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REPORTS

DATE:

11/15/2006

R. T. HICKS CONSULTANTS, LTD.

901 Rio Grande Blvd NW ▲ Suite F-142 ▲ Albuquerque, NM 87104 ▲ 505.266.5004 ▲ Fax: 505.266-0745

November 15, 2006

Mr. Glenn von Gonten
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

RE: Samson BD-04, T12S-R33E-Section 2, Unit Letter H
(latitude 33° 18′ 35″ N, longitude 103° 34′ 39″ W)

Dear Mr. von Gonten:

As requested in your October 19, 2006 letter, R.T. Hicks Consultants is pleased to submit the attached Corrective Action Plan on behalf of Samson Resources. A copy of the report, including the appendices, will be submitted to your office via FEDEX within the next several days.

We understand that the NMOCD workload may dictate that several weeks or months may pass before the agency reviews the information contained in this submission. However, we respectfully request your approval to install the proposed recovery/monitoring well as soon as possible. If the release from the pit has caused impairment of ground water quality, then rapid implementation of the proposed pump-and-use ground water restoration strategy is in the best interest of New Mexico and Samson Resources.

The location of the proposed well (in the center of the former pit) is shown in Plate 3 of the Corrective Action Plan and Plate 7 of the CAP presents the well design. As stated in the CAP the proposed recovery/monitoring well is designed to:

- Permit long-term withdrawal of ground water in the event that the release from the pit during operation or post-operation drying has caused localized impairment of ground water quality (i.e. ground water quality exceeds WQCC Standards below the former pit)
- Accommodate installation of a wide range of pumps for extraction of ground water that exceeds WQCC Standards (e.g. solar powered)
- Allow discrete sampling of the upper screened zone and the lower screened zone to test for chemical stratification of the aquifer beneath the former reserve pit
- Allow for placement of packers in the well to restrict flow and permit pumping only the interval exhibiting water quality in excess of the WQCC Standards

In anticipation of your approval to move forward with construction of this well, we have scheduled a drill rig for after Thanksgiving but before December 8. In January, we could have laboratory data from this well and then meet with NMOCD to present the data and address any comments or questions that you may have at that time.

Sincerely,
R.T. Hicks Consultants, Ltd.

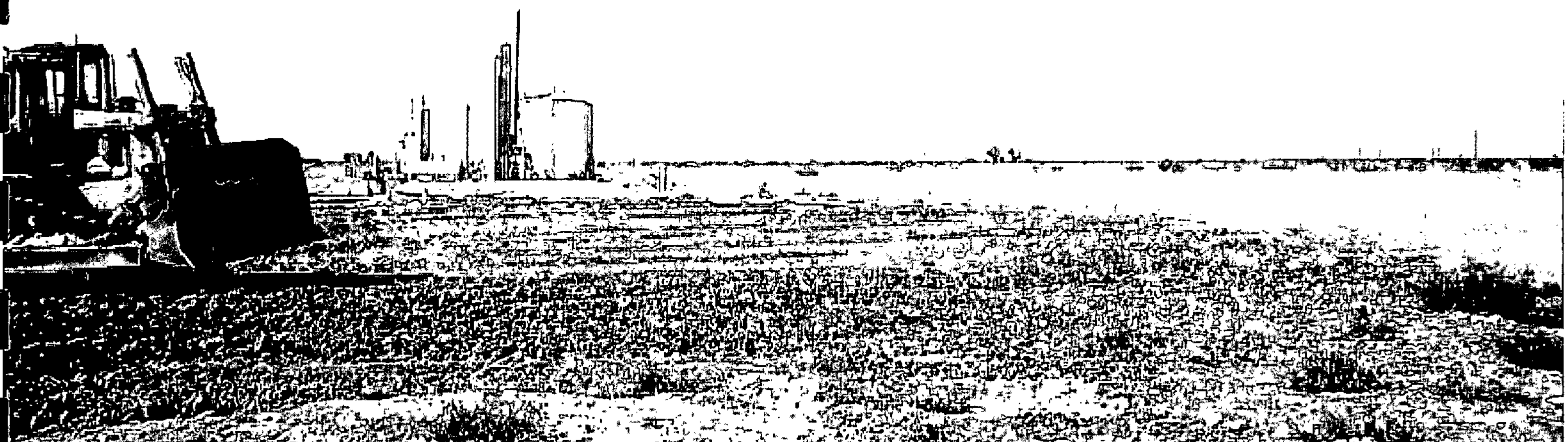
Randall T. Hicks
Principal

Copy:
Samson Investments, Tom Kocelny, Scott Rose
New Mexico State Land Office

IR0474

November 2006

Corrective Action Plan



Samson BD-04 Reserve Pit
Samson Resources

R.T. HICKS CONSULTANTS, LTD.

901 RIO GRANDE BLVD. NW, SUITE F-142, ALBUQUERQUE, NM 87104

November 2006

Corrective Action Plan

SAMSON BD-04 RESERVE PIT

Prepared for:

Samson Resources
Two West Second Street
Tulsa, OK 74103

R.T. HICKS CONSULTANTS, LTD.

901 RIO GRANDE, SUITE F-142, ALBUQUERQUE, NM, 87104

1.0 EXECUTIVE SUMMARY

This Corrective Action Plan presents the results of the characterization activities performed by R.T. Hicks Consultants (Hicks Consultants) at the Samson State BD-04 site located about 15 miles west of Tatum, New Mexico. Ground water beneath the site does not exceed WQCC Standards. After vegetation is established over the infiltration barrier at the site, water contaminants in the vadose zone will not with reasonable probability contaminate ground water or surface water in excess of the Water Quality Control Commission standards through leaching, percolation, or other transport mechanisms, or as the water table elevation fluctuates.

After re-vegetation of the site and two post-vegetation quarterly ground water monitoring events, Samson will submit a final closure report.

1.1 DATA SUMMARY

The Closure Plan Investigation Report presents all information collected by Hicks Consultants and others until August 2006.

1. Regional ground water elevation data from the USGS (1996) show that ground water flow at the site is east-southeast. The bearing of the ground water flow direction is North 100° East if one employs the elevation data from wells north of the site. If one uses data from wells south of the site to determine the flow direction, the bearing is North 125° East.

2. Data collected from nearby wells in October 2006 suggest a ground water flow direction of North 115° East.

3. Three ground water sampling events demonstrate that, at the time of writing, ground water at MW-1, which is down gradient of the former reserve pit, does not exceed the WQCC standards.

4. Chloride concentration data from vadose zone samples show that the chloride center of mass resides from about 10 feet below ground surface to at least 27 feet below ground surface and probably to the water table (43 feet bgs). The maximum chloride concentration is 5,400 mg/kg from a composite sample that represents a depth interval of 13-27 feet located in the west-central portion of the former reserve pit. The average chloride concentration of six samples taken from this depth interval is about 2,700 mg/kg.

5. Samples from this depth interval obtained from the southern portion of the former pit show chloride concentrations less than 1,000 mg/kg.

6. Neither field PID analyses nor observed characteristics of samples (e.g. odor) suggest that hydrocarbons are present in the vadose zone.

7. Ground water flows east-southeast in the area of the former reserve pit under a hydraulic gradient of 0.003.

8. Recovery tests conducted on MW-1 suggests the hydraulic conductivity of the uppermost portion of the aquifer is as low as 0.4 ft/day.

9. Published reports suggest that the hydraulic conductivity of the Ogallala Aquifer in this area is about 40 ft/day.

1.2 CONCULSIONS

- Assuming a porosity of 30% for the sand of the uppermost portion of the aquifer and the measured hydraulic properties estimated from the recovery test, ground water average linear velocity at the site is less than 2 ft/year.

- The release from the former reserve pit occurred when the pit was in operation or during the drying process. Chloride probably entered ground water no later than early 2005, before initial pit closure activities. Chloride probably entered groundwater via saturated flow through preferential pathways. Saturated flow ceased soon after the pit was dry - in early 2005.

- Unsaturated transport of chloride from the vadose zone to ground water would be greatest from early 2005 to present due to the absence of a vegetative cover over the former reserve pit and observed limited run-on of stormwater into the pit.

- In the southern portion of the former reserve pit, the mass of chloride from 10 feet below ground surface to ground water is not sufficient to cause ground water to exceed the WQCC standards at the site due to migration of chloride from the vadose zone to ground water. The concentrations of chloride in this portion of the vadose zone are less than 1,000 mg/kg.

- The majority of chloride released from the pit occurred in the northern portion of the former reserve pit.

- Assuming an average linear water velocity of less than 2 ft/year and a documented southeast ground water flow direction, ground water that was beneath the northern portion of the former reserve pit in May 2005 migrated about 2 feet to the southeast in one year. If well inefficiencies or other factors have caused the recovery test at MW-1 to underestimate the hydraulic conductivity of the uppermost Ogallala Aquifer, then the average linear water velocity would be greater than 2 ft/year.

- Site-specific HYDRUS-1D simulations and decades of monitoring data beneath infiltration barriers show that the recharge rate at this site (after re-vegetation over the installed infiltration barrier) will be slightly greater than zero.

- The chloride mass that resides from 10 feet bgs to the water table will migrate downward over decades or centuries entering ground water at a very slow rate.

- HYDRUS-1D simulations predict that ground water beneath the site will not be impaired as a result of the very slow migration of salt load detected from 10 feet below ground surface to ground water.

- Site specific ground water monitoring strongly suggest that the HYDRUS-1D simulations overestimate the chloride flux from the vadose zone to ground water.

1.3 RECOMMENDATIONS

I. Install a recovery/monitoring well in the east-central portion of the former reserve pit and collect discrete samples from the uppermost 10 feet of the aquifer and from the lower 10 foot screen, which is about 20-30 feet below the water table.

II. Re-vegetate the surface of the installed infiltration barrier at the BD-04 Site.

III. If data from the proposed recovery/monitoring well demonstrate that ground water does not exceed WQCC Standards, continue ground water monitoring for two additional quarters after vegetation is re-established at the former reserve pit site.

IV. If data from the proposed recovery/monitoring well show that WQCC Standards are exceeded, implement a risk-based pump-and-use aquifer restoration strategy.

V. Upon documentation of surface restoration and verification that ground water quality remains below WQCC Standards, submit a closure report for the BD-04 site.

The selected remedy is the creation of an infiltration barrier and re-vegetation of the site. This remedy is protective of ground water quality and human health and the environment.

2.0 BACKGROUND

Appendix A is the August 2006 Investigation Report previously submitted to the NMOCD. Appendix B is the Closure Plan Design Report that describes the infiltration barrier installed at the site.

2.1 LOCATION

Appendix A includes information and maps showing the site relative to nearby landmarks (see also Plates 1 &2).

The site location is in T12S-R33E-Section 2, Unit Letter H (latitude 33° 18′ 35″ N, longitude 103° 34′ 39″ W)

2.2 CHARACTERIZATION ACTIVITIES

Section 2.2 of Appendix A describes all characterization activities conducted from 2005 to August 2006. In summary, characterization included:

- Laboratory analysis of two samples from the pit excavation surface after removal and disposal of dried drilling fluids.
- Laboratory analysis of two samples from six sampling trenches in the former reserve pit.
- Laboratory analysis of composite samples obtained from each of the six sampling trenches.
- Laboratory analysis of four composite samples obtained from the southern spoil pile that represents material excavated from the pit (from about 8 feet below ground surface to about 13 feet below ground surface).
- Laboratory analysis of eight composite samples from the eastern spoil pile that represents native material excavated below the soil horizon during pit construction.
- One sample of cobble-sized material from the southern spoil pile and one sample of cobble-sized material from the native material of the eastern spoil pile.
- Installation of two ground water monitoring wells.
- Collection of ground water samples in May and August of 2006.

Subsequent to the August 2006 report, Hicks Consultants conducted the following activities in October 2006 to provide additional characterization of the site:

- Construction and sampling of a trench located in the southwest corner of the former reserve pit.
- Measurement of depth to ground water in the two monitoring wells, one abandoned supply well and two windmills in the area.
- Discrete sampling of the uppermost portion of the screened interval of MW-1.
- Sampling of the entire screened interval of MW-1.
- Recovery testing of MW-1 to determine hydraulic characteristics of the aquifer.

The method used to collect depth discrete ground water samples from MW-1 deserves some explanation. A small sampling pump placed at the base of the well screen withdrew water at a rate of 0.2 to 0.4 gallons per minute. This pump discharge rate created about 1 foot of draw down and caused water to enter the well in response to this gradient. After pumping 20 gallons in this manner, a bailer collected a grab sample from the water column about 3 feet below the pumping water level. Five minutes after collecting the bailer grab sample, we collected a sample from the pump at the base of the well screen. The pumped sample would be representative of ground water quality in the uppermost 15 feet of the aquifer and the sample from the bailer represents the top 3-4 feet of the aquifer.

3.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

Appendix A describes the hydrogeology of the area.

4.0 CHARACTERISTICS OF THE VADOSE ZONE

The data from the southwest corner of the former reserve pit that was derived from sampling conducted in October 2006 does not contradict the data presented in Appendix A. Figure 6 of Appendix A, which is reproduced here as Figure 1, remains an appropriate characterization of the vertical chloride distribution. As suggested in Figure 1, the average chloride concentration in the undisturbed vadose zone ranges from 2,700 mg/kg (one sample at 27 feet) to about 600 mg/kg in the capillary fringe. The lower chloride concentrations in the capillary fringe are not based upon analyses but are an estimate based upon the HYDRUS-1D modeling predictions, as described in Appendix A.

Figure 1: Chloride Profile of BD 4 Site

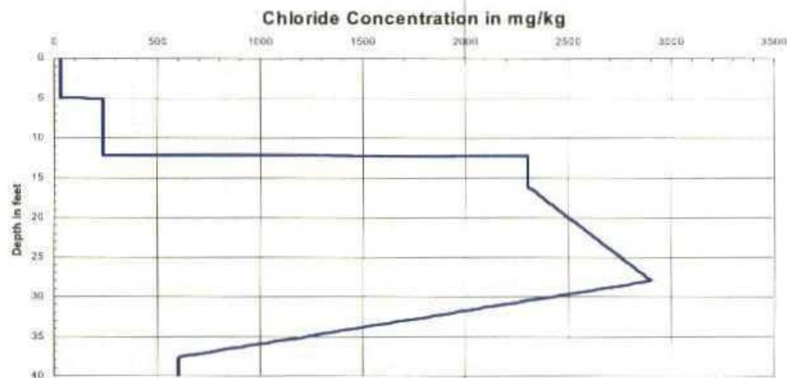


Plate 3 summarizes the horizontal distribution of chloride based upon the results of the reserve pit characterization program conducted before and since the August 2006 Investigation Report. The southern portion of the former reserve pit does not exhibit chloride concentrations greater than 1,000 mg/kg.

Plate 4 is a north-south cross section showing the chloride concentrations and characteristics of the former pit and the installed infiltration barrier. The chloride concentration of the southern spoil pile is about 1,900 mg/kg (average of four composite samples). All material from the northern and eastern spoil piles were excavated from the reserve pit prior to operation and are native, un-impacted material.

5.0 CHARACTERISTICS OF THE AQUIFER

At the BD-04 site, saturated sand occured at 39 feet bgs and static depth to water is about 45 feet bgs. A more detailed discussion of the area hydrogeology is contained in Appendix A including documentation of regional ground water flow direction and background water quality.

Since the August 2006 report presented in Appendix A, depth to water sampling in nearby windmills and abandoned water supply wells allow creation of a site-specific potentiometric surface map. As shown in Plate 5, the ground water flow direction and gradient is not dissimilar to the regional map presented in Plate 6 (also part of Appendix A). Plate 5 documents that ground water flows southeast at a hydraulic gradient of 0.005 at the time of the October 2006 well gauging event. When we measured water levels to create Plate 3, a windmill (#27 on Plate 5) was pumping and the depth to water may be slightly greater than static.

During the October 2006 field program, a single well pump and recovery test yielded an estimate of the hydraulic conductivity of the uppermost portion of the aquifer beneath the former reserve pit. The methods of testing, the data, and the calculations associated with this test are described in Appendix C. The calculated hydraulic conductivity using the Hvorslev method of analysis is 0.4 ft/day. This result is 100 times smaller than the 41-60 feet/day estimate of hydraulic conductivity used by Musharrafieh and Chudnoff (1999) shown in Figure 10 of their report and reproduced here as Figure 2.

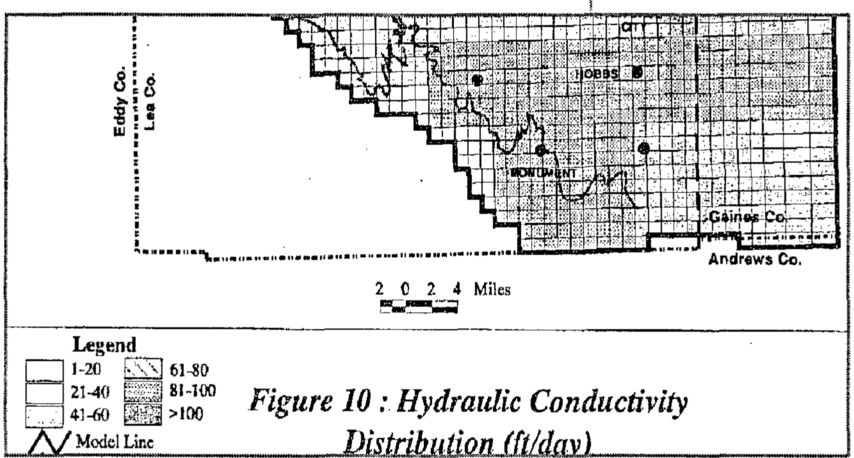


Figure 10 : Hydraulic Conductivity Distribution (ft/day)

Figure 2- Map showing estimated hydraulic conductivity near the site.

One expects a slug-test from the uppermost portion of the aquifer to yield a lower hydraulic conductivity for at least two reasons:

- The Ogallala Aquifer displays a fining-upward sequence that is common to alluvial deposits. At the base of the Ogallala, a conglomeratic gravel deposit is common. Aquifer tests of the Ogallala used in the Musharafieh and Chundoff (1999) report would include a large contribution from the lower, coarser layers, creating much higher hydraulic conductivity measurements than tests that are limited to the uppermost portion of the saturated zone.

- The 2-inch diameter monitoring well produced silt during the sampling and pumping event employed to create the recovery test. The efficiency of this well is probably much less than a well-developed supply well. Poor well efficiency can contribute to the significantly lower hydraulic conductivity value relative to the published value.

In the absence of any data to the contrary, we must conclude that the hydraulic conductivity of the uppermost portion of the aquifer is relatively low, as suggested by the slug test. Observations in the field suggest that MW-2 recovered more quickly from the sampling exercise, suggesting that well inefficiency of MW-1 could be a contributing factor in the calculation of the hydraulic conductivity values.

Assuming a porosity of 30%, a hydraulic gradient of 0.003 and a hydraulic conductivity of 0.4 feet/day, the average linear velocity at the site is less than 2-feet per year in the uppermost portion of the aquifer. Using a hydraulic conductivity of 0.4 ft/day, which is consistent with published reports for the entire aquifer, the average linear velocity beneath the site is about 150 feet per year. Although MW-1 is down gradient from the reserve pit, these calculations and the local hydraulic gradient suggest that the center of mass of any release from the former reserve pit may exist up gradient from and north of MW-1 (i.e. directly beneath the central and north central portions of the former pit).

Ground water sampling shows that chloride and TDS concentrations exceed background concentrations in MW-1 but are well below WQCC standards. As discussed in Appendix A, TDS and chloride concentrations in MW-2 are equivalent to the regional background. Field data and lab data are summarized in table 1.

On November 1, 2006, discrete samples from the top and bottom of the well screen of MW-1 suggest a slight stratification of water chemistry.

Samples bailed from the uppermost 3-4 feet of the aquifer show a chloride concentration of 140 mg/L, similar to the initial sampling event of the entire 15 foot well screen. The sample from the pump, which would represent the water quality of the 15 foot screen length, is 95 mg/L, slightly lower than the chloride concentration from the second sampling event. Although any meaningful conclusion regarding chemical stratification in the aquifer will require additional sampling, the fact that all ground water samples are well below WQCC Standards makes the question of chemical stratification at MW-1 academic.

Table 1- Feild and lab data.

	Date	Cl	TDS	Br
MW-1	5/12/2006	131	838	0.48
	8/2/2006	115	648	
MW-1 bottom screen (pump)	11/1/2006	95	660	
MW-1 top screen (bailer)	11/1/206	140	590	
MW-2	5/12/2006	44.5	530	0.44
	8/2/2006	42.2	444	

6.0 EVALUATION OF VERTICAL CHLORIDE FLUX

Empirical evidence from soil sampling within the former reserve pit shows chloride concentrations above background levels to a depth of at least 26 feet, which is about 20 feet above the water table. The fact that ground water at the down gradient well MW-1exhibits chloride levels well above background chloride concentrations demonstrates that fluid from the former reserve pit has entered ground water. Preliminary HYDRUS-1D simulation modeling mentioned in Appendix A permitted a conclusion that the residual mass of chloride in the vadose zone could move into ground water and cause chloride concentrations to exceed 250 mg/L.

7.0 PROPOSED REMEDY

Experience at similar sites and HYDRUS-1D simulations of the conditions at this site allowed a recommendation for placement of an infiltration barrier over the former reserve pit to limit the chloride flux from the vadose zone to ground water. The design of the infiltration barrier and the data and conclusions employed to support this design are presented in Appendix B.

In October and November 2006, R.T. Hicks Consultants oversaw construction of the infiltration barrier described in Appendix B. Appendix D presents field notes, photographs and other data verifying that construction of the infiltration barrier was consistent with the design criteria set forth in Appendix B.

In addition to the construction of the infiltration barrier, the remedy calls for the installation of a 4-inch diameter recovery/monitoring well near the center of the former reserve pit. Plate 3 shows the location of the proposed recovery/monitoring well and Plate 7 presents the design drawing for the well. The measured hydraulic gradient and the confirmation of the east-southeast flow direction with water level elevation data from nearby wells confirms that MW-1 is down gradient from the former reserve pit. Although this well is impacted by the release, MW-1 may not be directly down gradient from the area of the reserve pit that was impacted by the largest mass of the fluids release. The proposed well will provide excellent data to quantify any impact to ground water caused by the release from the pit. The well is designed to:

- Permit long-term withdrawal of ground water in the event that the release from the pit during operation or post-operation drying has caused localized impairment of ground water quality (i.e. ground water quality exceeds WQCC Standards below the former pit)
- Accommodate installation of a wide range of pumps for extraction of ground water that exceeds WQCC Standards (e.g. solar-powered)
- Allow discrete sampling of the upper screened zone and the lower screened zone to test for chemical stratification of the aquifer beneath the former reserve pit
- Allow for placement of packers in the well to restrict flow and pumping from only the interval exhibiting water quality in excess of the WQCC Standards

The remedy calls for sampling each screened interval of the proposed recovery/monitor well one week and one month after installation of this well (proposed for December 2006). Four quarters of ground water sampling at the proposed recovery/monitor well and MW-1 during 2007 are part of the proposed remedy.

If the first two sampling events of the proposed recovery/monitor well demonstrate that ground water exceeds the WQCC standards, a pump will be placed in the well and water withdrawn for beneficial use. The results of the samples will determine the ultimate use of the pumped water based upon a simple risk assessment. Water high in dissolved solids may be employed for oil and gas well drilling while water less than 3,000 mg/L total dissolved solids may be used for livestock.

8.0 CRITERIA FOR CLOSURE

If four quarters of monitoring demonstrate that the site has not caused ground water to exceed the WQCC Standards, Samson will submit a closure report. The closure report will provide documentation that the surface of the infiltration barrier exhibits vegetation that is equal to at least 70% of the adjacent, undisturbed landscape.

If monitoring demonstrates the need, the proposed pump-and-use ground water restoration strategy will be operated until water from MW-1 and the recovery well meets the WQCC Standards. After cessation of restoration pumping, MW-1 and the recovery well will be sampled quarterly. If concentrations rise after cessation of pumping and data suggest the WQCC Standards may be exceeded in the absence of pumping, pumping will re-start.

After cessation of pumping, eight quarters of ground water monitoring will demonstrate that ground water is restored and Samson will submit a final closure report.

9.0 REFERENCES

Ash, S.R., 1963, Ground water conditions in northern Lea County, U.S. Geological Survey Hydrologic Investigations Atlas HA-62

Hendrickx, J., Rodriguez, G., Hicks, R. T., and Simunek, January 2005, Modeling Study of Produced Water Release Scenarios, API Publication Number 4734, 11 pp.

Intera Incorporated, July 8, 2003, Windmill Oil Site Ground Water Sampling Results, prepared for the New Mexico Oil Conservation Division, 3 pp.

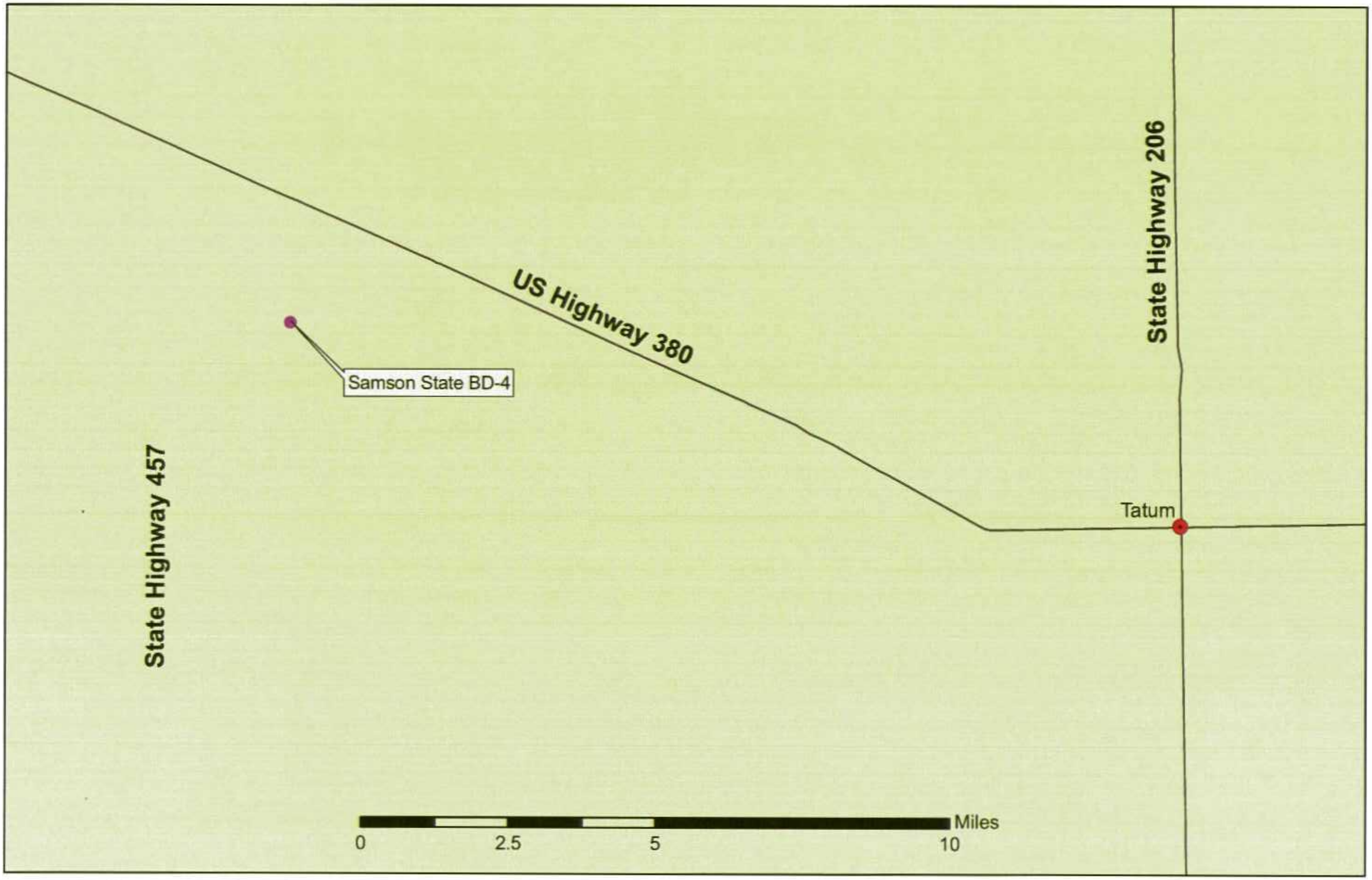
McAda, D.P., 1985, Projected water-level declines in the Ogallala aquifer in Lea County, New Mexico, US Geological Survey Water-Resources Investigations Report 84-4062, 84 pp.

Musharrafieh, G. and Chudnoff, M., January 1999, Numerical Simulation of Groundwater Flow for Water Rights Administration in the Lea County Underground Water Basin New Mexico, New Mexico Office of the State Engineer Technical Report 99-1, 6 pp.

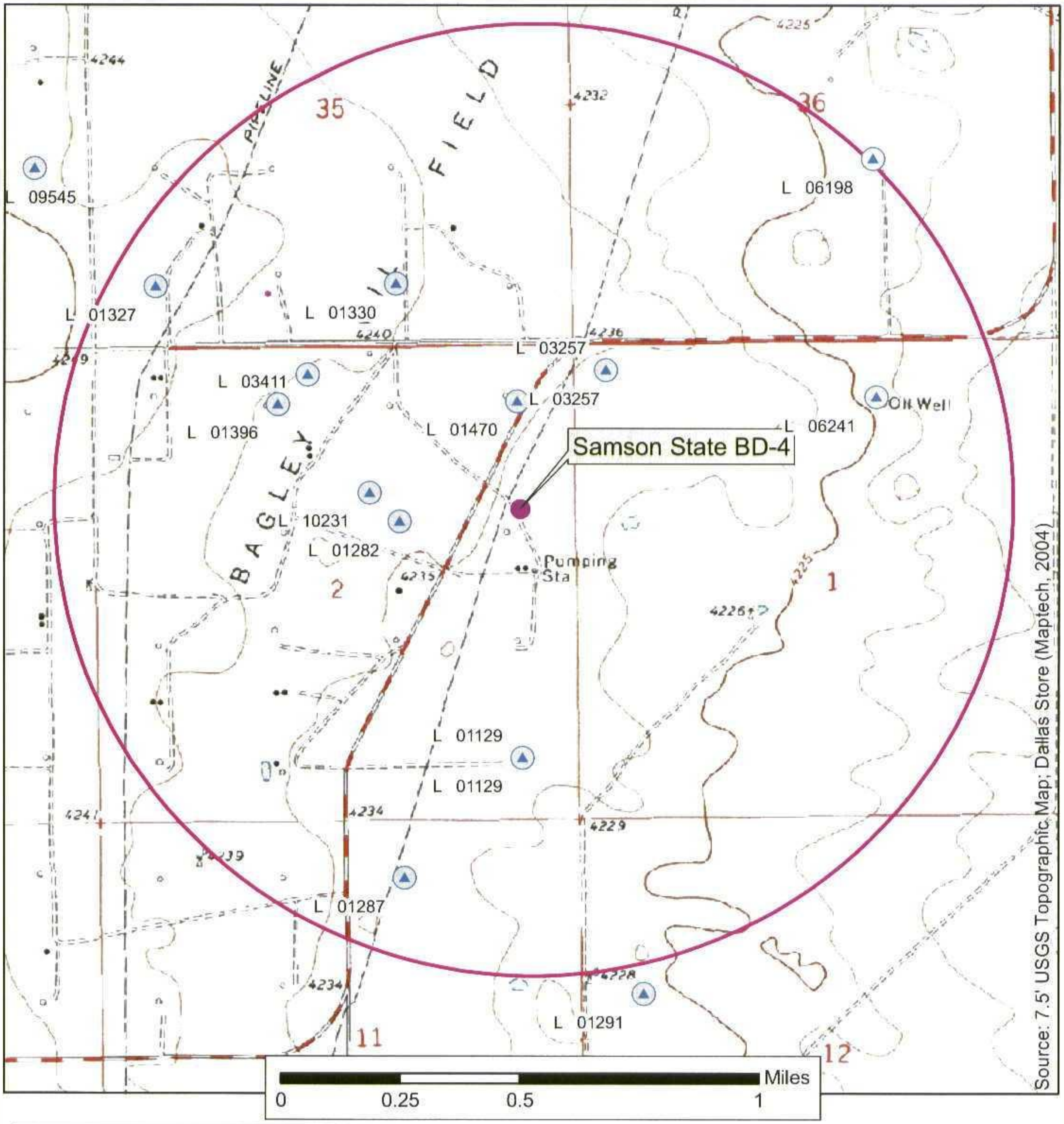
Nicholson Jr., A. and Clebsch, A., 1961, Geology and Ground Water Conditions of Southern Lea County, New Mexico, Ground Water Report 6, US Geological Survey, New Mexico Bureau of Mines and Mineral Resources

PLATES

To access the site, proceed west from Tatum, NM approximately 15 miles on US Highway 380. Head south on State Highway 457 for approximately 2.5 miles. The site is on the east side of the highway.



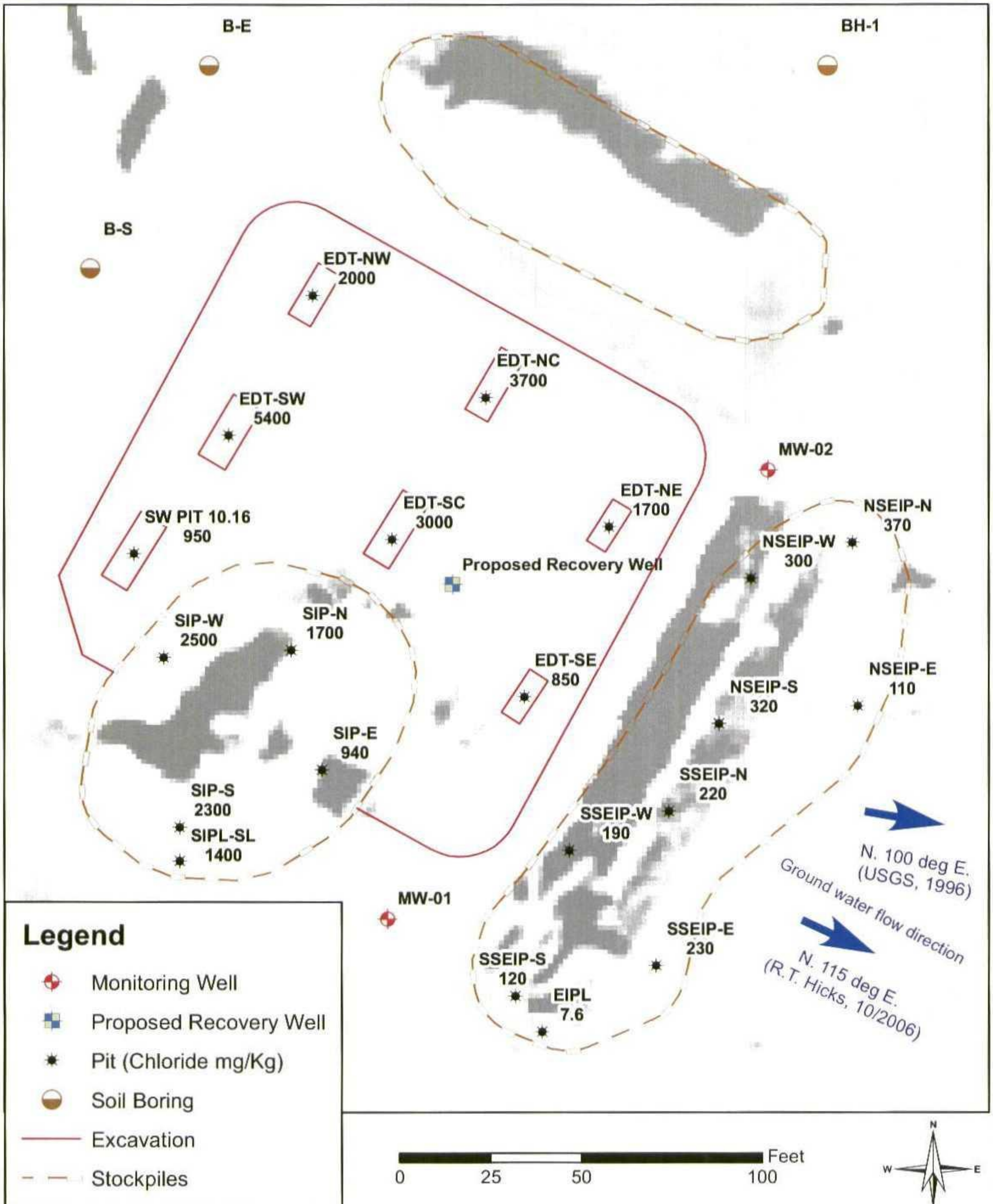
R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Site Location Map	Plate 1
	Samson Resource Company: State BD-04 CAP	November 2006



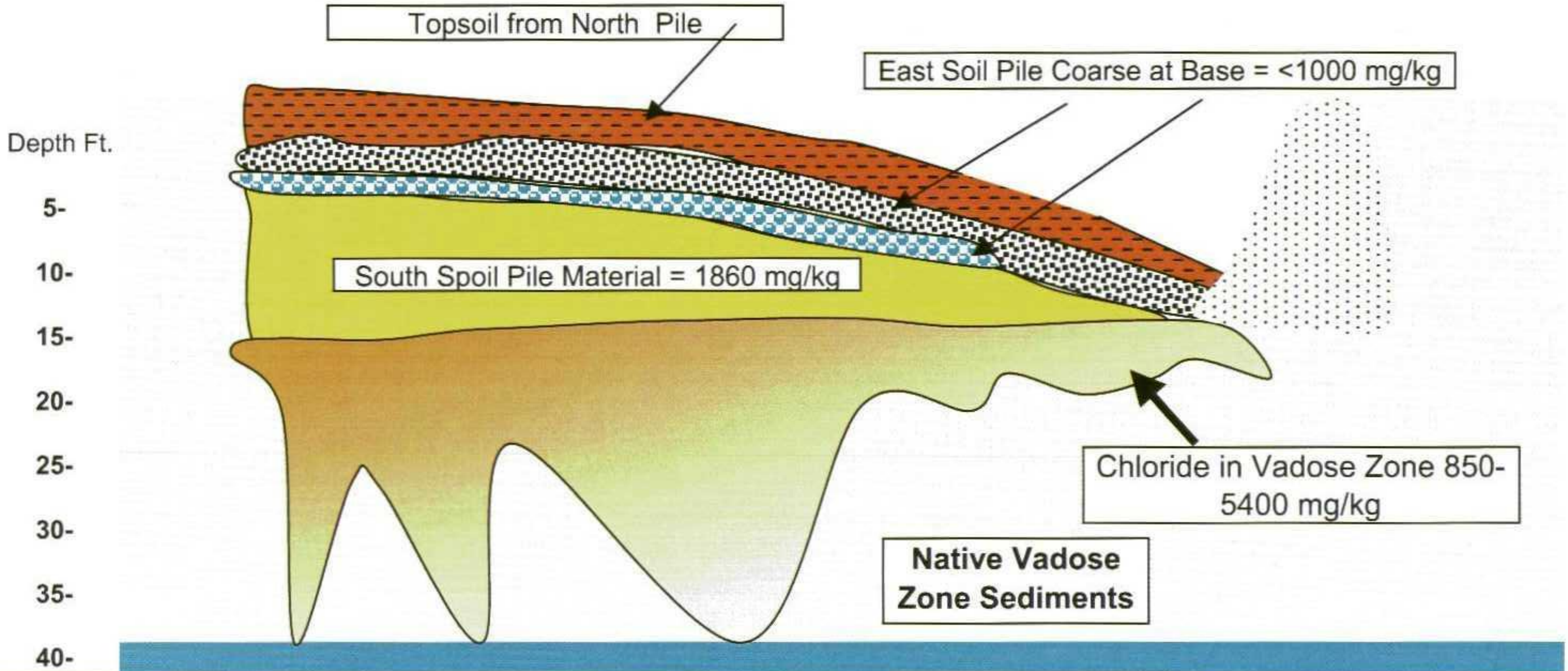
Legend

- Supply Wells listed in the OSE database
- 1-Mile Radius from State BD-04

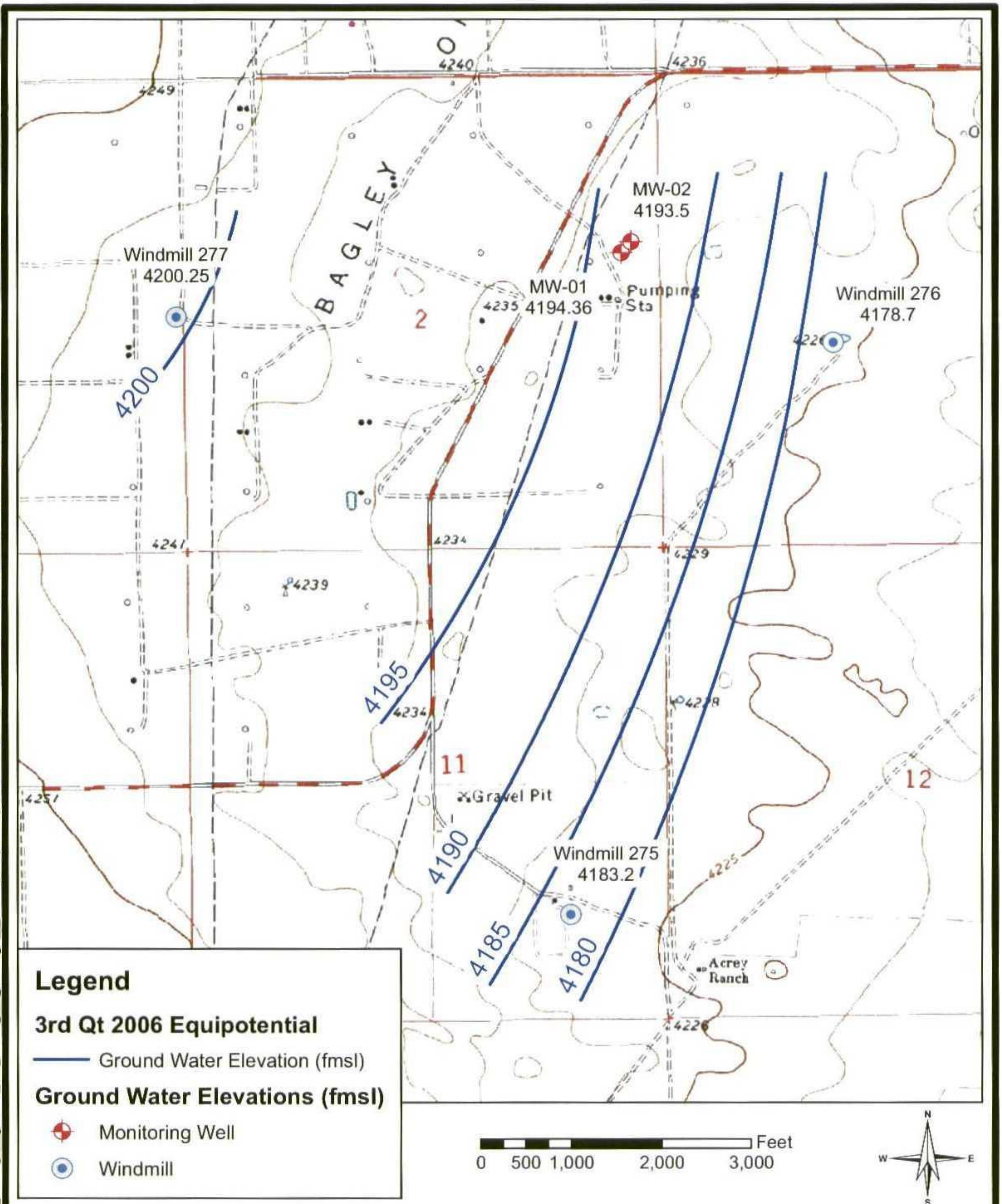
R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	USGS Topographic Map with nearby supply wells.	Plate 2
	Samson Resources Company State BD-04 CAP	November 2006



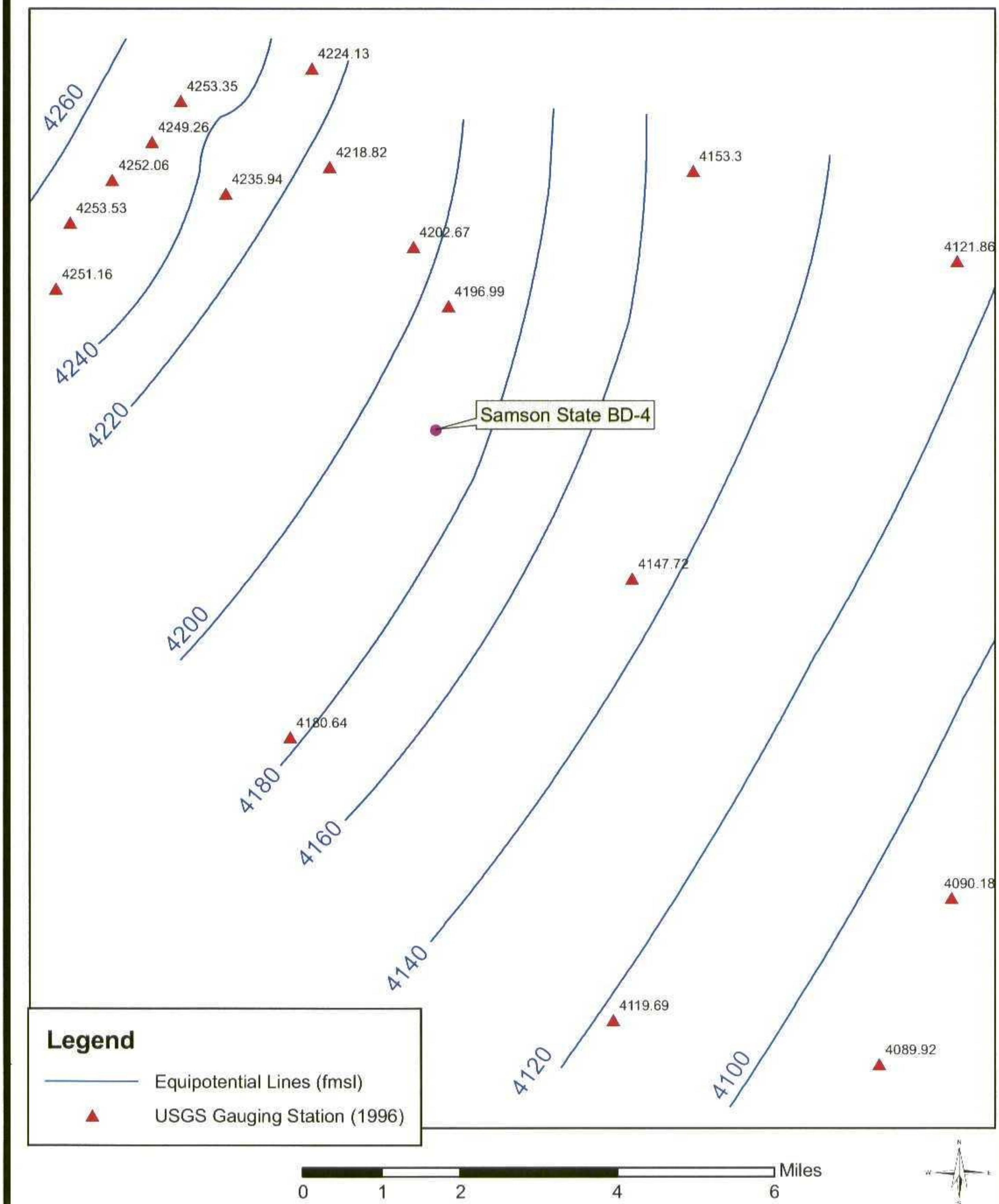
R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Chloride Sampling Results (7/12/06 and 10/16/06)	Plate 3
	Samson Resources Company State BD-04 CAP	November 2006



R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104	**BD-04 Schematic Cross Section**	**Plate 4**
	Samson Resources	**November, 2006**



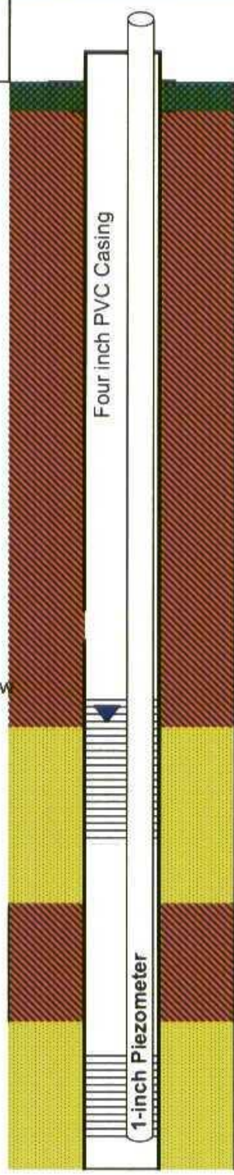
R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	3rd Quarter 2006 (10/17/06) Potentiometric Surface	Plate 5
	Samson Resource Company State BD-04 CAP	November 2006



R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Potentiometric Surface Map (USGS 1996)	Plate 6
	Samson Resources Company State BD-04 CAP	November 2006

Client:	Samson Resources
Project Name:	BD-04
Location:	

Depth (feet)	**Comments:**	**Material Descriptions:**	
0.0		Cement, 0-2 feet	4-inch PVC well casing and screen. Removable 1-inch blank casing to permit discrete sampling of lower screened interval
2.0		Hydrated bentonite, 2-40 feet	
4.0			
6.0			
8.0			
10.0			
12.0			
14.0			
16.0			
18.0			
20.0			
22.0			
24.0			
26.0			
28.0			
30.0			
32.0			
34.0			
36.0			
38.0			
40.0	Ground Water is assumed to be 42 feet below ground surface. Well Depths are to be adjusted to actual depth to water.		
42.0			
44.0		Sand, 35-52 feet Screen 40-50 feet	
46.0			
48.0			
50.0			
52.0			
54.0			
56.0		3-feet of Hydrated bentonite between 52 62- feet	
58.0			
60.0			
62.0			
64.0		Sand, 62-72 feet Screen 65-70 feet	
66.0			
68.0			
70.0			
72.0			



R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104	**Samson BD-04**	**Plate 7**
	Monitoring/Recovery Well Boring	**November 2006**

APPENDIX A

August 2006

Closure Plan Investigation Report

Samson BD-04 Reserve Pit
Samson Investment Company

R.T. Hicks Consultants, Ltd.

901 Rio Grande Blvd. NW, Suite F-142, Albuquerque, NM 87104

August 2006

Closure Plan Investigation Report

SAMSON BD-04 RESERVE PIT

Prepared for:

Samson Investment Company
Two West Second Street
Tulsa, OK 74103

R.T. HICKS CONSULTANTS, LTD.

901 RIO GRANDE, SUITE F-142, ALBUQUERQUE, NM, 87104

1.0 INTRODUCTION

Plate 1 shows the location of the site relative to the junction of US highway 380 and State Highway 457, about 15.5 miles west-northwest of Tatum, New Mexico. The State "BD" No. 4 Reserve Pit is in T12S-R33E-Section 2, Unit Letter H (latitude 33° 18′ 35″ N, longitude 103° 34′ 39″ W). The photographs in Figures 1 and 2 (below) depict the site and nearby environs.

Figures 1 & 2 - Site and surrounding area.

The drilling reserve pit was constructed in 2004 by removing the top 1-2 feet of soil and placing it along the northeastern edge. Caliche below the topsoil excavated as part of the original pit construction was stockpiled on the eastern edge of the pit. The pit was used for approximately 60 days in 2004 and contained an average of 2 to 3 feet of brine water during that time. During the closure of the pit, sampling suggested that a release of brine drilling mud had occurred, impacting the underlying earth material. The reserve pit was over-excavated to a depth of 13 to 20 feet and all of the excavated material is stockpiled in two piles – the existing pile east of the pit and one on the southern edge of the pit.

Figure 1 is looking east from the tank battery with the excavated reserve pit in the background. In Figure 1, the eastern (red/pink) spoil pile, which contains material excavated prior to use of the pit, lies behind the pit. The southern spoil pile (white) to the right of the pit is material excavated from the pit as part of the release delineation program conducted after the residual pit material had dried. The clean top soil from the original reserve pit excavation is visible behind the equipment in Figure 1. Figure 2 is a view to the south of the eastern edge of the excavation, showing both monitoring wells and the general grain size of the material excavated from the pit. Figure 3 shows the wall of the excavation and the nature of the uppermost 10-13 feet of the vadose zone – the barbed wire fence on the top of the photo provides a reference scale.

Figure 3 - Wall of the excavation shows upper 10-13 feet of the vadose zone.

Plate 2 is a topographic map of the site and the environs, showing the locations of nearby water supply wells. Plate 3 is 2005 image from Google Earth of the same radius, and indicates that the surrounding area is used primarily for oil and gas production and grazing.

The reserve pit was active during the drilling of the new well, a period of about 60 days in 2004. After sufficient time had passed to dry the residual material, closure of the pit commenced in 2005. Samson then directed the excavation of the residual material and the over excavation of the pit in late Fall 2005 as part of a delineation program. Plate 4 presents three aerial photographs of the area:

a) an aerial photograph prior to drilling BD-04 (1996-98)
b) an aerial photograph during the drilling (2004), and
c) a 2005 image showing the excavator during delineation operations

2.0 INVESTIGATION RESULTS

2.1 HYDROGEOLOGY

The State "BD" No. 4 site is located on the Llano Estacado or southern High Plains which is a plateau standing from 100 to 300 feet above the surrounding region. Near the site, in northern Lea County, the plains are nearly flat, broken only by low swales and small depressions. The southeast trending surface drainage system is poorly formed along the regional slope of approximately 10-15 feet/mile. Run-off from the average 14 inches of annual precipitation is largely captured by the shallow depressions where it infiltrates or is lost to evapotranspiration.

The rocks exposed at the surface are Tertiary age alluvial deposits and petrocalcic soils of the Tertiary Ogallala formation (see Plate 5). Descriptions of the samples from a site soil boring (background) and two monitoring wells (see Appendix A) indicate that a thin (less than 1-foot) layer of topsoil is present from which sparse vegetation, including mesquite trees and various native grasses exist. Underlying the top soil to a depth of approximately 28 feet is a broken caliche layer, which includes interbedded silt and find-grain sand with some hard, massive caliche boulders (see Figure 3).

Below the broken caliche layer, the Ogallala consists of fine-grain sand that varies in color, cementation, and grain size. Generally the grain size increases with depth and may include discontinuous beds of coarse-grain sand and gravel. The maximum thickness of the Ogallala formation is found approximately 15 miles west of the site, at the Mescalero Ridge (escarpment). According to state records from the area water wells the Ogallala formation is approximately 160 feet thick at the site, although very few of the wells actually penetrate the underlying Triassic red clays. Appendix B provides the well logs for these nearby wells from the Office of the State Engineer.

All ground water production in the area surrounding the site, based on data from the state well records, is from the Ogallala aquifer from approximately 50 to 160 feet bgs. Ground water was encountered in both of the site monitoring wells at approximately 40 feet bgs. Plate 6 shows the regional potentiometric surface of the aquifer based upon available data. It indicates that the regional ground water gradient is to the southeast at 0.0029 ft/ft. There are no prominent surface features that would suggest that the local ground water gradient should be different from what is observed on a regional scale.

Many reports discuss the hydrogeologic characteristics of the Ogallala Aquifer. The report from Masharrafieh and Chudnoff (Numerical Simulation of Groundwater Flow for Water Rights in the Lea County Underground Water Basin New Mexico, New Mexico Office of the State Engineer Technical Report 99-1, 1999, Figure 10) provides an estimate of the hydraulic conductivity and other parameters near the site (Figure 4). The State "BD" No. 4 site area is about 15 miles west of Tatum, which is within the model boundary. In this area, the 1999 report indicates a hydraulic conductivity for the underlying aquifer of approximately 41-60 feet/day. Based upon our drilling at the site and experience in the area, this value at the site appears reasonable.

An assessment of the background chemical quality of the Ogallala ground water in the surrounding area is based on information from New Mexico Infrastructure Data System. Water well L-1331 is located approximately 1.3 miles west-northwest of the site and has been sampled for chloride concentrations on May 9, 1984 (133 mg/l), June 20, 1990 (167 mg/L), and September 20, 1995 (116 mg/L). Water well L-6241 is located approximately 0.8 miles east-northeast of the site and has been sampled for chloride concentrations on November 8, 1979 (48 mg/L), June 13, 1984 (52 mg/L), June 20, 1990 (83 mg/L), and September 20, 1995 (38 mg/L). Total dissolved solids (TDS) concentrations were not available for these wells.

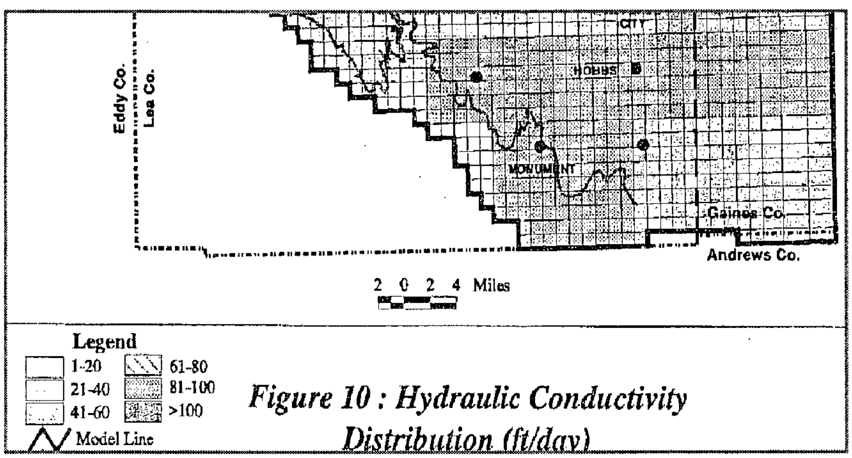


Figure 4- Map showing estimated hydraulic conductivity near the site.

2.2 CHARACTERIZATION ACTIVITIES AND METHODS

A composite soil sample from the bottom of the excavation was collected by others on December 2, 2005. Also on that date six 8- to 12-foot deep trenches were installed at the base of the excavation so that soil samples could be recovered at approximately 28 feet bgs. Plate 7 shows the locations of the sampling trenches.

Instead of taking a composite sample similar to what was done at the 13-foot depth, the samples from the six trenches were field screened using a HACH kit tester and the individual trench sample with the highest chloride concentration was submitted to the laboratory for analysis. The results indicate that the single chloride concentration at the 28-foot depth (6,958 mg/kg) is greater than the chloride concentration from the composite sample obtained at the 13-foot depth (4,958 mg/kg).

On May 8 and 9, 2006 Hicks Consultants collected soil samples from two hollow-stem auger borings placed adjacent to the reserve pit excavation, the borings were then converted to ground water monitoring wells. Monitoring Well No. 1 (MW-1) was placed near the south corner of the excavation and Monitoring Well No. 2 (MW-2) was placed near the east corner of the excavation. The highest chloride concentration in the soil was observed in MW-1 at nine feet below the surface (49.4 mg/kg); none of the other chloride concentrations in the soil samples exceeded 12 mg/kg. The results of the soil sampling at the site are summarized in Tables 1a and 1b, attached.

In addition to the two monitoring wells, a background soil boring was installed in a vegetated area to the north of the reserve pit.

Each well was completed by advancing the augers to approximately fifteen feet below the first ground water depth and installing 20 feet of 2-inch, 0.02-inch slotted PVC screens with 2-inch PVC blanks to the surface. The screens were covered with 8/16 silica sand (filterpack) and topped with at least 17 feet of bentonite, then cuttings to 1.5 feet bgs. The casing above the surface is protected by a steel locking access box set in a 3-foot by 3-foot concrete pad.

On May 11, 2006 both monitoring wells were developed by purging at least 50 gallons (20 well volumes) of water and on May 12, 2006 ground water samples were recovered. Prior to sampling, each monitoring well was purged of at least 3 well volumes of water using a disposable bailer at an average purge rate of 0.4 to 0.5 gallons per min (gpm). Temperature, pH, and conductivity were measured using a Hydac testing instrument during the purging operations to ensure that the ground water samples were representative of the aquifer. Each monitoring well sample was recovered using a disposable bailer. The samples were placed (unfiltered and unpreserved) in 1-liter plastic bottles, chilled to 4°C and hand delivered to Environmental Labs of Texas (Odessa) for analyses of bromide and chloride using EPA method 300.0 and TDS using EPA method 160.1.

On July 12, 2006, Hicks Consultants elected to provide a better characterization of the chloride mass released at the site by collecting additional samples from the spoil piles and trenches.

Figure 5 - Example of a sample location.

We obtained:

From the south impacted pile:

- 4 representative samples from the south impacted pile (SIP-S, SIP-N, SIP-E, SIP-W)
- 1 sample of the coarse-clasts (about golf ball size) from the south impacted pile (SIPL-SL)

From the east impacted pile:

- 4 representative samples from the north side of the east impacted pile (NSEIP-S, NSEIP-N, NSEIP-E, NSEIP-W)
- 4 representative samples from the south side of the east impacted pile (SSEIP-S, SSEIP-N, SSEIP-E, SSEIP-W)
- 1 sample of coarse-clasts from the east impacted pile (EIPL)

From piles associated with each of the six trenches dug in the floor of the current excavation, one representative sample:

- 1 representative sample from the spoil pile associated with each of the six bottom excavation backhoe trenchs (EDT-NW, EDT-NC, EDT-NE, EDT-SW, EDT-SC, EDT-SE)

Plate 7 shows the locations of these samples with the identifying nomenclature as referenced above. Figure 5 shows a typical sample location. This sample site is the South Impacted Pile Southern location (SIPS). Note that the pile consists of about 20% cobble-sized clasts, 50% large clasts (smaller than cobbles and larger than 5mm), and 30% sand-sized. Note also that the photograph shows the surface crust of salt that exists due to the upward wicking of soil moisture, evaporation of the water and crystallization of the salt due to the evaporation. In all of the samples taken during this event, we dug a small trench as shown and placed a representative sample in a plastic bag for laboratory analysis. We attempted to capture a limited amount of the salty crust with each sample to collect what we believe is a sample representative of the entire pile.

Because we are interested in estimating the total mass of residual chloride and are not interested in maximum chloride concentrations, we asked Hall Analytical to modify their standard soil sample preparation procedure. Instead of extracting 10 grams of the sample for analysis, Hall used the entire sample consisting of large clasts and fine-grained material. In order to understand if chloride was concentrated in the fine-grained portion of the sample, as suspected, we also collected two samples of large (golf-ball size) clasts for separate analysis, as discussed above.

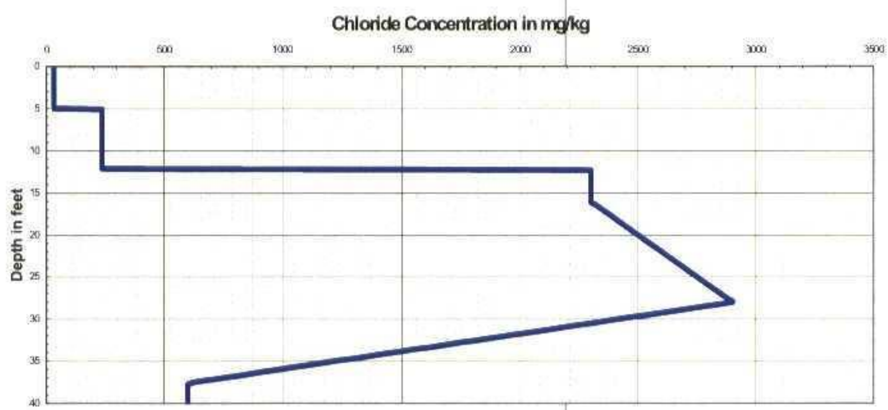
Finally, in August 2006, we collected a second set of ground water samples from the two monitoring wells which confirmed the previous results.

3.0 CONCENTRATIONS OF CONSTITUENTS IN THE UPPER VADOSE ZONE

Soil sampling results are presented in Table 1a and 1b. A summary of the ground water sample results from the monitoring wells is provided on Table 2 and the laboratory reports for both the soil and ground water samples are provided in Appendix C.

In ground water, the measured concentrations of TDS and chloride do not exceed the New Mexico Water Quality Control Commission (WQCC) standards. The result from MW-2 (44.5 mg/L) corresponds with the background measurements reported from the area water wells. At MW-1, located directly down gradient from the pit, the chloride concentration is 131 mg/L, which is above background but below WQCC Standards. A comparison of the ground water chloride-bromide (Cl/Br) ratio with that of the soil indicates that the chloride concentrations in the ground water may be slightly higher than the expected natural conditions as the Cl/Br ratio should be consistent in non-impacted media.

Figure 6: Chloride Profile of BD 4 Site

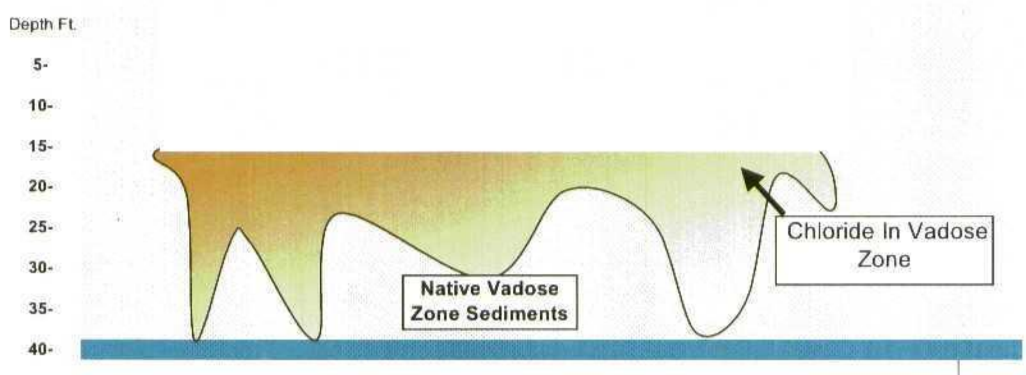


We used the data from Table 1 to create a chloride concentration profile of the site (see Figure 6). To create Figure 6, we used all of the available data. We calculated the concentration for the material from 10-13 feet bgs by averaging the concentration from the composite sample of the pit excavation bottom obtained in December 2005 with the four samples from the south spoil pile. This calculation yielded an average chloride concentration of 2300 mg/kg. We understand that the south spoil pile is the material excavated from 10-13 feet below ground surface. To arrive at a concentration for the material from 13-28 feet, we averaged the "hot spot" sample taken from these trenches in December 2005 with the six spoil pile samples obtained in July 2006, which yielded an average of about 2900 mg/kg. We assumed that the concentration increased in a linear fashion between 16 and 28 feet bgs, as shown in Figure 6.

We have no chloride data for soil below 28 feet bgs, but the monitoring wells provide data from which we can estimate the chloride concentration in the lowermost vadose zone. We know that about 18 months after the pit dried (summer 2006) the ground water chloride background concentration is about 45 mg/L and the concentration in down gradient well MW-1 is about 130 mg/L. Therefore, ongoing seepage of chloride from the vadose zone to ground water has caused chloride to increase by 85 mg/L. We employed the unsaturated zone simulation model HYDRUS-1D to estimate the natural flux from the vadose zone to ground water for an un-vegetated surface and the ground water data to estimate the ground water flux beneath the pit. We used a simple mixing equation in order to estimated the average chloride concentration in the material just above the water table. We conclude that the material between 28 feet and the ground water table is most likely about 600 mg/kg.

We believe that the chloride was distributed through the vadose zone relatively uniformly immediately below the original pit bottom (5 feet bgs) to a depth of about 13-16 feet. The relative uniformity of the chloride concentrations in the southern spoil pile and their agreement with the value from the 5-point composite sample at 13 feet provides support for this conclusion. The trench sample concentrations show a higher degree of scatter, demonstrating that some areas of the former pit were more highly impacted by seepage than others. From this data and our experience with other reserve pit sites we conclude that below 13-16 feet, preferential pathways of saturated flow caused an uneven distribution of chloride in the vadose zone. The mass of chloride within these pathways diminished with depth, creating an average chloride concentration of 600 mg/kg near the water table. Figure 7 presents the conceptual model of chloride distribution below the BD-04 reserve pit.

Figure 7. Sketch showing extent of chloride below moist areas.



Note also that Figure 6 also assumes that the chloride concentration of the material from 5-13 is about 250 mg/kg, the same concentration as the average obtained from sampling the east spoil pile. From 0-5 feet, we assumed the background concentration of about 30 mg/kg.

From the site characterization data we conclude that:

1. Elevated chloride concentrations in the upper vadose zone extend to at least 28 feet bgs.
2. In some limited areas of the former pit, preferential saturated flow have caused a small mass of chloride to penetrate the underlying aquifer.
3. The lateral extent of the subsurface impact is limited to the area below the pit.
4. Additional ground water characterization is not required.

TABLES

Table 1a
Laboratory Results of Soil Samples Obtained by Others
Results in mg/kg

Sample Location	Pit Comp.	Pit (max)*
Sample Depth (ft)	16 ft	28 ft
Sample Date	12/2/05	12/2/05
Benzene	--	--
Toluene	--	--
Ethyl Benzene	--	--
Total Xylenes	--	--
GRO (C_6-C_{10})	--	--
DRO (>C_{10}-C_{28})	--	--
Total Alkalinity	208	96
Chloride	**4,958**	**6,958**
Carbonate	0	76
Bicarbonate	254	40
Sulfate	943	298
Calcium	128	705
Magnesium	78	467
Potassium	136	70
Sodium	2,928	2,928
Bromide	--	--

* - Sample taken from area of highest Cl concentration based on HACH kit field screening

Table 1b
Laboratory Results Soil Borings and Spoil Pile Samples

Monitoring Well/Spoil Pile	Sample Date	Depth (ft)	PID (ppm)	Br (mg/kg)	Cl (mg/kg)
MW-1	5/8/2006	9	0	--	49.4
		19	0	--	7.86
		29	0	--	3.38
		34	0	<0.1	5.02
MW-2	5/9/06	9	0	--	10.0
		19	0	--	7.30
		29	0	--	8.27
		34	0	--	7.77
		39	0	0.187	12.0
Spoil Pile Samples					
SSEIP-E	7/12/2006	2.0-5.0			230
SSEIP-S	7/12/2006	2.0-5.0			120
SSEIP-W	7/12/2006	2.0-5.0			190
SSEIP-N	7/12/2006	2.0-5.0			220
NSEIP-S	7/12/2006	2.0-5.0			320
NSEIP-E	7/12/2006	2.0-5.0			110
NSEIP-W	7/12/2006	2.0-5.0			300
NSEIP-N	7/12/2006	2.0-5.0			370
EIPL	7/12/2006	2.0-5.0			7.6
SIPL-SL	7/12/2006	5.0-13.0			1400
SIP-S	7/12/2006	5.0-13.0			2300
SIP-E	7/12/2006	5.0-13.0			940
SIP-N	7/12/2006	5.0-13.0			1700
SIP-W	7/12/2006	5.0-13.0			2500
EDT-SW	7/12/2006	13-28		<3	5400
EDT-NW	7/12/2006	13-28		<3	2000
EDT-SC	7/12/2006	13-28		<3	3000
EDT-NC	7/12/2006	13-28		<3	3700
EDT-SE	7/12/2006	13-28		<3	850
EDT-NE	7/12/2006	13-28		<3	1700

Table 2

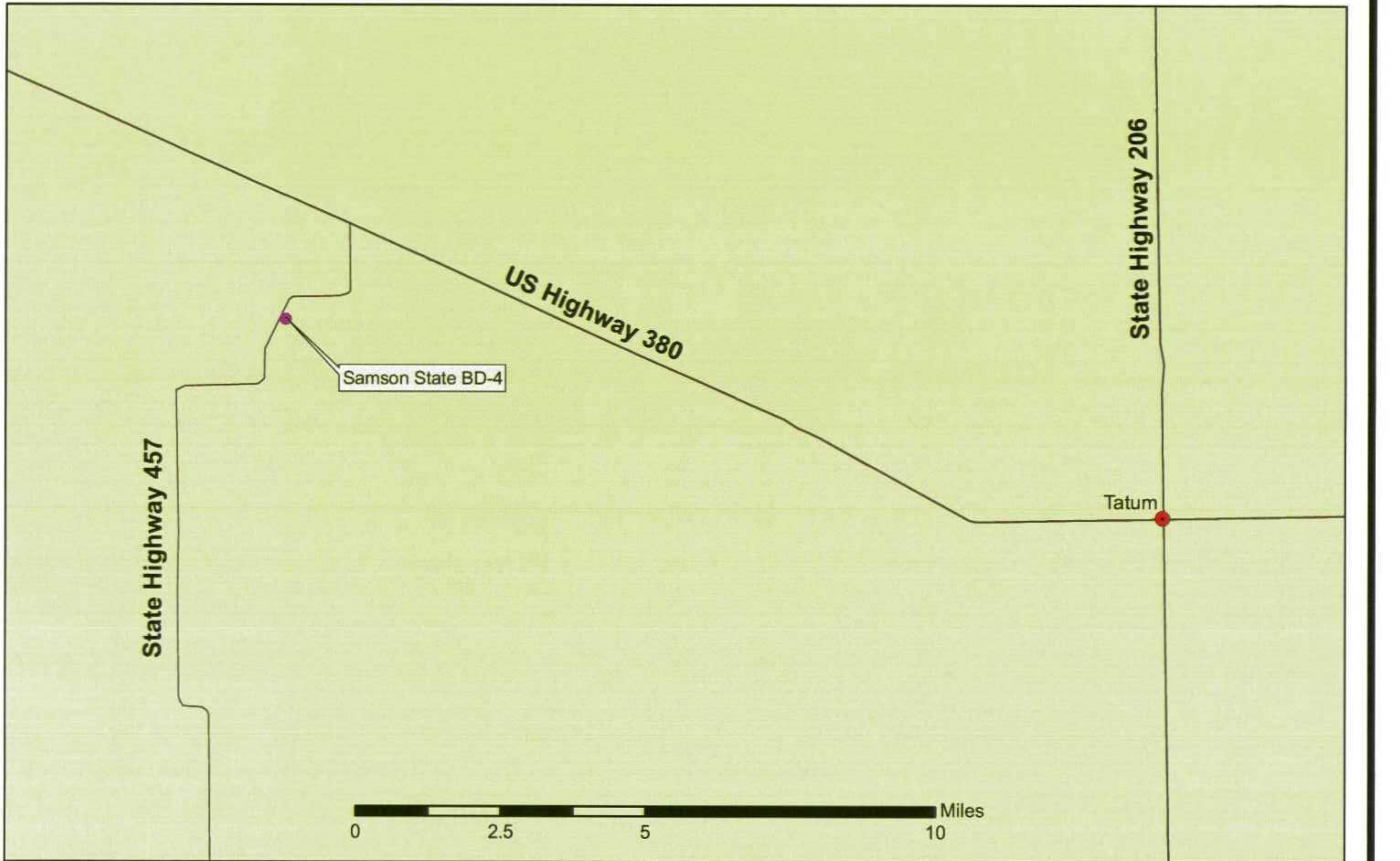
Laboratory Results Summary - Groundwater Samples

Results in mg/L

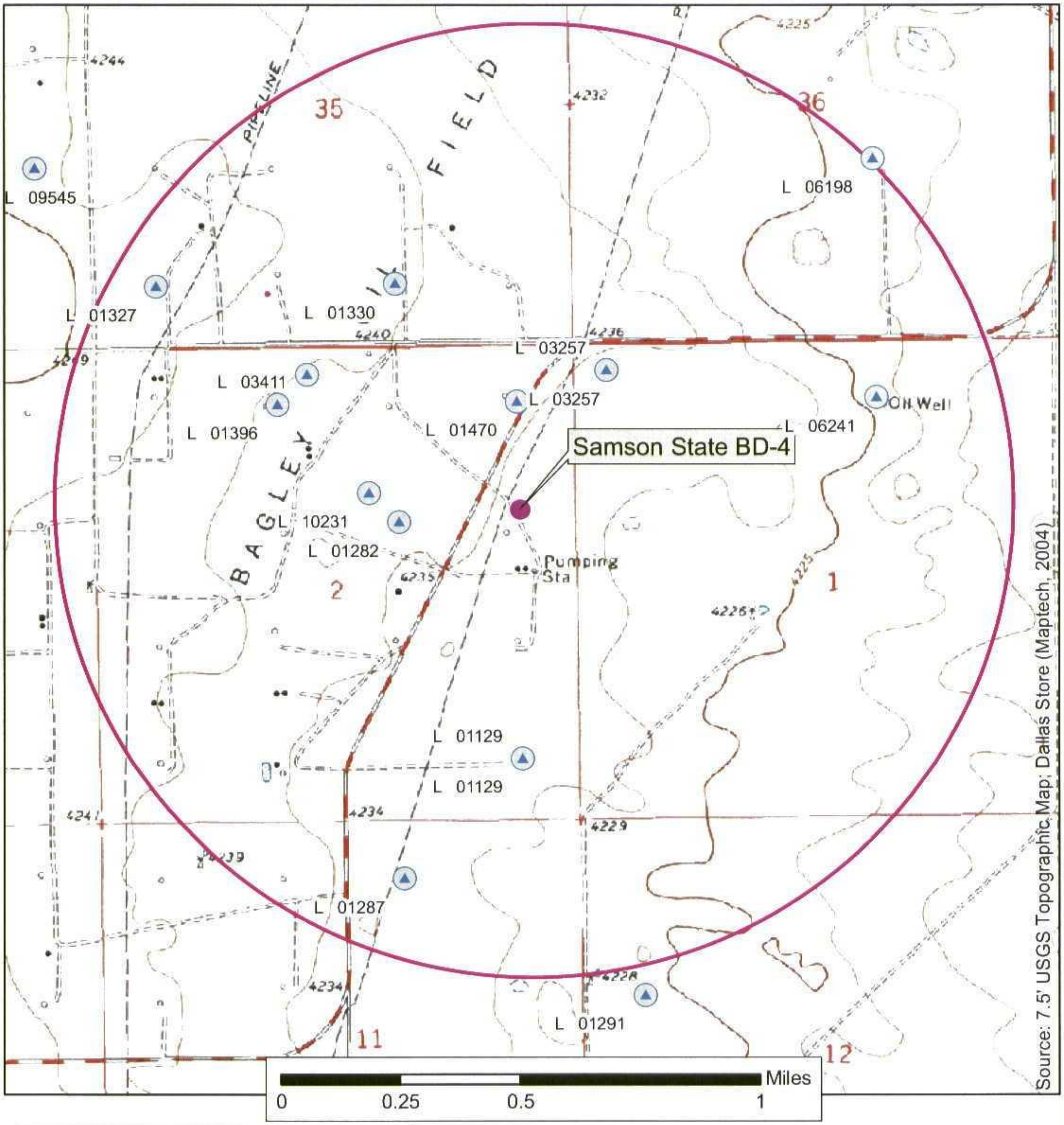
Monitor Well Sample Date	MW-1 5/12/06	MW-2 5/12/06	MW-1 8/2/06	MW-2 8/2/06	WQCC Standard
Bromide	0.482	0.446			--
Chloride	131	44.5	115	42.2	**250**
Total Dissolved Solids	838	530	648	444	**1,000**
Cl/Br Ratio (unitless)	272	100			--

PLATES

To access the site, proceed west from Tatum, NM approximately 15 miles on US Highway 380. Head south on State Highway 457 for approximately 2.5 miles. The site is on the east side of the highway.



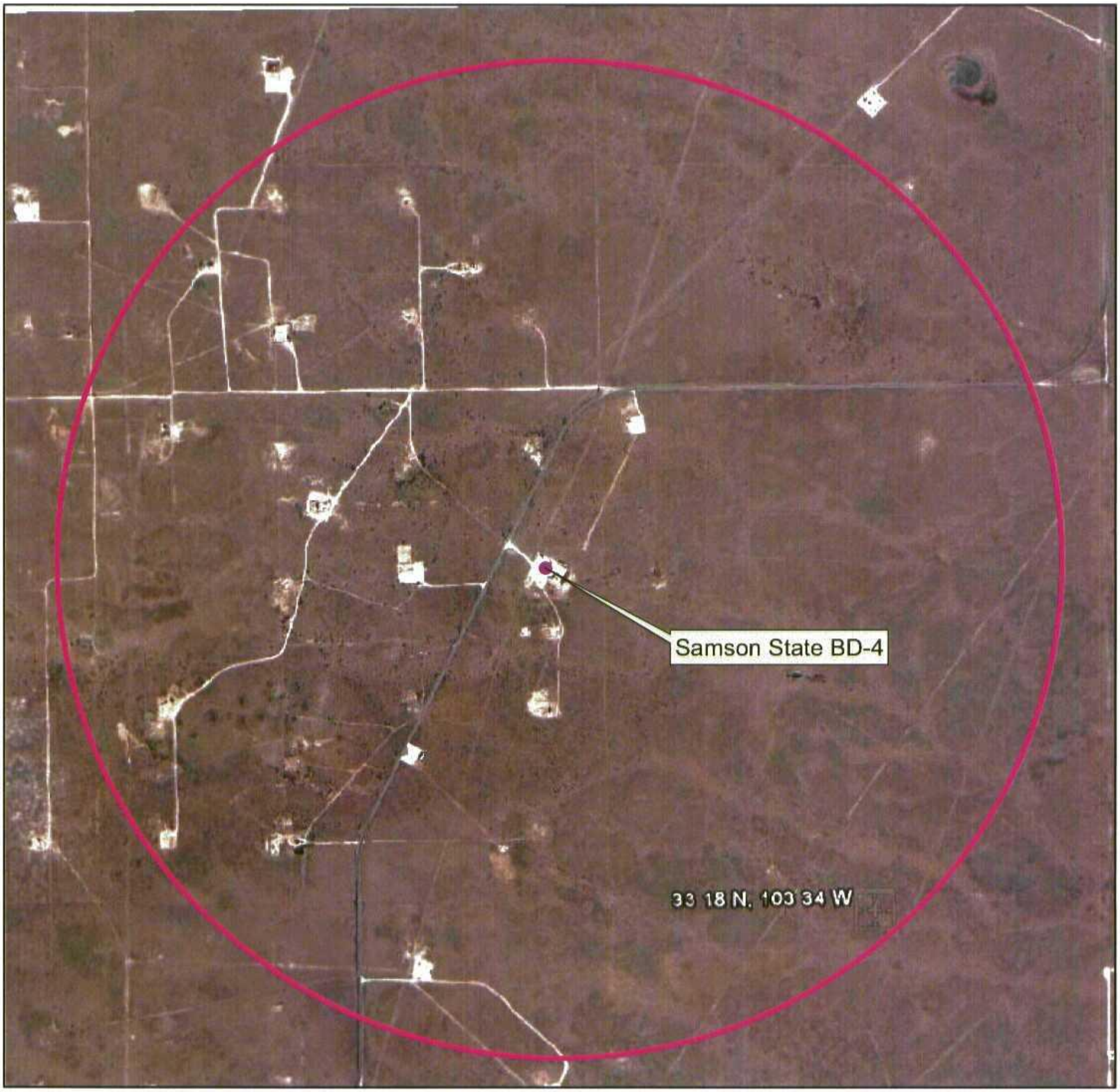
R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Site Location Map	Plate 1
	Samson Investment Company: State BD-04 Site Investigation Report	August 2006



Legend

- Supply Wells listed in the OSE database
- 1-Mile Radius from State BD-04

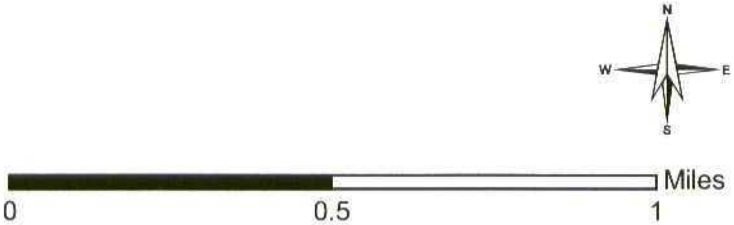
R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	USGS Topographic Map with nearby supply wells.	Plate 2
	Samson Investment Company State BD-04 Site Investigation Report	August 2006



Source: Google Earth (2005 Aerial)

Legend

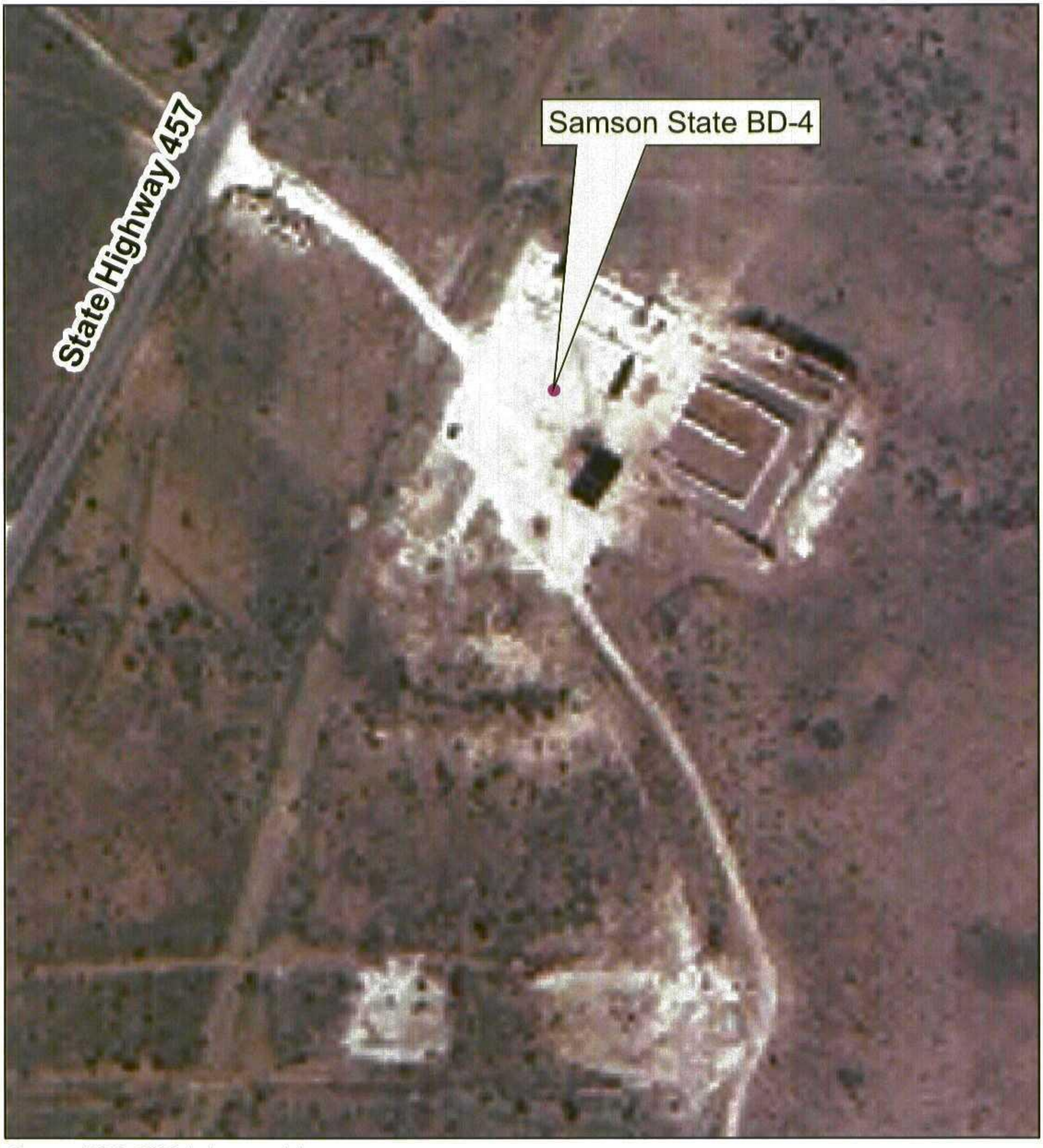
One-Mile Radius from State BD-04



R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	2005 Aerial Photograph of Site and Environs	Plate 3
	Samson Investment Company State BD-04 Site Investigation Report	August 2006

Source: RGIS, 2006 (rgis.unm.edu)

R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	1996-98 Aerial Photograph of Site prior to drilling	Plate 4a
	Samson Investment Company State BD-04 Site Investigation Report	August 2006

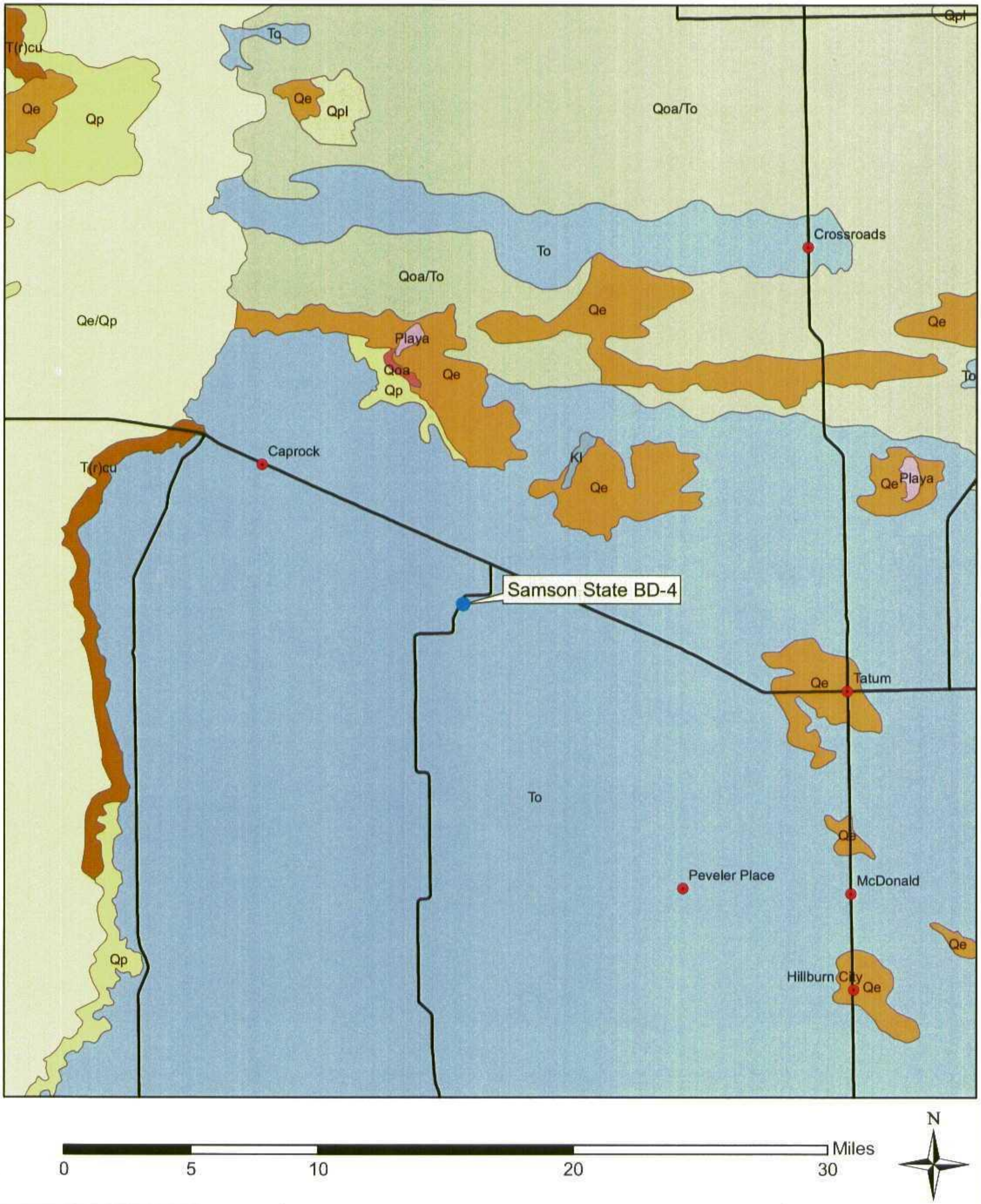


Source: RGIS, 2006 (rgis.unm.edu)

R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	2004 Aerial Photograph of Site during drilling	Plate 4b
	Samson Investment Company State BD-04 Site Investigation Report	August 2006

Source: Google Earth (2005 Aerial)

R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	2005 Aerial Photograph of Site during pit closure	Plate 4c
	Samson Investment Company State BD-04 Site Investigation Report	August 2006



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Albuquerque, NM 87104
Ph: 505.266.5004

Geologic Map relative to
Samson State BD#4

Plate 5

Samson Investment Company
State BD-04 Site Closure Report

August 2006

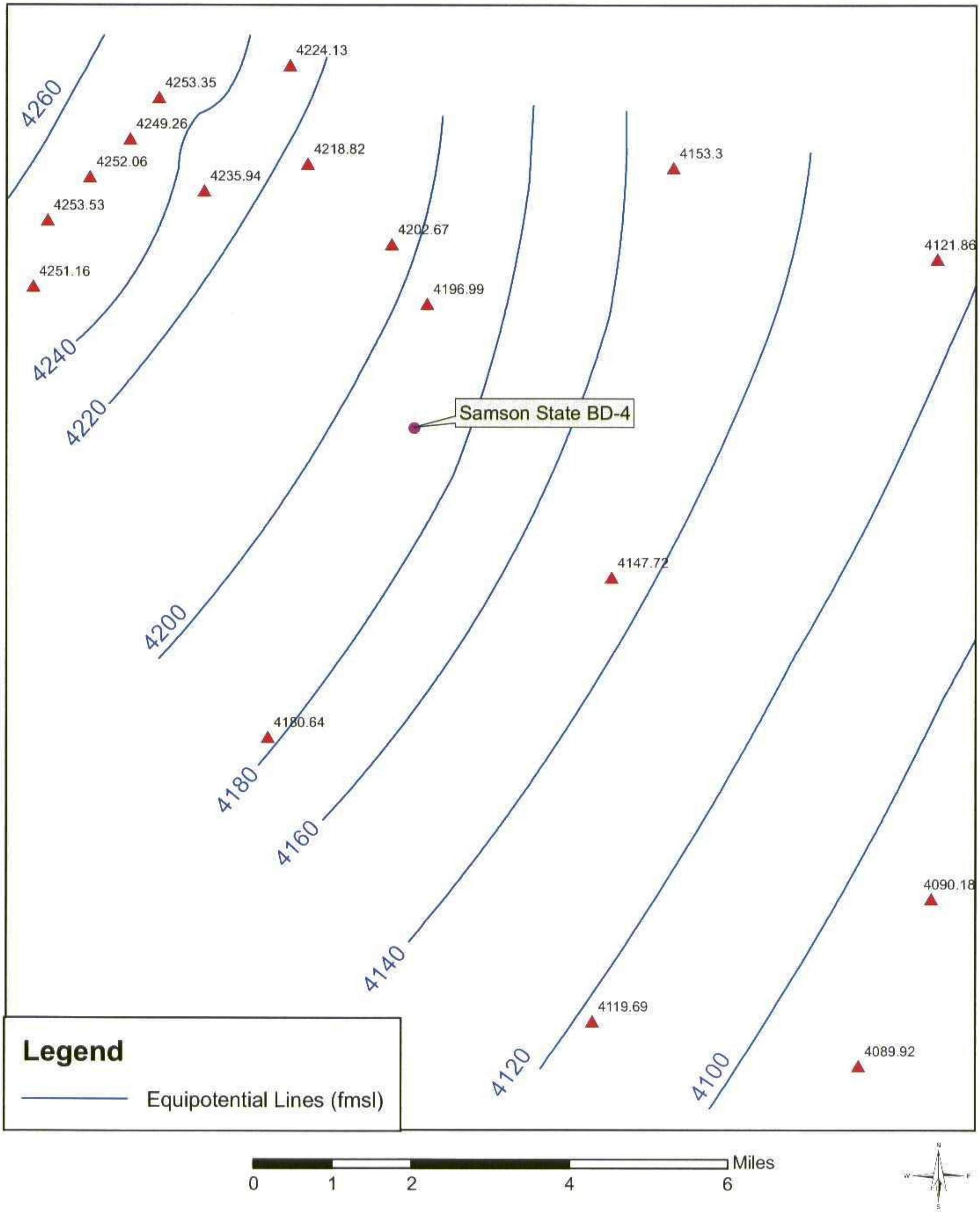
Legend

Geologic Map

Map Unit, Description

- Kl, Lower Cretaceous, undivided
- Playa, Playa Deposits
- Qe, Quaternary-Eolian Deposits
- Qe/Qp, Quaternary-Eolian Piedmont Deposits
- Qoa, Quaternary-Older Alluvial Deposits
- Qoa/To, Quaternary-Older Alluvial Deposits/Ogalalla
- Qp, Quaternary-Piedomon Alluvial Deposits
- Qpl, Quaternary-Lacustrine and Playa Deposits
- T(r)cu, Triassic-Upper Chinle Group
- To, Tertiary-Ogallala Formation

R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Geologic Map Legend	Plate 5-Legend
	Samson Investment Company State BD-04 Site Closure Report	August 2006



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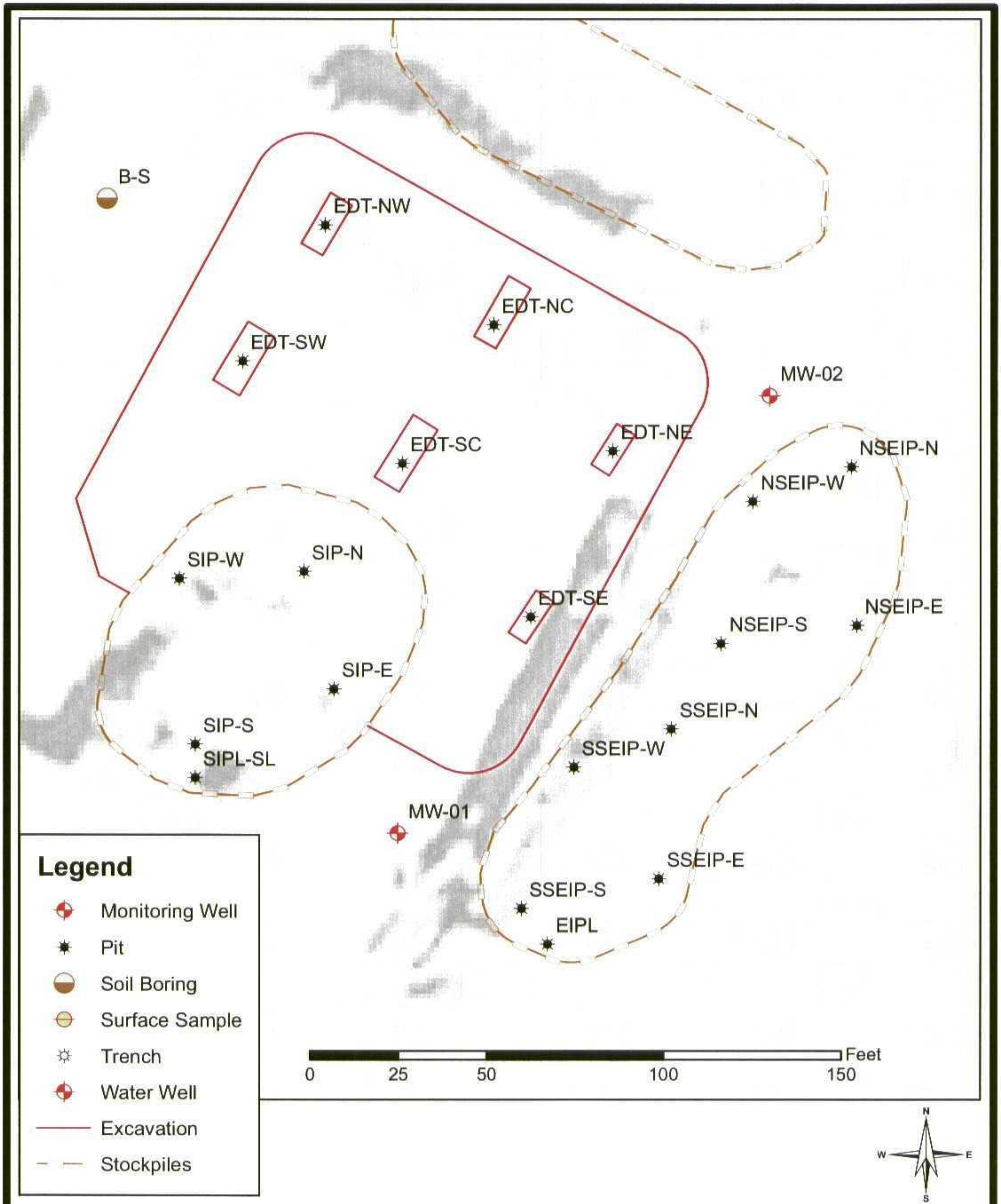
Potentiometric Surface Map (USGS 1996)

Samson Investment Company
State BD-04 Site Investigation Report

Plate 6

August 2006



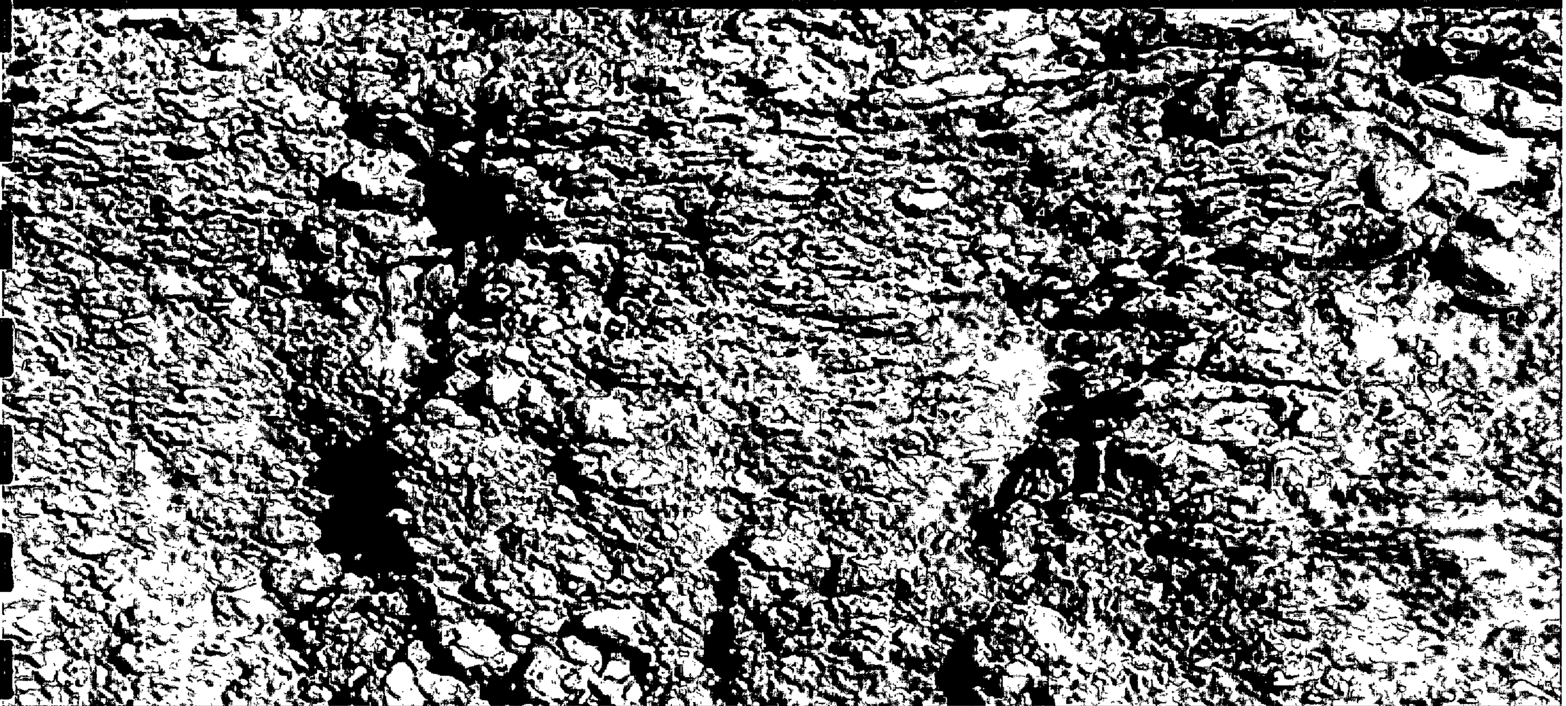
R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Pit closure site map showing spoil piles and trench sample locations	Plate 7
	Samson Investment Company State BD-04 Site Investigation Report	August 2006

CLOSURE PLAN INVESTIGATION REPORT APPENDICES ARE INCLUDED IN THE ATTACHED CD

APPENDIX B

August 2006

Closure Plan Design Report



Samson BD-04 Reserve Pit
Samson Investment Company

R.T. HICKS CONSULTANTS, LTD.

901 RIO GRANDE BLVD. NW, SUITE F-142, ALBUQUERQUE, NM 87104

August 2006

Closure Plan Design Document

SAMSON BD-04 RESERVE PIT

Prepared for:

Samson Investment Company
Two West Second Street
Tulsa, OK 74103

R.T. HICKS CONSULTANTS, LTD.

901 RIO GRANDE, SUITE F-142, ALBUQUERQUE, NM, 87104

1.0 CLOSURE PLAN DESIGN DOCUMENT FOR PITS, BELOW GRADE TANKS & ACCIDENTAL RELEASES

Data and modeling demonstrate that, in the absence of a vadose zone remedy at the BD-04 site, the residual chloride beneath the former pit represents a threat to ground water quality. The data and analysis generated by our characterization activities coupled with long-term testing data available through Sandia National Laboratories allow us to conclude that placement of a monolithic evapotranspiration (ET) infiltration barrier will effectively protect fresh water, public health, and the environment. Because the materials on site allow the creation of a capillary break between the residual chloride and the proposed monolithic ET barrier, we have elected to incorporate this design modification.

The ET barrier will minimize the downward and upward migration of soluble salts such that the rate of vertical migration, down or up, has no material impact on ground water quality or soil productivity. Patch seeding for the vegetative cover will be placed at a time of year recommended by a range specialist.

As described below, monolithic evapotranspiration barriers are routinely employed as the final covers for hazardous and radioactive waste landfills. Sandia National Laboratories (SNL) compared the efficacy of the monolithic barrier to other landfill cover designs and concluded that this system can work very well in arid and semi-arid environments, such as the Permian Basin of southeast New Mexico. The design modification of a capillary break, while not absolutely necessary, can improve the efficacy of the cover. Our unsaturated zone modeling of this proposed remedy is consistent with the findings of SNL.

1.0 PROPOSED INFILTRATION BARRIER DESIGN & CONSTRUCTION PROTOCOLS

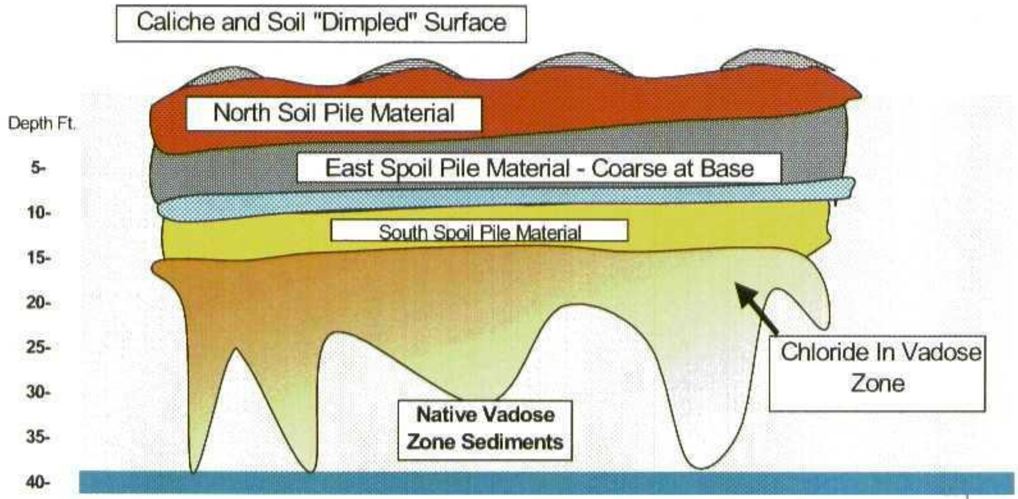


Figure 1: Final Closure Design

Figure 1 shows the design of the Monolithic ET cover for the BD-04 site. As shown, Samson will first place the material from the south spoil pile into the former pit and create a 5% surface slope to the east. The overlying infiltration barrier design calls for the following elements:

1 Screen or segregate about ½ of the material in the eastern spoil pile into coarse and fine-grained fractions.

2. Over the replaced material from the southern spoil pile, place 2-to 4-feet of coarse-grained material. This layer should also slope about 5% to the east.

3. Over the coarse-grained layer, place the un-screened remainder of the eastern spoil pile, again retaining a 5% surface slope to the east.

4. Over the well-graded material from the eastern spoil pile, place the fine-grained fraction from the screening/segregation process described above.

5. A 5% grade at the surface will prevent excess accumulation of precipitation over the ET barrier and shed excess water away from the former pit area. The slope requirement will result in a small mound over the former pit area.

6. The material from the northern soil pile is placed to create a topsoil dressing with variable thickness and "dimples" that will allow for concentration of small volumes of precipitation in areas of soil about 1-foot thick. As represented in Figure 2, these dimpled areas, may be about 20 feet square and spaced 20 feet apart. In the center of each dimpled depression is a 5-10 foot square area of 1-foot thick exposed soil planted with warm- and cold-weather grasses and forbs.

7. A very thin (about 1-inch) layer of coarse-caliche remaining from the screening/segregation process is placed between the dimpled/seeded areas where the topsoil dressing may be only 4- to 6-inches thick and within the dimpled areas where the thicker, seeded soil is not exposed. The gravel will create a cover/mulch that is more resistant to wind or water erosion and will reduce evaporation of infiltrated precipitation. These soil areas that are overlain by the thin caliche layer will not be seeded except as occurs naturally due to surrounding vegetation. Over time, vegetation from the established colonies within the dimples will spread over the site and wind-blown sand and dirt will fill the voids of the caliche cover.

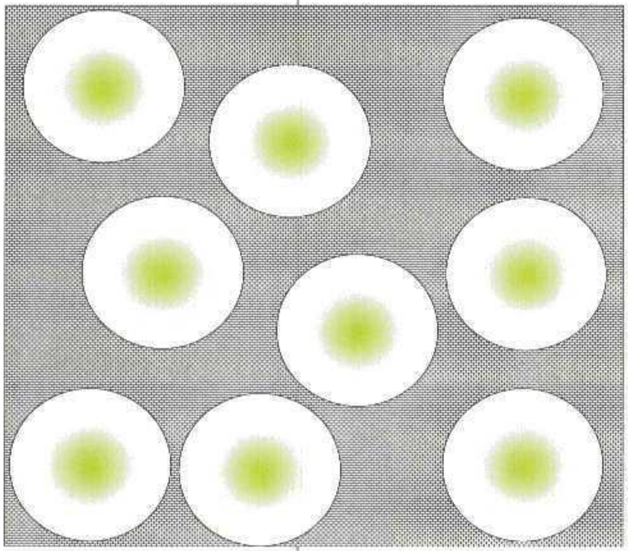


Figure 2: Plan View of Dimpled, Patch-Seeding Restoration

8. A qualified person who is versed in construction earthwork, oilfield activities and environmental protection will supervise all aspects of the implementation of the proposed vadose zone remedy and act as a supervisor of completed work. This individual will:

   - Oversee topsoil surface placement, then survey the site to meet the design criteria of the 5% grade and the supervisor will retain the records of this survey.

   - Select areas for seeded "dimples" and direct the placement of topsoil and gravel mulch.

   - Direct the patch seeding seeding effort.

   - Prepare a report that provides the documentation of appropriate construction of the remedy and submit the report to NMOCD as part of the surface final restoration of the disposal facility.

We recommend that Samson request final closure for this injection well site after the former pit area and the entire well pad is re-vegetated to 70% of the ground cover observed in adjacent areas unaffected by oilfield activities. We also recommend eight quarters of ground water monitoring to verify that the ET Barrier was correctly constructed.

2.0 BACKGROUND DATA AND PROOF OF CONCEPT

The researched performance criteria of numerous landfill closure designs included examination of the following documents, all of which are available through the Internet:

- www.sandia.gov/caps provides a synopsis of landfill liner cover performance for the proposed designs
- www.sandia.gov/caps/designs.htm#landfill1 describes the various landfill cover designs tested by SNL
- cluin.org/products/altcovers/usersearch/lf_list.cfm provides links to performance monitoring of similar sites
- www.sandia.gov/caps/alternative_covers.pdf is the Sandia National Laboratory Report that fully describes the landfill cover evaluation project
- www.epa.gove/superfun/new/evapo.pdf provides useful links and data
- www.beg.utexas.edu/staffinfo/pdf/scanlon_vadosezj.pdf provides more case studies of ET cover performance

From this literature, we identified several alternatives that we believed could be feasible for the closure of pits, below grade tanks, and sites where accidental releases created a subsurface mass of constituents of concern. These alternatives are:

1. RCRA Subtitle C Barrier - with minor modification
2. Capillary ET (Evapotraspiration) Barrier
3. Monolithic ET Barrier

The SNL website references provide a brief description of each barrier design (see Appendix A).

3.0 PROOF OF DESIGN

The references listed above represent years (and sometimes decades) of field monitoring and simulation modeling, and clearly demonstrate the efficacy of these designs. The EPA Fact Sheet provides a recent summary of the monitoring data including the three barrier systems that we considered for the vadose zone remedy. Below is a data table from the Fact Sheet that presents the measured infiltration rates below these cover systems (Table 1).

Table 1: Comparison of Percolation Rates of Several Landfill Cover Designs (EPA Fact Sheet)

	1997 (May 1 - Dec 31)		1998		1999		2000		2001		2002 (Jan 1 - Jun 25)	
	Precip. (mm)	Perc. (mm)	Precip. (mm)	Perc. (mm)	Precip. (mm)	Perc. (mm)	Precip. (mm)	Perc. (mm)	Precip. (mm)	Perc. (mm)	Precip. (mm)	Perc. (mm)
Monolithic ET	267.00	0.08	291.98	0.22	225.23	0.01	299.92	0.00	254.01	0.00	144.32	0.00
Capillary barrier ET	267.00	0.54	291.98	0.41	225.23	0.00	299.92	0.00	254.01	0.00	144.32	0.00
Anisotropic (layered capillary barrier) ET	267.00	0.05	291.98	0.07	225.23	0.14	299.92	0.00	254.01	0.00	144.32	0.00
Geosynthetic clay liner	267.00	0.51	291.98	0.19	225.23	2.15	299.92	0.00	254.01	0.02	144.32	0.00
Subtitle C	267.00	0.04	291.98	0.15	225.23	0.02	299.92	0.00	254.01	0.00	144.32	0.00
Subtitle D	267.00	3.56	291.98	2.48	225.23	1.56	299.92	0.00	254.01	0.00	144.32	0.74

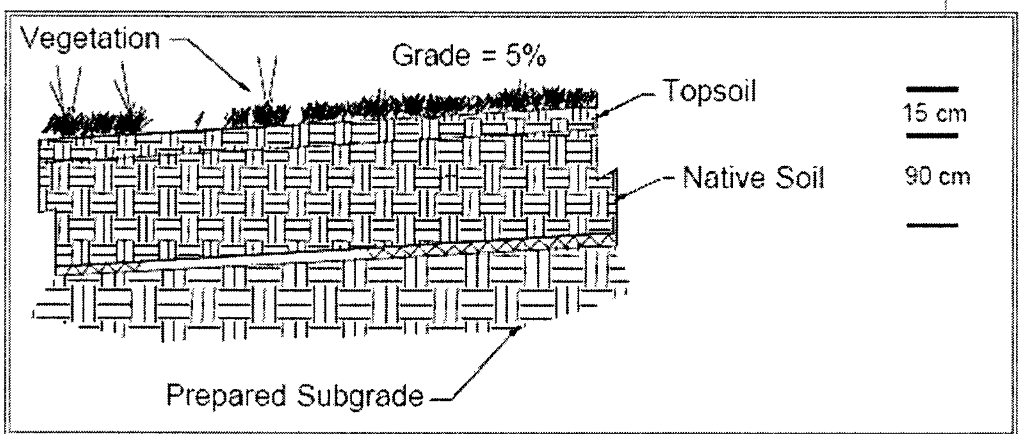
The systems that performed best during the first year after installation were the Subtitle C Cover (0.04 mm/year), the Monolithic ET barrier (0.08 mm/year) and the Capillary Barrier (0.54 mm/year). All three of the infiltration barrier systems under consideration performed equally well four years after installation and did not measure any infiltration. The efficacy of these three systems being equal, we considered other factors such as ease of installation and potential traffic to the site in making our recommendation:

The Capillary Barrier can be more difficult to install than other considered systems under oilfield conditions. Although this design performs no better than the Subtitle C or Monolithic design, we considered this option because the coarse-grained material required to install this design is on-site. A capillary break is a proven technology to prevent salts from upward migration from the waste to the root zone – a factor that was not important in the SNL study and was not fully considered.

The Subtitle C Barrier performs best during the first year of operation and we strongly considered this design. Because the clay-rich drilling fluids were removed from the site, no nearby clay is available to meet the design criteria of a 60 cm compacted clay layer. Importation of clay to the site would create significant truck traffic, dust and diesel exhaust. The environmental gain relative to other designs is only a short-term and may be offset by the environmental impact of the traffic.

The Monolithic ET Barrier is easy to install and performs well as a landfill cover. This design became our preferred alternative. The design of the Monolithic ET Barrier from the SNL website (see also Appendix A) is presented in Figure 3.

Figure 3 - Design of Monolithic ET Barrier from Sandia National Laboratory Report SAND2000-2427



4.0 SIMULATION MODELING OF A MONOLITHIC ET BARRIER

To predict the effect of the proposed monolithic ET Barrier, we used HYDRUS-1D and a ground water mixing model with site-specific data. Appendix B describes the input data and assumptions employed in this site-specific modeling.

Figures 4a and 4b show a HYDRUS-1D simulation of the impact to ground water quality assuming installation of the proposed monolithic/capillary barrier remedy at time = 0. Both figures employ the same input data as that described in the companion Investigation Report. Figure 4b expands the scale to show predicted ground water concentrations, with the barrier in place, relative to actual ground water data. Figure 4 assumes the vadose zone chloride concentration profile as delineated by the field investigation (Figure 5) and the lithology represented in Figure 1.

Figure 4a: Chloride Concentration in the Aquifer, BD-4 Site with Evapotranspiration Barrier Installed

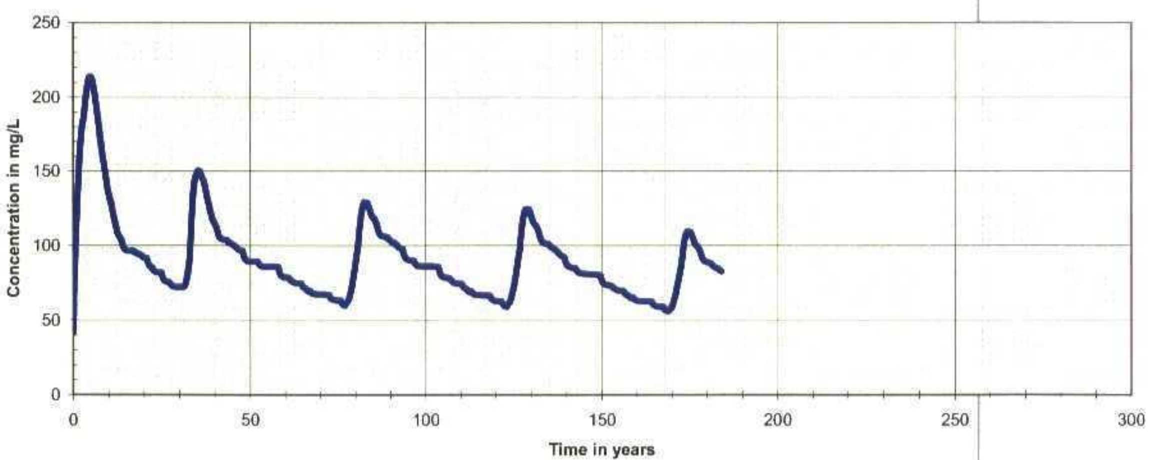
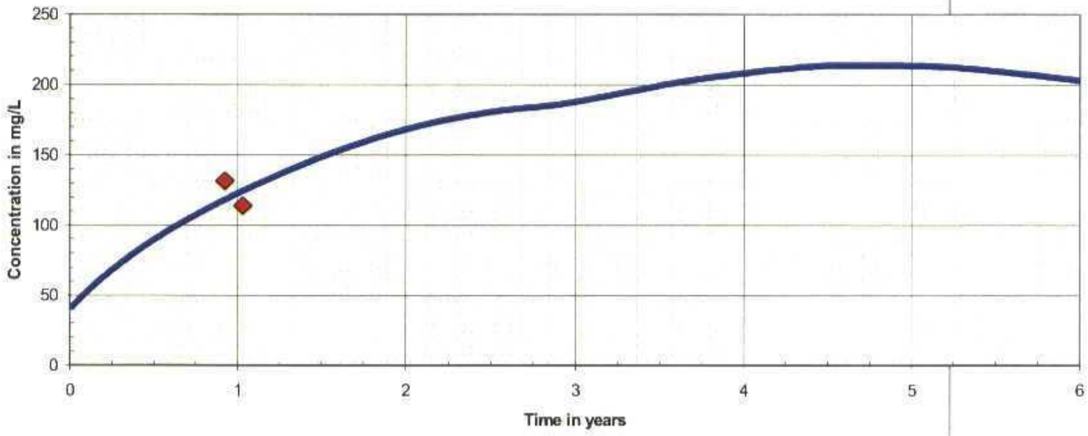


Figure 4b: Predicted Chloride Concentration in the Aquifer, BD-4 Site with Evapotranspiration Barrier Installed at Year 0 - Diamonds Represent Ground Water Samples in May and August 2006



Peak chloride concentration in ground water occurs about 5 years after installation of the ET barrier and is less than 215 mg/L (see Figure 4b). As a result of installation of the ET barrier, vadose zone water flux to ground water is reduced about an order of magnitude less than the flux at the currently un-vegetated pit site (Figure 6). Note that the rate of recharge to the aquifer for both scenarios is exactly the same until about year two. After year two, flux to the aquifer without the barrier increases due to greater infiltration at the un-vegetated surface. The conclusion we can draw from this graph is quite simple, the ET barrier should be installed as soon as possible.

Figure 5: Chloride Profile of the Proposed Remedy, BD 4 Site

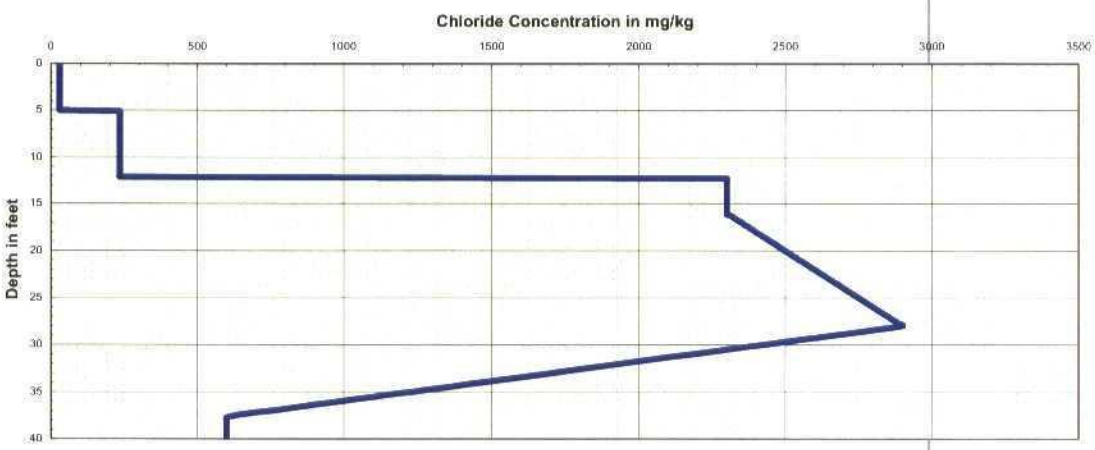


Figure 6: Vadose Zone Water Flux to Ground Water at the BD-4 Site

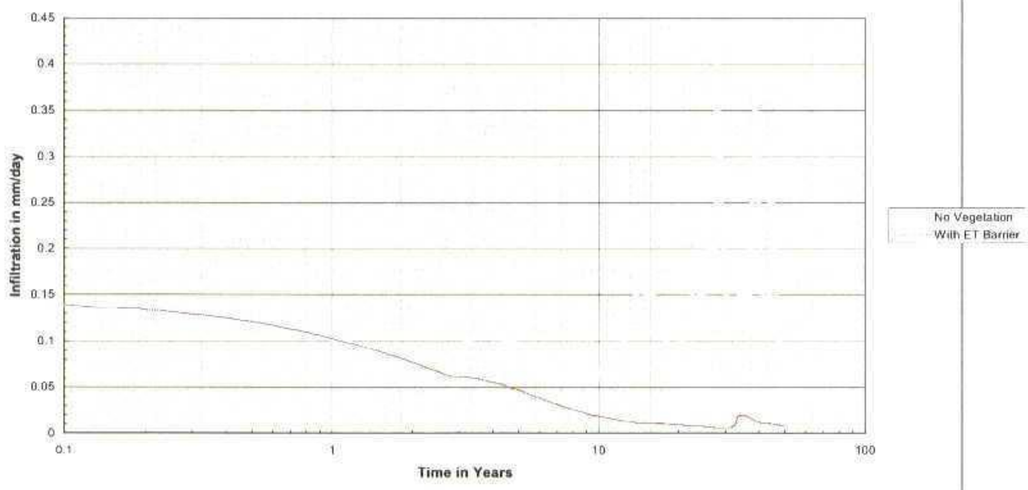
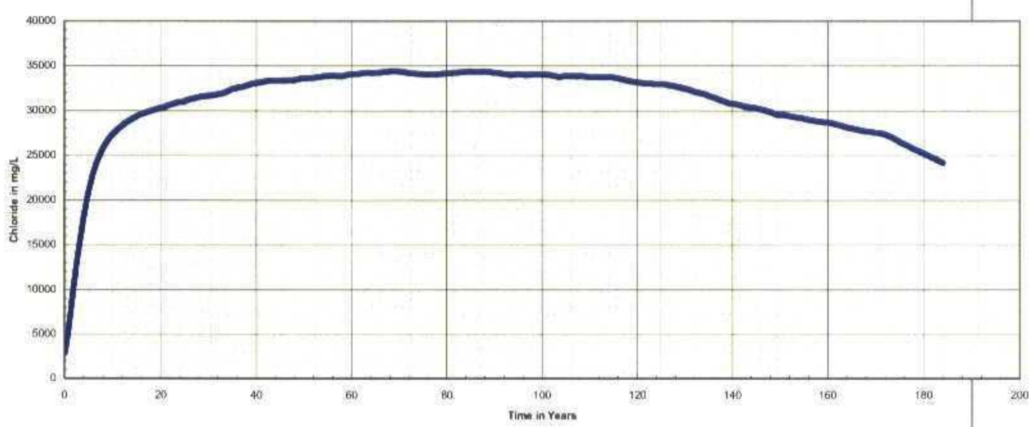


Figure 7: Chloride Concentration of Vadose Zone Water at the Ground Water Interface, BD-4 Site with Installed Evapotranspiration Barrier



As stated above, with the ET cover in place, the vadose zone chloride flux to ground water peaks at about year five (see Figure 4a) as a result of reduction of vadose zone water flux by about an order of magnitude. However, peak chloride concentration (34,400 mg/L) of the vadose zone water enters ground water between years 68 and 86 (Figure 7). From this graph we can conclude that the chloride center of mass in the vadose zone profile (2,900 mg/kg at 28 feet bgs) enters ground water at this later time step. Because of the reduced vadose zone water flux, between years 68 and 86, the maximum chloride concentration in ground water is about 125 mg/L (year 84 in Figure 4a)

The simulation shows that the monolithic ET barrier permanently and immediately protects fresh water, public health and the environment. We believe that the monolithic/capillary ET barrier remedy effectively meets all mandates of the Oil and Gas Act. A two-year ground water monitoring program will serve to verify the predictions presented herein. The efficacy of the ET Barrier design, however, has been verified by decades of monitoring at various sites throughout the US.

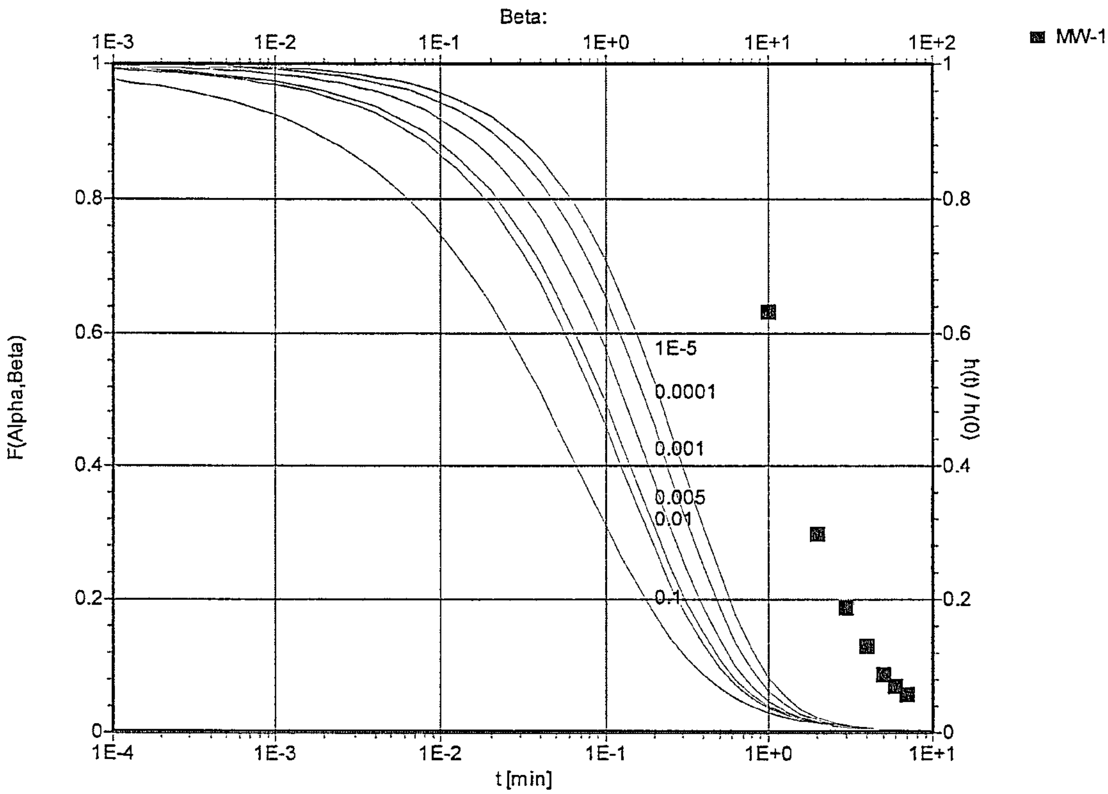
CLOSURE PLAN DESIGN REPORT

APPENDICES ARE INCLUDED IN THE ATTACHED CD

APPENDIX C

Waterloo Hydrogeologic, Inc. 460 Philip Street - Suite 101 Waterloo, Ontario, Canada Phone: +1 519 746 1798	**Slug Test Analysis Report** Project: BD-04 final Number: Client: Samson Resources

New Slug Test [Cooper-Bredehoeft-Papadopulos]



Slug Test: **New Slug Test**

Analysis Method: **Cooper-Bredehoeft-Papadopulos**

Analysis Results:				
	Transmissivity:	1.44E+2 [ft²/d]	Conductivity:	9.60E+0 [ft/d]
	Storativity:	8.00E-6		

Test parameters:				
	Test Well:	MW-1	Aquifer Thickness:	15 [ft]
	Casing radius:	0.1 [ft]	Alpha:	0.005
	Screen length:	15 [ft]		
	Boring radius:	0.3 [ft]		
	r(c):	2.5 [ft]		

Comments:

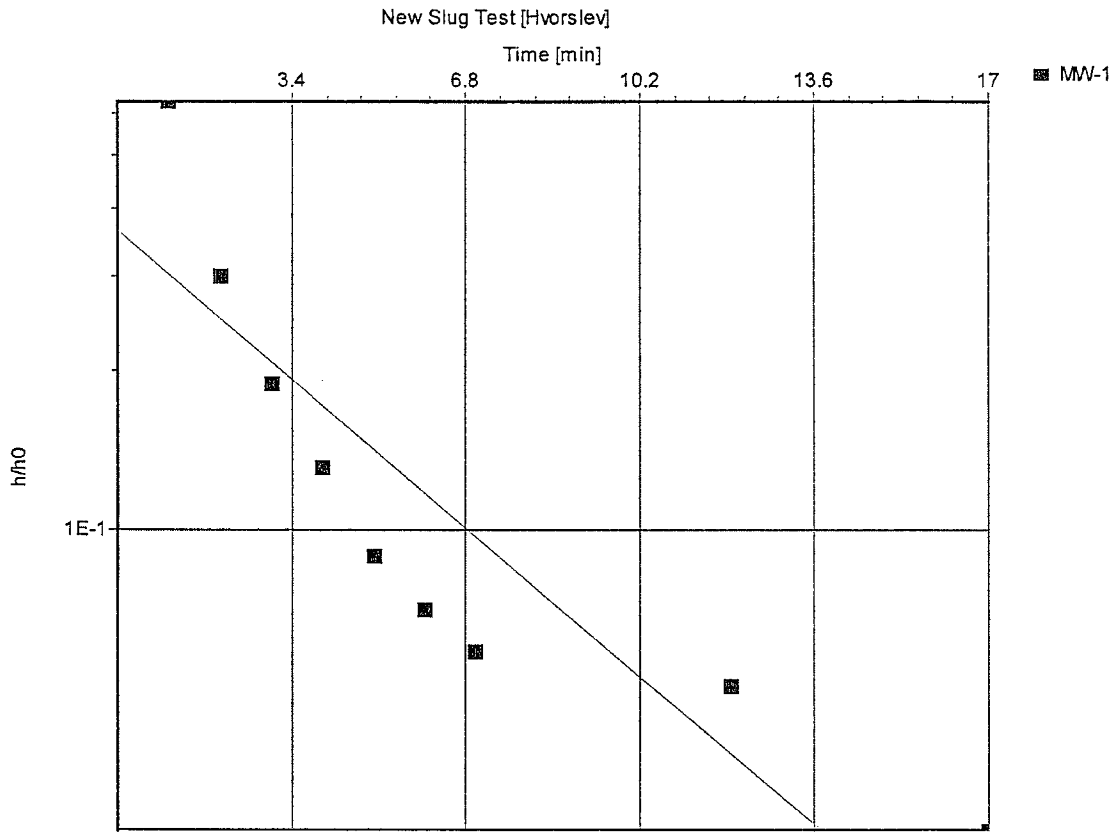
Evaluated by:

Evaluation Date: 11/21/2006

Waterloo Hydrogeologic, Inc.
460 Philip Street - Suite 101
Waterloo, Ontario, Canada
Phone: +1 519 746 1798

Slug Test Analysis Report

Project:	BD-04 final
Number:	
Client:	Samson Resources



Slug Test: **New Slug Test**

Analysis Method: **Hvorslev**

Analysis Results:			Conductivity:	3.58E-1 [ft/d]
Test parameters:	Test Well:	MW-1	Aquifer Thickness:	15 [ft]
	Casing radius:	0.1 [ft]		
	Screen length:	15 [ft]		
	Boring radius:	0.3 [ft]		

Comments:

Evaluated by: R. Hicks

Evaluation Date: 11/10/2006

APPENDIX D

Field Data from Pumping Test and sampling

Well	Time	DTW	TD	1 casing vol	3 casing vol
MW-1	1232	41.14	54.75	2.22	6.66
MW-2	1234	41.82	56.9	2.46	no change on static during purge

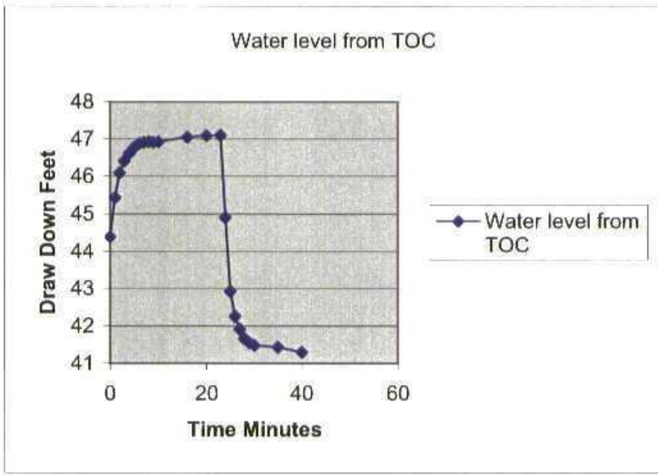
MW-1

Time	Purge Vol	GPM	pH	Temp	Cond	DTW	Comment
1232						41.14	pump off
1245						41.36	purge rate ~ 0.5 L/min pump in bottom of hole 1.75 inch grunfos sub
1250						41.59	
1254	2.5		7.4	68.3	707	41.65	
1300	5	0.05	6.84	67.4	698	41.68	
1305	7	0.40	6.92	68.2	672	41.78	
1310	8.5	0.30	7.03	68.4	676	41.75	
1315	10	0.30	6.79	68.5	696	41.75	
1320	11	0.20	6.85	68.9	723		
1330	pump stopped silted in pulled pump and cleaned out						
1350	16		6.97	69.3	680	41.92	resumed pumping at slow rate
1355	17	0.20	7	70	712		
1400	19	0.04	7.05	69.7	721		
1405	20	0.20	7.07	69.9	725		
1410	sampled top of well first water with disposable bailer while pumping						
1420	sampled well from grunfos 1.75 inch sub at bottom of hole						

Field Data from Pumping Test

Time (Minutes)	Water level from	Comment			
0	44.4	Start test after previous purginging of 20 gallons clock time 14:38			
1	45.44	pump flow rate 3 GPM			
2	46.09	draw down			
3	46.41	draw down			
4	46.62	draw down			
5	46.77	draw down			
6	46.88	draw down			
7	46.91	draw down			
8	46.93	draw down			
9	46.91	draw down			
10	46.93	draw down			
16	47.05	draw down	41.14	12.65846	
20	47.09	draw down			
23	47.1	pull pump start recovery	0	14.49231	
24	44.91	recovery	60	13.81846	0.673846
25	42.92	recovery	120	13.20615	0.612308
26	42.26	recovery	180	13.00308	0.203077
27	41.92	recovery	240	12.89846	0.104615
28	41.67	recovery	300	12.82154	0.076923
29	41.56	recovery	360	12.78769	0.033846
30	41.49	recovery	420	12.76615	0.021538
35	41.44	recovery	720	12.75077	0.015385
40	41.3	recovery	1020	12.70769	0.043077

47.1

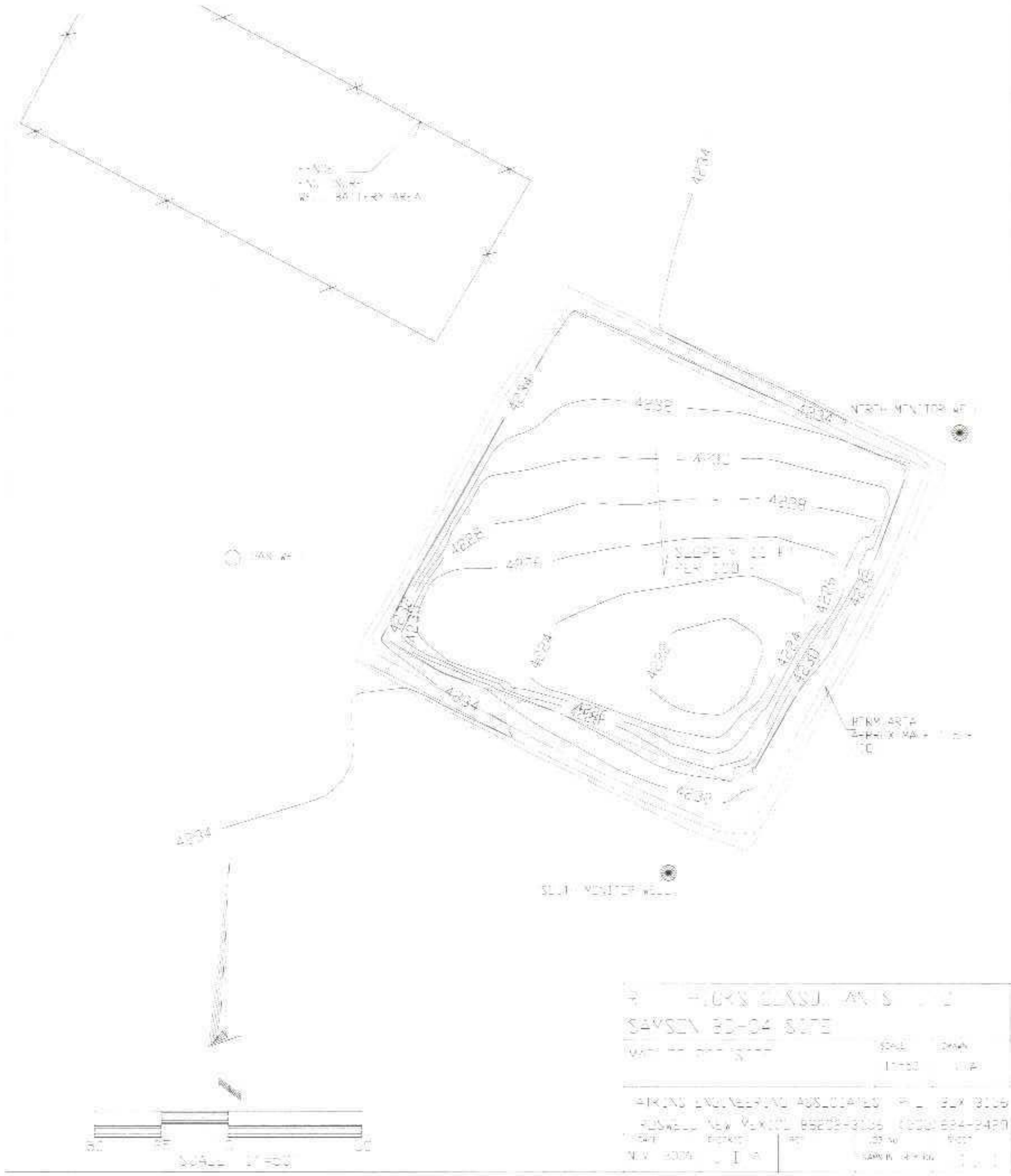


24	44.91	-2.19	1
25	42.92	-1.99	2
26	42.26	-0.66	3
27	41.92	-0.34	4
28	41.67	-0.25	5
29	41.56	-0.11	6
30	41.49	-0.07	7
35	41.44	-0.05	12
40	41.3	-0.14	17

Field Notes from Water Level Measurments

Nearby wells	DTW	Comment
GPS 275	44.8	
GPS 276	47.3	pumping windmill unable to stop
GPS 277	42.75	

Well	Time	DTW	TD
MW-1	1232	41.14	54.75
MW-2	1234	41.82	56.9



SAMSON BD-04 SITE
NORTH MONITOR WELL
SOUTH MONITOR WELL
4232
4230
4228
4226
4224
4234


North view topsoil grade


View west topsoil grade