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REPORTS

DATE:

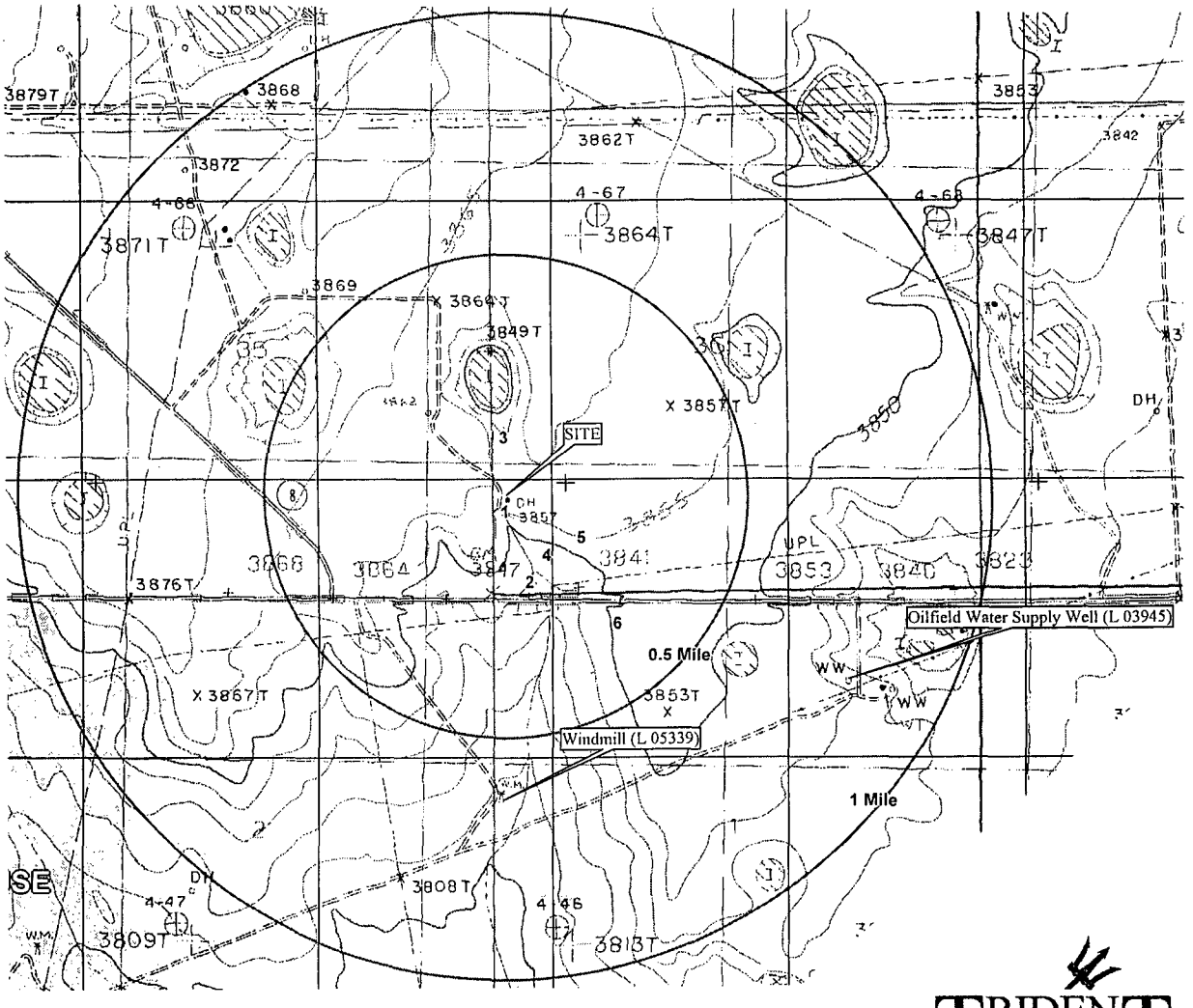
2002

UNOCAL CORPORATION
2002 ANNUAL GROUNDWATER MONITORING REPORT
FORMER UNOCAL SOUTH VACUUM UNIT
LEA COUNTY, NEW MEXICO

MARCH 4, 2003

Prepared For:

Unocal Corporation
Real Estate & Remediation
P. O. Box 1283
Nederland, Texas 77627



TRIDENT ENVIRONMENTAL

P. O. Box 7624
Midland, Texas 79708

2002 Annual Groundwater Monitoring Report

Unocal Corporation

Real Estate and Remediation Services

Former Unocal South Vacuum Unit

Lea County, New Mexico

Prepared by:

Trident Environmental
P. O. Box 7624
Midland, Texas 79708
(915) 682-0808
FAX (915) 682-0727

SBMITTED BY:

Gilbert J. Van Deventer, REM
Project Manager

DATE:

March 4, 2003

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

1.0 Executive Summary

Trident Environmental (Trident) was retained by ENSR Corporation (ENSR) and Unocal Real Estate and Remediation Services (Unocal) to perform the 2002 annual groundwater sampling and monitoring operations at the Former Unocal South Vacuum Unit in Lea County, New Mexico. This report documents the 2002 annual sampling event performed by Trident at the site on July 11, 2002. This report also contains the historical groundwater elevation and analytical data and includes data from all monitoring wells (MW-1 through MW-6) on site. The sampling event was conducted in accordance with the November 2, 2000 Groundwater Remediation Plan submitted by Unocal and the requirements specified in the New Mexico Oil and Conservation Division (OCD) letter dated February 8, 2001.

Based on the sampling and monitoring data to date, the following conclusions relevant to groundwater conditions at the Former Unocal South Vacuum Unit are evident:

- The fate and transport modeling results continue to support the contention that the chloride and total dissolved solids (TDS) plume is not likely to impact existing sources of water supply, the closest of which, a livestock well, lies approximately 3,200 feet south of the source.

- According to conservative model simulations, the chloride plume will travel a maximum of 4,620 feet southeast of the source in approximately 218 years before concentrations return to levels below the New Mexico Water Quality Control Commission (WQCC) standard of 250 mg/L. The same analysis indicates that the TDS plume will travel only 2,320 feet in approximately 111 years before concentrations return to levels below the WQCC standard of 1,000 mg/L.

- Based on the modeling results and predicted natural attenuation processes (advection and dispersion), there will be no adverse impact to human health and the environment nor will the livestock well exceed WQCC standards for chlorides or TDS due to the plume originating and traveling southeast, versus south, from the former emergency overflow pit.

- Groundwater elevations have been steadily decreasing at a rate of approximately 0.3 feet per year since the initial sampling event of monitoring well MW-1 in January 1995.

Based on the identified potential receptor and fate and transport modeling results, the chloride/TDS plume at the site presents low risk to human health and the environment; therefore Trident recommends the following actions:

- Continue the natural attenuation annual monitoring program with groundwater sampling and analysis of chloride and TDS concentrations for each of the six monitoring wells.

- Update flow and transport model to confirm the plume is naturally attenuating as described.

- Submit the 2003 annual groundwater monitoring report to OCD by April 2004 to document natural attenuation conditions.

- Provide an alternate means for supplying freshwater in the event there is a need for municipal, domestic, livestock, and/or irrigation water in the plume area.

2.0 Groundwater Sampling Procedures

Each of the six monitoring wells, MW-1 through MW-6, was gauged for depth to groundwater using a Solinst Model 101 electronic water indicator immediately prior to purging operations. A total of 48 gallons of groundwater was purged from each site monitoring well (5 to 10 gallons per well) using a decontaminated 2-inch diameter PVC bailer. After purging, groundwater samples were collected and parameters were measured using a Hydac Model 910 pH-Conductivity-Temperature meter. Water samples for each monitoring well were transferred into 500 milliliter (ml) plastic containers for laboratory analysis of total dissolved solids (TDS) (EPA Method 160.1) and chloride (EPA Method 325.3). For each set of samples, chain of custody forms documenting sample identification numbers, collection times, and delivery times to the laboratory were completed. All water samples were placed in an ice-filled cooler immediately after collection and transported to SPL, Inc. in Houston, Texas for analysis.

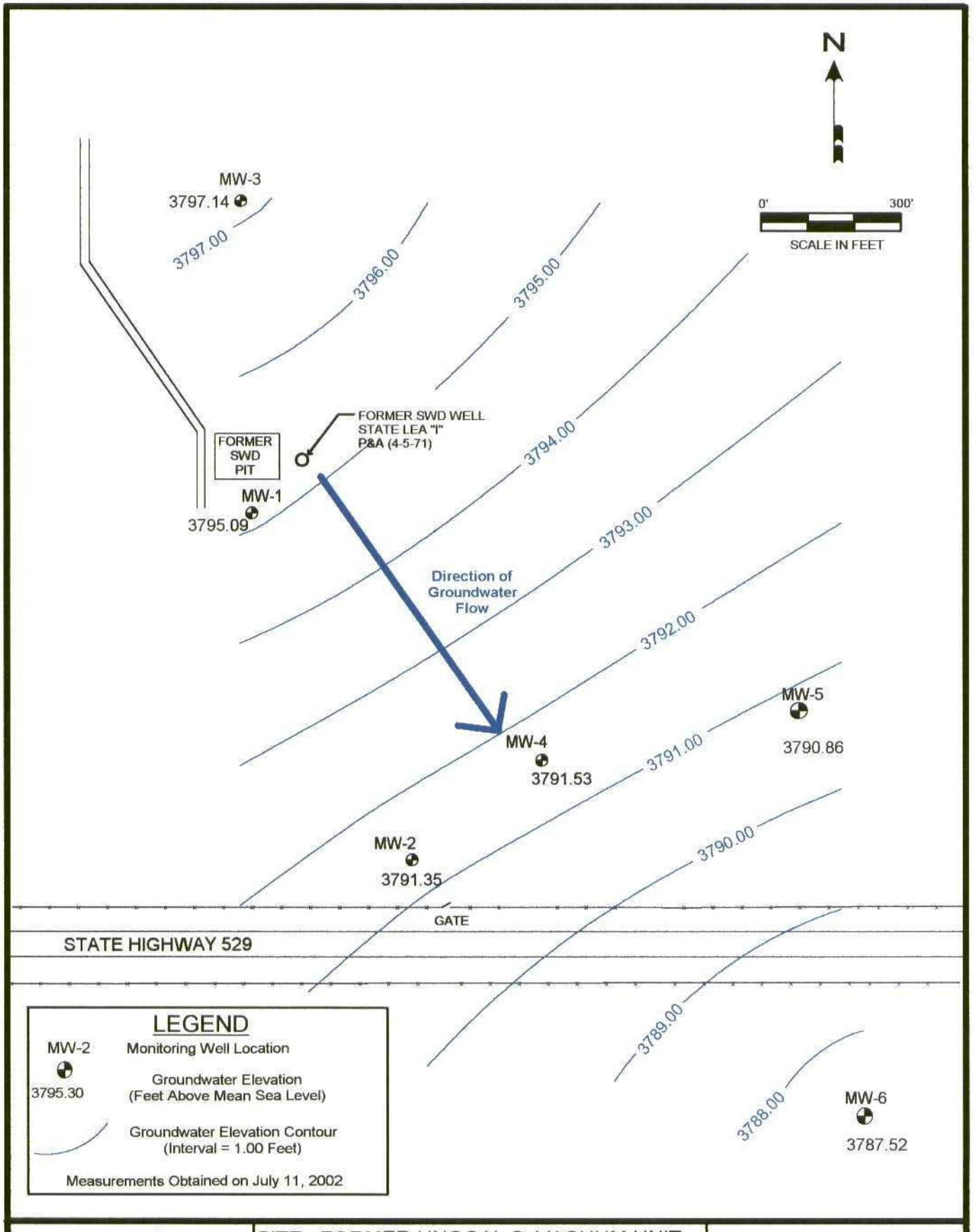
3.0 Groundwater Elevations, Hydraulic Gradient and Flow Direction

Depth to groundwater varies from approximately 47 to 67 feet below ground surface at the site. Groundwater elevations are summarized in Table 1. A groundwater gradient map indicating the direction of groundwater flow is illustrated in Figure 1. A historical groundwater elevation graph is shown in Figure 2. The groundwater gradient direction is to the southeast with a hydraulic gradient of approximately 0.004 ft/ft. According to published reports (*Ground-Water Conditions in Northern Lea County, New Mexico*, Ash, 1963 and *Geology and Ground-Water Conditions in Southern Lea County, New Mexico*, Nicholson and Clebsch, 1961) the groundwater encountered at the site is that of the Tertiary Ogallala Formation. The Ogallala Formation unconformably overlies the impermeable red-beds of the Triassic Chinle Formation at an elevation of approximately 3700 feet above mean sea level (AMSL). Based on the current groundwater elevations measured on site and published data referenced, the saturated thickness of the Ogallala Formation at the site ranges from approximately 85 to 95 feet.

Table 1
Summary of Groundwater Elevations and Chloride and TDS Concentrations
Former Unocal South Vacuum Unit

Monitoring Well	Sample Date	Ground Surface Elevation (feet AMSL)	Top of Casing Elevation (feet AMSL)	Depth to Groundwater (feet BTOC)	Groundwater Elevation (feet AMSL)	Chloride (mg/L)	TDS (mg/L)
MW-1	01/27/95	3856.76	3858.37	59.57	3798.80	**1174**	**2250**
	05/18/95	3856.76	3858.37	61.30	3797.07	**983**	**2251**
	08/28/96	3856.76	3858.37	61.57	3796.80	**1420**	**2730**
	08/13/97	3856.76	3858.37	61.75	3796.62	**1400**	**2800**
	12/14/98	3858.37	3858.37	NM	NM	**1400**	**2400**
	09/30/99	3856.76	3858.37	62.51	3795.86	**1094**	**2318**
	06/14/00	3856.76	3858.37	62.85	3795.52	**927**	**2040**
	06/18/01	3856.76	3858.37	63.07	3795.30	**813**	**1790**
	07/11/02	3856.76	3858.37	63.28	3795.09	**784**	**1680**
MW-2	09/30/99	3839.11	3841.64	49.51	3792.13	**298**	922
	06/14/00	3839.11	3841.64	49.81	3791.83	**317**	852
	06/18/01	3839.11	3841.64	50.06	3791.58	**288**	878
	07/11/02	3839.11	3841.64	50.29	3791.35	**284**	808
MW-3	09/30/99	3862.20	3864.73	66.74	3797.99	73.6	427
	06/14/00	3862.20	3864.73	67.01	3797.72	75.5	433
	06/18/01	3862.20	3864.73	67.29	3797.44	86.4	495
	07/11/02	3862.20	3864.73	67.59	3797.14	103	509
MW-4	09/30/99	3849.87	3852.51	60.18	3792.33	**1576**	**2981**
	06/14/00	3849.87	3852.51	60.55	3791.96	**1500**	**2910**
	06/18/01	3849.87	3852.51	60.78	3791.73	**1530**	**3180**
	07/11/02	3849.87	3852.51	60.98	3791.53	**1290**	**2660**
MW-5	06/14/00	3856.59	3859.84	68.57	3791.27	13.7	274
	06/18/01	3856.59	3859.84	68.80	3791.04	13.6	322
	07/11/02	3856.59	3859.84	68.98	3790.86	15.5	308
MW-6	06/14/00	3855.32	3858.78	70.79	3787.99	48	382
	06/18/01	3855.32	3858.78	70.98	3787.80	50.8	431
	07/11/02	3855.32	3858.78	71.26	3787.52	50	422
Water Quality Control Commission (WQCC) Standards						250	1000

AMSL – Above Mean Sea Level; BTOC – Below Top of Casing; NM – No Measurement
Groundwater flow direction is to the southeast with a gradient of approximately 0.004 feet/foot.
Elevations and state plane coordinates surveyed by Basin Surveys, Hobbs, NM.



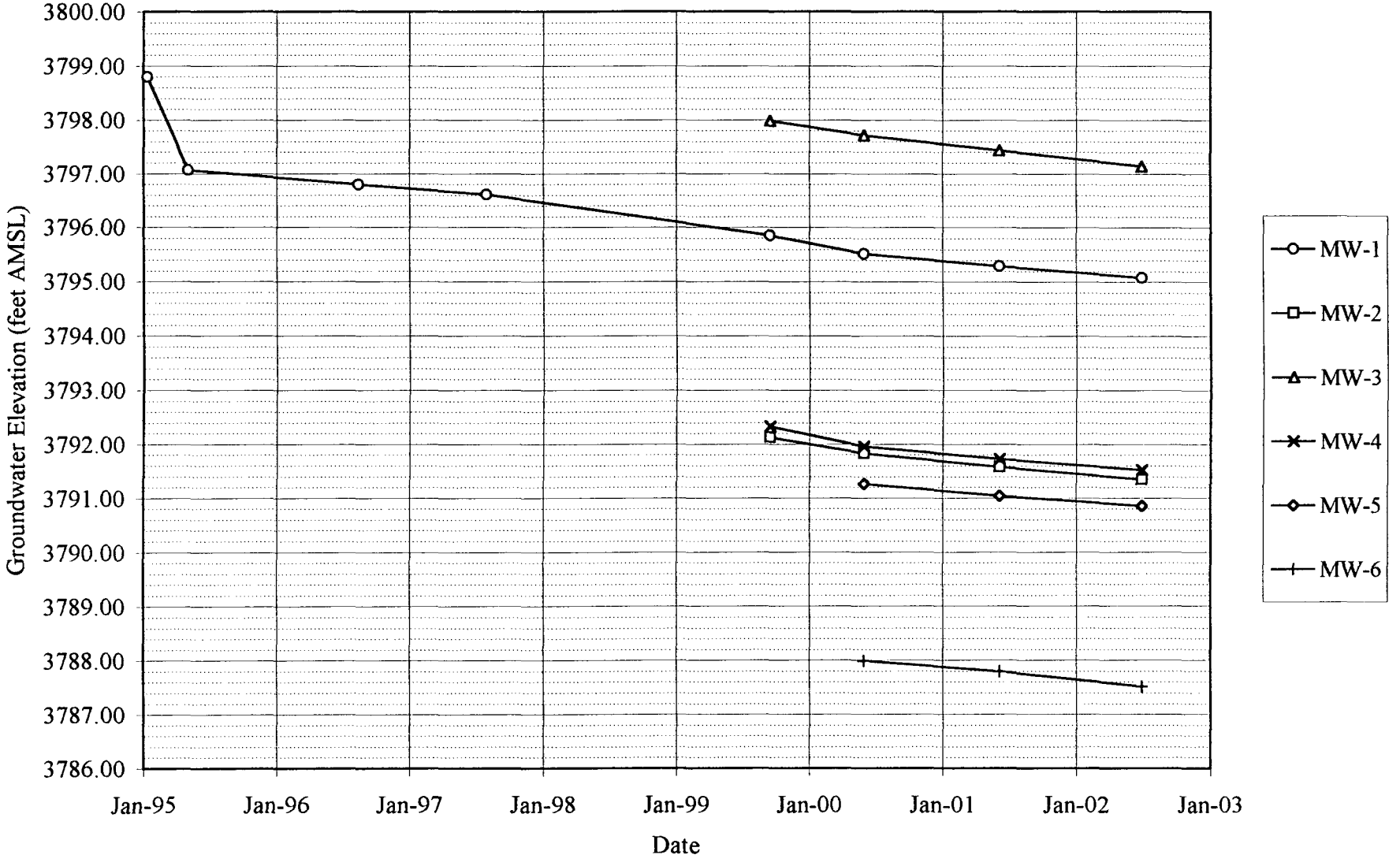
TRIDENT ENVIRONMENTAL

SITE: FORMER UNOCAL S. VACUUM UNIT	
DATE: 07/11/02	SCALE: 1 IN = 300 FT
AUTHOR: GJV	DRN BY: GJV
CK'D BY: DTL	FILE: VAC 2002

FIGURE 1

GROUNDWATER ELEVATION MAP

Figure 2
Historical Groundwater Elevations

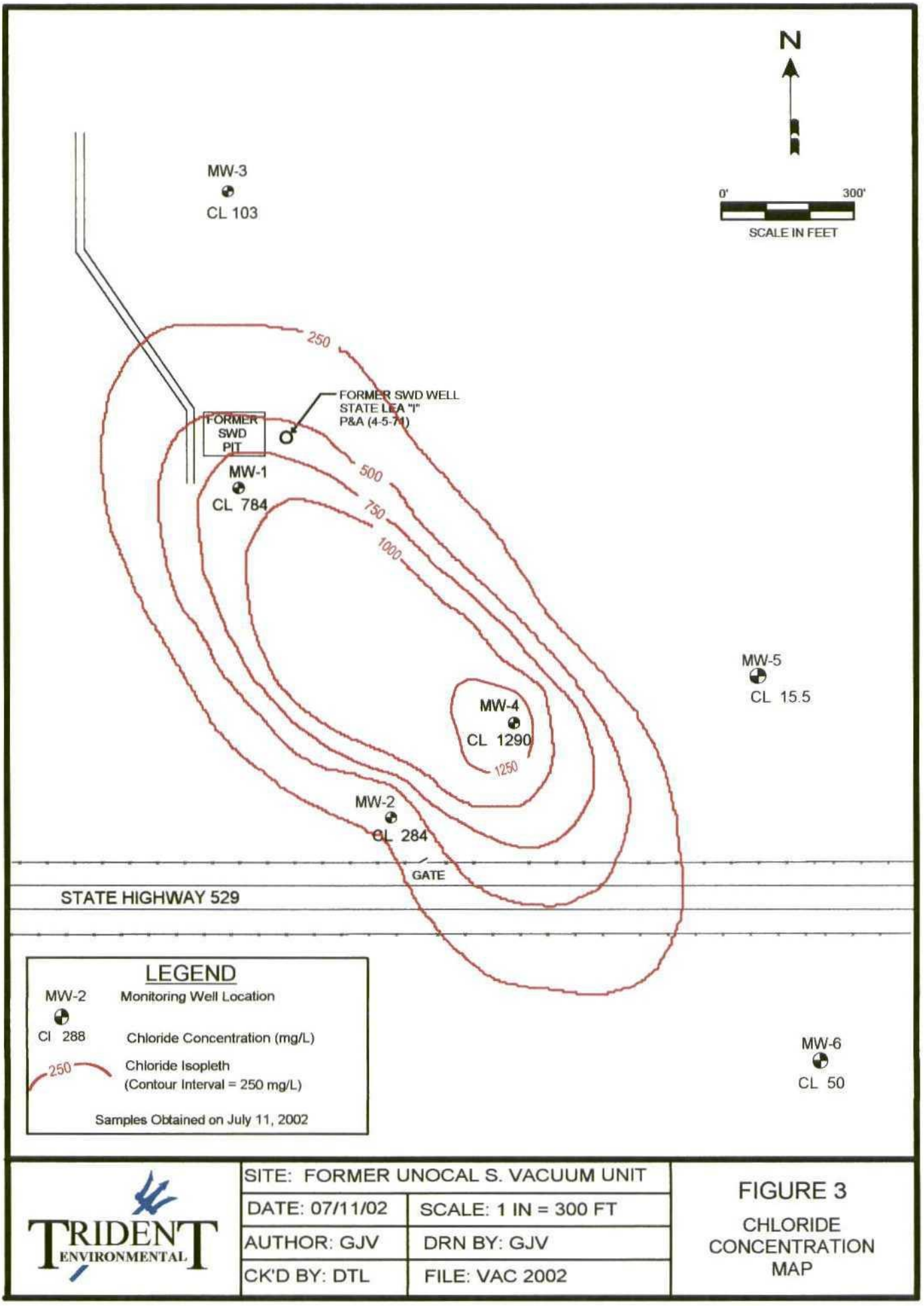


4.0 Groundwater Quality Conditions

Groundwater sample analytical results are presented in Table 1. The WQCC standards are presented for comparison. Those constituents that recorded concentrations above the WQCC standards are highlighted in boldface type. The WQCC standard of 250 mg/L for chloride was exceeded in MW-1 (784 mg/L), MW-2 (284 mg/L), and MW-4 (1,290 mg/L). The WQCC standard of 1,000 mg/L for TDS was exceeded in MW-1 (1,680 mg/L) and MW-4 (2,660 mg/L). The groundwater samples obtained from upgradient monitoring well MW-3 and downgradient wells MW-5 and MW-6 had chloride and TDS concentrations below WQCC standards.

The chloride and TDS concentrations are depicted graphically in Figure 3 and 4, respectively. The concentration isopleths were drawn utilizing the Surfer® (version 6.0) contour modeling program (Kriging method). Since this contouring program does not take into account the known groundwater gradient, some of the isopleths were manually converged into a more southeasterly orientation. Graphs depicting historical TDS and chloride concentrations in monitoring wells MW-1and MW-4 are shown in Figures 5 and 6.

Chloride and TDS concentrations in MW-1, near the source area, have consistently decreased since 1996. Similarly, chloride and TDS levels have decreased in the closest downgradient well, MW-4, since 1999 when that well was installed. Chloride and TDS concentrations in the remaining wells (MW-2, MW-3, MW-5, and MW-6) have remained relatively consistent with previous levels.

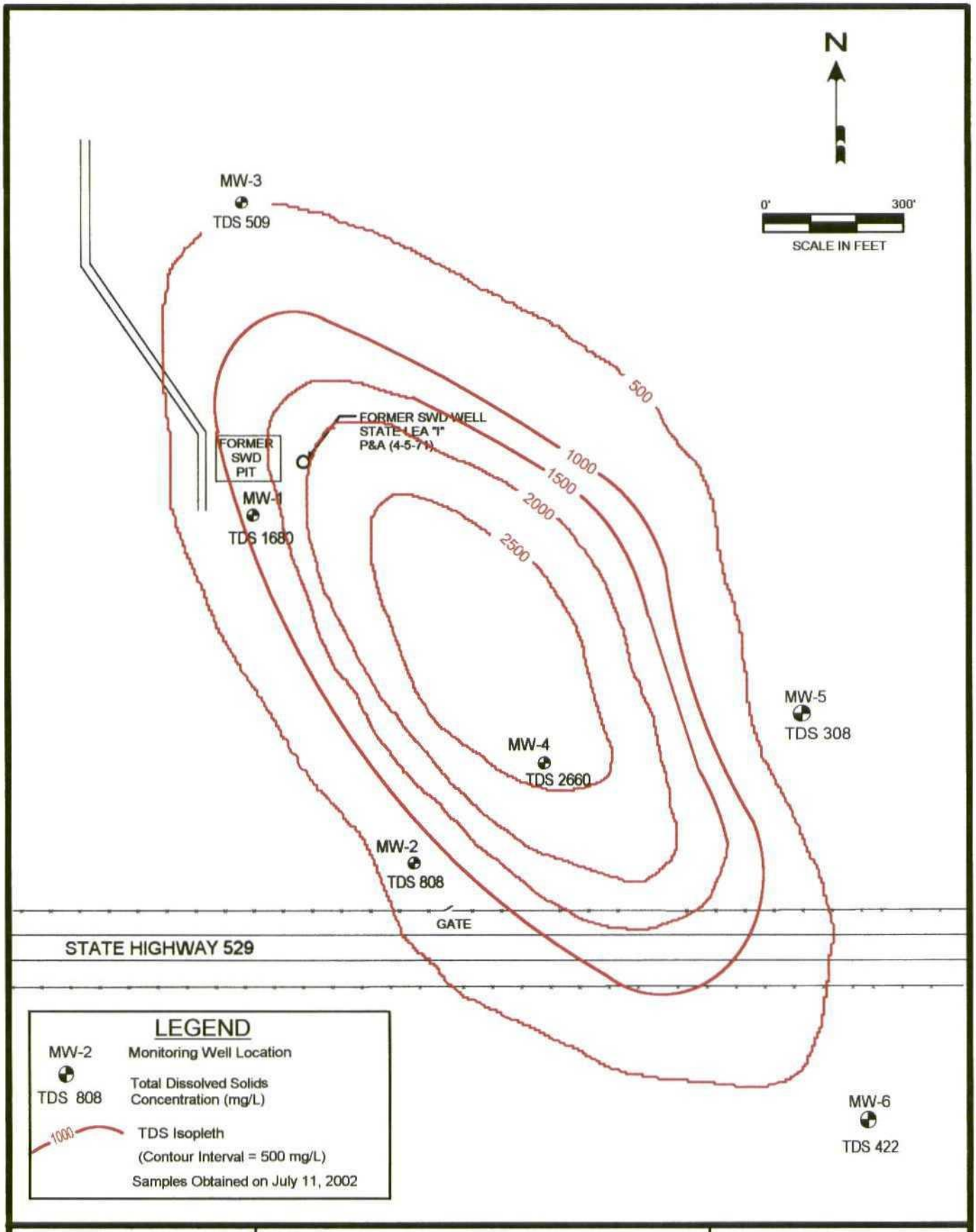


TRIDENT ENVIRONMENTAL

SITE: FORMER UNOCAL S. VACUUM UNIT	
DATE: 07/11/02	SCALE: 1 IN = 300 FT
AUTHOR: GJV	DRN BY: GJV
CK'D BY: DTL	FILE: VAC 2002

FIGURE 3

CHLORIDE CONCENTRATION MAP



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SITE: FORMER UNOCAL S. VACUUM UNIT	
DATE: 07/11/02	SCALE: 1 IN = 300 FT
AUTHOR: GJV	DRN BY: GJV
CK'D BY: DTL	FILE: VAC 2002

FIGURE 4

TOTAL DISSOLVED SOLIDS CONCENTRATION MAP

Figure 5
Chloride Concentrations Versus Time Graph

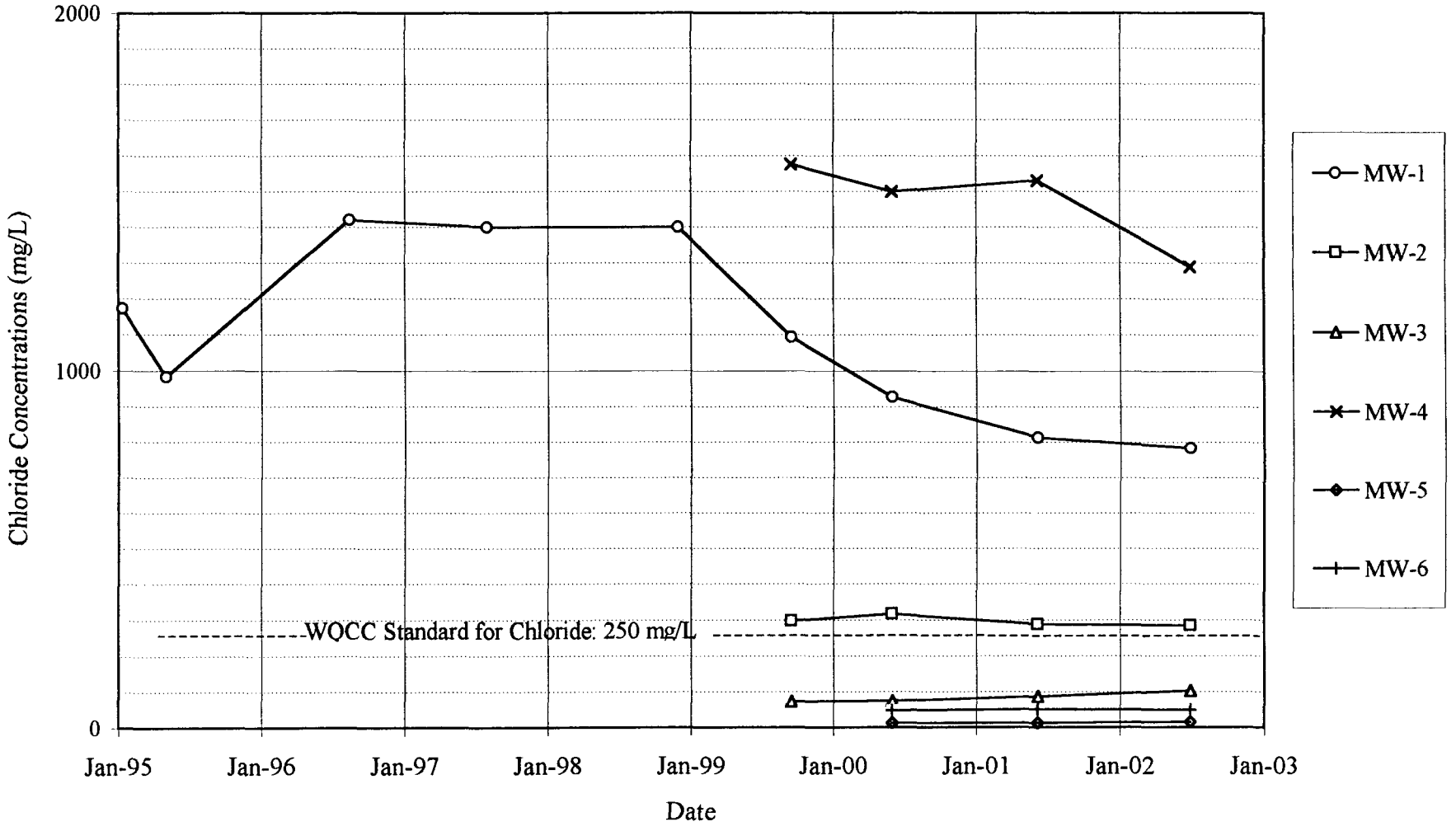
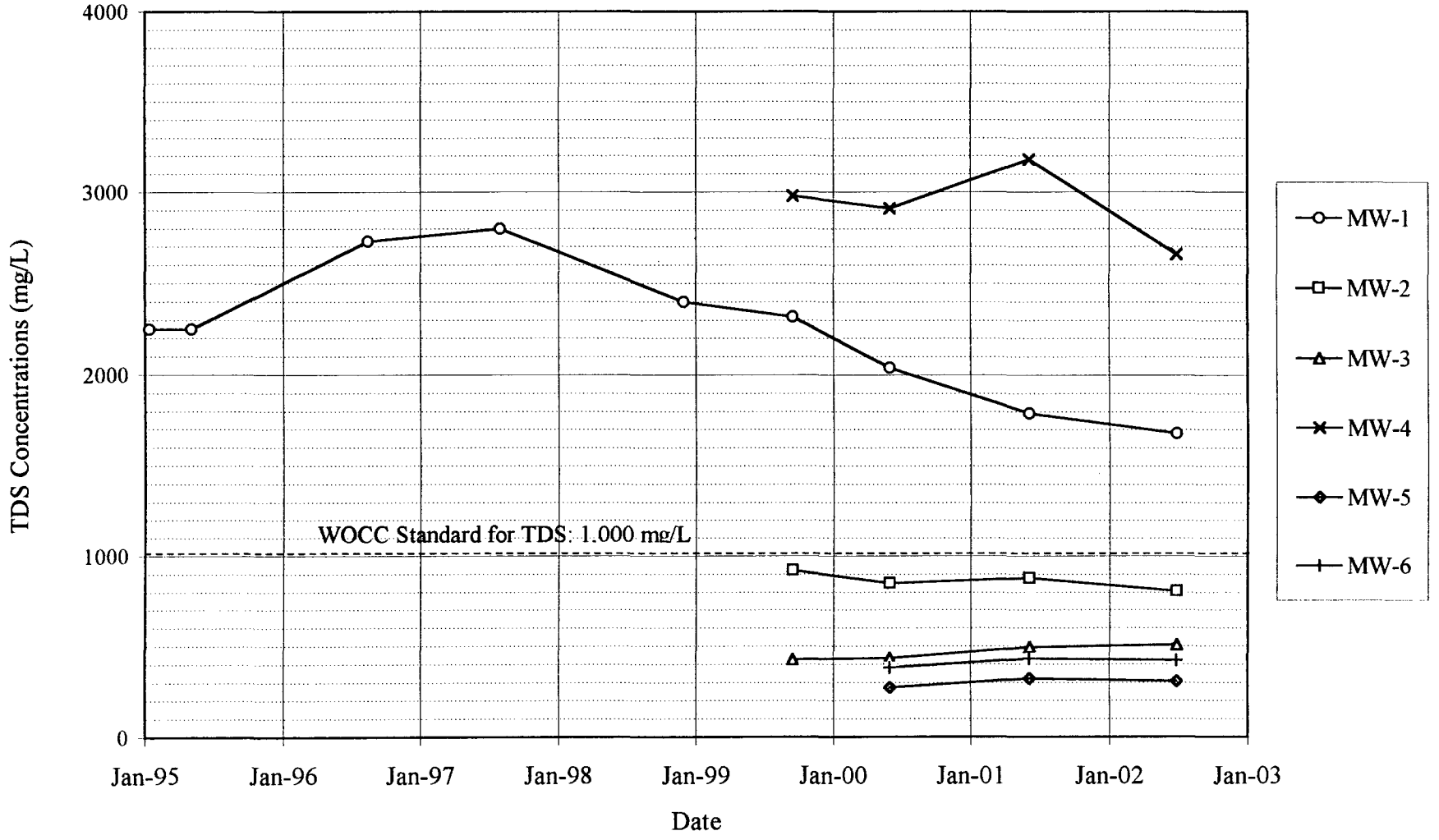


Figure 6
Total Dissolved Solids Concentrations Versus Time Graph



5.0 Fate and Transport Modeling Results

Fate and transport modeling was performed by Trident to simulate the movement of the chloride and TDS groundwater plume over time. Simulations were conducted using the two-dimensional groundwater flow and contaminant transport model WinTran, version 1.03 (1995) designed and distributed by Environmental Simulations, Inc. (ESI) of Herndon, Virginia. WinTran is built around a steady-state analytical element flow model, linked to a finite element contaminant transport model. A more detailed discussion of the flow and transport parameters used, assumptions, model calibrations, and simulation results are described in Appendix C.

Figures 7A and 7B show the close match achieved by the chloride and TDS modeling simulations as compared to the current observed plume (Figures 3 and 4). Dispersion serves to broaden the dimensions of the plume while reducing the concentrations in the middle of the plume, as depicted in Figures 8A and 8B (50 years from now). Advective flow moves the center of plume mass downgradient by a distance of approximately 800 feet from an initial current position just upgradient from well MW-4.

Continued attenuation and dispersion of the plume, after the maximum chloride and TDS concentrations attenuate to levels below WQCC standards, is shown in Figures 9A (year 2220) and 9B (year 2113), respectively. The center of the chloride plume is approximately 4,620 ft away from the pit and well source in the year 2220. The center of the TDS plume is approximately 2,320 ft away from the pit and well source in the year 2113.

The portions of the chloride and TDS plumes that are above WQCC standards do not reach any of the identified potential receptors at any time during their attenuation. The updated fate and transport model is consistent with that determined in the two previous annual reports, however the plumes attenuate sooner as a result of inputting the most recent chloride and TDS concentrations.

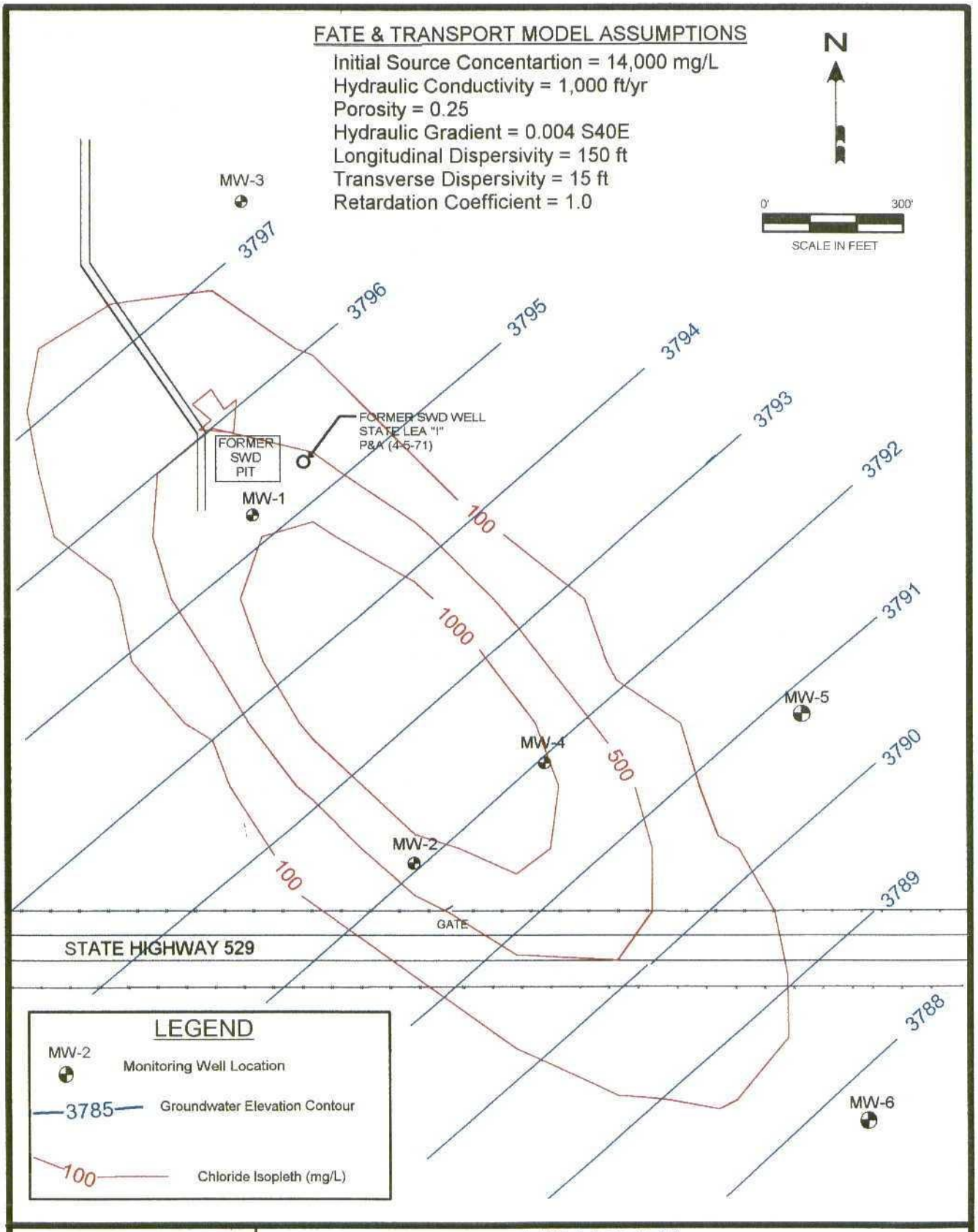


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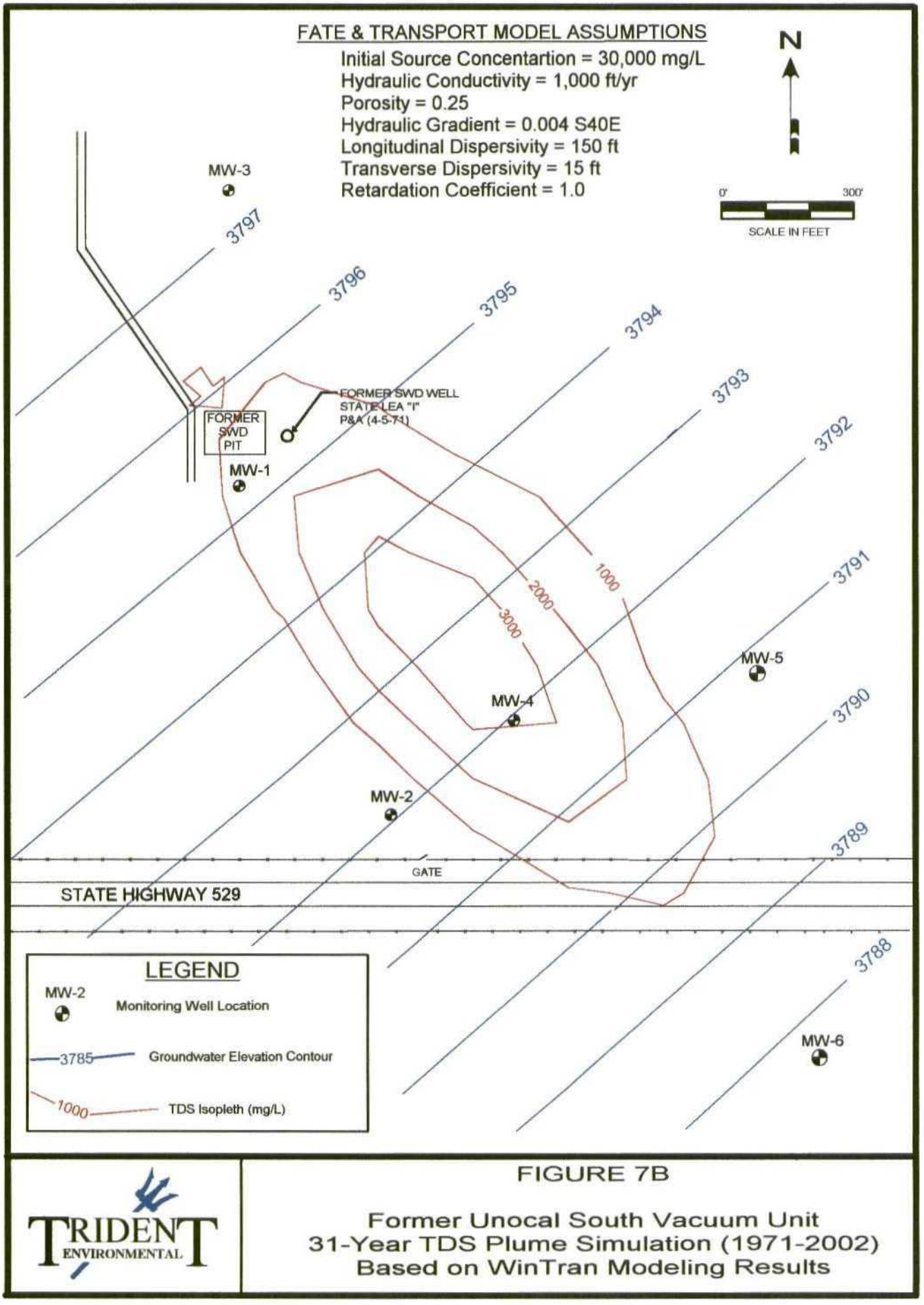
FIGURE 7A

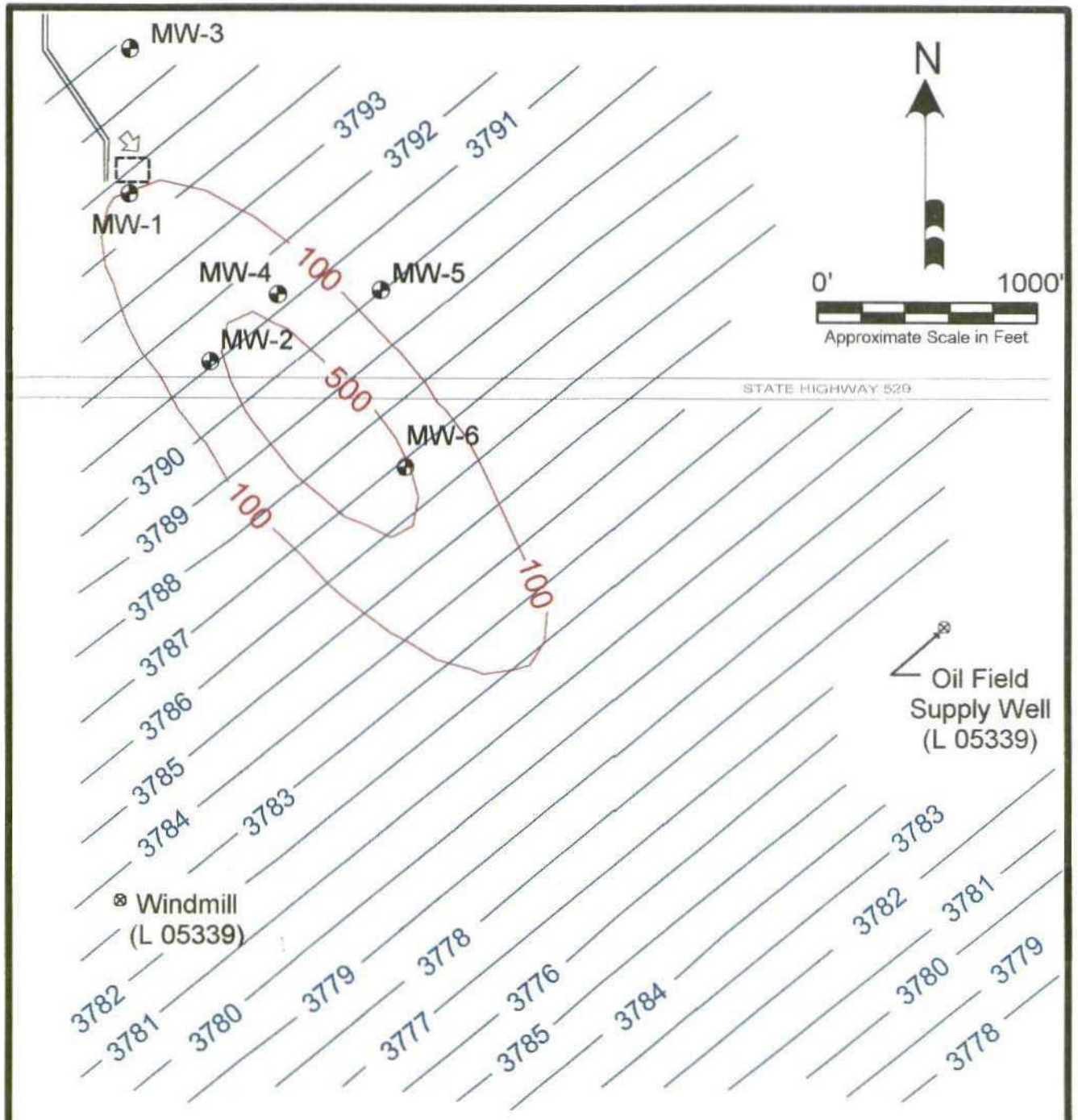
Former Unocal South Vacuum Unit
31-Year Chloride Plume Simulation (1971-2002)
Based on WinTran Modeling Results



TRIDENT ENVIRONMENTAL

FIGURE 7B

Former Unocal South Vacuum Unit
31-Year TDS Plume Simulation (1971-2002)
Based on WinTran Modeling Results



FATE & TRANSPORT MODEL ASSUMPTIONS

Initial Source Concentartion = 14,000 mg/L
Hydraulic Conductivity = 1,000 ft/yr
Porosity = 0.25
Hydraulic Gradient = 0.004 S40E
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Retardation Coefficient = 1.0

LEGEND

MW-5 — Monitoring Well Location

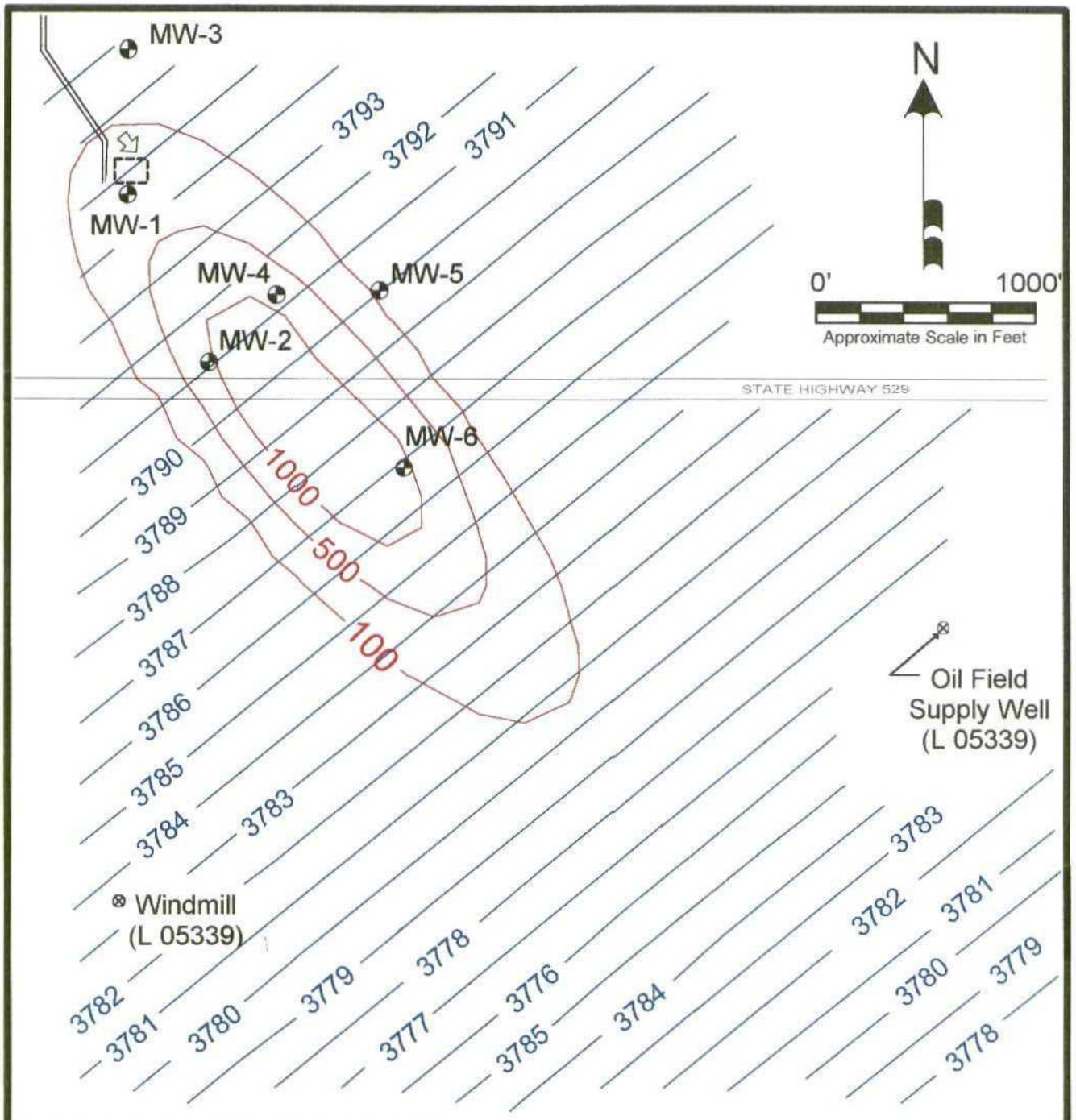
3785 — Groundwater Elevation Contour

100 — Chloride Isopleth (mg/L)

TRIDENT ENVIRONMENTAL

FIGURE 8A

Former Unocal South Vacuum Unit
50-Year Chloride Plume Simulation (2002-2052)
Based on WinTran Modeling Results



FATE & TRANSPORT MODEL ASSUMPTIONS

Initial Source Concentartion = 30000 mg/L
Hydraulic Conductivity = 1000 ft/yr
Porosity = 0.25
Hydraulic Gradient = 0.004 S40E
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Retardation Coefficient = 1.0

LEGEND

MW-5 Monitoring Well Location

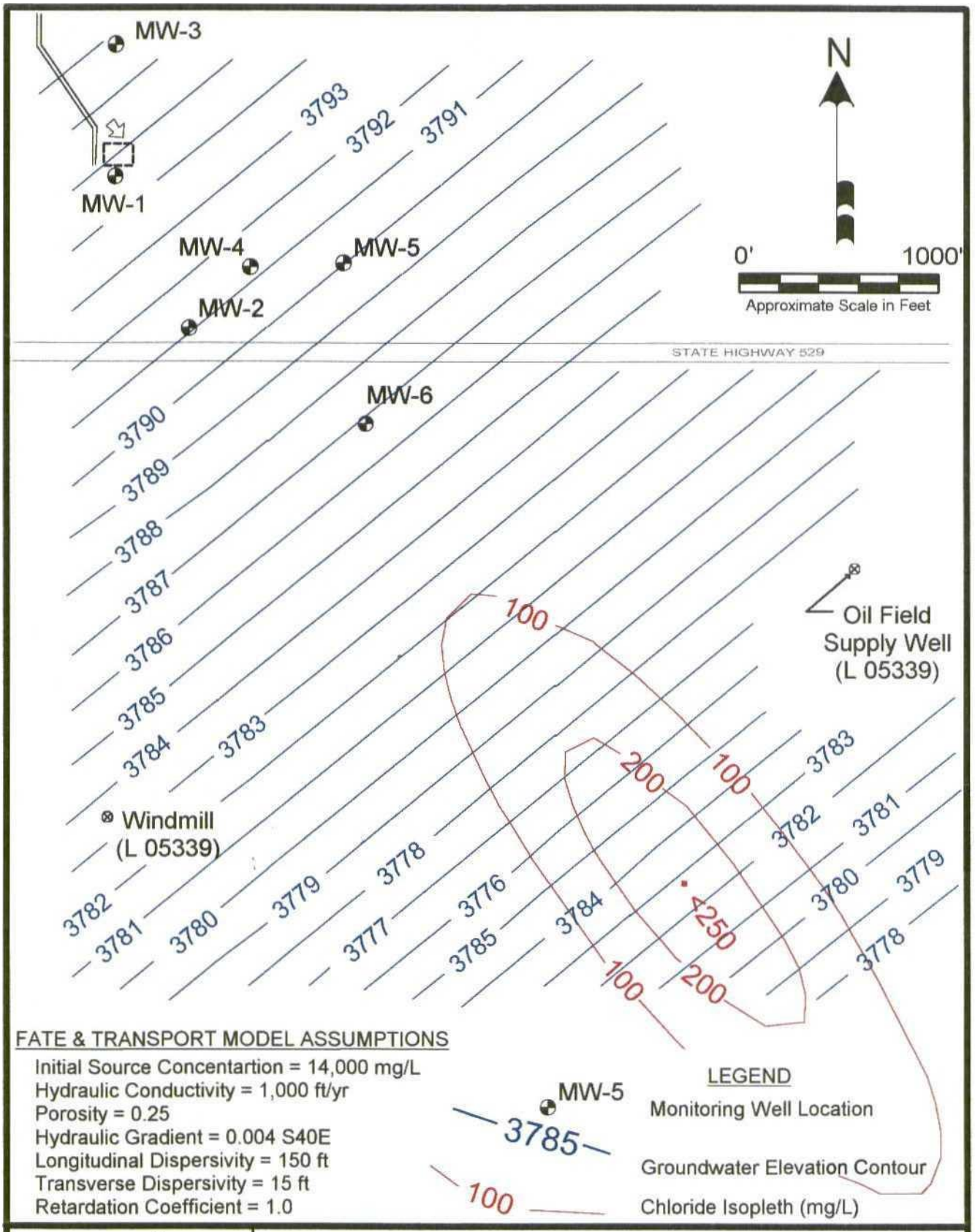
3778 Groundwater Elevation Contour

100 TDS Isopleth (mg/L)

TRIDENT ENVIRONMENTAL

FIGURE 8B

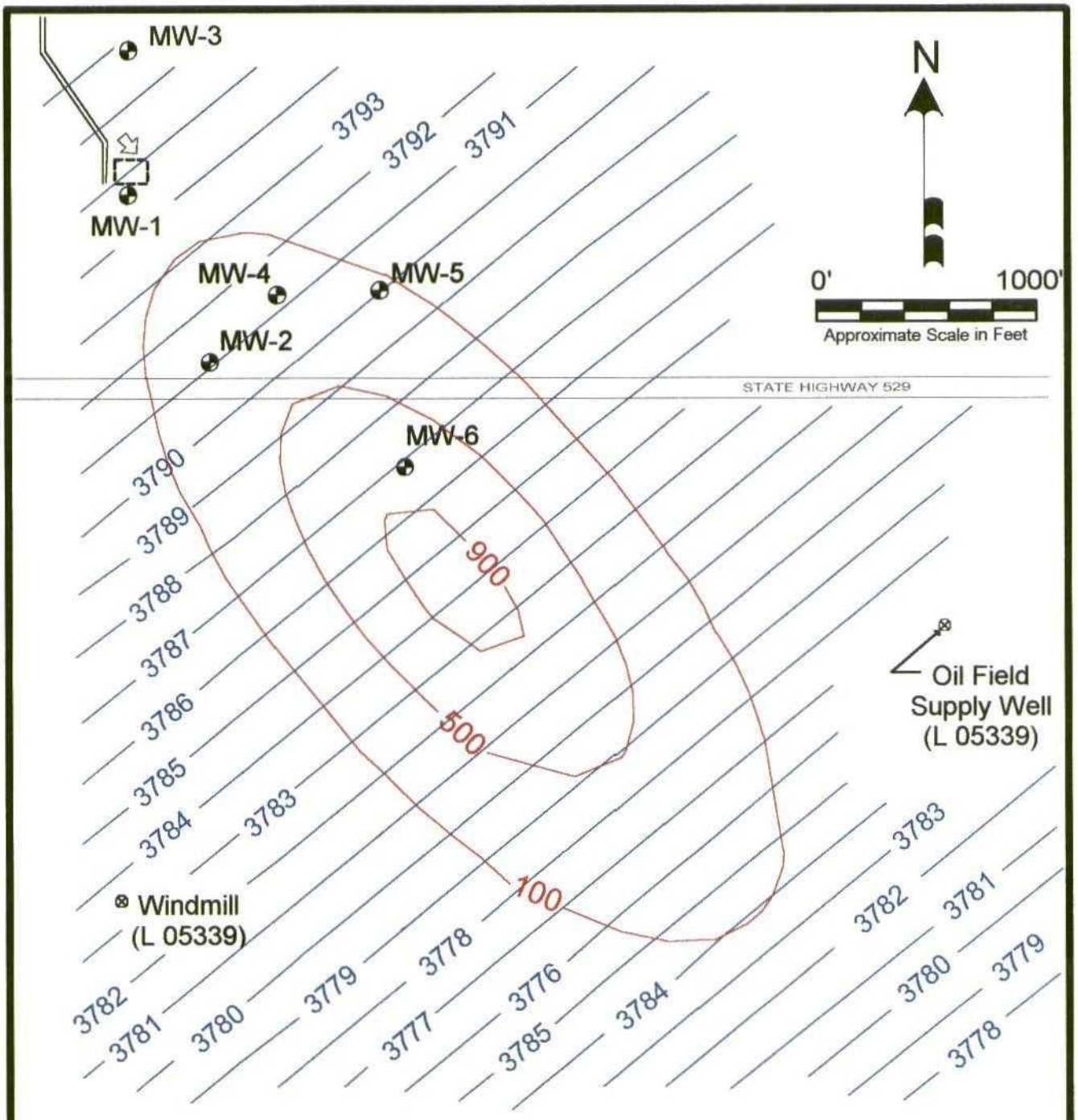
Former Unocal South Vacuum Unit
50-Year TDS Plume Simulation (2002-2052)
Based on WinTran Modeling Results



TRIDENT ENVIRONMENTAL

FIGURE 9A

Former Unocal South Vacuum Unit
218-Year Chloride Plume Simulation (2002-2220)
Based on WinTran Modeling Results



FATE & TRANSPORT MODEL ASSUMPTIONS

Initial Source Concentartion = 30000 mg/L
Hydraulic Conductivity = 1000 ft/yr
Porosity = 0.25
Hydraulic Gradient = 0.004 S40E
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Retardation Coefficient = 1.0

LEGEND

MW-5 Monitoring Well Location

3778 Groundwater Elevation Contour

100 TDS Isopleth (mg/L)

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FIGURE 9B

Former Unocal South Vacuum Unit
111-Year TDS Plume Simulation (2002-2113)
Based on WinTran Modeling Results

6.0 Conclusions

Conclusions relevant to groundwater conditions and the remediation performance at the Former Unocal South Vacuum Unit are presented below.

- Chloride and TDS concentrations in MW-1, near the source area, have consistently decreased since 1996. Similarly, chloride and TDS levels have decreased in the closest downgradient well, MW-4, since 1999 when that well was installed. Chloride and TDS concentrations in the remaining wells (MW-2, MW-3, MW-5, and MW-6) have remained relatively consistent with previous levels.

- The fate and transport modeling results continue to support the contention that the chloride and TDS plume is not likely to impact existing sources of water supply, the closest of which, a livestock well, lies approximately 3,200 feet south of the source.

- According to conservative model simulations, the chloride plume will travel a maximum of 4,620 feet southeast of the source in approximately 218 years before concentrations return to levels below the WQCC standard of 250 mg/L. The same analysis indicates that the TDS plume will travel only 2,320 feet in approximately 111 years before concentrations return to levels below the WQCC standard of 1,000 mg/L.

- Based on the modeling results and predicted natural attenuation processes (advection and dispersion), there will be no adverse impact to human health and the environment nor will the livestock well exceed WQCC standards for chlorides or TDS due to the plume originating and traveling southeast, versus south, from the former emergency overflow pit.

- Groundwater elevations have been steadily decreasing at a rate of approximately 0.3 feet per year since the initial sampling event of monitoring well MW-1 in January 1995.

7.0 Recommendations

Based on the identified potential receptor and fate and transport modeling results, the chloride/TDS plume at the site presents low risk to human health and the environment; therefore Trident recommends the following actions:

- Continue the natural attenuation annual monitoring program with groundwater sampling and analysis of chloride and TDS concentrations for each of the six monitoring wells.
- Update flow and transport model to confirm the plume is naturally attenuating as described.
- Submit the 2003 annual groundwater monitoring report to OCD by April 2004 to document natural attenuation conditions.
- Provide an alternate means for supplying freshwater in the event there is a need for municipal, domestic, livestock, and/or irrigation water in the plume area.

APPENDICES

APPENDIX A

LABORATORY ANALYTICAL REPORTS

AND

CHAIN-OF-CUSTODY DOCUMENTATION

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Unocal Corporation

Certificate of Analysis Number:

02070546

Report To:	
Trident Environmental	
Gil Van Deventer	
P.O. Box 7624	
Midland	
TX	
79708-7624	
ph: (915) 682-0808 fax: (915) 682-0028	
Project Name:	8864-9924770-4675-64430
Site:	Former Unocal S Vacuum Unit
Site Address:	
PO Number:	APS140OC
State:	New Mexico
State Cert. No.:	
Date Reported:	8/2/02

This Report Contains A Total Of 13 Pages

Excluding This Page

And

Chain Of Custody

8/2/02

Date

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Case Narrative for:

Unocal Corporation

Certificate of Analysis Number:

02070546

Report To:		Project Name:	8864-9924770-4675-64430
Trident Environmental		Site:	Former Unocal S Vacuum Unit
Gil Van Deventer		Site Address:	
P.O. Box 7624			
Midland		PO Number:	APS140OC
TX		State:	New Mexico
79708-7624		State Cert. No.:	
ph: (915) 682-0808	fax: (915) 682-0028	Date Reported:	8/2/02

Due to lab error, the TDS analysis was performed outside of hold time.

Matrix spike (MS) and matrix spike duplicate (MSD) samples are chosen and tested at random from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. Since the MS and MSD are chosen at random from an analytical batch, the sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The Laboratory Control Sample (LCS) and the Method Blank (MB) are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

Any other exceptions associated with this report will be footnoted in the analytical result page(s) or the quality control summary page(s).

Please do not hesitate to contact us if you have any questions or comments pertaining to this data report. Please reference the above Certificate of Analysis Number.

SPL, Inc. is pleased to be of service to you. We anticipate working with you in fulfilling all your current and future analytical needs.

Elessa Sommers
Senior Project Manager

8/2/02
Date

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Unocal Corporation

Certificate of Analysis Number:

02070546

Report To: Trident Environmental
Gil Van Deventer
P.O. Box 7624

Midland
TX
79708-7624
ph: (915) 682-0808 fax:

Fax To: Trident Environmental
Gil Van Deventer fax : (915) 682-0028

Project Name: 8864-9924770-4675-64430
Site: Former Unocal S Vacuum Unit
Site Address:

PO Number: APS140OC
State: New Mexico
State Cert. No.:
Date Reported: 8/2/02

Client Sample ID	Lab Sample ID	Matrix	Date Collected	Date Received	COC ID	HOLD
MW-1	02070546-01	Water	7/11/02 2:50:00 PM	7/16/02 10:00:00 AM	11460	☐
MW-2	02070546-02	Water	7/11/02 3:25:00 PM	7/16/02 10:00:00 AM	11460	☐
MW-3	02070546-03	Water	7/11/02 11:55:00 AM	7/16/02 10:00:00 AM	11460	☐
MW-4	02070546-04	Water	7/11/02 4:25:00 PM	7/16/02 10:00:00 AM	11460	☐
MW-5	02070546-05	Water	7/11/02 1:50:00 PM	7/16/02 10:00:00 AM	11460	☐
MW-6	02070546-06	Water	7/11/02 10:45:00 AM	7/16/02 10:00:00 AM	11460	☐

8/2/02

Elessa Sommers
Senior Project Manager

Date

Joel Grice
Laboratory Director

Ted Yen
Quality Assurance Officer

8/2/02 12:00:34 PM

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID MW-1 **Collected:** 07/11/2002 14:50 **SPL Sample ID:** 02070546-01

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**		**Units: mg/L**		
Chloride	784	10		10		07/26/02 18:00	CV	1239683
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**		**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	1680	10		1		07/19/02 17:00	J_G	1226916

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID MW-2 **Collected:** 07/11/2002 15:25 **SPL Sample ID:** 02070546-02

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**	**Units: mg/L**		
Chloride	284	5	5		07/26/02 18:00	CV	1239685
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**	**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	808	10	1		07/19/02 17:00	J_G	1226918

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID MW-3 **Collected:** 07/11/2002 11:55 **SPL Sample ID:** 02070546-03

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**	**Units: mg/L**		
Chloride	103	2	2		07/26/02 18:00	CV	1239686
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**	**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	509	10	1		07/19/02 17:00	J_G	1226919

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID MW-4 **Collected:** 07/11/2002 16:25 **SPL Sample ID:** 02070546-04

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**		**Units: mg/L**		
Chloride	1290	25		25		07/26/02 18:00	CV	1239687
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**		**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	2660	20		2		07/19/02 17:00	J_G	1226920

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID MW-5 **Collected:** 07/11/2002 13:50 **SPL Sample ID:** 02070546-05

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**		**Units: mg/L**		
Chloride	15.5	1		1		07/26/02 18:00	CV	1239688
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**		**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	308	10		1		07/19/02 17:00	J_G	1226921

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID MW-6 **Collected:** 07/11/2002 10:45 **SPL Sample ID:** 02070546-06

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**		**Units: mg/L**		
Chloride	50	1		1		07/26/02 18:00	CV	1239689
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**		**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	422	10		1		07/19/02 17:00	J_G	1226922

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

Quality Control Documentation

8/2/02 12:00:39 PM

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Quality Control Report

Unocal Corporation

8864-9924770-4675-64430

Analysis: Total Dissolved Solids
Method: E160.1
WorkOrder: 02070546
Lab Batch ID: R63814A

Method Blank

RunID: WET_020719R-1226900 Units: mg/L
Analysis Date: 07/19/2002 17:00 Analyst: J_G

Analyte	Result	Rep Limit
Total Dissolved Solids (Residue,Filterable)	ND	10

Samples in Analytical Batch:

Lab Sample ID	Client Sample ID
02070546-01A	MW-1
02070546-02A	MW-2
02070546-03A	MW-3
02070546-04A	MW-4
02070546-05A	MW-5
02070546-06A	MW-6

Laboratory Control Sample (LCS)

RunID: WET_020719R-1226904 Units: mg/L
Analysis Date: 07/19/2002 17:00 Analyst: J_G

Analyte	Spike Added	Result	Percent Recovery	Lower Limit	Upper Limit
Total Dissolved Solids (Residue,Filtera	200	198	99	95	107

Sample Duplicate

Original Sample: 02070546-01
RunID: WET_020719R-1226916 Units: mg/L
Analysis Date: 07/19/2002 17:00 Analyst: J_G

Analyte	Sample Result	DUP Result	RPD	RPD Limit
Total Dissolved Solids (Residue,Filtera	1680	1680	0	20

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits

The percent recoveries for QC samples are correct as reported. Due to significant figures and rounding, the reported RPD may differ from the displayed RPD values but is correct as reported.

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Quality Control Report

Unocal Corporation

8864-9924770-4675-64430

Analysis: Chloride, Total
Method: E325.3
WorkOrder: 02070546
Lab Batch ID: R64364A

Method Blank

RunID: WET_020726L-1239661 Units: mg/L
Analysis Date: 07/26/2002 18:00 Analyst: CV

Analyte	Result	Rep Limit
Chloride	ND	1.0

Samples in Analytical Batch:

Lab Sample ID	Client Sample ID
02070546-01A	MW-1
02070546-02A	MW-2
02070546-03A	MW-3
02070546-04A	MW-4
02070546-05A	MW-5
02070546-06A	MW-6

Laboratory Control Sample (LCS)

RunID: WET_020726L-1239663 Units: mg/L
Analysis Date: 07/26/2002 18:00 Analyst: CV

Analyte	Spike Added	Result	Percent Recovery	Lower Limit	Upper Limit
Chloride	142	141	99	90	110

Matrix Spike (MS) / Matrix Spike Duplicate (MSD)

Sample Spiked: 02070761-01
RunID: WET_020726L-1239679 Units: mg/L
Analysis Date: 07/26/2002 18:00 Analyst: CV

Analyte	Sample Result	MS Spike Added	MS Result	MS % Recovery	MSD Spike Added	MSD Result	MSD % Recovery	RPD	RPD Limit	Low Limit	High Limit
Chloride	130	250	388	102	250	388	102	0	20	85	115

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits

The percent recoveries for QC samples are correct as reported. Due to significant figures and rounding, the reported RPD may differ from the displayed RPD values but is correct as reported.

8/2/02 12:00:42 PM

Sample Receipt Checklist

And

Chain of Custody

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Sample Receipt Checklist

Workorder:	02070546	Received By:	RE
Date and Time Received:	7/16/02 10:00:00 AM	Carrier name:	FedEx
Temperature:	4	Chilled by:	Water Ice

1.	**Shipping container/cooler in good condition?**	Yes ☑	No ☐	Not Present	☐
2.	**Custody seals intact on shippping container/cooler?**	Yes ☑	No ☐	Not Present	☐
3.	**Custody seals intact on sample bottles?**	Yes ☐	No ☐	Not Present	☑
4.	**Chain of custody present?**	Yes ☑	No ☐		
5.	**Chain of custody signed when relinquished and received?**	Yes ☑	No ☐		
6.	**Chain of custody agrees with sample labels?**	Yes ☑	No ☐		
7.	**Samples in proper container/bottle?**	Yes ☑	No ☐		
8.	**Sample containers intact?**	Yes ☑	No ☐		
9.	**Sufficient sample volume for indicated test?**	Yes ☑	No ☐		
10.	**All samples received within holding time?**	Yes ☑	No ☐		
11.	***Container/Temp Blank temperature in compliance?***	Yes ☑	No ☐		
12.	***Water - VOA vials have zero headspace?***	Yes ☐	No ☐	Not Applicable	☑
13.	**Water - pH acceptable upon receipt?**	Yes ☑	No ☐	Not Applicable	☐

SPL Representative: **Contact Date & Time:**

Client Name Contacted:

Non Conformance Issues:

Client Instructions:

0207546

SPL Laboratories, Inc.

☐ 1511 East Orangethorpe Ave.
Fullerton, CA 92631
(714) 447-6868
Fax:(714) 447-6800

☒ 8880 Interchange Drive
Houston, Texas 77054
(713) 660-0901
Fax: (713) 660-8975

☐ 500 Ambassador Caffery Pkwy.
Scott, Louisiana 70583
(318) 237-4775
Fax: (318) 237-7080

UNOCAL 76

Chain of Custody Record 11460

Company Name: Trident Environmental	Project Name: Former Unocal South Vacuum Unit
Address: PO Box 7624	UNOCAL Project Manager: Ben F. Terry
City: Midland State: TX Zip Code: 79708-7624	AFE#: 8864-9924770-4675-64430
Telephone: 915-682-0808 FAX: 915-682-0727	Site #: 9924770
Report To: Gil VanDeventer Sampler: Gil Van Deventer	QC Data: ☒ Level D (Standard) ☐ Level C ☐ Level B ☐ Level A

Turnaround Time: (Calendar Days) ☒ 10 Days (Standard) ☐ 5 Days ☐ 3 Days ☐ 2 Days ☐ 1 Day

CODE: ☐ Misc. ☒ Detecl. ☐ Eval. ☐ Remed. ☐ Demol. ☐ Closure

☐ Drinking Water
☐ Waste Water
☒ Other

Analyses Requested: Chloride (325.3), TDS (160.1)

Client Sample I.D.	Date/Time Sampled	Matrix Desc.	# of Cont.	Cont. Type	Laboratory Sample #	Chloride	TDS	Comments
MW-1	7-11-02 1450	Water	1	P/500		✓	✓	
MW-2	7-11-02 1525	Water	1	P/500		✓	✓	
MW-3	7-11-02 1155	Water	1	P/500		✓	✓	
MW-4	7-11-02 1625	Water	1	P/500		✓	✓	
MW-5	7-11-02 1350	Water	1	P/500		✓	✓	
MW-6	7-11-02 1045	Water	1	P/500		✓	✓	
								4c

Relinquished By:	Date: 7/15/02	Time: 5:30 pm	Received By:	Date:	Time:
Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Relinquished By:	Date:	Time:	Received By:	Date: 7/16/02	Time: 1000

Were Samples Received in Good Condition? ☐ Yes ☐ No Samples on Ice? ☐ Yes ☐ No Method of Shipment _____ Page ____ of ____

APPENDIX B

MONITORING WELL SAMPLING DATA FORMS

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-1**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 7/11/01
PROJECT NO. V-107
SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 70.00 Feet
DEPTH TO WATER: 63.28 Feet
HEIGHT OF WATER COLUMN: 6.72 Feet
WELL DIAMETER: 2.0 Inch

3.3 Minimum Gallons to purge 3 well volumes

TIME	VOLUME PURGED	TEMP. °C / °F	COND. *m*S/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
	2	71.8°F	3070	7.05			
	5	70.7°F	3080	6.93			
	8	70.2°F	2450	6.98			
1525							

COMMENTS: Sample collected at 1450, placed into 500 ml plastic container, and put on ice in cooler.
Parameters obtained using a Hydac Model 910 pH-Temperature-Conductivity meter.

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-2**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 7/11/01
PROJECT NO. V-107
SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 71.00 Feet
DEPTH TO WATER: 50.29 Feet
HEIGHT OF WATER COLUMN: 20.71 Feet
WELL DIAMETER: 2.0 Inch

10.1 Minimum Gallons to purge 3 well volumes

TIME	VOLUME PURGED	TEMP. °C / °F	COND. *m*S/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
	2	78.9°F	2290	8.19			
	5	79.4°F	1770	8.33			
	8	75.6°F	1620	8.22			
	10.5	74.5°F	1331	7.96			

COMMENTS: Sample collected at 1525, placed into 500 ml plastic container, and put on ice in cooler.

Parameters obtained using a Hydac Model 910 pH-Temperature-Conductivity meter.

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-3**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 7/11/01
PROJECT NO. V-107
SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 77.00 Feet
DEPTH TO WATER: 67.59 Feet
HEIGHT OF WATER COLUMN: 9.41 Feet
WELL DIAMETER: 2.0 Inch

4.6 Minimum Gallons to purge 3 well volumes

TIME	VOLUME PURGED	TEMP. °C / °F	COND. *m*S/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
	4	80.2°F	586	7.69			
	8	75.6°F	580	7.62			

COMMENTS: Sample collected at 1155, placed into 500 ml plastic container, and put on ice in cooler.

Parameters obtained using a Hydac Model 910 pH-Temperature-Conductivity meter.

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-4**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 7/11/01
PROJECT NO. V-107
SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 71.00 Feet
DEPTH TO WATER: 60.98 Feet
HEIGHT OF WATER COLUMN: 10.02 Feet
WELL DIAMETER: 2.0 Inch

4.9 Minimum Gallons to purge 3 well volumes

TIME	VOLUME PURGED	TEMP. °C / °F	COND. mS/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
	3	72.3°F	4480	7.41			
	6	73.4°F	3980	7.27			
	8	70.6°F	4710	7.35			

COMMENTS: Sample collected at 1625, placed into 500 ml plastic container, and put on ice in cooler.
Parameters obtained using a Hydac Model 910 Temperature-Conductivity meter and an Oakton pH meter.

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-5**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 7/11/01
PROJECT NO. V-107
SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 75.00 Feet
DEPTH TO WATER: 68.98 Feet
HEIGHT OF WATER COLUMN: 6.02 Feet
WELL DIAMETER: 2.0 Inch

2.9 Minimum Gallons to purge 3 well volumes

TIME	VOLUME PURGED	TEMP. °C / °F	COND. *m*S/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
	1	73.4°F	393	7.39			
	5	74.0°F	500	7.34			
	9	77.2°F	431	7.32			

COMMENTS: Sample collected at 1350, placed into 500 ml plastic container, and put on ice in cooler.

Parameters obtained using a Hydac Model 910 Temperature-Conductivity meter and an Oakton pH meter.

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-6**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 7/11/01
PROJECT NO. V-107
SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 76.00 Feet
DEPTH TO WATER: 71.26 Feet
HEIGHT OF WATER COLUMN: 4.74 Feet
WELL DIAMETER: 2.0 Inch

2.3 Minimum Gallons to purge 3 well volumes

TIME	VOLUME PURGED	TEMP. °C / °F	COND. *m*S/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
	5	72.0°F	541	7.80			

COMMENTS: Sample collected at 1045, placed into 500 ml plastic container, and put on ice in cooler.

Parameters obtained using a Hydac Model 910 pH-Temperature-Conductivity meter.

APPENDIX C

DESCRIPTION OF FATE AND TRANSPORT MODELING

Description of Fate and Transport Modeling

Conceptual Model

Liquid waste brine containing high concentrations of chloride, and resultant high levels of total dissolved solids (TDS), was reportedly discharged into a surface pit and adjoining injection well for a period of about 10 years, until the well was plugged and abandoned in the early 1970s. The chloride and TDS plume continued to migrate southeastwards for the next approximately 31 years after the source input was stopped, producing the configuration and constituent concentration distribution observed currently. Extrapolating from current conditions for decades into the future, taking account of both advective flow and attenuation by hydrodynamic dispersion, enables prediction of the probable distance that the residual plume will travel as well as the gradually declining concentrations in the plume.

Basic Site Data

Information about site conditions was obtained from data in a TRW Inc. "Report of Additional Groundwater Investigation, Former Unocal South Vacuum Unit, Lea County, New Mexico" (July 18, 2000). This included lithologic records from well installations, water level data, and water quality analytical results. In addition, the water quality analytical results from the "2001 Annual Groundwater Monitoring Report, Former Unocal South Vacuum Unit, Lea County, New Mexico" (July 8, 2002) and the most recent sampling event conducted on July 11, 2002, were input into the model.

Simulation Model

Simulations were conducted with the two-dimensional groundwater flow and contaminant transport model WinTran, version 1.03 (1995) designed and distributed by Environmental Simulations, Inc. (ESI) of Herndon, Virginia. WinTran is built around a steady-state analytical element flow model, linked to a finite element contaminant transport model. The Windows interface allows for rapid data input, processing, parameter manipulation and optimization, and output in multiple formats. The fundamental mathematics of the model solutions, model verification (benchmarked against MODFLOW), and use of WinTran is documented in the "Guide to Using WinTran" published by ESI.

Map Output

The contour map output from WinTran, was exported to a universal drawing exchange file (DXF) file format. The DXF WinTran output map was then imported into TurboCAD (Version 7), while preserving the original units of measurement.

Flow Parameters

Input requirements for the steady-state groundwater flow simulation include: hydraulic gradient and direction of flow, hydraulic conductivity, aquifer top and bottom elevations, and reference head. The values used were based on the following sources:

- Hydraulic gradient – measured gradient of 0.004 feet/foot from July 2002 site measurements reported by Trident.

- Direction of flow – measured direction of approximately S 40° E from July 2002 site measurements reported by Trident.

- Hydraulic conductivity – no site measurements were available; therefore, a literature value based on the saturated zone lithology was selected. Typical lithology is described as silty sand and very fine sand. Fetter (1988, Table 4.5, p. 80) cites an average range of 10^{-5} to 10^{-3} cm/sec for hydraulic conductivity of silty sands and fine sands. A conservative upper limit was selected, and converted from S.I. unit to 2.8 ft/day, or approximately 1000 ft/yr.

- Aquifer top and bottom elevations – bottom elevation of Ogallala Formation at 3700 feet reported by Trident. The top elevation for an unconfined aquifer must be greater than the reference head. An elevation of 4000 feet was assumed.

- Reference head – measured unconfined head of 3795.5 feet adjacent to the former pit and upgradient well MW-1 from July 2002 measurements reported by Trident.

Transport Parameters

Input requirements for the contaminant transport numerical simulation include: longitudinal and transverse dispersivity, porosity, diffusion coefficient, contaminant half-life, and retardation coefficient. The values used were based on the following sources:

- Longitudinal and transverse dispersivity – no site measurements were available; therefore, a literature value based on the plume length was selected. Fetter (1993, Section 2.11, pp. 71-77) notes the apparent scale-dependency of longitudinal dispersivity, which typically may be about 0.1 times the flow length. For the current site scale and plume length of approximately 1500 feet, a value of 150 feet was selected for longitudinal dispersivity. According to the WinTran user's guide (ESI, 1995, p.11), longitudinal dispersivity is usually 5 to 10 times higher than transverse dispersivity; therefore, a value of 15 feet (i.e., one-tenth of the longitudinal value) was selected for transverse dispersivity.

- Porosity – no site measurements were available; therefore a literature value based on saturated zone lithology was selected. Typical lithology is described as silty sand and very fine sand. A range of 0.25 to 0.50 is typically given for unconsolidated "sand" (e.g., Freeze & Cherry, 1979, Table 2.4, p. 37); however, the Ogallala Formation is predominantly very fine grained, compacted and partly cemented, and may also fit within the range of 0.05 to 0.30 for sandstone. Fetter (1988, Table 4.3 and Figure 4.10, pp. 74-75) cites an average value of 0.20 for the specific yield of very fine sands. Specific retention of silty fine sand is approximately 0.05, for a total porosity of 0.25, which is the value selected for the transport modeling. WinTran uses the porosity term to estimate groundwater velocity, and actually requires an effective porosity value. Fetter (1988, Section 4.4, pp. 84-85) notes that pores of most sediments down to clay size are interconnected and that the effective porosity is virtually equal to the total porosity.

- Diffusion coefficient – this parameter is normally only relevant for very slow fluid movement, and is commonly assumed to be zero for advective-dominated transport, as in the present case.

- Contaminant half-life – this parameter accounts for chemical decay (e.g., radioisotopes, biological transformation of organic molecules); however, the species of interest in the present case are inorganic ions and are not expected to decay to any appreciable extent. A conservative value of 1000 years was used, which produces a negligible decay coefficient of less than 0.001 yr^{-1}.

- Retardation coefficient – this parameter accounts for sorption processes that slow the movement of contaminants relative to the groundwater velocity. Inorganic ions such as chloride are commonly taken as conservative tracers in groundwater and are not considered to be retarded; therefore, a value of 1.0 was selected for the retardation coefficient.

Flow Model Calibration

The vicinity of the site where water level measurements were recorded in July 2002 is simulated closely by the flow model. It is known that groundwater levels in the Ogallala Formation are decreasing slowly (less than 0.5 ft/yr), but this effect cannot be reproduced in the steady-state flow model. Water levels were probably somewhat higher than the present day during the period of brine disposal and initial transport. Even if the declining trend continues into the future, it does not affect the transport model solution for long extrapolation times, since sufficient saturated thickness remains (i.e., above the assumed aquifer base elevation of 3700 feet) for a valid flow and transport solution.

Flow lines with 25-year time steps show the distance that water moves perpendicular to the equipotential lines. The average groundwater velocity may be estimated using the darcy expression: $v = (k \cdot i) / n$ where k is the hydraulic conductivity (ft/yr), i is the hydraulic gradient (ft/foot), and n is the effective porosity (unitless). The resultant average velocity is 16 ft/yr.

Transport Model Calibration

The objective of the transport modeling was to first obtain a plume configuration with concentration values that closely match current observed values. This was done by simulating an initial contaminant release to groundwater for a period of 11 years (c. 1960 to 1971) with a constant source concentration located at the pit and injection well, then simulating a 31-Year transport period (c. 1971 to 2002) with no further contaminant input but restarting the model from the end of Year 11 by retaining the mass of contaminant from the initial plume. An iterative approach was needed to optimize the initial source concentration so that the plume at Year 42 resembled the current actual plume. An initial value of 14,000 mg/L for chloride and 30,000 mg/L for TDS were found to produce the best match. The initial chloride value was also chosen because it is typical of chloride concentrations within the producing formation (Devonian) in the South Vacuum Oil Field according to chemists at Martin Water Laboratories (verbal communication, 12-05-01). Actual disposal concentrations during the 1960s are unknown, and may have been higher than these values, but it is presumed that some attenuation and dilution may have occurred in the vadose zone, which is currently 47 to 67 feet thick. WinTran does not account for vadose zone transport, and the source input is treated as an injection well with instantaneous transfer of contaminant mass to groundwater.

Figures 7A and 7B show the close match achieved by the chloride and TDS simulations compared to the current observed plume.

Simulation of Fate and Transport

Estimation of chloride and TDS fate and transport was achieved by restarting the transport model from the end of Year 42 (2002) by retaining the distribution of contaminant mass and projecting for a further 50 years into the future. As depicted in Figures 8A and 8B, dispersion serves to broaden the dimensions of the plume while reducing the concentrations in the middle of the plume. Advective flow moves the center of plume mass downgradient by a distance of approximately 1,400 feet from an initial current position to an area between MW-2 and MW-6.

Running the model for 218 years in the future (Year 2220) produces a chloride plume center concentration of 249 mg/L (below the WQCC standard of 250 mg/L) as shown in Figure 9A. The center of the chloride plume is approximately 4,620 ft away from the pit and well source at that time.

Running the model for 111 years in the future (Year 2113) produces a TDS plume center concentration of 998 mg/L (below the WQCC standard of 1,000 mg/L) as shown in Figure 9B. The center of the TDS plume is approximately 2,320 ft away from the pit and well source at that time.

These results support the contention that the chloride and TDS plume is not likely to impact any existing sources of water supply, the closest of which lies approximately 3,200 feet south of the source.

The trend of decreasing concentration is not linear (exponential e^{-kt} function). Interestingly, the center of the plume moves at a greater rate (21 feet/year) over successive time intervals than would be assumed from the groundwater velocity alone (16 feet/year), due to the added effect of dispersion.

1R - 277

REPORTS

DATE:

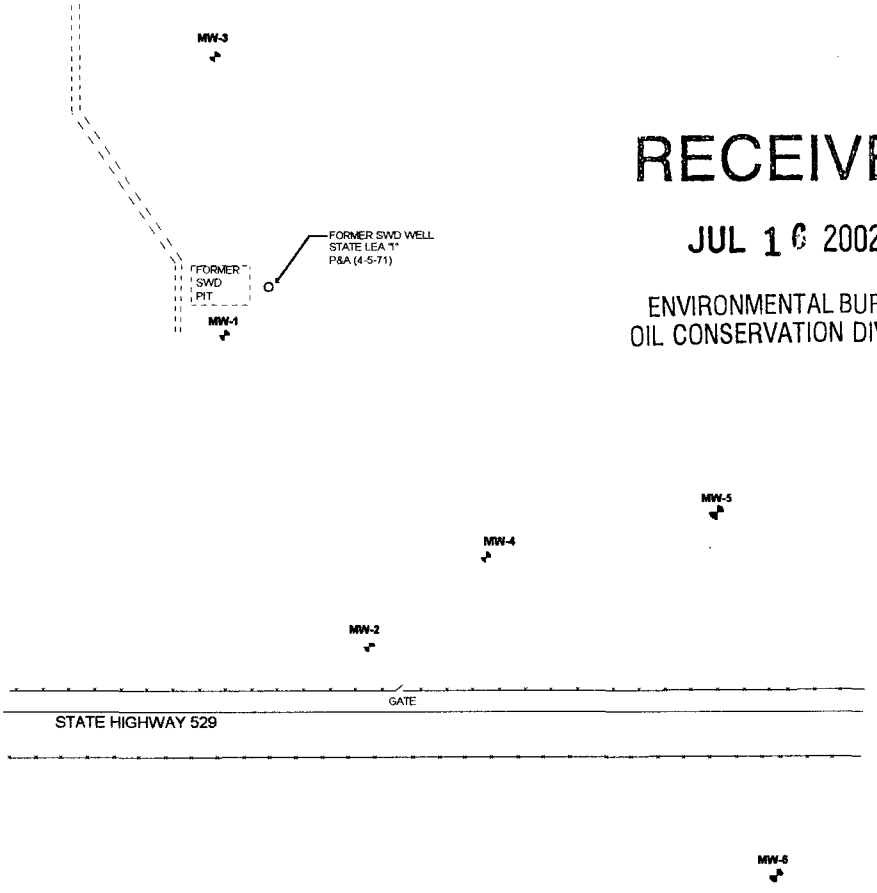
2001

UNOCAL CORPORATION
2001 ANNUAL GROUNDWATER MONITORING REPORT
FORMER UNOCAL SOUTH VACUUM UNIT
LEA COUNTY, NEW MEXICO

JULY 8, 2002

Prepared For:

Unocal Corporation
Real Estate & Remediation
P. O. Box 1283
Nederland, Texas 77627



TRIDENT ENVIRONMENTAL

P. O. Box 7624
Midland, Texas 79708

2001 Annual Groundwater Monitoring Report

Unocal Corporation

Real Estate and Remediation

Former Unocal South Vacuum Unit

Lea County, New Mexico

Prepared by:

Trident
Environmental
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SBMITTED BY:

Gilbert J. Van Deventer, REM
Project Manager

DATE: 7-10-02

REVIEWED BY:

Dale T. Littlejohn
Quality Assurance/Control Officer

DATE: 7-10-02

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

1.0 Executive Summary

Trident Environmental (Trident) was retained by the IT Group (IT) and Unocal Real Eastate and Remediation (Unocal) to perform the 2001 annual groundwater sampling and monitoring operations at the Former Unocal South Vacuum Unit in Lea County, New Mexico. This report documents the 2001 annual sampling event performed by Trident at the site on June 18, 2001. This report also contains the historical groundwater elevation and analytical data and includes data from all monitoring wells (MW-1 through MW-6) on site. The sampling event was conducted in accordance with the November 2, 2000 Groundwater Remediation Plan submitted by Unocal and the requirements specified in the New Mexico Oil and Conservation Division (OCD) letter dated February 8, 2001.

Based on the sampling and monitoring data to date, the following conclusions relevant to groundwater conditions at the Former Unocal South Vacuum Unit are evident:

- The fate and transport modeling results continue to support the contention that the chloride and total dissolved solids (TDS) plume is not likely to impact existing sources of water supply, the closest of which, a live stock well, lies approximately 3,200 feet south of the source.

- According to conservative model simulations, the chloride plume will travel a maximum of 5,650 feet southeast of the source in approximately 148 years before concentrations return to levels below the WQCC standard of 250 mg/L. The same analysis indicates that the TDS plume will travel only 2,000 feet in approximately 110 years before concentrations return to levels below the New Mexico Water Quality Control Commission (WQCC) standard of 1,000 mg/L.

- Based on the modeling results and predicted natural attenuation processes (advection and dispersion), there will be no adverse impact to human health and the environment nor will the live stock well exceed WQCC standards for chlorides or TDS due to the plume originating from the former emergency overflow pit.

- Groundwater elevations have been steadily decreasing at a rate of approximately 0.3 feet per year since the initial sampling event of monitoring well MW-1 in January 1995.

Based on the identified potential receptor and fate and transport modeling results, the chloride/TDS plume at the site presents low risk to human health and the environment; therefore Trident recommends the following actions for site closure:

- Continue the natural attenuation monitoring program with one more year of annual groundwater sampling and analysis of chloride and TDS concentrations for each of the six monitoring wells.

- Recalibrate flow and transport model to confirm the plume is naturally attenuating as described.

- Submit the 2002 annual groundwater monitoring report to OCD in January 2003 to document natural attenuation conditions.

- If, after one more year of monitoring, the plume is naturally attenuating as described, request no further action from OCD.

2.0 Groundwater Sampling Procedures

Each of the six monitoring wells, MW-1 through MW-6, was gauged for depth to groundwater using a Solinst Model 101 electronic water indicator immediately prior to purging operations. Eight gallons of groundwater was then purged from each site monitoring well using a decontaminated 2-inch diameter PVC bailer. After purging, groundwater samples were collected and parameters were measured using a YSI Model 33 Salinity-Conductivity-Temperature meter. Water samples for each monitoring well were transferred into 1,000 milliliter (ml) plastic containers for laboratory analysis of total dissolved solids (TDS) (EPA Method 160.1) and chloride (EPA Method 325.3). For each set of samples, chain of custody forms documenting sample identification numbers, collection times, and delivery times to the laboratory were completed. All water samples were placed in an ice-filled cooler immediately after collection and transported to SPL, Inc. in Houston, Texas for analysis.

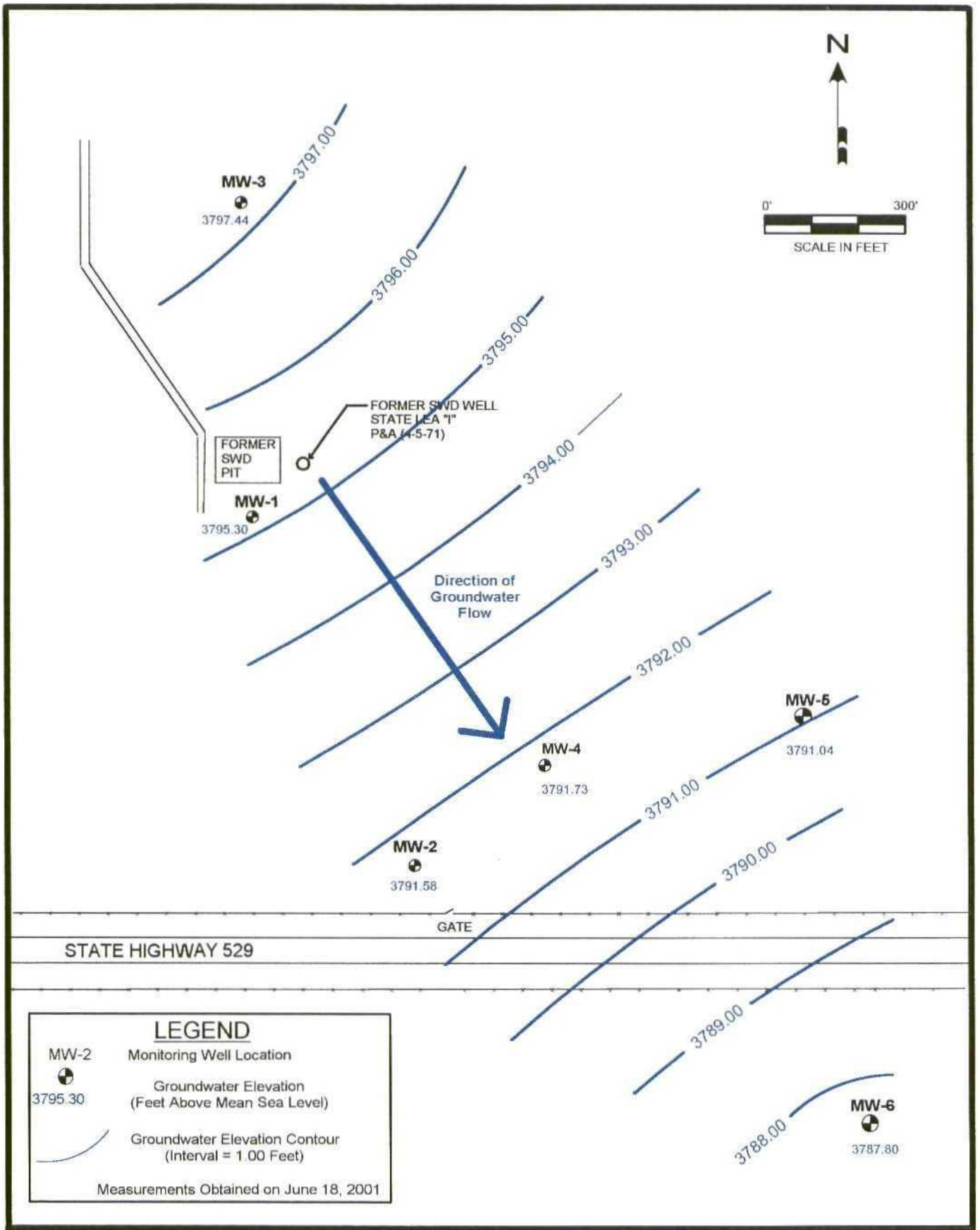
3.0 Groundwater Elevations, Hydraulic Gradient and Flow Direction

Depth to groundwater varies from approximately 47 to 67 feet below ground surface at the site. Groundwater elevations are summarized in Table 1. A groundwater gradient map indicating the direction of groundwater flow is illustrated in Figure 1. A historical groundwater elevation graph is shown in Figure 2. The groundwater gradient direction is to the southeast with a hydraulic gradient of approximately 0.004 ft/ft. According to published reports (*Ground-Water Conditions in Northern Lea County, New Mexico*, Ash, 1963 and *Geology and Ground-Water Conditions in Southern Lea County, New Mexico*, Nicholson and Clebsch, 1961) the groundwater encountered at the site is that of the Tertiary Ogallala Formation. The Ogallala Formation unconformably overlies the impermeable red-beds of the Triassic Chinle Formation at an elevation of approximately 3700 feet above mean sea level (AMSL). Based on the current groundwater elevations measured on site and published data referenced, the saturated thickness of the Ogallala Formation at the site ranges from approximately 85 to 95 feet.

Table 1
Summary of Groundwater Elevations and Chloride and TDS Concentrations
Former Unocal South Vacuum Unit

Monitoring Well	Sample Date	Ground Surface Elevation (feet AMSL)	Top of Casing Elevation (feet AMSL)	Depth to Groundwater (feet BTOC)	Groundwater Elevation (feet AMSL)	Chloride (mg/L)	TDS (mg/L)
MW-1	01/27/95	3856.76	3858.37	59.57	3798.80	**1174**	**2250**
	05/18/95	3856.76	3858.37	61.30	3797.07	**983**	**2251**
	08/28/96	3856.76	3858.37	61.57	3796.80	**1420**	**2730**
	08/13/97	3856.76	3858.37	61.75	3796.62	**1400**	**2800**
	12/14/98	3858.37	3858.37	NM	NM	**1400**	**2400**
	09/30/99	3856.76	3858.37	62.51	3795.86	**1094**	**2318**
	06/14/00	3856.76	3858.37	62.85	3795.52	**927**	**2040**
	06/18/01	3856.76	3858.37	63.07	3795.30	**813**	**1790**
MW-2	09/30/99	3839.11	3841.64	49.51	3792.13	**298**	922
	06/14/00	3839.11	3841.64	49.81	3791.83	**317**	852
	06/18/01	3839.11	3841.64	50.06	3791.58	**288**	878
MW-3	09/30/99	3862.20	3864.73	66.74	3797.99	73.6	427
	06/14/00	3862.20	3864.73	67.01	3797.72	75.5	433
	06/18/01	3862.20	3864.73	67.29	3797.44	86.4	495
MW-4	09/30/99	3849.87	3852.51	60.18	3792.33	**1576**	**2981**
	06/14/00	3849.87	3852.51	60.55	3791.96	**1500**	**2910**
	06/18/01	3849.87	3852.51	60.78	3791.73	**1530**	**3180**
MW-5	06/14/00	3856.59	3859.84	68.57	3791.27	13.7	274
	06/18/01	3856.59	3859.84	68.80	3791.04	13.6	322
MW-6	06/14/00	3855.32	3858.78	70.79	3787.99	48	382
	06/18/01	3855.32	3858.78	70.98	3787.80	50.8	431
Water Quality Control Commission (WQCC) Standards						250	1000

AMSL – Above Mean Sea Level; BTOC – Below Top of Casing; NM – No Measurement
Groundwater flow direction is to the southeast with a gradient of approximately 0.004 feet/foot.
Elevations and state plane coordinates surveyed by Basin Surveys, Hobbs, NM.



LEGEND

MW-2 — Monitoring Well Location

3795.30 — Groundwater Elevation (Feet Above Mean Sea Level)

Groundwater Elevation Contour (Interval = 1.00 Feet)

Measurements Obtained on June 18, 2001

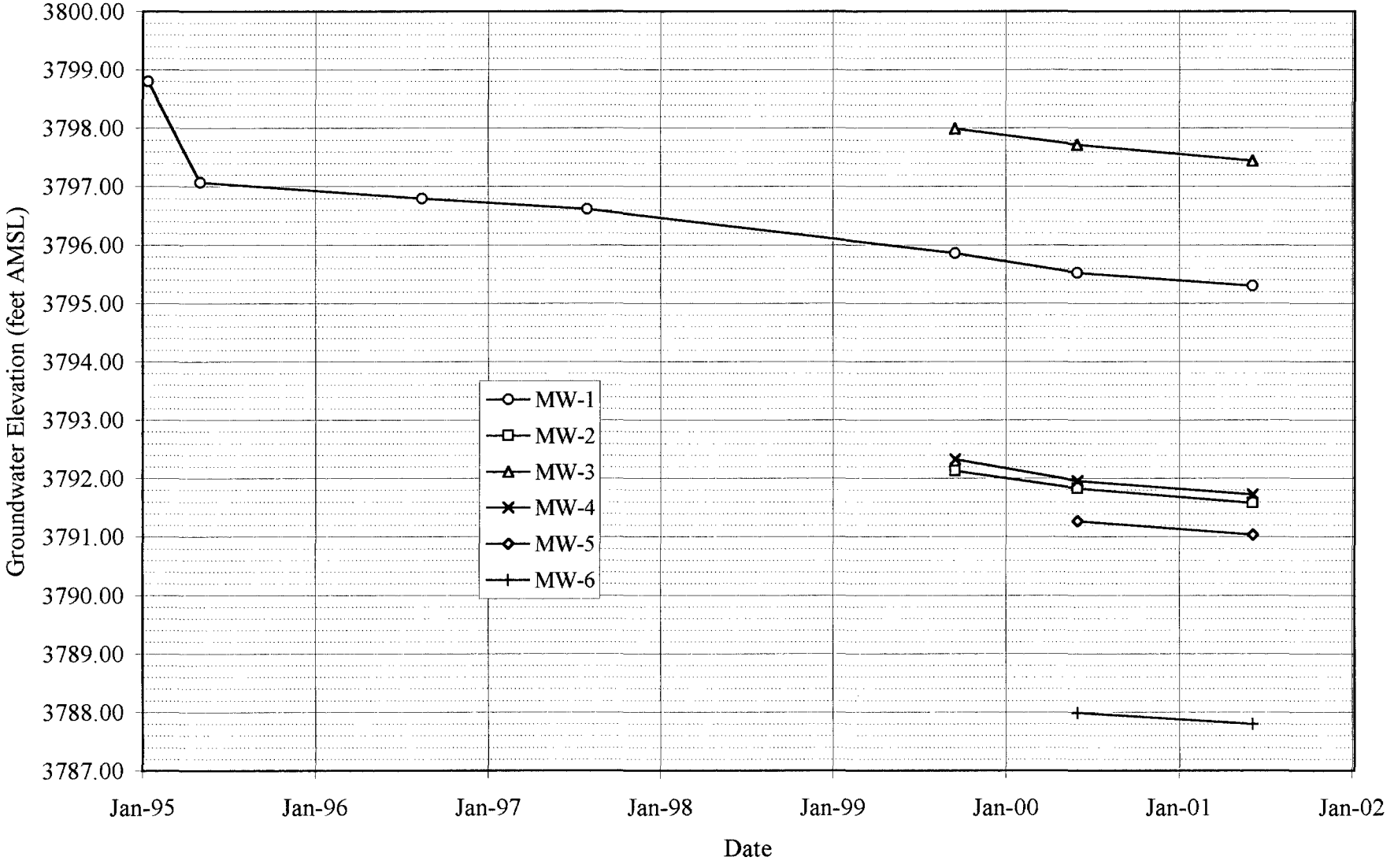
TRIDENT ENVIRONMENTAL

SITE: FORMER UNOCAL S. VACUUM UNIT	
DATE: 06/18/01	REV. NO.: 062600
AUTHOR: GJV	DRN BY: GJV
CK'D BY: DTL	FILE: VAC2001

FIGURE 1

GROUNDWATER ELEVATION MAP

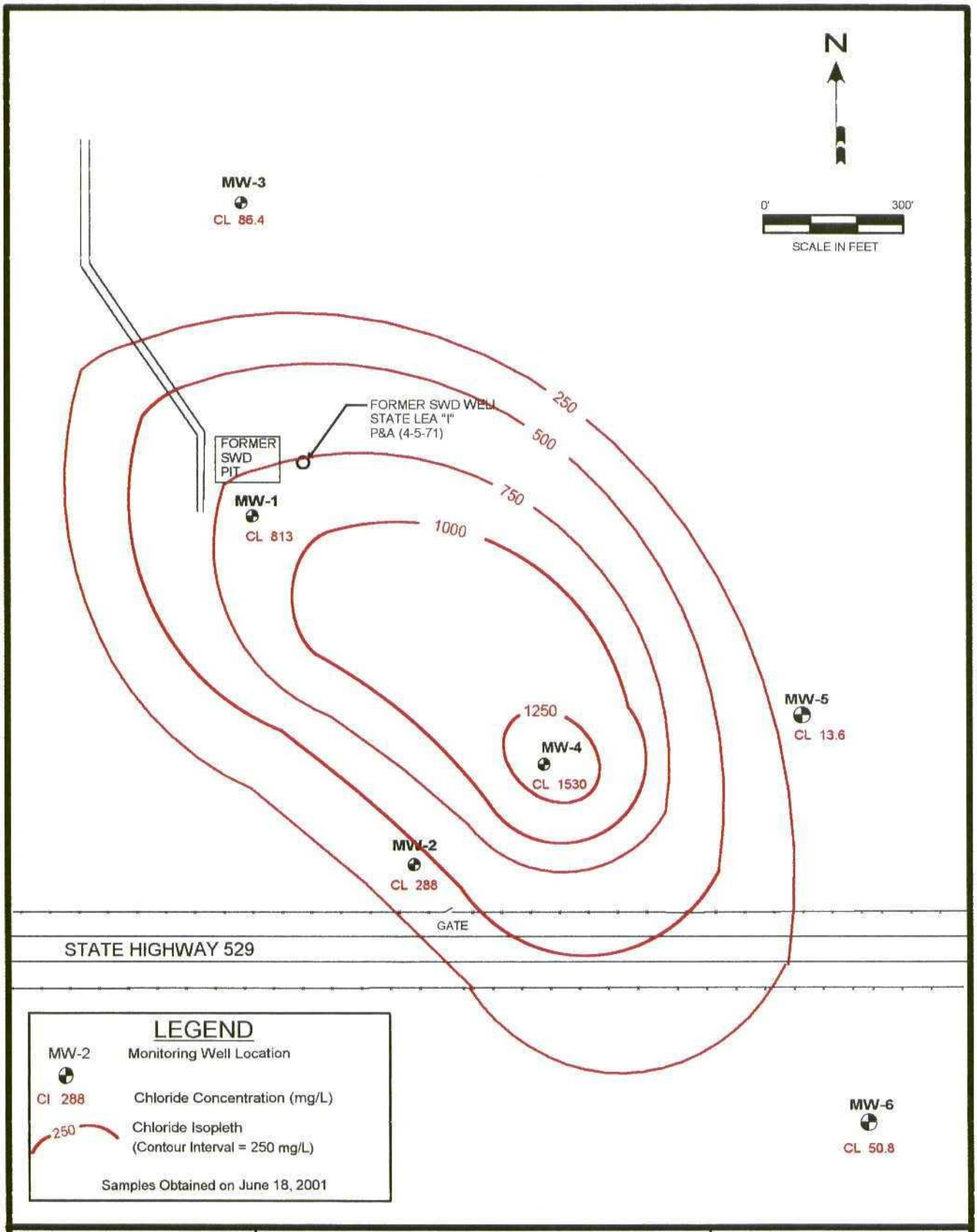
Figure 2
Historical Groundwater Elevations



4.0 Groundwater Quality Conditions

Groundwater sample analytical results are presented in Table 1. The New Mexico Water Quality Control Commission (WQCC) standards are presented for comparison. Those constituents that recorded concentrations above the WQCC standards are highlighted in boldface type. The WQCC standard of 250 mg/L for chloride was exceeded in MW-1 (813 mg/L), MW-2 (288 mg/L), and MW-4 (1,530 mg/L). The WQCC standard of 1,000 mg/L for TDS was exceeded in MW-1 (1,790 mg/L) and MW-4 (3,180 mg/L). The groundwater samples obtained from upgradient monitoring well MW-3 and downgradient wells MW-5 and MW-6 had chloride and TDS concentrations below WQCC standards.

The chloride and TDS concentrations are depicted graphically in Figure 3 and 4, respectively. The concentration isopleths were drawn utilizing the Surfer® (version 6.0) contour modeling program (Kriging method). Since this contouring program does not take into account the known groundwater gradient, some of the isopleths were manually converged into a more southeasterly orientation. Graphs depicting historical TDS and chloride concentrations in monitoring wells MW-1and MW-4 are shown in Figures 5 and 6.



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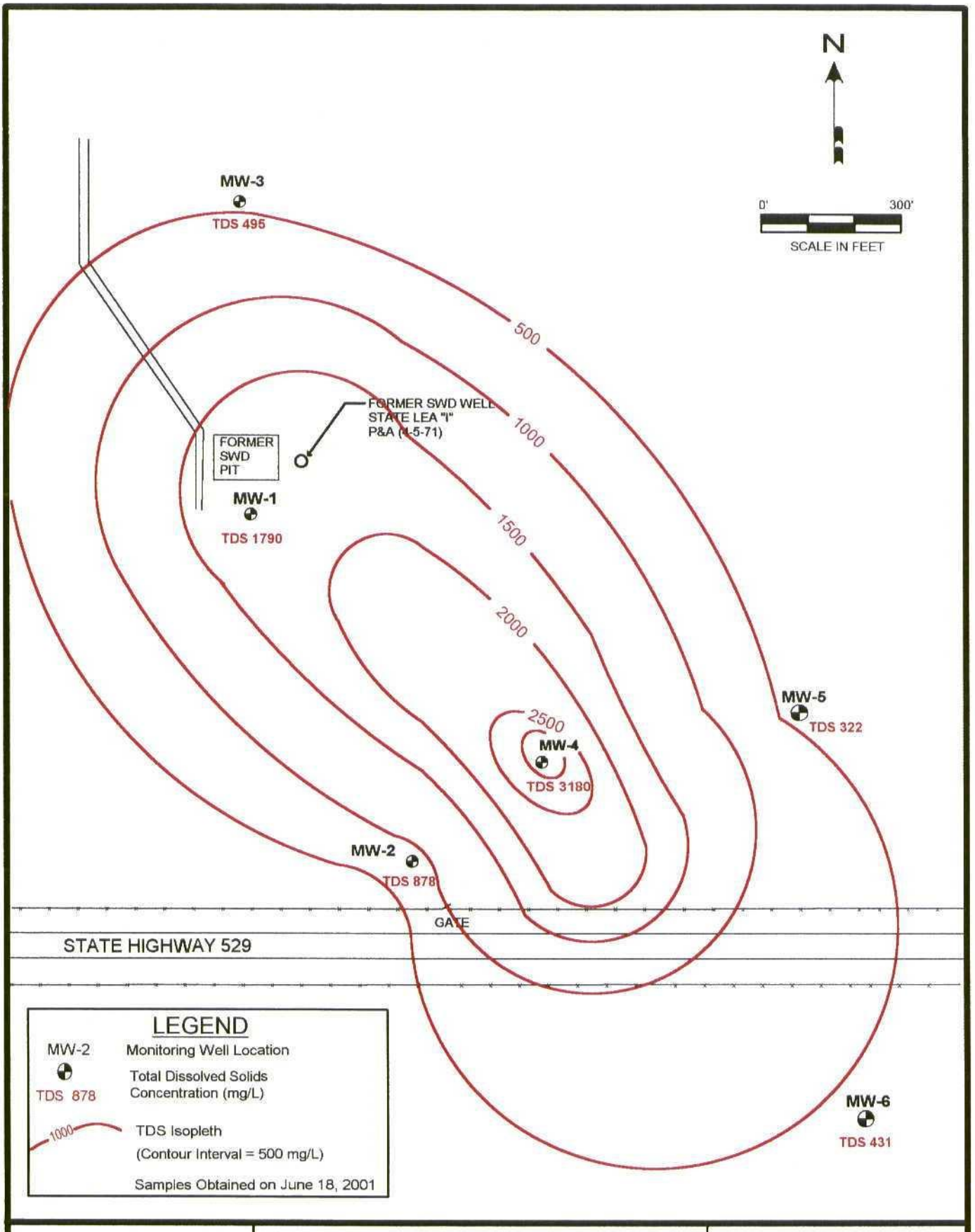
SITE: FORMER UNOCAL S. VACUUM UNIT	
DATE: 06/18/01	REV. NO.: 062600
AUTHOR: GJV	DRN BY: GJV
CK'D BY: DTL	FILE: VAC2001

FIGURE 3
CHLORIDE CONCENTRATION MAP



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SITE: FORMER UNOCAL S. VACUUM UNIT	
DATE: 06/18/01	REV. NO.: 062600
AUTHOR: GJV	DRN BY: GJV
CK'D BY: DTL	FILE: VAC2001

FIGURE 4

TOTAL DISSOLVED SOLIDS CONCENTRATION MAP

Figure 5
Chloride Concentrations Versus Time Graph

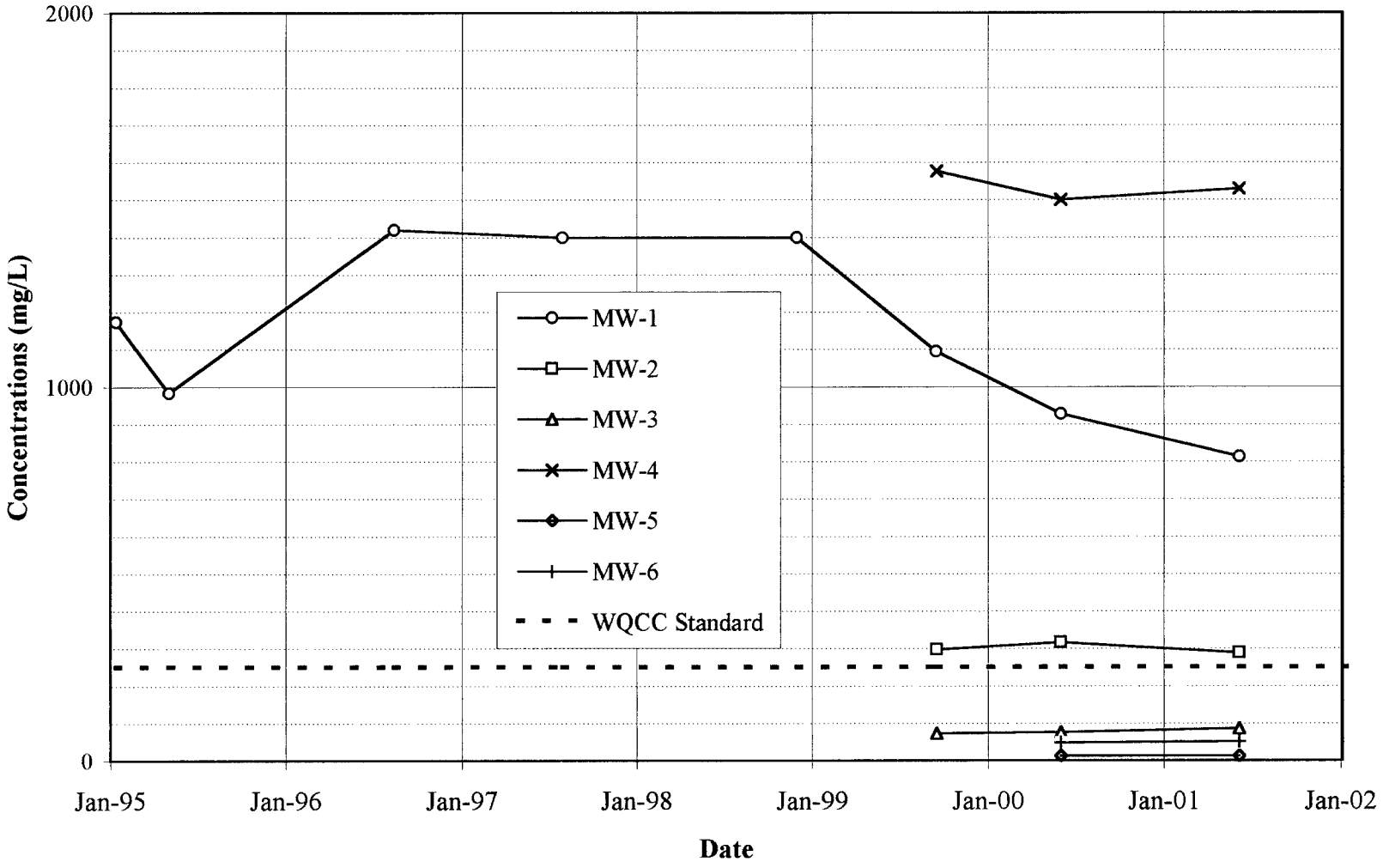
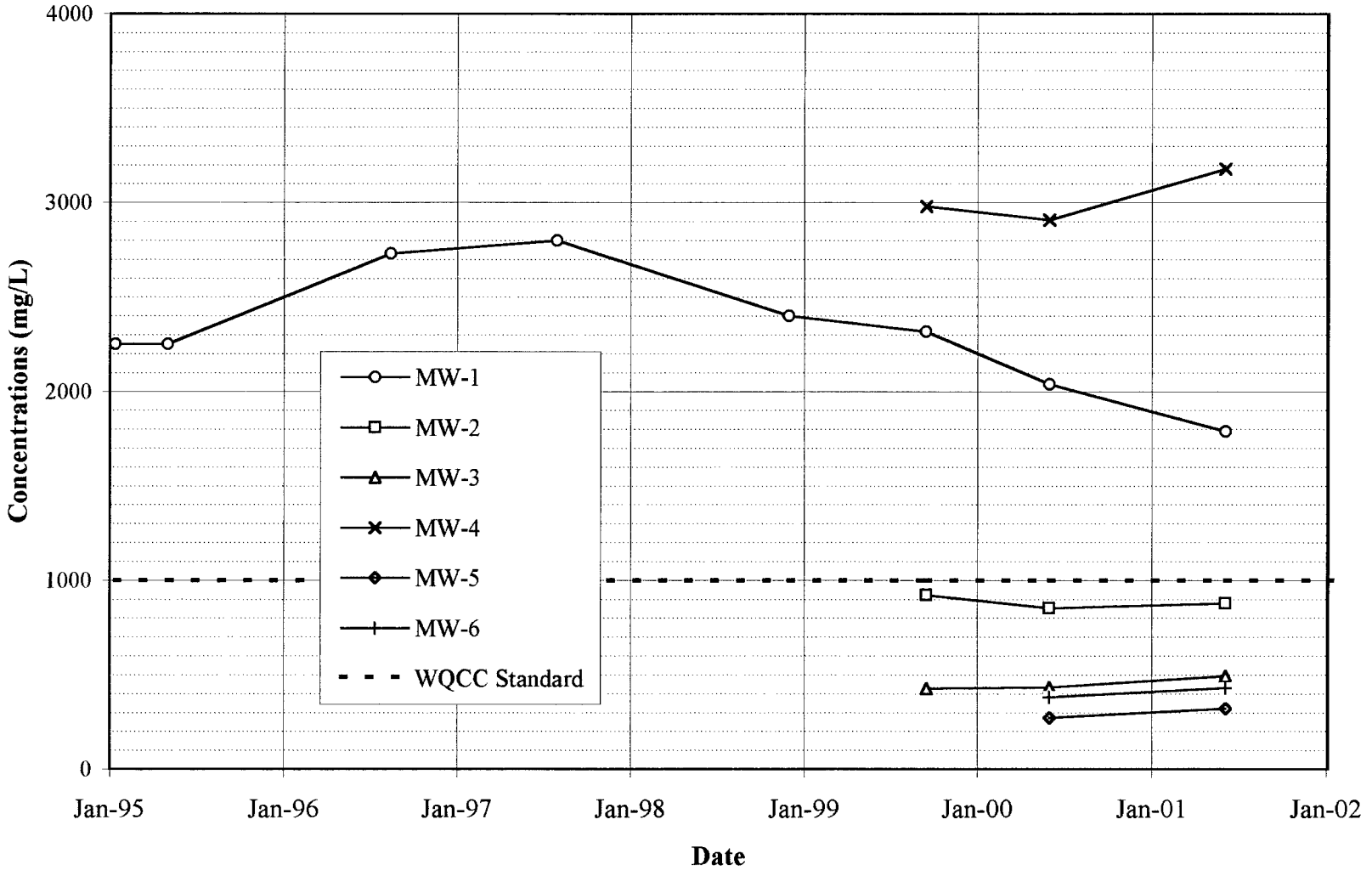


Figure 6
Total Dissolved Solids Concentrations Versus Time Graph



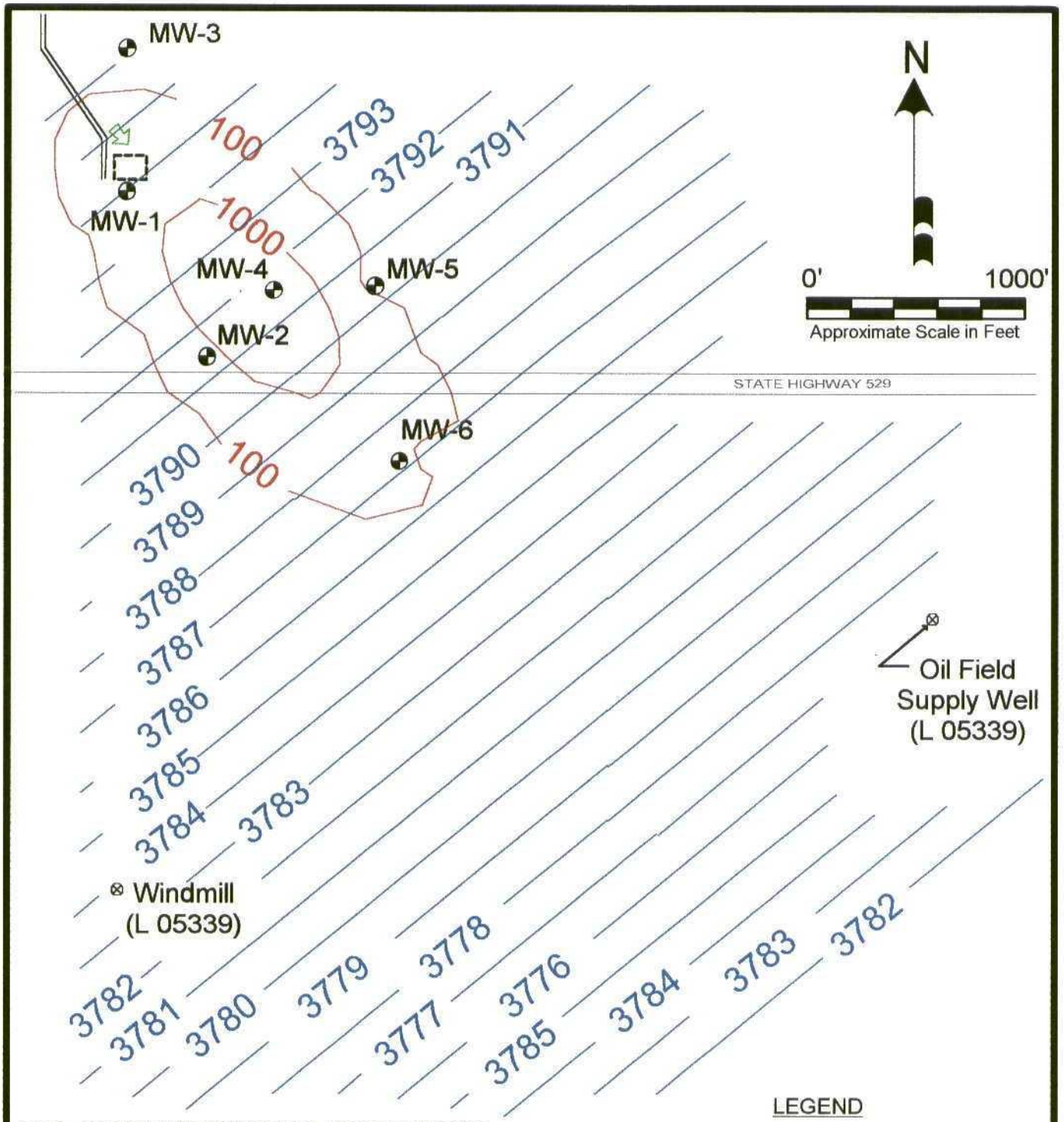
5.0 Fate and Transport Modeling Results

Fate and transport modeling was performed by Trident to simulate the movement of the chloride and TDS groundwater plume over time. Simulations were conducted with the two-dimensional groundwater flow and contaminant transport model WinTran, version 1.03 (1995) designed and distributed by Environmental Simulations, Inc. (ESI) of Herndon, Virginia. WinTran is built around a steady-state analytical element flow model, linked to a finite element contaminant transport model. A more detailed discussion of the flow and transport parameters used, assumptions, model calibrations, and simulation results are described in Appendix C.

Figures 7A and 7B show the close match achieved by the chloride and TDS simulations compared to the current observed plume. Dispersion serves to broaden the dimensions of the plume while reducing the concentrations in the middle of the plume, as depicted in Figures 8A and 8B (50 years from now). Advective flow moves the center of plume mass downgradient by a distance of approximately 800 feet from an initial current position just upgradient from well MW-4.

Successive attenuation and dispersion of the plume after the maximum chloride and TDS concentrations attenuate to levels below WQCC standards are shown in Figures 9A (year 2133) and 9B (year 2090), respectively. The center of the chloride plume is approximately 5,400 ft away from the pit and well source in the year 2133. The center of the TDS plume is approximately 2,200 ft away from the pit and well source in the year 2090.

The portions of the chloride and TDS plumes that are above WQCC standards do not reach any of the identified potential receptors at any time during their attenuation. The updated fate and transport model is consistent with that determined in the previous annual report, however the plumes attenuate sooner based as a result of revised initial chloride concentration.



FATE & TRANSPORT MODEL ASSUMPTIONS

Initial Source Concentartion = 14000 mg/L
Hydraulic Conductivity = 1000 ft/yr
Porosity = 0.25
Hydraulic Gradient = 0.004 S40E
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 30 ft
Retardation Coefficient = 1.0

LEGEND

MW-5 Monitoring Well Location

3785 Groundwater Elevation Contour

100 Chloride Isopleth (mg/L)

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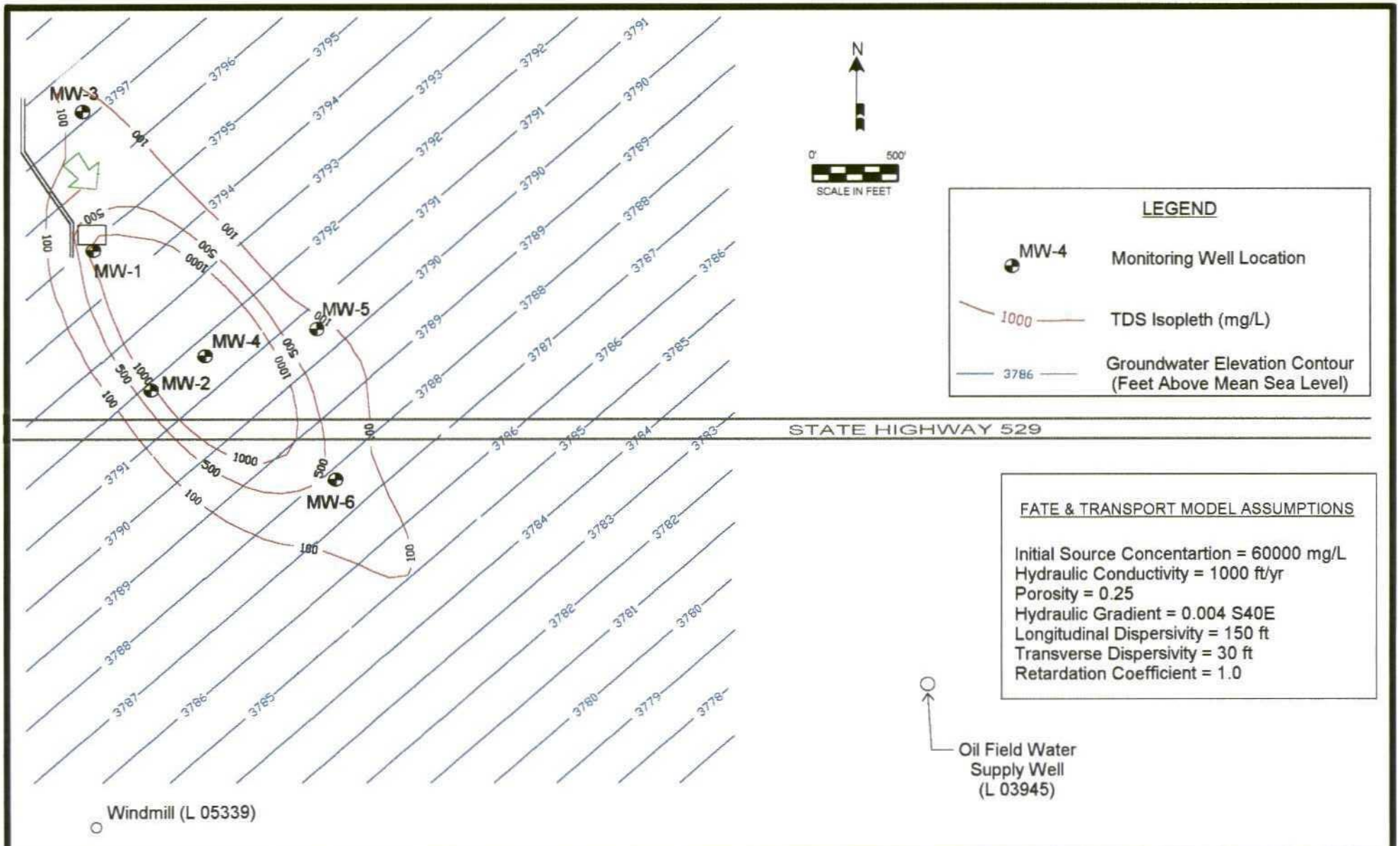
FIGURE 7A

Former Unocal South Vacuum Unit
Current Condition of Chloride Plume 31 Years After
SWD Well Plugging and Abandonment (1971-2001)

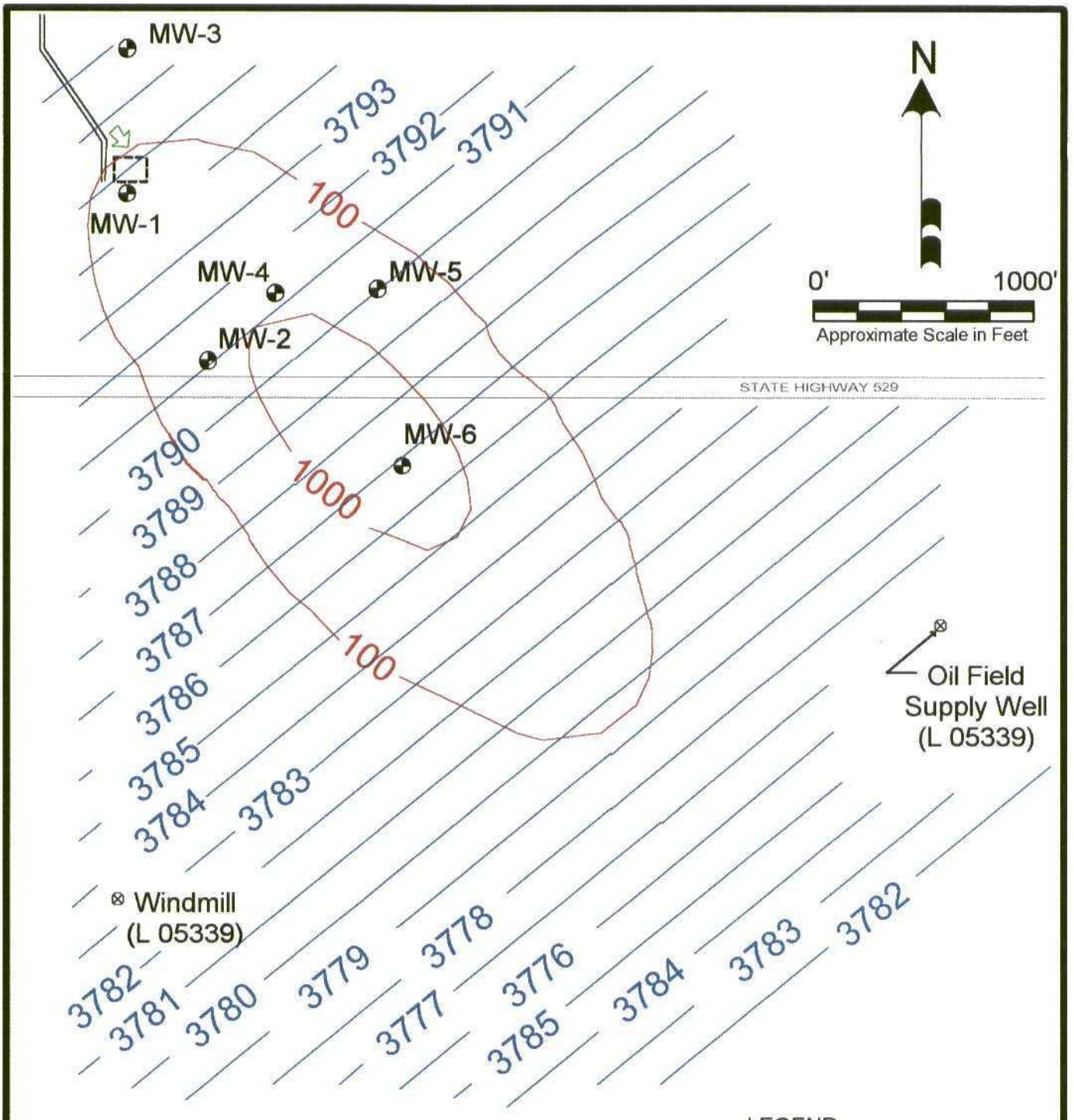


TRIDENT ENVIRONMENTAL

SITE: FORMER UNOCAL S. VACUUM UNIT	
DATE: 06/18/01	FILE: TDS2001
DRAWN BY: GJV	CHECKED BY: DTL
APPROXIMATE SCALE: 1 INCH = 710 FEET	

FIGURE 7B

Current Conditions of TDS Plume 30 Years After
SWD Well Plugging and Abandonment (1971 - 2001)



FATE & TRANSPORT MODEL ASSUMPTIONS

Initial Source Concentartion = 14000 mg/L
Hydraulic Conductivity = 1000 ft/yr
Porosity = 0.25
Hydraulic Gradient = 0.004 S40E
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 30 ft
Retardation Coefficient = 1.0

LEGEND

MW-5 Monitoring Well Location

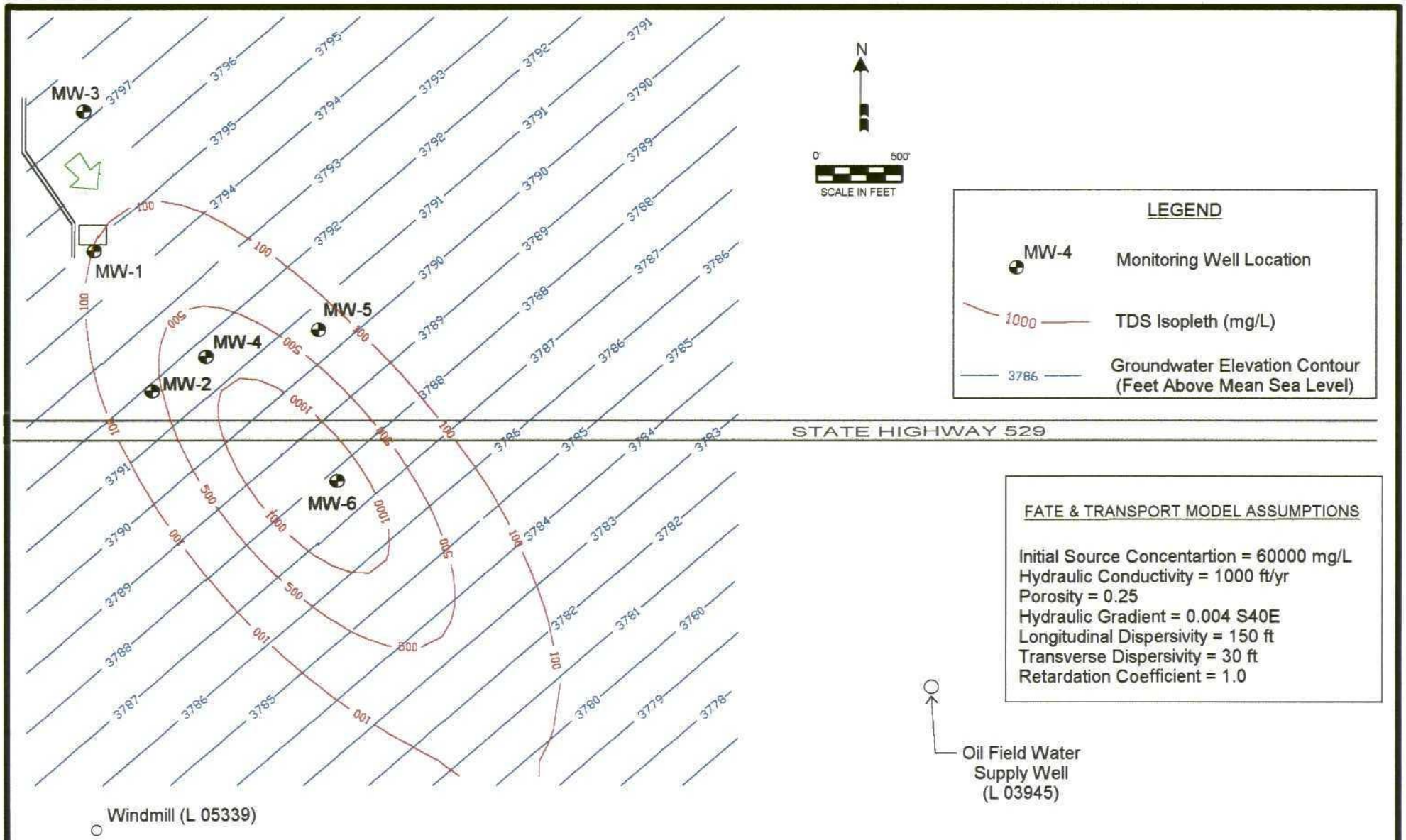
3785 Groundwater Elevation Contour

100 Chloride Isopleth (mg/L)

TRIDENT ENVIRONMENTAL

FIGURE 8A

Former Unocal South Vacuum Unit
Chloride Plume 50 Years After
Current Conditions (2001-2051)



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SITE: FORMER UNOCAL S. VACUUM UNIT	
DATE: 06/18/01	FILE: TDS2001
DRAWN BY: GJV	CHECKED BY: DTL
APPROXIMATE SCALE: 1 INCH = 710 FEET	

FIGURE 8B

TDS Plume 50 Years After Current Conditions (2001 - 2051)

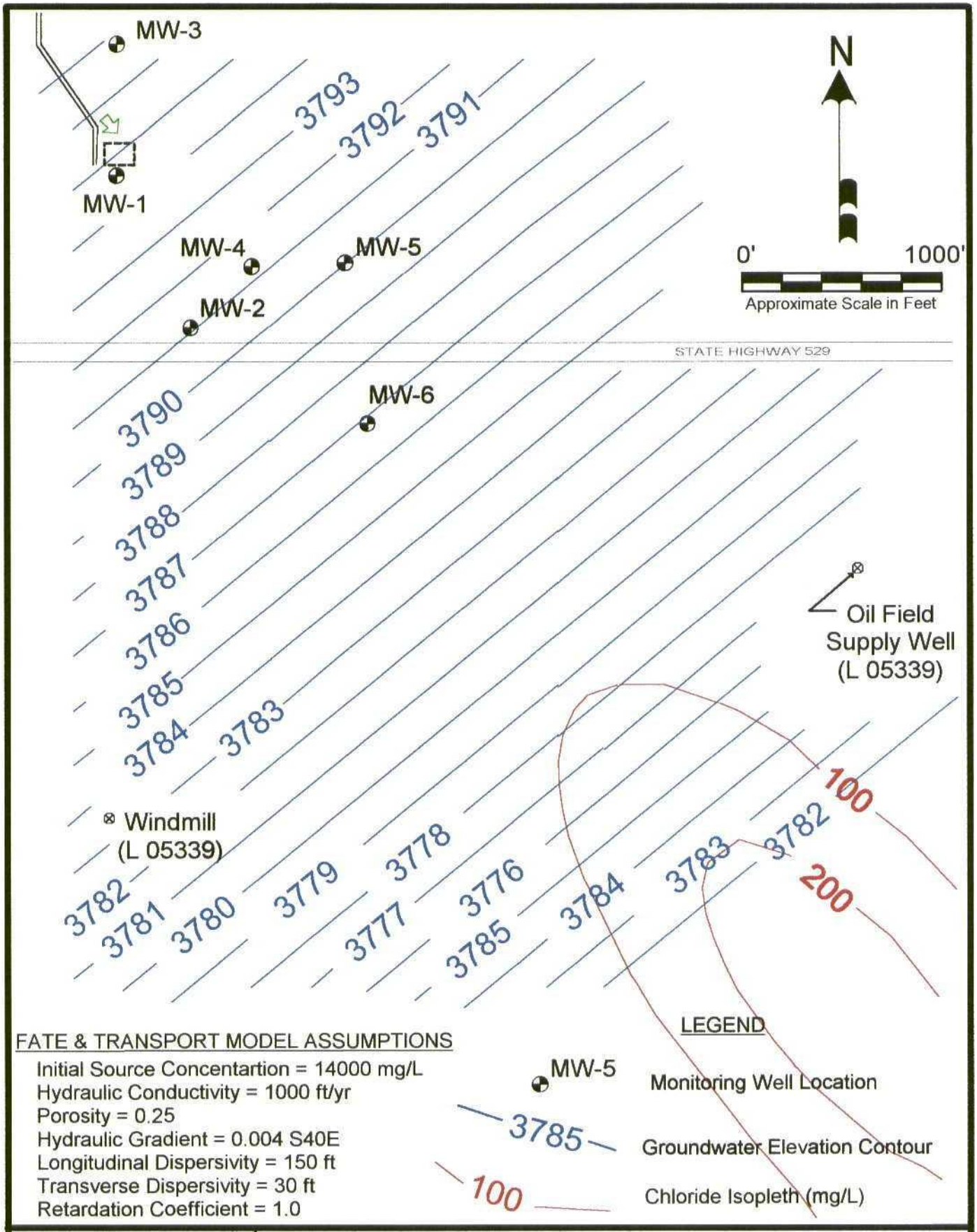

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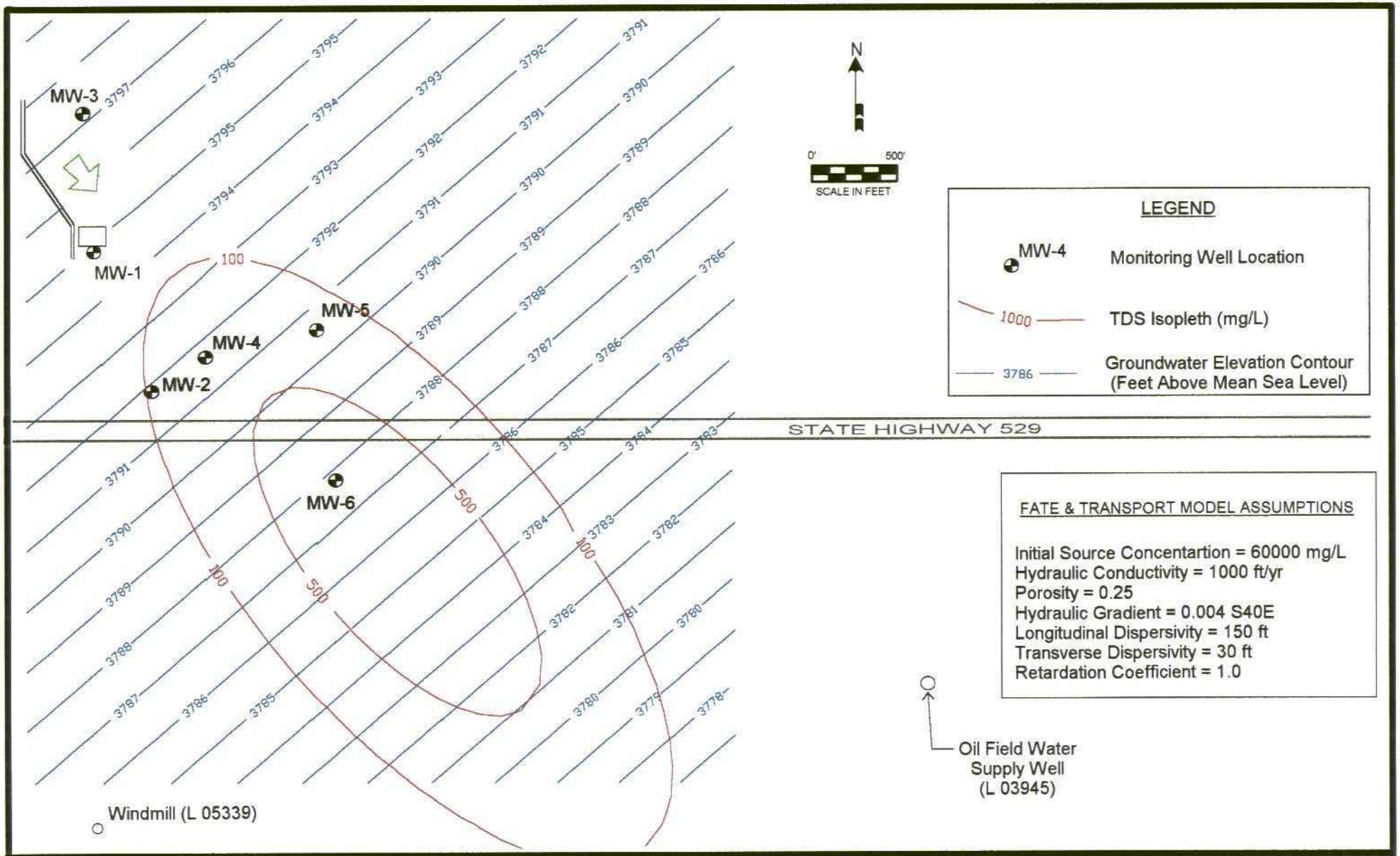
FIGURE 9A

Former Unocal South Vacuum Unit
Chloride Plume 132 Years After
Current Conditions (2001-2133)



TRIDENT ENVIRONMENTAL

SITE: FORMER UNOCAL S. VACUUM UNIT	
DATE: 06/18/01	FILE: TDS2001
DRAWN BY: GJV	CHECKED BY: DTL
APPROXIMATE SCALE: 1 INCH = 710 FEET	

FIGURE 9B

TDS Plume 89 Years After Current Conditions (2001 - 2090)

6.0 Conclusions

Conclusions relevant to groundwater conditions and the remediation performance at the Former Unocal South Vacuum Unit are presented below.

- The fate and transport modeling results continue to support the contention that the chloride and TDS plume is not likely to impact existing sources of water supply, the closest of which, a live stock well, lies approximately 3,200 feet south of the source.

- According to conservative model simulations, the chloride plume will travel a maximum of 5,400 feet southeast of the source in approximately 133 years before concentrations return to levels below the WQCC standard of 250 mg/L. The same analysis indicates that the TDS plume will travel only 2,200 feet in approximately 90 years before concentrations return to levels below the WQCC standard of 1,000 mg/L.

- Based on the modeling results and predicted natural attenuation processes (advection and dispersion), there will be no adverse impact to human health and the environment nor will the live stock well exceed WQCC standards for chlorides or TDS due to the plume originating from the former emergency overflow pit.

- Groundwater elevations have been steadily decreasing at a rate of approximately 0.3 feet per year since the initial sampling event of monitoring well MW-1 in January 1995.

7.0 Recommendations

Based on the identified potential receptor and fate and transport modeling results, the chloride/TDS plume at the site presents low risk to human health and the environment; therefore Trident recommends the following actions for site closure:

- Continue monitoring natural attenuation with one more year of annual groundwater sampling and analysis of chloride and TDS concentrations for each of the six monitoring wells.

- Recalibrate flow and transport model to confirm the plume is naturally attenuating as described.

- Submit the 2002 annual groundwater monitoring report to OCD in January 2003 to document natural attenuation conditions.

- If, after one more year of monitoring, the plume is naturally attenuating as described, request no further action from OCD.

APPENDICES

APPENDIX A

LABORATORY ANALYTICAL REPORTS

AND

CHAIN-OF-CUSTODY DOCUMENTATION

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Unocal-Mid Continent-CERT

Certificate of Analysis Number:

01060673

Report To:		Project Name:	Former Unocal S Vacuum Unit
TRW Energy and Environmental Integration Systems		Site:	Former Unocal S Vacuum Unit
Gil Van Deventer		Site Address:	
415 West Wall Suite 1818.			
Midland		PO Number:	
Texas		State:	New Mexico
79701-		State Cert. No.:	
ph: (915) 682-0008	fax: (915) 682-0028	Date Reported:	6/28/01

This Report Contains A Total Of 13 Pages

Excluding This Page

And

Chain Of Custody

6/28/01

Date

HOUSTON LABORATORY
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HOUSTON, TEXAS 77054
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Case Narrative for:

Unocal-Mid Continent-CERT

Certificate of Analysis Number:

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Report To:		**Project Name:**	Former Unocal S Vacuum Unit
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415 West Wall Suite 1818.			
Midland		**PO Number:**	
Texas		**State:**	New Mexico
79701-		**State Cert. No.:**	
ph: (915) 682-0008	fax: (915) 682-0727	**Date Reported:**	6/28/01

Matrix spike (MS) and matrix spike duplicate (MSD) samples are chosen and tested at random from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. Since the MS and MSD are chosen at random from an analytical batch, the sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The Laboratory Control Sample (LCS) and the Method Blank (MB) are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

Any other exceptions associated with this report will be footnoted in the analytical result page(s) or the quality control summary page(s).

Please do not hesitate to contact us if you have any questions or comments pertaining to this data report. Please reference the above Certificate of Analysis Number.

This report shall not be reproduced except in full, without the written approval of the laboratory. The reported results are only representative of the samples submitted for testing.

SPL, Inc. is pleased to be of service to you. We anticipate working with you in fulfilling all your current and future analytical needs.

Sommers, Elessa
Senior Project Manager

6/29/01
Date

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Unocal-Mid Continent-CERT

Certificate of Analysis Number:

01060673

Report To: TRW Energy and Environmental Integration Systems
Gil Van Deventer
415 West Wall Suite 1818.

Midland
Texas
79701-
ph: (915) 682-0008 fax:

Fax To: *TRW Energy and Environmental Integration Systems*
Gil Van Deventer *fax: (915) 682-0727*

Project Name: Former Unocal S Vacuum Unit
Site: Former Unocal S Vacuum Unit
Site Address:

PO Number:
State: New Mexico
State Cert. No.:
Date Reported: 6/28/01

Client Sample ID	Lab Sample ID	Matrix	Date Collected	Date Received	COC ID	HOLD
MW-1	01060673-01	Water	6/18/01 9:20:00 AM	6/20/01 10:00:00 AM	9377	☐
MW-2	01060673-02	Water	6/18/01 10:20:00 AM	6/20/01 10:00:00 AM	9377	☐
MW-3	01060673-03	Water	6/18/01 8:30:00 AM	6/20/01 10:00:00 AM	9377	☐
MW-4	01060673-04	Water	6/18/01 9:40:00 AM	6/20/01 10:00:00 AM	9377	☐
MW-5	01060673-05	Water	6/18/01 8:40:00 AM	6/20/01 10:00:00 AM	9377	☐
MW-6	01060673-06	Water	6/18/01 9:50:00 AM	6/20/01 10:00:00 AM	9377	☐

Sommers, Elessa
Senior Project Manager

6/29/01
Date

Joel Grice
Laboratory Director

Ted Yen
Quality Assurance Officer

6/29/01 12:27:33 PM

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Client Sample ID: MW-1 **Collected:** 6/18/01 9:20:00 **SPL Sample ID:** 01060673-01

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**		**Units: mg/L**		
Chloride	813	10		10		06/21/01 11:20	CV	716053
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**		**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	1790	20		2		06/24/01 15:00	J_G	717414

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

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8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Client Sample ID: MW-2 **Collected:** 6/18/01 10:20:00 **SPL Sample ID:** 01060673-02

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**	**Units: mg/L**		
Chloride	288	5	5		06/21/01 11:20	CV	716055
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**	**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	878	20	2		06/24/01 15:00	J_G	717416

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Client Sample ID: MW-3 **Collected:** 6/18/01 8:30:00 **SPL Sample ID:** 01060673-03

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**		**Units: mg/L**		
Chloride	86.4	1		1		06/21/01 11:20	CV	716056
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**		**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	495	10		1		06/24/01 15:00	J_G	717417

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Client Sample ID: MW-4 **Collected:** 6/18/01 9:40:00 **SPL Sample ID:** 01060673-04

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**		**Units: mg/L**		
Chloride	1530	25		25		06/21/01 11:20	CV	716057
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**		**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	3180	20		2		06/24/01 15:00	J_G	717418

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Client Sample ID: MW-5 **Collected:** 6/18/01 8:40:00 **SPL Sample ID:** 01060673-05

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**		**E325.3**	**Units: mg/L**		
Chloride	13.6	1		1		06/21/01 11:20	CV	716058
TOTAL DISSOLVED SOLIDS			**MCL**		**E160.1**	**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	322	10		1		06/24/01 15:00	J_G	717419

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

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8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Client Sample ID: MW-6 **Collected:** 6/18/01 9:50:00 **SPL Sample ID:** 01060673-06

Site: Former Unocal S Vacuum Unit

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORIDE, TOTAL			**MCL**	**E325.3**		**Units: mg/L**		
Chloride	50.8	1		1		06/21/01 11:20	CV	716059
TOTAL DISSOLVED SOLIDS			**MCL**	**E160.1**		**Units: mg/L**		
Total Dissolved Solids (Residue,Filterable)	431	10		1		06/24/01 15:00	J_G	717420

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

Quality Control Documentation

6/28/01 5:33:06 PM

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Quality Control Report

Unocal-Mid Continent-CERT

Former Unocal S Vacuum Unit

Analysis: Chloride, Total **WorkOrder:** 01060673
Method: E325.3 **Lab Batch ID:** R37661A

Method Blank

RunID: WET_010621T-716031 Units: mg/L
Analysis Date: 06/21/2001 11:20 Analyst: CV

Analyte	Result	Rep Limit
Chloride	ND	1.0

Samples in Analytical Batch:

Lab Sample ID	Client Sample ID
01060673-01A	MW-1
01060673-02A	MW-2
01060673-03A	MW-3
01060673-04A	MW-4
01060673-05A	MW-5
01060673-06A	MW-6

Laboratory Control Sample (LCS)

RunID: WET_010621T-716033 Units: mg/L
Analysis Date: 06/21/2001 11:20 Analyst: CV

Analyte	Spike Added	Result	Percent Recovery	Lower Limit	Upper Limit
Chloride	76.2	75.4	99	90	110

Matrix Spike (MS) / Matrix Spike Duplicate (MSD)

Sample Spiked: 01060489-06
RunID: WET_010621T-716048 Units: mg/L
Analysis Date: 06/21/2001 11:20 Analyst: CV

Analyte	Sample Result	MS Spike Added	MS Result	MS % Recovery	MSD Spike Added	MSD Result	MSD % Recovery	RPD	RPD Limit	Low Limit	High Limit
hloride	210	250	458	98.3	250	458	98.3	0	20	85	115

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits

The percent recoveries for QC samples are correct as reported. Due to significant figures and rounding, the reported RPD may differ from the displayed RPD values but is correct as reported.

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Quality Control Report

Unocal-Mid Continent-CERT

Former Unocal S Vacuum Unit

Analysis: Total Dissolved Solids **WorkOrder:** 01060673
Method: E160.1 **Lab Batch ID:** R37745

Method Blank

RunID: WET_010624A-717411 Units: mg/L
Analysis Date: 06/24/2001 15:00 Analyst: J_G

Analyte	Result	Rep Limit
Total Dissolved Solids (Residue,Filterable)	ND	10

Samples in Analytical Batch:

Lab Sample ID	Client Sample ID
01060673-01A	MW-1
01060673-02A	MW-2
01060673-03A	MW-3
01060673-04A	MW-4
01060673-05A	MW-5
01060673-06A	MW-6

Laboratory Control Sample (LCS)

RunID: WET_010624A-717413 Units: mg/L
Analysis Date: 06/24/2001 15:00 Analyst: J_G

Analyte	Spike Added	Result	Percent Recovery	Lower Limit	Upper Limit
Total Dissolved Solids (Residue,Filtera	200	213	106	90	110

Sample Duplicate

Original Sample: 01060673-01
RunID: WET_010624A-717414 Units: mg/L
Analysis Date: 06/24/2001 15:00 Analyst: J_G

Analyte	Sample Result	DUP Result	RPD	RPD Limit
Total Dissolved Solids (Residue,Filtera	1790	1780	1	20

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits

The percent recoveries for QC samples are correct as reported. Due to significant figures and rounding, the reported RPD may differ from the displayed RPD values but is correct as reported.

Sample Receipt Checklist

And

Chain of Custody

6/28/01 5:33:26 PM

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
(713) 660-0901

Sample Receipt Checklist

Workorder:	01060673	Received By:	DS
Date and Time Received:	6/20/01 10:00:00 AM	Carrier name:	FedEx
Temperature:	4	Chilled by:	Water Ice

		Yes	No	Not Present
1.	Shipping container/cooler in good condition?	☑	☐	☐
2.	Custody seals intact on shippping container/cooler?	☐	☐	☑
3.	Custody seals intact on sample bottles?	☐	☐	☑
4.	Chain of custody present?	☑	☐	
5.	Chain of custody signed when relinquished and received?	☑	☐	
6.	Chain of custody agrees with sample labels?	☑	☐	
7.	Samples in proper container/bottle?	☑	☐	
8.	Sample containers intact?	☑	☐	
9.	Sufficient sample volume for indicated test?	☑	☐	
10.	All samples received within holding time?	☑	☐	
11.	Container/Temp Blank temperature in compliance?	☑	☐	
12.	Water - VOA vials have zero headspace?	☐	☐	Not Applicable ☑
13.	Water - pH acceptable upon receipt?	☑	☐	Not Applicable ☐

SPL Representative: _____ **Contact Date & Time:** _____

Client Name Contacted: _____

Non Conformance Issues: _____

Client Instructions: _____

010601673

SPL Laboratories, Inc.

☐ 1511 East Orangethorpe Ave. Fullerton, CA 92631 (714) 447-6868 Fax:(714) 447-6800

☒ 8880 Interchange Drive Houston, Texas 77054 (713) 660-0901 Fax: (713) 660-8975

☐ 500 Ambassador Caffery Pkwy. Scott, Louisiana 70583 (318) 237-4775 Fax: (318) 237-7080

UNOCAL 76

Chain of Custody Record 9377

Company Name: Trident Environmental	Project Name: Former Unocal S. Vacuum Unit
Address: P.O. Box 7624	UNOCAL Project Manager: Ben Terry
City: Midland State: Tx Zip Code: 79708	AFE#:
Telephone: 915/682-0808 FAX: 915/682-0727	Site #:
Report To: Gil Van Deventer Sampler:	QC Data: ☒ Level D (Standard) ☐ Level C ☐ Level B ☐ Level A

Turnaround Time: (Calendar Days) ☒ 10 Days (Standard) ☐ 5 Days ☐ 3 Days ☐ 2 Days ☐ 1 Day

CODE: ☐ Misc. ☐ Detecl. ☐ Eval. ☐ Remed. ☐ Demol. ☐ Closure

☐ Drinking Water ☐ Waste Water ☐ Other

Analyses Requested

Client Sample I.D.	Date/Time Sampled	Matrix Desc.	# of Cont.	Cont. Type	Laboratory Sample #	Chlorides	TDS	pH	BTEX						Comments
MW-1	6-18-01 0920	Water	1	P/500		✓	✓								
MW-2	6-18-01 1020	Water	1	P/500		✓	✓								
MW-3	6-18-01 0830	Water	1	P/500		✓	✓								
MW-4	6-18-01 0940	Water	1	P/500		✓	✓								
MW-5	6-18-01 0840	Water	1	P/500		✓	✓								
MW-6	6-18-01 0950	Water	1	P/500		✓	✓								
															4°

Relinquished By:	Date: 6/19/01	Time: 4:00 pm	Received By:	Date:	Time:
Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Relinquished By:	Date:	Time:	Received By:	Date: 6/20/01	Time: 1000

Were Samples Received in Good Condition? ☐ Yes ☐ No Samples on Ice? ☐ Yes ☐ No Method of Shipment Fed Ex B28G5478-5560 Page 1 of 1

50 10lb

PINK - Client

YELLOW - Laboratory

WHITE - Laboratory

APPENDIX B

MONITORING WELL SAMPLING DATA FORMS

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-1**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 6/19/01
PROJECT NO. V-107
SAMPLER: Fergerson / Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 70.00 Feet
DEPTH TO WATER: 63.07 Feet
HEIGHT OF WATER COLUMN: 6.93 Feet
WELL DIAMETER: 2.0 Inch

3.4 Minimum Gallons to purge 3 well volumes

TIME	VOLUME PURGED	TEMP. °C / °F	COND. *m*S/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
830	8	17°C	1500				

COMMENTS: _____

C:/FORMS/SAMPLING DATA FORM

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-2**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 6/19/01
PROJECT NO. V-107
SAMPLER: Fergerson / Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 71.00 Feet
DEPTH TO WATER: 50.06 Feet
HEIGHT OF WATER COLUMN: 20.94 Feet
WELL DIAMETER: 2.0 Inch

10.3 Minimum Gallons to purge 3 well volumes

TIME	VOLUME PURGED	TEMP. °C	COND. *m*S/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
1020	8	19.5°C	1600				

COMMENTS: _____

C:/FORMS/SAMPLING DATA FORM

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-3**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 6/19/01
PROJECT NO. V-107
SAMPLER: Fergerson / Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 77.00 Feet
DEPTH TO WATER: 67.29 Feet
HEIGHT OF WATER COLUMN: 9.71 Feet
WELL DIAMETER: 2.0 Inch

4.8 Minimum Gallons to purge 3 well volumes

TIME	VOLUME PURGED	TEMP. °C	COND. *m*S/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
0830	8	19.5°C	398				

COMMENTS: _____

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-5**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 6/19/01
PROJECT NO. V-107
SAMPLER: Fergerson / Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 75.00 Feet
DEPTH TO WATER: 68.8 Feet
HEIGHT OF WATER COLUMN: 6.20 Feet
WELL DIAMETER: 2.0 Inch

3.0 Minimum Gallons to purge 3 well volumes

TIME	VOLUME PURGED	TEMP. °C	COND. *m*S/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
0840	8	18.5°C	322				

COMMENTS: _____

C:/FORMS/SAMPLING DATA FORM

WELL SAMPLING DATA FORM

CLIENT: Unocal Corporation
WELL ID: **MW-6**
SITE NAME: Former Unocal S. Vacuum Unit
DATE: 6/19/01
PROJECT NO. V-107
SAMPLER: Fergerson / Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: _____

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other: _____

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse ☐ Other: _____

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 76.00 Feet
DEPTH TO WATER: 70.98 Feet
HEIGHT OF WATER COLUMN: 5.02 Feet
2.5 Minimum Gallons to purge 3 well volumes
WELL DIAMETER: 2.0 Inch

TIME	VOLUME PURGED	TEMP. °C	COND. *m*S/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
0950	8	22.5°C	490				

COMMENTS: _____

APPENDIX C

DESCRIPTION OF FATE AND TRANSPORT MODELING

Description of Fate and Transport Modeling

Conceptual Model

Liquid waste brine containing high concentrations of chloride, and resultant high levels of total dissolved solids (TDS), was reportedly discharged into a surface pit and adjoining injection well for a period of about 10 years, until the well was plugged and abandoned in the early 1970s. The chloride and TDS plume continued to migrate southeastwards for the next approximately 30 years after the source input was stopped, producing the configuration and constituent concentration distribution observed currently. Extrapolating from current conditions for decades into the future, taking account of both advective flow and attenuation by hydrodynamic dispersion, enables prediction of the probable distance that the residual plume will travel as well as the gradually declining concentrations in the plume.

Basic Site Data

Information about site conditions was obtained from data in a TRW Inc. "Report of Additional Groundwater Investigation, Former Unocal South Vacuum Unit, Lea County, New Mexico" (July 18, 2000). This included lithologic records from well installations, water level data, and water quality analytical results.

Simulation Model

Simulations were conducted with the two-dimensional groundwater flow and contaminant transport model WinTran, version 1.03 (1995) designed and distributed by Environmental Simulations, Inc. (ESI) of Herndon, Virginia. WinTran is built around a steady-state analytical element flow model, linked to a finite element contaminant transport model. The Windows interface allows for rapid data input, processing, parameter manipulation and optimization, and output in multiple formats. The fundamental mathematics of the model solutions, model verification (benchmarked against MODFLOW), and use of WinTran is documented in the "Guide to Using WinTran" published by ESI.

Base Map

A simplified site base map, edited with TurboCAD (Version 7), was exported to a universal drawing exchange file (DXF) file format. The DXF base map was imported into WinTran, which preserves the original units of measurement.

Flow Parameters

Input requirements for the steady-state groundwater flow simulation include: hydraulic gradient and direction of flow, hydraulic conductivity, aquifer top and bottom elevations, and reference head. The values used were based on the following sources:

- Hydraulic gradient – measured gradient of 0.004 feet/foot from June 2001 site measurements reported by Trident.
- Direction of flow – measured direction of approximately S 40° E from June 2001 site measurements reported by Trident.

- Hydraulic conductivity – no site measurements were available; therefore, a literature value based on the saturated zone lithology was selected. Typical lithology is described as silty sand and very fine sand. Fetter (1988, Table 4.5, p. 80) cites an average range of 10^{-5} to 10^{-3} cm/sec for hydraulic conductivity of silty sands and fine sands. A conservative upper limit was selected, and converted from S.I. unit to 2.8 ft/day, or approximately 1000 ft/yr.

- Aquifer top and bottom elevations – bottom elevation of Ogallala Formation at 3700 feet reported by Trident. The top elevation for an unconfined aquifer must be greater than the reference head. An elevation of 4000 feet was assumed.

- Reference head – measured unconfined head of 3795.5 feet adjacent to the former pit and upgradient well MW-1 from June 2001 measurements reported by Trident.

Transport Parameters

Input requirements for the contaminant transport numerical simulation include: longitudinal and transverse dispersivity, porosity, diffusion coefficient, contaminant half-life, and retardation coefficient. The values used were based on the following sources:

- Longitudinal and transverse dispersivity – no site measurements were available; therefore, a literature value based on the plume length was selected. Fetter (1993, Section 2.11, pp. 71-77) notes the apparent scale-dependency of longitudinal dispersivity, which typically may be about 0.1 times the flow length. For the current site scale and plume length of approximately 1500 feet, a value of 150 feet was selected for longitudinal dispersivity. According to the WinTran user's guide (ESI, 1995, p.11), longitudinal dispersivity is usually 5 to 10 times higher than transverse dispersivity; therefore, a value of 30 feet (i.e., one-fifth of the longitudinal value) was selected for transverse dispersivity.

- Porosity – no site measurements were available; therefore a literature value based on saturated zone lithology was selected. Typical lithology is described as silty sand and very fine sand. A range of 0.25 to 0.50 is typically given for unconsolidated "sand" (e.g., Freeze & Cherry, 1979, Table 2.4, p. 37); however, the Ogallala Formation is predominantly very fine grained, compacted and partly cemented, and may also fit within the range of 0.05 to 0.30 for sandstone. Fetter (1988, Table 4.3 and Figure 4.10, pp. 74-75) cites an average value of 0.20 for the specific yield of very fine sands. Specific retention of silty fine sand is approximately 0.05, for a total porosity of 0.25, which is the value selected for the transport modeling. WinTran uses the porosity term to estimate groundwater velocity, and actually requires an effective porosity value. Fetter (1988, Section 4.4, pp. 84-85) notes that pores of most sediments down to clay size are interconnected and that the effective porosity is virtually equal to the total porosity.

- Diffusion coefficient – this parameter is normally only relevant for very slow fluid movement, and is commonly assumed to be zero for advective-dominated transport, as in the present case.

- Contaminant half-life – this parameter accounts for chemical decay (e.g., radioisotopes, biological transformation of organic molecules); however, the species of interest in the present case are inorganic ions and are not expected to decay to any appreciable extent.

A conservative value of 1000 years was used, which produces a negligible decay coefficient of less than 0.001 yr^{-1}.

- Retardation coefficient – this parameter accounts for sorption processes that slow the movement of contaminants relative to the groundwater velocity. Inorganic ions such as chloride are commonly taken as conservative tracers in groundwater and are not considered to be retarded; therefore, a value of 1.0 was selected for the retardation coefficient.

Flow Model Calibration

The vicinity of the site where water level measurements were recorded in June 2001 is simulated closely by the flow model. It is known that groundwater levels in the Ogallala Formation are decreasing slowly (less than 0.5 ft/yr), but this effect cannot be reproduced in the steady-state flow model. Water levels were probably somewhat higher than the present day during the period of brine disposal and initial transport. Even if the declining trend continues into the future, it does not affect the transport model solution for long extrapolation times, since sufficient saturated thickness remains (i.e., above the assumed aquifer base elevation of 3700 feet) for a valid flow and transport solution.

Flow lines with 25-year time steps show the distance that water moves perpendicular to the equipotential lines. The average groundwater velocity may be estimated using the darcy expression: $v = (k . i) / n$ where k is the hydraulic conductivity (ft/yr), i is the hydraulic gradient (ft/foot), and n is the effective porosity (unitless). The resultant average velocity is 16 ft/yr.

Transport Model Calibration

The objective of the transport modeling was to first obtain a plume configuration with concentration values that closely match current observed values. This was done by simulating an initial contaminant release to groundwater for a period of 11 years (c. 1960 to 1971) with a constant source concentration located at the pit and injection well, then simulating a 30-year transport period (c. 1971 to 2001) with no further contaminant input but restarting the model from the end of Year 11 by retaining the mass of contaminant from the initial plume. An iterative approach was needed to optimize the initial source concentration so that the plume at Year 41 resembled the current actual plume. An initial value of 14,000 mg/L for chloride and 60,000 mg/L for TDS were found to produce the best match. The initial chloride value was also chosen because it is typical of chloride concentrations within the producing formation (Devonian) in the South Vacuum Oil Field according to chemists at Martin Water Laboratories (verbal communication, 12-05-01). Actual disposal concentrations during the 1960s are unknown, and may have been higher than these values, but it is presumed that some attenuation and dilution may have occurred in the vadose zone, which is currently 47 to 67 feet thick. WinTran does not account for vadose zone transport, and the source input is treated as an injection well with instantaneous transfer of contaminant mass to groundwater.

Figures 7A and 7B show the close match achieved by the chloride and TDS simulations compared to the current observed plume.

Simulation of Fate and Transport

Estimation of chloride and TDS fate and transport was achieved by restarting the transport model from the end of Year 41 (2001) by retaining the distribution of contaminant mass and projecting for a further 50 years into the future. As depicted in Figures 8A and 8B, dispersion serves to broaden the dimensions of the plume while reducing the concentrations in the middle of the plume. Advective flow moves the center of plume mass downgradient by a distance of approximately 800 feet from an initial current position just upgradient from well MW-4.

Successive attenuation and dispersion of the chloride plume in the year 2149 is shown in Figure 9A. Successive attenuation and dispersion of the TDS plume in the year 2090 is shown in Figure 9B when TDS concentrations. These results support the contention that the chloride and TDS plume is not likely to impact any existing sources of water supply, the closest of which lies approximately 3000 feet south of the source.

Running the model for 148 years in the future (Year 2149) produces a chloride plume center concentration of 249 mg/L (below the WQCC standard of 250 mg/L) as shown in Figure 9A. The center of the chloride plume is approximately 5,300 ft away from the pit and well source at that time.

Running the model for 89 years in the future (Year 2090) produces a TDS plume center concentration of 962 mg/L (below the WQCC standard of 1,000 mg/L) as shown in Figure 9B. The center of the TDS plume is approximately 2,200 ft away from the pit and well source at that time.

The trend of decreasing concentration is not linear (exponential e^{-kt} function). Interestingly, the center of the plume moves at a greater rate (27 feet/year) over successive time intervals than would be assumed from the groundwater velocity alone (16 feet/year), due to the added effect of dispersion.