uses of these waters. Operators shall submit data evaluated and analysis used in the determination to the Director.*

According to Rule 901.f sensitive area operations shall incorporate adequate measures and controls to prevent significant adverse environmental impacts and ensure compliance with the concentration levels in Table 910-1, with consideration to Colorado Department of Public Health and Environment Water Quality Control Commission (WQCC) standards and classifications.

1.3 Pits - General and Special Rules (Rule 902)

Pits used for E&P operations shall be constructed and operated to protect public health, safety, and welfare and the environment, including soil, waters of the state, and wildlife, from significant adverse environmental, public health, or welfare impacts from E&P waste, except as permitted by applicable laws and regulations.

Pits shall be constructed, monitored, and operated to provide for a minimum of two (2) feet of freeboard at all times between the top of the pit wall at its point of lowest elevation and the fluid level of the pit. A method of monitoring and maintaining freeboard shall be employed. Any unauthorized release of fluids from a pit shall be subject to the reporting requirements of Rule 906.

In Sensitive Areas, the Director may require a leak detection system for the pit or other equivalent protective measures, including, but not limited to, increased record-keeping requirements, monitoring systems, and underlying gravel fill sumps and lateral systems. In making such determination, the Director shall consider the surface and subsurface geology, the use and quality of potentially-affected groundwater, the quality of the produced water, the hydraulic conductivity of the surrounding soils, the depth to groundwater, the distance to surface water and water wells, and the type of liner.

1.4 Rice Lease Produced Water Pits

There are three unlined produced water pits located at the Rice Unit in the Cliff Field. These pits have been in operation at least since the early 1970s or before. The spud date of the Rice 2 oil well is listed as June 2, 1955, and a completion date of June 14, 1955. Produced water passes through a 400-barrel capacity skim tank prior to being discharged to the produced water pits.

These Pits are identified in the COGCC GIS Database as follows:

- Cliff Unit (Rice Lease) Pit – Facility ID# 100570 CNW 33 12N 54W
  Latitude 40.975324; Longitude -103.41664
- Cliff Unit UPRR Casement 2 – Facility ID#100572 CSW 33 12N 54W
  Latitude 40.967964; Longitude -103.415653
- Rice – SW NW 33 12N 54W
  Latitude: 40.973494; Longitude: -103.418794

Based on where the pits plot on the COGCC database these locations do not appear to be correct.

2.0 GEOLOGY AND HYDROGEOLOGY

Olsson reviewed appropriate geologic and hydrologic data to evaluate the potential for impact to groundwater and surface water in the vicinity of the Rice Lease produced water pits. The information included published geologic and hydrologic maps and reports from the United States Geologic Survey (USGS), the Colorado Geologic Survey (CGS), and online resources including the COGCC GIS database and maps, and the Division of Water Resources. Figure 3 shows the Cliff Unit – Rice Field geology, well locations, and COGCC plotted pit locations.

2.1 Geology

The site is located within the Denver-Julesburg Basin, a geologic structural basin, sometimes referred to as the DJ Basin or simply the Denver Basin. The Denver Basin is a roughly elliptical-shaped depression the earth's crust that resulted from tectonic forces throughout geologic time and associated with the uplift of the Colorado Rocky Mountains. The Denver Basin is centered in eastern Colorado but extends into southeastern Wyoming, western Nebraska, and western Kansas.

The site is located in a landscape created through the natural processes of erosion. It is important to differentiate between the natural process of erosion and erosive conditions that are caused as a result of human activities. As responsible stewards of the land it is important to employ best management practices to prevent soil erosion by human activities so that it does not adversely impact the surface owner or contribute to impacts that may impair the quality of waters of the State.

The two major physiographic features of northeastern Colorado area a high sloping tableland formed from the Ogallala Formation and underlying units, and a large and intricately dissected stream-valley system created by the South Platte River and its tributaries. In the northwestern part of Logan County there is a high tableland, locally known as the Chalk Bluffs and Peetz Table that represents a separate physiographic area in the form of a high, gently rolling plateau that slopes eastward. Steep to nearly vertical Chimney Canyons and Lewis Canyons consisting of siltstone exposures capped by calcareous sandstone of the Ogallala Formation border the Peetz Table on the southwest. Southeast of the Peetz Table is a steeply sloping area of reddish colored gravelly alluvium that occurs as ridges and resembles remnants of old high terraces. This area is dissected by many intermittent drainage ways that flow to the southeast toward the South Platte River.

Well defined scarps have been carved into the bedrock where tributaries of the South Platte River cut headward into the tableland since Quaternary time. The Chalk Bluffs north of the river are steeper than the scarp on the south of the river due to the evolution of the South Platte River system. Except for the river valley cut by the South Platte River and its tributaries, the surface on the Ogallala has remained relatively unchanged since it was established during the middle to late Tertiary period (Miocene Epoch – ending 5 m.y. ago). (Scott, 1982)

According to the COGCC online GIS database maps the site is underlain by the White River Group that was deposited during the Oligocene Epoch (ending 24 m.y. ago) of the Tertiary period and which includes the Brule Formation (Scott, 1978). The Brule Formation crops out in northeastern Colorado north of the South Platte River. The Brule Formation primarily consists of massive siltstone which contains localized beds of sandstone, volcanic ash, claystone, and fine sand. The thickness of the Brule Formation ranges from 200 feet to 500 feet. It is relatively impermeable and is not part of the High Plains aquifer except in areas where the rock has been extensively fractured (Robson and Banta, 1995).

The Cretaceous age Pierre shale underlies the White River Group and High Plains aquifer and is considered to be relatively impermeable. In some areas, water yielding sandstone is interlayered with the shale near the base of the High Plains aquifer. These sandstone layers can yield moderate to high volumes of water to wells and be of local importance, but they lack the areal extent to constitute a principal aquifer.

2.2 Hydrogeology

According to the Colorado Geological Survey – Special Publication 4 Geology of Ground Water Resources in Colorado (Pearl, 1974 – Reprinted 1980) the High Plains of extreme eastern Colorado is an area that receives very little precipitation, and unlike other areas of Colorado there are no rivers that head in the mountains. As a result, this area has very little surface-water supplies available for use and groundwater resources have been extensively developed. The northern High Plains is drained by the South Platte River, and the Republican-Arikaree River and Smoky Hill River systems (Pearl, 1974).

The High Plains aquifer is the principal aquifer underlying the northern High Plains and consists primarily of the Ogallala Formation, the underlying Arikaree Formation, and to a lesser extent the upper part of the White River Group where the Brule Formation is extensively fractured (Robson and Banta, 1995). Measurements of horizontal and vertical hydraulic conductivities of core samples without secondary permeability features generally are similar and fall within expected ranges. The horizontal hydraulic conductivity (Kr) measurements of relatively unfractured Brule siltstone have a narrow range. The Log mean Kr of dominantly siltstone intervals ranged from 10^{-6} to 10^{-7} meters per second (Barrash, 1986). In northeastern Colorado, the Brule Formation typically yields less than 300 gallons per minute to wells (gpm). Groundwater yields to wells as much as 1,400 gpm have been reported from the Brule Formation in some areas, but these volumes are not common (Pearl, 1974).

The Arikaree Formation and Ogallala Formation crop out approximately a half mile to the north of the site and make up the upper tableland of the Chalk Bluffs and Peetz Table. This is an area of recharge for the High Plains aquifer. The Ogallala and Arikaree Formations comprise the majority of the High Plains aquifer, with the Ogallala Formation as the most significant hydrogeologic unit, and contain the bulk of the groundwater resources (Topper et al, 2003). The High Plains aquifer consists of unconsolidated to partly-consolidated gravel, sand, silt, and clay. Cemented “mortar” or caliche beds are common within the Ogallala Formation, with calcium carbonate being the primary cement. Quaternary age alluvial, valley-fill, dune sand, and loess deposits are also considered part of the High Plains aquifer where they are hydraulically connected to the underlying Ogallala Formation.

These units are located topographically and stratigraphically above the Site location. The site is expected to lie cross gradient of water wells that are completed in the High Plains aquifer to the north.

2.3 Groundwater Quality

The water from the Colorado High Plains aquifer is generally of good quality, and is typically of a calcium bicarbonate type (Topper et al, 2003). The total dissolved solids (TDS) range from less than 250 parts per million (ppm) to about 1,000 ppm (Robson and Banta, 1995). The best quality water is found in the northern part of the area where dune sand overlies the aquifer and the saturated thickness is greater than in other parts of the northern High Plain. The main part of the High Plains aquifer would be to the north of the Cliff Unit - Rice Lease in the Ogallala Formation and Arikaree Formation that form the Chalk Bluffs and Peetz Table. Poorer quality water is found along the western edge and southern part of the area where saturation is limited and the formation is underlain by shales of the Pierre Shale and Niobrara Formation (Pearl, 1974).

2.4 Site Surficial Geology and Soil

According to the COGCC GIS database website, the soil types present in the vicinity of the Cliff Unit – Rice Lease consist of Badland (Soil Unit #13) and adjacent areas of Mitchell – Keota loams (Soil unit #70) which occupy 3% to 9% slopes. Figure 4 shows the Cliff Field – Rice Lease Soil Types. According to the Soil Survey of Logan County, Colorado, the Badland soil unit consists of steep and very steep barren land dissected by many intermittent drainage channels that have entrenched into the soft shale and siltstone of the Brule Formation and the Algal Limestone of the Ogallala Formation. The soil survey states that about 75 percent or more of the Badlands unit is un-vegetated. The potential for other uses is poor as the unit is barren or nearly barren and is too steep or inaccessible for livestock. Soils are droughty and are susceptible to blowing and water erosion. Water for livestock is also difficult to locate in these areas. It is located mainly in the northwestern part of Logan County. Runoff is very high and geologic erosion is active.

The Ustic Torriorthents (50% of the unit) – Badland (40% of the unit) soils are shallow, steep, well-drained, loamy soils underlain by siltstone and calcareous sandstone. The unit occurs as narrow bands of steep rocky land and siltstone outcrops divided by deep gullies and ravines, mostly in the northern part of the county.

Small, isolated areas of Keota, Mitchell, Canyon, and Epping soils are included within the Badland soil areas. These soils support some vegetation with very limited value for grazing by livestock and wildlife. The Mitchell-Keota loams are gently sloping to moderately sloping soils formed on upland ridges and hills. The average annual precipitation ranges from 13 inches to 17 inches. The Mitchell loam, occupies 3% to 5% slopes, and makes up 55 percent of the unit, while the Keota loam, occupies 1% to 9% slopes, makes up 35 percent of the unit. The Mitchell soil is formed at mid-slope and on foot-slopes where the eolian deposits are thickest. The Keota soils are on ridge crests and knobs where the siltstone bedrock is near the surface.

The Mitchell soil is deep, well-drained, and formed in calcareous, loamy alluvial and eolian materials derived from weathered siltstone. The Mitchell loam typically has a light brownish-gray surface layer that is approximately 5 inches thick, and an underlying layer that is light gray to very pale brown, consisting of a calcareous silt loam that extends to depths of 60 inches or more.

Permeability is moderate, the effective rooting depth is 60 inches or more, and the available water capacity is high. Surface runoff is medium to rapid, and the erosion hazard is moderate and soil blowing hazard is moderate.

The Keota loam is a moderately deep, well-drained soil formed in calcareous, loamy alluvium and eolian materials derived from weathered Brule siltstone. The surface layer is typically light brownish-gray loam about four inches thick, and the underlying layer is light brownish gray to very pale brown, calcareous loam which is about 20 inches thick. White siltstone of the Brule Formation is encountered at a depth of about 24 inches.

Permeability is moderate, the effective rooting depth is between 20 inches and 40 inches, and the available water capacity is moderate. The surface runoff is slow, the wind erosion hazard is moderate and the erosion hazard is slight.

These soils are best suited and used almost entirely for grazing and wildlife. The potential for non-irrigated cropland is fair due to the limited precipitation and high erosion hazard. The potential for irrigated cropland is poor mainly because of the lack of underground water.

Some small areas, once cultivated have been seeded to grass. Windbreaks and environmental plantings are difficult to establish on these soils. The Mitchell soil is well suited for home sites, roads, and other urban developments and has only minor limitations that can be easily modified. The Keota soil is limited by depth to bedrock. Special provisions for sewage systems must be expected and septic leach fields and sewage lagoons will not function properly because of the moderate depth to bedrock.

2.5 Proximity to Surface Water

There are no lakes, rivers, creeks, ponds, irrigation canals, or wetlands in close proximity to the pits. There is an intermittent drainage located approximately 195 feet east of the north pit (H1), 500 feet east of the south pit (H2), and 70 feet east of the southeast pit (H3). This unnamed intermittent drainage, and numerous others in the area flow to the south and terminate. Based on a review of the 1978 Chimney Canyons 7.5-minute topographic map, they do not coalesce or feed into a named creek or stream, but terminate in Section 4 and Section 5 to the south. George Creek is located approximately six miles to the south, but there is no defined drainage or a significant nexus between the intermittent drainages and George Creek. The Site is located approximately 12 miles north of Northwest Sterling Reservoir and 22 miles northwest of the South Platte River.

2.6 Climate

The climate of Logan County is semiarid continental, and is characterized by low humidity, and a wide variation in precipitation. According to the Logan County Soil Survey, the site is in an area where annual precipitation is between 13 inches and 15 inches in the western part of the County. The groundwater recharge in Logan County is chiefly from precipitation. Most precipitation falls during the growing season, commonly as thunderstorms. Not all of this precipitation is available for plant growth because of high runoff. Springs commonly occur along the contact of the relatively impermeable Brule Formation and the overlying more permeable gravel of the Arikaree Formation. Water derived from springs is used primarily for livestock (Amen, Anderson, Hughes, and Weber, 1977).

Most precipitation is lost to evaporation from the soil or is transpired by vegetation before it can percolate to the water table and recharge the aquifer. Of the total annual precipitation approximately 12 inches, or 81%, falls during the period from April through September. In two years out of 10, the April-September rainfall is less than 10 inches. Thunderstorms occur on about 45 days each year and most occur in June and July. The heaviest one day rainfall of 4.88 inches that occurred during the period of record from 1951 to 1973 was on August 15, 1968 (Amen, Anderson, Hughes, and Weber, 1977).

2.7 Permitted Water Wells

Figure 5 shows the proximity of water wells permitted with the State Engineer's Office, Division of Water Resources to the Site. There are no permitted water wells shown within one mile of the Site based on a review of the COGCC GIS database, and the Division of Water Resources database. Figure 5 shows the well depths, static water level, well owner, well use, and pumping rate. The listed uses of these wells are primarily identified as livestock or commercial water sources. No public water supply wells were identified at distances of more than one mile from the Site.

Figure 6 includes a portion of the Chimney Canyons 7.5-minute topographic map that shows a well as being located in the SW ¼ SW ¼ Section 33, and another located in the NE ¼ SE ¼ Section 32. Both of these wells are more than 1/8 of a mile (660 feet) from the site and neither appears to be permitted in the State Engineer's Office records. The status of these wells is unknown, and due to the location and surface land use they are likely used for livestock water. Both of these wells are located on the opposite sides of intermittent drainages that separate the wells from the drainage on which the Site is located. Based on the proximity to oil wells, it is possible that these were drilled as industrial water wells to provide a water source during the well completion. Since the oil wells were drilled in the 1950s, the development pre-dates the formation of the Division of Water Resources. These wells are cross gradient to the Site location and are separated from the Site by other intermittent drainages.

2.8 Previous Sensitive Area Determination

According to the COGCC GIS database, only one of the pits, referred to as "Rice" (Facility #116281) had any associated documents attached. These documents included the following:

- An earthen pit permit application 10/29/1971
- A lease inspection form 09/19/1984
- A pit inspection report 07/30/1986
- A sundry Notice 06/03/1997

The permit application from 1971 indicates that the final produced water separation system consists of a 400 barrel skimmer tank, and that all produced water passes through this tank prior to dumping into the pits. Water discharged from the pits into a dry stream bed on the lease at that time. The operator is listed as Union Texas Petroleum.

In a Memorandum from G.C. Hazenbush to D.V. Rogers, an office evaluation was made by Union Texas Petroleum on January 28, 1974 of this pit. The pit dimensions were reportedly 150 feet by 90 feet by 6 feet deep and handled an estimated inflow of 303 barrels of water per day from the "D" sand wells. The TDS of the water was reportedly 9, 776 parts per million (ppm), and the water from the pits was discharged into a dry stream bed on the lease.

> "*The pit (was) constructed in the White River Group which crops out at the surface. The electric log of the nearest oil well, operated by Sinclair Oil & Gas Company – Hiscock No. 2 located ¼ mile to the west, shows the base of the White River Formation at about 190 feet below the surface, and a well developed fresh water sand from 134 feet to 190 feet*."

The memorandum recommended that the pit be lined or sealed and that the produced water be disposed by reinjection as soon as possible. The records do not indicate if Union Texas Petroleum or subsequent operators ever lined or sealed the pit.

A description of the pit and a detail log of the lithologies present in the area was provided by S.E. Williams, geologist for Union Texas Petroleum Division, in a memorandum dated October 18, 1971, The description stated that silty marlstone was present from the ground surface to the bottom of the pit at six feet, and from six feet to 1,250 feet there was yellow grey-buff silty shale and silty marlstone of the White River Group, with 'a possible small fresh water zone' however, the depth is not indicated.

A letter dated October 28, 1971 from Union Texas Petroleum Division had attached analytical results for five samples; however, the locations of the samples are not indicated. The TDS reported for the five samples were from 1,026 ppm, 2,298 ppm, 9,776 ppm, 1,136 ppm, and 2,860 ppm. The results were signed by Gary C. Stebbins, Project manager for Rocky Mountain Technology, Inc.

The September 19, 1984 lease inspection form describes a 10 feet by 10 feet skim pit with a mesh cover, and a 100 feet by 100 feet pit. Under the section for describing the condition of the lease the operator is listed as Rex Monahan. The inspector wrote "Going to rework old pits – close by draw." The records do not indicate whether this was done.

The scan of the July 30, 1986 pit inspection form is of poor quality. The operator is listed as Rex Monahan. Four pits are indicated, which included two 20 feet by 20 feet skim pits, one 100 feet by 170 feet evaporation pit, and one 100 feet by 100 feet evaporation pit. The comments on the form indicated tanks in "D33" and a lot of water produced, but it appears that they were not overflowing the pits. The form indicates that they reported 275 barrels of water per day.

The Form 4 Sundry dated 06/26/1997 was for a pit evaluation conducted by James W. Rowland, engineer. The operator is identified as Rex Monahan. The form indicates that

> *"This produced water pit is not considered to be in a sensitive area as determined by the use of the COGCC Decision Tree. The pit bottom is greater than 20' above the average high ground water table. This pit is not within a WQCC or WHPA, is not within ¼ mile of a public water supply well and is not within 1/8 mile of a domestic water supply well."*

Laboratory analytical data was attached that indicated the chloride content of the produced water from the Cliff Unit Pit was 1,710 milligrams per liter (mg/L), sulfate was 178 mg/L, and the TDS was 5580 mg/L. Concentrations of benzene, toluene, ethylbenzene, and total xylenes were below groundwater standards.

3.0 SENSITIVE AREA DETERMINATION ASSESSMENT

The following sections present Olsson's Sensitive Area Determination Assessment of the Cliff Field Pits. The 900 Series Rules included a Sensitive Area Decision Tree, Figure 901-1, which was removed from the rules during the rulemaking in 2008. The sensitive area decision now is based on the wording in Rule 901 e. The three pits have been used for the storage of produced water since at least 1971. The pits formerly discharged water to the intermittent drainage on location. The correspondence from Union Texas Petroleum indicates that initially there was no sealing material, but notes that the pit(s) should be lined or sealed and that the produced water should be disposed of by re-injection as soon as possible. The duration of the discharge to the intermittent drainage is unknown; however, it appears that by the mid-1980s this practice had stopped based on the available COGCC inspection notes of when it was operated by Rex Monahan. CM Production has owned/operated the field since October 2010.

3.1 Results of Geology and Hydrogeology Assessment

There are no shallow groundwater resources indicated in the area of the Site. Review of the hydrogeology of the area indicates that the Brule Formation is not part of the High Plains aquifer and that groundwater resources in the area are limited. A review of the area groundwater resources indicated that the depth to groundwater is more than 100 feet below ground surface in the vicinity of the site. The quantity of groundwater is likely to be low considering that the Site is approximately ½ mile south of highland area and is topographically and stratigraphically below the main part of the High Plains aquifer.

The Brule Formation is relatively impermeable and bedrock crops out in the vicinity of the Site. The pits were reportedly constructed in the bedrock of the Brule Formation of the White River Group. The geologist for Union Texas Petroleum indicated that the surface consisted of silty marlstone. The hydraulic conductivity of the siltstones of the Brule Formation and soils are less than or equal to 10^{-6} centimeters per second.

The COGCC records indicate that one of the previous owners considered sealing or lining at least one of the pits in 1971, but there is no information as to whether this was performed or not. The COGCC records indicate that the produced water from the pits was formerly discharged to the intermittent drainage. The salt impacts reported in the COGCC samples could be the result of this historic discharge rather than from releases from the pits as suggested by the COGCC. The only way to remediate salt impacted soils is to flush the salts with fresh water to dilute them out or to force them down below the root zone. With bedrock at depths of 60 inches and the silty sandy matrix, it is likely that historic impacts could wick back up to the surface, especially considering the lack of precipitation in the area.

The only surface water is an intermittent drainage, the seldom flows. There is no clearly defined nexus with live waters of the state. These intermittent drainages do not coalesce or connect to any coherent drainage or waterway. The nearest named surface water is George Creek, which is shown as an intermittent stream approximately six miles to the south. None of the intermittent streams are shown as connecting with this creek or any drainage on the Chimney Canyons 7.5-minute topographic map.

3.2 Potentially Sensitive Receptors

No public water supply wells were identified within more than one mile radius of the site. The sensitive area determination criteria stipulate that there are no public water supply wells within ¼-mile of the Site. There are no permitted domestic water wells located within more than one mile of the site. The sensitive area determination criteria are that there not be any domestic water wells within 1/8-mile of the Site. Therefore, neither of these criteria applies.

The topographic map shows a water well in the SE ¼, SW ¼ of Section 33, and another water well located in SE ¼, SE ¼ of Section 32. Neither of these wells appears to have been permitted with the Division of Water Resources. These wells may have been drilled to provide a water source for the oil well drilling in the 1950s or they may be livestock wells that pre-date the creation of the Division of Water Resources. The status of these wells is unknown.

3.3 Produced Water Quality

The available analytical results for the Cliff Unit produced water samples show a range from 1,026 ppm to 9,776 ppm. The results for the other three samples collected by Union Texas Petroleum had TDS that were reported at 1,136 ppm, 2,298 ppm, and 2,860 ppm. One ppm is equivalent to one milligram per liter. During the June 1997 non-sensitive area determination the TDS for the produced water in the Cliff Unit Pit was reported at 5,580 mg/L.

According to COGCC Rule 907. Management of E&P Waste c. Produced Water (2). Produced Water may be disposed as follows:

> *A. Injection into a Class II well, permitted in accordance with Rule 325;*
>
> *B. Evaporation/percolation in a properly permitted pit;*
>
> *C. Disposal at permitted commercial facilities;*
>
> *D. Disposed by road spreading on lease roads outside sensitive areas for produced water with less than 3,500 mg/L TDS when authorized by the surface owner. Road spreading of produced water shall not impact water of the state, shall not result in pooling or runoff, and the adjacent soils shall meet the concentration levels in Table 910-1."*

The COGCC rules are clear that produced water may be disposed through evaporation/percolation in a properly permitted pit. The pit has been in existence since 1971 and was permitted by Union Texas Petroleum. The COGCC inspected the site and noted the pits in 1984, 1986, and 1996. The COGCC Rule 907 c.(2) D even allows for the produced water to be spread on lease roads if the produced water has a TDS less than 3,500 mg/L, meets the Table 910-1 criteria, and if road spreading is authorized by the surface owner.

4.0 Conclusions

CM Production has owned/operated the site since October 2010. According to CM Production there have not ever been any produced water releases during the time they have operated the site. The CM Production, Cliff Unit – Rice Lease pits are located in a non-sensitive area in accordance with Rule 901.e. Sensitive Area Determination. Published geology and hydrogeologic data clearly indicate that there is not a significant threat of impact to groundwater or surface water in the vicinity of the pits as summarized below.

- A sensitive area determination performed for the previous operator, Rex Monahan, in June 1997, found that the site is located in a non-sensitive area, and cited the criteria that the maximum depth of the pit is greater than 20 feet above the seasonal high water table. The reported depth to groundwater in the area is more than 100 feet below ground surface.
- The Ogallala Formation and Arikaree Formation are located approximately ½ mile to the north, topographically and stratigraphically uphill from the Site. The Ogallala and Arikaree Formations are the primary host rock of the High Plains aquifer, and these formations are not present beneath the site.
- The Brule Formation consists primarily of massive siltstone containing beds of sandstone, volcanic ash, claystone, and fine sand. It is relatively impermeable and is not part of the High Plains aquifer except in areas where the rock has been extensively fractured. In northeastern Colorado, the Brule typically yields less than 300 gpm.
- The siltstone has a horizontal and vertical hydraulic conductivity of more than 10^{-6} cm/second. The Brule Formation and the Chadron Formation of the White River Group are confining units.
- There are no public water supply wells within more than one mile of the Site.
- There are no permitted domestic water supply wells within more than one mile of the Site. The Site is not located in an area classified for domestic use by the Water Quality Control Commission (WQCC), or a local water supply, or wellhead protection area (WHPA).
- According to the Division of Water Resources, the permitted water wells located more than one mile from the site have static water levels that are reportedly more than 100 feet below ground surface.
- There is an intermittent drainage located to the east of the Site at distances of 70 feet to more than 500 feet from the pits. The intermittent drainage does not represent a significant nexus to live waters of the state, and does not flow three months out of the year. A review of the Chimney Canyons topographic map shows no clear connection that the intermittent drainages coalesce or flow into any recognized creek or stream.
- The COGCC records indicate that historically the produced water from the pits was discharged to the intermittent drainage adjacent to the site in the 1970s. It is unknown how long this practice continued, but it appears to have ceased by the mid-1980s based on the COGCC inspections. The salt impacts identified by the COGCC during the January 2014 inspection may be due to historic produced water discharges.

5.0 Professional Geologist Certification

By means of this certification, I attest that:

- I am qualified to prepare a Sensitive Area Determination Evaluation in accordance with the provisions of COGCC Rule 901 e. Sensitive area determination criteria.
- I am a member of the American Institute of Professional Geologists.
- I have a Bachelors of Science degree in geology from Colorado State University and have been employed as a professional geologist since 1991.
- Although the Colorado Geological Survey does not currently have a licensing or registration program for professional geologists practicing in the state of Colorado, there are requirements within local and State statutes that require that geologic reports be prepared by a professional geologist. I attest that I meet the requirements of the Colorado Geological Survey's definition of a professional geologist having completed and met the educational requirements of the Colorado Geological Survey definition.
- I am a licensed Professional Geologist and Professional Geoscientist in other States, including Texas, Utah, and Wyoming which do have licensing programs for professional geologists.
- I have reviewed published geologic maps and reports applicable to this area and have considered the implications of these conditions in the context of the Site.
- I visited the site with Mr. John Teff on March 27, 2014 and observed the site conditions after a light snow fall and melt water was present in the intermittent drainage.
- This report has been prepared in accordance with good scientific principles and engineering practices including consideration of applicable industry standards, and with consideration of the requirements of the National Association of State Boards of Geology. The conclusions and recommendations contained in this report are based on information available and known to me at the time of this report. Good scientific principles and standard engineering practices were taken into consideration to in arriving at the conclusions and recommendations made in this report.

James W. Hix
Senior Geologist

Date: __04/24/2014_____

Note: The PG's certification does not relieve the owner/operator of the facility of the duty to review this report or fully implementing the recommendations in accordance with all applicable Federal, State, and local requirements in order to achieve the desired goals or objectives.

7.0 References

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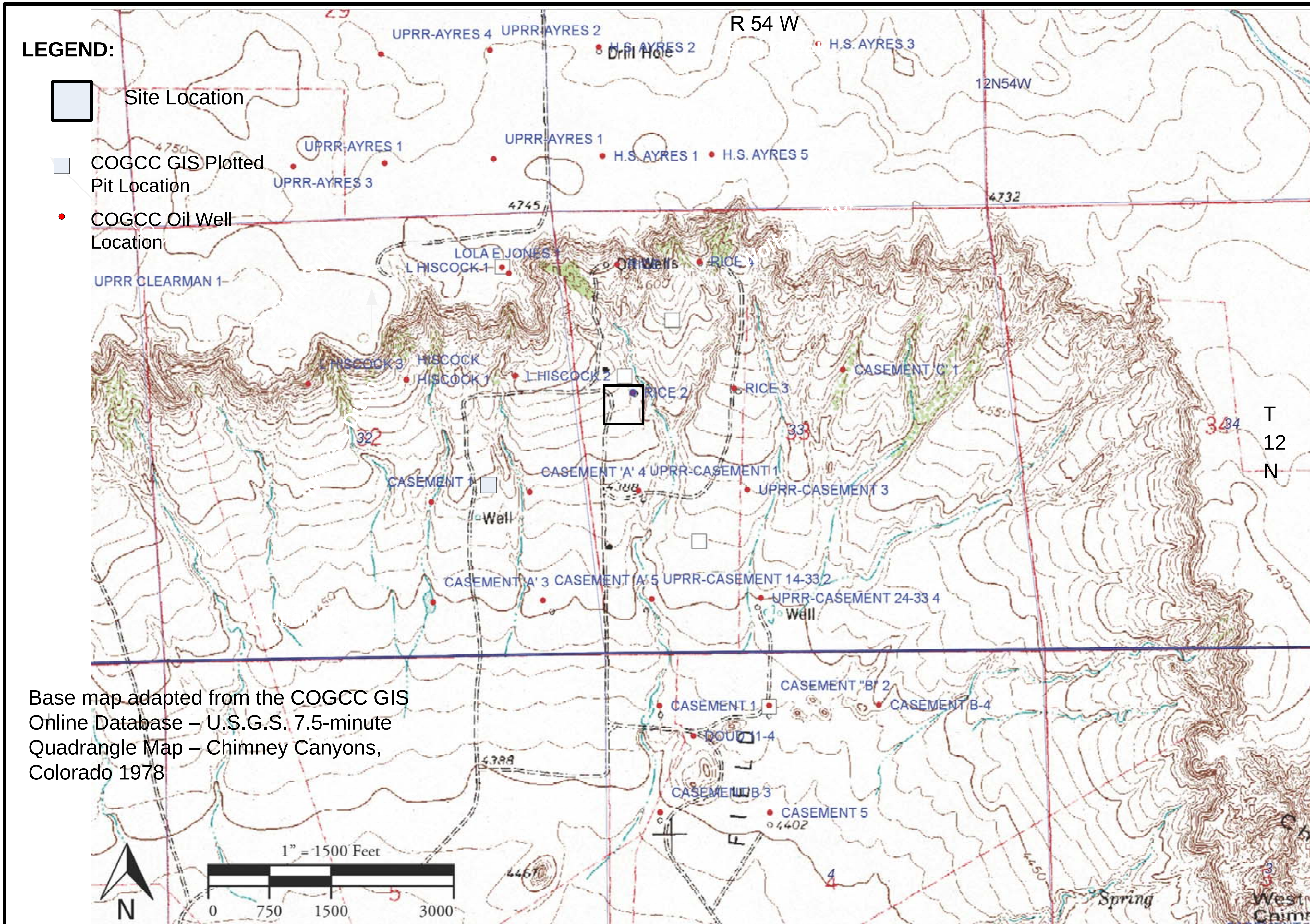
- Natural Resources Conservation Service - Soil Survey http://www.nrcs.usda.gov/
- Colorado Geological Survey website: http://geosurvey.state.co.us/hazards
- Division of Water Resources Website: http://water.state.co.us/Home/Pages/default.aspx

FIGURES

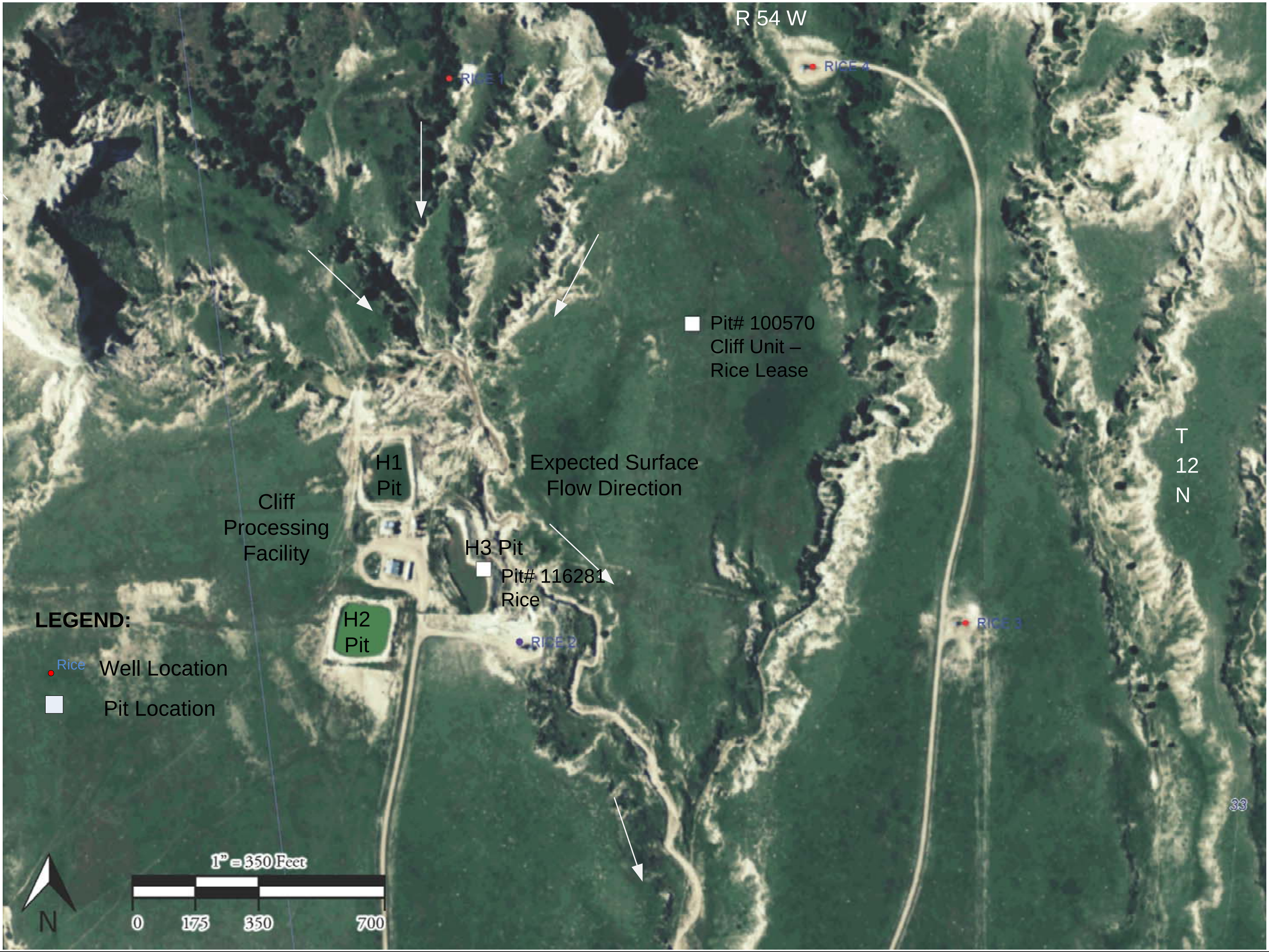


PROJECT NO:	013-1681
DRAWN BY:	JWH
DATE:	03/14/2014

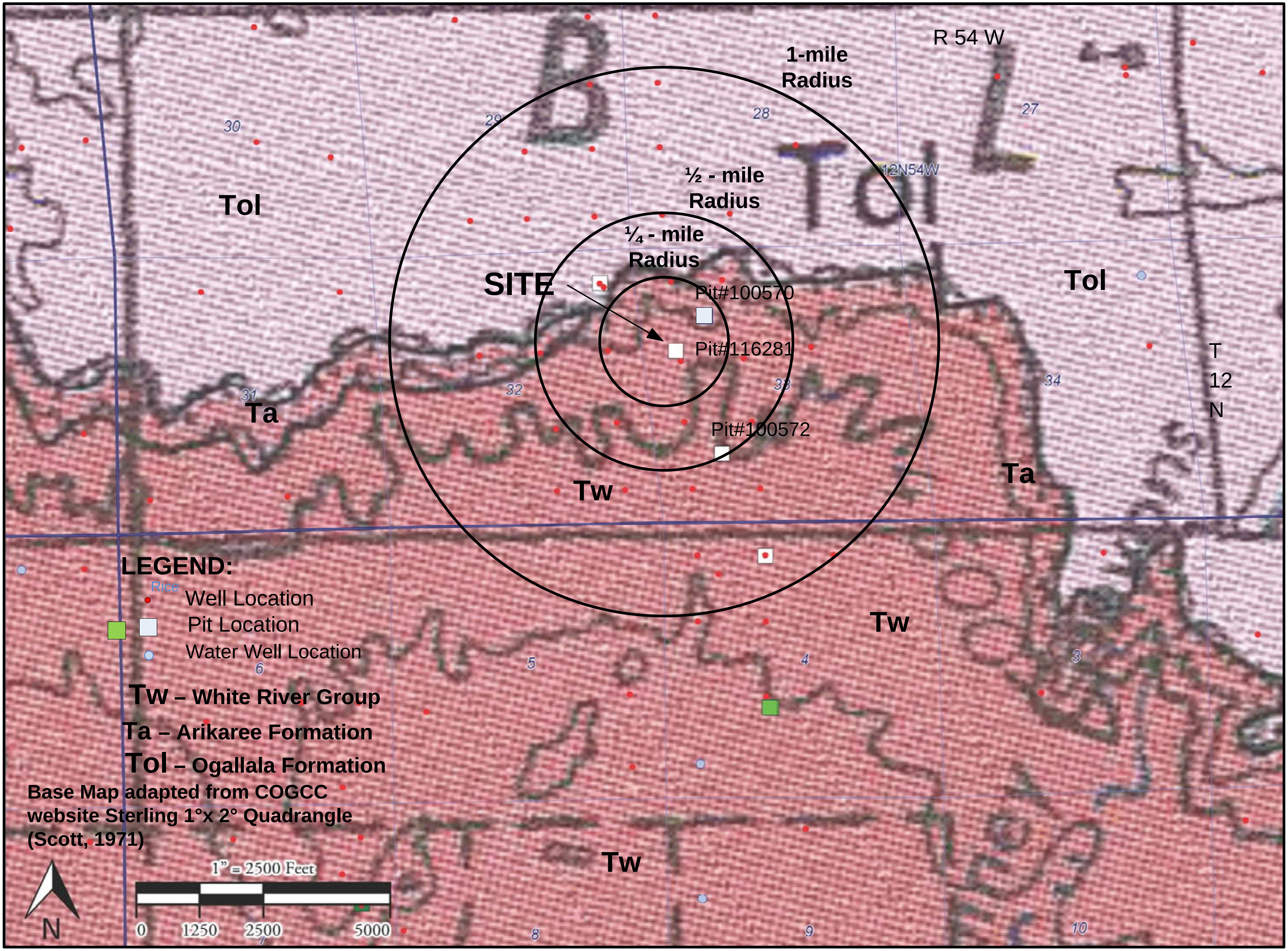
General Site Location Map
CM Production, LLC
Cliff Field, Rice Lease, Logan County, Colorado

OLSSON ASSOCIATES
4690 Table Mountain Drive #200
Golden, Colorado 80403
TEL 303.237.2072
FAX 303.237.2659

FIGURE
1



PROJECT NO: 013-1681	Rice Lease Site Map	OLSSON ASSOCIATES	FIGURE
DRAWN BY: JWH	CM Production, LLC	4690 Table Mountain Drive #200, Golden, Colorado 80403, TEL 303.237.2072, FAX 303.237.2659	2
DATE: 03/14/2014	Cliff Field, Rice Lease, Logan County, Colorado		



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DRAWN BY:	JWH
DATE:	03/14/2014

Cliff Field - Rice Lease Geologic Map

CM Production, LLC

Cliff Field, Rice Lease, Logan County, Colorado

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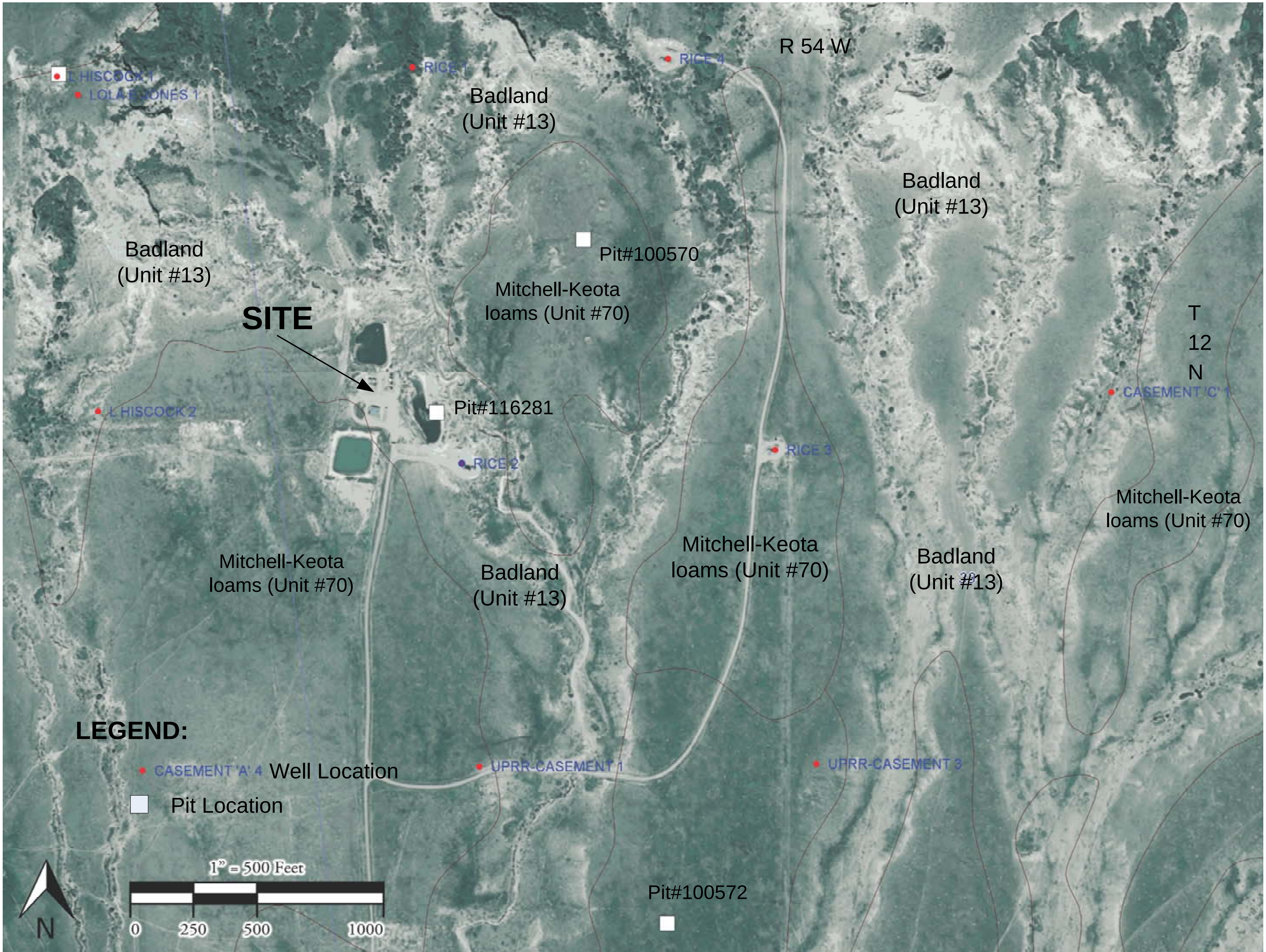
FIGURE 3



PROJECT NO:	013-1681	
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DATE:	03/14/2014	

Cliff Field - Rice Lease Soil Map

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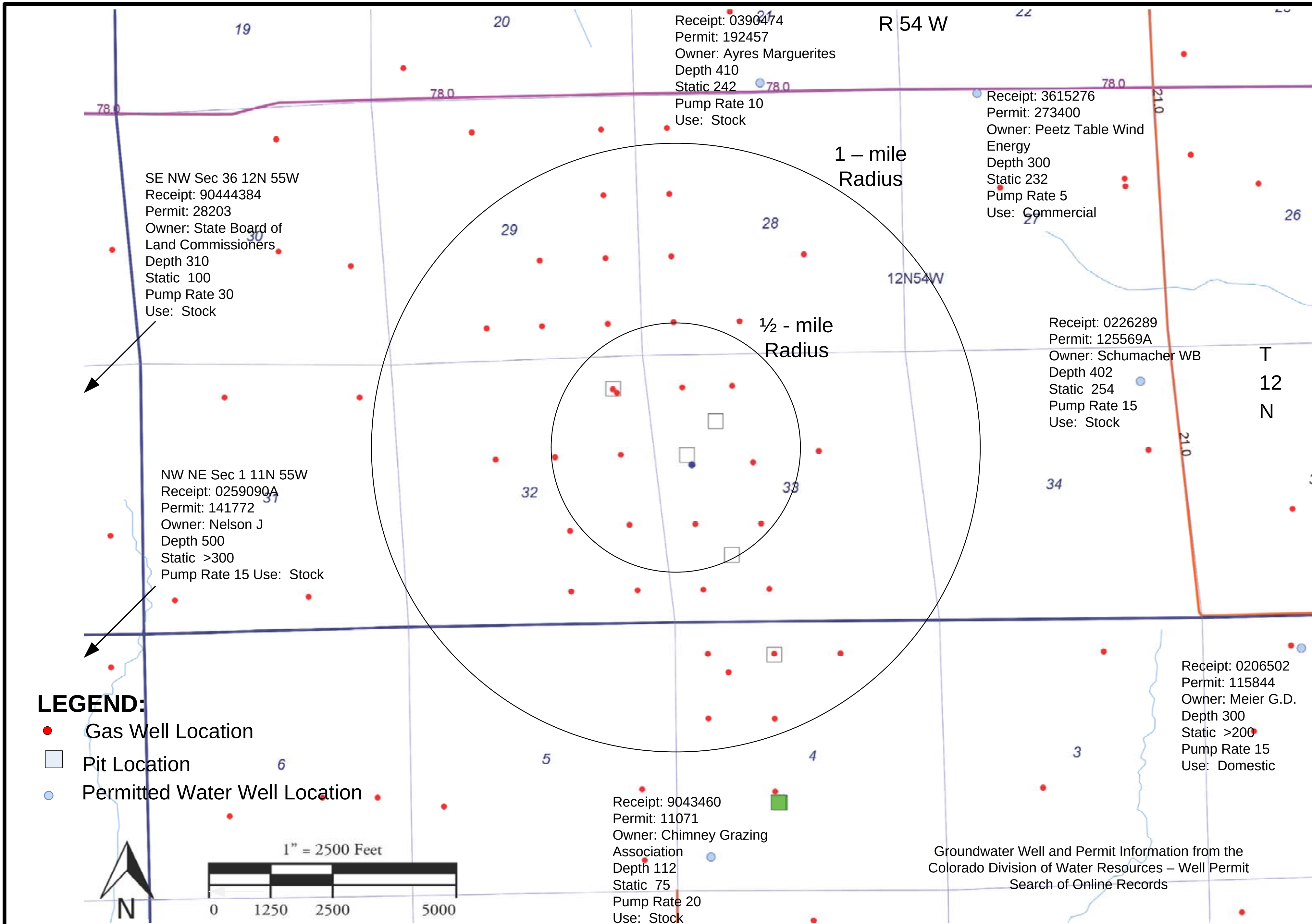
FIGURE 4



PROJECT NO:	013-1681
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Cliff Field - Rice Lease Permitted Water Well Map
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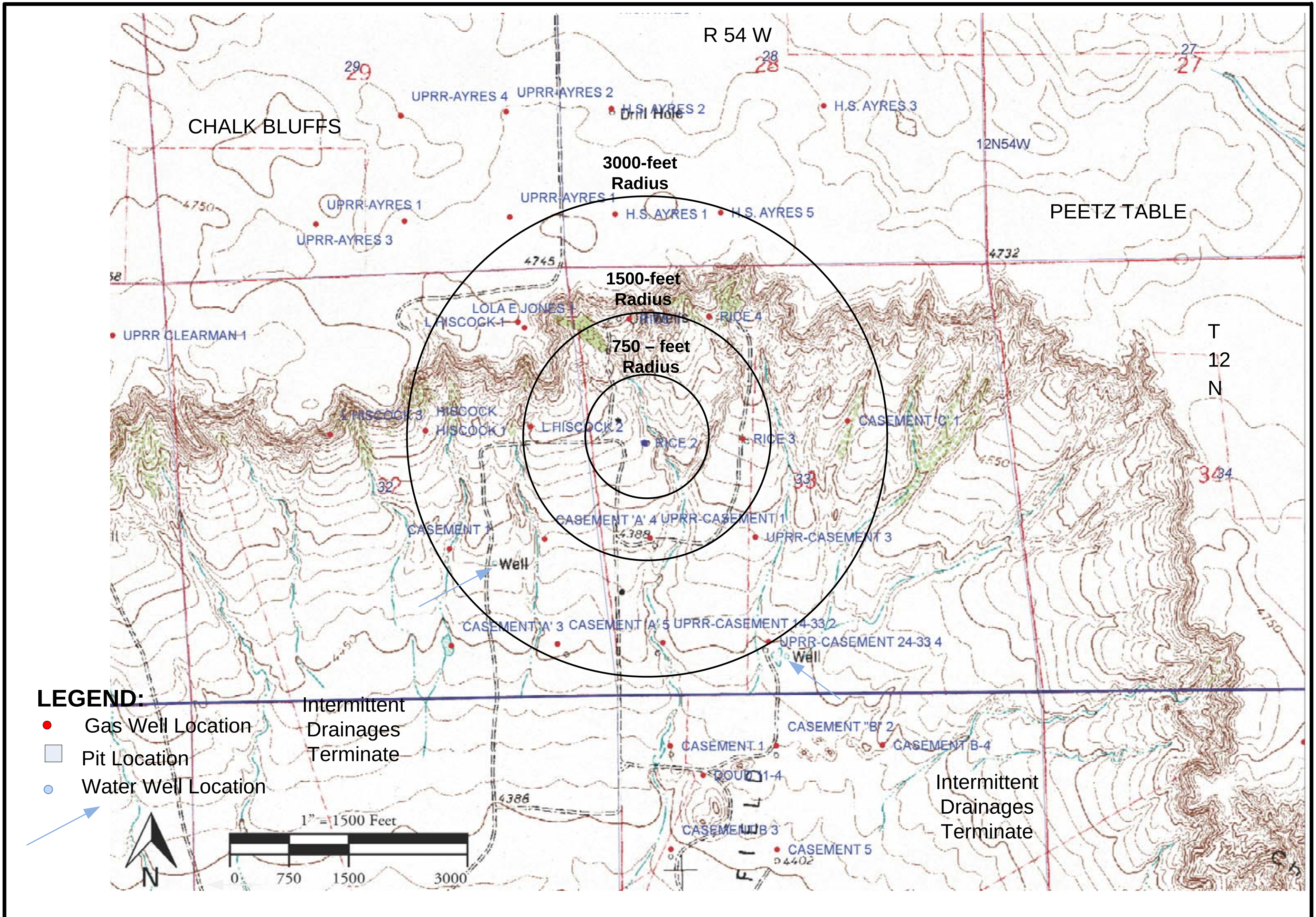
FIGURE 5



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Cliff Field - Rice Lease Water Wells on Topographic Map

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FIGURE 6