AP - 50

STAGE 2 REPORTS

DATE: 4-1-08

BD Zachary Hinton EOL

AP-50

CLOSURE

4-1-08

RICE OPERATING COMPANY

JUNCTION BOX CLOSURE REPORT

BOX LOCATION

SWD SYSTEM	JUNCTION	UNIT	SECTION	TOWNSHIP	RANGE	COUNTY	BOX DIMENSIONS - FEET		
							Length	Width	Depth
BD	Zachary Hinton EOL	O	12	22S	37E	Lea	6	5	6

LAND TYPE: BLM ______ STATE ______ FEE LANDOWNER Tom Kennann OTHER ______

Depth to Groundwater 56 feet NMOCD SITE ASSESSMENT RANKING SCORE: 10

Date Started 2/6/2001 Date Completed 1/24/2007 NMOCD Witness no

Soil Excavated 0 cubic yards Excavation Length 0 Width 0 Depth 0 feet

Soil Disposed 0 cubic yards Offsite Facility n/a Location n/a

General Description of Remedial Action:

This junction box was delineated according the the Junction Box Upgrade Work Plan. One monitoring well was installed on site in Feb. 2002.

A March 2007 "Final Site Investigation Report & Abatement Completion Report" by Hicks requests closure of this junction box site and is included with this form.

enclosures: Closure letter from Hicks (Dec. 2007)

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

REPORT ASSEMBLED BY Kristin Farris Pope SIGNATURE Kristin Farris Pope

DATE 3/12/2007 TITLE Project Scientist

R. T. HICKS CONSULTANTS, LTD.

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

March 15, 2007

Mr. Wayne Price
Environmental Bureau Chief
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

RE: Zachary Hinton EOL Junction Box Final Site Investigation and Abatement Completion Report, NMOCD #: AP-50

Dear Mr. Price:

On behalf of Rice Operating Company, we are pleased to submit the Final Site Investigation and Abatement Completion Report for the above-referenced site. This report fulfills the obligations of ROC presented in the Stage 1 & 2 Abatement Plan of October, 2005, verbally approved by NMOCD in March, 2006. The signed Junction Box Closure Report is attached. We are pleased to report that the chloride concentration in samples from the on-site monitoring well has returned to background levels. We conclude that the residual chloride in the vadose zone poses no threat to human health or the environment. We recommend filling the excavation with soil capable of sustaining vegetation and plugging the monitoring well.

Please contact us with any comments or questions regarding our recommended closure protocol for this site.

Sincerely,
R.T. Hicks Consultants, Ltd.

Randall Hicks
Principal

CC: NMOCD Hobbs office, Rice Operating Company

RICE OPERATING COMPANY

JUNCTION BOX CLOSURE REPORT

BOX LOCATION

SWD SYSTEM	JUNCTION	UNIT	SECTION	TOWNSHIP	RANGE	COUNTY	BOX DIMENSIONS - FEET		
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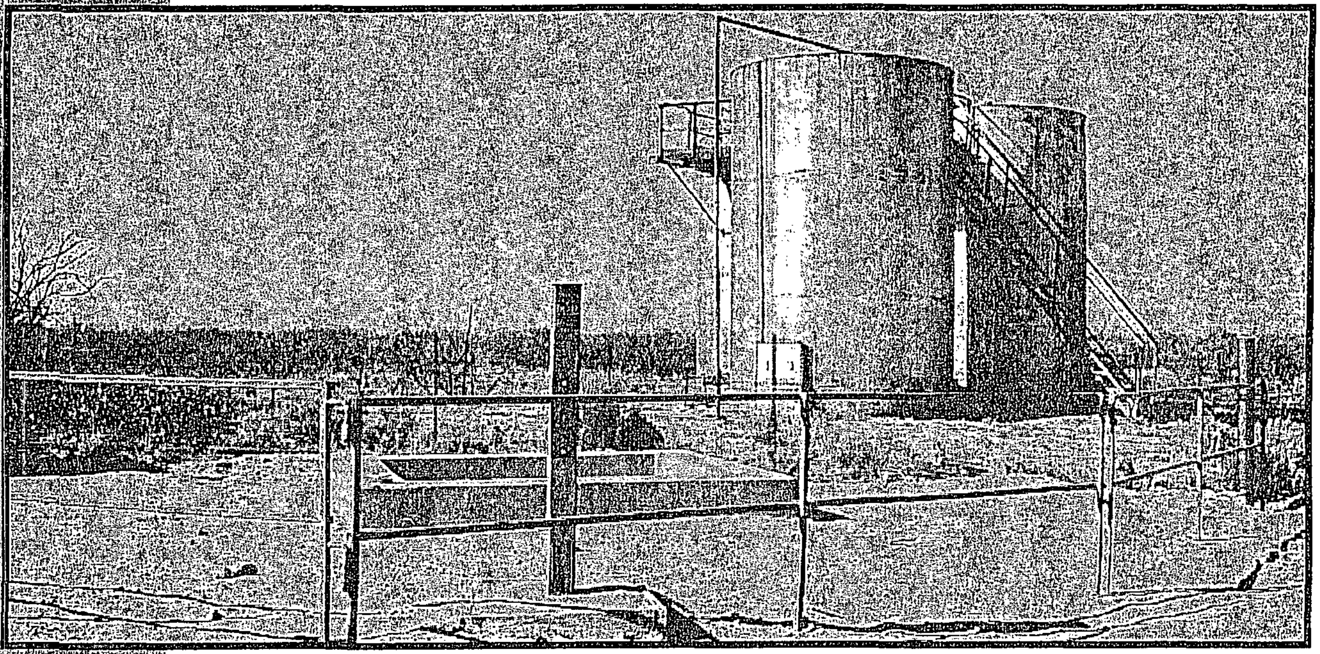
March 13, 2007



Final Site Investigation Report & Abatement Completion Report: Zachary Hinton EOL Junction Box

R.T. Hicks Consultants, Ltd.

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

March 13, 2007

Final Site Investigation Report & Abatement Completion Report: Zachary Hinton EOL Junction Box

(O-12) Sec. 12, T22S-R37E

NMOCD case #: AP-50

prepared for:

Rice Operating Company
122 West Taylor
Hobbs, NM 88240

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

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

This final Site Investigation and Abatement Completion Report presents the results of the characterization activities performed by R.T. Hicks Consultants (Hicks Consultants) and the characterization and site closure activities performed by Rice Operating Company (ROC) at the Zachary Hinton EOL Junction Box site. This report fulfills the obligations of ROC presented in the Stage 1 & 2 Abatement Plan of October. 2005, verbally approved by NMOCD in March, 2006. Based on field data, laboratory results, and predictive modeling, the selected remedy for the site involved placing clean fill within the excavation and placing about 3 feet of topsoil and over the site installed with a slight crown to promote surface runoff, then seeding the site with native vegetation. Using highly conservative input data, a MODFLOW transport module of this scenario predicts that resulting ground water chloride concentrations due to migration of residual chloride to ground water will be less than 70 ppm above background concentrations after five years.

Ground water monitoring data confirm that the HYDRUS-1D predictions are conservative in that they over estimate the impact of residual chloride transport to ground water. After two years of ground water monitoring, chloride concentrations in ground water beneath the site have returned to ambient conditions (300–400 ppm).

Background conditions at the site have been confirmed through chemical analysis of several surrounding wells and consultation of local ground water research. Ground water quality at the site (MW-1) has returned to background conditions. We do not believe that additional ground water monitoring is necessary. Based on our physical findings, the findings of the MODFLOW simulations (see Appendix C), and the documentation that the site is backfilled and re-seeded, we conclude that this remedy is protective of ground water quality, human health, and the environment. On behalf of ROC, we repectfully request that NMOCD close the regulatory file.

2.0 CHRONOLOGY OF EVENTS

The Disclosure Report prepared by Rice Operating Company (ROC) in January 21. 2003 (see Appendix A). summarizes the initial activities at the site. On August 21, 2003, NMOCD approved the Hicks Consultants workplan dated July 2, 2003, for the site (see Appendix B). Since the initial upgrade of the end-of-line box and installation of the monitoring well in 2002, ROC has overseen nearly four years of ground water sampling. In October, 2005. Hicks Consultants submitted a Stage 1 & 2 Abatement plan for the site, which NMOCD verbally approved after public notice on March 30, 2006. In October, 2006, Hicks Consultants constructed and ran a MODFLOW model to predict the fate and transport of chloride at the Zachary Hinton EOL Junction Box site. Table A, below, summarizes the chronology of events at the site.

Table A. Chronology of Events at the Zachary Hinton EOL Box

Date	Event
February 6, 2002	ROC upgrades EOL junction box and characterizes upper vadose zone
February 28, 2002	ROC installs monitoring well adjacent to EOL junction box
March 12, 2002	ROC notifies NMOCD of groundwater impact
April, 2002, to June, 2003	ROC conducts four quarters of ground water monitoring to confirm initial results and collect data in preparation for a corrective action plan
July 2, 2003	Hicks Consultants submits a work plan to NMOCD for approval
August 21, 2003	NMOCD approves the workplan, including collection of ground water quality data from nearby supply wells and HYDRUS-1D simulation modeling
January 30, 2004	Hicks Consultants submits a Corrective Action Plan for NMOCD approval
December 3, 2004	NMOCD requests additional information
December 8, 2004	Hicks Consultants provides requested information
May 5, 2005	NMOCD orders ROC to submit an Abatement Plan pursuant to Rule 19
June 29, 2005	Hicks Consultants requests reconsideration of Abatement Plan Requirement
July 13, 2005	NMOCD reiterates Abatement Plan Requirement
October 12, 2005	Hicks Consultants submits a Stage 1 & 2 Abatement Plan
December 28, 2005	NMOCD approves public notice
January 11, 2006	ROC sends public notice to appropriate landowners
January 18, 2006	Public notice published in *Albuquerque Journal* and *Hobbs News Sun*
February 10, 2006	ROC mails proof of public notice publication to NMOCD
March 30, 2006	NMOCD verbally approves the Stage 1 & 2 Abatement Plan and public notice
October 6, 2006	Hicks Consultants runs a MODFLOW model for the site
November, 2006	ROC backfills excavation with clean, imported fill and installs a new junction box at the site
January, 2007	ROC re-seeds the site

3.0 BACKGROUND

3.1 SITE LOCATION AND LAND USE

The Zachary Hinton EOL Junction Box is located about 2.5 miles southeast of the intersection of State Routes 18 and 8/176, near Eunice, New Mexico. Plate 1 shows the location of the site. The general area of the site is used for grazing and production.

3.2 SUMMARY OF DATA PREVIOUSLY SUBMITTED TO NMOCD

1. In early 2002, ROC upgraded the junction box, characterized the upper vadose zone, and installed a monitoring well about 20 feet down gradient from the former box.
2. Chloride concentrations in the vadose zone exceeded 1,000 ppm from 5 feet below ground surface to ground water.
3. The first ground water sample from the monitoring well exhibited a chloride concentration of 1,000 ppm.
4. Sampling of nearby supply wells demonstrates that the ambient chloride concentration in ground water is 300-400 ppm near the site.
5. Nine months of quarterly monitoring after installation of the monitoring well, chloride concentrations in samples from the monitoring well returned to the regional background concentration, 300–400 ppm.

Previous submissions to NMOCD that provide additional detail regarding these data are presented in Appendix A.

4.0 GEOLOGY & HYDROGEOLOGY

The Ogallala Formation is present throughout much of the area and is underlain by the Dockum Group red-beds. Along Monument Draw, erosion has stripped the Ogallala and deposition of alluvium over the red-beds has created a separate aquifer that is hydraulically connected to the Ogallala in many locations (see Nicholson and Clebsch, 1961).

The Zachary Hinton EOL Junction Box is in the middle of the alluvium within Monument Draw. The Dockum Group red beds are an aquiclude below the Ogallala and alluvial aquifers. In the area of the Zachary Hinton EOL junction box, the red bed elevation contours define a paleo-valley just west of and subparallel to Monument Draw. The elevation of the red-bed surface exerts controls on ground water flow. Where this surface is higher than the water table elevation, it obviously creates a barrier to flow. Where the red-bed surface is an expression of a paleo-valley, such as our area of interest, ground water may be directed toward the axis of this subsurface feature and the saturated thickness of the aquifer can increase as a result.

Plate 2 is the ground water map of southern Lea County (Nicholson and Clebsch, 1961). The water table elevation mimics the red-bed elevation. At the Zachary Hinton EOL junction box site, ground water flows south, parallel to Monument Draw. Nicholson and Clebsch (1961) conclude that "The bulk of the water [in the sediments along Monument Draw and under the Eunice Plain] is derived by underground flow from the Laguna Valley [Monument] area." The red-bed surface map and the water table map support this hypothesis.

Although Nicholson and Clebsch note that the quality of the City of Eunice water supply wells is about 100 mg/L chloride (locations of the wells noted in Nicholson and Clebsch are noted on Plate 3 with sample dates from the late 1950s), a more detailed investigation of ground water quality in the area near the Zachary Hinton EOL site shows higher background levels. Plate 3 shows the locations of wells with past water quality found by Nicholson and Clebsch and present water quality data collected since 2003. Table 2 (below) presents the results for chloride.

Table 2: Chloride Data for Wells Surrounding Zachary Hinton Site (see Plate 3)

Well Name	**Sample Date**	**Chloride (mg/L)**
22S.37E.24.133B	9/8/1958	580
22S.37E.01.P.444	9/8/1958	320
Windmill	12/18/2003	460
Peters Well West	11/7/2003	200
Peters Well East	11/7/2003	438
Jct. E-15 MW #1	10/26/2006	396
Jct J-26 MW #1	10/23/2006	193
Jct. Zachary Hinton (O-12)	8/10/2005	361
Jct. I-27	12/2/2002	266

Using Nicholson and Clebsch (1961) data, we estimate the saturated thickness of the alluvium in our area of interest is approximately 25–75 feet (2.6–22 meters). As shown on Plate 2, the hydraulic gradient in our area of interest is about 0.004. From these data and information provided in Freeze and Cherry (1979), we calculate the rate of ground water flow as 0.14 m/d.

Surface water in the area is ephemeral and flows in Monument Draw occur only after large precipitation events. We found no evidence to suggest that the release from the junction box affected Monument Draw in any manner; therefore, this document does not provide information on surface water hydrogeology.

5.0 MODFLOW SIMULATION

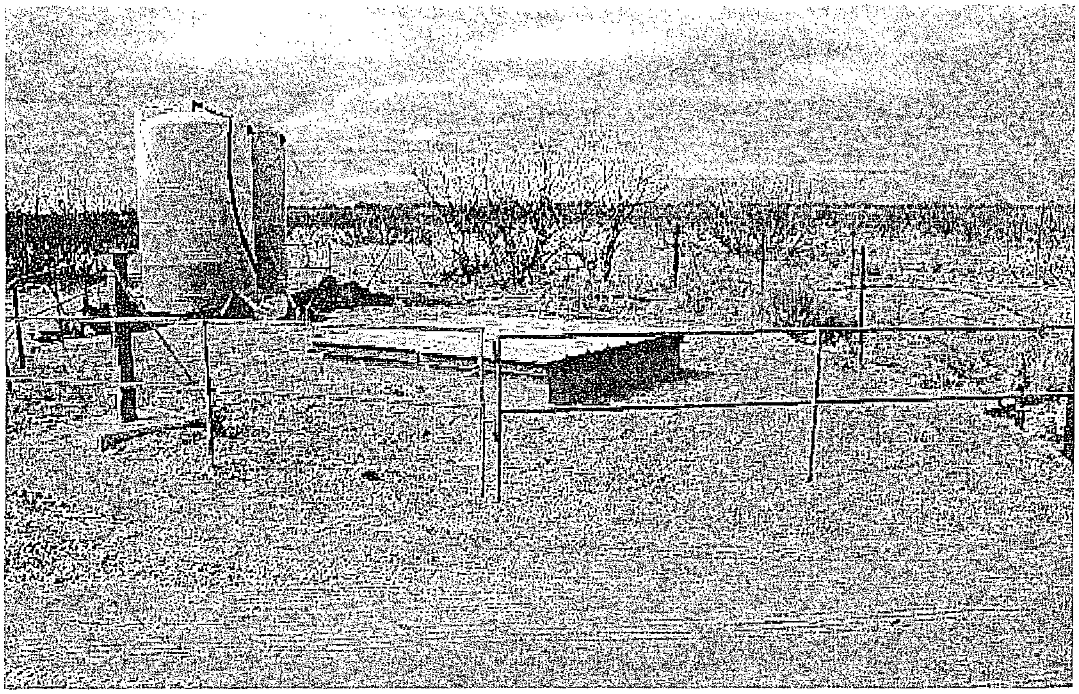
As proposed in the Stage 1 & 2 Abatement Plan of the October 12, 2005, Hicks Consultants used MODFLOW and its contaminant transport module to predict the fate and transport of the historic impact to ground water quality evidenced by the first sample analysis. Appendix C presents a thorough explanation of the model design, inputs and results. The predictive modeling tested the hypothesis that natural dilution and dispersion effectively mitigated any past impact to ground water quality at the site and down-gradient from the site.

The model predicts that natural dilution and dispersion rapidly reduce chloride concentrations in ground water after the cessation of recharge (i.e. intermittent brine releases from the EOL Junction Box).

6.0 Closure of the Excavation

In early November 2006, ROC imported twenty-four yards of clean soil and back-filled the hole at the site according to our proposal. A new junction box was built in the original location. The surrounding area was re-seeded with a mixture of native grasses and plants that will re-vegetate the area at a natural rate. Figure 1 shows the site after the excavation was filled, the box was replaced, and the site was re-seeded.

Figure 1: Zachary Hinton Site After Box Replacement Filling, and Re-Seeding



7.0 QUALITY ASSURANCE/QUALITY CONTROL PROTOCOLS

Sampling and analytical procedures were performed in accordance with Title 20 NMAC 6.3107.B and Section 103 of the Water Quality Standards for Interstate and Intrastate Streams in New Mexico (20 NMAC 6.1). Specific quality procedures for obtaining ground water samples are included in Appendix E.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Natural dilution and dispersion have restored ground water quality down-gradient from the release site as well as at the release site. Additional monitoring of the existing well provides no value as ground water quality has returned to background conditions. The ground surface is now restored and re-seeded. On behalf of ROC, we respectfully request closure of the Rule 19 regulatory file associated with this site.

Plates

R.T. Hicks Consultants, Ltd.

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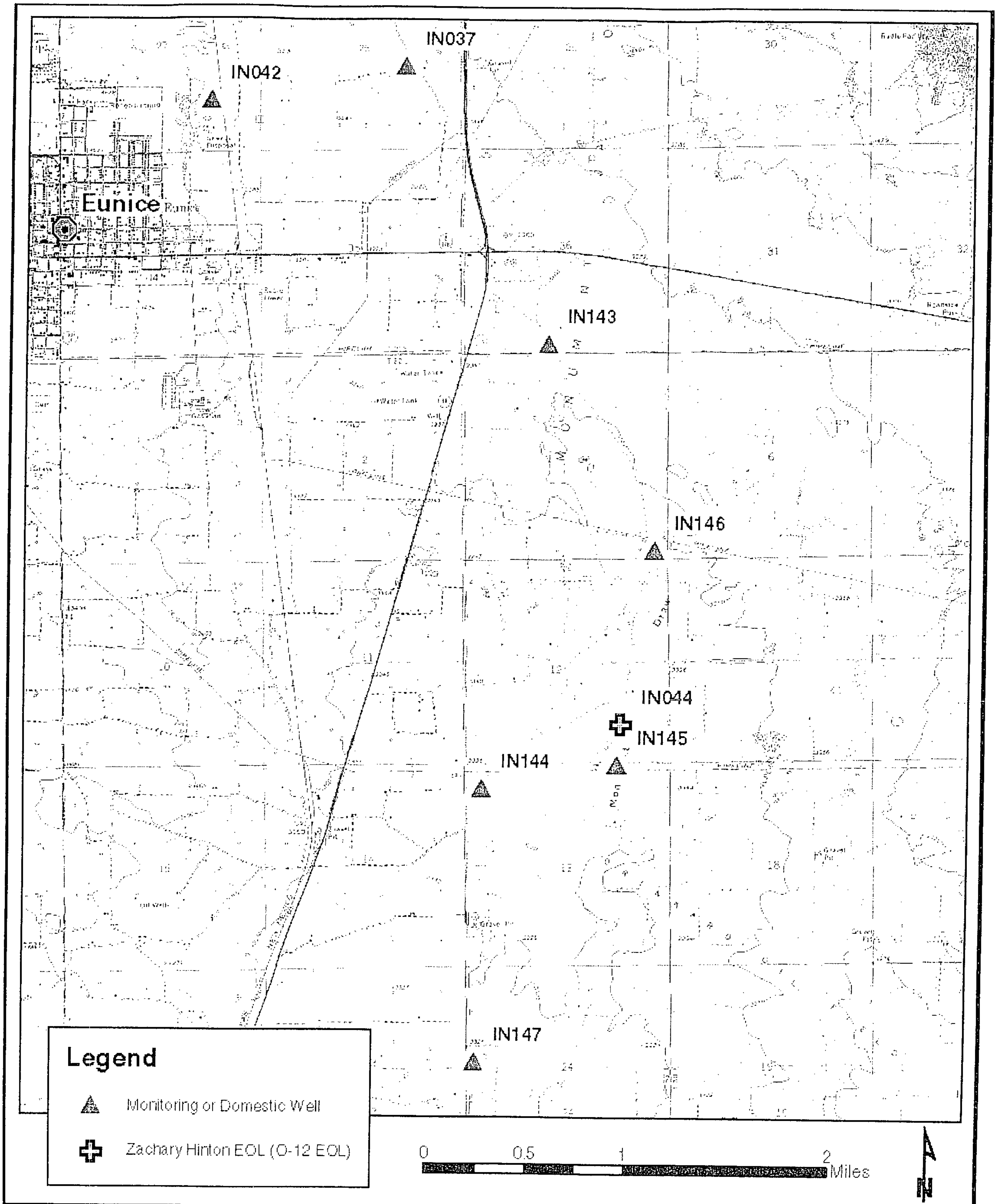
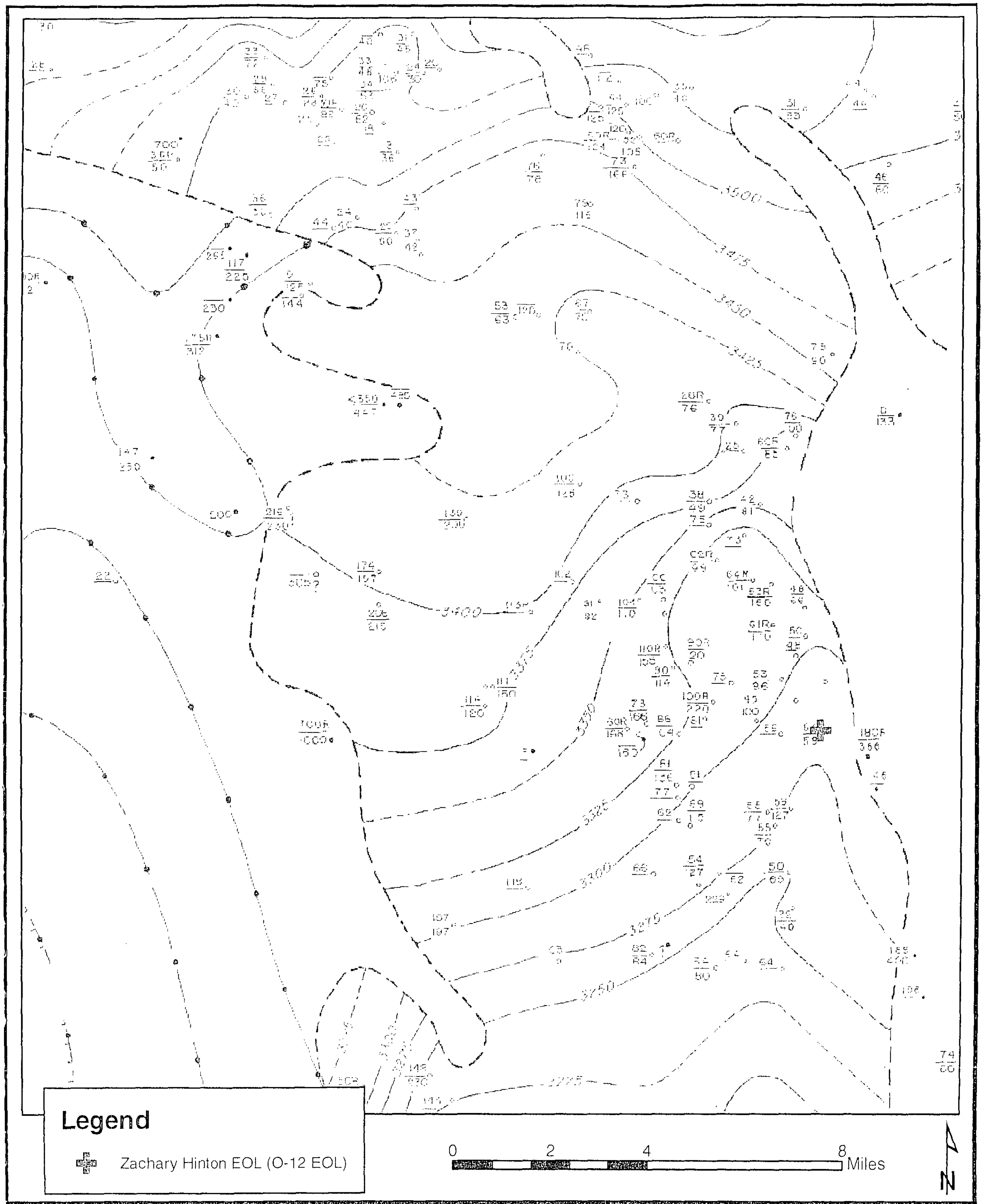


R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505-266-5004	Location of Zachary Hinton EOL Relative to Eunice, NM	Plate 1
	ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)	October 2005

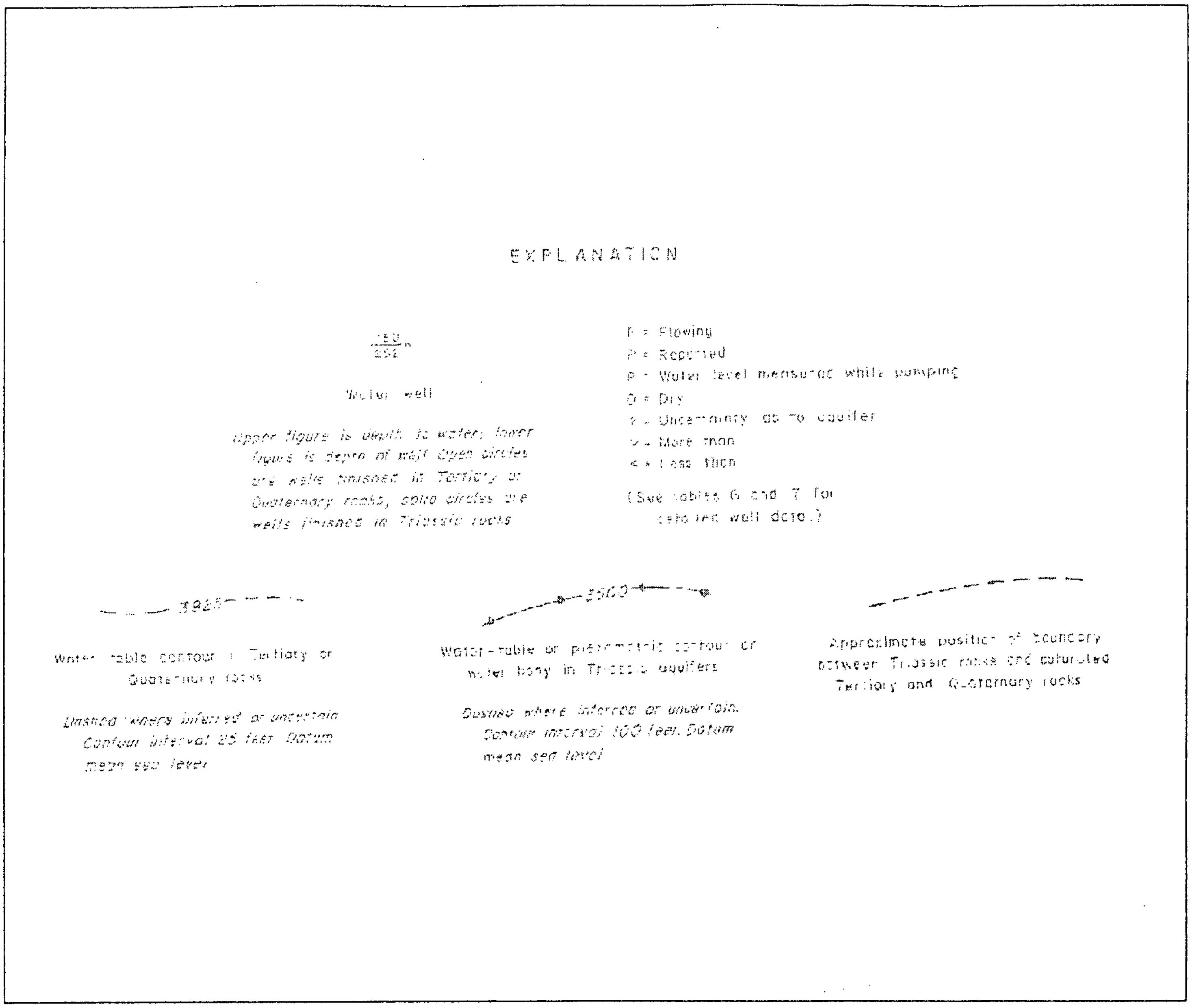


Local Ground Water Map (Nicholson & Clebsch, 1961)

Plate 2

ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)

February 2007



EXPLANATION

Water well

Upper figure is depth to water; lower figure is depth of well. Open circles are wells finished in Tertiary or Quaternary rocks, solid circles are wells finished in Triassic rocks

F = Flowing
R = Reported
P = Water level measured while pumping
D = Dry
? = Uncertainty as to aquifer
> = More than
< = Less than

(See tables 6 and 7 for detailed well data.)

Water-table contour in Tertiary or Quaternary rocks

Dashed where inferred or uncertain. Contour interval 25 feet. Datum mean sea level

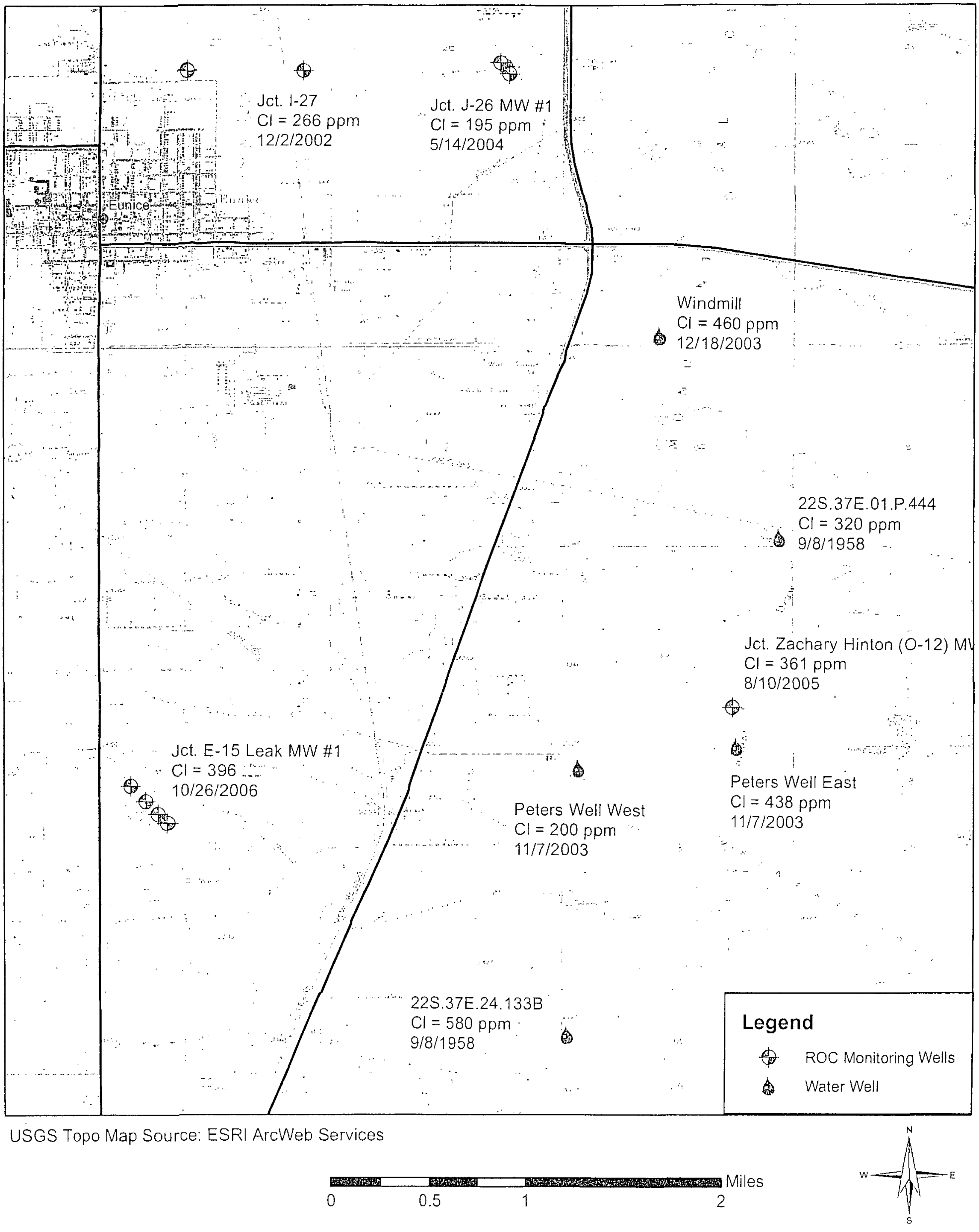
Water-table or piezometric contour of water body in Triassic aquifers

Dashed where inferred or uncertain. Contour interval 100 feet. Datum mean sea level

Approximate position of boundary between Triassic rocks and saturated Tertiary and Quaternary rocks

Legend to Nicholson & Clebsch (1961) Ground Water Map

R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Supplemental Legend to Ground Water Map	Plate 2 Supplemental
	ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)	February 2007



USGS Topo Map Source: ESRI ArcWeb Services

R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Dissolved Chloride Concentration Map	Plate 3
	Rice Operating Company Zachary Hinton EOL (NMOCD# 1R0426-36)	February 2007

Tables

R.T. Hicks Consultants, Ltd.

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

TABLE 1

Comparison of physical and chemical data from Texas, New Mexico, and Australia

	Precipitation (mm yr^{-1})	Water table depth (m)	Geomorphic setting	Soil texture	Maximum chloride (g m^{-2})	Moisture flux (mm yr^{-1})
Texas[a] (Hueco Bolson)	280 (arid)	150	Ephemeral stream	Clay to muddy-sandy-gravel	9300	0.01 to 0.7
			interstream	Clay to muddy-sandy-gravel	6300	0.02 to 0.27
New Mexico[b,c]	444 or 385	30	Playa		≤ 100	2.8-12.4[e]
(Eastern)	(semiarid)		Sand hills		≤ 300	1.3-4.3[e]
(Central)	220 (arid)	5	Pleistocene alluvium	Sandy loam to loamy sand	60 to 2720	1-3
24 km N of Socorro[b,c] (^3H) (^{36}Cl)		100	Holocene terrace	sand		1-3
40 km NE of Las Cruces[d]	220 (arid)	100		Sandy loam to Sandy clay loam	680	0.1
South Australia 100 km NE of Adelaide[f]	300 (arid)	28-40	Undisturbed calcrete		7500	0.1-0.17
			1° sinkhole		22500	0.07-0.09
			2° sinkhole		30	≥ 60
			Vegetated dunes		20000	0.06
			Cleared dunes			13
Western Australia 40 km N of Perth[g]	800 (humid)	90	Dunes	sand	250-500	50-115

[a]This paper; [b]Phillips and Stone, 1985; [c]Stone (1990); [d]Mattick et al., 1987; Phillips et al., 1988; [e]Phillips et al., 1984; [f]Allison et al., 1985; [g]Sharma and Hughes, 1985.

Table 2. Simulation Results for the Four Basic Scenarios[a]

	MAP		Nonvegetated Sand					Nonvegetated Texturally Variable Soils					Vegetated Sand			Vegetated Texturally Variable Soils				
			Recharge					Recharge					Recharge			Recharge				
Region	Total	CV	Total	CV	R/P	AE	PET/AE	Total	R/P	AE	R_O	ΔS	Total	R/P	AET	Total	R/P	AET	R_O	ΔS
1	224	0.35	51	0.22	23	173	12.1	19	9	205	0	0.0	2	1	222	0.2	0.1	224	0	−0.7
2	380	0.35	137	0.20	36	243	8.9	80	21	286	14	0.0	34	9	346	11.1	2.9	356	14	−0.7
3	380	0.35	137	0.20	36	243	8.9	56	15	316	7	−0.1	11	3	369	1.5	0.4	375	4	−0.6
4	474	0.23	180	0.24	38	294	6.9	19	4	366	90	−0.4	33	7	441	0.8	0.2	390	85	−0.9
5	497	0.21	174	0.16	35	323	6.5	16	3	286	195	−1.0	29	6	468	0.4	0.1	312	186	−1.4
6	620	0.23	269	0.19	43	351	6.1	88	14	364	168	−0.4	80	13	540	5.6	0.9	435	180	−0.8
7	671	0.24	338	0.19	50	334	5.4	191	29	454	25	0.0	115	17	556	33.8	5.0	610	27	−0.1
8	810	0.21	406	0.20	50	403	4.3	98	12	586	125	0.0	95	12	715	10.1	1.3	619	181	−0.8
9	855	0.22	432	0.18	51	423	4.3	193	23	587	74	0.0	106	12	749	29.0	3.4	727	99	−0.4
10	855	0.22	432	0.18	51	423	4.3	146	17	663	46	0.0	83	10	772	4.7	0.6	792	59	−0.4
11	855	0.22	432	0.18	51	423	4.3	193	23	639	24	0.0	111	13	744	35.1	4.1	795	25	−0.2
12	933	0.23	507	0.22	54	427	3.9	91	10	423	419	−0.2	285	31	648	25.7	2.8	520	388	−0.3
13	1184	0.22	709	0.18	60	475	2.9	230	19	619	335	−0.2	369	31	815	117.7	9.9	748	319	−0.2

[a]Runoff and change in storage is 0 for nonvegetated and vegetated monolithic sand profiles. All ratios are expressed as percent. Units are mm/yr. MAP, measured 30 year mean annual precipitation; CV, coefficient of variation; R, simulated 30 year mean annual recharge; R/P, recharge to precipitation ratio; AE, actual evaporation; AET, actual evapotranspiration; ΔS, change in water storage; R_O, runoff.

Appendix A

Previous Reports

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

Appendices Associated with Previously Submitted Reports are Available on the Attached CD

RICE OPERATING COMPANY

JUNCTION BOX CLOSURE REPORT

BOX LOCATION

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REPORT ASSEMBLED BY Kristin Farris Pope SIGNATURE ______

DATE 3/12/2007 TITLE Project Scientist

R. T. HICKS CONSULTANTS, LTD.
901 Rio Grande Blvd NW ▲ Suite F-142 ▲ Albuquerque, NM 87104 ▲ 505.266.5004 ▲ Fax: 505.266-0745

February 12, 2007

Wayne Price
Oil Conservation Division
1220 S. St. Francis Drive
Santa Fe, NM 87505

RE: 2006 Annual Ground Water Monitoring Report
Jct. Zachary Hinton (O-12), Sec 12, T22S, R37E, Unit "O"
NMOCD Case #: AP-50

Dear Mr. Wayne Price:

R.T. Hicks Consultants, Ltd is pleased to submit the 2006 Annual Ground Water Monitoring Report for the Jct. Zachary Hinton (O-12) site located in the BD Salt Water Disposal System (SWD). This report consists of the following sections:

1. A table summarizing all laboratory results, depth to ground water and other pertinent data associated with ground water sampling at the site, including this past year.
2. Graphs showing chemical concentration vs. time for chloride and TDS.
3. Laboratory data sheets associated with the routine sampling for 2006.

The Final Closure Report will be submitted to NMOCD by February 26, 2007. Per agreement with NMOCD, the monitoring well at the site will be sampled twice a year, during the first and third quarters of the year..

Thank you for your consideration of this annual summary information. The attached CD contains an electronic copy of the annual report. If you have any questions, please contact us at 505-266-5004, or Kristin Farris Pope at ROC, 505-393-9174.

Sincerely,
R.T. Hicks Consultants, Ltd.

Randall H

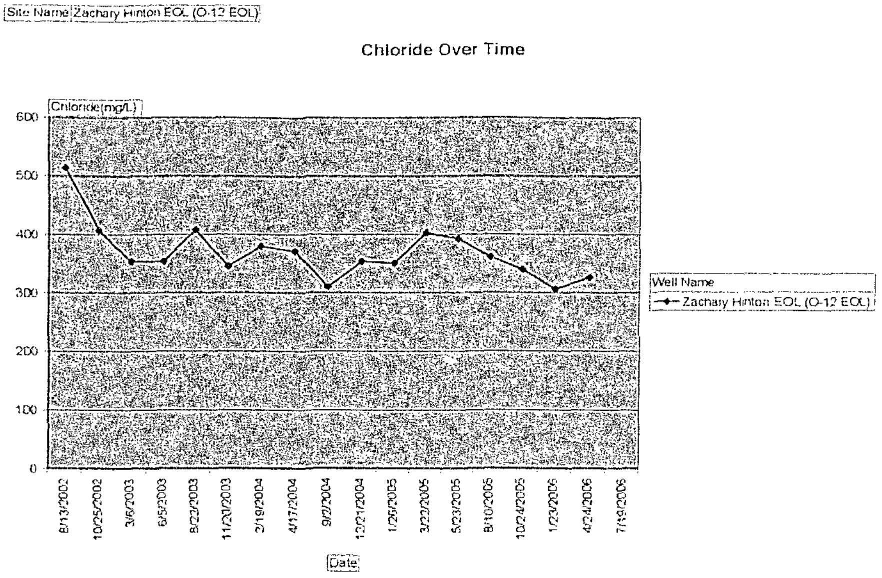
Randall T. Hicks
Principal

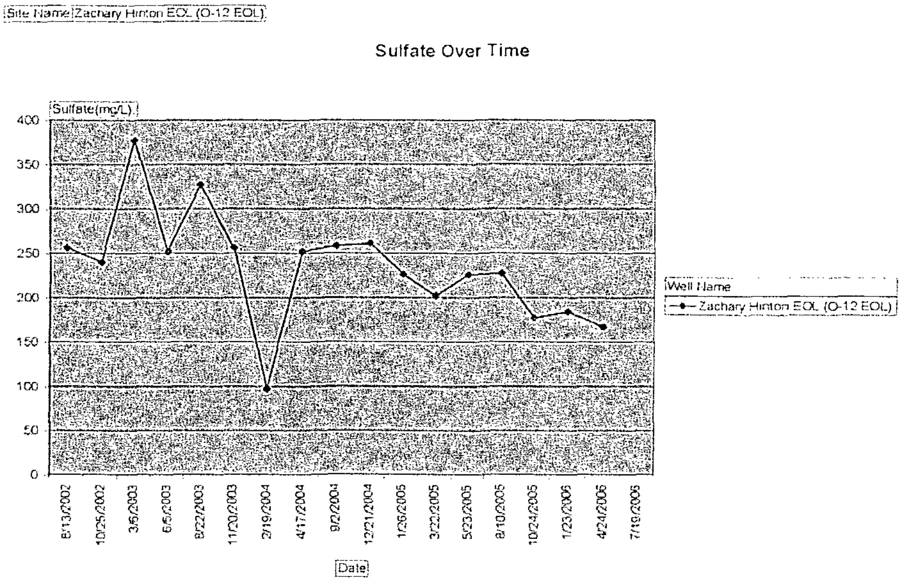
Copy: Hobbs NMOCD office; Rice Operating Company

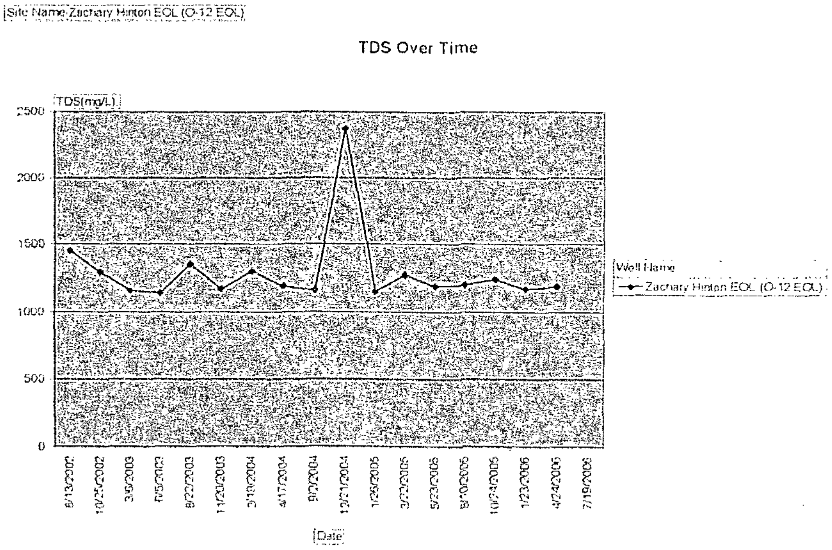
Jct. Zachary Hinton (O-12)

Well Name	*Date*	*DTW (ft)*	*Chloride*	*nments*
MW-01	8/13/2002	56.10	5	silty
MW-01	10/25/2002	56.14	4	
MW-01	3/6/2003	56.07	3	
MW-01	6/5/2003	56.00	3	
MW-01	8/22/2003	56.00	4	
MW-01	11/20/2003	56.00	3	
MW-01	2/19/2004	56.59	3	
MW-01	4/17/2004	55.65	3	
MW-01	9/2/2004	56.00	31	own; cloudy
MW-01	12/21/2004	55.90	3	silty
MW-01	1/26/2005	55.94	35	
MW-01	3/22/2005	55.80	40	r; no odor
MW-01	5/23/2005	55.84	39	
MW-01	8/10/2005	55.82	36	
MW-01	10/24/2005	55.10	34	r; no odor
MW-01	1/23/2006	55.75	30	
MW-01	4/24/2006	55.70	32	
MW-01	7/19/2006	55.68		

Ground Water Quality at Zachary Hinton







ENVIRONMENTAL
LAB OF

12600 West I-20 East - Odessa, Texas 79765

Analytical Report

Prepared for:

Kristin Farris-Pope
Rice Operating Co.
122 W. Taylor
Hobbs, NM 88240

Project: BD Zachary Hinton
Project Number: None Given
Location: Lea County

Lab Order Number: 6A25021

Report Date: 02/01/06

Rice Operating Co. 122 W. Taylor Hobbs NM, 88240	Project: BD Zachary Hinton Project Number: None Given Project Manager: Kristin Farris-Pope	Fax: (505) 397-1471 **Reported:** 02/01/06 11:42

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
Monitor Well #1	6A25021-01	Water	01/23/06 09:45	01/25/06 13:25

Organics by GC
Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6A25021-01) Water									
Benzene	ND	0.00100	mg/L	1	EA62618	01/26/06	01/27/06	EPA 8021B	
Toluene	ND	0.00100	"	"	"	"	"	"	
Ethylbenzene	ND	0.00100	"	"	"	"	"	"	
Xylene (p/m)	ND	0.00100	"	"	"	"	"	"	
Xylene (o)	ND	0.00100	"	"	"	"	"	"	
Surrogate: a,a,a-Trifluorotoluene		*95.2 %*	*80-120*		"	"	"	"	
Surrogate: 4-Bromofluorobenzene		*89.2 %*	*80-120*		"	"	"	"	

General Chemistry Parameters by EPA / Standard Methods

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6A25021-01) Water									
Total Alkalinity	172	2.00	mg/L	1	EA62406	01/26/06	01/26/06	EPA 310.1M	
Chloride	306	10.0	"	20	EA63004	01/30/06	01/30/06	EPA 300.0	
Total Dissolved Solids	1170	5.00	"	1	EA63003	01/26/06	01/27/06	EPA 160.1	
Sulfate	184	10.0	"	20	EA63004	01/30/06	01/30/06	EPA 300.0	

Total Metals by EPA / Standard Methods
Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6A25021-01) Water									
Calcium	93.8	0.100	mg/L	10	EA62615	01/26/06	01/26/06	EPA 6010B	
Magnesium	44.4	0.0100	"	"	"	"	"	"	
Potassium	8.85	0.500	"	"	"	"	"	"	
Sodium	208	0.500	"	50	"	"	"	"	

Organics by GC - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EA62618 - EPA 5030C (GC)										
Blank (EA62618-BLK1)				Prepared: 01/26/06 Analyzed: 01/27/06						
Benzene	ND	0.00100	mg/L							
Toluene	ND	0.00100	"							
Ethylbenzene	ND	0.00100	"							
Xylene (p/m)	ND	0.00100	"							
Xylene (o)	ND	0.00100	"							
Surrogate: a,a,a-Trifluorotoluene	*38.5*		*ug/l*	*40.0*		*96.2*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*42.4*		*"*	*40.0*		*106*	*80-120*			
LCS (EA62618-BS1)				Prepared: 01/26/06 Analyzed: 01/27/06						
Benzene	0.0566	0.00100	mg/L	0.0500		113	80-120			
Toluene	0.0557	0.00100	"	0.0500		111	80-120			
Ethylbenzene	0.0547	0.00100	"	0.0500		109	80-120			
Xylene (p/m)	0.102	0.00100	"	0.100		102	80-120			
Xylene (o)	0.0538	0.00100	"	0.0500		108	80-120			
Surrogate: a,a,a-Trifluorotoluene	*41.2*		*ug/l*	*40.0*		*103*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*32.8*		*"*	*40.0*		*82.0*	*80-120*			
Calibration Check (EA62618-CCV1)				Prepared: 01/26/06 Analyzed: 01/28/06						
Benzene	51.3		ug/l	50.0		103	80-120			
Toluene	52.5		"	50.0		105	80-120			
Ethylbenzene	54.5		"	50.0		109	80-120			
Xylene (p/m)	101		"	100		101	80-120			
Xylene (o)	55.6		"	50.0		111	80-120			
Surrogate: a,a,a-Trifluorotoluene	*34.3*		*"*	*40.0*		*85.8*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*39.5*		*"*	*40.0*		*98.8*	*80-120*			
Matrix Spike (EA62618-MS1)	**Source: 6A24010-01**			Prepared: 01/26/06 Analyzed: 01/27/06						
Benzene	0.0559	0.00100	mg/L	0.0500	ND	112	80-120			
Toluene	0.0548	0.00100	"	0.0500	ND	110	80-120			
Ethylbenzene	0.0515	0.00100	"	0.0500	ND	103	80-120			
Xylene (p/m)	0.0835	0.00100	"	0.100	ND	83.5	80-120			
Xylene (o)	0.0512	0.00100	"	0.0500	ND	102	80-120			
Surrogate: a,a,a-Trifluorotoluene	*37.5*		*ug/l*	*40.0*		*93.8*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*34.3*		*"*	*40.0*		*85.8*	*80-120*			

Organics by GC - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EA62618 - EPA 5030C (GC)										
Matrix Spike Dup (EA62618-MSD1)	**Source: 6A24010-01**		Prepared: 01/26/06 Analyzed: 01/28/06							
Benzene	0.0482	0.00100	mg/L	0.0500	ND	96.4	80-120	15.0	20	
Toluene	0.0484	0.00100	"	0.0500	ND	96.8	80-120	12.8	20	
Ethylbenzene	0.0456	0.00100	"	0.0500	ND	91.2	80-120	12.2	20	
Xylene (p/m)	0.0841	0.00100	"	0.100	ND	84.1	80-120	0.716	20	
Xylene (o)	0.0448	0.00100	"	0.0500	ND	89.6	80-120	12.9	20	
Surrogate: a,a,a-Trifluorotoluene	*33.0*		*ug/l*	*40.0*		*82.5*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*32.4*		*"*	*40.0*		*81.0*	*80-120*			

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Batch EA62406 - General Preparation (WetChem)

Blank (EA62406-BLK1) Prepared & Analyzed: 01/26/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity	ND	2.00	mg/L							

LCS (EA62406-BS1) Prepared & Analyzed: 01/26/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Bicarbonate Alkalinity	220		mg/L	200		110	85-115			

Duplicate (EA62406-DUP1) **Source: 6A19005-01** Prepared & Analyzed: 01/26/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity	258	2.00	mg/L		256			0.778	20	

Reference (EA62406-SRM1) Prepared & Analyzed: 01/26/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Alkalinity	97.0		mg/L	100		97.0	90-110			

Batch EA63003 - General Preparation (WetChem)

Blank (EA63003-BLK1) Prepared: 01/26/06 Analyzed: 01/27/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Dissolved Solids	ND	5.00	mg/L							

Duplicate (EA63003-DUP1) **Source: 6A25018-01** Prepared: 01/26/06 Analyzed: 01/27/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Total Dissolved Solids	2020	5.00	mg/L		2080			2.93	5	

Batch EA63004 - General Preparation (WetChem)

Blank (EA63004-BLK1) Prepared & Analyzed: 01/30/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Sulfate	ND	0.500	mg/L							
Chloride	ND	0.500	"							

LCS (EA63004-BS1) Prepared & Analyzed: 01/30/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Sulfate	9.61	0.500	mg/L	10.0		96.1	80-120			
Chloride	8.40	0.500	"	10.0		84.0	80-120			

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EA63004 - General Preparation (WetChem)										
Calibration Check (EA63004-CCV1)				Prepared & Analyzed: 01/30/06						
Sulfate	9.82		mg/L	10.0		98.2	80-120			
Chloride	8.64		"	10.0		86.4	80-120			
Duplicate (EA63004-DUP1)	**Source: 6A25018-01**			Prepared & Analyzed: 01/30/06						
Sulfate	84.4	25.0	mg/L		88.2			4.40	20	
Chloride	879	25.0	"		886			0.793	20	

Total Metals by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EA62615 - 6010B/No Digestion										
Blank (EA62615-BLK1)				Prepared & Analyzed: 01/26/06						
Calcium	ND	0.0100	mg/L							
Magnesium	ND	0.00100	"							
Potassium	ND	0.0500	"							
Sodium	ND	0.0100	"							
Calibration Check (EA62615-CCV1)				Prepared & Analyzed: 01/26/06						
Calcium	2.12		mg/L	2.00		106	85-115			
Magnesium	1.99		"	2.00		99.5	85-115			
Potassium	1.88		"	2.00		94.0	85-115			
Sodium	1.94		"	2.00		97.0	85-115			
Duplicate (EA62615-DUP1)	**Source: 6A19005-01**			Prepared & Analyzed: 01/26/06						
Calcium	224	0.500	mg/L		222			0.897	20	
Magnesium	115	0.0500	"		120			4.26	20	
Potassium	14.6	0.500	"		15.2			4.03	20	
Sodium	306	0.500	"		313			2.26	20	

Notes and Definitions

DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
LCS	Laboratory Control Spike
MS	Matrix Spike
Dup	Duplicate

Report Approved By: Raland K Date: 2/1/2006

Raland K. Tuttle, Lab Manager
Celey D. Keene, Lab Director, Org. Tech Director
Peggy Allen, QA Officer

Jeanne Mc Murrey, Inorg. Tech Director
LaTasha Cornish, Chemist
Sandra Sanchez, Lab Tech.

Environmental Lab of Texas

12600 West I-20 East
Odessa, Texas 79765

Phone: 432-563-1800
Fax: 432-563-1713

CHAIN OF CUSTODY RECORD AND ANALYSIS REQUEST

Project Manager: Kristin Farris Pope kpriceswd@valornet.com
Company Name: RICE Operating Company
Company Address: 122 W. Taylor Street
City/State/Zip: Hobbs, New Mexico 88240
Telephone No: (505) 393-9174
Fax No: (505) 397-1471
Sampler Signature: Rozanne Johnson (505) 631-9310
Email: rozanne@valornet.com

Project Name: BD Zachary Hinton
Project #:
Project Loc: Lea County
PO #:

					Preservative							Matrix				Analyze For:															
																TCLP:															
																TOTAL:							X								
LAB # (lab use only) 6A25021	FIELD CODE	Date Sampled	Time Sampled	No. of Containers	Ice	HNO_3	HCl (2) 40 ml glass vials	NaOH	H_2SO_4	None (1) 1 Liter HDPE	Other (Specify)	Water	Sludge	Soil	Other (specify):	TPH: 418.1 8015M 1005 1006	Cations (Ca, Mg, Na, K)	Anions (Cl, SO4, CO3, HCO3)	SAR / ESP / CEC	Metals: As Ag Ba Cd Cr Pb Hg Se	Volatiles	Semivolatiles	BTEX 8021B/5030	RCI	N.O.R.M.	Total Dissolved Solids				RUSH TAT (Pre-Schedule)	Standard TAT
	Monitor Well #1	1/23/2006	9:45	3	X		2			1		X					X	X					X			X					X

Special Instructions:

PLEASE Email RESULTS TO: kpriceswd@valornet.com & mfranks@riceswd.com

Sample Containers Intact? [✓ Y] N
Labels on container? [✓ Y] N
Custody Seals: [✓ Containers] [✓ Cooler]
Temperature Upon Receipt: -2.5 C
Laboratory Comments: not frozen

Relinquished by: Rozanne Johnson	Date 1/23/06	Time 1:25	Received by:	Date	Time
Relinquished by:	Date	Time	Received by ELOT: Jeanne McMurry	Date 01-23-06	Time 1325

Environmental Lab of Texas
Variance / Corrective Action Report – Sample Log-In

Client: Rice Op.

Date/Time: 1/25/06 13:26

Order #: 6A25021

Initials: CK

Sample Receipt Checklist

Temperature of container/cooler?	Yes	No	-2.5 C
Shipping container/cooler in good condition?	[✓ Yes]	No	
Custody Seals intact on shipping container/cooler?	[✓ Yes]	No	Not present
Custody Seals intact on sample bottles?	[✓ Yes]	No	Not present
Chain of custody present?	[✓ Yes]	No	
Sample Instructions complete on Chain of Custody?	[✓ Yes]	No	
Chain of Custody signed when relinquished and received?	[✓ Yes]	No	
Chain of custody agrees with sample label(s)	[✓ Yes]	No	
Container labels legible and intact?	[✓ Yes]	No	
Sample Matrix and properties same as on chain of custody?	[✓ Yes]	No	
Samples in proper container/bottle?	[✓ Yes]	No	
Samples properly preserved?	[✓ Yes]	No	
Sample bottles intact?	[✓ Yes]	No	
Preservations documented on Chain of Custody?	[✓ Yes]	No	
Containers documented on Chain of Custody?	[✓ Yes]	No	
Sufficient sample amount for indicated test?	[✓ Yes]	No	
All samples received within sufficient hold time?	[✓ Yes]	No	
VOC samples have zero headspace?	[✓ Yes]	No	Not Applicable

Other observations:

Variance Documentation:

Contact Person: - Date/Time: Contacted by:

Regarding:

Corrective Action Taken:

ENVIRONMENTAL
LAB OF

12600 West I-20 East - Odessa, Texas 79765

Analytical Report

Prepared for:

Kristin Farris-Pope
Rice Operating Co.
122 W. Taylor
Hobbs, NM 88240

Project: BD Zachary Hinton
Project Number: None Given
Location: Lea County

Lab Order Number: 6D27011

Report Date: 05/04/06

Rice Operating Co.	Project: BD Zachary Hinton	Fax: (505) 397-1471
122 W. Taylor	Project Number: None Given	**Reported:**
Hobbs NM, 88240	Project Manager: Kristin Farris-Pope	05/04/06 14:09

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
Monitor Well #1	6D27011-01	Water	04/24/06 09:30	04/27/06 10:30

Organics by GC

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6D27011-01) Water									
Benzene	ND	0.00100	mg/L	1	ED62807	04/28/06	04/30/06	EPA 8021B	
Toluene	ND	0.00100	"	"	"	"	"	"	
Ethylbenzene	ND	0.00100	"	"	"	"	"	"	
Xylene (p/m)	ND	0.00100	"	"	"	"	"	"	
Xylene (o)	ND	0.00100	"	"	"	"	"	"	
Surrogate: a,a,a-Trifluorotoluene		*102 %*	*80-120*		"	"	"	"	
Surrogate: 4-Bromofluorobenzene		*103 %*	*80-120*		"	"	"	"	

General Chemistry Parameters by EPA / Standard Methods
Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6D27011-01) Water									
Total Alkalinity	184	2.00	mg/L	1	EE60301	05/03/06	05/03/06	EPA 310.1M	
Chloride	326	5.00	"	10	EE60116	05/01/06	05/01/06	EPA 300.0	
Total Dissolved Solids	1190	5.00	"	1	EE60115	04/27/06	04/28/06	EPA 160.1	
Sulfate	167	5.00	"	10	EE60116	05/01/06	05/01/06	EPA 300.0	

Total Metals by EPA / Standard Methods

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6D27011-01) Water									
Calcium	**85.0**	0.100	mg/L	10	ED62719	04/27/06	04/27/06	EPA 6010B	
Magnesium	**43.4**	0.0100	"	"	"	"	"	"	
Potassium	**9.70**	0.500	"	"	"	"	"	"	
Sodium	**238**	0.500	"	50	"	"	"	"	

Organics by GC - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch ED62807 - EPA 5030C (GC)										
Blank (ED62807-BLK1)				Prepared: 04/28/06 Analyzed: 04/30/06						
Benzene	ND	0.00100	mg/L							
Toluene	ND	0.00100	"							
Ethylbenzene	ND	0.00100	"							
Xylene (p/m)	ND	0.00100	"							
Xylene (o)	ND	0.00100	"							
Surrogate: a,a,a-Trifluorotoluene	*42.7*		*ug/l*	*40.0*		*107*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*42.2*		*"*	*40.0*		*106*	*80-120*			
LCS (ED62807-BS1)				Prepared: 04/28/06 Analyzed: 04/30/06						
Benzene	0.0599	0.00100	mg/L	0.0500		120	80-120			
Toluene	0.0580	0.00100	"	0.0500		116	80-120			
Ethylbenzene	0.0551	0.00100	"	0.0500		110	80-120			
Xylene (p/m)	0.120	0.00100	"	0.100		120	80-120			
Xylene (o)	0.0596	0.00100	"	0.0500		119	80-120			
Surrogate: a,a,a-Trifluorotoluene	*43.0*		*ug/l*	*40.0*		*108*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*42.2*		*"*	*40.0*		*106*	*80-120*			
Calibration Check (ED62807-CCV1)				Prepared: 04/28/06 Analyzed: 05/01/06						
Benzene	55.0		ug/l	50.0		110	80-120			
Toluene	53.0		"	50.0		106	80-120			
Ethylbenzene	55.9		"	50.0		112	80-120			
Xylene (p/m)	110		"	100		110	80-120			
Xylene (o)	55.9		"	50.0		112	80-120			
Surrogate: a,a,a-Trifluorotoluene	*39.0*		*"*	*40.0*		*97.5*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*39.1*		*"*	*40.0*		*97.8*	*80-120*			
Matrix Spike (ED62807-MS1)	**Source: 6D27008-01**			Prepared: 04/28/06 Analyzed: 05/01/06						
Benzene	0.0576	0.00100	mg/L	0.0500	ND	115	80-120			
Toluene	0.0568	0.00100	"	0.0500	ND	114	80-120			
Ethylbenzene	0.0587	0.00100	"	0.0500	ND	117	80-120			
Xylene (p/m)	0.120	0.00100	"	0.100	ND	120	80-120			
Xylene (o)	0.0600	0.00100	"	0.0500	ND	120	80-120			
Surrogate: a,a,a-Trifluorotoluene	*41.7*		*ug/l*	*40.0*		*104*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*47.5*		*"*	*40.0*		*119*	*80-120*			

Organics by GC - Quality Control

Environmental Lab of Texas

Batch ED62807 - EPA 5030C (GC)

Matrix Spike Dup (ED62807-MSD1) **Source: 6D27008-01** Prepared: 04/28/06 Analyzed: 05/01/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Benzene	0.0597	0.00100	mg/L	0.0500	ND	119	80-120	3.42	20	
Toluene	0.0579	0.00100	"	0.0500	ND	116	80-120	1.74	20	
Ethylbenzene	0.0585	0.00100	"	0.0500	ND	117	80-120	0.00	20	
Xylene (p/m)	0.120	0.00100	"	0.100	ND	120	80-120	0.00	20	
Xylene (o)	0.0598	0.00100	"	0.0500	ND	120	80-120	0.00	20	
Surrogate: a,a,a-Trifluorotoluene	*43.5*		*ug/l*	*40.0*		*109*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*46.4*		*"*	*40.0*		*116*	*80-120*			

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EE60115 - General Preparation (WetChem)										
Blank (EE60115-BLK1)				Prepared: 04/27/06 Analyzed: 04/28/06						
Total Dissolved Solids	ND	5.00	mg/L							
Duplicate (EE60115-DUP1)	**Source: 6D27015-01**			Prepared: 04/27/06 Analyzed: 04/28/06						
Total Dissolved Solids	3020	5.00	mg/L		3040			0.660	5	
Batch EE60116 - General Preparation (WetChem)										
Blank (EE60116-BLK1)				Prepared & Analyzed: 05/01/06						
Chloride	ND	0.500	mg/L							
Sulfate	ND	0.500	"							
LCS (EE60116-BS1)				Prepared & Analyzed: 05/01/06						
Sulfate	9.47	0.500	mg/L	10.0		94.7	80-120			
Chloride	9.71	0.500	"	10.0		97.1	80-120			
Calibration Check (EE60116-CCV1)				Prepared & Analyzed: 05/01/06						
Chloride	9.86		mg/L	10.0		98.6	80-120			
Sulfate	8.11		"	10.0		81.1	80-120			
Duplicate (EE60116-DUP1)	**Source: 6D27008-01**			Prepared & Analyzed: 05/01/06						
Sulfate	80.0	2.50	mg/L		79.2			1.01	20	
Chloride	49.3	2.50	"		49.0			0.610	20	
Batch EE60301 - General Preparation (WetChem)										
Blank (EE60301-BLK1)				Prepared & Analyzed: 05/03/06						
Total Alkalinity	ND	2.00	mg/L							

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EE60301 - General Preparation (WetChem)										
LCS (EE60301-BS1)				Prepared & Analyzed: 05/03/06						
Bicarbonate Alkalinity	214		mg/L	200		107	85-115			
Duplicate (EE60301-DUP1)		**Source: 6D26006-01**		Prepared & Analyzed: 05/03/06						
Total Alkalinity	29.0	2.00	mg/L		28.0			3.51	20	
Reference (EE60301-SRM1)				Prepared & Analyzed: 05/03/06						
Total Alkalinity	96.0		mg/L	100		96.0	90-110			

Total Metals by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch ED62719 - 6010B/No Digestion										
Blank (ED62719-BLK1)				Prepared & Analyzed: 04/27/06						
Calcium	ND	0.0100	mg/L							
Magnesium	ND	0.00100	"							
Potassium	ND	0.0500	"							
Sodium	ND	0.0100	"							
Calibration Check (ED62719-CCV1)				Prepared & Analyzed: 04/27/06						
Calcium	2.08		mg/L				85-115			
Magnesium	2.16		"				85-115			
Potassium	1.94		"				85-115			
Sodium	1.96		"				85-115			
Duplicate (ED62719-DUP1)	**Source: 6D26006-01**			Prepared & Analyzed: 04/27/06						
Calcium	0.0366	0.0100	mg/L		0.0367			0.273	20	
Magnesium	ND	0.00100	"		ND				20	
Potassium	0.275	0.0500	"		0.275			0.00	20	
Sodium	13.0	0.100	"		12.1			7.17	20	

Notes and Definitions

DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
LCS	Laboratory Control Spike
MS	Matrix Spike
Dup	Duplicate

Report Approved By: Raland K Tuttle Date: 5/4/2006

Raland K. Tuttle, Lab Manager	Jeanne Mc Murrey, Inorg. Tech Director
Celey D. Keene, Lab Director, Org. Tech Director	LaTasha Cornish, Chemist
Peggy Allen, QA Officer	Sandra Sanchez, Lab Tech.

Environmental Lab of Texas

12600 West I-20 East
Odessa, Texas 79765

Phone: 432-563-1800
Fax: 432-563-1713

CHAIN OF CUSTODY RECORD AND ANALYSIS REQUEST

Project Manager: Kristin Farris Pope kpope@riceswd.com
Company Name: RICE Operating Company
Company Address: 122 W. Taylor Street
City/State/Zip: Hobbs, New Mexico 88240
Telephone No: (505) 393-9174
Fax No: (505) 397-1471
Sampler Signature: Rozanne Johnson (505) 631-9310
Email: rozanne@valornet.com

Project Name: BD Zachary Hinton
Project #:
Project Loc: Lea County
PO #:

					Preservative							Matrix				Analyze For:															
																			TCLP:												
																			TOTAL:				X								
LAB # (lab use only) 6D27011	FIELD CODE	Date Sampled	Time Sampled	No. of Containers	Ice	HNO_3	HCl (2) 40 ml glass vials	NaOH	H_2SO_4	None (1) 1 Liter HDPE	Other (Specify)	Water	Sludge	Soil	Other (specify):	TPH: 418.1 8015M 1005 1006	Cations (Ca, Mg, Na, K)	Anions (Cl, SO4, CO3, HCO3)	SAR / ESP / CEC	Metals: As Ag Ba Cd Cr Pb Hg Se	Volatiles	Semivolatiles	BTEX 8021B/5030	RCI	N.O.R.M.	Total Dissolved Solids				RUSH TAT (Pre-Schedule)	Standard TAT
01	Monitor Well #1	4/24/2006	9:30	3	X		2			1		X					X	X					X			X					X

Special Instructions:

PLEASE Email RESULTS TO: kpope@riceswd.com & mfranks@riceswd.com

Relinquished by:	Date	Time	Received by:	Date	Time
Rozanne Johnson	4/27/06	6:00	James Johnson	4/27/06	6:01
Relinquished by:	Date	Time	Received by ELOT:	Date	Time
	4/27/06	10:30		4/27/06	10:30

Sample Containers Intact? [✓ Y] N
Labels on container? [✓ Y] N
Custody Seals: Containers / [✓ Cooler]
Temperature Upon Receipt: 2.0
Laboratory Comments:

Environmental Lab of Texas
Variance / Corrective Action Report – Sample Log-In

nt: Rice Op.
e/Time: 4/27/06 10:30
er #: 6D27011
als: CK

Sample Receipt Checklist

perature of container/cooler?	Yes	No	2.0 C
ping container/cooler in good condition?	[✓ Yes]	No	
ody Seals intact on shipping container/cooler?	[✓ Yes]	No	Not present
ody Seals intact on sample bottles?	[✓ Yes]	No	Not present
in of custody present?	[✓ Yes]	No	
ple Instructions complete on Chain of Custody?	[✓ Yes]	No	
in of Custody signed when relinquished and received?	[✓ Yes]	No	
in of custody agrees with sample label(s)	[✓ Yes]	No	
tainer labels legible and intact?	[✓ Yes]	No	
ple Matrix and properties same as on chain of custody?	[✓ Yes]	No	
ples in proper container/bottle?	[✓ Yes]	No	
ples properly preserved?	[✓ Yes]	No	
ple bottles intact?	[✓ Yes]	No	
servations documented on Chain of Custody?	[✓ Yes]	No	
tainers documented on Chain of Custody?	[✓ Yes]	No	
ficient sample amount for indicated test?	[✓ Yes]	No	
samples received within sufficient hold time?	[✓ Yes]	No	
C samples have zero headspace?	[✓ Yes]	No	Not Applicable

er observations:

Variance Documentation:

ntact Person: - ____________ Date/Time: ____________ Contacted by: ____________
egarding:

rrective Action Taken:

TRACEANALYSIS, INC.

6701 Aberdeen Avenue, Suite 9 Lubbock, Texas 79424 800•378•1296 806•794•1296 FAX 806•794•1298
155 McCutcheon, Suite H El Paso, Texas 79932 888•588•3443 915•585•3443 FAX 915•585•4944
E-Mail lab@traceanalysis.com

Analytical and Quality Control Report

Kristen Farris-Pope
Rice Operating Company
122 W Taylor Street
Hobbs, NM, 88240

Report Date: August 9, 2006

Work Order: 6072143

Project Location: Lea County,NM
Project Name: BD Zachary Hinton
Project Number: BD Zachary Hinton

Enclosed are the Analytical Report and Quality Control Report for the following sample(s) submitted to TraceAnalysis, Inc.

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
96140	Monitor Well #1	water	2006-07-19	12:55	2006-07-21

These results represent only the samples received in the laboratory. The Quality Control Report is generated on a batch basis. All information contained in this report is for the analytical batch(es) in which your sample(s) were analyzed.

This report consists of a total of 10 pages and shall not be reproduced except in its entirety, without written approval of TraceAnalysis, Inc.

Michael Abel

Dr. Blair Leftwich, Director

Analytical Report

Sample: 96140 - Monitor Well #1

Analysis:	Alkalinity	Analytical Method:	SM 2320B	Prep Method:	N/A
QC Batch:	28340	Date Analyzed:	2006-07-26	Analyzed By:	LJ
Prep Batch:	24777	Sample Preparation:	2006-07-25	Prepared By:	LJ

Parameter	Flag	RL Result	Units	Dilution	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1	1.00
Bicarbonate Alkalinity		**188**	mg/L as CaCo3	1	4.00
Total Alkalinity		**188**	mg/L as CaCo3	1	4.00

Sample: 96140 - Monitor Well #1

Analysis:	BTEX	Analytical Method:	S 8021B	Prep Method:	S 5030B
QC Batch:	28277	Date Analyzed:	2006-07-24	Analyzed By:	MT
Prep Batch:	24759	Sample Preparation:	2006-07-24	Prepared By:	MT

Parameter	Flag	RL Result	Units	Dilution	RL
Benzene		<0.00100	mg/L	1	0.00100
Toluene		<0.00100	mg/L	1	0.00100
Ethylbenzene		<0.00100	mg/L	1	0.00100
Xylene		<0.00100	mg/L	1	0.00100

Surrogate	Flag	Result	Units	Dilution	Spike Amount	Percent Recovery	Recovery Limits
Trifluorotoluene (TFT)		0.0961	mg/L	1	0.100	96	66.2 - 127.7
4-Bromofluorobenzene (4-BFB)	1	0.0585	mg/L	1	0.100	58	70.6 - 129.2

Sample: 96140 - Monitor Well #1

Analysis:	Cations	Analytical Method:	S 6010B	Prep Method:	S 3005A
QC Batch:	28356	Date Analyzed:	2006-07-26	Analyzed By:	TP
Prep Batch:	24749	Sample Preparation:	2006-07-24	Prepared By:	TS

Parameter	Flag	RL Result	Units	Dilution	RL
Dissolved Calcium		**98.2**	mg/L	1	0.500
Dissolved Potassium		**12.8**	mg/L	1	1.00
Dissolved Magnesium		**49.3**	mg/L	1	1.00
Dissolved Sodium		**230**	mg/L	10	1.00

Sample: 96140 - Monitor Well #1

Analysis:	Ion Chromatography	Analytical Method:	E 300.0	Prep Method:	N/A
QC Batch:	28782	Date Analyzed:	2006-08-02	Analyzed By:	WB
Prep Batch:	25167	Sample Preparation:	2006-08-02	Prepared By:	WB

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[1] BFB surrogate recovery outside normal limits. ICV/CCV and TFT surrogate recovery show the method to be in control.

Parameter	Flag	RL Result	Units	Dilution	RL
Chloride		**375**	mg/L	50	0.500
Sulfate		**234**	mg/L	50	0.500

Sample: 96140 - Monitor Well #1

Analysis:	TDS	Analytical Method:	SM 2540C	Prep Method:	N/A
QC Batch:	28406	Date Analyzed:	2006-07-27	Analyzed By:	SM
Prep Batch:	24850	Sample Preparation:	2009-07-26	Prepared By:	SM

Parameter	Flag	RL Result	Units	Dilution	RL
Total Dissolved Solids		**1318**	mg/L	2	10.00

Method Blank (1) QC Batch: 28277

QC Batch:	28277	Date Analyzed:	2006-07-24	Analyzed By:	MT
Prep Batch:	24759	QC Preparation:	2006-07-24	Prepared By:	MT

Parameter	Flag	MDL Result	Units	RL
Benzene		<0.000255	mg/L	0.001
Toluene		<0.000210	mg/L	0.001
Ethylbenzene		<0.000317	mg/L	0.001
Xylene		<0.000603	mg/L	0.001

Surrogate	Flag	Result	Units	Dilution	Spike Amount	Percent Recovery	Recovery Limits
Trifluorotoluene (TFT)		0.0949	mg/L	1	0.100	95	76.1 - 117
4-Bromofluorobenzene (4-BFB)		0.0633	mg/L	1	0.100	63	58.5 - 118

Method Blank (1) QC Batch: 28340

QC Batch:	28340	Date Analyzed:	2006-07-26	Analyzed By:	LJ
Prep Batch:	24777	QC Preparation:	2006-07-25	Prepared By:	LJ

Parameter	Flag	MDL Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1
Bicarbonate Alkalinity		<4.00	mg/L as CaCo3	4
Total Alkalinity		<4.00	mg/L as CaCo3	4

Method Blank (1) QC Batch: 28356

QC Batch:	28356	Date Analyzed:	2006-07-26	Analyzed By:	TP
Prep Batch:	24749	QC Preparation:	2006-07-24	Prepared By:	TS

Parameter	Flag	MDL Result	Units	RL
Dissolved Calcium		0.132	mg/L	0.5
Dissolved Potassium		1.08	mg/L	1
Dissolved Magnesium		<0.704	mg/L	1
Dissolved Sodium		0.836	mg/L	1

Method Blank (1) QC Batch: 28406

QC Batch: 28406 Date Analyzed: 2006-07-27 Analyzed By: SM
Prep Batch: 24850 QC Preparation: 2006-07-26 Prepared By: SM

Parameter	Flag	MDL Result	Units	RL
Total Dissolved Solids		<5.000	mg/L	10

Method Blank (1) QC Batch: 28782

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB
Prep Batch: 25167 QC Preparation: 2006-08-02 Prepared By: WB

Parameter	Flag	MDL Result	Units	RL
Chloride		<0.0181	mg/L	0.5
Sulfate		<0.0485	mg/L	0.5

Duplicates (1)

QC Batch: 28340 Date Analyzed: 2006-07-26 Analyzed By: LJ
Prep Batch: 24777 QC Preparation: 2006-07-25 Prepared By: LJ

Param	Duplicate Result	Sample Result	Units	Dilution	RPD	RPD Limit
Hydroxide Alkalinity	<1.00	<1.00	mg/L as CaCo3	1	0	20
Carbonate Alkalinity	<1.00	<1.00	mg/L as CaCo3	1	0	20
Bicarbonate Alkalinity	110	108	mg/L as CaCo3	1	2	12.6
Total Alkalinity	110	108	mg/L as CaCo3	1	2	11.5

Duplicates (1)

QC Batch: 28406 Date Analyzed: 2006-07-27 Analyzed By: SM
Prep Batch: 24850 QC Preparation: 2006-07-26 Prepared By: SM

Param	Duplicate Result	Sample Result	Units	Dilution	RPD	RPD Limit
Total Dissolved Solids	768.0	928.0	mg/L	2	19	17.2

Laboratory Control Spike (LCS-1)

QC Batch: 28277
Prep Batch: 24759

Date Analyzed: 2006-07-24
QC Preparation: 2006-07-24

Analyzed By: MT
Prepared By: MT

Param	LCS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Benzene	0.109	mg/L	1	0.1	0	109	
Toluene	0.108	mg/L	1	0.1	0	108	
Ethylbenzene	0.109	mg/L	1	0.1	0	109	
Xylene	0.322	mg/L	1	0.3	0	107.333	

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	LCSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Benzene	0.104	mg/L	1	0.1	0	109		4.7	20
Toluene	0.103	mg/L	1	0.1	0	108		4.7	20
Ethylbenzene	0.101	mg/L	1	0.1	0	109		7.6	20
Xylene	0.306	mg/L	1	0.3	0	107.333		5.1	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Surrogate	LCS Result	LCSD Result	Units	Dil.	Spike Amount	LCS Rec.	LCSD Rec.	Rec. Limit
Trifluorotoluene (TFT)	0.101	0.101	mg/L	1	0.100	101	101	81.8 - 114
4-Bromofluorobenzene (4-BFB)	0.112	0.111	mg/L	1	0.100	112	111	72.7 - 116

Laboratory Control Spike (LCS-1)

QC Batch: 28356
Prep Batch: 24749

Date Analyzed: 2006-07-26
QC Preparation: 2006-07-24

Analyzed By: TP
Prepared By: TS

Param	LCS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Dissolved Calcium	51.7	mg/L	1	50	0	103.4	
Dissolved Potassium	50.8	mg/L	1	50	0	101.6	
Dissolved Magnesium	51.5	mg/L	1	50	0	103	
Dissolved Sodium	50.5	mg/L	1	50	0	101	

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	LCSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Dissolved Calcium	51.7	mg/L	1	50	0	103.4		0	20
Dissolved Potassium	49.3	mg/L	1	50	0	101.6		3	20
Dissolved Magnesium	49.8	mg/L	1	50	0	103		3.4	20
Dissolved Sodium	48.6	mg/L	1	50	0	101		3.8	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Laboratory Control Spike (LCS-1)

QC Batch: 28782
Prep Batch: 25167

Date Analyzed: 2006-08-02
QC Preparation: 2006-08-02

Analyzed By: WB
Prepared By: WB

Param	LCS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Chloride	12.2	mg/L	1	12.5	0	97.6	
Sulfate	12.5	mg/L	1	12.5	0	100	

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	LCSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Chloride	12.3	mg/L	1	12.5	0	97.6		0.8	20
Sulfate	12.5	mg/L	1	12.5	0	100		0	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Matrix Spike (MS-1) Spiked Sample: 96149

QC Batch:	28277	Date Analyzed:	2006-07-24	Analyzed By:	MT
Prep Batch:	24759	QC Preparation:	2006-07-24	Prepared By:	MT

Param	MS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Benzene	0.107	mg/L	1	0.100	<0.000255	107	70.9 - 126
Toluene	0.105	mg/L	1	0.100	<0.000210	105	70.8 - 125
Ethylbenzene	0.106	mg/L	1	0.100	<0.000317	106	74.8 - 125
Xylene	0.311	mg/L	1	0.300	<0.000603	104	75.7 - 126

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	MSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Benzene [2]	NA	mg/L	1	0.100	<0.000255	0	70.9 - 126	200	20
Toluene [3]	NA	mg/L	1	0.100	<0.000210	0	70.8 - 125	200	20
Ethylbenzene [4]	NA	mg/L	1	0.100	<0.000317	0	74.8 - 125	200	20
Xylene [5]	NA	mg/L	1	0.300	<0.000603	0	75.7 - 126	200	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Surrogate	MS Result	MSD Result	Units	Dil.	Spike Amount	MS Rec.	MSD Rec.	Rec. Limit
Trifluorotoluene (TFT) [6]	0.101	NA	mg/L	1	0.1	101	0	73.6 - 121
4-Bromofluorobenzene (4-BFB) [7]	0.110	NA	mg/L	1	0.1	110	0	81.8 - 114

Matrix Spike (MS-1) Spiked Sample: 96124

QC Batch:	28356	Date Analyzed:	2006-07-26	Analyzed By:	TP
Prep Batch:	24749	QC Preparation:	2006-07-24	Prepared By:	TS

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[2] RPD is out of range because a matrix spike duplicate was not prepared.
[3] RPD is out of range because a matrix spike duplicate was not prepared.
[4] RPD is out of range because a matrix spike duplicate was not prepared.
[5] RPD is out of range because a matrix spike duplicate was not prepared.
[6] RPD is out of range because a matrix spike duplicate was not prepared.
[7] RPD is out of range because a matrix spike duplicate was not prepared.

Param	MS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Dissolved Calcium	416	mg/L	1	50.0	361	110	68.4 - 138
Dissolved Potassium	73.8	mg/L	1	50.0	22	104	82 - 129
Dissolved Magnesium	208	mg/L	1	50.0	147	122	61.2 - 135
Dissolved Sodium	633	mg/L	1	50.0	578	110	81.8 - 125

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	MSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Dissolved Calcium	406	mg/L	1	50.0	361	90	68.4 - 138	2	20
Dissolved Potassium	81.3	mg/L	1	50.0	22	119	82 - 129	10	20
Dissolved Magnesium	194	mg/L	1	50.0	147	94	61.2 - 135	7	20
Dissolved Sodium	637	mg/L	1	50.0	578	118	81.8 - 125	1	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Matrix Spike (MS-1) Spiked Sample: 96141

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB
Prep Batch: 25167 QC Preparation: 2006-08-02 Prepared By: WB

Param	MS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Chloride	2210	mg/L	100	12.5	988	98	25.4 - 171
Sulfate	1580	mg/L	100	12.5	298	102	0 - 677

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	MSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Chloride	2200	mg/L	100	12.5	988	97	25.4 - 171	0	20
Sulfate	1550	mg/L	100	12.5	298	100	0 - 677	2	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Standard (ICV-1)

QC Batch: 28277 Date Analyzed: 2006-07-24 Analyzed By: MT

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Benzene		mg/L	0.100	0.104	104	85 - 115	2006-07-24
Toluene		mg/L	0.100	0.104	104	85 - 115	2006-07-24
Ethylbenzene		mg/L	0.100	0.104	104	85 - 115	2006-07-24
Xylene		mg/L	0.300	0.314	105	85 - 115	2006-07-24

Standard (CCV-1)

QC Batch: 28277 Date Analyzed: 2006-07-24 Analyzed By: MT

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Benzene		mg/L	0.100	0.107	107	85 - 115	2006-07-24
Toluene		mg/L	0.100	0.105	105	85 - 115	2006-07-24
Ethylbenzene		mg/L	0.100	0.106	106	85 - 115	2006-07-24
Xylene		mg/L	0.300	0.311	104	85 - 115	2006-07-24

Standard (ICV-1)

QC Batch: 28340 Date Analyzed: 2006-07-26 Analyzed By: LJ

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Alkalinity		mg/L as CaCo3	250	240	96	90 - 110	2006-07-26

Standard (CCV-1)

QC Batch: 28340 Date Analyzed: 2006-07-26 Analyzed By: LJ

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Alkalinity		mg/L as CaCo3	250	240	96	90 - 110	2006-07-26

Standard (ICV-1)

QC Batch: 28356 Date Analyzed: 2006-07-26 Analyzed By: TP

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Dissolved Calcium		mg/L	50.0	50.7	101	90 - 110	2006-07-26
Dissolved Potassium		mg/L	50.0	52.0	104	90 - 110	2006-07-26
Dissolved Magnesium		mg/L	50.0	49.6	99	90 - 110	2006-07-26
Dissolved Sodium		mg/L	50.0	50.9	102	90 - 110	2006-07-26

Standard (CCV-1)

QC Batch: 28356 Date Analyzed: 2006-07-26 Analyzed By: TP

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Dissolved Calcium		mg/L	50.0	51.2	102	90 - 110	2006-07-26
Dissolved Potassium		mg/L	50.0	54.6	109	90 - 110	2006-07-26
Dissolved Magnesium		mg/L	50.0	50.0	100	90 - 110	2006-07-26
Dissolved Sodium		mg/L	50.0	53.2	106	90 - 110	2006-07-26

Standard (ICV-1)

QC Batch: 28406 Date Analyzed: 2006-07-27 Analyzed By: SM

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Dissolved Solids		mg/L	1000	1056	106	90 - 110	2006-07-27

Standard (CCV-1)

QC Batch: 28406 Date Analyzed: 2006-07-27 Analyzed By: SM

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Dissolved Solids		mg/L	1000	1075	108	90 - 110	2006-07-27

Standard (ICV-1)

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Chloride		mg/L	12.5	12.4	99	90 - 110	2006-08-02
Sulfate		mg/L	12.5	12.7	102	90 - 110	2006-08-02

Standard (CCV-1)

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Chloride		mg/L	12.5	12.2	98	90 - 110	2006-08-02
Sulfate		mg/L	12.5	12.4	99	90 - 110	2006-08-02

Page 1 of 1

6701 Aberdeen Ave, Ste 9
Lubbock,Texas 79424
Tel (806) 794-1296
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1 (800) 378-1296

TraceAnalysis, Inc.

155 McCutcheon Way, Suite H
El Paso,Texas 79932
Tel (915) 585-3443
Fax (915) 585-4944
1 (888) 588-3443

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6072143

Company Name: RICE Operating Company
Phone #: (505)393-9174
Address: (Street, City, Zip) 122 W Taylor Street - Hobbs, New Mexico 88240
Fax #: (505) 397-1471
Contact Person: Kristin Farris - Pope, Project Scientist
kpope@riceswd.com
Invoice to: (If different from above)
Project #: None Given
Project Name: BD Zachary Hinton
Project Location: Lea County - New Mexico
Sampler Signature: Rozanne Johnson (505)631-9310
rozanne@valornet.com

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX					PRESERVATIVE METHOD						SAMPLING	
				WATER	SOIL	AIR	SLUDGE		HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE	NONE	DATE 2006	TIME
96140	Monitor Well #1	2	40 ml	X					X				X		7-19	12:55
	Monitor Well #1	1	1L	X									X		7-19	12:55

ANALYSIS REQUEST
(Circle or Specify Method No.)

FIELD CODE	MTBE 8021B/602	BTEX 8021B/602	TPH 418.1/TX1005 / TX1005 Extended (C35)	PAH 8270C	Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	TCLP Metals Ag As Ba Cd Cr Pb Se Hg	TCLP Volatiles	TCLP Semi Volatiles	TCLP Pesticides	RCI	GC/MS Vol. 8260B/624	GC/MS Semi. Vol. 8270C/625	PCB's 8082/608	Pesticides 8081A/608	BOD, TSS, pH	Moisture Content	Cations (Ca, Mg, Na, K)	Anions (Cl, SSSSO4, CO3, HCO3)	Total Dissolved Solids		Turn Around Time if different from standard	Hold
Monitor Well #1		X																				
Monitor Well #1																	X	X	X			

Relinquished by: Rozanne Johnson Date: 7-20-06 Time: 8:00
Received by: Date: Time:

Relinquished by: Date: Time:
Received by: Date: Time:

Relinquished by: Date: Time:
Received at Laboratory by: Megan McKeel Date: 7-21-06 Time: 1105

LAB USE ONLY
Intact [✓ Y] N
Headspace Y [✓ N]
Temp 4.0 °
Log-in Review NA
Carrier # Bus GU 1690177159

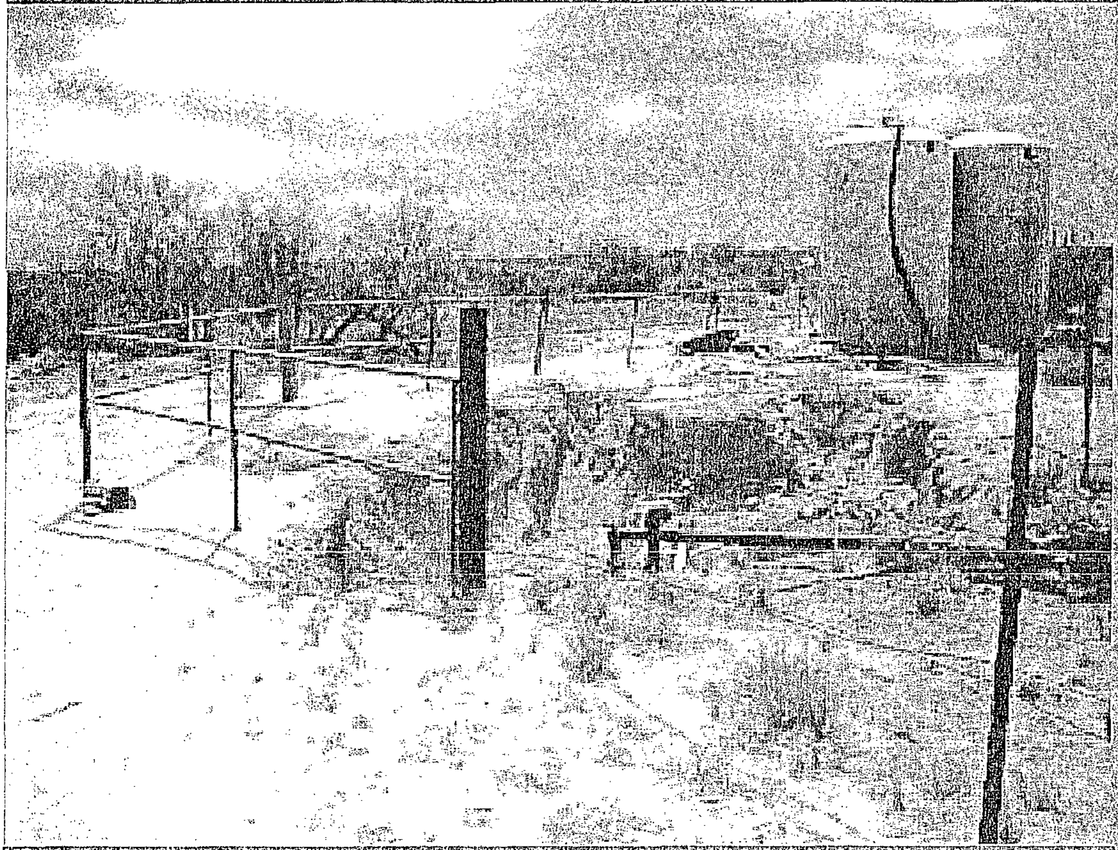
REMARKS:

☐ check if special reporting limits needed

Submittal of samples constitutes agreement to Terms and Conditions listed on reverse side of COC

October 2005

Stage I & II Abatement Plan



Zachary Hinton

EOL Junction Box

R.T. HICKS CONSULTANTS, LTD.

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

1.0 EXECUTIVE SUMMARY

This report presents the results of the characterization activities performed by R.T. Hicks Consultants (Hicks Consultants) and Rice Operating Company (ROC) at the Zachary Hinton EOL Junction Box site. Based on field data, laboratory results, and predictive modeling, the selected remedy for the site involves placing clean fill within the excavation and placing about 3-feet of topsoil and over the site installed with a slight crown to promote surface runoff, then seeding the site with native vegetation. Using highly conservative input data, HYDRUS-1D modeling of this scenario predicts that resulting ground water chloride concentrations due to migration of residual chloride to ground water are less than 70 ppm above background concentrations (assumed as 100 ppm) after five years.

Ground water monitoring data confirm that the HYDRUS-1D predictions are conservative in that they over estimate the impact of residual chloride transport to ground water. After two years of ground water monitoring, chloride concentrations in ground water beneath the site have returned to ambient conditions (300-400 ppm).

We propose to employ MODFLOW and its contaminant transport module to predict the fate and transport of the historic impact to ground water quality evidenced by the first sample analysis. We hypothesize that the simulation modeling will show that natural dilution and dispersion has effectively mitigated any past impact to ground water quality.

This remedy is protective of ground water quality, human health, and the environment. We recommend that NMOCD close the regulatory file after completion of surface restoration and proposed modeling and forego regulation of this site under Rule 19.

2.0 DATA SUMMARY & CONCLUSIONS

2.1 DATA SUMMARY

1. In early 2002, ROC upgraded the junction box, characterized the upper vadose zone, and installed a monitoring well about 20 feet down gradient from the former box.
2. Chloride concentrations in the vadose zone exceed 1,000 ppm from 5 feet below ground surface to ground water.
3. The first ground water sample from the monitoring well exhibited a chloride concentration of 1,000 ppm.
4. Sampling of nearby supply wells demonstrates that the ambient chloride concentration in ground water is 300-400 ppm at the site.
5. Nine months of quarterly monitoring after installation of the monitoring well, chloride concentrations in samples from the monitoring well returned to the regional background concentration, 300-400 ppm.

2.2 CONCLUSIONS

1. The chemical data, the sandy lithology of the vadose zone, the lack of hydrocarbons in soil, and the water production history of the site support a conclusion that periodic small releases of produced water moved vertically from the junction box to ground water without horizontal dispersion.
2. The nature of the release and the site investigation results support a conclusion that the magnitude and extent of the release is sufficiently defined to permit design of a remedy.
3. In the past, leakage from the site caused a highly localized zone of ground water impairment.
4. Due to the nature of the release, the cross-gradient (east-west) extent of the historic impairment of ground water is probably less than 40 feet.
5. Although a single monitoring well cannot define the down gradient (north-south) extent of chloride in ground water caused by past releases, the Second Law of Thermodynamics supports a conclusion that natural dispersion and dilution will cause chloride to reach background concentrations after a relatively short down gradient transport distance.
6. Ground water data from nearby wells and data from the Zachary Hinton EOL site monitoring wells support the conclusion that 2004-2005 ground water samples from the Zachary Hinton EOL monitoring well are at background concentrations

and therefore do not now exceed the state ground water standards for chloride and TDS.

7. Other than TDS and chloride, no other constituents of concern exceed the New Mexico numerical ground water standards in the area near the site.
8. The HYDRUS-1D simulation that considers re-vegetation of the site provides an accurate representation of the current condition and agrees with site ground water data.

2.3 PROPOSED REMEDY

We recommend restoring the ground surface in the excavation using soil that will permit re-vegetation. Because the water quality at the site has returned to background conditions, we recommend plugging and abandonment of the existing monitoring well and closure of the regulatory file for this site, pending documentation of appropriate surface reclamation and presentation of the proposed saturated zone modeling experiment.

3.0 STAGE 1 ABATEMENT PLAN

ROC characterized the uppermost vadose zone during the junction box upgrade program. The results of this characterization are included in the disclosure report (Appendix A). ROC obtained samples of the deep vadose zone using an air-rotary technique and split spoon sampling. This delineation program adequately defines site conditions, and provide the data necessary to select and design an effective abatement option for the vadose zone (see Rule 19.15.1.19.E.3).

ROC characterized the saturated zone through more than three years of ground water monitoring. Hicks Consultants and ROC augmented this ground water quality database by collecting samples from nearby wells and by researching historic ground water quality data. The ground water delineation program adequately defines site conditions, and provides the data necessary to select and design an effective abatement option for the saturated zone (see Rule 19.15.1.19.E.3).

The following sections of this report present the results of the characterization programs.

3.1 CHRONOLOGY OF EVENTS

The disclosure report prepared by Rice Operating Company (ROC) in January 21, 2003 (Appendix A) summarizes the initial activities at the site. NMOCD approved the Hicks Consultants July 2, 2003 work plan for the site on August 21, 2003 (see Appendix B). Since the initial upgrade of the end-of-line box and installation of the monitoring well in 2002, ROC has overseen nearly four years of ground water sampling. Table 1 summarizes the chronology of events.

3.2 SITE LOCATION AND LAND USE

The Zachary Hinton EOL Junction Box is located about 2.5 miles southeast of the intersection of State Routes 18 and 8/176, near Eunice, New Mexico. Plate 1 shows the location of the site relative to Eunice, New Mexico. The general area of the site is employed for grazing and oil production. Plate 2 is a 2004 image showing the site, nearby oil wells and other development on this rangeland.

3.3 GEOLOGY & HYDROGEOLOGY

3.3.1 Regional & Site Hydrogeology

Plate 3 presents a geologic map of southern Lea County. This map shows the Ogallala Formation is present throughout much of the area and is underlain by the Dockum Group redbeds (the Dockum Group is mapped as T (r) cu on Plate 3). Along Monument Draw, erosion has

Table 1. Chronology of Events at the Zachary Hinton EOL Box

February 6, 2002	ROC upgrades EOL junction box and characterizes upper vadose zone
February 28, 2002	ROC installs monitoring well adjacent to EOL junction box
March 12, 2002	ROC notifies NMOCD of groundwater impact
April 2002 to June 2003	ROC conducts four quarters of ground water monitoring to confirm initial result and collect data in preparation for a corrective action plan
July 2, 2003	Hicks Consultants submits a corrective action workplan to NMOCD for review
August 21, 2003	NMOCD approves the workplan, which includes collection of ground water quality data from nearby supply wells and HYDRUS-1D simulation modeling
January 30, 2004	Hicks Consultants submits a Corrective Action Plan for NMOCD Review
December 3, 2004	NMOCD requests additional information
December 8, 2004	Hicks Consultants provides requested information
May 5, 2005	NMOCD orders ROC to submit an Abatement Plan pursuant to Rule 19
June 29, 2005	Hicks Consultants requests reconsideration of Abatement Plan Requirement
July 13, 2005	NMOCD re-iterates Abatement Plan Requirement

stripped the Ogallala and deposition of alluvium over the redbeds has created a separate aquifer that is hydraulically connected to the Ogallala in many locations (see Nicholsen and Clebsch, 1961).

Plate 4 displays the portion of the geologic map of southern Lea County southeast of Eunice, New Mexico (Nicholsen and Clebsch, 1961). The Ogallala Formation underlies the City of Eunice and the eastern boundary of Plate 4. Quaternary erosion and deposition removed the Ogallala and deposited alluvium within the central part of Plate 4, which effectively outlines the active channel of Monument Draw. The Zachary Hinton EOL junction box is plotted on Plate 4 and is in the middle of the alluvium within Monument Draw.

Plate 4 also shows the elevation of the top of the red-bed surface. The Dockum Group red beds are an aquiclude below the Ogallala and alluvial aquifers. In the area of the Zachary Hinton EOL junction box, the red bed elevation contours define a paleo-valley just west of and sub-parallel to Monument Draw. The elevation of the red-bed surface exerts controls on ground water flow. Where this surface is higher than the water table elevation, it obviously creates a barrier to flow. Where the red-bed surface is an expression of a paleo-valley, such as our area of interest, ground water may be directed toward the axis of this subsurface feature and the saturated thickness of the aquifer can increase as a result.

Plate 5 is the ground water map of southern Lea County (Nicholsen and Clebsch, 1961) covering the same area as Plate 4. This plate shows that the water table elevation mimics the red-bed elevation. At the Zachary Hinton EOL junction box site, ground water flows south, parallel to Monument Draw. Nicholsen and Clebsch (1961) conclude that "The bulk of the water [in the sediments along Monument Draw and under the Eunice Plain] is derived by underground flow from the Laguna Valley [Monument] area." The red-bed surface map and the water table map support this hypothesis.

Although the quality of the City of Eunice water supply wells is about 100 mg/L chloride (see Nicholson and Clebsch, 1961), a more detailed investigation of the area near the Zachary Hinton EOL site shows higher background levels. Plate 6 shows the locations of wells with past and present water quality data and Table 2 (attached) presents the results for chloride. A later section of this report discusses the local ground water chemistry.

By comparing the data from Nicholsen and Clebsch (1961) presented in Plates 4 and 5 of this report, one can estimate the saturated thickness of the alluvium in our area of interest is approximately 25-75 feet (2.6-22 meters). As shown on Plate 5, the hydraulic gradient in our area of interest is about 0.004.

Freeze and Cherry (1979) present a chart that compares hydraulic conductivity values to grain size and employing this chart for the unconsolidated sand in the uppermost saturated zone (50-60 feet below ground surface) yeilds a hydraulic conductivity value of 10^{-4} m/s. The resultant transmissivity of the unit is 1.5×10^{-3} m/s. The storativity (specific yield or porosity for this unconsolidated water table aquifer) of this sand should be about 0.25. From these data we calculate the rate of ground water flow as 0.14 m/d.

Surface water in the area is ephemeral and flows in Monument Draw occur only after large precipitation events. We found no evidence to suggest that the release from the junction box affected Monument Draw in any manner. Therefore, this document does not provide information on surface water hydrogeology.

3.4 WATER WELL INVENTORY

Appendix D presents the locations and other data of wells within the Office of the State Engineer database for the area within 1-mile of the Zachary Hinton EOL junction box site and the adjacent area. To this table we have added several wells discovered by field reconnaissance.

A later section of this report presents data to show that no existing supply wells are threatened by the release from the Zachary Hinton EOL junction box.

3.5 SUBSURFACE SOILS MONITORING PROGRAM

3.5.1 Results

The soil boring (Plate 7 and Appendix E) and backhoe excavation data (Appendix A) demonstrate that the vadose zone is sand and does not contain the caliche horizons that are common to the Ogallala Formation. This vadose zone profile is typical of the Quaternary Alluvium and is consistent with the geologic mapping presented in Plate 4.

The investigations did not detect evidence of regulated petroleum hydrocarbons in the vadose zone. Because regulated hydrocarbons were not present, further inquiry with respect to hydrocarbons is not warrented. In borehole samples, chemical data show concentrations of chloride greater than 200 ppm from 11 feet below ground surface to 50 feet below ground surface (Figure 1). The chloride concentrations greater than 1,000 ppm prompted ROC to complete a monitoring well at this site.

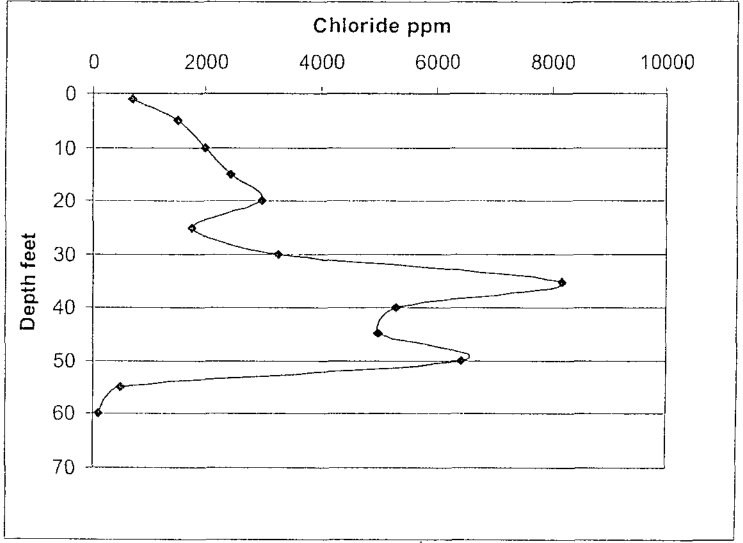


Figure 1. Borehole Chloride vs. Depth

3.5.2 Nature of the Release

Appendix C presents our conceptual model of produced water releases from junction boxes, such as the Zachary Hinton EOL site. In the absence of crude within the pores of the vadose zone at the release site, the vertical flow of produced water is less restricted. At this site, we believe that episodic releases of produced water entered the vadose zone and migrated vertically.

Chloride concentrations in excess of 1,000 ppm from below the junction box to ground water suggest that past releases from the junction box created saturated conditions in the vadose zone. Additionally, the geometry of the chloride v. depth profile of the boring may cause one to hypothesize that chloride concentration peaks at 20, 35 and 50 feet below ground surface represent three separate release events. However, without definitive grain size or moisture content analyses, these types of hypotheses are not always correct. A fine-grained horizon (such as a caliche) will have materially higher chloride concentrations than a sand horizon that immediately overlies the fine-grained horizon due to the higher moisture content.

We believe that the large difference between chloride values from 0-30 feet versus the higher values observed below 30 feet suggest that releases from the Zachary Hinton EOL junction box decreased significantly about 15-20 years ago. We base this hypothesis on measurements of chloride migration in the vadose zone of 1 to 3 feet per year at a site near Lovington, New Mexico. We also believe that the chloride concentrations from 0-30 feet suggest that some leakage continued at the site until ROC replaced the box in 2003.

3.5.3 Extent & Magnitude of Brine in the Vadose Zone

The chemical data, the sandy lithology of the vadose zone and the lack of hydrocarbons in the release allow us to conclude that produced water moved vertically from the junction box to ground water. Therefore the vertical extent of the release in the vadose zone is the entire 50-60 foot thick column. The horizontal extent of the release to the vadose zone is defined by the footprint of the former junction box. We believe that produced water moved vertically without the horizontal dispersion because the absence of fine-grained caliche horizons or clay layers in the vadose zone permits one-dimensional vertical flow. We also conclude that the chloride concentration data of the borehole adequately define the magnitude of the release to the vadose zone.

3.6 GROUND WATER QUALITY MONITORING PROGRAM

3.6.1 Results

As stated above, ROC found no hydrocarbons in soil and have not detected hydrocarbons in ground water.

Figure 2 presents ground water quality data from the monitoring well that is located within 20 feet of the former Zachary Hinton EOL junction box. Chloride concentrations were about 1,000 mg/L in early 2002, soon after replacement of the junction box. The concentration of chloride declined significantly after the first sampling event then continued to decline until June 2003. Since mid summer of 2003, chloride concentrations remained stable (less than 500 mg/L). With the exception of an anomalous analysis tied to documented laboratory errors in December 2004, TDS concentrations have followed the trend established by the chloride ion. Note that the scale of Figure 2 eliminates plotting of this anomalous data point and permits one to observe the parallel trends of chloride and TDS.

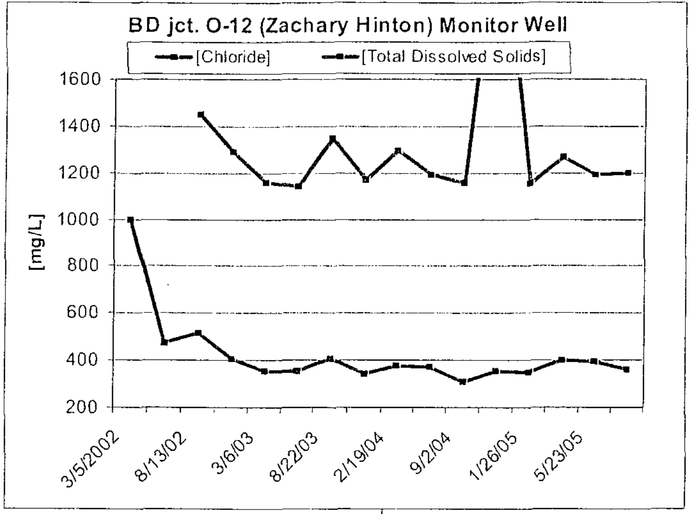


Figure 2. Chloride and TDS in site monitor well over time.

As part of our evaluation of water quality in the area, we examined the past and current ground water quality of nearby water supply wells. Plate 6 shows the locations of nearby wells that have historical water quality data and presents the chloride concentration in ground water for each of these wells.

West of Monument Draw, the data show the chloride concentration in the City of Eunice wells and the Peters West well are below Water Quality Control Commission numerical standards for ground water. Wells within or near Monument Draw, however, generally exceed the numerical standards. The difference between the water quality west of Monument Draw and the water quality within and near the Draw has been evident since the 1950s when Nicholson and Clebsch sampled the water of the area (Table 2).

Up gradient (north) from the Zachary Hinton EOL site, chloride concentration in the Active Windmill of Section 36 is 460 ppm. Like the Zachary Hinton EOL site, this well lies within Monument Draw. The chloride in this active windmill is consistent with the chloride concentrations observed in wells 22.37.1.440 and 22.37.24.133b (average of 422 and 675 ppm respectively) in the 1950s, both of which are located within Monument Draw. The Peters East well, which lies within Monument Draw and is down gradient of the Zachary Hinton EOL site, exhibits a chloride concentration of 438 ppm. As stated above the recent chloride concentrations in the Zachary Hinton EOL monitoring well are less than 400 ppm. This measurable difference in chemistry between the Zachary Hinton Site and the Peters East well could be due to the effect of higher quality ground water flowing into the Monument Draw area from the west (e.g. 200 ppm chloride in the Peters West well), or the difference may be due to normal variance associated with sampling and analysis. From these data we can conclude that 2004-2005 ground water samples from the Zachary Hinton EOL monitoring well are at background concentrations and therefore do not now exceed the state ground water standards for chloride and TDS.

3.6.2 Other Constituents of Concern

The laboratory did not detect any regulated petroleum hydrocarbons in ground water. Sulfate concentrations in ground water are below New Mexico numerical standards. The evidence allows us to conclude that only chloride and total dissolved solids exceed the numerical ground water standards.

3.6.3 Extent and Magnitude of TDS and Chloride in Ground Water

As suggested above, we conclude that the horizontal extent of the near surface release was confined to the size of the junction box itself and produced water flowed vertically through the vadose zone without material lateral dispersion to ground water. Therefore, the monitoring well, which is located about 20 feet down gradient from the former junction box, provides representative ground water chemistry data for the aquifer immediately below the release. These data show chloride concentrations of 1,000 mg/L several months after replacement of the junction box and a 6-month decline in chloride concentrations after the source of leakage ceased (i.e. replacement of the junction box).

Earlier sections of this report also provide evidence that saturated flow existed from the base of the junction box to ground water until the box was replaced in 2002. Because saturated flow continued until 2002 and the highest chloride concentrations are deep in the vadose zone, we can also conclude that the 1,000 mg/L chloride concentration of the initial ground water sample represents a reasonable estimate of the maximum chloride concentration in ground water caused by the release. A later section of this report suggests a maximum chloride concentration in ground water of less than 2,000 mg/L may have occurred in the past. Today concentrations of chloride in down gradient ground water are unlikely to be greater than 1,000 mg/L because of dispersion and dilution with transport would reduce chloride concentration.

Although we can definitively state that the water quality at the site currently meets state standards (i.e. background or existing water quality), one well cannot define the full extent of any impairment caused by the past leakage from the site. We can conclude, however, that the cross-gradient (east-west) extent of chloride concentrations exceeding background levels may be about twice the cross-gradient dimension of the junction box, or about 40 feet. We propose to test this hypothesis with the ground water modeling exercise proposed as part of the Stage 2 Abatement Plan: Saturated Zone.

A single monitoring well cannot define the down gradient (north-south) extent of chloride in ground water caused by past releases. We believe that natural dispersion and dilution will cause chloride to reach background concentrations after a relatively short down gradient transport distance. We propose to test this hypothesis with the ground water modeling proposed as part of the Stage 2 Abatement Plan: Saturated Zone.

4.0 STAGE 2 ABATEMENT PLAN: VADOSE ZONE

We used the numerical model HYDRUS-1D to simulate the transport of residual chloride from the surface through the vadose zone to ground water. We used the predicted flux of chloride to ground water from HYDRUS-1D as input into a simple ground water mixing-model to evaluate the impact on ground water quality. As Hendickx and others (2005) describe in *Modeling Study of Prodiced Water Release Scenarios*, this modeling effort requires 10 input parameters. Section 3.0 of Hendrickx and others describes the modeling approach.

4.1 DATA EMPLOYED FOR THE ZACHARY HINTON SITE

For some input parameters we employed regional data or values based upon professional judgment (see Table 3). For most of the input data to our simulations, we relied upon site data collected by Rice Operating Company. Our field inspection of the site and our evaluation of the data allow us to conclude that the site data used in our simulations reflect the conditions at the site.

Plate 7 shows the soil profile texture and thickness of the vadose zone at the site (input parameters # 1 and #2 of Table 3). We input the soil texture into HYDRUS-1D and allowed the model's library to generate the hydraulic properties. We then used these hydraulic properties in simulations of these scenarios.

Table 3. Input parameters in HYDRUS model

Parameter	Values	Source of Data
1. Depth to Ground Water (feet)	56	Site Data
2. Vadose Zone Texture (see Plate 7)	Attached well log	Site Data
3. Dispersion Length (cm)	100	Professional Judgment
4. Water Content θg (%)	High θg Layer 1: 10% Layer 2: 30% Layer 3: 25%	Estimated from HYDRUS simulations
5. Vadose Zone Chloride Distribution (gr/kg)	Soil boring, Plate 7	ROC data from Disclosure Report
6. Length of release perpendicular to ground water flow (feet)	20	Field measurements
7. Climate Index	Pearl, NM station (Hobbs area)	NOAA data
8. Background Ground Water Chloride (mg/L)	100	Samples from nearby wells
9. Ground Water Flux (cm/day)	0.014	Calculated from regional hydrological data
10. Aquifer Thickness (feet)	35	Nicholson & Clebsh (1961) and OSE data

Based upon our experience, we employed a dispersion length of 100 cm (input #3). The selected dispersion length is 7% of the total length of the HYDRUS-1D model (55 feet). Many researchers suggest that a dispersion length that is 7-10% of the total model length provides reasonable results for simulation experiments.

We used the soil moisture content (input # 4) presented in Table 3 from HYDRUS-1D simulations. Because we did not have site-specific soil moisture data, we assumed a "dry" soil profile then used the climate data to add moisture to the profile via precipitation over 100 years. We found that initial soil moisture in the profile changed over this 100-year period, responding to the climatic conditions. Therefore, we ran the simulations under both "wet" and "dry" conditions as determined by the 100-year simulation experiment. As Table 3 shows, we elected to employ the "wet" conditions in our simulations because leakage from the junction box over the past years has created "wet" conditions within the profile.

Plate 7 shows the measured soil chloride concentration per unit weight of soil. We converted these values to concentrations per liter of soil water (input #5) by using the equations in Hendrickx and others (2005). The length of the release (input #6) was measured in the field.

The daily climate data available from the Pearl weather station near the Hobbs Airport served as input for all climate indices required by HYDRUS-1D (input #7). We simulated 10 years after the release with average precipitation 36 cm/year.

For the input parameter #8, background ground water chloride concentration, we used 100 mg/L based upon data from the City of Eunice. We used data for the Ogallala Aquifer as described in Nicholsen and Clebsch, (1961) as input to the mixing model (input #9, ground water flux; input #10, aquifer thickness).

We also used data from the BD Zachary Hinton site monitor well to verify the predictions of the HYDRUS-1D model and the mixing model.

4.2 SETUP OF SIMULATIONS

Scenario 1: Current Conditions

The current condition scenario evaluates the potential of the chloride mass in the vadose zone to materially impair ground water quality at the site in the absence of any action by Rice Operating Company and in the absence of any natural restoration (e.g. re-establishing vegetation). As described in Hendickx and others (2005), the distribution of the mass of chloride in the vadose zone (input #5) is the most important input parameter for prediction of chloride concentrations in ground water. For this and all simulations, we assumed the chloride concentrations shown in Plate 7 existed in the profile at time zero. At time zero, we also assume that man-made leakage of produced water has ceased and the chloride concentration in the monitoring well is equal to background (100 mg/L). While the first and second assumptions are acceptable, the assumption that the chloride concentration in the monitoring well is equal to background is false. We make this last assumption as a matter of convenience to simplify our model and we explain the effect of this simplification in our discussion of the results of the simulations.

The chloride concentration of soil water $Cl^{soil\ water}$ (mg/liter) depends on the gravimetric chloride content of moist soil $Cl_g^{moist\ soil}$ (mg/kg of moist soil), the bulk density of the soil D_{soil}^{dry} (kg/m³), and the volumetric water content of the soil $è_v$ (m³/m³) input #4 . To convert the chloride concentration in the soil to chloride concentration in soil water (see Hendrickx and others, 2005), we used a soil density of 1,858 kg/cubic meter and the soil moisture content in Table 3.

We entered the chloride concentration of soil water in the soil profile in HYDRUS and ran the simulation for 10 years with total precipitation and evaporation from the soil. Vegetation was assumed to not be present to enhance water transfer from soil to the atmosphere. We calibrated the results from the model with the chloride data from a monitoring well located 20 feet down gradient from the center of the spill.

Scenario 2: Reduce Infiltration

To minimize the potential for any leaching of residual chloride from the vadose zone, we assumed a surface remedy that would reduce infiltration of precipitation. To simulate such a remedy, we simply reduced the precipitation by assuming that heavy rains (that cause the majority of the infiltration) ran off after 1.5 cm fell. This simulation predicts the effect of (a) sloping the site to cause runoff of the larger precipitation events and/or (b) placement of a graded compacted layer at the surface to minimize infiltration, facilitate runoff and prevent ponding of precipitation. All other input parameters are the same as Scenario 1.

Scenario 3: Vegetation

This scenario consists of placing 30 cm of silt loam and reseeding with pasture. The transpiration is zero during the winter months but soil evaporation takes place. During the growing season, evapotranspiration is greatest. All other input parameters are the same as Scenario 1.

Scenario 4: A Silt Clay Below the Top Soil

In this scenario we placed 60 cm of a silt clay below the topsoil under the same conditions of Scenario 3. Placing the clay below the top soil minimizes infiltration into the deeper profile and provides a place for the infiltration of winter precipitation to reside until the plants take it up in the following spring and summer. All other input parameters are the same as Scenario 1.

4.3 SIMULATION RESULTS AND DISCUSSION

Figure 3 shows the response of Scenario 1 in a monitoring well located 20 feet from the center of the spill at the release site. The simulation shows chloride concentration increasing to a maximum of 1,652 ppm in year 1.7. As stated in the previous section, in this and other simulations, when man-made leakage ceased, the chloride concentrations in the vadose zone are equal to that represented in Plate 7 and Figure 1. To simplify our modeling experiment, we assumed that the chloride concentration in the monitoring well at time zero in Figure 3 is equal to background (100 mg/L). Therefore, the initial increase in chloride concentration from background (100 mg/L) to a maximum (1,652 in this simulation) is the model's response to the downward movement of the initial distribution of chloride in the profile. Because the well was installed after replacement of the junction box and cessation of periodic leakage, we cannot know the chloride concentration at the monitoring well during past man-made leakage events. We hypothesize, however, that chloride concentration in ground water would be 1,652 mg/L or more during the time that the junction box periodically released produced water. Chloride concentrations in the monitoring well might remain at or above the 1,652 mg/L during the years of periodic discharges from the former junction box, as chloride migrated from the ground surface to ground water via saturated flow. After replacement of the junction box, water additions to the soil profile cease and the soil profile would drain. During the drainage of the soil profile, chloride concentrations in the monitoring well would decrease as saturated flow ceased and slower, unsaturated flow conditions occurred in the profile.

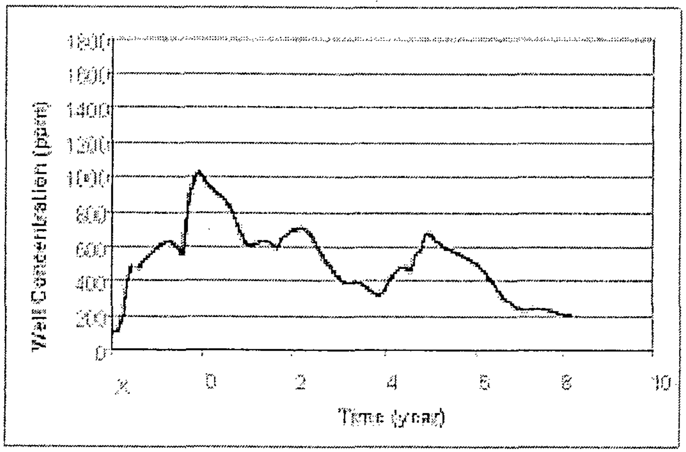


Figure 3. Chloride concentration in the monitoring well for the current conditions scenario. (Scenario 1)

Figure 4 modifies the HYDRUS-1D output to better represent the conditions described above. In this Figure, time X represents background conditions, before any leakage from the junction box. As periodic leakage occurs, chloride concentration in ground water rises and chloride is distributed throughout the unsaturated zone. We believe that the maximum chloride concentration in ground water in Figure 4 (1,652 mg/L) is approximately what we would have observed during the period of leakage from the junction box if the monitoring well had been installed. After upgrade of the junction box (here noted as approximately time zero), chloride concentrations decline as discussed above and as shown in Figure 4. About five years after upgrade of the junction box under the Current Condition Scenario, ground water chloride approaches the background concentration assumed in the model (100 mg/L).

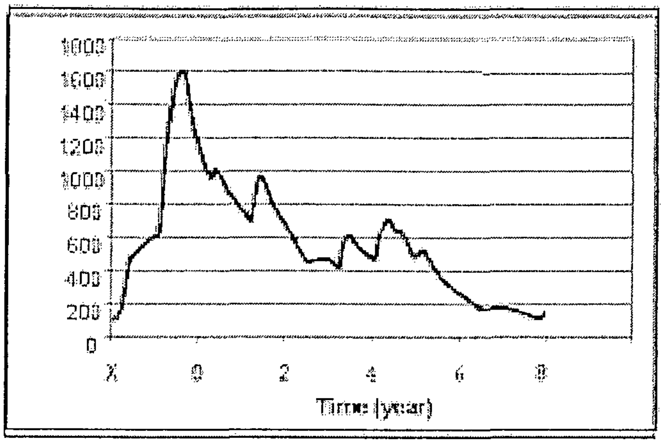


Figure 4. Modification of HYDRUS-1D simulation results to illustrate a more realistic time scale for Scenario 1.

Figure 5 shows the results of our simulations of Scenario 2 with the same modified time line as in Figure 3. Reducing infiltration of precipitation creates a maximum concentration 1,048 mg/L marked approximately as year 0 to show when junction box upgrade occured. Reducing infiltration slows the drainage of vadose zone water relative to the current condition scenario. Therefore, water and chloride enter the ground water more slowly in this scenario as compared to the no action scenario. In other words, the chloride flux (mass/time) into ground water is lower in scenario 2 than in scenario 1. The ground water flux and aquifer thickness, however, remain the same in both scenarios. The lower chloride flux into ground water results in a lower maximum concentration observed in the monitoring well. This lower flux also results in a longer time of predicted non-compliance at the monitoring well.

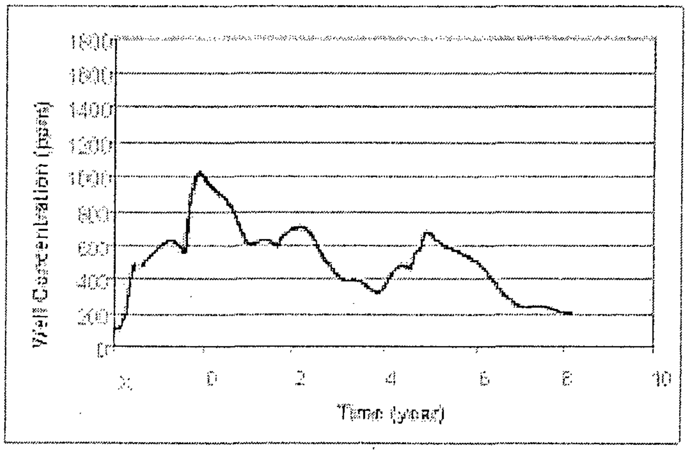


Figure 5. Modification of HYDRUS-1D simulation results to show a more realistic time scale for chloride concentration in the monitoring well for the scenario reducing the infiltration. (Scenario 2)

About six years after upgrade of the junction box, the majority of the chloride has drained from the vadose zone and concentrations in the well declines to the standard of 250 mg/L. We did not simulate the length of time necessary for ground water to reach background conditions under this scenario.

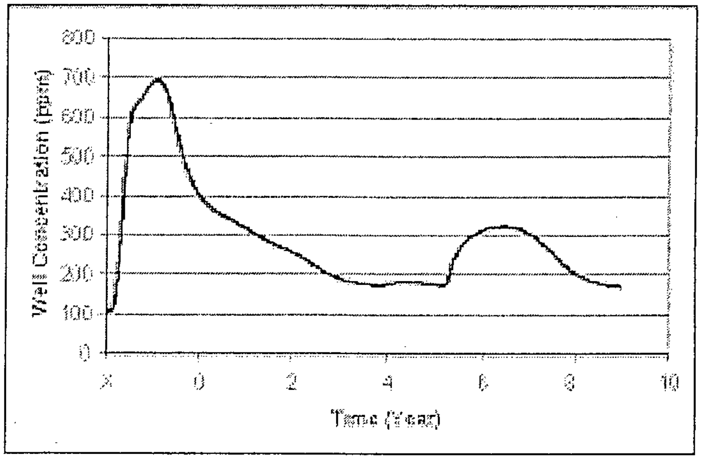


Figure 6. Modification of HYDRUS-1D simulation results to illustrate a more realistic time scale, chloride concentration in the well for the vegetation scenario. (Scenario 3)

Figure 6 shows the results of the Scenario 3, which assumes further reduction of infiltration due to evapotranspiration as a result of plant cover. The maximum chloride concentration in the well is 693 mg/L (or about 600 mg/L above the assumed background concentration of 100 mg/L) at approximately zero time on the modified scale. As discussed previously, the time of maximum chloride concentration is the time when the junction box is upgraded. The chloride concentration declines to the standard of 250 mg/L in year 2.11. However, we predict an increase in ground water chloride concentrations to 323 mg/L in year 6.5 followed by a decrease to the standard by year 7.5. This increase at year 6.5 is probably due to increased infiltration associated with the El Niño weather pattern. Because most the chloride has drained from the profile by year 6.5, we conclude that any additional increase in ground water chloride concentration (perhaps at year 14) would not exceed the ground water standard of 250 mg/L.

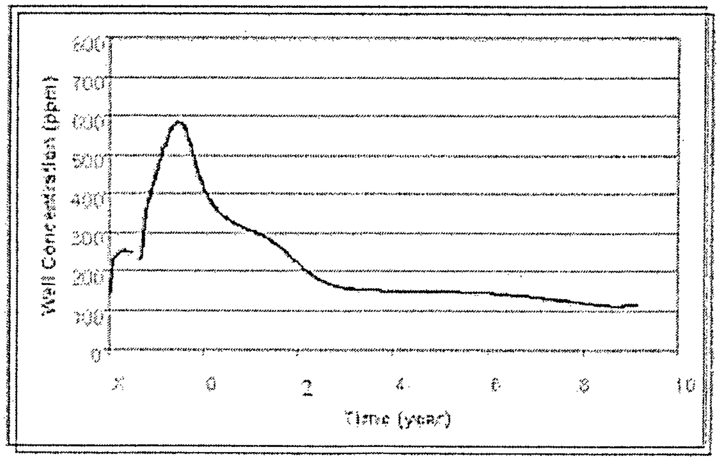


Figure 7. Modification of HYDRUS-1D simulation results showing a more realistic time scale of chloride concentration in the well for the scenario with vegetation and a silt clay layer below the topsoil. (Scenario 4).

The concentrations in the root zone in Scenario 3 are quite high as result of capillary rise that accumulates the salts at the top of the profile. Concentrations of 4,000 mg/L will prevent the grass of developing unless chloride moves deeper into the subsurface due to a soil flushing program or natural rainfall.

Figure 7 shows the result of Scenario 4 with the modified time scale. The maximum concentration in the well is 604 mg/L in year 0. It declines to 250 ppm in year 1.75. The concentrations in the root zone are about 1,300 mg/L, suitable for vegetation. By year 8, background conditions exist in the monitoring well.

Figure 2 of this report is reproduced in Plate 8 with the HYDRUS-1D simulation for Scenario 3 to permit comparison. The monitoring well data show chloride concentrations declining from 1,000 mg/L to 400 mg/L over a nine-month period. Obviously, these data do not correlate with the model predictions of Scenario 1, current conditions. Instead, the field data are more similar to the predictions of Scenario 3, where infiltration into the vadose zone is relatively low due to evapotranspiration associated with vegetation. What is most striking about the field data and the predictions of Scenario 3 is that both show a maximum chloride concentration of 600 mg/L above background at time zero. The field data and the HYDRUS-1D prediction also show relatively good agreement with respect to the time required for ground water to re-equilibrate with background water quality conditions. The simulation predicts that chloride will be less than 200 mg/L after about 2.5 years. The ground water data show that the monitoring well is at background chloride concentrations (between 350 and 400 mg/L) after about 1.5 years from cessation of saturated or "wet" conditions.

The similarity shown in Plate 10 should not be surprising if one visits the site. Vegetation does exist around the area of the suspected release (Figure 8). We believe the current flux of chloride from the vadose zone to ground water is approximately the same as that simulated in Scenario 3. We can also conclude from Figure 8 that the chloride concentration in the root zone is low enough to support vegetation. The current condition scenario, which does not provide for evapotranspiration or any reduced infiltration, obviously overestimates the impact of the chloride load to ground water quality.

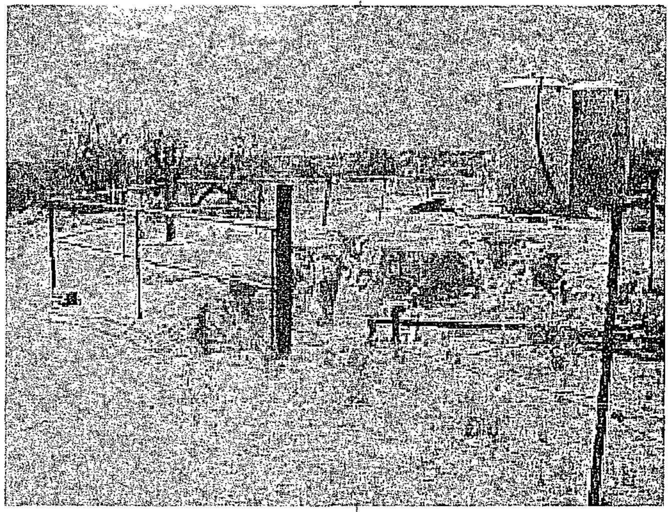


Figure 8. Vegetation at the site.

4.4 CONCLUSION AND RECOMMENDED ACTION: VADOSE ZONE

The HYDRUS-1D simulations for the Zachary Hinton site provide reasonably good, albeit conservative, predictions of chloride concentrations in ground water for the various scenarios. The simulation showed that about two years after the upgrade of the junction box and cessation of accidental and periodic water leakage, HYDRUS-1D predicts that chloride concentrations in the ground water monitoring well are at background correlations. The field data correlate well with early time predictions of Scenario 3, reduced flux due to vegetation. We conclude Scenario 3 predicts higher chloride concentrations than observed.

We conclude that the background chloride concentration in ground water at the Zachary Hinton EOL site is about 350-400 mg/L. We base this conclusion on historical and recent water quality analyses from the area. Natural restoration has mitigated the transient impact of past leakage from the site.

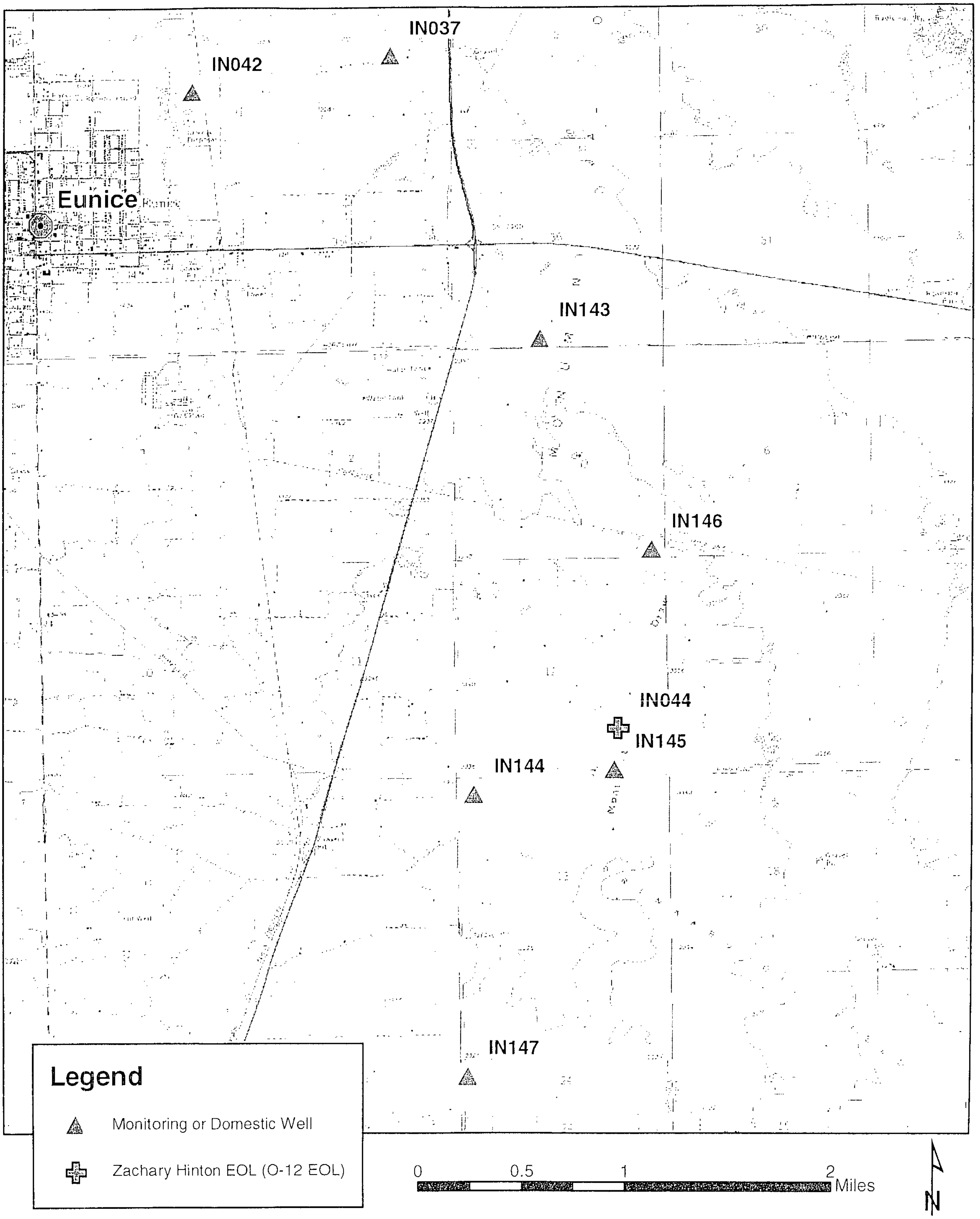
We recommend restoring the ground surface in the excavation using soil that will permit re-vegetation. Because the water quality at the site has returned to background conditions, we recommend plugging and abandonment of the existing monitoring well and closure of the regulatory file for this site, pending documentation of appropriate surface reclamation.

5.0 STAGE 2 ABATEMENT PLAN: SATURATED ZONE

The monitoring well at the Zachary Hinton EOL Junction Box site does not exceed New Mexico ground water standards because ambient (background) concentrations are equal or greater than those currently observed. Therefore, there exists no zone of ground water impairment to define. Additional monitoring wells at the site are not warranted.

We propose to employ MODFLOW and its contaminant transport module to predict the fate and transport of the historic impact to ground water quality evidenced by the first sample analysis. We hypothesize that the simulation modeling will show that natural dilution and dispersion has effectively mitigated any past impact to ground water quality.

PLATES

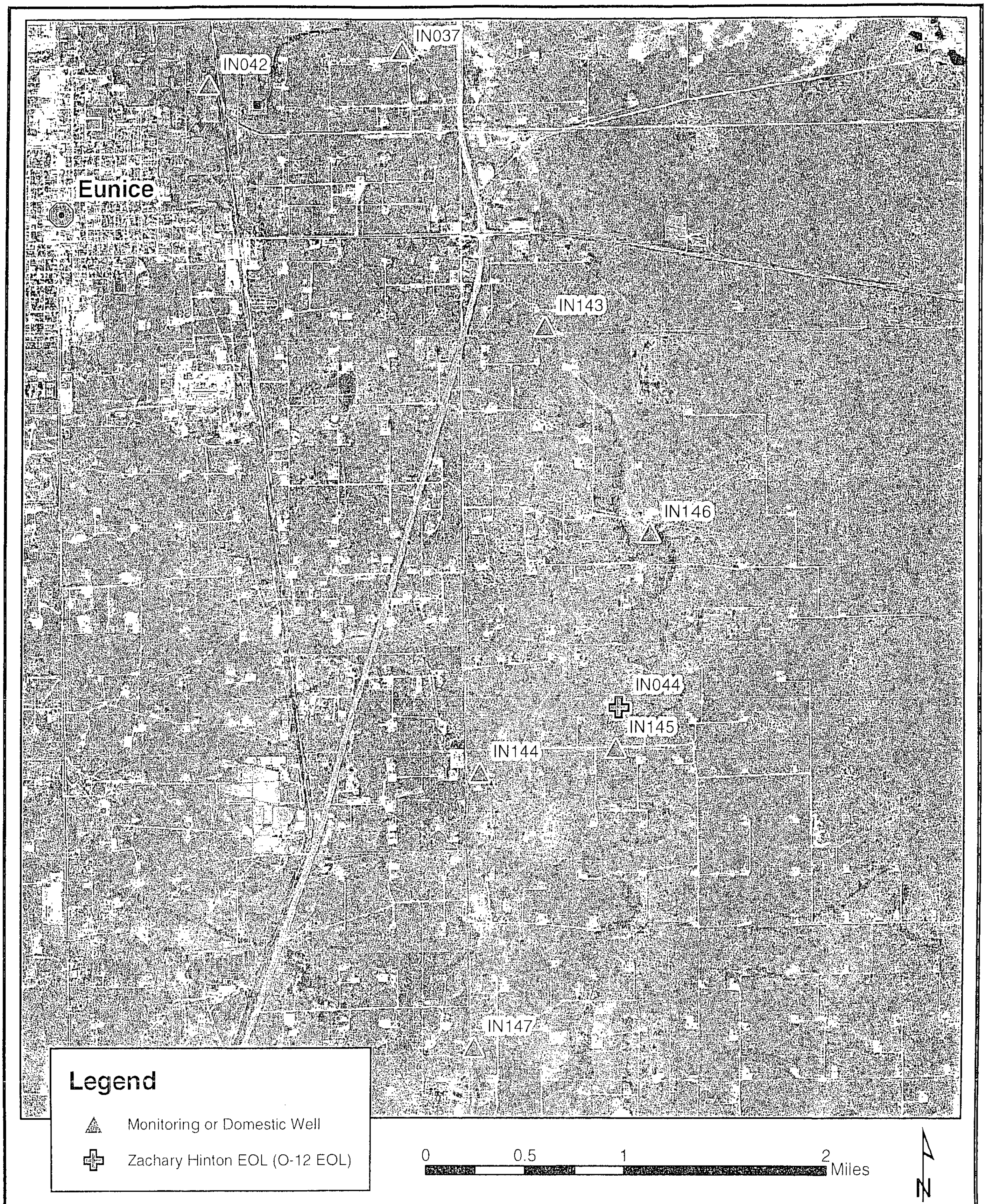


Location of Zachary Hinton EOL Relative to Eunice, NM

Plate 1

ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)

October 2005



2004 Aerial Photograph of Site and Surrounds

Plate 2

ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)

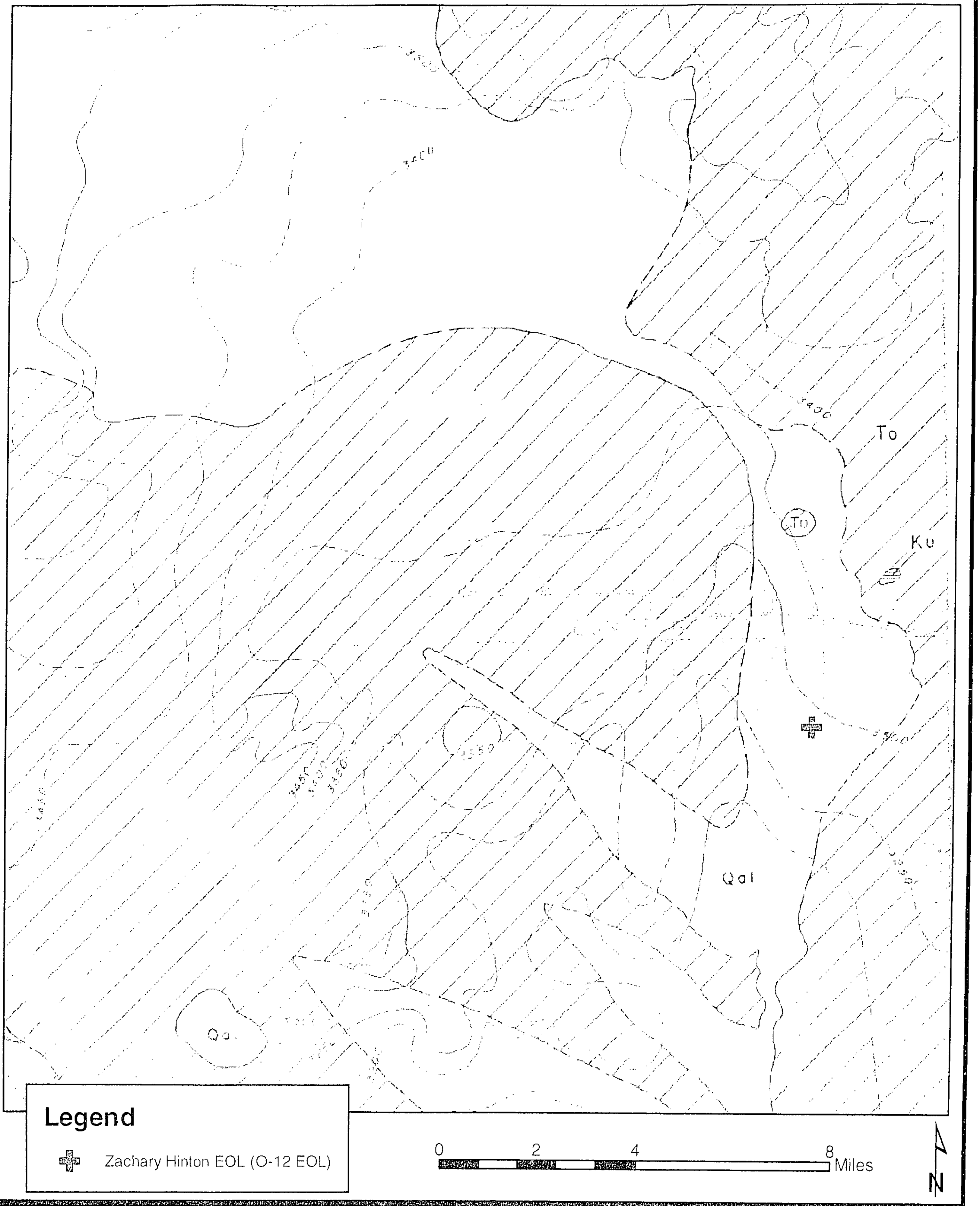
October 2005

Regional Geologic Map (USGS Open File Report OF-97-52)

Plate 3

ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)

October 2005

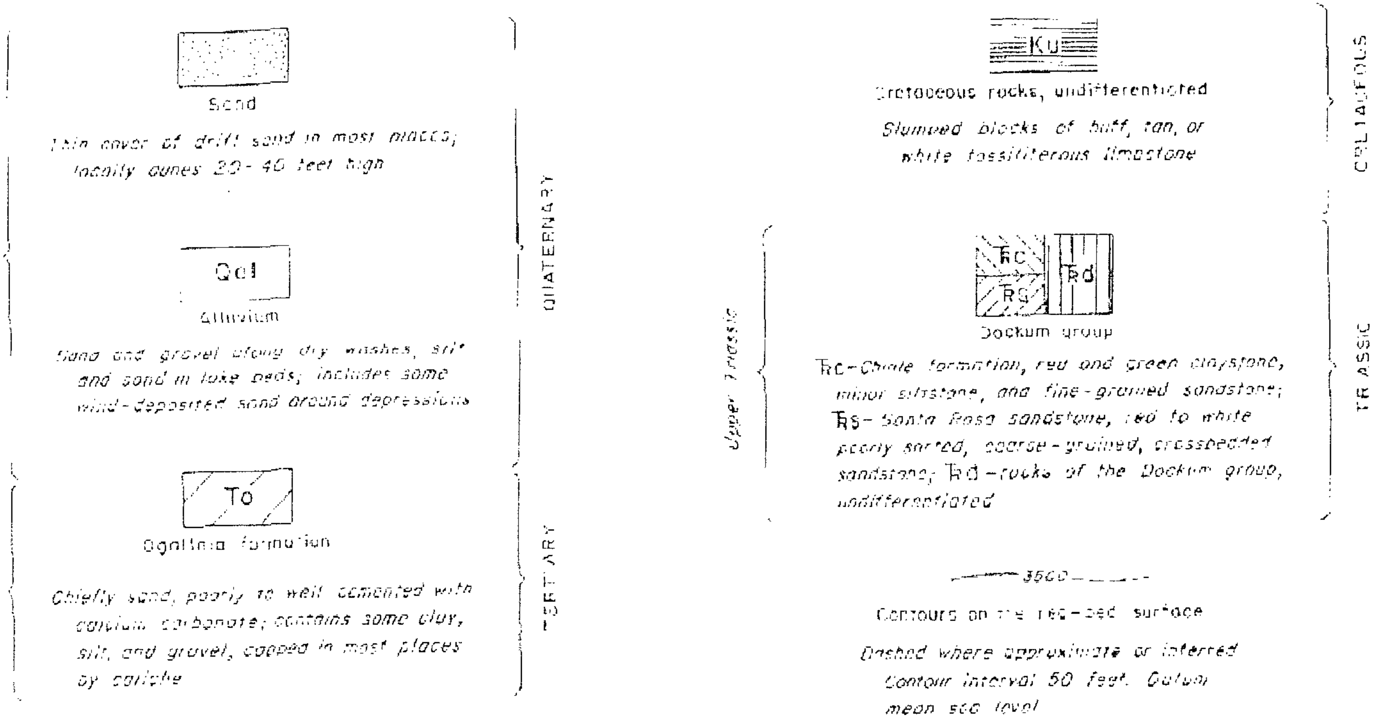


Legend

🟏 Zachary Hinton EOL (O-12 EOL)

	Local Geologic Map (Nicholson & Clebsch, 1961)	Plate 4
	ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)	October 2005

EXPLANATION



Sand

Thin cover of drift sand in most places; locally dunes 20-40 feet high

Qal Alluvium

Sand and gravel along dry washes, silt and sand in lake beds; includes some wind-deposited sand around depressions

To Ogallala formation

Chiefly sand, poorly to well cemented with calcium carbonate; contains some clay, silt, and gravel, capped in most places by caliche

Ku Cretaceous rocks, undifferentiated

Slumped blocks of buff, tan, or white fossiliferous limestone

Dockum group

T̄Rc—Chinle formation, red and green claystone, minor siltstone, and fine-grained sandstone; T̄Rs—Santa Rosa sandstone, red to white poorly sorted, coarse-grained, crossbedded sandstone; T̄Rd—rocks of the Dockum group, undifferentiated

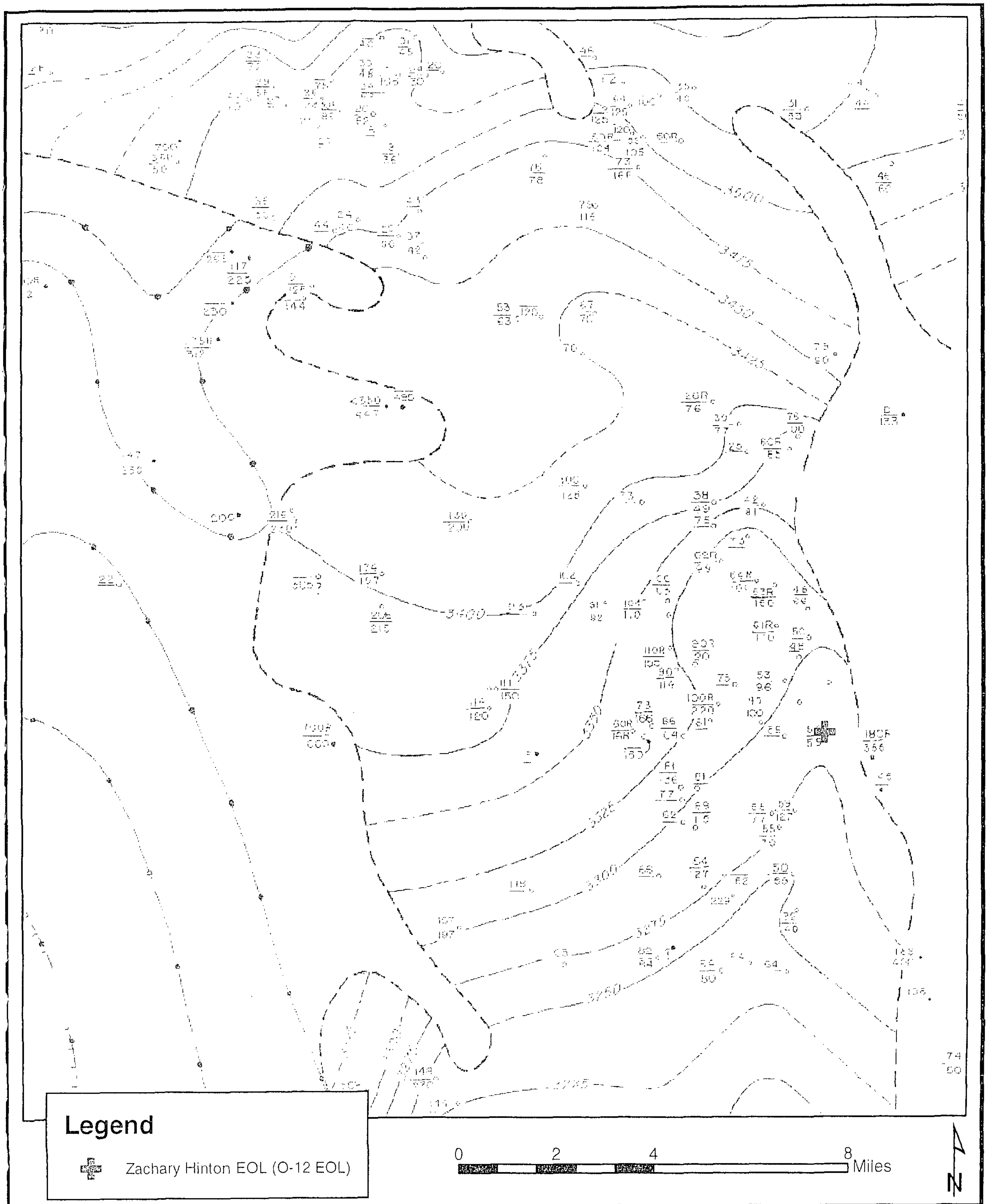
——— 3500 — — — —

Contours on the red-bed surface

Dashed where approximate or inferred Contour interval 50 feet. Datum mean sea level

Legend to Nicholson & Clebsch (1961) Geologic Map

	Supplemental Legend to Geologic Map	Plate 4 Supplemental
	ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)	October 2005



Legend

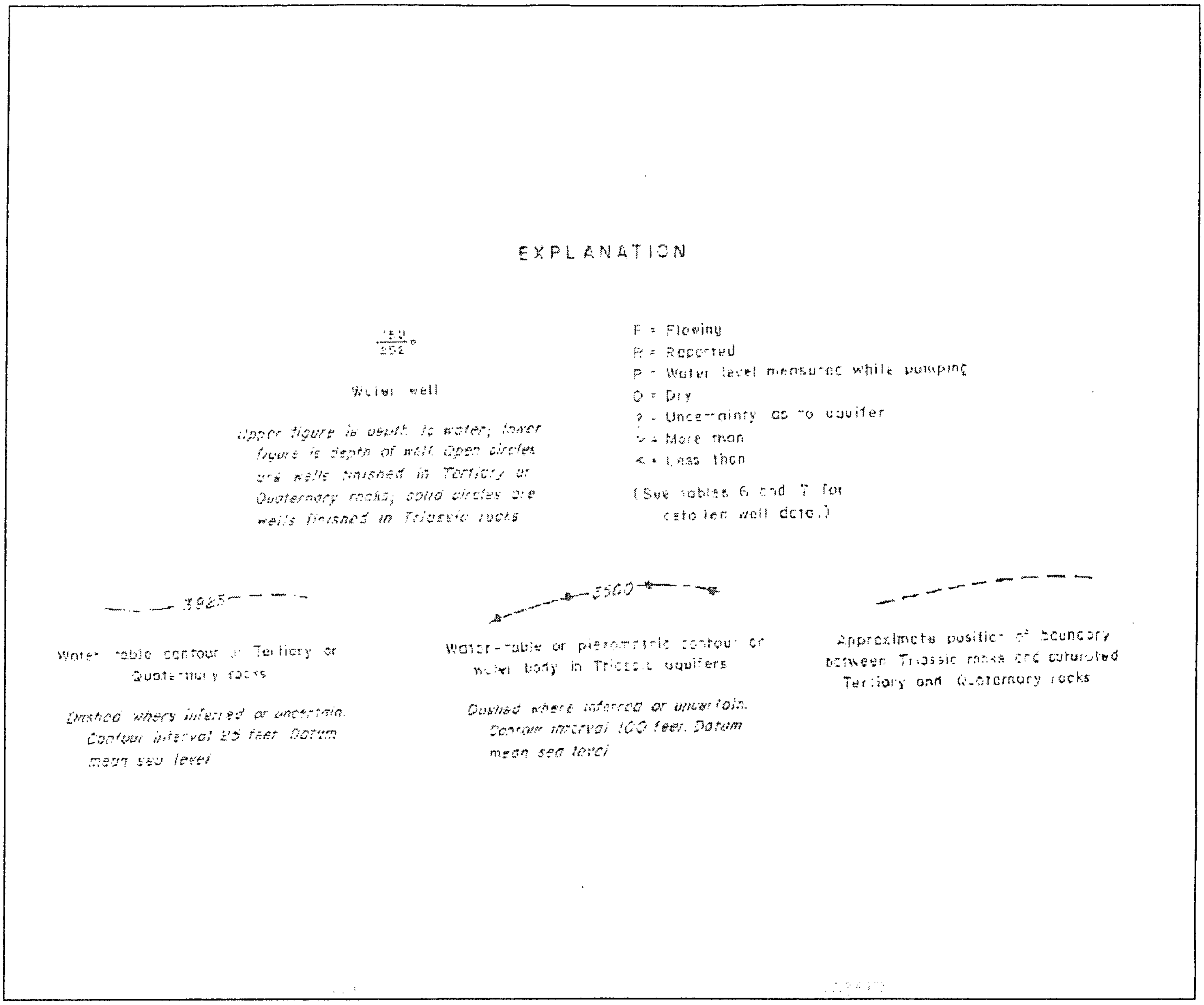
✚ Zachary Hinton EOL (O-12 EOL)

Local Ground Water Map (Nicholson & Clebsch, 1961)

Plate 5

ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)

October 2005



EXPLANATION

Water well

Upper figure is depth to water; lower figure is depth of well. Open circles are wells finished in Tertiary or Quaternary rocks; solid circles are wells finished in Triassic rocks

F = Flowing
R = Reported
P - Water level measured while pumping
O = Dry
? - Uncertainty as to aquifer
> = More than
< = Less than

(See tables 6 and 7 for detailed well data.)

Water-table contour in Tertiary or Quaternary rocks

Dashed where inferred or uncertain. Contour interval 25 feet. Datum mean sea level

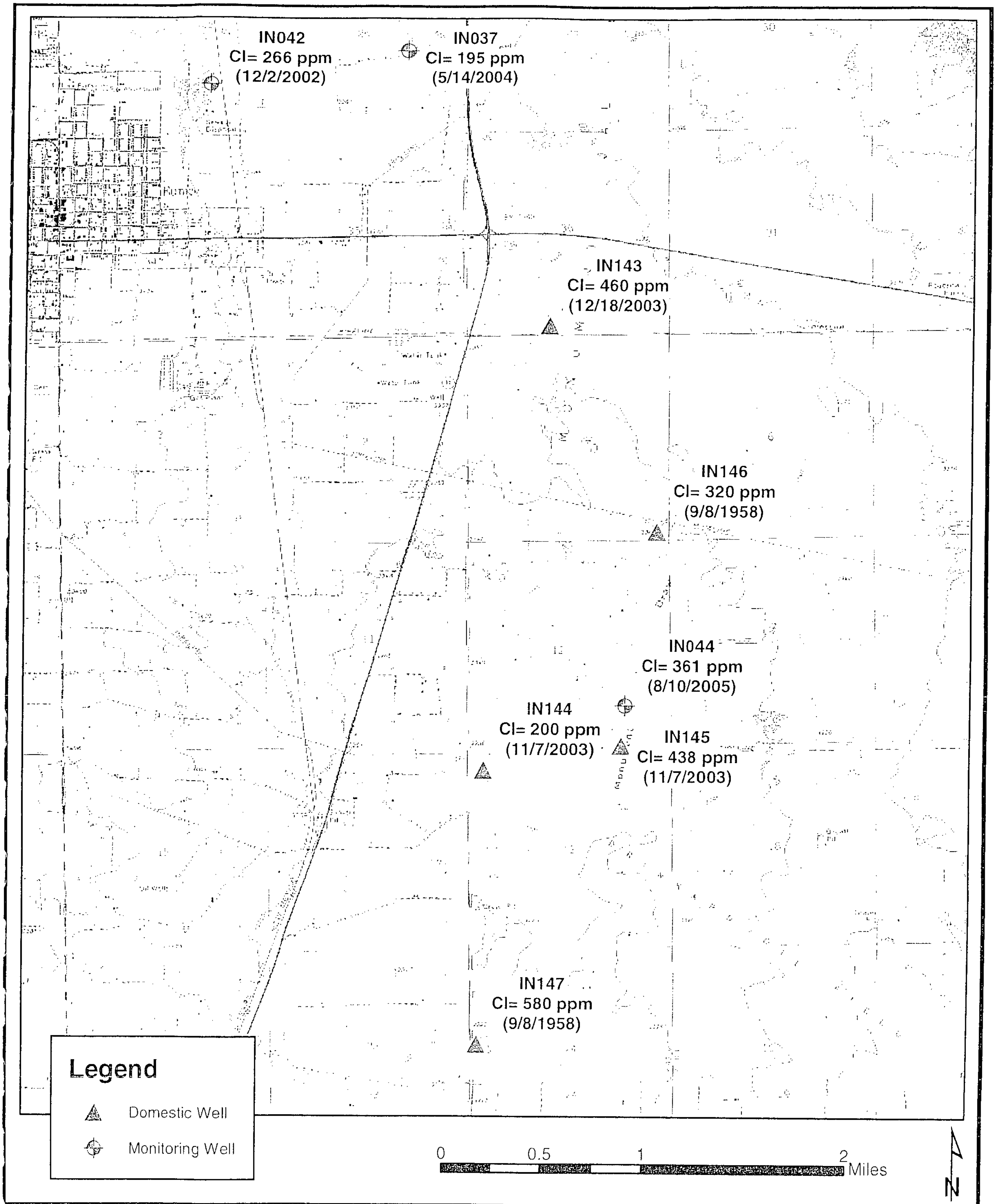
Water-table or piezometric contour on water body in Triassic aquifers

Dashed where inferred or uncertain. Contour interval 100 feet. Datum mean sea level

Approximate position of boundary between Triassic rocks and saturated Tertiary and Quaternary rocks

Legend to Nicholson & Clebsch (1961) Ground Water Map

R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Supplemental Legend to Ground Water Map	Plate 5 Supplemental
	ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)	October 2005



Dissolved Chloride Concentration Map

Plate 6

ROC: CAP Zachary Hinton EOL (NMOCD #: 1R0426-36)

October 2005

Depth	Lithologic Description	Measured Soil Chloride Concentration mg/kg	Bulk Density of Sample kg/cubic meter	Thickness of Column (ft)	Calculated Chloride Mass in Column (kg/m2)
ground surface					
	0-3 feet Sandy Top Soil				
	3-13 feet Caliche and Sand	1500	1858	5	4.616726087
10		2000	1858	5	6.155634783
	13-19 feet Sandy Clay	2450	1858	5	7.540652609
20	19-56 feet Various Colored Sands	3000	1856	5	9.223513043
		1750	1858	5	5.386180435
30		3270	1858	5	10.06446287
		8160	1858	5	25.11498991
40		5300	1858	5	16.31243217
		5000	1858	5	15.38908696
50		6410	1858	5	19.72880948
Aquifer 56		500	1858	5	1.538908696
60	Aquifer = Gray Sand 56-60 ft				
Total Depth of MW	Aquifer = Sandy Clay 60-63 ft	Calculated Chloride Load			121.071397

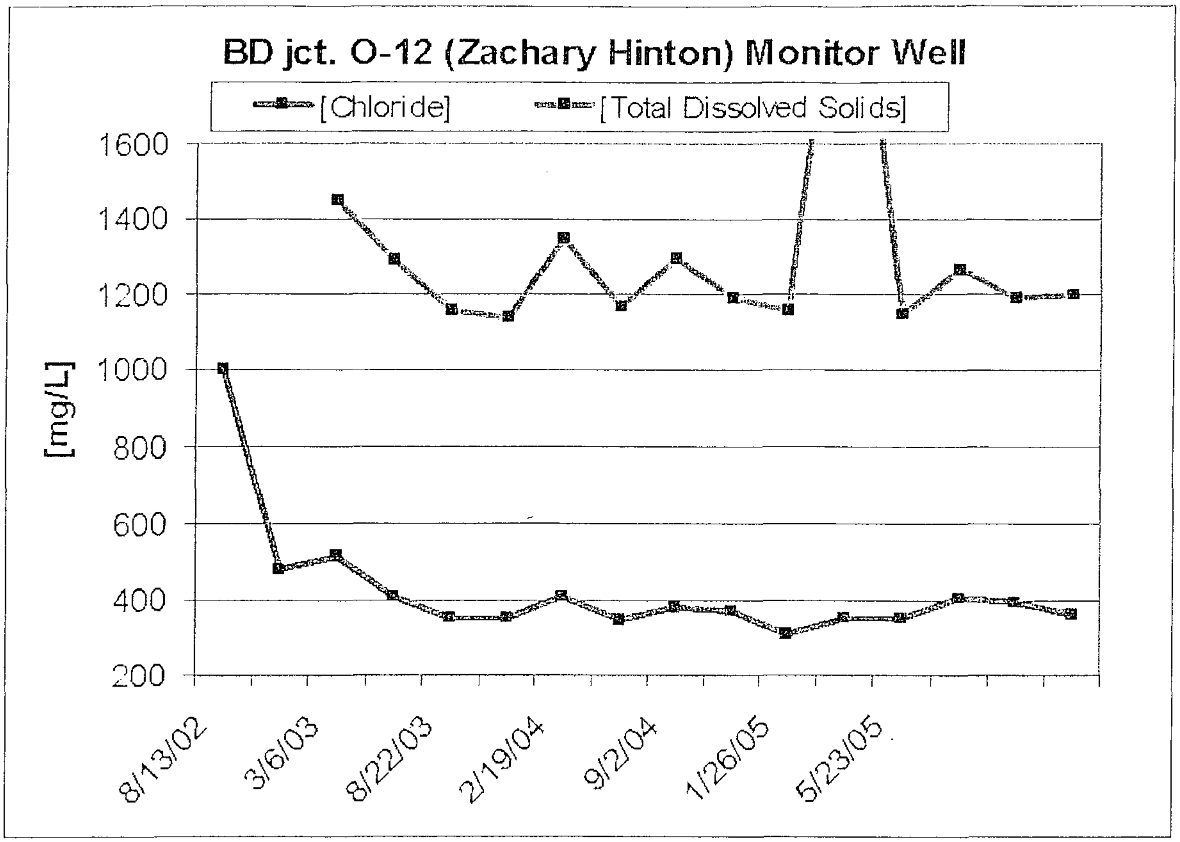
R.T. Hicks Consultants, Ltd.
901 Rio Grande NW
Albuquerque, NM

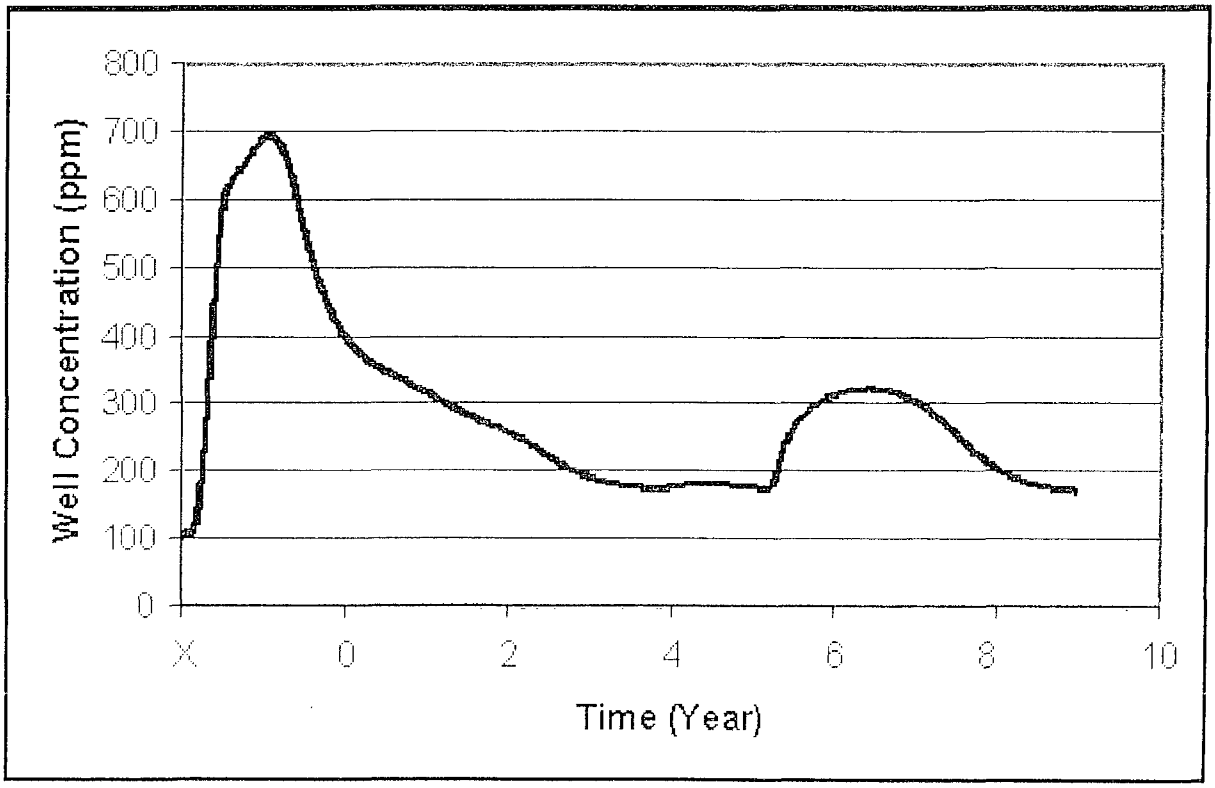
RICE Operating Company

Borehole Lithology Calculation of Chloride Load, Zachary Hinton EOL, Lea County

Plate 7

October 2005





R.T. Hicks Consultants, Ltd. 901 Rio Grande Blvd. NW, Suite F-142 Albuquerque, NM 87104 505.266.5004 ☐ Fax: 505.266.0745	Figures 2 & 6 From Text	Plate 8
	ROC Zachary Hinton EOL (O-12)	October 2005

TABLES

Table 2a: Wells Within Area of Interest

Internal Number	Site ID	Common Name	Easting (UTM NAD 83)	Northing (UTM NAD 83)	Location	System	Data From	Well Type	Well Operator	Well Owner	Land Owner
IN037	21S.373.26.J.JCT.1	Jct. J-26-1	675771.36	3591704.7	Sec 26, T21S, R37E	Hobbs BD	ROC	Monitoring Well			
IN042	21S.37E.27.I.JCT.1	Jct. I-27-1	674232.27	3591428.4	Sec 27, T21S, R37E	Hobbs BD	ROC	Monitoring Well			
IN044	22S.37E.12.O.EOL.1	Zachary Hinton EOL (O-12 EOL)	677561.08	3586541.5	Sec 12, T22S, R37E	Hobbs BD	ROC	Monitoring Well	ROC		
IN143	22S.37E.36.N.344	Windmill NE of Zach Hinton	676940.77	3589522.0	Sec 36, T22S, R37E	Domestic Well	RT Hicks	Domestic Well			
IN144	22S.37E.13.D.111	Peters Well West	676440.95	3/58/6034	Sec 13, T22S, R37E	Domestic Well	ROC	Domestic Well			
IN145	22S.37E.13.A.221	Peters Well East	677533.62	3586224 7	Sec 13, T22S, R37E	Domestic Well	ROC	Domestic Well			
IN146	22S 37E.01.P.444	22.37.1.44	677802.92	3587913.7	Sec 01, T22S, R37E	Domestic Well	Nicholson & Clebsch	Domestic Well			
IN147	22S.37E.24.E.133B	22.37.24.133B	676401.38	3583865.7	Sec 24, T22S, R37E	Domestic Well	Nicholson & Clebsch	Domestic Well			

Table 2d: Inorganic Chemistry - Cations

Internal Number (IN)	*Common Name*	*Date*	*Calcium (ppm)*	*Potassium (ppm)*	*Magnesium (ppm)*	*Sodium (ppm)*	*K + Na (ppm)*
IN037	Jct. J-26-1	5 /14/2004	NS	NS	NS	NS	NS
IN037	Jct. J-26-1	5 /7 /2004	NS	NS	NS	NS	NS
IN037	Jct. J-26-1	2 /18/2004	NS	NS	NS	NS	NS
IN037	Jct. J-26-1	10/30/2003	NS	NS	NS	NS	NS
IN037	Jct. J-26-1	8 /22/2003	NS	NS	NS	NS	NS
IN037	Jct. J-26-1	6 /5 /2003	NS	NS	NS	NS	NS
IN037	Jct. J-26-1	2 /28/2003	NS	NS	NS	NS	NS
IN037	Jct. J-26-1	10/29/2002	NS	NS	NS	NS	NS
IN042	Jct. I-27-1	12/2 /2002	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	8 /10/2005	88	10.7	45.6	242	NS
IN044	Zachary Hinton EOL (O-12 EOL)	5 /23/2005	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	3 /22/2005	120	18.9	61.9	344	NS
IN044	Zachary Hinton EOL (O-12 EOL)	1 /26/2005	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	12/21/2004	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	9 /2 /2004	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	4 /17/2004	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	2 /19/2004	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	11/20/2003	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	8 /22/2003	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	6 /5 /2003	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	3 /6 /2003	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	10/25/2002	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	8 /13/2002	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	5 /15/2002	NS	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	3 /5 /2002	NS	NS	NS	NS	NS
NMWQCC Standards (ppm)							

Table 2d: Inorganic Chemistry - Cations

Internal Number (IN)	*Common Name*	*Date*	*Calcium (ppm)*	*Potassium (ppm)*	*Magnesium (ppm)*	*Sodium (ppm)*	*K + Na (ppm)*
IN044	Zachary Hinton EOL (O-12 EOL)	3 /5 /2002	NS	NS	NS	NS	NS
IN064	B-20		NS	NS	NS	NS	NS
IN065	B-30	12/22/2000	NS	NS	NS	NS	NS
IN070	C-13		NS	NS	NS	NS	NS
IN078	H-4		NS	NS	NS	NS	NS
IN101	O-17-1	8 /17/2001	NS	NS	NS	NS	NS
IN143	Windmill NE of Zach Hinton	12/18/2003	101	8.56	66	176	NS
IN144	Peters Well West	11/7 /2003	65	4.49	46	96	NS
IN145	Peters Well East	11/7 /2003	102	8.51	67	154	NS
IN146	22.37.1.44	9 /8 /1958	NS	NS	NS	NS	NS
IN146	22.37.1.44	10/14/1953	222	NS	107	NS	375
IN147	22.37.24.133B	9 /8 /1958	NS	NS	NS	NS	NS
IN147	22.37.24.133B	4 /22/1955	NS	NS	NS	NS	247
IN147	22.37.24.133B	10/14/1953	218	NS	131	NS	254

NS: Not Sampled, ND: Non-Detect

NMWQCC Standards (ppm)

Table 2b: Historic Organic Chemistry

Internal Number (IN)	Common Name	Date	Benzene (ppm)	Toluene (ppm)	Ethylbenzene (ppm)	Total Xylene (ppm)
IN037	Jct. J-26-1	5 /14/2004	NS	NS	NS	NS
IN037	Jct. J-26-1	5 /7 /2004	ND	ND	ND	ND
IN037	Jct. J-26-1	2 /18/2004	ND	ND	ND	ND
IN037	Jct. J-26-1	10/30/2003	ND	ND	ND	ND
IN037	Jct. J-26-1	8 /22/2003	ND	ND	ND	ND
IN037	Jct. J-26-1	6 /5 /2003	ND	ND	ND	ND
IN037	Jct. J-26-1	2 /28/2003	ND	ND	ND	ND
IN037	Jct. J-26-1	10/29/2002	ND	ND	ND	ND
IN042	Jct. I-27-1	12/2 /2002	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	8 /10/2005	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	5 /23/2005	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	3 /22/2005	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	1 /26/2005	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	12/21/2004	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	9 /2 /2004	ND	NS	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	4 /17/2004	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	2 /19/2004	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	11/20/2003	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	8 /22/2003	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	6 /5 /2003	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	3 /6 /2003	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	10/25/2002	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	8 /13/2002	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	5 /15/2002	ND	ND	ND	ND
IN044	Zachary Hinton EOL (O-12 EOL)	3 /5 /2002	NS	NS	NS	NS
NMWQCC Standards (ppm)			*0.01*	*0.75*	*0.75*	*0.62*

Table 2b: Historic Organic Chemistry

Internal Number (IN)	Common Name	Date	Benzene (ppm)	Toluene (ppm)	Ethylbenzene (ppm)	Total Xylene (ppm)
IN044	Zachary Hinton EOL (O-12 EOL)	3 /5 /2002	ND	ND	ND	ND
IN064	B-20		NS	NS	NS	NS
IN065	B-30	12/22/2000	NS	NS	NS	NS
IN070	C-13		NS	NS	NS	NS
IN078	H-4		NS	NS	NS	NS
IN101	O-17-1	8 /17/2001	NS	NS	NS	NS
IN143	Windmill NE of Zach Hinton	12/18/2003	NS	NS	NS	NS
IN144	Peters Well West	11/7 /2003	ND	ND	ND	ND
IN145	Peters Well East	11/7 /2003	ND	ND	ND	ND
IN146	22.37.1.44	9 /8 /1958	NS	NS	NS	NS
IN146	22.37.1.44	10/14/1953	NS	NS	NS	NS
IN147	22.37.24.133B	9 /8 /1958	NS	NS	NS	NS
IN147	22.37.24.133B	4 /22/1955	NS	NS	NS	NS
IN147	22.37.24.133B	10/14/1953	NS	NS	NS	NS

NS: Not Sampled, ND: Non-Detect

NMWQCC Standards (ppm)			0.01	0.75	0.75	0.62

Table 2c: Historic Inorganic Chemistry - Anions and General Chemisty

Internal Number (IN)	Common Name	Date	Chloride (ppm)	Sulfate (ppm)	TDS (ppm)	Total Alkalinity (ppm)	Bicarbonate (ppm)	Carbonate (ppm)	Conductivity (microhmos)
IN037	Jct. J-26-1	5/14/2004	195	NS	736	NS	NS	NS	NS
IN037	Jct. J-26-1	5/7/2004	390	NS	1440	NS	NS	NS	NS
IN037	Jct. J-26-1	2/18/2004	478	NS	1630	NS	NS	NS	NS
IN037	Jct. J-26-1	10/30/2003	620	NS	2040	NS	NS	NS	NS
IN037	Jct. J-26-1	8/22/2003	957	NS	2620	NS	NS	NS	NS
IN037	Jct. J-26-1	6/5/2003	1460	NS	3280	NS	NS	NS	NS
IN037	Jct. J-26-1	2/28/2003	3470	NS	6870	NS	NS	NS	NS
IN037	Jct. J-26-1	10/29/2002	4520	NS	9020	NS	NS	NS	NS
IN042	Jct. I-27-1	12/2/2002	266	NS	1200	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	8/10/2005	361	227	1200	180	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	5/23/2005	393	NS	1190	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	3/22/2005	403	202	1270	192	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	1/26/2005	351	NS	1150	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	12/21/2004	354	NS	2370	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	9/2/2004	310	NS	1160	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	4/17/2004	372	NS	1190	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	2/19/2004	380	NS	1297	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	11/20/2003	346	NS	1170	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	8/22/2003	408	NS	1350	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	6/5/2003	354	NS	1140	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	3/6/2003	354	NS	1160	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	10/25/2002	408	NS	1290	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	8/13/2002	514	NS	1450	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	5/15/2002	478	NS	1470	NS	NS	NS	NS
IN044	Zachary Hinton EOL (O-12 EOL)	3/5/2002	NS	NS	NS	NS	NS	NS	NS
NMWQCC Standards (ppm)			*250*	*600*	*1000*				

Table 2c: Historic Inorganic Chemistry - Anions and General Chemisty

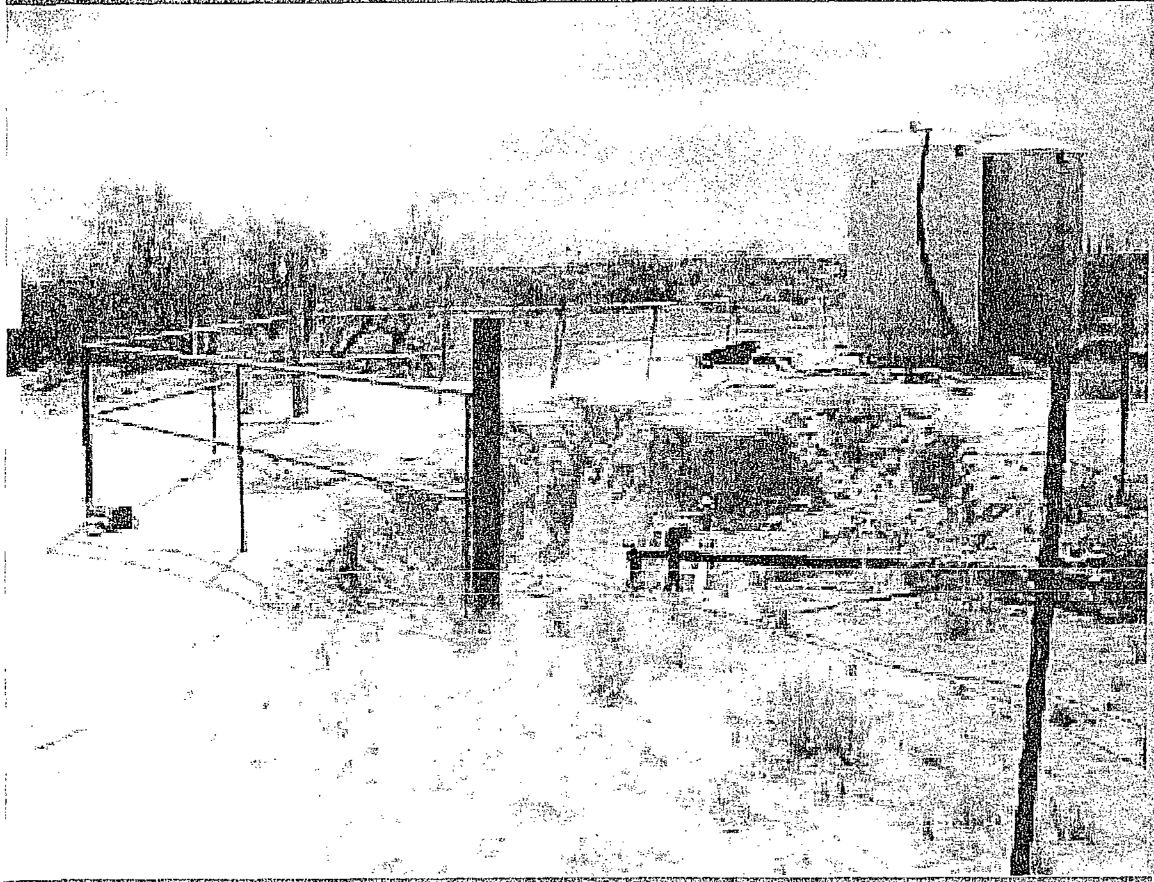
Internal Number (IN)	*Common Name*	*Date*	*Chloride (ppm)*	*Sulfate (ppm)*	*TDS (ppm)*	*Total Alkalinity (ppm)*	*Bicarbonate (ppm)*	*Carbonate (ppm)*	*Conductivity (microhmos)*
IN044	Zachary Hinton EOL (O-12 EOL)	3/5/2002	1000	NS	2403	NS	NS	NS	NS
IN064	B-20		NS	NS	NS	NS	NS	NS	NS
IN065	B-30	12/22/2000	NS	NS	NS	NS	NS	NS	NS
IN070	C-13		NS	NS	NS	NS	NS	NS	NS
IN078	H-4		NS	NS	NS	NS	NS	NS	NS
IN101	O-17-1	8/17/2001	NS	NS	NS	NS	NS	NS	NS
IN143	Windmill NE of Zach Hinton	12/18/2003	460	118	1391	207	180	NS	180
IN144	Peters Well West	11/7/2003	200	62	892	221	269	NS	269
IN145	Peters Well East	11/7/2003	438	93	NS	166	202	NS	202
IN146	22.37.1.44	9/8/1958	320	448	NS	580	211	NS	211
IN146	22.37.1.44	10/14/1953	525	841	2280	994	189	NS	189
IN147	22.37.24.133B	9/8/1958	580	622	NS	1080	216	NS	216
IN147	22.37.24.133B	4/22/1955	770	598	NS	1360	216	NS	216
IN147	22.37.24.133B	10/14/1953	675	482	1960	1080	187	NS	187

NS: Not Sampled, ND: Non-Detect

NMWQCC Standards (ppm)	*250*	*600*	*1000*

January 30, 2004

Corrective Action Plan



Zachary Hinton

EOL Junction Box

R.T. HICKS CONSULTANTS, LTD.

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

1.0 PURPOSE AND BACKGROUND

The Zachary Hinton EOL Junction Box is located about 2.5 miles southeast of the intersection of State Routes 18 and 8/176, near Eunice, New Mexico. Plate 1 of the NMOCD-approved work plan (Appendix A) shows the location of the site relative to Eunice. The work plan identified the following tasks:

1. Collection and Evaluation of Data for Simulation Modeling
2. Evaluate Migration of Chloride Flux from the Vadose Zone to Ground Water
3. Design Remedy and Submit Report

The goal of our work is to identify the surface and subsurface remedy for the site that creates the greatest environmental benefit while causing the least environmental damage.

The disclosure report prepared by Rice Operating Company (ROC) in January 21, 2003 (Appendix B) summarizes the initial activities at the site. The soil boring and backhoe excavation data show relatively consistent concentrations of chloride from 11 feet below ground surface (2000 ppm chloride) to 50 feet below ground surface (6410 ppm chloride). The consistency of these chloride concentrations suggests that a release from the junction box may have created saturated conditions in the vadose zone. Hydrocarbons, often associated with releases from produced water pipelines, were not present in concentrations that warrant further inquiry (see ROC Disclosure Report.)

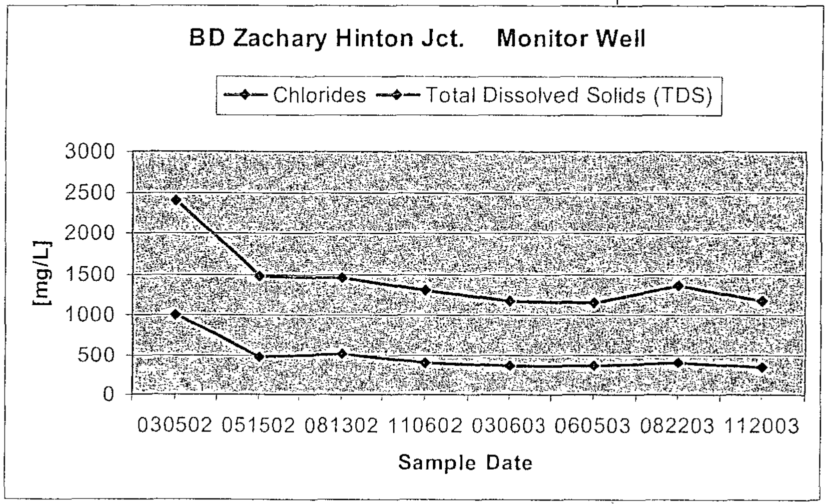


Figure 1. Ground water quality data near Zachary Hinton EOL junction box.

Figure 1 presents ground water quality data from the monitoring well that is located within 20 feet of the former Zachary Hinton EOL junction box (Table 1). Chloride concentrations were about 1000 mg/L in early 2002, soon after replacement of the junction box. Throughout 2003, chloride concentrations remained stable (less than 500 mg/L).

As stated in the work plan, R.T. Hicks Consultants, Ltd. used HYDRUS-1D to simulate chloride fate and transport to ground water and to develop a surface remedy for the site. This report presents the results of our study and proposes a final remedy for the site to permit closure of the regulatory file.

2.0 APPROACH

We used the numerical model HYDRUS-1D to simulate the transport of chloride from the surface through the vadose zone to ground water. We used the predicted flux of chloride to ground water from HYDRUS-1D as input into a simple ground water mixing-model to evaluate the impact on ground water quality. As Appendix C describes, this modeling effort requires 11 input parameters. Appendix C also describes the modeling approach used in this effort.

In our previous work with HYDRUS-1D, we found that some input parameters had little effect on the prediction of chloride concentration in ground water while other factors had a profound effect. The Sensitivity Analysis presented in Appendix C describes the relative importance of each of the eleven input paramerters. Two of these eleven factors (release volume and height of the spill) are not relevant in our simulations, since we evaluated the movement of the chloride load already in the soil profile. Site specific data exist for the most important input factors (e.g. chloride load, depth of ground water, soil texture, etc.).

3.0 DATA EMPLOYED FOR THE ZACHARY HINTON SITE

For some input parameters we employed regional data or values based upon professional judgment (see Table 2). For most of the input data to our simulations, we relyed upon site data collected by Rice Operating Company. Our field inspection of the site and our evaluation of the data allow us to conclude that the site data used in our simulations reflect the conditions at the site.

Plate 2 shows the soil profile texture and thickness of the vadose zone at the site (input parameters # 1 and #2 of Table 2). We input the soil texture into HYDRUS-1D and allowed the model's library to generate the hydraulic properties. We then used these hydraulic properties in simulations of these scenarios.

Based upon our experience, we employed a dispersion length of 100 cm (input #3). The selected dispersion length is 7% of the total length of the HYDRUS-1D model (55 feet). Many researchers suggest that a dispersion length that is 7-10% of the total model length provides reasonable results for simulation experiments.

We used the soil moisture content (input # 4) presented in Table 2 from HYDRUS-1D simulations. Because we did not have site-specific soil moisture data, we assumed a "dry" soil profile then used the climate data to add moisture to the profile via precipitation over 100 years. We found that initial soil moisture in the profile changed over this 100-year period, responding to the climatic conditions. Therefore, we ran the simulations under both "wet" and "dry" conditions as determined by the 100-year simulation experiment. As Table 2 shows, we elected to employ the "wet" conditions in our simulations because leakage from the junction box over the past years has created "wet" conditions within the profile.

Plate 2 shows the measured soil chloride concentration per unit weight of soil. We converted these values to concentrations per liter of soil water (input #5) by using the equations in Appendix D . The length of the release (input #6) was measured in the field.

The daily climate data available from the Pearl weather station near the Hobbs Airport served as input for all climate indices required by HYDRUS-1D (input #7). We simulated 10 years after the release with average precipitation 36 cm/year.

For the input parameter #8, background ground water chloride concentration, we used 100 mg/L based upon data from the City of Eunice. We used data for the Ogallala Aquifer as described in Nicholsen and Clebsch, (1961) as input to the mixing model (input #9, ground water flux; input#10, aquifer thickness).

We also used data from the BD Zachary Hinton Jct monitor well to verify the predictions of the HYDRUS-1D model and the mixing model.

4.0 SET-UP OF SIMULATIONS

SCENARIO 1: NO ACTION

The no action alternative evaluates the potential of the chloride mass in the vadose zone to materially impair ground water quality at the site in the absence of any action by Rice Operating Company and in the absence of any natural restoration (e.g. re-establishing vegetation). As described in Appendix C, the distribution of the mass of chloride in the vadose zone (input #5) is the most important input parameter for prediction of chloride concentrations in ground water. For this and all simulations, we assumed the chloride concentrations shown in Plate 1 existed in the profile at time zero. At time zero, we also assume that man-made leakage of produced water has ceased and the chloride concentration in the monitoring well is equal to background (100 mg/L). While the first and second assumptions are acceptable, the assumption that the chloride concentration in the monitoring well is equal to background is false. We make this last assumption as a matter of convenience to simplify our model and we explain the effect of this simplification in our discussion of the results of the simulations.

The chloride concentration of soil water $Cl^{soil\ water}$ (mg/liter) depends on the gravimetric chloride content of moist soil $Clg^{moist\ soil}$ (mg/kg of moist soil), the bulk density of the soil $Dsoil^{dry}$ (kg/m^3), and the volumetric water content of the soil èv (m^3/m^3) input #4 . To convert the chloride concentration in the soil to chloride concentration in soil water (see Appendix D), we used a soil density of 1,858 kg/cubic meter and the soil moisture content in Table 2.

We entered the chloride concentration of soil water in the soil profile in HYDRUS and ran the simulation for 10 years with total precipitation and evaporation from the soil. Vegetation was assumed to not be present to enhance water transfer from soil to the atmosphere. We calibrated the results from the model with the chloride data from a monitoring well located 20 feet downgradient from the center of the spill.

SCENARIO 2: REDUCE INFILTRATION

To minimize the potential for any leaching of residual chloride from the vadose zone, we assumed a surface remedy that would reduce infiltration of precipitation. To simulate such a remedy, we simply reduced the precipitation by assuming that heavy rains (that cause the majority of the infiltration) run off after 1.5 cm fell. This simulation predicts the effect of (a) sloping the site to cause runoff of the larger precipitation events and/or (b) placement of a graded compacted layer at the surface to minimize infiltration, facilitate runoff and prevent ponding of precipitation. All other input parameters are the same as Scenario 1.

SCENARIO 3: VEGETATION

This scenario consists of placing 30 cm of silt loam and reseeding with pasture. The transpiration is zero during the winter months but soil evaporation takes place. During the growing season, evapotranspiration is greatest. All other input parameters are the same as Scenario 1.

SCENARIO 4: A SILT CLAY BELOW THE TOP SOIL

In this scenario we placed 60 cm of a silt clay below the top soil under the same conditions of Scenario 3. Placing the clay below the top soil minimizes infiltration into the deeper profile and provides a place for the infiltration of winter precipitation to reside until the plants take it up in the following spring and summer. All other input parameters are the same as Scenario 1.

5.0 SIMULATION RESULTS AND DISCUSSION

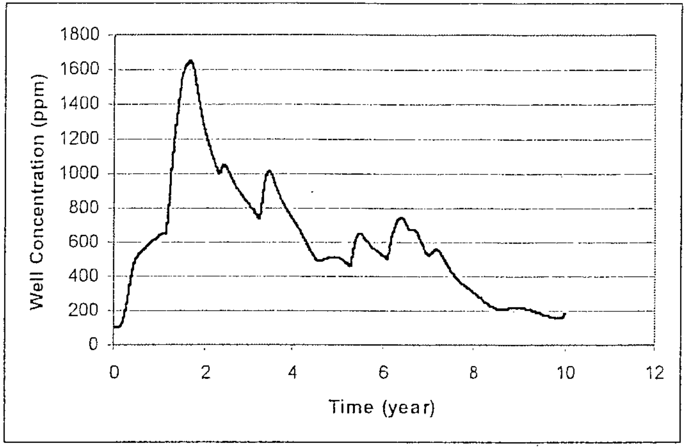


Figure 2. Chloride concentration in the monitoring well for the no action scenario. (Scenario 1)

Figure 2 shows the response of Scenario 1 in a monitoring well located 20 feet from the center of the spill at the release site. The simulation shows chloride concentration increasing to a maximum of 1,652 ppm in year 1.7. As stated in the previous section, in this and other simulations, when man-made leakage ceased, the chloride concentrations in the vadose zone are equal to that represented in Plate 1. To simplify our modeling experiment, we assumed that the chloride concentration in the monitoring well at time zero in Figure 2 is equal to background (100 mg/L). Therefore, the initial increase in chloride concentration from background (100 mg/L) to a maximum (1,652 in this simulation) is the model's response to the downward movement of the initial distribution of chloride in the profile. Because the well was installed after replacement of the junction box and cessation of periodic leakage, we cannot know the chloride concentration at the monitoring well during past man-made leakage events. We hypothesize, however, that chloride concentration in ground water would be 1,652 mg/L or more during the time that the juction box periodically released produced water. Chloride concentrations in the monitoring well might remain at or above the 1,652 mg/L during the years of periodic discharges from the former junction box, as chloride migrated from the ground surface to ground water via saturated flow. After replacement of the junction box, water additions to the soil profile cease and the soil profile would drain. During the drainage of the soil profile, chloride concentrations in the monitoring well would decrease as saturated flow ceased and slower, unsaturated flow conditions occurred in the profile.

Figure 3 modifies the HYDRUS-1D output to better represent the conditions described above. In this Figure, time X represents background conditions, before any leakage from the junction box. As periodic leakage occurs, chloride concentration in ground water rises and chloride is distributed throughout the unsaturated zone, as shown in Plate 1. We believe that the maximum chloride concentration in ground water in Figure 3 (1,652 mg/L) is approximately what we would have observed during the period of leakage from the junction box if the monitoring well had been installed. After repair of the junction box (here noted as approximately time zero), chloride concentrations decline as discussed above and as shown in Figure 3. About five years after repair of the junction box under the No Action Scenario, ground water chloride approaches background concentrations.

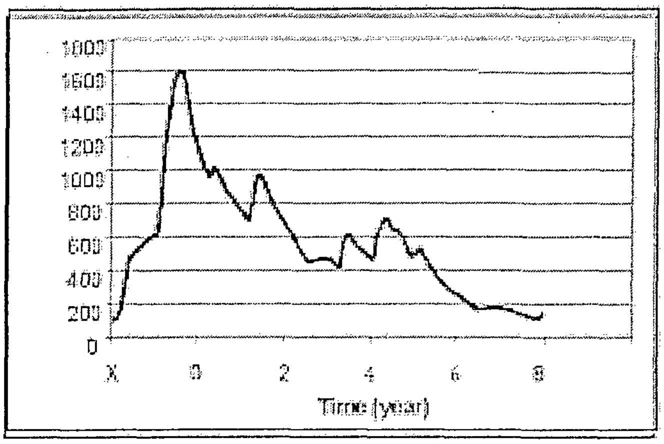


Figure 3. Modification of HYDRUS-1D simulation results to illustrate a more realistic time scale for Scenario 1.

Figure 4 shows the results of our simulations of Scenario 2 with the same modified time line as in Figure 3. Reducing infiltration of precipitation creates a maximum concentration 1,048 mg/L marked approximately as year 0 to show when junction box repair occured. Reducing infiltration slows the drainage of vadose zone water relative to the no action scenario. Therefore, water and chloride enter the ground water more slowly in this scenario as compared to the no action scenario. In other words, the chloride flux (mass/time) into ground water is lower in Scenario 2 than in scenario 1. The ground water flux and aquifer thickness, however, remain the same in both scenarios. The lower chloride flux into ground water results in a lower maximum concentration observed in the monitoring well. This lower flux also results in a longer time of predicted non-compliance at the monitoring well.

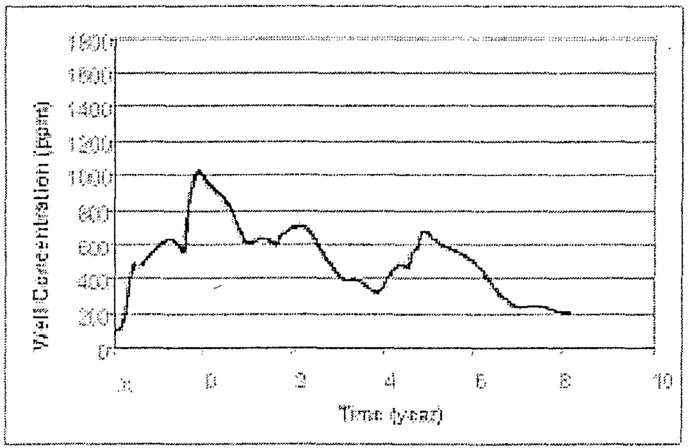


Figure 4. Modification of HYDRUS-1D simulation results to show a more realistic time scale for chloride concentration in the monitoring well for the scenario reducing the infiltration. (Scenario 2)

About six years after repair of the junction box, the majority of the chloride has drained from the vadose zone and concentrations in the well declines to the standard of 250 mg/L. We did not simulate the length of time necessary for ground water to reach background conditions under this scenario.

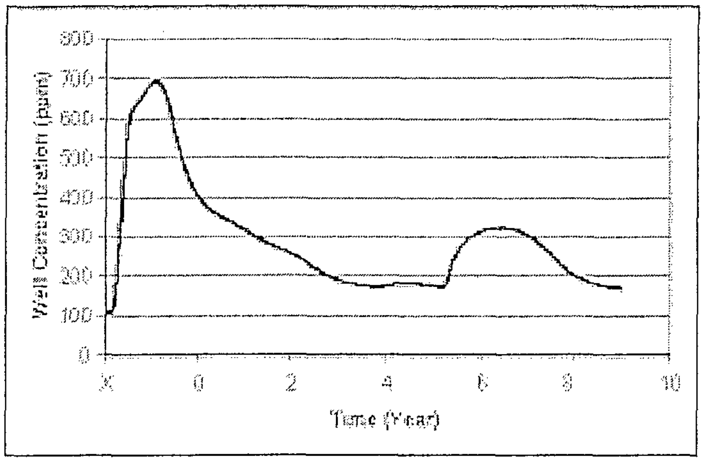


Figure 5. Modification of HYDRUS-1D simulation results to illustrate a more realistic time scale, chloride concentration in the well for the vegetation scenario. (Scenario 3)

Figure 5 shows the results of the Scenario 3, which assumes further reduction of infiltration due to evapotranspiration as a result of plant cover. The maximum chloride concentration in the well is 693 mg/L at approximately zero time on the modified scale. As discussed previously, the time of maximum chloride concentration is the time when the junction box is repaired. The chloride concentration declines to the standard of 250 mg/L in year 2.11. However, we predict an increase in ground water chloride concentrations to 323 ppm in year 6.5 followed by a decrease to the standard by year 7.5. This increase at year 6.5 is probably due to increased infiltration associated with the El Niño weather pattern. Because most the chloride has drained from the profile by year 6.5, we conclude that any additional increase in ground water chloride concentration (perhaps at year 14) would not exceed the ground water standard of 250 mg/L.

The concentrations in the root zone in Scenario 3 are quite high as result of capillary rise that accumulates the salts at the top of the profile. Concentrations of 4,000 ppm will prevent the grass of developing unless chloride moves deeper into the subsurface due to a soil flushing program or natural rainfall.

Figure 6 shows the result of Scenario 4 with the modified time scale. The maximum concentration in the well is 604 ppm in year 0. It declines to 250 ppm in year 1.75. The concentrations in the root zone are about 1300 ppm, suitable for vegetation. By year 8, background conditions exist in the monitoring well.

Figure 1 shows the chloride concentration in the monitoring well at the Zachary Hinton site. This well was installed after replacement of the

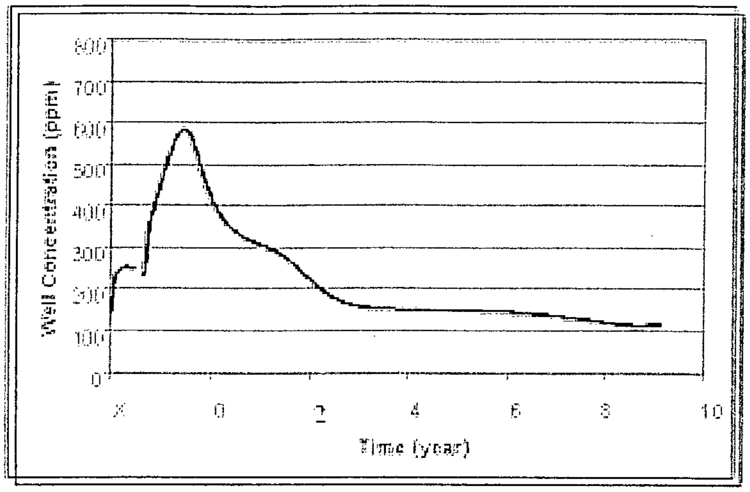


Figure 6. Modification of HYDRUS-1D simulation results showing a more realistic time scale of chloride concentration in the well for the scenario with vegetation and a silt clay layer below the topsoil. (Scenario 4).

produced water pipeline junction that we believe caused the release of chloride to the subsurface. The data show chloride concentraton declining from 1,000 mg/L to 500 mg/L over a two-month period. The concentration then declines to about 400 mg/L after one year. Obviously, these data do not correlate with the model predictions of Scenario 1, no action. Instead, the field data are more similar to the predictions of Scenario 3, where infiltration into the vadose zone is relatively low due to evapotranspiration associated with vegetation.

The similarity between Figures 1 and 5 should not be surprising if one visits the site. Vegetation does exist around the area of the suspected release (Figure 7). We believe the current flux of chloride from the vadose zone to ground water is approximately the same as that simulated in Scenario 3. We can also conclude from Figure 7 that the chloride concentration in the root zone is low enough to support vegetation. The no action scenario, which does not provide for evapotranspiration or any reduced infiltration, obviously overestimates the impact of the chloride load to ground water quality.

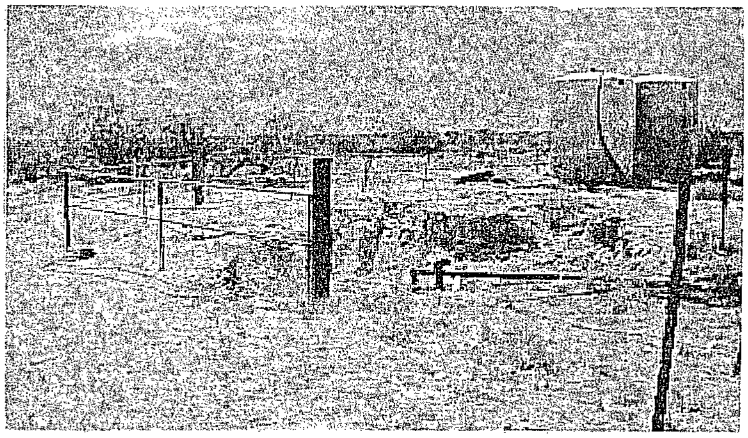


Figure 7. Vegetation near the release site.

6.0 GROUND WATER QUALITY AND FLOW

Although the quality of the City of Eunice water supply wells is about 100 mg/L chloride (see Nicholson and Clebsch, 1961), a more detailed investigation of the area near the Zachary Hinton EOL site shows higher background levels. Plate 2 shows the locations of wells with past and present water quality data and Table 3 presents the results for chloride.

The chloride concentration in the City of Eunice wells and the Peters West well are below Water Quality Control Comission standards for ground water. Wells within or near Monument Draw, however, generally exceed the standards. The difference between the water quality west of Monument Draw and the water quality within and near the Draw has been evident since the 1950s when Nicholson and Clebsch sampled the water of the area (Table 3).

Today, as in the 1950s, ground water flows from the west toward Monument Draw. Ground water then flows south within the draw as shown in Plate 3 from Nicholson and Clebsch (1961). Up gradient from the Zachary Hinton EOL site, chloride concentrations in the Active Windmill of Section 36 (see Plate 2) is 460 ppm. The chloride in this active windmill is consistent with the chloride concentrations observed in wells 22.37.1.440 and 22.37.24.133b (average of 422 and 675 ppm respectively) in the 1950s. The Peters East well, which lies within Monument Draw, exhibits a chloride concentration of 438 ppm while the chloride concentration in the Zachary Hinton EOL monitoring well is 354 ppm. This measuable difference in chemistry between the Zachary Hinton Site and the Peters East well could be due to the effect of higher quality ground water flowing into the Monument Draw area from the west (e.g. 200 ppm chloride in the Peters West well), or the difference may be due to normal variance associated with sampling and analysis.

7.0 CONCLUSION AND RECOMMENDED ACTION

The HYDRUS-1D simulations for the Zachary Hinton site provide reasonably good, albeit conservative, predictions of chloride concentrations in ground water for the various scenarios. Currently, about two years after the repair of the pipeline and cessation of water leakage, chloride concentrations in the ground water monitoring well are 354 ppm, background correlations. The field data correlate well with early time predictions of Scenario 3, reduced flux due to vegetation. We conclude Scenario 3 predicts higher chloride concentrations than observed.

We conclude that the background chloride concentration in ground water at the Zachary Hinton EOL site is about 350 ppm. We base this conclusion on historical and recent water quality analyses from the area. Natural restoration has mitigated the transient impact of past leakage from the site. Data from the Peters East well suggest that past leakage from the Zachary Hinton EOL Junction box have not caused measurable degradation of ground water quality.

We recommend restoring the ground surface in the excavation using soil that will permit re-vegetation. Because the water quality at the site has returned to background conditions, we recommend plugging and abandonment of the existing monitoring well and closure of the regulatory file for this site, pending documentation of appropriate surface reclamation.

September 12, 2003

Simulation of Chloride Transport

RICE OPERATING COMPANY
ZACHARY HINTON

Prepared for:

Rice Operating Company
122 West Taylor
Hobbs, NM 88240

R.T. HICKS CONSULTANTS, LTD.
901 RIO GRANDE BLVD. NW, SUITE F-142, ALBUQUERQUE, NM 87104

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FIGURES

TABLES

PLATES

APPENDICES

1.0 PURPOSE

The Zachary Hinton EOL Junction Box is loacated about 2.5 miles southeast of the intersection of State Routes 18 and 8/176, near Eunice, New Mexico. The disclosure report prepared by Rice Operating Company (ROC) in January 21, 2003 summarizes activities to date. The soil boring and backhoe excavation data show relatively consistent concentrations of chloride from 11 feet below ground surface (2000 ppm chloride) to 50 feet below ground surface (6410 ppm chloride). The consistency of these chloride concentrations suggests that a release from the junction box may have created saturated conditions in the vadose zone. Hydrocarbons, often associated with releases from produced water pipelines, were not present in concentrations that warrant further inquiry (see ROC Disclosure Report).

R.T. Hicks Consultants, Ltd. used HYDRUS1D to simulate chloride fate to address potential environmental concerns at the site. This report presents the results of our study and proposes a final remedy for the site to permit closure of the regulatory file.

2.0 APPROACH

We used the numerical model HYDRUS1D to simulate the transport of chloride from the surface through the vadose zone to ground water. We used the predicted flux of chloride to ground water from HYDRUS1D as input into a simple ground water mixing-model to evaluate the impact on ground water quality. As Appendix A describes, this modeling effort requires 11 input parameters. Appendix A also describes our modeling approach used in this effort.

In our previous work with HYDRUS1D, we found that some input parameters had little effect on the prediction of chloride concentration in ground water while other factors had a profound effect. The Sensitivity Analysis presented in Appendix A describes the relative importance of each of the eleven input paramerters. *Two of these eleven factors (release volume and height of the* spill) are not relevant in our simulations, since we will evaluate the movement of the chloride load already in the soil profile. Site specific data exist for the most important input factors (e.g. chloride load, depth ot ground water). For some input parameters we employed regional data or values based upon professional judgment (see Table 1).

3.0 DATA EMPLOYED FOR THE ZACHARY HINTON SITE

We present four scenarios to describe possible chloride migration at the site. Plate 1 shows a typical soil profile texture and thickness of the vadose zone at the site (input parameters # 1 and #2). We input the soil texture into HYDRUS1D and allowed the model's library to generate the hydraulic properties . We then used these hydraulic properties in simulations of these scenarios.

Based upon our experience, we employed a dispersion length of 100 cm (input #3). The selected dispersion length is 7% of the total length of the HYDRUS1D model (55 feet). Many researchers suggest that a dispersion length that is 7-10% of the total model length provides reasonable results for simulation experiments. We used the soil moisture content (input # 4) presented in Table 1 from hydrus simulations.

Plate 1 shows the measured soil chloride concentration per unit weight of soil. We convert these values to concentrations per liter of soil water (input #5) by using the equations in Appendix B . The length of the release (input #6) was measured in the field.

The daily climate data available from the Pearl weather station near the Hobbs Airport served as input for all climate indices required by HYDRUS1D (input #7). We simulated 10 years with average precipitation 36 cm/year.

For the input parameter #8, background ground water chloride concentration, we used 100 m g/L based upon site data. We used data for the Ogallala Aquifer as described in Nicholsen and Clebsch, (1961) as input to the mixing model (input #9, ground water flux; input#10, aquifer thickness).

We also used data from the BD Zachary Hinton Jct monitor well to verify the predictions of the HYDRUS1D model and the mixing model.

3.1 SCENARIO 1: NO ACTION

The no action alternative evaluates the potential of the chloride mass in the vadose zone to materially impair ground water quality at the site. As described in Appendix A, the distribution of the mass of chloride in the vadose zone (input 5) is the most important input parameter for prediction of chloride concentrations in ground water. The chloride concentration of soil water Cl^{soil}_{water} (mg/liter) depends on the gravimetric chloride content of moist soil Clg^{moist}_{soil} (mg/kg of moist soil), the bulk density of the soil $Dsoil^{dry}$ (kg/m^3), and the volumetric water content of the soil èv (m^3/m^3) input #4 . To convert the chloride concentration in the soil to chloride concentration in soil water (Appendix B), we used a soil density of 1858 kg/cubic meter and the soil moisture content in table 1.

We enter the chloride concentration of soil water in the soil profile in HYDRUS and run the simulation for 10 years with total precipitation and evaporation from the soil.

We calibrate the results from the model with the chloride data from a monitoring well located 20 feet downgradient from the center of the spill.

3.2 SCENARIO 2: REDUCE INFILTRATION

To minimize the potential for any leaching of residual chloride from the vadose zone, we assumed a surface remedy that would reduce infiltration of precipitation. To simulate such a remedy, we simply reduced the precipitation by assuming that heavy rains (that cause the majority of the infiltration) run off after 1.5 cm fell. This simulation predicts the effect of (a) sloping the site to cause runoff of the larger precipitation events (b) placement of a graded compacted layer at the surface to minimize infiltration, facilitate runoff and prevent ponding of precipitation. All other input parameters are the same as Scenario 1.

3.3 SCENARIO 3: VEGETATION

This scenario consists of placing 30 cm of silt loam and reseeding with pasture. The transpiration is zero during the winter months but soil evaporation takes place. All other input parameters are the same as Scenario 1.

3.4 SCENARIO 4: A SILT CLAY BELOW THE TOP SOIL

In this scenario we place a 60 cm of a silt clay below the top soil under the same conditions of Scenario 3. Placing the clay below the top soil minimizes infiltration into the deeper profile and provides a place for the infiltration of winter to reside until the plants take it up in the following spring and summer. All other input parameters are the same as Scenario 1.

4.0 RESULTS

Figure 1 shows the response of Scenario 1 in a monitoring well located 20 feet from the center of the spill at the release site. The simulation shows chloride concentration increasing to a maximum of 1652 ppm in year 1.7. In this and other simulations, this early-time increase in chloride concentration from background (100 mg/L) to a maximum is due to the initial conditions assumed in the model – it does not represent our prediction of ground water chloride concentration. Because we assume a background chloride concentration in ground water of 100 mg/L, the chloride concentration in ground water returned by our simulation at time zero is 100 mg/L. After time zero, chloride-rich pore water in the vadose zone begins to drain into the aquifer. Examination of Plate 1 shows that the bottom of the vadose zone (50-56 feet below land surface) exhibits 500 ppm chloride in soil samples while the sampling interval from 45-50 feet shows 6410 ppm. Therefore, the calculated mass of chloride per unit time (the flux of chloride) that enters the aquifer during the early time of the simulation considers the drainage of relatively low chloride concentrations in pore water from the 50-56 foot depth interval. As the chloride-rich water from the 45-50 foot depth interval drains into the aquifer, the chloride concentration in the well begins to rise. At time 1.7 years, we believe the chloride mass associated with the depth interval 30-35 feet (8160 ppm in soil samples) is draining into the aquifer. After 1.7 years, the concentration in the well declines and increases repeatedly as the model responds to weather changes (e.g. monsoon cycles) and differences in the chloride load of the depth intervals. After year 8.3, most of the chloride is leached from the profile and the concentration in the observation well meets the ground water standard of 250 mg/L.

Figure 2 shows the results of our simulations of Scenario 2. Reduction of infiltration of precipitation creates a maximum concentration 1048 mg/L in year 1.7. Reducing infiltration slows the drainage of vadose zone water relative to the no action scenario. Therefore, water and chloride enter the ground water more slowly in this scenario as compared to the no action scenario. In other words, the chloride flux (mass/time) into ground water is lower in scenario 2 than in scenario 1. The ground water flux and aquifer thickness, however, remain the same in both scenarios. The lower chloride flux into ground water results in a lower maximum concentration observed in the monitoring well. This lower flux also results in a longer time of predicted non-compliance at the monitoring well. Nine and one half years pass before the majority of the chloride has drained from the vadose zone and concentrations in the well decline to the standard of 250 mg/L.

Figure 3 shows the results of the Scenario 3, which assumes further reduction of infiltration due to evapotranspiration of a plant cover. The maximum concentration in the well is 693 mg/L in year 1.08, which declines to the standard of 250 mg/L in year 4.11. However we predict an increase in ground water chloride concentrations to 323 ppm in year 8.5 followed by a decreas to the standard by year 9.5. This increase at year 8.5 is probably due to increased infiltration associated with the El Niño weather pattern. Because most the chloride has drained from the profile by year 8.5, we conclude that any additional increase in ground water chloride concentration (perhaps at year 16) would not exceed the ground water standard of 250 mg/L.

However, the concentrations in the root zone in scenario 3 are quite high as result of capillary rise that accumulates the salts at the top of the profile. Concentrations 4000 ppm will prevent the grass of developing unless chloride moves deeper into the subsurface due to a soil flushing program.

Figure 4 shows the result of Scenario 4. The maximum concentration in the well is 604 ppm in year 1.28. It declines to 250 ppm in year 3.75. The concentrations in the root zone are about 1300 ppm, suitable for vegetation.
Figure 5 shows the chloride concentration in the monitoring well at the Zachary Hinton site. This well was installed after replacement of the produced water pipeline junction that we believe caused the release of chloride to the subsurface. The data show chloride concentraton declining from 1000 mg/L to 500 mg/L over a two-month period. The concentration then declines to about 300 mg/L after one year. Obviously, these data do not correlate with the model predictions of Scenario 1, no action. Instead, the field data appear to agree with the predictions of Scenario 3, where infiltration into the vadose zone is relatively low due to evapotranspiration associated with vegetation. In fact, the correlation between the field data of Figure 5 and the predictions of Figure 3 are striking.

The similarity between Figures 3 and 5 should not be surprising if one visits the site. Vegetation does exist around the area of the suspected release (Figure 6 – to be inserted after the field program). We believe the current flux of chloride from the vadose zone to ground water is approximately the same as that simulated in Figure 3. We can also conclude from Figure 6 that the chloride concentration in the root zone is low enough to support vegetation. The no action scenario, which does not provide for evapotranspiration or any reduced infiltration, obviously overestimates the impact of the chloride load to ground water quality.

5.0 CONCLUSION AND RECOMMENDED ACTION

The HYDRUS1D simulations for the Zachary Hinton site provide reasonably good predictions of chloride concentrations in ground water for the various scenarios. Currently, about two years after the repair of the pipeline and cessation of water leakage, chloride concentrations in the ground water monitoring well are 345 ppm. The field data correlate very well with Scenario 3, reduced flux do to vegetation. We conclude that future chloride concentrations in the existing monitoring well will continue to follow the pattern predicted by Scenario 3.

What is most encouraging is that all scenarios, even the most conservative "no action" scenario, lead to chloride concentrations less than 250 ppm within ten years.

We recommend restoring the ground surface near the excavation using soil that will permit revegetation. Because the industry has little long-term ground water data on such sites with excellent characterization of the chloride load, we recommend semi-annual sampling of the existing monitoring well and analysis of TDS and chloride for two years. If the data continues to correlate with the predictions expressed in Figure 3, as we suspect, this ground water data will provide comfort to the State and landowners that the predictions of the HYDRUS and mixing model can be employed for other sites throughout the Permian Basin.

FIGURES

Figure 1. Chloride concentration in the monitoring well for the no action scenario. (Scenario 1).

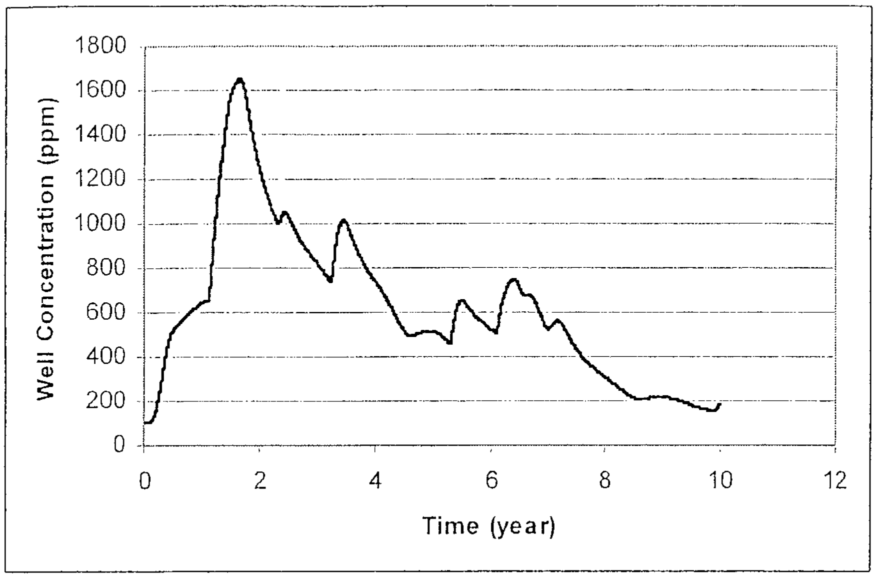


Figure 2. Chloride concentration in the monitoring well for the scenario reducing the infiltration. (Scenario 2).

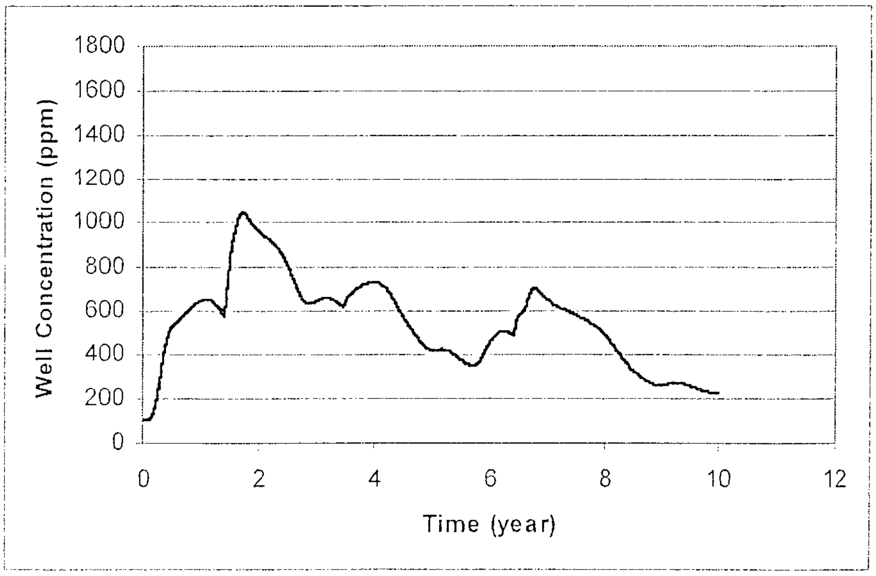


Figure 3. Chloride concentration in the well for the vegetation scenario. (Scenario3).

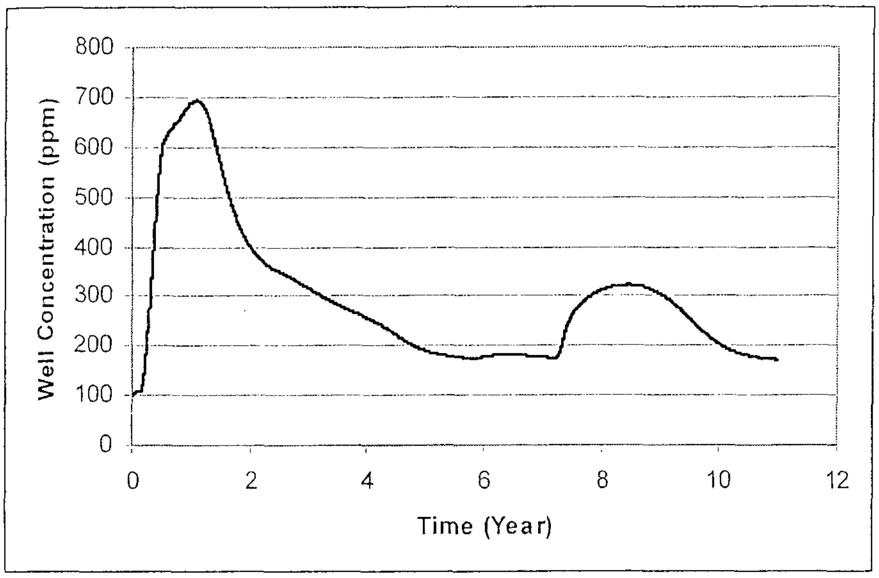


Figure 4. Chloride concentration in the well for the scenario with vegetation and a silt clay layer below the topsoil.(Scenario 4).

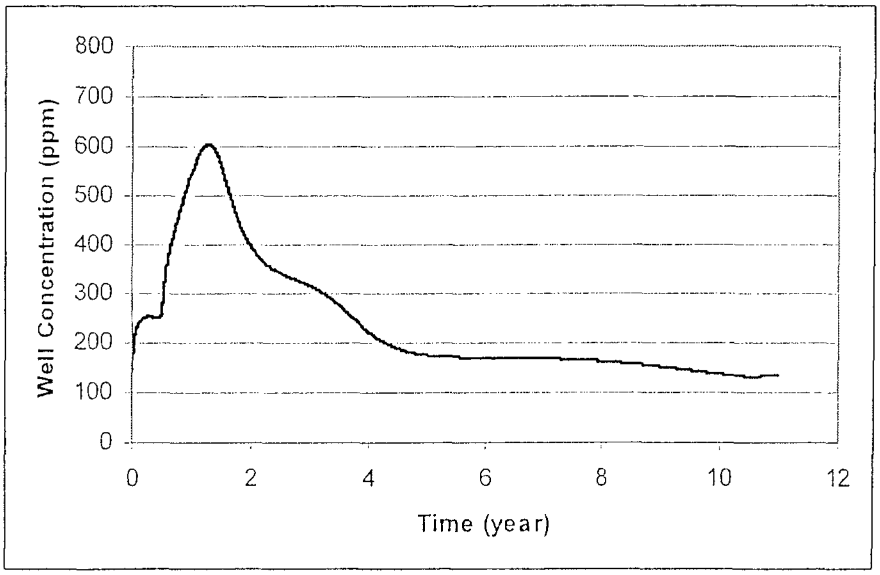
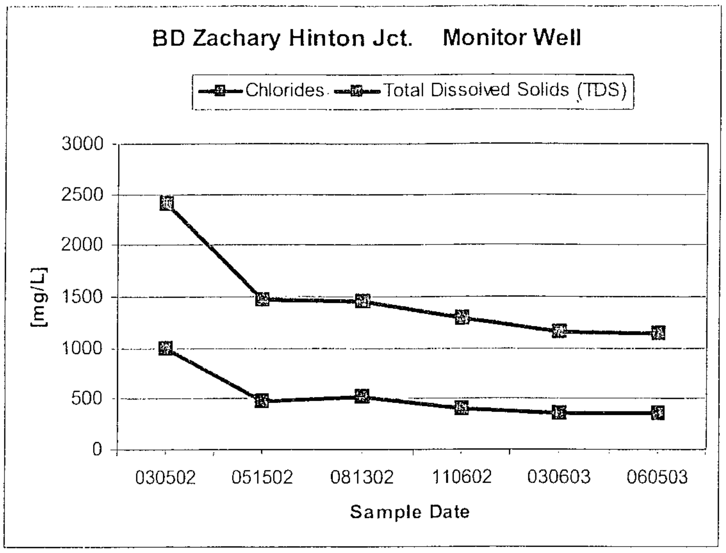


Figure 5. Chloride concentration in the monitoring well at Zachary Hinton

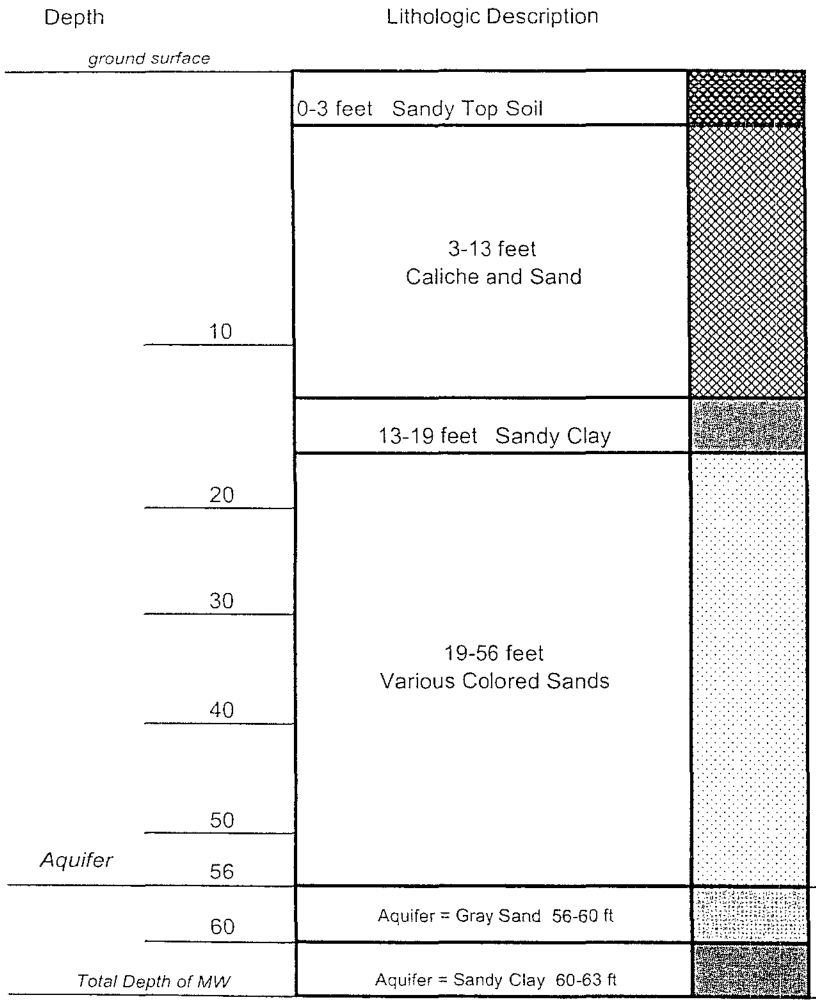


TABLES

Table 1. Input parameters for the simulations

Parameter	Values	Source of Data
1. Depth to Ground Water (feet)	56	Site Data
2. Vadose Zone Texture (see Plate 1)	Attached well log	Site Data
3. Dispersion Length (meters)	1	Professional Judgment
4. Water Content θ_g (%)	High θ_g Layer 1 : 10% Layer 2 : 30% Layer 3 : 25%	Estimated from hydrus simulations
5. Vadose Zone Chloride Distribution (gr/kg)	Attached well log	ROC data from Disclosure Report
6. Length of release perpendicular to ground water flow (feet)	20	Field measurements
7. Cimate Index	Pearl, NM station (Hobbs)	NOAA data
8. Background Ground Water Chloride (mg/L)	100	Samples from nearby wells
9. Ground Water Flux (cm/day)	1.4	Calculated from regional hydrological data
10. Aquifer Thickness (feet)	35	Nicholson and Clebsh (1960) and SEO data

PLATES



Measured Soil Chloride Concentration mg/kg	Bulk Density of Sample kg/cubic meter	Thickness of Column (ft)	Calculated Chloride Mass in Column (kg/m2)
1500	1858	5	5
2000	1858	5	6
2450	1858	5	8
3000	1856	5	9
1750	1858	5	5
3270	1858	5	10
8160	1858	5	25
5300	1858	5	16
5000	1858	5	15
6410	1858	5	20
500	1858	5	2
Calculated Chloride Load			121

R.T. Hicks Consultants, Ltd. **901 Rio Grande Blvd. NW, Suite F-142** **Albuquerque, NM 87104**	RICE Operating Company	Plate 1
	Calculation of Chloride Load, Zachary Hinton EOL, Lea County	12-Sep-2003

Appendix B

Relevant Correspondence

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

October 13, 2005

Mr. Daniel Sanchez
Enforcement & Compliance Manager
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

RE: Zachary Hinton EOL Junction Box (O-12) Sec 12, T22S, R37E
NMOCD Case #1R0426-36

Dear Mr. Sanchez:

R.T. Hicks Consultants, Ltd. is pleased to submit the attached Stage I & II Abatement Plan for the above referenced site. If you have any questions or concerns, please don't hesitate to contact us.

Sincerely,
R.T. Hicks Consultants, Ltd.

Katie Lee

Katie Lee
Staff Scientist

Copy:

Wayne Price, NMOCD; OCD Hobbs Office;
& Kristin Pope, Rice Operating Company

R. T. HICKS CONSULTANTS, LTD.

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

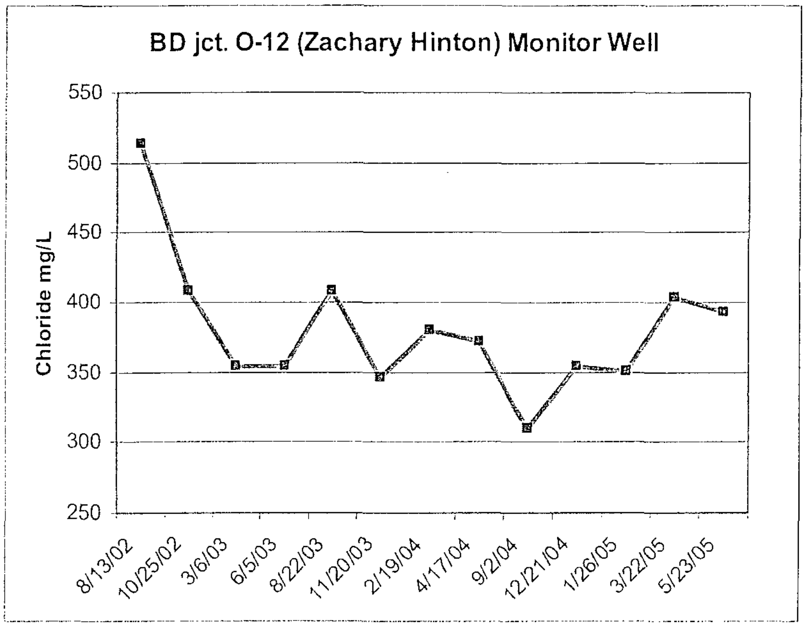
June 29, 2005

Mr. Daniel Sanchez
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

RE: Zachary Hinton EOL UL O Sec 12, T22S, R37E 1R0426-36

Dear Mr. Sanchez:

In your letter of May 5, 2005, NMOCD required Rice Operating Company (ROC) to submit an abatement plan for the above-referenced site on or before July 15, 2005. We respectfully request that NMOCD re-consider this request based upon the information presented in our January 2004 Corrective Action Plan (2004 CAP), our response to NMOCD comments (December 2004), and the ground water data presented below. All of these submissions are included in the attached disc.



As the recent data (figure) show, ground water chloride concentrations decreased from over 500 ppm in 2002 to the regional background concentration of 300-400 ppm by 2003. Data presented on page 12 of the 2004 CAP discuss the regional water quality.

Eleven quarters of ground water monitoring allow us to conclude that natural attenuation has effectively restored ground water quality at the site. Alternatively, one could also conclude from these data that the first sample taken in 2002 was unusually high, perhaps due to disequilibrium in the ground water caused by the drilling process.

We believe that the HYDRUS-1D modeling within the CAP demonstrates that:

1. Water contaminants in the vadose zone will not with reasonable probability contaminate ground water or surface water, in excess of the standards in Paragraphs (2) and (3) below, through leaching, percolation, or other transport mechanisms, or as the water table elevation fluctuates.

We believe the 11 quarters of ground water monitoring and the research on regional ground water quality presented within the CAP show:

2. Ground-water pollution at any place of withdrawal for present or reasonably foreseeable future use (e.g. the Zachary Hinton monitoring well or future down gradient wells), where the TDS concentration is 10,000 mg/L or less, conforms to the following standards:
   a. *Toxic pollutant(s) as defined in 20.6.2.7 NMAC are not present; and*
   b. The standards of 20.6.2.3103 NMAC are met.

Due to the location of the site, we believe it is obvious that:

3. Surface-water is not affected by the site and surface water conforms to the Water Quality Standards for Interstate and Intrastate Surface Waters in New Mexico 20.6.4 NMAC.

Therefore, we respectfully request NMOCD:

- withdraw their request for an Abatement Plan for this site,
- carefully review our previous submissions, and
- evaluate the site for closure of the regulatory file.

Thank you for consideration of this request.

Sincerely,
R.T. Hicks Consultants, Ltd.

Randall T. H

Randall Hicks
Principal

Copy:

Kristin Pope, Rice Operating Company

R. T. HICKS CONSULTANTS, LTD.
901 Rio Grande Blvd NW ▲ Suite F-142 ▲ Albuquerque, NM 87104 ▲ 505.266.5004 ▲ Fax: 505.266-0745

January 30, 2004

Mr. Wayne Price
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

RE: Zachary Hinton EOL Final Report

Dear Mr. Price

On behalf of Rice Operating Company, we are pleased to submit the final Corrective Action Plan for the above-referenced site. We are pleased to report that the chloride concentration in samples from the on-site monitoring well has returned to background levels. We conclude that the residual chloride in the vadose zone poses no threat to human health or the environment. We recommend filling the excavation with soil capable of sustaining vegetation and plugging the monitoring well.

Please contact us with any comments or questions regarding our recommended closure protocol for this site.

Sincerely,
R.T. Hicks Consultants, Ltd.

Randall T. H

Randall Hicks
Principal

R.T. HICKS CONSULTANTS, LTD.

219 Central Avenue NW Suite 266 Albuquerque, NM 87112 505.266.5004 Fax: 505.246-1818

July 2, 2003

Mr. Wayne Price
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

RE: Zachary Hinton EOL Junction Box, Section 12, 22S, 37E Unit O

Dear Mr. Price

Rice Operating Company retained R.T. Hicks Consultants, Ltd. to address potential environmental concerns at the above referenced site. This submission proposes a scope of work that we believe will best mitigate any threat to human health and the environment and lead to closure of the regulatory file for this site.

Background

The Zachary Hinton EOL Junction Box is located about 2.5 miles southeast of the intersection of State Routes 18 and 8/176, near Eunice, New Mexico. Plate 1 shows the location of the site.

Rice Operating Company (ROC) prepared a disclosure report dated January 21, 2003 that summarizes activities to date. This report is part of the annual submission to NMOCD, due in April of each year. For your convenience, we have attached a copy of this ROC report and a copy of recent ground water data from the adjacent monitoring well. The soil boring and backhoe excavation data show relatively consistent concentrations of chloride from 11 feet below ground surface (5200 ppm chloride) to 50 feet below ground surface (6410 ppm chloride). The consistency of these concentrations suggests that a release from the junction box may have created saturated conditions in the vadose zone.

ROC installed a monitoring well adjacent to the junction box. Four quarters of ground water data show chloride concentrations in ground water are currently between 400 and 500 mg/L. The most recent analysis of total dissolved solids (11/6/02) from this well shows a result of 1290 mg/L. Because these values exceed the New Mexico Water Quality Commission Standards, we propose the work outlined below.

1. Evaluate Migration of Chloride Flux from the Vadose Zone to Ground Water

We propose to employ HYDRUS1D and a simple ground water mixing model to evaluate the potential of residual chloride mass in the vadose zone to materially impair ground water quality at the site. We will employ predictions of the migration of chloride ion from the vadose zone to ground water in our selection of an appropriate remedy for the land surface and underlying vadose zone. This simulation is the "no action" alternative, which predicts chloride flux to ground water in the absence of any action by ROC.

We might provide simulations of two "no action" scenarios. For both simulations, we will employ the input parameters to HYDRUS and the mixing model outlined in Table 1. In the first simulation, we will assume that vegetation is not present over the release site (no evapotranspiration) and a minimum aquifer thickness of 10 feet. This will simulate restriction of any released chloride to a portion of the underlying aquifer. If this first simulation does not return results that are consistent with the existing ground water monitoring data, we will increase the aquifer thickness in the mixing model to the maximum value allowed by data (a bout 35 feet). At other sites, we have found that chloride can be distributed throughout the thickness of the aquifer. Employing the entire thickness of the aquifer in the mixing model calculations may be appropriate for the Zachary Hinton site.

Table 1: Input Parameters for Simulation Modeling

Input Parameter	Source
Vadose Zone Thickness	Attached well log
Vadose Zone Texture	Attached well log
Dispersion Length	Professional judgment
Soil Moisture	Nearby Field Measurements
Vadose Zone Chloride Load	ROC Data from Disclosure Report
Length of release perpendicular to ground water flow	Field Measurements
Climate	Pearl, NM station (Hobbs)
Background Chloride in Ground Water	Samples from nearby wells
Ground Water Flux	Calculated from regional hydraulic data
Aquifer Thickness	Nicholson and Clebsch (1960) and SEO data

2. Collection and Evaluation of Data for Simulation Modeling

The HYDRUS1D and mixing model simulation requires input of 10 parameters. As Table 1 shows, we must collect site specific data for several of these parameters, some data are available from previous ROC work at the site, and other data are available from public sources. Our previous work with the American Petroleum Institute showed that soil moisture values did not strongly influence the ability of the model to predict chloride migration from the vadose zone to ground water. We plan to use soil moisture data from nearby sites for model input.

We propose a field program to collect important site-specific data for model input. First we will measure the depth to ground water at five nearby windmills and the adjacent monitoring well to determine the hydraulic gradient (Plate 1). We have examined these abandoned and active windmills; we can measure these water levels. To establish background chloride concentrations in ground water, we propose to sample the active windmill located in Section 13 (Plate 1) and, if possible, two additional up gradient wells in Sections 2 and 11 (identified as "Field Check Required" on Plate 1).

3. Design Remedy and Submit Report

ROC has completed the repair of the pipeline junction at the Zachary Hinton EOL. We do not anticipate additional releases of produced water at this site. Our modeling of the "no action alternative" (Task 1) may show that the residual chloride mass in the vadose zone poses a threat to ground water quality. If such a threat does exist, we will use the HYDRUS-1D model predictions to develop a remedy for the vadose zone. If necessary, we will simulate:

1. excavation, disposal and replacement of clean soil to remove the chloride mass,
2. installation of a low permeability barrier to minimize natural infiltration,
3. surface grading and seeding to eliminate any ponding of precipitation and promote evapotranspiration, thereby minimizing natural infiltration, and
4. a combination of the above potential remedies.

We will select the vadose zone remedy that offers the greatest environmental benefit while causing the least environmental damage.

We will use the ground water mixing model or a suitable alternative to assist in the design of a ground water remedy. It is possible, however, that the background chloride concentrations in ground water measured in the nearby windmills are equal to or higher than the chloride concentration in the adjacent monitoring well. Such data would strongly suggest that the Zachary Hinton EOL Junction Box has not caused any material impairment of ground water quality. If we find no evidence of impairment of water quality due to past activities at Zachary Hinton EOL Junction Box, we will not prepare a ground water remedy. If data suggest that the Zachary Hinton EOL Junction Box has contributed chloride to ground water and caused ground water impairment, we will examine the following alternatives:

1. Natural restoration due to dilution and dispersion,

2. Pump and dispose to remove the chloride mass in the saturated zone,

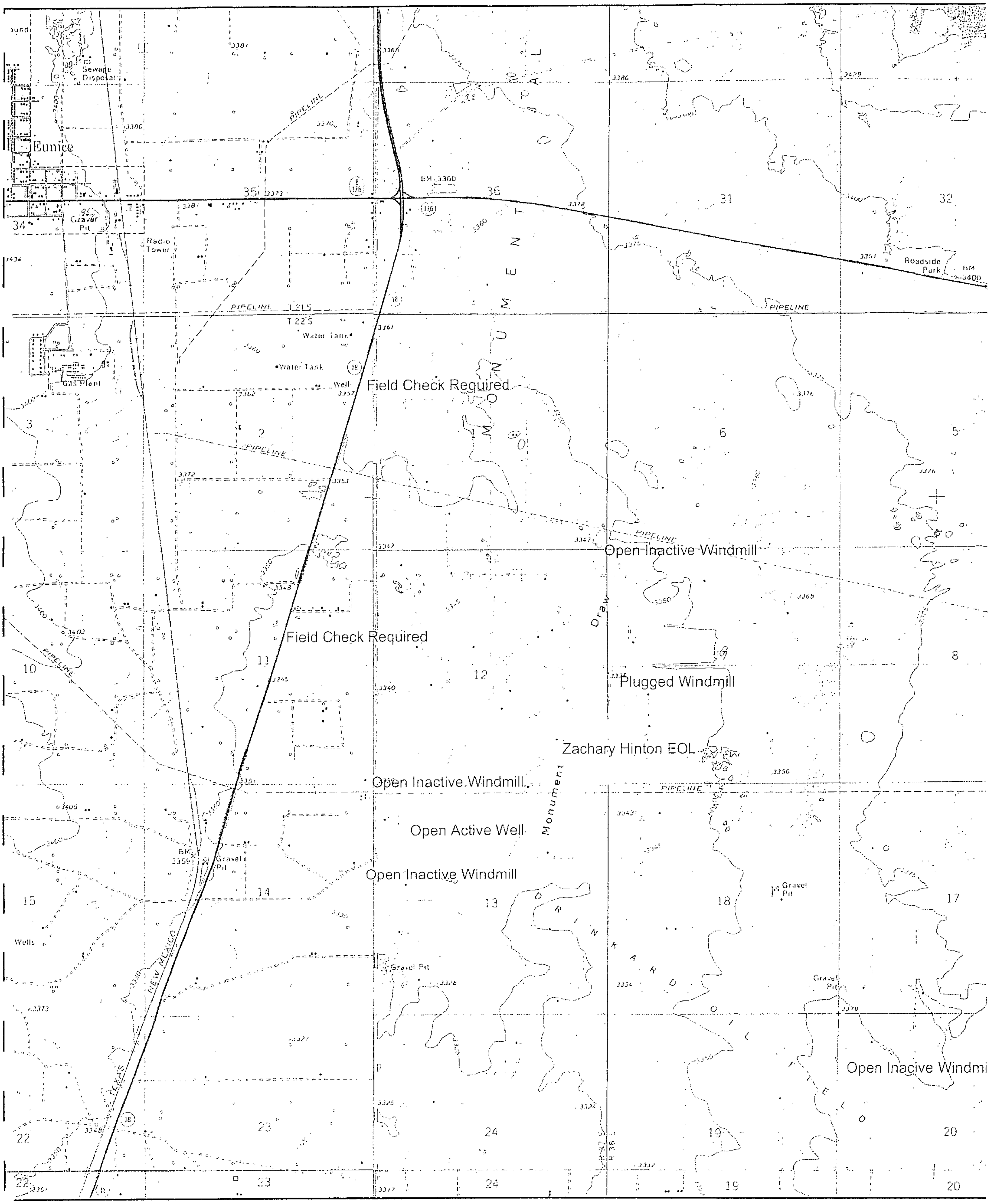
3. Pump and treat to remove the chloride mass in the saturated zone,

4. Because of the location of the site, institutional controls negotiated with the landowner may provide an effective remedy. Such controls may be restriction of water use to livestock until natural restoration returns the water quality to state standards, a provision for alternative supply well design, or a provision for well head treatment to mitigate any damage to the water resource.

We plan to commence data collection for the HYDRUS1D simulations described above in mid July. Your approval to move forward with this workplan will facilitate our access to nearby windmills and speed the implementation of a surface remedy.

Sincerely,
R.T. Hicks Consultants, Ltd.

Randall T. Hicks
Principal



Name: EUNICE NE
Date: 3/14/2003
Scale: 1 inch equals 2666 feet

Location: 032° 24' 36.8" N 103° 06' 56.8" W
Caption: Plate 1: Location Map

Appendix C

Model Explanation

R.T. Hicks Consultants, Ltd.

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

MODFLOW SIMULATION

Model Input

Plate C-1 presents the model grid and shows the location of the former EOL junction box as two recharge cells lying side-by-side, each 4m by 6m in size, up-gradient from MW-1. Although the EOL junction box is about 4 meters by 4 meters (12 feet by 12 feet), the model assumes that recharge of brine leakage from the site disperses as it infiltrates the sub-surface, impacting an area wider than the size of the junction box. Because saturated and unsaturated flow in the vadose zone is generally vertical with small lateral spreading in sandy vadose zone profiles, the size of the recharge cells is a conservative assumption in this model.

The model assumes that the chloride concentration in the released brine is 100,000 mg/L and employs this concentration for the quality of recharge to the aquifer. The recharge rate employed by the model is 150 mm/year. Published reports suggest that recharge to ground water in the arid southwest ranges from 0.01 to more than 150 mm/year (Table 1, from Scanlon, 1991, and Table 2, from Keese et. al., 2005; both are included at the end of this appendix). In their model, Musharrarieh and Chudnoff (1999) employ a value of 9.6 mm/year for the area near Eunice. Using 150 mm/year as a recharge rate appears appropriate for this site where periodic releases of brine would cause a higher moisture content than the sites described in the referenced publications.

These two input parameters yield the chloride flux to the aquifer at the recharge cells and we adjusted these two factors to create the observed 1000 mg/L in ground water at MW-1 (about 650 mg/L above background). For example, if the produced water chemistry from the Zachary Hinton battery exhibited an average chloride concentration of only 50,000 mg/L, model calibration would demand increasing the recharge rate to about 300 mm/year. We tested a recharge rate of 600 mm/year in the model and found no perturbation of the water table elevation; therefore, higher recharge rates for the simulation experiment would be acceptable for model calibration. The full text of the publications that describe recharge is included at the end of this appendix.

Table C-1 (below) shows the other input data and the source of the data. The model assumes that the background chloride concentration of the aquifer is 0.0 mg/L. The down-gradient and up-gradient boundary conditions are constant head, forcing a uniform hydraulic gradient across the model that is consistent with site observations.

Table C-1: MODFLOW and MT3D Input Data

Modflow and MT3D Input Parameters			
Description	Value	Unit	Source of Data
Model X Extent	2000	meters	
Model Y Extent	3000	meters	
Number of Layers	1	--	
Hydraulic Conductivity (Kx, Ky, K	1.6E-04	m/sec	Musharrafieh and Chudnoff, 1999
Layer Thickness	19	meters	Site Data
Depth to Water	16	meters	Site Data
Transmissivity	4.8E-04	m^2/sec	Musharrafieh and Chudnoff, 1999
Saturated Thickness	3	meters	Nicholson and Clebsch, 1960 and Site Data
Total Porosity	0.3	--	Professional Judgement
Effecitive Porosity	0.15	--	Professional Judgement
Specific Yeild (Sy)	0.2	--	Musharrafieh and Chudnoff, 1999
Recharge (0 to 20 years)	150	mm/year	Professional Judgement
Recharge Concentration (0 to 20	100,000	mg/L	Professional Judgement
Specific Storage (Ss)	1.00E-05	1/m	Musharrafieh and Chudnoff, 1999
Long. Dispersitvity	10	m	Professional Judgement
Horiz/Long Dispersivity	0.1	--	Professional Judgement
Vert/Long Dispersivity	0.01	--	Professional Judgement
Diffusion Coeff	0	m^2/day	Professional Judgement

Results of Simulations

Plate C-2 shows the chloride concentration in the aquifer five years after recharge begins. This simulation suggests that five years of periodic brine releases at the Zachary Hinton EOL Junction Box would cause a chloride concentration of 780 mg/L above background in an observation well 10 meters down-gradient from the release site and a chloride concentration 900 mg/L above background at the release site itself. After 10 years of periodic brine releases that result in an average flux of brine to the aquifer of 150 mm/year, ground water at the simulated observation well is about 780 mg/L above background chloride concentration. The resultant ground water plume (defined by the 100 mg/L contour line) is 1,018 meters long and 55 meters wide, as Plate C-3 shows.

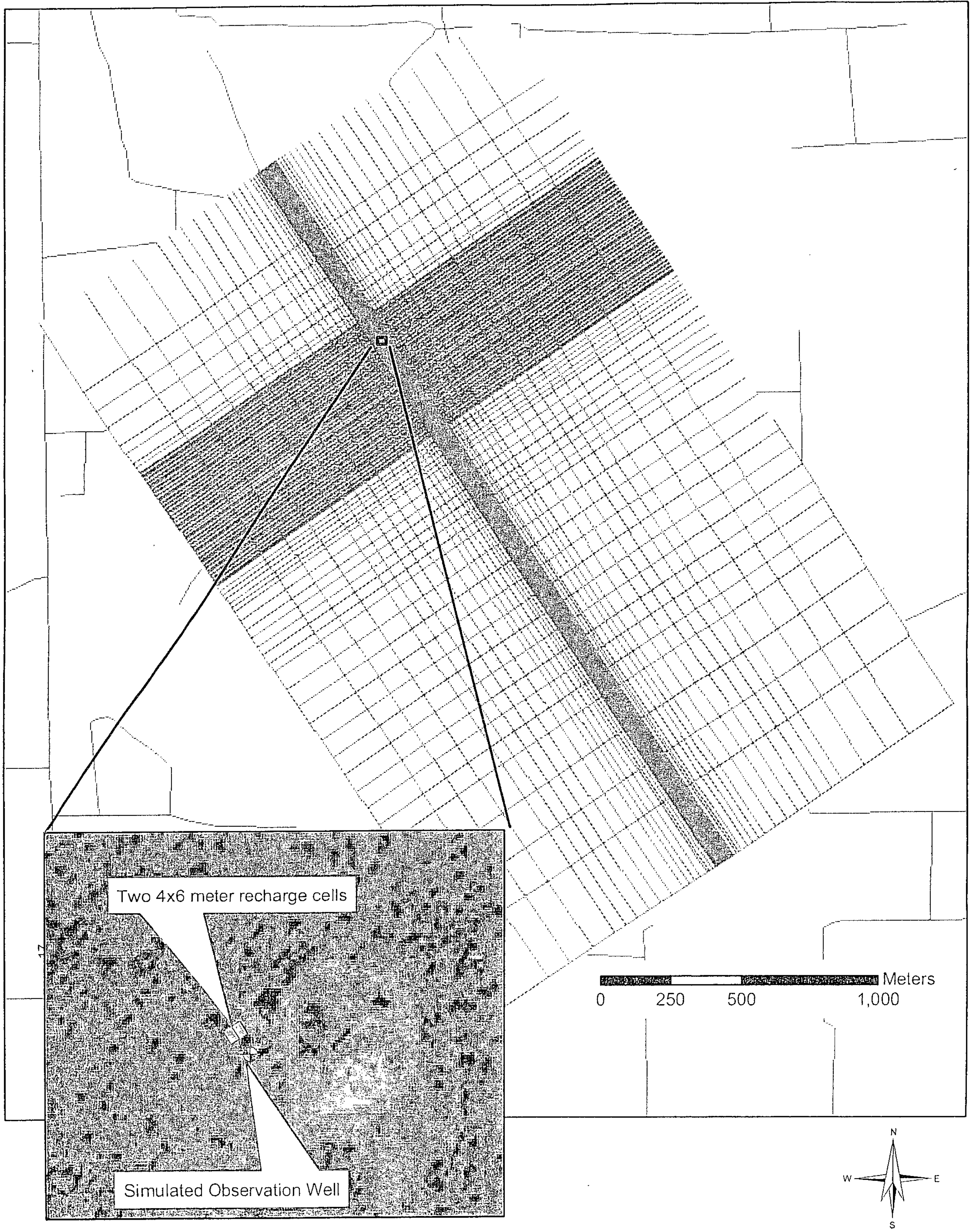
Twenty years of periodic releases do not materially change the extent or magnitude of the simulated ground water plume. As illustrated in Plate C-4, after 20 years, the chloride concentration in the monitoring well is 760 mg/L above back ground chloride concentration, the plume is 1,060 meters long and 55 meters wide. This simulation suggests a dynamic equilibrium between the input of chloride at the recharge (release) site and the dispersion/dilution effects of ground water transport.

At year 20, the recharge rate in the model is 0.0 mm/year, which simulates cessation of periodic brine releases after upgrade of the line. One year after cessation of recharge, the chloride concentration in the monitoring well returns to background level as the chloride migrates down-gradient, dilutes, and disperses. The magnitude and extent of the plume decreases, as shown in Plate C-4. Plate C-5 of the main report shows the simulation two years after cessation of intermittent brine releases. Three years after cessation of recharge, the area of interest returns to background ground water quality.

Simulation Conclusions

This simple simulation experiment predicts that periodic releases of brine from the Zachary Hinton site will cause ground water chloride to rise above background quality by about 900 mg/L near the source area (the recharge cells). Because background chloride in the aquifer is about 300–400 mg/L, the model predicts a chloride concentration of about 1,100–1,200 mg/L at the source. This prediction is consistent with the initial chloride concentration at MW-1 because we manipulated the chloride flux to ground water (within reasonable limits) to create this result. This adjustment is part of model calibration.

The model predicts that natural dilution and dispersion rapidly reduce chloride concentrations in ground water after the cessation of recharge (i.e. intermittent brine releases from the EOL Junction Box). Although the model is simple and assumes that the recharge stops immediately, the predictions conform with the data from this site and to observed ground water impairment at other junction box sites; therefore, additional adjustment of input data (e.g.: hydraulic conductivity) is not required to calibrate the model to observed conditions.



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Location of Modflow model grid, chloride recharge cells, and observation Well.

Plate C-1

ROC: BD Zachary Hinton (O-12) EOL

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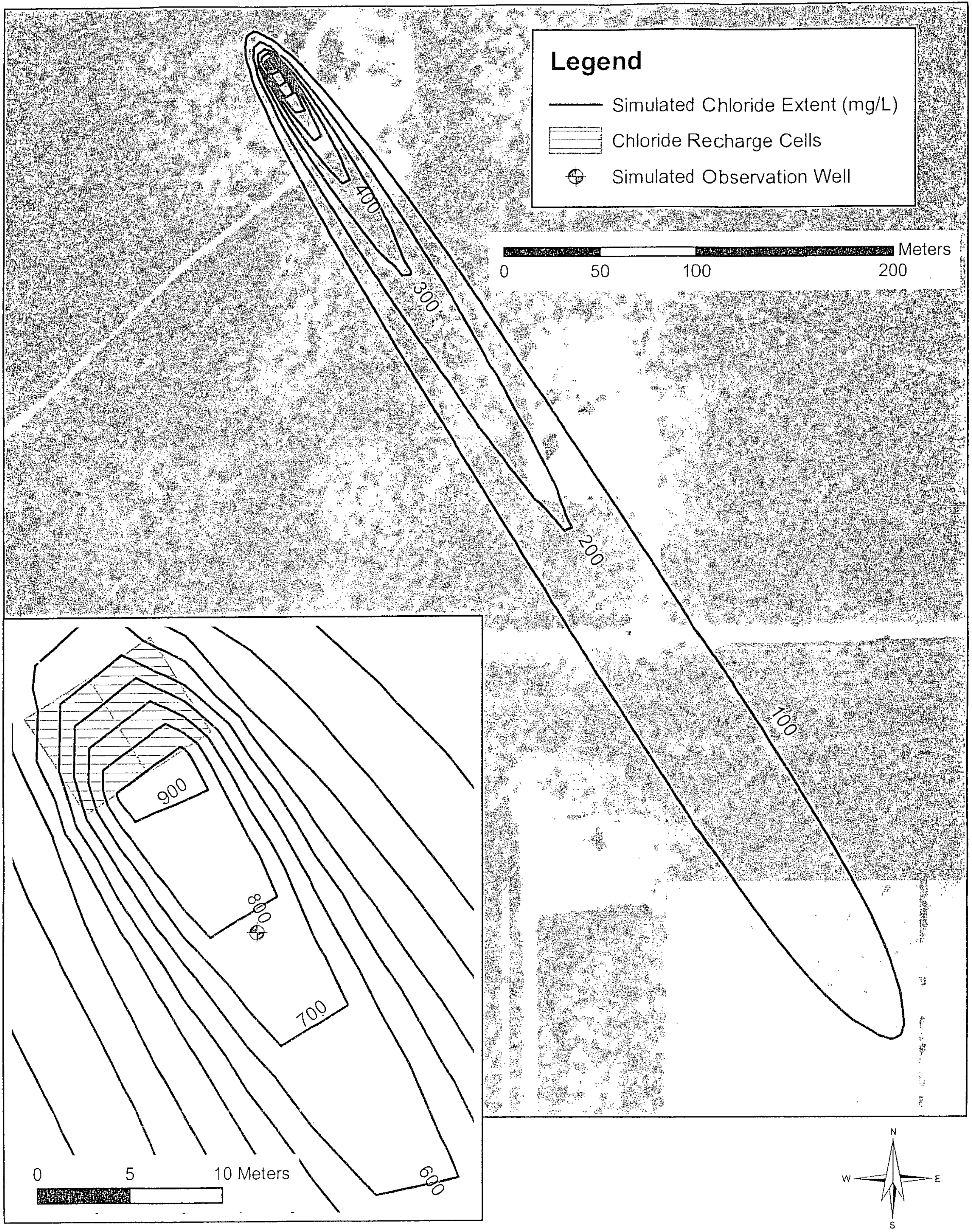

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Simulated chloride extent after 5 years from start of recharge

Plate C-2

ROC: BD Zachary Hinton (O-12) EOL Modflow Simulation

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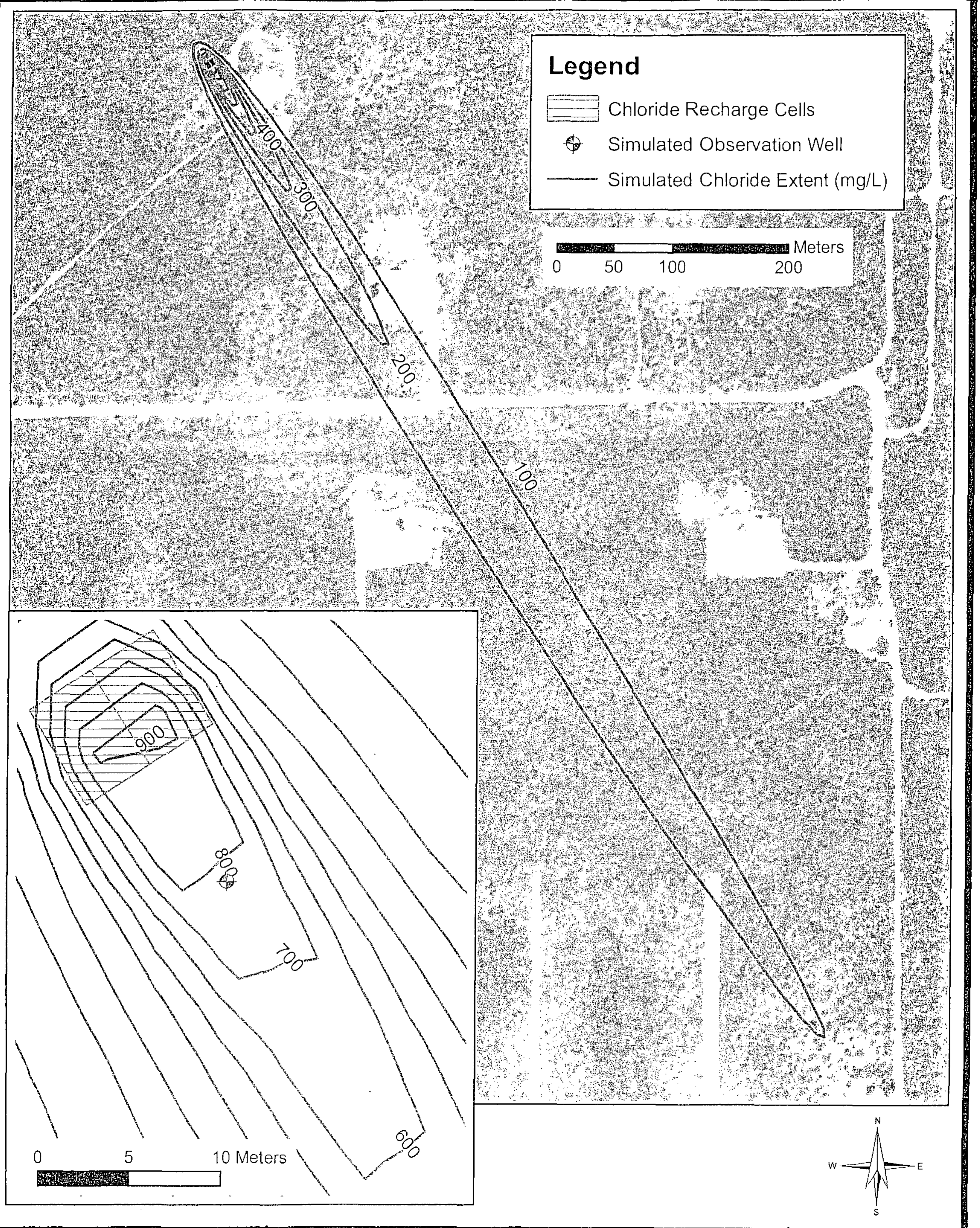

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Simulated chloride extent after 10 years from start of recharge

Plate C-3

ROC: BD Zachary Hinton (O-12) EOL Modflow Simulation

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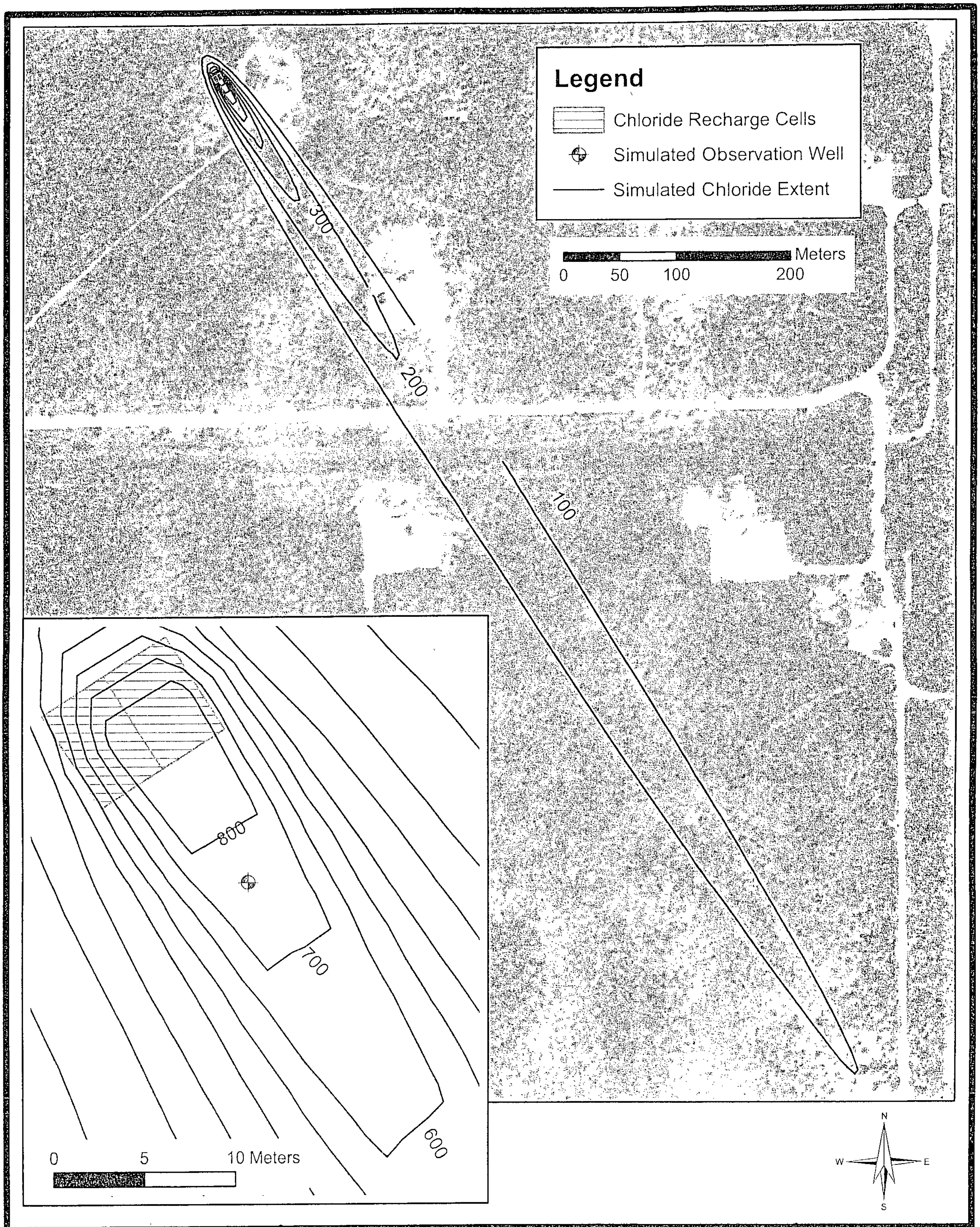

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Simulated chloride extent at 20 years
Recharge Stopped

Plate C-4

ROC: BD Zachary Hinton (O-12) EOL Modflow Simulation

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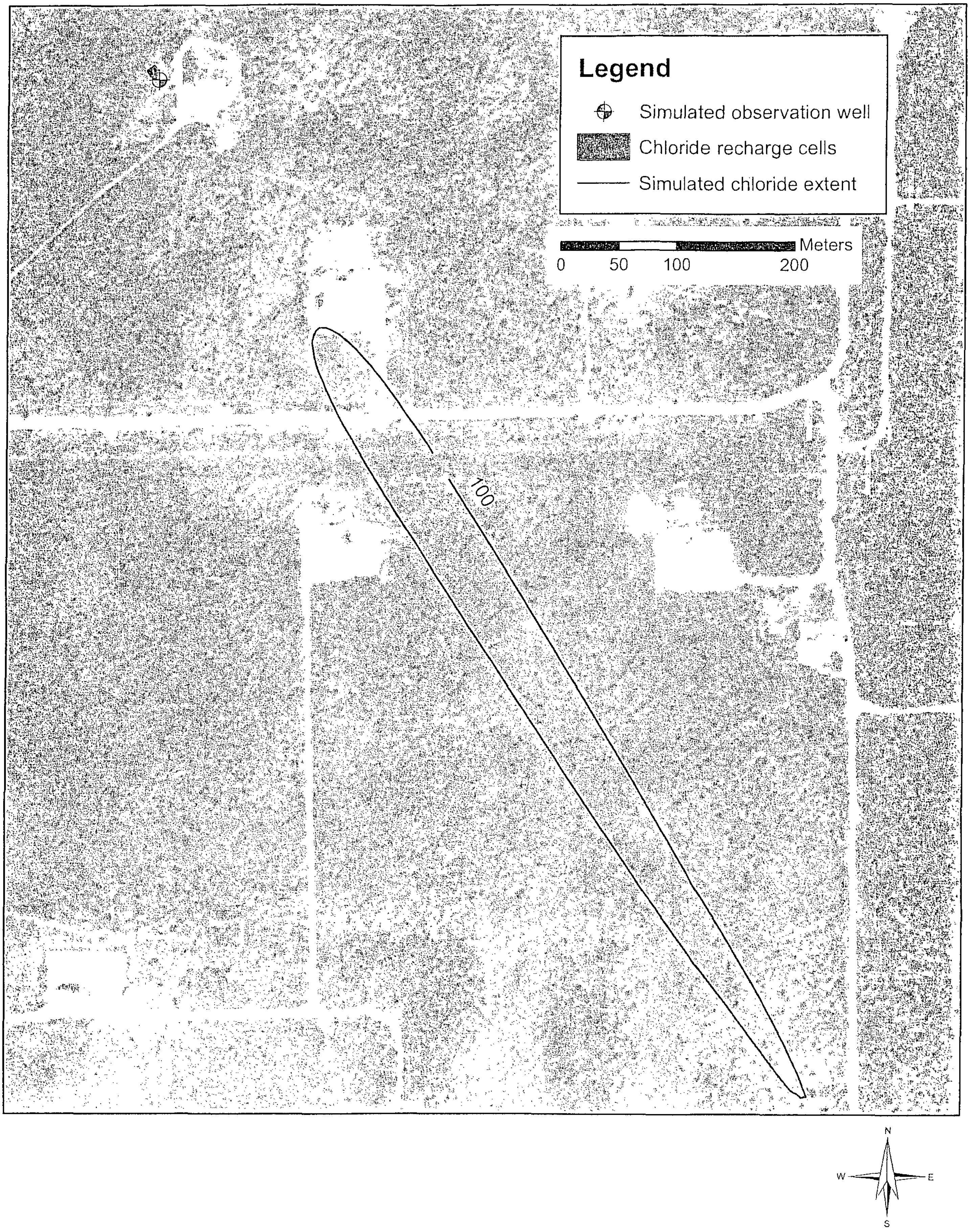

R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Simulated chloride extent at 22 years 2nd year after no recharge.	Plate C-5
	ROC: BD Zachary Hinton (O-12) EOL Modflow Simulation	March 2007

EVALUATION OF MOISTURE FLUX FROM CHLORIDE DATA IN DESERT SOILS*

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(Recieved 19 November 1990; revised and accepted 23 January 1991)

ABSTRACT

Scanlon, B.R., 1991. Evaluation of moisture flux from chloride data in desert soils. J. Hydrol., 128: 137-156.

Chloride-concentration data from 10 soil profiles in a 40 km^2 area of the Chihuahuan Desert of Texas were used to assess chloride mass balance methods of evaluating moisture flux. The relative importance of advective and diffusive transport mechanisms was determined. Moisture fluxes were calculated from measured chloride concentrations on the basis of a steady-state flow model. To evaluate controls on unsaturated flow, moisture fluxes from this study were compared with those from other regions.

The chloride profiles displayed large variations in concentrations and had (a) low chloride concentrations ($\leq$ 100 g m^{-3}) near land surface, (b) maximum chloride concentrations (1,900 to 9,300 g m^{-3}) at depths of 1.3 to 4.6 m, and (c) gradually decreasing chloride concentrations with depth below the peak. Steep concentration gradients (up to 12,000 g m^{-3} m^{-1}), characteristic of chloride profiles in these desert soils, indicate a potential for molecular diffusion; however, low moisture contents ($\leq$ 0.1) in the zone of steep concentration gradients resulted in diffusive fluxes that were 2 to 3 orders of magnitude lower than the advective fluxes; therefore, diffusive fluxes were neglected in flux calculations. Because the chloride accession rate was assumed to be constant throughout the study area, calculated moisture fluxes are inversely proportional to chloride concentrations in the soil water. Highest moisture fluxes (up to 6 mm yr^{-1}) were calculated near land surface and are related to chloride leaching as a result of precipitation. Within the upper meter of the unsaturated zone, soil moisture fluxes decreased sharply to 0.1 mm yr^{-1} as most of the water evapotranspired in this zone. Soil moisture fluxes decreased to a minimum at the chloride peak and then increased gradually as chloride concentrations decreased with depth below the peak. Reductions in chloride concentrations below the peak are attributed to differences in moisture fluxes as a result of paleoclimatic variations. Comparisons of chloride profiles from different regions indicate that geomorphic setting plays a major role in controlling moisture flux in the unsaturated zone.

INTRODUCTION

Chloride profiles have been used in a variety of settings to evaluate moisture fluxes in the unsaturated zone (Allison et al., 1985; Phillips et al., 1988). In arid

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*Publication authorized by the Director, Bureau of Economic Geology, The University of Texas at Austin.

systems, downward water flux is very difficult to quantify because it represents a small percentage of the total water balance. The chloride mass balance approach, which provides estimates of moisture flux during long time periods, has many advantages over conventional physical approaches in partly vegetated, arid systems because meteorologic data from these systems indicate large interannual variations in precipitation that would necessitate monitoring physical parameters over a long time to obtain reliable estimates of moisture flux. The water balance approach, in which downward water flux is computed from the difference between precipitation, evapotranspiration, and runoff, is generally inaccurate in arid systems because evapotranspiration constitutes most of the total water budget and estimates of evapotranspiration from micrometeorologic techniques are not sufficiently accurate in partly vegetated desert regions. The use of Darcy's Law to estimate moisture fluxes is also problematic because of the complexity of flow in desert soils where liquid and vapor transport may occur in response to water potential and temperature gradients. Highly nonlinear relationships between moisture content, water potential, and hydraulic conductivity result in large uncertainties in these flux calculations.

In contrast to physical methods that provide moisture flux data for the duration of the monitoring period, profiles of chloride concentrations yield information on moisture fluxes over long periods (up to 50,000 yr; Allison et al., 1985). In addition, unlike many of the physical methods in which the accuracy of moisture flux calculations decreases as the flux decreases, the accuracy of flux estimates from the chloride mass balance approach does not necessarily decrease because chloride concentrations increase as the moisture flux decreases. This increase in chloride concentrations results from evapotranspiration because chloride is nonvolatile and because plant uptake is minimal. Chloride data also provide information on spatial variability in downward water movement because each profile represents a point estimate of moisture flux. Good agreement has been found between estimates of moisture flux based on the chloride approach and those based on tritium data in a humid region (Allison et al., 1985). Results from chloride profiles have also been corroborated with data from stable isotope profiles (Sharma and Hughes, 1985; Fontes et al., 1986).

Thick unsaturated zones in arid regions are being considered as potential sites for radioactive waste disposal facilities because low precipitation and high evapotranspiration rates result in low recharge potentials and because the low permeability of a thick unsaturated zone may provide a natural barrier to radionuclide migration to the water table. The unsaturated zone in a 40 km^2 area of the Chihuahuan Desert in Texas (Fig. 1) is being considered as a potential repository of low-level radioactive waste. The objective of this study was to

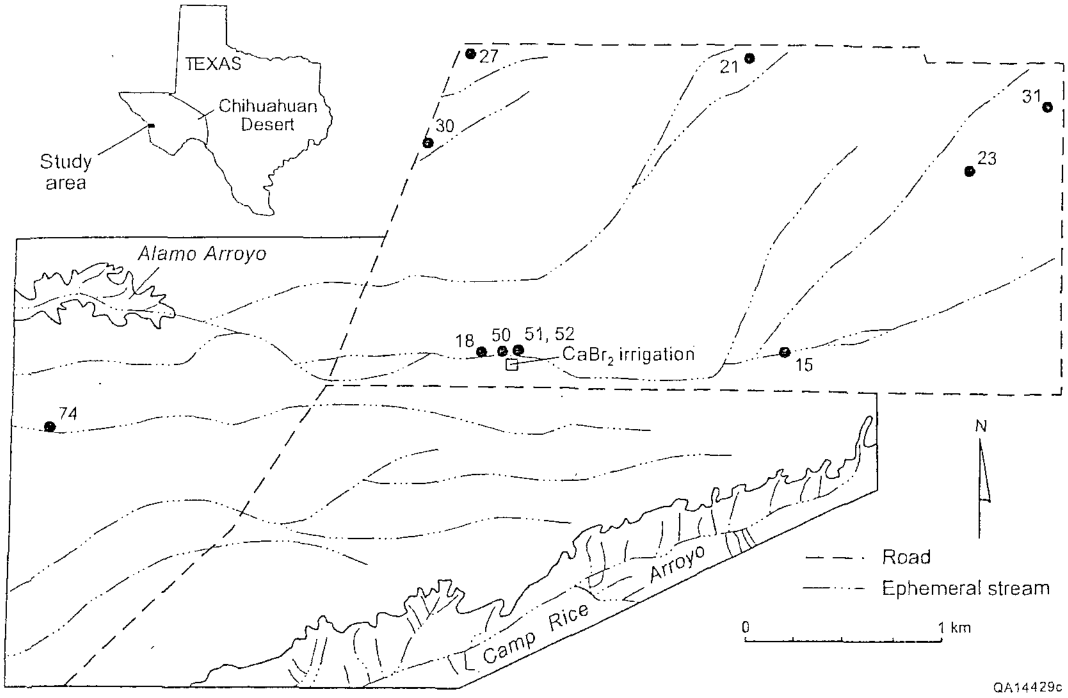


Figure 1. Location of sampled boreholes. Inset shows location of study area within the Chihuahuan Desert of Texas.

evaluate the moisture flux and its spatial variability in the upper 15 m of the unsaturated zone of this system. This paper focuses on chemical methods of analyzing water movement based on the distribution of environmental chloride. Key components of the research include evaluation of (1) the chloride mass balance method for determination of moisture fluxes, (2) the relative importance of advective and diffusive fluxes, (3) the spatial variability in moisture fluxes, and (4) controls on chloride profiles and moisture fluxes based on comparisons with other regions.

Chloride Mass Balance

Chloride concentrations in soil water have been used to evaluate moisture fluxes in semiarid systems (Bresler, 1973; Peck et al., 1981; Sharma and Hughes, 1985; Johnston, 1987). Chloride is an ideal tracer because it is chemically conservative. According to the theory of chloride transport (Bresler, 1973; Peck et al., 1981), the solute flux (J_S), under steady-state conditions, can be described by:

$$J_s = -D_h(\theta, v)\frac{\partial c}{\partial z} + cq_w \qquad (1)$$

where D_h is the hydrodynamic dispersion coefficient, a function of θ (the volumetric moisture content) and v (the average soil moisture velocity); z is the vertical space coordinate; c is the concentration; and q_w is the volumetric soil-moisture flux. J_s was approximated by the mean annual precipitation rate (P: 280 mm yr^{-1} [J. Griffiths, pers. comm., 1990]), times the chloride concentration in precipitation and in dry fallout (Cl_p) for this study area (Sharma and Hughes, 1985; Mattick et al., 1987). The mean chloride concentration (Cl_p: 0.29 g m^{-3}) was calculated from the prebomb $^{36}Cl/Cl$ ratio (0.46×10^{-12}) measured in soil water from borehole 51, and the natural ^{36}Cl fallout at the site estimated as 20 atoms ^{36}Cl m^{-2} s^{-1} (Bentley et al., 1986; Scanlon et al., 1990). The resultant J_s value was 0.08 g m^{-2} yr^{-1}.

Rearranging equation (1) yields the soil-moisture flux:

$$q_w = \frac{1}{c}\left(J_s + D_h(\theta, v)\,\frac{\partial c}{\partial z}\right) \tag{2}$$

The first term in the outer parentheses represents the flux that results from advection and the second term represents the flux from dispersion. The mechanical dispersion coefficient (D_m) and the effective molecular diffusion coefficient (D_e) comprise the hydrodynamic dispersion coefficient. D_m is assumed to be negligible because flow velocities are less than 7 m yr^{-1}, which Olsen and Kemper (1968) specify as the water velocity below which mechanical dispersion can be ignored. D_e includes the effects of tortuosity and water content. Recent studies of D_e values of silts, sands, and gravels indicate that D_e is primarily a function of moisture content and only secondarily dependent on soil type (Conca, in press; Conca and Wright, 1990). At low-moisture fluxes, the diffusive flux may be dominant. The diffusive flux was estimated from the first derivative of c(z) times D_e. Cubic splines were fitted to the observed chloride profiles to smooth the data and to calculate the first derivative in equation (2). Moisture content data from the profiles were used to calculate D_e based on the relationship between moisture content and D_e from Conca (pers. comm., 1990). The moisture flux is divided by the volumetric moisture content to obtain the moisture velocity (q_w/θ), which represents the actual rate of solute transport.

In many arid systems the hydrodynamic dispersion coefficient was assumed to be negligible (Allison et al., 1985; Stone, 1990) and equation (2) was simplified to:

$$q_w = J_s / c \tag{3}$$

The travel time (t) represented by chloride at depth z can be evaluated by dividing the total mass of chloride from the surface to that depth by the chloride flux:

$$t = \frac{\Sigma Cl_{sw} \times z}{J_s} \qquad (4)$$

where c is approximated by Cl_{SW} (chloride concentration in soil water).

Chloride profiles provide a qualitative estimate of moisture flux because there are many assumptions associated with the chloride mass balance approach. These assumptions are:

(1) one-dimensional, vertical, downward, piston-type flow; (2) precipitation as the only source of chloride; (3) mean annual precipitation and chloride concentration of precipitation constant through time; and (4) steady-state chloride flux equal to the chloride accession rate in rainfall. The accuracy of the flux estimates from chloride data depends on the reliability of the physical flow model used to interpret the data. Although this model of chloride movement predicts that chloride concentrations should increase through the root zone and remain constant below the root zone, many previously published chloride profiles show that chloride concentration decreases below the peak; therefore, some of the assumptions associated with the model may not be valid for different systems. The reduction in chloride concentration below the peak was attributed to groundwater dilution (Phillips et al., 1988), nonpiston-type flow (Sharma and Hughes, 1985), or failure of the steady-state flow assumption as a result of paleoclimatic variations (Allison et al., 1985; Phillips and Stone, 1985). An alternative method was used to analyze some chloride profiles in Western Australia that did not assume a downward moisture flux (Peck et al., 1981). This analysis showed that steep concentration gradients below the chloride peak resulted in the flux being dominated by diffusion rather than advection and that the calculated moisture flux was upward, in contrast to the downward flux assumed by the chloride mass balance theory. These studies underline the importance of evaluating the conceptual flow model that is used to analyze the chloride data and the applicability of the assumptions to each study area.

Anion exclusion may also affect the accuracy of flux estimates based on chloride data. Most studies of anion exclusion are restricted to laboratory column experiments in which ionic Cl or ^{36}Cl migrated faster than ^{3}H (Biggar and Nielsen, 1962; Krupp et al., 1972; Wierenga and van Genuchten, 1989). Faster migration of Cl relative to that of ^{3}H was also recorded in field tracer experiments (Gvirtzman et al., 1986; van de Pol et al., 1977). Calculated anion velocities were as much as twice the estimated water velocities in clay-rich soils (Gvirtzman et al., 1986; James and Rubin, 1986). In desert soils, such as in New Mexico and the present study area, deeper penetration of ^{3}H relative to that of ^{36}Cl was attributed to downward movement of ^3H in the vapor phase (Phillips et al., 1988; Scanlon, in press). These data suggest that although Cl may be excluded from the liquid phase, flux estimates based on Cl data should not overestimate the water (liquid + vapor) flux in desert soils.

Study Area Description

This study area (31° 25' N, 105° 40' E) is located in the Hueco Bolson, which is a 200-m- thick sediment-filled basin within the Chihuahuan Desert of Texas (Fig. 1). The Hueco Bolson is part of the Rio Grande Rift and formed as a result of Basin and Range deformation during the Tertiary (Henry and Price, 1986). The unsaturated zone consists of 0 to 15 m of silty to gravelly loam of the Tertiary and Quaternary Camp Rice Formation, underlain by approximately 140 m of clay with interbedded silt and sand of the upper Tertiary Fort Hancock Formation. Shallow coarse-grained material was deposited in alluvial and eolian environments, whereas the deeper clay sediments were deposited in a predominantly lacustrine environment. A discontinuous layer of caliche occurs at a depth of 1 to 2 m.

Regional climate is subtropical arid (Larkin and Bomar, 1983); mean annual precipitation is 280 mm and has large interannual variations that range from 110 to 440 mm in El Paso, located 65 km northwest of the study area. Approximately 60% of the precipitation falls between June 1 and September 30 as convective storms. Mean annual potential evapotranspiration (Class A pan) is approximately seven times mean annual precipitation.

The present surface of the Hueco Bolson is an alluvial plain that slopes 1 to 1.5% toward the Rio Grande. Modern ephemeral streams that drain the alluvial plain lack well-defined channels (maximum relief 0.6 m). The upper reaches of the ephemeral streams drain into incised channels (arroyos) southwest of the study area (Fig. 1). Streams are generally dry except after precipitation events. Shrubs, such as creosote (*Larrea tridentata*) and mesquite (*Prosopis glandulosa*), are common and root to depths of 1 to 5 m. The topography is relatively flat with slopes of less than 1%. Because of the low topography, precipitation events predominantly result in sheet flow across the area (S. Akhter, pers. comm., 1989).

METHODS

To determine ambient moisture and chloride contents, approximately 230 soil samples were collected from 10 boreholes drilled during 1988 and 1989 (Fig. 1). These boreholes were rotary drilled with hollow-stem augers without drilling fluids. Samples were collected in Shelby tubes, and the sampling interval varied from approximately 0.3 to 1 m. Many of the boreholes were drilled to the top of the clay-rich Fort Hancock Formation at a depth of 10 to 15 m, which the auger could not penetrate.

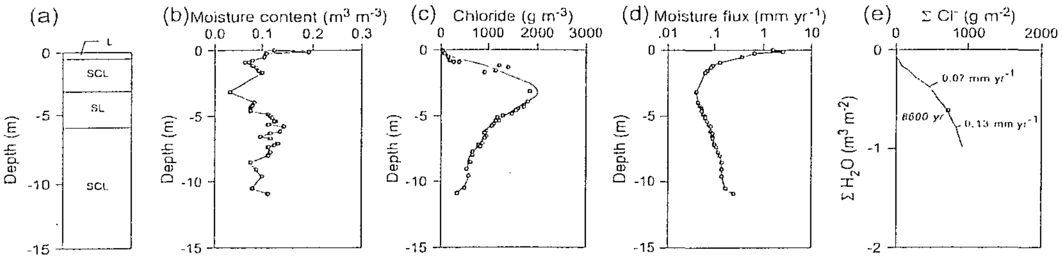
Gravimetric-moisture content was determined by drying at least 80 g of soil at 105°C for 48 hr. Although volumetric-moisture content could not be directly determined in 90% of the samples because the material was not sufficiently cohesive, volumetric-moisture content of these samples was calculated from gravimetric-moisture content using a bulk density of 1.4 (average bulk density measured in 27 samples). To determine chloride content, double-deionized water was added to the oven-dried soil sample in a 1:1 or 2:1 ratio. Samples were agitated on a reciprocal shaker table for 8 hr, then centrifuged for 10 min at 5,000 rpm. The supernatant was filtered through 0.45 μm filters. Chloride was then analyzed by ion chromatography or by potentiometric titration. To test if oven drying had any effect on chloride concentration, four samples at field moisture were split and one half of each was oven dried. Soil texture of these samples was not determined. Comparison of the chloride concentrations of the splits showed that oven drying had no effect on chloride concentrations.

Textures of approximately 100 soil samples were measured. The samples were ground to disaggregate calichified materials. The greater-than-2-mm fraction was determined by dry sieving, and the percent of sand, silt, and clay was evaluated by hydrometer analysis following Bouyoucos (1962). Sediment samples that contained gravel were classified according to Folk (1974) and those that did not contain gravel were classified according to the U.S. Department of Agriculture (1975).

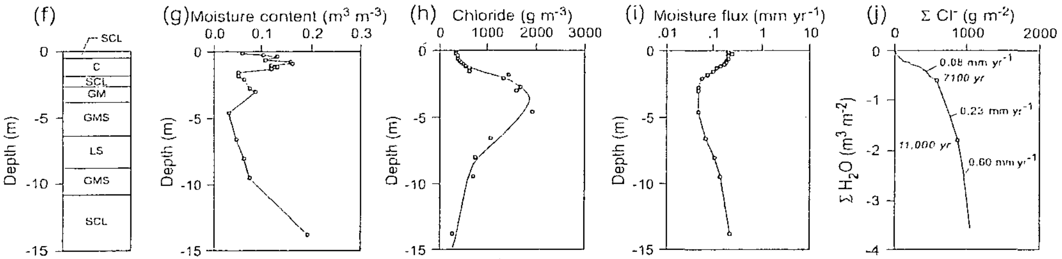
RESULTS AND DISCUSSION

In the following sections, 6 of the 10 measured chloride profiles are described in detail; descriptions of the other profiles can be found in Scanlon (in press). The chloride profiles are plotted at different scales in figure 2. All measured chloride profiles are bulge shaped and consist of low chloride concentrations near the surface, at depths of generally less than 0.3 m, and maximum chloride concentrations at depths of 1.3 to 4.6 m that decrease to low concentrations with depth (Fig. 2). Chloride profiles display a wide variability in their maximum chloride concentrations, which range from 1,900 g m^{-3} (Figs. 2c and 2h) to 9,300 g m^{-3} (Fig. 2aa).

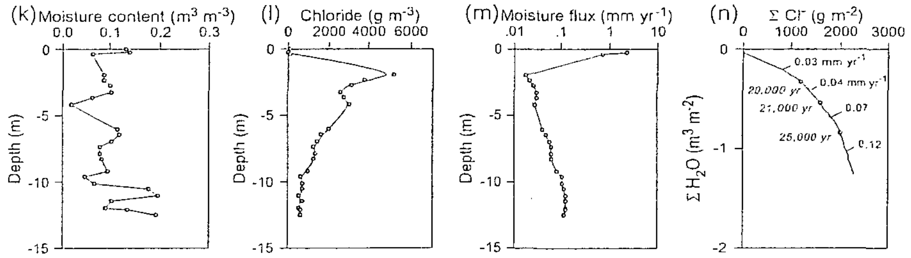
The chloride profile from borehole 15 is characterized by low concentrations (< 100 g m^3) in the upper meter of the unsaturated zone (Fig. 2c). This zone of low concentration corresponds to high moisture content (0.11 to 0.19 m^3 m^{-3}) that reflects infiltration of a recent precipitation event. Below this surficial leached zone, chloride concentrations increase sharply to 1,900 g m^{-3} as a result of



Borehole 15 (Ephemeral stream setting)



Borehole 18 (Ephemeral stream setting)



Borehole 27 (Interstream setting)

Figure 2(a-ac). Data from six boreholes on soil texture, moisture content, chloride concentration, and fitted cubic spline, and calculated moisture flux based on equation (3) plotted against depth, and cumulative chloride plotted against cumulative water content. Note the different scales used for various profiles. Soil textures: g, gravel; s, sand; l, loam; c, clay; msg, muddy sandy gravel; gms, gravelly muddy sand; ls, loamy sand; sl, sandy loam; scl, sandy clay loam; cl, clay loam; gm, gravelly mud; and sc, sandy clay.

evapotranspirative enrichment. Chloride concentration gradients increased with depth at rates of up to −900 g m^{-3} m^{-1}. The peak chloride concentration was recorded at a depth of 3.2 m. Chloride concentrations decrease gradually to 340 g m^{-3} below the peak, and chloride concentration gradients range from 500 g m^{-3} m^{-1} to 10 g m^{-3} m^{-1} in this zone. Chloride concentrations in samples from the shallow zone of borehole 18 are much higher (350 to 400 g m^{-3}) (Fig. 2h) and the moisture contents much lower (0.06 to 0.13 m^3 m^{-3}) (Fig. 2g) than those from borehole 15 because borehole 18 was sampled after a long dry period. The chloride concentration gradients, peak concentrations, and depth of the chloride peak are similar in the profiles from boreholes 15 and 18. Both profiles sample the ephemeral stream setting.

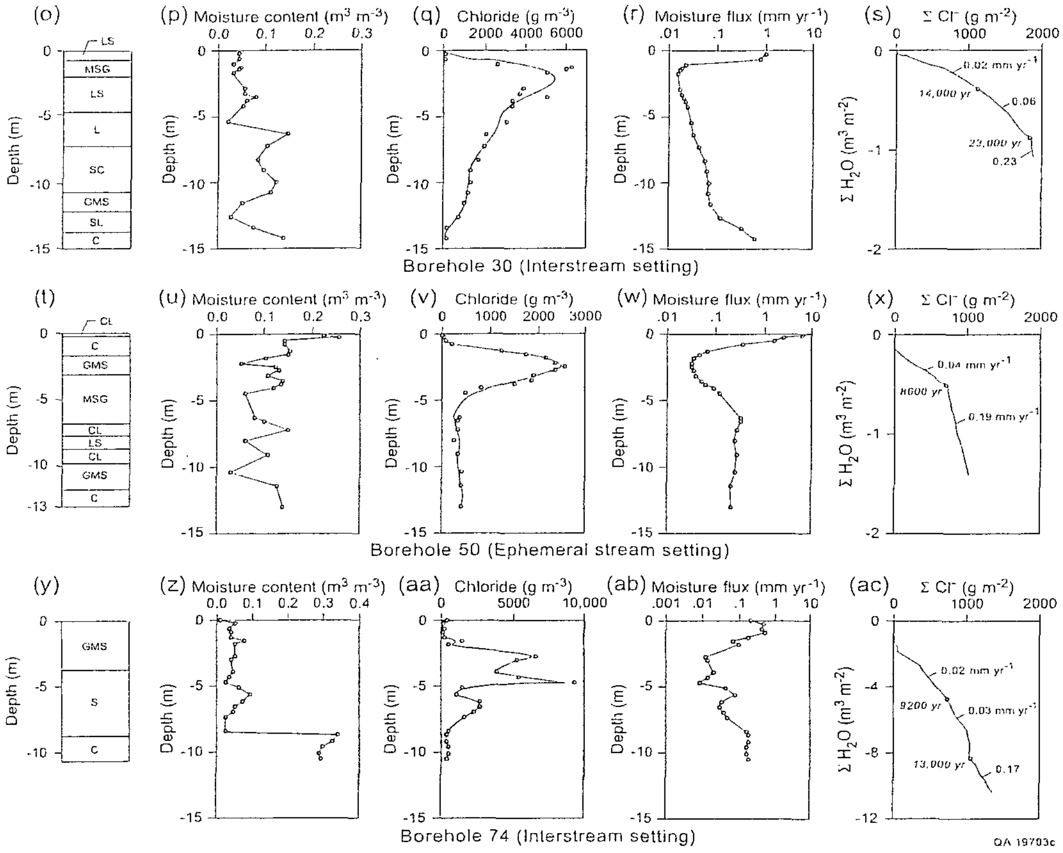


Figure 2. (continued)

Boreholes 27 and 30 were located in interstream settings (Fig. 1) and their chloride profiles are similar (Figs. 2l and 2q). Both profiles have a leached section of approximately 0.5 m. Chloride concentration gradients are very steep above the peak (≥ –6,000 g m^{-3} m^{-1}), whereas these gradients are much lower (2,000 to 10 g m^{-3} m^{-1}) below the peak.

Borehole 50 was sampled in an ephemeral stream after a rainfall event. The shallow zone is characterized by low chloride concentrations (2 to 7 g m^{-3}) and high moisture contents (0.14 to 0.26 m^3 m^{-3}) (Figs. 2u and 2v). Below the surficial leached zone, moisture content shows no systematic relationship with depth. Chloride concentration gradients above the chloride peak are ≥ –2,000 g m^{-3} m^{-1}, whereas those below the peak range from 1,200 to 5 g m^{-3} m^{-1}. Comparisons of chloride concentrations in samples from nearby (10 m away) borehole 51 (Fig. 1) give an indication of local variability. Peak chloride concentrations (2,000 g m^{-3}) are similar in the two profiles; however, the depth of the peak is approximately 1 m deeper in the profile from borehole 50.

Chloride concentrations in samples from borehole 74 (Fig. 2aa), also located in an ephemeral stream setting (Fig. 1), are higher than those recorded in all other profiles. The chloride profile is multipeaked and not as smooth as other measured profiles. Chloride concentration gradients are steepest in this profile (up to 12,000 g m^{-3} m^{-1}) and vary markedly with depth. The soil texture above 8 m depth (gravelly muddy sand to sand; Fig. 2y) is much coarser grained than that in the other profiles (predominantly sandy clay loam). The transition from shallow coarse material to deeper clay corresponds to a marked increase in moisture content of 0.3 m^3 m^{-3} (Fig. 2z). The clay-rich Fort Hancock Formation is found at a shallower depth (8 m) in this borehole than in the other boreholes to the northeast (13 to 15 m in boreholes 23, 30, and 50).

Chloride concentrations in the surficial sediments vary depending on the relationship between the sampling time and precipitation events. At depths greater than approximately 0.5 m, chloride concentrations represent longer time periods and are not affected by individual precipitation events. No systematic relationship was found between the chloride profiles and the present geomorphic setting. The lack of a relationship may result from these two geomorphic systems being hydrologically similar because most of the runoff occurs as sheet flow (S. Akhter, pers. comm., 1989), and the topographic difference between the two settings is small (0.6 m). Alternative hypotheses are that the geomorphic systems are not stable over the long time periods reflected in these chloride profiles, or that soil textural variations are more important in controlling moisture flux, as shown by the profile from borehole 74.

Transport Mechanisms

The general advection-dispersion equation (equation 2) was fitted to the chloride concentration data to evaluate the relative importance of advection and diffusion. Smooth chloride profiles are generally thought to reflect redistribution of chloride as a result of diffusion. Chloride concentration gradients were up to 12,000 g m^{-3} (borehole 74). These large concentration gradients should yield high diffusive fluxes. Effective diffusion coefficients (D_e) estimated from the moisture content data in the profiles and the relationship between moisture content and D_e developed by Conca (pers. comm., 1990) was approximately 10^{-11} m^2 s^{-1} in most profiles. The range in D_e (10^{-10} to 10^{-12}) was higher in samples from borehole 74 because the range of moisture content was greater with lower moisture contents in the coarser grained material and higher moisture contents in the clay section (Fig. 2z).

Above the chloride peak, increasing chloride concentrations with depth gave rise to upward diffusive fluxes that ranged from 10^{-3} to 10^{-4} mm yr^{-1}. Below the chloride peak, downward diffusive fluxes ranged from 10^{-3} to 10^{-5} mm yr^{-1}. Although the multipeaked chloride profile from borehole 74 could be expected to reflect lower diffusive fluxes in this profile relative to those in other profiles, the diffusive fluxes are actually similar because the effect of steeper concentration gradients cancels the lower D_e values in samples from borehole 74. The low calculated diffusive fluxes for all profiles (10^{-3} to 10^{-5} mm yr^{-1}) are attributed in part to low moisture contents (≤ 0.1 m^3 m^{-3}) in the zone of high concentration gradients. D_e gradually decreases with moisture content, from a value of 10^{-9} m^2 s^{-1} at a moisture content of 0.5 m^3 m^{-3} to a value of 10^{-10} m^2 s^{-1} at a moisture content of 0.1 m^3 m^{-3} (Conca, in press). Below a moisture content of 0.1 m^3 m^{-3}, D_e decreases sharply to 10^{-13} m^2 s^{-1} at a moisture content of 0.01 to 0.005 m^3 m^{-3}. Another factor that contributes to the low diffusive fluxes is that the effects of absolute concentrations and steep concentration gradients on the diffusive flux cancel each other (equation 2) as the zones of high chloride concentrations and steep concentration gradients coincide.

In contrast to the diffusive flux, which varies in direction according to the chloride concentration gradients, the calculated advective flux must always be downward because the chloride approach assumes a constant downward chloride flux. The calculated advective flux ranges from 10^{-2} to 10^{-1} mm yr^{-1} in most profiles and is approximately 2 to 3 orders of magnitude higher than the diffusive flux. These data suggest that the diffusive flux can be neglected and soil moisture flux can be approximated by the advective flux, as seen in equation (3).

Because the chloride flux is assumed to be constant throughout the study area, variations in the soil moisture chloride concentrations reflect differences in moisture flux. Therefore, the chloride concentration in soil water increases to the peak value as the moisture flux decreases, and chloride concentrations decrease below the peak as moisture flux increases (Fig. 2). The highest moisture fluxes were recorded in samples from the shallow zone of borehole 50 (Fig. 2w) where chloride had been leached (≤ 10 g m^{-3}) by a recent precipitation event. The advective fluxes in all profiles decrease sharply to 0.1 mm yr^{-1} within the top meter of the unsaturated zone because almost 100% of the soil water is evapotranspired in this zone. Calculated moisture fluxes are at a minimum where soil moisture chloride concentrations peak, and they increase gradually with depth below the peak as chloride concentrations decrease. Soil moisture velocities (q_w/θ) generally parallel soil moisture flux profiles and are approximately 2 orders of magnitude greater than soil moisture fluxes.

In addition to diffusion, chloride concentration gradients also give rise to osmotic potential gradients that cause advective flux in the direction of higher chloride concentrations. Osmotic potentials (ψ_π; units mega Pascals, MPa) were calculated from soil water chloride concentrations according to the Vant Hoff equation (Campbell, 1985):

$$\psi_\pi = (\nu C\chi\ R\ T)/1000$$

where ν is the number of osmotically active particles (2 for NaCl), C is the concentration (moles kg^{-1}), χ is the osmotic coefficient (Robinson and Stokes, 1959), R is the gas constant (8.3142 J $mole^{-1}$ $°K^{-1}$), and T is temperature (°K). Osmotic coefficients decrease with increasing chloride concentration. Maximum osmotic potential gradients of 2 MPa m^{-1} were calculated for the chloride profile from borehole 74 (Scanlon et al., in press). The remaining profiles were characterized by osmotic potential gradients generally less than 0.4 MPa m^{-1}. These osmotic potential gradients are negligible compared with the measured water potential gradients ($\leq$ 15 MPa m^{-1} in borehole 74 [Scanlon et al., in press]), and fluxes resulting from the osmotic potential gradients should have a minimal effect on flow.

Validity of Assumptions of Chloride Approach

As outlined in the introduction, many assumptions are used to estimate moisture fluxes from chloride data, and the validity of these assumptions in this study area needs to be examined. The one-dimensional vertical flow assumption is considered valid because, except at borehole 74 where topographic slopes are up to 2%, all chloride profiles are from topographically flat areas having slopes of less than 1%. In sloping topography, the chloride method underestimates moisture fluxes because lateral flow is neglected (Mattick et al., 1987). The direction of moisture flux is assumed to be downward. If the moisture flux were in fact upward, the highest chloride concen-trations would occur at the land surface, as seen in chloride profiles from the Sahara (Fontes et al., 1986). Maximum chloride concentrations observed at depths of 1.3 to 4.6 m in the Hueco Bolson indicate that the net moisture flux is downward in this depth interval of the unsaturated zone. Precipitation is assumed to be the only source of chloride; there are no chloride sources or sinks below the root zone. The sediments in this study area are terrestrial and do not contain any chloride of marine origin. The low observed chloride concentrations in soil water indicate that chloride is not in equilibrium with chloride minerals. The bases of some of the profiles are characterized by chloride

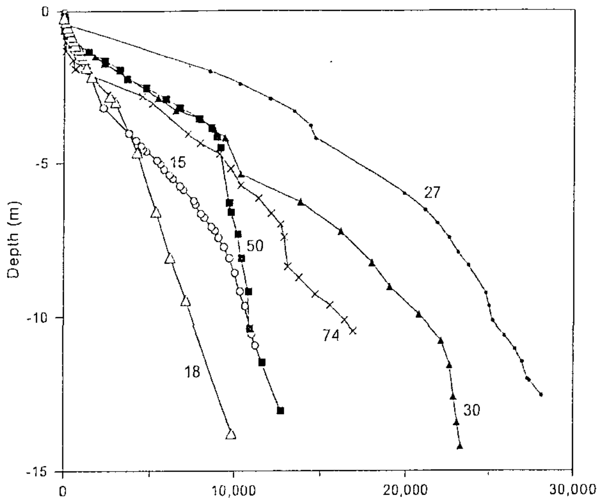


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Figure 3. Chloride mass balance age calculated according to equation (4). Borehole numbers shown adjacent to each line.

concentrations as low as 100 g m^{-3}, which further indicates that any in situ chloride source is negligible.

The piston-flow assumption is more difficult to assess. The applicability of piston flow depends on the temporal and spatial scales being considered. Near the soil surface where desiccation cracks develop, nonpiston flow may be dominant. Higher moisture fluxes based on groundwater chloride relative to those based on chloride concentration in the unsaturated zone in many areas have been attributed to nonpiston flow or bypass of the matrix with low-chloride water (Peck et al., 1981; Sharma and Hughes, 1985; Johnston, 1987). Chloride profiles in these areas are generally smooth, which indicates that the smoothness of the profiles does not help discriminate between piston and nonpiston flow. Flow along preferential pathways that bypasses the matrix is used to explain the reduction in chloride concentrations below the peak in some profiles (Sharma and Hughes, 1985). Many profiles characterized by a large amount of preferential flow are from wetter regions (precipitation 800 to 1,200 mm yr^{-1} [Sharma and Hughes, 1985; Johnston, 1987]) than the Hueco Bolson (precipitation 280 mm yr^{-1}). The water potentials (matric and osmotic potentials) in the Hueco Bolson are very low (−2 to −16 MPa [Scanlon et al., in press]); therefore, most of the water is adsorbed onto grain surfaces and is unlikely to move along larger openings or root channels.

The long time period represented by chloride profiles in this study (10,000 to 30,000 yr; Fig. 3) spans paleoclimatic variations and may invalidate the steady-state subsurface flow assumption. The decrease in soil water chloride concentrations below the peak may represent temporally varying precipitation, chloride input, moisture flux, or other environmental conditions (Allison et al., 1985). To examine the possibility of changing environmental conditions, cumulative chloride concentration was plotted against cumulative water content for each borehole. Cumulative water content was used instead of depth to factor out variations in water content (Allison et al., 1985). Moisture fluxes were calculated from the straight-line portions of these plots, which signify uniform environmental conditions. In these flux calculations, Cl_{SW} is the weighted mean soil water chloride concentration in a depth interval that has a constant ratio of cumulative chloride to water content; the constant ratio indicates uniform environmental conditions during a period of recharge. Profiles have either multiple line segments or curved lines, both of which suggest varying environmental conditions (Figs. 2e, 2j, 2n, 2s, 2x, and 2ac). An increase in slope of the cumulative-chloride-versus-water-content profiles with depth reflects past conditions with greater water and/or chloride flux than present rates of flux. If a constant chloride flux is assumed, calculated moisture fluxes range from 0.03 to 0.7 mm yr^{-1}. Many of the profiles indicate a change in the moisture flux from 9,000 to 6,000 yr, higher moisture fluxes having occurred before this period and lower moisture fluxes from this period to the present. This is consistent with paleoclimatic data that suggest that the climate during the late Wisconsinan and early Holocene (22,000 to 8,000 yr) was much wetter than middle to late Holocene (8,000 yr to present) (Van Devender and Spaulding, 1979). In addition to higher precipitation rates in the past, the seasonality of the precipitation is also thought to differ, winter frontal storms being dominant before 8,000 yr, summer convective storms being more typical of the climate since then (Van Devender and Spaulding, 1979), which would further reduce the moisture flux from 8,000 yr to the present.

Controls on Chloride Profiles and Moisture Fluxes

Chloride profiles and moisture fluxes from the Hueco Bolson were compared with those from other regions to evaluate controls on unsaturated flow and solute transport processes. Possible controls on these processes include climate and paleoclimate, geomorphic and hydrologic settings, and soil texture.

Moisture fluxes from chloride profiles in sand dunes in a humid region in Western Australia ranged from 50 to 115 mm yr^{-1}, which is much higher than those estimated for sand dunes in an arid region (flux 0.06 mm yr^{-1}) in South Australia (Table 1). The wetter region was characterized by up to 50% flow along preferential pathways that bypassed the matrix (Sharma and Hughes, 1985). Moisture flux differences between these two regions are much greater than flux

TABLE 1

Comparison of physical and chemical data from Texas, New Mexico, and Australia

	Precipitation (mm/yr^{-1})	Water table depth (m)	Geomorphic setting	Soil texture	Maximum chloride (g/m^{-3})	Moisture flux (mm/yr^{-1})
Texas[a] (Hueco Bolson)	280 (arid)	150	Ephemeral stream	Clay to muddy-sandy-gravel	9300	0.01 to 0.7
			interstream	Clay to muddy-sandy-gravel	6300	0.03 to 0.27
New Mexico[b,c]	444 or 385	30	Playa		≤ 100	2.8-12.4[c]
(Eastern)	(semiarid)		Sand hills		≤ 300	1.3-4.3[a]
(Central) 24 km N of Socorro[d,e]	220 (arid)	5	Pleistocene alluvium	Sandy loam to loamy sand	60 to 2720	1-3
(3*) (3**)		100	Holocene terrace	sand		1-3
40 km NE of Las Cruces[d]	220 (arid)	100		Sandy loam to Sandy clay loam	680	0.1
South Australia 100 km NE of Adelaide[f]	300 (arid)	28-40	Undisturbed calcrete		7500	0.1-0.17
			1° sinkhole		22500	0.07-0.09
			2° sinkhole		30	≥ 60
			Vegetated dunes		20000	0.06
			Cleared dunes			13
Western Australia 40 km N of Perth[g]	800 (humid)	90	Dunes	sand	250 -500	50-115

This paper; [b]Phillips and Stone, 1985; [c]Stone (1990); [d]Mattick et al., 1987; Phillips et al., 1988; [e]Phillips et al., 1984; [f]Allison et al., 1985; [g]Sharma and Hughes, 1985.

differences attributed to paleoclimatic variations in the Hueco Bolson (0.01 to 0.26 mm yr^{-1}) and in South Australia (0.01 to 0.17 mm yr^{-1}) (Allison et al., 1985). Calculated moisture fluxes are directly affected by uncertainty in the estimated chloride accession rate. Estimated moisture fluxes for chloride profiles in eastern New Mexico ranged from 1 to 12 mm yr^{-1} (Stone, 1990) based on measured chloride concentrations in precipitation of 2.4 g m^{-3}; however, moisture fluxes for the same chloride profiles were four times less when a value of chloride concentration of precipitation from a nearby area of 0.6 g m^{-3} was used (Phillips and Stone, 1985).

Chloride profiles were measured in a variety of geomorphic settings in New Mexico and South Australia. Geomorphic settings that varied from sand hills to playas (depressions that are frequently ponded) were sampled in eastern New Mexico, and moisture fluxes ranged from 1 to 4 mm yr^{-1} in the sandy areas to 12 mm yr^{-1} in the playas (Stone, 1990). The moisture-flux estimate for the playas represents the lower limit of the actual moisture flux because runoff into the playa was not included in the calculations. Undisturbed calcrete, primary and secondary sinkholes, and vegetated and unvegetated sand dunes were sampled for chloride in South Australia (Allison et al., 1985). Calculated moisture fluxes in the undisturbed calcrete and primary sinkhole ranged from 0.07 to 0.17 mm yr^{-1}, and an increase in moisture flux in the past was attributed to paleoclimatic variations. Because runoff was not included in the chloride calculations for secondary sinkholes, the recharge estimate of 60 mm yr^{-1} represents the lower limit of moisture flux in this geomorphic setting. Higher moisture fluxes in the unvegetated dunes relative to the vegetated dunes signify the importance of transpiration in reducing the moisture flux in these systems (Table 1). These variations in moisture flux with geomorphic setting are much greater than those recorded between ephemeral stream and interstream settings in the Hueco Bolson, probably because differences in topography between these two geomorphic systems in the Hueco Bolson are small (0.6 m).

The subsurface hydrologic system may also affect the shape of the chloride profile and calculated moisture fluxes. The unsaturated zone in the northern Sahara is characterized by maximum chloride concentrations at the soil surface and an exponential decrease in concentration to the water table that is at a depth of 20 m (Fontes et al., 1986). The profiles are attributed to groundwater discharge, which is corroborated by stable isotope data. The lack of sensitivity of the chloride profiles to subsurface hydrology is demonstrated by two closely spaced (2 km apart) chloride profiles in New Mexico. The water table in the Pleistocene alluvium site near Socorro is 5 m deep, and measured water potentials are high (≥ -0.8 MPa) (Stephens and Knowlton, 1986). The water table is much deeper in the Holocene terrace (Table 1), and under steady-state flow equilibrium water potentials should be approximately 1 order of magnitude lower than those in the Pleistocene alluvium. Soil texture in both systems ranges from sandy loam to sand. Moisture fluxes based on chloride profiles are similar (1 to 3 mm yr^{-1}) and suggest that long-term moisture fluxes are insensitive to variations in water potential in the unsaturated zone or in water-table depth.

The effect of soil texture on calculated moisture fluxes was examined by comparing chloride profiles and moisture fluxes in Holocene terrace environments near Socorro and in another site near Las Cruces (Phillips et al., 1988). Water-table depth and geomorphic setting are similar in both areas (Table 1). Lower moisture fluxes calculated from chloride profiles near Las Cruces relative to those recorded in the Holocene terrace area were attributed to finer grained sediments near Las Cruces compared with those measured in the Holocene terrace (Table 1). Large porosities associated with finer grained sediments retain water for longer periods of time in the shallow zone where it is more readily evapotranspired.

The combined effects of grain size and climatic factors also affect transport mechanisms in the unsaturated zone. Soil texture in profiles from an area in Western Australia ranges from gravel in the shallow zone (1 to 5 m) to clay at a depth of 5 to 30 m (Peck et al., 1981; Johnston, 1987). Precipitation rates are high in this area (600 to 1,300 mm yr^{-1}) and result in high moisture contents of 0.4 m^3 m^{-3} in the clay section. The chloride profiles are bulge shaped and are characterized by steep concentration gradients. The combination of high moisture contents in the clay and steep chloride concentration gradients results in downward diffusive fluxes being dominant below the chloride peak and net upward advective fluxes of 0.05 to 0.5 mm yr^{-1} below the chloride peak in some profiles.

Implications for Waste Disposal

Data from chloride profiles have direct implications for evaluation of waste-disposal sites. One of the primary uncertainties associated with waste disposal is the prediction of long-term climatic variations and their effect on moisture flux. Chloride profiles in the Hueco Bolson represent up to 30,000 yr of moisture flux and probably span paleoclimatic variations. The range in moisture fluxes, represented by the chloride profiles, can be used to evaluate sensitivity of contaminant migration from proposed sites to variations in flux. Moisture fluxes in wetter regions may approximate the flux beneath leaking waste-disposal facilities in more arid systems. Flow along preferential pathways appears to be more prevalent in wetter climates (Sharma and Hughes, 1985; Johnston, 1987). If unsaturated flow bypasses the matrix, contaminant transport rates would be much greater than those estimated on the basis of piston flow.

Comparison of chloride profiles in several regions showed that calculated recharge rates are much more sensitive to geomorphic settings than to paleoclimatic variations. Because of the strong dependence of moisture flux on geomorphic setting it is important to characterize geomorphic variations within an area and to measure chloride profiles in each setting to adequately quantify recharge at a site. The variability in moisture fluxes gives some indication of the number of chloride profiles required to obtain an estimate of the areal moisture flux.

CONCLUSIONS

Chloride profiles were quite variable in the study area, and maximum concentrations ranged from 1,900 to 9,300 g m^{-3} m^{-1}. Although chloride-concentration gradients were steep (up to 12,000 g m^{-3} m^{-1}), diffusive moisture fluxes were negligible (10^{-3} to 10^{-5} mm yr^{-1}) because of the low observed moisture contents (≤ 0.1 m^3 m^{-3}) in the zone of steep concentration gradients. Advective moisture fluxes ranged from 10^{-1} to 10^{-2} mm yr^{-1} in most profiles and approximated the total moisture flux. Because the chloride flux (0.08 g m^{-2} yr^{-1}) was assumed to be constant throughout the area, the moisture flux was inversely related to the chloride concentration in the soil water. Reductions in chloride concentration with depth below the peak were attributed to higher moisture fluxes in the past, an inference that was generally consistent with paleoclimatic reconstructions of the area.

Comparisons among chloride profiles in different regions indicated that variations in geomorphic setting, climate, and soil texture are among the primary controls of moisture fluxes in the unsaturated zone. Information on the relative importance of different controls on unsaturated moisture flux can be used to evaluate various parameters in site characterization studies related to waste disposal. In addition, data on soil moisture flux variations provided by chloride profiles can be used in sensitivity analyses related to performance assessment of different sites.

ACKNOWLEDGMENTS

This project was funded by the Texas Low-Level Radioactive Waste Disposal Authority under interagency contract no. IAC (88-89)0932. The conclusions of the author are not necessarily approved or endorsed by the Authority. The assistance of B. C. Richter in sample collection is gratefully appreciated. Grain-size analyses were conducted by the Soils Laboratory at the University of Wisconsin. A. R. Dutton provided helpful review of the report. The manuscript was edited by T. F. Hentz and A. R. Masterson. Word processing was by Melissa Snell. Figures were drafted by J. Jobst under the direction of R. L. Dillon.

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WATER RESOURCES RESEARCH, VOL. 41, W06010, doi:10.1029/2004WR003841, 2005

Assessing controls on diffuse groundwater recharge using unsaturated flow modeling

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Received 23 November 2004; revised 16 February 2005; accepted 28 February 2005; published 16 June 2005.

[1] Understanding climate, vegetation, and soil controls on recharge is essential for estimating potential impacts of climate variability and land use/land cover change on recharge. Recharge controls were evaluated by simulating drainage in 5-m-thick profiles using a one-dimensional (1-D) unsaturated flow code (UNSAT-H), climate data, and vegetation and soil coverages from online sources. Soil hydraulic properties were estimated from STATSGO/SSURGO soils data using pedotransfer functions. Vegetation parameters were obtained from the literature. Long-term (1961–1990) simulations were conducted for 13 county-scale regions representing arid to humid climates and different vegetation and soil types, using data for Texas. Areally averaged recharge rates are most appropriate for water resources; therefore Geographic Information Systems were used to determine spatial weighting of recharge results from 1-D models for the combination of vegetation and soils in each region. Simulated 30-year mean annual recharge in bare sand is high (51–709 mm/yr) and represents 23–60% (arid–humid) of mean annual precipitation (MAP). Adding vegetation reduced recharge by factors of 2–30 (humid–arid), and soil textural variability reduced recharge by factors of 2–11 relative to recharge in bare sand. Vegetation and soil textural variability both resulted in a large range of recharge rates within each region; however, spatially weighted, long-term recharge rates were much less variable and were positively correlated with MAP ($r^2 = 0.85$ for vegetated sand; $r^2 = 0.62$ for variably textured soils). The most realistic simulations included vegetation and variably textured soils, which resulted in recharge rates from 0.2 to 118 mm/yr (0.1–10% of MAP). Mean annual precipitation explains 80% of the variation in recharge and can be used to map recharge.

Citation: Keese, K. E., B. R. Scanlon, and R. C. Reedy (2005), Assessing controls on diffuse groundwater recharge using unsaturated flow modeling, *Water Resour. Res.*, *41*, W06010, doi:10.1029/2004WR003841.

1. Introduction

[2] Understanding controls on the water cycle, such as climate, vegetation, and soils, is important in evaluating the potential impact of climate variability and land use/land cover (LU/LC) change on the water cycle. Land surface models are currently being used on regional scales to assess the relative importance of these influences on the water cycle [*Bonan*, 1997; *Pielke et al.*, 1998]. These models focus on evapotranspiration (ET) and feedback between the land surface and climate and have not been applied to estimating subsurface components of the water cycle. Recharge (addition of water to an aquifer) is a critical component of the water cycle for water resources and as a vector for nutrients and contaminants from the land surface to underlying aquifers. The need to control recharge at regional scales for environmental purposes, such as management of water resources and reduction in salinization, underscores the importance of understanding fundamental controls on recharge. Examples include removal of brush and riparian vegetation in semiarid regions of the southwestern United States to increase recharge and reforestation in areas of Australia to reduce recharge and associated salinity problems [*Allison et al.*, 1990; *Dugas et al.*, 1998; *Dawes et al.*, 2002; *Wilcox*, 2002].

[3] The basic controls on diffuse groundwater recharge include climate, vegetation, soils, and topography. Diffuse recharge refers to areally distributed recharge derived from precipitation or irrigation and should be distinguished from focused or concentrated recharge in topographic depressions, such as streams, lakes, and playas. Comparison of previous recharge estimates from various studies indicates that recharge is higher in humid versus arid regions; however, most studies focus on recharge in arid regions [*Lerner et al.*, 1990; *Robins*, 1998]. The presence of vegetation markedly reduces recharge in semiarid to arid basins [*Gee et al.*, 1994]. Vegetation type also significantly impacts recharge rates: recharge is higher in areas of annual crops and grasses than in areas of trees and shrubs [*Prych*, 1998]. Replacement of deep-rooted native eucalyptus trees with shallow-rooted crops in Australia increased recharge by about two orders of magnitude (≤0.1 mm/yr for native mallee vegetation to 5–30 mm/yr for crop/pasture rotations) [*Allison et al.*, 1990]. Field and modeling studies have shown that recharge is greater in coarser versus finer textured soils [*Cook and Kilty*, 1992; *Rockhold et al.*, 1995; *Kearns and Hendrickx*, 1998]. The influence of topography on recharge is variable. Catchment-scale modeling studies indi-

0043-1397/05/2004WR003841$09.00

cate that subsurface lateral flow was negligible in some catchments and flow could be treated as 1-D [*Dawes et al.*, 1997; *Hatton*, 1998; *Zhang et al.*, 1999].

[4] Previous studies have evaluated controls on groundwater recharge using field studies or numerical modeling. *Kennett-Smith et al.* [1994] related variations in recharge to precipitation and clay content using a simple water balance model and field recharge estimates. *Sophocleous* [1992] used multiple regression analysis to link variations in field-based recharge estimates primarily to variations in precipitation and also to variations in soil water storage, water table depth, and spring precipitation rate for a 3,400-km^2 area in Kansas. *Petheram et al.* [2002] evaluated impacts of land use on recharge by reviewing previous recharge studies in Australia and correlated recharge to precipitation in areas of annual vegetation and sandy soils ($r^2 = 0.6$). However, comparison of recharge rates among the different studies was difficult because of the wide variety of techniques used that represented a range of space and timescales.

[5] Physical, chemical, and modeling approaches can be used to estimate recharge on the basis of surface water, unsaturated zone, and groundwater data [*Scanlon et al.*, 2002b]. Numerical modeling is the only tool that can predict recharge, and it is also extremely useful in isolating the relative importance of different controls on recharge, provided that the model properly accounts for physical and biological processes. Various types of codes can be used to simulate recharge, such as land-atmosphere, watershed, unsaturated zone, and groundwater codes. Although land-atmosphere codes simulate all the processes required to estimate recharge, including Richards' equation for simulating unsaturated flow and a variety of approaches for simulating evapotranspiration (ET) [*Cotton et al.*, 2003; *Dai et al.*, 2003], these codes have generally not been used to simulate recharge. Watershed codes have been used to estimate groundwater recharge [*Hatton*, 1998; *Zhang et al.*, 1999]; however, the large number of parameters required makes it difficult to obtain a unique solution. Unsaturated zone codes range from simple bucket codes [*Hatton*, 1998; *Hevesi et al.*, 2002; *Lewis and Walker*, 2002] to those based on Richards' equation [*Braud et al.*, 1995; *Fayer et al.*, 1996], as well as some that include plant growth modules [*Dawes and Hatton*, 1993; *Zhang et al.*, 1996]. Simulation studies of recharge using unsaturated zone codes range from bare ground [*Scanlon and Milly*, 1994; *Scott et al.*, 2000] to vegetated systems [*Rockhold et al.*, 1995; *Kearns and Hendrickx*, 1998]. One-dimensional unsaturated zone modeling has been used with GIS coverages of vegetation and soils to determine areally distributed recharge [*Fayer et al.*, 1996]. Sensitivity analyses to assess controls on recharge using unsaturated zone codes were fairly simplistic, ranging from monolithic to simple two-layered soil profiles, with or without vegetation and different vegetation types (shrubs/grasses) [*Rockhold et al.*, 1995; *Kearns and Hendrickx*, 1998]. Groundwater model calibration or inversion can also be used to estimate recharge rates; however, model inversion using hydraulic head data is limited only to estimating the ratio of recharge to hydraulic conductivity [*Sanford*, 2002]. Such recharge estimates are generally not considered highly reliable because hydraulic conductivity can vary over several orders of magnitude. More reliable recharge estimation requires information on water fluxes or ages in addition to hydraulic head to calibrate the model [*Sanford*, 2002].

[6] Primary difficulties with modeling recharge are data requirements and model parameterization. The following online data sources have made recharge simulations much more feasible. Weather generators, such as GEM (Generation of weather Elements for Multiple applications), include databases of meteorological stations and can generate data for other regions [*Hanson et al.*, 1994; *Richardson*, 2000]. Geographic Information Systems (GIS) distributions of soils are provided by the State Soil Geographic (STATSGO) database (1:250,000 scale) and Soil Survey Geographic (SSURGO) database (1:24,000 scale). Pedotransfer functions are available to transfer soil texture information into water retention and hydraulic properties required for modeling [*Schaap et al.*, 2001]. Vegetation distribution and land use (National Land Cover Data) can be obtained from online sources [*McMahon et al.*, 1984; *Vogelmann et al.*, 2001]. Remote sensing also provides information on vegetation parameters at different resolutions (30 m; LandSat TM to 1.1 km; MODIS). Percent bare area can be estimated from fractional vegetation coverage using satellite data such as AVHRR or MODIS. Information on leaf area index is available from normalized difference vegetation index (NDVI) [*Myneni et al.*, 1997]. It is more difficult to obtain information on rooting depths; however, estimates can be obtained from the literature [e.g., *Canadell et al.*, 1996].

[7] The purpose of this study was to determine the relative importance of different controls on diffuse groundwater recharge using unsaturated, one-dimensional flow models of recharge for regions representing a range of climate (arid–humid), vegetation (shrubs, grasses, forests, crops), and soil (fine-coarse grained, monolithic and layered) conditions on the basis of data from Texas. This study focuses on long-term (30 year), areally averaged recharge rates that are appropriate for assessing water resources and evaluating aquifer vulnerability to nutrient loading. Unique aspects of the study are the (1) range of climate, vegetation, and soil conditions examined, (2) use of online and published data for input and parameterization of models, (3) combination of 1-D modeling and GIS coverages to develop areally averaged recharge estimates, (4) length of simulations (1961–1990), and (5) comparison with field-based estimates.

2. Materials and Methods

2.1. Study Area Description: Climate, Soils, and Vegetation

[8] The broad study area is the state of Texas (~700,000 km^2) (Figure 1). Thirteen study regions, representing a variety of climate, vegetation, and soil types were used in this study to simulate the water balance for a 30 year period (1961–1990). Simulated regions were also located to represent recharge areas of major porous media aquifers in the state (Figure 1 and Table 1). Each study region represents a one- or two-county area above an aquifer (1152–3042 km^2), with the exception of region 2 (entire outcrop of Cenozoic Pecos Alluvium Aquifer: 14,980 km^2). The topography of the regions is generally flat, with average slopes ≤0.5% in the High Plains and Gulf Coast regions and slightly higher slopes in the remaining regions (≤1.3%) (Table 1). Long-term (1961–1990) mean annual precipita-

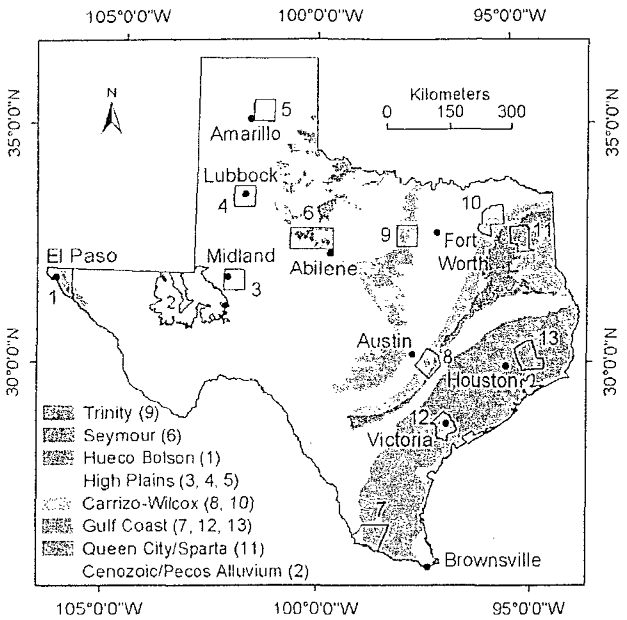

Figure 1. Modeled study regions (1–13), meteorological station locations (city name), and major porous media aquifer outcrop areas. Regions are numbered in order of increasing precipitation; refer to Table 1 for region names.

tion (MAP) ranges from 224 mm/yr in the west to 1,184 mm/yr in the east. Annual precipitation at individual meteorological stations ranged from 110 mm (region 1, El Paso, 1969) to 1783 mm (region 13, Houston, 1973). Summer precipitation (June–August) is dominant throughout much of the state, particularly in western (43%) and northern (33–48%) regions (Figure 2). Spring precipitation is dominant in central regions (29–33%), whereas fall precipitation is dominant in southeastern regions (28–39%). Precipitation is fairly uniformly distributed in the more humid regions in the east. Winter precipitation (December–February) is generally low throughout most of the state (8–16%), with the exception of the humid east (21%). The coefficient of variation (CV) in annual precipitation is greatest in semiarid regions in the west (0.35) and less throughout the rest of the area (CV: 0.21–0.24) (Figure 3 and Table 2). Vegetation ranges from predominantly shrubs and grasses in the west, shrub/forest to forest/shrub in the central area, and forest and forest/shrub in the east (Figure 4). Cropland areas dominate much of the northern and southeastern regions. Variations in clay content in the upper 1.5 to 2 m soil profile depths based on STATSGO data generally follow the distribution of underlying geologic units, e.g., high clay content in the central region of the Southern High Plains (region 5), corresponding to the underlying Blackwater Draw Formation, and high clay content in the northern and central parts of the Gulf Coast (regions 12 and 13), corresponding to the underlying Beaumont Formation (Figure 5).

2.2. Model Description

[9] Unsaturated flow modeling was used to simulate drainage below the root zone, which is equated to groundwater recharge and assumes that climate and land use/land cover remain constant over timescales required for water to move from the root zone to the water table. The UNSAT-H code (version 3.0 [*Fayer*, 2000]) was chosen because previous code comparison studies showed that water balance simulations based on UNSAT-H compare favorably with field data [*Scanlon et al.*, 2002a]. UNSAT-H is a 1-D, finite difference code that simulates nonisothermal liquid flow and vapor diffusion in response to meteorological forcing. The simulations focus on the water balance:

$$D = P - ET - R_0 - \Delta S \qquad (1)$$

where D is deep drainage below the root zone, P is precipitation, ET is evapotranspiration, R_0 is surface runoff, and ΔS is change in water storage. UNSAT-H simulates subsurface water flow using Richards' equation:

$$\begin{aligned}\frac{\partial\theta}{\partial t} &= -\frac{\partial q}{\partial z} = \frac{\partial}{\partial z}\left(K(\theta)\frac{\partial H}{\partial z}\right) - S(z,t)\\ &= \frac{\partial}{\partial z}\left(K(\theta)\frac{\partial h}{\partial z} - K(\theta)\right) - S(z,t) \qquad (2)\end{aligned}$$

where θ is volumetric water content, q is water flux, K is hydraulic conductivity, H is hydraulic head, h is matric potential head, and S is a sink term used to describe the removal of water by plants. UNSAT-H includes multiple analytical functions for water retention and unsaturated hydraulic conductivity.

Table 1. General Characteristics of Modeled Regions[a]

Region Number	Region	MAP, mm/yr	PET, mm/yr	P/PET	HZ	Region Area, km^2	Topographic Slope Mean, %	Slope SD, %	Mean Sand, %	Mean Silt, %	Mean Clay, %
1	El Paso	224	2087	0.11	A	2079	0.73	1.36	69	20	11
2	CPA	380	2169	0.18	A	14980	0.38	0.42	60	21	19
3	Midland	380	2169	0.18	A	1388	0.25	0.27	56	20	24
4	Lubbock	474	2034	0.23	SA	2313	0.46	0.72	43	26	31
5	Carson	497	2096	0.24	SA	2363	0.54	0.88	29	35	35
6	Fisher/Jones	620	2132	0.29	SA	1577	0.45	0.42	52	21	26
7	Starr	671	1788	0.38	SA	2474	0.55	0.61	64	13	24
8	Bastrop	810	1732	0.47	SA	1197	1.01	1.04	49	21	30
9	Parker	855	1819	0.47	SA	1464	1.31	1.17	48	23	28
10	Hopkins/Rains	855	1819	0.47	SA	1152	0.52	0.49	41	28	31
11	Upshur/Gregg	855	1819	0.47	SA	1972	1.05	1.20	51	23	26
12	Victoria	933	1651	0.57	SH	2303	0.22	0.31	41	23	36
13	Liberty	1184	1362	0.87	H	3042	0.17	0.31	27	33	40

[a] CPA, Cenozoic Pecos Alluvium aquifer; MAP, 30 year mean annual precipitation; PET, 30 year mean annual potential evapotranspiration; HZ, humidity zone [*United Nations Environment Programme*, 1992]. A, arid; SA, semiarid; SH, subhumid; H, humid.

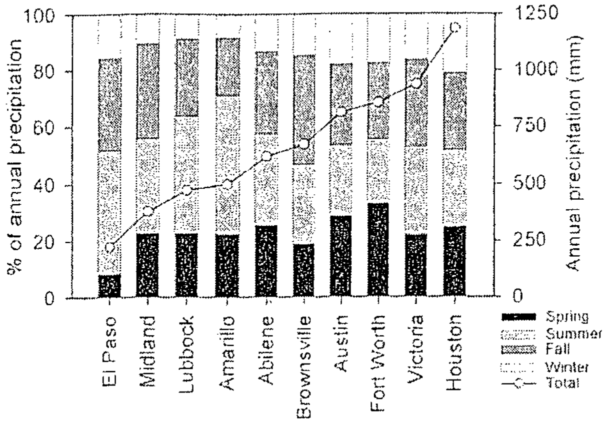

Figure 2. Mean (30 year) annual precipitation and seasonal distribution of mean annual precipitation for the 10 meteorological stations used in the simulations: spring (March–May), summer (June–August), fall (September–November), and winter (December–February).

[10] The upper atmospheric boundary condition is simulated as a system-dependent boundary condition that changes from a prescribed head to a prescribed flux, depending on climate and subsurface conditions. If the applied flux (precipitation or evapotranspiration) is $\leq$ the potential flux and the matric potential head at the surface is between 0 and a prespecified dry value (h_{dry}), then the potential flux, which is controlled by external conditions, applies. Runoff is simulated implicitly by UNSAT-H. If the precipitation rate exceeds the infiltration capacity of the soil, excess water runs off (infiltration excess or Hortonian runoff). If the matric potential head at the surface reaches 0, the soil becomes saturated, a constant head boundary condition applies ($h = 0$), and excess water runs off (saturation excess or Dunne runoff). If the soil surface becomes too dry ($h \leq h_{dry}$), a constant head boundary condition applies ($h = h_{dry}$) and evaporation or evapotranspiration is controlled by the rate at which water can be transmitted to the surface. Ponding is not simulated with this code. Plant water uptake is simulated according to the approach proposed by *Feddes et al.* [1978] that partitions PET into potential evaporation (PE) and potential transpiration (PT) using an empirical equation developed by *Ritchie and Burnett* [1971], which distributes PT over the root zone on the basis of depth variations in root density and reduces this PT to actual transpiration on the basis of matric potential head [*Fayer*, 2000].

2.3. Model Application

[11] The water balance for a 30 year period (1961–1990) was simulated for 13 study regions. Input data requirements for the model include meteorologic forcing, vegetation parameters, hydraulic parameters for different soil types, and initial conditions. To assess the relative importance of different controls on groundwater recharge, four different scenarios were used: (1) nonvegetated, monolithic sand, (2) nonvegetated, texturally variable soil, (3) vegetated, monolithic sand, and (4) vegetated, texturally variable soil. The simplest simulations of nonvegetated, monolithic sand were used to provide an upper bound on recharge rates. Complex, texturally variable soil profiles were simulated without vegetation to evaluate the impact of soil textural variability on recharge. Vegetation was added to the monolithic and texturally variable soil profiles to determine its impact on simulated recharge. The most realistic scenario is represented by vegetated, texturally variable soils.

[12] A soil-profile depth of 5 m was chosen for the simulations because it is deeper than root zone depths of the vegetation used. In addition, soil textural information is available only for the upper 2 m from STATSGO and SSURGO, and texture in the 2 to 5 m zone was assumed equal to that of the lowest data available. Sensitivity of simulated recharge to profile depth was evaluated. In monolithic profiles, nodal spacing ranged from 2 mm at the top and base of the profile and increased by a factor of ~1.2 with depth to a maximum value of 230 mm within the profile. In layered soil profiles, nodal spacing was also reduced near textural interfaces to a value of ~20 mm. Initial conditions were set arbitrarily at a matric potential head of −3 m for higher precipitation regions (6–13) and −10 m for all other regions. The impact of initial conditions on simulation results was evaluated by reinitializing simulations multiple times with the final conditions of each run; however, rerunning simulations once was found to be sufficient for minimizing the impact of initial conditions.

[13] Meteorological data for 10 stations were obtained from the database in the GEM code [*Hanson et al.*, 1994]. Some station data were used to simulate recharge in more than one region (Midland station, regions 2 and 3; Fort Worth station, regions 9–11). The 1961–1990 period was chosen because of availability of solar radiation for potential evapotranspiration calculations from the National Solar Radiation Data Base (National Renewable Energy Laboratory, Golden, Colorado; 1992). Meteorologic input to the model included daily precipitation, daily average dew point temperature, wind speed and cloud cover, total daily solar radiation, and minimum and maximum daily temperatures. Daily precipitation was applied at a prespecified default intensity of 10 mm/hr, and ET is not simulated during this time. Previous code comparisons showed that the approach used in codes to simulate precipitation and evapotranspiration when daily precipitation is used as input can have a large impact on simulated recharge and that the UNSAT-H approach adequately simulates measured data [*Scanlon et*

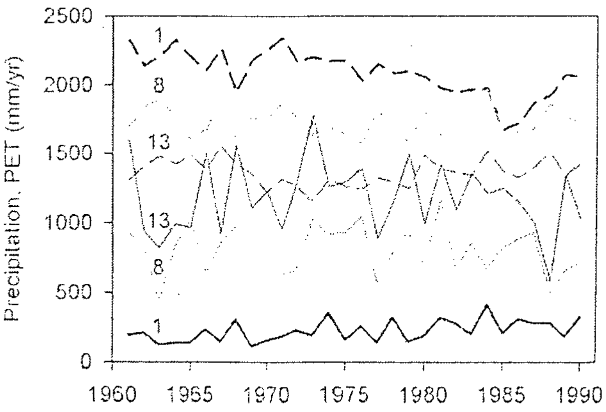

Figure 3. Total annual precipitation (solid lines) and PET (dashed lines) for stations that represent a range of precipitation and PET (1, El Paso; 8, Austin; 13, Houston).

Table 2. Simulation Results for the Four Basic Scenarios[a]

	MAP		Nonvegetated Sand					Nonvegetated Texturally Variable Soils					Vegetated Sand			Vegetated Texturally Variable Soils				
			Recharge					Recharge					Recharge			Recharge				
Region	Total	CV	Total	CV	R/P	AE	PET/AE	Total	R/P	AE	R_O	ΔS	Total	R/P	AET	Total	R/P	AET	R_O	ΔS
1	224	0.35	51	0.22	23	173	12.1	19	9	205	0	0.0	2	1	222	0.2	0.1	224	0	−0.7
2	380	0.35	137	0.20	36	243	8.9	80	21	286	14	0.0	34	9	346	11.1	2.9	356	14	−0.7
3	380	0.35	137	0.20	36	243	8.9	56	15	316	7	−0.1	11	3	369	1.5	0.4	375	4	−0.6
4	474	0.23	180	0.24	38	294	6.9	19	4	366	90	−0.4	33	7	441	0.8	0.2	390	85	−0.9
5	497	0.21	174	0.16	35	323	6.5	16	3	286	195	−1.0	29	6	468	0.4	0.1	312	186	−1.4
6	620	0.23	269	0.19	43	351	6.1	88	14	364	168	−0.4	80	13	540	5.6	0.9	435	180	−0.8
7	671	0.24	338	0.19	50	334	5.4	191	29	454	25	0.0	115	17	556	33.8	5.0	610	27	−0.1
8	810	0.21	406	0.20	50	403	4.3	98	12	586	125	0.0	95	12	715	10.1	1.3	619	181	−0.8
9	855	0.22	432	0.18	51	423	4.3	193	23	587	74	0.0	106	12	749	29.0	3.4	727	99	−0.4
10	855	0.22	432	0.18	51	423	4.3	146	17	663	46	0.0	83	10	772	4.7	0.6	792	59	−0.4
11	855	0.22	432	0.18	51	423	4.3	193	23	639	24	0.0	111	13	744	35.1	4.1	795	25	−0.2
12	933	0.23	507	0.22	54	427	3.9	91	10	423	419	−0.2	285	31	648	25.7	2.8	520	388	−0.3
13	1184	0.22	709	0.18	60	475	2.9	230	19	619	335	−0.2	369	31	815	117.7	9.9	748	319	−0.2

[a] Runoff and change in storage is 0 for nonvegetated and vegetated monolithic sand profiles. All ratios are expressed as percent. Units are mm/yr. MAP, measured 30 year mean annual precipitation; CV, coefficient of variation; R, simulated 30 year mean annual recharge; R/P, recharge to precipitation ratio; AE, actual evaporation; AET, actual evapotranspiration; ΔS, change in water storage; R_O, runoff.

al., 2002a]. A modified Penman-Monteith equation was used to calculate PET [*Doorenbos and Pruitt*, 1977]. Parameter h_{dry} was set to −100 m. A unit gradient lower boundary condition was used that corresponds to free drainage or gravitational flow and is most appropriate for simulating unimpeded recharge.

[14] Distribution of vegetation types for each of the modeled regions was obtained from a GIS coverage of vegetation in Texas [*McMahon et al.*, 1984] (Figures 4 and 6). Crop vegetation types were derived from the percentage of area harvested over the simulation period (USDA National Agricultural Statistics Service). Vegetation parameters required for UNSAT-H include percent bare area, planting and harvesting dates for crops, time series of leaf area index (LAI) and rooting depth (RD), and root length density (RLD). These parameters were obtained mostly from the literature (see auxiliary material).[1] Additional information was obtained from discussions with ecologists and crop specialists. Time series for LAI and root growth were specified on particular days of the year and linearly interpolated. Root growth was simulated for crops only; other plant types were perennial. The RLD function is based on the assumption that normalized total root biomass is related directly to RLD (ρ_{rL}) and can be related to depth below the surface (z) by

$$\rho_{rL} = a\exp(-bz) + c \tag{3}$$

where a, b, and c are coefficients that optimize fit to normalized biomass data. Some vegetation classes contain more than one vegetation type. For example, forests are classified as 75% trees and 25% grasses. Recharge estimates for these regions were obtained by simulating different vegetation types separately and areally weighting results. The 1-D modeling approach used in this study does not account for effects of neighboring plant root systems and may overestimate recharge in areas where deeper rooted vegetation extends into areas with shallower rooted vegetation. Recharge would be overestimated most in areas where the difference in rooting depths is greatest. However, this error is considered relatively minor considering that information on the distribution of different vegetation types is only approximate. Dominant vegetation types that represented ~70–80% of the area of each region were simulated.

[15] Soil profiles for the simulations ranged from monolithic sand to texturally variable profiles. Hydraulic properties for the sand were obtained from the UNSODA database (UNSODA 4650: K_s: 5.87 m/day; θ_s: 0.38; θ_r: 0; α: 5.03 1/m; n: 1.7736 [*Leij et al.*, 1996]). SSURGO version 2 data [*U.S. Department of Agriculture* (*USDA*), 1994] were used to provide information for texturally variable soil profiles for all regions but were unavailable for region 2, where STATSGO data [*USDA*, 1995] were used for the entire (multicounty) outcrop area of the aquifer. Pedotransfer functions were used to determine soil hydraulic properties. Rosetta software uses neural network programming and a database of measured texture, water retention, and saturated hydraulic conductivity to provide estimates of van

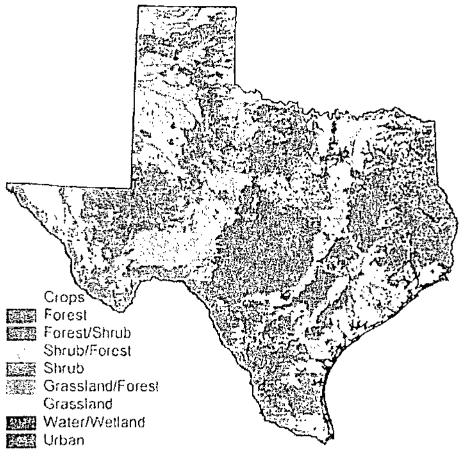

Figure 4. Dominant vegetation associations in Texas [*McMahon et al.*, 1984].

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[1] Auxiliary material is available at ftp://ftp.agu.org/apend/wr/2004WR003841.

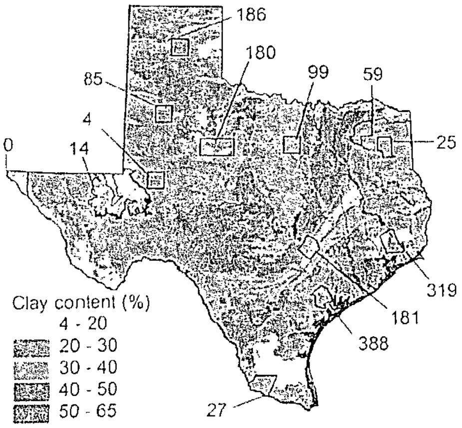

Figure 5. Average soil profile clay content derived from STATSGO database. Water-covered areas are shown in blue. Simulated runoff using vegetated, texturally variable soils are shown for each region.

Genuchten water retention parameters and saturated hydraulic conductivity for input to unsaturated flow models [*Schaap et al.*, 2001]. Only texture and bulk density information was available from the STATSGO database for input to Rosetta. Soil layer texture, bulk density, and volumetric water content at −3 and −150 m head were available from the SSURGO version 2 database for input to Rosetta. Simulations were run for soil profiles that represented ~80% of the area of each simulated region, which corresponded to 6–29 profiles for different regions. Examination of recharge results for all profiles for a region showed that recharge rates could be categorized into distinct groups, resulting in a more manageable 3–7 representative profiles for each region.

[16] Simulated recharge results are represented by a single temporal (30 year) and spatial average recharge value for each region, using GIS coverages to determine the area represented by each vegetation type, soil type, or combination of vegetation and soil types to spatially weight 1-D results. A total of 460 simulations were conducted for the final analysis. For monolithic profile simulations, models were developed for each of the 10 meteorological stations, resulting in 10 representative recharge values. For vegetated and texturally variable soil profile simulations, 13 recharge values representative of each of the study regions were determined. Recharge rates for each region (30 year, spatially weighted average) were plotted versus long-term (30 year) MAP, and equations were fit to the results for each of the four modeling scenarios (i.e., nonvegetated monolithic and texturally variable soil profiles and vegetated monolithic and texturally variable soil profiles). Power law equations were used because they resulted in higher correlation coefficients and lower residual standard deviations than linear or log linear equations. Finally, the power law equation representing the vegetated, texturally variable soils scenario was used to generate a continuous statewide recharge rate map based on the distribution of MAP. Although shown for the entire state, results should be applied only to outcrop areas of the porous media aquifers shown.

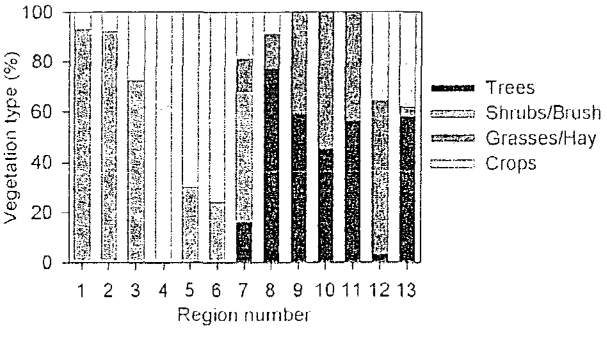

Figure 6. Percentages of vegetation types found in each region.

[17] Sensitivity of recharge to climate, vegetation, and soils was evaluated in the four different scenarios considered, isolating the impact of each of these parameters. Additional sensitivity analyses were conducted to evaluate variations in vegetation parameters, initial conditions, PET, and depth of soil profile. Vegetation parameters evaluated included percent bare area, leaf area index, root depth, and root length density. Each parameter was increased and decreased by 50 percent, with the exception of percent bare area, which is 0 for the base case and was increased to 25 and 50%, and profile depth, which was increased from 5 to 10 m in the sensitivity analysis. Sensitivity analyses were conducted using data from region 6.

3. Results and Discussion

[18] Simulation results are represented for the four basic scenarios to assess relative importance of climate, vegetation, and soils in controlling recharge. Final mass balance errors were <5% of final recharge rates and <0.5 mm/yr.

3.1. Nonvegetated, Monolithic Sand Simulations

[19] Simulated mean (30 year) annual recharge for bare sand is high and ranges from 51 mm/yr in the arid west to 709 mm/yr in the more humid east, representing 23 (arid) to

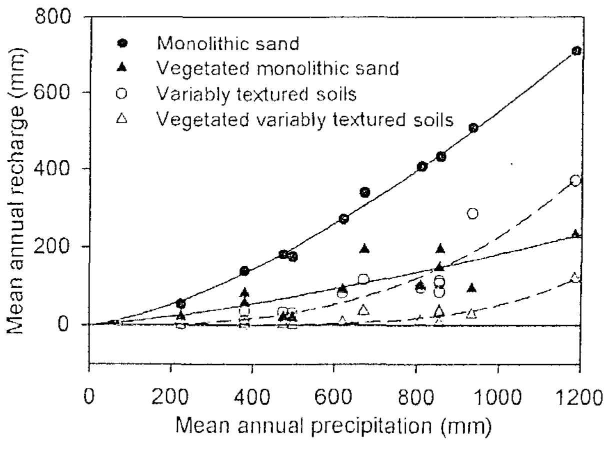

Figure 7. Relationships between long-term (30 year) MAP and simulated mean annual areally weighted recharge. Power law equations were fit to the results for monolithic sand profiles (solid lines) and variably textured soil profiles (dashed lines).

Table 3. *Power Law Equation Coefficients and Residual Statistics for Estimating Long-Term (30 Year) Mean Annual Recharge From Precipitation*[a]

	Coefficients			*Residual*	
Modeling Scenario	a	b	r^2	σ	$\lvert v_r \rvert$
Nonvegetated, monolithic sand	1.956×10^{-02}	1.484	0.996	8.5	8.5
Vegetated, monolithic sand	6.131×10^{-07}	2.855	0.854	28.6	28.4
Nonvegetated, layered soil profiles	1.661×10^{-02}	1.345	0.624	28.2	34.3
Vegetated, layered soil profiles	3.242×10^{-09}	3.407	0.805	9.2	10.2

[a] Recharge rates estimated from the power law equation for vegetated, texturally variable soils are shown in Figure 10. The power law model is $y = ax^b$, where y is mean annual recharge (mm/yr) and x is precipitation (mm/yr). Here r^2, coefficient of determination; σ, standard deviation; $\lvert v_r \rvert$, average absolute deviation.

60% (humid) of MAP (Table 2). Variations in mean annual recharge can be explained entirely by variations in MAP, using the power law relationship. Recharge increases with precipitation (r^2 = 1.0: Figure 7 and Tables 2 and 3). These recharge estimates provide an upper bound on actual recharge rates because vegetation and soil textural variability were not included. In addition, simulated runoff from the 1-D model is zero, whereas runoff estimates based on a statewide water balance range from 0 mm/yr in the west to 415 mm/yr in the east [*Reed et al.*, 1997]. Lack of simulated runoff was attributed to the high saturated hydraulic conductivity of the sand (0.24 m/hr) relative to the prespecified precipitation intensity (0.01 m/hr).

[20] Temporal variability in mean annual recharge is similar throughout the state (CV: 0.16–0.24) and is less than that of precipitation (Table 2). Lower correlations between mean annual recharge and summer precipitation (r^2 = 0.66) relative to precipitation during the other seasons (r^2 = 0.83–0.96 for spring, fall, and winter) were attributed to higher evaporation during summer (Figures 2 and 8). Potential ET is much greater than simulated actual E; the PET/AE ratio decreased from 12.1 in the west (region 1) to 2.9 in the east (region 13) (Table 2). In arid regions most infiltrated water is returned to the atmosphere through evaporation, as shown by the tracking of precipitation and evaporation in region 1 (Figure 9). The high correlation (r^2 = 0.83) between evaporation and precipitation in this region may be attributed to evaporation rarely being energy limited (high PET). Annual recharge is not directly correlated with annual precipitation (r^2 = 0.03) because there is a lag between elevated precipitation and recharge. In contrast, in more humid settings evaporation and precipitation are not as highly correlated (r^2 = 0.66, region 13), which may be related to energy limitations on ET (lower PET). There is little lag between high precipitation and recharge, as shown by the strong correlation between annual precipitation and recharge (r^2 = 0.90, region 13).

3.2. Nonvegetated, Texturally Variable Soil Simulations

[21] Simulated mean (30 year) annual, areally averaged recharge ranges from 16 mm/yr in the north to 230 mm/yr in the southeast for texturally variable soil profiles, representing 3 to 29% of MAP (Figure 7 and Table 2). These recharge rates are 2 to 11 times lower than those based on monolithic sand profiles, indicating the importance of soil textural variability in controlling recharge. The lower recharge rates may reflect finer textured soils, or they may be related to reductions in recharge caused by profile layering, both fine over coarse (capillary barrier effect) and coarse over fine layering. Reductions in recharge in the texturally variable soil simulations correspond to increased runoff, evaporation, or both. Approximately 60% of the variation in recharge can be explained by variations in precipitation using the power law relationship (r^2 = 0.62, Table 3). Multiple linear regression using log-log data shows that including clay content (profile average) with precipitation explains 80% of the variation in recharge. Recharge varies over 1 to 2 orders of magnitude locally, within each region, because of textural variability among soil profiles.

[22] Variations in simulated mean (30 year) annual runoff generally reflect differences in climate and texture among

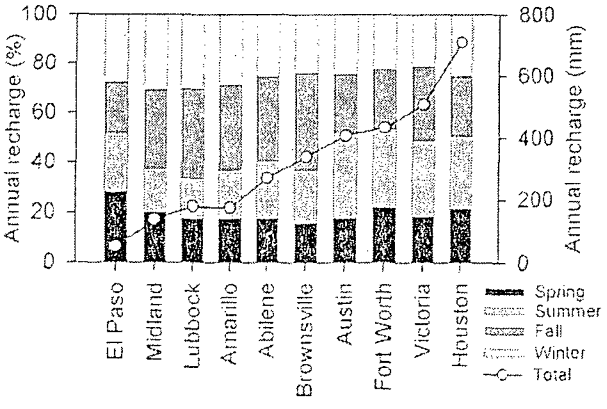

Figure 8. Seasonal distribution of simulated recharge for *monolithic sand at each of the meteorological station locations.*

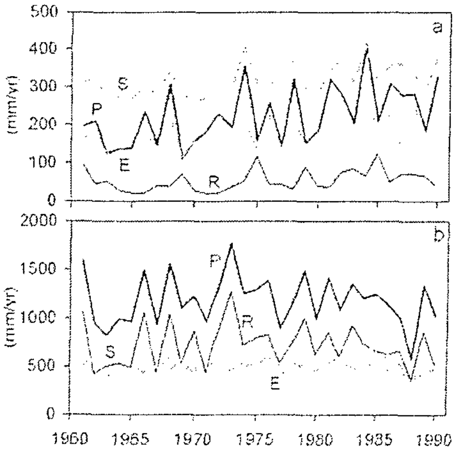

Figure 9. Mean annual water budget parameters for nonvegetated, monolithic sand simulations at (a) region 1 and (b) region 13. P, precipitation; E, evaporation; R, recharge; S, storage.

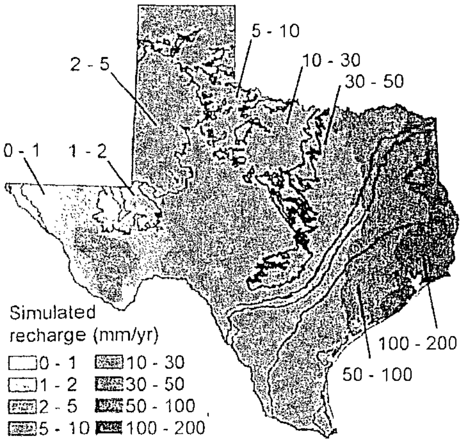

Figure 10. Predicted recharge using the relationship between precipitation and simulated recharge for vegetated, texturally variable soils.

regions. Simulated runoff is positively correlated with mean clay content ($r^2 = 0.57$) and negatively correlated with mean sand content ($r^2 = -0.49$). Sandy areas, particularly regions 1, 2, 3, and 7, have low runoff and generally correspond to areas of low or moderate precipitation. Most regions with clay-rich soils have higher runoff and generally overlie fine-grained geologic units. Simulated recharge rates in clay-rich soils may not accurately reflect actual recharge rates if preferential flow occurs in these settings because this process is not included in the simulations.

3.3. Vegetated, Monolithic Sand Simulations

[23] To assess the impact of vegetation without the influence of soil textural variability, simulations of recharge were conducted in vegetated, monolithic sands (Table 2). Vegetation markedly reduces simulated mean annual recharge (2–369 mm/yr; 1–31% of MAP) by factors of 2 to 30 relative to recharge for nonvegetated simulations. MAP explains 85% of the variance in simulated recharge using the power law relationship (Table 3 and Figure 7). Simulated runoff was 0 for nonvegetated and vegetated simulations. Vegetation type also affects simulated recharge, as seen in the 1 to 2 orders of magnitude range in simulated recharge for different vegetation types within a study region. In general, lower recharge rates in areas with trees relative to grasses can be attributed to greater rooting depth of trees (≤4.3 m) relative to grasses (1 m). Shrubs are generally more effective than crops in reducing recharge because of greater rooting depth and longer growing season. Crops also differ in their recharge rates: e.g., factor of 4 lower recharge beneath cotton (maximum rooting depth 2.1 m) relative to sorghum (maximum rooting depth 1.5 m), in region 4.

3.4. Vegetated, Texturally Variable Soil Simulations

[24] Texturally variable soils with vegetation are the most realistic representation of actual conditions and should provide the most reliable recharge estimates for the different regions. Simulated mean (30 year) annual, areally averaged recharge is lowest in the arid west (0.2 mm/yr) and highest in the humid east (118 mm/yr), representing 0.1 to 10% of MAP (Figure 7 and Table 2). Variability of MAP explains 80% of the variability in recharge among regions using the power law relationship ($r^2 = 0.81$, Table 3). The correlation between recharge and precipitation was used to map recharge throughout the entire study area (Figure 10).

[25] Vegetation markedly reduced recharge relative to that for nonvegetated, texturally variable soils. Reduction factors were greater in more arid regions in the west (7–78) relative to more humid regions in the east (2–31) and reflect the enhanced ability of vegetation to reduce recharge in more water-limited regions (Table 2). Local variability in simulated recharge within regions was generally within an order of magnitude and reflects variability due to differences in vegetation and soil texture.

[26] Simulated mean (30 year) annual runoff and runoff estimates based on measured stream gauge data (1961–1990) used to develop a statewide water balance [*Reed et al.*, 1997] are generally consistent in many regions considering that the 1-D modeling approach does not account for subsurface lateral flow and routing (Table 4). Discrepancies between the two estimates in other regions cannot readily be explained, with the exception of regions 4 and 5 in the Southern High Plains, where overestimation of runoff may be attributed to predominantly internal drainage to ephemeral lakes or playas and little runoff to gauged stream networks. Runoff is one of the most difficult parameters to simulate because it depends on accurate representation of rainfall intensity and hydraulic conductivity of surficial sediments that may be crusted, as shown by detailed comparisons of simulated and measured runoff at a controlled field experiment [*Scanlon et al.*, 2002a].

[27] Relative controls of different vegetation types in vegetated, texturally variable soil simulations are similar to those for vegetated monolithic sands: lower recharge in deep-rooted trees relative to shallow-rooted grasses, shrubs relative to crops, and cotton relative to sorghum. For example, in region 9, simulated recharge beneath trees is 0, whereas simulated recharge beneath grasses ranges from 1 to 156 mm/yr for different soils. Relative amounts of evaporation and transpiration vary with vegetation type and soil texture. Transpiration is much greater than evaporation for trees, irrespective of texture. Evaporation is higher than transpiration in finer textured soils than in coarser textured soils, irrespective of vegetation type, which is attributed to

Table 4. Comparison of Simulated Runoff (RO_{sim}) With Spatially Averaged Runoff Estimates (RO_{est}) Determined From *Reed et al.* 1997 for Each Region[a]

Region	RO_{sim}	RO_{est}	RO_{est} SD
1	0	4	5
2	14	0	4
3	4	0	1
4	85	6	1
5	186	3	8
6	179	15	4
7	27	3	7
8	180	118	37
9	99	55	41
10	59	268	53
11	25	232	22
12	387	148	26
13	314	328	22

[a] Units are in mm/yr. SD, standard deviation.

Table 5. Sensitivity of Recharge to Variations in Leaf Area Index (LAI), Root Depth (RD), Bare Area (% BA), Initial Conditions (IC), Potential Evapotranspiration (PET), and Profile Depth (PD) for Four Soil Profiles in Region 6[a]

		Effect	
	BC R	R	F
LAI variable			
50% LAI	0.7	1.3	1.8
50% LAI	3.2	7.2	2.2
50% LAI	15.6	27.6	1.8
50% LAI	23.5	38.0	1.6
150% LAI	0.7	0.6	0.8
150% LAI	3.2	2.4	0.7
150% LAI	15.6	12.1	0.8
150% LAI	23.5	18.8	0.8
RD constant			
50% RD	0.7	3.7	5.1
50% RD	3.2	14.8	4.6
50% RD	15.6	27.7	1.8
50% RD	23.5	43.2	1.8
150% RD	0.7	0.1	0.2
150% RD	3.2	0.7	0.2
150% RD	15.6	6.2	0.4
150% RD	23.5	11.5	0.5
Percent BA constant			
25% BA	0.7	1.2	1.6
25% BA	3.2	6.1	1.9
25% BA	15.6	25.0	1.6
25% BA	23.5	35.1	1.5
50% BA	0.7	5.9	8.1
50% BA	3.2	21.7	6.7
50% BA	15.6	47.3	3.0
50% BA	23.5	59.3	2.5
PET variable			
50% PET	0.7	27.9	38.2
50% PET	3.2	47.4	14.6
50% PET	15.6	77.6	5.0
50% PET	23.5	88.4	3.8
150% PET	0.7	0.3	0.4
150% PET	3.2	0.3	0.1
150% PET	15.6	4.5	0.3
150% PET	23.5	7.9	0.3
PD constant			
10 m PD	0.7	0.9	1.2
10 m PD	3.2	3.3	1.0
10 m PD	15.6	13.5	0.9
10 m PD	23.5	22.0	0.9

[a] In order of fine–coarse grained soil profiles. Factor (F) refers to the ratio of 30 year mean annual recharge (R), including the effect (e.g., LAI × 50%) to the base case (BCR) recharge rate. Variable/constant indicates that a parameter changes or is held constant with time during the simulated period. Units are in mm/yr.

finer textured soils retaining more water near the soil surface longer, allowing greater evaporation.

3.5. Sensitivity Analyses

[28] Sensitivity analyses were conducted for region 6 because it represents average climate and soil conditions in the study area. Sensitivity of simulated recharge to different vegetation parameters is variable (Table 5). Increasing percent bare area from 0 to 50% increases recharge up to a factor of 8. Simulated recharge is inversely related to root depth because decreasing root depth allows water to drain more readily below the root zone. Decreasing root depth increases recharge by factors of 2 to 5, whereas increasing root depth decreases recharge by factors of 0.2 to 0.5. Simulated recharge is more sensitive to decreasing LAI than increasing LAI. Decreasing LAI by 50% almost doubles recharge, while increasing LAI by 50% decreases recharge by 20%. Models were insensitive to variations in root-length density. Decreasing PET increases recharge by factors ranging from 4 in coarse-grained soils to 38 in fine-grained soils and was balanced by a reduction in ET, whereas increasing PET had the opposite effect.

[29] It is important to assess sensitivity of model output to variations in initial conditions, profile depth, and equilibration times to assess reliability of simulated recharge. The model is insensitive to variations in initial conditions. Increasing profile depth from 5 to 10 m decreases recharge in coarse-grained soils by a factor of 0.9 and increases recharge by a factor of 1.2 in fine-grained soil, which may be an artifact of drainage of initial water in the profile. Model equilibration times are greater for more arid settings and more clay-rich soils. Therefore final recharge estimates in these settings may represent an upper bound on actual recharge rates.

3.6. Comparison of Simulated Recharge Estimates With Those Based on Other Techniques

[30] Simulated recharge rates from this study were compared with those based on earlier studies (Table 6). Previous field and modeling investigations in the Chihuahuan Desert in west Texas indicate that there is no recharge in interdrainage settings [*Scanlon et al.*, 1999], which is generally consistent with the low (0.2 mm/yr) simulated recharge in this study (Table 2). Bulge-shaped chloride profiles and upward matric potential gradients indicate that this system has been drying out for the last 10,000 to 15,000 years since the Pleistocene [*Scanlon et al.*, 2003a].

Table 6. Comparison of Simulated Recharge Estimates (R_{sim}) With Recharge Estimated Using Other Techniques (R_{est})[a]

Region	R_{sim}, mm/yr	R_{est}, mm/yr	Method	Source[b]
1	0.2	0	WP; UZ CMB	1
4, 5	0.4–0.8	11	GW CMB	2
3, 4	0.8–1.5	4–28	UZ CMB	3
6	5.6	5–30	UZ CMB	3
8	10.1	5–20	UZ/GW CMB	4
11	35.1	43–71	GW CMB	5

[a] Estimation methods include: WP, water potential; UZ CMB, unsaturated zone chloride mass balance approach; GW CMB, groundwater chloride mass balance approach.

[b] Sources are as follows: 1, *Scanlon et al.* [1999]; 2, *Wood and Sanford* [1995]; 3, *Scanlon et al.* [2003b]; 4, *Dutton et al.* [2003]; 5, R. C. Reedy (Bureau of Economic Geology, University of Texas at Austin, unpublished data, 2002).

[31] In the Southern High Plains, it is difficult to compare simulated recharge rates from this study, which represent diffuse recharge in interdrainage settings, with previous recharge estimates from groundwater data because most recharge in this region is focused beneath playas. Therefore simulated recharge at regions in the Southern High Plains (4 and 5) (0.4–0.8 mm/yr) is less than recharge estimates based on the chloride mass balance (CMB) approach applied to groundwater (11 mm/yr [*Wood and Sanford*, 1995]), as expected. Field studies indicate that there is no recharge in natural ecosystems in interplaya settings, as shown by chloride bulges and upward matric potential gradients [*Wood and Sanford*, 1995; *Scanlon and*

Goldsmith, 1997; *Dennehy et al.*, 2005]. Recharge estimates based on chloride profiles from nonirrigated cultivated settings in the south part of the Southern High Plains range from 4 to 28 mm/yr [*Scanlon et al.*, 2003b]. Simulated recharge rates at regions 3 and 4 (1.5 and 0.8 mm/yr) fall within the range of values for natural and cultivated regions and may underestimate actual recharge because the effect of cultivation on hydraulic properties of surficial sediments was not included in the simulations.

[32] Simulated recharge in region 6 (5.6 mm/yr) is within the lower range of field-based estimates, using the CMB approach applied to the unsaturated zone (UZ) in natural and nonirrigated cultivated regions (5–30 mm/yr) [*Scanlon et al.*, 2003b]. Higher values from the field studies may be attributed to restriction of field regions to a large sand dune setting, whereas the spatially averaged value from this modeling study also includes finer grained soils found in other regions.

[33] Simulated recharge at region 8 (10.1 mm/yr) is within the range of field-based recharge estimates based on the chloride mass balance (CMB) approach applied to the unsaturated zone and groundwater (5–20 mm/yr [*Dutton et al.*, 2003]). Recharge estimates based on the CMB approach applied to groundwater for region 11 range from 43 to 71 mm/yr and are slightly higher than that simulated (35.1 mm/yr). The discrepancy may be attributed to bias toward high-permeability units in field-based estimates.

[34] Although the number of comparisons between simulated and field-based recharge estimates is limited, simulated recharge rates in this study are generally consistent with those based on previous field studies, and discrepancies can generally be explained by inclusion or exclusion of different types of recharge (e.g., focused versus diffuse recharge in the Southern High Plains) and concentrating on different zones (e.g., high-permeability versus low-permeability units).

3.7. Recommendations for Future Studies

[35] This study represents a relatively simple approach to estimating recharge using a 1-D unsaturated flow model and data found online and in the literature. Future simulations should consider using actual precipitation intensity where data are available and develop input to simulate recharge in irrigated regions. The most fundamental conceptual aspect of unsaturated flow modeling that should be addressed is simulation of vegetation dynamics. Current simulations prescribe vegetation input that precludes vegetation response to variability in soil moisture and precipitation. Two-way coupling between vegetation growth and soil moisture variability related to climate should provide more realistic simulations of recharge, particularly in semiarid–arid regions. In addition, representation of the continuum of roots and various rooting depths associated with vegetation communities is essential for reliable recharge estimation.

3.8. Implications for Water Resources

[36] Reliable recharge estimates are critical for evaluation of and optimal management of water resources. Long-term average recharge rates are beneficial to groundwater managers because management plans are developed generally for decadal timescales. The relationship between precipitation and recharge developed in this study for vegetated, texturally variable soils was used to map spatial variability of recharge for the groundwater model of the Carrizo-Wilcox aquifer in Texas [*Kelley et al.*, 2004]. Scaling factors were developed for the groundwater model that varied these recharge rates with topography and subsurface geology with high recharge in upland areas and above more permeable geologic units, similar to the B value discussed by *Hatton* [1998].

[37] Understanding of climatic and vegetation controls on groundwater recharge shown by simulations in this study can be used to assess potential impacts of climate variability and land use/land cover change on groundwater availability by using space as a proxy for time. The effect of vegetation types on simulated recharge can be used to provide preliminary estimates of potential impacts of removing invasive woody species in many areas of Texas. The state is currently investing millions of dollars in this program to increase water availability [*Wilcox*, 2002].

4. Conclusions

[38] 1. Unsaturated zone modeling using online data is a useful approach for simulating diffuse recharge in porous media systems from point to regional scales where input data are available.

[39] 2. Climate, vegetation, and soils each exert controls on groundwater recharge. (1) High simulated long-term (30 year) mean annual recharge (51–709 mm/yr) in nonvegetated sandy profiles represents 23 to 60% (arid–humid) of MAP and provides an upper bound on actual recharge. (2) Soil textural variability controls recharge, as shown by the large reduction by factors of 2 to 11 in simulated recharge for nonvegetated, texturally variable soils relative to those in monolithic sands. (3) Presence and type of vegetation control recharge, as shown by the reduction in recharge in vegetated relative to that in nonvegetated monolithic sand (factors of 2–30, humid–arid) and vegetated relative to that in nonvegetated, texturally variable soil (factors of 2–80, humid–arid). Relative reductions in recharge due to vegetation were greater in semiarid–arid relative to more humid regions and reflect the enhanced ability of vegetation to reduce recharge in more water-limited regions.

[40] 3. The most realistic long-term (30 year) recharge estimates based on vegetated, texturally variable soils range from 0.2 to 118 mm/yr, representing 0.1 to 10% (arid–humid) of long-term MAP.

[41] 4. Approximately 80% of the variability in simulated recharge can be explained by variability in MAP in vegetated, layered soil profiles using the power law relationship. MAP can be used as a predictor of mean annual recharge.

[42] 5. Simulated long-term, spatially averaged recharge rates generally compare favorably with recharge estimates based on previous field studies.

[43] 6. Simulated long-term (30 year), spatially averaged runoff is generally within the range of estimates based on gauge data in statewide water balance modeling for most regions. Discrepancies in the Southern High Plains can be explained by internal drainage to playas.

[44] 7. Unsaturated zone modeling provides a valuable tool for isolating controls on groundwater recharge. Understanding these controls can be used to assess potential

impacts of climate variability and land use/land cover change on groundwater recharge.

[45] **Acknowledgments.** The authors would like to acknowledge the funding for this study provided by the Environmental Protection Agency through the Texas Commission for Environmental Quality. Additional funding was also provided to Kelley Keese through the Jackson School of Geosciences and the Geology Foundation. Mike Fayer provided valuable insights on UNSAT-H simulations and water balance modeling. The authors greatly appreciate extremely helpful and thorough reviews provided by Seann Reed, Marcel Schaap, Lu Zhang, and two anonymous reviewers.

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K. E. Keese, R. C. Reedy, and B. R. Scanlon, Bureau of Economic Geology, Jackson School of Geosciences, University of Texas at Austin, Austin, TX 78713-8924, USA. (keese@mail.utexas.edu)

Appendix D

Laboratory Analyses

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

ENVIRONMENTAL
LAB OF

12600 West I-20 East - Odessa, Texas 79765

Analytical Report

Prepared for:

Kristin Farris-Pope
Rice Operating Co.
122 W. Taylor
Hobbs, NM 88240

Project: BD Zachary Hinton
Project Number: None Given
Location: Lea County

Lab Order Number: 6A25021

Report Date: 02/01/06

Rice Operating Co.	Project: BD Zachary Hinton	Fax: (505) 397-1471
122 W. Taylor	Project Number: None Given	**Reported:**
Hobbs NM, 88240	Project Manager: Kristin Farris-Pope	02/01/06 11:42

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
Monitor Well #1	6A25021-01	Water	01/23/06 09:45	01/25/06 13:25

Organics by GC

Environmental Lab of Texas

Analyte	*Result*	*Reporting Limit*	*Units*	*Dilution*	*Batch*	*Prepared*	*Analyzed*	*Method*	*Notes*
Monitor Well #1 (6A25021-01) Water									
Benzene	ND	0.00100	mg/L	1	EA62618	01/26/06	01/27/06	EPA 8021B	
Toluene	ND	0.00100	"	"	"	"	"	"	
Ethylbenzene	ND	0.00100	"	"	"	"	"	"	
Xylene (p/m)	ND	0.00100	"	"	"	"	"	"	
Xylene (o)	ND	0.00100	"	"	"	"	"	"	
Surrogate: a,a,a-Trifluorotoluene		*95.2 %*	*80-120*		"	"	"	"	
Surrogate: 4-Bromofluorobenzene		*89.2 %*	*80-120*		"	"	"	"	

Rice Operating Co.	Project: BD Zachary Hinton	Fax: (505) 397-1471
122 W. Taylor	Project Number: None Given	**Reported:**
Hobbs NM, 88240	Project Manager: Kristin Farris-Pope	02/01/06 11:42

General Chemistry Parameters by EPA / Standard Methods
Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6A25021-01) Water									
Total Alkalinity	172	2.00	mg/L	1	EA62406	01/26/06	01/26/06	EPA 310.1M	
Chloride	306	10.0	"	20	EA63004	01/30/06	01/30/06	EPA 300.0	
Total Dissolved Solids	1170	5.00	"	1	EA63003	01/26/06	01/27/06	EPA 160.1	
Sulfate	184	10.0	"	20	EA63004	01/30/06	01/30/06	EPA 300.0	

Total Metals by EPA / Standard Methods

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6A25021-01) Water									
Calcium	93.8	0.100	mg/L	10	EA62615	01/26/06	01/26/06	EPA 6010B	
Magnesium	44.4	0.0100	"	"	"	"	"	"	
Potassium	8.85	0.500	"	"	"	"	"	"	
Sodium	208	0.500	"	50	"	"	"	"	

Organics by GC - Quality Control
Environmental Lab of Texas

Batch EA62618 - EPA 5030C (GC)

Blank (EA62618-BLK1) Prepared: 01/26/06 Analyzed: 01/27/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Benzene	ND	0.00100	mg/L							
Toluene	ND	0.00100	"							
Ethylbenzene	ND	0.00100	"							
Xylene (p/m)	ND	0.00100	"							
Xylene (o)	ND	0.00100	"							
Surrogate: a,a,a-Trifluorotoluene	*38.5*		*ug/l*	*40.0*		*96.2*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*42.4*		*"*	*40.0*		*106*	*80-120*			

LCS (EA62618-BS1) Prepared: 01/26/06 Analyzed: 01/27/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Benzene	0.0566	0.00100	mg/L	0.0500		113	80-120			
Toluene	0.0557	0.00100	"	0.0500		111	80-120			
Ethylbenzene	0.0547	0.00100	"	0.0500		109	80-120			
Xylene (p/m)	0.102	0.00100	"	0.100		102	80-120			
Xylene (o)	0.0538	0.00100	"	0.0500		108	80-120			
Surrogate: a,a,a-Trifluorotoluene	*41.2*		*ug/l*	*40.0*		*103*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*32.8*		*"*	*40.0*		*82.0*	*80-120*			

Calibration Check (EA62618-CCV1) Prepared: 01/26/06 Analyzed: 01/28/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Benzene	51.3		ug/l	50.0		103	80-120			
Toluene	52.5		"	50.0		105	80-120			
Ethylbenzene	54.5		"	50.0		109	80-120			
Xylene (p/m)	101		"	100		101	80-120			
Xylene (o)	55.6		"	50.0		111	80-120			
Surrogate: a,a,a-Trifluorotoluene	*34.3*		*"*	*40.0*		*85.8*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*39.5*		*"*	*40.0*		*98.8*	*80-120*			

Matrix Spike (EA62618-MS1) **Source: 6A24010-01** Prepared: 01/26/06 Analyzed: 01/27/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Benzene	0.0559	0.00100	mg/L	0.0500	ND	112	80-120			
Toluene	0.0548	0.00100	"	0.0500	ND	110	80-120			
Ethylbenzene	0.0515	0.00100	"	0.0500	ND	103	80-120			
Xylene (p/m)	0.0835	0.00100	"	0.100	ND	83.5	80-120			
Xylene (o)	0.0512	0.00100	"	0.0500	ND	102	80-120			
Surrogate: a,a,a-Trifluorotoluene	*37.5*		*ug/l*	*40.0*		*93.8*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*34.3*		*"*	*40.0*		*85.8*	*80-120*			

Organics by GC - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EA62618 - EPA 5030C (GC)										
Matrix Spike Dup (EA62618-MSD1)	**Source: 6A24010-01**		Prepared: 01/26/06 Analyzed: 01/28/06							
Benzene	0.0482	0.00100	mg/L	0.0500	ND	96.4	80-120	15.0	20	
Toluene	0.0484	0.00100	"	0.0500	ND	96.8	80-120	12.8	20	
Ethylbenzene	0.0456	0.00100	"	0.0500	ND	91.2	80-120	12.2	20	
Xylene (p/m)	0.0841	0.00100	"	0.100	ND	84.1	80-120	0.716	20	
Xylene (o)	0.0448	0.00100	"	0.0500	ND	89.6	80-120	12.9	20	
Surrogate: a,a,a-Trifluorotoluene	*33.0*		*ug/l*	*40.0*		*82.5*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*32.4*		*"*	*40.0*		*81.0*	*80-120*			

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EA62406 - General Preparation (WetChem)										
Blank (EA62406-BLK1)				Prepared & Analyzed: 01/26/06						
Total Alkalinity	ND	2.00	mg/L							
LCS (EA62406-BS1)				Prepared & Analyzed: 01/26/06						
Bicarbonate Alkalinity	220		mg/L	200		110	85-115			
Duplicate (EA62406-DUP1)	**Source: 6A19005-01**			Prepared & Analyzed: 01/26/06						
Total Alkalinity	258	2.00	mg/L		256			0.778	20	
Reference (EA62406-SRM1)				Prepared & Analyzed: 01/26/06						
Total Alkalinity	97.0		mg/L	100		97.0	90-110			
Batch EA63003 - General Preparation (WetChem)										
Blank (EA63003-BLK1)				Prepared: 01/26/06 Analyzed: 01/27/06						
Total Dissolved Solids	ND	5.00	mg/L							
Duplicate (EA63003-DUP1)	**Source: 6A25018-01**			Prepared: 01/26/06 Analyzed: 01/27/06						
Total Dissolved Solids	2020	5.00	mg/L		2080			2.93	5	
Batch EA63004 - General Preparation (WetChem)										
Blank (EA63004-BLK1)				Prepared & Analyzed: 01/30/06						
Sulfate	ND	0.500	mg/L							
Chloride	ND	0.500	"							
LCS (EA63004-BS1)				Prepared & Analyzed: 01/30/06						
Sulfate	9.61	0.500	mg/L	10.0		96.1	80-120			
Chloride	8.40	0.500	"	10.0		84.0	80-120			

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EA63004 - General Preparation (WetChem)										
Calibration Check (EA63004-CCV1)				Prepared & Analyzed: 01/30/06						
Sulfate	9.82		mg/L	10.0		98.2	80-120			
Chloride	8.64		"	10.0		86.4	80-120			
Duplicate (EA63004-DUP1)		**Source: 6A25018-01**		Prepared & Analyzed: 01/30/06						
Sulfate	84.4	25.0	mg/L		88.2			4.40	20	
Chloride	879	25.0	"		886			0.793	20	

Total Metals by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Batch EA62615 - 6010B/No Digestion

Blank (EA62615-BLK1) Prepared & Analyzed: 01/26/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Calcium	ND	0.0100	mg/L							
Magnesium	ND	0.00100	"							
Potassium	ND	0.0500	"							
Sodium	ND	0.0100	"							

Calibration Check (EA62615-CCV1) Prepared & Analyzed: 01/26/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Calcium	2.12		mg/L	2.00		106	85-115			
Magnesium	1.99		"	2.00		99.5	85-115			
Potassium	1.88		"	2.00		94.0	85-115			
Sodium	1.94		"	2.00		97.0	85-115			

Duplicate (EA62615-DUP1) **Source: 6A19005-01** Prepared & Analyzed: 01/26/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Calcium	224	0.500	mg/L		222			0.897	20	
Magnesium	115	0.0500	"		120			4.26	20	
Potassium	14.6	0.500	"		15.2			4.03	20	
Sodium	306	0.500	"		313			2.26	20	

Notes and Definitions

DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
LCS	Laboratory Control Spike
MS	Matrix Spike
Dup	Duplicate

Report Approved By: Raland K. Tuttle Date: 2/1/2006

Raland K. Tuttle, Lab Manager
Celey D. Keene, Lab Director, Org. Tech Director
Peggy Allen, QA Officer

Jeanne Mc Murrey, Inorg. Tech Director
LaTasha Cornish, Chemist
Sandra Sanchez, Lab Tech.

Environmental Lab of Texas

12600 West I-20 East
Odessa, Texas 79765

Phone: 432-563-1800
Fax: 432-563-1713

CHAIN OF CUSTODY RECORD AND ANALYSIS REQUEST

Project Manager: Kristin Farris Pope kpriceswd@valornet.com
Company Name RICE Operating Company
Company Address: 122 W. Taylor Street
City/State/Zip: Hobbs, New Mexico 88240
Telephone No: (505) 393-9174
Fax No: (505) 397-1471
Sampler Signature: Rozanne Johnson (505) 631-9310
Email: rozanne@valornet.com

Project Name: BD Zachary Hinton
Project #:
Project Loc: Lea County
PO #:

					Preservative							Matrix				Analyze For:															
																TCLP:															
																TOTAL:							X								
(42502) LAB # (lab use only)	FIELD CODE	Date Sampled	Time Sampled	No. of Containers	Ice	HNO_3	HCl (2) 40 ml glass vials	NaOH	H_2SO_4	None (1) 1 Liter HDPE	Other (Specify)	Water	Sludge	Soil	Other (specify):	TPH: 418.1 8015M 1005 1006	Cations (Ca, Mg, Na, K)	Anions (Cl, SO4, CO3, HCO3)	SAR / ESP / CEC	Metals: As Ag Ba Cd Cr Pb Hg Se	Volatiles	Semivolatiles	BTEX 8021B/5030	RCI	N.O.R.M.	Total Dissolved Solids				RUSH TAT (Pre-Schedule)	Standard TAT
	Monitor Well #1	1/23/2006	9:45	3	X		2			1		X					X	X					X			X					X

Special Instructions:

PLEASE Email RESULTS TO: kpriceswd@valornet.com & mfranks@riceswd.com

Sample Containers Intact? [✓ Y] N
Labels on container? [✓ Y] N
Custody Seals: [✓ Containers] [✓ Cooler]
Temperature Upon Receipt: -2.5 C
Laboratory Comments: not frozen

Relinquished by: Rozanne Johnson	Date 1/23/06	Time 1:25	Received by:	Date	Time
Relinquished by:	Date	Time	Received by ELOT:	Date 01-23-06	Time 1325

Environmental Lab of Texas
Variance / Corrective Action Report – Sample Log-In

Client: Rice Op.

Date/Time: 1/25/06 13:26

Order #: 6A25021

Initials: CK

Sample Receipt Checklist

Temperature of container/cooler?	Yes	No	-2.5 C
Shipping container/cooler in good condition?	[✓ Yes]	No	
Custody Seals intact on shipping container/cooler?	[✓ Yes]	No	Not present
Custody Seals intact on sample bottles?	[✓ Yes]	No	Not present
Chain of custody present?	[✓ Yes]	No	
Sample Instructions complete on Chain of Custody?	[✓ Yes]	No	
Chain of Custody signed when relinquished and received?	[✓ Yes]	No	
Chain of custody agrees with sample label(s)	[✓ Yes]	No	
Container labels legible and intact?	[✓ Yes]	No	
Sample Matrix and properties same as on chain of custody?	[✓ Yes]	No	
Samples in proper container/bottle?	[✓ Yes]	No	
Samples properly preserved?	[✓ Yes]	No	
Sample bottles intact?	[✓ Yes]	No	
Preservations documented on Chain of Custody?	[✓ Yes]	No	
Containers documented on Chain of Custody?	[✓ Yes]	No	
Sufficient sample amount for indicated test?	[✓ Yes]	No	
All samples received within sufficient hold time?	[✓ Yes]	No	
VOC samples have zero headspace?	[✓ Yes]	No	Not Applicable

Other observations:

Variance Documentation:

Contact Person: - Date/Time: Contacted by:

Regarding:

Corrective Action Taken:

ENVIRONMENTAL
LAB OF

12600 West I-20 East - Odessa, Texas 79765

Analytical Report

Prepared for:

Kristin Farris-Pope
Rice Operating Co.
122 W. Taylor
Hobbs, NM 88240

Project: BD Zachary Hinton
Project Number: None Given
Location: Lea County

Lab Order Number: 6D27011

Report Date: 05/04/06

Rice Operating Co. 122 W. Taylor Hobbs NM, 88240	Project: BD Zachary Hinton Project Number: None Given Project Manager: Kristin Farris-Pope	Fax: (505) 397-1471 **Reported:** 05/04/06 14:09

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
Monitor Well #1	6D27011-01	Water	04/24/06 09:30	04/27/06 10:30

Organics by GC

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6D27011-01) Water									
Benzene	ND	0.00100	mg/L	1	ED62807	04/28/06	04/30/06	EPA 8021B	
Toluene	ND	0.00100	"	"	"	"	"	"	
Ethylbenzene	ND	0.00100	"	"	"	"	"	"	
Xylene (p/m)	ND	0.00100	"	"	"	"	"	"	
Xylene (o)	ND	0.00100	"	"	"	"	"	"	
Surrogate: a,a,a-Trifluorotoluene		*102 %*	*80-120*		"	"	"	"	
Surrogate: 4-Bromofluorobenzene		*103 %*	*80-120*		"	"	"	"	

General Chemistry Parameters by EPA / Standard Methods

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6D27011-01) Water									
Total Alkalinity	**184**	2.00	mg/L	1	EE60301	05/03/06	05/03/06	EPA 310.1M	
Chloride	**326**	5.00	"	10	EE60116	05/01/06	05/01/06	EPA 300.0	
Total Dissolved Solids	**1190**	5.00	"	1	EE60115	04/27/06	04/28/06	EPA 160.1	
Sulfate	**167**	5.00	"	10	EE60116	05/01/06	05/01/06	EPA 300.0	

Total Metals by EPA / Standard Methods

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Monitor Well #1 (6D27011-01) Water									
Calcium	85.0	0.100	mg/L	10	ED62719	04/27/06	04/27/06	EPA 6010B	
Magnesium	43.4	0.0100	"	"	"	"	"	"	
Potassium	9.70	0.500	"	"	"	"	"	"	
Sodium	238	0.500	"	50	"	"	"	"	

Organics by GC - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch ED62807 - EPA 5030C (GC)										
Blank (ED62807-BLK1)				Prepared: 04/28/06 Analyzed: 04/30/06						
Benzene	ND	0.00100	mg/L							
Toluene	ND	0.00100	"							
Ethylbenzene	ND	0.00100	"							
Xylene (p/m)	ND	0.00100	"							
Xylene (o)	ND	0.00100	"							
Surrogate: a,a,a-Trifluorotoluene	*42.7*		*ug/l*	*40.0*		*107*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*42.2*		*"*	*40.0*		*106*	*80-120*			
LCS (ED62807-BS1)				Prepared: 04/28/06 Analyzed: 04/30/06						
Benzene	0.0599	0.00100	mg/L	0.0500		120	80-120			
Toluene	0.0580	0.00100	"	0.0500		116	80-120			
Ethylbenzene	0.0551	0.00100	"	0.0500		110	80-120			
Xylene (p/m)	0.120	0.00100	"	0.100		120	80-120			
Xylene (o)	0.0596	0.00100	"	0.0500		119	80-120			
Surrogate: a,a,a-Trifluorotoluene	*43.0*		*ug/l*	*40.0*		*108*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*42.2*		*"*	*40.0*		*106*	*80-120*			
Calibration Check (ED62807-CCV1)				Prepared: 04/28/06 Analyzed: 05/01/06						
Benzene	55.0		ug/l	50.0		110	80-120			
Toluene	53.0		"	50.0		106	80-120			
Ethylbenzene	55.9		"	50.0		112	80-120			
Xylene (p/m)	110		"	100		110	80-120			
Xylene (o)	55.9		"	50.0		112	80-120			
Surrogate: a,a,a-Trifluorotoluene	*39.0*		*"*	*40.0*		*97.5*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*39.1*		*"*	*40.0*		*97.8*	*80-120*			
Matrix Spike (ED62807-MS1)	**Source: 6D27008-01**			Prepared: 04/28/06 Analyzed: 05/01/06						
Benzene	0.0576	0.00100	mg/L	0.0500	ND	115	80-120			
Toluene	0.0568	0.00100	"	0.0500	ND	114	80-120			
Ethylbenzene	0.0587	0.00100	"	0.0500	ND	117	80-120			
Xylene (p/m)	0.120	0.00100	"	0.100	ND	120	80-120			
Xylene (o)	0.0600	0.00100	"	0.0500	ND	120	80-120			
Surrogate: a,a,a-Trifluorotoluene	*41.7*		*ug/l*	*40.0*		*104*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*47.5*		*"*	*40.0*		*119*	*80-120*			

Organics by GC - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch ED62807 - EPA 5030C (GC)										
Matrix Spike Dup (ED62807-MSD1)	**Source: 6D27008-01**		Prepared: 04/28/06 Analyzed: 05/01/06							
Benzene	0.0597	0.00100	mg/L	0.0500	ND	119	80-120	3.42	20	
Toluene	0.0579	0.00100	"	0.0500	ND	116	80-120	1.74	20	
Ethylbenzene	0.0585	0.00100	"	0.0500	ND	117	80-120	0.00	20	
Xylene (p/m)	0.120	0.00100	"	0.100	ND	120	80-120	0.00	20	
Xylene (o)	0.0598	0.00100	"	0.0500	ND	120	80-120	0.00	20	
Surrogate: a,a,a-Trifluorotoluene	*43.5*		*ug/l*	*40.0*		*109*	*80-120*			
Surrogate: 4-Bromofluorobenzene	*46.4*		*"*	*40.0*		*116*	*80-120*			

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EE60115 - *General Preparation* (WetChem)										
Blank (EE60115-BLK1)				Prepared: 04/27/06 Analyzed: 04/28/06						
Total Dissolved Solids	ND	5.00	mg/L							
Duplicate (EE60115-DUP1)		**Source: 6D27015-01**		Prepared: 04/27/06 Analyzed: 04/28/06						
Total Dissolved Solids	3020	5.00	mg/L		3040			0.660	5	
Batch EE60116 - General Preparation (WetChem)										
Blank (EE60116-BLK1)				Prepared & Analyzed: 05/01/06						
Chloride	ND	0.500	mg/L							
Sulfate	ND	0.500	"							
LCS (EE60116-BS1)				Prepared & Analyzed: 05/01/06						
Sulfate	9.47	0.500	mg/L	10.0		94.7	80-120			
Chloride	9.71	0.500	"	10.0		97.1	80-120			
Calibration Check (EE60116-CCV1)				Prepared & Analyzed: 05/01/06						
Chloride	9.86		mg/L	10.0		98.6	80-120			
Sulfate	8.11		"	10.0		81.1	80-120			
Duplicate (EE60116-DUP1)		**Source: 6D27008-01**		Prepared & Analyzed: 05/01/06						
Sulfate	80.0	2.50	mg/L		79.2			1.01	20	
Chloride	49.3	2.50	"		49.0			0.610	20	
Batch EE60301 - General Preparation (WetChem)										
Blank (EE60301-BLK1)				Prepared & Analyzed: 05/03/06						
Total Alkalinity	ND	2.00	mg/L							

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EE60301 - General Preparation (WetChem)										
LCS (EE60301-BS1)				Prepared & Analyzed: 05/03/06						
Bicarbonate Alkalinity	214		mg/L	200		107	85-115			
Duplicate (EE60301-DUP1)		**Source: 6D26006-01**		Prepared & Analyzed: 05/03/06						
Total Alkalinity	29.0	2.00	mg/L		28.0			3.51	20	
Reference (EE60301-SRM1)				Prepared & Analyzed: 05/03/06						
Total Alkalinity	96.0		mg/L	100		96.0	90-110			

Total Metals by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Batch ED62719 - 6010B/No Digestion

Blank (ED62719-BLK1) Prepared & Analyzed: 04/27/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Calcium	ND	0.0100	mg/L							
Magnesium	ND	0.00100	"							
Potassium	ND	0.0500	"							
Sodium	ND	0.0100	"							

Calibration Check (ED62719-CCV1) Prepared & Analyzed: 04/27/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Calcium	2.08		mg/L				85-115			
Magnesium	2.16		"				85-115			
Potassium	1.94		"				85-115			
Sodium	1.96		"				85-115			

Duplicate (ED62719-DUP1) **Source: 6D26006-01** Prepared & Analyzed: 04/27/06

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Calcium	0.0366	0.0100	mg/L		0.0367			0.273	20	
Magnesium	ND	0.00100	"		ND				20	
Potassium	0.275	0.0500	"		0.275			0.00	20	
Sodium	13.0	0.100	"		12.1			7.17	20	

Notes and Definitions

DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
LCS	Laboratory Control Spike
MS	Matrix Spike
Dup	Duplicate

Report Approved By: Raland K Tuttle Date: 5/4/2006

Raland K. Tuttle, Lab Manager
Celey D. Keene, Lab Director, Org. Tech Director
Peggy Allen, QA Officer

Jeanne Mc Murrey, Inorg. Tech Director
LaTasha Cornish, Chemist
Sandra Sanchez, Lab Tech.

Environmental Lab of Texas

12600 West I-20 East
Odessa, Texas 79765

Phone: 432-563-1800
Fax: 432-563-1713

CHAIN OF CUSTODY RECORD AND ANALYSIS REQUEST

Project Manager: Kristin Farris Pope kpope@riceswd.com
Company Name RICE Operating Company
Company Address: 122 W. Taylor Street
City/State/Zip: Hobbs, New Mexico 88240
Telephone No: (505) 393-9174
Fax No: (505) 397-1471
Sampler Signature: Rozanne Johnson (505) 631-9310
Email: rozanne@valornet.com

Project Name: BD Zachary Hinton
Project #:
Project Loc: Lea County
PO #:

					Preservative							Matrix				Analyze For:															
																				TCLP:											
																				TOTAL:			X								
LAB # (lab use only) [illegible]	FIELD CODE	Date Sampled	Time Sampled	No. of Containers	Ice	HNO_3	HCl (2) 40 ml glass vials	NaOH	H_2SO_4	None (1) 1 Liter HDPE	Other (Specify)	Water	Sludge	Soil	Other (specify):	TPH: 418.1 8015M 1005 1006	Cations (Ca, Mg, Na, K)	Anions (Cl, SO4, CO3, HCO3)	SAR / ESP / CEC	Metals: As Ag Ba Cd Cr Pb Hg Se	Volatiles	Semivolatiles	BTEX 8021B/5030	RCI	N.O.R.M.	Total Dissolved Solids				RUSH TAT (Pre-Schedule)	Standard TAT
01	Monitor Well #1	4/24/2006	9:30	3	X		2			1		X					X	X					X			X					X

Special Instructions:

PLEASE Email RESULTS TO: kpope@riceswd.com & mfranks@riceswd.com

Sample Containers Intact? [✓ Y] N
Labels on container? [✓ Y] N
Custody Seals: Containers / Cooler
Temperature Upon Receipt: 2c

Laboratory Comments:

Relinquished by: Rozanne Johnson	Date 4/27/06	Time 6:00	Received by: James Johnson	Date 4/27/06	Time 6:01
Relinquished by:	Date 4/27/06	Time 10:30	Received by ELOT:	Date 4/27/06	Time 10:50

Environmental Lab of Texas
Variance / Corrective Action Report – Sample Log-In

nt: Rice Op.

e/Time: 4/27/06 10:30

er #: 6042701

els: ck

Sample Receipt Checklist

perature of container/cooler?	Yes	No	2.0 C
ping container/cooler in good condition?	[✓ Yes]	No	
ody Seals intact on shipping container/cooler?	[✓ Yes]	No	Not present
ody Seals intact on sample bottles?	[✓ Yes]	No	Not present
in of custody present?	[✓ Yes]	No	
iple Instructions complete on Chain of Custody?	[✓ Yes]	No	
in of Custody signed when relinquished and received?	[✓ Yes]	No	
in of custody agrees with sample label(s)	[✓ Yes]	No	
tainer labels legible and intact?	[✓ Yes]	No	
nple Matrix and properties same as on chain of custody?	[✓ Yes]	No	
nples in proper container/bottle?	[✓ Yes]	No	
nples properly preserved?	[✓ Yes]	No	
nple bottles intact?	[✓ Yes]	No	
servations documented on Chain of Custody?	[✓ Yes]	No	
itainers documented on Chain of Custody?	[✓ Yes]	No	
ficient sample amount for indicated test?	[✓ Yes]	No	
samples received within sufficient hold time?	[✓ Yes]	No	
C samples have zero headspace?	[✓ Yes]	No	Not Applicable

ner observations:

Variance Documentation:

ntact Person: - ________ Date/Time: ________ Contacted by: ________

egarding:

rrective Action Taken:

TraceAnalysis, Inc.
6701 Aberdeen Avenue, Suite 9 Lubbock, Texas 79424 800•378•1296 806•794•1296 FAX 806•794•1298
155 McCutcheon, Suite H El Paso, Texas 79932 888•588•3443 915•585•3443 FAX 915•585•4944
E-Mail lab@traceanalysis.com

Analytical and Quality Control Report

Kristen Farris-Pope
Rice Operating Company
122 W Taylor Street
Hobbs, NM, 88240

Report Date: August 9, 2006

Work Order: 6072143

Project Location: Lea County,NM
Project Name: BD Zachary Hinton
Project Number: BD Zachary Hinton

Enclosed are the Analytical Report and Quality Control Report for the following sample(s) submitted to TraceAnalysis, Inc.

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
96140	Monitor Well #1	water	2006-07-19	12:55	2006-07-21

These results represent only the samples received in the laboratory. The Quality Control Report is generated on a batch basis. All information contained in this report is for the analytical batch(es) in which your sample(s) were analyzed.

This report consists of a total of 10 pages and shall not be reproduced except in its entirety, without written approval of TraceAnalysis, Inc.

Michael Abel

Dr. Blair Leftwich, Director

Analytical Report

Sample: 96140 - Monitor Well #1

Analysis:	Alkalinity	Analytical Method:	SM 2320B	Prep Method:	N/A
QC Batch:	28340	Date Analyzed:	2006-07-26	Analyzed By:	LJ
Prep Batch:	24777	Sample Preparation:	2006-07-25	Prepared By:	LJ

Parameter	Flag	RL Result	Units	Dilution	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1	1.00
Bicarbonate Alkalinity		**188**	mg/L as CaCo3	1	4.00
Total Alkalinity		**188**	mg/L as CaCo3	1	4.00

Sample: 96140 - Monitor Well #1

Analysis:	BTEX	Analytical Method:	S 8021B	Prep Method:	S 5030B
QC Batch:	28277	Date Analyzed:	2006-07-24	Analyzed By:	MT
Prep Batch:	24759	Sample Preparation:	2006-07-24	Prepared By:	MT

Parameter	Flag	RL Result	Units	Dilution	RL
Benzene		<0.00100	mg/L	1	0.00100
Toluene		<0.00100	mg/L	1	0.00100
Ethylbenzene		<0.00100	mg/L	1	0.00100
Xylene		<0.00100	mg/L	1	0.00100

Surrogate	Flag	Result	Units	Dilution	Spike Amount	Percent Recovery	Recovery Limits
Trifluorotoluene (TFT)		0.0961	mg/L	1	0.100	96	66.2 - 127.7
4-Bromofluorobenzene (4-BFB)	[1]	0.0585	mg/L	1	0.100	58	70.6 - 129.2

Sample: 96140 - Monitor Well #1

Analysis:	Cations	Analytical Method:	S 6010B	Prep Method:	S 3005A
QC Batch:	28356	Date Analyzed:	2006-07-26	Analyzed By:	TP
Prep Batch:	24749	Sample Preparation:	2006-07-24	Prepared By:	TS

Parameter	Flag	RL Result	Units	Dilution	RL
Dissolved Calcium		**98.2**	mg/L	1	0.500
Dissolved Potassium		**12.8**	mg/L	1	1.00
Dissolved Magnesium		**49.3**	mg/L	1	1.00
Dissolved Sodium		**230**	mg/L	10	1.00

Sample: 96140 - Monitor Well #1

Analysis:	Ion Chromatography	Analytical Method:	E 300.0	Prep Method:	N/A
QC Batch:	28782	Date Analyzed:	2006-08-02	Analyzed By:	WB
Prep Batch:	25167	Sample Preparation:	2006-08-02	Prepared By:	WB

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[1] BFB surrogate recovery outside normal limits. ICV/CCV and TFT surrogate recovery show the method to be in control.

Parameter	Flag	RL Result	Units	Dilution	RL
Chloride		**375**	mg/L	50	0.500
Sulfate		**234**	mg/L	50	0.500

Sample: 96140 - Monitor Well #1

Analysis:	TDS	Analytical Method:	SM 2540C	Prep Method:	N/A
QC Batch:	28406	Date Analyzed:	2006-07-27	Analyzed By:	SM
Prep Batch:	24850	Sample Preparation:	2009-07-26	Prepared By:	SM

Parameter	Flag	RL Result	Units	Dilution	RL
Total Dissolved Solids		**1318**	mg/L	2	10.00

Method Blank (1) QC Batch: 28277

QC Batch:	28277	Date Analyzed:	2006-07-24	Analyzed By:	MT
Prep Batch:	24759	QC Preparation:	2006-07-24	Prepared By:	MT

Parameter	Flag	MDL Result	Units	RL
Benzene		<0.000255	mg/L	0.001
Toluene		<0.000210	mg/L	0.001
Ethylbenzene		<0.000317	mg/L	0.001
Xylene		<0.000603	mg/L	0.001

Surrogate	Flag	Result	Units	Dilution	Spike Amount	Percent Recovery	Recovery Limits
Trifluorotoluene (TFT)		0.0949	mg/L	1	0.100	95	76.1 - 117
4-Bromofluorobenzene (4-BFB)		0.0633	mg/L	1	0.100	63	58.5 - 118

Method Blank (1) QC Batch: 28340

QC Batch:	28340	Date Analyzed:	2006-07-26	Analyzed By:	LJ
Prep Batch:	24777	QC Preparation:	2006-07-25	Prepared By:	LJ

Parameter	Flag	MDL Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1
Bicarbonate Alkalinity		<4.00	mg/L as CaCo3	4
Total Alkalinity		<4.00	mg/L as CaCo3	4

Method Blank (1) QC Batch: 28356

QC Batch:	28356	Date Analyzed:	2006-07-26	Analyzed By:	TP
Prep Batch:	24749	QC Preparation:	2006-07-24	Prepared By:	TS

Parameter	Flag	MDL Result	Units	RL
Dissolved Calcium		0.132	mg/L	0.5
Dissolved Potassium		1.08	mg/L	1
Dissolved Magnesium		<0.704	mg/L	1
Dissolved Sodium		0.836	mg/L	1

Method Blank (1) QC Batch: 28406

QC Batch: 28406 Date Analyzed: 2006-07-27 Analyzed By: SM
Prep Batch: 24850 QC Preparation: 2006-07-26 Prepared By: SM

Parameter	Flag	MDL Result	Units	RL
Total Dissolved Solids		<5.000	mg/L	10

Method Blank (1) QC Batch: 28782

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB
Prep Batch: 25167 QC Preparation: 2006-08-02 Prepared By: WB

Parameter	Flag	MDL Result	Units	RL
Chloride		<0.0181	mg/L	0.5
Sulfate		<0.0485	mg/L	0.5

Duplicates (1)

QC Batch: 28340 Date Analyzed: 2006-07-26 Analyzed By: LJ
Prep Batch: 24777 QC Preparation: 2006-07-25 Prepared By: LJ

Param	Duplicate Result	Sample Result	Units	Dilution	RPD	RPD Limit
Hydroxide Alkalinity	<1.00	<1.00	mg/L as CaCo3	1	0	20
Carbonate Alkalinity	<1.00	<1.00	mg/L as CaCo3	1	0	20
Bicarbonate Alkalinity	110	108	mg/L as CaCo3	1	2	12.6
Total Alkalinity	110	108	mg/L as CaCo3	1	2	11.5

Duplicates (1)

QC Batch: 28406 Date Analyzed: 2006-07-27 Analyzed By: SM
Prep Batch: 24850 QC Preparation: 2006-07-26 Prepared By: SM

Param	Duplicate Result	Sample Result	Units	Dilution	RPD	RPD Limit
Total Dissolved Solids	768.0	928.0	mg/L	2	19	17.2

Laboratory Control Spike (LCS-1)

QC Batch: 28277
Prep Batch: 24759

Date Analyzed: 2006-07-24
QC Preparation: 2006-07-24

Analyzed By: MT
Prepared By: MT

Param	LCS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Benzene	0.109	mg/L	1	0.1	0	109	
Toluene	0.108	mg/L	1	0.1	0	108	
Ethylbenzene	0.109	mg/L	1	0.1	0	109	
Xylene	0.322	mg/L	1	0.3	0	107.333	

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	LCSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Benzene	0.104	mg/L	1	0.1	0	109		4.7	20
Toluene	0.103	mg/L	1	0.1	0	108		4.7	20
Ethylbenzene	0.101	mg/L	1	0.1	0	109		7.6	20
Xylene	0.306	mg/L	1	0.3	0	107.333		5.1	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Surrogate	LCS Result	LCSD Result	Units	Dil.	Spike Amount	LCS Rec.	LCSD Rec.	Rec. Limit
Trifluorotoluene (TFT)	0.101	0.101	mg/L	1	0.100	101	101	81.8 - 114
4-Bromofluorobenzene (4-BFB)	0.112	0.111	mg/L	1	0.100	112	111	72.7 - 116

Laboratory Control Spike (LCS-1)

QC Batch: 28356
Prep Batch: 24749

Date Analyzed: 2006-07-26
QC Preparation: 2006-07-24

Analyzed By: TP
Prepared By: TS

Param	LCS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Dissolved Calcium	51.7	mg/L	1	50	0	103.4	
Dissolved Potassium	50.8	mg/L	1	50	0	101.6	
Dissolved Magnesium	51.5	mg/L	1	50	0	103	
Dissolved Sodium	50.5	mg/L	1	50	0	101	

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	LCSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Dissolved Calcium	51.7	mg/L	1	50	0	103.4		0	20
Dissolved Potassium	49.3	mg/L	1	50	0	101.6		3	20
Dissolved Magnesium	49.8	mg/L	1	50	0	103		3.4	20
Dissolved Sodium	48.6	mg/L	1	50	0	101		3.8	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Laboratory Control Spike (LCS-1)

QC Batch: 28782
Prep Batch: 25167

Date Analyzed: 2006-08-02
QC Preparation: 2006-08-02

Analyzed By: WB
Prepared By: WB

Param	LCS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Chloride	12.2	mg/L	1	12.5	0	97.6	
Sulfate	12.5	mg/L	1	12.5	0	100	

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	LCSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Chloride	12.3	mg/L	1	12.5	0	97.6		0.8	20
Sulfate	12.5	mg/L	1	12.5	0	100		0	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Matrix Spike (MS-1) Spiked Sample: 96149

QC Batch: 28277
Prep Batch: 24759

Date Analyzed: 2006-07-24
QC Preparation: 2006-07-24

Analyzed By: MT
Prepared By: MT

Param	MS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Benzene	0.107	mg/L	1	0.100	<0.000255	107	70.9 - 126
Toluene	0.105	mg/L	1	0.100	<0.000210	105	70.8 - 125
Ethylbenzene	0.106	mg/L	1	0.100	<0.000317	106	74.8 - 125
Xylene	0.311	mg/L	1	0.300	<0.000603	104	75.7 - 126

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	MSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Benzene [2]	NA	mg/L	1	0.100	<0.000255	0	70.9 - 126	200	20
Toluene [3]	NA	mg/L	1	0.100	<0.000210	0	70.8 - 125	200	20
Ethylbenzene [4]	NA	mg/L	1	0.100	<0.000317	0	74.8 - 125	200	20
Xylene [5]	NA	mg/L	1	0.300	<0.000603	0	75.7 - 126	200	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Surrogate	MS Result	MSD Result	Units	Dil.	Spike Amount	MS Rec.	MSD Rec.	Rec. Limit
Trifluorotoluene (TFT) [6]	0.101	NA	mg/L	1	0.1	101	0	73.6 - 121
4-Bromofluorobenzene (4-BFB) [7]	0.110	NA	mg/L	1	0.1	110	0	81.8 - 114

Matrix Spike (MS-1) Spiked Sample: 96124

QC Batch: 28356
Prep Batch: 24749

Date Analyzed: 2006-07-26
QC Preparation: 2006-07-24

Analyzed By: TP
Prepared By: TS

---

[2] RPD is out of range because a matrix spike duplicate was not prepared.
[3] RPD is out of range because a matrix spike duplicate was not prepared.
[4] RPD is out of range because a matrix spike duplicate was not prepared.
[5] RPD is out of range because a matrix spike duplicate was not prepared.
[6] RPD is out of range because a matrix spike duplicate was not prepared.
[7] RPD is out of range because a matrix spike duplicate was not prepared.

Param	MS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Dissolved Calcium	416	mg/L	1	50.0	361	110	68.4 - 138
Dissolved Potassium	73.8	mg/L	1	50.0	22	104	82 - 129
Dissolved Magnesium	208	mg/L	1	50.0	147	122	61.2 - 135
Dissolved Sodium	633	mg/L	1	50.0	578	110	81.8 - 125

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	MSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Dissolved Calcium	406	mg/L	1	50.0	361	90	68.4 - 138	2	20
Dissolved Potassium	81.3	mg/L	1	50.0	22	119	82 - 129	10	20
Dissolved Magnesium	194	mg/L	1	50.0	147	94	61.2 - 135	7	20
Dissolved Sodium	637	mg/L	1	50.0	578	118	81.8 - 125	1	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Matrix Spike (MS-1) Spiked Sample: 96141

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB
Prep Batch: 25167 QC Preparation: 2006-08-02 Prepared By: WB

Param	MS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Chloride	2210	mg/L	100	12.5	988	98	25.4 - 171
Sulfate	1580	mg/L	100	12.5	298	102	0 - 677

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	MSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Chloride	2200	mg/L	100	12.5	988	97	25.4 - 171	0	20
Sulfate	1550	mg/L	100	12.5	298	100	0 - 677	2	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Standard (ICV-1)

QC Batch: 28277 Date Analyzed: 2006-07-24 Analyzed By: MT

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Benzene		mg/L	0.100	0.104	104	85 - 115	2006-07-24
Toluene		mg/L	0.100	0.104	104	85 - 115	2006-07-24
Ethylbenzene		mg/L	0.100	0.104	104	85 - 115	2006-07-24
Xylene		mg/L	0.300	0.314	105	85 - 115	2006-07-24

Standard (CCV-1)

QC Batch: 28277 Date Analyzed: 2006-07-24 Analyzed By: MT

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Benzene		mg/L	0.100	0.107	107	85 - 115	2006-07-24
Toluene		mg/L	0.100	0.105	105	85 - 115	2006-07-24
Ethylbenzene		mg/L	0.100	0.106	106	85 - 115	2006-07-24
Xylene		mg/L	0.300	0.311	104	85 - 115	2006-07-24

Standard (ICV-1)

QC Batch: 28340 Date Analyzed: 2006-07-26 Analyzed By: LJ

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Alkalinity		mg/L as CaCo3	250	240	96	90 - 110	2006-07-26

Standard (CCV-1)

QC Batch: 28340 Date Analyzed: 2006-07-26 Analyzed By: LJ

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Alkalinity		mg/L as CaCo3	250	240	96	90 - 110	2006-07-26

Standard (ICV-1)

QC Batch: 28356 Date Analyzed: 2006-07-26 Analyzed By: TP

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Dissolved Calcium		mg/L	50.0	50.7	101	90 - 110	2006-07-26
Dissolved Potassium		mg/L	50.0	52.0	104	90 - 110	2006-07-26
Dissolved Magnesium		mg/L	50.0	49.6	99	90 - 110	2006-07-26
Dissolved Sodium		mg/L	50.0	50.9	102	90 - 110	2006-07-26

Standard (CCV-1)

QC Batch: 28356 Date Analyzed: 2006-07-26 Analyzed By: TP

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Dissolved Calcium		mg/L	50.0	51.2	102	90 - 110	2006-07-26
Dissolved Potassium		mg/L	50.0	54.6	109	90 - 110	2006-07-26
Dissolved Magnesium		mg/L	50.0	50.0	100	90 - 110	2006-07-26
Dissolved Sodium		mg/L	50.0	53.2	106	90 - 110	2006-07-26

Standard (ICV-1)

QC Batch: 28406 Date Analyzed: 2006-07-27 Analyzed By: SM

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Dissolved Solids		mg/L	1000	1056	106	90 - 110	2006-07-27

Standard (CCV-1)

QC Batch: 28406 Date Analyzed: 2006-07-27 Analyzed By: SM

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Dissolved Solids		mg/L	1000	1075	108	90 - 110	2006-07-27

Standard (ICV-1)

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Chloride		mg/L	12.5	12.4	99	90 - 110	2006-08-02
Sulfate		mg/L	12.5	12.7	102	90 - 110	2006-08-02

Standard (CCV-1)

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Chloride		mg/L	12.5	12.2	98	90 - 110	2006-08-02
Sulfate		mg/L	12.5	12.4	99	90 - 110	2006-08-02

Page 1 of 1

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TraceAnalysis, Inc.

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El Paso,Texas 79932
Tel (915) 585-3443
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1 (888) 588-3443

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6072143

Company Name: RICE Operating Company
Phone #: (505)393 9174
Address: (Street, City, Zip) 122 W Taylor Street - Hobbs, New Mexico 88240
Fax #: (505) 397-1471
Contact Person: Kristin Farris - Pope, Project Scientist
kpope@riceswd.com
Invoice to: (If different from above)
Project #: None Given
Project Name: BD Zachary Hinton
Project Location: Lea County - New Mexico
Sampler Signature: Rozanne Johnson (505)631-9310
rozanne@valornet.com

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX					PRESERVATIVE METHOD						SAMPLING	
				WATER	SOIL	AIR	SLUDGE		HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE	NONE	DATE 2006	TIME
96140	Monitor Well #1	2	40 ml	X					X				X		7-19	12:55
	Monitor Well #1	1	1L	X									X		7-19	12:55

ANALYSIS REQUEST
(Circle or Specify Method No.)

FIELD CODE	MTBE 8021B/602	BTEX 8021B/602	TPH 418.1/TX1005 / TX1005 Extended (C35)	PAH 8270C	Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	TCLP Metals Ag As Ba Cd Cr Pb Se Hg	TCLP Volatiles	TCLP Semi Volatiles	TCLP Pesticides	RCI	GC/MS Vol. 8260B/624	GC/MS Semi. Vol. 8270C/625	PCB's 8082/608	Pesticides 8081A/608	BOD, TSS, pH	Moisture Content	Cations (Ca, Mg, Na, K)	Anions (Cl, SSSO4, CO3, HCO3)	Total Dissolved Solids		Turn Around Time if different from standard	Hold
Monitor Well #1		X																				
Monitor Well #1																	X	X	X			

Relinquished by: Rozanne Johnson	Date: 7-20-06	Time: 8:00	Received by:	Date:	Time:
Relinquished by:	Date:	Time:	Received by:	Date:	Time:
Relinquished by:	Date:	Time:	Received at Laboratory by:	Date: 7-21-06	Time: 1105

LAB USE ONLY
Intact [✓ Y] N
Headspace Y [✓ N]
Temp 4°
Log-in Review MA

REMARKS:

☐ check if special reporting limits needed

Carrier # Bus GU 1690177159

Submittal of samples constitutes agreement to Terms and Conditions listed on reverse side of COC

TRACEANALYSIS, INC.

6701 Aberdeen Avenue, Suite 9 Lubbock, Texas 79424 800•378•1296 806•794•1296 FAX 806•794•1298
155 McCutcheon, Suite H El Paso, Texas 79932 888•588•3443 915•585•3443 FAX 915•585•4944
E-Mail lab@traceanalysis.com

Analytical and Quality Control Report

Kristen Farris-Pope
Rice Operating Company
122 W Taylor Street
Hobbs, NM, 88240

Report Date: August 9, 2006

Work Order: 6072143

Project Location: Lea County,NM
Project Name: BD Zachary Hinton
Project Number: BD Zachary Hinton

Enclosed are the Analytical Report and Quality Control Report for the following sample(s) submitted to TraceAnalysis, Inc.

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
96140	Monitor Well #1	water	2006-07-19	12:55	2006-07-21

These results represent only the samples received in the laboratory. The Quality Control Report is generated on a batch basis. All information contained in this report is for the analytical batch(es) in which your sample(s) were analyzed.

This report consists of a total of 10 pages and shall not be reproduced except in its entirety, without written approval of TraceAnalysis, Inc.

Dr. Blair Leftwich, Director

Analytical Report

Sample: 96140 - Monitor Well #1

Analysis:	Alkalinity	Analytical Method:	SM 2320B	Prep Method:	N/A
QC Batch:	28340	Date Analyzed:	2006-07-26	Analyzed By:	LJ
Prep Batch:	24777	Sample Preparation:	2006-07-25	Prepared By:	LJ

Parameter	Flag	RL Result	Units	Dilution	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1	1.00
Bicarbonate Alkalinity		**188**	mg/L as CaCo3	1	4.00
Total Alkalinity		**188**	mg/L as CaCo3	1	4.00

Sample: 96140 - Monitor Well #1

Analysis:	BTEX	Analytical Method:	S 8021B	Prep Method:	S 5030B
QC Batch:	28277	Date Analyzed:	2006-07-24	Analyzed By:	MT
Prep Batch:	24759	Sample Preparation:	2006-07-24	Prepared By:	MT

Parameter	Flag	RL Result	Units	Dilution	RL
Benzene		<0.00100	mg/L	1	0.00100
Toluene		<0.00100	mg/L	1	0.00100
Ethylbenzene		<0.00100	mg/L	1	0.00100
Xylene		<0.00100	mg/L	1	0.00100

Surrogate	Flag	Result	Units	Dilution	Spike Amount	Percent Recovery	Recovery Limits
Trifluorotoluene (TFT)		0.0961	mg/L	1	0.100	96	66.2 - 127.7
4-Bromofluorobenzene (4-BFB)	[1]	0.0585	mg/L	1	0.100	58	70.6 - 129.2

Sample: 96140 - Monitor Well #1

Analysis:	Cations	Analytical Method:	S 6010B	Prep Method:	S 3005A
QC Batch:	28356	Date Analyzed:	2006-07-26	Analyzed By:	TP
Prep Batch:	24749	Sample Preparation:	2006-07-24	Prepared By:	TS

Parameter	Flag	RL Result	Units	Dilution	RL
Dissolved Calcium		**98.2**	mg/L	1	0.500
Dissolved Potassium		**12.8**	mg/L	1	1.00
Dissolved Magnesium		**49.3**	mg/L	1	1.00
Dissolved Sodium		**230**	mg/L	10	1.00

Sample: 96140 - Monitor Well #1

Analysis:	Ion Chromatography	Analytical Method:	E 300.0	Prep Method:	N/A
QC Batch:	28782	Date Analyzed:	2006-08-02	Analyzed By:	WB
Prep Batch:	25167	Sample Preparation:	2006-08-02	Prepared By:	WB

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[1] BFB surrogate recovery outside normal limits. ICV/CCV and TFT surrogate recovery show the method to be in control.

Parameter	Flag	RL Result	Units	Dilution	RL
Chloride		**375**	mg/L	50	0.500
Sulfate		**234**	mg/L	50	0.500

Sample: 96140 - Monitor Well #1

Analysis:	TDS	Analytical Method:	SM 2540C	Prep Method:	N/A
QC Batch:	28406	Date Analyzed:	2006-07-27	Analyzed By:	SM
Prep Batch:	24850	Sample Preparation:	2009-07-26	Prepared By:	SM

Parameter	Flag	RL Result	Units	Dilution	RL
Total Dissolved Solids		**1318**	mg/L	2	10.00

Method Blank (1) QC Batch: 28277

QC Batch:	28277	Date Analyzed:	2006-07-24	Analyzed By:	MT
Prep Batch:	24759	QC Preparation:	2006-07-24	Prepared By:	MT

Parameter	Flag	MDL Result	Units	RL
Benzene		<0.000255	mg/L	0.001
Toluene		<0.000210	mg/L	0.001
Ethylbenzene		<0.000317	mg/L	0.001
Xylene		<0.000603	mg/L	0.001

Surrogate	Flag	Result	Units	Dilution	Spike Amount	Percent Recovery	Recovery Limits
Trifluorotoluene (TFT)		0.0949	mg/L	1	0.100	95	76.1 - 117
4-Bromofluorobenzene (4-BFB)		0.0633	mg/L	1	0.100	63	58.5 - 118

Method Blank (1) QC Batch: 28340

QC Batch:	28340	Date Analyzed:	2006-07-26	Analyzed By:	LJ
Prep Batch:	24777	QC Preparation:	2006-07-25	Prepared By:	LJ

Parameter	Flag	MDL Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1
Bicarbonate Alkalinity		<4.00	mg/L as CaCo3	4
Total Alkalinity		<4.00	mg/L as CaCo3	4

Method Blank (1) QC Batch: 28356

QC Batch:	28356	Date Analyzed:	2006-07-26	Analyzed By:	TP
Prep Batch:	24749	QC Preparation:	2006-07-24	Prepared By:	TS

Parameter	Flag	MDL Result	Units	RL
Dissolved Calcium		0.132	mg/L	0.5
Dissolved Potassium		1.08	mg/L	1
Dissolved Magnesium		<0.704	mg/L	1
Dissolved Sodium		0.836	mg/L	1

Method Blank (1) QC Batch: 28406

QC Batch: 28406
Prep Batch: 24850
Date Analyzed: 2006-07-27
QC Preparation: 2006-07-26
Analyzed By: SM
Prepared By: SM

Parameter	Flag	MDL Result	Units	RL
Total Dissolved Solids		<5.000	mg/L	10

Method Blank (1) QC Batch: 28782

QC Batch: 28782
Prep Batch: 25167
Date Analyzed: 2006-08-02
QC Preparation: 2006-08-02
Analyzed By: WB
Prepared By: WB

Parameter	Flag	MDL Result	Units	RL
Chloride		<0.0181	mg/L	0.5
Sulfate		<0.0485	mg/L	0.5

Duplicates (1)

QC Batch: 28340
Prep Batch: 24777
Date Analyzed: 2006-07-26
QC Preparation: 2006-07-25
Analyzed By: LJ
Prepared By: LJ

Param	Duplicate Result	Sample Result	Units	Dilution	RPD	RPD Limit
Hydroxide Alkalinity	<1.00	<1.00	mg/L as CaCo3	1	0	20
Carbonate Alkalinity	<1.00	<1.00	mg/L as CaCo3	1	0	20
Bicarbonate Alkalinity	110	108	mg/L as CaCo3	1	2	12.6
Total Alkalinity	110	108	mg/L as CaCo3	1	2	11.5

Duplicates (1)

QC Batch: 28406
Prep Batch: 24850
Date Analyzed: 2006-07-27
QC Preparation: 2006-07-26
Analyzed By: SM
Prepared By: SM

Param	Duplicate Result	Sample Result	Units	Dilution	RPD	RPD Limit
Total Dissolved Solids	768.0	928.0	mg/L	2	19	17.2

Laboratory Control Spike (LCS-1)

QC Batch: 28277
Prep Batch: 24759

Date Analyzed: 2006-07-24
QC Preparation: 2006-07-24

Analyzed By: MT
Prepared By: MT

Param	LCS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Benzene	0.109	mg/L	1	0.1	0	109	
Toluene	0.108	mg/L	1	0.1	0	108	
Ethylbenzene	0.109	mg/L	1	0.1	0	109	
Xylene	0.322	mg/L	1	0.3	0	107.333	

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	LCSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Benzene	0.104	mg/L	1	0.1	0	109		4.7	20
Toluene	0.103	mg/L	1	0.1	0	108		4.7	20
Ethylbenzene	0.101	mg/L	1	0.1	0	109		7.6	20
Xylene	0.306	mg/L	1	0.3	0	107.333		5.1	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Surrogate	LCS Result	LCSD Result	Units	Dil.	Spike Amount	LCS Rec.	LCSD Rec.	Rec. Limit
Trifluorotoluene (TFT)	0.101	0.101	mg/L	1	0.100	101	101	81.8 - 114
4-Bromofluorobenzene (4-BFB)	0.112	0.111	mg/L	1	0.100	112	111	72.7 - 116

Laboratory Control Spike (LCS-1)

QC Batch: 28356
Prep Batch: 24749

Date Analyzed: 2006-07-26
QC Preparation: 2006-07-24

Analyzed By: TP
Prepared By: TS

Param	LCS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Dissolved Calcium	51.7	mg/L	1	50	0	103.4	
Dissolved Potassium	50.8	mg/L	1	50	0	101.6	
Dissolved Magnesium	51.5	mg/L	1	50	0	103	
Dissolved Sodium	50.5	mg/L	1	50	0	101	

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	LCSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Dissolved Calcium	51.7	mg/L	1	50	0	103.4		0	20
Dissolved Potassium	49.3	mg/L	1	50	0	101.6		3	20
Dissolved Magnesium	49.8	mg/L	1	50	0	103		3.4	20
Dissolved Sodium	48.6	mg/L	1	50	0	101		3.8	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Laboratory Control Spike (LCS-1)

QC Batch: 28782
Prep Batch: 25167

Date Analyzed: 2006-08-02
QC Preparation: 2006-08-02

Analyzed By: WB
Prepared By: WB

Param	LCS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Chloride	12.2	mg/L	1	12.5	0	97.6	
Sulfate	12.5	mg/L	1	12.5	0	100	

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	LCSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Chloride	12.3	mg/L	1	12.5	0	97.6		0.8	20
Sulfate	12.5	mg/L	1	12.5	0	100		0	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Matrix Spike (MS-1) Spiked Sample: 96149

QC Batch:	28277	Date Analyzed:	2006-07-24	Analyzed By:	MT
Prep Batch:	24759	QC Preparation:	2006-07-24	Prepared By:	MT

Param	MS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Benzene	0.107	mg/L	1	0.100	<0.000255	107	70.9 - 126
Toluene	0.105	mg/L	1	0.100	<0.000210	105	70.8 - 125
Ethylbenzene	0.106	mg/L	1	0.100	<0.000317	106	74.8 - 125
Xylene	0.311	mg/L	1	0.300	<0.000603	104	75.7 - 126

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	MSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Benzene [2]	NA	mg/L	1	0.100	<0.000255	0	70.9 - 126	200	20
Toluene [3]	NA	mg/L	1	0.100	<0.000210	0	70.8 - 125	200	20
Ethylbenzene [4]	NA	mg/L	1	0.100	<0.000317	0	74.8 - 125	200	20
Xylene [5]	NA	mg/L	1	0.300	<0.000603	0	75.7 - 126	200	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Surrogate	MS Result	MSD Result	Units	Dil.	Spike Amount	MS Rec.	MSD Rec.	Rec. Limit
Trifluorotoluene (TFT) [6]	0.101	NA	mg/L	1	0.1	101	0	73.6 - 121
4-Bromofluorobenzene (4-BFB) [7]	0.110	NA	mg/L	1	0.1	110	0	81.8 - 114

Matrix Spike (MS-1) Spiked Sample: 96124

QC Batch:	28356	Date Analyzed:	2006-07-26	Analyzed By:	TP
Prep Batch:	24749	QC Preparation:	2006-07-24	Prepared By:	TS

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[2] RPD is out of range because a matrix spike duplicate was not prepared.
[3] RPD is out of range because a matrix spike duplicate was not prepared.
[4] RPD is out of range because a matrix spike duplicate was not prepared.
[5] RPD is out of range because a matrix spike duplicate was not prepared.
[6] RPD is out of range because a matrix spike duplicate was not prepared.
[7] RPD is out of range because a matrix spike duplicate was not prepared.

Param	MS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Dissolved Calcium	416	mg/L	1	50.0	361	110	68.4 - 138
Dissolved Potassium	73.8	mg/L	1	50.0	22	104	82 - 129
Dissolved Magnesium	208	mg/L	1	50.0	147	122	61.2 - 135
Dissolved Sodium	633	mg/L	1	50.0	578	110	81.8 - 125

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	MSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Dissolved Calcium	406	mg/L	1	50.0	361	90	68.4 - 138	2	20
Dissolved Potassium	81.3	mg/L	1	50.0	22	119	82 - 129	10	20
Dissolved Magnesium	194	mg/L	1	50.0	147	94	61.2 - 135	7	20
Dissolved Sodium	637	mg/L	1	50.0	578	118	81.8 - 125	1	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Matrix Spike (MS-1) Spiked Sample: 96141

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB
Prep Batch: 25167 QC Preparation: 2006-08-02 Prepared By: WB

Param	MS Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit
Chloride	2210	mg/L	100	12.5	988	98	25.4 - 171
Sulfate	1580	mg/L	100	12.5	298	102	0 - 677

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Param	MSD Result	Units	Dil.	Spike Amount	Matrix Result	Rec.	Rec. Limit	RPD	RPD Limit
Chloride	2200	mg/L	100	12.5	988	97	25.4 - 171	0	20
Sulfate	1550	mg/L	100	12.5	298	100	0 - 677	2	20

Percent recovery is based on the spike result. RPD is based on the spike and spike duplicate result.

Standard (ICV-1)

QC Batch: 28277 Date Analyzed: 2006-07-24 Analyzed By: MT

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Benzene		mg/L	0.100	0.104	104	85 - 115	2006-07-24
Toluene		mg/L	0.100	0.104	104	85 - 115	2006-07-24
Ethylbenzene		mg/L	0.100	0.104	104	85 - 115	2006-07-24
Xylene		mg/L	0.300	0.314	105	85 - 115	2006-07-24

Standard (CCV-1)

QC Batch: 28277 Date Analyzed: 2006-07-24 Analyzed By: MT

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Benzene		mg/L	0.100	0.107	107	85 - 115	2006-07-24
Toluene		mg/L	0.100	0.105	105	85 - 115	2006-07-24
Ethylbenzene		mg/L	0.100	0.106	106	85 - 115	2006-07-24
Xylene		mg/L	0.300	0.311	104	85 - 115	2006-07-24

Standard (ICV-1)

QC Batch: 28340 Date Analyzed: 2006-07-26 Analyzed By: LJ

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Alkalinity		mg/L as CaCo3	250	240	96	90 - 110	2006-07-26

Standard (CCV-1)

QC Batch: 28340 Date Analyzed: 2006-07-26 Analyzed By: LJ

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Alkalinity		mg/L as CaCo3	250	240	96	90 - 110	2006-07-26

Standard (ICV-1)

QC Batch: 28356 Date Analyzed: 2006-07-26 Analyzed By: TP

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Dissolved Calcium		mg/L	50.0	50.7	101	90 - 110	2006-07-26
Dissolved Potassium		mg/L	50.0	52.0	104	90 - 110	2006-07-26
Dissolved Magnesium		mg/L	50.0	49.6	99	90 - 110	2006-07-26
Dissolved Sodium		mg/L	50.0	50.9	102	90 - 110	2006-07-26

Standard (CCV-1)

QC Batch: 28356 Date Analyzed: 2006-07-26 Analyzed By: TP

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Dissolved Calcium		mg/L	50.0	51.2	102	90 - 110	2006-07-26
Dissolved Potassium		mg/L	50.0	54.6	109	90 - 110	2006-07-26
Dissolved Magnesium		mg/L	50.0	50.0	100	90 - 110	2006-07-26
Dissolved Sodium		mg/L	50.0	53.2	106	90 - 110	2006-07-26

Standard (ICV-1)

QC Batch: 28406 Date Analyzed: 2006-07-27 Analyzed By: SM

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Dissolved Solids		mg/L	1000	1056	106	90 - 110	2006-07-27

Standard (CCV-1)

QC Batch: 28406 Date Analyzed: 2006-07-27 Analyzed By: SM

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Total Dissolved Solids		mg/L	1000	1075	108	90 - 110	2006-07-27

Standard (ICV-1)

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB

Param	Flag	Units	ICVs True Conc.	ICVs Found Conc.	ICVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Chloride		mg/L	12.5	12.4	99	90 - 110	2006-08-02
Sulfate		mg/L	12.5	12.7	102	90 - 110	2006-08-02

Standard (CCV-1)

QC Batch: 28782 Date Analyzed: 2006-08-02 Analyzed By: WB

Param	Flag	Units	CCVs True Conc.	CCVs Found Conc.	CCVs Percent Recovery	Percent Recovery Limits	Date Analyzed
Chloride		mg/L	12.5	12.2	98	90 - 110	2006-08-02
Sulfate		mg/L	12.5	12.4	99	90 - 110	2006-08-02

Page 1 of 1

6701 Aberdeen Ave, Ste 9
Lubbock,Texas 79424
Tel (806) 794-1296
Fax (806) 794-1298
1 (800) 378-1296

TraceAnalysis, Inc.

155 McCutcheon Way, Suite H
El Paso,Texas 79932
Tel (915) 585-3443
Fax (915) 585-4944
1 (888) 588-3443

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6072143

Company Name: RICE Operating Company
Phone #: (505)393-9174
Address: (Street, City, Zip) 122 W Taylor Street - Hobbs, New Mexico 88240
Fax #: (505) 397-1471
Contact Person: Kristin Farris - Pope, Project Scientist
kpope@riceswd.com
Invoice to: (If different from above)
Project #: None Given
Project Name: BD Zachary Hinton
Project Location: Lea County - New Mexico
Sampler Signature: Rozanne Johnson (505)631-9310
rozanne@valornet.com

ANALYSIS REQUEST
(Circle or Specify Method No.)

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX					PRESERVATIVE METHOD						SAMPLING		MTBE 8021B/602	BTEX 8021B/602	TPH 418.1/TX1005 / TX1005 Extended (C35)	PAH 8270C	Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	TCLP Metals Ag As Ba Cd Cr Pb Se Hg	TCLP Volatiles	TCLP Semi Volatiles	TCLP Pesticides	RCI	GC/MS Vol. 8260B/624	GC/MS Semi. Vol. 8270C/625	PCB's 8082/608	Pesticides 8081A/608	BOD, TSS, pH	Moisture Content	Cations (Ca, Mg, Na, K)	Anions (Cl, SSSSO4, CO3, HCO3)	Total Dissolved Solids		Turn Around Time if different from standard	Hold
				WATER	SOIL	AIR	SLUDGE		HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE	NONE	DATE 2006	TIME																						
96140	Monitor Well #1	2	40 ml	X					X				X		7-19	12:55		X																				
	Monitor Well #1	1	1L	X									X		7-19	12:55																	X	X	X			

Relinquished by: Rozanne Johnson Date: 7-20-06 Time: 8:00
Received by: Date: Time:
Relinquished by: Date: Time:
Received by: Date: Time:
Relinquished by: Date: Time:
Received at Laboratory by: Megan Mc[illegible] Date: 7-21-06 Time: 1105

LAB USE ONLY
Intact [✓ Y] N
Headspace Y [✓ N]
Temp 40 °
Log-in Review MA

REMARKS:

☐ check if special reporting limits needed

Carrier # Bus GL 1690177159

Submittal of samples constitutes agreement to Terms and Conditions listed on reverse side of COC

Appendix E

Quality Assurance Protocols

R.T. Hicks Consultants, Ltd.

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

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EA62406 - General Preparation (WetChem)										
Blank (EA62406-BLK1)				*Prepared & Analyzed: 01/26/06*						
Total Alkalinity	ND	2.00	mg/L							
LCS (EA62406-BS1)				Prepared & Analyzed: 01/26/06						
Bicarbonate Alkalinity	220		mg/L	200		110	85-115			
Duplicate (EA62406-DUP1)	**Source: 6A19005-01**			Prepared & Analyzed: 01/26/06						
Total Alkalinity	258	2.00	mg/L		256			0.778	20	
Reference (EA62406-SRM1)				Prepared & Analyzed: 01/26/06						
Total Alkalinity	97.0		mg/L	100		97.0	90-110			
Batch EA63003 - General Preparation (WetChem)										
Blank (EA63003-BLK1)				Prepared: 01/26/06 Analyzed: 01/27/06						
Total Dissolved Solids	ND	5.00	mg/L							
Duplicate (EA63003-DUP1)	**Source: 6A25018-01**			Prepared: 01/26/06 Analyzed: 01/27/06						
Total Dissolved Solids	2020	5.00	mg/L		2080			2.93	5	
Batch EA63004 - General Preparation (WetChem)										
Blank (EA63004-BLK1)				Prepared & Analyzed: 01/30/06						
Sulfate	ND	0.500	mg/L							
Chloride	ND	0.500	"							
LCS (EA63004-BS1)				Prepared & Analyzed: 01/30/06						
Sulfate	9.61	0.500	mg/L	10.0		96.1	80-120			
Chloride	8.40	0.500	"	10.0		84.0	80-120			

General Chemistry Parameters by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EA63004 - General Preparation (WetChem)										
Calibration Check (EA63004-CCV1)				Prepared & Analyzed: 01/30/06						
Sulfate	9.82		mg/L	10.0		98.2	80-120			
Chloride	8.64		"	10.0		86.4	80-120			
Duplicate (EA63004-DUP1)	**Source: 6A25018-01**			Prepared & Analyzed: 01/30/06						
Sulfate	84.4	25.0	mg/L		88.2			4.40	20	
Chloride	879	25.0	"		886			0.793	20	

Total Metals by EPA / Standard Methods - Quality Control

Environmental Lab of Texas

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch EA62615 - 6010B/No Digestion										
Blank (EA62615-BLK1)				Prepared & Analyzed: 01/26/06						
Calcium	ND	0.0100	mg/L							
Magnesium	ND	0.00100	"							
Potassium	ND	0.0500	"							
Sodium	ND	0.0100	"							
Calibration Check (EA62615-CCV1)				Prepared & Analyzed: 01/26/06						
Calcium	2.12		mg/L	2.00		106	85-115			
Magnesium	1.99		"	2.00		99.5	85-115			
Potassium	1.88		"	2.00		94.0	85-115			
Sodium	1.94		"	2.00		97.0	85-115			
Duplicate (EA62615-DUP1)	**Source: 6A19005-01**			Prepared & Analyzed: 01/26/06						
Calcium	224	0.500	mg/L		222			0.897	20	
Magnesium	115	0.0500	"		120			4.26	20	
Potassium	14.6	0.500	"		15.2			4.03	20	
Sodium	306	0.500	"		313			2.26	20	

Notes and Definitions

DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
LCS	Laboratory Control Spike
MS	Matrix Spike
Dup	Duplicate

Report Approved By: Raland K Tuttle Date: 2/1/2006

Raland K. Tuttle, Lab Manager
Celey D. Keene, Lab Director, Org. Tech Director
Peggy Allen, QA Officer

Jeanne Mc Murrey, Inorg. Tech Director
LaTasha Cornish, Chemist
Sandra Sanchez, Lab Tech.

Environmental Lab of Texas

12600 West I-20 East
Odessa, Texas 79765

Phone: 432-563-1800
Fax: 432-563-1713

CHAIN OF CUSTODY RECORD AND ANALYSIS REQUEST

Project Manager: Kristin Farris Pope kpriceswd@valornet.com
Company Name RICE Operating Company
Company Address: 122 W. Taylor Street
City/State/Zip: Hobbs, New Mexico 88240
Telephone No: (505) 393-9174
Fax No: (505) 397-1471
Sampler Signature: Rozanne Johnson (505) 631-9310
Email: rozanne@valornet.com

Project Name: BD Zachary Hinton
Project #:
Project Loc: Lea County
PO #:

					Preservative							Matrix				Analyze For:															
																TCLP:															
																TOTAL:							X								
LAB # (lab use only) (A42502)	FIELD CODE	Date Sampled	Time Sampled	No. of Containers	Ice	HNO_3	HCl (2) 40 ml glass vials	NaOH	H_2SO_4	None (1) 1 Liter HDPE	Other (Specify)	Water	Sludge	Soil	Other (specify):	TPH: 418.1 8015M 1005 1006	Cations (Ca, Mg, Na, K)	Anions (Cl, SO4, CO3, HCO3)	SAR / ESP / CEC	Metals: As Ag Ba Cd Cr Pb Hg Se	Volatiles	Semivolatiles	BTEX 8021B/5030	RCI	N.O.R.M.	Total Dissolved Solids				RUSH TAT (Pre-Schedule)	Standard TAT
	Monitor Well #1	1/23/2006	9:45	3	X		2			1		X					X	X					X			X					X

Special Instructions:

PLEASE Email RESULTS TO: kpriceswd@valornet.com & mfranks@riceswd.com

Relinquished by: Rozanne Johnson	Date 1/23/06	Time 1:25	Received by:	Date	Time
Relinquished by:	Date	Time	Received by ELOT:	Date 01-23-06	Time 1325

Sample Containers Intact? [✓ Y] N
Labels on container? [✓ Y] N
Custody Seals: [✓ Containers] / [✓ Cooler]
Temperature Upon Receipt: -2.5 C
Laboratory Comments: not frozen