AP - ___75______

STAGE 2 REPORTS

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TRIDENT ENVIRONMENTAL

November 20, 2007

AP-75

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NOV 26 2007

Environmental Bureau
Oil Conservation Division

Mr. Edward Hansen
New Mexico Energy, Minerals, & Natural Resources
Oil Conservation Division, Environmental Bureau
1220 S. St. Francis Drive
Santa Fe, New Mexico 87504

RE: Stage 2 Final Investigation and Abatement Closure Report
BD Jct. J-26 Site (Case # 1R0426-40)
T20S-R37E-Section 5, Unit Letter N
Lea County, New Mexico

Dear Mr. Hansen

On behalf of Rice Operating Company (ROC), enclosed is the *Stage 2 Final Investigation and Abatement Completion Report* for the above-referenced site which presents the results of the characterization activities performed by Trident Environmental and the characterization and site closure activities performed by ROC at the BD Jct. J-26 site. This report fulfills the obligations of ROC presented in the Stage 1 and 2 Abatement Plan of December 5, 2005, which was approved by NMOCD on June 26, 2006. The *Final Junction Box Closure Report* is also attached.

Based on the physical findings, source removal activities, backfilling with moisture barriers (clay and poly liner), re-establishment of native vegetation, and results of the WinTran fate and transport simulations, ROC has performed sufficient remedies which have resulted in the protection of groundwater quality, human health, and the environment. On behalf of ROC, we respectfully request that NMOCD approve the plugging and abandonment of the three onsite monitoring wells and close the regulatory file for this site.

If you have any questions please call me at 432-638-8740 or Kristin Pope at 505-393-9174.

Sincerely,

Gilbert Van Deventer, REM, PG
Trident Environmental

cc: CDH, JSC, KFP

RICE OPERATING COMPANY
JUNCTION BOX FINAL REPORT

BOX LOCATION

SWD SYSTEM	JUNCTION	UNIT	SECTION	TOWNSHIP	RANGE	COUNTY	NEW BOX DIMENSIONS - FEET		
							Length	Width	Depth
Blinebry-Drinkard (BD)	J-26 boot	J	26	21S	37E	Lea	no box; junction eliminated		

LAND TYPE: BLM ______ STATE ______ FEE LANDOWNER Delrose Scott OTHER ______

Depth to Groundwater 42 feet NMOCD SITE ASSESSMENT RANKING SCORE: 20

Date Started 4/23/2002 Date Completed 10/2/2002 NMOCD Witness YES

Soil Excavated 1000 cubic yards Excavation Length 115 Width 75 Depth 40 feet

Soil Disposed 480 cubic yards Offsite Facility Sundance Location Eunice, New Mexico

General Description of Remedial Action:

For a summary of the junction box remediation and excavation activities, refer to the previously-submitted Junction Box Disclosure Report (2002). Since the vadose remediation, groundwater at this site has been monitored on a quarterly basis.

The attached November 2007 Abatement Completion Report by Trident Environmental of Midland, Texas requests closure of this junction box site

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

REPORT ASSEMBLED BY Kristin Farris Pope SIGNATURE Kristin Farris Pope

DATE 11/15/2007 TITLE Project Scientist

AP-75

November 20, 2007

Stage 2 Final Investigation and Abatement Completion Report

BD Jct. J-26 Site (1R0426-40)

T21S, R37E, Section 26, Unit Letter J
Lea County, New Mexico

Prepared by:

TRIDENT ENVIRONMENTAL

P. O. Box 7624
Midland, Texas 79708

Prepared for:

RICE Operating Company

122 West Taylor

Hobbs, New Mexico 88240

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TABLES

FIGURES

APPENDICES

1.0 EXECUTIVE SUMMARY

This Stage 2 Final Investigation and Abatement Completion Report presents the results of the characterization activities performed by Trident Environmental and the characterization and site closure activities performed by ROC at the Jct. J-26 site. This report fulfills the obligations of ROC presented in the Stage 1 and 2 Abatement Plan of December 5, 2005, which was approved by NMOCD on June 26, 2006.

The following corrective actions were performed in accordance with the Stage 1 and 2 Abatement Plan:

- Quarterly groundwater monitoring activities of the three on site monitoring wells were continued to document the return of chloride and total dissolved solids (TDS) concentrations to background levels. The 2006 Annual Groundwater Monitoring Report was submitted to the NMOCD on February 5, 2007.
- Regional groundwater sampling was conducted to confirm that remediation of the constituents of concern is taking place, changes in the local and regional ground water flow directions were noted, and ambient ground water chemistry was confirmed.
- Data was input into a fate and transport model (WinTran - Version 1.3) to forecast the movement and attenuation of the chloride/TDS plume by dispersion and abatement by the water supply wells.

Since July 2004, chloride and TDS concentrations at the Jct. J-26 site have generally remained at or near background levels in each of the three on site monitoring wells. Background concentrations of chlorides and TDS at the site have been confirmed through recent laboratory analysis of several surrounding wells and research of local groundwater data. There is strong evidence that the continual withdrawal of groundwater by several supply wells for the operation of the Eunice Gas Plant has assisted in the redirection and recovery of residual chloride and TDS constituents from the Jct. J-26 site. In addition, WinTran fate and transport simulations show the effects of the water supply wells and natural dispersion in attenuating chloride and TDS constituents.

Based on the physical findings, source removal activities, backfilling with an infiltartion barrier, re-establishment of native vegetation, and results of the WinTran fate and transport simulations, ROC has performed sufficient remedies which have resulted in the protection of groundwater quality, human health, and the environment. On behalf of ROC, we respectfully request that NMOCD approve the plugging and abandonment of the three onsite monitoring wells and close the regulatory file for this site. A copy of the Final Junction Box Closure Report is included in Appendix E.

2.0 CHRONOLOGY OF EVENTS

April 23, 2002	Initial soil sampling activities were conducted to delineate the extent of chloride and hydrocarbon-impacted soils near the Jct. J-26.
September 2002	Excavation of chloride and TPH-impacted soil was completed to a depth of 42 feet bgs. 480 yd^3 of the impacted soils were removed and disposed. Imported backfill was placed in the deep excavation from 42 feet to 27 feet bgs. A 12-inch compacted clay layer was then installed prior to backfilling with the remediated soil in 3-foot lifts. A second 12-inch compacted clay layer was installed at 5 feet bgs. The remaining remediated soil was placed above the clay layer and contoured to drain rainwater away from the area. A new replacement junction box was installed about 60 feet north of the former location. The surface was then reseeded and monitored for growth which resulted in re-establishing the native vegetation.
October 10, 2002	One monitoring well (MW-1) was installed immediately adjacent to the southeast corner of the excavated area to further assess if groundwater was impacted with chlorides. Subsequent sampling of MW-1 confirmed that groundwater was impacted with chloride and TDS levels above WQCC standards; however there was no hydrocarbon impact based on BTEX concentrations below laboratory detection limit of 0.001 mg/L.
October 29, 2002	The disclosure report detailing all of the above-referenced work was completed and forwarded to the NMOCD in early 2003 along with the disclosure reports for other sites.
December 13, 2002	ROC notified the NMOCD Environmental Bureau Chief of groundwater impact in accordance with NM Rule 116.
June 20, 2003	A work plan addressing further actions was submitted by Trident Environmental to Wayne Price at the NMOCD office in Santa Fe.
June 27, 2003	The work plan was approved by Wayne Price of the NMOCD office in Santa Fe.
August 19, 2003	Monitoring wells MW-2 and MW-3 were installed approximately 220 feet down gradient (south-southeast) and approximately 150 feet upgradient (northwest) of MW-1, respectively. Subsequent sampling results indicated MW-2 and MW-3 delineated the downgradient and upgradient extent of chloride and TDS impact to groundwater.

December 16, 2004	Trident Environmental submitted a request to Wayne Price of the NMOCD office in Santa Fe for further actions regarding the chloride and TDS-impacted groundwater at the BD Jct. J-26 site.
January 28, 2005	Trident Environmental submitted an Update to the Site Plan which described the findings of assessment activities and proposed corrective actions for the Jct. J-26 site.
May 5, 2005	Mr. Daniel Sanchez of the NMOCD requested that ROC submit an abatement plan to the NMOCD pursuant to Rule 19.
December 5, 2005	A Stage 1 and 2 Abatement Plan was prepared by R. T. Hicks Consultants Ltd. and submitted to the NMOCD
April 17, 2006	ROC submitted proof of public notifications to the NMOCD
June 26, 2006	NMOCD approved the Stage 1 & 2 Abatement Plan
August 1, 2006	Depth to water measurements and samples for chloride and TDS analysis were obtained from several off site wells in the surrounding area.
October 4, 2006	Trident Environmental initiated fate and transport simulations for the site.
November 22, 2006	Trident Environmental performed an aquifer test at two nearby water supply wells to determine site-specific hydrological parameters.
February 5, 2007	Trident Environmental submitted the 2006 Annual Groundwater Monitoring Report to the NMOCD.
February 19, 2007	Trident completed fate and transport simulations for the site.

3.0 BACKGROUND

3.1 SITE LOCATION AND LAND USE

The Jct. J-26 site is located in township 21 south, range 37 east, section 26, unit letter J approximately 1 mile north-northwest of the intersection of NM State Highway 18 and County Highway 176 near Eunice, NM as shown on the attached topographic map (Figure 1) and aerial photographic map (Figure 2). Land in the site area is primarily utilized for oil and gas production and cattle ranching.

3.2 SUMMARY OF PREVIOUS WORK AND INVESTIGATIONS

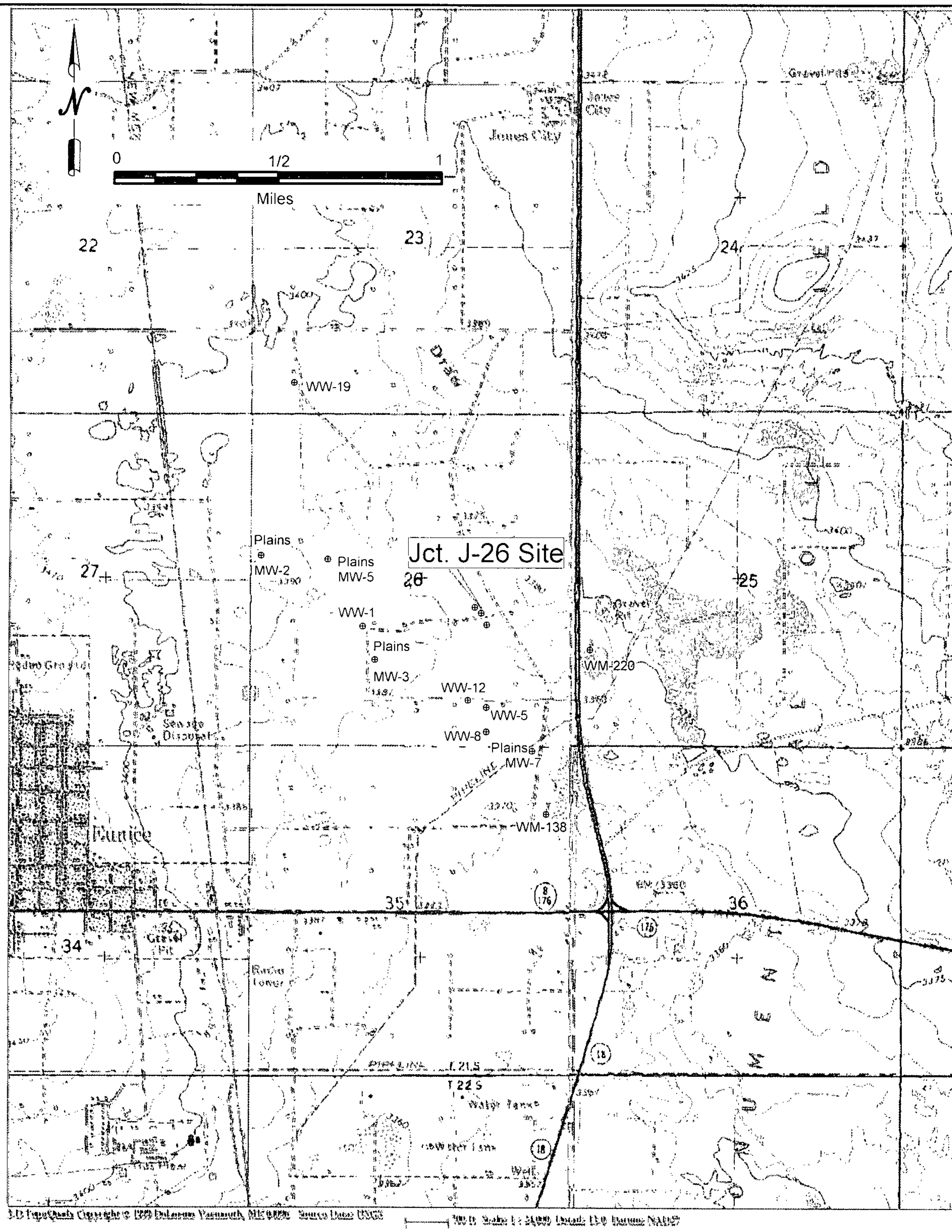
Initial soil sampling activities for delineation of the Jct. J-26 area began on May 2, 2002, as part of ROC's junction box upgrade program.

In September 2002, excavation of TPH impacted soil was completed to a depth of 42 feet bgs where groundwater was encountered. 480 cubic yards of TPH impacted soil was transported to the Sundance facility in Eunice, New Mexico and the remaining excavated soil was remediated on site. Imported backfill was placed in the deep excavation from 42 feet to 27 feet bgs. A 12-inch compacted clay layer was then installed prior to backfilling with the remediated soil in 3-foot lifts. A second 12-inch compacted clay layer was installed at 5 feet bgs. The remaining remediated soil was placed above the clay layer and contoured to drain rainwater away from the area. A new replacement junction box was installed about 60 feet north of the former location. The surface was then reseeded and monitored for growth.

On October 10, 2002, a monitoring well (MW-1) was installed immediately adjacent to the southeast corner of the excavated area, which was the presumed down gradient direction. Subsequent sampling of MW-1 confirmed that groundwater was impacted with chloride and TDS levels above WQCC standards, however there was no hydrocarbon impact based on BTEX concentrations below the WQCC standards. ROC notified the Director of the NMOCD, Environmental Bureau of groundwater impact in accordance with NM Rule 116.

Monitoring wells MW-2 and MW-3 were installed approximately 220 feet down gradient (south-southeast) and approximately 150 feet upgradient (northwest) of MW-1, respectively, on August 19, 2003. Subsequent sampling results indicated MW-2 and MW-3 delineated the downgradient and upgradient extent of chloride and TDS impact to groundwater.

A Stage 1 and 2 Abatement Plan was submitted to the NMOCD on December 5, 2005, and approved by the NMOCD on June 26, 2006.



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BD J-26 Junction Box Site

T21S - R37E - Section 26 - Unit J

RICE Operating Company

FIGURE 1

TOPOGRAPHIC MAP

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BD J-26 Junction Box Site

T21S - R37E - Section 26 - Unit J

RICE ***Operating Company***

FIGURE 2

AERIAL PHOTO (2005)

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GEOLOGY AND HYDROGEOLOGY

4.1 REGIONAL AND LOCAL GEOLOGY

The Jct. J-26 site is situated within the center of Monument Draw. According to published information (Nicholson and Clebsch, 1961, Barnes, 1976, and Anderson, Jones, and Green, 1997) the site is underlain by Quaternary Colluvial Deposits composed of sand, silt, and gravel deposited by slopewash, and talus from the Tertiary Ogallala Formation. These colluvial deposits are often calichified (indurated with cemented calcium carbonate) with caliche layers from 1 to 20 feet thick. The thickness of the colluvial deposits and Ogallala Formation is approximately 45 feet; however it varies locally as a result of significant paleo-topography at the top of the underlying Triassic Dockum Group. Since Cretaceous Age rocks in the region have been removed by pre-Tertiary erosion, the alluvium and Ogallala Formation rest unconformably on the Triassic Dockum Group. The uppermost unit of the Dockum Group is the Chinle Formation, which primarily consists of micaceous red clay and shale but also contains thin interbeds of fine-grained sandstone and siltstone. The red clays and shale of the Chinle Formation act as an aquitard beneath the water bearing colluvial deposits/Ogallala Formation and therefore limit the amount of recharge to the underlying Dockum Group.

Based on the lithologic log descriptions provided by Trident Environmental the subsurface soils are composed of caliche with varying amounts of very fine to fine-grained sand in matrix (0-40 ft), calcareous fine to medium-grained sand (40-50 ft), and fine to medium-grained sand (50-60 ft). More detailed descriptions of the subsurface lithology are provided on the lithologic logs in Appendix A of the Stage 1 and 2 Abatement Plan.

4.2 REGIONAL AND LOCAL HYDROGEOLOGY

Potable ground water used in southern Lea County is derived primarily from the Ogallala Formation and the Quaternary alluvium. Water from the Ogallala and alluvium aquifers in southern Lea County is used for irrigation, stock, domestic, industrial, and public supply purposes.

Based on the total depths of water wells in the area (85 feet) and the depth to groundwater (average of 40 feet bgs), the saturated thickness of the Ogallala Formation in the site area is estimated at approximately 45 feet.

Nicholsen and Clebsch (1961) found that the regional gradient of the Ogallala and interconnected colluvial aquifer in the site area generally flows toward the southeast and the hydraulic gradient varies from approximately 0.001 to 0.01 feet/feet.

Based on the recent depth to groundwater data from accessible wells located within a mile of the Jct. J-26 site the magnitude of the regional groundwater gradient is 0.003 feet/foot and the direction of flow is to the southeast (Figure 3). However, the local groundwater gradient in the more immediate area of the site has indicated magnitudes of 0.005 feet/foot or greater with direction of flow towards the south (Figure 4). The difference between the localized and regional gradient is attributed to the effect of the continual groundwater withdrawal from several nearby water supply wells that provide water for the Eunice Gas Plant. Based on records from the New Mexico Office of the State Engineer (NMSEO) these wells have been pumping at a combined rate of approximately 82 gallons per minute between July 6, 2005 and January 8, 2007. The groundwater withdrawal induces groundwater to flow from the site towards the water supply wells, which are located south (WW-5, WW-8, and WW12) and west (WW-1) of the site, as evidenced by a local groundwater gradient trending to the south (Figure 4) which differs from the regional gradient to the southeast (Figure 3).

No water wells are located within 1,000 feet of the site. A summary of active water wells located in the vicinity of the Jct. J-26 site are listed in Table 1 below. These wells are also depicted in Figure 3.

Table 1
Summary of Water Well Data

Well ID	Well Type/Use	Permit Holder (Site Name)	T21S-R37E		Distance from Jct. J-26 Site
			Sec	UL	
WM-220	Windmill/Livestock	Owens (L-0220)	25	I	1,610 ft East
WW-1	Industrial Supply	Targa (Eunice Gas Plant)	26	K	2,100 ft West
WW-5	Industrial Supply	Targa (Eunice Gas Plant)	26	P	1,450 ft South
WW-8	Industrial Supply	Targa (Eunice Gas Plant)	26	P	1,960 ft South
WW-12	Industrial Supply	Targa (Eunice Gas Plant)	26	O	1,410 ft SSW

There are no surface water bodies located within a mile of the site.

5.0 GROUND WATER QUALITY

5.1 Monitoring Program

The on site monitoring wells at the Jct. J-26 site have been sampled on a quarterly basis for major ions, TDS, and benzene, toluene, ethylbenzene, and xylenes (BTEX). A complete summary of historical analytical results and ground water elevations are provided in the 2006 Annual Groundwater Monitoring Report.

Each constituent of BTEX has been below the New Mexico Water Quality Control Commission (WQCC) standards at this site since the installation of monitoring well MW-1 in October 2002 (18 consecutive quarters).

Background concentrations of chlorides and TDS at the site have been confirmed through recent laboratory analysis of several surrounding wells and research of regional groundwater data. During the third quarter (August 1, 2006) access was granted for a one-time monitoring event (depth to water measurements and chloride and TDS analysis) for the following wells:

- Targa (Eunice Gas Plant) water supply wells (WW-1, WW-5, WW-8, WW-12, WW-19).
- One monitoring well at each of four nearby Plains Petroleum monitoring sites.
- One windmill (L-0220)

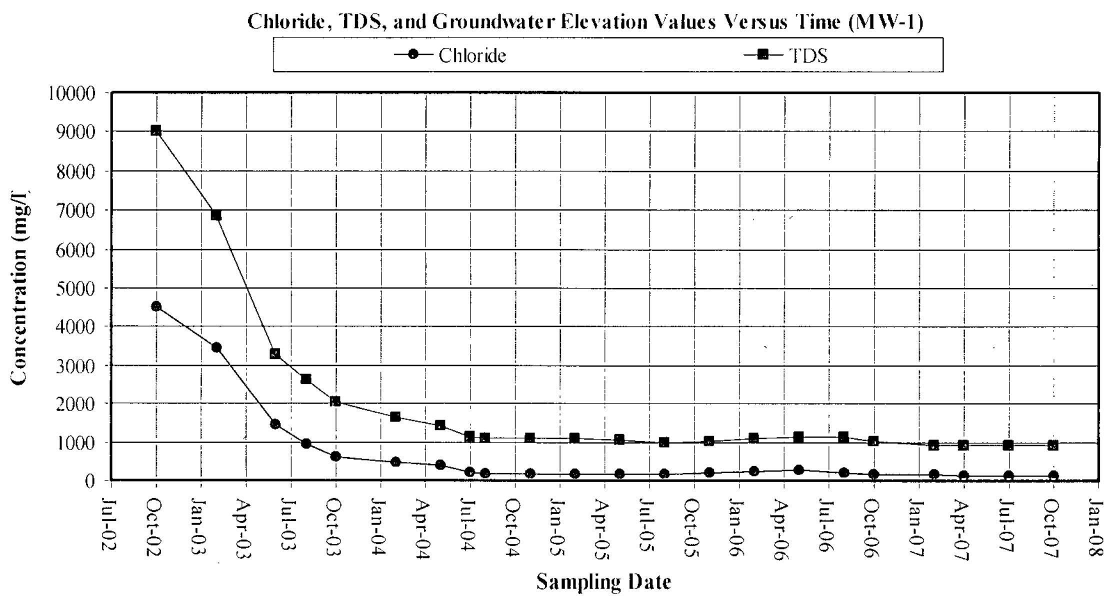
Results of this one time sampling event are summarized in Table 2 below and depicted in Figure 3. A copy of the laboratory analytical reports and chains of custody form are included in Appendix D.

Table 2
Regional Ground Water Sampling Results (August 1, 2006)

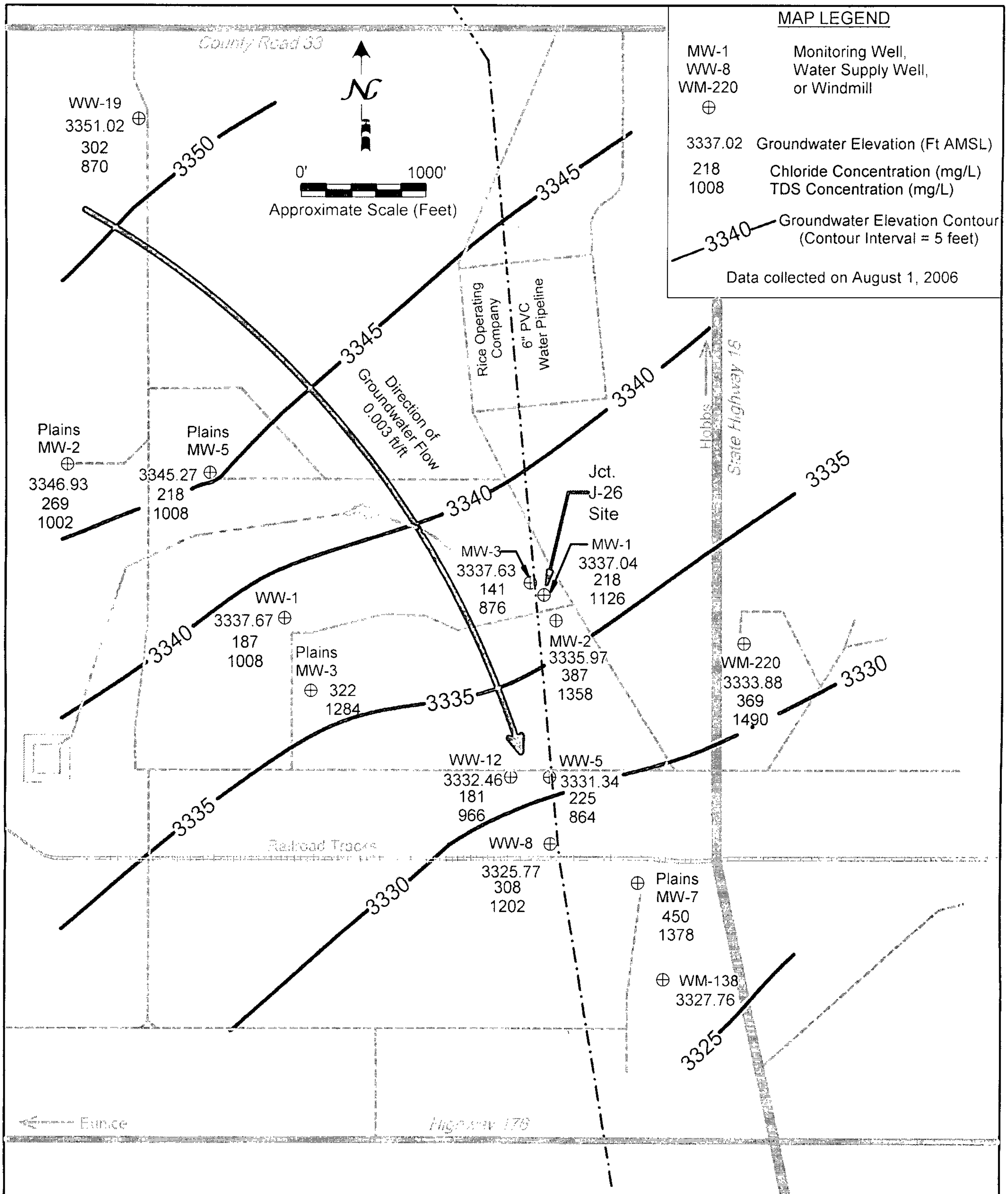
Well ID	Well Type/Use	Permit Holder	Site Name	Depth to Groundwater (feet BTOC)	Chloride (mg/L)	TDS (mg/L)
MW-1	Monitoring	ROC	Jct. J-26	38.80	218	1126
MW-2	Monitoring	ROC	Jct. J-26	39.35	387	1358
MW-3	Monitoring	ROC	Jct. J-26	38.22	141	876
WM-220	Windmill	Owens	L-0220	37.49	369	1490
MW-3	Monitoring	Plains	DH Gathering	45.52	322	1284
MW-7	Monitoring	Plains	Vacuum to Jal 14" Mainline#3	49.04	450	1378
MW-2	Monitoring	Plains	TNM 98-5B	47.82	269	1002
MW-5	Monitoring	Plains	TNM 98-5A	46.26	218	1008
WW-1	Industrial	Targa	Eunice Gas Plant	49.32	187	1008
WW-5	Industrial	Targa	Eunice Gas Plant	48.11	225	864
WW-8	Industrial	Targa	Eunice Gas Plant	51.00	308	1202
WW-12	Industrial	Targa	Eunice Gas Plant	49.28	181	966
WW-19	Abandoned	Targa	Eunice Gas Plant	47.28	302	870
Average (Background) Chloride and TDS Concentrations					275	1110

Based on the sampling results listed in the table above average (background) chloride and TDS concentrations in section 26 have ranged from 141 mg/L to 450 mg/L and 870 mg/L to 1,490 mg/L, respectively.

The highest chloride (4,520 mg/L) and TDS (9,020 mg/L) concentrations in MW-1 were observed during the first sampling event on October 29, 2002. The decreased chloride and TDS concentrations observed in MW-1, as shown in the graph below, can be attributed to the excavation activities (source removal) and the effect of groundwater withdrawal from the industrial water wells that supply process water for the Eunice Gas Plant. The groundwater withdrawal induces groundwater to flow from the site towards the water supply wells, which are located south (WW-5, WW-8, and WW-12) and west (WW-1) of the site and thus has assisted in the removal of any remnant chloride/TDS mass from the area of the Jct. J-26 site. Further evidence for this conclusion is supported by the fate and transport modeling simulations as explained in the following section.



There is no longer a threat of impact from the vadose zone at this site because of the excavation, source removal, and backfilling with an infiltration barrier over the former source area near MW-1 that was completed in 2002. The surrounding area was re-seeded with a mixture of native grasses and plants which has resulted in the re-establishment of native vegetation as depicted on the cover page photo of this report. ROC has been monitoring the site for continued healthy growth of native vegetation.



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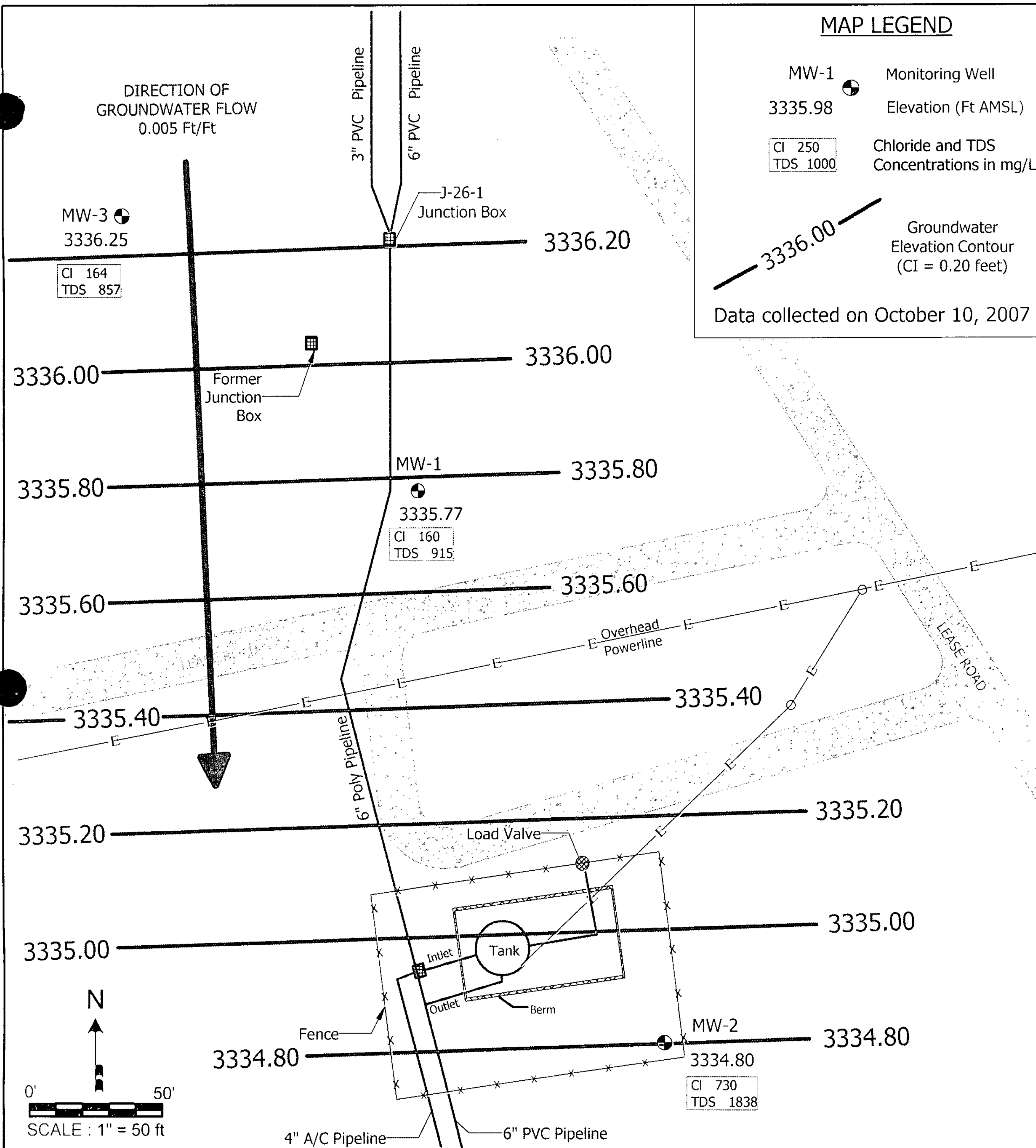
BD J-26 Junction Box Site

T21S - R37E - Section 26 - Unit J

RICE Operating Company

FIGURE 3

REGIONAL GROUNDWATER GRADIENT & CHLORIDE/TDS CONCENTRATION MAP



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BD J-26 Junction Box Site

T21S - R37E - Section 26 - Unit J

RICE ***Operating Company***

FIGURE 4

LOCAL GROUNDWATER GRADIENT & CHLORIDE/TDS CONCENTRATION MAP

Table 3

Historical Groundwater Sampling Results

Monitoring Well	Sample Date	Depth to Groundwater (feet BTOC)	Groundwater Elevation (feet AMSL)	Chloride (mg/L)	TDS (mg/L)	Benzene (mg/L)	Toluene (mg/L)	Ethylbenzene (mg/L)	Xylene (mg/L)
MW-1	10/29/02	43.02	3332.82	**4520**	**9020**	< 0.001	< 0.001	< 0.001	< 0.001
	02/28/03	42.33	3333.51	**3470**	**6870**	< 0.001	< 0.001	< 0.001	< 0.001
	06/05/03	43.00	3332.84	**1460**	**3280**	< 0.001	< 0.001	< 0.001	< 0.001
	08/22/03	43.72	3332.12	**957**	**2620**	< 0.001	< 0.001	< 0.001	< 0.001
	10/30/03	43.91	3331.93	**620**	**2040**	< 0.001	< 0.001	< 0.001	< 0.001
	02/18/04	43.70	3332.14	**478**	**1630**	< 0.001	< 0.001	< 0.001	< 0.001
	05/05/04	40.80	3335.04	**390**	**1440**	< 0.001	< 0.001	< 0.001	< 0.001
	07/08/04	40.80	3335.04	230	**1140**	< 0.001	< 0.001	< 0.001	< 0.001
	08/10/04	37.02	3338.82	195	**1080**	< 0.001	< 0.001	< 0.001	< 0.001
	11/09/04	36.61	3339.23	177	**1100**	< 0.001	< 0.001	< 0.001	< 0.001
	02/09/05	36.62	3339.22	179	**1090**	< 0.001	< 0.001	< 0.001	< 0.001
	05/05/05	37.00	3338.84	179	**1060**	< 0.001	< 0.001	< 0.001	< 0.001
	08/13/05	37.56	3338.28	193	**1000**	< 0.001	< 0.001	< 0.001	< 0.001
	11/07/05	37.98	3337.86	233	**1020**	< 0.001	< 0.001	< 0.001	< 0.001
	02/06/06	38.39	3337.45	**262**	**1080**	< 0.001	< 0.001	< 0.001	< 0.001
	05/08/06	38.55	3337.29	**282**	**1140**	< 0.001	< 0.001	< 0.001	< 0.001
	08/01/06	38.80	3337.04	218	**1126**	< 0.001	< 0.001	< 0.001	< 0.001
	10/23/06	39.21	3336.63	193	**1010**	< 0.001	< 0.001	< 0.001	< 0.001
	02/08/07	39.52	3336.32	182	912	< 0.001	< 0.001	< 0.001	< 0.001
	04/18/07	39.66	3336.18	161	898	< 0.001	< 0.001	< 0.001	< 0.001
	07/18/07	39.86	3335.98	149	900	---	---	---	---
	10/10/07	40.07	3335.77	160	915	---	---	---	---
MW-2	08/22/03	43.99	3331.33	239	**1180**	< 0.001	< 0.001	< 0.001	< 0.001
	10/30/03	44.17	3331.15	239	**1240**	< 0.001	< 0.001	< 0.001	< 0.001
	02/18/04	43.91	3331.41	221	**1150**	< 0.001	0.001	< 0.001	< 0.001
	05/05/04	40.98	3334.34	204	**1060**	< 0.001	0.001	< 0.001	< 0.001
	08/10/04	37.14	3338.18	230	**1120**	< 0.001	< 0.001	< 0.001	< 0.001
	11/09/04	36.99	3338.33	230	**1120**	< 0.001	< 0.001	< 0.001	< 0.001
	02/09/05	37.03	3338.29	**294**	**1220**	< 0.001	< 0.001	< 0.001	< 0.001
	05/06/05	37.46	3337.86	**257**	**1210**	< 0.001	< 0.001	< 0.001	< 0.001
	08/13/05	38.02	3337.30	237	**1180**	< 0.001	< 0.001	< 0.001	< 0.001
	11/07/05	38.44	3336.88	206	**1130**	< 0.001	< 0.001	< 0.001	< 0.001
	02/06/06	38.83	3336.49	**250**	**1090**	< 0.001	< 0.001	< 0.001	< 0.001
	05/08/06	39.02	3336.30	**257**	**1210**	< 0.001	< 0.001	< 0.001	< 0.001
	08/01/06	39.35	3335.97	**387**	**1358**	< 0.001	< 0.001	< 0.001	< 0.001
	10/23/06	39.71	3335.61	**395**	**1370**	< 0.001	< 0.001	< 0.001	< 0.001
	02/08/07	40.03	3335.29	**378**	**1220**	< 0.001	< 0.001	< 0.001	< 0.001
	04/18/07	40.09	3335.23	**446**	**1380**	< 0.001	< 0.001	< 0.001	< 0.001
	07/18/07	40.30	3335.02	**679**	**1720**	---	---	---	---
	10/10/07	40.52	3334.80	**730**	**1838**	---	---	---	---
MW-3	08/22/03	43.06	3332.79	160	904	< 0.001	< 0.001	< 0.001	< 0.001
	10/30/03	43.28	3332.57	168	**1070**	< 0.001	< 0.001	< 0.001	< 0.001
	02/18/04	43.03	3332.82	160	862	< 0.001	< 0.001	< 0.001	< 0.001
	05/05/04	40.04	3335.81	160	891	< 0.001	< 0.001	< 0.001	< 0.001
	08/10/04	36.55	3339.30	164	941	< 0.001	< 0.001	< 0.001	< 0.001
	11/09/04	36.22	3339.63	142	**1160**	< 0.001	< 0.001	< 0.001	< 0.001
	02/09/05	36.17	3339.68	138	**1010**	< 0.001	< 0.001	< 0.001	< 0.001
	05/06/05	36.56	3339.29	141	870	< 0.001	< 0.001	< 0.001	< 0.001
	08/13/05	37.12	3338.73	125	842	< 0.001	< 0.001	< 0.001	< 0.001
	11/07/05	37.55	3338.30	125	826	< 0.001	< 0.001	< 0.001	< 0.001
	02/06/06	37.84	3338.01	119	748	< 0.001	< 0.001	< 0.001	< 0.001
	05/08/06	38.00	3337.85	142	806	< 0.001	< 0.001	< 0.001	< 0.001
	08/01/06	38.22	3337.63	141	876	< 0.001	< 0.001	< 0.001	< 0.001
	10/23/06	38.68	3337.17	147	834	< 0.001	< 0.001	< 0.001	< 0.001
	02/08/07	39.01	3336.84	147	788	< 0.001	< 0.001	< 0.001	< 0.001
	04/18/07	39.16	3336.69	150	818	< 0.001	< 0.001	< 0.001	< 0.001
	07/18/07	39.40	3336.45	139	848	---	---	---	---
	10/10/07	39.60	3336.25	164	857	---	---	---	---
WQCC Standards				250	1000	0.01	0.75	0.75	0.62

6.0 FATE AND TRANSPORT MODELING RESULTS

6.1 FATE AND TRANSPORT MODELING

As proposed in the NMOCD-approved Stage 1 and 2 Abatement Plan, fate and transport model simulations were performed to forecast the movement and attenuation of the chloride plume by dispersion and abatement by the water supply wells. 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. WinTran is built around a steady-state analytical element flow model, which is uniquely linked to a finite element contaminant transport model. A detailed description of the modeling procedure, parameter inputs, and the simulated results are provided in Appendix A. The features, equations, and benchmarking documentation are included in Appendix B.

The fate and transport model simulations demonstrate how chloride concentrations in the center of the plume will decrease to background levels by the year 2047 as the mass of the plume is captured by the water supply wells and does not migrate beyond them. The results of the fate and transport modeling simulations support the conclusion that the chloride plume is not likely to impact any drinking water, livestock, municipal, or irrigation water supplies, the closest of which is a windmill (NM File No. CP-220) located approximately 1,610 feet east of the Jct. J-26 site. This windmill, which is used for livestock watering, is cross-gradient from the junction box and, therefore not in the direct path of the simulated plume.

7.0 CONCLUSIONS AND REQUEST FOR CLOSURE

Since July 2004, chloride and TDS concentrations at the Jct. J-26 site have generally remained at or near background levels in each of the three on site monitoring wells. Chloride and TDS concentrations in downgradient monitoring well MW-2 have exhibited a slight increase over background levels in the most recent quarter however, that is consistent with the modeling simulations as described in Appendix A. The fate and transport modeling simulates chloride concentrations in MW-2 peaking at 737 mg/L in year 2009 and then resume a decreasing trend.

Continued operation of the water supply wells is essential in maintaining the operation of the Eunice Gas Plant. The withdrawal of groundwater by several of these wells has resulted in redirecting and recovery of residual chloride and TDS constituents from the Jct. J-26 site. In addition, WinTran fate and transport modeling simulations show the capture effects of the water supply wells and natural dispersion in attenuating chloride and TDS constituents.

Based on the physical findings, source removal activities, backfilling with an infiltration barrier, re-establishment of native vegetation, and results of the WinTran fate and transport simulations, ROC has performed sufficient remedies which have resulted in the protection of groundwater quality, human health, and the environment. Therefore, additional groundwater monitoring is not necessary. On behalf of ROC, we respectfully request that NMOCD approve the plugging and abandonment of the three onsite monitoring wells and close the regulatory file for this site. A copy of the Final Junction Box Closure Report is included in Appendix E.

APPENDIX A

Description of Fate and Transport Modeling Procedures and Parameter Inputs

Description of Fate and Transport Modeling

Conceptual Model

Produced water containing high concentrations of chloride, and resultant high levels of total dissolved solids (TDS), reportedly leaked from the J-26 junction box. 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 collected by Rice Operating Company and Trident Environmental. 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 12), 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.

Model Input Parameters

The following table lists the various parameters input into the fate and transport model simulations.

Parameter	Value	Source of Data
Hydraulic Conductivity (K_x, K_y, K_z)	4.4 ft/day (1.2E-03 cm/sec)	Aquifer test (Appendix C)
Hydraulic Gradient	0.003 ft/ft	Observed and measured
Gradient Direction	56° south of due east (SE)	Observed and measured
Longitudinal Dispersivity	328 ft	Estimated plume length (2002)
Transverse Dispersivity	32.8 ft	One-tenth of longitudinal
Porosity	0.25	Professional judgement
Base elevation of aquifer	3250 ft AMSL	Observed and measured
Depth to groundwater	40 ft	Observed and measured
Saturated thickness	45 ft	Observed and measured
Model X Extent (100 nodes)	2.5 miles	Professional judgement
Model Y Extent (100 nodes)	2.5 miles	Professional judgement
Coefficient of molecular diffusion	0.34 ft^2/yr (1.0E-07 cm^2/sec)	Bear and Verruijt (1987)

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 0.003 feet/foot based on historical site measurements.
- Direction of flow – measured direction of approximately 56° south of due east (SE) based on past local and current regional measurements.
- Hydraulic conductivity – This is one of the most critical parameters used for any fate and transport modeling effort, and the various published values researched range widely from less than 2 ft/day to 200 ft/day. Therefore an aquifer test was performed at two nearby industrial water supply wells (WW-1 and WW-5) to determine the most accurate site-specific value. A hydraulic conductivity of 4.4 ft/day was determined by performing a Cooper-Jacob analysis of the recovery data, and a program from USGS Open-File 02-197 (Keith Halford, 2002). Documentation of the aquifer test procedures, results, and USGS program is included in Appendix C).
- Aquifer top and bottom elevations – bottom elevation of Ogallala Formation at 3250 feet based on published information (Nicholson & Clebsch, 1961). The top elevation for an unconfined aquifer must be greater than the reference head. An elevation of 3400 feet was assumed.
- Reference head – measured unconfined head of 3345 feet located upgradient of the site so as not to be influenced by pumping wells during modeling simulations.

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 – Longitudinal dispersivity represents the spreading of the contaminant plume in the direction of groundwater flow. The transverse component represents spreading perpendicular to the flow direction. Dispersivity is a scale-dependent parameter which is generally larger as the scale of the contaminant plume increases. 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. However, values of dispersivity reported in the literature generally range from 1 to 100 percent of the problem scale (Gelhar, 1986). For the current site scale, a conservative value of 328 feet (100 meters) was selected for longitudinal dispersivity. A value of 32.8 feet (i.e., 10 meters, or one-tenth of the longitudinal value) was selected for transverse dispersivity. These conservative values also minimized modeling transport errors.

- 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 – occurs when a contaminant spreads in water due to concentration gradients. That is, dissolved contaminants will spread in water from areas of high concentration to areas of lower concentration. This process is caused by random movement of molecules in a fluid. The coefficient of molecular diffusion (or simply the diffusion coefficient) is expressed in units of L^2/T (e.g., cm^2/s) and is often assumed to equal zero in advective-dominated transport. Only in very slow-moving groundwater is diffusion important. Bear and Verruijt (1987) estimate the diffusion coefficient to be approximately 1 x 10-5 cm^2/s (0.34 ft^2/yr) in dilute systems.

- 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 (chloride) 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 between October 2002 and August 2006 is simulated closely by the flow model.

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 importing a grid file created from an isopleth map using Surfer (version 6.04) contouring program, producing the configuration and constituent concentration distribution observed in October 2002 at the completion of the upgrade of the junction box. The model again ran for 4 years (2002 to 2006) after entering in the known concentrations at each of the three monitoring wells and other area wells (Targa water recovery wells and two monitoring wells from nearby Plains Petroleum sites, and a windmill east-southeast of the site).

Simulation of Fate and Transport

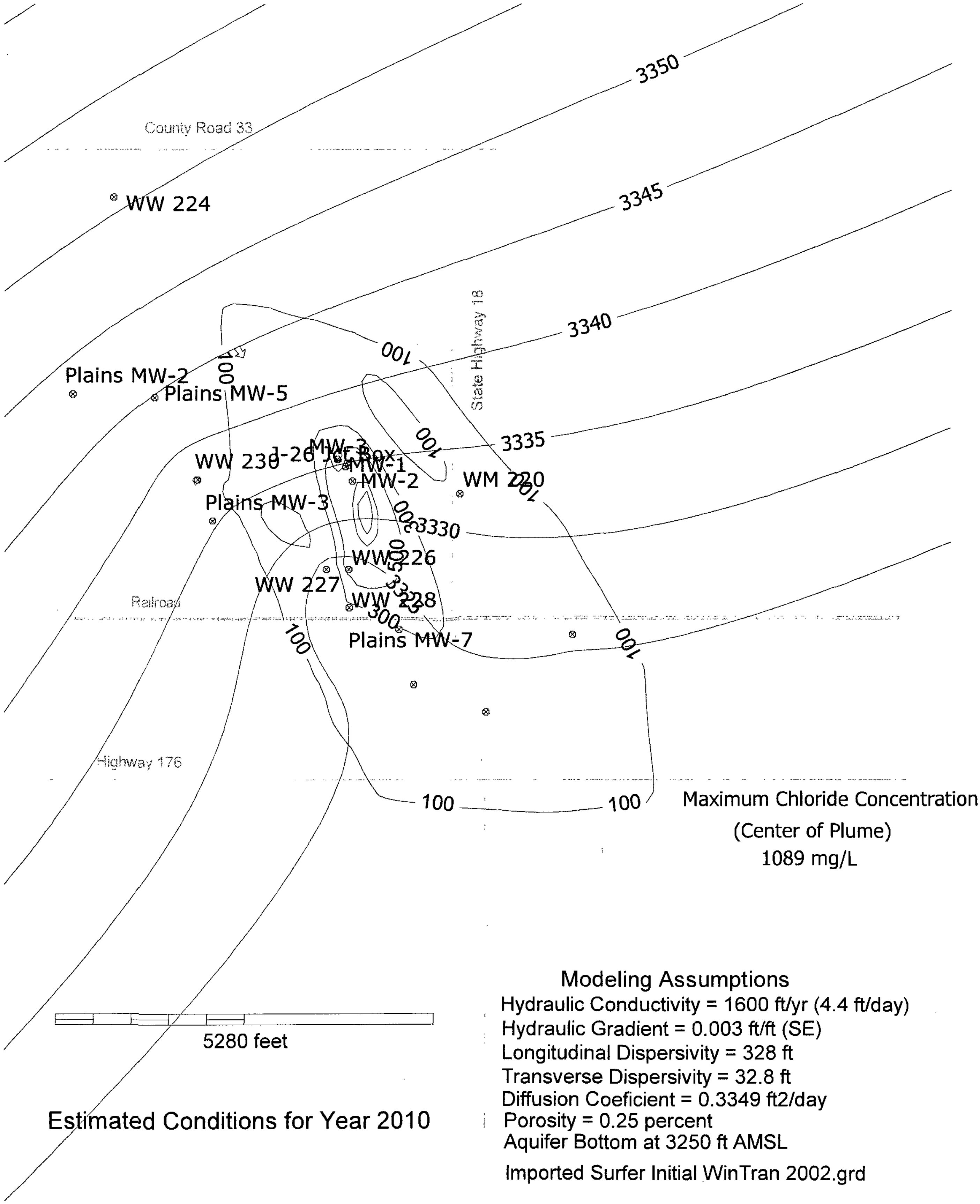
After model calibration, estimation of the fate and transport of chlorides was then achieved by restarting the transport model from the end of 2006 by retaining the distribution of contaminant mass and projecting into the future. Hydrodynamic dispersion serves to broaden the dimensions of the plume while reducing the concentrations in the middle of the plume. Advective flow moves the center of plume mass downgradient (southeast) while the groundwater withdrawal from the industrial supply wells directs the plume in a more southerly direction. Water supply wells WW-1 and WW-12 cause further dilution of the plume by directing the chloride mass transverse to the natural gradient direction. Similarly water supply wells WW-5 and WW-8 direct the chloride mass in a southerly direction. Various time increments were input to show the fate and transport of the chloride mass over a 41 year period (Years 2006 through 2047) after which the chloride plume center attenuated to a concentration of 276 mg/L (background conditions). Results of the fate and transport modeling output (Years 2010, 2015, 2020, 2025, 2030, 2035, 2040 and 2047) are depicted on site maps in the pages that follow.

For a hydraulic conductivity value of 4.4 ft/day the resultant average velocity is 14.9 ft/yr based on the darcy expression: $v = (k \cdot i) / n$, where k is the hydraulic conductivity (ft/yr), i is the hydraulic gradient (ft/ft), and n is the effective porosity (unitless). The center of the modeled plume moves at a greater rate (22.8 ft/yr) over successive time intervals than the average groundwater velocity based on Darcy's law, due to the added effect of dispersion and the capture effect from the water supply wells.

The fate and transport model simulations demonstrate how chloride concentrations in the center of the plume will decrease to background levels by the year 2047 as the mass of the plume is captured by the water supply wells and does not migrate beyond them. These results strongly support the evidence that the chloride plume is not likely to impact any existing sources of water supply, the closest of which is a windmill (NM File No. CP-220) located approximately 1,610 feet east of the Jct. J-26 site. This windmill, which is used for livestock watering, is cross-gradient from the junction box and, therefore not in the direct path of the simulated plume.

It is not necessary to simulate the fate and transport of TDS because those concentrations are closer to meeting background concentrations in comparison with chloride values. In other words, the standard for TDS concentrations will be met before those for chloride concentrations.

BD J-26 Junction Box Site
WinTran Fate & Transport Modeling Results

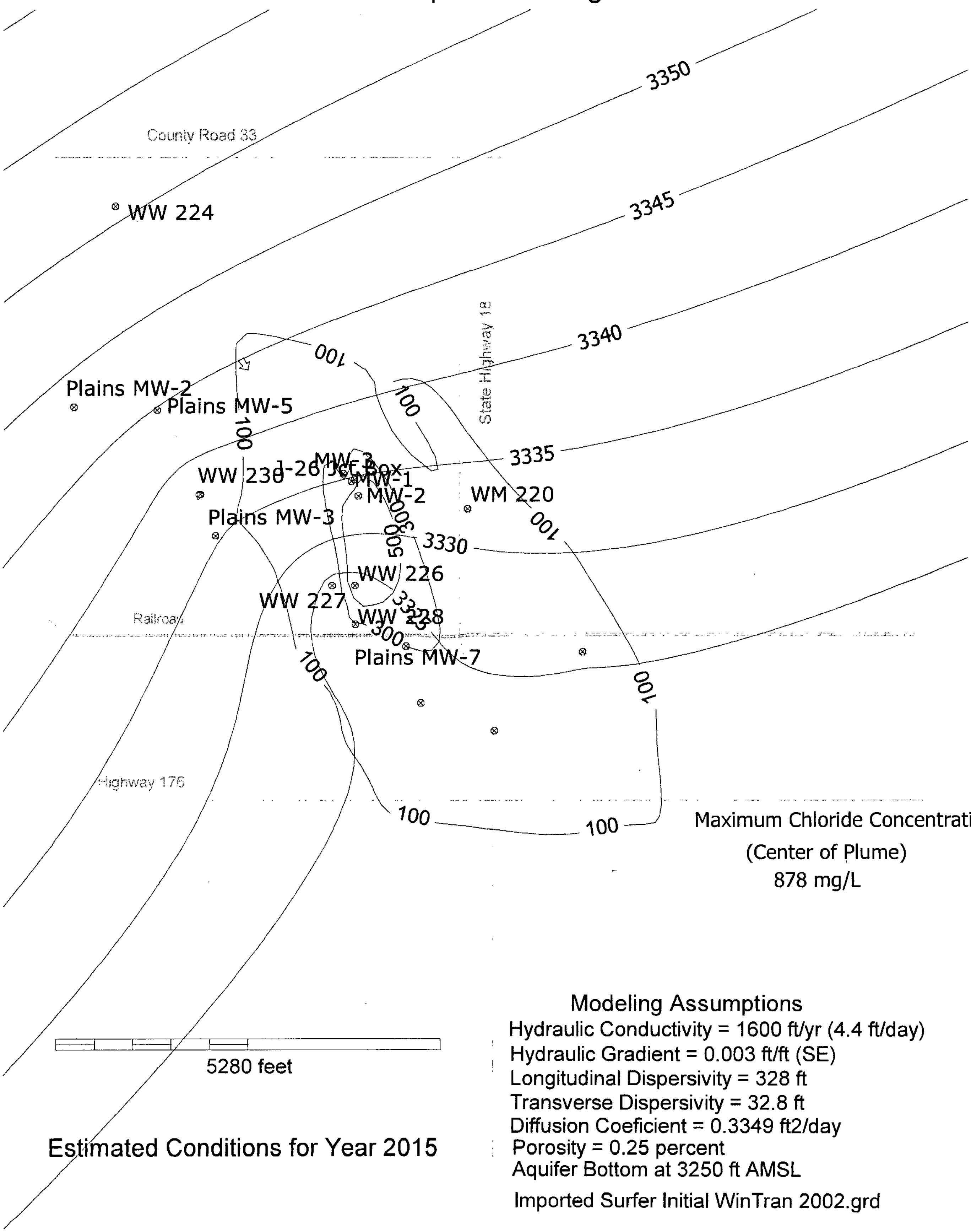


Estimated Conditions for Year 2010

Modeling Assumptions

Hydraulic Conductivity = 1600 ft/yr (4.4 ft/day)
Hydraulic Gradient = 0.003 ft/ft (SE)
Longitudinal Dispersivity = 328 ft
Transverse Dispersivity = 32.8 ft
Diffusion Coeficient = 0.3349 ft2/day
Porosity = 0.25 percent
Aquifer Bottom at 3250 ft AMSL
Imported Surfer Initial WinTran 2002.grd

BD J-26 Junction Box Site
WinTran Fate & Transport Modeling Results



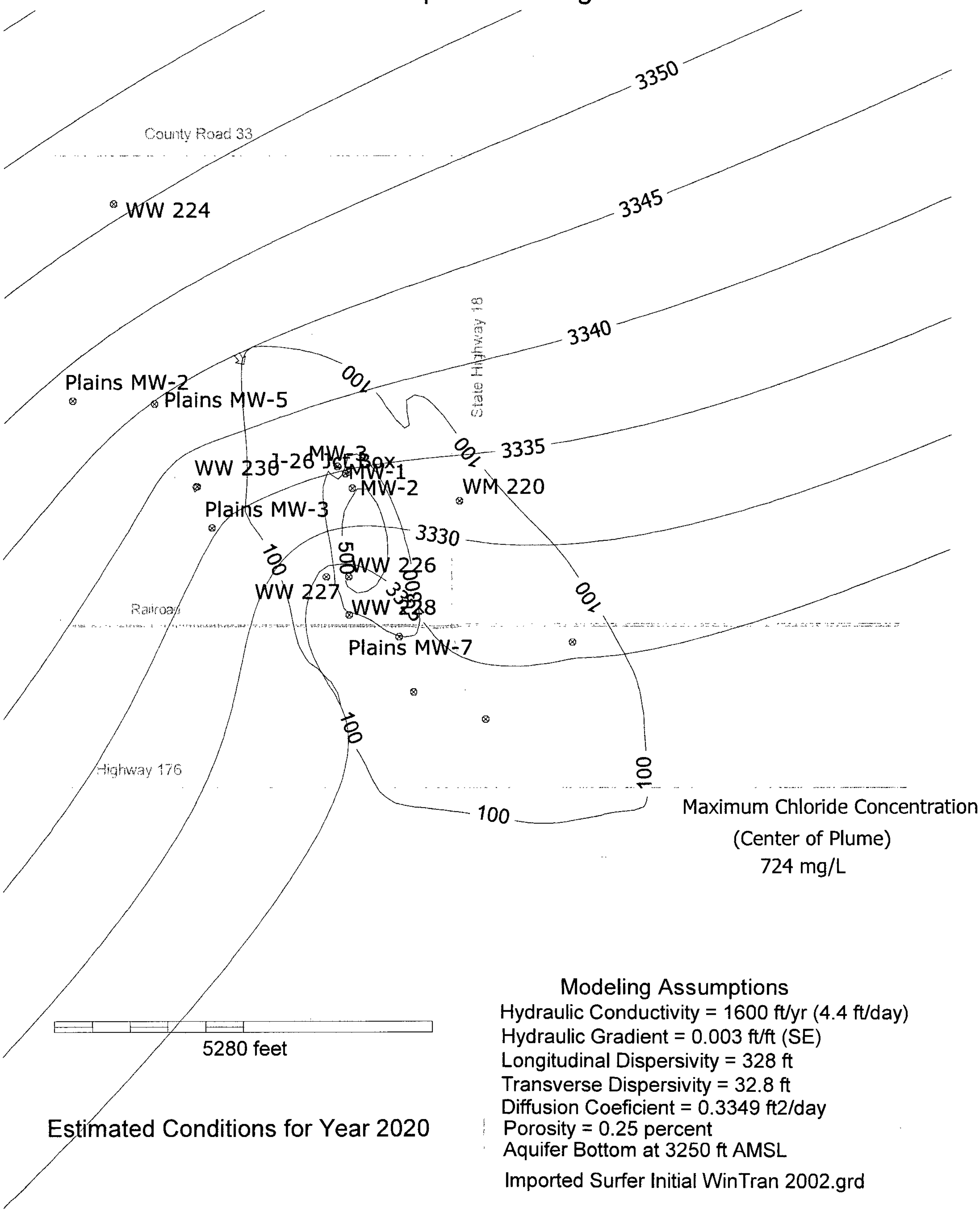
Maximum Chloride Concentration
(Center of Plume)
878 mg/L

Modeling Assumptions

Hydraulic Conductivity = 1600 ft/yr (4.4 ft/day)
Hydraulic Gradient = 0.003 ft/ft (SE)
Longitudinal Dispersivity = 328 ft
Transverse Dispersivity = 32.8 ft
Diffusion Coeficient = 0.3349 ft2/day
Porosity = 0.25 percent
Aquifer Bottom at 3250 ft AMSL
Imported Surfer Initial WinTran 2002.grd

Estimated Conditions for Year 2015

BD J-26 Junction Box Site
WinTran Fate & Transport Modeling Results



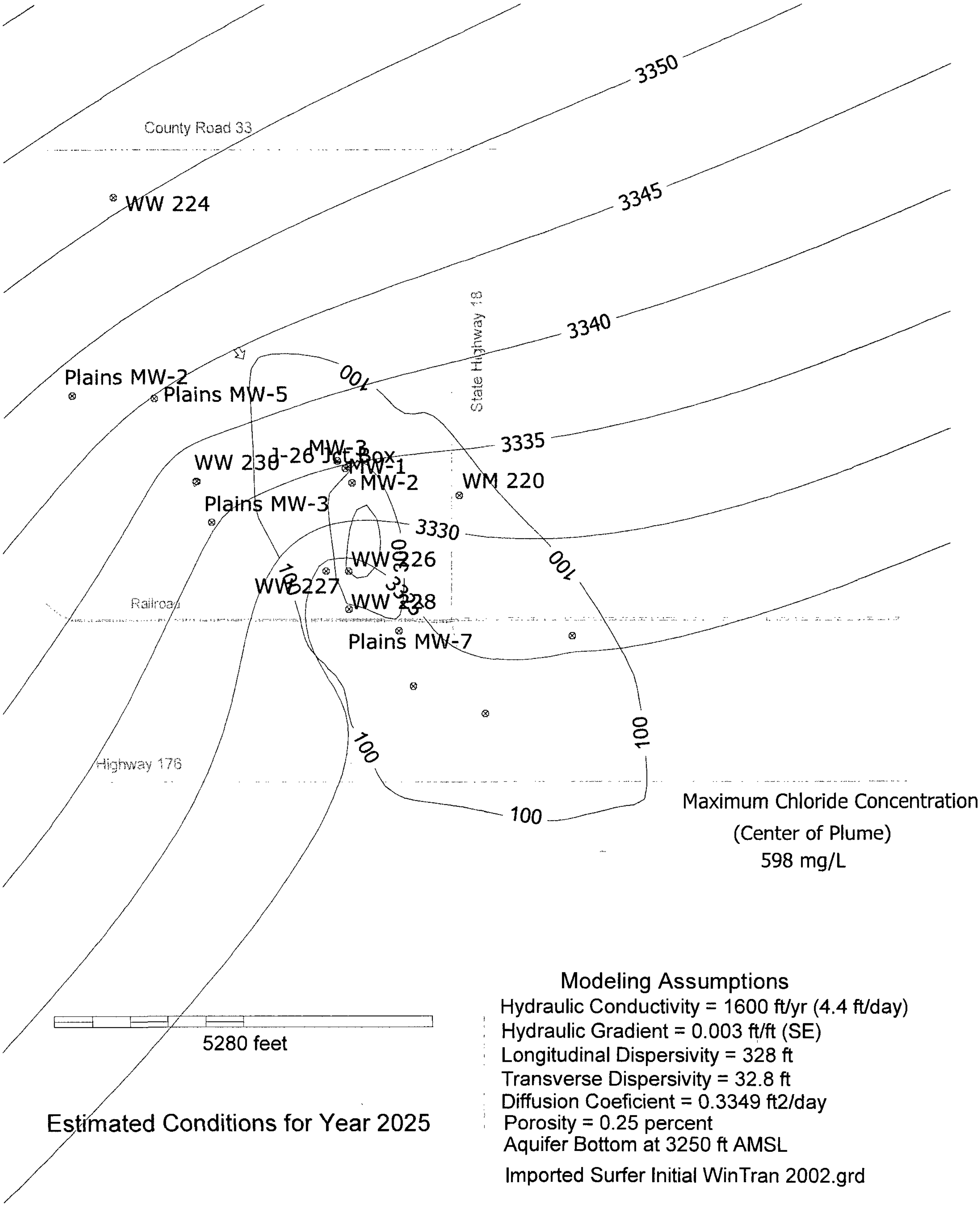
Maximum Chloride Concentration
(Center of Plume)
724 mg/L

Modeling Assumptions

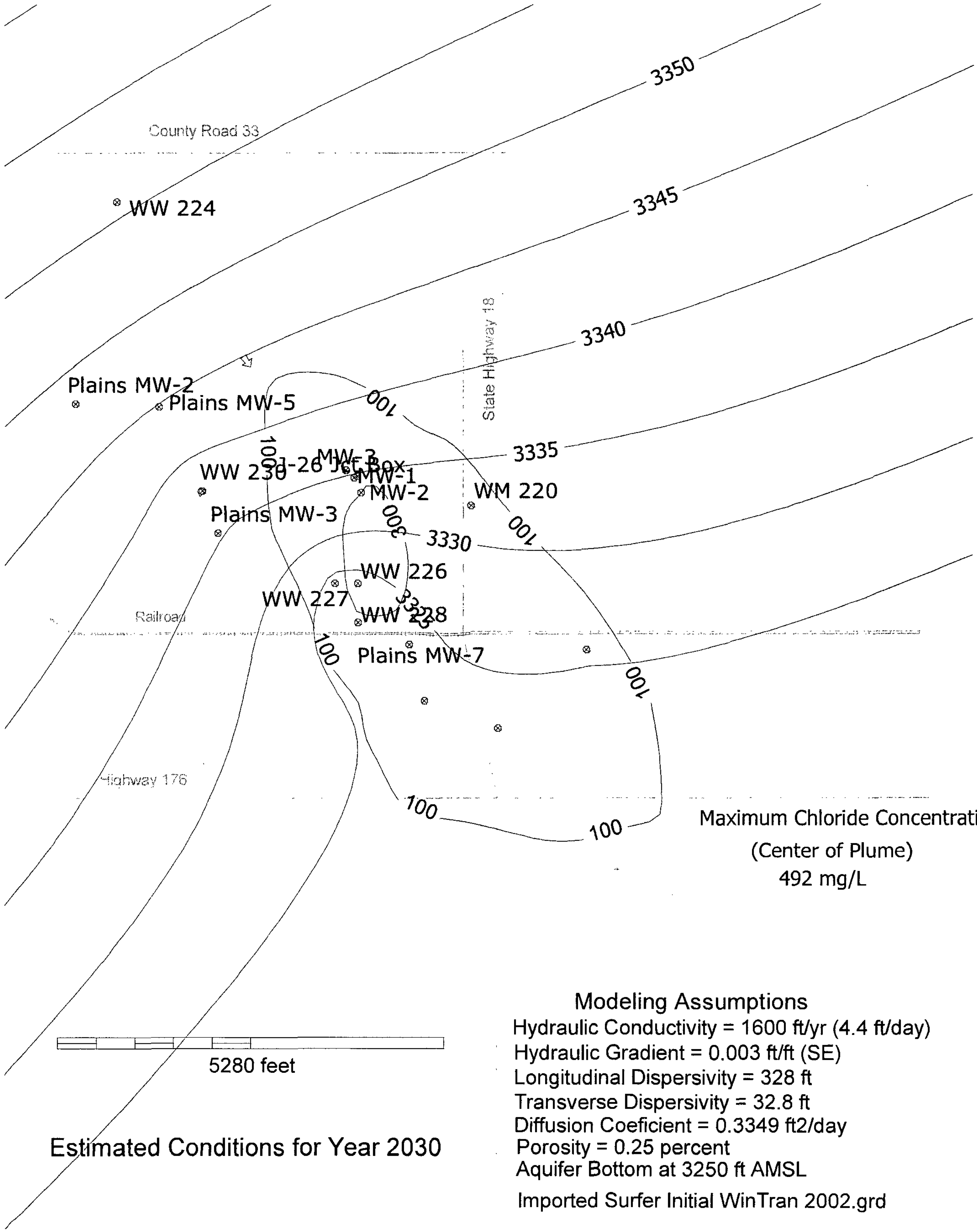
Hydraulic Conductivity = 1600 ft/yr (4.4 ft/day)
Hydraulic Gradient = 0.003 ft/ft (SE)
Longitudinal Dispersivity = 328 ft
Transverse Dispersivity = 32.8 ft
Diffusion Coeficient = 0.3349 ft2/day
Porosity = 0.25 percent
Aquifer Bottom at 3250 ft AMSL
Imported Surfer Initial WinTran 2002.grd

Estimated Conditions for Year 2020

BD J-26 Junction Box Site
WinTran Fate & Transport Modeling Results



BD J-26 Junction Box Site
WinTran Fate & Transport Modeling Results



Maximum Chloride Concentration
(Center of Plume)
492 mg/L

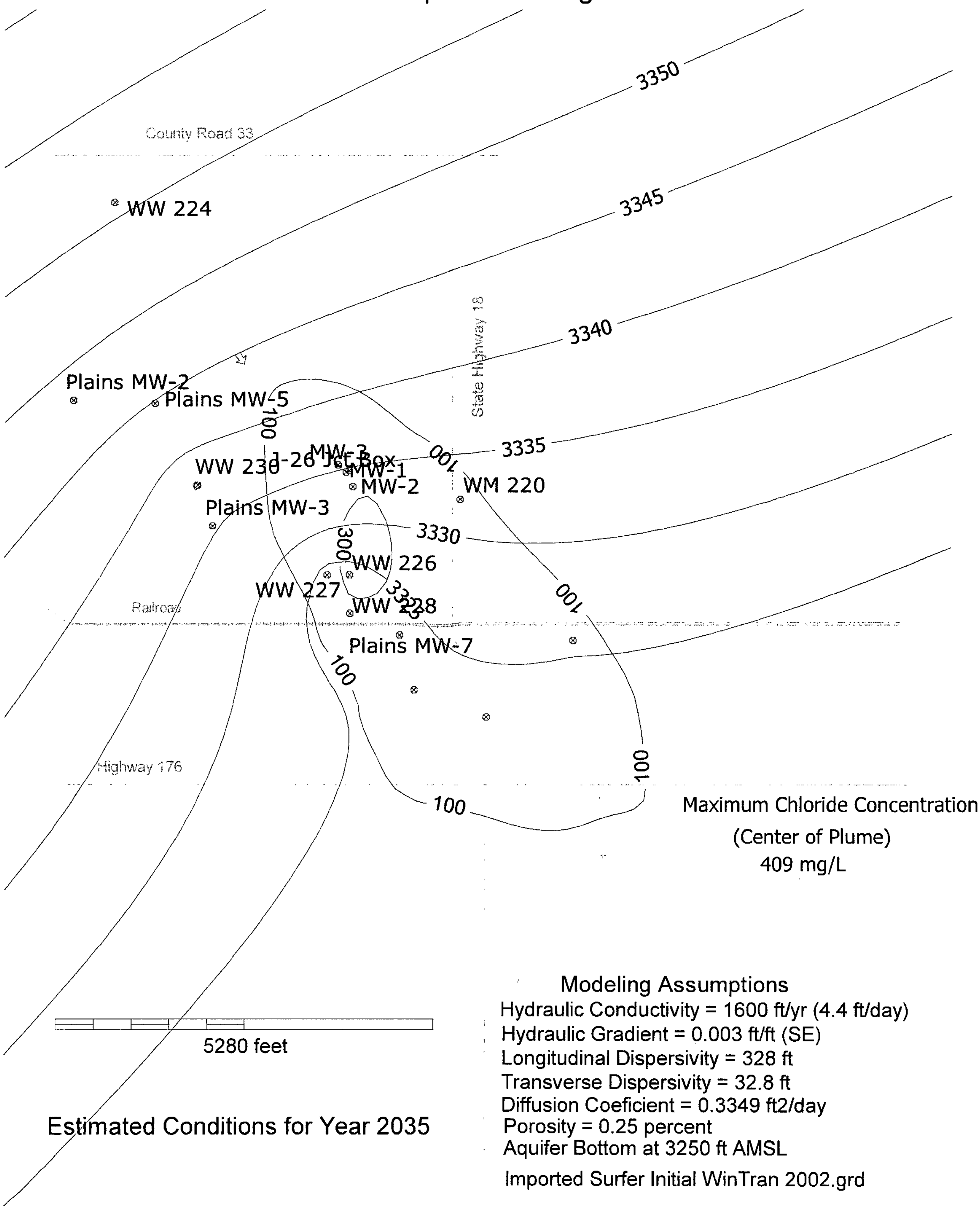
5280 feet

Estimated Conditions for Year 2030

Modeling Assumptions

Hydraulic Conductivity = 1600 ft/yr (4.4 ft/day)
Hydraulic Gradient = 0.003 ft/ft (SE)
Longitudinal Dispersivity = 328 ft
Transverse Dispersivity = 32.8 ft
Diffusion Coeficient = 0.3349 ft2/day
Porosity = 0.25 percent
Aquifer Bottom at 3250 ft AMSL
Imported Surfer Initial WinTran 2002.grd

BD J-26 Junction Box Site
WinTran Fate & Transport Modeling Results



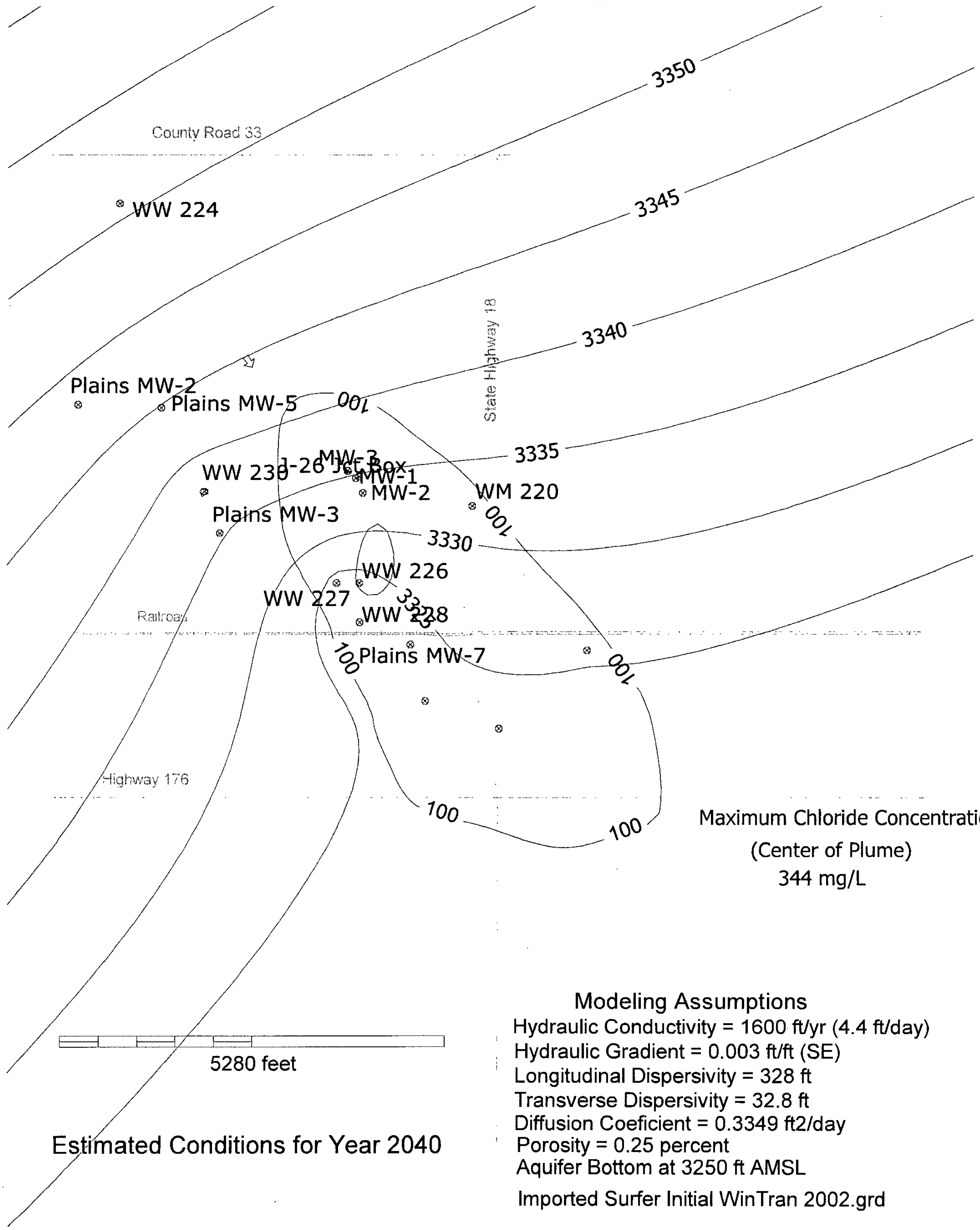
Maximum Chloride Concentration
(Center of Plume)
409 mg/L

Modeling Assumptions

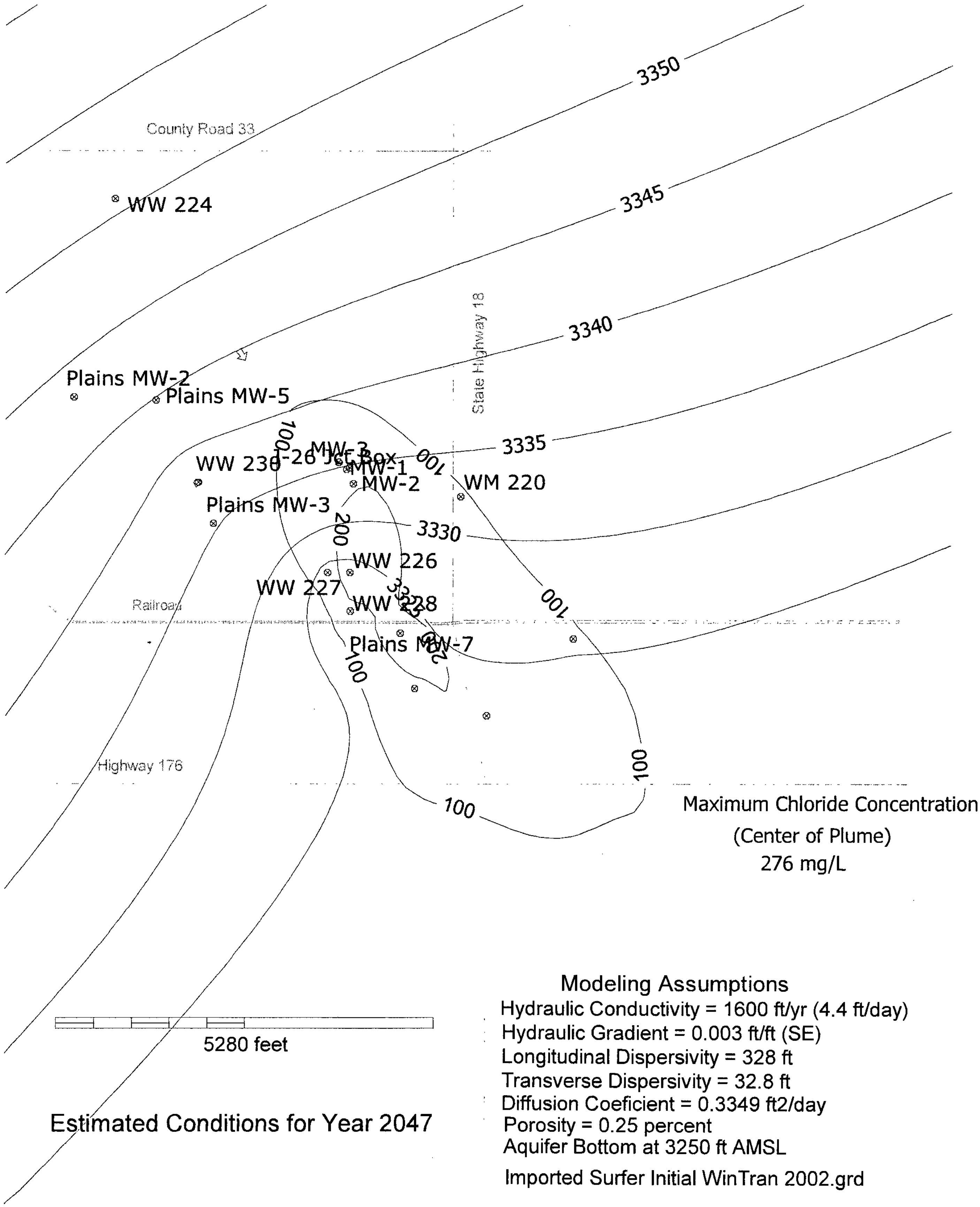
Hydraulic Conductivity = 1600 ft/yr (4.4 ft/day)
Hydraulic Gradient = 0.003 ft/ft (SE)
Longitudinal Dispersivity = 328 ft
Transverse Dispersivity = 32.8 ft
Diffusion Coeficient = 0.3349 ft2/day
Porosity = 0.25 percent
Aquifer Bottom at 3250 ft AMSL
Imported Surfer Initial WinTran 2002.grd

Estimated Conditions for Year 2035

BD J-26 Junction Box Site
WinTran Fate & Transport Modeling Results



BD J-26 Junction Box Site
WinTran Fate & Transport Modeling Results



Maximum Chloride Concentration
(Center of Plume)
276 mg/L

Modeling Assumptions
Hydraulic Conductivity = 1600 ft/yr (4.4 ft/day)
Hydraulic Gradient = 0.003 ft/ft (SE)
Longitudinal Dispersivity = 328 ft
Transverse Dispersivity = 32.8 ft
Diffusion Coeficient = 0.3349 ft2/day
Porosity = 0.25 percent
Aquifer Bottom at 3250 ft AMSL

Imported Surfer Initial WinTran 2002.grd

Estimated Conditions for Year 2047

==

WinTran
Analytical Model of 2D Ground-Water Flow and
Finite-Element Contaminant Transport Model

Developed by

James O. Rumbaugh, III

Douglas B. Rumbaugh

==

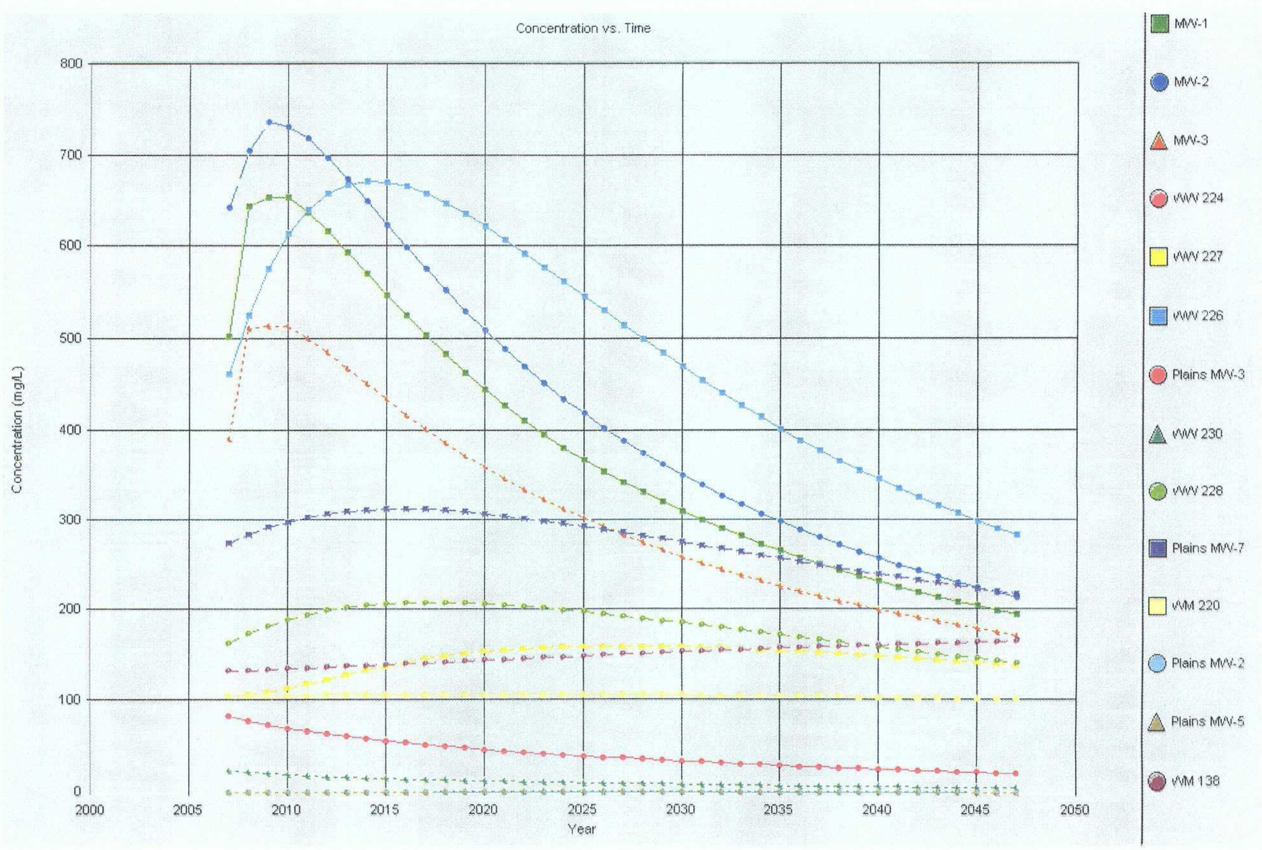
Model performed by: Trident Environmental (Gilbert Van Deventer)

Date: 03/02/07

Time: 13:19:54.00

Input File: 2006 CHLORIDE J26

Map File : D:\PROJECTS\RICE\BD\J-26\WINTRAN RESULTS\WINTRAN2002BASE.MAP



```
================================================================================
                          Model Entities

Number of Wells = 17

     Well #1
        Center of Well --  x: 3873.000000   y: 5443.000000
        Radius = 0.083330
        Pumping Rate = 0.000000
        Concentration of Injected Water = 218.000000
        Head at Well Radius           = 3334.738437
     Well #2
        Center of Well --  x: 3969.000000   y: 5243.000000
        Radius = 0.083330
        Pumping Rate = 0.000000
        Concentration of Injected Water = 387.000000
        Head at Well Radius           = 3333.495421
     Well #3
        Center of Well --  x: 3764.000000   y: 5540.000000
        Radius = 0.083330
        Pumping Rate = 0.000000
        Concentration of Injected Water = 141.000000
        Head at Well Radius           = 3335.402430
     Well #4
        Center of Well --  x: 631.000000   y: 9185.000000
        Radius = 0.083330
        Pumping Rate = 0.000000
        Concentration of Injected Water = 302.000000
        Head at Well Radius           = 3355.727045
     Well #5
        Center of Well --  x: 3611.000000   y: 4012.000000
        Radius = 0.375000
        Pumping Rate = 721412.000000
        Concentration of Injected Water = 181.000000
        Head at Well Radius           = 3318.357873
     Well #6
        Center of Well --  x: 3921.000000   y: 4012.000000
        Radius = 0.375000
        Pumping Rate = 543819.000000
        Concentration of Injected Water = 225.000000
        Head at Well Radius           = 3318.856940
     Well #7
        Center of Well --  x: 2012.000000   y: 4694.000000
        Radius = 0.083330
        Pumping Rate = 0.000000
        Concentration of Injected Water = 322.000000
        Head at Well Radius           = 3335.282440
     Well #8
        Center of Well --  x: 1802.000000   y: 5262.000000
        Radius = 0.375000
        Pumping Rate = 1202639.000000
        Concentration of Injected Water = 187.000000
        Head at Well Radius           = 3328.076355
     Well #9
        Center of Well --  x: 3927.000000   y: 3481.000000
        Radius = 0.375000
        Pumping Rate = 2748248.000000
        Concentration of Injected Water = 308.000000
        Head at Well Radius           = 3289.944035
     Well #10
        Center of Well --  x: 4628.000000   y: 3178.000000
        Radius = 0.083330
```

```
      Pumping Rate = 0.000000
      Concentration of Injected Water = 450.000000
      Head at Well Radius            = 3323.670009
   Well #11
      Center of Well --  x: 5472.000000   y: 5065.000000
      Radius = 0.250000
      Pumping Rate = 1000.000000
      Concentration of Injected Water = 620.000000
      Head at Well Radius            = 3332.262314
   Well #12
      Center of Well --  x: 60.000000   y: 6446.000000
      Radius = 0.083330
      Pumping Rate = 0.000000
      Concentration of Injected Water = 269.000000
      Head at Well Radius            = 3348.295561
   Well #13
      Center of Well --  x: 1205.000000   y: 6403.000000
      Radius = 0.083330
      Pumping Rate = 0.000000
      Concentration of Injected Water = 225.000000
      Head at Well Radius            = 3344.810629
   Well #14
      Center of Well --  x: 4829.000000   y: 2410.000000
      Radius = 0.250000
      Pumping Rate = 0.000000
      Concentration of Injected Water = 341.000000
      Head at Well Radius            = 3324.074809
   Well #15
      Center of Well --  x: 5838.000000   y: 2032.000000
      Radius = 0.250000
      Pumping Rate = 0.000000
      Concentration of Injected Water = 971.000000
      Head at Well Radius            = 3323.649345
   Well #16
      Center of Well --  x: 7050.000000   y: 3103.000000
      Radius = 0.375000
      Pumping Rate = 100000.000000
      Concentration of Injected Water = 405.000000
      Head at Well Radius            = 3324.822825
   Well #17
      Center of Well --  x: 3914.520000   y: 5464.310000
      Radius = 4.000000
      Pumping Rate = 0.000000
      Concentration of Injected Water = 60000.000000
      Head at Well Radius            = 3334.824298

Reference Head = 3345.000000    Defined at -- x: 2360.290000   y: 7094.260000
```

```
===========================================================================
                          Aquifer Properties

.... Steady-State Flow Model ....

Permeability...............= 1606.000000 [L/T]
Porosity...................= 0.250000
Elevation of Aquifer Top....= 3400.000000
Elevation of Aquifer Bottom.= 3250.000000
Uniform Regional Gradient...= 0.003000
Angle of Uniform Gradient...= 304.000000
Recharge...................= 0.000000


.... Transient Transport Model ....

Longitudinal Dispersivity...= 328.000000 [L]
Transverse Dispersivity.....= 32.800000 [L]
Diffusion Coefficient.......= 0.000000 [L2/T]
Contaminant half-life...... = 0.000000 [T]
Retardation Coefficient.....= 1.000000
Upstream Weighting in X.....= 0.000000
Upstream Weighting in Y.....= 0.000000

.... Time Stepping Information ....

Number of time steps........= 41
Starting time value.........= 2006.000000
Initial time step size......= 1.000000
Time step multiplier....... = 1.000000
Maximum time step size......= 1.000000
Time stepping scheme........= Central Differencing

.... Simulation Summary ....

Starting time..............= 2006.000000
Ending time................= 2047.000000
Number of time steps........= 41

(NOTE: following mass balance errors expressed as percent)
Transport Mass Balance Error= 7.032368

Peclet Criterion............= 0.516657
Courant Number.............= 0.867743
Flow Model Type............= Analytic Element
```

APPENDIX B

Documentation of WinTran (Version 1.03) Fate and Transport Model Capabilities and Benchmarking

WinFlow/WinTran Verification

Introduction

Verification is the process of demonstrating that the computer program performs as documented. In the case of a model, such as WinFlow, verification tests for proper implementation of the applicable equations. These equations are documented in Chapter 5 and are tested in this chapter.

The steady-state and transient models are tested separately, as described below. In each case, the model is first tested using a simple example that can be solved with a calculator. Next, WinFlow computations are compared against either another code solving the same problem or against published answers. The steady-state model is further tested by comparing WinFlow results against those of a popular numerical model, MODFLOW (McDonald and Harbaugh, 1988).

Steady-state Model

Three sets of verification problems are presented for the steady-state analytical functions used in WinFlow: In the first problem, a simple uniform flow field with a single pumping well is solved using WinFlow and a calculator. This is one of the more common uses for WinFlow and illustrates that the basic code functions are programmed accurately. In the second case, a series of problems are benchmarked against the program SLWL (Strack, 1989). Finally, a simple test case of a single well in a uniform unconfined flow field is a benchmark against the numerical model, MODFLOW.

Transient Model

Three sets of verification problems are presented for the transient analytical functions used in WinFlow. In the first problem, drawdown is computed for a single well. In the second case, a uniform regional gradient is added to the problem. In each of the first two test cases, WinFlow calculations are compared to those performed with a calculator. The final test presents tables of the Theis (1935) and Hantush and Jacob (1955) well functions for comparison with published tables.

Transport Model

The finite-element transportmodel in WinTran is verified through comparison with an analytical solution from Wexler (1992) and with another finite-element transport model called SEFTRAN (Huyakorn et al., 1984). The Wexler analytical solution models transport of a dissolved contaminant from a point source in a two-dimensional uniform flow field. Six test cases were investigated with SEFTRAN for the three different source configurations (injection well, pond, and linesink) in both uniform flow and in non-uniform flow fields.

Steady-state Model

Three sets of verification problems are presented for the steady-state analytical functions used in WinFlow. In the first problem, a simple uniform flow field with a single pumping well is solved using WinFlow and a calculator. This is one of the more common uses for WinFlow and illustrates that the basic code functions are programmed accurately. In the second case, a series of problems are benchmarked against the program SLWL (Strack, 1989). Finally, a simple test case of a single well in a uniform unconfined flow field is a benchmark against the numerical model, MODFLOW.

Case 1: Uniform Flow with a Single Well

The steady-state analytic function for a single well in a uniform flow field is given by Strack (1989) as follows:

$$\Phi = -Q_o(x\cos\alpha + y\sin\alpha) + \frac{Q}{4\pi}\ln[r^2(x,y)] + C$$

where

Φ	= discharge potential [L^3/T],
Q_o	= uniform ground-water flow [L^2/T],
x,y	= coordinates of the calculation point,
α	= angle between uniform flow and x-axis,
r(x,y)	= distance from the well to the calculation point (x,y),
Q	= well discharge [L^3/T],
C	= constant.

In a confined aquifer system, the discharge potential, Φ, is converted to head (ϕ) by the following equation.

$$\phi = \frac{\Phi + \frac{1}{2}KH^2}{KH}$$

where

ϕ	= head [L],
K	= hydraulic conductivity [L/T],
H	= aquifer thickness [L].

The constant, C, is evaluated by specifying a reference head at a certain location within the flow system. The reference head remains constant during all subsequent calculations. The constant, C, is computed as follows:

$$C = \Phi_o + Q_o(x_o \cos\alpha + y_o \sin\alpha) - \frac{Q}{4\pi}\ln[r^2(x_o, y_o)]$$

where

Φ_o = reference discharge potential,

(x_o, y_o) = coordinates of reference head.

In the first verification problem, the aquifer is confined with a uniform regional gradient parallel to the x-axis. The problem assumptions and parameters are listed below.

K = 100 ft/d

H = 100 ft

Gradient (i) = 0.01 ft/ft

Q_o = KiH = 100 ft^2/d

reference head, ϕ_o = 200 ft at (x_o=0,y_o=0)

$\Phi_o = KH\phi_o - \frac{1}{2}KH^2 = 1500000\ ft^3/d$

Q = 100,000 ft^3/d at (x=1000,y=1000)

Using these parameters and equation (3), the constant C equals 1,384,541. Table 1 lists the results of hand calculations and WinFlow results (using the Point Calculation option) for a series of coordinates. The two results are identical to five significant figures; the calculator results were rounded to five figures. Thus, WinFlow computes the correct answer for this test case.

Table 1 Comparison between WinFlow and calculator results for test case 1.

X	Y	Φ	ϕ	ϕ (WinFlow)
0	1000	1,494,480	199.45	199.448
250	1000	1,464,902	196.49	196.491
500	1000	1,433,449	193.34	193.345
750	1000	1,397,417	189.74	189.742
1000	1000	1,284,441	178.44	178.444
1250	1000	1,347,417	184.74	184.742
1500	1000	1,333,449	183.34	183.345
1750	1000	1,314,902	181.49	181.491
2000	1000	1,294,481	179.45	179.448

Case 2: Benchmark with SLWL

The SLWL program is provided with the book, Groundwater Mechanics, (Strack, 1989). SLWL performs the same calculations as WinFlow. The primary difference between the two codes is that SLWL is written in FORTRAN, while WinFlow is written in the C programming language. SLWL has additional capabilities to those of WinFlow but is not as user-friendly nor does SLWL have good output capabilities.

A series of twelve test cases are developed to test each of the major components in WinFlow, including wells, ponds, linesinks, and recharge. Each feature added to the simulation is designed to produce a significant impact on the flow field, so that significant errors would be easily detected. Both confined and unconfined conditions are tested. These verification data sets are included on the WinFlow disk. The data file names are VER1.WFL, VER2.WFL, ..., and VER12.WFL.

SLWL was modified to export a SURFER contour matrix (grid file) in the same manner as WinFlow. The SURFER grid files were then subtracted from one another to create a matrix of differences. A simple program was created to compute the mean and maximum difference. The results are summarized in Table 2. The features tested in each simulation are summarized in Table 2, along with the mean and maximum differences between the two codes. The specific details of each test may be examined by retrieving the verification data files from within WinFlow.

The maximum difference for each simulation was a uniform value of 0.000198 feet. The maximum error was constant, probably due to a consistent difference in the computational algorithms used in the C and FORTRAN compilers used for the two codes (Microsoft FORTRAN and Microsoft Visual C++). The mean error for each run varied from a low of 0.00000186 (VER6.WFL) to a high of 0.0000139 (VER7.WFL). In all cases, the differences between the two codes are on the order of 1.0×10^{-6} percent.

Table 2 Mean and maximum differences between WinFlow and SLWL in 12 test cases.

Data File	Uniform	Wells	Ponds	Line-sinks (head)	Line-sinks (flux)	Recharge	Aquifer Type (C/U)	Max. Error	Mean Error
ver1.wfl	✓	✓					C	0.000198	0.0000037
ver2.wfl	✓	✓					U	0.000198	0.0000019
ver3.wfl	✓	✓	✓				C	0.000198	0.0000038
ver4.wfl	✓	✓	✓				U	0.000198	0.0000020
ver5.wfl	✓	✓		✓			C	0.000198	0.0000051
ver6.wfl	✓	✓		✓			U	0.000198	0.0000019
ver7.wfl	✓	✓			✓		C	0.000198	0.0000014
ver8.wfl	✓	✓			✓		U	0.000198	0.0000066
ver9.wfl	✓	✓	✓	✓	✓		C	0.000198	0.0000048
ver10.wfl	✓	✓	✓	✓	✓		U	0.000198	0.0000030
ver11.wfl	✓	✓	✓	✓	✓	✓	C	0.000198	0.0000048
ver12.wfl	✓	✓	✓	✓	✓	✓	U	0.000198	0.0000030

Case 3: Benchmark with Numerical Model

A final test of the steady-state analytic functions in WinFlow is a comparison with a numerical model. The model chosen for comparison is MODFLOW (McDonald and Harbaugh, 1988), which is a three-dimensional, finite-difference ground-water flow model developed by the United States Geological Survey. MODFLOW is one of the most widely used numerical ground-water flow models.

A simple problem involving a single pumping well in a uniform flow field is chosen as the test case. The aquifer is unconfined with homogeneous properties. The model parameters are summarized below for the WinFlow data set.

K = 100 ft/d;

Aquifer bottom elevation = 0.0 ft;

Gradient (i) = 0.001 ft/ft at an angle of 0° to the x-axis;

$Q_0 = KiH = 10\ ft^2/d$;

[illegible]$_0$ = 100 ft at (x_0=0, y_0=0).

A single well located at coordinates (x=5000, y=5000) pumps 100,000 ft^3/d. The WinFlow input data file for this problem is provided on the distribution disk. The file name is "modf1.wfl".

Additional information is required to simulate the same system with a numerical model, such as MODFLOW. A finite-difference grid was constructed measuring 10,000 feet in both the x- and y-directions. There are 125 rows and 125 columns in the grid, with a cell spacing of 80 ft. A constant head of 100 ft was placed along the first column and a constant head of 89.532 was placed along the last column. The odd number was used to maintain a constant regional flow of 10 $ft^3/d/ft$ across the finite-difference grid under nonpumping conditions. The MODFLOW data set for this problem are contained on the WinFlow disk. Several files are required for input to the MODFLOW code. The files have a common root file name of "wflow" and a three-letter extension designating the MODFLOW package name. The MODFLOW files for this problem are as follows:

WFLOW.BAS	Basic Package Input
WFLOW.BCF	Block-Centered-Flow Package Input
WFLOW.SIP	Strongly Implicit Package Input
WFLOW.WEL	Well Package Input
WFLOW.OC	Output Control Input

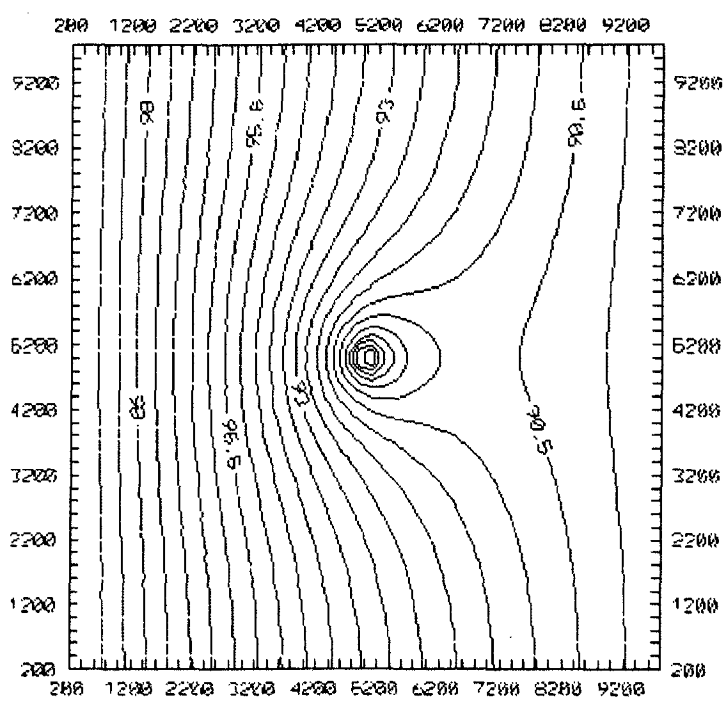
The WinFlow and MODFLOW calculations were compared by producing a SURFER grid file with 50 rows and 50 columns. The grid corners are located at (x=200, y=200) and (x=9800, y=9800). The two grid files were subtracted from each other to obtain a head difference file. A simple program was written to compute the maximum and mean differences. Contour maps produced for the WinFlow and MODFLOW results are also shown in Figure 1.

In the initial test case, MODFLOW and WinFlow compare favorably, with a maximum error of 0.84 feet and a mean error of 0.25 feet. The change in head across the model is 10.468 feet. Thus, there is a maximum difference of about 8 percent between the two codes. The contour maps shown in Figure 1 for the two codes are very similar. The primary difference is the behavior of the contours at the upper and lower (north and south) edge of the model. Contours from the MODFLOW run are perpendicular to the boundary, while WinFlow generated contours hit the boundary at an angle. This happens because MODFLOW treats the edge of the model as a no-flow or impermeable boundary forcing the contours to hit the boundary at right angles. WinFlow, on the other hand, assumes that the aquifer is infinite without any no-flow or impermeable boundaries.

A second test case was simulated by both WinFlow and MODFLOW in which no-flow boundaries were simulated with WinFlow. The northern and southern no-flow boundaries were reproduced in WinFlow using image wells. Two image wells were placed at coordinates (x=5000, y=15000) and (x=5000, y=-5000). Each image well pumped 100,000 ft^3/d. Contour maps for the second test case are shown in Figure 2. Now the WinFlow contours also strike the boundary at close to right angles. The maximum difference between WinFlow and MODFLOW for the second case is 0.39 feet, with a mean difference of 0.11 feet. This represents a significant improvement over the first test case. The maximum difference is 3.7 percent in this case.

The two test cases presented for the benchmark between WinFlow and MODFLOW show that both codes calculate similar head fields for the same problem. Even though the method of solution is different (analytical vs. numerical), each software package gives similar results. These comparisons provide the user with confidence that WinFlow is solving the ground-water flow equations properly.

MODFLOW



WinFlow

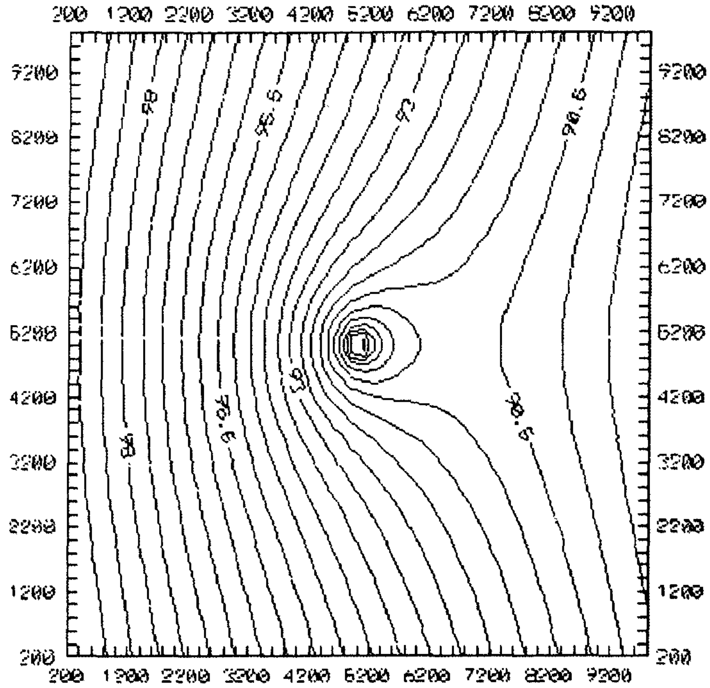
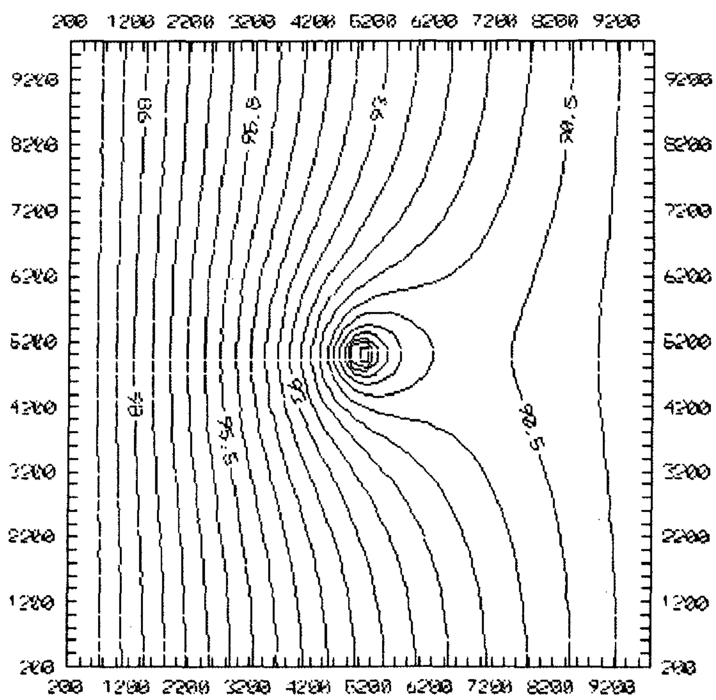


Figure 1. Comparison between WinFlow and MODFLOW for Test Case 1.

MODFLOW



WinFlow with Image Wells

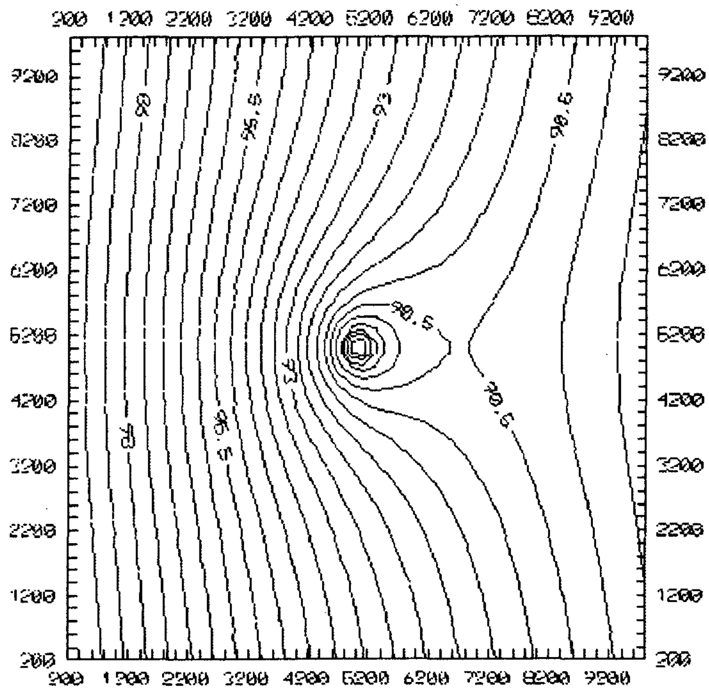


Figure 2. Comparison between WinFlow and MODFLOW for Test Case 2.

Transient Model

Three sets of verification problems are presented for the transient analytical functions used in WinFlow. In the first problem, drawdown is computed for a single well. In the second case, a uniform regional gradient is added to the problem. In each of the first two test cases, WinFlow calculations are compared to those performed with a calculator. The final test presents tables of the Theis (1935) and Hantush and Jacob (1955) well functions for comparison with published tables.

Case 1: Drawdown from a Single Well

The drawdown due to a single pumping well may be computed for any point in an aquifer using the following equation (Theis 1935):

$$s = \frac{Q}{4\pi T} W(u)$$

where

s = drawdown [L],

Q = well pumping rate [L^3/T],

T = transmissivity [L^2/T],

u = (r^2 S)/(4 T t),

r = distance between well and calculation point,

S = storage coefficient [dimensionless],

t = time after start of pumping [T],

W(u) = Theis well function.

In this example problem, we will choose the values of the parameters so that calculation is straightforward on a hand calculator and published tables of the Theis well function. The following parameters are used for Case 1:

T = 2500 ft^2/d

S = 0.01

t = 1.0 d

Q = 10,000 ft^3/d

WinFlow computed the same values of drawdown (s) as those computed using a calculator to four significant figures. The results of Case 1 are presented in Table 3.

Table 3 Comparison between WinFlow and calculator results for transient case 1.

Radius (ft)	u	W(u)	s (ft)	s (WinFlow)
1.0	10^{-6}	13.24	4.214	4.214
10.0	10^{-4}	8.633	2.748	2.748
20.0	4×10^{-4}	7.247	2.307	2.307
30.0	9×10^{-4}	6.437	2.049	2.049
40.0		5.862	1.866	1.866

	1.6×10^{-3}			
50.0	2.5×10^{-3}	5.417	1.724	1.724
60.0	3.6×10^{-3}	5.053	1.608	1.608
70.0	4.9×10^{-3}	4.746	1.511	1.511
80.0	6.4×10^{-3}	4.481	1.426	1.426
90.0	8.1×10^{-3}	4.247	1.352	1.352
100.0	0.01	4.038	1.285	1.285

Case 2: Drawdown from a Single Well in a Uniform Flow Field

The same parameters used in Case 1 above will be used in Case 2 and a uniform regional gradient will be added. Assume that the gradient is 0.001 ft/ft, with a reference head of 100 ft at the well. Because the transient model does not assume that the reference head is constant, the reference head may be specified anywhere (even at the well). We will also assume that the origin of the coordinate system (x=0; y=0) is at the well center.

The equation for a single well in a uniform flow field under transient conditions was given in the last chapter as

$$\phi(x,y,t) = C - G(x\cos\alpha + y\sin\alpha) - s$$

where

ϕ	= head [L],
G	= regional gradient [L/L],
α	= angle between regional gradient and x-axis,
(x,y)	= coordinates of calculation point,
t	= time since start of pumping,
s	= drawdown from well,
C	= constant.

The constant, C, is equal to the reference head in this case.

The heads computed by WinFlow and using a hand calculator are presented in Table 4. Again, WinFlow results and the calculator results are identical to six significant figures.

Table 4 Comparison between WinFlow and hand calculations for transient case 2.

X	Y	ϕ	ϕ (WinFlow)
1.0	0.0	95.786	95.786
10.0	0.0	97.152	97.152
20.0	0.0	97.493	97.493
30.0	0.0	97.651	97.651
40.0	0.0	97.734	97.734
50.0	0.0	97.776	97.776
60.0	0.0	97.792	97.792
70.0	0.0	97.789	97.789
80.0	0.0	97.774	97.774
90.0	0.0	97.748	97.748
100.0	0.0	97.715	97.715

Case 3: Calculation of Well Function Tables

The first two transient test cases tested the ability of WinFlow to compute drawdown with and without a regional gradient. These tests illustrated that WinFlow internal drawdown calculations are properly implemented. A further test of the software is calculation of well function tables, which tests WinFlow's ability to accurately compute drawdown over a wide range of conditions.

WinFlow uses two transient analytical functions: (1) the Theis (1935) equation for confined aquifers, and (2) the Hantush and Jacob (1955) equation for semi-confined (or leaky) aquifers. Values of the Theis well function, W(u), were computed using the numerical routines in WinFlow for a wide range of values of u. These calculations are shown in Table 5. These values can be compared to any published values, although the format of the table is identical to that published by Kruseman and deRidder (1990) in Annex 3.1, page 294. Table 5 and Annex 3.1 (Kruseman and deRidder 1990) are identical, illustrating that WinFlow can calculate the Theis well function accurately over a wide range in u.

Similarly, the Hantush and Jacob (1955) well function, W(u,r/L), was computed using the routines in WinFlow for a range of u and r/L values. These are shown in Tables 6, 7, and 8. Kruseman and deRidder (1990) have published similar tables in Annex 4.2 (pages 298 and 299). The Kruseman and deRidder (1990) tables and Tables 6, 7, and 8 are identical, confirming that WinFlow accurately computes values for the Hantush and Jacob leaky well function.

Table 5 Theis well function, W(u), computed using routines in WinFlow.

u	W(u)	W(u 10^{-1})	W(u 10^{-2})	W(u 10^{-3})	W(u 10^{-4})	W(u 10^{-5})	W(u 10^{-6})	W(u 10^{-7})	W(u 10^{-8})	W(u 10^{-9})	W(u 10^{-10})
1.0	2.194e-01	1.823e+00	4.038e+00	6.332e+00	8.633e+00	1.094e+01	1.324e+01	1.554e+01	1.784e+01	2.015e+01	2.245e+01
1.2	1.584e-01	1.660e+00	3.858e+00	6.149e+00	8.451e+00	1.075e+01	1.306e+01	1.536e+01	1.766e+01	1.996e+01	2.227e+01
1.5	1.000e-01	1.464e+00	3.637e+00	5.927e+00	8.228e+00	1.053e+01	1.283e+01	1.514e+01	1.744e+01	1.974e+01	2.204e+01
2.0	4.890e-02	1.223e+00	3.355e+00	5.639e+00	7.940e+00	1.024e+01	1.255e+01	1.485e+01	1.715e+01	1.945e+01	2.176e+01
2.5	2.491e-02	1.044e+00	3.137e+00	5.417e+00	7.717e+00	1.002e+01	1.232e+01	1.462e+01	1.693e+01	1.923e+01	2.153e+01
3.0	1.305e-02	9.057e-01	2.959e+00	5.235e+00	7.535e+00	9.837e+00	1.214e+01	1.444e+01	1.674e+01	1.905e+01	2.135e+01
3.5	6.970e-03	7.942e-01	2.810e+00	5.081e+00	7.381e+00	9.683e+00	1.199e+01	1.429e+01	1.659e+01	1.889e+01	2.120e+01
4.0	3.779e-03	7.024e-01	2.681e+00	4.948e+00	7.247e+00	9.549e+00	1.185e+01	1.415e+01	1.646e+01	1.876e+01	2.106e+01
4.5	2.073e-03	6.253e-01	2.568e+00	4.831e+00	7.129e+00	9.432e+00	1.173e+01	1.404e+01	1.634e+01	1.864e+01	2.094e+01
5.0	1.148e-03	5.598e-01	2.468e+00	4.726e+00	7.024e+00	9.326e+00	1.163e+01	1.393e+01	1.623e+01	1.854e+01	2.084e+01
6.0	3.601e-04	4.544e-01	2.295e+00	4.545e+00	6.842e+00	9.144e+00	1.145e+01	1.375e+01	1.605e+01	1.835e+01	2.066e+01
7.0	1.155e-04	3.738e-01	2.151e+00	4.392e+00	6.688e+00	8.990e+00	1.129e+01	1.359e+01	1.590e+01	1.820e+01	2.050e+01
8.0	3.767e-05	3.106e-01	2.027e+00	4.259e+00	6.554e+00	8.856e+00	1.116e+01				

1.346e+01	1.576e+01	1.807e+01	2.037e+01				
9.0	1.245e-05	2.602e-01	1.919e+00	4.142e+00	6.437e+00	8.739e+00	1.104e+01
1.334e+01	1.565e+01	1.795e+01	2.025e+01				

Table 6 Hantush well function, W(u,r/L), computed using routines in WinFlow.

u	r/L = 0	0.005	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.0e-06	1.32e+01	1.08e+01	9.44e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
2.0e-06	1.25e+01	1.08e+01	9.44e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
4.0e-06	1.19e+01	1.07e+01	9.44e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
6.0e-06	1.14e+01	1.06e+01	9.44e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
8.0e-06	1.12e+01	1.05e+01	9.43e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
1.0e-05	1.09e+01	1.04e+01	9.42e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
2.0e-05	1.02e+01	9.95e+00	9.30e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
4.0e-05	9.55e+00	9.40e+00	9.01e+00	8.03e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
6.0e-05	9.14e+00	9.04e+00	8.77e+00	7.98e+00	7.24e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
8.0e-05	8.86e+00	8.78e+00	8.57e+00	7.91e+00	7.23e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
1.0e-04	8.63e+00	8.57e+00	8.40e+00	7.84e+00	7.21e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
2.0e-04	7.94e+00	7.91e+00	7.82e+00	7.50e+00	7.07e+00	6.62e+00	6.22e+00	5.86e+00	5.56e+00	5.29e+00	5.06e+00
4.0e-04	7.25e+00	7.23e+00	7.19e+00	7.01e+00	6.76e+00	6.45e+00	6.14e+00	5.83e+00	5.55e+00	5.29e+00	5.06e+00
6.0e-04	6.84e+00	6.83e+00	6.80e+00	6.68e+00	6.50e+00	6.27e+00	6.02e+00	5.77e+00	5.51e+00	5.27e+00	5.05e+00
8.0e-04	6.55e+00	6.55e+00	6.52e+00	6.43e+00	6.29e+00	6.11e+00	5.91e+00	5.69e+00	5.46e+00	5.25e+00	5.04e+00
1.0e-03	6.33e+00	6.33e+00	6.31e+00	6.23e+00	6.12e+00	5.97e+00	5.80e+00	5.61e+00	5.41e+00	5.21e+00	5.01e+00
2.0e-03	5.64e+00	5.64e+00	5.63e+00	5.59e+00	5.53e+00	5.45e+00	5.35e+00	5.24e+00	5.12e+00	4.98e+00	4.85e+00
4.0e-03	4.95e+00	4.95e+00	4.94e+00	4.92e+00	4.89e+00	4.85e+00	4.80e+00	4.74e+00	4.67e+00	4.59e+00	4.51e+00
6.0e-03	4.54e+00	4.54e+00	4.54e+00	4.53e+00	4.51e+00	4.48e+00	4.45e+00	4.41e+00	4.36e+00	4.30e+00	4.24e+00
8.0e-03	4.26e+00	4.26e+00	4.26e+00	4.25e+00	4.23e+00	4.21e+00	4.19e+00	4.15e+00	4.12e+00	4.08e+00	4.03e+00
1.0e-02	4.04e+00	4.04e+00	4.04e+00	4.03e+00	4.02e+00	4.00e+00	3.98e+00	3.95e+00	3.93e+00	3.89e+00	3.86e+00
2.0e-02	3.35e+00	3.35e+00	3.35e+00	3.35e+00	3.34e+00	3.34e+00	3.33e+00	3.31e+00	3.30e+00	3.28e+00	3.26e+00
4.0e-02	2.68e+00	2.68e+00	2.68e+00	2.68e+00	2.68e+00	2.67e+00	2.67e+00	2.66e+00	2.66e+00	2.65e+00	2.64e+00
6.0e-02	2.30e+00	2.30e+00	2.29e+00	2.29e+00	2.29e+00	2.29e+00	2.29e+00	2.28e+00	2.28e+00	2.27e+00	2.27e+00
8.0e-02	2.03e+00	2.03e+00	2.03e+00	2.03e+00	2.02e+00	2.02e+00	2.02e+00	2.02e+00	2.02e+00	2.01e+00	2.01e+00
1.0e-01	1.82e+00	1.82e+00	1.82e+00	1.82e+00	1.82e+00	1.82e+00	1.82e+00	1.82e+00	1.81e+00	1.81e+00	1.81e+00
2.0e-01	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00
4.0e-01	7.02e-01	7.02e-01	7.02e-01	7.02e-01	7.02e-01	7.02e-01	7.02e-01	7.02e-01	7.01e-01	7.01e-01	7.00e-01
6.0e-01	4.54e-01	4.54e-01	4.54e-01	4.54e-01	4.54e-01	4.54e-01	4.54e-01	4.54e-01	4.54e-01	4.54e-01	4.53e-01
8.0e-01	3.11e-01	3.11e-01	3.11e-01	3.11e-01	3.11e-01	3.10e-01	3.10e-01	3.10e-01	3.10e-01	3.10e-01	3.10e-01

Table 7 Hantush well function, W(u,r/L), computed using routines in WinFlow.

u	r/L = 0	0.1	0.2	0.3	0.4	0.6	0.8
1.0e-04	8.63e+00	4.85e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
2.0e-04	7.94e+00	4.85e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
4.0e-04	7.25e+00	4.85e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
6.0e-04	6.84e+00	4.85e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
8.0e-04	6.55e+00	4.84e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00

1.0e-03	6.33e+00	4.83e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
2.0e-03	5.64e+00	4.71e+00	3.50e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
4.0e-03	4.95e+00	4.42e+00	3.48e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
6.0e-03	4.54e+00	4.18e+00	3.43e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
8.0e-03	4.26e+00	3.98e+00	3.36e+00	2.73e+00	2.23e+00	1.56e+00	1.13e+00
1.0e-02	4.04e+00	3.82e+00	3.29e+00	2.71e+00	2.23e+00	1.56e+00	1.13e+00
2.0e-02	3.35e+00	3.24e+00	2.95e+00	2.57e+00	2.18e+00	1.55e+00	1.13e+00
4.0e-02	2.68e+00	2.63e+00	2.48e+00	2.27e+00	2.02e+00	1.52e+00	1.13e+00
6.0e-02	2.30e+00	2.26e+00	2.17e+00	2.02e+00	1.85e+00	1.46e+00	1.11e+00
8.0e-02	2.03e+00	2.00e+00	1.94e+00	1.83e+00	1.69e+00	1.39e+00	1.08e+00
1.0e-01	1.82e+00	1.80e+00	1.75e+00	1.67e+00	1.56e+00	1.31e+00	1.05e+00
2.0e-01	1.22e+00	1.22e+00	1.19e+00	1.16e+00	1.11e+00	9.96e-01	8.58e-01
4.0e-01	7.02e-01	7.00e-01	6.93e-01	6.81e-01	6.65e-01	6.21e-01	5.65e-01
6.0e-01	4.54e-01	4.53e-01	4.50e-01	4.44e-01	4.36e-01	4.15e-01	3.87e-01
8.0e-01	3.11e-01	3.10e-01	3.08e-01	3.05e-01	3.01e-01	2.89e-01	2.73e-01
1.0e+00	2.19e-01	2.19e-01	2.18e-01	2.16e-01	2.14e-01	2.06e-01	1.97e-01
2.0e+00	4.89e-02	4.89e-02	4.87e-02	4.85e-02	4.82e-02	4.72e-02	4.60e-02

Table 8 Hantush well function, W(u,r/L), computed using routines in WinFlow.

u	r/L = 0	1.0	2.0	3.0	4.0	5.0	6.0
1.0e-02	4.04e+00	8.42e-01	2.28e-01	6.95e-02	2.23e-02	7.38e-03	2.49e-03
2.0e-02	3.35e+00	8.42e-01	2.28e-01	6.95e-02	2.23e-02	7.38e-03	2.49e-03
4.0e-02	2.68e+00	8.42e-01	2.28e-01	6.95e-02	2.23e-02	7.38e-03	2.49e-03
6.0e-02	2.30e+00	8.39e-01	2.28e-01	6.95e-02	2.23e-02	7.38e-03	2.49e-03
8.0e-02	2.03e+00	8.32e-01	2.28e-01	6.95e-02	2.23e-02	7.38e-03	2.49e-03
1.0e-01	1.82e+00	8.19e-01	2.28e-01	6.95e-02	2.23e-02	7.38e-03	2.49e-03
2.0e-01	1.22e+00	7.15e-01	2.27e-01	6.95e-02	2.23e-02	7.38e-03	2.49e-03
4.0e-01	7.02e-01	5.02e-01	2.10e-01	6.91e-02	2.23e-02	7.38e-03	2.49e-03
6.0e-01	4.54e-01	3.54e-01	1.77e-01	6.64e-02	2.22e-02	7.38e-03	2.49e-03
8.0e-01	3.11e-01	2.54e-01	1.44e-01	6.07e-02	2.17e-02	7.36e-03	2.49e-03
1.0e+00	2.19e-01	1.85e-01	1.14e-01	5.34e-02	2.07e-02	7.27e-03	2.49e-03
2.0e+00	4.89e-02	4.44e-02	3.34e-02	2.10e-02	1.12e-02	5.13e-03	2.10e-03
4.0e+00	3.78e-03	3.58e-03	3.06e-03	2.35e-03	1.63e-03	1.03e-03	5.86e-04

Transport Model

The finite-element transportmodel in WinTran is verified through comparison with an analytical solution from Wexler (1992) and with another finite-element transport model called SEFTRAN (Huyakorn et al., 1984). The Wexler analytical solution models transport of a dissolved contaminant from a point source in a two-dimensional uniform flow field. Six test cases were investigated with SEFTRAN for the three different source configurations (injection well, pond, and linesink) in both uniform flow and in non-uniform flow fields.

Comparison to an Analytical Solution

Wexler (1992) presents a series of analytical solutions to the partial differential equations of dissolved contaminant transport in porous media. WinTran was compared to the solution for a continuous point source in an aquifer of infinite extent (see page 26 of Wexler, 1992). The analytical solution was implemented by Wexler in a FORTRAN program called POINT2.

The data for the test problem are presented in Table 1. Concentration is plotted versus time at two locations downgradient of the source for both WinTran and SEFTRAN (see Figure 1). These curves show that WinTran results are virtually identical to those of the analytical solution. Contours for both WinTran results and POINT2 results are shown in Figure 2. Again, these contours are almost identical for the two solutions. The largest difference is at the source, where WinTran slightly underpredicts the source concentration. This is probably caused by dilution of the source concentration in the finite-element cell. The majority of the plume, however, matches quite well between WinTran and POINT2.

Comparison of WinTran to an analytical solution confirms that the basic transport model has been coded properly. The analytical solution, however, assumes that the flow field is uniform and the source is a single point and continuous over time. The next section presents a series of tests that illustrate that WinTran performs properly for more complex scenarios.

Table 1. Model Parameters for the Analytical Solution Comparison

Parameter	Value
Hydraulic conductivity	100 ft/d
Top Elevation	-75 ft
Bottom Elevation	-100 ft
Porosity	0.2
Hydraulic Gradient	0.01 to the East
Groundwater Velocity	5 ft/d
Longitudinal Dispersivity	30 ft
Transverse Dispersivity	3 ft
Retardation Coefficient	1
X coordinate of source	212.32 ft
Y coordinate of source	230.87 ft
Source fluid flow rate	-1 ft^3/d
Source concentration	100
Number of X nodes	70
Number of Y nodes	70
Minimum X coordinate	50.0 ft
Minimum Y coordinate	50.0 ft

Nodal Spacing in X	8.116 ft
Nodal Spacing in Y	5.652 ft

Number of time steps	50
Minimum time step size	0.5 day
Maximum time step size	10 days
Time step multiplier	1.1
Final time value	280.569 days

Figure 1. Time-series comparison between WinTran and an analytical solution at two downgradient nodes

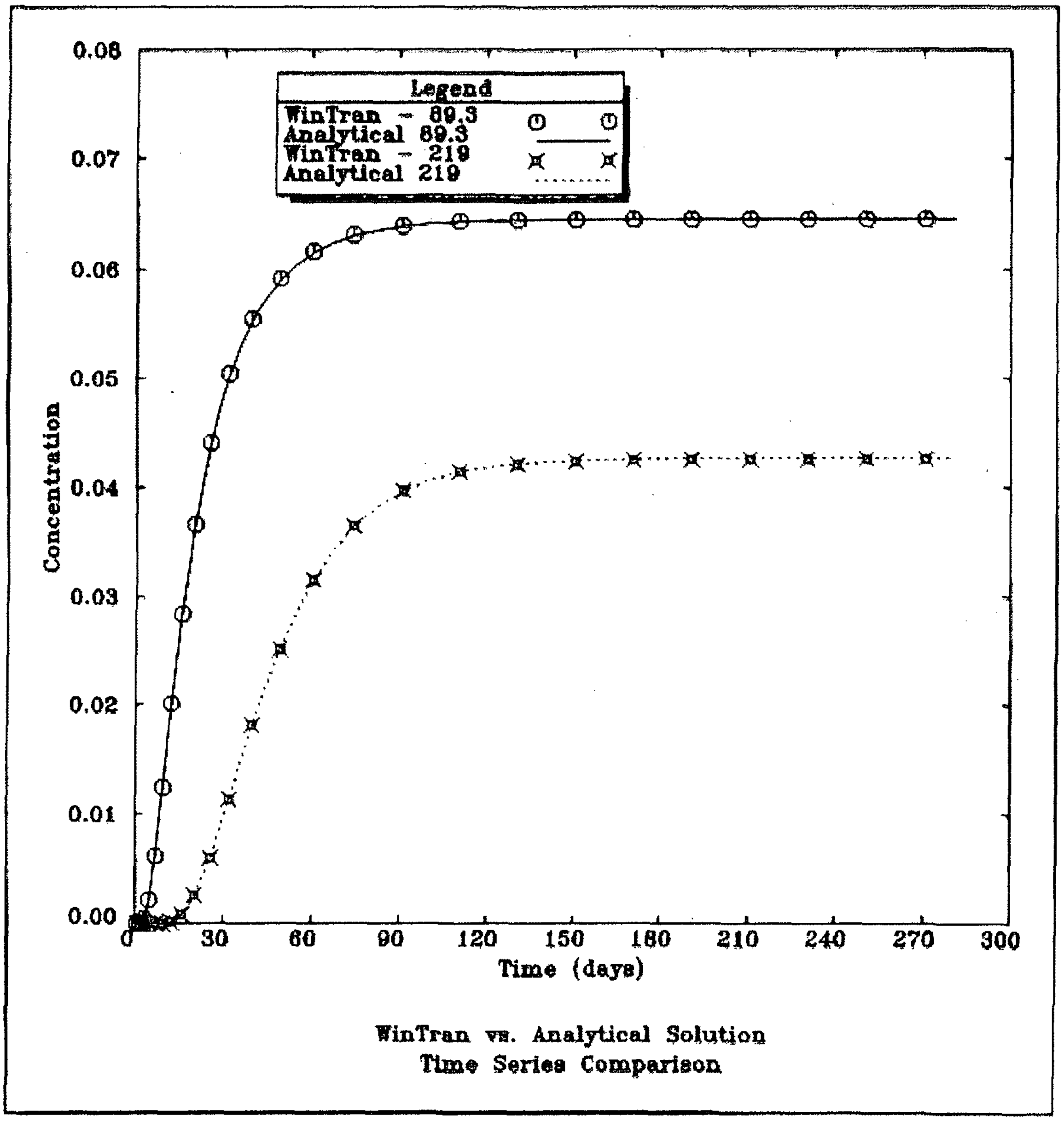
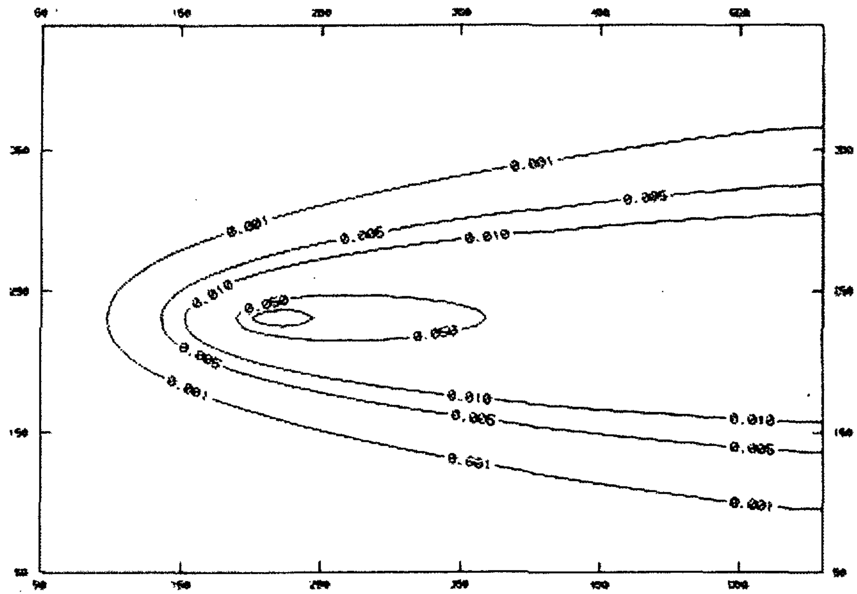
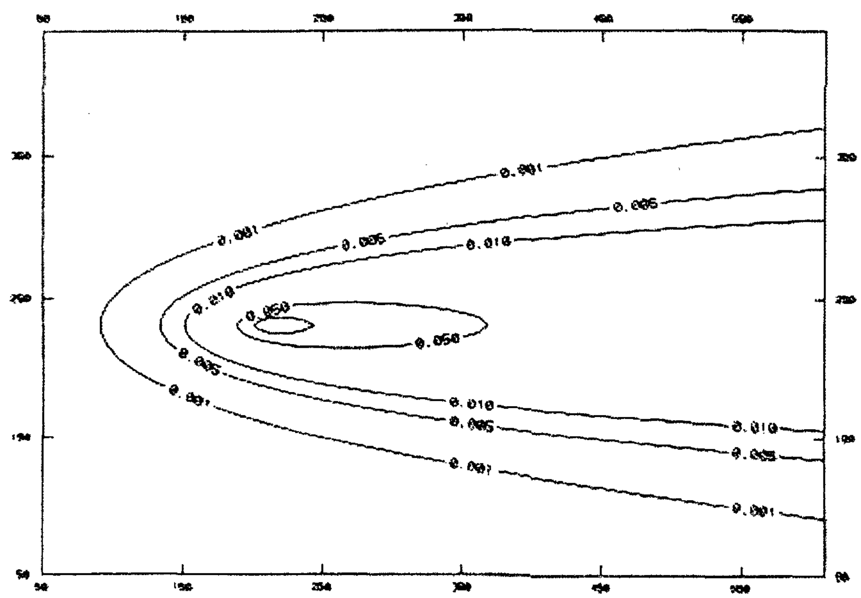


Figure 2. Concentration contours for WinTran and the analytical solution at time=260.569 days.

WinTran



Analytical Model



Benchmarking with SEFTRAN

SEFTRAN (Huyakorn et al., 1984) was chosen for the majority of testing because it uses the same finite-element techniques that are employed by WinTran. SEFTRAN also makes a good choice for benchmark testing because it has undergone a significant amount of testing at the International Ground Water Modeling Center (Huyakorn et al., 1984).

To facilitate this testing, a special option has been added to the WinTran Export menu allowing WinTran to create SEFTRAN data input files. Three files are created, (1) a SEFTRAN flow data set (always called FLOW.IN), (2) a SEFTRAN transport data set (you specify the name in the dialog), and (3) a velocity file with analytically-computed velocities (always called FLOW.VEL).

A series of six simulations were performed to test the three different source configurations (point source using an injection well, pond infiltration, and linesink injection). Each of the three source terms was tested in both a uniform flow field and a non-uniform flow field. The non-uniform flow field was produced by adding a pumping well downgradient from the source. The results for the six simulations are summarized in Table 2 and Table 2b. Data for the simulations are shown in Table 3.

The benchmark simulations are evaluated by presenting the following in Table 2: (1) maximum source concentration computed by WinTran and SEFTRAN, (2) the mean and maximum differences (errors) when SEFTRAN uses WinTran-computed velocities, (3) the mean and maximum differences when SEFTRAN uses SEFTRAN-computed velocities, and (4) mass balance errors for the two models. The source concentrations were scaled to a value of 1.0 in WinTran. The mass balance errors are in percent.

The mean and maximum differences between the two codes are very low for the case when each code uses velocities computed by WinTran. This tests the WinTran transport model because both codes are using the same velocity field. The tests illustrate that the transport model in WinTran is functioning properly for all cases. The mass balance error for each code is comparable for all cases and the source concentrations are accurate to the fourth decimal place.

The second set of errors (differences) presented in Table 2 are for SEFTRAN results computed using velocities computed by the SEFTRAN flow model. In the first set of differences described in the previous paragraph, the SEFTRAN transport model read velocity data computed by WinTran. The second set of comparisons, therefore, are used to evaluate the hybrid modeling approach. The results show that for uniform flow conditions, WinTran and SEFTRAN velocities produce virtually the same results. In a non-uniform flow field, however, the differences are larger. This indicates that the analytically-computed velocities are slightly in error.

Table 2b presents the differences between SEFTRAN and WinTran when velocities in WinTran are computed using finite elements (rather than the analytical model). In this case, the differences are very minor. Thus, for complex flow fields, you may want to consider using the finite-element flow model to compute velocities. You may select this option using the **Model->Flow Model Type** menu.

Figures 3 through 8 present concentration contour maps created by WinTran and SEFTRAN. These figures further substantiate that the two models are producing the same results.

Table 2. Comparison Between WinTran and SEFTRAN for Six Simulations.

Description	Maximum Conc.	Maximum Conc.	WinTran Velocities		Seftran Velocities		Mass Balance Error	Mass Balance Error
	WinTran	Seftran	Mean Error	MaximumError	Mean Error	MaximumError	WinTran	Seftran

Test 1 Point Source Uniform Flow	1.0	1.000052	-1.1e-05	7.5e-05	3.8e-05	7.0e-05	0.0129	0.00082
Test 2 Pond Source Uniform Flow	1.0	1.00024	-4.2e-05	2.4e-04	4.9e-05	1.99e-04	0.00758	0.0069
Test 3 Line Source Uniform Flow	1.0	0.99992	1.66e-05	2.04e-04	1.47e-04	2.4e-03	0.00438	0.018
Test 4 Point Source Nonuniform Flow	1.0	1.00005	-9.8e-06	7.3e-05	7.5e-06	5.8e-03	0.2057	0.195
Test 5 Pond Source Nonuniform Flow	1.0	0.99996	7.5e-06	7.23e-05	2.0e-05	0.045	0.147	0.136
Test 6 Line Source Nonuniform Flow	1.0	0.99991	1.06e-05	1.4e-04	4.2e-05	0.025	0.056	0.046

Table 2b. Comparison Between WinTran (Using the Finite Element Flow Model) and SEFTRAN for the Nonuniform Flow Test Cases.

Description	Mean Error	Maximum Error	WinTran Mass Balance Error
Test 4	-6.33e-06	6.78e-05	0.145
Test 5	1.3e-06	1.4e-04	0.161
Test 6	2.6e-05	2.7e-04	0.20

Table 3. Model Parameters for the SEFTRAN Benckmarking

Parameter	Value
Hydraulic conductivity	100 ft/d
Top Elevation	100 ft
Bottom Elevation	0 ft
Reference Head	25 ft at (75,65)
Porosity	0.2
Hydraulic Gradient	0.01 to the East
Longitudinal Dispersivity	30 ft
Transverse Dispersivity	6 ft
Retardation Coefficient	1
Number of X nodes	35
Number of Y nodes	35
Minimum X coordinate	45.03 ft

Minimum Y coordinate	42.29 ft
Maximum X coordinate	678.81 ft
Maximum Y coordinate	413.66 ft
Number of time steps	30
Minimum time step size	1 day
Maximum time step size	100 days
Time step multiplier	1.2

Point Source Information (Simulation 1 and 4)

Fluid Injection Rate	-1.0 ft^3/d
Concentration in fluid	100
Coordinates of Well (x,y)	(138.23,227.98)

Pumping Well Information (Simulations 4 through 6)

Pumping Rate	10,000 ft^3/d
Coordinates of Well (x,y)	(604.25,315.36)

Table 3 (continued). Model Parameters for the SEFTRAN Benckmarking

Linesink Source Information (Simulations 3 and 6)

Linesink Injection Rate	-1 ft^2/d
Concentration in fluid	100
Beginning Coordinates of line (x,y)	(145.27,275.11)
Ending Coordinates of line (x,y)	(143.65,167.59)

Pond Source Information (Simulations 2 and 5)

Pond Infiltration Rate	0.0015 ft/d
Concentration in fluid	100
Pond Radius	24.68 ft
Coordinates of pond center (x,y)	(137.99,227.41)

Figure 3. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 1.

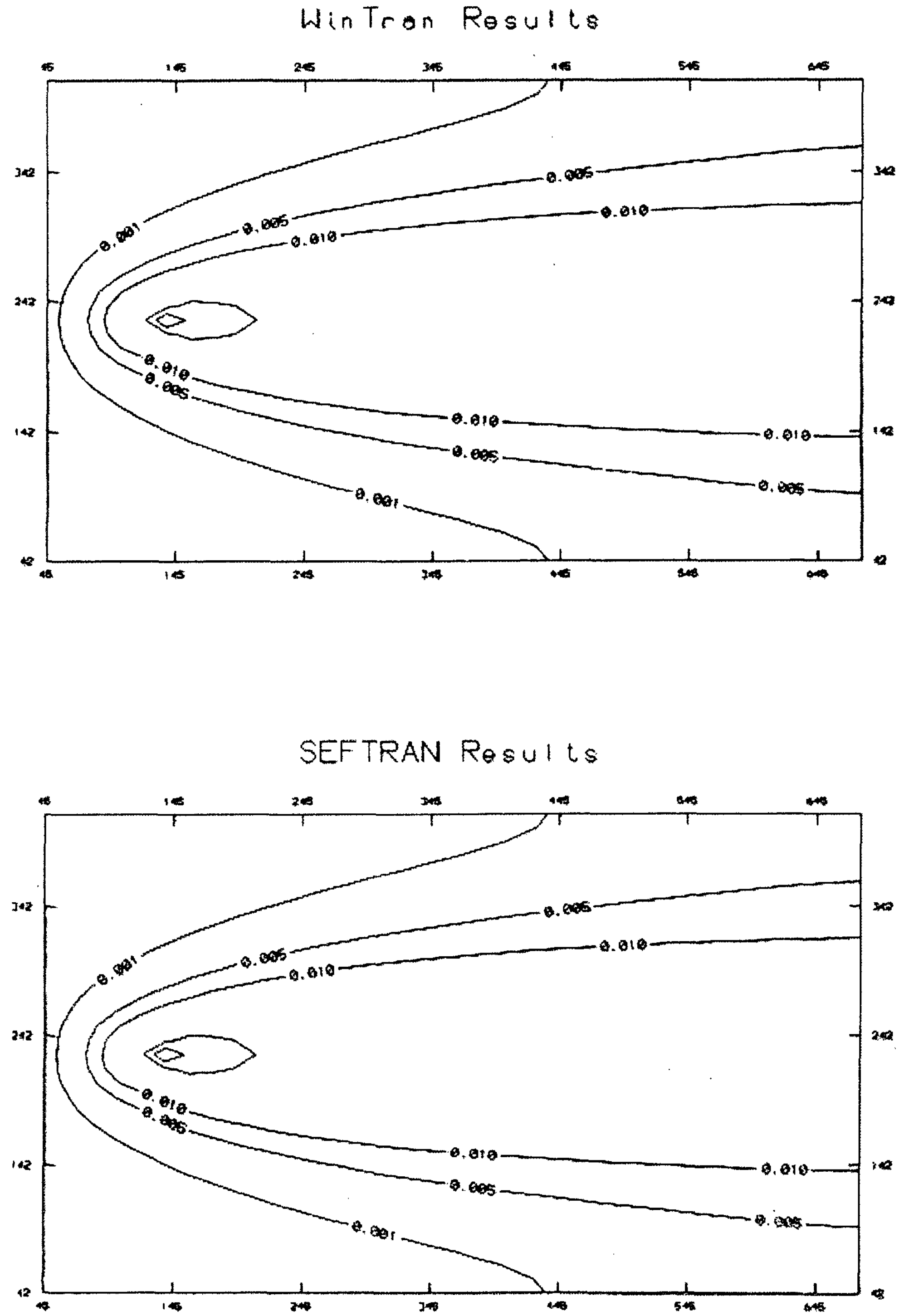


Figure 4. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 2.

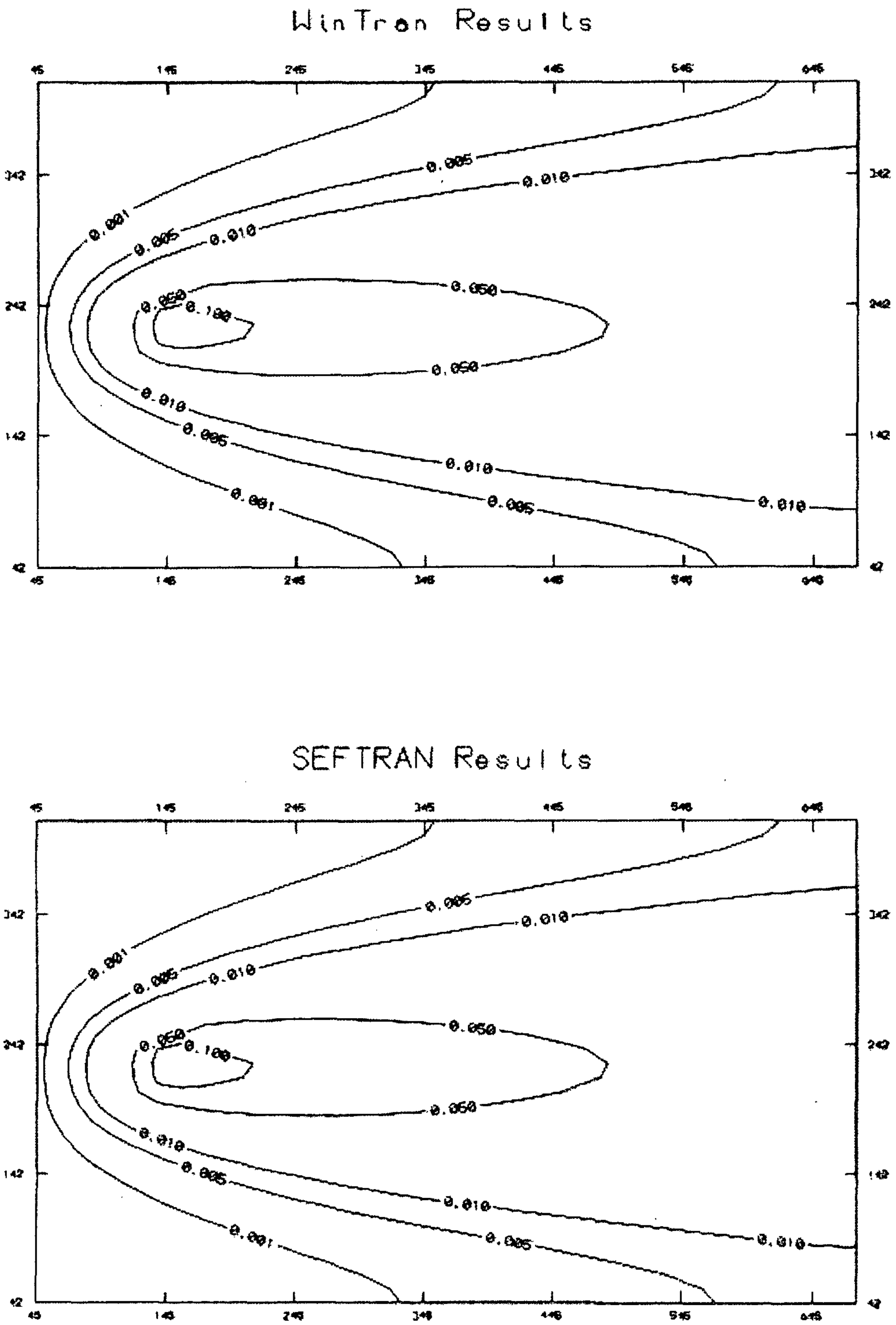
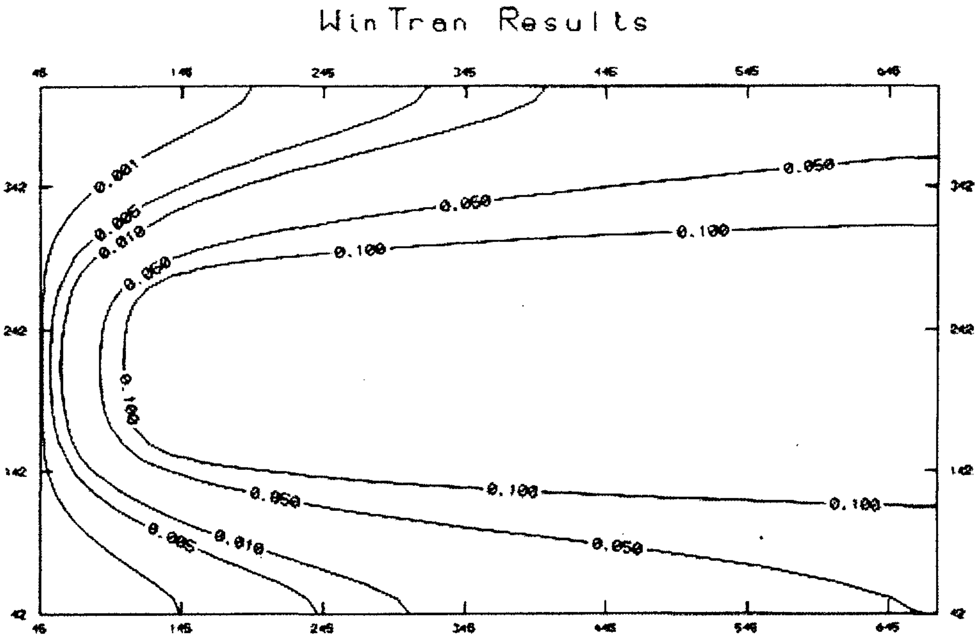


Figure 5. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 3.



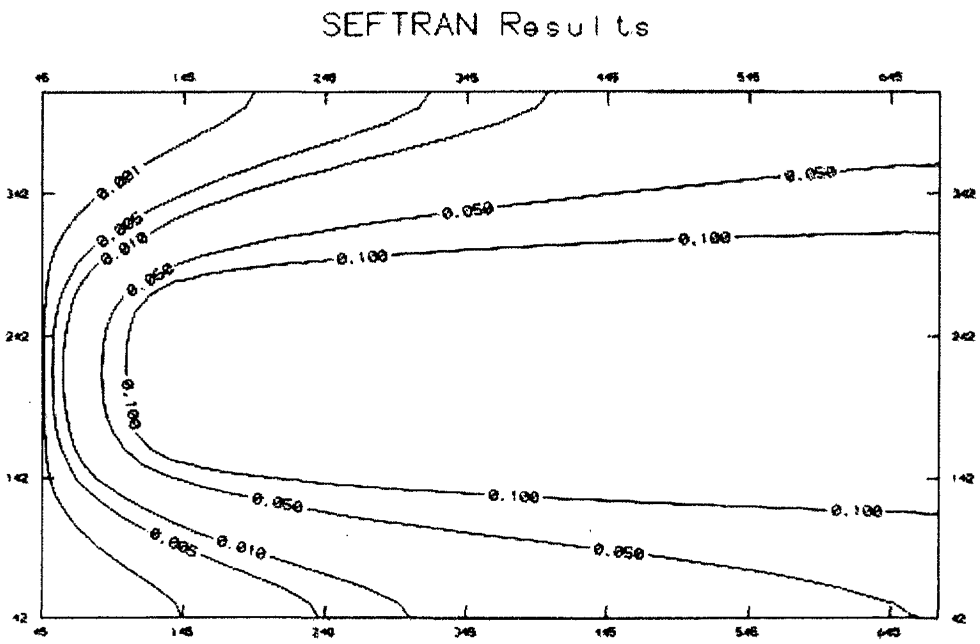
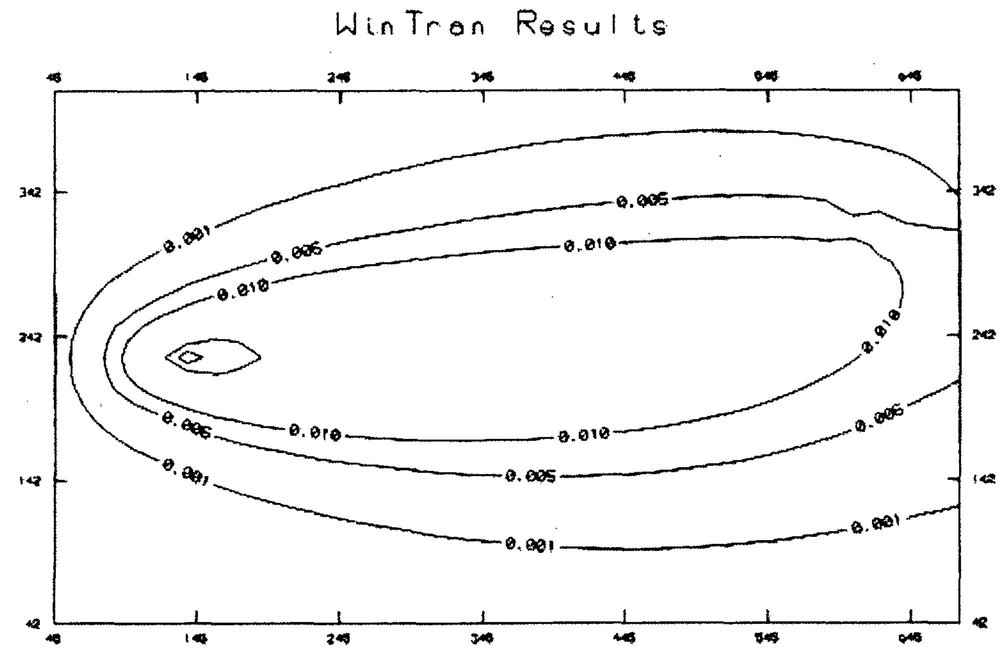


Figure 6. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 4.



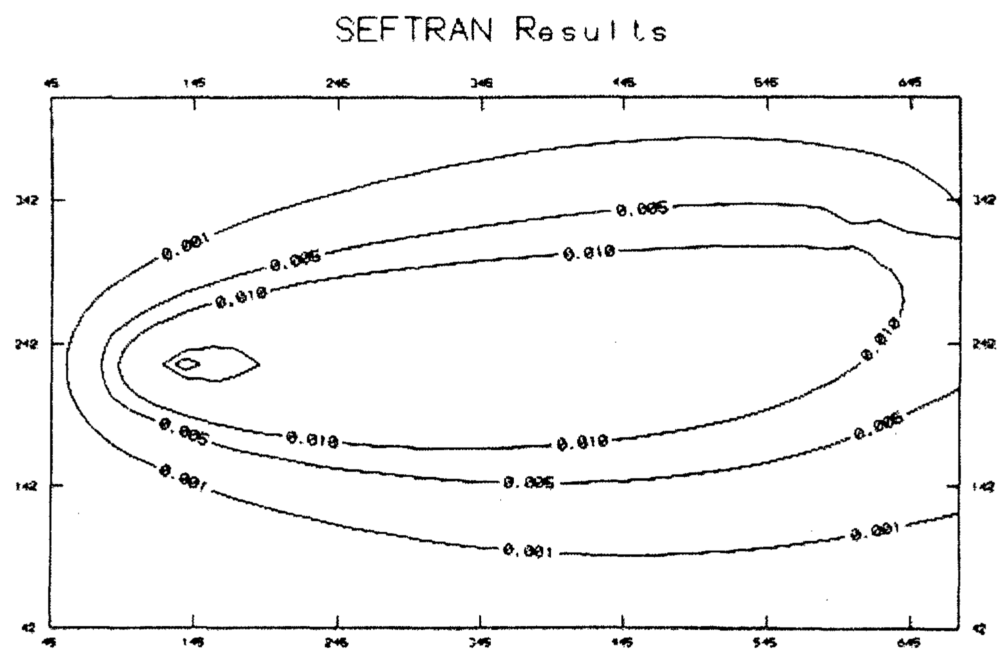
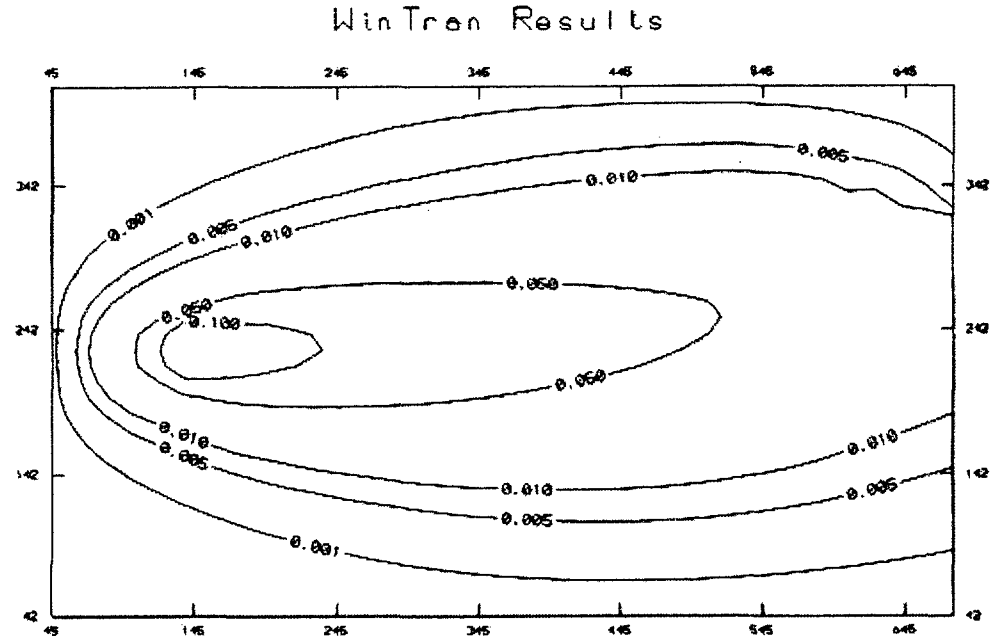


Figure 7. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 5.



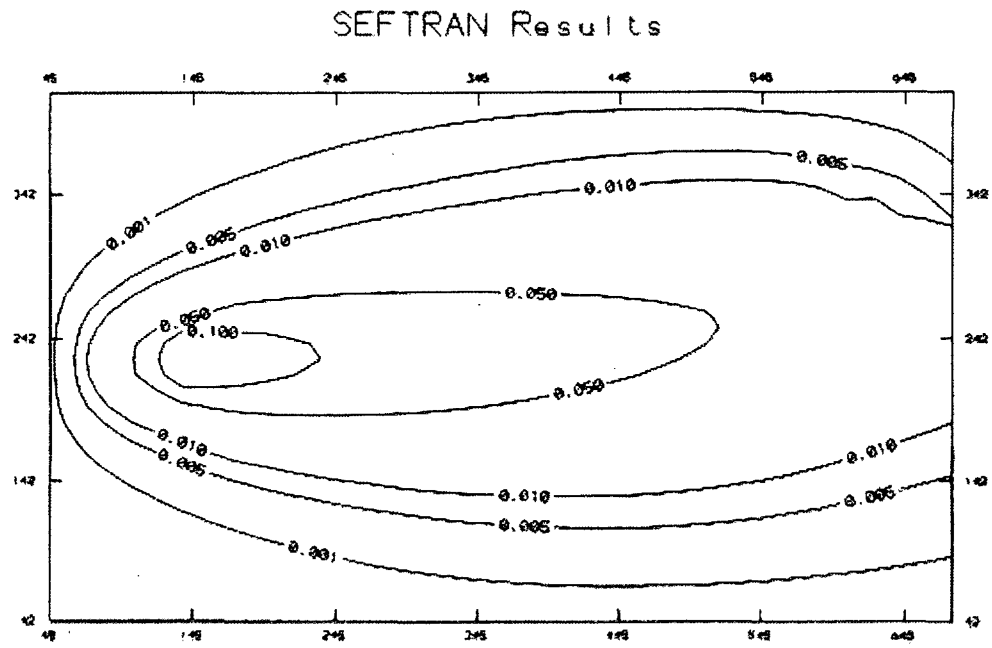
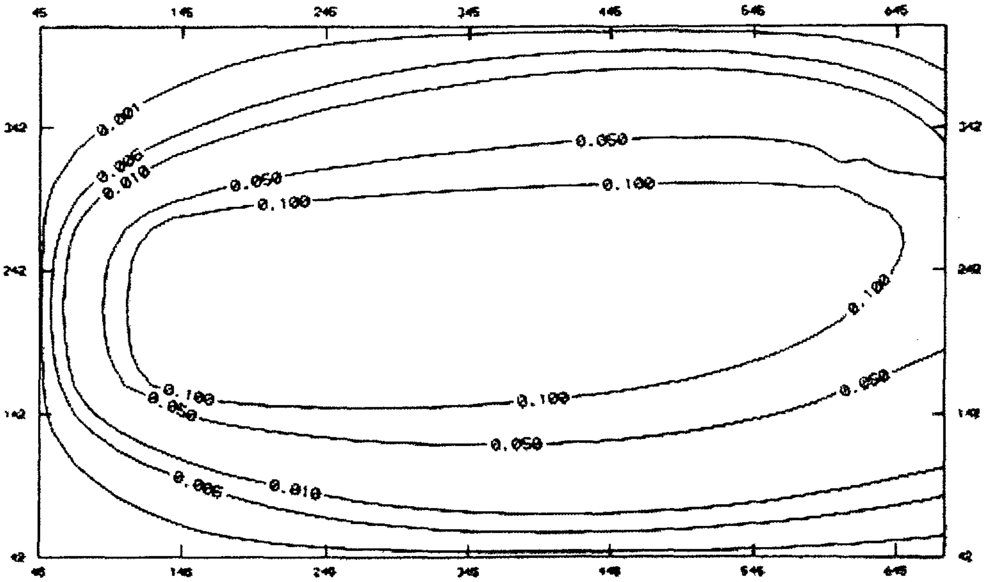
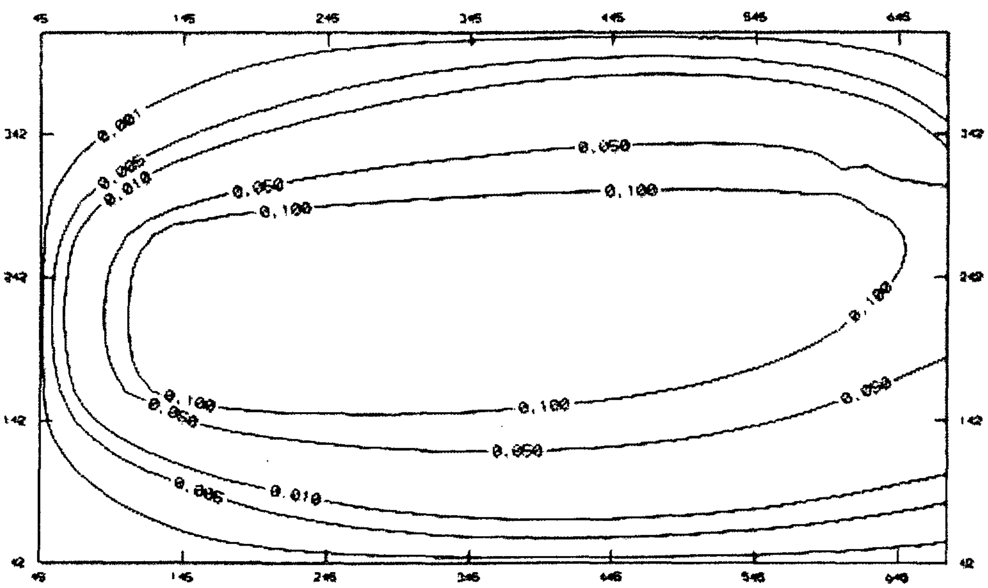


Figure 8. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 6.

WinTran Results



SEFTRAN Results



WinFlow Assumptions

It is important to understand the many simplifying assumptions inherent in an analytical model before the model can be applied to a real-world problem. Chapter 5 described the equations that are solved in WinFlow. Chapter 6 verified that these equations are properly implemented in the WinFlow software. This chapter presents potential applications of WinFlow to the solution of ground-water problems. First, however, some important assumptions are discussed as they apply to the practical application of WinFlow. For easy identification, the primary assumptions are underlined.

WinFlow is designed to solve two-dimensional ground-water flow problems in a horizontal plane. It is not designed for two-dimensional cross-sections (2D vertical plane). <u>The two primary assumptions are that ground-water flow is horizontal and occurs in an infinite aquifer</u>. WinFlow should not be applied to aquifers exhibiting strong vertical gradients unless the scale of the problem is such that horizontal flow can still be considered dominant. WinFlow can be used even in cases where there are significant vertical gradients if the horizontal scale of the model is much larger than the vertical scale, such as in regional studies.

Another assumption is that the <u>aquifer hydraulic conductivity is assumed to be isotropic and homogeneous.</u> The base of the aquifer is horizontal and fixed at a given elevation. In the steady-state and transient models, the top of the aquifer is also horizontal and fixed at a given elevation. In the steady-state model, however, unconfined conditions are simulated when the hydraulic head is below the top of the aquifer. In the transient model, the aquifer is always confined, even when the head falls below the top of the aquifer.

<u>The reference head in the steady-state model is constant throughout all calculations</u>. The reference head is analogous to a constant head boundary condition in a numerical model. It is therefore very important to keep the reference head far from the area of interest so that model predictions are not impacted.

The reference head in the transient model is only used in combination with the uniform gradient to compute an initial planar potentiometric surface. Drawdowns computed by either the Theis (1935) or the Hantush and Jacob (1955) methods are then subtracted from the planar potentiometric surface to obtain the resulting flow field. Drawdowns are also subtracted from the reference head in the transient model; however, there is an option that allows the user to keep the reference head constant in the transient model. This option should only be used when trying to compare the transient model to the steady-state model.

<u>All pumping rates, linesink fluxes, pond recharge, and elliptical recharge rates are constant through time</u>. In the transient model, all wells start pumping or injecting water at time zero.

<u>All wells are assumed to fully penetrate the aquifer</u>. <u>Wells are assumed to be perfectly efficient and linesinks are in perfect hydraulic communication with the aquifer</u>. Both assumptions are rarely encountered in practice. There is often head loss around the well screen or stream bottom caused by clogging of the pore-space by fine-grained material (clay). There are two important consequences of imperfect hydraulic communication.

(1) Pumping rates predicted by WinFlow to achieve a desired response may not be attainable because more drawdown will be encountered in the actual well. The increased drawdown encountered in the field is caused by inefficiency around the well screen. The same effect will happen using linesinks to simulate trenches or drains.

(2) The amount of water produced or injected by a linesink to maintain a specified head in the linesink will be overestimated if the actual drain has less than 100 percent efficiency.

<u>Particle traces and streamlines are two-dimensional</u>. In cases where the aquifer receives recharge, the capture zone of a pumping well will be large enough to capture the amount of recharge equaling the pumping rate of the well (Larson et al., 1987). In two-dimensional analyses, such as in WinFlow, the capture zone extends upgradient until encountering a ground-water divide or infinity. This is an important consideration in designing a containment system.

Analysis of Remedial Actions

WinFlow can provide valuable guidance in designing a ground-water remediation system. The most obvious remedial action that WinFlow can simulate is "pump & treat" where the goal is to contain a volume of contaminated aquifer. WinFlow can simulate the effects of both pumping and injection wells. To illustrate the capture zone of a well, use reverse particle-tracking and start the particles in a circle around the well.

WinFlow can simulate trenches and drains using linesinks. There are two options in simulating drains: (1) specify a head to be maintained in the drain and WinFlow will compute the discharge rate necessary to achieve the given head; or (2) specify the discharge rate and compute the resulting head in the drain. To illustrate the capture zone of the drain, use reverse particle-tracking and start the particles along two lines on either side of the linesink.

WinFlow can simulate a lagoon closure by using ponds. To do this, set up the initial analytical model with ponds that simulate the lagoon. Adjust the pond recharge rate to match field-measured heads. Finally, remove the pond (or set the pond recharge equal to zero) to simulate the effects of closure.

The effects of capping can be simulated with a combination of elliptical recharge and circular ponds. Set up the initial analytical model using recharge to match field-measured heads. A circular cap can then be simulated with a pond that has a recharge rate equivalent to the regional recharge rate but opposite in sign (e.g. negative).

Pumping Test Analysis and Design

WinFlow's transient model can simulate the effects of a pumping test to facilitate interpreting test results or designing a future test. Pumping test results can be interpreted by contouring drawdown at a specified time after the start of the test. To contour drawdown, set the reference head equal to zero and the gradient equal to zero. Make sure that the top of the aquifer is less than zero if the steady-state model is used.

Drawdowns computed by WinFlow can be compared to drawdown contours from the pumping test. Hydraulic conductivity and storage can be adjusted until a reasonable match between observed and computed drawdown is achieved. Image wells can be added to the model to simulate boundary effects. Use calibration targets to provide a quantitative match between the results of your aquifer test and the model calculations.

When designing an aquifer test, WinFlow estimates the drawdown likely to occur at selected times and at various distances from the pumping well. Time and drawdown estimates can help select appropriate wells to monitor and determine the length of the test.

Regional Modeling

Strack (1989) advocates the use of "analytic element models" (his term for the superposition of analytical functions) in regional flow system modeling. At a regional scale, most aquifers are very thin compared to the distance across the aquifer in the horizontal plane. Thus, the z-axis (vertical dimension) becomes quite small and vertical gradients are negligible compared to horizontal gradients. In this case, the problem becomes two-dimensional and can be easily simulated with analytical functions.

The regional model is constructed using linesinks to simulate rivers and streams. Recharge from precipitation is applied in a large ellipse covering the area of interest. Circular recharge areas (ponds) simulate lakes. Obviously, wells represent areas of ground-water extraction, such as wellfields.

Strack (1989) has developed many complex analytical functions or analytic elements to facilitate regional modeling. The Single-Layer Analytic Element Model (SLAEM) developed by Strack contains these advanced functions not available in WinFlow. SLAEM is available from Dr. Strack.

Introduction

This chapter presents the major assumptions inherent in WinTran and guidelines for the use of the transport model. These guidelines include estimating memory requirements, dealing with model instabilities, and suggestions for simulating various transport scenarios.

WinTran Assumptions

It is important to understand the many simplifying assumptions inherent in any model before the model can be applied to a real-world problem. This chapter presents potential applications of WinTran to the solution of contaminant fate and transport problems. First, however, some important assumptions are discussed as they apply to practical application of WinTran. For easy identification, the primary assumptions are underlined.

WinTran is designed to solve two-dimensional ground-water flow and transport problems in a horizontal plane. It is not designed for two-dimensional cross-sections (2D vertical plane). The two primary assumptions are that ground-water flow is horizontal and contaminant concentrations are the same throughout the entire aquifer thickness. WinTran should not be applied to aquifers exhibiting strong vertical gradients unless the scale of the problem is such that horizontal flow can still be considered dominant. WinTran can be used even in cases where there are significant vertical gradients if the horizontal scale of the model is much larger than the vertical scale, such as in regional studies.

Another assumption is that the aquifer hydraulic conductivity is assumed to be isotropic and homogeneous. The base of the aquifer is horizontal and fixed at a given elevation. The top of the aquifer is also horizontal and fixed at a given elevation. Unconfined conditions are simulated when the hydraulic head is below the top of the aquifer.

The reference head in the flow model is constant throughout all calculations. The reference head is analogous to a constant head boundary condition in a numerical model. It is therefore very important to keep the reference head far from the area of interest so that model predictions are not impacted.

All pumping rates, linesink fluxes, pond recharge, and elliptical recharge rates are constant through time. The transport model simulates transient movement of the contaminant in this steady-state velocity field.

All wells are assumed to fully penetrate the aquifer. Wells are assumed to be perfectly efficient and linesinks are in perfect hydraulic communication with the aquifer. Both assumptions are rarely encountered in practice. There is often head loss around the well screen or stream bottom caused by clogging of the pore-space by fine-grained material (clay). There are two important consequences of imperfect hydraulic communication.

(1) Pumping rates predicted by WinTran to achieve a desired response may not be attainable because more drawdown will be encountered in the actual well. The increased drawdown encountered in the field is caused by inefficiency around the well screen. The same effect will happen using linesinks to simulate trenches or drains.

(2) The amount of water produced or injected by a linesink to maintain a specified head in the linesink will be overestimated if the actual drain has less than 100 percent efficiency.

Particle traces and streamlines are two-dimensional. In cases where the aquifer receives recharge, the capture zone of a pumping well will be large enough to capture the amount of recharge equaling the pumping rate of the well (Larson et al. 1987). In two-dimensional analyses, such as in WinTran, the capture zone extends upgradient until encountering a ground-water divide or infinity. This is an important consideration in designing a containment system.

Chemical reactions are reduced to two types, (1) linear, fully-reversible sorption using a retardation coefficient, and (2) first-order decay. WinTran can be used to simulate biological decay of organic compounds only if the biological reactions can be reduced to a first-order decay reaction. That is, a contaminant half-life is estimated for the compound.

Memory Requirements

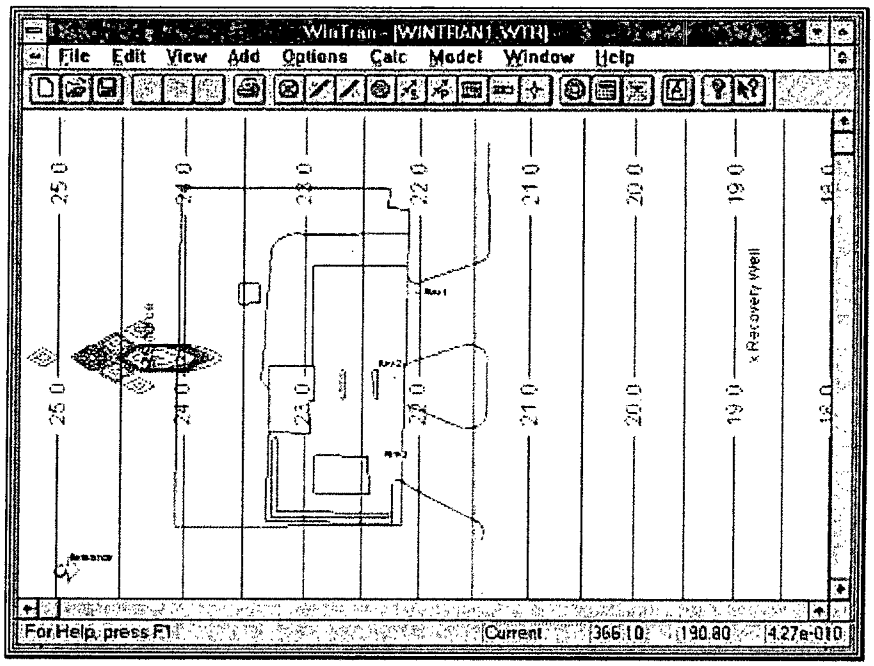
WinTran uses a substantial amount of computer memory to solve the finite-element transport model. The amount of memory required for each model is determined by the size of the contour matrix. The default size of the contour matrix is 35 x 35 (35 nodes in both the X- and Y-directions). In this case, the model requires about 1 megabyte of memory. The maximum matrix size allowed in WinTran is 100 x 100, requiring about 18 megabytes of memory. Other matrix sizes and memory requirements are shown below:

Matrix Size	Memory Required
35 x 35	1 megabyte
50 x 50	2.6 megabytes
75 x 75	8 megabytes
100 x 100	18 megabytes

Problems with Model Stability

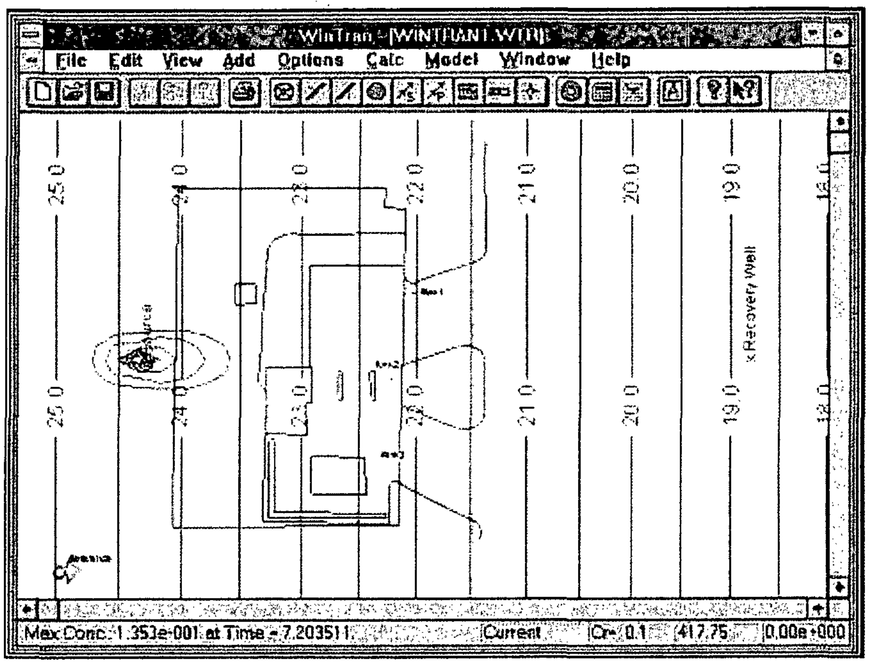
Numerical transport models require the user to carefully evaluate each simulation for potential errors. WinTran assists you in evaluating model error by displaying the mass balance error on the status bar when the transport model is running. The mass balance error is expressed as a percentage and should be less than 10 percent for a valid simulation. Usually, the mass balance error is less than 1 percent.

Even if the mass balance error is below 10 percent, there can be oscillations in the transport solution. Oscillations are indicated by negative concentrations computed by WinTran. In extreme cases, alternating nodes will have positive and negative concentrations producing diamond-shaped contours. The following screen shows a contour pattern that is typical of numerical oscillations:



Note the diamond shaped contours upgradient of the source. These contours are produced because alternating nodes are positive and negative. The contouring routine draws "bulls-eyes" around these high and low points producing the diamond-shaped contours. This is very typical of oscillating solutions and is probably the most common problem you will run into with WinTran.

The pattern above was produced in the tutorial model by lowering the time-step size to 0.1 days, using centered-in-time, and reducing the longitudinal dispersivity to 3 ft. This produces a Peclet number of 6.2, which is above the recommended limit of 2. In the screen shown below, the dispersivity value was increased to 30 ft, dropping the Peclet number to 0.62. This was enough to remove the oscillations.



When the transport solution oscillates, check the following:

(1) The Peclet number is displayed on the status bar as "Pe=" and is computed by dividing the nodal spacing (the distance between nodes in the contour matrix) by the longitudinal dispersivity. The Peclet number should generally be less than 2 for a stable solution. If you are experiencing mass balance problems or oscillations, increase dispersivity until the Peclet number is less than 2, as described above.

(2) The Courant number is another criterion used to judge the stability of a transport simulation. The Courant number is computed as the velocity times time-step size divided by nodal spacing. This criterion is displayed as "Cr=" on the status bar and should generally be less than 1. Again, if you are experiencing mass balance or oscillation problems, try decreasing the initial and maximum time-step sizes.

There are also times when the Courant number is too low. In cases where the Courant number is less than 0.1, there can be round-off errors in the matrix solver. In this case, you should increase the initial and maximum time-step sizes until the Courant number is close to 1.

There are two other WinTran options that can aid in model stability. These include the time discretization method (backward and centered in time) and upstream weighting. The time discretization methods are selected using the **Edit->Time Stepping** menu. Backward in time is unconditionally stable but is only first-order accurate, while centered in time is second-order accurate but may be subject to instability (Javandel et al., 1984). It is usually best to start with backward in time.

Upstream weighting factors in the X- and Y-directions are edited from the **Edit->Transport Parameters** menu. Upstream weighting factors of 1.0 indicate full upstream weighting, while a weighting factor of 0.0 turns off upstream weighting. Upstream weighting adds stability to the solution (helps eliminate oscillations) at the expense of added numerical dispersion. Numerical dispersion is artificial dispersion that produces similar results to an increase in the dispersivity coefficient.

Setting Up the Flow Model

WinTran can provide valuable guidance in designing a ground-water remediation system. The most obvious remedial action that WinTran can simulate is "pump & treat" where the goal is to contain a volume of contaminated aquifer. WinTran can simulate the effects of both pumping and injection wells.

WinTran can simulate trenches and drains using linesinks. There are two options in simulating drains: (1) specify a head to be maintained in the drain and WinTran will compute the discharge rate necessary to achieve the given head; or (2) specify the discharge rate and compute the resulting head in the drain. To illustrate the capture zone of the drain, use reverse particle-tracking and start the particles along two lines on either side of the linesink.

WinTran can simulate a lagoon closure by using ponds. To do this, set up the initial analytical model with ponds that simulate the lagoon. Adjust the pond recharge rate to match field-measured heads. Finally, remove the pond (or set the pond recharge equal to zero) to simulate the effects of closure.

The effects of capping can be simulated with a combination of elliptical recharge and circular ponds. Set up the initial analytical model using recharge to match field-measured heads. A circular cap can then be simulated with a pond that has a recharge rate equivalent to the regional recharge rate but opposite in sign (e.g. negative).

Setting Up the Transport Model

Remedial alternatives are usually simulated in several stages, as described below:

(1) Calibrate the transport model to the observed contaminant plume. This is accomplished by adding source terms to the model (injection wells, infiltrating ponds, or injecting linesinks) and adjusting the source concentration until the desired plume is simulated. The length of the simulation should be chosen to approximate the length of time that the source of contamination has been effecting the groundwater system.

An alternative approach to calibrating the plume configuration is to import a SURFER grid file (e.g. test.grd) containing the contaminant distribution data (use **File->Import** from the main menu). The contoured concentrations are then used as initial conditions for the remedial simulation.

(2) Save the calibrated concentrations as initial conditions using the **Calc->Restart** option on the main menu. Skip this step if you have imported a SURFER grid file for initial conditions.

(3) Add the remediation system (pumping wells or linesinks, etc.) and rerun the transport model. To simulate source removal, delete the source terms added in State 1 above. This is accomplished by moving the cursor over the source element (well, pond, or linesink) until the four-arrow cursor ( ) is displayed. Click the left mouse button to select the element and then press the delete key or select **Edit->Delete** from the main menu. Now, rerun the transport model to simulate source removal.

At any time during the simulations, you may save concentrations for later restart using the **File->Export** menu. Exporting concentration as a restart file (*.rst) will allow you to **Import** these concentrations in later simulations.

Simulating Biodegradation

Simulating the biodegradation of organic compounds is a popular modeling scenario, especially for dissolved hydrocarbons. WinTran does not simulate these complex degradation processes; however, the decay term in WinTran can be used to approximate biodecay. The biodegradation process is reduced to specifying a half-life for the compound. The half-life is the time required to remove half of the original mass. While the half-life is most often used for radioactive elements, such as uranium, it can also be used to express the decay of organic compounds through biodecay. The *Handbook of Environmental Degradation Rates* (Howard et al., 1991) is a good reference for contaminant half-life data.

Performing Risk Assessments

WinTran is not a risk assessment model but can be useful in risk assessments by providing concentration data over time at receptor locations. To obtain the concentration over time at these receptor locations, you must add a well at the receptor. Specify the flow rate as zero (0.0) and check the "Observation well" option on the well dialog. These concentration-time data may then be saved to a file for use in other programs. To save these data, select **File->Export** and choose the file time **Conc-Time** (*.cvt). The file is a DOS text file delimited by commas. The first line contains the well names and subsequent lines list the time and concentration for each well.

Digitized Map File Format

Digitized base maps increase the efficiency of site-specific modeling by placing the modeling results in context with the area to be modeled. As shown in the tutorial, WinFlow overlays the base map on head contours and streamlines, making it easier to interpret the results.

WinFlow uses a very simple file format for the digitized base map, as shown in Table 9. The file is made up of two sections. The first defines a series of line segments, while the second set of data defines a series of text strings. Each line segment requires the following data (1) the beginning and ending **X** and **Y** coordinates, (2) the line style, e.g., dashed or solid, and (3) the line color. The data for each line segment should appear on one line and be separated by at least one space between each data item. Commas may not be used to separate data items.

The following data items are required for each text item (1) **X** and **Y** coordinates of the lower left corner of the text, (2) angle of rotation of the text string, (3) height of the text, (4) color, and (5) a text string. The first four data items are entered on one line separated by at least one space between each data item. The text string is located on the following line and the height of the text string is in map coordinates (not in inches!).

Line and text colors are defined as integer numbers from 0 through 15. Each integer defines a unique color. The possible colors are shown in Table 10. These colors are all displayed on VGA color displays.

The digitized map file is a simple ASCII file that may be created in any text editor. You may also find it advantageous to write a simple program to convert files from your digitizing software to the WinFlow format. WinFlow also has the ability to convert DXF files directly. Simply choose **File** from the main menu and **Map** from the pull-down menu. Next select **DXF** from the menu. Specify the DXF file name and a conversion factor, which is explained below. The DXF file format is a relatively standard file format for CAD packages, such as AutoCad.

Table 9 File Format for WinFlow Digitized Maps.
Line 1 NLS, NTEXT
NLS = Number of line segments in map
NTEXT = Number of Text Strings in map
Lines 2 to NLS+1 (Enter one line for each line segment)
X1, Y1, X2, Y2, NDASH, NCOLOR
X1, Y1 = Beginning line coordinates
X2, Y2 = Ending line coordinates
NDASH = Positive integer for solid line, negative for dashed
NCOLOR = Color index (integer)
Lines NLS+2 to end (Enter one set per text item)
X1, Y1, ANGLE, HEIGHT, NCOLOR
TEXT
X1, Y1 = Coordinates of left side of text string
ANGLE = Angle of text string
HEIGHT = Height of text string
NCOLOR = Color index of text string
TEXT = Text string

Table 10 Definition of color indices.

Index	Color
0	BLACK
1	BLUE
2	GREEN
3	CYAN
4	RED
5	MAGENTA
6	BROWN
7	WHITE
8	GRAY
9	LIGHT BLUE
10	LIGHT GREEN
11	LIGHT CYAN
12	LIGHT RED
13	LIGHT MAGENTA
14	YELLOW
15	BRIGHT WHITE

DXF Translator

The DXF (Drawing Interchange Format) file is a fairly standard format for exchanging data between CAD systems. In particular, the popular AutoCAD software uses DXF files extensively. A translator is provided with WinFlow to extract digitized information from DXF files and convert it to the WinFlow digitized map format.

The DXF file contains detailed data describing numerous CAD entities. An entity is a line or symbol placed on the drawing by the CAD system. The WinFlow DXF translator supports the following CAD entities:

LINES

POLYLINES

POINTS

ARCS

CIRCLES

TEXT

Certain aspects about these entities are ignored by the translator, such as elevation (for 3D CAD software such as AutoCAD Release 10), line style, and line thickness. In addition, the curve-fit and spline options applied to POLYLINES are ignored. The coordinates and color of the entity are preserved, however.

Many CAD drawings contain entities called BLOCKS, which are a collection of other entities (e.g., lines, circles, text, etc.). WinFlow will not interpret BLOCKS properly, so make sure that these are converted to other entities before creating the DXF file in your CAD package. In AutoCAD terminology, this is called "exploding" the blocks.

The DXF translator is activated from the File menu, as described above. Next, specify the DXF file name and a Map file name using standard Windows file dialogs. You only have to answer one additional prompt after starting the DXF translator - a conversion factor for the translation. Normally, a conversion factor of 1.0 will work; however, sometimes your CAD software will store coordinates in the DXF file in units of inches. If this happens, use a conversion factor of 0.0833333 (1.0/12.0). Each coordinate in the DXF file is multiplied by the conversion factor before being written to the WinFlow map file.

After all entities are processed in the DXF file, the digitized map file is created. A message to that effect is displayed at the bottom of the screen. After the translation is finished, the map file is imported into the model and displayed on your screen.

ASTM Standards

D 4104 Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to instantaneous Change in Head (Slug Tests), ASTM, 4 p.

D 4105 Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method, ASTM, 5 p.

D 4106 Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method, ASTM, 5 p.

D5920-96. Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method, ASTM, 8 p.

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APPENDIX C

Aquifer Test Procedures and Output

Description of Aquifer Test

Hydraulic conductivity is one of the most critical parameters used for any fate and transport modeling effort, and the various published values researched range widely over two orders of magnitude, from less than 2 ft/day to 200 ft/day. Therefore, an aquifer test at two nearby industrial water supply wells (WW-1 and WW-5) was performed on November 22, 2006, to determine site-specific hydraulic conductivity. There were several advantages in using these wells as follows:

- Each well is fully penetrating (screened across entire thickness of the aquifer)
- The wells had been reportedly running continuously for over 16-20 hours prior to recording the recovery drawdown data.
- The wells are located nearby the Jct. J-26 site thus available for site-specific testing.
- The wells were constructed efficiently as they are designed to provide maximum yields for supply to the Eunice Gas Plant.
- The wells play a useful role in abatement of chlorides and TDS in the area.

The wells had been running continuously for about 16-20 hrs according to the Eunice Gas Plant personnel who graciously allowed access to their wells for aquifer testing. Immediately prior to turning off the pump in each well, depth to groundwater was measured using an electronic water level indicator. A 10 psi pressure transducer and Hermit 2000 Data logger were then used to capture and record the recovery drawdown data. This instrumentation made it possible to obtain many data points early on in the test (first few minutes) which was essential for subsequent analysis and interpretation of the results. Data was recorded immediately after the water well pump was turned off to provide recovery drawdown data. Collection of data was terminated after the water table equilibrated to near static conditions; consequently the tests were of relatively short duration (less than 1 hour).

Hydraulic conductivity values were determined using a Cooper-Jacob analysis of the recovery data, and a program from USGS Open-File 02-197 (Keith Halford, 2002, documentation attached in Appendix C). The USGS program uses Thiem's equation and the Cooper-Jacob plotting methods for determining hydraulic conductivity. Results of the aquifer test analysis are shown on the following graphs and tables attached herein. The slope near the earlier time drawdown data (within the first few minutes of the test) provided the best estimation. Note that the time axis is plotted as t/t' so time increases from right to left. This is the preferred method to analyze recovery data from a pumping well.

Hydraulic conductivity values of 3.4 ft/day and 4.4 ft/day were calculated from water supply wells WW-1 and WW-5, respectively. Results from water supply well WW-1 probably provided better data because that well was pumping at a rate that stressed the aquifer, that is, the pumping water level was over 9 feet below the static level, whereas with WW-5 the pumping level was less than 2 feet from static. Either way the results from both tests are consistent with each other. The higher hydraulic conductivity value of 4.4 ft/day was used in the fate and transport modeling because it provided a more conservative value.

WELL ID: WW-1

Local ID: T21S-R37E-Section 26-J
Date: 11/22/06
Time: 2:00 PM

INPUT

Construction:		
Casing dia. (d_c)	8	Inch
Annulus dia. (d_w)	8	Inch
Screen Length (L)	40	Feet
Depths to:		
water level (DTW)	45	Feet
Top of Aquifer	45	Feet
Base of Aquifer	85	Feet
Annular Fill:		
across screen -- Gravel		
above screen -- Cement		
Aquifer Material -- Fine Sand		
FLOW RATE	53	GPM

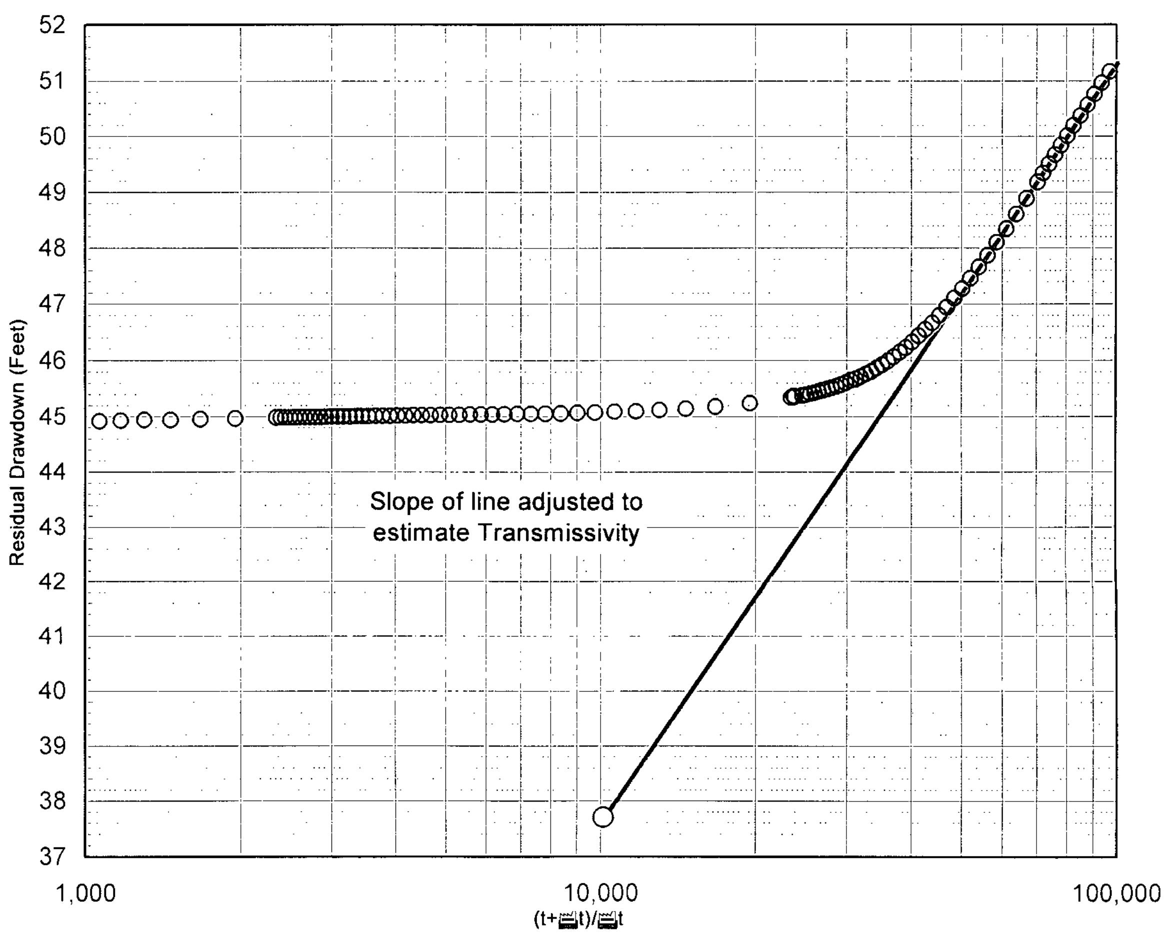
COMPUTED

Aquifer thickness = 40 Feet

Slope = 13.708543 Feet/log10

Input is consistent.

K =	3.4	Feet/Day
T =	140	Feet²/Day



REMARKS: Cooper-Jacob recovery analysis of single-well aquifer test

This recovery test was done on a water supply well (WW-1) that had been running continuously at ~53 gpm for 16-20 hours. A Hermit 2000 data logger was used to record the water level data for the length of the test (~50 minutes).

Depth to water before shutting off pump 54.09 ft (t = 0 min).

Depth to water at end of recovery test 44.84 ft (t = 50 min).

Raw input recovery data for water supply well WW-1

Entry	Reduced Data Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet
1	1/0/00 0:00:00	0.00	51	11/22/06 14:00:44	45.71	101	11/22/06 14:07:48	45.00
2	11/22/06 14:00:00	54.09	52	11/22/06 14:00:45	45.67	102	11/22/06 14:08:00	45.00
3	11/22/06 14:00:08	54.09	53	11/22/06 14:00:46	45.65	103	11/22/06 14:08:12	44.99
4	11/22/06 14:00:08	53.99	54	11/22/06 14:00:47	45.61	104	11/22/06 14:08:24	44.99
5	11/22/06 14:00:09	53.74	55	11/22/06 14:00:48	45.57	105	11/22/06 14:08:36	44.99
6	11/22/06 14:00:09	53.47	56	11/22/06 14:00:49	45.55	106	11/22/06 14:08:48	44.99
7	11/22/06 14:00:10	53.22	57	11/22/06 14:00:50	45.52	107	11/22/06 14:09:00	44.99
8	11/22/06 14:00:11	52.96	58	11/22/06 14:00:51	45.50	108	11/22/06 14:09:12	44.99
9	11/22/06 14:00:11	52.72	59	11/22/06 14:00:52	45.47	109	11/22/06 14:09:24	44.99
10	11/22/06 14:00:11	52.48	60	11/22/06 14:00:53	45.45	110	11/22/06 14:09:36	44.99
11	11/22/06 14:00:12	52.25	61	11/22/06 14:00:54	45.43	111	11/22/06 14:09:48	44.99
12	11/22/06 14:00:12	52.02	62	11/22/06 14:00:55	45.42	112	11/22/06 14:10:00	44.98
13	11/22/06 14:00:13	51.80	63	11/22/06 14:00:56	45.40	113	11/22/06 14:12:00	44.96
14	11/22/06 14:00:14	51.59	64	11/22/06 14:00:57	45.38	114	11/22/06 14:14:00	44.96
15	11/22/06 14:00:14	51.37	65	11/22/06 14:00:59	45.36	115	11/22/06 14:16:00	44.94
16	11/22/06 14:00:14	51.16	66	11/22/06 14:00:59	45.37	116	11/22/06 14:18:00	44.94
17	11/22/06 14:00:15	50.96	67	11/22/06 14:01:00	45.34	117	11/22/06 14:20:00	44.93
18	11/22/06 14:00:15	50.76	68	11/22/06 14:01:12	45.24	118	11/22/06 14:22:00	44.92
19	11/22/06 14:00:16	50.56	69	11/22/06 14:01:24	45.18	119	11/22/06 14:24:00	44.91
20	11/22/06 14:00:17	50.37	70	11/22/06 14:01:36	45.14	120	11/22/06 14:26:00	44.90
21	11/22/06 14:00:17	50.19	71	11/22/06 14:01:48	45.12	121	11/22/06 14:28:00	44.89
22	11/22/06 14:00:17	50.01	72	11/22/06 14:02:00	45.10	122	11/22/06 14:30:00	44.89
23	11/22/06 14:00:18	49.84	73	11/22/06 14:02:12	45.09	123	11/22/06 14:34:00	44.88
24	11/22/06 14:00:18	49.67	74	11/22/06 14:02:24	45.08	124	11/22/06 14:36:00	44.87
25	11/22/06 14:00:19	49.50	75	11/22/06 14:02:36	45.07	125	11/22/06 14:38:00	44.86
26	11/22/06 14:00:20	49.34	76	11/22/06 14:02:48	45.06	126	11/22/06 14:40:00	44.86
27	11/22/06 14:00:20	49.18	77	11/22/06 14:03:00	45.05	127	11/22/06 14:42:00	44.86
28	11/22/06 14:00:21	48.89	78	11/22/06 14:03:12	45.05	128	11/22/06 14:44:00	44.85
29	11/22/06 14:00:22	48.61	79	11/22/06 14:03:24	45.05	129	11/22/06 14:46:00	44.84
30	11/22/06 14:00:23	48.34	80	11/22/06 14:03:36	45.04	130	11/22/06 14:48:00	44.84
31	11/22/06 14:00:24	48.10	81	11/22/06 14:03:48	45.04	131	11/22/06 14:50:00	44.84
32	11/22/06 14:00:25	47.87	82	11/22/06 14:04:00	45.04			
33	11/22/06 14:00:26	47.66	83	11/22/06 14:04:12	45.04			
34	11/22/06 14:00:27	47.46	84	11/22/06 14:04:24	45.03			
35	11/22/06 14:00:28	47.27	85	11/22/06 14:04:36	45.03			
36	11/22/06 14:00:29	47.10	86	11/22/06 14:04:48	45.03			
37	11/22/06 14:00:30	46.94	87	11/22/06 14:05:00	45.03			
38	11/22/06 14:00:31	46.80	88	11/22/06 14:05:12	45.02			
39	11/22/06 14:00:32	46.66	89	11/22/06 14:05:24	45.02			
40	11/22/06 14:00:33	46.55	90	11/22/06 14:05:36	45.02			
41	11/22/06 14:00:34	46.43	91	11/22/06 14:05:48	45.02			
42	11/22/06 14:00:35	46.32	92	11/22/06 14:06:00	45.02			
43	11/22/06 14:00:36	46.23	93	11/22/06 14:06:12	45.02			
44	11/22/06 14:00:37	46.14	94	11/22/06 14:06:24	45.01			
45	11/22/06 14:00:38	46.06	95	11/22/06 14:06:36	45.01			
46	11/22/06 14:00:39	45.99	96	11/22/06 14:06:48	45.01			
47	11/22/06 14:00:40	45.92	97	11/22/06 14:07:00	45.01			
48	11/22/06 14:00:41	45.86	98	11/22/06 14:07:12	45.00			
49	11/22/06 14:00:42	45.81	99	11/22/06 14:07:24	45.00			
50	11/22/06 14:00:43	45.76	100	11/22/06 14:07:36	45.00			

WELL ID: WW-5

Local ID: T21S-R37E-Section 26-J
Date: 11/22/06
Time: 11:00 AM

INPUT

Construction:	
Casing dia. (d_c)	8 Inch
Annulus dia. (d_w)	8 Inch
Screen Length (L)	34 Feet
Depths to:	
water level (DTW)	46 Feet
Top of Aquifer	46 Feet
Base of Aquifer	80 Feet
Annular Fill:	
across screen -- Gravel	
above screen -- Cement	
Aquifer Material -- Fine Sand	
FLOW RATE	20 GPM

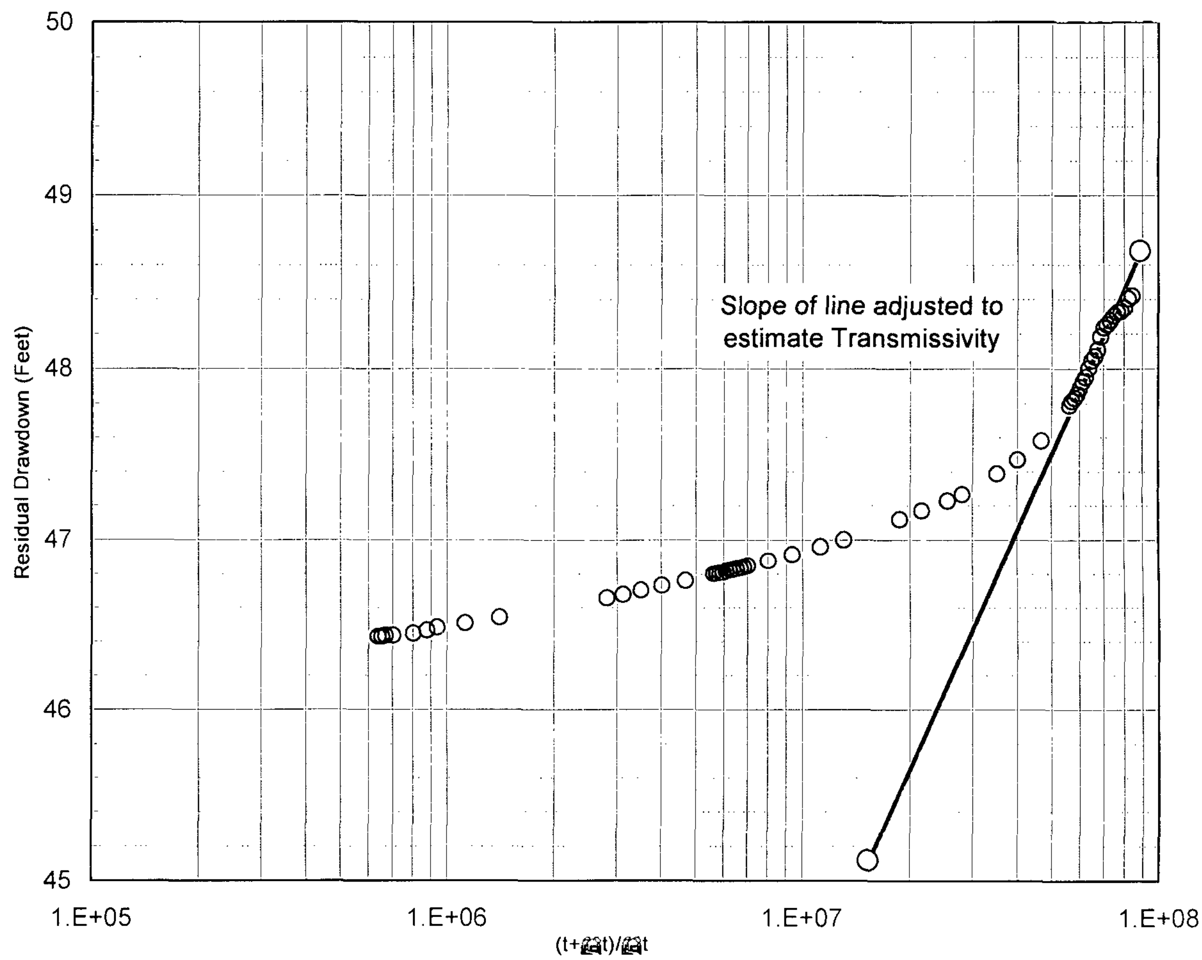
COMPUTED

Aquifer thickness = 34 Feet

Slope = 4.6657929 Feet/log10

Input is consistent.

K = 4.4 Feet/Day
T = 150 Feet²/Day



REMARKS: Cooper-Jacob recovery analysis of single-well aquifer test

This recovery test was done on a water supply well (WW-1) that had been running continuously at ~53 gpm for 16-20 hours. A Hermit 2000 data logger was used to record the water level data for the length of the test (~50 minutes).

Depth to water before shutting off pump 54.09 ft (t = 0 min).

Depth to water at end of recovery test 44.84 ft (t = 50 min).

Raw input recovery data for water supply well WW-5

Entry	Reduced Data Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet
1	11/22/06 11:00:00	0.00	31	11/22/06 11:05:00	47.00
2	11/22/06 11:00:40	48.42	32	11/22/06 11:06:00	46.96
3	11/22/06 11:00:41	48.42	33	11/22/06 11:07:00	46.92
4	11/22/06 11:00:42	48.40	34	11/22/06 11:08:00	46.88
5	11/22/06 11:00:43	48.35	35	11/22/06 11:08:12	46.85
6	11/22/06 11:00:44	48.33	36	11/22/06 11:08:24	46.84
7	11/22/06 11:00:45	48.32	37	11/22/06 11:08:36	46.84
8	11/22/06 11:00:46	48.31	38	11/22/06 11:08:48	46.83
9	11/22/06 11:00:47	48.28	39	11/22/06 11:09:00	46.83
10	11/22/06 11:00:48	48.25	40	11/22/06 11:09:12	46.82
11	11/22/06 11:00:49	48.24	41	11/22/06 11:09:24	46.82
12	11/22/06 11:00:50	48.18	42	11/22/06 11:09:36	46.81
13	11/22/06 11:00:51	48.11	43	11/22/06 11:09:48	46.81
14	11/22/06 11:00:52	48.07	44	11/22/06 11:10:00	46.80
15	11/22/06 11:00:53	48.05	45	11/22/06 11:12:00	46.80
16	11/22/06 11:00:54	48.00	46	11/22/06 11:14:00	46.76
17	11/22/06 11:00:55	47.95	47	11/22/06 11:16:00	46.73
18	11/22/06 11:00:56	47.93	48	11/22/06 11:18:00	46.70
19	11/22/06 11:00:57	47.89	49	11/22/06 11:20:00	46.68
20	11/22/06 11:00:58	47.85	50	11/22/06 11:40:00	46.66
21	11/22/06 11:00:59	47.83	51	11/22/06 11:50:00	46.54
22	11/22/06 11:01:00	47.81	52	11/22/06 12:00:00	46.51
23	11/22/06 11:01:12	47.79	53	11/22/06 12:04:00	46.48
24	11/22/06 11:01:24	47.58	54	11/22/06 12:10:00	46.47
25	11/22/06 11:01:36	47.47	55	11/22/06 12:20:00	46.45
26	11/22/06 11:02:00	47.39	56	11/22/06 12:24:00	46.44
27	11/22/06 11:02:12	47.27	57	11/22/06 12:26:00	46.44
28	11/22/06 11:02:36	47.23	58	11/22/06 12:28:00	46.43
29	11/22/06 11:03:00	47.17			
30	11/22/06 11:04:18	47.12			

APPENDIX D

Summary Laboratory Analytical Reports

And

Chain of Custody Documentation

(Full length lab reports with all QA/QC information are included separately on compact disk in Adobe Reader format)

Summary Report

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

Report Date: August 14, 2006

Work Order: 6080433

Project Location: Lea County,NM
Project Name: BD Junction J-26

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
98085	Monitor Well #1	water	2006-08-01	09:45	2006-08-04
98086	Monitor Well #2	water	2006-08-01	10:25	2006-08-04
98087	Monitor Well #3	water	2006-08-01	08:35	2006-08-04

Sample: 98085 - Monitor Well #1

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**226**	mg/L as CaCo3	4.00
Total Alkalinity		**226**	mg/L as CaCo3	4.00
Dissolved Calcium		**86.2**	mg/L	0.500
Dissolved Potassium		**41.6**	mg/L	1.00
Dissolved Magnesium		**23.9**	mg/L	1.00
Dissolved Sodium		**225**	mg/L	1.00
Chloride		**218**	mg/L	0.500
Sulfate		**248**	mg/L	0.500
Total Dissolved Solids		**1126**	mg/L	10.00

Sample: 98086 - Monitor Well #2

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**216**	mg/L as CaCo3	4.00
Total Alkalinity		**216**	mg/L as CaCo3	4.00
Dissolved Calcium		**144**	mg/L	0.500
Dissolved Potassium		**18.3**	mg/L	1.00
Dissolved Magnesium		**42.4**	mg/L	1.00
Dissolved Sodium		**241**	mg/L	1.00
Chloride		**387**	mg/L	0.500
Sulfate		**247**	mg/L	0.500

continued ...

sample 98086 continued ...

Param	Flag	Result	Units	RL
Total Dissolved Solids		**1358**	mg/L	10.00

Sample: 98087 - Monitor Well #3

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**208**	mg/L as CaCo3	4.00
Total Alkalinity		**208**	mg/L as CaCo3	4.00
Dissolved Calcium		**91.8**	mg/L	0.500
Dissolved Potassium		**10.4**	mg/L	1.00
Dissolved Magnesium		**33.0**	mg/L	1.00
Dissolved Sodium		**140**	mg/L	1.00
Chloride		**141**	mg/L	0.500
Sulfate		**190**	mg/L	0.500
Total Dissolved Solids		**876.0**	mg/L	10.00

Page 1 of 1

6701 Aberdeen Ave, Ste 9
Lubbock,Texas 79424
Tel (806) 794-1296
Fax (806) 794-1298
1 (800) 378-1296

TraceAnalysis, Inc.

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

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6080433

Company Name: RICE Operating Company
Phone #: (505)393-9174
Address: (Street, City, Zip) 122 W Taylor Street - Hobbs, New Mexico 88240
Fax #: (505) 397-1471
Contact Person: Kristin Farris - Pope, Project Scientist
kpope@riceswd.com
Invoice to: (If different from above)
Project #: None Given
Project Name: BD Junction J-26
Project Location: Lea County - New Mexico
Sampler Signature: Rozanne Johnson (505)631-9310
rozanne@valornet.com

ANALYSIS REQUEST (Circle or Specify Method No.)

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX: WATER	SOIL	AIR	SLUDGE	PRESERVATIVE METHOD: HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE	NONE	SAMPLING: DATE 2006	TIME	MTBE 8021B/602	BTEX 8021B/602	TPH 418.1/TX1005 / TX1005 Extended (C35)	PAH 8270C	Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	TCLP Metals Ag As Ba Cd Cr Pb Se Hg	TCLP Volatiles	TCLP Semi Volatiles	TCLP Pesticides	RCI	GC/MS Vol. 8260B/624	GC/MS Semi. Vol. 8270C/625	PCB's 8082/608	Pesticides 8081A/608	BOD, TSS, pH	Moisture Content	Cations (Ca, Mg, Na, K)	Anions (Cl, SSSSO4, CO3, HCO3)	Total Dissolved Solids	Turn Around Time if different from standard
98085	Monitor Well #1	2	40 ml	X				X				X		8-1	9:45		X																		
	Monitor Well #1	1	1L	X								X		8-1	9:45																	X	X	X	
86	Monitor Well #2	2	40 ml	X				X				X		8-1	10:25		X																		
	Monitor Well #2	1	1L	X								X		8-1	10:25																	X	X	X	
87	Monitor Well #3	2	40 ml	X				X				X		8-1	8:35		X																		
	Monitor Well #3	1	1L	X								X		8-1	8:35																	X	X	X	

Relinquished by: Rozanne Johnson Date: 8/3/06 Time: 2:35pm
Received by: Date: Time:

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

Relinquished by: Date: Time:
Received at Laboratory by: [signature] Date: 8/4/06 Time: 1030 hrs

LAB USE ONLY
Intact Y / N
Headspace Y / N
Temp 4°
Log-in Review
Carrier # Greyhound GLI 169017 06

REMARKS: Please email results to:
kpope@riceswd.com
mfranks @ riceswd.com
rozanne@valornet.com

☐ check if special reporting limits needed

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

Cation-Anion Balance Sheet

DATE: 8/16/2006

Sample #	Calcium ppm	Magnesium ppm	Sodium ppm	Potassium ppm	Alkalinity ppm	Sulfate ppm	Chloride ppm	Nitrate ppm	Fluoride ppm	TDS ppm	EC µMHOs/cm
98085	86.2	23.9	225	41.6	226	248	217.755			1130	
98086	144	42.4	241	18.3	216	247	387			1360	
98087	91.8	33	140	10.4	208	190	140.922			876	

Sample #	Calcium in meq/L	Magnesium in meq/L	Sodium in meq/L	Potassium in meq/L	Alkalinity in meq/L	Sulfate in meq/L	Chloride in meq/L	Nitrate in meq/L	Fluoride in meq/L	Total Cations in meq/L	Total Anions in meq/L	Percentage Error
98085	4.30	1.97	9.79	1.06	4.52	5.16	6.14			17.12	15.83	7.85
98086	7.19	3.49	10.48	0.47	4.32	5.14	10.92			21.63	20.38	5.93
98087	4.58	2.72	6.09	0.27	4.16	3.96	3.98			13.65	12.09	12.13

	EC/Cation	EC/Anion					
98085			range	0	to	0
98086			range	0	to	0
98087			range	0	to	0

TDS/EC	TDS/Cat	TDS/Anion	
	0.66	0.71	needs to be 0.55-0.77
	0.63	0.67	needs to be 0.55-0.77
	0.64	0.72	needs to be 0.55-0.77

Summary Report

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

Report Date: August 22, 2006

Work Order: 6080425

Project Location: Lea County,NM
Project Name: Windmill 220

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
98071	Windmill 220	water	2006-08-01	09:40	2006-08-04

Sample: 98071 - Windmill 220

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**248**	mg/L as CaCo3	4.00
Total Alkalinity		**248**	mg/L as CaCo3	4.00
Dissolved Calcium		**137**	mg/L	0.500
Dissolved Potassium		**15.3**	mg/L	1.00
Dissolved Magnesium		**47.8**	mg/L	1.00
Dissolved Sodium		**277**	mg/L	1.00
Chloride		**369**	mg/L	0.500
Sulfate		**292**	mg/L	0.500
Total Dissolved Solids		**1490**	mg/L	10.00

Page 1 of 1

6701 Aberdeen Ave, Ste 9
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El Paso,Texas 79932
Tel (915) 585-3443
Fax (915) 585-4944

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6080425

Company Name: RICE Operating Company
Phone #: (505)393-9174
Address: (Street, City, Zip) 122 W Taylor Street - Hobbs, New Mexico 88240
Fax #: (505) 397-1471
Contact Person: Kristin Farris - Pope, Project Scientist
kpope@riceswd.com
Invoice to: (If different from above)
Project #: None Given
Project Name: Windmill ~ 220
Project Location: Lea County - New Mexico
Sampler Signature: [signature] Rozanne Johnson (505)631-9310
rozanne@valornet.com

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX: WATER	SOIL	AIR	SLUDGE		PRESERVATIVE METHOD: HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE	NONE	SAMPLING: DATE 2006	TIME
98071	Windmill ~ 220	1	1L	X									X		8-1	9:40

ANALYSIS REQUEST (Circle or Specify Method No.)

LAB #	MTBE 8021B/602	BTEX 8021B/602	TPH 418.1/TX1005 / TX1005 Extended (C35)	PAH 8270C	Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	TCLP Metals Ag As Ba Cd Cr Pb Se Hg	TCLP Volatiles	TCLP Semi Volatiles	TCLP Pesticides	RCI	GC/MS Vol. 8260B/624	GC/MS Semi. Vol. 8270C/625	PCB's 8082/608	Pesticides 8081A/608	BOD, TSS, pH	Moisture Content	Cations (Ca, Mg, Na, K)	Anions (Cl, SSSSO4, CO3, HCO3)	Total Dissolved Solids		Turn Around Time if different from standard	Hold
98071																	X	X	X			

Relinquished by:	Date:	Time:	Received by:	Date:	Time:
Rozanne Johnson [signature]	8/3/06	2:30pm			
Relinquished by:	Date:	Time:	Received by:	Date:	Time:
Relinquished by:	Date:	Time:	Received at Laboratory by: [signature]	Date: 8/4/06	Time: 10AM

LAB USE ONLY
Intact Y/N
Headspace Y/N
Temp 4°C
Log-in Review [initials]
Carrier # Greyhound 16901706675

REMARKS: Please email results to:
kpope@riceswd.com
mfranks @ riceswd.com
rozanne@valornet.com
☐ check if special reporting limits needed

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

Cation-Anion Balance Sheet

DATE: 8/22/2006

Sample #	Calcium ppm	Magnesium ppm	Sodium ppm	Potassium ppm	Alkalinity ppm	Sulfate ppm	Chloride ppm	Nitrate ppm	Fluoride ppm	Bromide ppm	TDS ppm	EC µMHOs/cm
98071	137	47.8	277	15.3	248	292	369				1490	

Sample #	Calcium in meq/L	Magnesium in meq/L	Sodium in meq/L	Potassium in meq/L	Alkalinity in meq/L	Sulfate in meq/L	Chloride in meq/L	Nitrate in meq/L	Fluoride in meq/L	Bromide in meq/L	Cations in meq/L	Anions in meq/L	Percentage Error
98071	6.84	3.93	12.05	0.39	4.96	6.08	10.41	0	0	0	23.21	21.45	7.889490014

	EC/Cation	EC/Anion
98071	2321.0636	2144.893

range 0 to 0

TDS/EC	TDS/Cat	TDS/Anion
#DIV/0!	0.64	0.69

needs to be 0.55-0.77

Summary Report

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

Report Date: August 23, 2006

Work Order: 6080427

Project Location: Lea County,NM
Project Name: Plains Pipeline-DS Hugh Gathering

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
98073	Monitor Well #3	water	2006-08-01	11:35	2006-08-04

Sample: 98073 - Monitor Well #3

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**280**	mg/L as CaCo3	4.00
Total Alkalinity		**280**	mg/L as CaCo3	4.00
Dissolved Calcium		**124**	mg/L	0.500
Dissolved Potassium		**10.3**	mg/L	1.00
Dissolved Magnesium		**63.3**	mg/L	1.00
Dissolved Sodium		**195**	mg/L	1.00
Chloride		**322**	mg/L	0.500
Sulfate		**255**	mg/L	0.500
Total Dissolved Solids		**1284**	mg/L	10.00

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TraceAnalysis, Inc.

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

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6080427

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

ANALYSIS REQUEST
(Circle or Specify Method No.)

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX: WATER	SOIL	AIR	SLUDGE	PRESERVATIVE METHOD: HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE	NONE	SAMPLING: DATE 2006	TIME	MTBE 8021B/602	BTEX 8021B/602	TPH 418.1/TX1005 / TX1005 Extended (C35)	PAH 8270C	Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	TCLP Metals Ag As Ba Cd Cr Pb Se Hg	TCLP Volatiles	TCLP Semi Volatiles	TCLP Pesticides	RCI	GC/MS Vol. 8260B/624	GC/MS Semi. Vol. 8270C/625	PCB's 8082/608	Pesticides 8081A/608	BOD, TSS, pH	Moisture Content	Cations (Ca, Mg, Na, K)	Anions (Cl, SSSSO4, CO3, HCO3)	Total Dissolved Solids	Turn Around Time if different from standard	Hold
98073	Monitor Well #3	1	1L	X								X		8-1	11:36																	X	X	X		

Relinquished by: Rozanne Johnson Date: 8/3/06 Time: 2:30pm
Received by: Date: Time:
Relinquished by: Date: Time:
Received by: Date: Time:
Relinquished by: Date: Time:
Received at Laboratory by: [signature] Date: 8/4/06 Time: 10AM

LAB USE ONLY
Intact Y / N
Headspace Y / N
Temp 4°C
Log-in Review
Carrier # [signature] 1440176675

REMARKS: Please email results to:
kpope@riceswd.com
mfranks @ riceswd.com
rozanne@valornet.com
☐ check if special reporting limits needed

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

Cation-Anion Balance Sheet

DATE: 8/22/2006

Sample #	Calcium ppm	Magnesium ppm	Sodium ppm	Potassium ppm	Alkalinity ppm	Sulfate ppm	Chloride ppm	Nitrate ppm	Fluoride ppm	Bromide ppm	TDS ppm	EC µMHOs/cm
98073	124	63.3	195	10.3	280	255	322				1284	

Sample #	Calcium in meq/L	Magnesium in meq/L	Sodium in meq/L	Potassium in meq/L	Alkalinity in meq/L	Sulfate in meq/L	Chloride in meq/L	Nitrate in meq/L	Fluoride in meq/L	Bromide in meq/L	**Cations in meq/L**	**Anions in meq/L**	**Percentage Error**
98073	6.19	5.21	8.48	0.26	5.60	5.31	9.08	0	0	0	20.14	19.99	0.746530774

	EC/Cation	EC/Anion
98073	2014.2531	1999.272

range 0 to 0

TDS/EC	TDS/Cat	TDS/Anion
#DIV/0!	0.64	0.64

needs to be 0.55-0.77

Summary Report

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

Report Date: August 24, 2006

Work Order: 6080429

Project Location: Lea County,NM
Project Name: Plains Pipeline-Vacuum to Jal 14 Inch Mainline #3

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
98075	Monitor Well 7	water	2006-08-01	10:55	2006-08-04

Sample: 98075 - Monitor Well 7

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**190**	mg/L as CaCo3	4.00
Total Alkalinity		**190**	mg/L as CaCo3	4.00
Dissolved Calcium		**138**	mg/L	0.500
Dissolved Potassium		**13.8**	mg/L	1.00
Dissolved Magnesium		**75.8**	mg/L	1.00
Dissolved Sodium		**196**	mg/L	1.00
Chloride		**450**	mg/L	0.500
Sulfate		**216**	mg/L	0.500
Total Dissolved Solids		**1378**	mg/L	10.00

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El Paso, Texas 79932
Tel (915) 585-3443
Fax (915) 585-4944

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6080429

Company Name: RICE Operating Company
Phone #: (505)393-9174
Address: (Street, City, Zip) 122 W Taylor Street - Hobbs, New Mexico 88240
Fax #: (505) 397-1471
Contact Person: Kristin Farris - Pope, Project Scientist
kpope@riceswd.com
Invoice to: (If different from above)
Project #: None Given
Project Name: Plains Pipeline ~ Vacuum to Jal 14" Mainline #3
Project Location: Lea County - New Mexico
Sampler Signature: Rozanne Johnson (505)631-9310
rozanne@valornet.com

ANALYSIS REQUEST
(Circle or Specify Method No.)

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX: WATER	SOIL	AIR	SLUDGE		PRESERVATIVE METHOD: HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE	NONE	SAMPLING: DATE 2006	TIME	MTBE 8021B/602	BTEX 8021B/602	TPH 418.1/TX1005 / TX1005 Extended (C35)	PAH 8270C	Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	TCLP Metals Ag As Ba Cd Cr Pb Se Hg	TCLP Volatiles	TCLP Semi Volatiles	TCLP Pesticides	RCI	GC/MS Vol. 8260B/624	GC/MS Semi. Vol. 8270C/625	PCB's 8082/608	Pesticides 8081A/608	BOD, TSS, pH	Moisture Content	Cations (Ca, Mg, Na, K)	Anions (Cl, SSSSO4, CO3, HCO3)	Total Dissolved Solids		Turn Around Time if different from standard	Hold
98075	Monitor Well #7	1	1L	X									X		8-1	10:55																	X	X	X			

Relinquished by:	Date:	Time:	Received by:	Date:	Time:
Rozanne Johnson	8/3/2006	2:30pm			
Relinquished by:	Date:	Time:	Received by:	Date:	Time:
Relinquished by:	Date:	Time:	Received at Laboratory by:	Date: 8/4/06	Time: 10AM

LAB USE ONLY
Intact Y / N
Headspace Y / N
Temp 4°C
Log-in Review
Carrier # Greyhound # 1640 1106075

REMARKS: Please email results to:
kpope@riceswd.com
mfranks @ riceswd.com
rozanne@valornet.com

☐ check if special reporting limits needed

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

Cation-Anion Balance Sheet

DATE: 8/24/2006

Sample #	Calcium ppm	Magnesium ppm	Sodium ppm	Potassium ppm	Alkalinity ppm	Sulfate ppm	Chloride ppm	Nitrate ppm	Fluoride ppm	Bromide ppm	TDS ppm	EC µMHOs/cm
98075	138	75.8	196	13.8	190	215.661	450				1378	

Sample #	Calcium in meq/L	Magnesium in meq/L	Sodium in meq/L	Potassium in meq/L	Alkalinity in meq/L	Sulfate in meq/L	Chloride in meq/L	Nitrate in meq/L	Fluoride in meq/L	Bromide in meq/L	**Cations in meq/L**	**Anions in meq/L**	**Percentage Error**
98075	6.89	6.24	8.53	0.35	3.80	4.49	12.69	0	0	0	22.00	20.98	4.73731936

	EC/Cation	EC/Anion
98075	2200.2786	2098.4562

range 0 to 0

TDS/EC	TDS/Cat	TDS/Anion
#DIV/0!	0.63	0.66

Summary Report

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

Report Date: August 22, 2006

Work Order: 6080426

Project Location: Lea County,NM
Project Name: Plains Pipeline-TNM 98-5B

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
98072	Monitor Well #2	water	2006-08-01	12:50	2006-08-04

Sample: 98072 - Monitor Well #2

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**162**	mg/L as CaCo3	4.00
Total Alkalinity		**162**	mg/L as CaCo3	4.00
Dissolved Calcium		**95.1**	mg/L	0.500
Dissolved Potassium		**8.10**	mg/L	1.00
Dissolved Magnesium		**45.5**	mg/L	1.00
Dissolved Sodium		**146**	mg/L	1.00
Chloride		**269**	mg/L	0.500
Sulfate		**197**	mg/L	0.500
Total Dissolved Solids		**1002**	mg/L	10.00

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El Paso, Texas 79932
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CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6080426

Company Name: RICE Operating Company
Phone #: (505)393-9174
Address: (Street, City, Zip) 122 W Taylor Street - Hobbs, New Mexico 88240
Fax #: (505) 397-1471
Contact Person: Kristin Farris - Pope, Project Scientist
kpope@riceswd.com
Invoice to: (If different from above)
Project #: None Given
Project Name: Plains Pipeline~TNM 98-5B
Project Location: Lea County - New Mexico
Sampler Signature: Rozanne Johnson (505)631-9310 rozanne@valornet.com

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX: WATER	SOIL	AIR	SLUDGE	PRESERVATIVE METHOD: HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE	NONE	SAMPLING: DATE 2006	TIME
98072	Monitor Well #2	1	1L	X								X		8-1	12:50

ANALYSIS REQUEST
(Circle or Specify Method No.)

Analysis	Monitor Well #2
MTBE 8021B/602	
BTEX 8021B/602	
TPH 418.1/TX1005 / TX1005 Extended (C35)	
PAH 8270C	
Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	
TCLP Metals Ag As Ba Cd Cr Pb Se Hg	
TCLP Volatiles	
TCLP Semi Volatiles	
TCLP Pesticides	
RCI	
GC/MS Vol. 8260B/624	
GC/MS Semi. Vol. 8270C/625	
PCB's 8082/608	
Pesticides 8081A/608	
BOD, TSS, pH	
Moisture Content	
Cations (Ca, Mg, Na, K)	X
Anions (Cl, SSSSO4, CO3, HCO3)	X
Total Dissolved Solids	X
Turn Around Time if different from standard	
Hold	

Relinquished by: Rozanne Johnson Date: 8/3/06 Time: 2:30pm
Received by: Date: Time:
Relinquished by: Date: Time:
Received by: Date: Time:
Relinquished by: Date: Time:
Received at Laboratory by: [signature] Date: 8/4/06 Time: 10AM

LAB USE ONLY
Intact Y / N
Headspace Y / N
Temp 4°C
Log-in Review [initials]
Carrier # Grey round 1690176675

REMARKS: Please email results to:
kpope@riceswd.com
mfranks @ riceswd.com
rozanne@valornet.com
☐ check if special reporting limits needed

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

Cation-Anion Balance Sheet

DATE: 8/22/2006

Sample #	Calcium ppm	Magnesium ppm	Sodium ppm	Potassium ppm	Alkalinity ppm	Sulfate ppm	Chloride ppm	Nitrate ppm	Fluoride ppm	Bromide ppm	TDS ppm	EC µMHOs/cm
98072	95.1	45.5	146	8.1	162	196.943	268.96				1002	

Sample #	Calcium in meq/L	Magnesium in meq/L	Sodium in meq/L	Potassium in meq/L	Alkalinity in meq/L	Sulfate in meq/L	Chloride in meq/L	Nitrate in meq/L	Fluoride in meq/L	Bromide in meq/L	**Cations in meq/L**	**Anions in meq/L**	**Percentage Error**
98072	4.75	3.74	6.35	0.21	3.24	4.10	7.59	0	0	0	15.05	14.93	0.801773099

	EC/Cation	EC/Anion
98072	1504.7883	1492.77149

range 0 to 0

TDS/EC	TDS/Cat	TDS/Anion
#DIV/0!	0.67	0.67

needs to be 0.55-0.77

Summary Report

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

Report Date: August 24, 2006

Work Order: 6080428

Project Location: Lea County, NM
Project Name: Plains Pipeline- TNM 98-5A

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
98074	Monitor Well #5	water	2006-08-01	12:15	2006-08-04

Sample: 98074 - Monitor Well #5

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**274**	mg/L as CaCo3	4.00
Total Alkalinity		**274**	mg/L as CaCo3	4.00
Dissolved Calcium		**96.3**	mg/L	0.500
Dissolved Potassium		**10.8**	mg/L	1.00
Dissolved Magnesium		**49.3**	mg/L	1.00
Dissolved Sodium		**167**	mg/L	1.00
Chloride		**218**	mg/L	0.500
Sulfate		**148**	mg/L	0.500
Total Dissolved Solids		**1008**	mg/L	10.00

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Fax (915) 585-4944

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6080428

Company Name: RICE Operating Company
Phone #: (505)393-9174
Address: (Street, City, Zip) 122 W Taylor Street - Hobbs, New Mexico 88240
Fax #: (505) 397-1471
Contact Person: Kristin Farris - Pope, Project Scientist
kpope@riceswd.com
Invoice to: (If different from above)
Project #: None Given
Project Name: Plains Pipeline~TNM 9805A
Project Location: Lea County - New Mexico
Sampler Signature: Rozanne Johnson (505)631-9310
rozanne@valornet.com

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX: WATER	SOIL	AIR	SLUDGE		PRESERVATIVE METHOD: HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE	NONE	SAMPLING: DATE 2006	TIME
98074	Monitor Well #6	1	1L	X									X		8-1	12:15

ANALYSIS REQUEST
(Circle or Specify Method No.)

Analysis	Monitor Well #6
MTBE 8021B/602	
BTEX 8021B/602	
TPH 418.1/TX1005 / TX1005 Extended (C35)	
PAH 8270C	
Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	
TCLP Metals Ag As Ba Cd Cr Pb Se Hg	
TCLP Volatiles	
TCLP Semi Volatiles	
TCLP Pesticides	
RCI	
GC/MS Vol. 8260B/624	
GC/MS Semi. Vol. 8270C/625	
PCB's 8082/608	
Pesticides 8081A/608	
BOD, TSS, pH	
Moisture Content	
Cations (Ca, Mg, Na, K)	X
Anions (Cl, SSSSO4, CO3, HCO3)	X
Total Dissolved Solids	X
Turn Around Time if different from standard	
Hold	

Relinquished by: Rozanne Johnson	Date: 8/3/06	Time: 2:30pm	Received by: Date: Time:
Relinquished by:	Date:	Time:	Received by: Date: Time:
Relinquished by:	Date:	Time:	Received at Laboratory by: [signature] Date: 8/4/06 Time: 10AM

LAB USE ONLY
Intact Y / N
Headspace Y / N
Temp 4°C
Log-in Review [initials]
Carrier # Greyhound 1690176[illegible]

REMARKS: Please email results to:
kpope@riceswd.com
mfranks @ riceswd.com
rozanne@valornet.com
☐ check if special reporting limits needed

[Su]bmittal of samples constitutes agreement to Terms and Conditions listed on reverse side of COC

Cation-Anion Balance Sheet

DATE: 8/24/2006

Sample #	Calcium ppm	Magnesium ppm	Sodium ppm	Potassium ppm	Alkalinity ppm	Sulfate ppm	Chloride ppm	Nitrate ppm	Fluoride ppm	Bromide ppm	TDS ppm	EC µMHOs/cm
98074	96.3	49.3	167	10.8	274	147.879	218.129				1008	

Sample #	Calcium in meq/L	Magnesium in meq/L	Sodium in meq/L	Potassium in meq/L	Alkalinity in meq/L	Sulfate in meq/L	Chloride in meq/L	Nitrate in meq/L	Fluoride in meq/L	Bromide in meq/L	**Cations in meq/L**	**Anions in meq/L**	**Percentage Error**
98074	4.81	4.06	7.26	0.28	5.48	3.08	6.15	0	0	0	16.40	14.71	10.8677829

	EC/Cation	EC/Anion
98074	1640.3031	1471.22599

range 0 to 0

TDS/EC	TDS/Cat	TDS/Anion
#DIV/0!	0.61	0.69

Summary Report

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

Report Date: August 29, 2006

Work Order: 6080422

Project Location: Lea County,NM
Project Name: TARGA

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
98065	Water Well #1	water	2006-08-01	15:40	2006-08-04
98066	Water Well #5	water	2006-08-01	14:50	2006-08-04
98067	Water Well #8	water	2006-08-01	15:03	2006-08-04
98068	Water Well #12	water	2006-08-01	15:12	2006-08-04

Sample: 98065 - Water Well #1

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**332**	mg/L as CaCo3	4.00
Total Alkalinity		**332**	mg/L as CaCo3	4.00
Dissolved Calcium		**101**	mg/L	0.500
Dissolved Potassium		**9.01**	mg/L	1.00
Dissolved Magnesium		**51.5**	mg/L	1.00
Dissolved Sodium		**143**	mg/L	1.00
Chloride		**187**	mg/L	0.500
Sulfate		**147**	mg/L	0.500
Total Dissolved Solids		**1008**	mg/L	10.00

Sample: 98066 - Water Well #5

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**156**	mg/L as CaCo3	4.00
Total Alkalinity		**156**	mg/L as CaCo3	4.00
Dissolved Calcium		**83.1**	mg/L	0.500
Dissolved Potassium		**8.44**	mg/L	1.00
Dissolved Magnesium		**39.8**	mg/L	1.00
Dissolved Sodium		**126**	mg/L	1.00
Chloride		**225**	mg/L	0.500

continued ...

sample 98066 continued ...

Param	Flag	Result	Units	RL
Sulfate		**177**	mg/L	0.500
Total Dissolved Solids		**864.0**	mg/L	10.00

Sample: 98067 - Water Well #8

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**268**	mg/L as CaCo3	4.00
Total Alkalinity		**268**	mg/L as CaCo3	4.00
Dissolved Calcium		**90.5**	mg/L	0.500
Dissolved Potassium		**9.56**	mg/L	1.00
Dissolved Magnesium		**49.1**	mg/L	1.00
Dissolved Sodium		**206**	mg/L	1.00
Chloride		**308**	mg/L	0.500
Sulfate		**224**	mg/L	0.500
Total Dissolved Solids		**1202**	mg/L	10.00

Sample: 98068 - Water Well #12

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**296**	mg/L as CaCo3	4.00
Total Alkalinity		**296**	mg/L as CaCo3	4.00
Dissolved Calcium		**86.8**	mg/L	0.500
Dissolved Potassium		**9.66**	mg/L	1.00
Dissolved Magnesium		**42.7**	mg/L	1.00
Dissolved Sodium		**168**	mg/L	1.00
Chloride		**181**	mg/L	0.500
Sulfate		**160**	mg/L	0.500
Total Dissolved Solids		**966.0**	mg/L	10.00

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1 (800) 378-1296

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El Paso, Texas 79932
Tel (915) 585-3443
Fax (915) 585-4944

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6080422

Company Name: RICE Operating Company
Phone #: (505)393-9174
Address: (Street, City, Zip) 122 W Taylor Street - Hobbs, New Mexico 88240
Fax #: (505) 397-1471
Contact Person: Kristin Farris - Pope, Project Scientist
kpope@riceswd.com
Invoice to: (If different from above)
Project #: None Given
Project Name: TARGA
Project Location: Lea County - New Mexico
Sampler Signature: Gil Van Deventer GJV

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX: WATER	SOIL	AIR	SLUDGE	PRESERVATIVE METHOD: HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE	NONE	SAMPLING: DATE 2006	TIME
98065	Water Well #1	1	1L	X								X		8-1	15:40
66	Water Well #6	1	1L	X								X		8-1	14:50
67	Water Well #8	1	1L	X								X		8-1	15:03
68	Water Well #12	1	1L	X								X		8-1	15:12

ANALYSIS REQUEST
(Circle or Specify Method No.)

FIELD CODE	MTBE 8021B/602	BTEX 8021B/602	TPH 418.1/TX1005 / TX1005 Extended (C35)	PAH 8270C	Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	TCLP Metals Ag As Ba Cd Cr Pb Se Hg	TCLP Volatiles	TCLP Semi Volatiles	TCLP Pesticides	RCI	GC/MS Vol. 8260B/624	GC/MS Semi. Vol. 8270C/625	PCB's 8082/608	Pesticides 8081A/608	BOD, TSS, pH	Moisture Content	Cations (Ca, Mg, Na, K)	Anions (Cl, SSSSO4, CO3, HCO3)	Total Dissolved Solids	Turn Around Time if different from standard	Hold
Water Well #1																	X	X	X		
Water Well #6																					
Water Well #8																					
Water Well #12																					

Relinquished by	Date	Time	Received by	Date	Time
Van Deventer	8/1/06	18:00	Rozanne Johnson	8/1/06	18:00
Rozanne Johnson	8/3/06	2:35pm	Received at Laboratory by: [signature]	8/4/06	10AM

LAB USE ONLY
Intact Y / N
Headspace Y / N
Temp 4°C
Log-in Review [initials]
Carrier # Greyhound 1690174675

REMARKS: Please email results to:
kpope@riceswd.com
mfranks @ riceswd.com
rozanne@valornet.com

☐ check if special reporting limits needed

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

Cation-Anion Balance Sheet

DATE: 8/29/2006

Sample #	Calcium ppm	Magnesium ppm	Sodium ppm	Potassium ppm	Alkalinity ppm	Sulfate ppm	Chloride ppm	Nitrate ppm	Fluoride ppm	Bromide ppm	TDS ppm	EC µMHOs/cm
98065	101	51.5	143	9.01	332	147.08	187.376				1008	
98066	83.1	39.8	126	8.44	156	177.095	224.772				864	
98067	90.5	49.1	206	9.56	268	224.084	308				1202	
98068	86.8	42.7	168	9.66	296	160.337	180.704				966	

Sample #	Calcium in meq/L	Magnesium in meq/L	Sodium in meq/L	Potassium in meq/L	Alkalinity in meq/L	Sulfate in meq/L	Chloride in meq/L	Nitrate in meq/L	Fluoride in meq/L	Bromide in meq/L	**Cations in meq/L**	**Anions in meq/L**	**Percentage Error**
98065	5.04	4.24	6.22	0.23	6.64	3.06	5.29	0	0	0	15.73	14.99	4.822937211
98066	4.15	3.28	5.48	0.22	3.12	3.69	6.34	0	0	0	13.12	13.15	0.222402212
98067	4.52	4.04	8.96	0.24	5.36	4.67	8.69	0	0	0	17.76	18.71	5.220824465
98068	4.33	3.51	7.31	0.25	5.92	3.34	5.10	0	0	0	15.40	14.36	7.019268334

	EC/Cation	EC/Anion				
98065	1572.88108	1498.80826	range	0	to	0
98066	1311.87272	1314.7936	range	0	to	0
98067	1776.19338	1871.41089	range	0	to	0
98068	1540.02058	1435.58762	range	0	to	0

TDS/EC	TDS/Cat	TDS/Anion	
#DIV/0!	0.64	0.67	needs to be 0.55-0.77
#DIV/0!	0.66	0.66	needs to be 0.55-0.77
#DIV/0!	0.68	0.64	needs to be 0.55-0.77
#DIV/0!	0.63	0.67	needs to be 0.55-0.77

Summary Report

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

Report Date: August 22, 2006

Work Order: 6080423

Project Location: Lea County,NM
Project Name: TARGA

Sample	Description	Matrix	Date Taken	Time Taken	Date Received
98069	Water Well #19	water	2006-08-01	17:55	2006-08-04

Sample: 98069 - Water Well #19

Param	Flag	Result	Units	RL
Hydroxide Alkalinity		<1.00	mg/L as CaCo3	1.00
Carbonate Alkalinity		<1.00	mg/L as CaCo3	1.00
Bicarbonate Alkalinity		**244**	mg/L as CaCo3	4.00
Total Alkalinity		**244**	mg/L as CaCo3	4.00
Dissolved Calcium		**92.7**	mg/L	0.500
Dissolved Potassium		**9.16**	mg/L	1.00
Dissolved Magnesium		**26.6**	mg/L	1.00
Dissolved Sodium		**156**	mg/L	1.00
Chloride		**302**	mg/L	0.500
Sulfate		**88.1**	mg/L	0.500
Total Dissolved Solids		**870.0**	mg/L	10.00

Page 1 of 1

TraceAnalysis, Inc.

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

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # 6080423

Phone #: (505)393-9174

Fax #: (505) 397-1471

... Taylor Street - Hobbs, New Mexico 88240

Contact Person: Kristin Farris - Pope, Project Scientist — kpope@riceswd.com

Invoice to: (If different from above)

Project #: None Given

Project Name: TARGA

Project Location: Lea County - New Mexico

Sampler Signature: RezAnne Johnson (505)631-9310 rozanne@valornet.com

LAB # (LAB USE ONLY)	FIELD CODE	# CONTAINERS	Volume/Amount	MATRIX: WATER	MATRIX: SOIL	MATRIX: AIR	MATRIX: SLUDGE	MATRIX: (blank)	PRESERVATIVE METHOD: HCL	PRESERVATIVE METHOD: HNO_3	PRESERVATIVE METHOD: $NaHSO_4$	PRESERVATIVE METHOD: H_2SO_4	PRESERVATIVE METHOD: ICE	PRESERVATIVE METHOD: NONE	SAMPLING: DATE 2006	SAMPLING: TIME
98069	Water Well #19	1	1L	X									X		8-1	17:55

ANALYSIS REQUEST
(Circle or Specify Method No.)

Analysis	Water Well #19
MTBE 8021B/602	
BTEX 8021B/602	
TPH 418.1/TX1005 / TX1005 Extended (C35)	
PAH 8270C	
Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	
TCLP Metals Ag As Ba Cd Cr Pb Se Hg	
TCLP Volatiles	
TCLP Semi Volatiles	
TCLP Pesticides	
RCI	
GC/MS Vol. 8260B/624	
GC/MS Semi. Vol. 8270C/625	
PCB's 8082/608	
Pesticides 8081A/608	
BOD, TSS, pH	
Moisture Content	
Cations (Ca, Mg, Na, K)	X
Anions (Cl, SSSSO4, CO3, HCO3)	X
Total Dissolved Solids	X
(blank)	
Turn Around Time if different from standard	

Relinquished by:	Date:	Time:	Received by:	Date:	Time:
RezAnne Johnson	8/3/06	2:30pm			
			Received at Laboratory by:	8/4/06	10AM

LAB USE ONLY
Intact Y / N
Headspace Y / N
Temp 4°C
Log-in Review
Carrier # Greyhound 16901766??

REMARKS: Please email results to:
kpope@riceswd.com
mfranks @ riceswd.com
rozanne@valornet.com

☐ check if special reporting limits needed

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

CARDINAL LABORATORIES

PHONE (325) 673-7001 • 2111 BEECHWOOD • ABILENE, TX 79603
PHONE (505) 393-2326 • 101 E. MARLAND • HOBBS, NM 88240

ANALYTICAL RESULTS FOR
RICE OPERATING COMPANY
ATTN: KRISTIN FARRIS-POPE
122 W. TAYLOR STREET
HOBBS, NM 88240
FAX TO: (575) 397-1471

Receiving Date: 10/12/07
Reporting Date: 10/16/07
Project Number: NOT GIVEN
Project Name: BD JUNCTION J-26
Project Location: T21S R37E SEC26 J~LEA COUNTY, NM

Sampling Date: 10/10/07
Sample Type: WATER
Sample Condition: COOL & INTACT
Sample Received By: BC
Analyzed By: HM/KS

LAB NUMBER	SAMPLE ID	Na (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Conductivity (u S/cm)	T-Alkalinity ($mgCaCO_3/L$)
ANALYSIS DATE:		10/15/07	10/15/07	10/15/07	10/12/07	10/15/07	10/15/07
H13494-1	MONITOR WELL #1	166	59.9	28.2	28.7	1,397	200
H13494-2	MONITOR WELL #2	323	174	68.6	10.7	3,040	192
H13494-3	MONITOR WELL #3	163	51.9	33.1	6.43	1,345	232
Quality Control		NR	47.9	51.6	1.87	9,770	NR
True Value QC		NR	50.0	50.0	2.00	10,000	NR
% Recovery		NR	95.8	103	93.6	97.7	NR
Relative Percent Difference		NR	2.7	< 0.1	< 0.1	0.4	NR
METHODS:			SM3500-Ca-D	3500-Mg E	8049	120.1	310.1

LAB NUMBER	SAMPLE ID	Cl^- (mg/L)	SO_4 (mg/L)	CO_3 (mg/L)	HCO_3 (mg/L)	pH (s.u.)	TDS (mg/L)
ANALYSIS DATE:		10/15/07	10/15/07	10/15/07	10/15/07	10/15/07	10/14/07
H13494-1	MONITOR WELL #1	160	228	0	244	7.90	915
H13494-2	MONITOR WELL #2	730	204	0	234	7.61	1,838
H13494-3	MONITOR WELL #3	164	160	0	283	7.77	857
Quality Control		500	22.6	NR	988	6.99	NR
True Value QC		500	25.0	NR	1000	7.00	NR
% Recovery		100	90.4	NR	98.8	99.9	NR
Relative Percent Difference		2.0	15.5	NR	1.2	0.1	NR
METHODS:		SM4500-Cl-B	375.4	310.1	310.1	150.1	160.1

Chemist

10/16/07
Date

H13494 RICE

101 East Marland - Hobbs, New Mexico 88240
Tel (505) 393-2326
Fax (505) 393-2476

Cardinal Laboratories, Inc.

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # ____________

Company Name: RICE Operating Company

Project Manager: Kristin Farris-Pope, Project Scientist

Address: (Street, City, Zip) 122 W Taylor Street ~ Hobbs, New Mexico 88240

Phone #: (505) 393-9174 Fax #: (505) 397-1471

Project #: Project Name: BD Junction J-26

Project Location: T21S R37E Sec26 J ~ Lea County New Mexico

BILL TO Company: RICE Operating Company PO#

Address: (Street, City, Zip) 122 W Taylor Street ~ Hobbs, New Mexico 88240

Phone#: (505) 393-9174 Fax#: (505)397-1471

Sampler Signature: Rozanne Johnson (505)631-9310 rozanne@valornet.com

LAB # (LAB USE ONLY)	FIELD CODE	(G)rab or (C)omp	# CONTAINERS	MATRIX: WATER	SOIL	AIR	SLUDGE		PRESERVATIVE METHOD: HCL	HNO_3	$NaHSO_4$	H_2SO_4	ICE (1-1Liter HDPE)	NONE	SAMPLING: DATE (2007)	TIME
H13444-1	Monitor Well #1	G	1	X									1		10-10	17:15
-2	Monitor Well #2	G	1	X									1		10-10	18:20
-3	Monitor Well #3	G	1	X									1		10-10	16:25

ANALYSIS REQUEST
(Circle or Specify Method No.)

FIELD CODE	MTBE 8021B/602	BTEX 8021B/602	TPH 418.1/TX1005 / TX1005 Extended (C35)	PAH 8270C	Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	TCLP Metals Ag As Ba Cd Cr Pb Se Hg	TCLP Volatiles	TCLP Semi Volatiles	TCLP Pesticides	RCI	GC/MS Vol. 8260B/624	GC/MS Semi. Vol. 8270C/625	PCB's 8082/608	Pesticides 8081A/608	BOD, TSS, pH	Moisture Content		Cations (Ca, Mg, Na, K)	Anions (Cl, SO4, CO3, HCO3)	Total Dissolved Solids	Chlorides	Turn Around Time ~ 24 Hours
Monitor Well #1																		X	X	X		
Monitor Well #2																		X	X	X		
Monitor Well #3																		X	X	X		

Relinquished by: Rozanne Johnson Date: 10-12-07 Time: 10:25

Received by: Date: Time:

Relinquished by: Date: Time:

Received By: (Laboratory Staff) Date: 10/12/07 Time: 10:26

Delivered By: (Circle One) Sampler - UPS - Bus - Other:

Sample Condition: Cool Yes ☒ No ☐ Intact Yes ☒ No ☐

CHECKED BY: (Initials)

Phone Results ☐ Yes ☐ No

Fax Results ☐ Yes ☐ No Additional Fax Number:

REMARKS:

Email Results to: kpope@riceswd.com
lweinheimer@riceswd.com
rozanne@valornet.com

APPENDIX E

Junction Box Final Closure Report

RICE OPERATING COMPANY
JUNCTION BOX FINAL REPORT

BOX LOCATION

SWD SYSTEM	JUNCTION	UNIT	SECTION	TOWNSHIP	RANGE	COUNTY	NEW BOX DIMENSIONS - FEET		
							Length	Width	Depth
Blinebry-Drinkard (BD)	J-26 boot	J	26	21S	37E	Lea	no box; junction eliminated		

LAND TYPE BLM ______ STATE ______ FEE LANDOWNER Delrose Scott OTHER ______

Depth to Groundwater 42 feet NMOCD SITE ASSESSMENT RANKING SCORE: 20

Date Started 4/23/2002 Date Completed 10/2/2002 NMOCD Witness YES

Soil Excavated 1000 cubic yards Excavation Length 115 Width 75 Depth 40 feet

Soil Disposed 480 cubic yards Offsite Facility Sundance Location Eunice, New Mexico

General Description of Remedial Action:

For a summary of the junction box remediation and excavation activities, refer to the previously-submitted Junction Box Disclosure Report (2002). Since the vadose remediation, groundwater at this site has been monitored on a quarterly basis.

The attached November 2007 Abatement Completion Report by Trident Environmental of Midland, Texas requests closure of this junction box site

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

REPORT ASSEMBLED BY Kristin Farris Pope SIGNATURE *Kristin Farris Pope*

DATE 11/15/2007 TITLE Project Scientist