1R - 425-64

WORKPLANS

Date:

11-23-10

Hansen, Edward J., EMNRD

From:	Katie Jones [kjones@riceswd.com]
Sent:	Monday, January 31, 2011 2:12 PM
To:	Hansen, Edward J., EMNRD
Cc:	Hack Conder; Katie Lee
Subject:	Corrected Vacuum F-25 EOL (1R425-64) CAP Addendum
Attachments:	Vacuum F-25 EOL (1R425-64) Proposed Liner - Plate 4.jpg

Mr. Hansen,

This email is an Addendum to the Vacuum F-25 EOL site (1R425-64) Corrective Action Plan, submitted to the NMOCD on November 24, 2010. Page 1, second paragraph: text in blue lettering, below, will be added to the paragraph. Red lettering marked with a strike-through will be deleted. The new plate 4 showing the proposed liner location is attached. If you need any further information, please let me or Hack know.

"Our recommended corrective action for the site is the installation of a 30 x ~~30~~40 foot synthetic liner 4-5 feet below ground surface centered over the former site and revegetation of an area 45 x 45 feet in size above the former site. This design meets the mandate of NMOCD Rules for protection of surface water, ground water and the environment. The investigation demonstrates that with this remedy in place residual chloride and hydrocarbons in the vadose zone will not with reasonable probability contaminate ground water or surface water in excess of the standards in Subsections B and C of 19.15.30.9 NMAC through leaching, percolation or other transport mechanisms, or as the water table elevation fluctuates."

Page 3, section: Recommendation: text in blue lettering, below, will be added to the paragraph. Red lettering marked with a strike-through will be deleted.

"Our recommended remedy includes:

- Installation of a liner at a depth of four-feet underneath the 30-foot by ~~30~~40-foot area centered over the former site. Excavated soil will be evaluated for use as backfill above the liner. All backfill material will contain a chloride concentration below 500 mg/kg and PID (field parameter) reading less than 100 ppm. Any soil requiring disposal will be properly disposed of at an NMOCD-approved facility. ~~Clean fill (with a chloride concentration below 500 mg/kg and PID (field parameter) reading less than 100 ppm) will be imported to replace excavated material above the liner.~~
- Upon completion of the liner installation, re-vegetate a 45-foot by 45-foot area centered east-west over the former excavation and adjacent to the road on the north to reduce infiltration (see Plate 4).

This remedy is protective of ground water quality, human health, and the environment. Vegetative cover removes water from the soil through transpiration in addition to water removed by evaporation. Such a cover can be called an evapotranspiration barrier (ET barrier). The amount of surface water that infiltrates to ground water at an area with an ET barrier is less than that for an identical bare area. For soil above the water table; hydraulic conductivity (the ability of a soil to transmit water) varies with the moisture content of the soil. Hence, installation of a vegetative ET barrier results in a considerably lowered migration rate of water and chloride to ground water. Installation of a liner beneath a vegetative ET barrier reduces water and chloride fluxes to ground water to negligible levels while the liner has integrity. As the liner develops tears and chemically degrades (likely decades to centuries after it was installed), downward movement of water and chloride beneath these areas increases to the rates equivalent to an area without a liner but with an ET barrier. The chloride beneath the disintegrating parts of a liner moves downwards to ground water before chloride underneath the intact parts of the liner. In this way, chloride from the site enters ground water at different times. The resulting chloride concentration in ground water is less than if chloride from the entire site enters ground water during a shorter time interval."

Page 4, section: Conclusions, paragraph 2: text in blue lettering, below, will be added to the paragraph. Red lettering marked with a strike-through will be deleted.

"The remedy design for the site is the installation of a 30 x ~~30~~40 foot synthetic liner 4-5 feet below ground surface centered over the former site and re-vegetation of an area 45 x 45 feet in size above the former site. Our recommended corrective action meets the mandate of NMOCD Rules for protection of surface water, ground water and the environment. The investigation demonstrates that with this remedy in place, residual chloride and hydrocarbons in the vadose zone will not with reasonable probability contaminate ground water or surface water in excess of the standards in Subsections B and C of 19.15.30.9 NMAC through leaching, percolation or other transport mechanisms, or as the water table elevation fluctuates. Upon documentation of installation of the liner and re-seeding of the site with an appropriate mix of native grasses we will submit a Termination Request for this site's regulatory file."

Thank you.

Katie Jones
Environmental Project Coordinator
RICE *Operating Company*

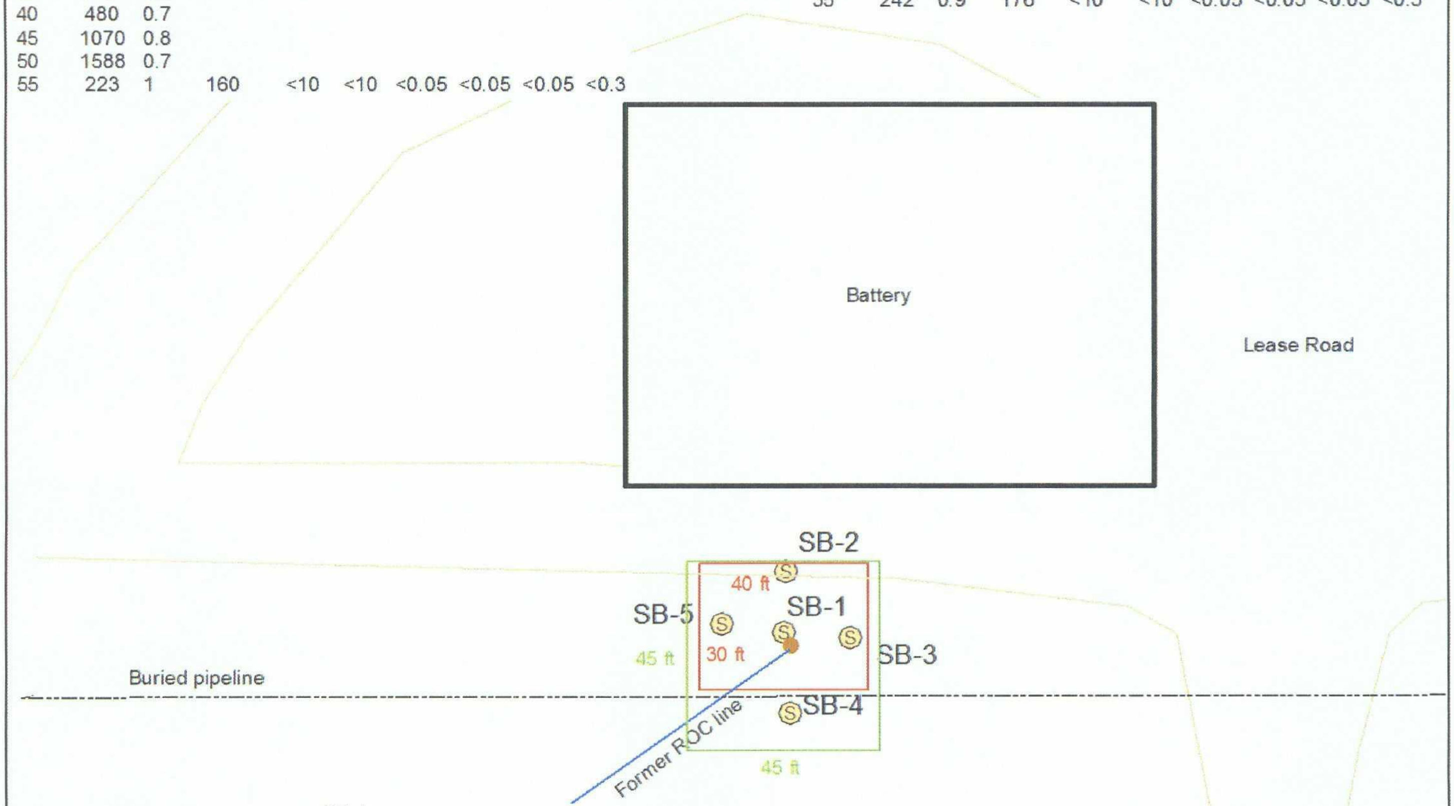
Proposed Liner

SB-2

Depth	Cl-	PID	LAB Cl-	GRO	DRO	B	T	E	X
5	610	1.7							
10	2940	1	3200	<10	<10	<0.05	<0.05	<0.05	<0.3
15	1176	0.8							
20	1782	0.7							
25	1147	0.4							
30	1376	0.2							
35	927	0.6							
40	480	0.7							
45	1070	0.8							
50	1588	0.7							
55	223	1	160	<10	<10	<0.05	<0.05	<0.05	<0.3

SB-3

Depth	Cl-	PID	LAB Cl-	GRO	DRO	B	T	E	X
5	1363	1.6	1710	<10	<10	<0.05	<0.05	<0.05	<0.3
10	1575	1							
15	558	0.9							
20	1013	0.6							
25	377	0.4							
30	444	0.8							
35	242	0.9	176	<10	<10	<0.05	<0.05	<0.05	<0.3



SB-1

Depth	Cl-	PID	LAB Cl-	GRO	DRO	B	T	E	X
15	440	1.4							
20	456	1							
25	325	0.6							
30	538	0.5							
35	513	0.4							
40	606	0.4	560	<10	<10	<0.05	<0.05	<0.05	<0.3
45	429	0.5							
50	260	0.4	288	<10	<10	<0.05	0.19	<0.05	<0.3

SB-5

Depth	Cl-	PID	LAB Cl-	GRO	DRO	B	T	E	X
5	824	2.6							
10	1610	2	1660	<10	<10	<0.05	<0.05	<0.05	<0.3
15	594	2.3							
20	518	2.5							
25	315	2.5							
30	418	2							
35	351	2.5							
40	234	2	160	<10	<10	<0.05	<0.05	<0.05	<0.3

SB-4

Depth	Cl-	PID	LAB Cl-	GRO	DRO	B	T	E	X
5	201	4.8							
10	929	3.2	986	<10	<10	<0.05	<0.05	<0.05	<0.3
15	552	4							
20	651	3.2							
25	363	3.4							
30	394	3.1							
35	268	4	208	<10	<10	<0.05	<0.05	<0.05	<0.3

RICE ENVIRONMENTAL
RECS
CONSULTING & SAFETY, LLC

Vacuum F-25 EOL

Legals: UL/F sec. 25 T17S R35E

Case #: 1R425-64

Proposed liner
Revegetation Area

N W E S

Plate 4

0 20 40 80 Feet

Drawing date: 1-21-10
Drafted by: L. Weinheimer

R. T. HICKS CONSULTANTS, LTD.

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

November 23, 2010

Edward Hansen
NMOCD
1220 South St. Francis Drive
Santa Fe, New Mexico 87505
Via E-mail

RE: Vacuum F-25 EOL
NMOCD Case #s: 1R425-64
F-25 EOL, T17S, R35E, Section 25
Correction Action Plan

Mr. Hansen,

On behalf of Rice Operating Company (ROC), R.T. Hicks Consultants, Ltd. is pleased to submit this Correction Action Plan (CAP) for the F-25 EOL site within the Vacuum Salt Water Disposal System. The Vacuum F-25 EOL site is located east of Buckeye, New Mexico in Section 25 of T17S, R35E, GPS coordinates for the site are approximately: N32° 48′ 29.125″ W -103° 24′ 56.843″ (Plate 1). The site was a part of the Vacuum System which was abandoned in 2001.

Our recommended corrective action for the site is the installation of a 30 x 30 foot synthetic liner 4-5 feet below ground surface centered over the former site and re-vegetation of an area 45 x 45 feet in size above the former site. This design meets the mandate of NMOCD Rules for protection of surface water, ground water and the environment. The investigation demonstrates that with this remedy in place residual chloride and hydrocarbons in the vadose zone will not with reasonable probability contaminate ground water or surface water in excess of the standards in Subsections B and C of 19.15.30.9 NMAC through leaching, percolation or other transport mechanisms, or as the water table elevation fluctuates.

Characterization Activities

June - August 2005

The site was initially assessed as part of Vacuum System abandonment. The EOL box was removed. Three sampling trenches were then advanced to 12′ below ground surface (bgs) to characterize impact at the source, 5 feet north and 5 feet west of the former EOL junction box. Samples were obtained at one-foot depth intervals and subjected to field chloride and PID measurements. A composite bottom sample was submitted for confirmatory laboratory analysis. The material was removed to a NMOCD-approved site and the site was filled and graded with imported clean material. Plate 2 presents soil sample results at the site.

The surface was contoured to the surrounding area and an identification plate was placed at the site to mark the location of the former junction box. The initial disclosure report for this site is included in Attachment A.

May 2010
ROC and Hicks Consultants had 5 soil borings completed at the site to vertically and horizontally characterize the site. SB-1 was drilled through the center of the former site to a depth of 50 feet.

SB-2, 15 feet north of the EOL junction box was drilled to a depth of 55 feet. SB-3, 15 feet east of the EOL junction box, and SB-4, 20 feet south of the EOL junction box were both drilled to a depth of 35 feet. SB-5, 15 feet west of the EOL junction box was drilled to a depth of 40 feet.

Chloride Profile Data Observations:

1. Trenches generally show increasing chloride concentration with increasing depth (12-feet).
2. Beneath the EOL junction box, concentrations increased from less than 600 mg/kg (1-foot) to above 2,000 mg/kg at 12-feet. Boring concentrations from 15-feet were less than 600 mg/kg to the total depth of 50 feet.
3. Highest chloride concentrations were found in SB-2, north of the EOL junction box (3,200 mg/kg at a depth of 10 feet). Additional local high chloride concentrations exist at 20-feet (1,782 mg/kg) and 50-feet (1,588 mg/kg).
4. To the south (SB-4) and west (SB-5), peak chloride concentrations of about 1,000 mg/kg and about 1,650 mg/kg respectively, occur at a depth of 10 feet. Concentrations decline to about 500 mg/kg at 20 feet and are less below this depth.
5. To the east (SB-3), chloride concentrations have a similar profile as to the west (SB-5) with a higher chloride concentration at the depth of 20 feet (1,013 mg/kg).

To summarize, chloride concentration data from the borings at the site demonstrate chloride masses at depths of about 10-feet, 20-feet, 30-feet, and 50-feet within the soil profile. Greatest chloride masses are to the north and east.

Hydrocarbon Data Results:
All samples were field checked with a photoionization detector (PID). All samples from the trenches measured less than 5.0 ppm with the exception of the uppermost sample and lowermost samples from the 5-feet west trench. The sample concentrations were 14.4 ppm and 41.6 ppm, respectively. Measurements from all the boring samples were less than 5.0 ppm.

Two samples from each of the five borings were submitted for laboratory analysis for BTEX. Concentrations from all samples were below laboratory detection limits. (Attachment B).

Hydrogeology of Site

Data collected regarding the hydrogeology of the site was used to create a conservative model of the remedy. More complete information about the hydrogeologic setting is included driller's logs for nearby wells (included in Attachment C) and in the model explanation, (see Attachment D).

Data from the USGS (Water Table Levels and Aquifer Saturated Thickness in Lea County, Tillery, 2008) and MW-1 show that:

- The site overlies the Ogallala Aquifer
- Depth to water is about 60 feet below ground surface
- Ground water flows southeast under a regional hydraulic gradient of about 0.003 (see Plate 3)

Recommendations

Our recommended remedy includes:

- Installation of a liner at a depth of four-feet underneath the 30-foot by 30-foot area centered over the former site. Clean fill (with a chloride concentration below 500 mg/kg and PID (field parameter) reading less than 100 ppm) will be imported to replace excavated material above the liner.
- Upon completion of the liner installation, re-vegetate a 45-foot by 45-foot area centered east-west over the former excavation and adjacent to the road on the north to reduce infiltration (see Plate 4).

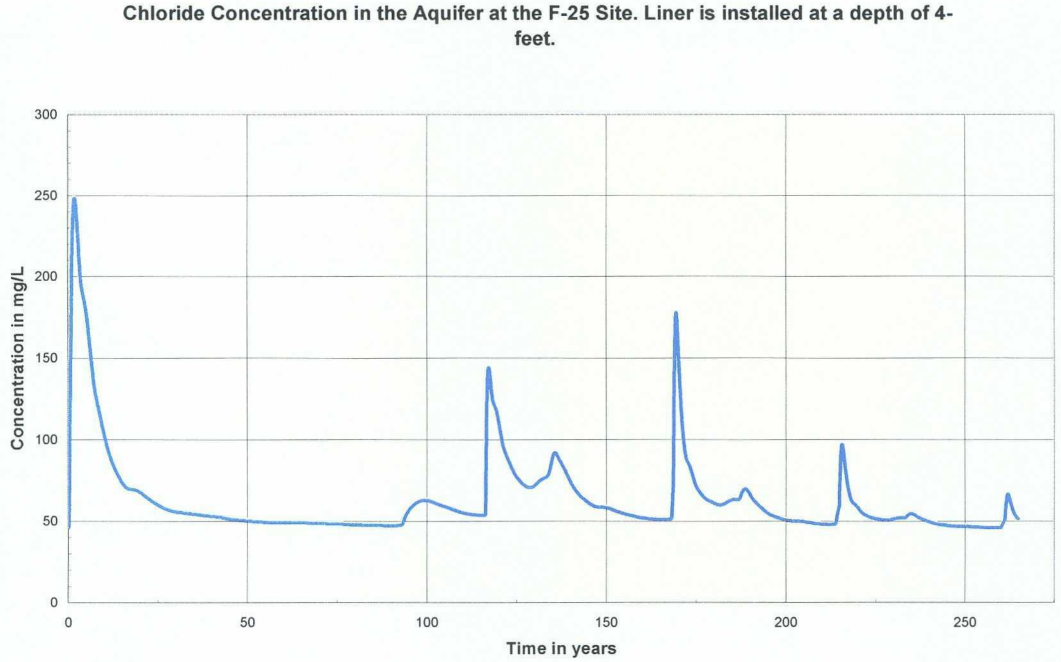
This remedy is protective of ground water quality, human health, and the environment. Vegetative cover removes water from the soil through transpiration in addition to water removed by evaporation. Such a cover can be called an evapotranspiration barrier (ET barrier). The amount of surface water that infiltrates to ground water at an area with an ET barrier is less than that for an identical bare area. For soil above the water table; hydraulic conductivity (the ability of a soil to transmit water) varies with the moisture content of the soil. Hence, installation of a vegetative ET barrier results in a considerably lowered migration rate of water and chloride to ground water.

Installation of a liner beneath a vegetative ET barrier reduces water and chloride fluxes to ground water to negligible levels while the liner has integrity. As the liner develops tears and chemically degrades (likely decades to centuries after it was installed), downward movement of water and chloride beneath these areas increases to the rates equivalent to an area without a liner but with an ET barrier. The chloride beneath the disintegrating parts of a liner moves downwards to ground water before chloride underneath the intact parts of the liner. In this way, chloride from the site enters ground water at different times. The resulting chloride concentration in ground water is less than if chloride from the entire site enters ground water during a shorter time interval.

Model Simulation of the Remedy

Figure 1 is a graph of predicted chloride concentration in ground water at the down gradient edge of the site. Inputs to the model were site-specific for all inputs for which site data existed. For all unknown inputs, values were chosen so as to overstate predicted chloride concentration in ground water. Hence, by construction, the model is conservative of ground water quality. The liner was assumed to have complete integrity for 40-years and to completely degrade over the following 100-years. Therefore, the model has no liner after 140-years. Attachment D presents an explanation of all inputs and the resulting output of the site-specific model for the F-25 EOL site.

Figure 1



Conclusions

The site data that documents the residual mass of chloride and hydrocarbons in the vadose zone permit a conclusion that these constituents in the vadose zone will not with reasonable probability contaminate ground water or surface water in excess of the standards in Subsection B and C of the 19.15.30.9 NMAC through leaching, percolation or other transport mechanisms, or as the water table elevation fluctuates.

The remedy design for the site is the installation of a 30 x 30 foot synthetic liner 4-5 feet below ground surface centered over the former site and re-vegetation of an area 45 x 45 feet in size above the former site. Our recommended corrective action meets the mandate of NMOCD Rules for protection of surface water, ground water and the environment. The investigation demonstrates that with this remedy in place, residual chloride and hydrocarbons in the vadose zone will not with reasonable probability contaminate ground water or surface water in excess of the standards in Subsections B and C of 19.15.30.9 NMAC through leaching, percolation or other transport mechanisms, or as the water table elevation fluctuates. Upon documentation of installation of the liner and re-seeding of the site with an appropriate mix of native grasses we will submit a Termination Request for this site's regulatory file.

ROC is the service provider (agent) for the Vacuum Salt Water Disposal System and has no ownership of any portion of pipeline, well or facility. The Vacuum SWD System is owned by a consortium of oil producers, System Parties, who provide all operating capital on a percentage ownership/usage basis. The Vacuum SWD system has been abandoned.

Please contact Hack Conder of ROC at 575-393-9174 if you have any questions concerning this submission. Thank you for your time and consideration.

Sincerely,
R.T Hicks Consultants, Ltd.

Katie Lee

Katie Lee
Project Scientist

Copy: Hack Conder, Rice Operating Company

Plates

R.T. Hicks Consultants, Ltd.
901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104

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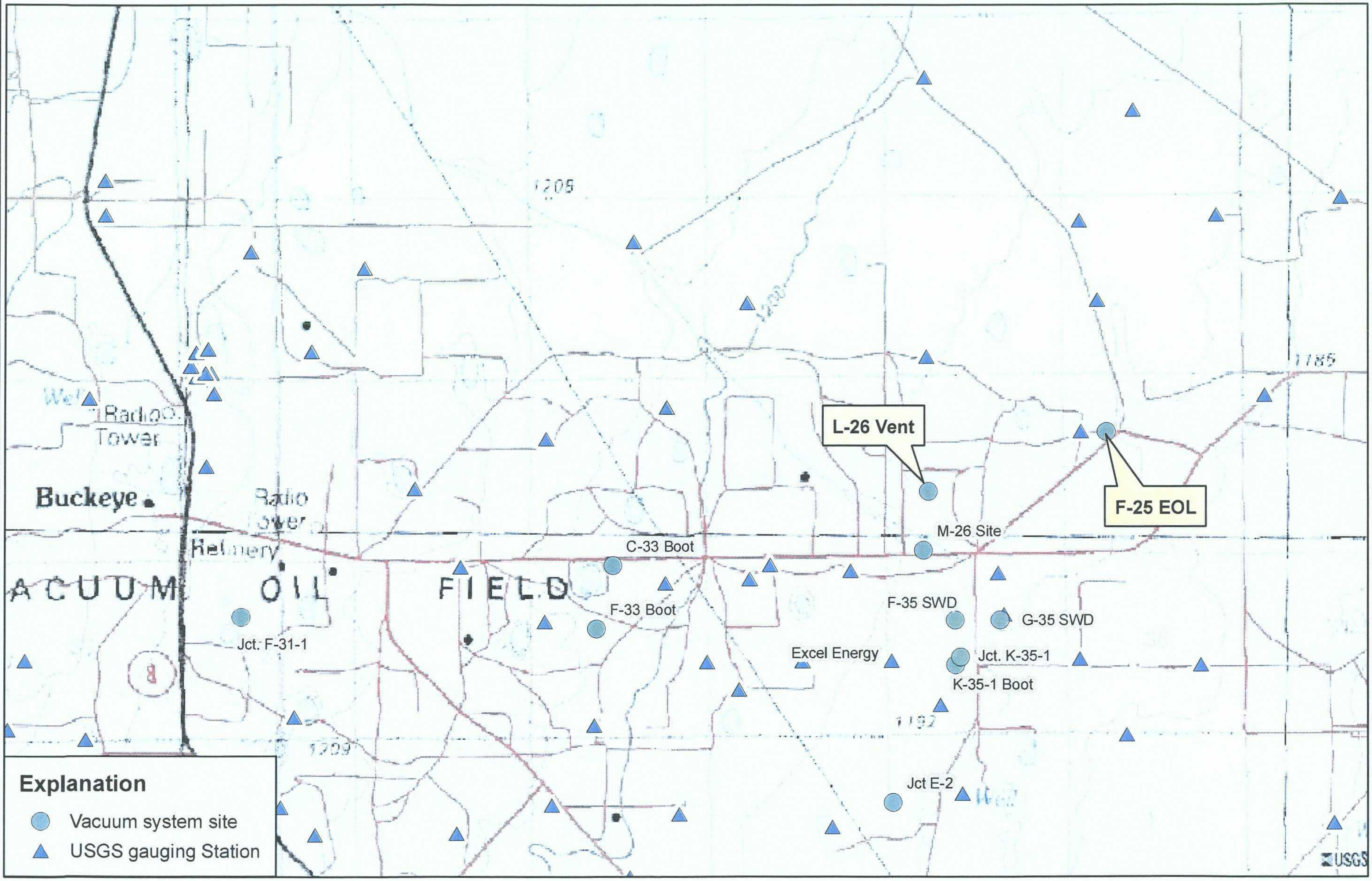


R.T. Hicks Consultants, Ltd
901 Rio Grande Blvd NW Suite F-142
Albuquerque, NM 87104
Ph: 505.266.5004

Location of Vacuum F-25 EOL Relative to ROC Sites and USGS Gauging Stations

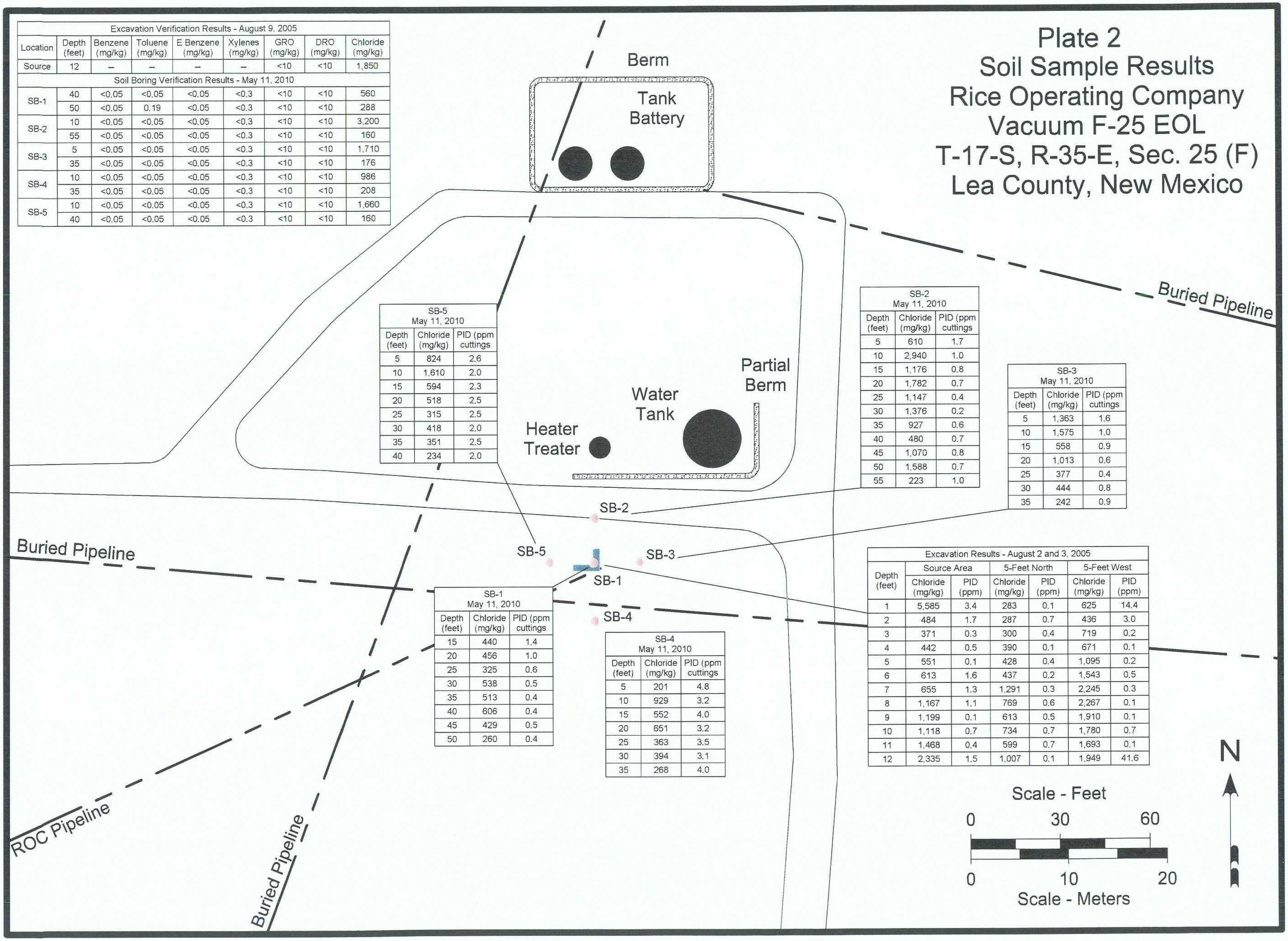
Rice Operating Company

Plate 1

November 2010

9/18/2009

Plate 2
Soil Sample Results
Rice Operating Company
Vacuum F-25 EOL
T-17-S, R-35-E, Sec. 25 (F)
Lea County, New Mexico



Excavation Verification Results - August 9, 2005								
Location	Depth (feet)	Benzene (mg/kg)	Toluene (mg/kg)	E Benzene (mg/kg)	Xylenes (mg/kg)	GRO (mg/kg)	DRO (mg/kg)	Chloride (mg/kg)
Source	12	–	–	–	–	<10	<10	1,850
Soil Boring Verification Results - May 11, 2010								
SB-1	40	<0.05	<0.05	<0.05	<0.3	<10	<10	560
	50	<0.05	0.19	<0.05	<0.3	<10	<10	288
SB-2	10	<0.05	<0.05	<0.05	<0.3	<10	<10	3,200
	55	<0.05	<0.05	<0.05	<0.3	<10	<10	160
SB-3	5	<0.05	<0.05	<0.05	<0.3	<10	<10	1,710
	35	<0.05	<0.05	<0.05	<0.3	<10	<10	176
SB-4	10	<0.05	<0.05	<0.05	<0.3	<10	<10	986
	35	<0.05	<0.05	<0.05	<0.3	<10	<10	208
SB-5	10	<0.05	<0.05	<0.05	<0.3	<10	<10	1,660
	40	<0.05	<0.05	<0.05	<0.3	<10	<10	160

SB-5 May 11, 2010		
Depth (feet)	Chloride (mg/kg)	PID (ppm cuttings
5	824	2.6
10	1,610	2.0
15	594	2.3
20	518	2.5
25	315	2.5
30	418	2.0
35	351	2.5
40	234	2.0

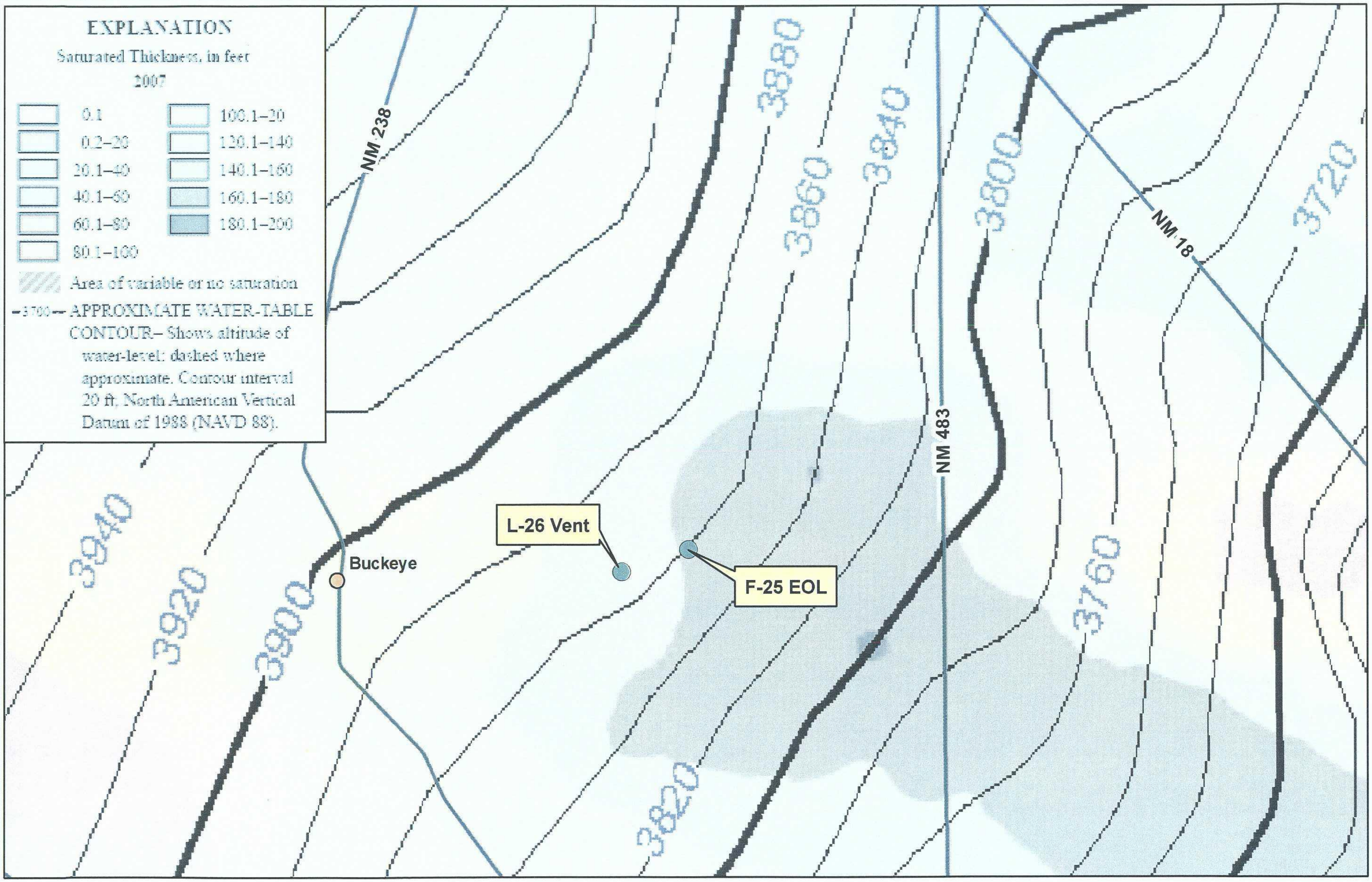
SB-2 May 11, 2010		
Depth (feet)	Chloride (mg/kg)	PID (ppm cuttings
5	610	1.7
10	2,940	1.0
15	1,176	0.8
20	1,782	0.7
25	1,147	0.4
30	1,376	0.2
35	927	0.6
40	480	0.7
45	1,070	0.8
50	1,588	0.7
55	223	1.0

SB-3 May 11, 2010		
Depth (feet)	Chloride (mg/kg)	PID (ppm cuttings
5	1,363	1.6
10	1,575	1.0
15	558	0.9
20	1,013	0.6
25	377	0.4
30	444	0.8
35	242	0.9

SB-1 May 11, 2010		
Depth (feet)	Chloride (mg/kg)	PID (ppm cuttings
15	440	1.4
20	456	1.0
25	325	0.6
30	538	0.5
35	513	0.4
40	606	0.4
45	429	0.5
50	260	0.4

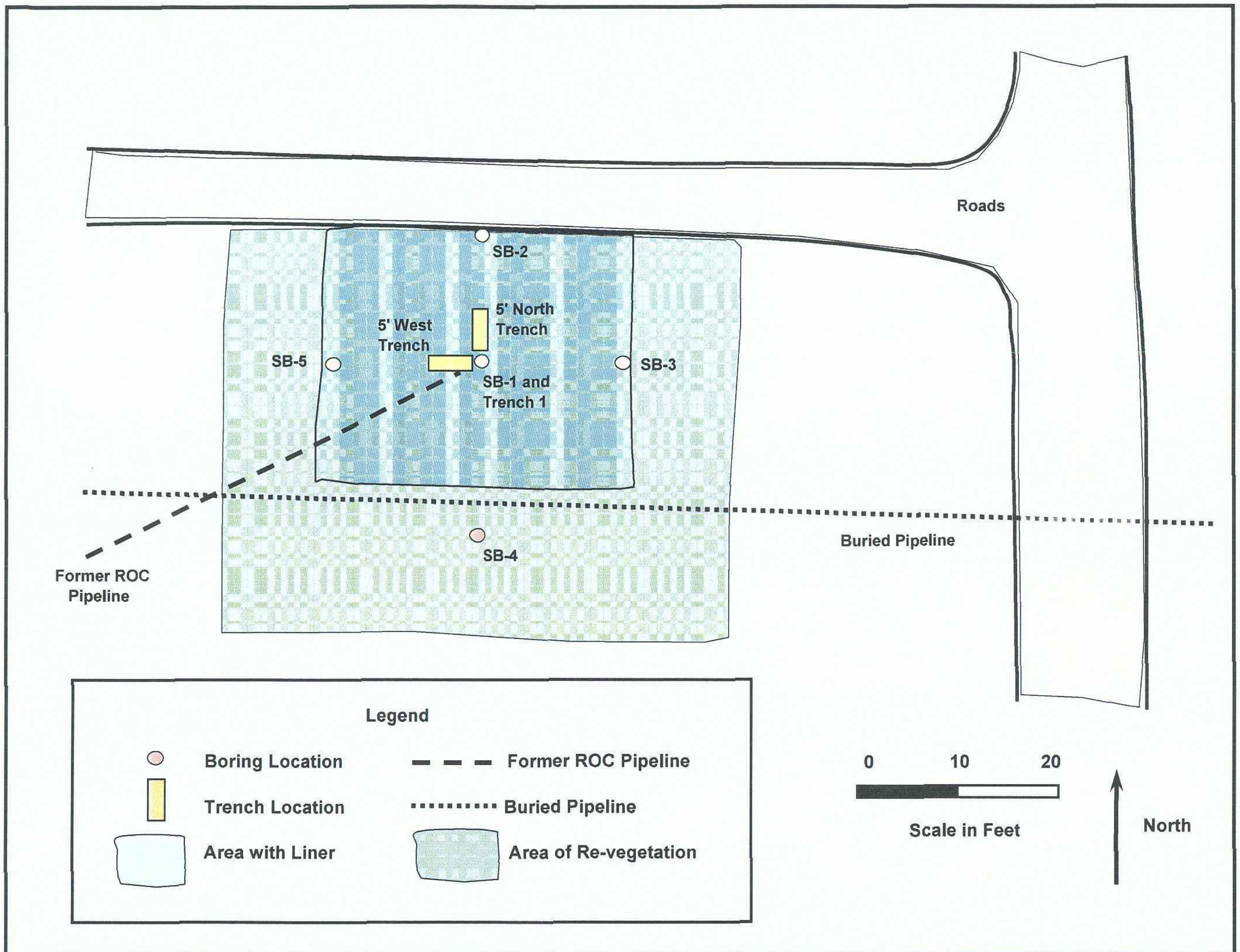
SB-4 May 11, 2010		
Depth (feet)	Chloride (mg/kg)	PID (ppm cuttings
5	201	4.8
10	929	3.2
15	552	4.0
20	651	3.2
25	363	3.5
30	394	3.1
35	268	4.0

Excavation Results - August 2 and 3, 2005						
Depth (feet)	Source Area		5-Feet North		5-Feet West	
	Chloride (mg/kg)	PID (ppm)	Chloride (mg/kg)	PID (ppm)	Chloride (mg/kg)	PID (ppm)
1	5,585	3.4	283	0.1	625	14.4
2	484	1.7	287	0.7	436	3.0
3	371	0.3	300	0.4	719	0.2
4	442	0.5	390	0.1	671	0.1
5	551	0.1	428	0.4	1,095	0.2
6	613	1.6	437	0.2	1,543	0.5
7	655	1.3	1,291	0.3	2,245	0.3
8	1,167	1.1	769	0.6	2,267	0.1
9	1,199	0.1	613	0.5	1,910	0.1
10	1,118	0.7	734	0.7	1,780	0.7
11	1,468	0.4	599	0.7	1,693	0.1
12	2,335	1.5	1,007	0.1	1,949	41.6



Source: USGS, 2008

R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Potentiometric Surface Map and Saturated Thickness for Area Around Vacuum F-25 EOL	Plate 3
	Rice Operating Company	November 2010



R.T. Hicks Consultants, Ltd. 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505 266 5004	Plan View of the Remedy Design for the Vaccum F-25 EOL Site	Plate 4
	Rice Operating Company	November 2010

Attachment A

Disclosure Report

R.T. Hicks Consultants, Ltd.
901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104

RICE OPERATING COMPANY
JUNCTION BOX DISCLOSURE* REPORT

BOX LOCATION

SWD SYSTEM	JUNCTION	UNIT	SECTION	TOWNSHIP	RANGE	COUNTY	BOX DIMENSIONS - FEET		
							Length 8'	Width 4'	Depth 2'
Vacuum	Bustamante EOL	F	25	17S	35E	Lea	no box; system abandonment		

LAND TYPE: BLM ___ STATE X FEE LANDOWNER ___ OTHER ___

Depth to Groundwater 60 feet NMOCD SITE ASSESSMENT RANKING SCORE: 20

Date Started 7/8/2005 Date Completed 9/12/2005 OCD Witness no

Soil Excavated 80 cubic yards Excavation Length 3 trenches Width ___ Depth 12 feet

Soil Disposed 40 cubic yards Offsite Facility Sundance Location Eunice, NM

FINAL ANALYTICAL RESULTS: **Sample Date** 8/9/2005 **Sample Depth** 12 ft

TPH and Chloride laboratory test results completed by using an approved lab and testing procedures pursuant to NMOCD guidelines.

Sample Location	PID (field) ppm	GRO mg/kg	DRO mg/kg	Chlorides mg/kg
BOTTOM 12' GRAB	13.8	<10.0	<10.0	1850

CHLORIDE FIELD TESTS

LOCATION	DEPTH	mg/kg
background	3"	98
vertical delineation trench at the junction (source)	1'	5585
	2'	484
	3'	371
	4'	442
	5'	551
	6'	613
	7'	655
	8'	1167
	9'	1199
	10'	1118
	11'	1468
	12'	2335

General Description of Remedial Action: This junction was eliminated during the Vacuum SWD system abandonment. After the former junction box was removed, an investigation was conducted using a trackhoe to excavated three trenches to 12 ft BGS. Soil samples were taken at regular intervals and field tested for chloride, which yielded elevated concentrations that did not relent with depth. Organic vapors were measured using a PID, which yielded low concentrations. A 12 ft bottom grab sample was sent a commercial laboratory for analysis of chloride and TPH, which confirmed elevated chloride concentrations. Clean soil was imported to backfill the excavation to ground surface and to contour the site to the surrounding area. NMOCD was notified of potential groundwater impact on 12/8/2008.

ADDITIONAL EVALUATION IS HIGH PRIORITY

enclosures: photos, lab results, PID field screenings, chloride curve

I HEREBY CERTIFY THAT THE INFORMATION ABOVE IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE AND BELIEF.

SITE SUPERVISOR Roy Rascon SIGNATURE not available COMPANY RICE OPERATING COMPANY

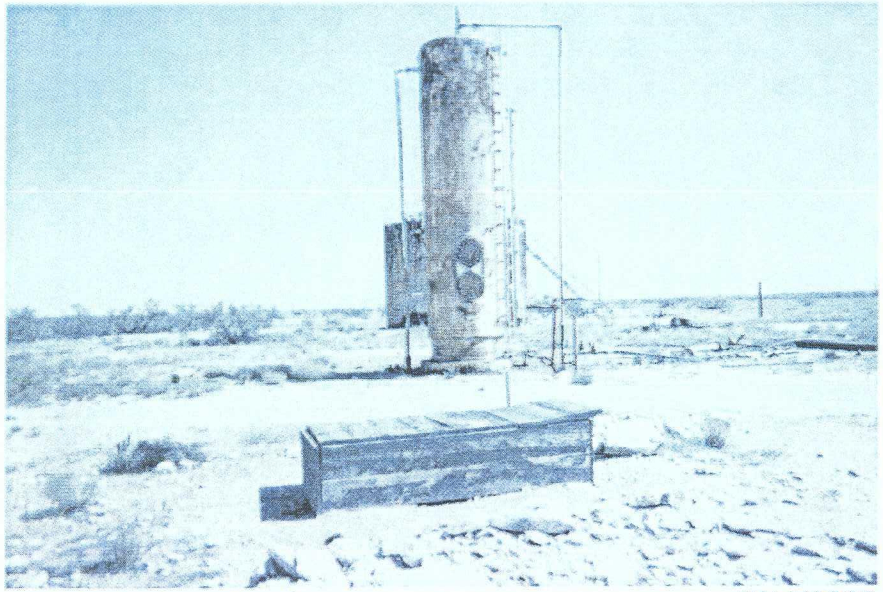
REPORT ASSEMBLED BY Katie Jones INITIAL KJ

PROJECT LEADER Larry Bruce Baker Jr. SIGNATURE Larry Bruce Baker Jr. DATE 12-16-08

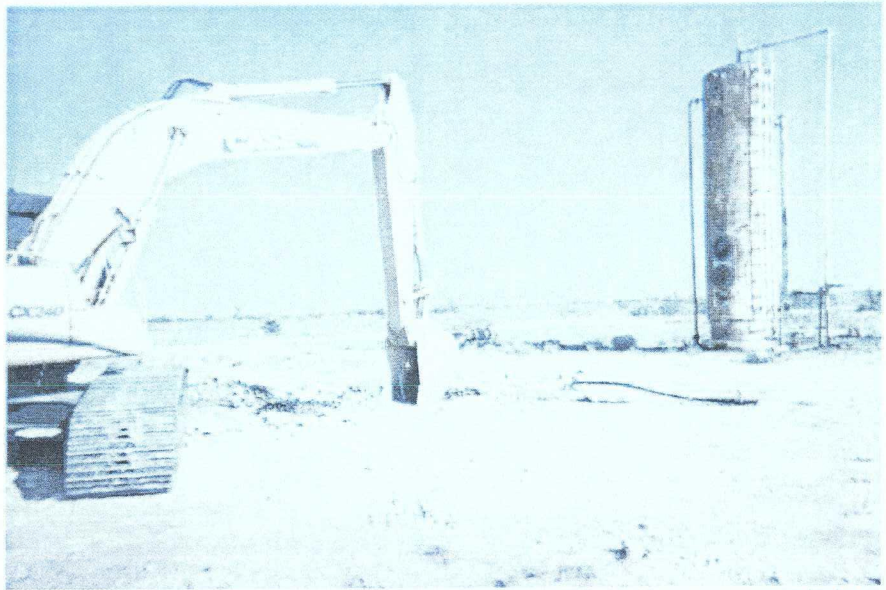
*This site is a "DISCLOSURE." It will be placed on a prioritized list of similar sites for further consideration.

Vacuum Bustamante EOL

Unit F, Section 25, T17S, R35E

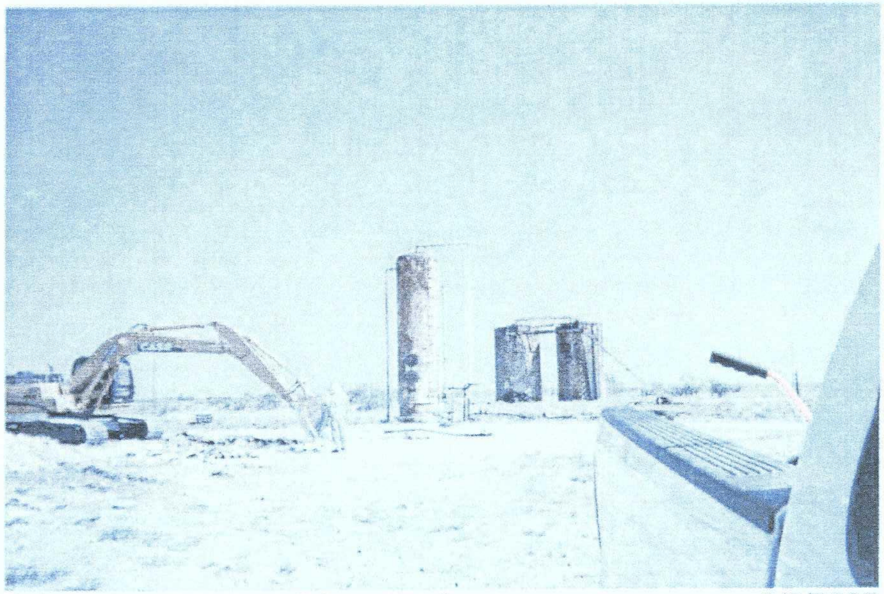


undisturbed junction box 7/11/2005



delineation trench at source 8/2/2005

delineation trench at 5 ft west of source 8/3/2005



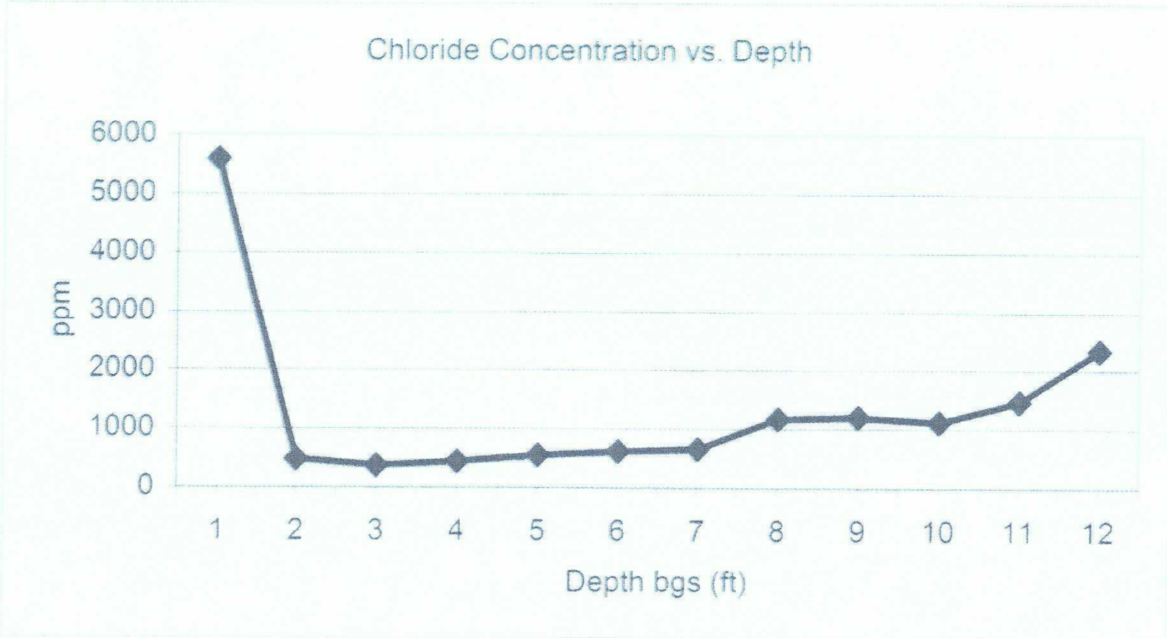
delineation trench at 5 ft north of source 8/3/2005

Vacuum Bustamante EOL

Unit 'F', Sec. 25, T17S, R35E

Trackhoe samples at junction (source)

Depth bgs (ft)	$[Cl^-]$ ppm
1	5585
2	484
3	371
4	442
5	551
6	613
7	655
8	1167
9	1199
10	1118
11	1468
12	2335



Groundwater = 60 ft

Attachment B

Laboratory Analyses

R.T. Hicks Consultants, Ltd.
901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104

CARDINAL
LABORATORIES

PHONE (575) 393-2326 • 101 E. MARLAND • HOBBS, NM 88240

May 19, 2010

Hack Conder
Rice Operating Company
112 West Taylor
Hobbs, NM 88240

Re: Vacuum F-25 EOL

Enclosed are the results of analyses for sample number H19890, received by the laboratory on 05/13/10 at 4:50 pm.

Cardinal Laboratories is accredited through Texas NELAP for:

Method SW-846 8021	Benzene, Toluene, Ethyl Benzene, and Total Xylenes
Method SW-846 8260	Benzene, Toluene, Ethyl Benzene, and Total Xylenes
Method TX 1005	Total Petroleum Hydrocarbons

Certificate number T104704398-08-TX. Accreditation applies to solid and chemical materials and non-potable water matrices.

Cardinal Laboratories is accredited though the State of Colorado Department of Public Health and Environment for:

Method EPA 552.2	Haloacetic Acids (HAA-5)
Method EPA 524.2	Total Trihalomethanes (TTHM)
Method EPA 524.2	Regulated VOCs (V2, V3)

Accreditation applies to public drinking water matrices.

Total Number of Pages of Report: 3 (includes Chain of Custody)

Sincerely,

Celey D. Keene
Laboratory Director

CARDINAL LABORATORIES

PHONE (575) 393-2326 • 101 E. MARLAND • HOBBS, NM 88240

ANALYTICAL RESULTS FOR
RICE OPERATING COMPANY
ATTN: HACK CONDER
112 W. TAYLOR
HOBBS, NM 88240
FAX TO: (575) 397-1471

Receiving Date: 05/13/10
Reporting Date: 05/18/10
Project Owner: NOT GIVEN
Project Name: VACUUM F-25 EOL
Project Location: VACUUM F-25 EOL

Sampling Date: 05/11/10
Sample Type: SOIL
Sample Condition: COOL & INTACT
Sample Received By: JH
Analyzed By: AB/ZL/HM

LAB NO.	SAMPLE ID	GRO (C_6-C_{10}) (mg/kg)	DRO (>C_{10}-C_{28}) (mg/kg)	BENZENE (mg/kg)	TOLUENE (mg/kg)	ETHYL BENZENE (mg/kg)	TOTAL XYLENES (mg/kg)	Cl* (mg/kg)
ANALYSIS DATE:		05/17/10	05/17/10	05/14/10	05/14/10	05/14/10	05/14/10	05/14/10
H19890-1	SB#1 @ 40FT	<10.0	<10.0	<0.050	<0.050	<0.050	<0.300	560
H19890-2	SB#1 @ 50FT	<10.0	<10.0	<0.050	0.190	<0.050	<0.300	288
H19890-3	SB#2 @ 10FT	<10.0	<10.0	<0.050	<0.050	<0.050	<0.300	3,200
H19890-4	SB#2 @ 55FT	<10.0	<10.0	<0.050	<0.050	<0.050	<0.300	160
H19890-5	SB#3 @ 5FT	<10.0	<10.0	<0.050	<0.050	<0.050	<0.300	1,710
H19890-6	SB#3 @ 35FT	<10.0	<10.0	<0.050	<0.050	<0.050	<0.300	176
H19890-7	SB#4 @ 10FT	<10.0	<10.0	<0.050	<0.050	<0.050	<0.300	986
H19890-8	SB#4 @ 35FT	<10.0	<10.0	<0.050	<0.050	<0.050	<0.300	208
H19890-9	SB#5 @ 10FT	<10.0	<10.0	<0.050	<0.050	<0.050	<0.300	1,660
H19890-10	SB#5 @ 40FT	<10.0	<10.0	<0.050	<0.050	<0.050	<0.300	160
Quality Control		505	495	0.018	0.018	0.019	0.058	500
True Value QC		500	500	0.020	0.020	0.020	0.060	500
% Recovery		101	99.0	90.0	90.0	95.0	96.7	100
Relative Percent Difference		2.7	0.2	14.5	18.1	17.9	17.5	< 0.1

METHODS: TPH GRO & DRO - EPA SW-846 8015 M; BTEX - SW-846 8021B; Cl-: Std. Methods 4500-Cl-B
*Analyses performed on 1:4 w:v aqueous extracts. Reported on wet weight.
TEXAS NELAP ACCREDITATION T104704398-08-TX FOR BENZENE, TOLUENE, ETHYL BENZENE, AND TOTAL XYLENES. Not accredited for GRO/DRO and Chloride.

[signature]
Lab Director

05/19/10
Date

H19890 TBCL RICE

CARDINAL LABORATORIES

101 East Marland, Hobbs, NM 88240 2111 Beechwood, Abilene, TX 79603
(505) 393-2326 FAX (505) 393-2476 (325) 673-7001 FAX (325)673-7020

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

		BILL TO	
Company Name: Rice Operating Company		P.O. #:	
Project Manager: Hack Conder		Company:	
Address: 122 West Taylor		Attn:	
City: Hobbs	State: NM Zip: 88240	Address:	
Phone #: 393-9174	Fax #: 397-1471	City:	
Project #:	Project Owner:	State:	Zip:
Project Name: Vacuum F-25 EOL		Phone #:	
Project Location: Vacuum F-25 EOL		Fax #:	
Sampler Name: Jordan Woodfin			

ANALYSIS REQUEST

Lab I.D. (FOR LAB USE ONLY)	Sample I.D.	(G)RAB OR (C)OMP.	# CONTAINERS	MATRIX: GROUNDWATER	MATRIX: WASTEWATER	MATRIX: SOIL	MATRIX: OIL	MATRIX: SLUDGE	MATRIX: OTHER:	PRESERV: ACID/BASE:	PRESERV: ICE / COOL	PRESERV: OTHER:	SAMPLING DATE (ALL 5-11-10)	SAMPLING TIME	Chlorides	TPH 8015 M	BTEX	Texas TPH	Complete Cations/Anions
H19890-1	SB #1 @ 40FT	g	1			✓					✓		5/5/10	08:14	✓	✓	✓		
2	SB #1 @ 50FT	g	1			✓					✓		5/5/10	08:22	✓	✓	✓		
3	SB #2 @ 10FT	g	1			✓					✓		5/5/10	08:59	✓	✓	✓		
4	SB #2 @55FT	g	1			✓					✓		5/5/10	09:25	✓	✓	✓		
5	SB #3 @ 5FT	g	1			✓					✓		5/5/10	10:04	✓	✓	✓		
6	SB #3 @ 35FT	g	1			✓					✓		5/5/10	10:23	✓	✓	✓		
7	SB #4 @ 10FT	g	1			✓					✓		5/5/10	10:57	✓	✓	✓		
8	SB #4 @ 35FT	g	1			✓					✓		5/5/10	11:13	✓	✓	✓		
9	SB #5 @ 10FT	g	1			✓					✓		5/5/10	13:29	✓	✓	✓		
10	SB #5 @ 40FT	g	1			✓					✓		5/5/10	13:47	✓	✓	✓		

PLEASE NOTE: Liability and Damages. Cardinal's liability and client's exclusive remedy for any claim arising whether based in contract or tort, shall be limited to the amount paid by the client for the analyses. All claims including those for negligence and any other cause whatsoever shall be deemed waived unless made in writing and received by Cardinal within 30 days after completion of the applicable service. In no event shall Cardinal be liable for incidental or consequential damages, including without limitation, business interruptions, loss of use, or loss of profits incurred by client, its subsidiaries, affiliates or successors arising out of or related to the performance of services hereunder by Cardinal, regardless of whether such claim is based upon any of the above stated reasons or otherwise.

Relinquished By: Jordan Woodfin	Date: Time:	Received By:	Phone Result: ☐ Yes ☑ No Add'l Phone #: Fax Result: ☐ Yes ☑ No Add'l Fax #:
Relinquished By:	Date: 5/13/10 Time: 4:50	Received By: Jodi Henson	REMARKS: email results Hconder@riceswd.com; Kjones@riceswd.com; Jwoodfin@riceswd.com
Delivered By: (Circle One) Sampler - UPS - Bus - Other:		Sample Condition Cool ☑ Yes ☐ No Intact ☑ Yes ☐ No CHECKED BY: (Initials)	

† Cardinal cannot accept verbal changes. Please fax written changes to 505-393-2476

~~NEED SAMPLES BACK, PLEASE~~

#26

Attachment C

Well Logs

R.T. Hicks Consultants, Ltd.
901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104

Form WR-23

STATE ENGINEER OFFICE

STATE OF NEW MEXICO

FIELD ENGR. LOG

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. *All sections, except Section 5, shall be answered as completely and* accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

330 FSL
330 FWL

(Plat of 640 acres)

(A) Owner of well [illegible]

Street and Number [illegible]

City Hobbs State New Mexico

Well was drilled under Permit No. L-4247 X2 and is located in the

SW 1/4 SW 1/4 [illegible] 1/4 of Section 30 Twp. 17 S Rge. 35 E

(B) Drilling Contractor Abbott Brothers License No. [illegible]

Street and Number [illegible]

City Hobbs State New Mexico

Drilling was commenced August 15 19

Drilling was completed August 17 19 63

Elevation at top of casing in feet above sea level Total depth of well 200

State whether well is shallow or artesian shallow Depth to water upon completion 83

Section 2

PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet From	Depth in Feet To	Thickness in Feet	Description of Water-Bearing Formation
1	83	115	32	water sand
2	135	190	55	water sand
3				
4				
5				

Section 3

RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth Top	Depth Bottom	Feet	Type Shoe	Perforations From	Perforations To
12 3/4	32	spiral welded	0	200	200	open	100	200

Section 4

RECORD OF MUDDING AND CEMENTING

Depth in Feet From	Depth in Feet To	Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used

1963 AUG 28 AM 10:47
STATE ENGINEER OFFICE
DISTRICT II
ROSWELL, N. MEX.

Section 5

PLUGGING RECORD

Name of Plugging Contractor License No.

Street and Number City State

Tons of Clay used Tons of Roughage used Type of roughage

Plugging method used Date Plugged 19

Plugging approved by:

Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug From	Depth of Plug To	No. of Sacks Used

FOR USE OF STATE ENGINEER ONLY

Date Received

STATE ENGINEER OFFICE
DISTRICT II
ROSWELL, N. MEX.
1963 AUG 28 AM 11:55

2-7791-3

File No. L-4247-X-2 Use S R O. Location No. 17.35.30.33300

#E or Cap 3-448-5

332144

Section 6

LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	20	20		caliche
20	35	15		sand
35	42	7		sand and gravel
42	80	38		sand
80	83	3		sand rock
83	115	32		water sand
115	135	20		dry sand
135	190	55		water sand
190	200	10		sandy clay

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

[signature]
Well Driller

Revised June 1972

12/11/89

STATE ENGINEER OFFICE

WELL RECORD

Section 1. GENERAL INFORMATION

(A) Owner of well Texaco Inc. Owner's Well No. ______
Street or Post Office Address Box 730
City and State Hobbs, New Mexico

Well was drilled under Permit No. L-7481-S and is located in the:

a. ___ ¼ ___ ¼ SW ¼ SW ¼ of Section 30 Township 17-S. Range 35-E. N.M.P.M.

b. Tract No. ______ of Map No. ______ of the ______

c. Lot No. ______ of Block No. ______ of the ______
Subdivision, recorded in ______ County.

d. X= ______ feet, Y= ______ feet, N.M. Coordinate System ______ Zone in the ______ Grant.

(B) Drilling Contractor Glenn's Water Well Service License No. WD 421

Address Box 692 Tatum, N.M. 88267

Drilling Began 12/1/89 Completed 12/2/89 Type tools rotary Size of hole 14 3/4 in.

Elevation of land surface or ______ at well is ______ ft. Total depth of well 234 ft.

Completed well is ☒ shallow ☐ artesian. Depth to water upon completion of well 105 ft.

Section 2. PRINCIPAL WATER-BEARING STRATA

Depth in Feet		Thickness in Feet	Description of Water-Bearing Formation	Estimated Yield (gallons per minute)
From	To			
105	228	113	sand	300

Section 3. RECORD OF CASING

Diameter (inches)	Pounds per foot	Threads per in.	Depth in Feet		Length (feet)	Type of Shoe	Perforations	
			Top	Bottom			From	To
10 3/4			1	234	234		128	228

Section 4. RECORD OF MUDDING AND CEMENTING

Depth in Feet		Hole Diameter	Sacks of Mud	Cubic Feet of Cement	Method of Placement
From	To				

STATE ENGINEER OFFICE
ROSWELL, NEW MEXICO
89 DEC 12 PM 3 44

Section 5. PLUGGING RECORD

Plugging Contractor ______
Address ______
Plugging Method ______
Date Well Plugged ______
Plugging approved by:

______
State Engineer Representative

No.	Depth in Feet		Cubic Feet of Cement
	Top	Bottom	
1			
2			
3			
4			

FOR USE OF STATE ENGINEER ONLY

Date Received December 12, 1989

Quad ______ FWL ______ FSL ______

File No. L-7481-S Use (CLOW) WF Location No. 17.35.30.33332

17.35.30.33332

Section 6. LOG OF HOLE

Depth in Feet		Thickness in Feet	Color and Type of Material Encountered
From	To		
0	3	3	soil
3	29	26	caleche
29	142	113	sand
142	144	2	cla y
144	215	71	sand
215	228	13	gravel
228	234	6	red clay

Section 7. REMARKS AND ADDITIONAL INFORMATION

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described hole.

Corky Glenn
Driller

INSTRUCTIONS: This for ·uld be executed in triplicate, preferably typewritten, and submitted t· appropriate district office of the State Engineer. Al. ·ns, except Section 5, shall be answered as completely and accurat· ·ossible when any well is drilled, repaired or deepeneo. ·nen this form is used as a plugging record, only Section 1(a) and Secti· ·eed be completed.

Form WR-23 STATE ENGINEER OFFICE FIELD ENGR. LOG

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

(Plat of 640 acres)

(A) Owner of well Republic Factors, Inc.
Street and Number P.O. Box 1540
City Midland, Texas State
Well was drilled under Permit No. L-6357-S and is located in the SW ¼ NW ¼ NW ¼ of Section 30 Twp. 17 Rge. 35
(B) Drilling Contractor Abbott Bros. License No. WD-46
Street and Number Box 637
City Hobbs, N.M. State
Drilling was commenced Sept. 18, 1972 19
Drilling was completed Sept. 20 19

Elevation at top of casing in feet above sea level Total depth of well 163'
State whether well is shallow or artesian Depth to water upon completion 85

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet From	Depth in Feet To	Thickness in Feet	Description of Water-Bearing Formation
1	80	163	83	sand water
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth Top	Depth Bottom	Feet	Type Shoe	Perforations From	Perforations To
7	23	10	1	163	163	noen	98	163

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet From	Depth in Feet To	Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used

Section 5 PLUGGING RECORD

Name of Plugging Contractor License No.
Street and Number City State
Tons of Clay used Tons of Roughage used Type of roughage
Plugging method used Date Plugged 19
Plugging approved by: Cement Plugs were placed as follows:

Basin Supervisor

No.	Depth of Plug From	Depth of Plug To	No. of Sacks Used

FOR USE OF STATE ENGINEER ONLY

Date Received STATE ENGINEER OFFICE DISTRICT II 1972 OCT 10 AM 8:37

File No. L-6357-S Use Com. Location No. 17.35.30.113-00

Section 6 **LOG OF WELL**

Depth in Feet From	Depth in Feet To	Thickness in Feet	Color	Type of Material Encountered
0	1	1	brown	surface soil
1	28	27	gray	caliche
28	80	52	brown	sand (tight)
80	163	83	brown	sand water

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Murrell Abbott
Well Driller

Form WR-23 FIEL[illegible] NGR. LOG STATE ENGINEER OFFICE

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

	B-1		

(Plat of 640 acres)

(A) Owner of well Kermac Potash Co.
Street and Number P. O. Box 610
City Hobbs State New Mexico
Well was drilled under Permit No. L-5850 and is located in the NE ¼ NE ¼ NW ¼ of Section 19 Twp. 17S Rge. 35E
(B) Drilling Contractor Abbott Bros. License No. WD-46
Street and Number P. O. Box 637
City Hobbs State New Mexico
Drilling was commenced Feb. 9 19 66
Drilling was completed Feb. 9 19 66

Elevation at top of casing in feet above sea level ______ Total depth of well 240 feet
State whether well is shallow or artesian shallow Depth to water upon completion hole caved

Section 2 PRINCIPAL WATER-BEARING STRATA

No.	Depth in Feet From	Depth in Feet To	Thickness in Feet	Description of Water-Bearing Formation
1	100	235	135	Alternating beds of fine grained sand, silt and gravel
2				
3				
4				
5				

Section 3 RECORD OF CASING

Dia in.	Pounds ft.	Threads in	Depth Top	Depth Bottom	Feet	Type Shoe	Perforations From	Perforations To

Section 4 RECORD OF MUDDING AND CEMENTING

Depth in Feet From	Depth in Feet To	Diameter Hole in in.	Tons Clay	No. Sacks of Cement	Methods Used
0	5	4-1/4		1	

Section 5 PLUGGING RECORD

Name of Plugging Contractor ______ License No. ______
Street and Number ______ City ______ State ______
Tons of Clay used ______ Tons of Roughage used ______ Type of roughage ______
Plugging method used ______ Date Plugged ______ 19 ______
Plugging approved by:

______ Basin Supervisor

Cement Plugs were placed as follows:

No.	Depth of Plug From	Depth of Plug To	No. of Sacks Used
1	0	5	1

FOR USE OF STATE ENGINEER ONLY

Date Received STATE ENGINEER OFFICE ROSWELL 1966 FEB 23 AM 8:41

File No. L-5850 Use Expl Location No. 17.35.19.122

Section 6 LOG OF WELL

Depth in Feet		Thickness in Feet	Color	Type of Material Encountered
From	To			
0	0.5	0.5	dark brown	alluvium
0.5	15	14.5	lt brn	caliche
15	75	60	lt brn	fine grained, poorly cemented sand
75	77	2	white	dense lens with chest stringers
77	80	3	lt brn	fine grained, poorly cemented sand
80	90	10	lt brn	fine grained unconsolidated sand
90	130	40	lt brn	fine grained poorly cemented sand
130	140	10	lt brn	fine grained unconsolidated sand
140	195	55	lt brn	fine to med. poorly cemented sand
195	210	15	red	arenaceous siltstone
210	235	25	variegated	quartz gravel
235	240	5	red	stilstone top Santa Rosa

L S Elev 3989

Depth to K ____ Tr 235

Elev of K ____ Tr 3754

Loc. No. 17.35.19.12222

Hydro. Survey Field Check X

SOURCE OF ALTITUDE GIVEN

Interpolated from Topo. Sheet X

Determined by Inst. Levelling ____

Other ____

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

____
Well Driller

L-5950

17.35.19.122

Attachment D
Explanation of HYDRUS Model

R.T. Hicks Consultants, Ltd.
901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104

R. T. HICKS CONSULTANTS, LTD.

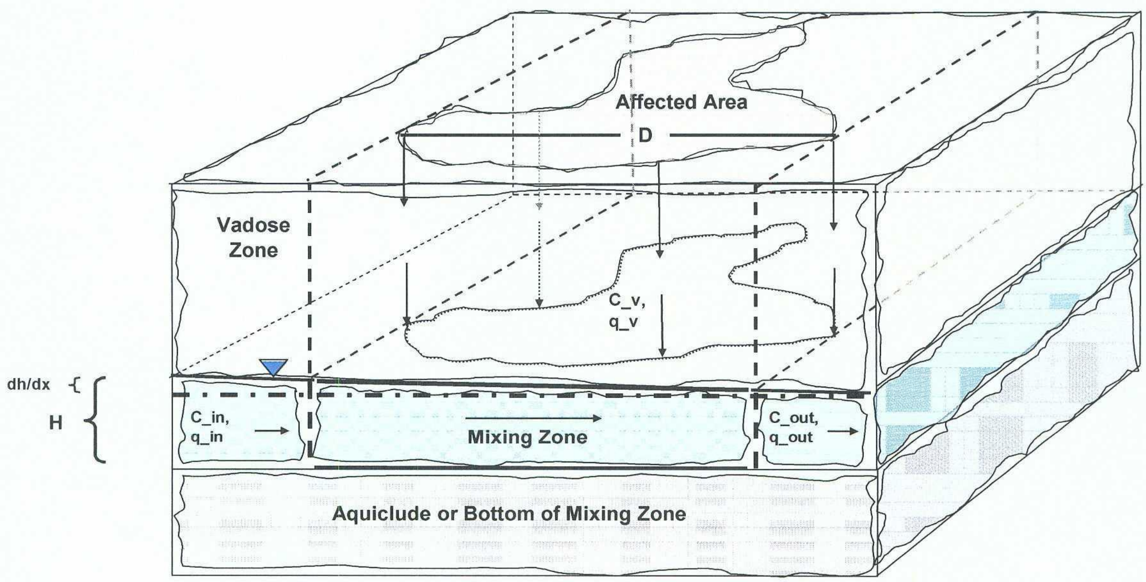
901 Rio Grande Blvd NW ▲ Suite F-142 ▲ Albuquerque, NM 87104 ▲ 505.266.5004 ▲ Fax: 505.266-0745

Attachment D: Explanation of Simulation Modeling

The simulation presented herein predicts the effects on ground water quality from the averaged chloride profile constructed from the trench and boring sample data obtained at the site. For all inputs for which there was not site-specific data, assumptions were used in the modeling which resulted in an exaggerated adverse impact to soil and/or ground water. Such a model is referred to as conservative of ground water quality in this attachment.

The simulation is designed to predict the effect chloride migration through the vadose zone has on ground water quality. To do this, the output of the unsaturated zone model HYDRUS-1D is used as input to a ground water mixing model that returns a calculation of the water quality at a hypothetical well at the down gradient edge of a site.

Figure 1: *HYDRUS-1D input to the mixing zone is the chloride flux through time (C_v(t) x q_v(t)). Mixing Model inputs include the entering ground water chloride flux (C_in x q_in) and aquifer properties and dimensions (K, D, H, and dh/dx).*



D - Maximum diameter of release or maximum diameter of release parallel to ground water flow
H - Height of mixing zone, assumed constant for the length of the mixing zone, D, and much larger than dh/dx
dh/dx - ground water gradient
K - Hydraulic conductivity of water bearing strata
C_in - background chloride concentration in ground water entering the mixing zone
C_v - chloride concentration of vadose zone water entering ground water
C_out - chloride concentration of ground water leaving the mixing zone
q_in - flux of ground water into the mixing zone
q_v - flux of vadose zone water into the mixing zone
q_out - flux of ground water leaving the mixing zone

HYDRUS-1D numerically solves the Richard's equation for vadose zone water flow (water flow between the ground surface and the water table) and the Fickian-based advection-dispersion equation for heat and solute transportation. The HYDRUS-1D flow equation allows the inclusion of a sink term (a term used to specify water leaving the system) to account for transpiration by plants when applicable. The solute transport equation considers advective, dispersive transport in the liquid phase. Depending on the solute, it can also consider diffusion in the gaseous phase, nonlinear and non-equilibrium sorption, linear equilibrium reactions between the liquid and gaseous phases, zero-order production, and first-order degradation.

The ground water mixing model uses the chloride flux from the vadose zone to ground water provided by HYDRUS-1D and instantaneously mixes this chloride flux with the ground water flux of chloride that enters the mixing cell beneath the subject site. The reader is referred to API Publication 4734, Modeling Study of Produced Water Release Scenarios (Hendrickx and others, 2005) for a general description of the techniques employed for this simulation experiment.

For these simulations, the migration through the vadose zone of a conservative solute (chloride) was modeled at a constant temperature. Vegetation, a sink term for water content in the root zone, was employed.

Input data includes:

Site Hydrogeology
Data from the USGS (Water Table Levels and Aquifer Saturated Thickness in Lea County, Tillery, 2008) and MW-1 show that:

- The site overlies the Ogallala Aquifer
- Depth to water is about 60 feet below ground surface
- Ground water flows southeast under a regional hydraulic gradient of about 0.003 (see Plate 3)

Data from an Office of the State Engineer (OSE) Technical Report 99-1 (Numerical Simulation of Groundwater Flow for Water Rights Administration in the Lea County Underground Water Basin New Mexico) characterized the area with these properties:

- The saturated thickness of the Ogallala at the site locale is 100-149 feet (USGS map of 2007 lists a thickness of 120-140 feet for this locale)
- The hydraulic conductivity of the Ogallala is between 21 to 40 ft/day

Data on chloride in ground water from the PTTC database shows the average chloride concentration in ground water near the site is about 40 mg/L. This concentration was used as a background concentration in the model, discussed below.

Attachment C presents water well driller's logs from a nearby water supply well and a detailed monitoring well log of the Ogallala Formation near Buckeye, NM which show:

- The saturated thickness in this area ranges between 60 and 80 feet
- The unsaturated zone is comprised of caliche, "rock" (well indurated caliche), fine-grained sand, silt, and/or fine-grained sand with interbedded caliche

A description of the model input parameters to HYDRUS-1D and then to the mixing model are listed below.

HYDRUS INPUTS

Soil Profile – The vadose zone is about 60-feet thick as shown by nearby well logs (see Attachment C). The soil profile was based upon the 3 trenches and 5 borings made at the site. To be conservative of ground water quality, the profile minimized the thickness of layers with low hydraulic conductivity. Such a soil profile moves soil moisture and solutes to ground water at a faster rate than a soil profile with higher hydraulic conductivities.

The profile was constructed to include 4 caliche layers with a total thickness of 13-feet. The rest of the soil profile is composed of sandy loam, loamy sand, and sand.

Dispersion lengths - Standard modeling practice calls for employing a dispersion length that is 10% of the model length and was used in the simulations.

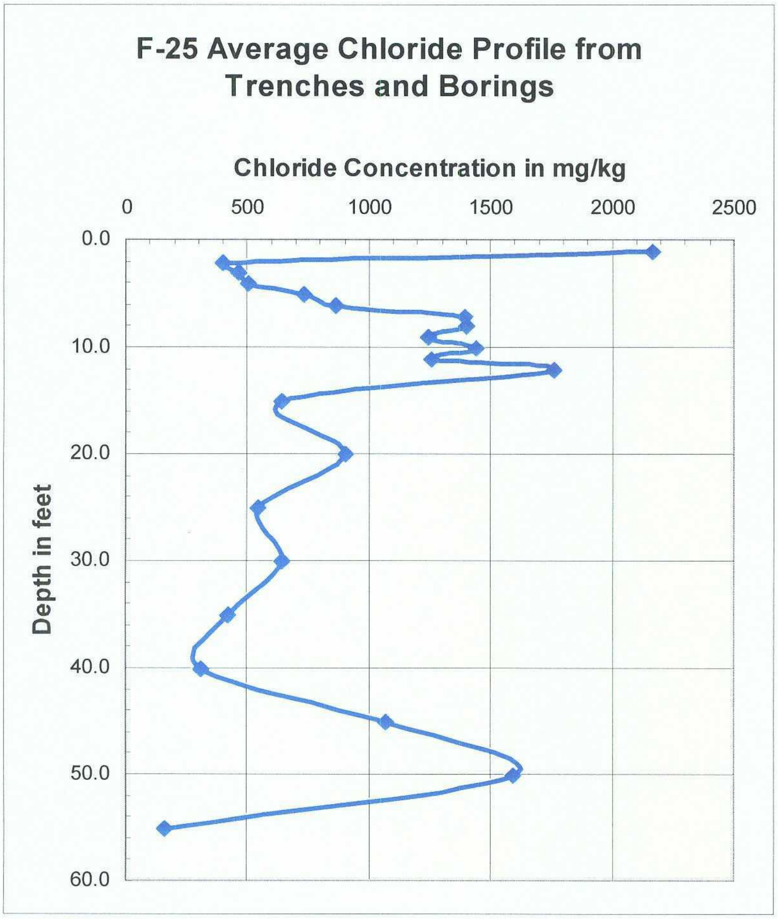
Climate - Weather data used in calculation of the initial condition and the predictive modeling was from the Pearl, New Mexico weather station, less than 15 miles south-southwest of the site. This station is the closest station to the site for which the necessary HYDRUS-1D input file exists. Climates on the Great Plains of eastern New Mexico are similar enough that this was considered an acceptable choice. The weather data spans the 46. 5 year period from July, 1946 to December, 1992

HYDRUS-1D can also employ a uniform yearly infiltration rate that will obviously smooth the temporal variations. However, because the atmospheric data are of high quality and nearby to the site, it is conservative of ground water quality to use this data as the surface input to HYDRUS-1D. Because vadose zone hydraulic conductivity varies with moisture content, the difference in predicted moisture movement rates between extended dry periods and extended wet periods can vary by a factor of 10. Using the daily atmospheric data results in higher predicted peak chloride concentrations in ground water and is, therefore, conservative of ground water quality.

Soil Moisture - Because soils are relatively dry in this climate and vadose zone hydraulic conductivity varies with moisture content, it is important that simulation experiments begin with representative soil moisture content. Commonly, the calculation of soil moisture content begins with using professional judgment as an initial input and then running sufficient years of weather data through the model to establish a "steady state" moisture content. For this simulation, only minimal changes in the HYDRUS-1D soil moisture content profile occurred after year 25 of the initial condition calculation. Therefore, 93 years (2 cycles of the 46.5 years of weather data) was considered sufficient to establish an initial moisture condition. This vadose zone moisture content profile was used as the initial condition for subsequent simulations.

Initial Chloride Profile – The averaged chloride concentration profile from the trench and boring data was used and is shown in Figure 2 below. This profile was used in the simulation with the exception that the uppermost 4-feet of the soil profile is replaced with clean soil in the selected site remedy.

Figure 2



Vegetation – In the initial condition simulation, no vegetation was assumed to exist. Without vegetation, there is no removal of water from the root zone through transpiration. There is only evaporation from the surface. This is conservative of ground water quality in that a "wetter" vadose zone has higher hydraulic conductivity resulting in a greater solute flux to ground water.

In the remedy simulation, vegetation is part of the design and was allowed a root zone depth of two-feet above the installed liner.

MIXING MODEL INPUTS

As described in API Publication 4734, the ground water mixing model takes the background chloride concentration in ground water multiplied by the ground water flux and the mixing zone thickness (aquifer height) to calculate the chloride flux entering the ground water mixing zone below the area of interest. The chloride concentration of vadose zone water multiplied by the water flux from the vadose zone, (both calculated by HYDRUS-1D) and the length of the release area results in the chloride flux entering the mixing zone from above. Addition of the two chloride fluxes gives the total chloride flux entering the mixing zone. Because the outgoing water flux and the thickness of the mixing zone (aquifer height) are known, the chloride concentration in ground water, the only unknown, can be calculated. This is equivalent to the chloride concentration in a conceptual monitoring well located at the down gradient edge of the mixing zone (the edge of the release area). See Figure 1 above.

Influence Distance (D) - The influence distance is defined as the maximal length of the application parallel to the direction of ground water flow. As the exact direction of ground water flow is not known, this dimension was assumed to be 42 feet, the maximum diagonal of the 30 foot by 30 foot site delineation.

Background Chloride Concentration (C_in) is an average of nearby wells in the PTTC database. The value of 45 mg/L chloride concentration in ground water was used.

Hydraulic Conductivity (K) - Freeze and Cherry (1979) list hydraulic conductivities for clean sands as 10 feet/day to more than 2,500 feet/day. Musharrafieh and Chudnoff (1999) assigned a range of hydraulic conductivity of 21 to 40 feet per day to the site area. To be conservative of ground water quality, the lowermost value was used. Lower hydraulic conductivities result in a lower ground water flux. As such, the solute flux from the vadose zone is mixed with a smaller volume of ground water giving a higher predicted chloride concentration in ground water at the down-gradient edge of a release site.

Groundwater Gradient (dh/dx) – In order to have a gradient representative of the system, the water table was assumed to be generally parallel to topography. A representative gradient for the area is 0.0033. The resulting ground water flux is 2.1 cm/day (0.07 feet/day).

Aquifer Thickness (H) - The Musharrafieh and Chudnoff model predicts that saturated thickness of the aquifer beneath the site will be between 100 and 149 feet from now through the year 2040. The USGS map of saturated thickness for Lea County (2007) lists a thickness of 140-160 feet for this locale. For the simulations, a conservative choice of a 15-foot thick aquifer was made.

Data from similar sites show that, unlike hydrocarbons, chloride that enters the upper portion of an aquifer will become distributed throughout the entire saturated thickness within a relatively short travel distance from the source. In either event, the predicted concentration is what would be observed in a well screened over the conservative thickness.

For all variables for which field data did not exist, assumptions conservative of ground water quality were made. A summary of the input parameters and a description of the source information used in the HYDRUS-1D model for this application are provided in Table 1 below.

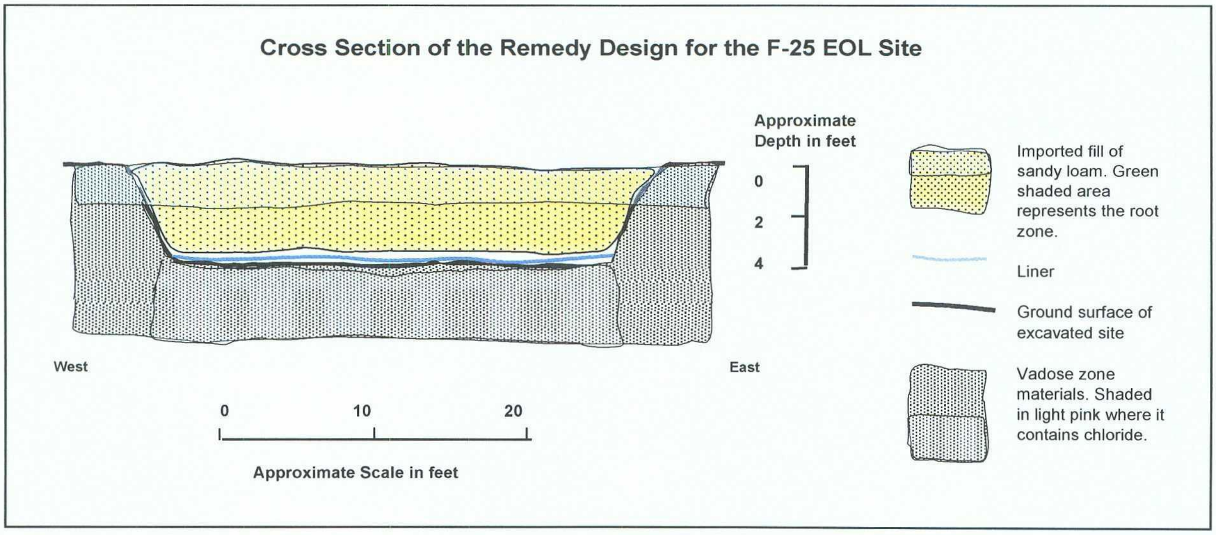
Table 1

Modeling Inputs for the F-25 Site Predictive Modeling	
Input Parameter	**Source**
Vadose Zone Thickness - 60 feet	From Nearby Well logs
Vadose Zone Texture	Five Boring logs from the site
Dispersion Length – 10% of model length	Standard Modeling Practice
Climate	46.5 years of Pearl N.M. Weather Station data
Soil Moisture	HYDRUS-1D initial condition simulation
Initial soil chloride Concentration Profile	Chloride Concentration data from the 3 trenches and 5 borings
Aquifer Thickness – 15 feet	Conservative assumption
Background Chloride in Ground Water 45 mg/L	PTTC/PRRC Chloride Concentration Data
Ground Water Flux – 2.1 cm/day (0.07 feet/day)	Calculated with conservative hydraulic conductivity estimate and slope of topography
Length of release parallel to ground water flow - 42 feet	Largest possible diameter of the site

REMEDY DESIGN

The proposed remedy for the site consists of a 30-foot by 30-foot liner placed at the bottom of a 4-foot deep excavation centered over the site. Clean fill is to be placed above the liner and vegetation will be established. Figure 3, below, is a schematic cross section of the remedy for the site.

Figure 3



Installation of the liner stops all infiltration of surface water to the vadose zone beneath the liner. As the moisture beneath the liner continues to move downwards due to gravity, the upper vadose zone beneath the liner becomes drier. Because unsaturated flow varies directly with moisture content, the downwards moisture movement rate through the drier soils decreases. The resulting decrease in moisture movement rate first occurs in the depth interval directly under the liner and the effect spreads downwards over time. The last depths affected are those closest to the water table.

In the 4-feet of soil above the liner, vegetation has been established. As such, the soil loses moisture through evaporation and from the plant's transpiration. The soil is "drier" than soil without vegetation which only loses water from evaporation. Since hydraulic conductivity in unsaturated soil decreases with decreasing moisture content, moisture movement rates are less than that of bare soil.

As the liner degrades, moisture that has infiltrated beneath the root zone begins to enter the dry soil beneath the liner. Hydraulic conductivity of the soils beneath the "holes" increases but will not equal the moisture movement rates of bare soils. As the liner completely degrades, moisture movement rates throughout the site increase to these rates.

METHOD OF REMEDY SIMULATION

Inputs for the simulation are synopsized above in Table 1. The liner was assumed to maintain integrity for 40 years and then to degrade completely in an additional 100-years. In order to simulate the effect of the remedy on ground water:

1) The simulation was started with the calculated initial condition moisture contents.

2) To model the lined 30-foot by 30-foot site, the HYDRUS 1-D model was constructed in two parts:
   i) The lower 56-feet of the vadose zone with the appropriate section of the averaged chloride concentration profile (Figure 2) was run in HYDRUS-1D for 40 years with a no flux upper boundary condition to simulate an intact liner. No moisture enters the soil column from above with this condition.
   ii) To model the assumed 100-year degradation of the liner, the 4.0-foot thick vadose zone above the liner was run for 100 years with the lower boundary modeled as a free drainage face. In this circumstance, at each time step, the amount of moisture entering the lowermost depth interval of the model is assumed to leave that depth interval. This moisture flux emerging from the bottom of the 4-feet of soil above the liner was saved for use in modified form as an input to the 56-foot thick lower soil profile. The flux was multiplied by a factor set equal to 0.0 at Time = 40 years, the beginning of the liner degradation. The flux was "turned on" linearly and reached "full value" (the factor =1.0) at the end of the assumed 100-year liner degradation. For example, at 50-years into the liner degradation time interval, half of the moisture flux was allowed to pass through to the soil profile below the liner.

3) At the end of the 100 year liner degradation, the two HYDRUS-1D models were re-combined. As the liner no longer exists, the upper boundary condition is now the weather data from Pearl, N.M. and the water table is the lower boundary condition. The time appropriate chloride and moisture content profiles were used with the rejoined soil profiles. The re-combined model was run for another 125 years, approximately 2.7 cycles of the Pearl, N.M. weather data.

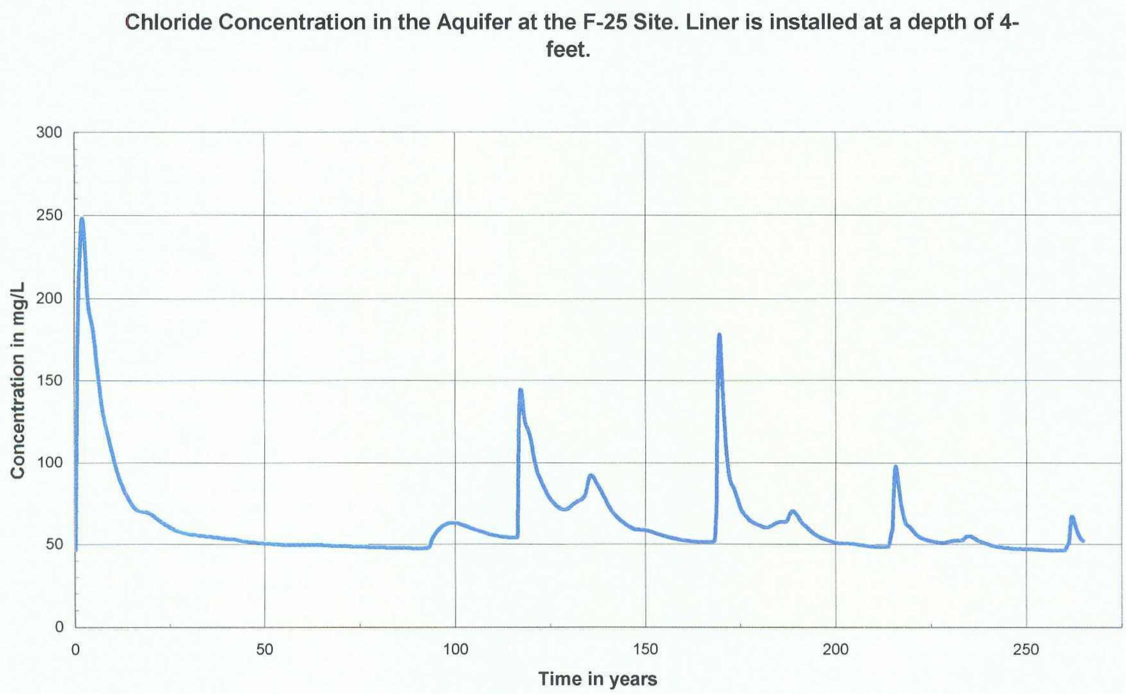
4) The resulting water and chloride fluxes from the site are used as inputs to the simple ground water mixing model to predict chloride concentration that would be seen in a monitoring well at the down-gradient edge of the F-25 site.

The simulation was run for a total time of about 265 years.

RESULTS OF SIMULATION

Figure 4 shows the predicted chloride concentration in ground water at the down gradient edge of the F-25 EOL site with the installed liner. As can be seen, chloride concentration exceeds 200 mg/L for about 2.5 years in the first 3.5 years of the simulation. This is due to the chloride mass near ground water in the soil profile (see Figure 2) entering ground water before the installation of the liner has taken full effect in the lowermost vadose zone.

Figure 4



Chloride concentration in ground water declines after this peak concentration for about 90 years to near background concentrations. After year 40 of the simulation, the liner has begun degrading and to allow moisture to infiltrate at an increasing rate. The moisture flux through the soil profile is sufficient to cause an increase in chloride concentration in ground water 52-years later at Year 92. The liner has completely degraded by year 140.

The local peak chloride concentrations (Years 117, 169, 215) are a result of high moisture fluxes from the vadose zone to ground water associated with earlier "wet" periods (closely associated El Nino years). The predicted maximum chloride concentration of about 170 mg/L occurs about 30 years after the assumed disintegration of the liner. For all but about 20-years of the 265-year simulation, chloride concentration in ground water is less than 100 mg/L.

CONCLUSIONS

1. No exceedance of WQCC water quality standards is predicted by the simulation of the site remedy.
2. Because data and assumptions made for the site were chosen to be conservative of ground water quality, the model is designed to over predict impact to ground water quality.