GW - 32

2/86

PERMITS, RENEWALS, & MODS

Application

ATTACHMENTS B-3 AND B-4

REPLY TO NMOCD COMMENTS RE:
DISCHARGE PLAN APPLICATION (GW-32)
GIANT REFINING COMPANY CINIZA REFINERY

RECEIVED
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OIL CONSERVATION DIVISION
SANTA FE

ATTACHMENT B-3

ATTACHMENT B-3

REPLY TO
EPA REGION VI COMMENTS ON
OBSERVED TOX AND METALS LEVELS IN GROUND WATER
CINIZA REFINERY, GALLUP NEW MEXICO

February 14, 1985

Submitted to:

Mr. David L. Olschewsky
Technical Section
U.S. Environmental Protection Agency
Region VI
1201 Elm Street
Dallas, Texas 75270

Prepared For:

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Albuquerque, New Mexico 87102

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 EXECUTIVE SUMMARY

This document addresses the first two items in the December 4 letter from the USEPA Region VI regarding the observed levels of TOX, lead and mercury in the monitoring and observation wells at the Giant Ciniza Refinery near Gallup, New Mexico. Based on the results of further sampling and analysis, the observed levels of TOX are the result of well contamination from solvents used to weld the joints in the PVC well casing, and show a statistically significant (correlation coefficient -0.90) rate of decline which regresses to 0 % TOX in approximately 1200 days after well installation.

The levels of lead and mercury found in the monitoring and observation wells are believed to be the result of high, naturally-occurring concentrations of these metals in the weathered bedrock and soils of derived from the the upper Chinle Formation. These metals are leached into the ground water at variable rates and concentrations, causing considerable spatial variations in the observed levels in ground water analyses. A proposed program of resampling selected wells, and an investigation of the natural background occurrence of these metals, will address and should resolve the questions concerning lead and mercury in the wells.

Selected upgradient and downgradient observation wells will be resampled according to a revised sampling, analytical and quality-control procedure, which should minimize any possible contamination, bias or analytical laboratory errors. In addition, Giant will undertake an investigation to better characterize the site-specific and regional geochemical background conditions. This investigation will include a thorough review of existing data, the collection of relevant published data on soils, bedrock and ground water chemistry in the Ciniza area, a program to collect and analyse soil, bedrock and ground water samples from areas adjacent to the plant site, tritium isotope dating to assist in establishing the infiltration and recharge rates and a thorough statistical analysis of the assembled data.

The results of this investigation of the natural background levels of lead and mercury will be presented to Region VI in response to their concerns stated in the letter of December 4, 1984 regarding the apparent levels of these metals in the observation wells at Ciniza. By better characterizing the natural background levels (and spatial variations) of these metals in the Chinle Formation and overlying soils, will provide the basis for demonstrating that the metals levels in the observation wells are likely the result of natural processes and not the result of any refinery practices.

Currently, the responses are being prepared to items numbered 3 and 4 of the December 4, 1984 letter. These two items will be discussed in detail in a report to be submitted to EPA by March 1, 1985. This report will discuss in detail the proposed resolution of the issue of adequacy of unsaturated zone monitoring at the landfarm (lysimeter issue) and the determination and definition of the uppermost aquifer at the landfarm/refinery site.

2.0 TOTAL ORGANIC HALOGENS (TOX) IN MONITORING WELLS

The Total Organic Halogen (TOX) levels observed in the monitoring wells (MW) are the result of well contamination from solvent-welded joints in the wells' casings, which were constructed of polyvinyl chloride (PVC). There is also a possibility that observed TOX levels were the result of sample contamination during well purging and sample collection or sample handling practices. After sampling according to revised sampling procedures, observed TOX levels (12/84) are below the detection limit (0.01 mg/l). We are confident that PVC solvents are the only significant source of observed TOX levels, and that no contamination of the Sonsela aquifer has occurred due to refinery operations. The levels of TOX in the monitoring wells show a consistent decline with time, and a corresponding decline in variance among the wells. Leaching of TOX from the casing joints is essentially complete, as all wells now show TOX levels below the detection limit (0.01 mg/l). For this reason, we do not believe that new monitoring wells are necessary.

Leaching of TOX into water which contacts solvent-welded PVC pipe joints has been documented by Barcelona, et al (1983), Boettner, et al (1982), Reich, et al (1981), and Wang and Bricker (1979). Levels of TOX remain elevated for months or years, but decline with time when the contacting water is continuously or periodically replaced. As seen in Figures 2-1 through 2-4, the TOX levels in all monitoring wells show a significant decline with time (correlation coeffecients of -.87 to -.95). Linear regressions for all wells intercept 0% TOX at 1077 to 1250 days after the

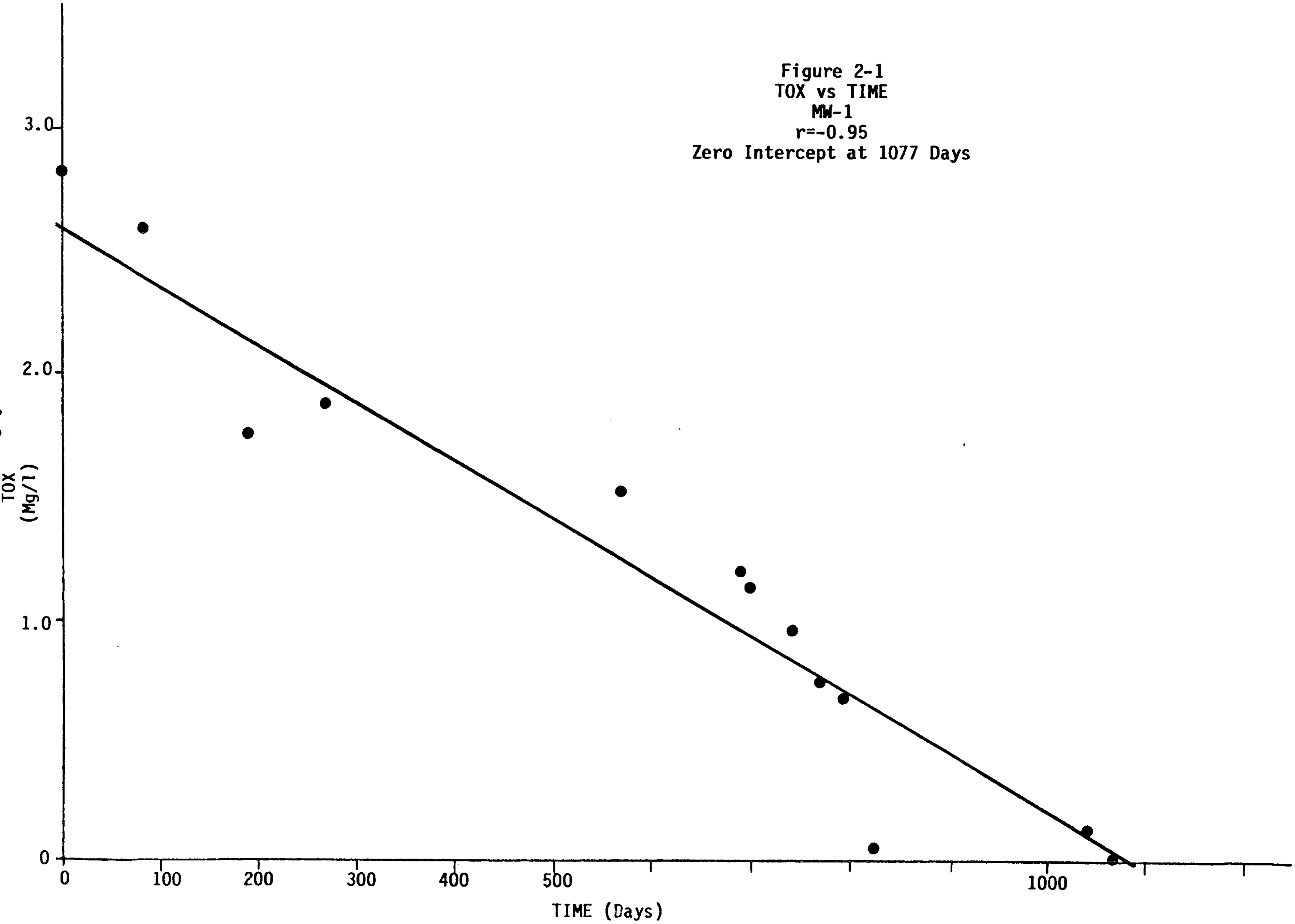

Figure 2-1
TOX vs TIME
MW-1
r=-0.95
Zero Intercept at 1077 Days

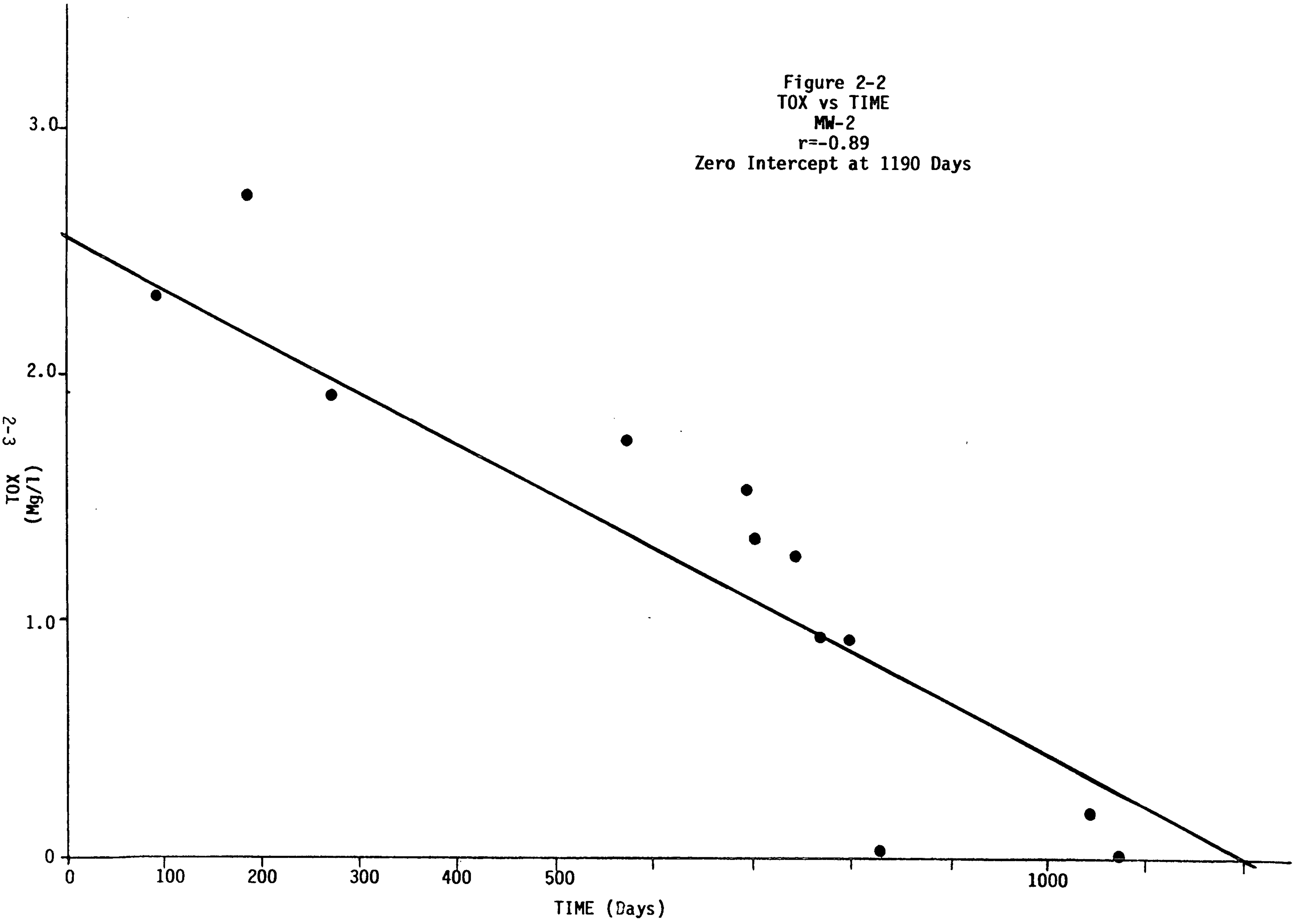

Figure 2-2
TOX vs TIME
MW-2
r=-0.89
Zero Intercept at 1190 Days

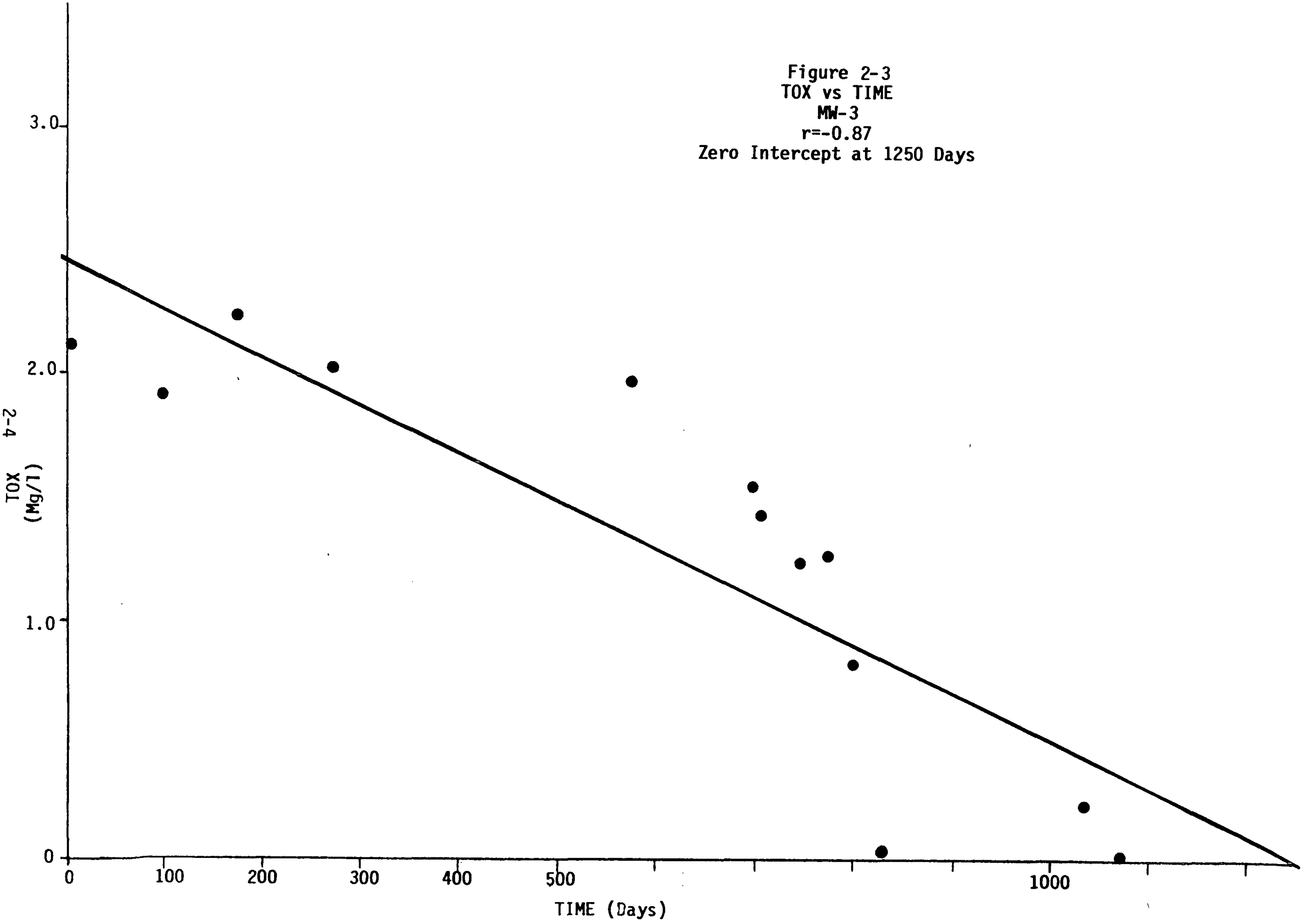

Figure 2-3
TOX vs TIME
MW-3
r=-0.87
Zero Intercept at 1250 Days

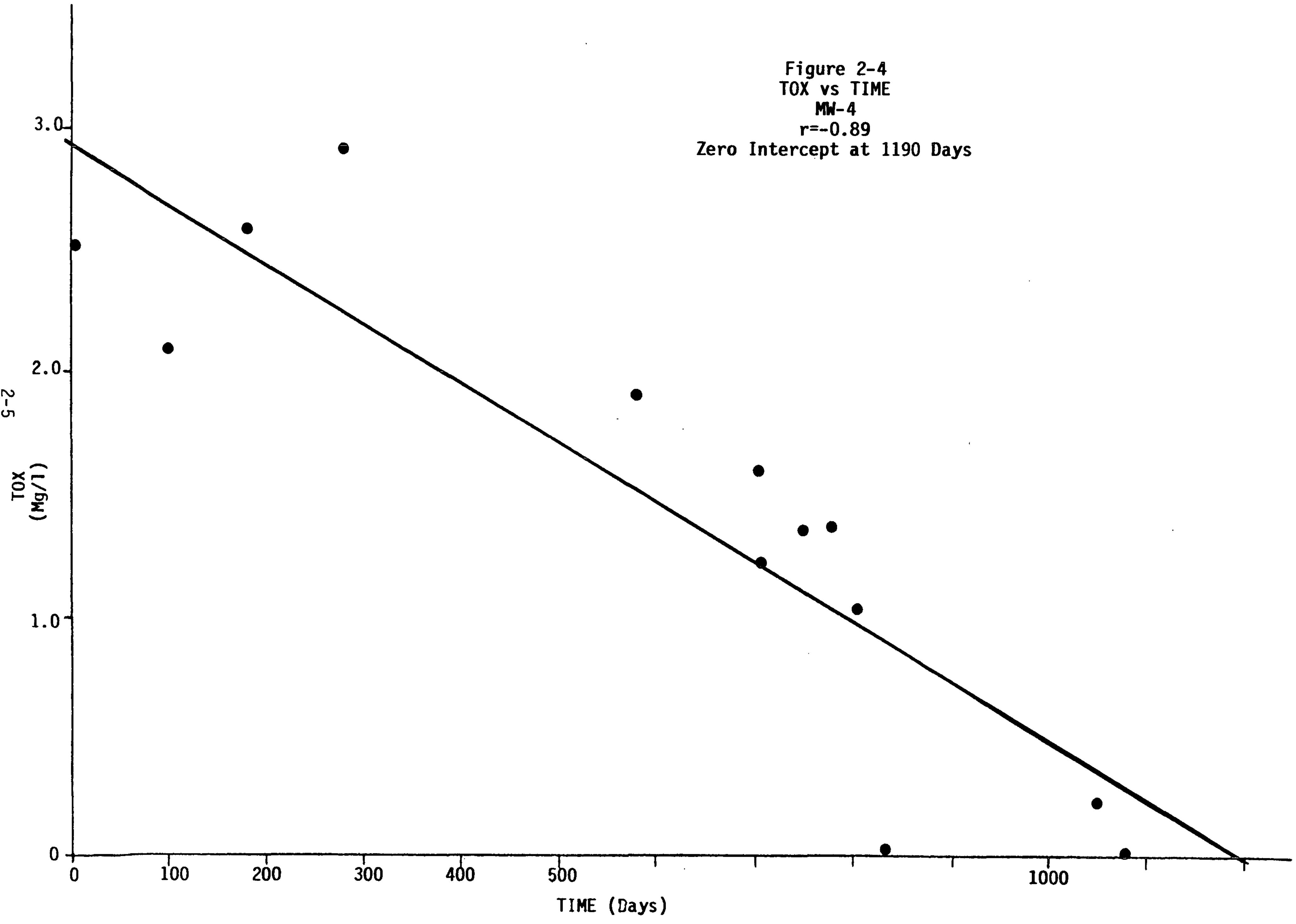

Figure 2-4
TOX vs TIME
MW-4
r=-0.89
Zero Intercept at 1190 Days

first sampling (1981).

Figure 2-5 shows that the variance in TOX among the 4 wells also declines with time, at a correlation of -.86, and intercepts 0 variance at 1125 days. These trends are all consistent with leaching of TOX species from a small, finite "reservoir" of halogenated solvents in the PVC pipe joints.

In addition to the above, general geohydrologic conditions at the Ciniza Refinery site prevent any migration of dissolved TOX species into the Sonsela aquifer. The artesian pressure in the Sonsela prevents downward migration dissolved contaminants into the Sonsela, and the extremely low hydraulic conductivities of the shale aquitard above the Sonsela would prevent any significant lateral or downward movement of leachate in the time since the construction of the land farm.

Recent analyses (Table 2-1) show that TOX levels in the MW wells are now below the detection limit of 0.01 mg/l. Repeated purging and sample removal have effectively removed the TOX contamination from these wells and they are now suitable for monitoring the Sonsela aquifer.

The revised sampling and analytical protocols (Appendix A) will further serve to assure representative samples, and to minimize possible sources of sample bias. Quality control and quality assurance procedures outlined in this appendix should identify any instances of laboratory bias or errors.

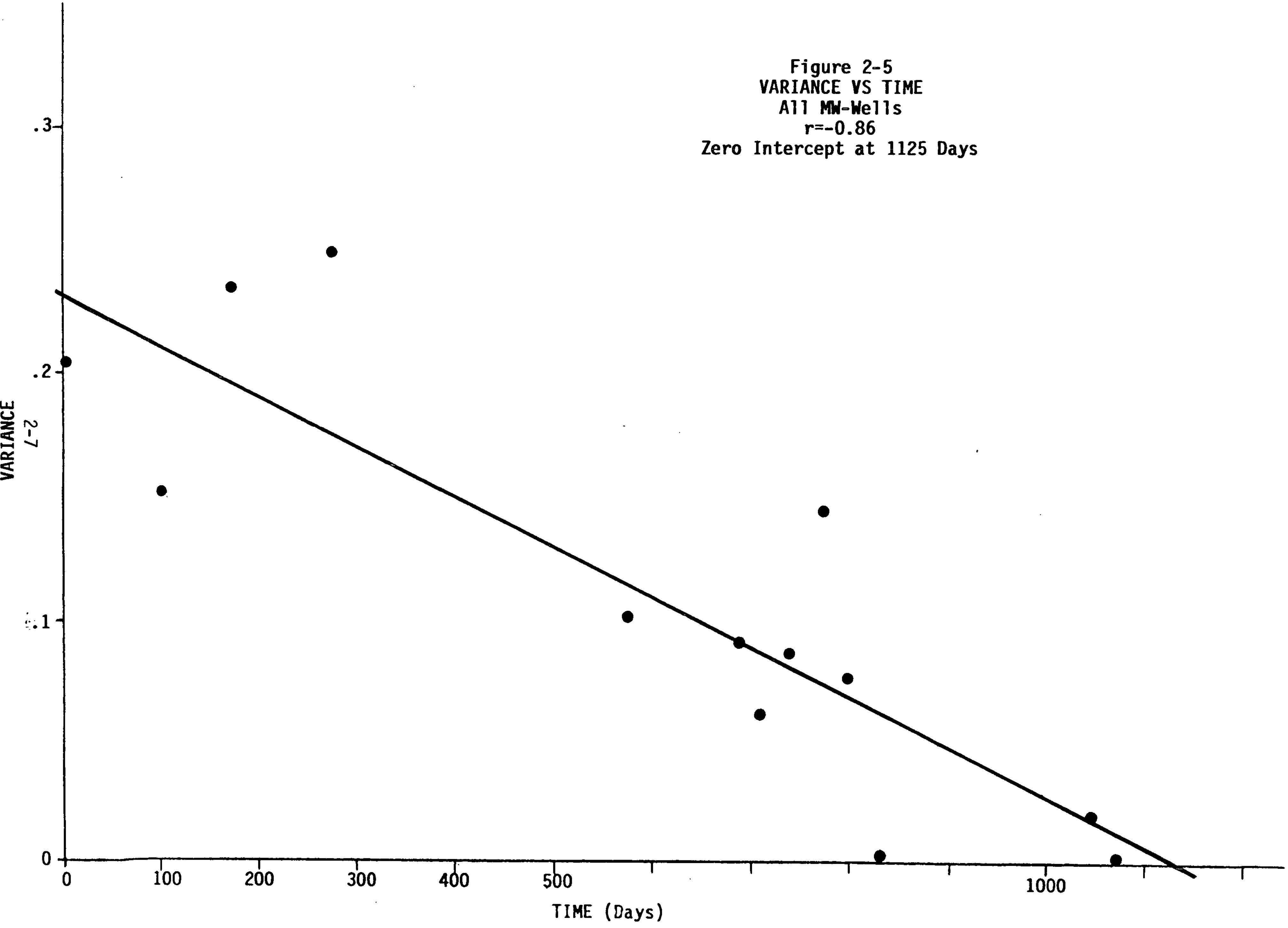

Figure 2-5
VARIANCE VS TIME
All MW-Wells
r=-0.86
Zero Intercept at 1125 Days

TABLE 2-1
December, 1984 TOX Analyses

To: Giant Refinery

1183
Page 2 of 2

ANALYTE	SAMPLE ID/ANALYTICAL RESULTS		
	Blank	MW-1 52	NOMINAL DETECTION LIMIT
pH	7.4	8.7	0.01
EC	1100 umhos/cm	1180 umhos/cm	0.1 umhos/cm

	MW-1 52 Vial	MW-2 52	MW-3 52	MW-4 52	OW-2
TOC	8.0 mg/l	7.0 mg/l	5.0 mg/l	6.0 mg/l	11.0 mg/l
TOX	<0.01 mg/l	<0.01 mg/l	<0.01 mg/l	<0.01 mg/l	<0.01 mg/l

	OW-7	OW-24 52	# 1 Pond Outlet	Blank	MW 1B
TOC	5.0 mg/l	12.0 mg/l	1560.0 mg/l	4.0 mg/l	4.0 mg/l
TOX	<0.01 mg/l	<0.01 mg/l	<0.05 mg/l	<0.01 mg/l	<0.01 mg/l

	NOMINAL DETECTION LIMIT
TOC	0.1 mg/l
TOX	0.01 mg/l

REFERENCES: 1."Standard Methods for the Examination of Water and Wastewater", 15th Edition, APHA, N.Y., 1980.

2. EPA-SW 846

An invoice for services is enclosed. Thank you for contacting Assaigai Laboratories.

Sincerely,

Jennifer V. Smith, Ph.D.
Laboratory Director

3.0 PROPOSED RESOLUTION OF METALS PROBLEMS: OBSERVATION WELLS

3.1 DISCUSSION OF POTENTIAL CAUSES: CURRENT METALS CONCENTRATIONS

Levels of lead (Pb) and mercury (Hg) have been found in ground water samples from the observation wells on the refinery site. These observed concentrations have locally and occasionally exceeded drinking water standards, but no clear pattern is presently apparent in space or in time. We are confident that these metals are not derived from any refinery process, product or effluent; but are rather the result of naturally-occurring levels of these elements in the Chinle Formation and its associated ground water, or the result of inconsistent sampling, filtration, preservation and analytical protocols. The revised sampling and analytical protocols (Appendix A) should resolve these problems.

Table 3-1 (Table 29.1-1 in the December 1, 1984 Part B application) summarizes the background levels of metals in shallow soils from the land farm area prior to any activity. The samples listed in Table 3-1 were taken prior to the first land application of wastes, and this Table shows the results of analyses using the RCRA extraction procedure and a total metals extraction. These analyses show that total Pb ranges from 23 to 29 ppm (average 25.8 ppm), and Hg ranges from < 0.04 to 0.9 ppm (average 0.10 ppm). These levels are very significant, and can affect ground water quality in two primary ways. First, the very slow pore velocity in the shales of the Chinle Formation allows long leaching times, which would increase the natural lead and mercury content of the ground water. Second, the previously-employed filtration practices may have allowed sample contamination by incomplete filtration of the highly turbid

TABLE 3-1

BACKGROUND SOIL ANALYSES[a]

SAMPLE LOCATION	pH	TOC	As	Ba	Cd	Cr	Cr^{+6}	Pb	Hg	Se	Ag
LF-1											
0-12"	8.6	4800									
EP Toxicity			<0.01	<10	0.002	<0.001	<0.01	<0.001	<0.0004	0.01	<0.01
(RCRA limits)			(5)	(100)	(1)	(5)	(5)	(5)	(0.2)	(1)	(5)
Total Metals 31			20	980	0.2	34	<1	26	0.04	<1	7.8
12-24"	-	4700									
EP Toxicity			<0.01	<10	0.001	<0.001	<0.01	0.003	<0.0004	<0.01	<0.01
Total Metals			50	970	0.2	34	1	27	<0.04	<1	<1.0
24-36"	-	4700									
EP Toxicity			<0.01	<10	0.001	<0.001	<0.01	0.002	<0.0004	<0.01	<0.01
Total Metals			50	860	0.2	34	<1	24	0.05	<1	2.2
LF-2											
0-12"	8.4	4800									
EP Toxicity			<0.01	<10	0.001	<0.001	<0.01	0.001	<0.0004	<0.01	<0.01
Total Metals			40	970	0.2	29	<1	28	<0.04	<1	2.0
12-24"	-	4700									
EP Toxicity			<0.01	<10	0.002	<0.001	<0.01	<0.001	<0.0004	<0.01	<0.01
Total Metals			50	1,100	0.3	39	1	26	0.1	<1	1.4
24-36"	-	4700									
EP Toxicity			<0.01	<10	<0.001	<0.001	<0.01	0.002	<0.0004	<0.01	<0.01
Total Metals			50	940	0.1	36	<1	23	<0.04	<1	<1.0
LF-3											
0-12"	8.9	4700									
EP Toxicity			<0.01	<10	0.002	<0.001	<0.01	<0.001	<0.0004	<0.01	<0.01
Total Metals			40	1,000	0.4	34	1	26	<0.04	<1	<1.0
12-24"	-	4700									
EP Toxicity			<0.01	<10	0.002	<0.001	<0.01	<0.001	<0.0004	<0.01	<0.01
Total Metals			50	970	0.2	45	<1	24	0.9	<1	<1.0
24-36"	-	4800									
EP Toxicity			<0.01	<10	0.002	<0.001	<0.01	0.001	<0.0004	<0.01	<0.01
Total Metals			40	870	0.2	40	<1	26	0.04	<1	<1.0
LF-4											
0-12"	8.7	4800									
EP Toxicity			<0.01	<10	0.001	<0.001	<0.01	<0.001	<0.0004	<0.01	<0.01
Total Metals			50	880	0.2	36	<1	29	<0.04	<1	2.7
12-24"	-	4700									
EP Toxicity			<0.01	<10	<0.001	<0.001	<0.01	<0.001	<0.0004	<0.01	<0.01
Total Metals			50	1000	0.1	33	<1	23	0.09	<1	<1.0
24-36"	-	4700									
EP Toxicity			<0.01	<10	0.002	<0.001	<0.01	0.002	<0.0004	<0.01	<0.01
Total Metals			50	880	0.2	23	2	28	0.05	<1	<1.0
OW-4											
0-12"	8.5	4800									
EP Toxicity			<0.01	<10	0.001	<0.001	<0.01	0.003	<0.0004	<0.01	<0.01
Total Metals			40	930	0.2	30	<1	29	<0.04	<1	<1.0
12-24"	-	4700									
EP Toxicity			<0.01	<10	<0.001	<0.001	<0.01	0.003	<0.0004	<0.01	<0.01
Total Metals			50	970	<0.1	34	<1	23	0.05	<1	3.2
24-36"	-	4700									
EP Toxicity			<0.01	<10	<0.001	<0.001	<0.01	<0.001	<0.0004	<0.01	<0.01
Total Metals			50	890	0.3	29	<1	25	<0.04	<1	<1.0
36-48"						20					
48-60"						20					
60-72"						30					

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[a] Dames and Moore, Albuquerque, NM; Groundwater and Soils Investigation, Ciniza Refinery, Near Gallup, New Mexico for Shell Oil Company, March 1981; p. 11. pH, standard units; Total Organic Carbon (TOC) and Total Metals, mg/kg.

samples obtained from OW wells. As calculated by Mr. Thomas Andrews (Delta H Engineering, Ltd.), a 1-litre water sample containing 1.0% silt with a Pb concentration of 25 ppm would, at 80% filtering efficiency, raise the <u>apparent</u> concentration of Pb in the water to 0.05 mg/l. A similar calculation for Hg gives apparent water concentrations of 0.0002 ppm Hg for the average soil Hg content of 0.10 ppm, and about 0.002 ppm for the highest (0.9 ppm) Hg soil analysis. This hypothesis is further supported by trace metal analyses performed by DOE under the National Uranium Resource Evaluation (NURE) program which show the ubiquitous occurrence of lead at the 10-30 ppm level in soils and sediments derived from the Chinle Formation.

The lead and mercury levels seen in the OW wells appear to be the result of leaching by ground water of naturally occurring concentrations of these elements in the Chinle-derived soils and bedrock of the Ciniza area, and the observed <u>temporal and spatial</u> variation in these levels is a natural phenomena. Variations which occur in levels of metals in consecutive samples from the same OW wells may be attributable to problems with sample collection and filtration, and to variations in the results from different laboratories. Giant proposes the following program as outlined in Section 3.2 to resolve this issue.

3.2 PROPOSED PROGRAM FOR METALS ANALYSES

Giant Refining Company will institute a new sampling program for lead and mercury. In addition to resampling a representative group of OW wells, Giant will undertake a comprehensive investigation of the regional background concentrations of Pb and Hg in the Chinle Formation and its associated ground water. This investigation will encompass:

- Available published data on Pb and Hg concentrations in upper members of the Chinle Formation near Ciniza
- Available ground water analyses for Pb and Hg in the Ciniza area
- New analyses of soil and bedrock samples from background areas adjacent to the refinery
- New analyses of ground water from from wells adjacent to the refinery which are completed in the upper members of the Chinle
- Tritium analyses of ground water from OW wells, which will provide an indication of the minimum age of ground water
- A thorough statistical analysis of the background data collected in this investigation

A complete summary of these investigations and their results and interpretations will be prepared and submitted to Region VI. This report will address the nature of the regional and local background variations in Pb and Hg concentrations in soil, bedrock and groundwater. The present observed levels of Pb and Hg in OW well samples will be re-interpreted in the context of these natural concentrations and their spatial variations. Specific proposals for modifying the ground water monitoring plan to accomodate this new and revised background data will be made at that time.

3.2.1 Resampling Of The OW Wells

When done?

Samples will be collected from a minimum of 3 upgradient and 9 downgradient observation wells, in strict accordance with the revised precedures. The exact wells to be sampled will be determined by a careful examination of the site hydrogeology and a review of the existing data base. A list of the proposed wells for re-sampling will be supplied to Region VI for review prior to sampling. These samples will be split between 2 EPA-certified laboratories, and reference "spikes" will be prepared by and exchanged between the laboratories. This phase of the metals program will identify: site-scale spatial variations in ground water chemistry, chemical variations associated with different well-completion intervals (sandstone lenses vs shale beds) and any laboratory biases or errors.

3.2.2 Review Published Data On Chinle Formation Hydro/Geochemistry

In addition to previous analyses performed by Giant, data from the Department of Energy's National Uranium Resource Evaluation (NURE) program has been obtained. The NURE data includes over 20 lead and other trace-metal analyses from soils in the Grants-Ciniza area, which demonstrate the ubiquitous occurrence of lead at the 10 to 30 ppm level in sediments directly derived from the Chinle Formation. A computer-assisted search will also be made for any other available information on trace-metal distributions in the Chinle Formation and its associated ground water.

3.2.3 Background Soil and Weathered Bedrock Analyses

To better characterize the local and regional concentrations of Pb and Hg in the Chinle and its associated soils, a program of sampling and analysis is proposed. Soil and weathered bedrock samples will be collected (under controlled conditions) from the land farm area, a selected background area adjacent to the land farm, and from selected areas on and adjacent to the refinery site. Locations of proposed sample sites and the justifications for their selection will be provided to Region VI prior to sampling. The "background" sites on and adjacent to the refinery will be selected by a qualified geologist, who will insure the use of appropriate sampling techniques, as outlined in Appendix A.

3.2.4 Regional Ground Water Quality Investigation

In order to more accurately characterize the natural concentrations and variations in lead and mercury in ground water from the upper Chinle Formation, Giant will initiate a program of identifying and sampling selected wells outside the refinery which are completed in the Chinle. Wells will be identified by searching New Mexico State Engineer's files, by inspection of area maps, field reconaissance, and by interviews with local residents and water-well drillers. Suitable wells will be sampled and ground water analysed according to the same protocols as the on-site monitoring and observation wells.

3.2.5 Tritium Isotope Analyses Of Ground Water Samples

Tritium (H^3) is a radioactive isotope of hydrogen with a half-life of 12.26 years. This isotope did not occur in detectable levels in the atmosphere prior to atmospheric testing of nuclear devices in the 1940's through the early 1960's. Atmospheric levels of tritium have been continuously monitored since the 1950's, and the relative concentration of H^3 in ground water samples can be used to assist in establishing the date of the recharge of water from the atmosphere (by precipitation) to the ground water. If no measurable tritium is found in the ground water, then it must be concluded that the ground water was recharged prior to the 1940's, or that recharge is so slow that any tritium influx is diluted below detection limits by pre-existing "fossil" water.

3.2.6 Statistical Analyses Of Background Data

Giant Refining Company will prepare a statistical analysis of data from previous published and new sources as proposed above. This analysis will include the Cochran's Approximation to the Behrens-Fisher Student's t-test (CFR 40.264.97 h(1) and CFR 40, Appendix IV), as well as other equivalent methodologies which might better characterize the significance of the observed on-site levels of metals in the context of complexly variable natural background concentrations.

APPENDIX A

SAMPLING AND ANALYSIS PROCEDURES

A.1.0 GROUND WATER SAMPLING PROCEDURES

A.1.1 Sampling Equipment

Equipment necessary for collecting representative ground water samples includes a 200 foot fiberglass, plastic or steel measuring tape with a weighted bottom, or an electronic water-level indicator; carpenters chalk or water-indicating paste if a tape is used to measure water levels; distilled water and wash bottles, steam cleaner, paper towels or clean rags, plastic sheeting, a bottom-filling PVC, teflon or stainless steel bailer; a submersible pump with appropriate attachments to enable purging the well; a graduated bucket; a hose to direct pump discharge away from the well; sample containers with the appropriate volume of preservatives added to the containers by the laboratory; waterproof marking pen; pH meter; thermometer; specific conductivity meter; field sample log book; pen; ice and ice chest for samples; strapping tape and shipping labels.

A.1.2 Sampling Techniques

A 1.2.1 Water Level Measurement

Prior to collecting any ground water samples, the depth to water in the well bore is measured and recorded in the field log book. An example of the field log form is shown in Figure A-1. The procedures to be used in measuring water levels are as follows:

1. Plastic sheeting is placed around the well to protect sampling equipment from possible contamination.
2. If the casing cap is not vented, the well must be allowed to

Geoscience Consultants, Ltd.
500 Copper Avenue N.W.
Suite 220
Albuquerque, New Mexico 87102

CLIENT ____________
LAB ____________
DATE RECEIVED ____________
DATE ANALYZED ____________

WATER QUALITY ANALYSIS

Sample Location ____________
Date ________ Time ______ Collected By ____________

SAMPLING CONDITIONS

Samp. Type	________	pH	________
Color	________	Cond	________
Odor/Taste	________	Temp	________
Water Level	________	Flow Rate	________
Datum	________	Elevation	________

Remarks on sampling and preservation ____________

____

____

WATER CHEMISTRY

_____ 1 liter plastic cool to 4° C

☐ Ca	_____mg/l	☐ HCO_3	_____mg/l
☐ Mg	_____mg/l	☐ CO_3	_____mg/l
☐ K	_____mg/l	☐ Cl	_____mg/l
☐ Na	_____mg/l	☐ F	_____mg/l
☐ Si	_____mg/l	☐ SO_4	_____mg/l
☐ TDS	_____mg/l	☐ TSS	_____mg/l

_____ 500 ml plastic HNO_3 to pH 2

☐ As	_____mg/l	☐ Ag	_____mg/l
☐ Ba	_____mg/l	☐ Se	_____mg/l
☐ Cd	_____mg/l	☐ Fe	_____mg/l
☐ Cr	_____mg/l	☐ Mn	_____mg/l
☐ Pb	_____mg/l	☐ Hg	_____mg/l

_____ VOA bottles

☐ Benz	_____mg/l	☐ Tol	_____mg/l
☐ Xyl	_____mg/l	☐ SCAN	

_____ 500 ml plastic H_2SO_4 to pH 2

☐ NO_3	_____mg/l	☐ TOC	_____mg/l
☐ NH_4	_____mg/l	☐ TKN	_____mg/l

_____ 250 ml glass TOX _____ mg/l
(use 6.25 mg N_aSO_4 if free
Cl is present)

_____ 250 ml glass H_3PO_4 $CuSO_4$
☐ Phenol _____mg/l

☐ Gr Al _____mg/l ☐ Gr Bet _____mg/l

Remarks on Analyses: ____________

____

CHAIN OF CUSTODY

Shipped or delivered to lab by ____________
Date ____________ Time ____________

I hereby certify that to the best of my knowledge water samples (amt/size ________) were obtained to accordance with ____________'s (Owner) sampling and analysis plan and are safely containerized and labeled for delivery to the laboratory.

Signature ____________ RECEIVING LABORATORY ____________
Address ____________
Attn: ____________
____________ All Samples received intact.
____________ List samples missing or damaged
Date Received ____________ Time ____________

Figure A-1

stand open for about 10 minutes to equilibrate to atmospheric pressure.

3. The sounder or tape is cleaned with distilled water and dried with a clean paper towel, and coiled on the plastic sheet.
4. If a tape is used, the bottom 2 feet of the tape is coated with chalk or paste and the tape is lowered into the well until it encounters water. The tape is held at the top of the casing and the measurement recorded ("hold"). The measurement where the water level cuts the chalk or paste is also recorded ("cut") and subtracted from the "hold" measurment to obtain the depth to water. Because the elevation of the casing top is known, the water level elevation is determined by subtracting the depth to water from the casing top elevation.

   An electronic sounder is used in a similar manner. When the sounder contacts ground water, a circuit is closed resulting in a "beep" from the sounder or a strong reading on a ammeter. The "hold" measurement is the depth to ground water. After determining the depth to water, the measuring device should be lowered to the bottom of the well, and the total depth (TD) below the casing top recorded.

A 1.2.2 Well Evacuation

At least three casing volumes of standing water must always be removed from the well bore prior to collecting ground water samples. The following two methods may be used to calculate the volume of water which must be removed from the well prior to sampling:

METHOD 1

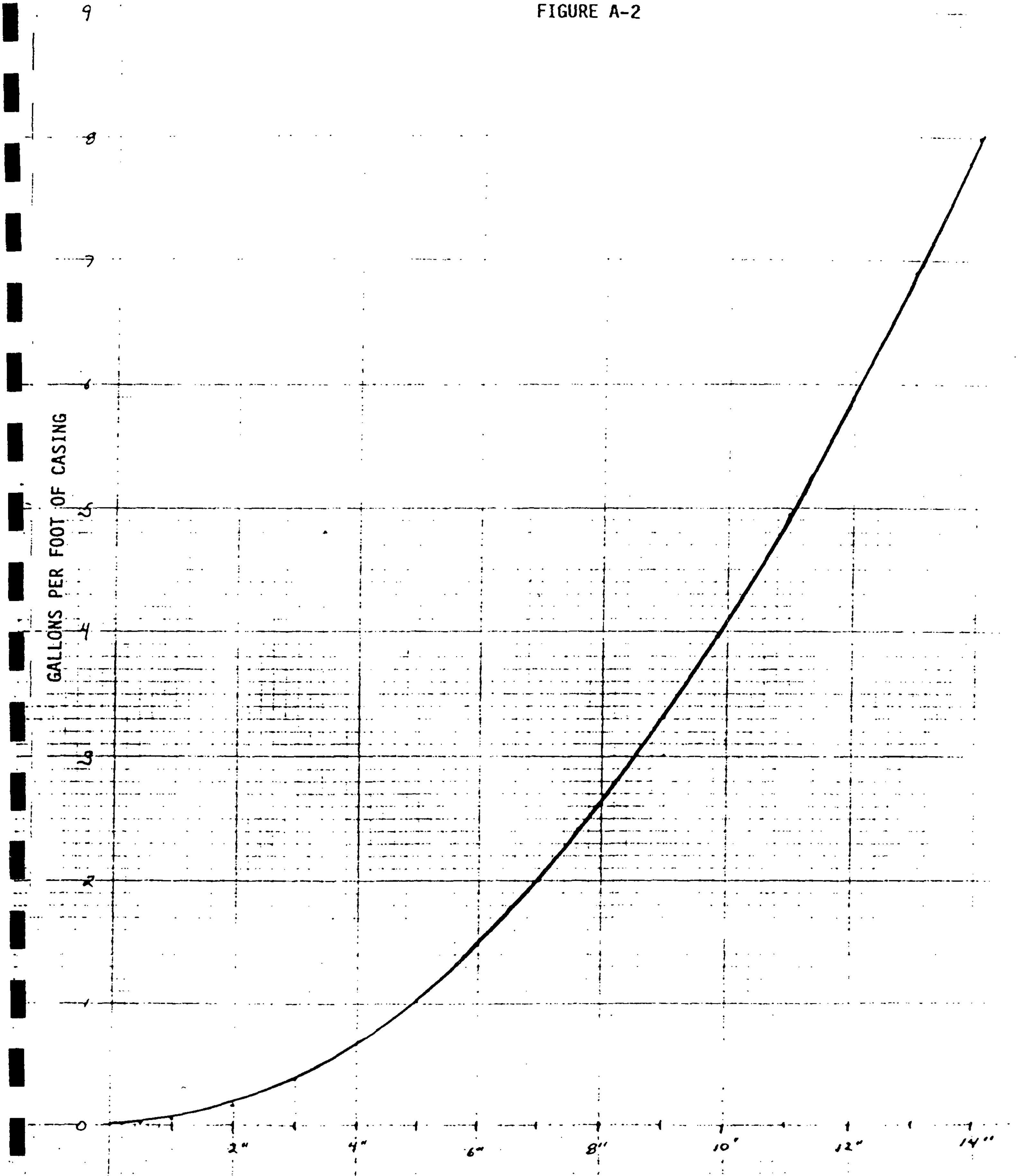
1. Measure the true inside diameter of the well casing (annulus) with a tape, and convert to "gallon per foot of casing" (Figure A-2)
2. Multiply the appropriate "gallons per foot of casing" by the standing water height (depth to water) - (total depth)
3. Multiply the resulting number of gallons in the casing by 3 (for 3 casing volumes). This is the number of gallons to be removed for purging.

METHOD 2

1. Measure the time diameter of the well bore, and convert to feet and find the radius by dividing by 2.
2. Volume (cubic feet) = 3.14 x $(\text{radius})^2$ x [(depth to water)-(total depth)]
3. Volume (gallons) = Volume (cubic feet) x 7.48 gal/cubic foot

A submersible pump will be employed to evacuate the wells prior to sampling. The pump will be thoroughly rinsed with distilled water or steam cleaned prior to use on each well. A graduated bucket will be used to measure the volume of water removed. By timing the interval required to fill the graduated bucket, the pump discharge rate in gallons per minute may be calculated by dividing the quantity measured (gallons) by the time required to fill the bucket (minutes). The time required to purge 3 casing volumes is calculated by dividing the volume of the well in gallons by the rate of discharge in gallons per minute.

FIGURE A-2



A 1.2.3 Sample Collection, Preservation and Field Analysis

Ground water samples will be collected with a teflon bailer which has been thoroughly cleaned with laboratory soap and rinsed in distilled water or steam cleaned. Prior to sample collection, the bailer will be rinsed with ground water by withdrawing three bailer volumes from the well. A 1500 ml glass flask which has been cleaned with laboratory soap, rinsed with distilled water and rinsed three times with well water will be filled for field determination of specific conductance, pH and temperature. The values are recorded in the log book and the sample discarded.

Sample containers will be rinsed three times with ground water except for those which contain a chemical preservative. Samples will be transferred from the bailer to sample containers using the apparatus shown in Figure A-3. This device reduces aeration and minimizes spillage. The bailer emptying device is cleaned in the same manner as the bailer. Table A-1 shows the volume of sample to be collected for each analysis and the volume and type of preservative used for each aliquot. Sample containers for volatile organic constituents must be filled in VOA glass containers so that no air space or bubbles are present in the sample

Selected samples for metals analysis will be filtered (0.45 micron) prior to preservation and analysis. Unfiltered samples will be collected from all sampling points. Samples of wastewater or surface water will be collected with a fully cleansed and rinsed dipper.

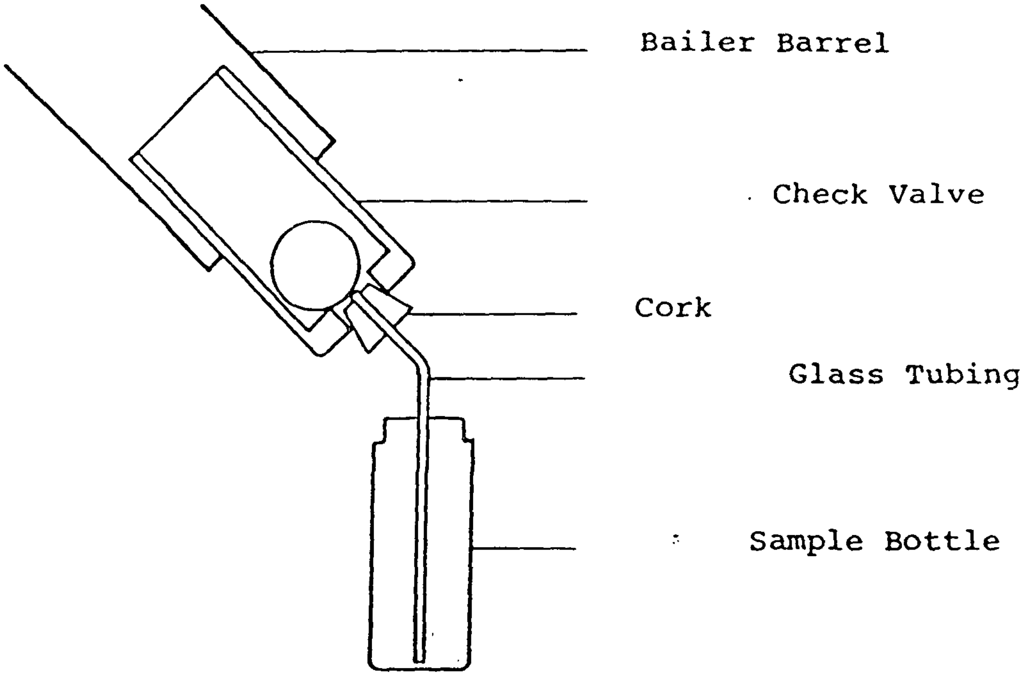
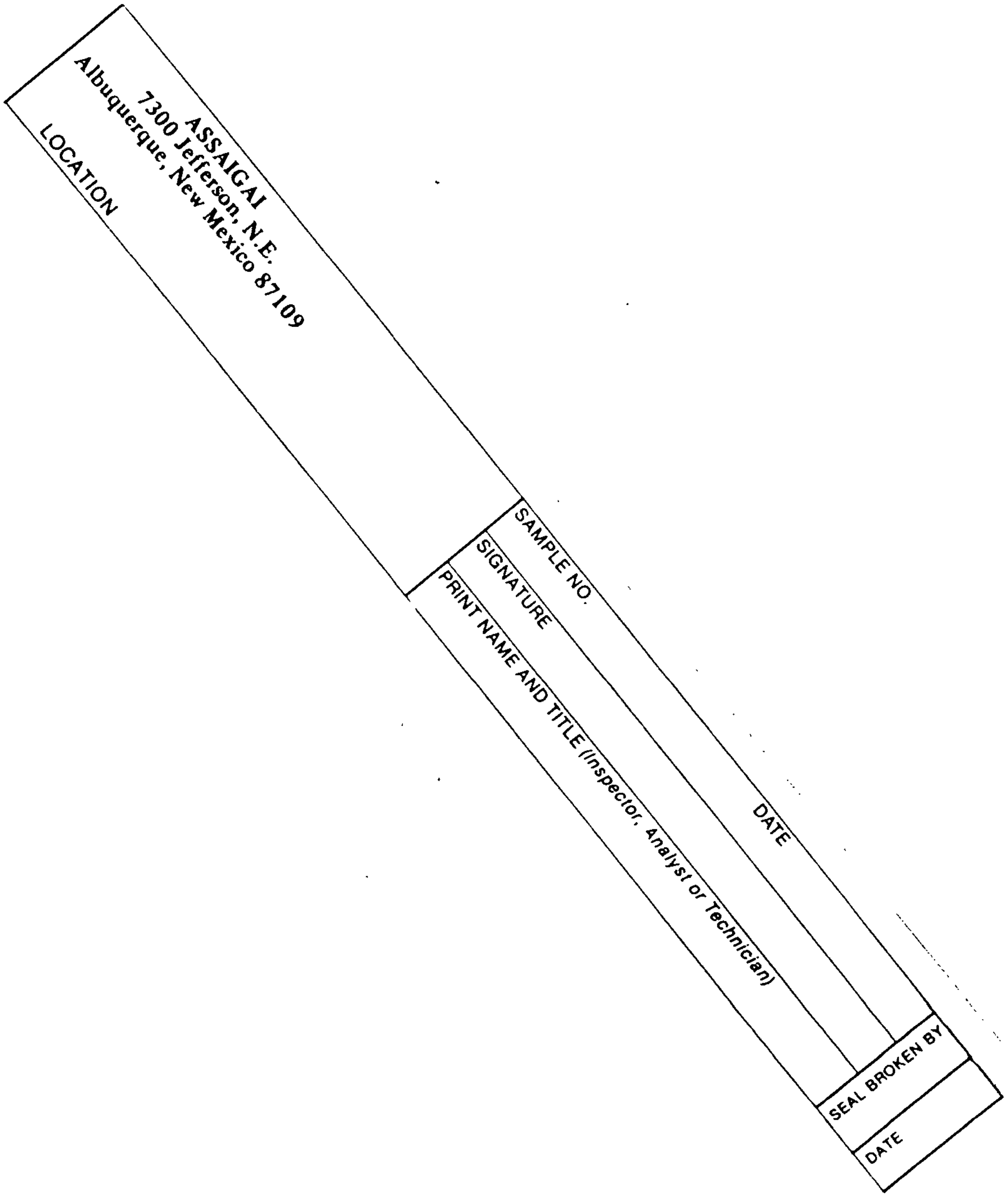


Figure A-3 Bailer Emptying Device

Table A-1 SAMPLE CONTAINERS AND ANALYTICAL METHODS.

W = water sample; S = soil sample; "Ice" = pack in a cooler with ice (approx. 4 degrees C)

SAMPLE CONTAINER	PRESERVATION	PARAMETER(S)	ANALYTICAL METHOD
GROUP I. ORGANICS			
40 ml glass vial (W;S)	Ice; keep in dark	Purgeables by GC/MS	EPA Method 624
1 gal. amber glass jug (W)	Ice; keep in dark		
or 1 liter amber glass jar (S)	Ice; keep in dark	Chlorinated Hydrocarbon Pesticides	EPA Method 608
		Chlorophenoxy Acid Herbicides	EPA 1979 Interim
		EP Toxicity (soil only)	40 CFR 261, App II
GROUP II. METALS			
1 liter cubitainer (W) or	Ice; 2 ml HNO_3	ICAP Scan	EPA Method 207
1 liter amber glass jar (S)	Ice	Arsenic	EPA Method 206.2
		Mercury	EPA Method 245.1
		Selenium	EPA Method 270.2
		EP Toxicity (soil only)	40 CFR 261, App II
GROUP III. NITROGEN and TOC			
1 liter cubitainer (W)	Ice; 2 ml H_2SO_4	Nitrate (water only)	EPA Method 353.2
same jar as metals (S)		Ammonia	EPA Method 350.1
		Total Organic Carbon	EPA Method 415.1
GROUP IV. GENERAL CHEMISTRY			
1 gallon cubitainer (W)	Ice	Carbonate/bicarbonate	EPA Method 310.1
		Chloride	EPA Method 325.2
		Fluoride	EPA Method 340.2
		pH	EPA Method 150.1
		Sodium/Potassium	Std. Methods 325(b)
		Specific Conductivity	EPA Method 120.1
		Sulfate	EPA Method 375.2
		Total Diss. Solids	EPA Method 160.1



ASSAIGAI
7300 Jefferson, N.E.
Albuquerque, New Mexico 87109

LOCATION

SAMPLE NO.

DATE

SIGNATURE

PRINT NAME AND TITLE (Inspector, Analyst or Technician)

SEAL BROKEN BY

DATE

Figure A-4 Chain of custody tape

A.2.0. SOIL SAMPLING PROCEDURES

A.2.1. Sampling Equipment

Necessary equipment for soils sampling includes:

- A detailed plat of the land farm and background-sample areas
- A methodology for random selection of sampling sites within the land farm and background areas
- Surveying equipment adequate for locating the selected sample locations
- Hand tools or a small backhoe, as necessary to clear the sample site to below the level of waste application
- Hand auger, powered auger or small drill rig with hollow-stem auger, as dictated by soil hardness and depth of required samples
- Split-spoon or other appropriate soil-coring device, with a diameter smaller than the auger used to advance the hole
- Steam cleaner (necessary for drill rig and backhoe) or laboratory soap and distilled water if hand tools and auger are used, brushes, clean rags or paper towels for clean-up
- Wyoming bentonite for refilling auger holes
- Plastic sheeting, steel tape measure, wash bottles with distilled water, 1-liter beaker, appropriate sample containers, stainless steel spoons, marking pens, sample log forms, chain-of-custody tapes, ice chest and ice, strapping tape and shipping labels.

A.2.2. Sampling Techniques For Land Farm Monitoring

A.2.2.1. Sample Site Location

Using the plat map of the land farm and background sample areas and the random location program, select three sample sites in the land farm, and one site in the background area. Reject any sites within five feet of a previous site. Locate the proposed sites on the plat, and stake these locations in the field, using appropriate surveying techniques and equipment. Record sample site coordinates on the field log form (Figure A-5), and note date and amount/density of last waste application in the site area.

A.2.2.2. Sampling Procedures

After locating the sampling site, carefully steam-clean all shovels, augers, etc. or wash tools with laboratory soap and rinse three times with distilled water. Then proceed as follows:

1. Excavate a small (2' x 2') hole to the bottom of the plowed zone of the land farm (about 1 or 2 feet); also dig to a similar depth in background areas, record depth on the log form. Spread plastic sheet around hole to protect tools and samples.
2. Using a clean stainless steel spoon, remove about one tablespoon of soil at each inch of depth from the side of the shallow hole, and put these samples in the cleaned 1-liter beaker.
3. Thoroughly mix the soil in the beaker with the sampling spoon.
4. Fill and seal appropriate number of VOA bottles with soil from the beaker, attach chain-of-custody tapes.
5. With a clean auger, advance the sample hole (from the bottom of the hole dug in step 1) to a depth of 1.0 feet below the depth of the disturbed (treatment) zone and log the depth. Never add water to the hole.
6. Drive the soil-core device into the soil at the bottom of the auger hole, and remove the barrel with core.
7. Remove the soil core from the coring device, and discard the upper and lower 1/4th of the core.
8. With a clean spoon; fill, seal and label appropriate number of VOA bottles with soil from the core, as in step 4.
9. Clean all tools.
10. Advance auger hole to 3.0' below the base of the treatment zone, and repeat steps 6-9.
11. Backfill the auger and surface holes with alternate layers of native material and bentonite, 1 or 2 shovels per layer. Compact the dry material firmly with hand tools.
12. Check that all samples are properly labeled and sealed, and store with ice in ice chest.
13. Clean all tools before moving to the next site.

A.2.3. Sampling Techniques for Regional Background

On a one-time basis, background samples should be collected from representative soils and outcrops in areas adjacent to but not involved in refinery operations. These samples should be taken from areas which are geologically and pedologically similar to the land treatment area. A qualified geologist should assist in selecting these sample sites, and should prepare a detailed map showing the location and geological environment of each site.

Where practical, samples should be collected, labeled and handled according to the procedures described in A.2.2.2. Any exceptions from the sampling procedures of that section should be clearly noted on the sample log form.

A.3.0. CHAIN OF CUSTODY

All samples are to be promptly labeled at the time and point of sampling. Labels include the following information:

- name of collector(s)
- year, month, date and military time (YYMMDDHHHH becomes the unique identification number)
- point of collection

written with a waterproof marker directly on the container. The information may need to be covered with transparent tape to prevent smearing, etc. The above information is also recorded in the sample log book with other information concerning the sampling.

Each sample will be sealed at the time and point of collection with a chain of custody tape (Figure A-4) which has been filled out by the sample collector. The original of the field form with the chain of custody information will accompany the sample to the laboratory. A copy of the field form will be retained by the collector.

Samples will be packed with ice and shipped to the laboratory to arrive at the laboratory on the next day. Samples will be collected early in the week to permit the laboratory to immediately analyze those samples with short holding times.

FIGURE A-5

Geoscience Consultants, Ltd.

500 Copper Avenue N.W.
Suite 220
Albuquerque, New Mexico 87102

CLIENT ______
LAB ______
DATE RECEIVED ______
DATE ANALYZED ______
SAMPLE NUMBER ______

Sample Location ______
Date ______ Time ______ Collected By ______

SAMPLING CONDITIONS

Elevation ______ Depth ______ to ______ Recovery ______%
Color ______ Odor ______ Waste ______ Moisture ______%
Boring Type: Hollow Stem ☐ Hand/Power Auger ☐ Hand Dug ☐ Surface ☐
Sample Type: Shelby ☐ Split Spoon ☐ Push Tube ☐ Cuttings ☐ Hand Dug ☐
Sample Purpose: Treatment Area Monitoring ☐ Upgradient ☐ Regional Background ☐
Formation ______ Member ______ Bedrock ☐ Fresh ☐ Weathered ☐
Sample Amount ______ gr Sample Container ______ Number of Splits ______
Remarks on sampling and preservation ______

______

______

ANALYSES

Metals

- ☐ As
- ☐ Ba
- ☐ Cd
- ☐ Cr
- ☐ Pb
- ☐ Hg
- ☐ Se
- ☐ Ag

- ☐ Fe
- ☐ Mn
- ☐ PH
- ☐ EC
- ☐ ______
- ☐ ______
- ☐ ______

Organics

- ☐ TOX
- ☐ TOC
- ☐ Oil & Grease
- ☐ Pest/Herbacide
- ☐ GC Scan
- ☐ ______
- ☐ ______
- ☐ ______

Remarks on Analyses: ______

______

CHAIN OF CUSTODY

Shipped or delivered to lab by ______
Date ______ Time ______

I hereby certify that to the best of my knowledge water samples (amt/size ______) were obtained to accordance with ______'s (Owner) sampling and analysis plan and are safely containerized and labeled for delivery to the laboratory.

Signature ______ RECEIVING LABORATORY ______
Address ______
Attn: ______

______ All Samples received intact.
______ List samples missing or damaged
Date Received ______ Time

A 4.0 ANALYTICAL PROCEDURES

A.4.1 ANALYTICAL METHODS

Table A-1 shows the method to be employed for each water or soil analysis. Samples will be analyzed by one or both of the following laboratories:

Assaigai Analytical Laboratories in Albuquerque, New Mexico

Rocky Mountain Analytical in Denver, Colorado

A.4.2 QUALITY ASSURANCE/QUALITY CONTROL

Laboratories which perform analyses will conform to the following minimum quality standards:

For water or soil samples, at least 5% or 1 sample per lot (whichever is larger) will be selected at random for duplicate analysis

Blanks will be included at 5% or 1 per lot, as above

A quality assurance analysis will be run with each lot, and a report of the results will be made available to the client

All samples, including quality controls, will be processed "blind", and processed in an identical manner

Laboratory standards will be derived from EPA standards

EPA standards will be run quarterly, and results shall be made available to the client

The laboratory shall designate a quality control/assurance officer, who shall be responsible for compliance with all quality control proceedures

It is understood that the above standards are considered to be adequate minimums for analyses for regulatory submissions. Higher levels of quality control and assurance may be specified, although such specifications will entail higher costs. Each laboratory will provide a "spiked" sample for each analytical parameter, at a concentration approximately equal to the groundwater standard for that parameter, and include an analysis of the spike. Spikes will be exchanged between laboratories.

ATTACHMENT B-4

ATTACHMENT B-4

RESPONSE TO ITEMS 3 AND 4
OF DECEMBER 4, 1984 EPA LETTER
RE: GROUND WATER MONITORING COMPLIANCE
DEFINITION OF UPPERMOST AQUIFER
UNSATURATED ZONE MONITORING
GIANT INDUSTRIES, INC.
CINIZA REFINERY
GALLUP, NEW MEXICO

February 28, 1985

Submitted to;

Mr. David L. Olschewsky
Chief, Technical Section
US Environmental Protection Agency Region VI
1201 Elm Street
Dallas, Texas 75270

Prepared for:

Giant Industries, Inc.
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Prepared by:

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TABLE OF CONTENTS

LIST OF APPENDICES

1.0 EXECUTIVE SUMMARY

Giant Refining Company has installed a ground water monitoring system at the Ciniza Refinery land treatment unit which is fully consistent with 40 CFR 264.92, 264.97 and 265.91. Four ground water monitor wells (three down gradient and one upgradient from the facility) are completed in the uppermost aquifer (Sonsela Sandstone). Between the uppermost aquifer and the treatment zone are 80-100 feet of saturated and unsaturated shales of the Chinle formation. The extremely low vertical and horizontal permeability of the shale (5.1×10^{-9} to 1.3×10^{-8} ft/sec) and the strong upward hydraulic gradient between the Sonsela Sandstone and the overlying shale form a very effective natural barrier between the treatment zone and the uppermost aquifer. This natural barrier is, in effect, a liner for the land treatment facility. The thickness of the aquitard, the high sorptive capacity of the shale and the hydrodynamic containment due to strong upward gradients combine to make this natural barrier more effective than engineered liners.

Although the natural barrier (aquitard) is saturated and could yield measurable quantities of water to a well, on July 26, 1982 EPA indicated that such barriers to leachate migration should not be subject to ground water monitoring as aquifers (47 Federal Register 32274).

Giant concurs with EPA's 1982 opinion which supports the determination of the Sonsela Sandstone as the uppermost aquifer at the site because:

- The Chinle shale cannot yield significant quantities of water to wells

- The saturated portion of the Chinle shale is an aquitard which acts as an effective natural barrier to potential downward migration of leachate from the treatment unit
- The Chinle shale has never been developed as a water resource in the southern San Juan Basin
- The Chinle shale could never effectively be developed as a water resource
- The Sonsela is recognized by <u>all</u> New Mexico state agencies as an aquifer utilized extensively for domestic, agricultural and industrial purposes.

The demonstration of the above points is presented in sections 2.0 and 3.0 of this document with supporting data and regulatory references included as Appendices A-F.

To insure that the natural barrier continues to be effective, the unsaturated zone monitoring system has been re-designed for increased effectiveness. Because lysimeters are not suited for the fine-grained, unsaturated portion of the aquitard, a soil and soil pore-fluid sampling program which is fully consistent with 40 CFR 264.278. is proposed for characterizing the pore-fluid chemistry immediately below the land treatment unit. Section 4.0 describes the proposed soil and soil pore-fluid sampling system.

2.0 REGULATORY BASIS FOR COMPLIANCE

RCRA regulations (40 CFR 264 Subpart F and 40 CFR 265 Subpart F) require the monitoring of ground water in the uppermost aquifer to characterize the ground-water quality in that unit and to ensure that hazardous constituents listed in 40 CFR 264.93, which may enter the ground water from the regulated unit at the Ciniza Refinery (land treatment area), do not exceed the concentration limits under 40 CFR 264.94 in the uppermost aquifer underlying the waste management area.

Giant has installed monitoring wells, has sampled ground water and has analyzed ground water samples from these wells which are located in the uppermost aquifer pursuant to the above-cited regulations. This response to item 3 in Mr. Olschewsky's (EPA Region VI, Chief Technical Section) letter of December 4, 1984 will clarify the apparent confusion which has developed regarding the hydrogeology at the Ciniza site, and the adequacy of the existing ground water monitoring system pursuant to the regulations cited herein.

2.1 DEFINITION OF AQUIFER AND COMPLIANCE WITH 40 CFR 264 SUBPART 260.10

For purposes of land-treatment facility monitoring under the Resource Conservation and Recovery Act ("RCRA"), the term "aquifer" is defined in 40 CFR 260.10 (Appendix A) as follows:

> "aquifer means a geologic formation, group of formations or part of a formation capable of yielding a significant amount of groundwater to wells or springs."

EPA's definition of "aquifer" was issued without discussion on May 2, 1980. This definition is similar to the proposed definition issued on

December 11, 1978, (40 CFR 250.41, December 18, 1978) (Appendix B) which stated:

> "Aquifer" means a geologic formation, group of formations, or part of a formation that is capable of yielding useable quantities of groundwater to wells or springs.

In the preamble to this proposed definition, EPA noted that it had received numerous inquiries about what constitutes a "useable quantity" of ground water, as used in the proposed definition. EPA stated that it had not yet decided how this quantity was to be determined, in light of the fact that relatively low yield aquifers can be "useable" in certain circumstances. The Agency suggested that a possible standard might be 600 gallons per day, which is enough water for a single household of four people. Comments on how the term "useable quantity" should be defined were specifically requested by EPA in 43 Fed. Reg. 59892-93 (December 18, 1978) (Appendix C).

Although the meaning of the term "aquifer" was not discussed in the preamble to the final definition adopted by EPA on May 2, 1980 (Appendix A), this issue was discussed in a subsequent Federal Register notice published on July 26, 1982, which added several definitions to 40 CFR 260.10 (47 Fed. Reg. 32274; July 26, 1982) (Appendix D). In the notice, EPA pointed out that the term "significant amount" used in the final definition is imprecise. According to the Agency, this concept is site-specific, depending on the demand for ground water. For example, the Agency stated that comments on the definition had suggested that the 600 gallons per day standard discussed in the preamble to the proposed definition is only applicable to municipal, public water-supply systems and that an individual demand of between 5 and 50 gallons per person per day would be appropriate for a family of four in a rural area relying on water from a single ground water supply well. Normal use of water for an individual for domestic purposes depends on lifestyle, plumbing type and other factors which are very difficult to quantify. However, the amount of water usually required for various domestic functions has been well established. Typical consumption rates which must be considered in arriving at a realistic number include:

o	5 - 10 minute shower	15 - 30 gallons
o	Direct consumption	0.5 - 1.0 gallons
o	Cooking	0.5 - 1.0 gallons
o	1 flush of a toilet	4.0 - 7.0 gallons
	TOTAL	20 - 39 gallons

Given these values it is difficult to imagine individual water usage to be much less than 20-40 gallons per day per person even for relatively frugal water users.

Also in the July 26, 1982 clarification (Appendix D), EPA cited comments stating that:

> " Many land disposal facilities are sited in areas where saturated upper clay layers are available to serve as a natural barrier to the migration of leachate into the groundwater in the actual uppermost aquifer." (emphasis added) (Appendix D)

This situation is exactly the case at Giant's Ciniza Refinery. The land treatment area at the refinery is sited on low permeability clays and shales of the Chinle Formation which are saturated approximately 15 feet below the land surface. These shales serve as a natural barrier (aquitard saturated from below) which confines and protects the Sonsela

Sandstone (uppermost aquifer at the site) from any potential downward migration of land treatment-area leachate, if such leachate exists. These characteristics of the hydrogeologic environment are fully demonstrated and quantified in Section 3.0 of this submission.

Furthermore, in the July 26, 1982 clarification it is stated that:

> "...any saturated soil material can yield quantities of groundwater to wells even at an extremely low rate..." (emphasis added) (Appendix D)

According to the clarification, one extreme interpretation of the definition of aquifer could require the monitoring (pursuant to 40 CFR 264 Subpart F) of these natural barriers or even water-saturated landfill liners made of clay. This is followed by a definitive statement by EPA that affirms that:

> "It was never the Agency's intent to consider saturated clay landfill liners to be subject to ground water monitoring as an aquifer." (emphasis added) (Appendix D)

It is obvious through this line of reasoning that ground water monitoring requirements should not apply to the aforementioned "saturated upper clay layers" cited in the preceeding paragraph of the clarification. Section 3.0 clearly demonstrates that the Chinle shale is the hydrogeologic equivalent of a clay liner, and would exceed the performance criteria of any such liner due to its thickness (80-100' at Ciniza).

In the July 26, 1982 Federal Register notice (Appendix D), EPA announced that it intended to define the term "aquifer" more precisely at a subsequent time, in a manner consistent with both the RCRA program and the Safe Drinking Water Act program.

Even though further clarification on this issue has not yet been published by EPA, the Safe Drinking Water Act protects "Underground Sources of Drinking Water" (USDW, see 40 CFR 144.3) which are defined as an aquifer or its portion:

> "(a)(1) Which supplies any public water system; or
>
> (2) Which contains a sufficient quantity of ground water to supply a public water system; and
>
> (i) Currently supplies drinking water for human consumption; or
>
> (ii) Contains fewer than 10,000 mg/l total dissolved solids; and
>
> (b) Which is not an exempted aquifer."

This definition clearly excludes a saturated-clay unit like the Chinle shale which overlies the Sonsela aquifer <u>because:</u>

- o it does not currently supply a public water system
- o it does not contain sufficient ground water to supply a public water system
- o it does not currently supply drinking water for human consumption due in part to naturally elevated TDS concentration.

Unlike the Chinle shale, the Sonsela Sandstone meets all of the technical and regulatory definitions of an aquifer. This aquifer, which lies a a depth of less than 100 feet throughout the refinery area, can yield usable quantities of good quality water at a reasonable cost. Even if development of the Chinle aquitard as a water source in this area was technically possible, it would require a substantial and questionable investment of time and funds.

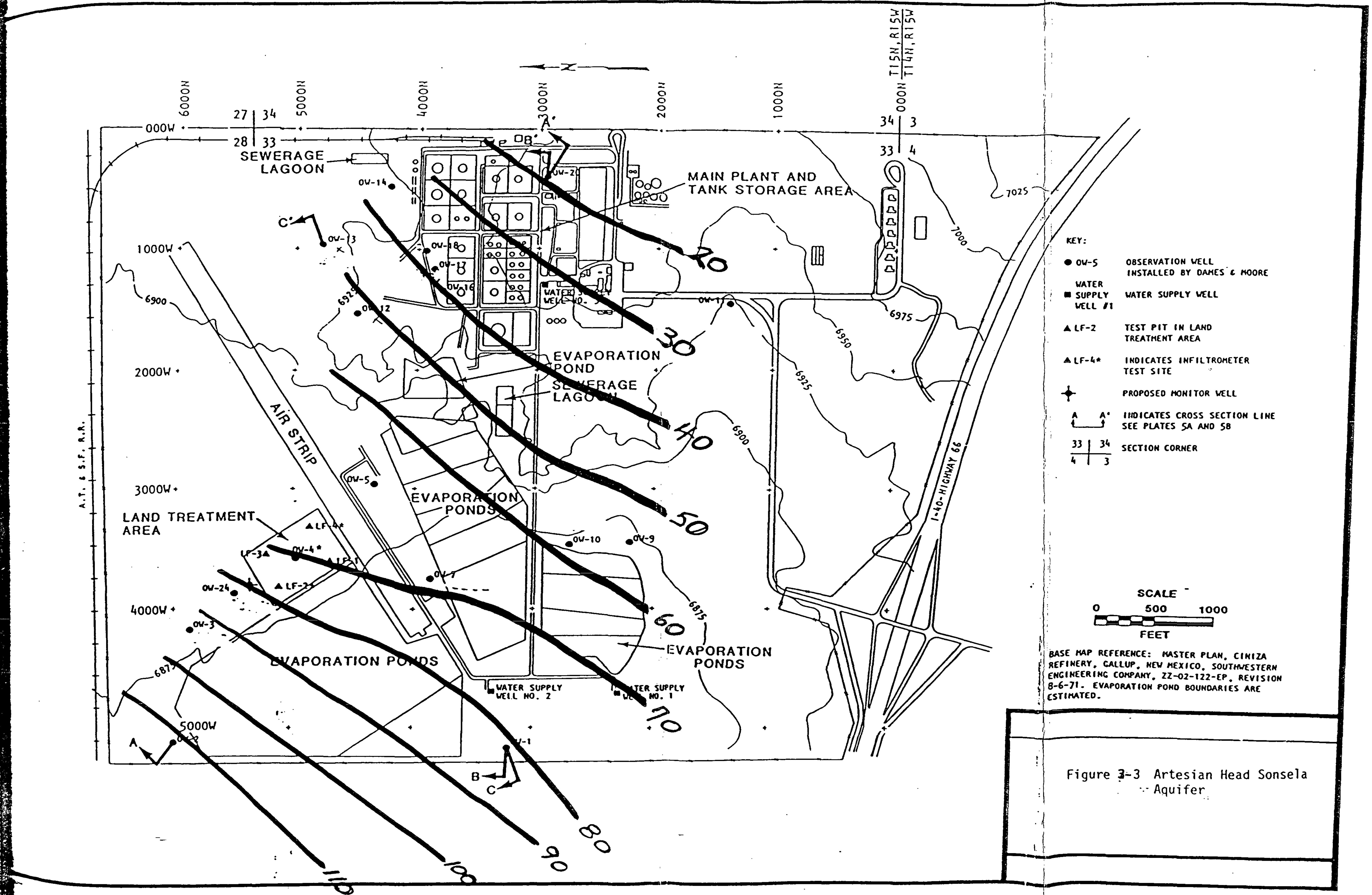
3.0 SITE HYDROGEOLOGY

3.1 INTRODUCTION

The Giant Refining Company land-treatment unit is directly underlain by two distinct hydrogeologic units. Beginning at the land surface and proceeding deeper, these units are: the Chinle Formation shales (clay aquitard), and, at a depth of 80-100 feet, the Sonsela Sandstone (uppermost aquifer). At the Ciniza Refinery, wastes are treated in the uppermost 12 inches of soils developed on the shales of the Chinle Formation. As seen in lithologic logs of MW-1, MW-2, MW-3 and MW-4 (Appendix E), approximately 80-100 feet of clayey shales separate the treatment zone from the uppermost aquifer (Sonsela Sandstone). Although the lower portion of these Chinle shales is saturated with ground water, the evidence presented in the following sections will demonstrate that this saturated clay shale is <u>not</u> an aquifer but rather an extremely effective "natural barrier" to any potential downward migration of contaminants from the treatment zone to the uppermost aquifer (Sonsela Sandstone).

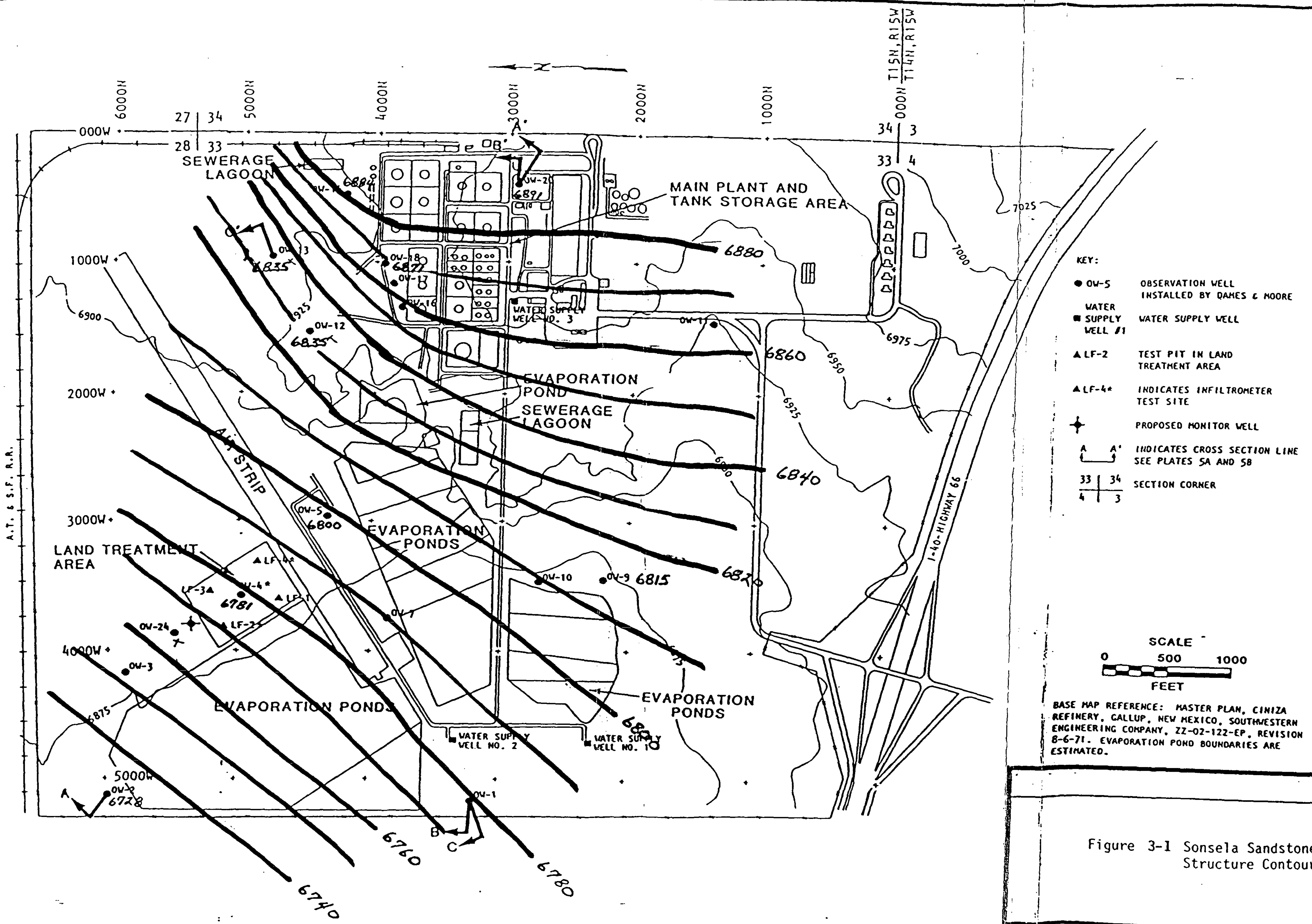
3.2 POTENTIOMETRIC SURFACES OF THE SONSELA SANDSTONE AND CHINLE SHALES

Artesian aquifers, such as the Sonsela, contain confined ground water under pressure. If a well is completed into an artesian aquifer, the water level in that well will rise above the upper surface of the aquifer. Figure 3-1 is a structure contour map showing the elevation of the upper surface of the Sonsela. Figure 3-2 is a potentiometric surface map showing the elevations of the water levels in wells completed only in the Sonsela. The difference between these two surfaces is the artesian pressure or head (Figure 3-3). This pressure acts to isolate and protect the confined ground water in this uppermost aquifer from any potential



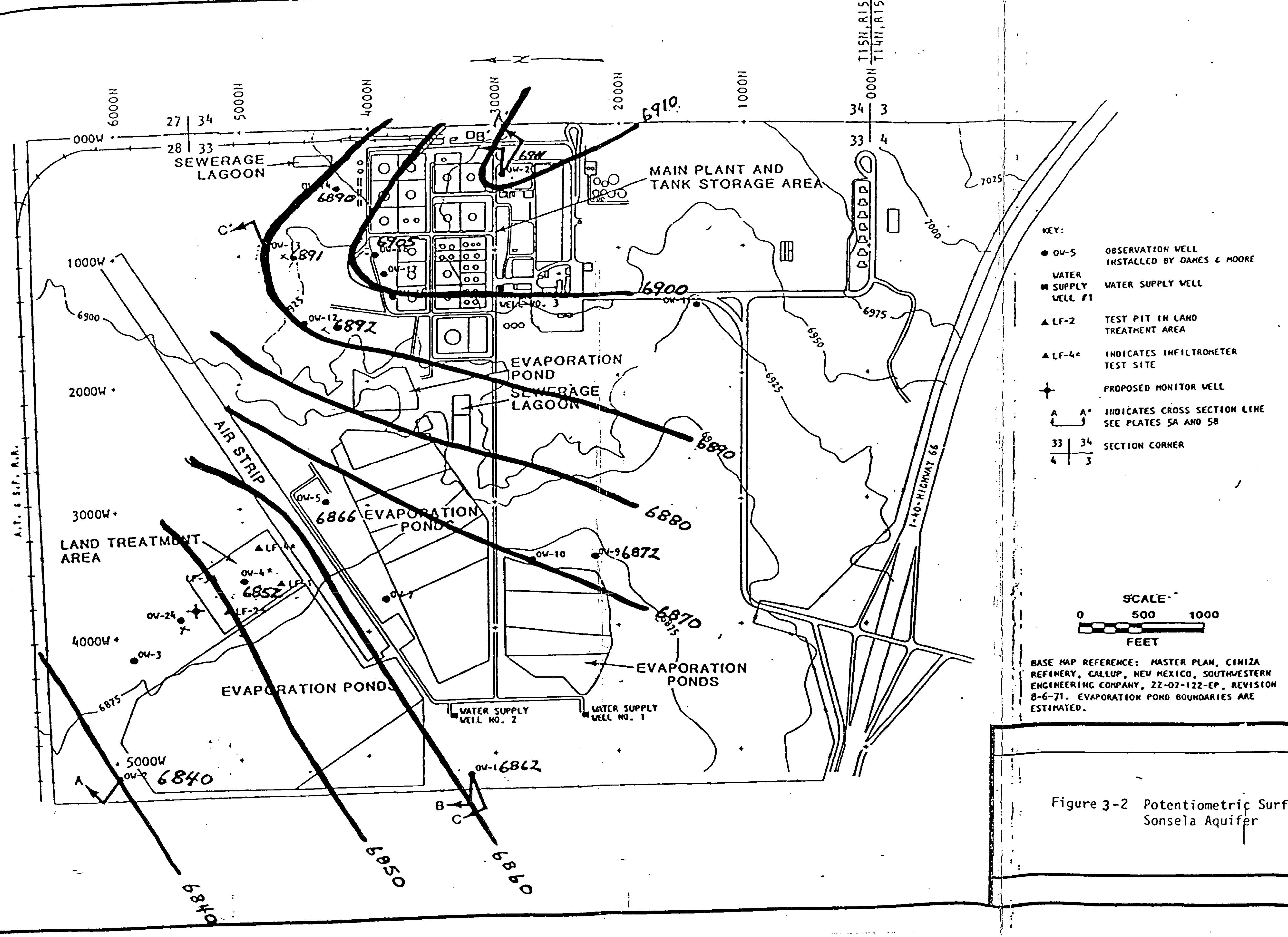
BASE MAP REFERENCE: MASTER PLAN, CINIZA REFINERY, GALLUP, NEW MEXICO, SOUTHWESTERN ENGINEERING COMPANY, 22-02-122-EP, REVISION 8-6-71. EVAPORATION POND BOUNDARIES ARE ESTIMATED.

Figure 3-3 Artesian Head Sonsela Aquifer



BASE MAP REFERENCE: MASTER PLAN, CINIZA REFINERY, GALLUP, NEW MEXICO, SOUTHWESTERN ENGINEERING COMPANY, ZZ-02-122-EP, REVISION 8-6-71. EVAPORATION POND BOUNDARIES ARE ESTIMATED.

Figure 3-1 Sonsela Sandstone Structure Contours



BASE MAP REFERENCE: MASTER PLAN, CINIZA REFINERY, GALLUP, NEW MEXICO. SOUTHWESTERN ENGINEERING COMPANY, 22-02-122-EP, REVISION 8-6-71. EVAPORATION POND BOUNDARIES ARE ESTIMATED.

Figure 3-2 Potentiometric Surface, Sonsela Aquifer downward migration of contaminants which might escape from the treatment zone.

Because the confining unit or "natural barrier" (Chinle shale aquitard) has slight vertical permeability, the upward hydraulic gradient between the Sonsela and Upper Chinle shales has resulted in saturation of the lower portion of the aquitard (Chinle Shale) over geologic time. This upward gradient also prevents the downward movement of any leachate into the uppermost aquifer (Sonsela Sandstone). This strong upward gradient is demonstrated by water levels in MW-1 and MW-2 (completed in the Sonsela) which are approximately 20 feet above water levels in the aquitard (as measured in nearby OW-24, completed in the shales).

Combined mapping of these two distinct water surfaces in previous submissions has generated some confusion about the hydrogeology at Ciniza. Some earlier Giant submissions to the EPA Region VI utilize the terms water level, water table, and potentiometric surface interchangeably. These reports combine data from wells completed in the Sonsela with data from much shallower wells completed in the overlying Chinle shales and label the result a "water table map". This confusion is corrected to some extent in the Part B application, but continued references to the "water table" in the shales gives the impression that single unconfined "water table" aquifer exists beneath the refinery site. This is definitely not the case at Ciniza.

Upward gradients within the Chinle shale aquitard are maintained by evapotranspiration. Because lake evaporation at the site is approximately 5 times the annual average precipitation, net pore-water movement in the soils and the unsaturated portion of the shale is upward (towards land surface).

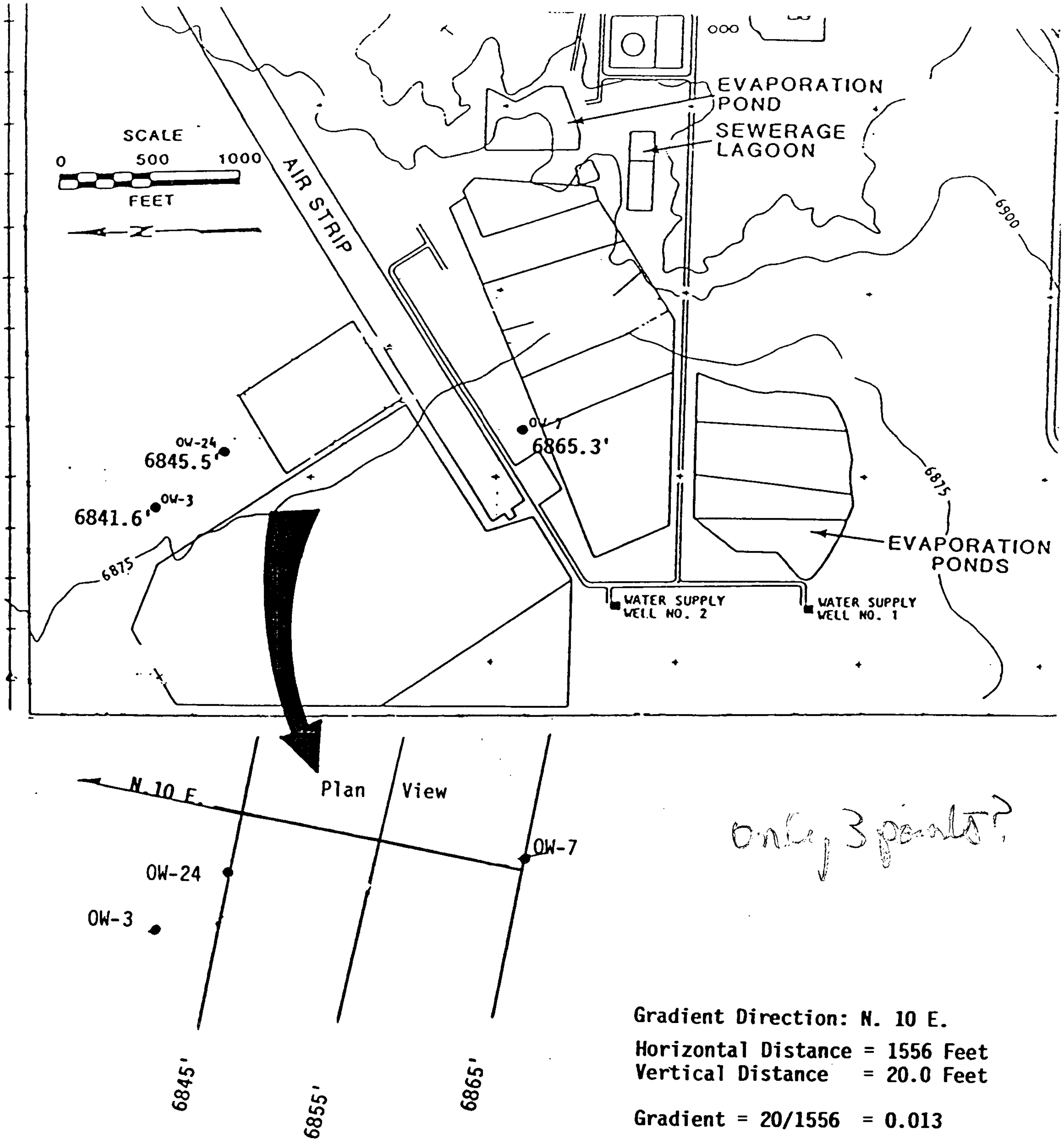
The horizontal hydraulic gradient of the Sonsela Sandstone is shown in Figure 3-2. In the area of the land treatment unit, ground water flows to the northwest, and the gradient is calculated to be 0.10. The hydraulic gradient in the Chinle shale aquitard can be calculated from water levels measured in three piezometers (OW 3, 7, and 24) completed only in this unit. Figure 3-4 shows that the calculation yields a gradient of 0.013 in a northeast direction in the Chinle shale aquitard.

3.3 HYDRAULIC PROPERTIES OF THE SONSELA SANDSTONE AND CHINLE SHALE AQUITARD

The strong upward hydraulic gradient between the Sonsela and the overlying shale aquitard demonstrates a lack of a good hydraulic connection between the two units. This is due to the extremely low permeability of the Chinle shales.

3.3.1 Slug Test Results

Because the duration of a slug test is very short, the observed hydraulic conductivity determined from the test will be representative <u>only</u> of the water-bearing material close to the well. A slug test is a good method for estimating the hydraulic conductivity of relatively low permeability units. However, caution must be exercised in the interpre-



Only 3 points?

Gradient Direction: N. 10 E.

Horizontal Distance = 1556 Feet
Vertical Distance = 20.0 Feet

Gradient = 20/1556 = 0.013

FIGURE 3-4
Determination of Hydraulic Gradient in Chinle Shale Aquitard

tation of results due to the significant difference between the hydraulic conductivity of the gravel pack (or the developed portion of the well) and the water-bearing unit itself. Because the hydraulic conductivity of the gravel pack surrounding OW-4 is orders of magnitude greater than that of the aquitard, a slug test of OW-4 will yield maximum values. Although slug tests are not recommended for unconfined units, the high anisotropy of the aquitard will approximate confined conditions over short test duration. Therefore, the slug test of OW-4 will yield reliable data to use in estimating the maximum horizontal hydraulic conductivity.

Slug-testing of OW-4 (see December, 1984 Part B Application, Delta H. Engineering, Ltd.) indicates a maximum horizontal permeability of about 1.3×10^{-8} ft/sec, or 1×10^{-3} ft/day in the Chinle shales. Vertical permeabilities of consolidated shales are typically up to an order of magnitude less than horizontal permeabilities (Freeze and Cherry, 1979). The vertical permeability would therefore be significantly less than the value of 1.57×10^{-8} ft/sec (1.3×10^{-3} ft/day) required for clay-pond liners in the New Mexico Water Quality Control Commission Regulations (3-109.C.b.1).

In contrast to the extremely low permeability of the shale, the slug test data of the confined Sonsela Sandstone aquifer indicate a hydraulic conductivity of about 3.93×10^{-6} ft/sec, or 0.35 ft/day. This permeability contrast of approximately 3 orders of magnitude permits the Sonsela to yield significant quantities of ground water to wells or springs throughout the region.

3.3.2 Test Pumping of the Chinle Shale

A low-discharge test of OW-24 was planned for early February, 1985. Significant delays in manufacturing and obtaining a low-discharge pump capable of pumping relatively turbid water forced delay of the test until February 20, 1985. This test was designed to accurately determine the hydraulic characteristics of the Chinle shale aquitard.

Recent pumping during sampling of the OW series indicated that wells completed in the aquitard could not sustain long-term pumping at rates greater than 0.5 gallons per minute. Testing the aquitard by rapid evacuation of the well using a standard submersible pump would have the same restrictions as slug testing because calculated hydraulic conductivity values would be influenced primarily by to gravel-pack drainage. Therefore, low-discharge pump testing was the preferred alternative.

Unexpected problems encountered during the test pumping necessitated the cessation of the test after 5 hours of pumping. Although OW-24 had been properly developed as an observation well after the completion of drilling, extremely turbid water was produced throughout the test. The low discharge rate caused the suspended solids to accumulate in the pump housing and in the discharge valve (Appendix F). After 5 hours of pumping, the pump discharge became unstable and pumping was ceased to prevent significant damage to the pump.

Following cessation of pumping, the water level's recovery was monitored until approximately 90 percent of the original level was regained.

Time-drawdown and time-recovery data are presented in Appendix F. In order to compensate for the time-length of the test and well-bore effects, an analytical method developed by Shafer was employed (Appendix F). Based on this analysis, the Chinle shale has a maximum transmissivity of 0.110 gallons per day per foot, or a conductivity of 8.3×10^{-9} ft/sec. This value is in excellent agreement with the slug-test value of 1.3×10^{-8} ft/sec. This indicates that the observed conductivity from the pump test performed on February 20 is also a maximum value, and may be strongly biased by borehole and gravel-pack storage.

Although Shafer recommends rapid evacuation of the well bore, a slower evacuation is more appropriate for OW-24. The gravel pack is considerably longer than the screen, so rapid evacuation would allow the recovery to be strongly influenced by gravel-pack drainage. By slowly evacuating the well, all or most of the water stored in the gravel pack is allowed to drain into the well. When pumping stops and recovery begins, water is produced only from the shale formation, and well-bore effects are minimized. Cessation of pumping prior to complete dewatering of the gravel pack and the developed portion of the unit will result in maximum apparent permeability values.

The calculations of hydraulic conductivity (Appendix F) are based on a formation thickness (b) of 20 feet which is the length of the screen. If water is derived throughout the length of the gravel pack (32.5 feet) in OW 24, then the calculated hydraulic conductivity is 5.17×10^{-9} ft/sec or 1.7×10^{-10} cm/sec.

3.4 NATURAL MOVEMENT OF GROUND WATER IN THE SONSELA AND CHINLE SHALE AQUITARD

Using the data calculated in the slug-test and the pump test, the rate of ground water movement beneath the land treatment unit can be calculated. Table 3-1 presents the calculation of ground water pore velocity (v), which determines the rate at which a contaminant particle in water could migrate by advection if no retardation occurred. This calculation is based on gradients taken from water-level surveys and on the slug test data presented in the original Part B application. Slug tests characteristically yield maximum values for horizontal permeability and hence tend to greatly overestimate the calculated vertical pore velocity.

3.5 WATER RESOURCES OF THE SONSELA SANDSTONE AND CHINLE SHALE

Throughout much of the southern San Juan Basin, the Sonsela Sandstone is used as a source of ground water for domestic, agricultural and industrial purposes. Extensive development of the Sonsela is restricted to the Bluewater area where the unit provides large quantities of water to irrigation wells. West of Bluewater to Ciniza and Gallup, the Sonsela is used primarily for stock wells or for limited domestic use.

The shales of the Chinle have not been developed as a source of water anywhere in the San Juan Basin nor, to the best of our knowledge, anywhere in the state of New Mexico. All wells which penetrate the Chinle shales derive their water from underlying aquifers such as the Sonsela or San Andres/Glorieta. Throughout New Mexico the Chinle shales are recognized as an important aquitard. Uranium tailings-ponds and disposal sites have been located in the Chinle shales to prevent migra-

TABLE 3-1
CALCULATIONS OF PORE VELOCITIES
CHINLE SHALE AQUITARD AND SONSELA SANDSTONES AQUIFER
(BASED ON SLUG-TEST DATA)

Pore velocity is defined as:

$$v = \frac{k}{n} \frac{dh}{dl}$$

Where:

v = Pore velocity

k = Hydraulic conductivity

n = Porosity

$\frac{dh}{dl}$ = hydraulic gradient

The following is based on data from Dames & Moore (1981) and Appendix G of the Giant Part B Application prepared by Delta H. Engineering, Ltd. Shale porosity is from Freeze and Cherry, Groundwater, 1979, p 37.)

	Chinle Shale	Sonsela Sandstone
n	.10	.13
k	1.3×10^{-8} ft/sec	3.94×10^{-6} ft/sec
$\frac{dh}{dl}$	.01 ft/ft	.01 ft/ft
v	1.0×10^{-9} ft/sec (.032 ft/year)	3.94×10^{-7} ft/sec (12.4 ft/year)

tion of toxic metals and radioactive contaminants into underlying aquifers. Unlined disposal sites in the Chinle shales for radioactive and heavy metal wastes from two uranium mills have been approved by the State of New Mexico.

Recognized (and protected) aquifers in the Ciniza area include the Sonsela, and the San Andres/Glorieta (Permian age). These aquifers are discussed in detail by Shomaker (1973) and Stone, et al (1983). Neither of these authors consider the Chinle shales an aquifer, and Shomaker states that the rocks above the Sonsela are "Not known to yield water to wells within the study area."

4.0 UNSATURATED-ZONE MONITORING: LYSIMETERS AND ALTERNATIVES

The regulations for unsaturated-zone monitoring (40 CFR 264.278) require, among other things, the monitoring of soil and soil-pore liquids "to determine whether hazardous constituents migrate out of the treatment zone" (40 CFR 264.278 (a)). This section addresses the concerns of EPA Region VI regarding the inability of currently-installed suction or collection lysimeters to produce soil-pore fluid, and proposes an alternative to lysimeters for unsaturated-zone monitoring which fully meets the intent of 40 CFR 264. 278.

4.1 PERFORMANCE OF CURRENTLY INSTALLED LYSIMETERS

The suitability of suction lysimeters for monitoring soil water in the unsaturated (vadose) zone is strongly influenced by several criteria:

- Design, materials and construction of the device
- Soil properties, such as moisture content, soil-water tension head, grain size and permeability
- Methods, materials and practices of lysimeter installation such as bore-hole conditions, depth of installation and the nature of the silica-flour packing around the lysimeter bulb
- Sample collection operating procedures and techniques

Lysimeter performance and efficiency is highly dependent on all of the above mentioned factors. Information presented in recent publications shows that failure to carefully consider these factors when choosing and installing a lysimeter may render the device useless (see Giddings, 1983 and Everett, L.G., 1984). When the lysimeters were installed at the Ciniza Refinery these data were not available, therefore, the failure to recognize the importance of these variables may have contributed to the failure of the lysimeters to operate properly.

Recent investigations suggest that soil conditions at the Ciniza Refinery site do not favor the adequate performance of most typical lysimeters. The soils are sparsely distributed, thin, dry and clay-rich, and are mostly derived from *in situ* weathering of the shales and mudstones of the Chinle Formation. In order to gain further information on soil moisture conditions in the land treatment area, Giant has excavated several test pits (collection lysimeters) to a depth of 12 feet west of the land farm area. *No soil moisture or leachate* has ever been observed in these pits. It is unlikely that even a well-designed and properly-installed suction lysimeter or collection lysimeter would reliably produce the volume of soil water necessary for representative analysis of the fluid immediately below the treatment zone.

The inability of most suction or collection lysimeters to produce fluids indicates that neither device, installed immediately below the treatment zone, is likely to be capable of effectively monitoring the unsaturated zone in the arid, clay-rich soils at Ciniza.

4.2 UNSATURATED-ZONE MONITORING OPTIONS AT CINIZA LAND FARM

Two options exist for determining whether hazardous constituents are migrating below the treatment zone:

1) Soil core monitoring below the treatment zone
2) Installation of lysimeters several feet above the saturated zone

Due to the fine-grained nature of the unsaturated zone at the Ciniza Refinery, lysimeters would be effective only in zones of relatively high moisture contents. A high moisture zone will only be encountered at a level several feet above the saturated zone in the Chinle shale aquitard, which underlies the treatment zone. This level will be over 25 feet below the land surface. Lysimeters could probably collect samples of pore-fluid in this zone (approximately 25ft depth). Although this type of a sampling program would satisfy 40 CFR 264.278(b) it would not accomplish the objectives of monitoring immediately below the treatment zone (40 CFR 264.278(d)).

The purpose of unsaturated zone monitoring is to provide an "early warning" for contaminant migration below the treatment zone. The Ciniza Refinery has defined the background soil chemistry at the land farm and will continue to collect soil samples from a "background" site at the refinery. By a careful statistical comparison of the chemistry of the background soils with the chemistry of the soils below the treatment zone, the migration of hazardous constituents below the treatment zone can be determined. Bulk soil analysis using EP Toxicity extraction procedures will be employed.

4.3 RECOMMENDED ALTERNATIVE TO CURRENTLY INSTALLED LYSIMETERS

The current regulations (CFR 40. 264. 278 (b)) specify unsaturated-zone monitoring by "... soil cores and soil-pore monitoring devices <u>such as</u> lysimeters ... to yield samples that:

1) Represent the quality of background soil-pore liquid and ...

2) Indicate the quality of soil pore liquid... "

(emphasis added). The observed non-performance of currently installed lysimeters, and the likely inability of any lysimeter to collect meaningful samples from below the treatment zone in this type of hydrogeologic environment, requires an alternative approach to soil-pore liquid monitoring in the unsaturated zone beneath the land farm.

Given the geologic conditions and waste management practices at Ciniza, Geoscience Consultants, Ltd. believes that soil-core analysis (as described below) is an environmentally sound and effective means of monitoring which is fully consistent with 40 CFR 264.278.

4.3.1 Sampling Methodology

Soil samples will be collected according to procedures outlined in Appendix A of our February 14, 1985 submission to EPA on TOX and metals levels at the Ciniza Refinery. Sample sites will be randomly selected from both the land farm area and a geologically similar "background" area where no refinery wastes have ever been applied. In accordance with the requirements of 40 CFR 264.278(c)(1), background values will be based on at least 1 year of quarterly sampling in the background plot. Soil samples will be analyzed according to the methods outlined in Appendix A of the February 14, 1985 submission.

Although frequency and timing of soil sampling may be modified by the Regional Administrator in accordance with 40 CFR 264.278(d), Giant proposes to continue the present system of collecting 6 soil cores every 6 months over the 3 active 2.6-acre treatment sections. These core sampling locations will be randomly selected, as described in Section 29.7.2 of the December 1, 1984 Part B permit application. Samples will be collected from 1 foot below the base of the treatment/soil zone, and from 6 feet below the base of the treatment zone (and from equivalent soil zones in the background area).

Collection of soil samples for analysis will be conducted in the following manner:

1) Samples will be collected from various depths
2) A sample to be used for moisture content analysis will be put into a plastic whirlpack and immediately sealed. The sealed whirlpack will be inserted into a second whirlpack and sealed. This method will prevent moisture loss from samples.
3) Samples for metals, organics and other parameters will be collected and put in glass VOA bottles.

4.3.2 Analytical Methodology

Samples will be split, labeled, sealed and analyzed according to Appendix A of our February 14, 1985 submission and shipped to 2 EPA-certified laboratories. As specified in part 29.7.5 of the Part B application, samples will be analyzed for:

pH
Oil content
Moisture Content
Lead
Chromium
Mercury
Electrical Conductance
Sodium Absorbtion Ratio
TOC
TOX

Moisture contents of the whirlpack samples, which were collected for unsaturated zone monitoring, will be determined by weighing the samples prior to and after evaporation. The double-bagged, sealed samples will be weighed and then opened to dry. The sample and container will be evenly distributed on a tray, and allowed to dry at 100 degrees Fahrenheit in a dessicating oven for 48 hours. The sample and container will then be re-weighed and moisture content calculated by subtraction.

The EP Toxicity method for extraction will be employed for the analysis of lead, chromium, mercury, TOX, TOC. Other parameters will be analyzed as specified in the Part B permit application.

Analytical results will be interpreted according to statistical methods specified in 40 CFR 264 Appendix IV. If regional background data on lead and mercury (see Section 3.0 of the February 14, 1985 submission) indicates high natural levels of these metals, Giant will propose an alternative statistical methodology which is more appropriate to the high variance in background data (see 40 CFR 264.278(f)(3)).

5.0 REFERENCES CITED

Barcelona, M.J., Gibb, J. P. and Miller, R.A., 1983. A Guide to the Selection of Materials for Monitoring Well Construction and Ground-Water Sampling: Illinois State Water Survey, Champaign, Illinois.

Boettner, E.A., Ball, G.L. Hollingsworth, Z. and Romulo, R., 1981. Organic and Organotin Compounds Leached from PVC and CPVC Pipe: EPA-600/1-8-062, USEPA, Washington, D.C.

Freeze, R.A. and Cherry, J.A., 1979. Groundwater: Prentice-Hall Inc., Englewood Cliffs, New Jersey.

Giddings, T., 1983. The Utilization of Pressure - Vacuum Lysimeters for Unsaturated Zone Monitoring: in Proceedings of the NWWA/USEPA Conference on Characterization and Monitoring of the Vadose (Unsaturated) Zone; Neilson, D. and Carl, M., eds. National Water Well Association, Worthington, Ohio.

Reich, K.D., Trussel, A.R., Lien, F.Y., Leong L.Y.C. and Trussel, R.R., 1981. Diffusion of Organics from Solvent-Bonded Plastic Pipes Used for Potable Water Plumbing: American Water Works Conference, St. Louis, Missouri.

Shoemaker, J., 1971. Water Resources of Fort Wingate Army Depot and Adjacent Areas: USGS Open File Report.

Stone, W.J., Lyford, F.P., Frenyell. P.F., Miyell, N.H. and Padgett, E.T., 1983. Hydrology and Water Resources of San Juan Basin, New Mexico, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico.

USEPA, 1984 Draft Permit Guidance Manual on Unsaturated Zone Monitoring for Hazardous Waste Land Treatment Units: EPA/530-510-84-016, Office of Solid Waste and Emergency Response, Washington, D.C.

Wang, T.C. and Bircker, J.L. 1979. 2-Butanone and Tetrahydrofuran Contamination in the Water Supply: Bulletin of Envrionmental Contamination Toxicology, V 23, pp. 620-623.

APPENDIX A
DEFINITION OF AQUIFER 40 CFR 260.10
(MAY 19, 1980)

assistance. Limited technological assistance may be available.

The Agency has also established an industry assistance program in the Office of Solid Waste. The staff of this program have been charged with (1) identifying industry and community RCRA compliance problems and seeking solutions to them, (2) coordinating assistance activities with the States, other parts of EPA, and other Federal agencies (e.g., the Small Business Administration and the Economic Development Administration), (3) planning and conducting seminars, and (4) coordinating production of written material designed to assist those least able to cope with the regulatory burden.

The Agency would ideally like to provide this assistance to anyone who wants it. However, because the industry assistance program may receive more requests for help than it can initially respond to, it may be necessary to establish priorities to determine which requests should be answered first. If this is the case, the program will concentrate first on the following industry sectors, which the Agency believes most need this help: chrome pigments, chlorine, electroplating (job shops), woven fabric finishing, felt fabric finishing, sheepskin tanneries, vegetable tanners, primary and secondary aluminum, primary and secondary copper, primary and secondary lead, primary tungsten, primary zinc, petroleum rerefining, pesticides, plastics, and pharmaceuticals. EPA plans to meet with the trade associations of these industries in order to define specific assistance responses.

Anyone having suggestions on how the Agency can help industry comply with these regulations should contact: Michael Barclay, RCRA Industry Assistance Coordinator, Office of Solid Waste (WH-565), U.S. Environmental Protection Agency, Washington, D.C. 20460 (202) 755-9190.

Dated: May 2, 1980.

Douglas M. Costle,

Administrator.

Title 40 CFR Part 260 is revised to read as follows:

PART 260—HAZARDOUS WASTE MANAGEMENT SYSTEM: GENERAL

Subpart A—General

Sec.

Subpart B—Definitions

Subpart C—Rulemaking Petitions

Authority: Secs. 1006, 2002(a), 3001 through 3007, 3010, and 7004, of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976, as amended (42 U.S.C. 6905, 6912(a), 6921 through 6927, 6930, and 6974).

Subpart A—General

§ 260.1 Purpose, scope, and applicability.

(a) This part provides definitions of terms, general standards, and overview information applicable to Parts 260 through 265 of this Chapter.

(b) In this part: (1) Section 260.2 sets forth the rules that EPA will use in making information it receives available to the public and sets forth the requirements that generators, transporters, or owners or operators of treatment, storage, or disposal facilities must follow to assert claims of business confidentiality with respect to information that is submitted to EPA under Parts 260 through 265 of this Chapter.

(2) Section 260.3 establishes rules of grammatical construction for Parts 260 through 265 of this Chapter.

(3) Section 260.10 defines terms which are used in Parts 260 through 265 of this Chapter.

(4) Section 260.20 establishes procedures for petitioning EPA to amend, modify, or revoke any provision of Parts 260 through 265 of this Chapter and establishes procedures governing EPA's action on such petitions.

(5) Section 260.21 establishes procedures for petitioning EPA to approve testing methods as equivalent to those prescribed in Parts 261, 264, or 265 of this Chapter.

(6) Section 260.22 establishes procedures for petitioning EPA to amend Subpart D of Part 261 to exclude a waste from a particular facility.

§ 260.2 Availability of information; confidentiality of information.

(a) Any information provided to EPA under Parts 260 through 265 of this Chapter will be made available to the public to the extent and in the manner authorized by the Freedom of Information Act, 5 U.S.C. section 552, section 3007(b) of RCRA and EPA regulations implementing the Freedom of Information Act and section 3007(b), Part 2 of this Chapter, as applicable.

(b) Any person who submits information to EPA in accordance with Parts 260 through 265 of this Chapter may assert a claim of business confidentiality covering part or all of that information by following the procedures set forth in § 2.203(b) of this Chapter. Information covered by such a claim will be disclosed by EPA only to the extent, and by means of the procedures, set forth in Part 2, Subpart B of this Chapter. However, if no such claim accompanies the information when it is received by EPA, it may be made available to the public without further notice to the person submitting it.

§ 260.3 Use of number and gender.

As used in Parts 260 through 265 of this Chapter:

(a) Words in the masculine gender also include the feminine and neuter genders; and

(b) Words in the singular include the plural; and

(c) Words in the plural include the singular.

Subpart B—Definitions

§ 260.10 Definitions.

(a) When used in Parts 260 through 265 of this Chapter, the following terms have the meanings given below: (1) "Act" or "RCRA" means the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976, as amended, 42 U.S.C. section 6901 et seq.

(2) "Active portion" means that portion of a facility where treatment, storage, or disposal operations are being or have been conducted after the effective date of Part 261 of this Chapter and which is not a closed portion. (See also "closed portion" and "inactive portion".)

(3) "Administrator" means the Administrator of the Environmental Protection Agency, or his designee.

(4) "Aquifer" means a geologic formation, group of formations, or part of a formation capable of yielding a significant amount of ground water to wells or springs.

(5) "Authorized representative" means the person responsible for the overall operation of a facility or an operational unit (i.e., part of a facility), e.g., the plant manager, superintendent or person of equivalent responsibility.

(6) "Closed portion" means that portion of a facility which an owner or operator has closed in accordance with the approved facility closure plan and all applicable closure requirements. (See also "active portion" and "inactive portion".)

(7) "Confined aquifer" means an aquifer bounded above and below by

impermeable beds or by beds of distinctly lower permeability than that of the aquifer itself; an aquifer containing confined ground water.

(8) "Constituent" or "hazardous waste constituent" means a constituent which caused the Administrator to list the hazardous waste in Part 261, Subpart D, of this Chapter, or a constituent listed in Table 1 of § 261.24 of this Chapter.

(9) "Container" means any portable device in which a material is stored, transported, treated, disposed of, or otherwise handled.

(10) "Contingency plan" means a document setting out an organized, planned, and coordinated course of action to be followed in case of a fire, explosion, or release of hazardous waste or hazardous waste constituents which could threaten human health or the environment.

(11) "Designated facility" means a hazardous waste treatment, storage, or disposal facility which has received an EPA permit (or a facility with interim status) in accordance with the requirements of 40 CFR Parts 122 and 124 of this Chapter, or a permit from a State authorized in accordance with Part 123 of this Chapter, that has been designated on the manifest by the generator pursuant to § 262.20.

(12) "Dike" means an embankment or ridge of either natural or man-made materials used to prevent the movement of liquids, sludges, solids, or other materials.

(13) "Discharge" or "hazardous waste discharge" means the accidental or intentional spilling, leaking, pumping, pouring, emitting, emptying, or dumping of hazardous waste into or on any land or water.

(14) "Disposal" means the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters.

(15) "Disposal facility" means a facility or part of a facility at which hazardous waste is intentionally placed into or on any land or water, and at which waste will remain after closure.

(16) "EPA hazardous waste number" means the number assigned by EPA to each hazardous waste listed in Part 261, Subpart D, of this Chapter and to each characteristic identified in Part 261, Subpart C, of this Chapter.

(17) "EPA identification number" means the number assigned by EPA to each generator, transporter, and treatment, storage, or disposal facility.

(18) "EPA region" means the states and territories found in any one of the following ten regions:

Region I—Maine, Vermont, New Hampshire, Massachusetts, Connecticut, and Rhode Island.
Region II—New York, New Jersey, Commonwealth of Puerto Rico, and the U.S. Virgin Islands.
Region III—Pennsylvania, Delaware, Maryland, West Virginia, Virginia, and the District of Columbia.
Region IV—Kentucky, Tennessee, North Carolina, Mississippi, Alabama, Georgia, South Carolina, and Florida.
Region V—Minnesota, Wisconsin, Illinois, Michigan, Indiana and Ohio.
Region VI—New Mexico, Oklahoma, Arkansas, Louisiana, and Texas.
Region VII—Nebraska, Kansas, Missouri, and Iowa.
Region VIII—Montana, Wyoming, North Dakota, South Dakota, Utah, and Colorado.
Region IX—California, Nevada, Arizona, Hawaii, Guam, American Samoa, Commonwealth of the Northern Mariana Islands.
Region X—Washington, Oregon, Idaho, and Alaska.

(19) "Equivalent method" means any testing or analytical method approved by the Administrator under §§ 260.20 and 260.21.

(20) "Existing hazardous waste management facility" or "existing facility" means a facility which was in operation, or for which construction had commenced, on or before October 21, 1976. Construction had commenced if:

(i) The owner or operator has obtained all necessary Federal, State, and local preconstruction approvals or permits; and either

(ii)(*a*) A continuous physical, on-site construction program has begun, or

(*b*) The owner or operator has entered into contractual obligations—which cannot be cancelled or modified without substantial loss—for construction of the facility to be completed within a reasonable time.

(21) "Facility" means all contiguous land, and structures, other appurtenances, and improvements on the land, used for treating, storing, or disposing of hazardous waste. A facility may consist of several treatment, storage, or disposal operational units (e.g., one or more landfills, surface impoundments, or combinations of them).

(22) "Federal agency" means any department, agency, or other instrumentality of the Federal Government, any independent agency or establishment of the Federal Government including any Government corporation, and the Government Printing Office.

(23) "Food-chain crops" means tobacco, crops grown for human consumption, and crops grown for feed for animals whose products are consumed by humans.

(24) "Freeboard" means the vertical distance between the top of a tank or surface impoundment dike, and the surface of the waste contained therein.

(25) "Free liquids" means liquids which readily separate from the solid portion of a waste under ambient temperature and pressure.

(26) "Generator" means any person, by site, whose act or process produces hazardous waste identified or listed in Part 261 of this Chapter.

(27) "Ground water" means water below the land surface in a zone of saturation.

(28) "Hazardous waste" means a hazardous waste as defined in § 261.3 of this Chapter.

(29) "Inactive portion" means that portion of a facility which is not operated after the effective date of Part 261 of this Chapter. (See also "active portion" and "closed portion".)

(30) "Incinerator" means an enclosed device using controlled flame combustion, the primary purpose of which is to thermally break down hazardous waste. Examples of incinerators are rotary kiln, fluidized bed, and liquid injection incinerators.

(31) "Incompatible waste" means a hazardous waste which is unsuitable for:

(i) Placement in a particular device or facility because it may cause corrosion or decay of containment materials (e.g., container inner liners or tank walls); or

(ii) Commingling with another waste or material under uncontrolled conditions because the commingling might produce heat or pressure, fire or explosion, violent reaction, toxic dusts, mists, fumes, or gases, or flammable fumes or gases.

(See Part 265, Appendix V, of this Chapter for examples.)

(32) "Individual generation site" means the contiguous site at or on which one or more hazardous wastes are generated. An individual generation site, such as a large manufacturing plant, may have one or more sources of hazardous waste but is considered a single or individual generation site if the site or property is contiguous.

(33) "In operation" refers to a facility which is treating, storing, or disposing of hazardous waste.

(34) "Injection well" means a well into which fluids are injected. (See also "underground injection".)

(35) "Inner liner" means a continuous layer of material placed inside a tank or container which protects the

APPENDIX B
PROPOSED DEFINITION OF AQUIFER 40 CFR 250.41
(DECEMBER 18, 1978)

(3) Bringing enforcement actions against a facility that:

(i) Has a State issued permit or license pursuant to authority under Subpart F, but where there is evidence that compliance with such permit or license will not provide compliance with the standards of this Subpart, or

(ii) Does not have a permit or a pending permit application.

(e) The requirements contained in these regulations do not apply to the following:

(1) Solid or dissolved materials in domestic sewage;

(2) Solid or dissolved materials in irrigation return follows;

(3) Industrial discharges which are point sources subject to permits under Section 402 of the Clean Water Act;

(4) Source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954, as amended;

(5) Point source air emissions regulated under the authority of Sections 111 and 112 of the Clean Air Act, as amended;

(6) The disposal of hazardous waste via underground injection pursuant to Safe Drinking Water Act (SDWA) regulations; or

(7) The disposal of hazardous waste via ocean disposal pursuant to Marine Protection, Research, and Sanctuaries Act (MPRSA) regulations.

§ 250.41 Definitions.

(a) When used in this Subpart, the following terms have the meanings given in the Act:

(1) "Administrator"—Sec. 1004(1)

(2) "disposal"—Sec. 1004(3)

(3) "Federal Agency"—Sec. 1004(4)

(4) "hazardous waste management"—Sec. 1004(7)

(5) "open dump"—Sec. 1004(14)

(6) "person"—Sec. 1004(15)

(7) "resource recovery"—Sec. 1004(22)

(8) "sanitary landfill"—Sec. 1004(26)

(9) "sludge"—Sec. 1004(26A)

(10) "solid waste"—Sec. 1004(27)

(11) "solid waste management"—Sec. 1004(28)

(12) "solid waste management facility"—Sec. 1004(29)

(13) "State"—Sec. 1004(31)

(14) "storage"—Sec. 1004(33)

(15) "treatment"—Sec. 1004(34)

(b) Other terms used in this Subpart have the following meanings:

(1) "Act" means the Resource Conservation and Recovery Act of 1976, Public Law 94-580.

(2) "Active Fault Zone" means a land area which, according to the weight of the geologic evidence, has a reasonable probability of being affected by movement along a fault to the extent that a hazardous waste facility would be damaged and thereby pose a threat to human health and the environment.

(3) "Active Portion" means that portion of a facility where treatment, storage, or disposal operations are being conducted. It includes the treated area of a landfarm and the active face of a landfill, but does not include those portions of a facility which have been closed in accordance with the facility closure plan and all applicable closure standards.

(4) "Annular Space" means the space between the bore hole and the casing. A bore hole is the man-made hole in a geological formation for installation of a monitoring well.

(5) "Aquifer" means a geologic formation, group of formations, or part of a formation that is capable of yielding useable quantities of groundwater to wells or springs.

(6) "Attenuation" means any decrease in the maximum concentration or total quantity of an applied chemical or biological constituent in a fixed time or distance traveled resulting from a physical, chemical, and/or biological reaction or transformation occurring in the zone of aeration or zone of saturation.

(7) "Basin" means any uncovered device constructed of artificial materials, used to retain wastes as part of a treatment process, usually with a capacity of less than 100,000 gallons. Examples of basins include open mixing tanks, clarifiers, and open settling tanks.

(8) "Cell" means a portion of waste in a landfill which is isolated horizontally and vertically from other portions of waste in the landfill by means of a soil barrier which meets criteria specified in Section 250.45-2(b) (14).

(9) "Chemical Fixation" means the treatment process involving reactions between the waste and certain chemicals, resulting in solids which encapsulate, immobilize or otherwise tie up hazardous components in the waste so as to minimize the leaching of hazardous components and render the waste nonhazardous or more suitable for disposal.

(10) "Close Out" means the point in time at which facility owners/operators discontinue operation by ceasing to accept hazardous waste for treatment, storage, or disposal.

(11) "Closed Portion" means that portion of a facility which has been closed in accordance with the facility closure plan and all applicable closure requirements in this Subpart.

(12) "Closing Date" means the date which marks the end of a reporting quarter or reporting year.

(13) "Closure" means the act of securing a facility pursuant to the requirements of Section 250.43-7.

(14) "Closure Procedures" means the measures which must be taken to effect closure in accordance with the requirements of Section 250.43-7 by a facility owner/operator who no longer accepts hazardous waste for treatment, storage, or disposal.

(15) "Coastal High Hazard Area" means the area subject to high velocity waters, including, but not limited to, hurricane wave wash or tsunamis as designated on Flood Insurance Rate Maps (FIRM) as zone VI-30.

(16) "Combustion Zone" means that portion of the internal capacity of an incinerator where the gas temperatures of the materials being burned are within 100°C of the specified operating temperature.

(17) "Common Code" means the unique code assigned by the Chemical Abstract Services to each EPA hazardous waste and to each DOT hazardous waste material listed in Section 250.14 of Subpart A.

(18) "Container" means any portable enclosure in which a material can be stored, handled, transported, treated, or disposed.

(19) "Contamination" means the degradation of naturally occurring water, air, or soil quality either directly or indirectly as a result of man's activities.

(20) "Contigency Plan" means an organized, planned, and coordinated course of action to be followed in the event of a fire, explosion, or discharge or release of waste into the environment which has the potential for endangering human health or the environment.

(21) "Cover Material" means soil or other material that is used to cover hazardous waste.

(22) "Delivery Document" means a shipping paper, bill of lading, waybill, dangerous cargo manifest, or other shipping document, used in lieu of the original manifest to fulfill the recordkeeping requirement of § 250.33 of Subpart C.

(23) "Direct Contact" means the physical intersection between the lowest part of a facility (e.g., the bottom of a landfill, a surface impoundment liner system or a natural in-place soil barrier, including leachate detection/removal systems) and a water table, a saturated zone, or an underground drinking water source, or between the active portion of a facility and any navigable water.

(24) "Disposal Facility" means any facility which disposes of hazardous waste.

(25) "Endangerment" means the introduction of a substance into groundwater so as to:

(i) Cause the maximum allowable contaminant levels established in the National Primary Drinking Water standards in effect as of the date of promulgation of this Subpart to be exceeded in the groundwater; or

APPENDIX C
DISCUSSION OF AQUIFER DEFINITION
PREAMBLE TO 40 CFR 250.41
(DECEMBER 18, 1978)

occurs in very large volumes, that the potential hazards posed by the waste are relatively low, and that the waste generally is not amendable to the control techniques developed in Subpart D. The Agency is calling such high-volume hazardous waste "special waste" and is proposing to regulate it with special standards.

The following table provides some information about those wastes which, when hazardous, the Agency proposes to regulate with special standards. With two exceptions, EPA does not know how much of the total amount of waste generated in these categories is, in fact, hazardous and thus subject to Subtitle C regulations. Only waste which is hazardous under Subpart A standards, however, is "special waste" under this Subpart. Any portion of the waste on the following table which is not hazardous under Subpart A standards is not regulated at all under Subtitle C and thus is not "special waste."

Special Waste

(Metric tons/yr)

Waste	Quantity	Possible hazard
Cement Kiln Dust	12 million*	Alkalinity and heavy metals
Utility Waste (fly ash, bottom ash, scrubber sludge).	66 million*	Heavy metals (trace)
Phosphate Mining, Beneficiation, and Processing Waste.	400 million	Radioactivity (low levels)
Uranium Mining	150 million	Radioactivity
Other Mining Waste	~' billion*	Heavy metals, acidity
Gas and Oil Drilling Muds and Oil Production Brines.	5 million*	Alkalinity, heavy metals, toxic organics, salinity

NOTE.—It is not yet known how much of the total quantity of waste marked with an asterisk (*) is, in fact, hazardous waste.

A proposed rulemaking will be published at a later date regarding the treatment, storage, and disposal of special waste. The Agency will be developing additional information in order to write substantive standards for special waste, and hereby solicits information and comment from the public which may assist the Agency in developing its proposals. For the time being, all facilities which handle special waste will be exempted from the storage standards (§ 250.44) and the treatment and disposal standards (§ 250.45). In order to provide some protection from special waste and to collect additional information on special waste streams, EPA has prepared special standards for each type of special waste. Many of the general facility standards in § 250.43 are prescribed for special waste. In addition, some special waste must meet standards which are designed to control potential problems unique to that waste.

Dredge Spoils

Certain dredge spoils may prove to be hazardous and thus subject to these regulations. The Agency has little information regarding hazard levels and potential threats to human health and the environment associated with on-land disposal of these wastes. Information on acceptable waste management techniques and associated economics is also limited. Therefore, EPA is considering designating dredge spoils as a special waste under Section 250.46, thus deferring most requirements pending further study. As an alternative, the agency is considering exempting these wastes from RCRA requirements and covering them solely via regulation under section 404 of the Clean Water Act. Comments on how these wastes should be managed are invited.

Infectious Waste

EPA has received comments from the U.S. Army Environmental Hygiene Agency (USAEHA) that infectious waste defined as a hazardous waste pursuant to Subpart A should be considered a special waste and allowed to be disposed of at a landfill facility which does not meet all of the Subpart D landfill standards. USAEHA also suggested that certain infectious waste could be adequately managed at facilities that meet the Section 4004 "Criteria for Classification of Solid Waste Disposal Facilities" proposed under Subtitle D of RCRA (43 FR 4914). The U.S. Army Environmental Hygiene Agency agrees, however, that certain infectious waste, because of the extreme hazard associated with it, should go to facilities with a demonstrated capability to manage such waste.

EPA believes the above proposal has some merit, and is considering various administrative and regulatory options which we could employ to accomplish it. Consideration is being given to designating all or certain categories of infectious waste which is hazardous under Subpart A as "special waste." The Agency would then write different Subpart D regulations for such infectious waste.

The Agency invites comments from the public on this issue.

OPERATING AND DESIGN MANUALS AND INDUSTRY-SPECIFIC MANUALS

To assist with the implementation of these regulations, the Agency is preparing a number of detailed manuals.

The operating and design manuals will provide much more detailed information on waste management technologies than that given in the regulations. The manuals will cover acceptable practices for different types of treatment, storage, and disposal facilities, including landfills, landfarms, storage facilities, incinerators, chemical, physical, and biological treatment facilities, and surface impoundments. Manuals on monitoring and training also are being developed. These manuals will be organized to correspond closely with the regulations, but will be guidance manuals with no regulatory effect. The Agency expects to issue the manuals prior to final promulgation of the Subtitle C regulations.

The industry-specific guidance manuals will help various industries understand how the regulations apply to them. They will be issued as concise brochures. Sample diagrams and terms meaningful to the particular industry will be used. Eventually, manuals will be prepared for all major industrial categories. Initially, though, these manuals will be prepared for industries comprised primarily of small companies which can least afford to devote much effort toward understanding these regulations. The first industry-specific guidance manuals are being prepared for the electroplating and battery manufacturing industries.

OTHER ISSUES

Definition of Aquifer

As defined in § 250.41, an aquifer means any water-bearing stratum or unit which, due to its ability to store and transmit water, is capable of yielding a useable quantity of groundwater to a well or spring. The key concept in this definition is "a useable quantity of groundwater." EPA has received many inquiries about how one determines a useable quantity. EPA, at this time, has not decided on what basis to make this determination (it could, for example, be 600 gal/day which is enough for a single household of 4 people) since relatively low yield aquifers can still be useable in certain circumstances. Comment is requested on the current definition of aquifer, specifically on how the Agency should define a "useable quantity" of water.

Test of Significance

The term "significant" or "significantly" as used in these proposed rules has not always been defined in quantitative terms. A statistical test or tests to quantitatively define "significant" will be developed where the Agency believes it is necessary and will be cited or referenced where appropriate in the final rules. One method specified in these rules is the use of Student's t-test.

Comment and information from the public regarding appropriate statistical methods or tests to apply in these regulations where the term "significant" is used, but no quantification is made would be appreciated.

INTEGRATION WITH OTHER ACTS

Underground Injection and Ocean Disposal

The disposal of hazardous waste by underground injection and ocean disposal is not covered by these proposed rules where these activities are regulated under the Safe Drinking Water Act (SDWA), and the Marine Protection, Research, and Sanctuaries Act (MPRSA). Most underground injection facilities, however, involve above-ground storage of waste prior to injection. Some of these facilities will have to comply with both the Subpart D (RCRA) standards and the Underground Injection Control (UIC) regulations to be promulgated under the SDWA. The UIC regulations also will include closure procedures for underground injection wells. Similarly, most ocean disposal operations involve onshore facilities which must comply with the Subpart D (RCRA) standards.

NPDES Permitted Facilities

These proposed rules apply to owners/operators of all treatment, storage, and disposal facilities which receive hazardous waste. Accordingly, they may apply to some National Pollutant Discharge Elimination System (NPDES) permitted facilities, such as publicly or industrially owned waste water treatment plants which handle hazardous waste. The regulatory considerations for publicly owned facilities differ from those for industrially owned facilities, and accordingly are discussed separately below.

These hazardous waste control regulations apply only to the transport of hazardous waste directly by truck or rail to publicly owned treatment works (POTW). Once a hazardous waste, transported to a POTW, has been mixed with sewage, the resulting mixture is no longer considered a solid waste under RCRA. However, the General Pretreatment Regulations (43 FR 27736, June 26, 1978) and the specific pretreatment standards (40 CFR Chapter I, Subchapter N) regulate these materials prior to their introduction by industry into the municipal system, during transport to the publicly owned treatment works, and their treatment and disposal at the treatment works. The pretreatment requirements apply regardless of whether the materials are discharged into municipal sewers or are transported by truck or rail to the publicly owned treatment works. Therefore, these proposed hazardous waste rules are in addition to the pretreatment requirements and only apply to the handling of hazardous waste during delivery to a POTW by truck or rail and before it is mixed with sewage.

Industrially owned waste water treatment plants which discharge directly to surface waters are currently permitted under the NPDES program. These NPDES permits apply only to surface discharges to navigable waters. Since these facilities frequently involve surface impoundments which receive and treat hazardous waste, the possibility exists for subsurface discharges and/or air emissions which are harmful to human health and the environment. Thus, if these impoundments receive hazardous waste, as defined in Subpart A, these facilities are subject to these proposed rules in addition to the current NPDES program. (It should be noted that any hazardous waste (sludge) generated by such industrial wastewater treatment plants is also subject to these regulations.)

Similarly, industrially owned wastewater treatment plants which discharge to publicly owned treatment works are currently regulated by pretreatment standards. Where these facilities involve surface impoundments for hazardous waste, as defined in Subpart A, such facilities are subject to these proposed rules in addition to the pretreatment standards.

Several commenters to previous drafts of these proposed rules have expressed concern that it is inappropriate to apply RCRA Subtitle C technical and other standards to hazardous waste inpoundments in an industrial wastewater treatment train subject to pretreatment standards and/or a NPDES permit, especially for existing impoundments which show no signs of leaching to groundwater or of emissions to the air. In response to these comments, it should be noted that these proposed rules allow the owner/operator of any existing hazardous waste impoundment which does not meet all the design and operating standards to show that such an impoundment provides the same or greater degree of performance (e.g., containment) as an impoundment which meets the standards. Thus, if an owner/operator of an existing hazardous waste impoundment can show by monitoring and other means that the impoundment does not leak or exceed air emission requirements, that impoundment may be issued a permit even if it does not meet all the design and operating standards specified herein. The Agency solicits comment on this point with respect to existing hazardous waste impoundments.

Integration with BAT/Pretreatment Standards

Best Available Technology (BAT) toxic effluent guidelines and pretreatment standards are being developed for specific industries under the Clean Water Act during the same time frame as these proposed rules. The Agency may review the Subpart D facility standards on a case-by-case basis for those industries for which BAT and pretreatment standards are being developed in order to ensure that the two programs together provide the greatest environmental protection. Such evaluation would include consideration of compliance costs. At present, however, the proposed regulations apply to all industries, except as specified in § 250.46.

Clean Air Act

Owners and operators of hazardous waste management facilities must comply with all applicable standards promulgated under the Clean Air Act. Where applicable, new source performance standards for industrial incinerators promulgated under Section 111 of the Clean Air Act supersede emission standards for hazardous waste incineration established in these Subpart D rules.

Toxic Substances Control Act

Final rules regarding disposal and marking requirements for polychlorinated biphenyls (PCB's) were promulgated on February 17, 1978, pursuant to Section 6(e) of the Toxic Substances Control Act (TSCA). Those rules are intended to protect the environment from further contamination resulting from improper handling and disposal of PCB's.

The Agency is now considering various options for the integration of the Subpart D standards and TSCA rules for disposal of PCB's and other special chemicals. The options with respect to integration of the PCB regulations with the Subpart D standards are:

(1) Publish two sets of rules which are totally independent;

(2) Specify that the PCB rules supersede the Subpart D regulations in areas of overlap;

APPENDIX D
CLARIFICATION OF AQUIFER DEFINITION 40 CFR 260
(JULY 26, 1982)

owner or operator engaged in hazardous waste management. Within the facility there will be an area where hazardous waste treatment, storage, and disposal activities occur. This is the waste management area.

The waste management area is made up of one or more waste management units. The provisions in the Part 264 and 265 regulations (principally the technical standards in Subparts K–N) establish requirements that are to be implemented on a unit by unit basis. A waste management unit is a contiguous area of land on or in which waste is placed. A waste management unit is the largest area in which there is a significant likelihood of mixing of waste constituents in the same area. Usually this is due to the fact that each waste management unit is subject to a uniform set of management practices (e.g., one liner and leachate collection and removal system).

Today's regulations establish specific requirements for surface impoundments, waste piles, land treatment units, and landfills. Generally, each of these four terms is synonymous with the concept of a waste management unit. For example, a surface impoundment is typically a single depression in the ground in which wastes are allowed to mix. Landfills may, however, present an exception to this general rule. Some landfills are designed as a series of adjacent trenches that are separately lined. In this situation, the term "landfill" can refer to the entire set of trenches. Yet, each individual trench is a separate waste management unit under today's regulations. (The principal practical implication of this distinction arises in determining what area of the facility is subject to the monitoring and response program in Subpart F. This will be discussed in more detail in Section VII.D. of this preamble.)

EPA's hazardous waste management regulations have also used the term "process" to describe a part of the facility. "Process" refers to general classes of waste management activities (e.g., surface impoundments, piles) and thus embodies a set of units that may be present at a facility. For example, a facility may contain three separate surface impoundments, two waste piles, and a single landfill. Such a facility contains six waste management units and three waste management processes (e.g., surface impoundment, waste pile, and landfill.)

In some parts of today's regulations and in this preamble, the term "facility permit" is used in describing a permit issued under Section 3005. While the broad term "facility" is used, this is not intended to mean that a permit can only be issued for all units at a facility. EPA may issue a permit for some set of units at a facility. (Under these circumstances, the interim status standards of Part 265 continue to apply to units that are not covered by the individual permit and have not been formally denied an individual permit.)

Today's regulations also refer to waste management "portions." This is the smallest area typically referred to in these regulations. This simply means some area within the confines of a waste management unit.

Finally, today's regulations have clarified somewhat the terminology used to describe areas used for land treatment. In the past, EPA has used the term "land treatment facility" to describe the plot of ground on or in which land treatment occurs. This area is esentially the waste management unit as just described. Therefore, EPA intends to use the term "land treatment unit" when describing these areas. This shift in terminology is designed to make the language used in the regulations more precise. It does not reflect a substantive change in the scope of the land treatment requirements. Thus, the term "land treatment unit" in today's regulations is synonymous with the term "land treatment facility" used in previously-issued regulations.

A. Definitions (Part 260)

In today's regulations, EPA is adding several definitions to 40 CFR Part 260 that are used in the land disposal regulations. In addition, EPA is replacing one definition and clarifying the meaning of another.

1. *Aquifer.* The term "aquifer" is defined in Part 260 (promulgated on May 19, 1980) as a geologic formation, group of formations or part of a formation capable of yeilding a significant amount of ground water to wells or springs. Public comments have suggested that "significant amount" is an imprecise term which may leave owners and operators in doubt as to which formations constitute aquifers. Commenters correctly pointed out that the concept of a "significant amount" was actually site-specific, depending upon the demand for ground water. Furthermore, commenters stated, the potential yield (amount) of ground water from one well could be dramatically lower than the yield from a cluster or field of wells at the same location. In water-scarce areas, it is not uncommon to install several wells into the same formation to collect sufficient ground water to feed into a public water supply system. The lower the yield to one well, the greater the number of wells necessary to serve the users of a given water supply system.

In the preamble to the December 18, 1978 proposal, the Agency had suggested 600 gallons per day as the minimum yield which would constitute a "usable quantity," based upon the needs of a family of four persons. The Agency used the design specification of 125 gallons per person per day in arriving at this minimum yield. Commenters pointed out, however, that this design specification is only applicable to municipal public water supply streams and includes allowances for washing of automobiles, lawn watering, central sewerage, minimal fire protection, etc. Commenters suggested that, if the agency wished to base the minimum yield specification on the needs of a family of four in a rural area (a typical situation where a single, private, ground-water supply well would be used) an individual demand of between 5 and 50 gallons per person per day, to satisfy health and personal hygiene needs, would be appropriate.

Commenters also stated that many land disposal facilities are sited in areas where saturated upper clay layers are available to serve as a natural barrier to the migration of leachate into the ground water in the actual uppermost aquifer. Since any saturated soil material can yield quantities of ground water to wells, even at an extremely low rate, one interpretation of the definition of aquifer could require the saturated clay landfill liner to be monitored in accordance with the ground-water monitoring requirements.

It was never the Agency's intent to consider saturated clay landfill liners to be subject to ground-water monitoring as an aquifer. However, no acceptable criterion was suggested, nor has the Agency been able to produce a universally acceptable interpretation of "significant amount" which is appropriate in all of the various circumstances that may be encountered.

The Agency wishes to define the term "aquifer" more precisely in a manner that is consistent with both the RCRA program and the Safe Drinking Water Act program, and that reflects the ground-water policy that EPA is currently developing to coordinate its ground-water protection programs. EPA is working on this issue, and will announce its result when the work is completed.

2. *Certification.* The terms "certification", "certify", and "certified" are used throughout the regulations, including those promulgated today, to refer to the rendering of a professional opinion concerning compliance with a

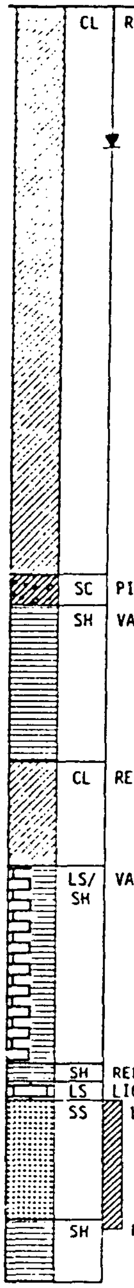
APPENDIX E
LITHOLOGIC LOGS
(MW-1, MW-2, MW-3, MW-4)

MONITORING WELL MW-1

SURFACE ELEVATION: 6876 FEET
(Unsurveyed)

LABORATORY TEST DATA

DEPTH IN FEET	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS		STRENGTH TEST DATA				MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLES
		LIQUID LIMIT (%)	PLASTICITY INDEX (%)	TYPE OF TEST	NORMAL OR CONFINING PRESSURE (PSF)	SHEAR STRENGTH (PSF)	DEVIATOR STRESS (PSF)				
0											
10											
20											
30											
40											
50											
60											
70											
80											
90											
100											
110											
120											
130											
140											
150											
160											



SYMBOLS	DESCRIPTION
CL	REDDISH-BROWN SILTY CLAY, TRACE OF MEDIUM TO COARSE SAND AS BLEBS AND THIN INTERBEDS
	WATER LEVEL 14.1 FEET B.G. 10/18/81
SC	PINKISH-PURPLE, SLIGHTLY SANDY (FINE) CLAY
SH	VARIEGATED SILTY SHALE, REDDISH BROWN GRADING TO GREEN AND LIGHT PURPLE
CL	REDDISH-BROWN SILTY CLAY, FIRM
LS/SH	VARIEGATED LIGHT GREEN AND DARK RED LIMESTONE INTERBEDDED WITH SHALE
SH	REDDISH-ORANGE SHALE
LS	LIGHT-GREEN LIMESTONE DENSE, HARD
SS	LIGHT GREENISH-GRAY, MEDIUM TO FINE, LOOSELY CEMENTED SANDSTONE INTERBEDDED WITH LIGHT GRAY, LOOSE CLAY
SH	REDDISH-PURPLE SHALE

BORING COMPLETED AT 130.4 FEET ON 10/14/81.

▨ SCREENED INTERVAL

FIGURE 30.2-1

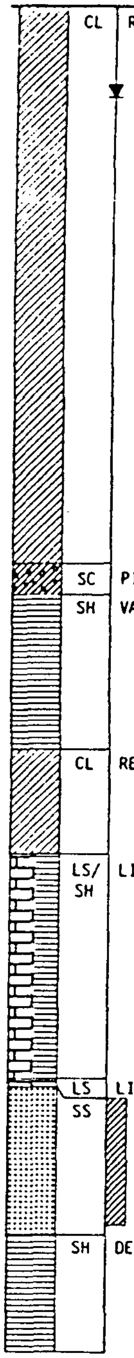
MONITORING WELL MW-2

SURFACE ELEVATION: 6877 FEET
(Unsurveyed)

LABORATORY TEST DATA

DEPTH IN FEET	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS		STRENGTH TEST DATA				MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLES
		LIQUID LIMIT (%)	PLASTICITY INDEX (%)	TYPE OF TEST	NORMAL OR CONFINING PRESSURE (PSF)	SHEAR STRENGTH (PSF)	DEVIATOR STRESS (PSF)				
0											
10											
20											
30											
40											
50											
60											
70											
80											
90											
100											
110											
120											
130											
140											
150											
160											

SYMBOLS **DESCRIPTION**



CL REDDISH-BROWN SILTY CLAY, TRACE MEDIUM TO COARSE SAND AS LOOSE TO FIRM BLEBS

WATER LEVEL 9.1 FEET B.G. 10/18/81

SC PINKISH-PURPLE, SLIGHTLY SANDY (FINE) CLAY

SH VARIEGATED REDDISH-BROWN, GREEN AND LIGHT PURPLE, SANDY TO SILTY SHALE

CL REDDISH-BROWN SILTY CLAY, FIRM

LS/SH LIGHT GREEN TO DARK RED LIMESTONE INTERBEDDED WITH SHALE

LS LIGHT GREEN LIMESTONE, HARD

SS WHITE TO LIGHT-GRAY, FINE TO MEDIUM SAND; SOME CLAY; GRADES GREENISH GRAY TO PINK, COARSE TO MEDIUM SAND

SH DEEP PURPLE SHALE, FIRM

BORING COMPLETED AT 138.0 FEET ON 10/15/81.

▨ SCREENED INTERVAL

FIGURE 30.2-2

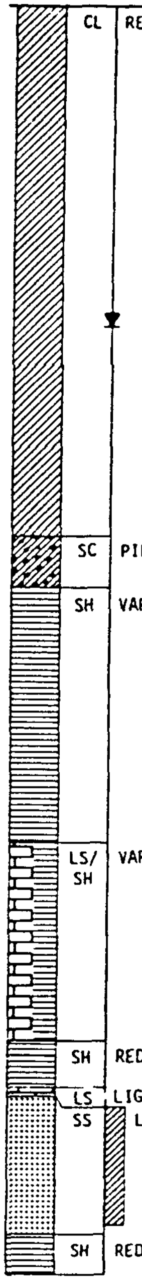
MONITORING WELL MW-3

SURFACE ELEVATION: 6880 FEET
(Unsurveyed)

LABORATORY TEST DATA

DEPTH IN FEET	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS LIQUID LIMIT (%)	PLASTICITY INDEX (%)	STRENGTH TEST DATA TYPE OF TEST	NORMAL OR CONFINING PRESSURE (PSF)	SHEAR STRENGTH (PSF)	DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLES
0											
10											
20											
30											
40											
50											
60											
70											
80											
90											
100											
110											
120											
130											
140											
150											
160											

SYMBOLS DESCRIPTION



CL REDDISH-BROWN SILTY CLAY LOOSE GRADING TO FIRM

GRADES SLIGHTLY SANDY 23-30 FEET AND AT 40 FEET

WATER LEVEL 32 FEET B.G. 11/10/81

SC PINKISH-PURPLE, SLIGHTLY SANDY CLAY

SH VARIEGATED REDDISH-BROWN AND RED SILTY SHALE, LOOSE

GRADES GREEN TO LIGHT PURPLE AND SANDY, 65-75 FEET

GRADES FIRM REDDISH-BROWN SILTY SHALE, 75-85 FEET

LS/SH VARIEGATED LIGHT GREEN AND DARK RED LIMESTONE WITH INTERBEDDED REDDISH-BROWN SHALE

SH REDDSIH-ORANGE SHALE, MODERATELY FIRM

LS LIGHT BROWN LIMESTONE, BLOCKY, DENSE

SS LIGHT GREENISH-GRAY, MEDIUM TO FINE SANDSTONE, LOOSE, SOME CLAY

GRADES PINK AND COARSE TO MEDIUM

SH REDDISH-PURPLE SHALE, MODERATELY FIRM

BORING COMPLETED AT 129.0 FEET ON 10/16/81.
WATER TABLE NOT MEASURED.

▨ SCREENED INTERVAL

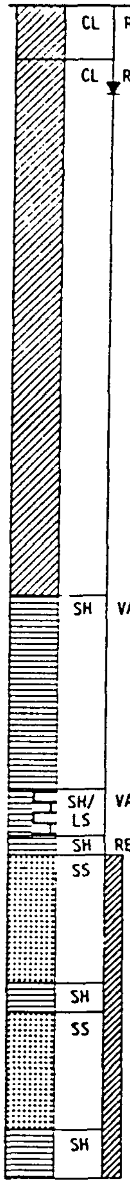
FIGURE 30.2-3

MONITORING WELL MW-4

SURFACE ELEVATION: 6883 FEET
(Unsurveyed)

DEPTH IN FEET	LABORATORY TEST DATA									BLOWS/FT.	SAMPLES
	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS		STRENGTH TEST DATA				MOISTURE CONTENT (%)	DRY DENSITY (PCF)		
		LIQUID LIMIT (%)	PLASTICITY INDEX (%)	TYPE OF TEST	NORMAL OR CONFINING PRESSURE (PSF)	SHEAR STRENGTH (PSF)	DEVIATOR STRESS (PSF)				
0											
10											
20											
30											
40											
50											
60											
70											
80											
90											
100											
110											
120											
130											
140											
150											
160											

SYMBOLS **DESCRIPTION**



REDDISH-BROWN SILTY CLAY, LOOSE

REDDISH-BROWN CLAY, FIRM
WATER LEVEL 8.7 FEET B.G. 10/18/81

GRADES SILTY AND SANDY (COARSE) 20-25 FEET

VARIEGATED REDDISH-BROWN, GREEN AND LIGHT PURPLE SILTY SHALE
GRADES REDDISH-BROWN TO RED-ORANGE, 65-70 FEET

VARIEGATED LIGHT GREEN TO DARK RED SHALE AND THIN LIMESTONE BED

REDDISH-ORANGE, SLIGHTLY SANDY SHALE

WHITE TO LIGHT GRAY, CLAYEY SANDSTONE

PURPLE SANDY SHALE

WHITE TO LIGHT GRAY SANDSTONE, HARD

PURPLE SHALE WITH THIN LENSES OF CLAYEY SAND

BORING COMPLETED AT 120.0 FEET ON 10/16/81.

▨ SCREENED INTERVAL

FIGURE 30.2-4

APPENDIX F
ANALYSIS OF TEST PUMPING OF CHINLE SHALES

APPENDIX F
TEST PUMPING OF CHINLE SHALE

METHODOLOGY AND DESCRIPTION OF THE TEST

The test consisted of a 5 hour pumping period and a 2 hour recovery period. An air-driven piston pump capable of sustaining pumping rates as low as 10 gallons/hour (0.167 gpm) was used for the test. Water level measurments were taken with an electronic sounder. The well (OW-24) is located approximately 250 feet northwest of the land treatment facility and is completed within the Chinle shale. The lithologic and completion log of the well is attached (Figure F-2).

Pumping began at 1515 hours on February 20, 1985 at a rate of 10 gallons/hour. The produced water was very turbid. Clogging of the pump and pump lines necessitated continuous monitoring and adjustment of the discharge.

After 4 hours of pumping at 10 gallons/hour, the drawdown of the well appeared to stabilize at about 7 feet. The discharge rate was increased to 20 gallons/hour in order to more effectively stress the aquitard. After one hour of additional pumping a total drawdown of 12 feet was observed. However, this higher pumping rate increased the turbidity of the discharge and caused instability of the pumping rate. The lack of control of the discharge rate and the potential of diamage to the pump forced the termination of the test after a total of 5 hours of pumping.

Water level recovery was observed for 100 minutes. At this time the water level had recovered to within 90% of the pre-pumping level.

PUMP TEST ANALYSIS

Field measurements are summarized in Table F-1. Due to the short pumping time and potential well-bore and gravel-pack effects, the final analysis was based on methods developed by Shafer, for low-conductivity materials.

Partial penetration effects were neglected in the analysis because the low pumping rates and the expected anisotropy of the aquitard would prevent significant vertical flow to the well bore. The low pumping rate was also designed to completely drain the gravel pack in the well to insure accurate recovery data.

A copy of Shafer's methodology is attached, and the data for his analysis is given in Table F-2. Figure F-1 is a plot of the recovery data, according to Shafer's methods. This Figure includes calculation of T and K for the Chinle shales.

TABLE F-1

Pump Test Data, OW-24

TD = 58'-4" = 58.33'
DW = 31.96
Pump @ 55
26.37' of water
≈ 18 gal

PUMPING DATA

Page 1 of 2

2

DATA SHEET FOR RECORDING PUMP TEST DATA

County: McKinley Co.
Location: Giant Refinery 2/20/85
Observation well no.
Pumped well no. GW-24

Average Q ____ gpm r = ____ ft. r^2 = ____

	Date	Hour	t (min)	t' (min)	t/t'	Depth to water	s (unadjusted)	Adjustment Δs	s' (adjusted)	gph Q (~~gpm~~)	Remarks
	2-20	1515	0			31'-11.5"	0 in	Feet		10 gph	STATIC LEVEL w/ PUMP
		1516	1			33-0	12.5	1.04			LARGE INITIAL DR[illegible] FROM HOSE FILL UP
		1517	2			33-1	13.5	1.13			Setting pump rate
		1518	3			33-4	16.5	1.38			
		1519	4			33-8¾	20.75	1.73			
		1520	5			33-11½	24.0	2.0'			
		1521	6			34-2	26.5	2.22			
		1522	7			34-2½	27.0	2.25			
1 min		1523	8			34-3	27.5	2.27			
		1524	9			34-4	28.5	2.37			
		1525	10			34-5	29.5	2.46			
		1527	12			34-6¾	30.75	2.56			
		1529	14			34-9	33.5	2.79			
		1531	16			35-0	36.5"	3.04			
2 min		1533	18			35'-2¾	38.75	3.23			
		1535	20			35-4½	41.0	3.42			
		1540	25			35-10½	47.0	3.92			
		1545	30			36-3	51.5	4.28			
		1550	35			36-2½	51.0	4.25			
		1555	40			36-8	56.5	4.71		10 gph	CLEARED PUMP value
5 min		1600	45			37-2¾	62.75	5.23			
		1605	50			36-10½	61.0	5.08			clear pump value
		1610	55			NR					
		1615	60			37-10¾	~~82.75~~ 70.75	5.90			Pumped 10 gal
10 min		1625	70			38'-½	85.0 73.0	6.08			

PUMPING DATA

Page 2 of 2

DATA SHEET FOR RECORDING PUMP TEST DATA

County :
Location: Ciniza Refinery
Observation well no. MW-24
Pumped well no. MW-24
Average Q 10gph gpm r = — ft. r^2 = —

Date	Hour	t (min)	t' (min)	t/t'	Depth to water	s // (unad-justed)	Adjust-ment Δs	s' (ad-justed)	% (~~gpm~~) gph	Remarks
2-20	1635	80			39-3½	~~88.0~~ 76	6.33		10	
	1645	90			38-7-	~~91.5~~ 79.5	6.79			Lift pump to 50'
	1655	100			37-8½	69.0	5.75			clear pump, ready pressure
	1705	110			38-11½	~~94.0~~ 84.0	7.00			
2 hours	1715	120			39-2½		7.27			Pumped 20 gal
	1730	135^{15}			38-11		6.97			
15 min	1745	150^{30}			39-2½		7.25			
	1800	165^{45}			39-0½		7.08			
3 h	1815	180^{60}			39-2		7.21			Pumped 30 gal
	1830	195^{15}			39-5		7.46			
	1845	210^{30}			39-5		7.46			
	1900	225^{45}			39-2		7.21			
4 h	1915	240^{60}			38-11½		7.00			Pumped 40 gal
	1930	255^{15}			39-0		7.04		10	
	1932	257^{17}			39-4		7.38		20	INCREASE PUMP RATE TO 20 GPH
	1934	259^{19}			39-10		7.87			PUMP SLIPPED APPROX 1 FEET - REPLACED TO APPROX SAME LEVEL
2 min	1936	261^{21}			40-3½		8.33			
	1938	263^{23}			40-3½		8.33			
	1940	265^{25}			40-1½		8.17			PUMPING RATE FELL-OFF SLIGHTLY
	1945	270^{30}			40-9		8.79			
	1950	275^{35}			41-9½		9.83			
5 min	1955	280^{40}			42-0		10.04			
	2000	285^{45}			41-8		9.72			
	2005	290^{50}			42-8½		9.75			
	2010	295^{55}			43-4		11.27			Silt in Pump
	2015	300^{60}			43-2½		11.25			Adj pump valve
15 min 5 h	2030	315^{15}			43-10½		11.92			pumped 60 gal

RECOVERY DATA

Page 1 of 1

DATA SHEET FOR RECORDING PUMP TEST DATA

Rec

County :

Location: Ciniza Refinery

Observation well no.

Pumped well no. MW - 24

Average Q ______ gpm r = ______ ft. r^2 = ______

Date	Hour	t (min)	t' (min)	t/t'	Depth to water	s (unadjusted)	Adjustment Δs	s' (adjusted)	Q (gpm)	Remarks
/23	20:32		0		43-11½	144"	12.0'	0	20gph	
	2034		2		42-7-		10.63'	1.37		
	2036		4		41-8¾		9.69	2.31		
2 min	2038		6		40-10¾		8.86	3.14		
	2040		8		40-2		8.21	3.79		
	2042		10		39-6¼		7.56	4.44		
	2047		15		38-0¾		6.11	5.89		
	2052		20		37-1½		5.17	6.83		
	2057		25		36'4-		4.38	7.62		
	2102		30		35-8½		3.75	8.25		
	2107		35		35-2¼		3.27	8.73		
	2112		40		34-9¾		2.86	9.14		
5 min	2117		45		34-5¾		2.52	9.48		
	2122		50		34-2¾		2.27	9.73		
	2127		55		34-0½		2.07	9.93		
	2132		60		33-10½		1.92	10.08		
	2142		70		33-7½		1.66	10.34		
10 min	2152		80		33-5¾		1.51	10.49		
	2202		90		33-4½		1.42	10.58		
	2212		100		33-3¼		1.32	10.68		
	2222		110							
	2232		120							
15 min	2247		135							
	2302		150							
	2317		165							

TABLE F-2

DATA FOR SHAFER'S METHOD

Time Since Pumping Started (min)	Drawdown (feet) (s)	Feet of Casing Filled (ft)	Time To Fill (min)	Q (gpm)	S/Q (ft/gpm)
317	12.0	0	0	---	----
319	10.63	1.37	2	.45	23.8
321	9.69	.94	2	.31	31.6
323	8.86	.83	2	.27	32.7
325	8.21	.65	2	.21	38.7
327	7.56	.65	2	.21	35.6
332	6.11	1.45	5	.19	32.3
337	5.17	.94	5	.13	42.1
342	4.38	.79	5	.10	42.5
347	3.75	.63	5	.08	45.6
352	3.27	.48	5	.06	52.2
357	2.86	.41	5	.05	53.4
362	2.52	.34	5	.04	56.8
367	2.27	.25	5	.03	69.5
372	2.07	.20	5	.026	79.3
377	1.92	.15	5	.019	98.0
387	1.66	.26	10	.017	97.8
397	1.51	.15	10	.009	154
407	1.42	.15	10	.009	145
417	1.32	.10	10	.006	202

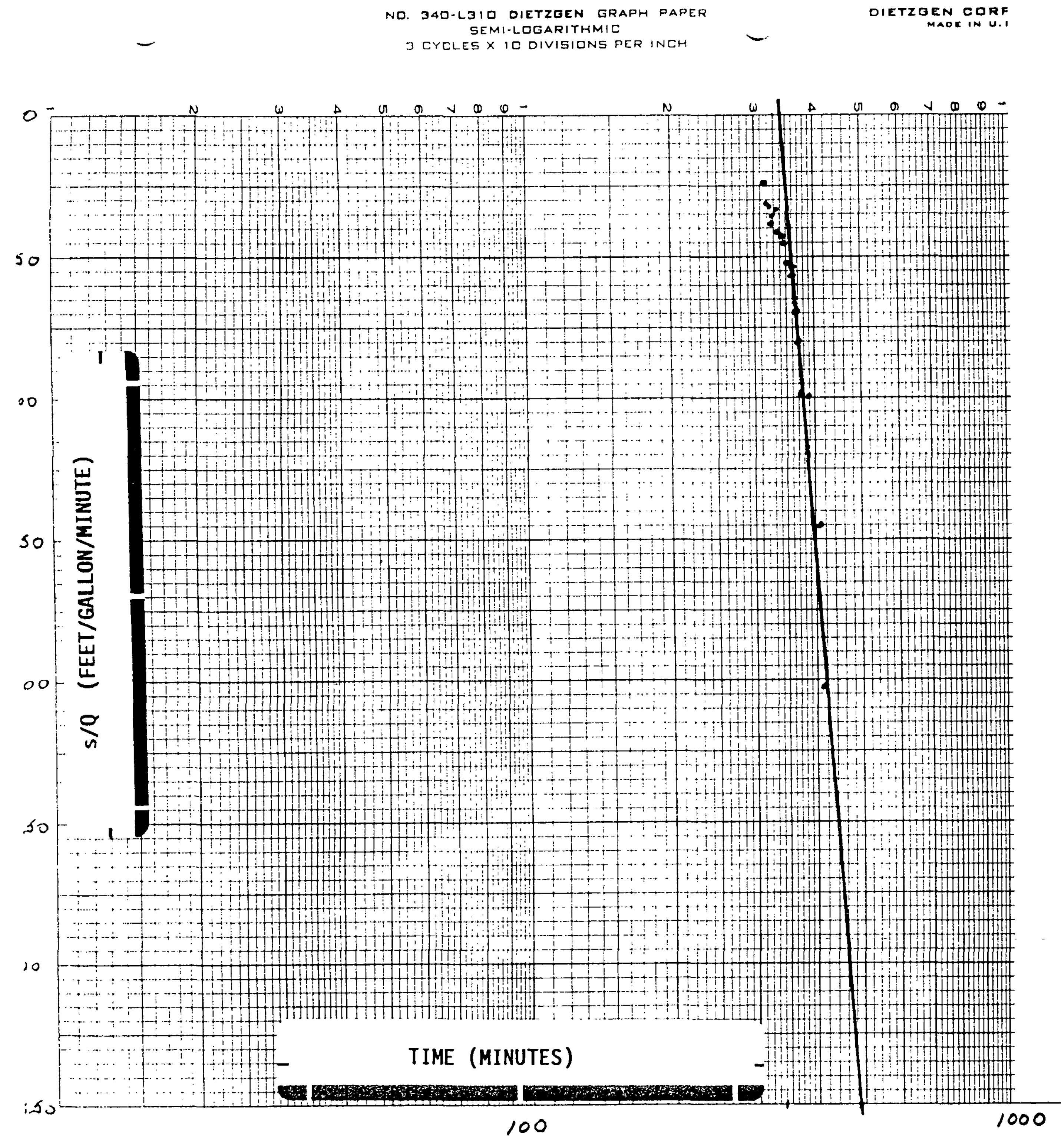


FIGURE F-1
SHAFER PLOT OF DATA FROM OW-24

Calculation of T & K

1) Over the total vertical scale of 350 feet/GPM, time varies by 0.1567 log cycles

2) For 1 full log cycle, s/Q equals 350/.1567 = 2233

3) T = 264/(s/Q) = 264/2233
   or T = 0.110 gallons/day/foot

4) For a 20 foot screened interval
   K = T/b = 0.0055 gallons/day/square foot.

5) .0055 g/d/ft x 1.55 x 10^{-6} (ft/sec)/(g/d/ft)

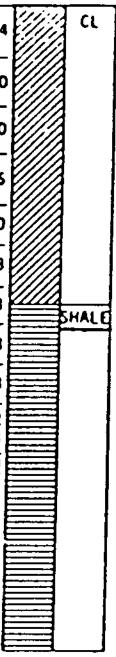
   = 8.3 x 10^{-9} ft/sec

BORING OW-24

SURFACE ELEVATION: 6878 FEET

LABORATORY TEST DATA

DEPTH IN FEET	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS		STRENGTH TEST DATA				MOISTURE CONTENT (%)	DRY DENSITY (PCF)
		LIQUID LIMIT (%)	PLASTICITY INDEX (%)	TYPE OF TEST	NORMAL OR CONFINING PRESSURE (PSF)	SHEAR STRENGTH (PSF)	DEVIATOR STRESS (PSF)		
0									
10									
20									
30									
40									
50									
60									
70									
80									
90									
100									
110									
120									
130									
140									
150									
160									



PENETRATION RATE MINUTES/FOOT	SYMBOLS	DESCRIPTION
2.4	CL	TRIASSIC PERIOD CHINLE FORMATION REDDISH BROWN, VERY FINE SANDY CLAY, SOFT, HIGHLY WEATHERED
2.0		
2.0		
1.6		
2.0		
1.8		
2.3	SHALE	30 FEET: SHALE, REDDISH BROWN, SANDY, SOFT, FRESH
1.8		
2.3		
3.5		
3.3		
4.0		
3.7		
4.0		
2.0		
3.0		
2.3		
2.4		

BORING COMPLETED AT 65.0 FEET ON 1/2/81.
4-INCH PVC PIEZOMETER INSTALLED WITH PERFORATIONS FROM 41.0 TO 61.0 FEET.
GRAVEL PLACED FROM 28.0 TO 61.0 FEET AND BORING SEALED WITH BENTONITE AND CEMENT TO SURFACE.
GROUND WATER LEVEL MEASURED AT 32.5 FEET BELOW GROUND ON 1/5/81.

FIGURE F-2
LOG OF WELL OW-24

LOG OF BORINGS

Pumping Test Analyses for Low Yield Formations

by David C. Shafer

William F. Achuff
Director

Occasionally it is necessary to determine aquifer characteristics of very low yielding formations—those with transmissivities less than 500 gallons per day per foot. Though interest in these aquifers is certainly not because of their productive capability, it may be desirable to determine groundwater flow characteristics even in these low yield formations in order to determine such things as regional groundwater flow patterns, effect of dewatering or migration of pollution plumes near point sources of contamination.

Different Approach

Conventional pumping test analysis using the standard time drawdown graph often does not work effectively in low T (transmissivity) formations for two reasons. First, the pumped well's low specific capacity (gallons per minute per foot of drawdown) may cause the pump to break suction during the test and it may be impractical to throttle back the pumping rate sufficiently to prevent this. Second, even if a constant pumping rate can be maintained without breaking suction, most of the data obtained will probably reflect casing storage effects rather than true aquifer parameters (see "Casing Storage Can Affect Pumping Test Data," Jan-Feb. 1978, Johnson Drillers Journal). Thus a different approach is required.

The best method for analyzing these formations is to pump a substantial portion of the casing empty, then shut the pump off and measure water levels as they recover. In ordinary pumping tests these measurements correspond to the nonpumping portion of the test. However, in the low T formations this "recovery period" is actually the "pumping period!"

After pump shut-off, the casing slowly begins filling with water. This water comes from the aquifer and actually represents the water pumped during this so called "pumping period." The pumping rate is determined by measuring the volume of

Pumping rate = 10 gpm
Pumping period = 15 minutes
Drawdown at pump shut off = 90 ft
Casing — 6" I.D.
Drop pipe — 1¼" I.D.

Time in minutes since pumping started (t)	Drawdown in feet (s)	Number of feet of casing filled	Time in minutes required to fill	Volume filled divided by time required in gallons per minute (Q)	s/Q in feet per gallon per minute
15 (pump shut off)	90				
17	85.66	4.34	2	3.04	28.2
20	79.7	5.96	3	2.78	28.6
30	64.2	15.5	10	2.17	29.5
40	51.9	12.3	10	1.72	30.2
60	35.6	13.3	20	1.14	31.1
80	24.6	11.0	20	.77	31.8

Table 1

casing filled in a given length of time.

During the test, careful measurements are made of time since pumping began (t) along with drawdown (s) at each of these times. Then a calculation is made to determine Q for each time t and finally the ratio s/Q is computed for each measured drawdown value. The ratio is simply the reciprocal of the specific capacity.

A graph is then constructed showing t versus the ratio s/Q plotted as usual on semi-logarithmic graph paper with t on the log scale. A straight line of best fit is drawn through the data points and T is calculated as follows:

$$T = \frac{264}{\Delta(s/Q)}$$

where $\Delta(s/Q)$ is the change in s/Q over one log cycle of graph paper.

This graph has the unique advantage that it will accurately reflect aquifer transmissivity independent of casing storage effects. In addition it will be sensitive to nearby recharge and/or negative boundaries and will reveal these conditions like any ordinary time drawdown graph.

To see how this technique works it is best to work an example. Table 1 shows data obtained from a 6-inch well pumped at 10 gpm for 15 minutes. Drawdown after 15 minutes of pumping measured 90 feet.

The next data point was recorded two minutes following pump shutoff or 17 minutes since pumping started. At this time the pumping water level was 85.66 feet, indicating that 4.34 feet of casing had filled during the two minute interval.

The annulus between the 6-inch casing and 1¼" drop pipe holds 1.4 gallons per foot so that the volume of casing filled is 1.4 times 4.34, or 6.08 gallons in two minutes. Thus,

$$\begin{aligned} Q &= 6.08 \text{ gallons/2 minutes} \\ &= 3.04 \text{ gpm} \end{aligned}$$

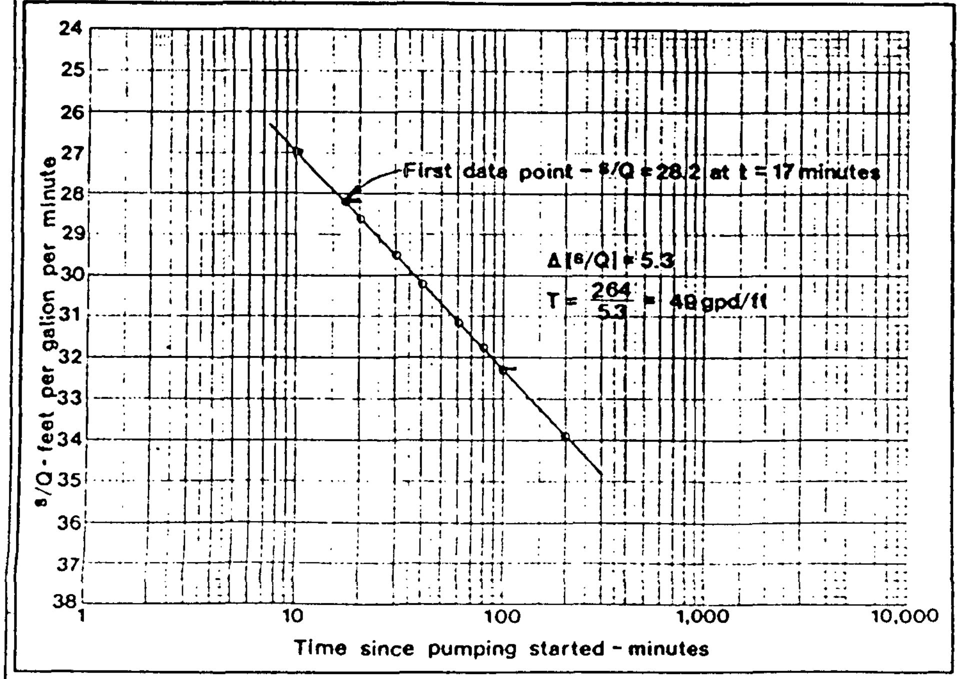
finally,

$$\begin{aligned} s/Q &= 85.66 \text{ ft}/3.04 \text{ gpm} \\ &= 28.2 \text{ ft/gpm} \end{aligned}$$

which is plotted at a time of 17 minutes on the graph shown here.

This analysis is repeated for each drawdown measurement. The resultant calculated s/Q values are shown in the table and plotted in the figure. The formation T value from the graph is

$$\begin{aligned} T &= \frac{264}{\Delta(s/Q)} \\ &= 264/5.3 \\ &= 49 \text{ gpd/ft} \end{aligned}$$



In low transmissivity situations, readings are taken after pump shut-off. In this method, s/Q is the reciprocal of the specific capacity and t is time, measured after shut-off as water begins to enter the casing.

Conventional Analysis

Examination of the hydraulic characteristics of this well (not included here) shows that if a conventional time drawdown graph had been used, casing storage effects would have lasted for approximately twelve hours. This means that data recorded in the first twelve hours of pumping would have been useless and longer pumping than this would have been required to obtain any usable data at all. However, data collected after twelve hours of pumping probably would be more influenced by boundary conditions than by aquifer transmissivity. Thus, in practice it actually might have been impossible to determine the T values using conventional analysis techniques regardless of the length of the test. The value of the method described above becomes very clear; it may be the only way to determine T values in certain low yielding aquifers.

In order to maximize the accuracy of this method, it is best to unload (empty) the casing as rapidly as possible. Thus it is actually better to use a high capacity pump than a low capacity pump in analyzing extremely low-yielding wells!

Another good idea is to unload the casing with compressed air since this can typically be done in one minute or less.

Recorded Data Must Be Accurate

An additional important consideration is that all data recorded for this type of analysis must be absolutely accurate. Small errors in the recorded values of time and/or drawdown can result in large errors in the calculated values of s/Q. For best results, drawdown should be recorded to the nearest hundredth of a foot and timed to the nearest second or two.