GW - 33

MONITORING REPORTS

DATE:

1987

File

EL PASO NATURAL GAS COMPANY
SAN JUAN RIVER PLANT
KIRTLAND, NEW MEXICO

LAND APPLICATION FEASIBILITY STUDY
SAN JUAN RIVER PLANT

PHASE II FINAL REPORT

SUBMITTED TO:

EL PASO NATURAL GAS COMPANY
FARMINGTON, NEW MEXICO

NOVEMBER, 1987

K. W. BROWN & ASSOCIATES

El Paso
Natural Gas Company

P. O. BOX 4990
FARMINGTON, NEW MEXICO 87499
PHONE: 505-325-2841

November 20, 1987

Mr. David G. Boyer
Hydrogeologist/Environmental Bureau Chief
Energy and Minerals Department
New Mexico Oil Conservation Division
P.O. Box 2088
Santa Fe, New Mexico 87501-2088

Subject: San Juan River Plant Land Application Study
Phase II Report

Dear David:

Enclosed for your review are three copies of the San Juan River Plant Land Application Study Phase II Report. Confirming Henry Van's conversation with you, Sid Johnson of K.W. Brown and Associates, Henry Van, and I are expecting to meet with you on December 2, 1987 at 10 A.M. to discuss the report. Feel free to call me or Henry in the interim if you have any questions.

Sincerely yours,

Kenneth E. Beasley III
Compliance Engineer

KEB:cam

Enclosures

LAND APPLICATION FEASIBILITY STUDY
SAN JUAN RIVER PLANT
PHASE II FINAL REPORT

prepared for

El Paso Natural Gas Company
Compliance Engineering Department
Farmington, New Mexico

prepared by

K. W. Brown & Associates, Inc.
6 Graham Rd.
College Station, Texas 77840

November, 1987

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

EXECUTIVE SUMMARY

This report represents the second phase of the land application feasibility study for the El Paso Natural Gas San Juan River Plant (EPNG SJRP) located in Kirtland, New Mexico. The first phase defined which proposed area would be most suitable and defined many of the physical aspects of the study sites. The Phase I report concluded that land application of wastewater at the EPNG SJRP was feasible, and that the East site was superior to the West site and should be selected for further study under Phase II. Phase I determined that the soils were well suited to accept saline wastewater and that the geology and local groundwater characteristics were also amenable.

Phase II further supports the conclusions of Phase I by closely examining the impact wastewater irrigation will have on the East site. Major topics addressed include changes in wastewater quality resulting from altering the wastewater system and the potential impact leaching water would have on groundwater. Additional topics addressed include identifying local features, re-examining local geologic and hydrologic conditions in light of additional information gathered, and providing a sampling plan which can be used during the active operation of the site. One item which was not re-examined was the soils and the impact irrigation would have on them. The reason for not taking a second look at the soils is based on the conclusions drawn in Phase I. The supporting data illustrated the soils are well suited for wastewater irrigation. Moreover, since the wastewater quality has been greatly improved by changes in the wastewater system, the

net effect would be to lower the level of soil management, as discussed in Phase I. Therefore, the discussion presented in the first report is believed to be sufficient in respect to soils at the proposed site.

Changes effected in the wastewater system included removing the CCD regeneration unit and altering the treatment process in the Softener regeneration unit. The net effect of these changes was to lower the total regeneration flow from 2.63 MG/yr to 0.64 MG/yr and to significantly improve the quality of the water (i.e., average TDS from 6,399 mg/l to 2,923 mg/l total wastewater flow).

Computer modeling the effects irrigation would have on groundwater quality were conducted using a 1-dimensional transport model (SUMATRA) and site specific data on the wastewater, geologic setting, and groundwater quality. The model indicates that over a period of 10 years of operation there will be no adverse impact to groundwater under either the conservative or non-conservative scenarios.

The end result of Phase II indicates that land application of wastewater is a viable option provided raw water is available for leaching. It is recommended that Phase III be omitted from the feasibility study since all the evidence to this point indicates land application will be successful, and a viable study taking into account the effects on site specific parameters would be a long-term effort.

Conditions for implementing land application without conducting Phase III of the feasibility study are that the site be monitored, as defined in this report (e.g., soils, soil-pore liquid, and groundwater), and that raw water be available for leaching purposes. It is also suggested that beneficial re-use of the wastewater be considered due to the greatly improved water quality.

1.0 INTRODUCTION

This report represents the second step in the wastewater land application feasibility study for the El Paso Natural Gas San Juan River Plant (EPNG SJRP) located in Kirtland, New Mexico. The first step in the feasibility study was a Phase I report, which was submitted in its final format in August, 1987. Information presented in the Phase I report detailed the quality and quantity of the wastewater to be land applied, identified the types of soils present on the proposed application areas, and defined the geologic and hydrologic setting of the proposed sites. Additionally, local water wells were located and sampled in an effort to define local groundwater quality. Further information on the physical features of the proposed sites was offered which included a complete review of the local water balance, a study of the local vegetation, and defining local topography.

Conclusions of the Phase I report were: 1) of the two sites identified for potential land application, the east site, was superior and should be selected over the west site; 2) based on the information gathered concerning wastewater quality and local physical features (i.e., geology, hydrology, soils, vegetation, and topography) it was determined that the east site was well suited to wastewater irrigation provided the site is managed properly; and 3) the feasibility study should proceed with the implementation of Phase II.

The Phase II report is intended to supplement the Phase I report by providing additional information concerning the actual operation of the land application project. For some topics, such as wastewater quality and geology, it was necessary to update the information presented in the Phase I report. Where information presented in the Phase I report has been changed or modified, it is noted and justification for the change is offered.

Specific topics addressed in this report include a detailed look at the surrounding area and the study site (Section 2.0), an update on the local geologic and hydrologic conditions (Section 3.0), and a re-assessment of the wastewater quality and water balance (Section 4.0) based on proposed changes in the wastewater system. In addition to these changes, information for the active operation of the land application area, which includes irrigation scheduling (Section 5.0) and a monitoring plan for groundwater, soil-pore water, and soil (Section 7.0), is included. Perhaps the most important information presented in this report is the computer models, which predict the fate of a tracer wastewater constituent under conservative and non-conservative scenarios (Section 6.0). Computer models were also used to analyze quality of the existing groundwater. All information was analyzed to justify the feasibility of the land application project.

Information presented in this report along with the information presented in the Phase I report provide the data necessary to support the submittal of a discharge permit for the land application of wastewater produced at the San Juan River Plant.

The original scope of work allowed for a Phase III in the feasibility study. If implemented, Phase III will address laboratory leaching columns and field vegetation studies to assess the suitability of the site for the application of wastewater. Information gathered and presented in this report and in the Phase I report strongly suggest that Phase III is not needed. Justification for omitting Phase III is offered in Section 8.0 of this report.

2.0 SITE DESCRIPTION

The objective of this section is to present relevant information concerning the proposed land application site and the surrounding area. To meet these objectives, several maps and figures are included which graphically illustrate physical characteristics of the site. Specifically, information illustrated on the maps and figures includes current surface topography, flow direction of surface runoff, relevant surface features (i.e., location of borings and monitoring wells), soil types present, surrounding land uses within one mile of the facility boundary, and the locations of known groundwater wells. (Information concerning the potentiometric surface and flow direction of groundwater is presented in Section 3.0.)

2.1 TOPOGRAPHY AND SURFACE RUNOFF

Surface topography (Figure 2-1) at the proposed site is relatively flat. The maximum elevation (approx. 5,312' MSL) occurs on the northeast corner and the minimum elevation (approx. 5,292' MSL) can be found on the southeast corner. Using these values, and given the separation between these points is approximately 2,000 ft, an average surface gradient of 0.01 ft/ft can be calculated.

In addition to determining the surface gradient, topography was used to illustrate potential paths for surface runoff. Localized variation in the flow direction of surface runoff most likely occurs, however, the paths illustrated on Figure 2-2 represent the general flow patterns. One item which is not clearly illustrated is the presence of ditches along the roadways. These ditches will reduce, if not eliminate, runoff from the land application site by retaining runoff on the site. One point which should also be noted is the rapid infiltration rates exhibited by the

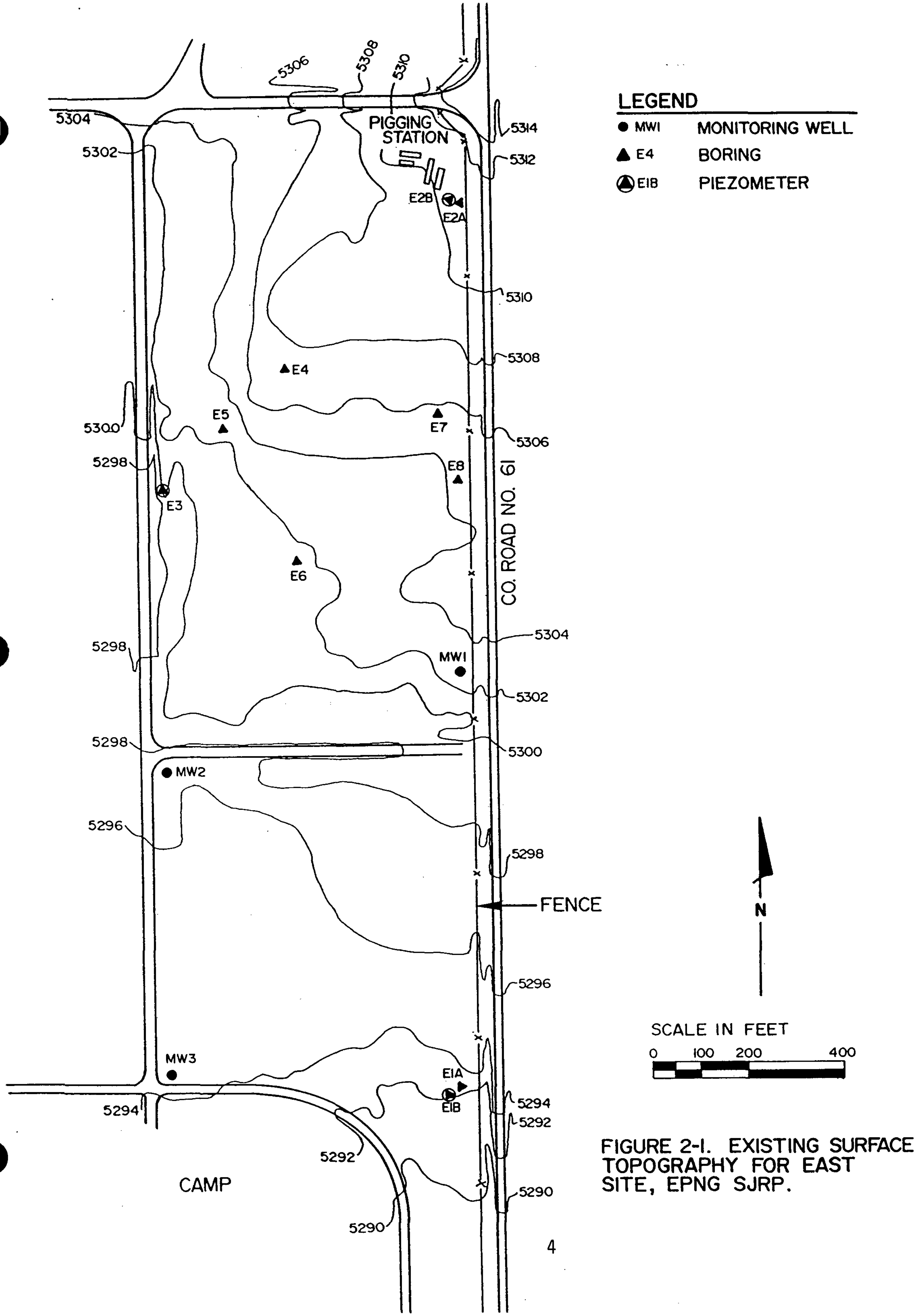


FIGURE 2-I. EXISTING SURFACE TOPOGRAPHY FOR EAST SITE, EPNG SJRP.

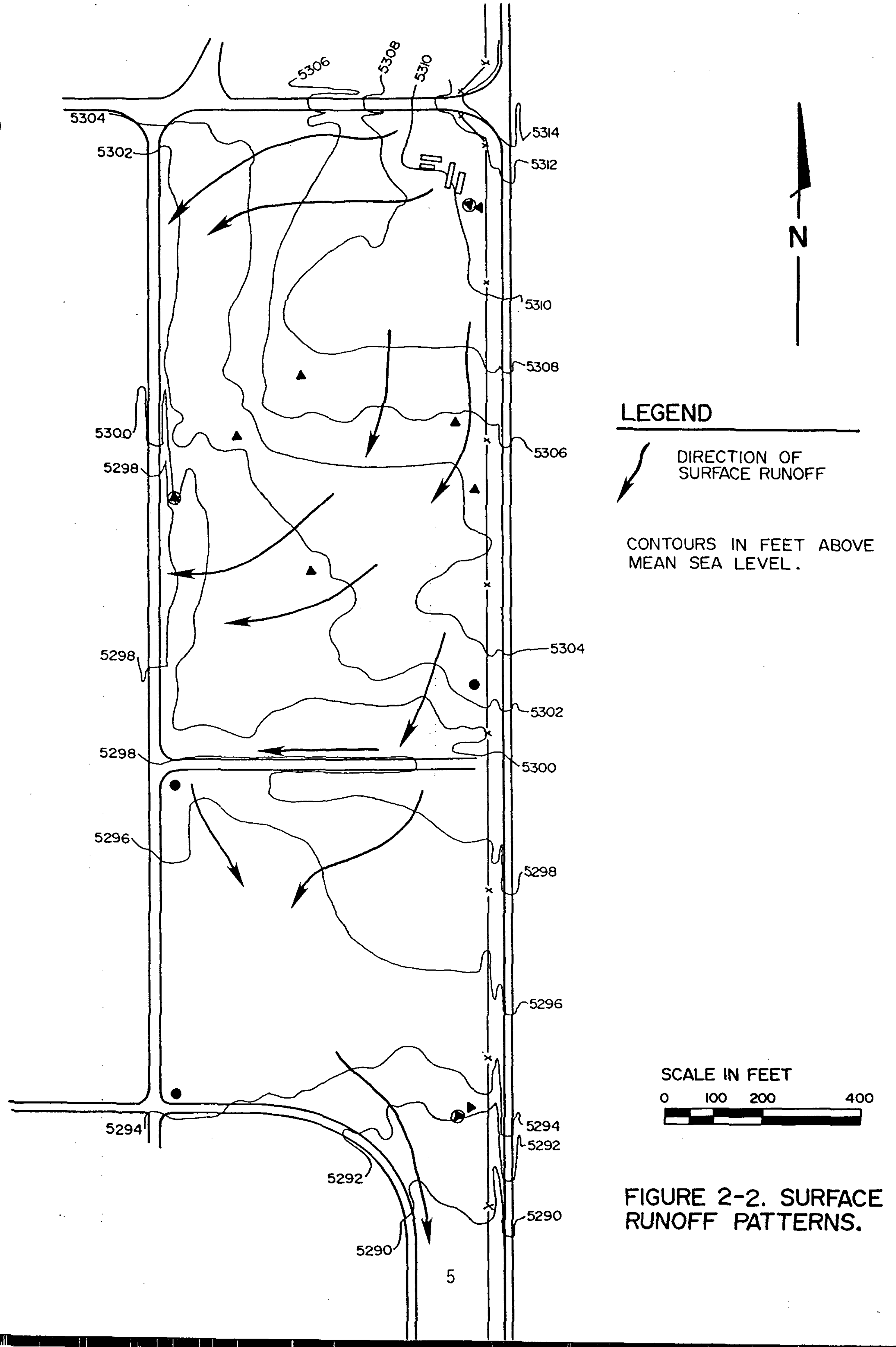


FIGURE 2-2. SURFACE RUNOFF PATTERNS.

majority of the soils at the site (Sheppard = 8.9 in/hr); the rapid infiltration rate, along with the low surface gradient, will virtually eliminate the potential for surface runoff.

2.2 RELEVANT SURFACE FEATURES AND SURROUNDING LAND USE

Relevant surface features illustrated on the various figures include the locations of the piezometers, soil borings, monitoring wells, soil pits, and local anthropogenic features such as pipe lines and roads. Particularly important features which could impact or be impacted by the operation of the land application site, such as residential areas and landfills, (Figure 2-3) and local water wells (Figure 2-4), are illustrated on separate maps.

In addition to these features, the locations of various soil types on the proposed irrigation site are illustrated (Figure 2-5). Refer to Section 3.0 of the Phase I report for a complete discussion on the soil types present.

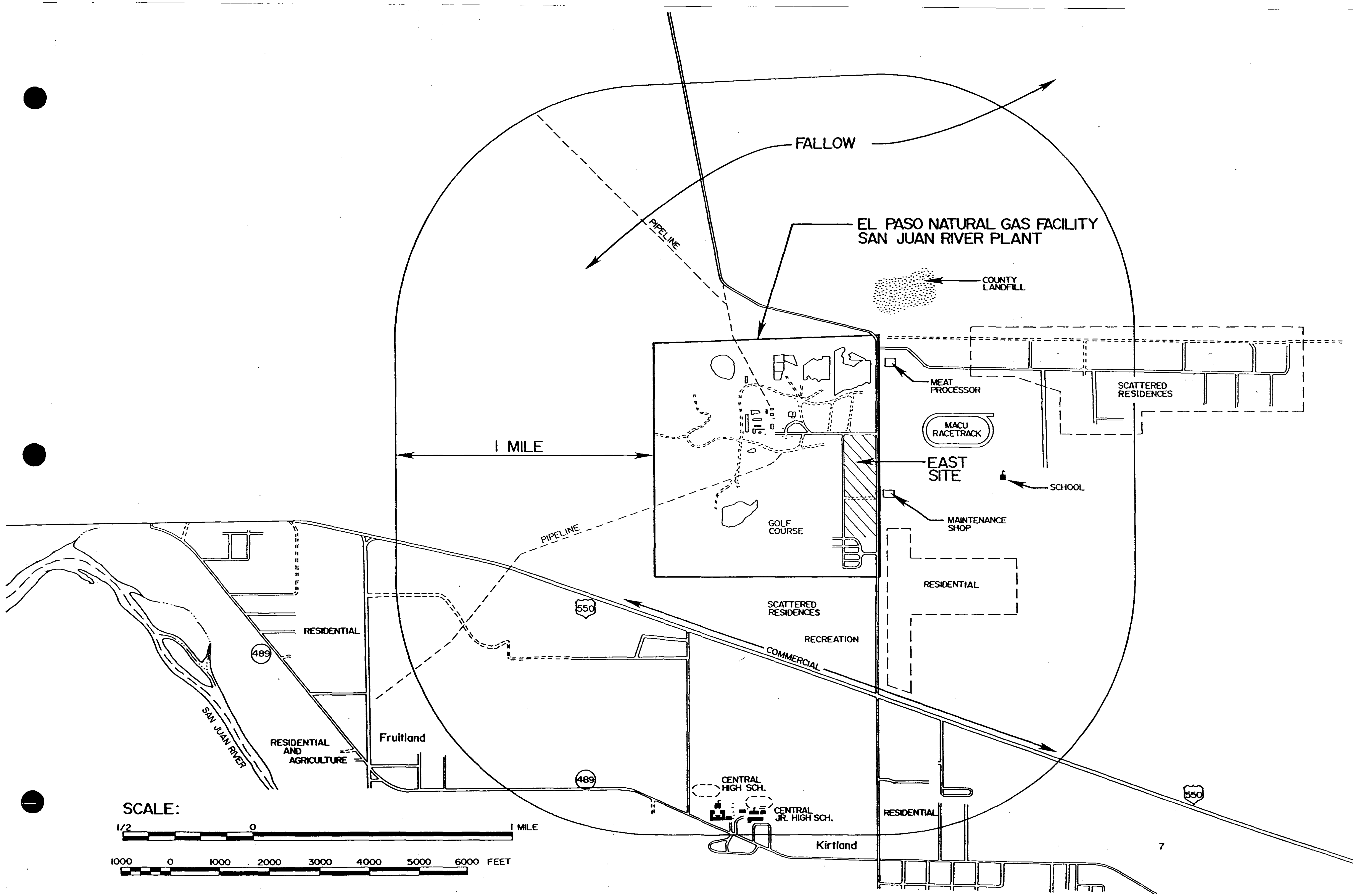


FIGURE 2-3. SURROUNDING LAND USE.

[redacted]

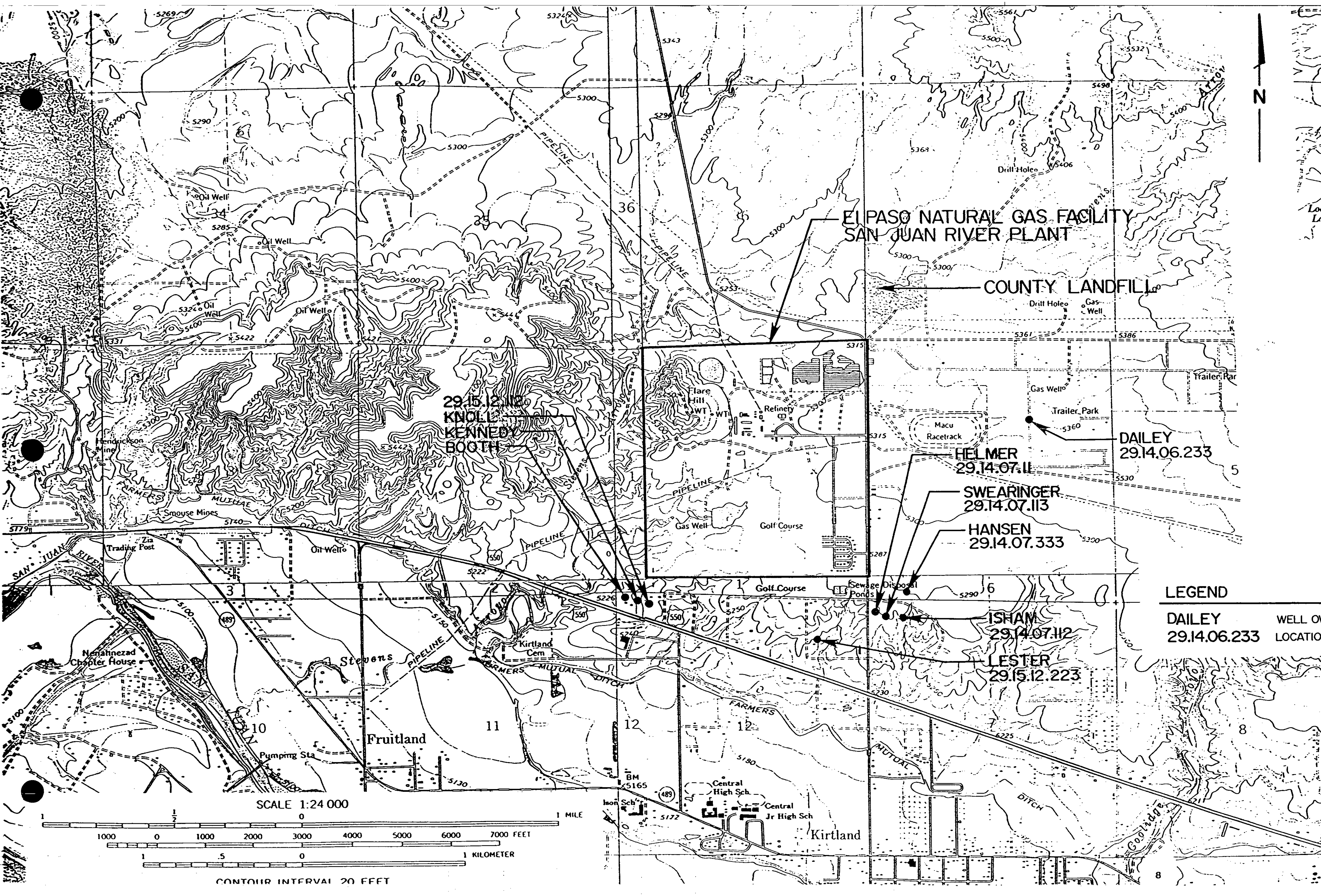


FIGURE 2-4. LOCAL WATER WELLS.

[redacted]

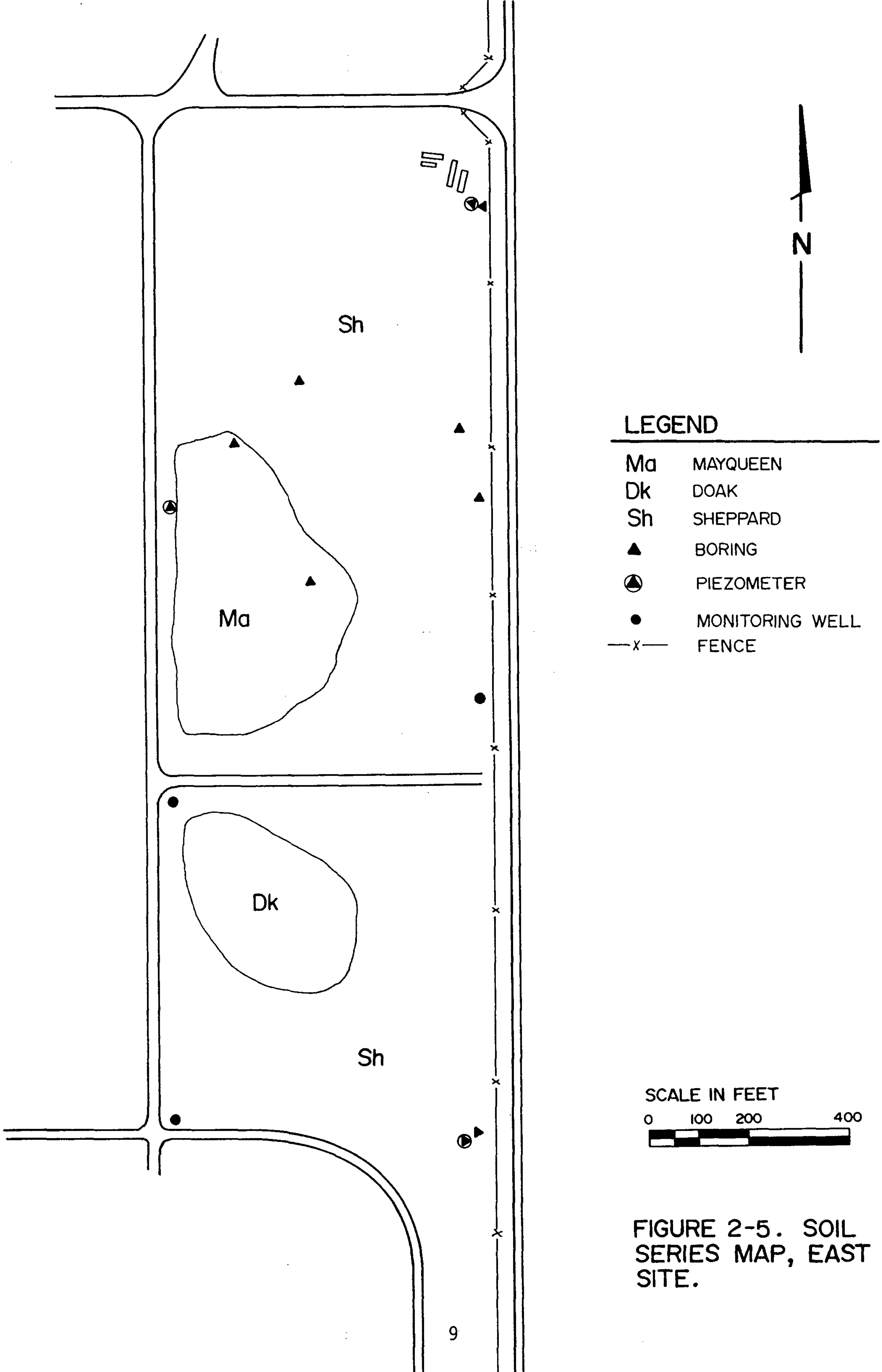


FIGURE 2-5. SOIL SERIES MAP, EAST SITE.

3.0 GEOLOGY, HYDROLOGY, AND GROUNDWATER QUALITY

The bulk of work concerning groundwater and geology was accomplished under the Phase I study; therefore, the purpose of this section is to present additional geologic information gathered during the installation of monitoring wells and piezometers. For a complete discussion on geologic setting and hydrologic conditions, refer to Sections 4.0 and 5.0 of the Phase I report.

The primary objective of the geologic/hydrologic work conducted under Phase II was to define the characteristics of local groundwater, and in doing so, confirm (or modify as needed) the findings of the Phase I report.

3.1 GEOLOGY

Four borings, three of which were completed as monitoring wells, were drilled along the perimeter of the proposed land application site (Figure 3-1). Locations for the borings were selected to provide geologic information for areas of the proposed land application site which were not addressed under the Phase I field work. Areas selected included two locations on the east boundary of the land application site and two on the west boundary. Depths for these borings are listed in Table 3-1.

Table 3-1. Drilling Footage for Phase II Investigation.

Location	Description	Depth (ft)
E8	Boring on east side of site	90
MW-1	Monitoring well on east side of site	95
MW-2	Monitoring well on west side of site	82
MW-3	Monitoring well on southwest corner	85

All borings were drilled by MO-TE Drilling, Inc. of Farmington, NM, using a rotary wash Mayhew-1000. Since the types of sediments at the site

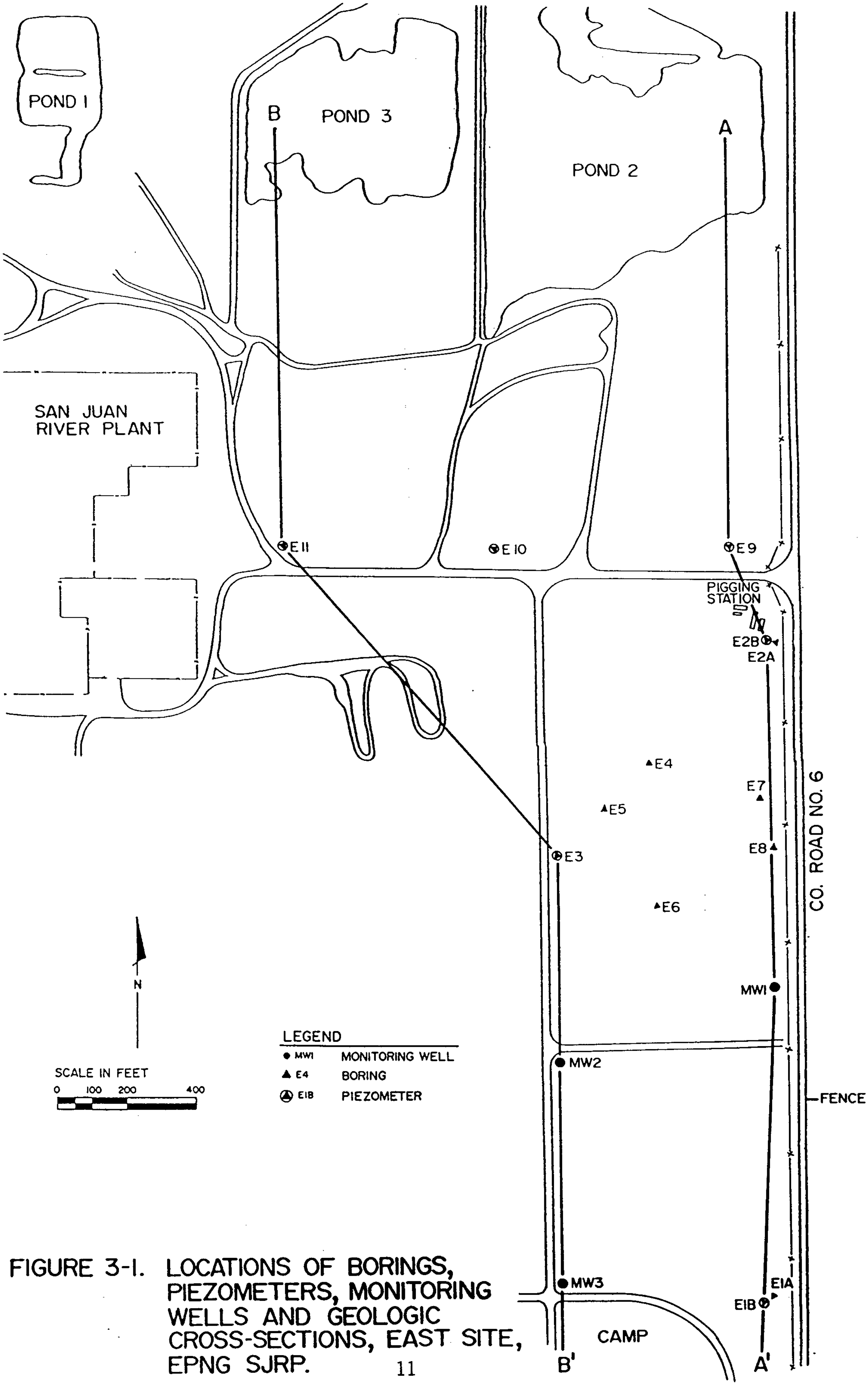


FIGURE 3-1. LOCATIONS OF BORINGS, PIEZOMETERS, MONITORING WELLS AND GEOLOGIC CROSS-SECTIONS, EAST SITE, EPNG SJRP.

were described in great detail during Phase I, the Phase II borings were logged from cuttings rather than from discrete samples. This type of logging does not provide a great deal of detail (i.e., sedimentary structure and discrete textural variations within a zone), however, it is possible to accurately define contacts between layers which vary in texture (logs included in Appendix A). The information gained from these borings was compared to the Phase I information and the correlation was strong.

Geologic information gathered from these borings supports the conclusions drawn in the Phase I report. Specifically, the site is characterized by the presence of a paleo-stream channel which eroded into the Kirtland Shale Formation, leaving behind a stratified sequence of alluvial sediments dominated by sandy textured materials. One important feature noted during the Phase II field work was the presence of channel lag sediments (coarse texture) on top of the erosional surface of the lower member of the Kirtland Shale (Kkl) (Figures 3-2 and 3-3). The varied rock types found in these channel sediments along with the textural sequence (a very coarse grained river sediment on top of a fine grained marine sediment) clearly support the conclusion that the geologic history of the site has been dominated by erosional and depositional stream processes.

Figure 4-3 of the Phase I report illustrates the middle member sandstone of the Kirtland Shale and shows terrace gravel deposits (Qat) overlying the sandstone. Further investigation of the area confirms the presence of the sandstone on the west side of Flare Hill, however, it is unclear as to the exact shape of and extent of the sandstone member in the study area between E2B and Flare Hill. Piezometers installed north of the proposed irrigation area (E9, E10, and E11) were drilled to a depth which was sufficient to encounter the sandstone member if its surface had the same elevation as what was observed in piezometer E2B. However, the

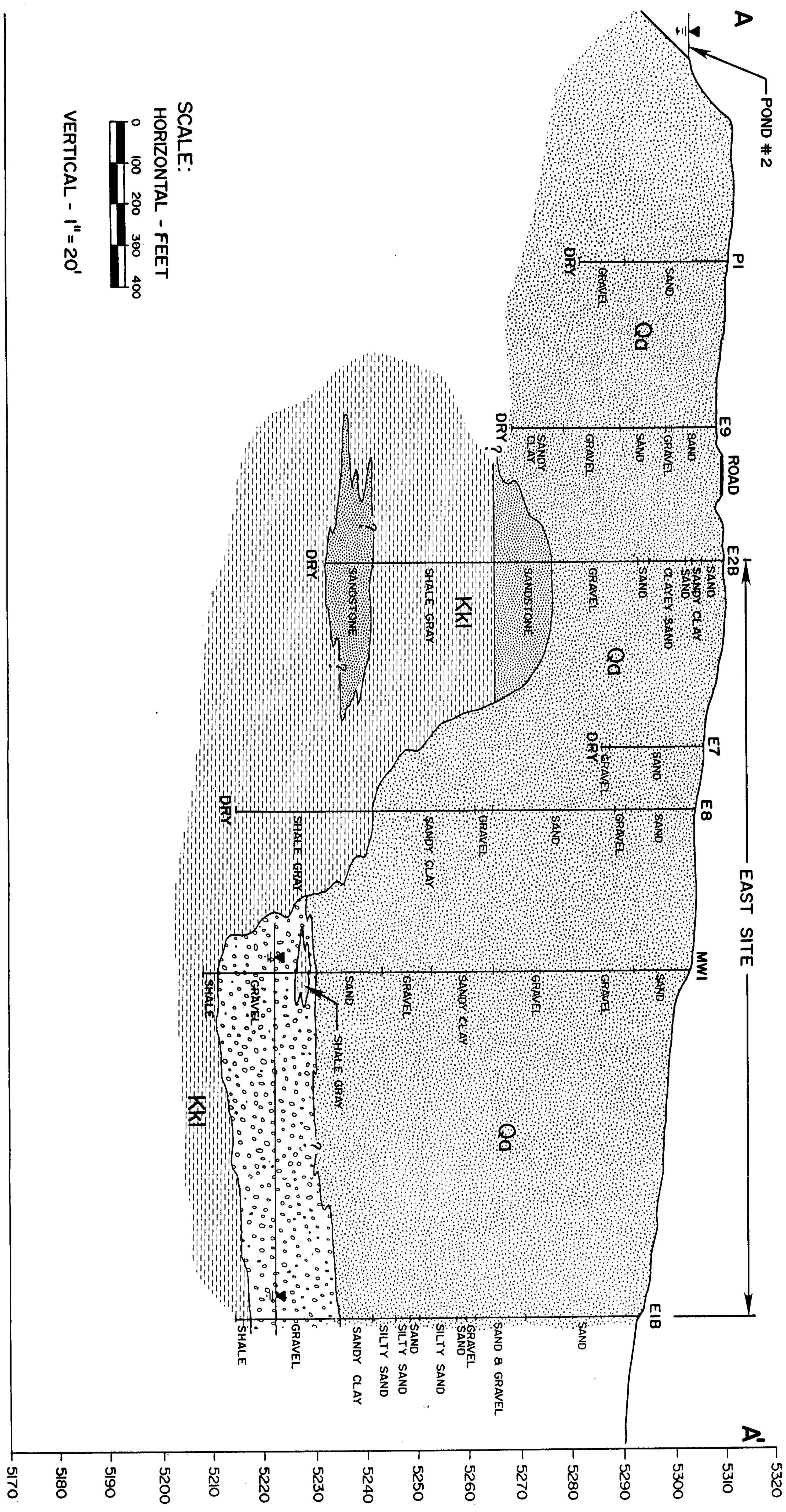


FIGURE 3-2. GEOLOGIC CROSS-SECTION A-A' OF EAST SITE, EPNG SJRP.

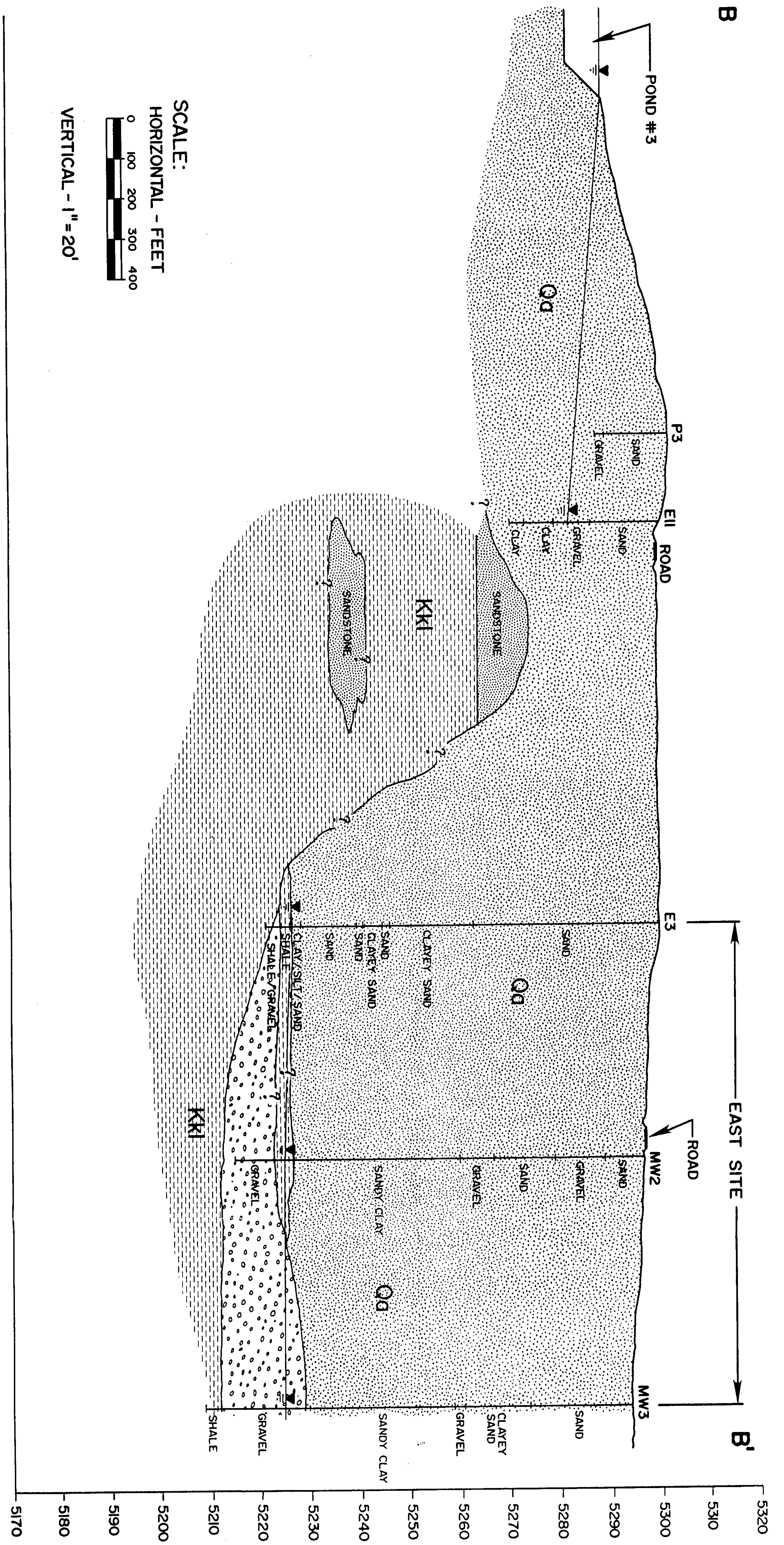


FIGURE 3-3. GEOLOGIC CROSS-SECTION B-B' OF EAST SITE, EPNG SJRP.

sandstone was not located in any of the borings for the piezometers, suggesting that the surface of the sandstone is eroded and irregular.

What can be stated concerning the location of the sandstone unit is that it is present at piezometer E2B and extends due west and outcrops on the west side of Flare Hill. Also, engineering boring conducted during construction activities at the plant indicates the presence of sandstone in the area of the main plant. Borings conducted by Geoscience Consultants (GCL) around the wastewater ponds, which are north of the proposed irrigation site, do not encounter sandstone. Additionally, boring conducted by KWB&A at the proposed irrigation site did not encounter the sandstone unit. Based on this information, it appears that the sandstone unit forms a narrow, subsurface ridge with an east-west trend.

The coarse grained sediments observed in piezometer E2B (identified as terrace deposits) were seen in the borings for piezometers E9 through E11. It should be noted, however, that from the samples collected at the new piezometers it could not be determined if the gravel was terrace deposits. Given that the gravel was underlain by alluvial sediments (sands and clays) it is felt that the gravel seen in these borings is channel gravels resulting from fluvial deposition which was not associated with the deposition of the terrace deposits.

3.2 HYDROLOGY

As previously mentioned, the locations selected for the borings and subsequent well installations were based on the need to gain additional geologic information about the proposed site. However, this was not the only consideration. The monitoring wells also had to be positioned to allow for the collection of groundwater samples that represent local groundwater quality. Since the site has not received any wastewater, it was decided that upgradient and downgradient considerations were not paramount issues. What was considered important was the need to collect a population of samples which reflect local variability in groundwater quality and thereby form a background data base prior to active operation of the site. One final consideration was the need to more clearly define the groundwater flow direction for the area since the initial interpretations formulated in Phase I were sketchy. To meet these demands, wells were positioned around the outer boundary of the site, as illustrated in Figure 3-1.

3.2.1 Monitoring Well Installation

Having selected the sites, completed the borings, and located the water bearing strata, the monitoring wells were set using 2-inch flush thread, Schedule 40 PVC casing. Each flush thread joint was sealed with a Viton O-ring; no solvent or glues were used. Where connections were needed, but flush threads were not available (i.e., bottom cap, connection at sumps, etc.), PVC pegs and PVC slip couplers were used, as illustrated in Figure 3-4. This type of connection, although not as tight as a flush thread, is sufficiently tight and strong to ensure well integrity without the use of solvents and glues.

Once the casing was set, Colorado Silica Sand was used around the well screen and the sensing section was isolated using a bentonite seal. Bentonite pellets (1/4") were used to form the seal and were allowed to hydrate for a minimum of three hours before the grout seal was set. The grout seal (Portland cement mixed with approximately 2% bentonite powder) was pumped through a tremme pipe into the bottom portion of the borehole. Pumping continued until the grout reached the surface. The seal was allowed to settle overnight before being "topped off" with a thick grout slurry. In some cases it was necessary to fill a portion of the bore-

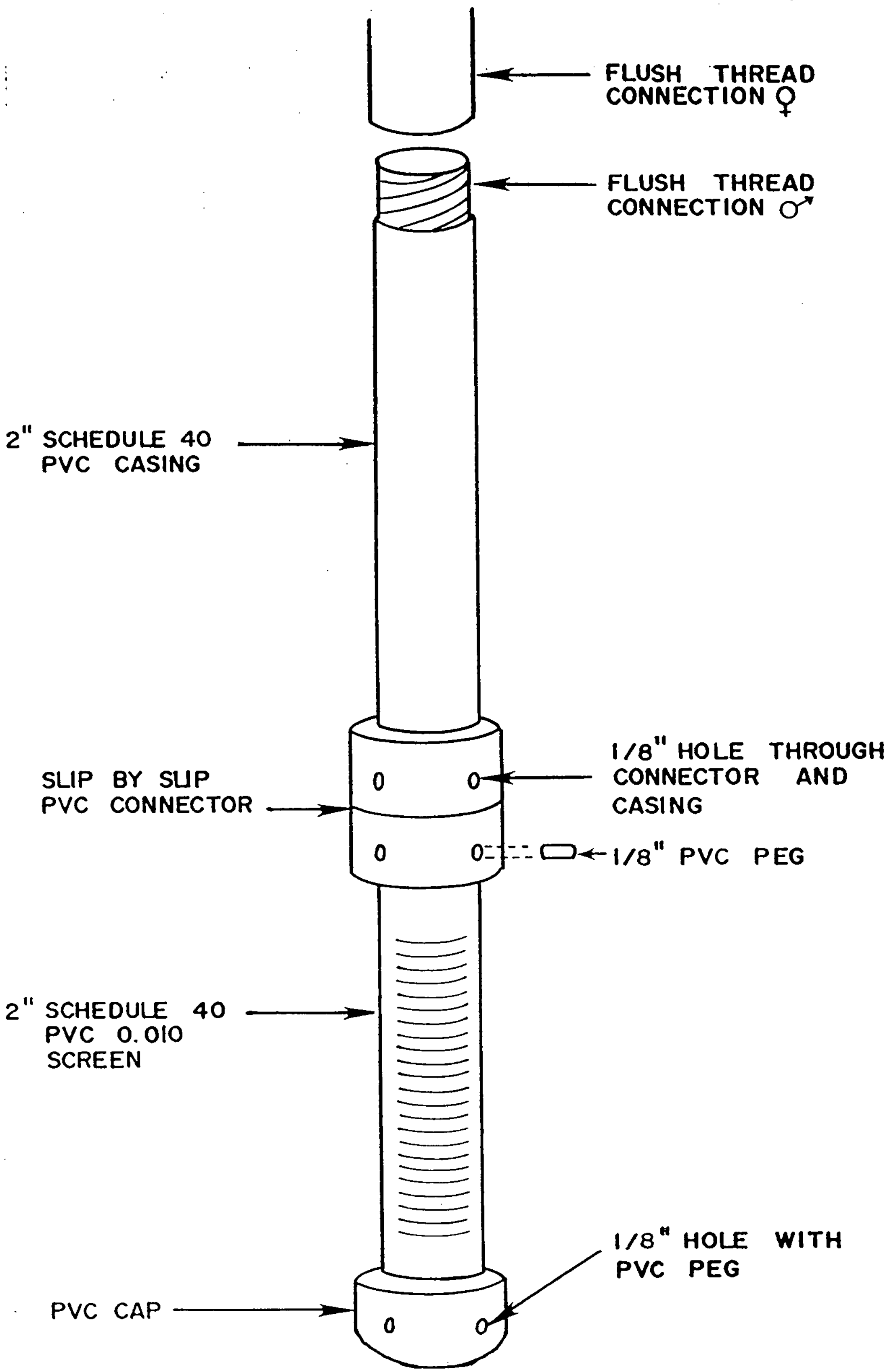


FIGURE 3-4. CONNECTIONS USED IN MONITORING WELLS MW1 THROUGH MW3.

holes with cuttings to prevent the loss of grout into the formation. All construction details are documented in Appendix A.

3.2.2 Monitoring Well Development and Testing

After completion, the monitoring wells were developed using raw water, compressed air, and extensive bailing. The first step in the development of the wells was to flush the borehole with water to remove suspended material. This actually was performed twice: first before the well was set to remove drilling mud from the borehole, and again following well installation to remove suspended material in the well. The second step, after setting the well casing, was to surge water from the well using compressed air. To do this, a 3/4-inch string of PVC pipe was lowered to the bottom of the well and compressed air was passed through the pipe to drive water from the well. Following purging with compressed air, the wells were bailed using a 5-ft long PVC bailer. As the wells were bailed, the electrical conductivity (EC) of the water was monitored. Bailing of the wells continued until the EC of the water stabilized, indicating ambient groundwater conditions had been achieved following well installation.

In association with well development, well tests were conducted to measure the hydraulic conductivity of the screened strata. To determine values for the monitoring wells, two methods were attempted: the falling head test and the rising head test. (For a discussion on these methods, refer to Section 5.2.1 of the Phase I report.) As was the case during Phase I, wells completed in the gravel layer exhibited recovery rates which exceeded the ability to measure the change in water levels. In the case of the falling head test, the amount of water added to each well was sufficient to bring the water level to the top of the casing, yet the well recovered in less than one minute. Throughout the recovery, attempts were made to measure the change in water levels; however, it was physically impossible to keep up and make accurate measurement.

What can be stated concerning the hydraulic conductivity and transmissivity of the water bearing strata is that the values are relatively high. Estimates based on field observations place the hydraulic conductivity (K) for the gravel strata in the neighborhood of 1×10^{-2} to 1×10^{-3} cm/sec. It should be emphasized that these are estimates; at the same time it should be noted the estimated K values are relatively close to values offered by Stone, et al. (1983) ($K = 10^{-1}$ to 10^{-2} cm/sec).

The value offered for hydraulic conductivity in the Phase I report was 2×10^{-5} cm/sec. Upon closer inspection it is believed that this value is valid for the sandy clay sediments above the gravel layer, but does not represent the gravel sediments. Justification for making this correction lies in additional data collected during Phase II, which clearly indicates that wells completed in the gravel exhibit recharge rates much greater than those characteristic of 10^{-5} cm/sec sediments.

3.2.3 Groundwater Flow Direction

Throughout the well installation, development, and sampling process, the water levels in the wells and piezometers were monitored. Depth-to-water values measured in the wells and piezometers are listed in Table 3-2 and the resulting elevations (relative to mean sea level) are listed in Table 3-3. Using these values and the survey elevations for the wells, it was possible to generate the piezometric surface illustrated in Figure 3-5. From this figure it is clear that the groundwater flow direction is to the south, with a slight easterly component.

Table 3-2. Depth to Water Measurements (feet) for the East Site, EPNG SJRP *.

WELL #	GRADE ELEV.	CASING ELEV.	DEPTH TO WATER 18-Jun-87	01-Sep-87	02-Sep-87	03-Sep-87	03-Sep-87	04-Sep-87	09-Oct-87
E1A	5290.7	5292.0	dry	dry	dry	dry	dry	dry	dry
E1B	5290.4	5292.8	68.8	68.9	68.9	68.9	NA	68.9	68.9
E2B	5310.0	5312.8	79.8	80.5	80.5	80.5	NA	NA	80.8
E3	5298.8	5299.7	73.2	72.7	72.8	NA	NA	72.6	72.4
E8	5301.9	NA	---	dry	dry	dry	---	---	---
E9	5307.5	5309.3	---	---	---	---	---	---	dry
E10	5302.9	5303.8	---	---	---	---	---	---	dry
E11	5299.6	5302.3	---	---	---	---	---	---	17.7
MW-1	5301.1	5302.5	---	---	---	77.9	77.8	78.0	78.0
MW-2	5296.2	5297.8	---	---	---	71.4	72.8	72.9	72.8
MW-3	5294.1	5296.4	---	---	---	70.0	71.7	71.8	71.7

Table 3-2. Continued *.

WELL #	DESCRIPTION	TOTAL DEPTH	INSIDE DIAMETER	SCREENED INTERVAL TOP	BOTTOM	INSTALLATION DATE
E1A	Piezometer	58.9	2-inch	53.0	58.9	08-Jun-87
E1B	Piezometer	79.0	2-inch	71.0	76.0	12-Jun-87
E2B	Piezometer	78.5	2-inch	73.5	78.5	11-Jun-87
E3	Piezometer	78.0	2-inch	72.0	77.0	10-Jun-87
E8	Open Bore Hole	90.0	---	open hole		01-Sep-87
E9	Piezometer	40.0	2-inch	30.0	30.0	08-Oct-87
E10	Piezometer	40.0	2-inch	25.0	25.0	08-Oct-87
E11	Piezometer	30.0	2-inch	30.0	30.0	08-Oct-87
MW-1	Monitoring Well	95.0	2-inch	77.0	92.0	02-Sep-87
MW-2	Monitoring Well	82.0	2-inch	74.0	80.0	01-Sep-87
MW-3	Monitoring Well	83.0	2-inch	63.0	83.0	01-Sep-87

* Depths in feet below natural grade.
NA - Not Available/Not Applicable

Table 3-3. Groundwater Elevations (feet MSL) for the East Site, EPNG SJRP *.

WELL #	GRADE ELEV.	CASING ELEV.	WATER ELEVATION 18-Jun-87	01-Sep-87	02-Sep-87	03-Sep-87	03-Sep-87	04-Sep-87	09-Oct-87
E1A	5290.7	5292.0	dry	dry	dry	dry	dry	dry	dry
E1B	5290.4	5292.8	5224.0	5224.0	5223.9	5223.9	NA	5223.9	5224.0
E2B	5310.0	5312.8	5233.0	5232.4	5232.3	5232.3	NA	NA	5232.0
E3	5298.8	5299.7	5226.5	5227.1	5227.0	NA	NA	5227.2	5227.3
E8	5301.9	NA	---	dry	dry	dry	---	---	---
E9	5307.5	5309.3	---	---	---	---	---	---	---
E10	5302.9	5303.8	---	---	---	---	---	---	---
E11	5299.6	5302.3	---	---	---	---	---	---	5284.7
MW-1	5301.1	5302.5	---	---	---	5224.6	5224.7	5224.6	5224.5
MW-2	5296.2	5297.8	---	---	---	5226.4	5225.1	5224.9	5225.0
MW-3	5294.1	5296.4	---	---	---	5226.5	5224.7	5224.6	5224.7

Table 3-3. Continued *.

WELL #	DESCRIPTION	TOTAL DEPTH	INSIDE DIAMETER	SCREENED INTERVAL TOP	BOTTOM	INSTALLATION DATE
E1A	Piezometer	58.9	2-inch	53.0	58.9	08-Jun-87
E1B	Piezometer	79.0	2-inch	71.0	76.0	12-Jun-87
E2B	Piezometer	78.5	2-inch	73.5	78.5	11-Jun-87
E3	Piezometer	78.0	2-inch	72.0	77.0	10-Jun-87
E8	Open Bore Hole	90.0	---	open hole		01-Sep-87
E9	Piezometer	40.0	2-inch	30.0	30.0	08-Oct-87
E10	Piezometer	40.0	2-inch	25.0	25.0	08-Oct-87
E11	Piezometer	30.0	2-inch	30.0	30.0	08-Oct-87
MW-1	Monitoring Well	95.0	2-inch	77.0	92.0	02-Sep-87
MW-2	Monitoring Well	82.0	2-inch	74.0	80.0	01-Sep-87
MW-3	Monitoring Well	83.0	2-inch	63.0	83.0	01-Sep-87

* Depths in feet below natural grade.
NA - Not Available/Not Applicable

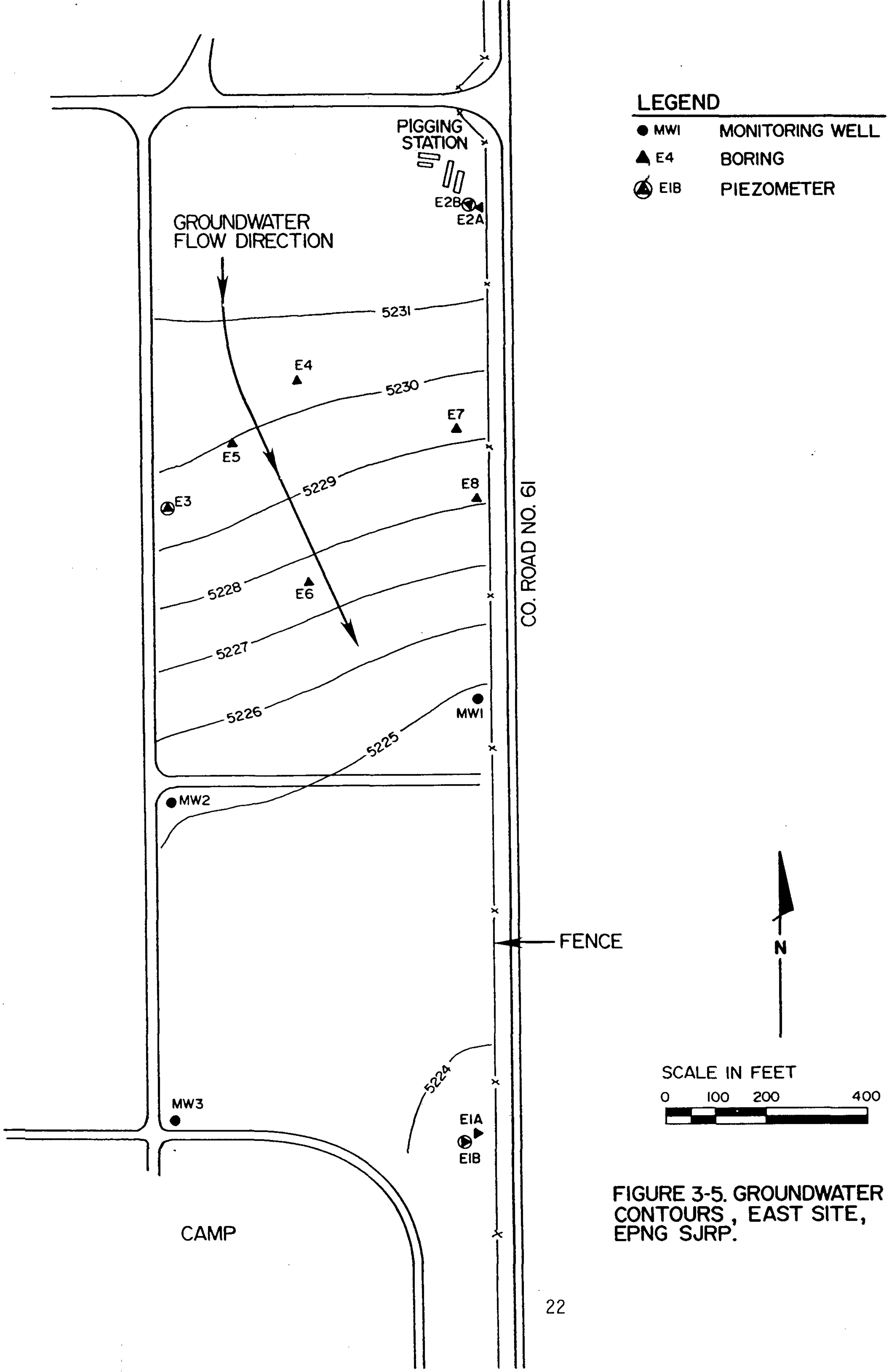


FIGURE 3-5. GROUNDWATER CONTOURS, EAST SITE, EPNG SJRP.

As pointed out in the Phase I report, the flow direction for this area was expected to be to the southwest. In fact, the figure presented in the original discharge plan (and included in the Phase I report as Figure 5-2) clearly illustrates a southwesterly flow direction for the area surrounding the EPNG SJRP facility. It is worth noting, however, that in the area of the proposed land application site, there is a distinctive southerly flow pattern indicated on this early figure. The fact that this flow direction continues to be observed indicates that it is not anomalous, but rather reflects true groundwater conditions as a function of local controlling factors.

There are four possible explanations for the localized southerly flow direction in the overall southwesterly regional flow pattern. The first, and most obvious, explanation is that the southerly flow is the true flow direction for the area and is being controlled by local geology and erosional structural features. The second possibility is that, through years of heavy irrigation at the golf course, a slight groundwater mound has been formed which causes a reversal in flow direction in the area to the east. If this is the case, it would be expected that the magnitude of the mound would be slight, and the perturbations occurring in the piezometric surface would not be very extensive. The third possibility is that leakage from the wastewater ponds to the north is crossing the topographic divide via the alluvial sediments, creating a source of artificial recharge and resulting in a slight alteration in the local flow direction. The final possibility is that a combination of the factors is leading to the observed groundwater flow direction.

To help define which of these conditions exist, three temporary piezometers (E9, E10, and E11) were installed in the alluvial sediments along the topographic divide between the proposed irrigation site and the wastewater ponds (refer to Figure 3-1). Each piezometer was installed so that the sensing section was lower than the elevation of the water in the wastewater ponds. Also, a clay confining layer was identified in each of the piezometers which would serve to perch any water leaking from the ponds.

Preliminary results indicate that E9 and E10 are dry. In addition to these piezometers, a boring completed in the same area by GCL (P-1) likewise indicated that water was not present in the upper 26 ft of sediments. Piezometer E11, however, was yielding relatively large quantities of water at the time of its completion, and the bailed water exhibited an electrical conductivity of 6,800 umhos/cm. Given the quantity of water observed, its poor quality, and its surface elevation, it appears the source for the water in E11 is the wastewater ponds. Information currently available indicates that the seeping water which is crossing the divide is restricted to the area around and possibly to the west of E11.

Based on the information available, it can be stated that the topographic divide appears to be forming an effective barrier at depths greater than approximately 30 ft in the area of the proposed irrigation site. It also appears that the hydrologic divide maintains its integrity above the 30 ft depth to the east of E11. However, it is also apparent that the divide has a breach in the area of E11.

Using the information gained from piezometers E9 through E11, it appears that the south-southeasterly groundwater flow direction observed at the proposed irrigation site is being influenced by seepage from the wastewater ponds as well as local geologic structure. Figure 3-3 clearly illustrates the extreme groundwater gradient which exists between E11 and E3. This figure also illustrates that the configuration of the erosional surface of the shale is most likely influencing the elevation of groundwater at E3. The groundwater elevation observed at E3 is believed to be influenced by the proximity of the piezometer to the vertical face of the shale. Specifically, water flowing down the face of the erosional surface would have a tendency to mound at this point, as the groundwater gradient is reduced.

From the data collected at the site it cannot be determined whether or not the irrigation at the golf course is influencing the groundwater flow direction.

In summary, to date, groundwater flow direction at the proposed irrigation site has consistently maintained a south-southeasterly flow pattern. It is believed that this flow direction is being influenced by the seepage from the wastewater ponds and is, to a certain extent, controlled by the local geology. Upon closure of the wastewater ponds, the water levels in the wells and pizeometers can be monitored for changes.

3.3 GROUNDWATER QUALITY

To establish the groundwater quality in the area, samples were collected from each of the three monitoring wells installed on the proposed site. As previously mentioned, the wells were bailed until the EC of the water stabilized. Once a stable EC value was obtained, the wells were left undisturbed for a period of 12 hours before the samples were collected. This was done to allow the sediments which entered the well during bailing to settle out.

Table 3-4 lists the analytical parameters requested for these samples and Table 3-5 lists the analytical results. The laboratory report for these samples is included in Appendix B. For comparison purposes,

Table 3-4. Analytical Parameters, Methods, and Detection Levels for Groundwater Samples, EPNG SJRP.*

	WQCC Standards (mg/l)	Method	Detection Level (mg/l)
pH	6 - 9	EPA 150.1	NA
EC	NS}	SM 908 A	3/100 ml
COD	NS	HACH	25
TOC	NS	EPA 415.1	1
TDS	1,000	EPA 160.1	10
Oil & Grease	NS	EPA 413.1	0.2
Total K Nitrogen	NS	EPA 351.3	1
Nitrate-N	10.0	EPA 354.1	0.01
Ammonia	NS	EPA 350.2	1
O-phosphate	NS	EPA 365.2	0.01
Alkalinity (total)	NS	EPA 310.1	5
Alkalinity (HCO3)	NS	EPA 310.1	5
Arsenic	0.1	EPA 206.2	0.005
Barium	1.0	EPA 208.1	1
Boron	0.75	EPA 212.3	0.1
Cadmium	0.01	EPA 213.1	0.05
Calcium	NS	EPA 215.1	0.2
Chloride	250	EPA 325.1	1
Chromium	0.05	EPA 218.1	0.5
Copper	1.0	EPA 220.1	0.2
Cobalt	0.05	EPA 219.1	0.5
Cyanide	0.2	EPA 235.2	0.1
Fluoride	1.6	EPA 340.1	0.1
Lead	0.05	EPA 239.1	1
Magnesium	NS	EPA 242.1	0.02
Manganese	0.2	EPA 243.1	0.1
Mercury	0.002	EPA 245.1	0.002
Molybdenum	1.0	EPA 246.1	1
Nickel	0.2	EPA 249.1	0.3
Potassium	NS	EPA 258.1	0.1
Selenium	0.05	EPA 270.2	0.005
Silver	0.05	EPA 272.1	0.1
Sodium	NS	EPA 273.1	0.03
Sulfate	600	EPA 275.3	10
Zinc	10.0	EPA 289.1	0.05

* Water Quality Control Commission Regulations amended June 18, 1986. EPA - Methods for Analysis of Waters and Wastes, EPA 600/4-79-020. SM - Standard Methods, AWWA 16th Ed.

} NS = No Standard

File Name: monwell.wk1 13-Nov-87

Table 3-5. Analytical Results for Groundwater Samples.

Parameters (reported in mg/l)	Monitoring Wells: Well # 1	Monitoring Wells: Well # 2	Monitoring Wells: Well # 3	Monitoring Wells: Well Avg.	Local Wells: Lester Well	Local Wells: Hansen Well	Local Wells: Isham Well	Local Wells: Dailey Well	Local Well Avg.	WQCC Standard	Wastewater Weighted Averages: All Sources	Wastewater Weighted Averages: Regen. Units Only	Wastewater Weighted Averages: All Sources w/o Regen. Units
COD	31	33	0.18	21	NA	NA	NA	NA	NA	NS	142.1	570.0	108.0
TOC	7	9	4	7	NA	NA	NA	NA	NA	NS	22	5	23
TDS	4,800	5,400	3,300	4,500	1,400	2,000	3,400	4,300	2,775	1,000	2,923	21,800	1,419
E.C. (umhos/cm)	5,800	6,800	4,200	5,600	3,000	2,950	4,075	4,800	3706	NS	4,479	35,000	2,047
SAR	8.8	10.3	7.2	8.8	16.7	9.7	13.4	14.0	13	NS	11.7	42.8	5.3
Oil & Grease	2.00	1.50	NA	NA	NA	NA	NA	NA	NA	NS	2.43	1.00	2.55
Total K Nitrogen	NA	NA	NA	NA	0.40	(0.4	5	3.9	2.43	NS	0.40	0.40	0.40
Nitrate-N	NA	NA	NA	NA	(0.10	(0.10	(0.10	(0.10	0.10	10.00	2.15	0.10	2.32
Ammonia	(0.40	(0.40	(0.40	0.40	(0.40	(0.40	(0.40	(0.40	0.40	NS	0.46	0.40	0.46
O-phosphate	(0.1	(0.1	(0.1	0.1	NA	NA	NA	NA	NA	NS	7.0	0.1	7.5
Alkalinity (total)	350	610	320	427	320	230	150	91	198	NS	33	100	28
Alkalinity (HCO3)	350	610	320	427	320	230	150	91	198	NS	NA	NA	NA
Arsenic	(0.010	(0.010	(0.010	0.010	NA	NA	NA	NA	NA	0.010	0.006	0.010	0.005
Barium	(0.30	(0.30	(0.30	0.30	NA	NA	NA	NA	NA	1.00	0.30	0.73	0.27
Boron	0.77	0.54	(0.5	0.60	NA	NA	NA	NA	NA	0.75	0.5	0.4	0.5
Cadmium	(0.01	(0.01	(0.01	0.01	NA	NA	NA	NA	NA	0.01	0.009	0.030	0.007
Calcium	320	340	280	313	31	130	190	280	158	NS	158	1,000	91
Chloride	170	320	110	200	110	400	400	450	340	250	1,177	11,990	316
Chromium	(0.02	(0.02	(0.02	0.02	NA	NA	NA	NA	NA	0.05	0.019	0.030	0.018
Copper	(0.01	(0.01	(0.01	0.01	NA	NA	NA	NA	NA	1.00	0.11	0.04	0.11
Cobalt	0.011	0.010	(0.005	0.009	NA	NA	NA	NA	NA	0.05	0.05	0.10	0.05
Cyanide	(0.01	(0.01	(0.01	0.01	NA	NA	NA	NA	NA	0.20	0.007	0.005	0.007
Floride	(0.1	(0.1	(0.1	0.1	NA	NA	NA	NA	NA	1.6	0.5	0.1	0.5
Lead	(0.05	(0.05	(0.05	0.05	NA	NA	NA	NA	NA	0.05	0.08	0.35	0.06
Magnesium	160	190	78	143	13	44	57	66	45	NS	47.1	330.0	24.6
Manganese	4.5	0.97	0.24	1.90	NA	NA	NA	NA	NA	0.20	0.07	0.61	0.03
Mercury	(0.001	(0.001	(0.001	0.001	NA	NA	NA	NA	NA	0.002	0.001	0.001	0.001
Molybdenum	0.28	0.022	0.015	0.106	NA	NA	NA	NA	NA	1.00	0.02	0.02	0.02
Nickel	0.1	0.1	0.1	0.1	NA	NA	NA	NA	NA	0.20	0.09	0.32	0.07
Potassium	17.00	8.70	4.90	10.20	3.10	5.6	6.3	3.5	4.6	NS	7.79	44.00	4.91
Selenium	(0.01	(0.01	(0.01	0.01	NA	NA	NA	NA	NA	0.05	0.007	0.010	0.007
Silver	(0.01	(0.01	(0.01	0.01	NA	NA	NA	NA	NA	0.05	0.009	0.030	0.007
Sodium	770	960	530	753	440	500	820	1,000	690	NS	656	6,117	221
Sulfate	2,800	3,000	1,900	2,567	780	790	1,800	2,470	1,460	600	510	96	543
Zinc	0.06	0.03	0.03	0.04	NA	NA	NA	NA	NA	10.00	0.64	0.12	0.68

* Values reported below detection (() are averaged at the detectioK. W. BROWN & ASSOCIATES, INC.
NA = value not available; NS = No standard

K.W. BROWN & ASSOCIATES

analytical results from local water wells obtained during Phase I, wastewater quality, and WQCC standards are also listed on Table 3-5.

Comparing the monitoring well results to local groundwater quality reveals there is a considerable variability in concentrations of individual parameters from well to well, but the overall averages and maximum reported values, in many cases, are comparable. For example, the average concentration for sodium in the monitoring wells was 753 mg/l, and the maximum reported value was 960 mg/l; while in the local private wells the average sodium concentration was 690 mg/l, and the maximum reported value was 1,000 mg/l. When compared to WQCC standards, local groundwater on the average meets the standards for metals, but exceeds the standards for many of the salts.

4.0 WASTEWATER QUALITY AND WATER BALANCE

In the Phase I report, wastewater quality and the sources for the wastewater were discussed (Section 2.0). In addition to the discussion on wastewater, a section on the water balance (Section 7.0) was presented. Following submission of the first report, some changes have been planned for the San Juan River Plant which will alter the wastewater quality and quantity. Since the changes in the wastewater will also affect the water balance, the information presented in the first report is updated in the following sections.

4.1 WASTEWATER QUALITY

Changes in the wastewater system include removing the CCD Regeneration unit from the wastewater system and altering the regeneration process for the Softener Regeneration unit. The net effect of these changes is to lower the total wastewater flow from the regeneration units from 2.63 million gallons/year to 0.64 million gallons/year (0.76% reduction). The resulting wastewater quality is shown on Table 4-1. For comparison purposes, the wastewater quality presented in the Phase I report is included as Table 4-2. The most notable changes in concentrations of individual parameters resulting from the proposed changes are listed in Table 4-3.

In addition to the changes in the wastewater streams, it is also possible that wastewater from the "new" Softener Regeneration unit will be removed completely from the wastewater flow destined for land application. Since this possibility exists, Table 4-1 presents the weighted averages for the wastewater with and without the Softener Regeneration unit.

File Name: WASTEH2O.WK1 13-Nov-87

Table 4-1. Watewater Analysis by Effluent Source, El Paso Natural Gas San Juan River Plant*.

Parameters (reported in mg/l)	Raw Water J87-22	Carbonate Regen.	CCD Alk Regen. J87-27	Cooling Tower A J87-26	Cooling Tower B J87-28	Evaporator Blowdown J87-23	Boiler Blowdown J87-24	Weighted Averages (Total)	Weighted Averages (Regen. Units)	Weighted Averages (Other Sources)
COD	< 25	570	0	46	90	77.2	212	142.1	570.0	108.0
TOC	3	5	0	18	29	8	43	22	5	23
TDS	240	21,800	0	1,350	2,130	1,240	1,140	2,923	21,800	1,419
E.C. (umhos/cm)	350	35,000	0	1,500	3,000	1,900	1,800	4,479	35,000	2,047
SAR	0.6	42.8	0	1.6	2.1	56.4	45.9	11.7	42.8	5.3
Oil & Grease	1.50	1.00	0	1.00	1.70	3.28	3.35	2.43	1.00	2.55
Total K Nitrogen	< 0.40	< 0.40	< 0	< 0.40	< 0.40	< 0.40	< 0.40	0.40	0.40	0.40
Nitrate-N	0.50	< 0.10	< 0	< 0.10	< 0.10	< 0.10	8.99	2.15	0.10	2.32
Ammonia	< 0.40	< 0.40	< 0	< 0.40	< 0.40	0.59	< 0.40	0.46	0.40	0.46
O-phosphate	< 0.1	< 0.1	< 0	< 0.1	< 0.1	< 0.1	30	7.0	0.1	7.5
Alkalinity (total)	100	100	0	27	18	50	0	33	100	28
Alkalinity (HCO3)	NA	NA	0	NA	NA	NA	NA	NA	NA	NA
Arsenic	< 0.010	< 0.010	< 0	< 0.010	< 0.010	< 0.002	< 0.002	0.006	0.010	0.005
Barium	< 0.30	0.73	< 0	< 0.30	0.40	< 0.20	< 0.20	0.30	0.73	0.27
Boron	0.52	0.36	0	0.85	0.67	0.4	< 0.3	0.5	0.4	0.5
Cadmium	< 0.01	0.03	< 0	< 0.01	< 0.01	< 0.005	< 0.005	0.009	0.030	0.007
Calcium	33	1,000	0	170	270	1.97	< 1	158	1,000	91
Chloride	13	11,990	0	51	64	821	53	1,177	11,990	316
Chromium	< 0.02	0.03	0	0.05	0.03	< 0.005	< 0.005	0.019	0.030	0.018
Copper	0.01	0.04	0	0.17	0.10	0.01	0.24	0.11	0.04	0.11
Cobalt	< 0.05	0.10	0	< 0.05	< 0.05	< 0.05	< 0.05	0.05	0.10	0.05
Cyanide	0.024	< 0.005	0	0.006	< 0.005	0.007	0.006	0.007	0.005	0.007
Floride	< 0.1	< 0.1	< 0	< 0.1	< 0.1	< 0.1	1.8	0.5	0.1	0.5
Lead	< 0.05	0.35	0	0.10	0.11	< 0.005	0.06	0.08	0.35	0.06
Magnesium	10	330	0	50	70	0.09	1.1	47.1	330.0	24.6
Manganese	< 0.01	0.61	0	0.08	0.04	< 0.01	< 0.01	0.07	0.61	0.03
Mercury	< 0.001	< 0.001	< 0	< 0.001	< 0.001	< 0.001	< 0.001	0.001	0.001	0.001
Molybdenum	< 0.01	0.02	0	0.02	0.03	0.01	< 0.01	0.02	0.02	0.02
Nickel	0.08	0.32	0	0.21	0.15	< 0.01	< 0.01	0.09	0.32	0.07
Potassium	1.60	44.00	0	7.80	13.00	1.54	0.32	7.79	44.00	4.91
Selenium	< 0.01	< 0.01	< 0	< 0.01	< 0.01	< 0.005	< 0.005	0.007	0.010	0.007
Silver	< 0.01	0.03	0	< 0.01	< 0.01	< 0.005	< 0.005	0.009	0.030	0.007
Sodium	15	6,117	0	90	150	298	280	656	6,117	221
Sulfate	77	96	0	730	1,140	450	30	510	96	543
Zinc	0.09	0.12	0	0.34	1.40	0.06	1.08	0.64	0.12	0.68
Estimated Flow										
(millions-gallons/year)	0.25	0.64	0.00	1.07	2.00	2.75	2.00	8.71	0.64	8.07
Percent of Total Flow	2.87%	7.38%	0.00%	12.28%	22.95%	31.56%	22.95%	100.00%	7.38%	92.62%
Regeneration Units Flow		100.00%	0.00%						100.00%	
All Other Sources Flow	3.10%			13.26%	24.78%	34.08%	24.78%			100.00%

* Weighted average based on percent flow; other averages based on percent segregated flow.
E.C. values for evaporator blowdown and boiler blowdown are estimates.
Values reported below detection (<) are averaged at the detection limit.

K.W. BROWN & ASSOCIATES

File Name: WASTWTR.WK1

Table 4-2. Wastewater Analysis by Effluent Source, El Paso Natural Gas San Juan River Plant*.

Parameters (reported in mg/l)	Raw Water J87-22	Softener Reg. J87-25	CCD Alk Reg. J87-27	Cooling Tower A J87-26	Cooling Tower B J87-28	Evaporator Blowdown J87-23	Boiler Blowdown J87-24	Weighted Averages (Total)
COD	< 25	570	600	46	90	77.2	212	244.6
TOC	3	5	15	18	29	8	43	20
TDS	240	21,800	17,800	1,350	2,130	1,240	1,140	6,399
E.C. (umhos/cm)	350	35,000	30,000	1,500	3,000	1,900	1,800	10,354
SAR	0.6	81.5	228.6	1.6	2.5	56.4	45.9	69.2
Oil & Grease	1.50	1.00	1.00	1.00	1.70	3.28	3.35	2.29
Total K Nitrogen	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	0.40
Nitrate-N	0.50	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	8.99	1.95
Ammonia	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	0.59	< 0.40	0.45
O-phosphate	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	30	6.3
Alkalinity (total)	64	36	310	27	18	143	436	185
Alkalinity (HCO3)	< 5	< 5	< 5	< 5	< 5	0	0	3
Arsenic	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.002	< 0.002	0.006
Barium	< 0.30	0.73	< 0.30	< 0.30	0.40	< 0.20	< 0.20	0.33
Boron	0.52	0.36	0.41	0.85	0.67	0.4	< 0.3	0.4
Cadmium	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.005	< 0.005	0.010
Calcium	33	360	45	170	270	1.97	< 1	111
Chloride	13	11,700	9,900	51	64	821	53	3,183
Chromium	< 0.02	0.03	0.02	0.05	0.03	< 0.005	< 0.005	0.016
Copper	0.01	0.04	0.02	0.17	0.10	0.01	0.24	0.08
Cobalt	< 0.05	0.10	0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.06
Cyanide	0.024	< 0.005	0.076	0.006	< 0.005	0.007	0.006	0.016
Floride	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	1.8	0.5
Lead	< 0.05	0.35	0.22	0.10	0.11	< 0.005	0.06	0.11
Magnesium	10	130	11	50	4	0.09	1.1	19.9
Manganese	< 0.01	0.61	0.01	0.08	0.04	< 0.01	< 0.01	0.09
Mercury	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001
Molybdenum	< 0.01	0.02	0.03	0.02	0.03	0.01	< 0.01	0.02
Nickel	0.08	0.32	0.27	0.21	0.15	< 0.01	< 0.01	0.12
Potassium	1.60	44.00	23.00	7.80	13.00	1.54	0.32	12.24
Selenium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.005	< 0.005	0.008
Silver	< 0.01	0.03	0.03	< 0.01	< 0.01	< 0.005	< 0.005	0.013
Sodium	15	7,100	6,600	90	150	298	280	2,034
Sulfate	77	96	570	730	1,140	172	30	390
Zinc	0.09	0.12	0.56	0.34	1.40	0.06	1.08	0.63
Estimated Flow (millions-gallons/year)	0.25	1.25	1.38	0.04	2.00	2.75	2.00	9.67
Percent of Total Flow	2.59%	12.93%	14.27%	0.41%	20.68%	28.44%	20.68%	100.00%
Regeneration Units Flow		47.53%	52.47%					
All Other Sources Flow	3.55%			0.57%	28.41%	39.06%	28.41%	

* Weighted average based on percent flow; other averages based on percent segregated flow. K.W. BROWN & ASSOCIATES
E.C. values for evaporator blowdown and boiler blowdown are estimates.
Values reported below detection (<) are averaged at the detection limit.

Table 4-3. Major Changes in Wastewater Quality.

Parameter (mg/l)	Phase I Weighted Total Average	Phase II Weighted Averages* (with)	(without)
TDS	6,399	2,923	1,419
EC (umhos/cm)	10,354	4,479	2,047
SAR	69.2	11.7	5.3
Total Alkalinity	185	33	28
Chloride	3,183	1,177	316
Magnesium	19.9	47.1	24.6
Sodium	2,034	656	221
Total Wastewater Flow (MG/yr)	9.67	8.71	8.07

* Phase II weighted averages for wastewater with and without the Softener Regeneration unit flow calculated into the average.

4.2 WATER BALANCE

Due to changes in the composition and quantity of wastewater, it is necessary to recalculate the local water balance. Also, since two possible options exist, land application with and without the regeneration water (Scenarios 1 and 2), two water balances are included. Tables 4-4 and 4-5 illustrate the water budget with the regeneration wastewater stream (Scenario 1), and Tables 4-6 and 4-7 represent the hydrologic budget excluding the regeneration wastewater flow. The current water budgets (Tables 4-4 through 4-7) differ from the water balance presented in the Phase I report primarily with respect to the amount of wastewater available for irrigation (Column 16), and the leaching requirement (Column 8). For a complete discussion on how the various components are used to calculate the water balance, refer to Section 7.0 of the Phase I report. In addition to these changes, two additional spreadsheets are included which expand and, hopefully, more clearly explain the calculation of the local water budget.

Table 4-4. Hydrologic Budget for Determining Wastewater Storage Requirements: Scenario 1.

										Beginning of Month		End of Month	
Month	Design precip. (in)	E.T. (in)	Root zone moisture deficit (in)	Leaching requirement (in)	Irr. requirements (in)	Eff.-adjusted irr. requirements (in)	Waste-water inflow (acre-in)	Req'd irr. area (acres)	Irr. area used (acres)	Tank volume (acre-in)	Avail. waste-water (acre-in)	Waste-water applied (acre-in)	Tank volume (acre-in)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Jan	1.58	0.96	0.00	0.00	0.00	0.00	27.24	0.00	0.00	27.24	54.48	0.00	54.48
Feb	1.07	1.56	0.49	0.27	0.76	0.95	24.61	25.92	26.00	54.48	79.09	24.68	54.41
Mar	1.26	3.79	2.53	1.39	3.92	4.90	27.24	5.56	16.66	54.41	81.65	81.65	0.00
Apr	1.33	6.34	5.01	2.76	7.77	9.71	26.37	2.72	2.72	0.00	26.37	26.37	0.00
May	0.70	8.02	7.32	4.03	11.35	14.18	27.24	1.92	1.92	0.00	27.24	27.24	0.00
Jun	0.75	8.83	8.08	4.44	12.52	15.66	26.37	1.68	1.68	0.00	26.37	26.37	0.00
Jul	1.37	8.74	7.37	4.05	11.42	14.28	27.24	1.91	1.91	0.00	27.24	27.24	0.00
Aug	1.91	7.38	5.47	3.01	8.48	10.60	27.24	2.57	2.57	0.00	27.24	27.24	0.00
Sep	1.47	5.72	4.25	2.34	6.59	8.23	26.37	3.20	3.20	0.00	26.37	26.37	0.00
Oct	1.91	3.79	1.88	1.03	2.91	3.64	27.24	7.48	7.48	0.00	27.24	27.24	0.00
Nov	1.02	2.03	1.01	0.56	1.57	1.96	26.37	13.48	13.48	0.00	26.37	26.37	0.00
Dec	1.75	1.00	0.00	0.00	0.00	0.00	27.24	0.00	0.00	0.00	27.24	0.00	27.24
Totals:	16.12	58.16	43.41	23.88	67.29	84.11	320.77					320.77	

Irrigation efficiency = 80 percent
Leaching coefficient = 55 percent

K. W. Brown & Associates, Inc.

Table 4-5. Hydrologic Budget for Determining Wastewater Application Rates: Scenario 1.

Month	Record mean precip. (in)	E.T. (in)	Root zone moisture deficit (in)	Leaching requirement (in)	Irr. requirements (in)	Eff.-adjusted irr. requirements (in)	Wastewater inflow (acre-in)	Req'd irr. area (acres)	Irr. area used (acres)	Beginning of Month: Tank volume (acre-in)	Beginning of Month: Avail. wastewater (acre-in)	End of Month: Wastewater applied (acre-in)	End of Month: Tank volume (acre-in)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Jan	0.90	0.96	0.06	0.00	0.00	0.00	27.24	0.00	0.00	27.24	54.48	0.00	54.48
Feb	0.61	1.56	0.95	0.52	1.47	1.84	24.61	13.37	26.00	54.48	79.09	47.86	31.23
Mar	0.72	3.79	3.07	1.69	4.76	5.95	27.24	4.58	9.83	31.23	58.47	58.47	0.00
Apr	0.76	6.34	5.58	3.07	8.65	10.81	26.37	2.44	2.44	0.00	26.37	26.37	0.00
May	0.40	8.02	7.62	4.19	11.81	14.76	27.24	1.85	1.85	0.00	27.24	27.24	0.00
Jun	0.43	8.83	8.40	4.62	13.02	16.28	26.37	1.62	1.62	0.00	26.37	26.37	0.00
Jul	0.78	8.74	7.96	4.38	12.34	15.42	27.24	1.77	1.77	0.00	27.24	27.24	0.00
Aug	1.09	7.38	6.29	3.46	9.75	12.19	27.24	2.24	2.24	0.00	27.24	27.24	0.00
Sep	0.84	5.72	4.88	2.68	7.56	9.46	26.37	2.79	2.79	0.00	26.37	26.37	0.00
Oct	1.09	3.79	2.70	1.49	4.19	5.23	27.24	5.21	5.21	0.00	27.24	27.24	0.00
Nov	0.58	2.03	1.45	0.80	2.25	2.81	26.37	9.39	9.39	0.00	26.37	26.37	0.00
Dec	1.00	1.00	0.00	0.00	0.00	0.00	27.24	0.00	0.00	0.00	27.24	0.00	27.24
Totals:	9.20	58.16	48.96	26.90	75.80	94.74	320.77					320.77	

Irrigation efficiency = 80 percent
Leaching coefficient = 55 percent

K. W. Brown & Associates, Inc.

Table 4-6. Hydrologic Budget for Determining Wastewater Storage Requirements: Scenario 2.

Month	Design precip. (in)	E.T. (in)	Root zone moisture deficit (in)	Leaching require-ment (in)	Irr. require-ments (in)	Eff.-adjusted irr. require-ments (in)	Waste-water inflow (acre-in)	Req'd irr. area (acres)	Irr. area used (acres)	Beginning of Month: Tank volume (acre-in)	Beginning of Month: Avail. waste-water (acre-in)	End of Month: Waste-water applied (acre-in)	End of Month: Tank volume (acre-in)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Jan	1.58	0.96	0.00	0.00	0.00	0.00	25.28	0.00	0.00	25.28	50.56	0.00	50.56
Feb	1.07	1.56	0.49	0.12	0.61	0.77	22.65	29.58	26.00	50.56	73.21	19.91	53.30
Mar	1.26	3.79	2.53	0.63	3.16	3.95	25.28	6.39	19.88	53.30	78.58	78.58	0.00
Apr	1.33	6.34	5.01	1.25	6.26	7.83	24.41	3.12	3.12	0.00	24.41	24.41	0.00
May	0.70	8.02	7.32	1.83	9.15	11.44	25.28	2.21	2.21	0.00	25.28	25.28	0.00
Jun	0.75	8.83	8.08	2.02	10.10	12.63	24.41	1.93	1.93	0.00	24.41	24.41	0.00
Jul	1.37	8.74	7.37	1.84	9.21	11.52	25.28	2.20	2.20	0.00	25.28	25.28	0.00
Aug	1.91	7.38	5.47	1.37	6.84	8.55	25.28	2.96	2.96	0.00	25.28	25.28	0.00
Sep	1.47	5.72	4.25	1.06	5.31	6.64	24.41	3.68	3.68	0.00	24.41	24.41	0.00
Oct	1.91	3.79	1.88	0.47	2.35	2.94	25.28	8.61	8.61	0.00	25.28	25.28	0.00
Nov	1.02	2.03	1.01	0.25	1.26	1.58	24.41	15.47	15.47	0.00	24.41	24.41	0.00
Dec	1.75	1.00	0.00	0.00	0.00	0.00	25.28	0.00	0.00	0.00	25.28	0.00	25.28
Totals:	16.12	58.16	43.41	10.85	54.26	67.83	297.25					297.25	

Irrigation efficiency = 80 percent
Leaching coefficient = 25 percent

K. W. Brown & Associates, Inc.

Table 4-7. Hydrologic Budget for Determining Wastewater Application Rates: Scenario 2.

Month	Record mean precip. (in)	E.T. (in)	Root zone moisture deficit (in)	Leaching requirement (in)	Irr. requirements (in)	Eff.-adjusted irr. requirements (in)	Wastewater inflow (acre-in)	Req'd irr. area (acres)	Irr. area used (acres)	Beginning of Month: Tank volume (acre-in)	Beginning of Month: Avail. wastewater (acre-in)	End of Month: Wastewater applied (acre-in)	End of Month: Tank volume (acre-in)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Jan	0.90	0.96	0.06	0.00	0.00	0.00	25.28	0.00	0.00	25.28	50.56	0.00	50.56
Feb	0.61	1.56	0.95	0.24	1.19	1.48	22.65	15.26	26.00	50.56	73.21	38.59	34.62
Mar	0.72	3.79	3.07	0.77	3.84	4.80	25.28	5.27	12.49	34.62	59.90	59.90	0.00
Apr	0.76	6.34	5.58	1.40	6.98	8.72	24.41	2.80	2.80	0.00	24.41	24.41	0.00
May	0.40	8.02	7.62	1.90	9.52	11.91	25.28	2.12	2.12	0.00	25.28	25.28	0.00
Jun	0.43	8.83	8.40	2.10	10.50	13.13	24.41	1.86	1.86	0.00	24.41	24.41	0.00
Jul	0.78	8.74	7.96	1.99	9.95	12.44	25.28	2.03	2.03	0.00	25.28	25.28	0.00
Aug	1.09	7.38	6.29	1.57	7.86	9.83	25.28	2.57	2.57	0.00	25.28	25.28	-0.00
Sep	0.84	5.72	4.88	1.22	6.10	7.63	24.41	3.20	3.20	-0.00	24.41	24.41	-0.00
Oct	1.09	3.79	2.70	0.68	3.38	4.22	25.28	5.99	5.99	-0.00	25.28	25.28	-0.00
Nov	0.58	2.03	1.45	0.36	1.81	2.27	24.41	10.77	10.77	-0.00	24.41	24.41	-0.00
Dec	1.00	1.00	0.00	0.00	0.00	0.00	25.28	0.00	0.00	0.00	25.28	0.00	25.28
Totals:	9.20	58.16	48.96	12.23	61.13	76.41	297.25					297.25	

Irrigation efficiency = 80 percent
Leaching coefficient = 25 percent

K. W. Brown & Associates, Inc.

4.2.1 Updated Hydrologic Budget

Since the present water balances show marked differences from that presented in the Phase I report, it is convenient to redefine each column of the respective tables (i.e., Tables 4-4 through 4-7). Where overlap in column descriptions occurs, reference to the Phase I report is made.

Column 1: Month

This column is unchanged from Phase I.

Column 2: Design precipitation

This is column 3 in the Phase I report.

Column 3: Evapotranspiration (E.T.)

This is column 6 in the Phase I report.

Column 4: Root zone moisture deficit

This is column 7 in the Phase I report.

Column 5: Leaching requirement

This column is essentially column 8 in the Phase I report. Since the water balance has been recomputed for Scenarios 1 and 2, the leaching coefficient for each case is different. As listed in the Phase I report, the following equations (from Richards, 1954) are used in the computation of leaching requirement:

$$LR = LC \times RZMD$$

Where: LR = leaching requirement (inches)
LC = leaching coefficient
RZMD = root zone moisture deficit (inches)

$$LC = EC_{iw} / EC_{dw}$$

Where: EC_{iw} = electrical conductivity of the irrigation water (mmhos/cm)
EC_{dw} = electrical conductivity of the drainage water (mmhos/cm)

The leaching coefficient is 55 and 25% under Scenarios 1 and 2, respectively.

Column 6: Irrigation requirements

This column is essentially column 10 in the Phase I report. Irrigation requirements are defined to be the root zone moisture deficit (Column 4) plus the leaching requirement (Column 5).

Column 7: Efficiency-adjusted irrigation requirements

This column is simply column 6 divided by the expected irrigation system efficiency (80%).

Column 8: Wastewater inflow

This is column 16 in the Phase I report.

Column 9: Required irrigation area

To ensure that the root zone moisture deficit and the leaching requirements are being satisfied, it is important to avoid applying the irrigation requirements over too large an area. The following equation is used to calculate required irrigation area:

$$A_r = Q_{WW} / I$$

Where: A_r = required irrigation area (acres)
Q_{WW} = wastewater inflow (acre-inches)
I = irrigation requirements (inches)

or

column (9) = column (8) / column (7)

Column 10: Irrigation area used

In those months where wastewater inflows must be stored, it is advantageous to apply the maximum amount of wastewater in order to deplete that storage over the course of the calendar year. Since the SJRP has a strongly negative annual hydrologic budget, storage of wastewater is only required during December and January. It is thus possible to apply the irrigation requirements of February and March over much larger areas than the required irrigation areas; this effectively drains the storage impoundment of wastewater stored over the winter months. Tables 4-4 through 4-7 show that the actual area used for irrigation (column 10) exceeds that computed in column 9 for the months of February and March.

Column 11: Tank volume

This quantity represents the volume of wastewater stored in the tank at the beginning of the month.

Column 12: Available wastewater

Available wastewater is the sum of the beginning-of-the-month tank volume (column 11) and the wastewater inflow (column 8).

Column 13: Wastewater applied

Wastewater applied is the product of efficiency-adjusted irrigation requirements (column 7) and irrigation area used (column 10).

Column 14: Tank volume

This quantity represents the volume of wastewater stored in the tank at the end of the month.

4.2.2 Results and Discussion

Comparison of Tables 4-4 through 4-7 with Table 7-1 of the Phase I report does not indicate many significant differences. Tables 4-4 and 4-6 were developed to assess wastewater storage requirements under Scenarios 1 and 2. For this exercise, design precipitation (the amount of precipitation for a 25-year storm) was used in the computation as this causes a depression in the irrigation requirements due to the fact that greater moisture is retained in the soil as a result of higher monthly precipitation. Maximum observed tank volume under Scenario 1 was 54.48 acre-inches, and 53.30 acre-inches for Scenario 2. Maximum storage volume required using the Phase I water balance was 60.49 acre-inches.

Estimates of wastewater application rates were determined through the development of Tables 4-5 and 4-7. Rather than use design precipitation, recorded mean precipitation was employed since this would result in average root zone moisture deficits, which then relates to higher irrigation and leaching requirements. Column 13 in Tables 4-5 and 4-7 gives the estimated wastewater application rates (in acre-inches per month) for Scenarios 1 and 2, respectively. The principal difference between the Phase I and Phase II irrigation schedules is the ability to apply a much greater volume of stored wastewater in February and March. By using variable irrigation areas (column 10, Tables 4-4 through 4-7), application of the irrigation requirements can be made over the full 26.00 acres, which results in a large decrease in stored wastewater volume. The following example should aid in understanding this concept. For the month of February, the efficiency-adjusted irrigation requirements are 1.84 inches and the required irrigation area is 13.37 acres (Table 4-5). By using only the required irrigation area, only (1.84 inches) x (13.37 acres) = 24.60 acre-inches of wastewater can be disposed. Usage of the entire 26.00 acres results in the disposal of (1.84 inches) x (26.00 acres) = 47.84 acre-inches (if available). Thus, an additional 23.24 acre-inches of wastewater can be applied by making use of the entire 26.00-acre tract.

Although some differences were identified in the Phase I and Phase II hydrologic budgets, the underlying mechanisms remain the same, and the wastewater storage requirements are essentially unchanged. The most significant difference in the two balances is the usage of variable irrigation area in Phase II; employment of this option ensures that the root zone moisture deficit and leaching requirements are being satisfied throughout the year. In addition, this alternative allows for the disposal of a greater quantity of stored wastewater in the spring to assure that a yearly accumulation of wastewater is avoided. The Phase II balances simply represent "fine-tuned" variations of the Phase I budget.

5.0 IRRIGATION REQUIREMENTS AND SCHEDULING

This section discusses recommendations concerning irrigation requirements and scheduling at the EPNG SJRP. These recommendations are based on the local water balance presented for two scenarios in Table 4-5, "Hydrologic Budget for Determining Wastewater Application Rates: Scenario 1", and Table 4-7, "Hydrologic Budget for Determining Wastewater Application Rates: Scenario 2."

In order to maintain adequate plant cover, the amount of irrigation and water movement into and through the soil must be adequate to meet the plant consumptive needs and provide adequate leaching to remove salts from the rooting zone. A leaching requirement is normally determined based on the quality of the irrigated wastewater and the threshold level of soil salinity which can be tolerated by plants without significant yield reduction. For the purposes of computing the local hydrologic budget presented in this report (Tables 4-5 and 4-7), plant consumptive needs were taken from the evapotranspiration estimates, and leaching requirement was determined by a method proposed by the U.S. Salinity Laboratory (Richards, 1954).

The acreage requirements for land disposal of the process wastewater were calculated from the monthly water balance. As shown in Table 5-1, the field area requirements vary considerably from month to month. This is due to the seasonal variation in evapotranspiration rates and the need to dispose of excess wastewater stored during winter months. Irrigation is not planned during the months of December and January due to the combined effects of low plant water requirements and occasional freezing soil temperatures.

Table 5-1. Monthly Field Acreage Requirements for the EPNG Irrigation System (Acres).

Month	Scenario 1 Field Area (Calculated)	Scenario 2 Field Area (Calculated)	Field Area (Proposed)
January	0.00	0.00	0.00
February	13.37	15.26	26.00
March	4.58	5.27	10.00
April	2.44	2.80	2.00
May	1.85	2.12	2.00
June	1.62	1.86	2.00
July	1.77	2.03	2.00
August	2.24	2.57	2.00
September	2.79	3.20	2.00
October	5.21	5.99	5.00
November	9.39	10.77	10.00
December	0.00	0.00	0.00

Irrigation of the entire 26 acres in the east tract will only be required during February. Beginning in March, the field area requirement decreases, and only 2 acres will be required throughout most of the growing season. In October, the field area needed increases to 5 acres, and then doubles to 10 acres in November. Although the field area requirements seem small in comparison with the amount of acreage available, it is important to restrict the number of acres irrigated. If the wastewater available was irrigated over a larger field area than required, the hydraulic loading rates would be lower, and this would increase the likelihood for salt accumulation in the rooting zone of the soils.

A proposed design for the irrigation tract layout is depicted in Figure 5-1. The monthly field area requirement is achieved by varying the travel distance of a moving sprinkler system. Only in February will the entire 26-acre tract be irrigated. During most of the growing season, only a 2-acre strip of land will be used. In order to distribute the irrigation applications evenly over the entire tract, a different 2-acre strip will be

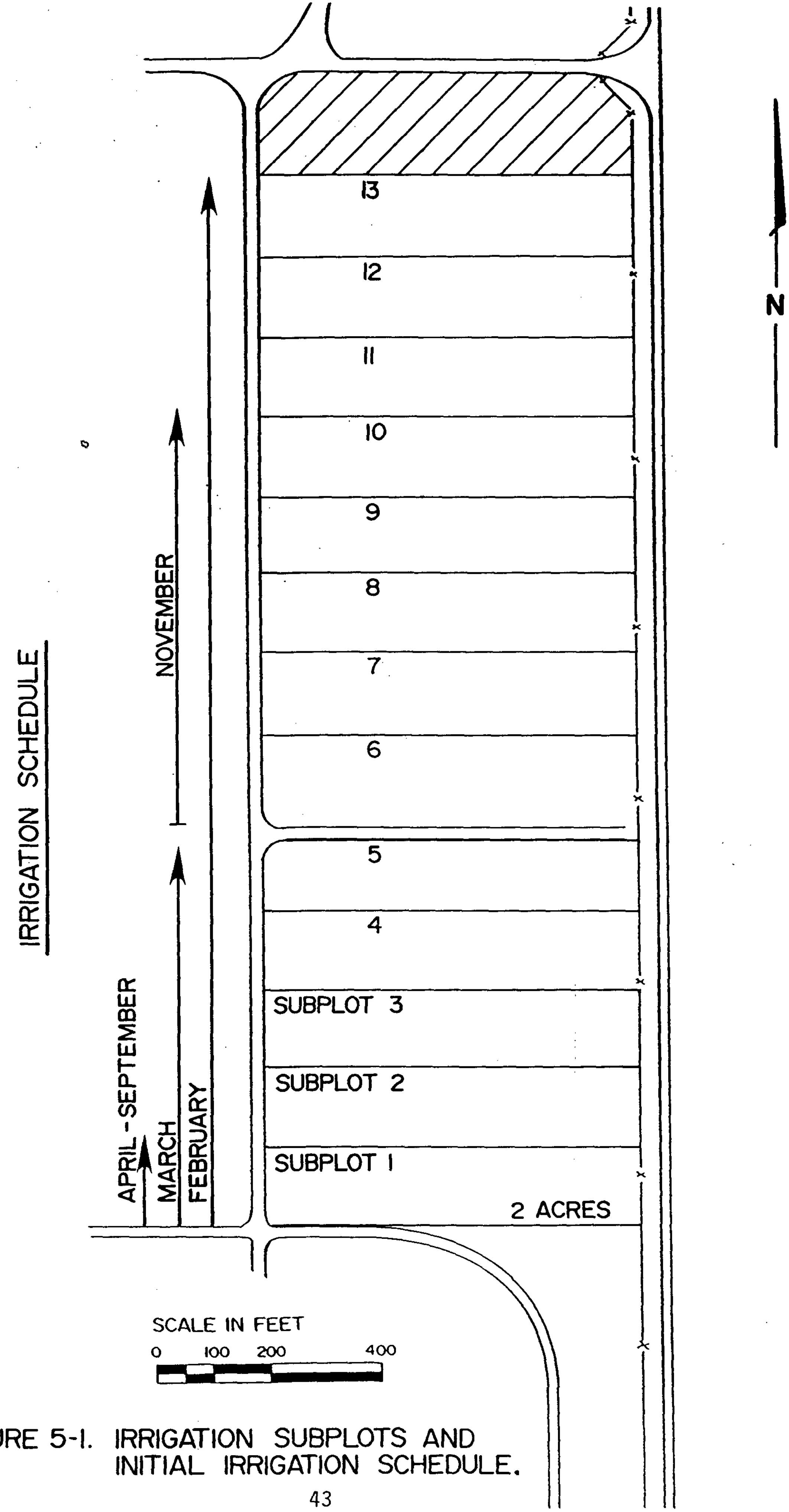


FIGURE 5-1. IRRIGATION SUBPLOTS AND INITIAL IRRIGATION SCHEDULE.

irrigated each year. The location of the 5-acre and 10-acre plots irrigated in the early spring and fall will likewise be rotated on an annual basis to ensure uniform wastewater applications. It is obvious that this field layout design will require a great deal of flexibility in locating the irrigation equipment. For this reason, it is recommended that a side-roll, wheeled distribution system be used. This type of sprinkler system has advantages over a fixed sprinkler system in that more uniform application rates are achieved and the area covered can be changed easily.

6.0 COMPUTER MODEL

An ancillary benefit of the water balance exercise is the definition of the depth of liquid that permeates below the soil surface; this quantity can then feed into a porous media, fluid flow model. An unsaturated/saturated, fluid flow/solute transport model has been developed to simulate irrigation operations at EPNG. The main objective of modeling the irrigation process is to assess the impacts, if any, on the groundwater system. The following sections describe assumptions used in setting up the model, boundary and initial conditions employed, synopses of the model results, and interpretations of the output.

6.1 MODEL DESCRIPTIONS

EPNG's proposed irrigation scenario involves the simultaneous introduction of water and solutes into the soil. To effectively simulate the physics of this situation, the simultaneous solution of the non-linear, partial differential equations of unsaturated/saturated fluid flow and solute transport is required. To allow the representation of a close approximation to reality, it becomes necessary to arrive at these solutions by means of a numerical solution to the aforementioned equations. The model employed by KWB&A to achieve this end consisted of a finite element code (SUMATRA1) possessing the capability of modeling unsaturated/saturated flow as well as solute transport considering advection, dispersion, linear solute adsorption, and solute production/decay. The model is considered to be one-dimensional in that output is given along a vertical line that is chosen to represent the soil(s) of interest. Model results are given in the form of pressure head (matric potential), volumetric moisture content, and solute concentration versus depth for specified times. With this output in hand, it is possible to determine the saturation state of the soil(s) as well as pore-water solute concentration. The following section describes assumptions and simplifications used by KWB&A in formulating model constraints and pertinent boundary and initial conditions.

6.2 MODEL CONSTRAINTS

Stratigraphy - The first step in modeling a geologic system involves the idealization/simplification of reality (e.g., lithology). Based on geologic log data, the stratigraphy chosen to represent the east tract consisted of a sandy silt 36 ft thick (Stratum 1) underlain by a silty clay 29.6 ft thick (Stratum 2). Each stratum is considered to be homogeneous in hydraulic properties (Figure 6-1). Table 6-1 lists all pertinent fluid flow/solute transport parameters used in the model.

Initial Conditions - Initial pressure head was chosen to be -500 cm of water for each stratum; saturated conditions were maintained at the base of Stratum 2. A pressure head gradient of -30.48 cm of water per foot was applied from 65.6 ft up to 49.2 ft to represent the initial capillary fringe. Initial pore-water chloride concentration was chosen to be 2.40 milliequivalents per liter (meq/l) for Stratum 1 and 1.05 meq/l for Stratum 2; these values are based on laboratory results from soil samples taken during Phase I (Figures 6-2 and 6-3).

Boundary Conditions - As stated previously, model boundary conditions (i.e., infiltration rate and wastewater chloride concentration) were derived through a formal hydrologic budget determination. Scenario 1 is defined to be the application of non-contact wastewater including flows from the carbonate regeneration unit; wastewater applied under Scenario 2 does not include the regeneration unit (Table 6-2). The finite element

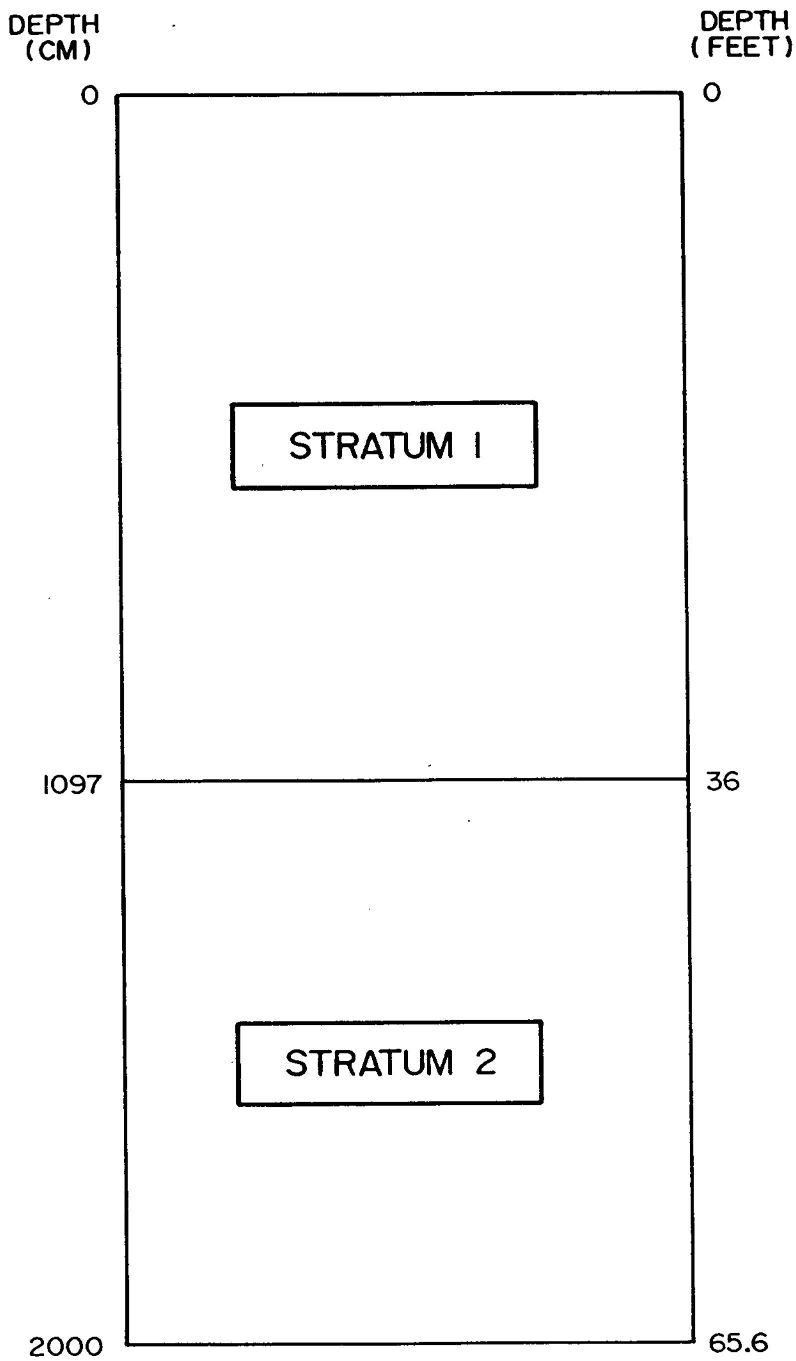


Figure 6-1. Modelled stratigraphy at EPNG.

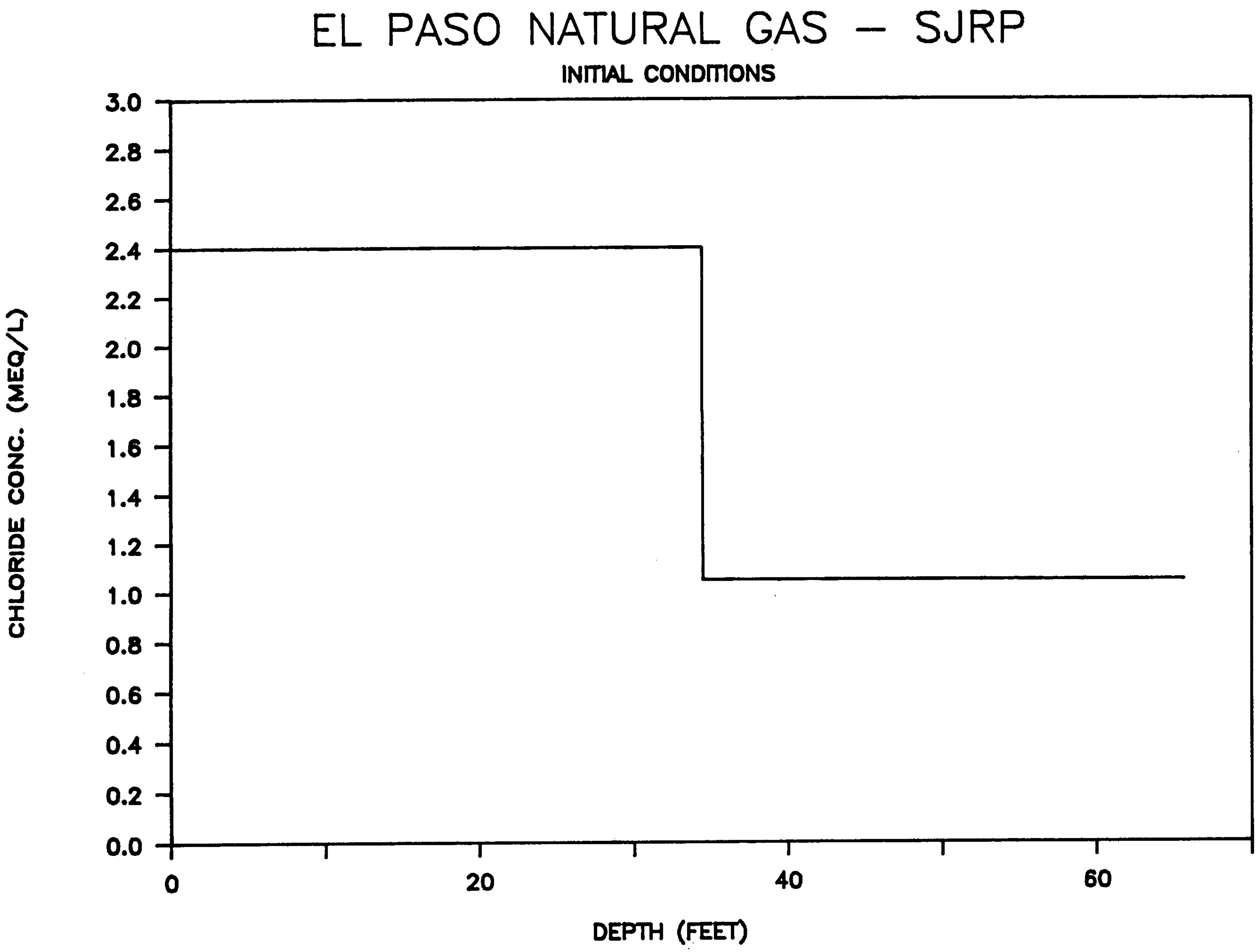


Figure 6-2. Initial conditions - chloride concentration (meq/l).

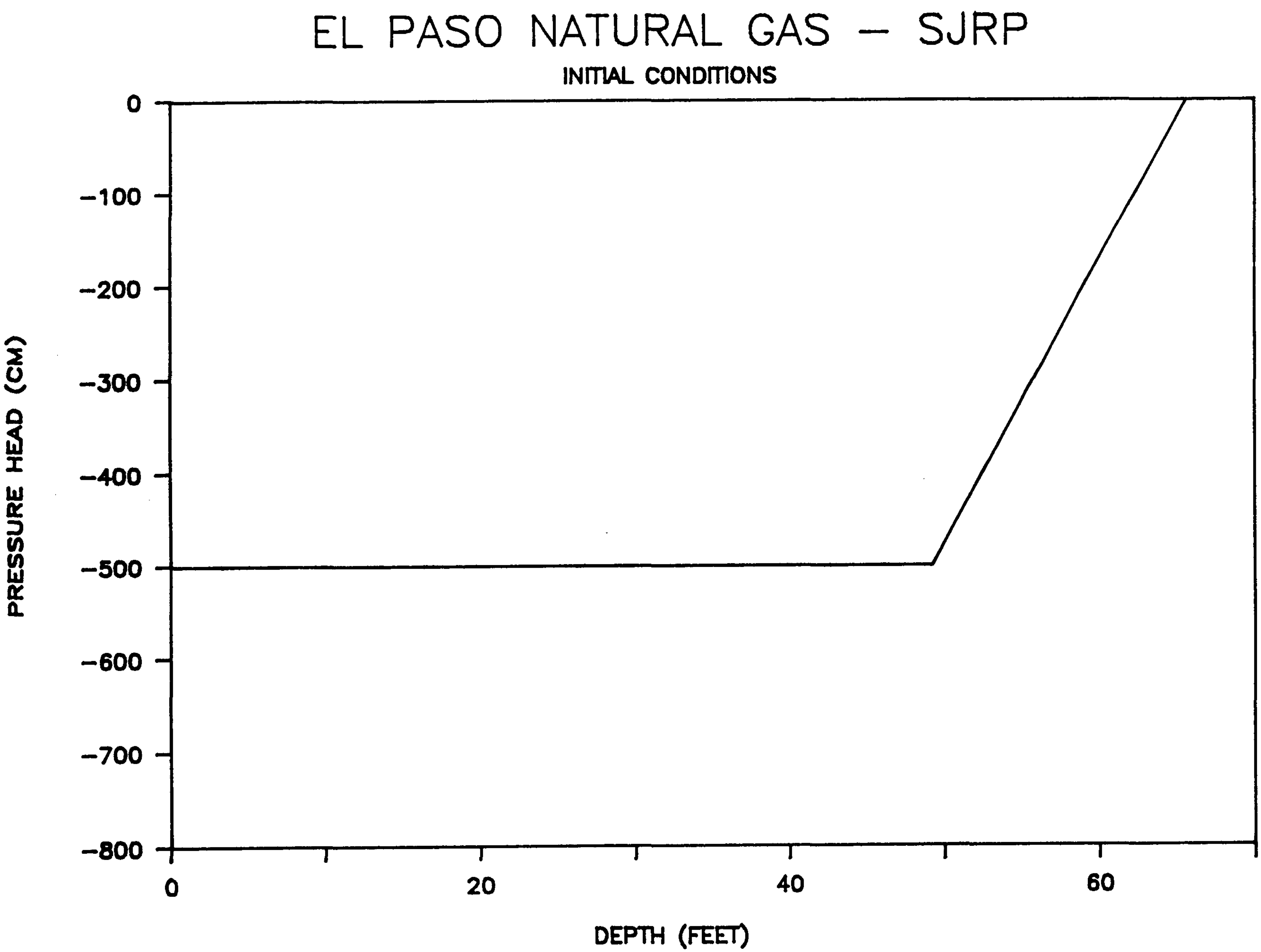


Figure 6-3. Initial conditions - pressure head (cm H_2O).

Table 6-1. SUMATRA1 Modeling Parameters.

Parameter	Units	Stratum 1	Stratum 2
Initial Chloride Concentration	(meq/l)	2.40	1.05
Thickness	(Feet)	36.0	29.6
Bulk Density	(g/cc)	1.65	1.55
Diffusion Coefficient	(cm^2/day)	1.30	1.30
Dispersivity	(cm)	1000	1000
Distribution Coefficient	(cc/g)	0	0
Saturated Hydraulic Conductivity	(cm/day)	190.0	7.3
Residual Moisture Content	(cc/cc)	0.06	0.25
Saturation Moisture Content	(cc/cc)	0.45	0.40

Table 6-2. Wastewater Chloride Concentrations (meq/l).

Scenario	Wastewater Chloride Concentration (meq/l)
1	33.00
2	8.91

was run using boundary conditions from both scenarios. Boundary conditions under Scenario 1 are given in Figures 6-4 and 6-5, while those for Scenario 2 are presented in Figures 6-19 and 6-20. A freely-draining soil column was used in the model, and a solute concentration gradient of zero, for all time, was maintained at the drainage point (65.6 ft).

Soil Hydraulic Properties - Saturated hydraulic conductivity of Stratum 1 was determined during Phase I by field infiltrometers, while that of Stratum 2 was measured through a bail test in accordance with the method of Hvorslev (Hvorslev, 1951). Unsaturated hydraulic conductivity was generated by the use of an empirical model based on soil texture.

6.3 MODEL RESULTS

Scenario 1 - Figures 6-6 through 6-7 are pore-water chloride concentration versus depth curves for times ranging from 1 to 10 years in 1-year increments for boundary conditions specific to Scenario 1. Based on wastewater quality (including contributions from the carbonate regeneration unit), source concentration under Scenario 1 is 33.0 meq/l. Examination of the figures in chronologic order indicates the curves to assume a hyperbolic shape over time. These observations indicate that progressively-higher saturation percentages are occurring with depth which serve to decrease the solute concentration via dilution; this is supported by the moisture content profiles given in Figures 6-9 through 6-18. Steady-state conditions also appear to be developing as the pore-water chloride concentrations for times 8.88 years and 9.87 years do not differ by significant amounts. Figure 6-8 contains the concentration history of the drainage water (65.6 ft), as well as the maximum allowable drainage water chloride concentration (7.90 meq/l); the maximum allowable chloride concentration is based on background groundwater quality. The curve

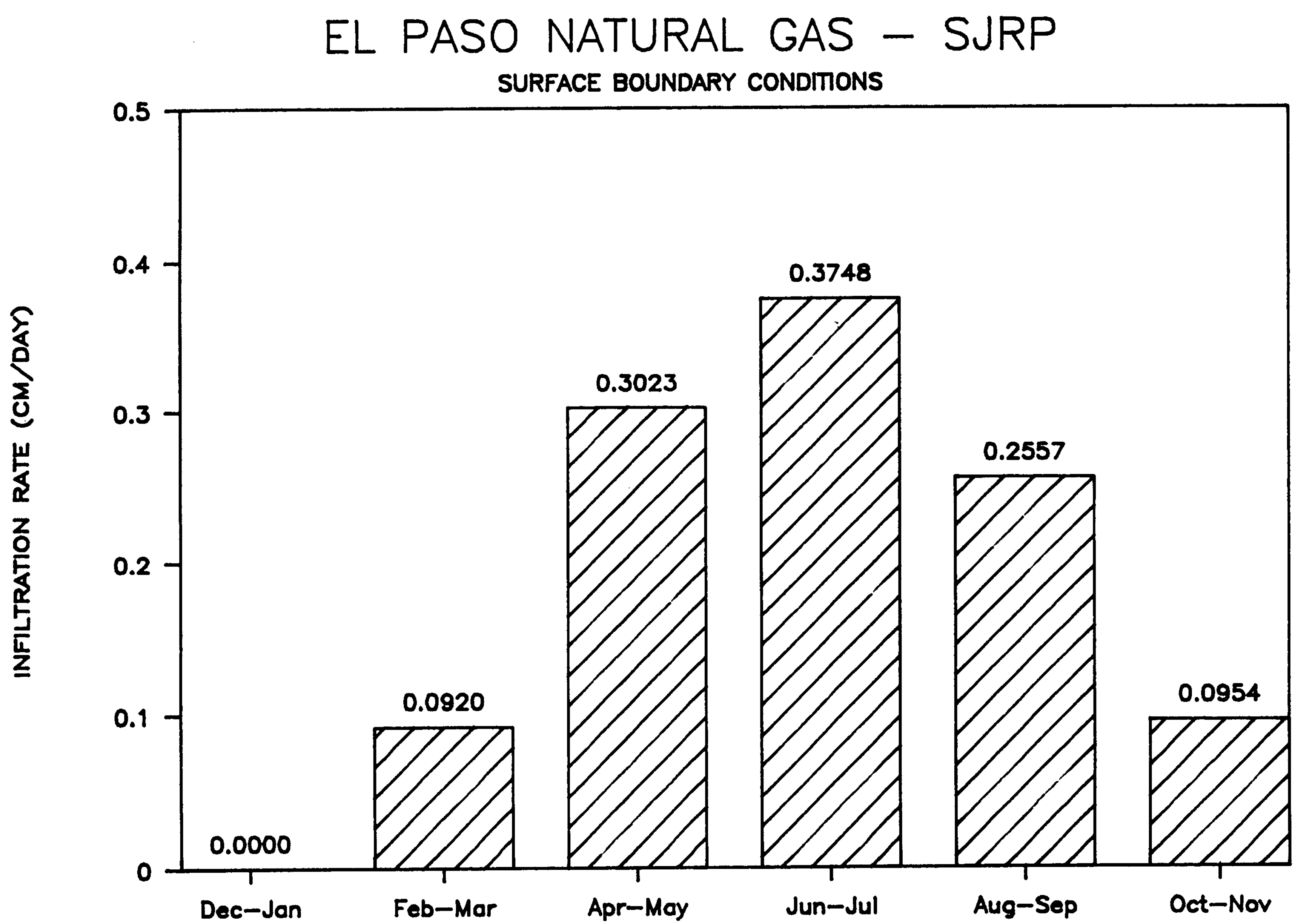


Figure 6-4. Surface boundary conditions (Scenario 1) - infiltration rate (cm/day).

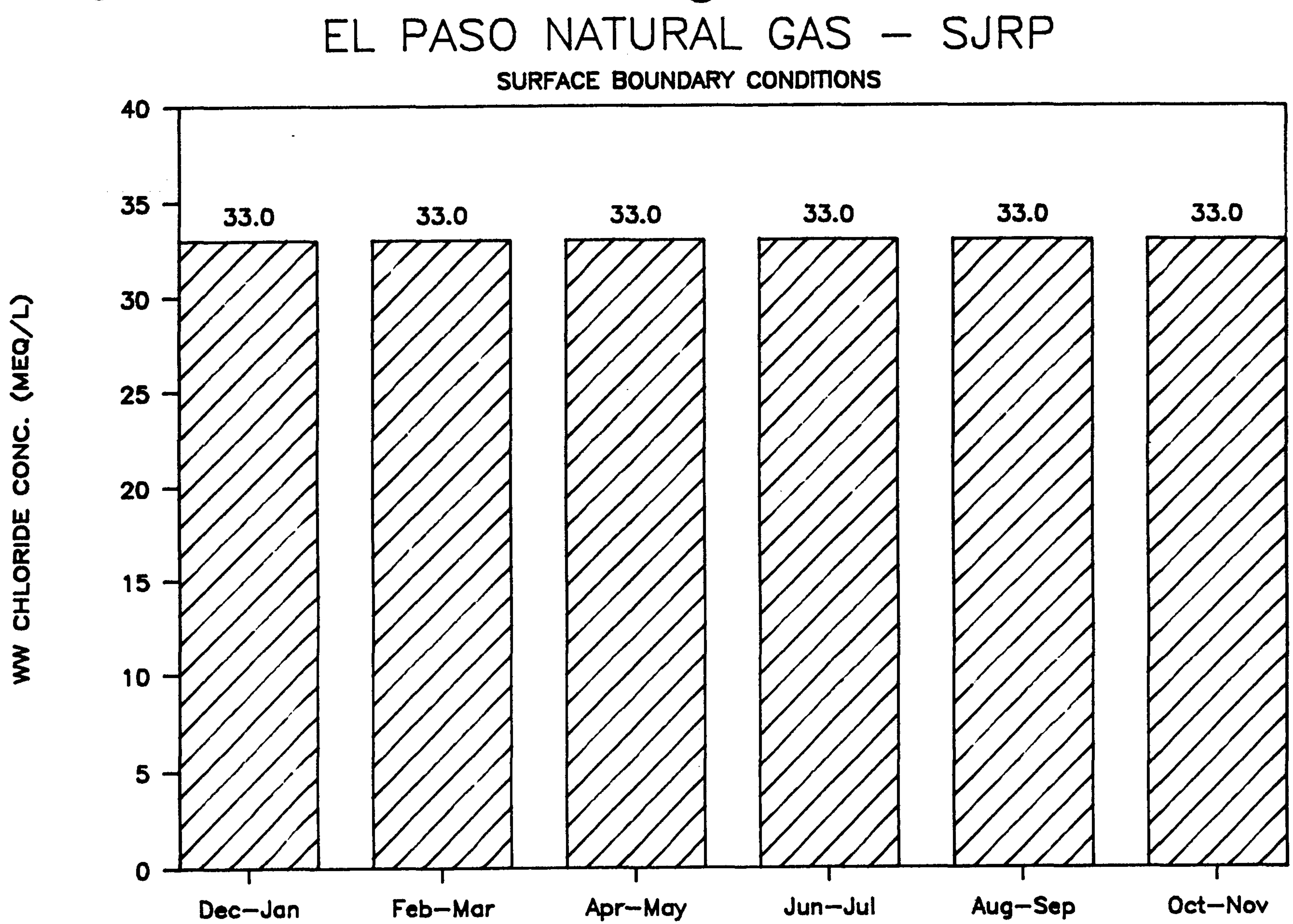


Figure 6-5. Surface boundary conditions (Scenario 1) - wastewater chloride concentration (meq/l).

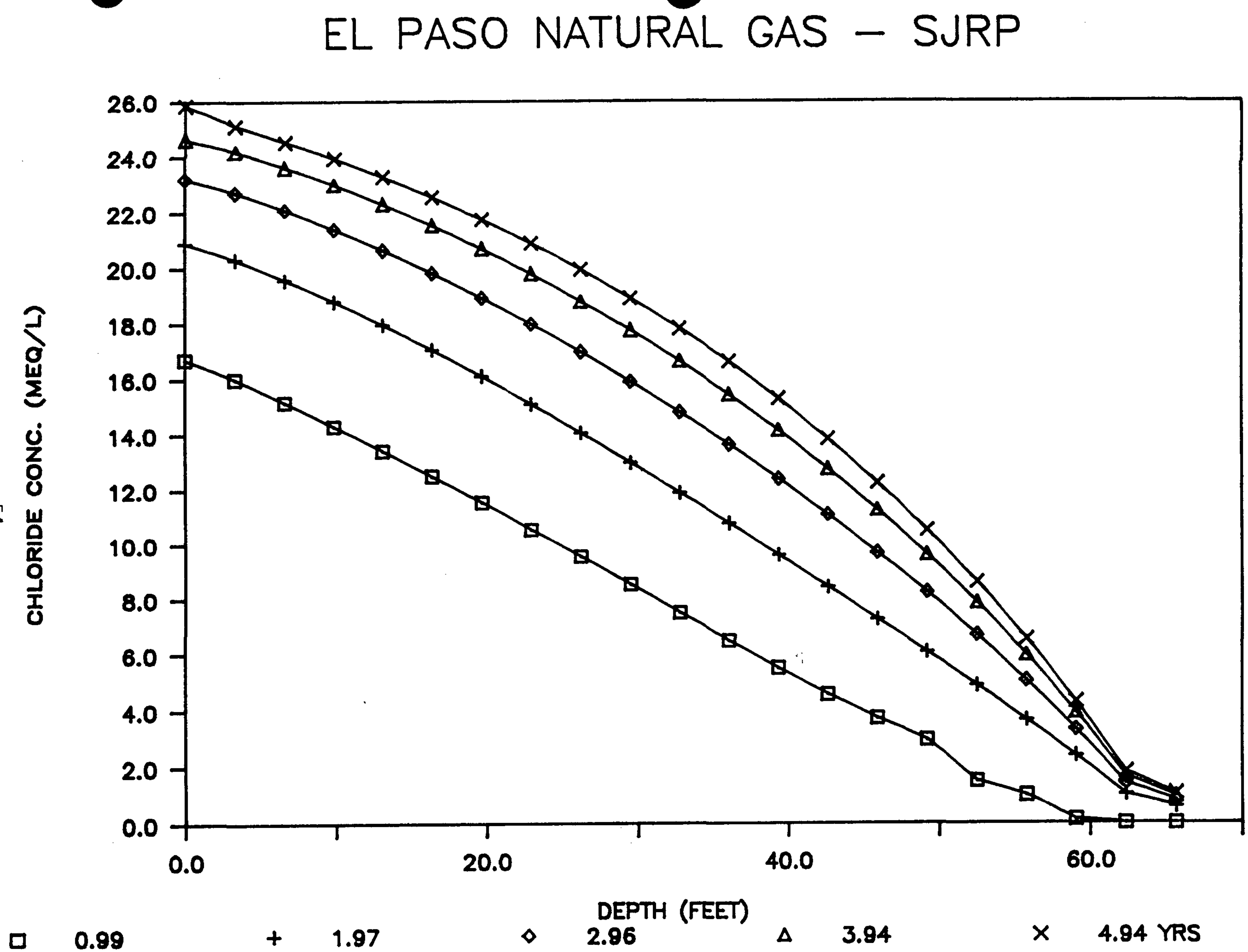


Figure 6-6. Pore-water chloride concentration (meq/l) versus depth (ft) at 0.99, 1.97, 2.96, 3.94, and 4.94 years (Scenario 1).

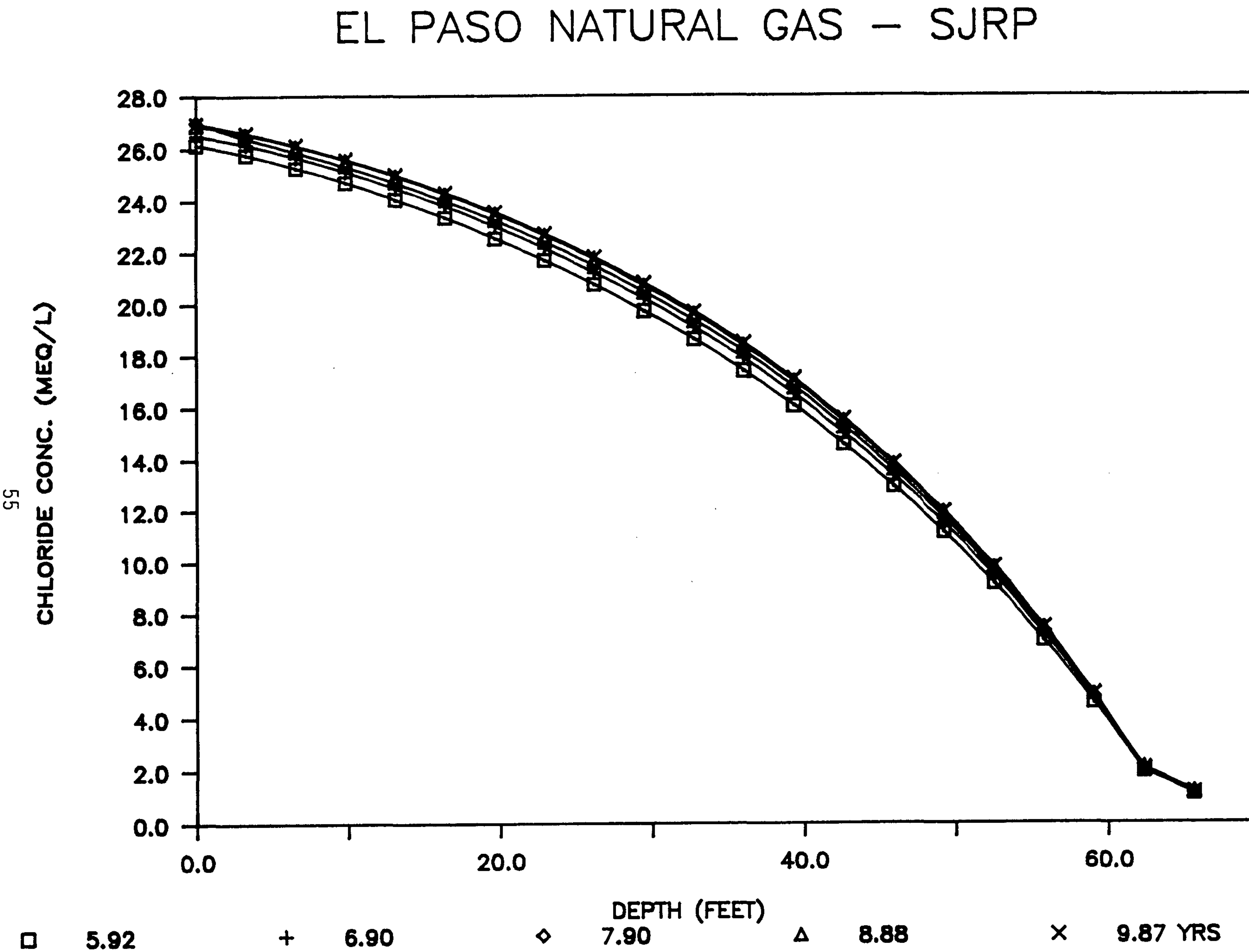


Figure 6-7. Pore-water chloride concentration (meq/l) versus depth (ft) at 5.92, 6.90, 7.90, 8.88, and 9.87 years (Scenario 1).

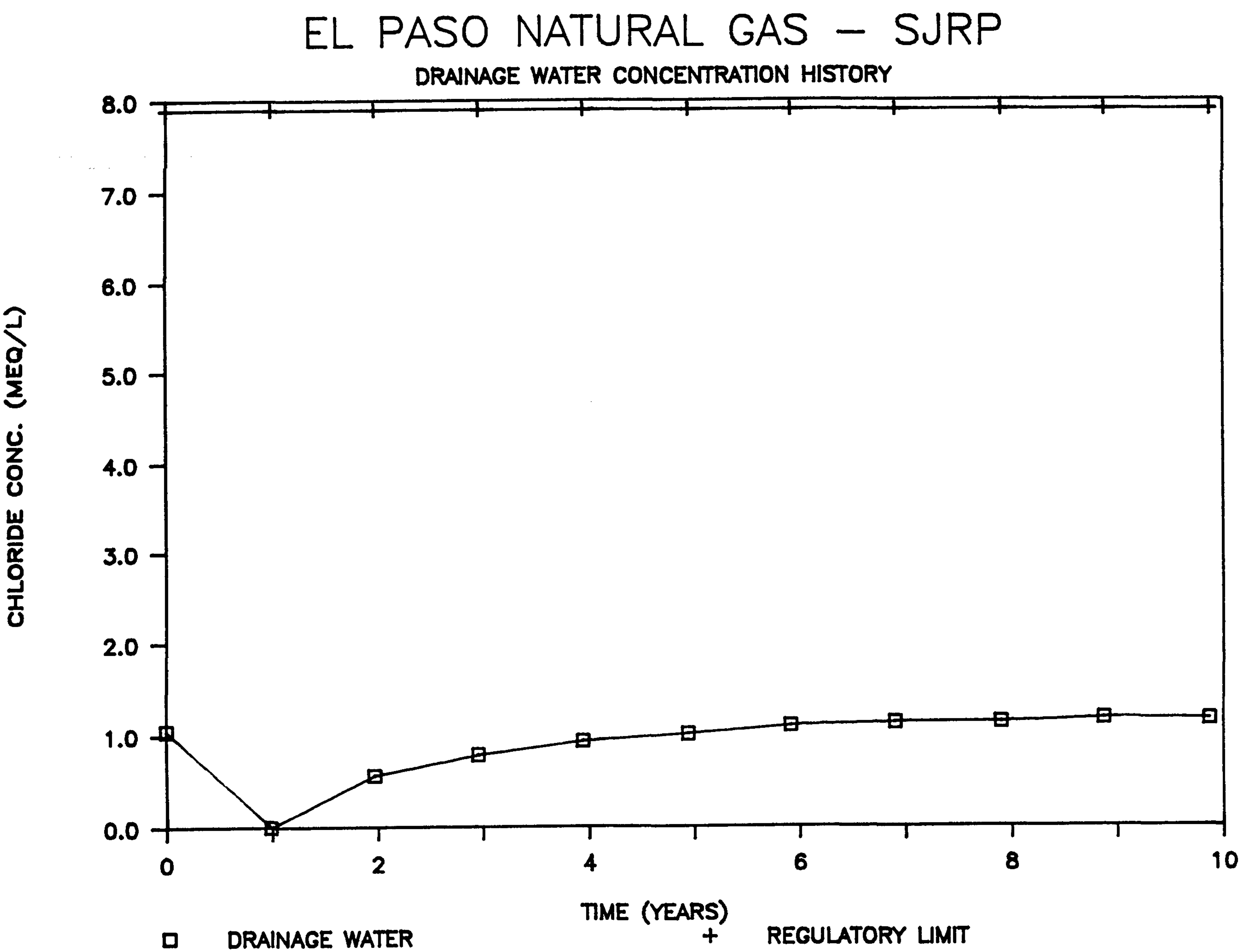


Figure 6-8. Drainage water concentration history (base of Stratum 2) under Scenario 1.

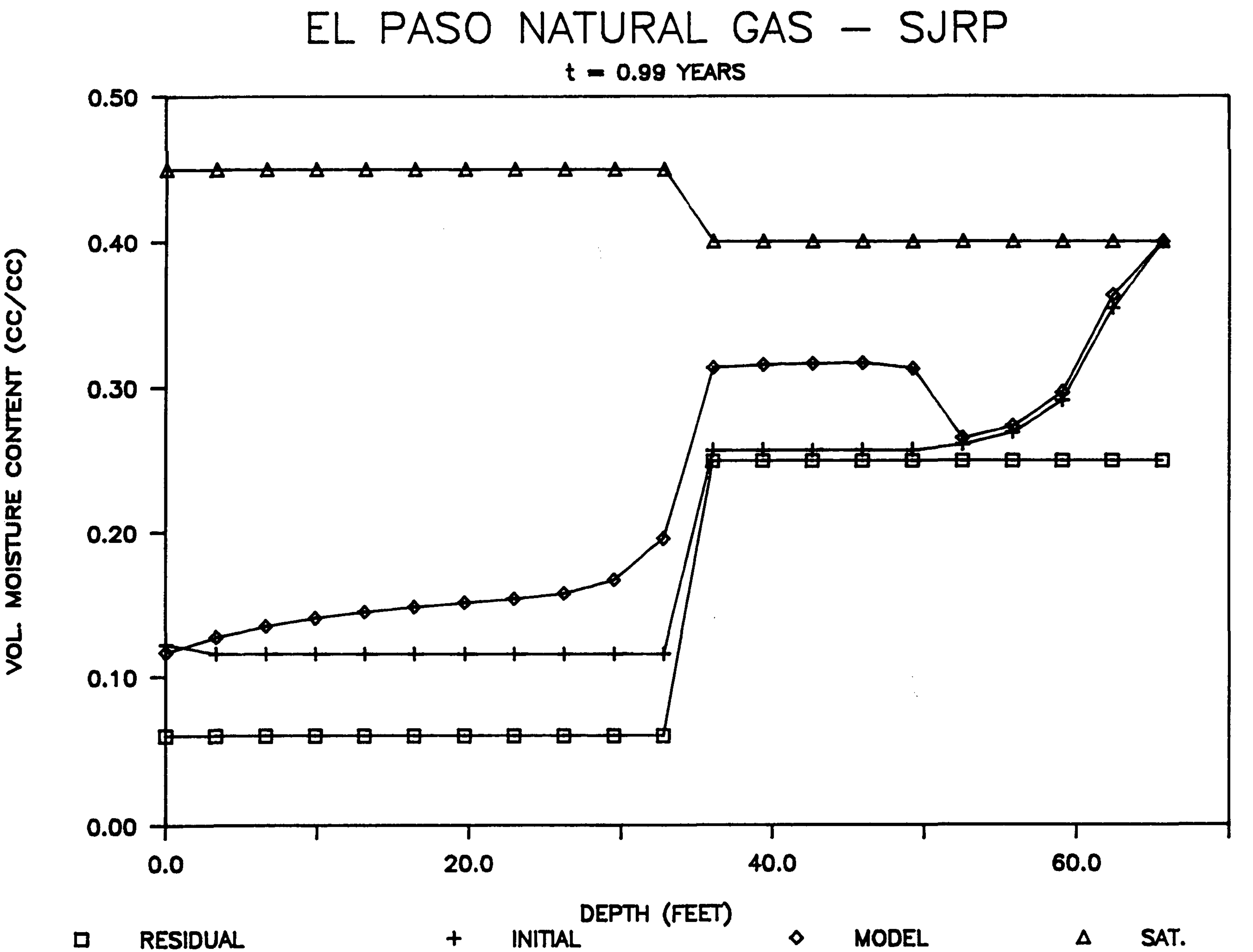


Figure 6-9. Volumetric moisture content (cc/cc) versus depth (ft) at 0.99 years (Scenario 1).

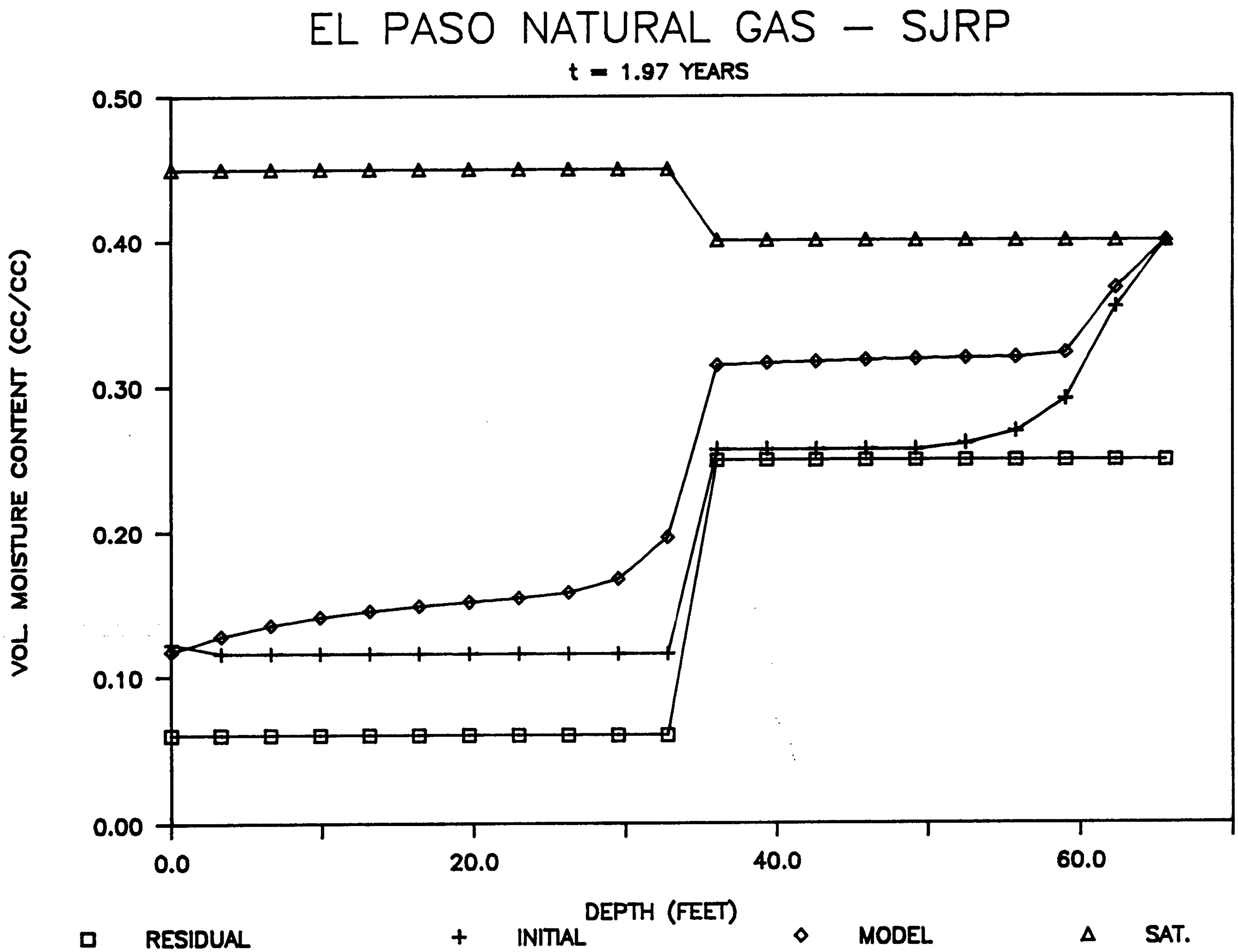


Figure 6-10. Volumetric moisture content (cc/cc) versus depth (ft) at 1.97 years (Scenario 1).

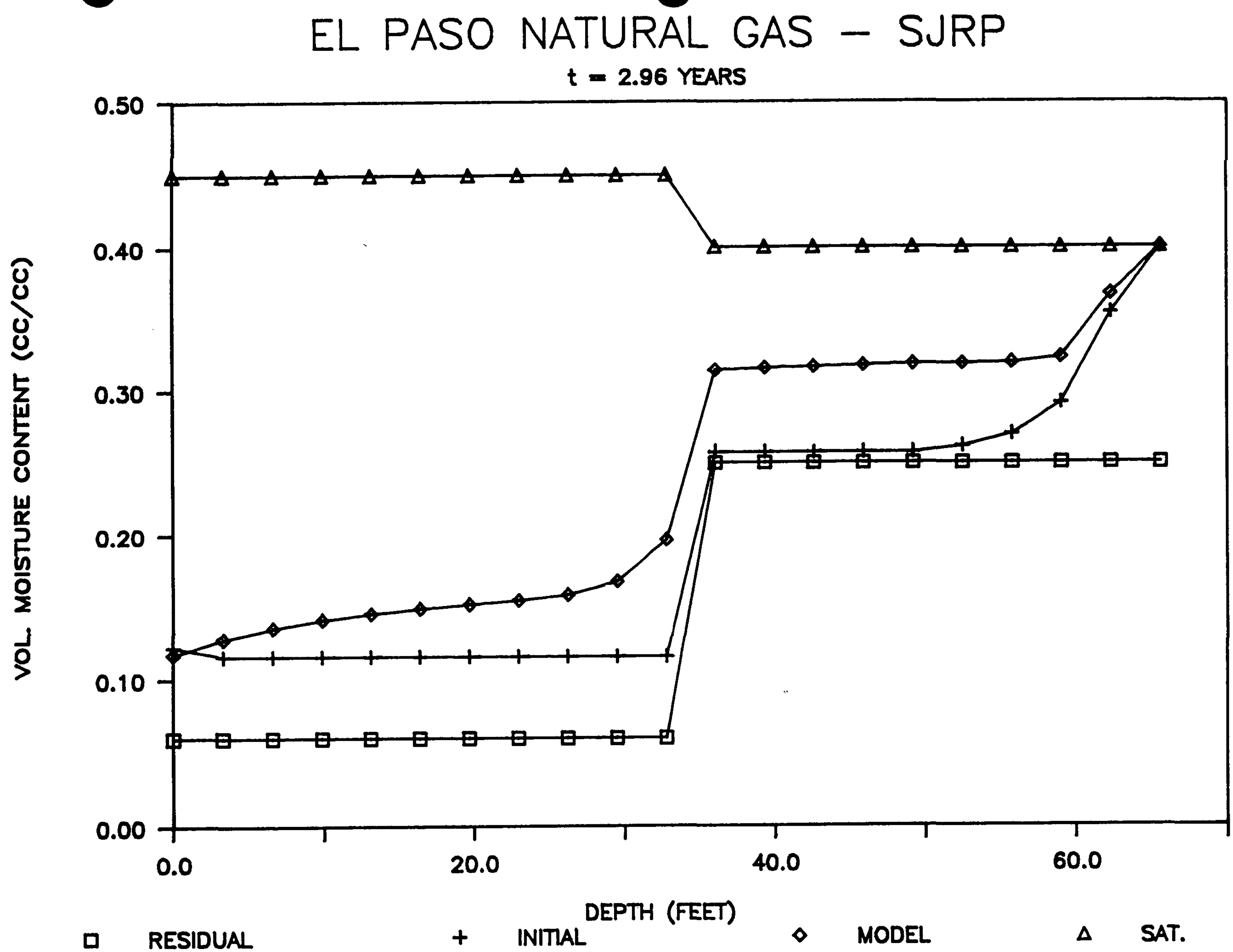


Figure 6-11. Volumetric moisture content (cc/cc) versus depth (ft) at 2.96 years (Scenario 1).

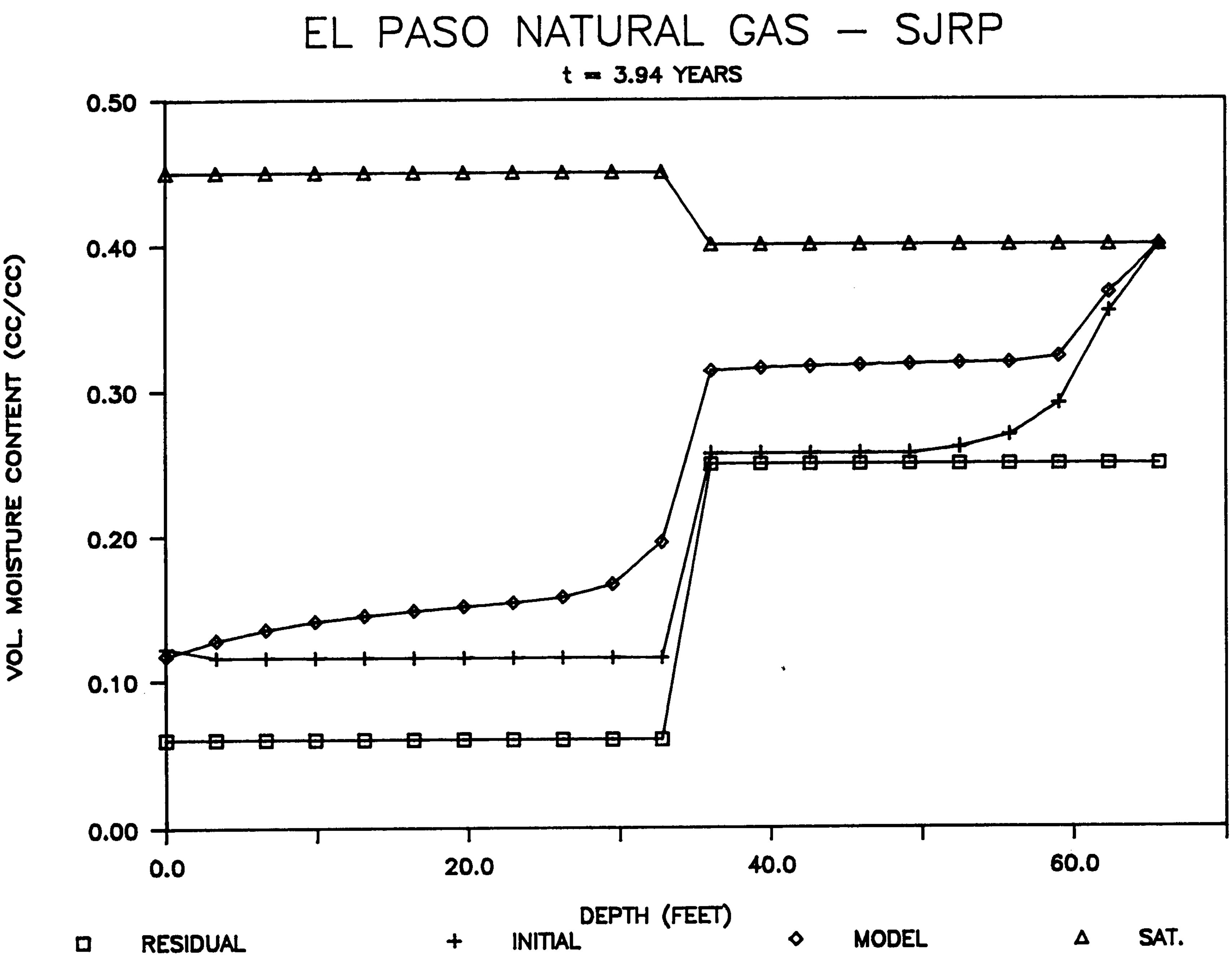


Figure 6-12. Volumetric moisture content (cc/cc) versus depth (ft) at 3.94 years (Scenario 1).

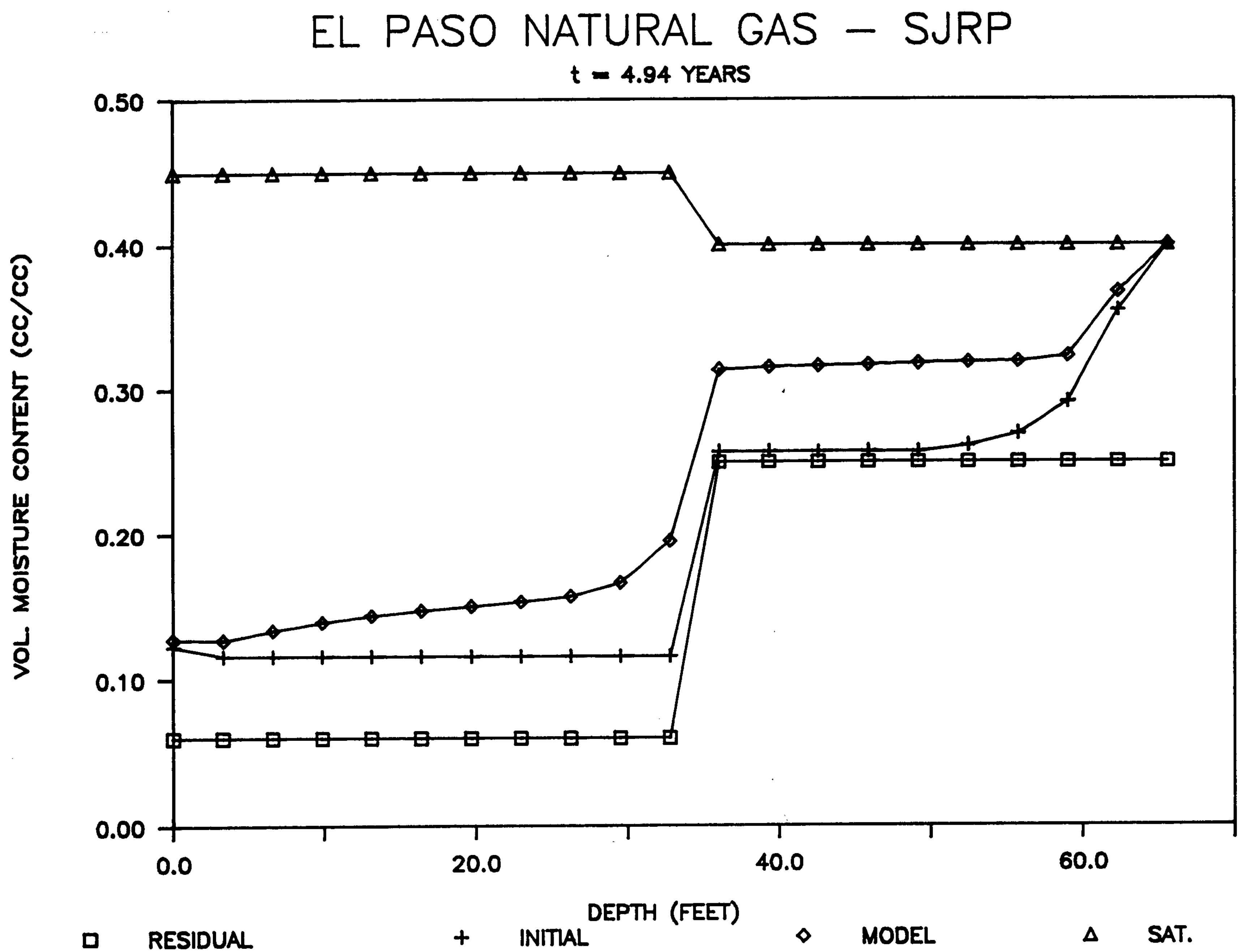


Figure 6-13. Volumetric moisture content (cc/cc) versus depth (ft) at 4.94 years (Scenario 1).

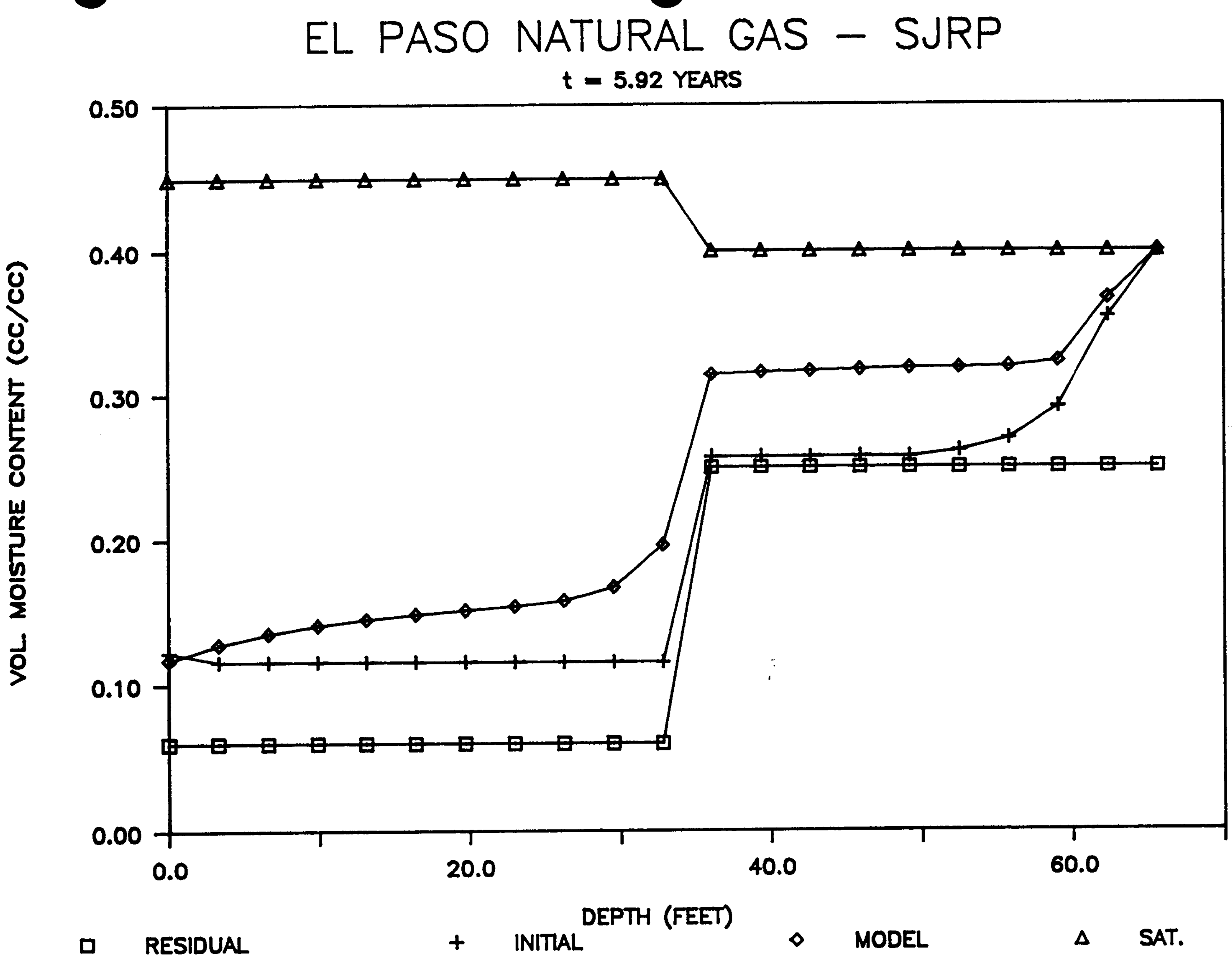


Figure 6-14. Volumetric moisture content (cc/cc) versus depth (ft) at 5.92 years (Scenario 1).

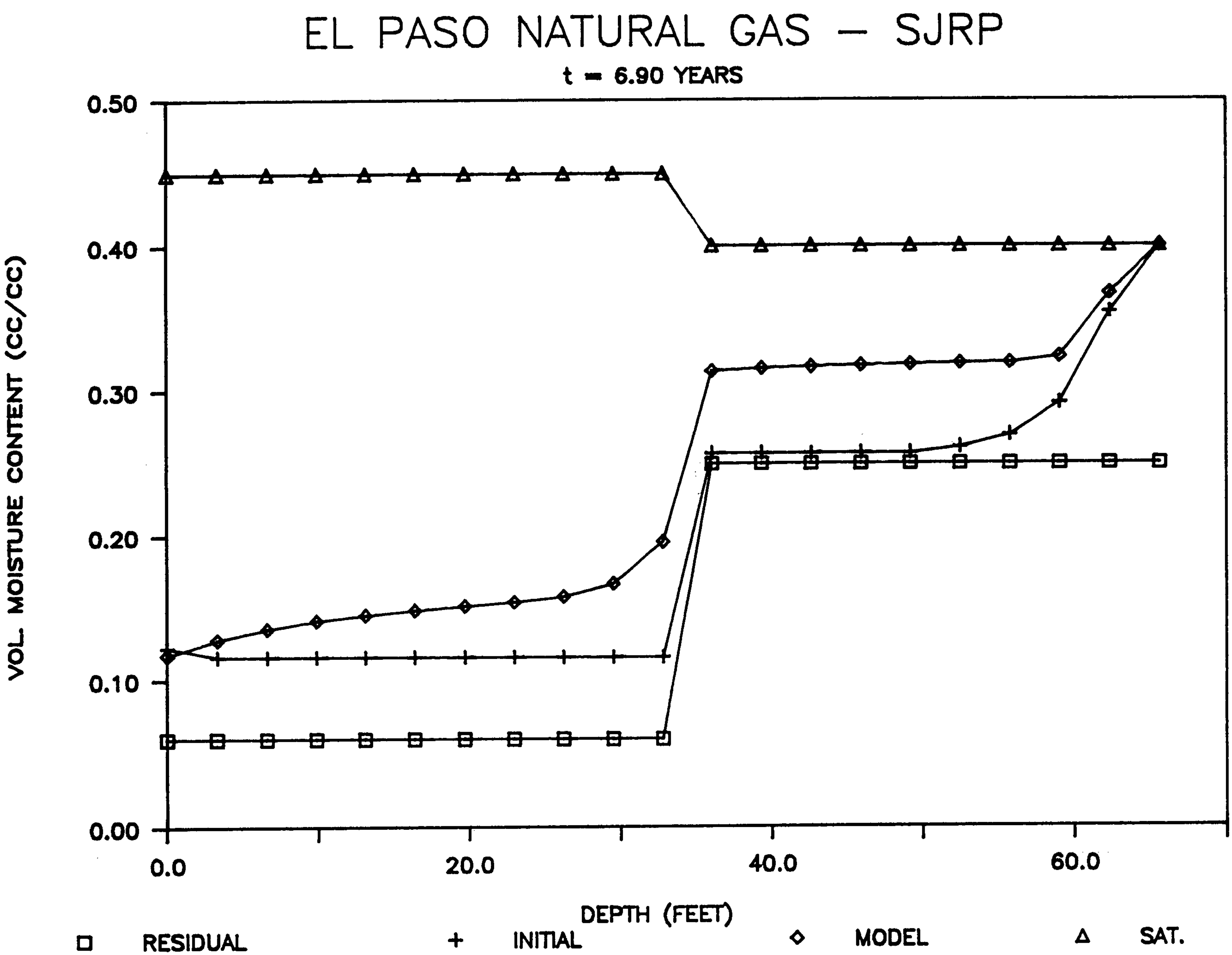


Figure 6-15. Volumetric moisture content (cc/cc) versus depth (ft) at 6.90 years (Scenario 1).

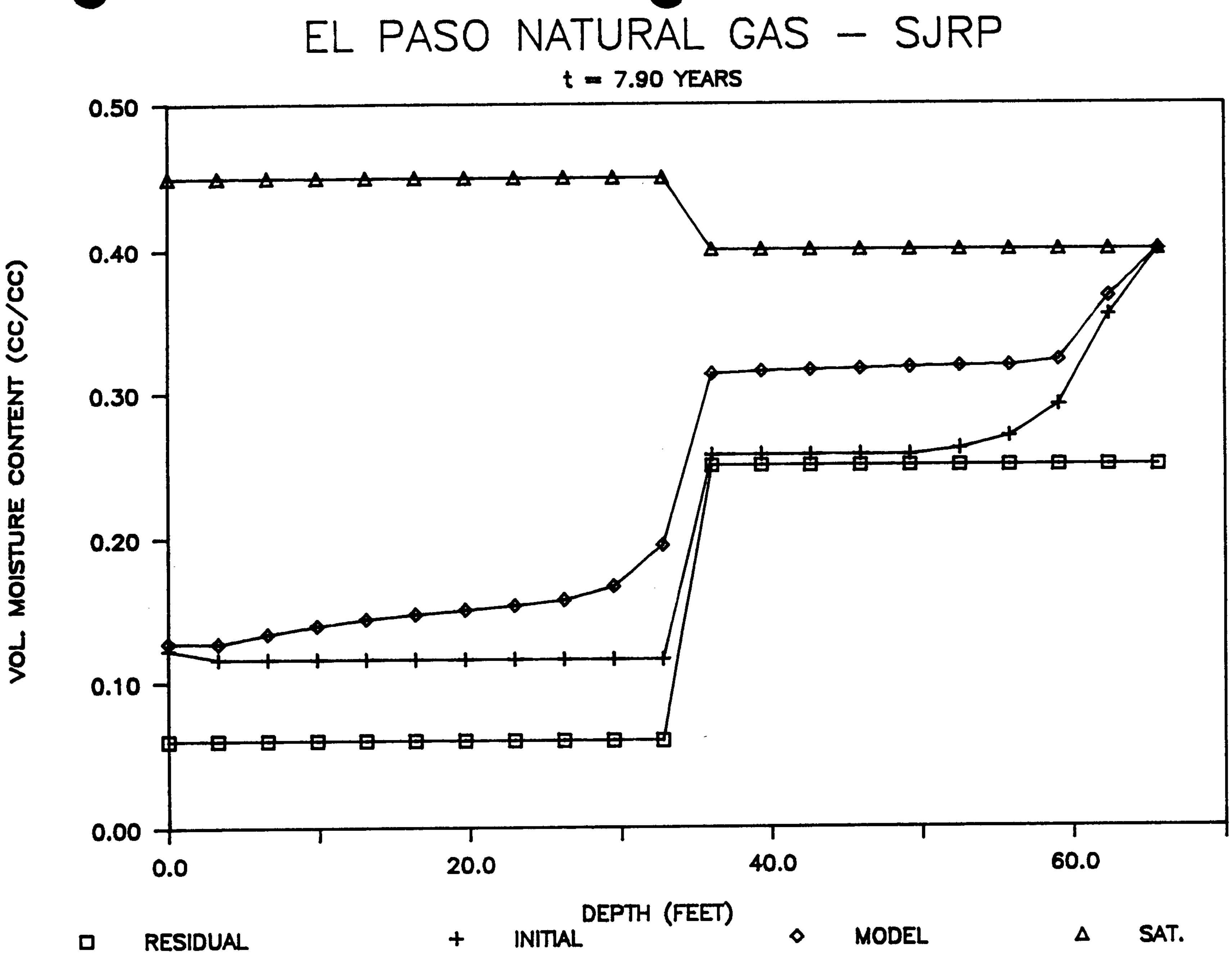


Figure 6-16. Volumetric moisture content (cc/cc) versus depth (ft) at 7.90 (Scenario 1).

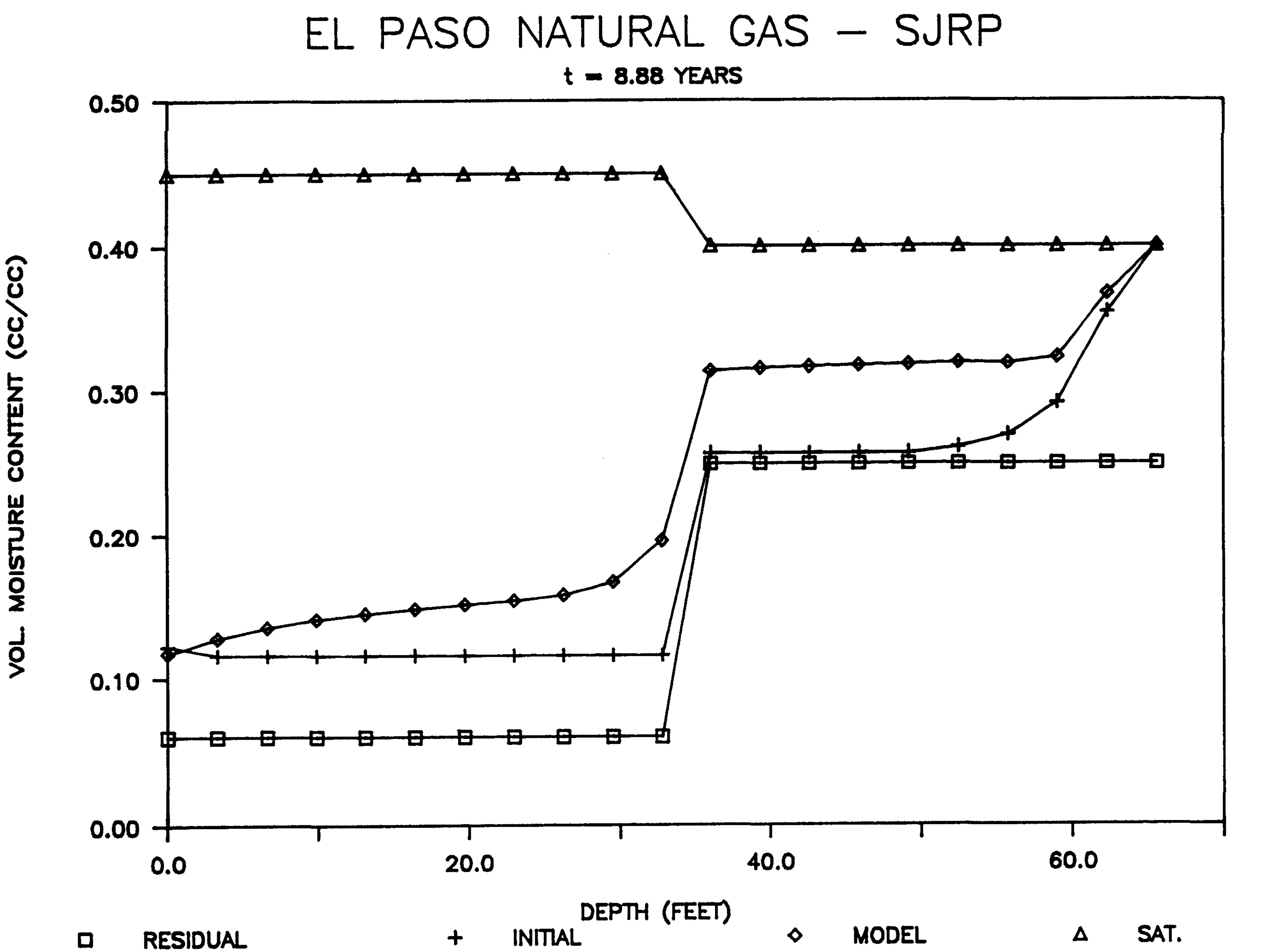


Figure 6-17. Volumetric moisture content (cc/cc) versus depth (ft) at 8.88 years (Scenario 1).

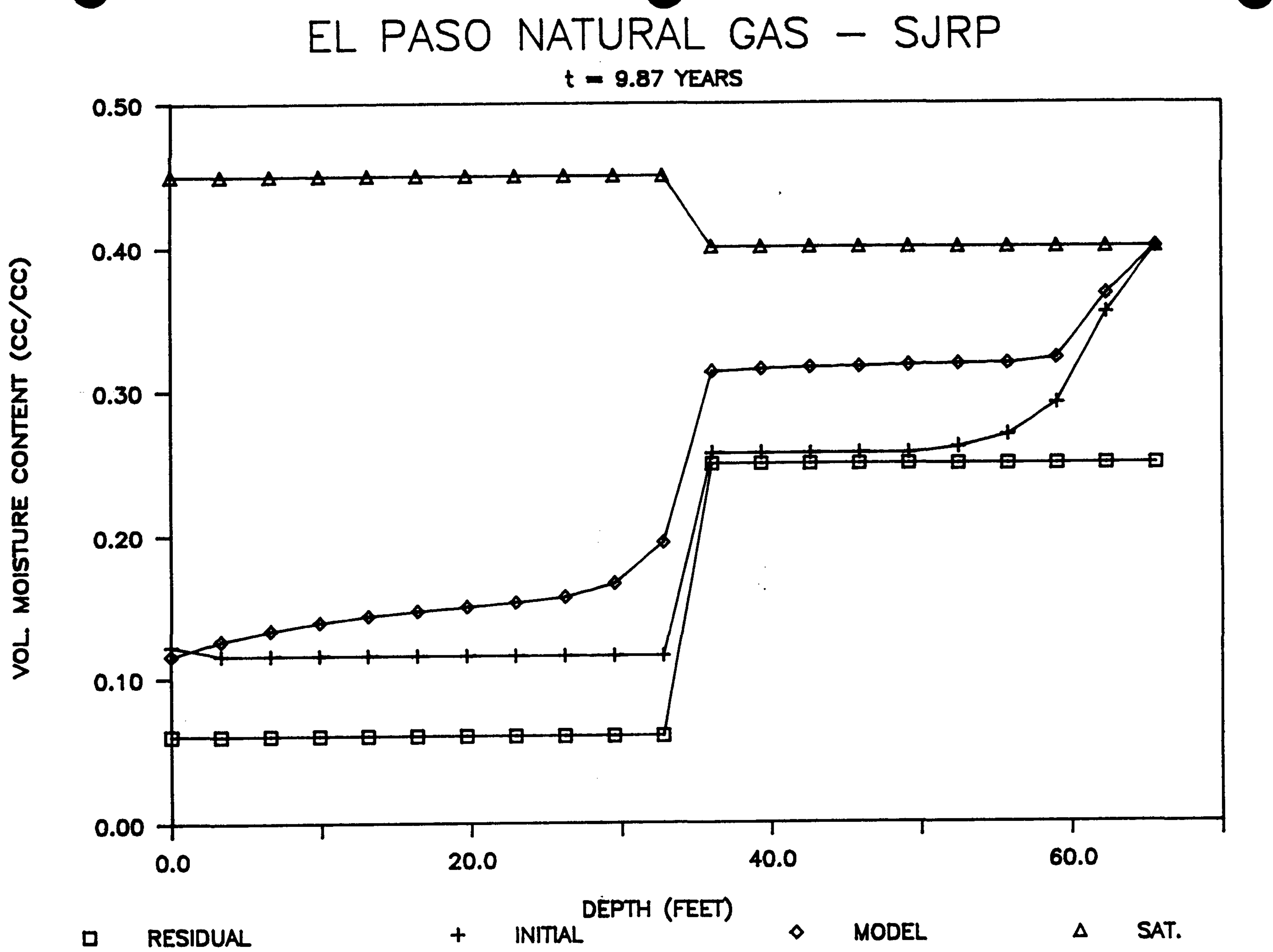


Figure 6-18. Volumetric moisture content (cc/cc) versus depth (ft) at 9.87 years (Scenario 1).

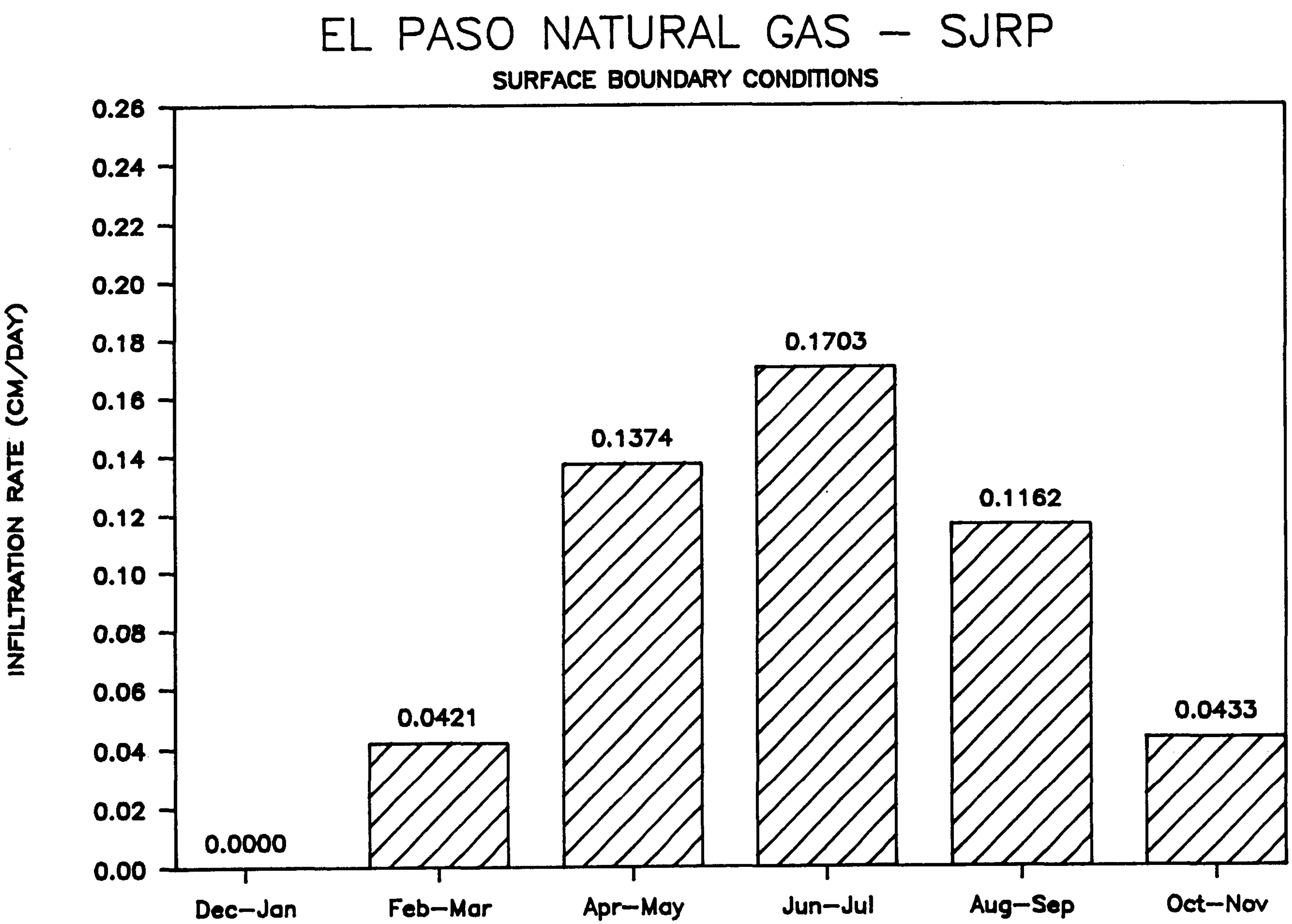


Figure 6-19. Surface boundary conditions (Scenario 2) - infiltration rate (cm/day).

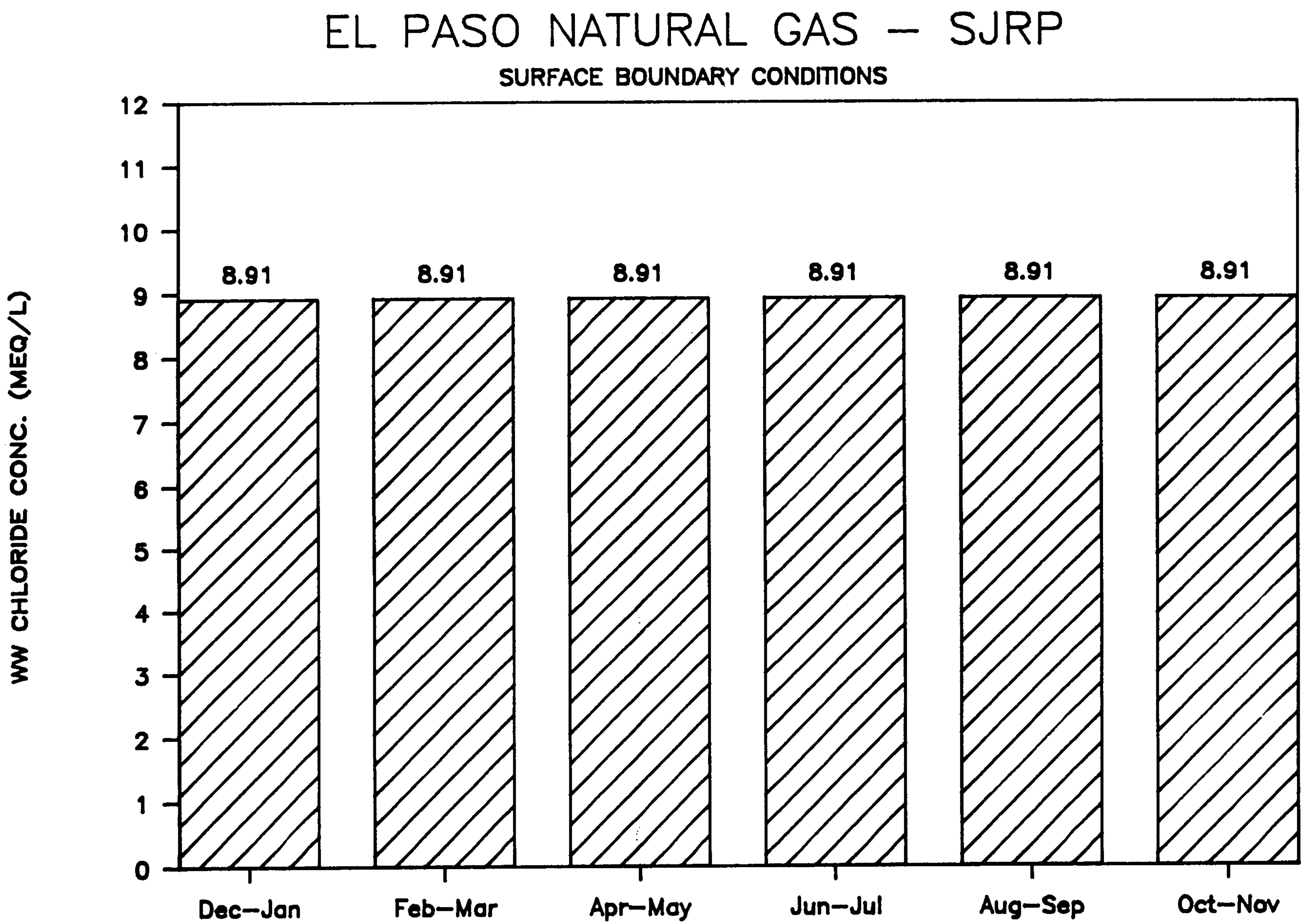


Figure 6-20. Surface boundary conditions (Scenario 2) - wastewater chloride concentration (meq/l).

appears to be asymptotic in nature, which effectively serves to support the belief that the unsaturated zone is assuming steady-state conditions. At no time do saturated conditions occur in the soil column (except at the drainage point since this is a boundary condition).

Scenario 2 - Figures 6-21 through 6-22 are solute concentration versus depth curves for irrigation conditions under Scenario 2. Wastewater chloride concentration (excluding the carbonate regeneration unit flows) for Scenario 2 is 8.91 meq/l. Figure 6-21 shows that Stratum 2 has yet to be influenced by irrigation operations as the chloride concentration in that unit remains at the initial level (i.e., 1.05 meq/l) at t=0.99 years. Figure 6-21, however, indicates that, after 1.97 years, the wetting front has successfully penetrated both geologic horizons. The remainder of the chloride concentration versus depth curves (Figures 6-21 and 6-22) shows a progression in shape from linear to hyperbolic. As in Scenario 1, it is believed that steady-state conditions are developing in the unsaturated zone. Again, unsaturated conditions are preserved in the 65.6 ft deep soil column at all times during the simulation (Figures 6-24 through 6-33). The flat nature of the drainage water chloride concentration history curve (Figure 6-23) supports the assertion that steady-state conditions have been reached. Using model results as a basis, it is emphatically stated that irrigation operations under Scenario 2 will not affect the groundwater quality beneath the east tract; this view is strongly supported by Figure 6-23.

6.4 CONCLUSIONS

Chloride has been chosen as the principal conservative solute/tracer due to its immunity to adsorption and decay, and to its salience in the wastewater. It is expected that a chloride ion will, on average, travel at

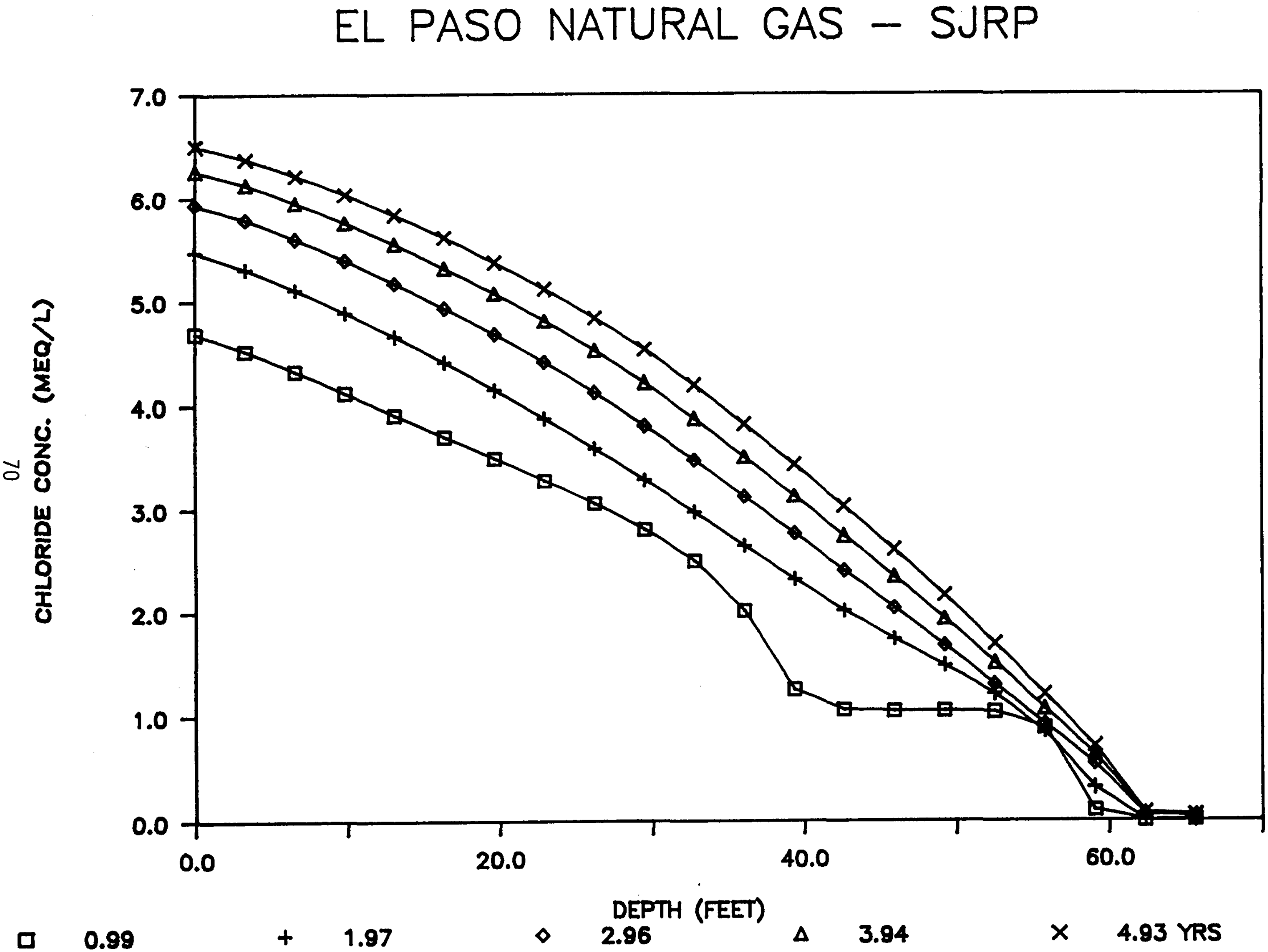


Figure 6-21. Pore-water chloride concentration (meq/l) versus depth (ft) at 0.99, 1.97, 2.96, 3.94, and 4.93 years (Scenario 2).

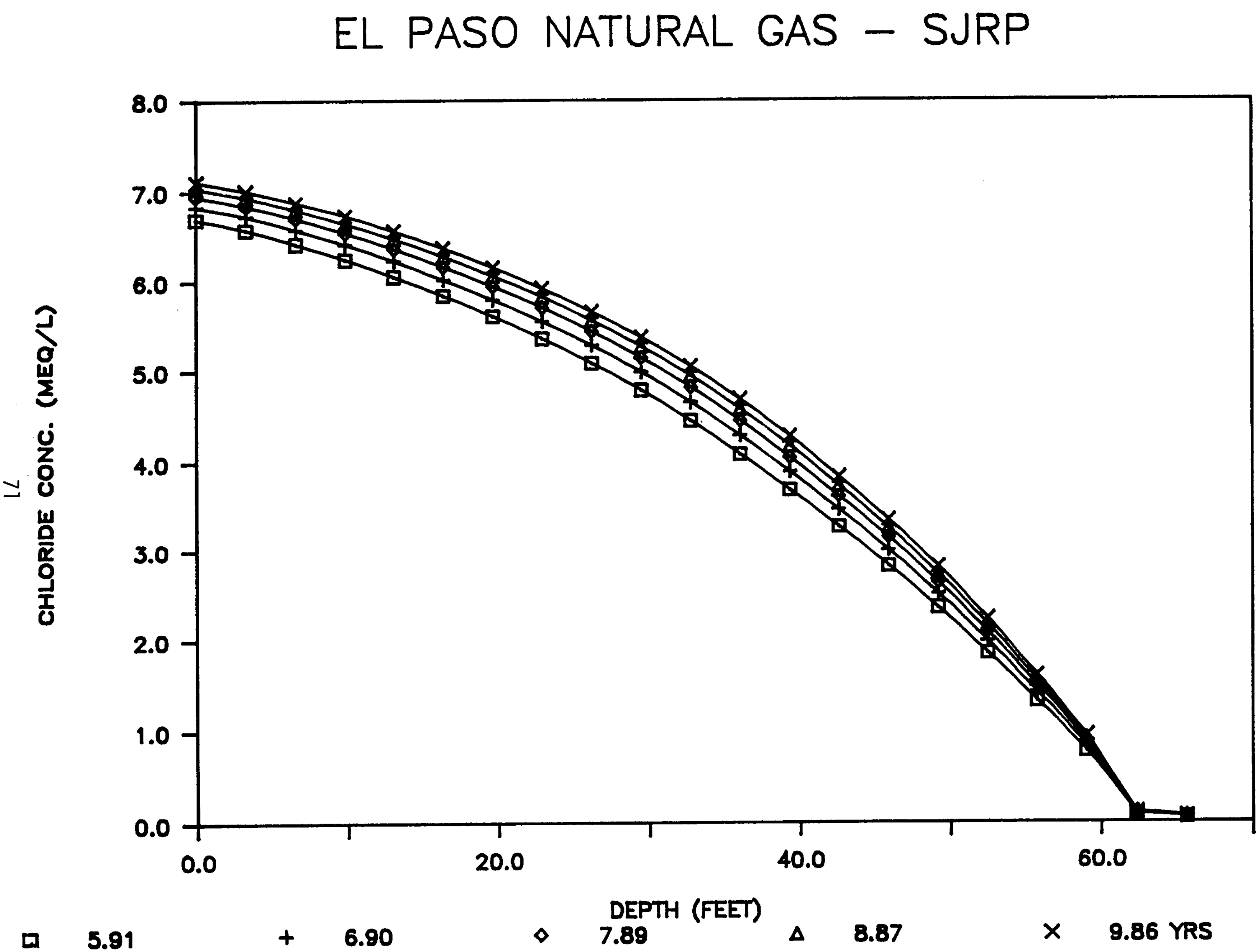


Figure 6-22. Pore-water chloride concentration (meq/l) versus depth (ft) at 5.91, 6.90, 7.89, 8.87, and 9.86 years (Scenario 2).

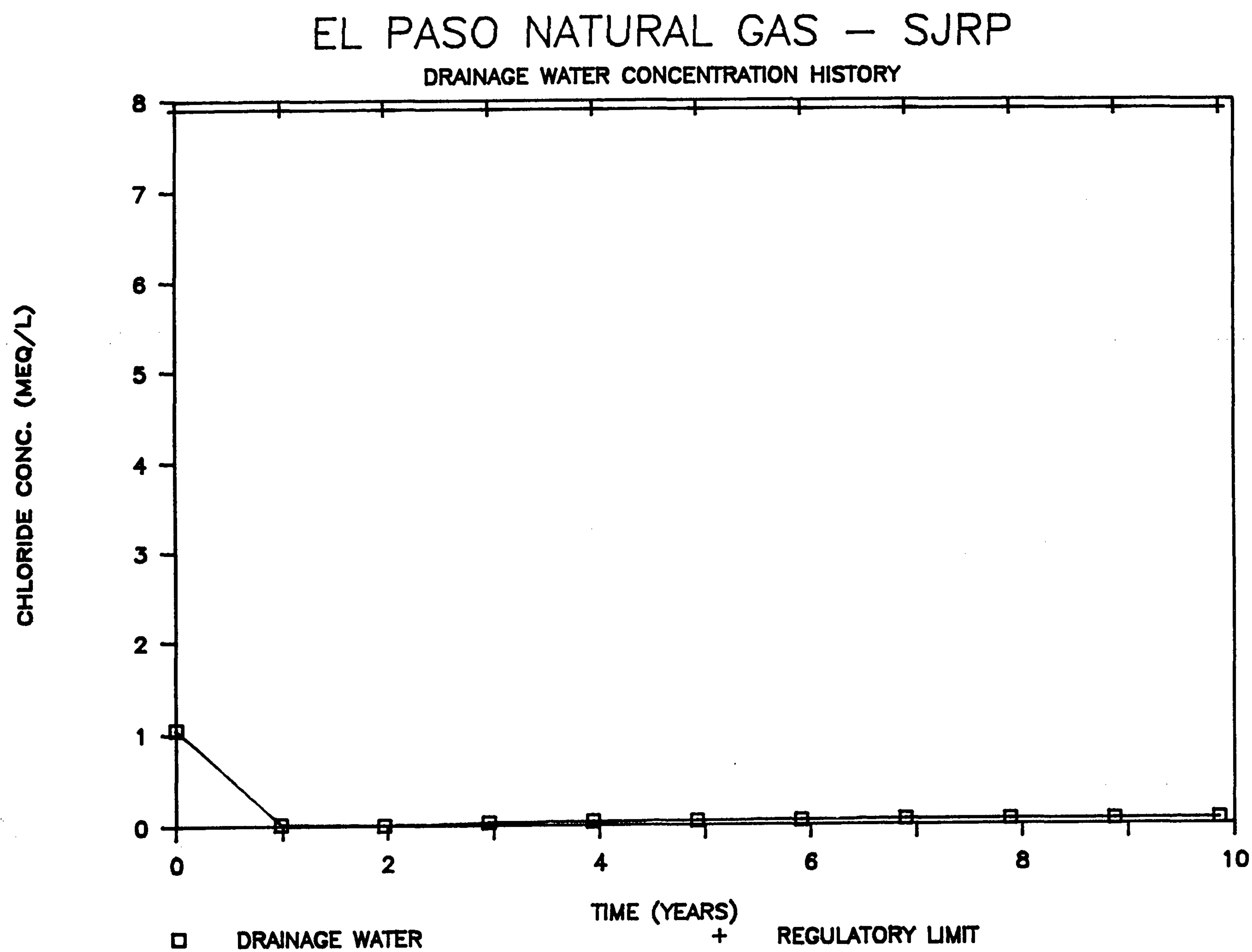


Figure 6-23. Drainage water concentration history (base of Stratum 2) under Scenario 2.

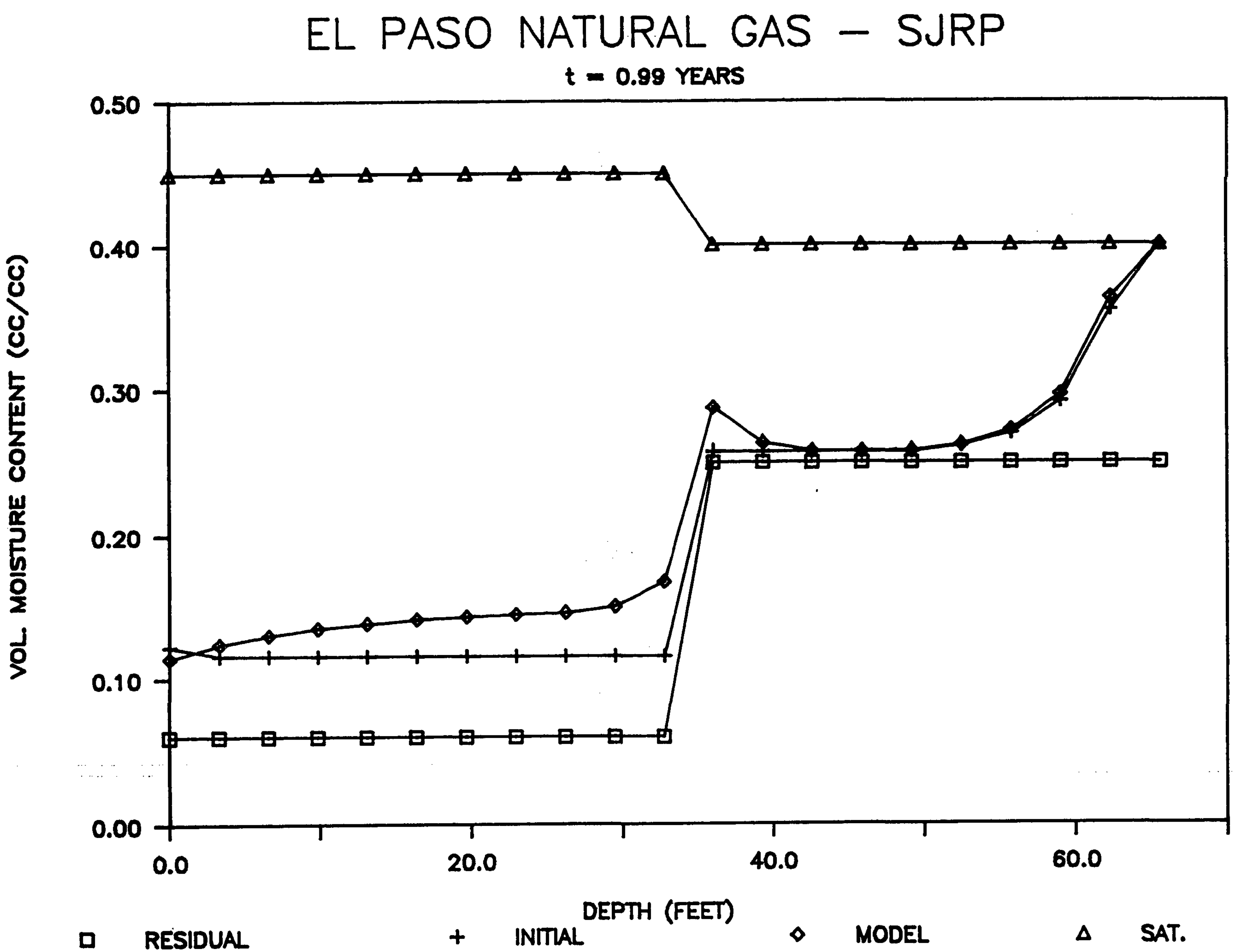


Figure 6-24. Volumetric moisture content (cc/cc) versus depth (ft) at 0.99 years (Scenario 2).

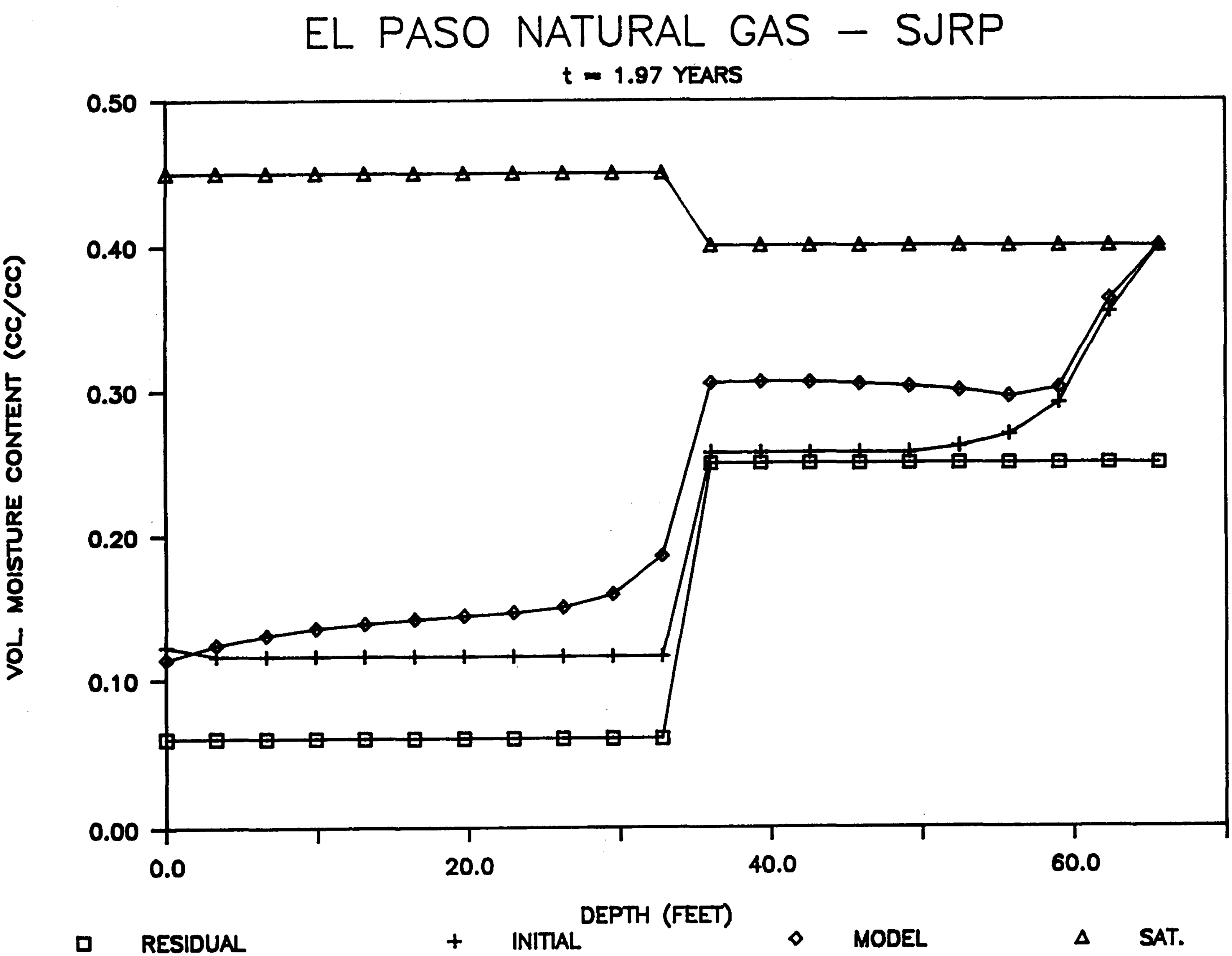


Figure 6-25. Volumetric moisture content (cc/cc) versus depth (ft) at 1.97 years (Scenario 2).

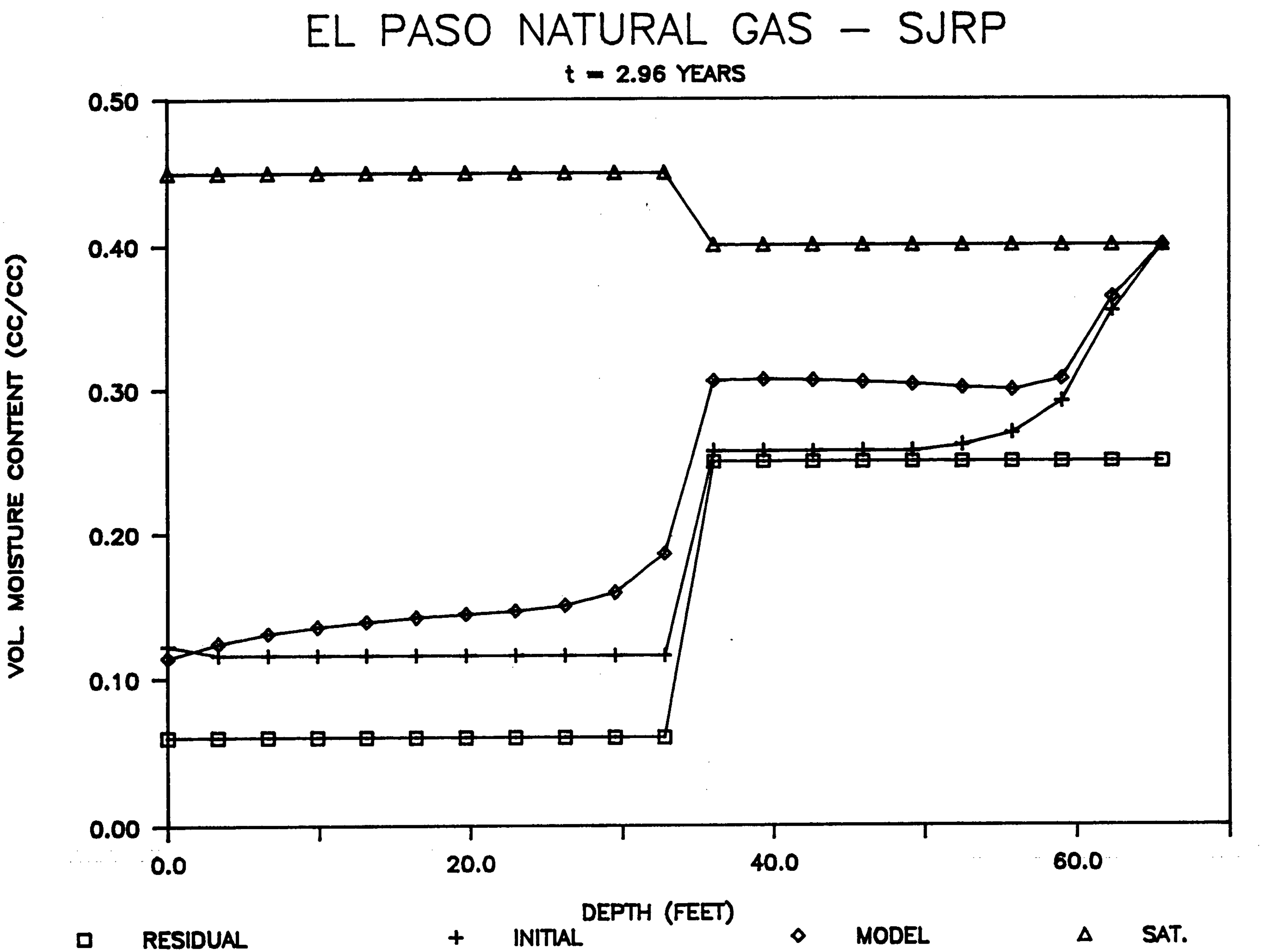


Figure 6-26. Volumetric moisture content (cc/cc) versus depth (ft) at 2.96 years (Scenario 2).

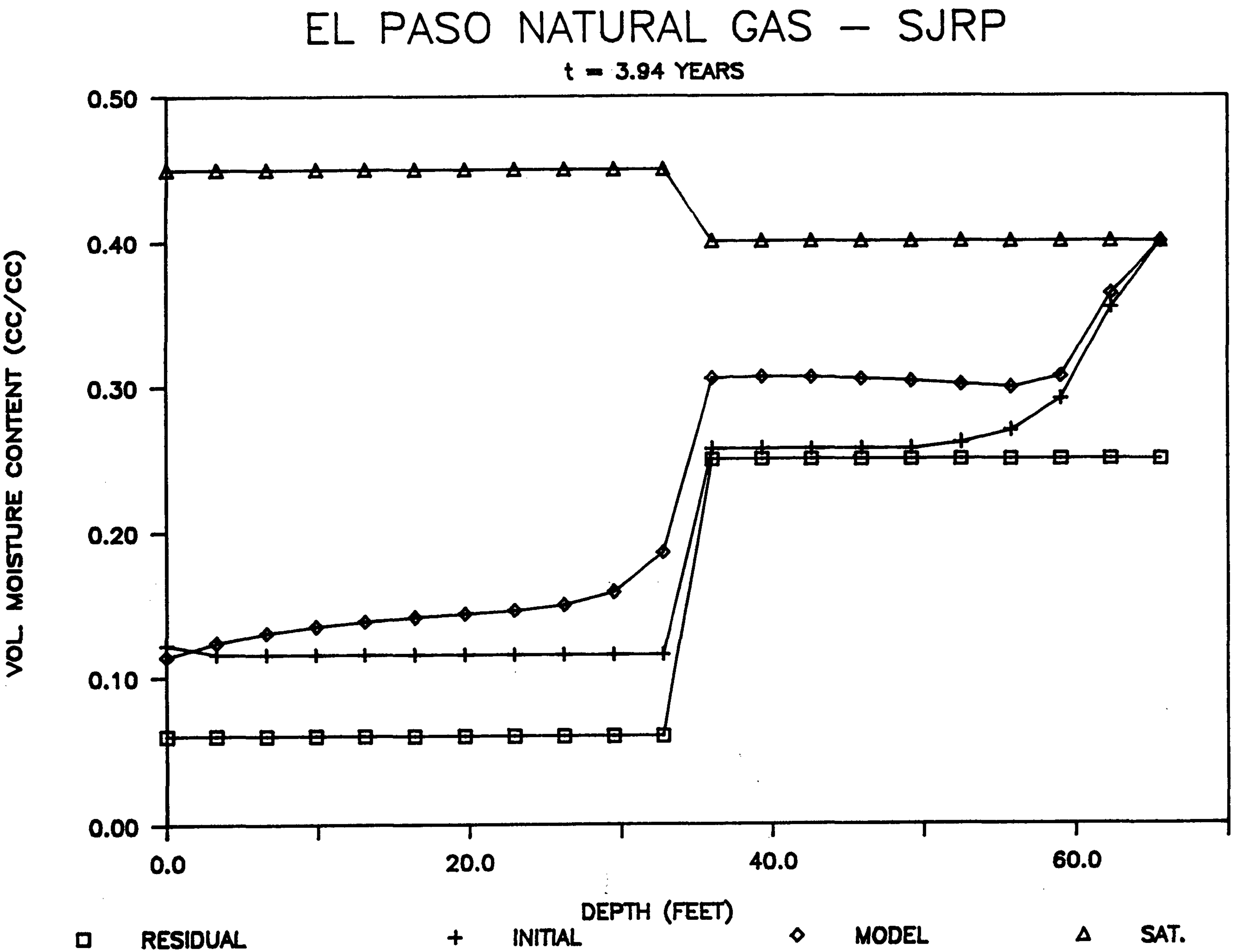


Figure 6-27. Volumetric moisture content (cc/cc) versus depth (ft) at 3.94 years (Scenario 2).

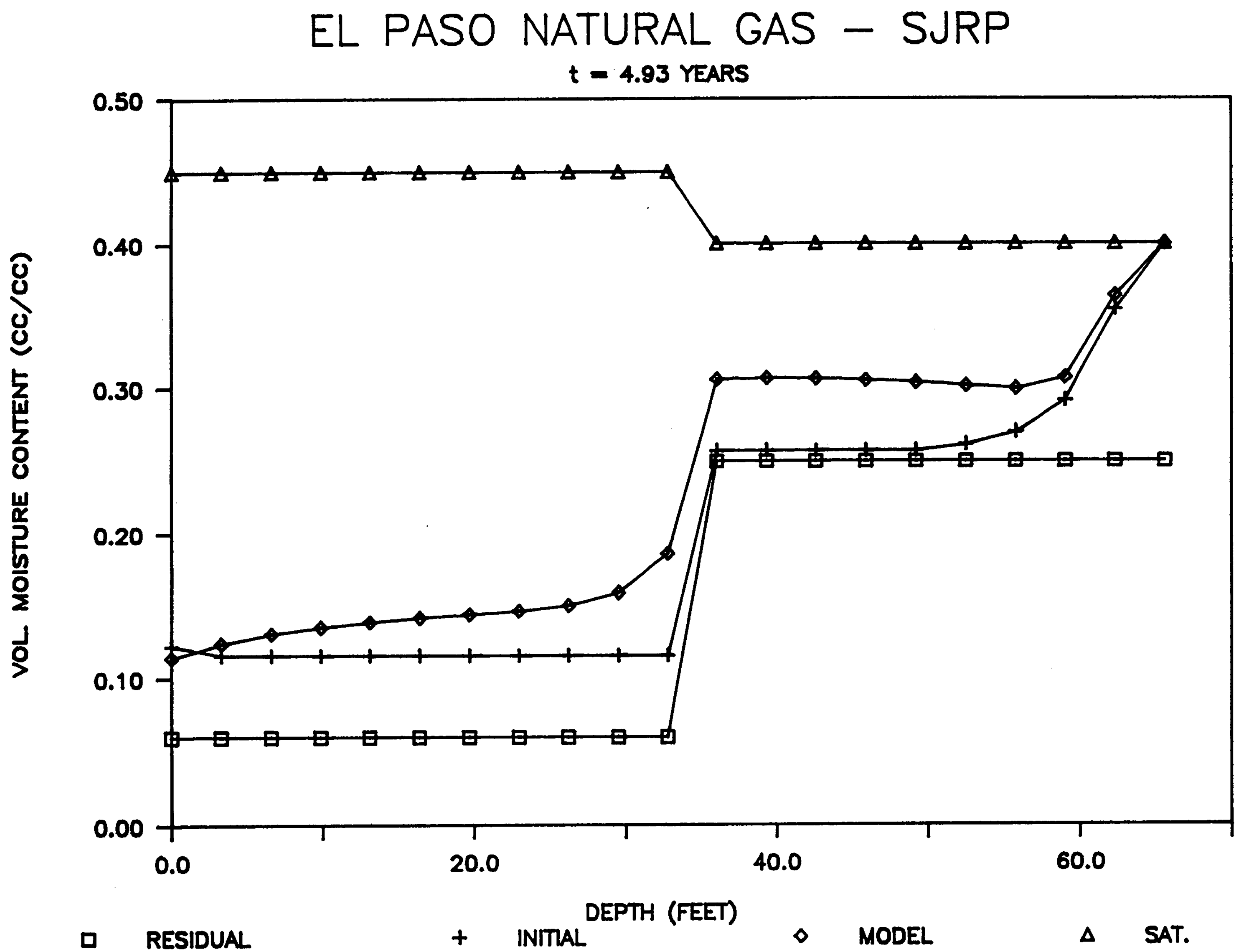


Figure 6-28. Volumetric moisture content (cc/cc) versus depth (ft) at 4.93 years (Scenario 2).

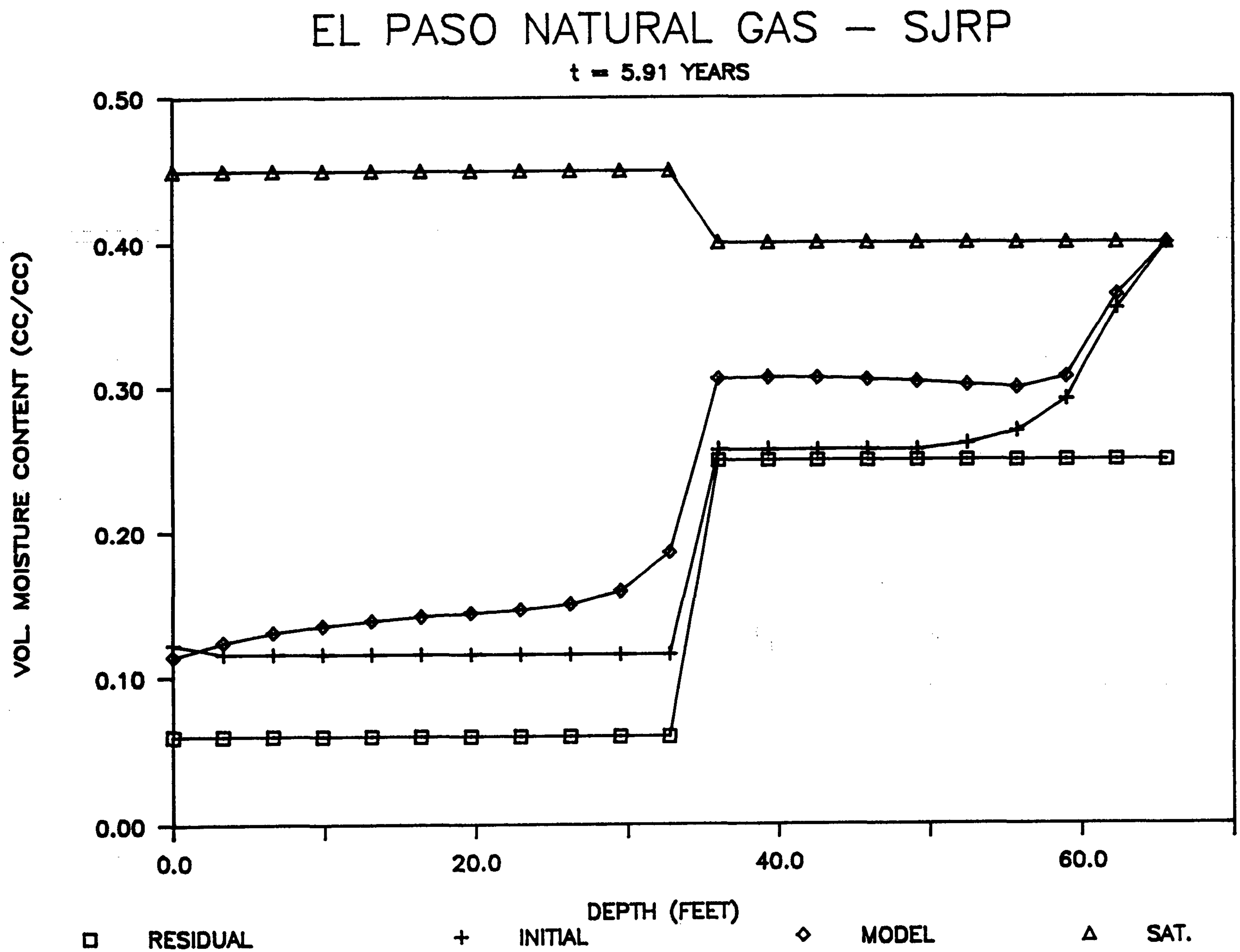


Figure 6-29. Volumetric moisture content (cc/cc) versus depth (ft) at 5.91 years (Scenario 2).

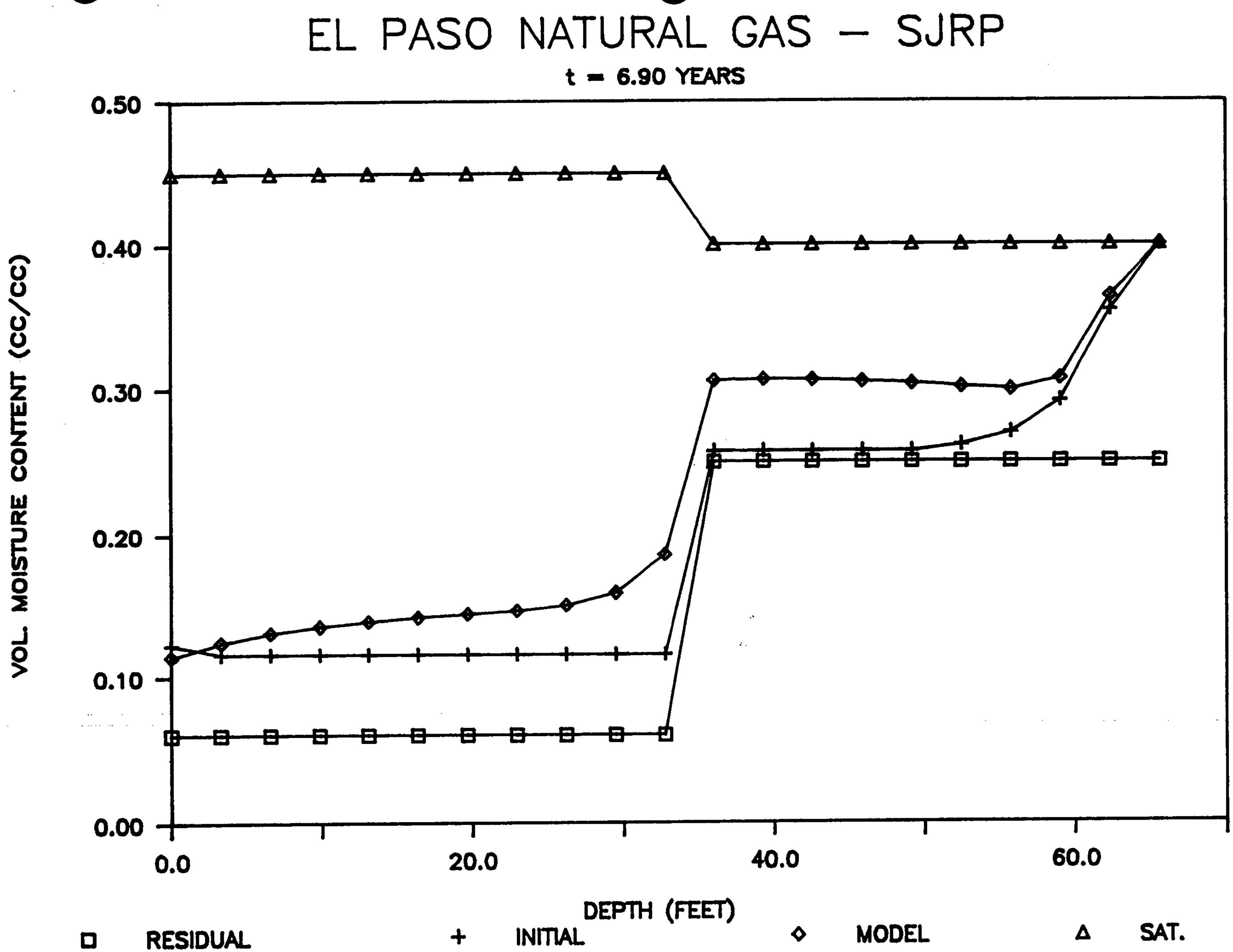


Figure 6-30. Volumetric moisture content (cc/cc) versus depth (ft) at 6.90 years (Scenario 2).

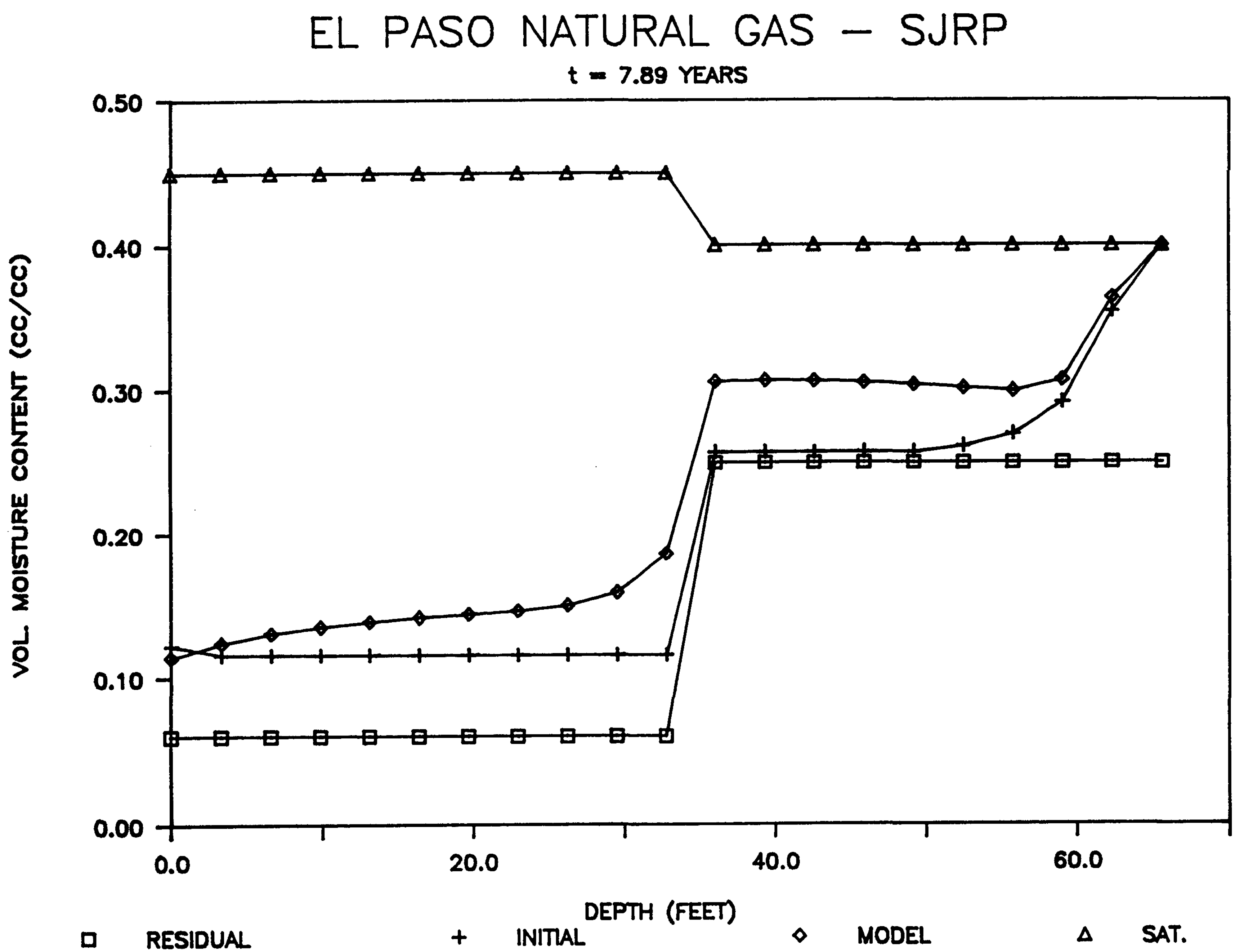


Figure 6-31. Volumetric moisture content (cc/cc) versus depth (ft) at 7.89 years (Scenario 2).

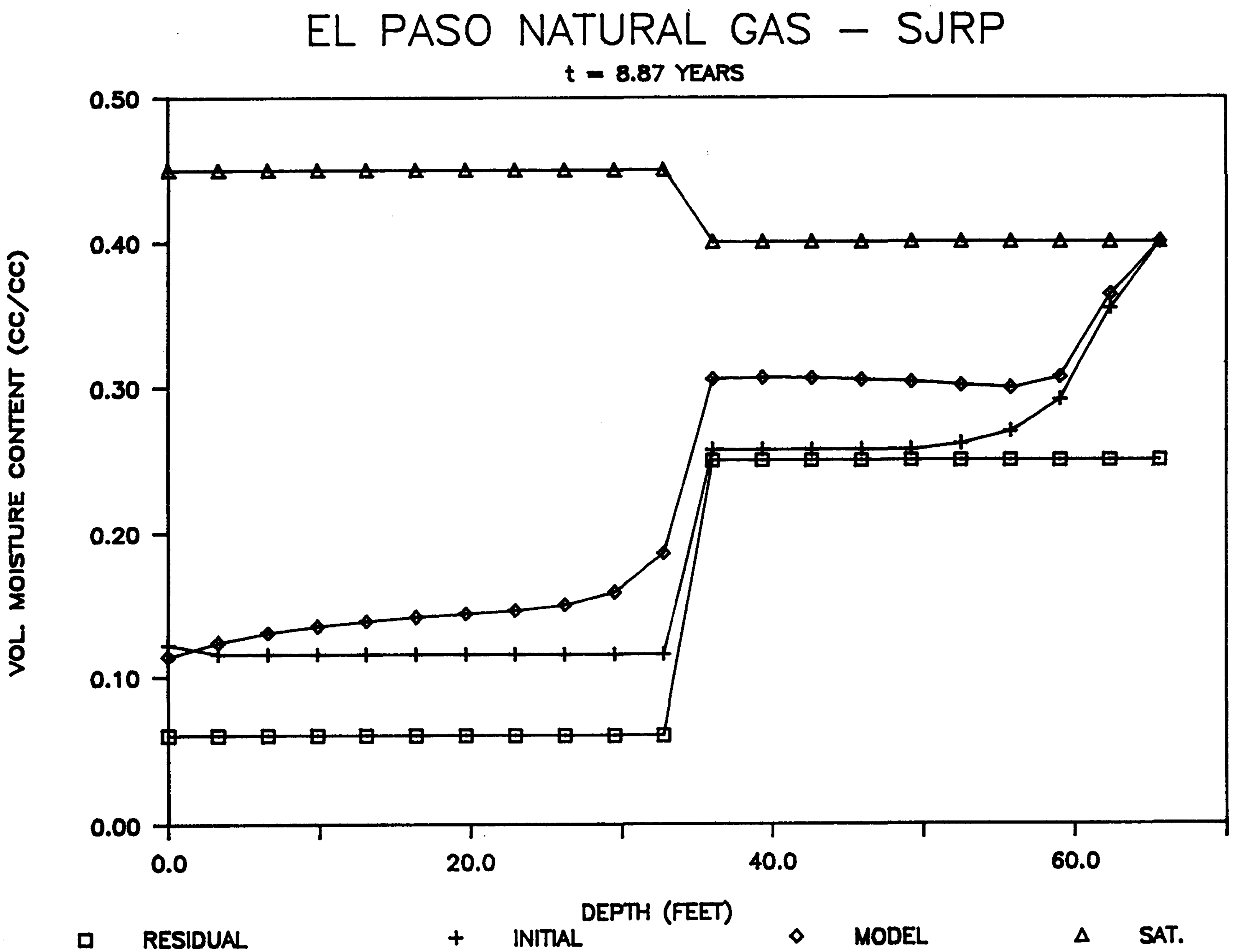


Figure 6-32. Volumetric moisture content (cc/cc) versus depth (ft) at 8.87 years (Scenario 2).

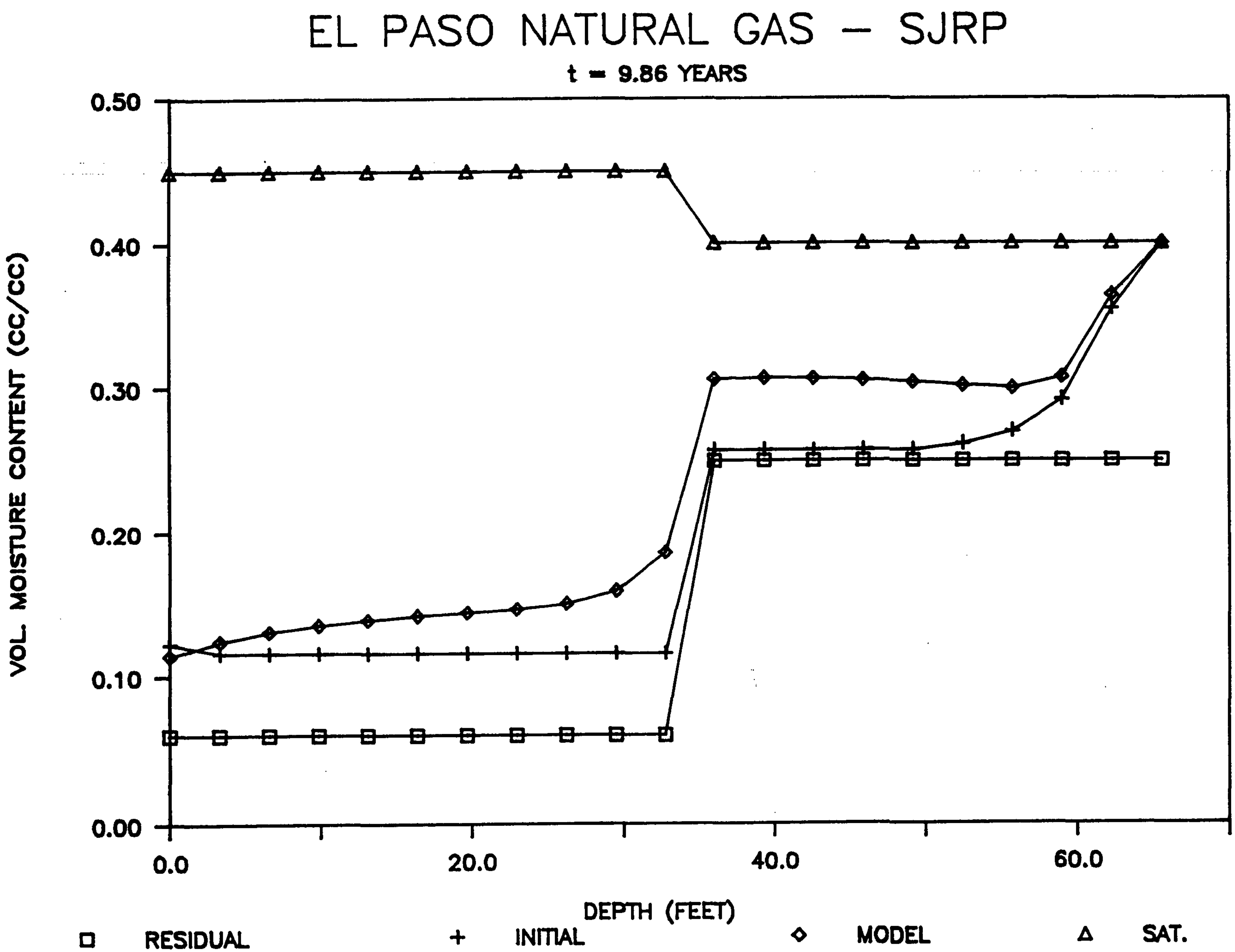


Figure 6-33. Volumetric moisture content (cc/cc) versus depth (ft) at 9.86 years (Scenario 2).

the same velocity as the infiltrating liquid. For this reason, it is believed that the predictions generated by the model are conservative in nature. The collective effects of retardation and decay will only serve to decrease pore-water chloride concentrations.

Both irrigation scenarios have been modeled by KWB&A in an attempt to ascertain the impacts, if any, upon the groundwater under the SJRP as a result of wastewater disposal operations. Scenario 1 represents a poorer-quality wastewater, or conservative approach, since flows from the carbonate regeneration unit are included. Conversely, Scenario 2 wastewater quality is very good as flows from the carbonate regeneration unit have been excluded. The chloride concentration of Scenario 2 wastewater is estimated at 8.91 meq/l; this concentration is only marginally-higher than that of the groundwater (7.90 meq/l).

Results of the modeling effort indicate acceptable pore-water chloride concentration distributions; this assertion is based on a simulation duration of 10 years. In addition, unsaturated, steady-state flow conditions are predicted by the model based on the selected boundary and initial conditions. Plots of drainage water chloride concentration versus time (Figures 6-18 and 6-23) show that no impacts from wastewater irrigation operations are anticipated during the life of the project for either scenario.

Simplifying assumptions accompany any type of modeling exercise. The unavoidable compromise of reality must be considered when assessing the utility of a computer model as a decision-making tool. The time-proven usage of professional judgment as a decision-making instrument has yet to be supplanted. Opinions can, however, be shaped and altered by the responsible application of computer modeling techniques. It is therefore recommended that the results of this model be applied synergistically with other analytical tools, such as analytical solutions of the relevant equations, to decide the feasibility of EPNG's proposed wastewater disposal project.

6.5 WATEQF GEOCHEMICAL MODEL

In addition to running the SUMATRA transport model, WATEQF, a geochemical speciation program, was run to determine the characteristics of the native groundwater quality. Specifically, this program calculates saturation indices for specific minerals based on the concentrations of individual constituents in the groundwater. The significance of the output from this model is that it illustrates similarities and differences between wells.

Analytical results from each of the wells sampled during Phase I and Phase II were analyzed using the WATEQF model. Output from the model is summarized in Table 6-3.

Table 6-3. Summary of WATEQF Geochemical Model Output*.

	WELL								
Mineral	MW1	MW2	MW3	DAILEY	HANSEN	ISHAM	LESTER	KENNEDY	BOOTH
Calcite	3	NR	NR	2	2	3	2	3	3
Aragonite	2	NR	NR	2	2	2	2	3	3
Dolomite	3	NR	NR	2	2	3	2	3	3
Gypsum	2	2	2	2	2	2	2	2	2
Anhydrite	2	NR	NR	2	2	2	2	2	2
Halite	1	1	1	1	1	1	1	1	1

* 1 = strongly undersaturated; 3 = slightly supersaturated
2 = slightly undersaturated; 4 = strongly supersaturated
NR = not recognized by model.

Information presented in Table 6-3 illustrates that local wells are clearly strongly undersaturated in respect to halite (NaCl), and consistently slightly undersaturated with respect to gypsum ($CaSO_4$) and anhydrite ($CaSO_4$). Saturation for the carbonates, calcite ($CaCO_3$), aragonite, ($CaCO_3$), and dolomite ($Ca,Mg(CO_3)_2$), vary from being slightly undersaturated to being slightly supersaturated.

Interpretation of this data indicates the native groundwater quality is fairly constant in that it is consistently undersaturated in respect to calcium sulfate, but is near equilibrium with respect to the carbonate minerals (slightly above or below saturation). This is consistent with the soil mineralogy identified in Phase I, which determined that the native salts present in the soil were predominately carbonates. The significance of this is that leaching of native carbonate salts will not have a significant impact on groundwater quality since native concentrations are near or above saturation indices.

7.0 SAMPLING AND ANALYSIS PROGRAM

Monitoring of the EPNG SJRP will consist of a three phase program conducted over the active life of the facility. The monitoring program will include periodic collection and analysis of combined wastewater sources, groundwater from designated monitoring wells, soil-pore liquids from lysimeters, and soil cores from the rooting zone of the active irrigation plots. Monitoring of surface water is not included in this program since the irrigation plots are nearly level and berms will be in place around the plots to prevent runoff of surface water onto adjacent land areas.

This sampling and analysis program may be modified to maintain and operate an environmentally sound and economically feasible land treatment operation. Modifications, if needed, will be based on results of the ongoing monitoring program and the increased ability of the operator to manage the land application system optimally as site specific factors become better understood. All proposed modifications to this program will be discussed and approved by ODC before implementation by the operator.

As part of the sampling and analysis program, Quality Control and Quality Assurance (QAQC) measures will be employed both in the field and in the laboratory.

7.1 WASTEWATER MONITORING

The Phase I report contains estimates of wastewater quality based on available analytical data for the various sources of wastewater identified at the EPNG SJRP. For several of these sources, only limited data on wastewater flow rates and quality were available. The wastewater quality and volumes listed in Section 4.0 (Phase 2) should therefore be considered as best estimates useful for evaluating the feasibility of the land application disposal option. Sampling and analysis of process wastewaters obtained during operation of the wastewater irrigation project will be needed to adjust key irrigation management parameters, such as leaching requirement, hydraulic loading rates, and area requirements, to more accurate and appropriate values.

During the first year of operation of the land application system, process wastewaters will be sampled on a monthly basis (Table 7-1). This will allow development of a data base on wastewater quality and flow rates to be used to "fine-tune" management parameters. In succeeding years, wastewater samples will be collected during the period of peak wastewater storage (January) and in the summer, after the accumulated storage has been depleted.

Table 7-1. Sampling and Analysis Program for Process Wastewaters.

Sampling Frequency	Number of Soil Samples	Parameters to be Analyzed
Monthly for first year; semi-annually succeeding years	Composite of 3 grab samples from the wastewater equalization tank	E.C., pH, NO_3, SAR, cations and anions, TDS, flow rate

Sampling Procedure

Wastewater grab samples will be collected from the outflow pipe of the planned wastewater equalization/storage tank during a period of steady-state outflow. This will ensure that the wastewater stream is well mixed and representative of the actual effluent to be land applied. Samples will be collected in the actual sample containers which will be used to transport the sample to the laboratory. The sampling procedure is as follows:

1. Open the bleed valve on the outflow pipe and allow wastewater to flow from the pipe for at least 10 minutes.

2. Rinse all sample containers twice in the wastewater flow.

3. Fill the sample containers to capacity with wastewater and cap, leaving no head space in the container.

4. Use pH and EC meters to measure pH immediately on a separate sample.

5. Place samples on ice in a cooler and ship by overnight courier to the laboratory.

Wastewater flow rates will be determined either by measuring the rate of tank inflow using a flow gauge or by measuring changes in stored volume over time.

7.2 GROUNDWATER MONITORING

The groundwater monitoring program will consists of four distinct components. These are: (1) collection of groundwater samples, (2) sample preservation and shipment, (3) analytical procedures, and (4) chain-of-custody control.

The primary goal of the groundwater monitoring program is to detect, through sampling and analytical data, any release of a wastewater constituent from the land application unit to groundwater. Continuous sampling and analysis of groundwater is not possible by means of monitoring wells, however, and each data set obtained will provide, at best, only an instantaneous "snap-shot" of the condition of the groundwater at the time of sampling. Additionally, any tentative identification of a constituent in a groundwater sample must be verified through the use of field QA/QC and laboratory QA/QC and may include additional analyses and repeated sampling due to possible sampling or analytical error. This section expands upon these ideas by integrating the complete monitoring process.

7.2.1 Sample Collection

During the first year of operation, groundwater samples will be collected quarterly to establish a data base which reflects seasonal variability in groundwater quality. In subsequent years, groundwater samples will be collected annually (Table 7-2).

Table 7-2. Sampling and Analysis Program for Groundwater.

Sampling Frequency	Number of Samples	Parameters to be Analyzed
Quarterly for the first year	1 sample set per well; no composites	E.C., pH, TDS, SAR, Ca, Cl, Mg, Na, Sulfate, Nitrate
Annually in subsequent years (early 2nd quarter)	1 sample set per well; no composites	E.C., pH, TDS, SAR, Ca, Cl, Mg, Na, Sulfate, Nitrate

Prior to beginning field activities, sample collection equipment, sample containers, and documents (forms to be completed in the field) associated with sampling are prepared. The types of equipment required to purge the wells and collect groundwater as well as a step-by-step process used to purge wells and collect groundwater samples are listed below.

Sampling Equipment

1. Depth to water meter
2. Several gallons of distilled water and wash bottles
3. Clean paper towels and disposable gloves
4. Bottom entry PVC bailers and 1,000 ft nylon cord. The nylon cord is tied to the bailers to purge the wells and is then discarded.
5. Labeled sample bottles containing appropriate preservatives (supplied by contract lab)
6. Electrical conductivity and pH meter with temperature probe and necessary standards
7. Field log book, standardized forms for field use, clip board, pencils and pens, and waterproof markers
8. Ice chests, wet ice, and waterproof bags for the chain-of-custody forms

Sample Collection Procedures

1. Inspect wells and record ambient conditions that may affect the sampling effort. Decontaminate (distilled water rinse) the depth to water probe and measure the depth to water from the top of the PVC well casing. Determine the height of the water column in the well and calculate the bore volume of the well using the following equation:

$$V = (\pi r^2)\ (12\ h)\ (0.00433)$$

or

$$= 0.163\ h \quad \text{(for 2 inch diameter monitoring well)}$$

Where V = bore volume of the well (gallons)
r = inside radius of the well (inches)
h = height of water column in well (feet)
0.00433 = convert cubic inches to gallons

Maintain a field book of all records concerning sample collection. Some data will be listed on forms specifically designed to aid in data collection.

2. Thoroughly rinse the PVC bailer with distilled water and proceed to purge the well, recording the volume of water removed. A minimum of 3 bore volumes will be purged unless the well reaches dryness before 3 bore volumes are removed. Water purged from each well will be examined for the presence of immiscible liquids. Record any immiscible liquids in the field log book or on the well inspection report. If desired, a pump may be substituted for the PVC bailer.

3. If a well is slow to recharge or if turbid conditions are encountered during purging, allow the well to recharge for a period of time which will not exceed 24 hours.

4. Collect samples using the PVC bailers and place samples into containers which were segregated, labeled, and treated with the proper preservatives prior to entering the field. Each set of sample containers is identified with a field ID number (not the well number). Rinse bailers with distilled water before lowering into wells to collect samples.

5. Release water through the check valve of the bailer and collect in the individual sample containers. The sample for metals analysis is collected first to reduce the likelihood of obtaining a turbid sample. Next, samples will be collected for pH, EC, and temperature, which will be measured in the field at the well head. In the case of collecting replicate samples, no two sample containers will be filled from the same bailer volume. All sample containers are filled so that there is no headspace in the bottle and then are placed on ice in the field. Specific steps used to retrieve a groundwater sample from a monitoring well using a dedicated bailer are:

a. Attach the decontaminated bailer to the nylon twine.

b. Lower bailer slowly into the well until it contacts water surface.

c. Allow bailer to sink and fill with a minimum of surface disturbance.

d. Steadily raise bailer to surface: do not allow bailer or line to contact ground or other objects.

e. Open bottom check valve to allow slow discharge to flow gently down the side of the given sample bottle with minimum entry turbulence, using a precleaned funnel if necessary to facilitate the transfer. Latex gloves are worn during sampling and changed between wells, thereby preventing contact with the groundwater and eliminating possible contamination between wells.

f. Repeat steps a through e as needed to acquire sufficient volume.

6. Following sample collection, cap the wells and rinse the bailers with distilled water before proceeding to the next well.

7. When sampling is completed, the chain-of-custody form which has been maintained in the field will be signed and placed in a waterproof plastic bag and enclosed in an ice chest which is clearly marked CHAIN-OF-CUSTODY ENCLOSED. All of the ice chests will be packed with ice in the field (to maintain the samples at or near 4° C) and sealed prior to being shipped by same-day or overnight carrier to the analyzing laboratory.

7.2.2 Sample Preservation and Shipment

The objective of preservation and handling procedures associated with collecting groundwater samples is to avoid any significant changes in sample composition until laboratory testing is conducted. This objective is achieved through consideration of two main factors: 1) compatibility of the sample container with the desired laboratory test, and 2) the time that elapses between sample collection and analysis. In order to increase the time allowed between sample collection and actual analysis, some samples may be "stabilized" using preservatives and all samples will be stored on ice.

Preservation

Preservation methods will be limited to pH control, refrigeration, and chemical additions. Preservation methods will be listed in the laboratory reports.

Shipment

Samples transported offsite will be packaged for shipment in compliance with current Department of Transportation (DOT) and commercial carrier regulations. Before the ice chests leave the facility, they will be packed with ice and sealed by the personnel who performed the sampling. Once sealed, the ice chests will be delivered to the laboratory either by field personnel or by a same-day or overnight carrier. The completed chain-of-custody records, laboratory analysis request forms (if needed), and any other shipping or sample documentation accompanying the shipment will be enclosed in a waterproof plastic bag and taped to the underside of the cooler lid. The laboratory receiving the samples will be notified when and where the samples are arriving.

Field Quality Assurance

In an effort to eliminate sample contamination and to identify the source of contamination (or rule out avenues of contamination) in the event data results are suspect, the following field quality control procedures may be employed:

- Bail all wells to dryness or remove a minimum of 3 bore volumes and sample within 24 hours of purging.
- Prepare all sampling equipment and sample containers prior to entering the field. This removes many of the difficulties encountered when trying to perform these tasks in the field when conditions may be less than favorable.
- Store all properly preserved samples on ice.
- Thoroughly rinse all equipment with distilled water and change gloves between wells to prevent cross contamination.

- Collect one duplicate sample set from a downgradient well.

Sample Labels

A legible label providing the specific sample identification code will be affixed to each sample container. The labels will be sufficiently durable to remain legible even when wet and will define which type of preservative is contained in the bottle. Analyses requested for each container will be defined by the identification code, which will be cross referenced on a separate sheet. The analyzing lab will not be informed as to the type of sample being submitted (e.g., blank samples will not be identified).

Field Records

Information associated with sampling will be recorded in a field log book. This log book serves as a record of field activities associated with sample collection and handling. The field log book will contain all additional information and observations not included on either the standardized forms or the chain-of-custody document. This information will describe such details as which well is being sampled and any factors or conditions which might affect sampling procedures (e.g., prevailing weather). All routine measurements and observations will be recorded in the field log book and on prepared forms including sampling blanks, static water depths, borehole volumes, soil core descriptions, and pertinent colors or odors.

Information to be Recorded in the Field Log Book

- Monitoring well number
- Date and time of collection
- Weather conditions
- Depth to water
- Analytical parameters
- Volume of water purged
- Number of samples
- Field observations
- Description of sampling methods

- Deviations from standard procedures
- Sample preservation procedures
- Sampler's name

7.2.3 Analytical Procedures

Sample analysis procedures are designed to insure that the monitoring results provide a reliable indication of groundwater quality. To insure analytical methods are appropriate for groundwater sampling and that they accurately measure the analytes in groundwater, U.S. EPA approved or an equivalent method will be used.

As part of the QA/QC protocol, the analyzing lab will be required to submit an addendum to each data set which details the quality control procedures employed.

Chain-of-Custody:

Chain-of-custody procedures are intended to document possession of the samples from the time of collection until they reach the laboratory. For the purpose of these procedures, a sample is considered in custody if it is:

- in one's actual possession
- in view, after being in physical possession
- sealed so that no one can tamper with it, after having been in physical custody
- in a secured area, restricted to authorized personnel

To establish documentation necessary to trace sample possession from the time of collection, a chain-of-custody record will be filled out and will accompany any sample or sample group transported for laboratory analysis. A carbon copy of this document will be retained by the field sampling personnel. An updated, signed copy of the chain-of-custody record completed by the receiving laboratory will be returned with the analytical results. An example of the chain-of-custody record is provided in Figure 7-1.

CHAIN OF CUSTODY RECORD

PROJ. NO.	PROJECT NAME					NO. OF CONTAINERS								REMARKS
SAMPLERS (signature)														
STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION									

Relinquished by: (signature)	Date / Time	Received by: (signature)	Relinquished by: (signature)	Date / Time	Received by: (signature)
Relinquished by: (signature)	Date / Time	Received by: (signature)	Relinquished by: (signature)	Date / Time	Received by: (signature)
Relinquished by: (signature)	Date / Time	Received for Laboratory by: (signature)	Date / Time	Remarks:	

FIGURE 7-1. CHAIN-OF-CUSTODY FORM.

7.3 UNSATURATED ZONE MONITORING

Unsaturated zone monitoring is essential for the following purposes: 1) to measure soil salinity; 2) to monitor the migration of salts and other waste constituents in the soil leachate; 3) to evaluate rooting zone leaching requirements and the need for soil amendments; and 4) to determine the amount of wastewater which can be applied in the successive disposal period. This section discusses sampling and analysis of soil samples and soil-pore liquids in the unsaturated zone.

7.3.1 Soil Cores

The general outline of the soil core sampling and analysis program is present in Table 7-3. Soil samples will be collected in the spring prior to onset of the growing season, and during the peak rainfall period (July or August). Irrigation plots designated for continuous irrigation during the growing season will be sampled semi-annually, once in early spring prior to the active growing season, and once during the mid-summer rainy period. Irrigation plots designated for spring irrigation only will be sampled annually, prior to the active growing season. To ensure representativeness of soil data obtained for each plot, equal volumes of soil will be collected from five locations within each plot and composited by thorough mixing prior to analysis. Sample locations in each plot will be determined randomly to assure collection of representative samples.

The soil coring system which will be used is capable of collecting bulk surface and subsurface soil samples for analysis of routine analytical parameters. This system consists of a standard 3-inch diameter auger bit, a drill rod, and a "T" handle. The procedure for sampling is to force the auger into the soil by turning until the desired completion depth (12 inches) is reached. The auger is then withdrawn from the soil and the bulk soil sample extruded from the auger into a clean stainless steel mixing

Table 7-3. Sampling and Analysis Program for Soils in the Rooting Zone (0 to 3 feet).

Sampling Frequency	Number of Soil Samples	Parameters to be Analyzed
Semi-annually for plots intended for continuous irrigation; annually for other plots	Composite of 5 samples per plot for 3 depths (0-12", 12-24", 24-36")	E.C., pH, NO_3, ESP, soluble cations and anions, organic matter, gypsum requirement, moisture content

bowl and covered to reduce moisture loss. The procedure is repeated to obtain the 12 to 24 inch and 24 to 36 inch samples. The sampling technician then moves to the next predetermined sampling location and begins collecting 0 to 12 inch, 12 to 24 inch, and 24 to 36 inch samples in similar fashion. The procedure is repeated until five locations have been sampled for three soil depths. At each location, samples are composited by depth by placing into the appropriate mixing bowl and mixing thoroughly.

Sampling Procedure

1. Clear the area to be sampled of any surface debris or cover;
2. Attach the precleaned steel auger/cylinder assembly to the drill rod and "T" handle;
3. Gradually turn the auger into the soil until it reaches the 12-inch depth for surface soil sample collection;
4. Carefully remove the auger device from the borehole and extrude the soil sample from the cylinder and place in a clean stainless steel bowl for mixing;
5. Cover the mixing bowl and set aside.
6. Repeat the procedure to obtain the 12-24 and 24-36 inch samples. Place each sample into a clean mixing bowl.
7. Move to the next pre-determined sampling location and repeat the procedure for three sampling depths. For each sample depth, place into the appropriate mixing bowl;

8. Repeat the procedure until three sample depths have been collected at five random locations within an irrigation plot;

9. Using a stainless steel spatula, mix the sample by scraping soil from the sides, corners, and bottom of the pan, and piling the material into the center. After initial mixing, the sample is quartered and moved to the four corners of the pan. Each quarter is then mixed individually. Each quarter is then rolled to the center of the container and the entire sample is mixed again.

10. Place the sample into 1 gallon polyethylene bags. Label the sample with irrigation plot number, depth, date, and sampler. Place the bag into an ice cooler; and

11. Repack the hole from which the sample has been collected with any unused portion of the soil sample.

7.3.2 Soil-Pore Liquids

A leachate collection system consisting of soil-pore liquid samplers (pan-type samplers) will be installed at two depths beneath the active irrigation plots at the EPNG facility. Figures 7-2 and 7-3 depict schematically the configuration and installation, respectively, of a glass block pan-type sampler. Lysimeters will be installed using a backhoe to dig an access pit. A cavity will be dug manually into the side of the pit and the brick will be inserted. Special care will be taken during installation to insure that the soil profile above the brick is not disturbed. The cavity will be sealed with bentonite and the pit filled and recompacted. Access lines will be placed underground and routed to a sample station located outside the active irrigation area.

The glass block lysimeter intercepts water moving through the soil profile under the influence of gravity. This is a passive system which continuously collects migrating water. This soil-pore monitoring system will serve as an early warning system for detecting the migration of salts and other waste constituents toward groundwater. It will also provide data on the concentration of salts leaching from the rooting zone. These data

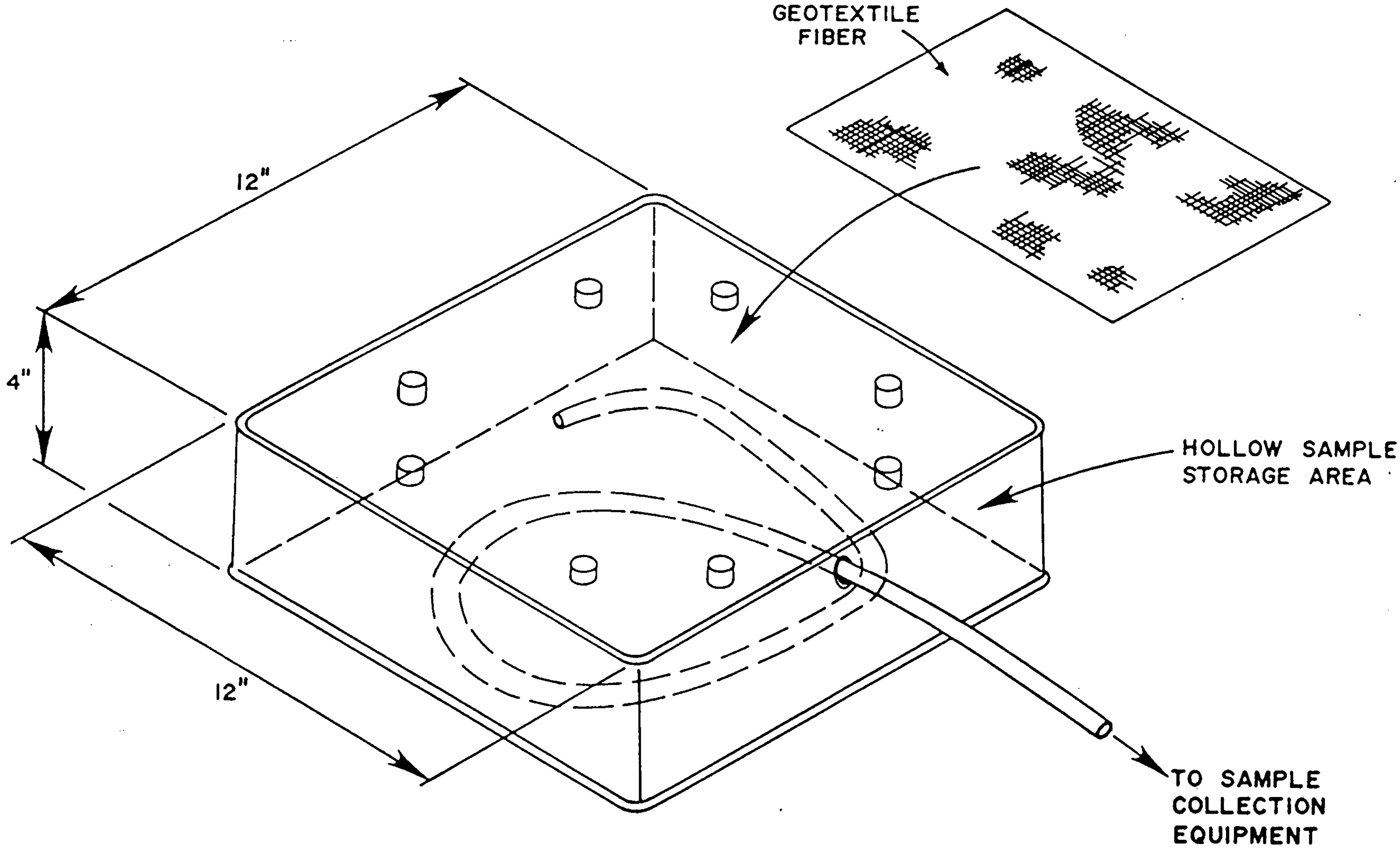


FIGURE 7-2. GLASS BLOCK SOIL-PORE-WATER SAMPLER (PAN TYPE)

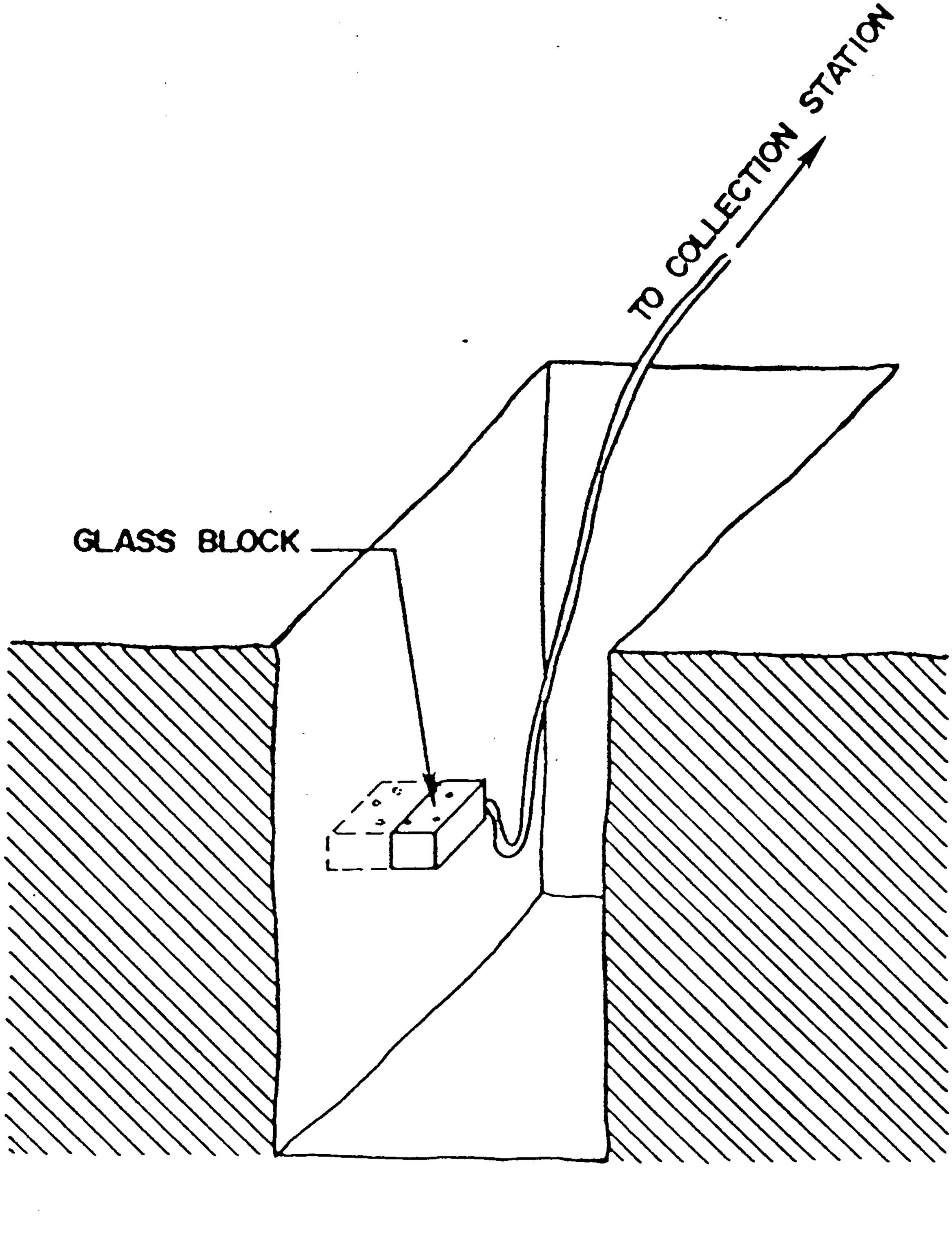


FIGURE 7-3. GLASS BRICK LYSIMETER INSTLLATION.

are needed to make interpretations concerning soil solution salinity effects on plants.

In each irrigation plot, one lysimeter will be installed at the bottom of the rooting zone (about a 4 ft depth) and one lysimeter will be placed at about a 10 ft depth, which is well below the rooting zone and the zone of native salt accumulation in these soils. Unlike soil core samples, soil-pore liquid samples are obtained from a fixed device which, once in place, will not be moved. If a random procedure for selecting lysimeter locations is followed, problems may arise if the random location does not reflect the facility as a whole. Therefore, in selecting the random location it will be necessary to evaluate the site before installing the sampling device.

The lysimeter sampling schedule and analysis program is summarized in Table 7-4. Lysimeters will be sampled semi-annually for continuously irrigated plots and annually for those plots which are only irrigated during early spring months.

Table 7-4. Sampling and Analysis Program for Soil-Pore Liquids.

Sampling Frequency	Number of Samples	Parameters to be Analyzed
Semi-annually for plots intended for continuous irrigation; annually for other plots	1 sample per lysimeter; 2 lysimeters per irrigation plot	E.C., pH, NO_3, SAR, soluble cations and anions

Sampling Procedure

The glass block lysimeters will be connected to the sample stations by double flexible polyethylene hoses. One of the hoses is used to apply a negative pressure to extract the sample from the brick. The other hose allows air into the brick to replace the evacuated liquid. To collect a sample, complete the following steps:

1. Connect the sample collection hose to an Erlenmeyer flask with a piece of neoprene tubing (Figure 7-4);

2. Connect the vacuum side of the pump to the other side of the Erlenmeyer flask;

3. Apply a vacuum of 70-80 centibars to the flask;

4. Allow the flask to fill to 2/3 of its capacity. CAUTION - do not allow water to be sucked into the pump;

5. Transfer the liquid from the flask to clean sample containers;

6. After a sufficient amount of sample has been collected and saved, continue to pump the system to remove all water from the lysimeter; and

7. Record the total volume of water removed in step 5.

8. Place samples on ice in a cooler and ship by overnight courier to the laboratory.

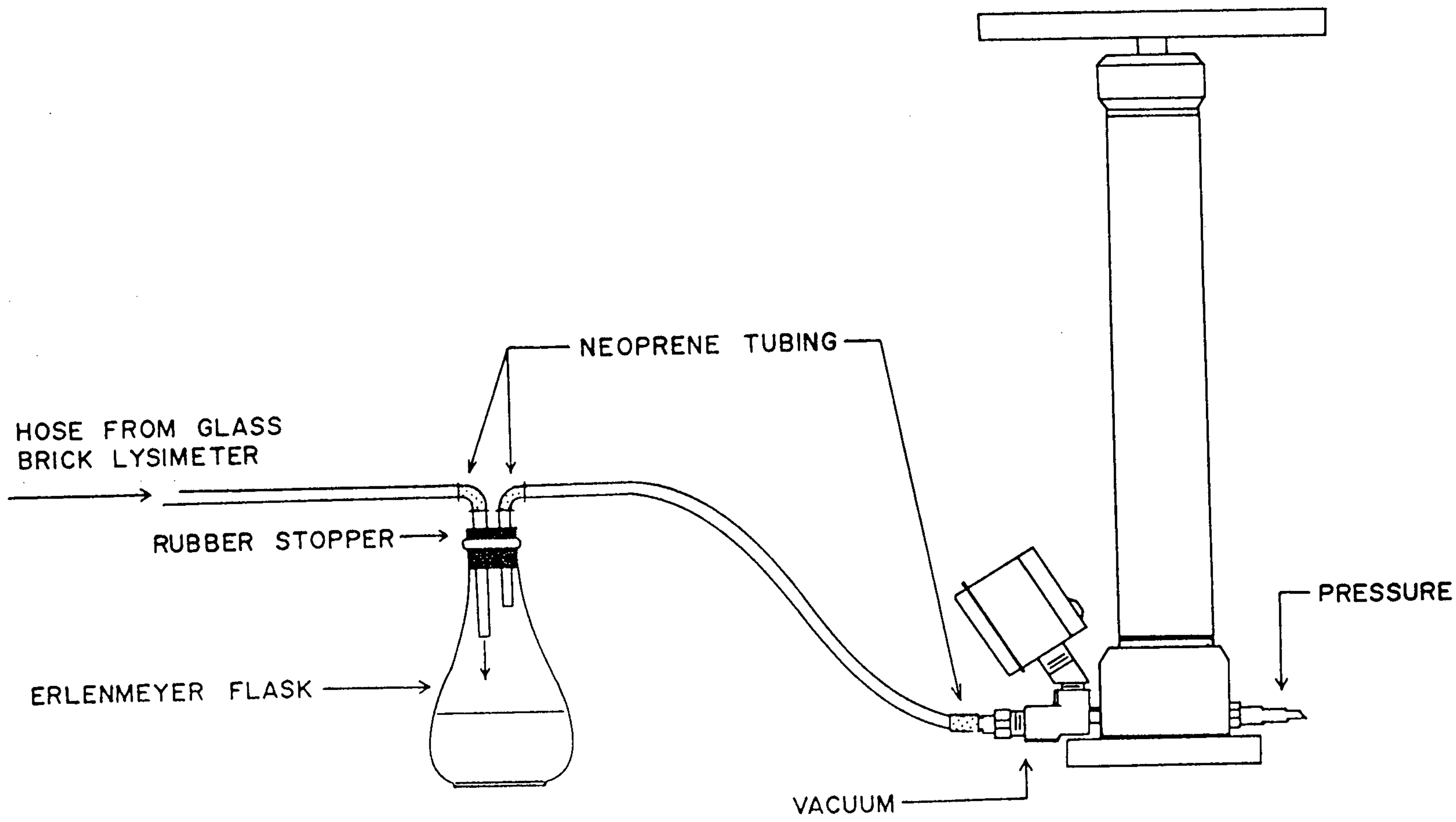


FIGURE 7-4. SAMPLE COLLECTION FROM GLASS BRICK LYSIMETER.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Since this report represents the second step in the feasibility study, it is necessary to consider the conclusions and recommendations offered in the Phase I report when summarizing the efforts of this report. From the Phase I report it was determined that of the two sites available for wastewater irrigation, the East site was clearly superior and should be selected over the West site. It was also determined that all of the physical characteristics of the East site, soils, geology, hydrology, water balance, native vegetation, and available area, were acceptable for the proposed project provided the site was managed properly. Proper management, as defined by Phase I, would include monitoring wastewater quality, managing the soils to increase their moisture holding capacity, and adding soil amendments, such as gypsum, to maintain soil structure as needed. It was also stated that it would be necessary to provide sufficient amounts of raw water to allow for leaching, thereby preventing the build up of salts in the rooting zone.

Conclusions drawn from the Phase II report confirm the initial findings of the Phase I report. Specifically, the East site is well suited for the proposed irrigation project. Further field investigations conducted during Phase II support the early interpretations and more clearly define the physical setting.

One important aspect which differs from Phase I is the quality of the wastewater which is slated for land application. Following the submittal of the Phase I report, it was suggested that removing the regeneration units from the wastewater flow would greatly increase operational efficiency of the project by reducing the salt loading rates. EPNG decided that this was a feasible option and decided to instigate changes in the wastewater process. Changes effected in the wastewater system at the SJRP removed the CCD regeneration unit from the wastewater system completely and greatly reduced the flow volume from the Softener regeneration unit (1.25 MG/yr to 0.64 MG/yr). The net result of these changes was a major improvement in wastewater quality and a sizable reduction in wastewater flow from the regeneration units.

Closer examination of the site under Phase II clearly indicates the site is acceptable for wastewater irrigation. This conclusion is supported by the physical evidence gathered in the field and empirical data generated from the field data. Parameters which were examined and determined to be acceptable are:

1. The improved wastewater quality greatly reduces demands for managing the site and the wastewater is of sufficient quality to pose no serious threat to groundwater.
2. Soils at the East site possess the necessary characteristics (i.e., infiltration rates, texture, etc.) for wastewater irrigation.
3. Local geologic conditions are conducive in that the thickness and composition of the alluvial materials will serve to restrict migration of wastewater constituents.
4. Interpretations of field hydrologic conditions indicate that the depth to water is in excess of 65 ft and that movement of moisture to the groundwater will be via unsaturated flow.
5. The local water balance will not place an undue burden on the project either in terms of insufficient or excess amounts of moisture.
6. Wastewater quality is comparable to native groundwater quality. Specifically, of all the major constituents examined, only chloride was present in the wastewater at concentrations greater than what was observed in the groundwater.
7. Computer modeling indicates that transport of a mobile chemical species (Cl), which is present in concentrations near or slightly above the concentration of the groundwater, will not significantly alter groundwater quality during the first 10 years of operation the facility.

After 10 years ?

8. Physical features of the site, such as topography and native vegetation, are amenable to wastewater irrigation.

9. All of the recommendations concerning soils management offered in the Phase I report are still necessary; however, the level of effort will be significantly less due to the planned reduction in salt loading rates compared to initial estimates.

Based on the body of data gathered it is recommended that the feasibility study be considered complete and successful, and plans for implementing the wastewater disposal system should be initiated. Termination of the feasibility study (omission of Phase III) is justified given that site-specific parameters clearly illustrate the site's ability to receive wastewater safely for a long period of time (in excess of 10 years). Improvements in wastewater quality resulting from the removal of a large portion of the regeneration wastewater flow help account for this outlook. Moreover, to conduct laboratory leaching and field vegetation studies, as provided for in Phase III, a long-term effort would be required (several months and at least one growing season) to simulate active operation and to determine the effectiveness of the land application effort.

It is believed that a more prudent approach is to begin active operation of the site and monitor the soils, soil-pore liquid, and groundwater as provided for in Section 7.0. Information presented in the first two phases of the feasibility study has illustrated that the level of risk assumed by beginning operation is minimal.

The final recommendation is that the Softener regeneration unit be omitted from the wastewater intended for land application. It is advised that raw water be available to meet leaching requirements, if needed in the future. Also, it is suggested that since the wastewater quality is within the standards for agricultural use, serious consideration be given to using this water for beneficial re-use, either in the form of raising a cash crop (i.e., alfalfa) or incorporating into the irrigation at the golf course.

9.0 REFERENCES

Hvorslev, M. J. 1951. Time lag and soil permeability in groundwater observations. U.S. Army Corps of Engineers Waterways Experiment Station Bulletin 36, Vicksburg, MS.

Stone, W. J., F. P. Lyford, P. F. Frenzel, N. H. Mizell and E. T. Padgett. 1983. Hydrogeology and water resources of the San Juan Basin, New Mexico. New Mexico Bureau of Mines and Mineral Resources.

Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soils. U.S. Dept. Agr. Handbook 60. U.S. Salinity Laboratory.

APPENDIX A

APPENDIX A

BORE LOGS AND MONITORING WELL REPORTS

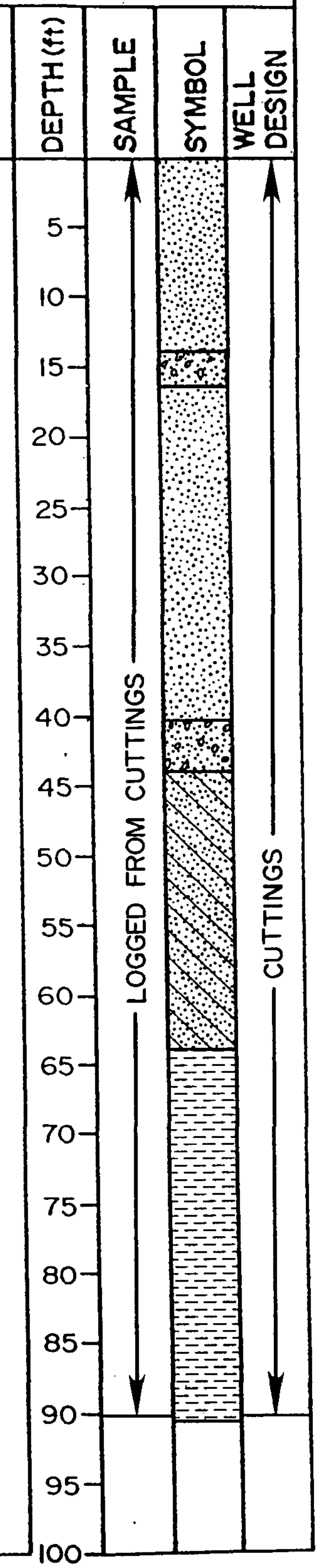
LOG DESCRIPTION: BORING E-8

Client: El Paso Natural Gas
Project: 63702
Location: San Juan River Plant
Well Number: None
First Encountered Water: Dry
Depth to Water: Dry

Drilled By: MO-TE
Logged By: S. Johnson
Date Completed: 9/1/87
Grade Elev.: 5304.1'
Casing Elev.: None
Total Depth: 90'

DESCRIPTION

0'-14'	Sand; light brown; fairly well sorted; fine- to medium-grained; some native salts above 6'
14'-16'	Gravel and coarse sand; gravel up to 4 cm; sand is coarse-grained; varied composition of gravel
16'-40'	Sand; tan; poorly sorted; fine- to coarse-grained
40'-43'	Gravel and coarse sand; gravel up to 3 cm; sand poorly sorted; medium- to coarse-grained; gravel varied in composition
43'-63'	Sandy clay; light brown with some orange mottling; sand fine- to medium-grained
63'-90'	Clay/shale; blue gray



K.W. BROWN & ASSOCIATES, INC.

BORING LOG E-9

Project: 63703
Client: El Paso Natural Gas
Well Number: Piezometer E-9
Location: San Juan River Plant
First Encountered Water: ?
Depth to Water: Dry 10/9/87

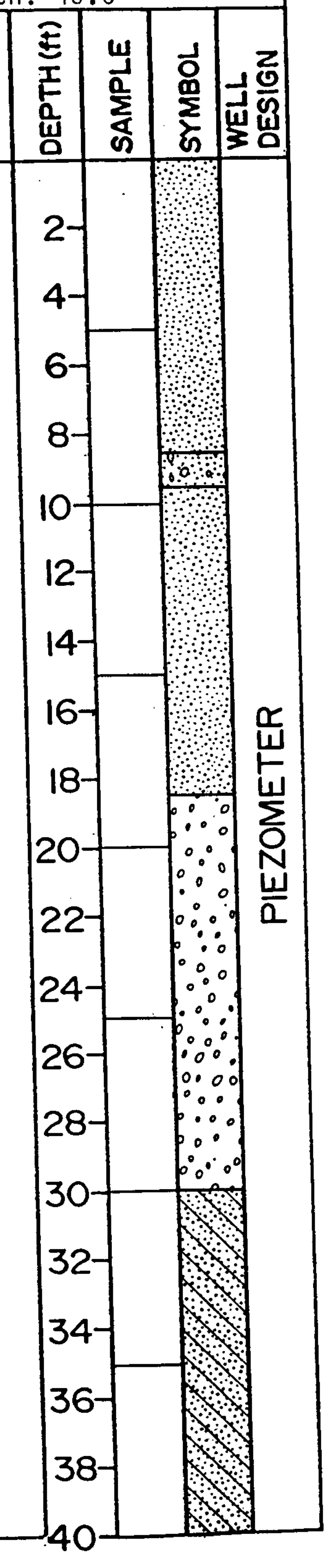
Drilled By: MO-TE
Logged By: S. Johnson
Grade Elev.: 5307.5'
Casing Elev.: 5309.3'
Date Completed: 10/8/87
Total Depth: 40.0'

DESCRIPTION

Rotary Wash; Logged from Cuttings

0.0'-8.5'	Sand; light brown/tan; fine to medium-grained; calcareous salts below 4'
8.5'-9.5'	Coarse sand and gravel; brown; poorly sorted; gravel of various rock types
9.5'-18.5'	Sand; tan; fine to medium-grained; poorly sorted
18.5'-30.0'	Gravel; various rock types
30.0'-40.0'	Sandy clay; brown to gray; firm; slightly friable

2" PVC casing open at bottom (30')
Back fill annulus with native sand



K.W. BROWN & ASSOCIATES, INC.

BORING LOG E-10

Project: 63703
Client: El Paso Natural Gas
Well Number: Piezometer E-10
Location: San Juan River Plant
First Encountered Water: ?
Depth to Water: Dry 10/9/87

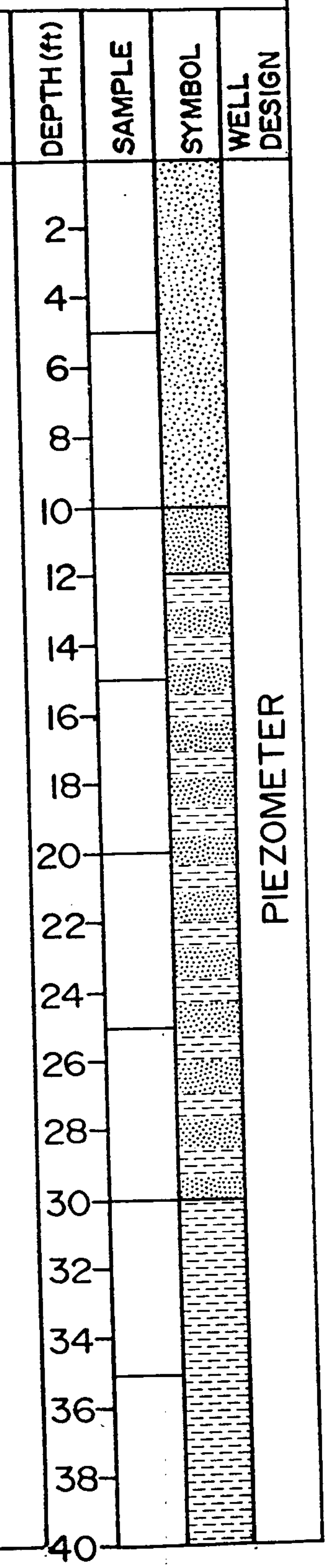
Drilled By: MO-TE
Logged By: S. Johnson
Grade Elev.: 5302.9'
Casing Elev.: 5303.8'
Date Completed: 10/8/87
Total Depth: 40.0'

DESCRIPTION

Rotary Wash; Logged from Cuttings

0.0'-10.0'	Sand; light brown/tan; fine to medium-grained; calcarous salts above 5'
10.0'-12.0'	Sandstone; brown; slightly lithofied; interbedded with loose sand
12.0'-30.0'	Interbedded sandstone and claystone (shale); brown to gray
30.0'-40.0'	Shale; brown to gray; friable

2" PVC casing open at bottom (25')
Back fill annulus with native sand



K.W. BROWN & ASSOCIATES, INC.

BORING LOG E-11

Project: 63703
Client: El Paso Natural Gas
Well Number: Piezometer E-11
Location: San Juan River Plant
First Encountered Water: ?
Depth to Water: 17.7' 10/9/87

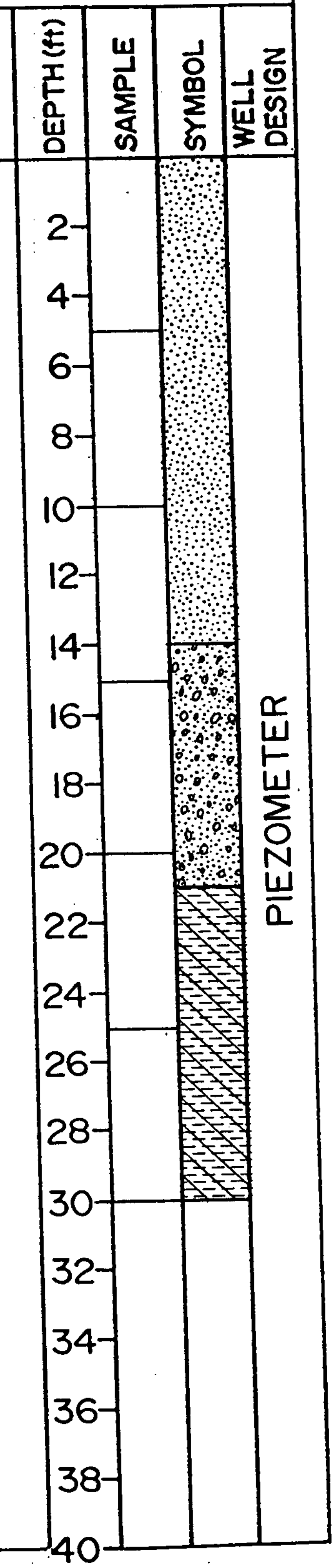
Drilled By: MO-TE
Logged By: S. Johnson
Grade Elev.: 5299.6'
Casing Elev.: 5302.3'
Date Completed: 10/8/87
Total Depth: 30.0'

DESCRIPTION

Rotary Wash; Logged from Cuttings

0.0'-14.0'	Sand; light brown/tan; fine to medium-grained; poorly sorted with some gravel
14.0'-21.0'	Coarse sand and gravel; brown; poorly sorted
21.0-30.0'	Clay (shale); gray; friable

2" PVC casing open at bottom (30')
Back fill annulus with native sand



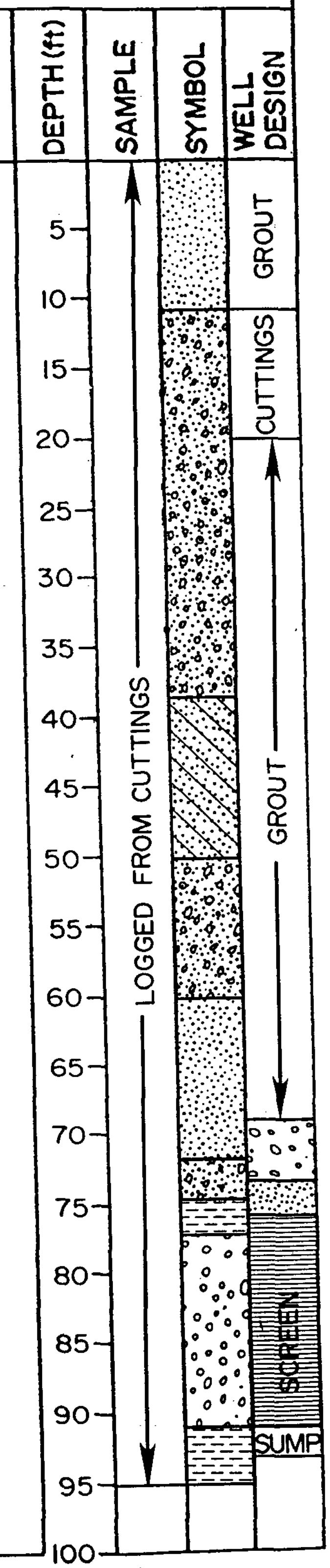
LOG DESCRIPTION: MW-1

Client: El Paso Natural Gas
Project: 63702
Location: San Juan River Plant
Well Number: Monitoring Well #1
First Encountered Water: ?
Depth to Water: 77.8' 9/3/87

Drilled By: MO-TE
Logged By: S. Johnson
Date Completed: 9/2/87
Grade Elev.: 5301.1'
Casing Elev.: 5302.5'
Total Depth: 95'

DESCRIPTION

0'-11'	Sand; light brown; moderately sorted; fine- to medium-grained; some native salts in upper 7 feet
11'-38'	Gravel and coarse sand; gravel up to 3 cm; sand poorly sorted; medium- to coarse-grained; gravel of various rock types
38'-50'	Sandy clay; light brown; sand is poorly sorted; fine- to medium-grained
50'-60'	Gravel and coarse sand; gravel up to 3 cm; sand poorly sorted; medium- to coarse-grained; gravel of various rock types
60'-73'	Sand; tan; fine-grained; well sorted
73'-74'	Gravel and coarse sand; sand is poorly sorted; medium- to coarse-grained; gravel of various composition
74'-77'	Clay/shale; gray
77'-92'	Gravel; various rock types
92'-95'	Clay/shale; gray



K.W. BROWN & ASSOCIATES, INC.

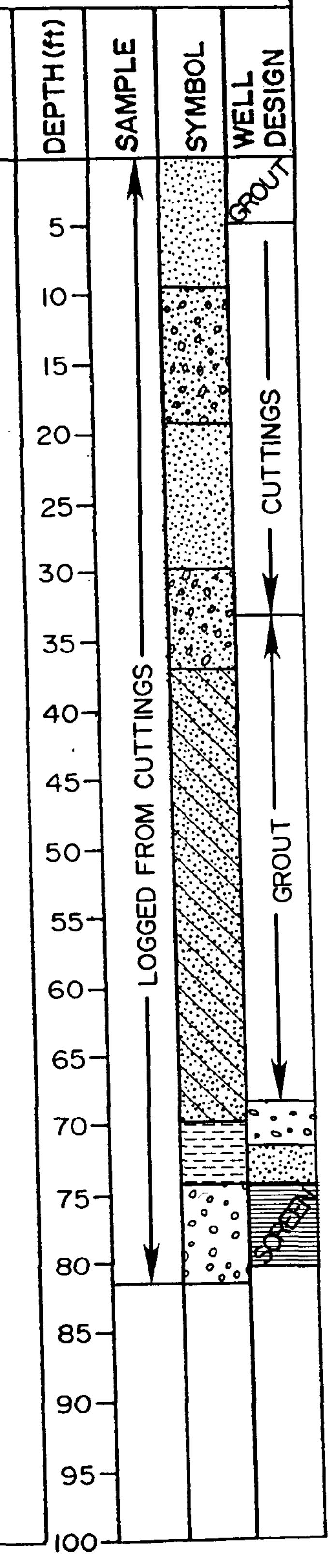
LOG DESCRIPTION: MW-2

Client: El Paso Natural Gas
Project: 63702
Location: San Juan River Plant
Well Number: Monitoring Well #2
First Encountered Water: ?
Depth to Water: 5225.1' 9/3/87

Drilled By: MO-TE
Logged By: S. Johnson
Date Completed: 9/1/87
Grade Elev.: 5296.2'
Casing Elev.: 5297.8'
Total Depth: 82'

DESCRIPTION

0'-8'	Sand; light brown; moderately sorted; fine- to medium-grained; some native salts in upper 5 to 6 feet
8'-18'	Gravel and coarse sand; gravel up to 3 cm; sand poorly sorted; medium- to coarse-grained; gravel of various rock types
18'-30'	Sand; light brown; fairly well sorted; medium-grained
30'-37'	Gravel and sand; olive brown; gravel up to 3 cm; sand medium- to coarse-grained; poorly sorted; gravel of various rock types
37'-70'	Sandy clay; olive brown; sand is moderately sorted; fine- to medium-grained
70'-74'	Clay/shale; blue gray
74'-82'	Gravel; various rock types
	Auger Refusal at 82'



K.W. BROWN & ASSOCIATES, INC.

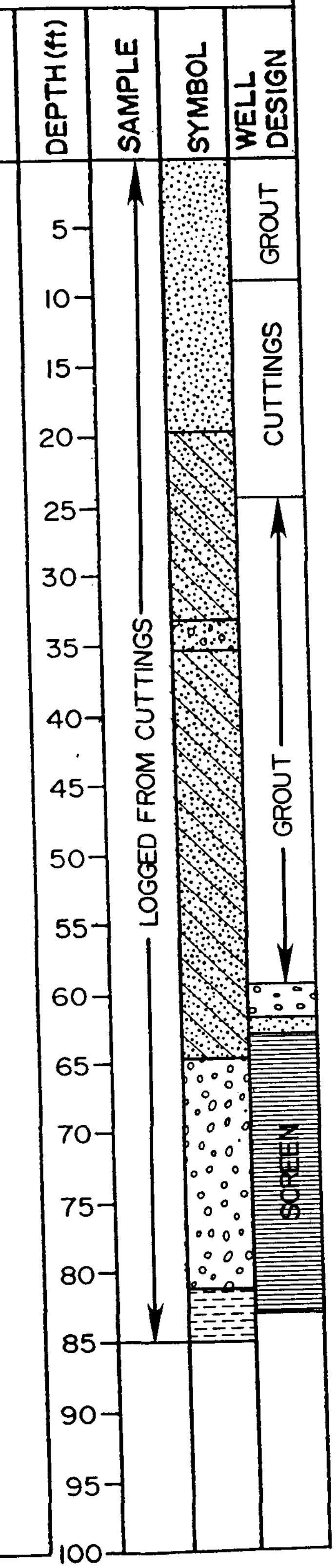
LOG DESCRIPTION: MW-3

Client: El Paso Natural Gas
Project: 63702
Location: San Juan River Plant
Well Number: Monitoring Well #3
First Encountered Water: ?
Depth to Water: 5224.7' 9/3/87

Drilled By: MO-TE
Logged By: S. Johnson
Date Completed: 9/1/87
Grade Elev.: 5294.1'
Casing Elev.: 5296.4'
Total Depth: 85'

DESCRIPTION

0'-20'	Sand; light brown; poorly sorted; fine- to coarse-grained; some native salts in upper 6 to 7 feet
20'-33'	Clayey sand; light brown; poorly sorted; fine- to medium-grained
33'-35'	Gravel and coarse sand; sand in coarse-grained and fairly well sorted; gravel of various rock types
35'-65'	Sandy clay; light brown; sand is moderately well sorted; fine- to medium-grained
65'-82'	Gravel; various rock types
82'-85'	Clay/shale; gray



K.W. BROWN & ASSOCIATES, INC.

MONITORING WELL REPORT

PROJECT: El Paso Natural Gas 63702

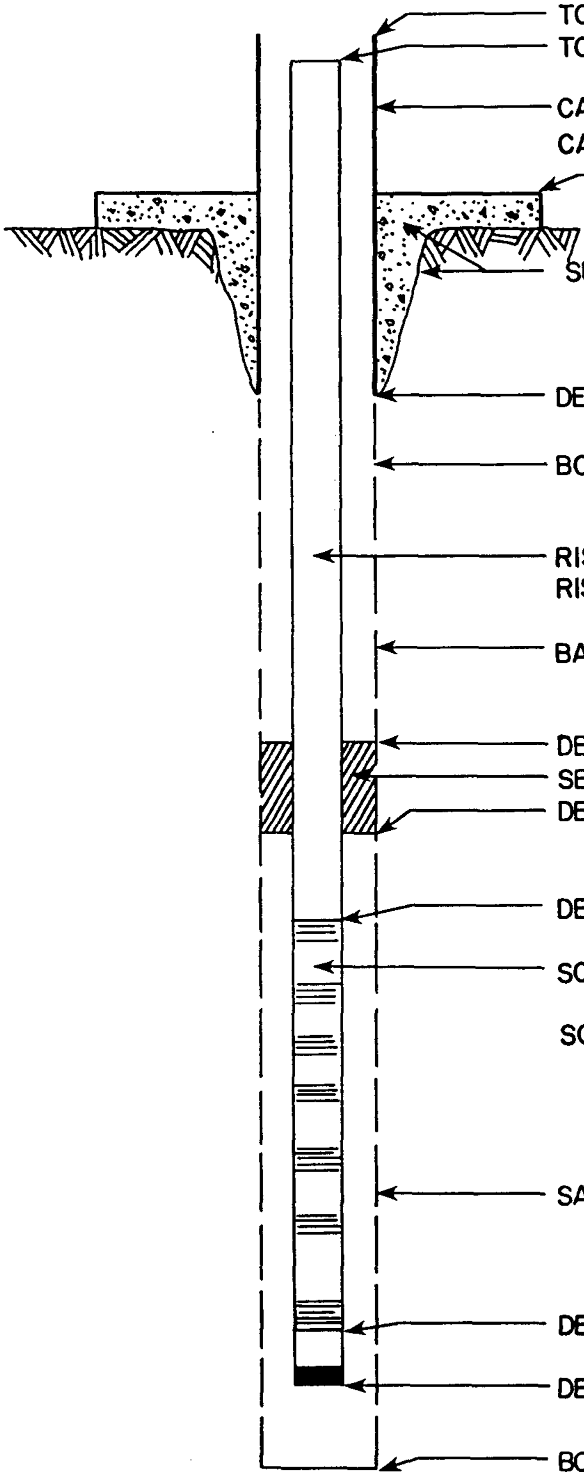
LOCATION: East Side of East Site

CLIENT: San Juan River Plant

WELL NO: Monitoring Well #1 DRILLED BY: MO-TE

DATE COMPLETED: 9/21/87 LOGGED BY: S. Johnson

SCREENED INTERVAL: 77-92 INSPECTED BY: S. Johnson



TOP OF CASING ELEVATION:

TOP OF RISER PIPE ELEVATION: 5302.5

CASING TYPE: None

CASING I.D.:

PLATFORM ELEVATION:

GROUND SURFACE ELEVATION: 5301.1

SURFACE SEAL: Grout

DEPTH OF CASING BELOW GROUND: 10'

BOREHOLE DIAMETER: 5 5/8" Ø

RISER PIPE TYPE: Schedule 40 PVC Flush Thread

RISER PIPE I.D.: 2"

BACKFILL TYPE: Grout & Cutting

DEPTH AT TOP OF SEAL: 69'

SEAL TYPE: ¼" Bentonite Pellets; hydrated

DEPTH AT BASE OF SEAL / TOP OF SAND PACK: 75'

DEPTH AT TOP OF SCREENED SECTION: 77'

SCREEN TYPE: Schedule 40 PVC Machine Slot

SCREEN OPENINGS: 0.010

SAND PACK TYPE: Colorado Silica Sand

DEPTH AT BASE OF SCREENED SECTION: 92'

DEPTH AT BASE OF PLUG: 94'

BOREHOLE DEPTH: 95'

K.W. BROWN & ASSOCIATES, INC.

MONITORING WELL REPORT

PROJECT: El Paso Natural Gas 63702

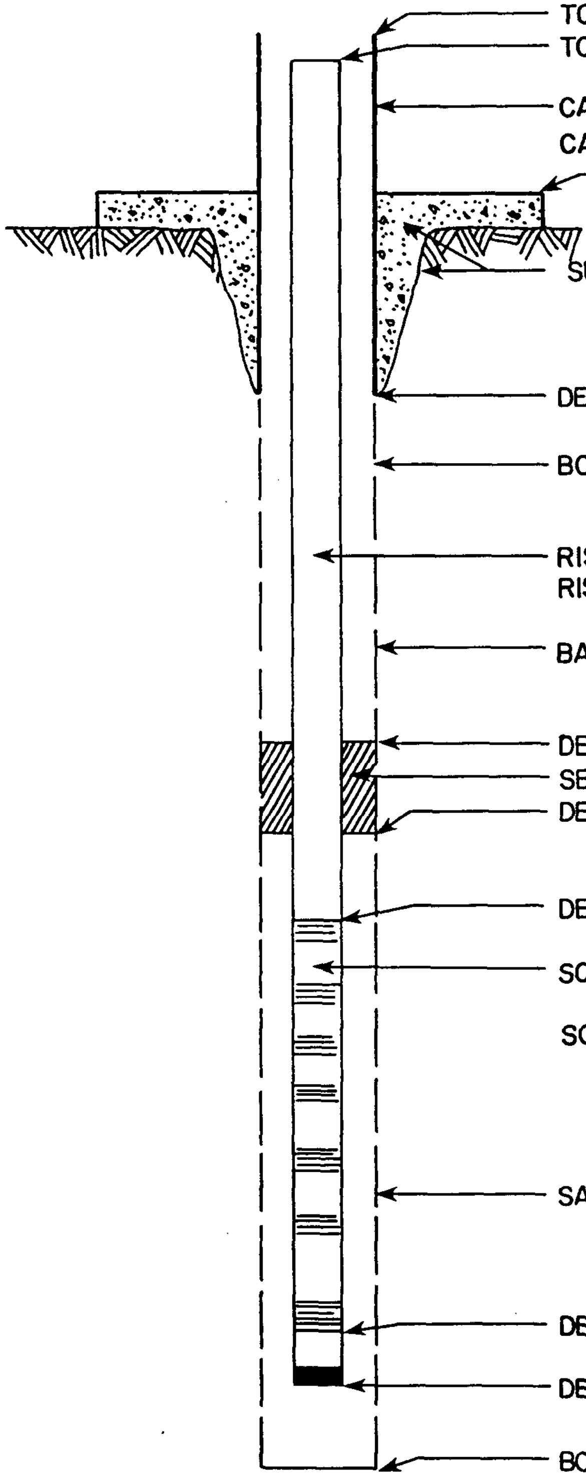
LOCATION: West side of East Site

CLIENT: San Juan River Plant

WELL NO: Monitoring Well #2 DRILLED BY: MO-TE

DATE COMPLETED: 9/1/87 LOGGED BY: S. Johnson

SCREENED INTERVAL: 74-80 INSPECTED BY: S. Johnson



TOP OF CASING ELEVATION:

TOP OF RISER PIPE ELEVATION: 5297.8

CASING TYPE: None

CASING I.D.:

PLATFORM ELEVATION:

GROUND SURFACE ELEVATION: 5296.2

SURFACE SEAL: Grout

DEPTH OF CASING BELOW GROUND: 5'

BOREHOLE DIAMETER: 5 5/8 Ø

RISER PIPE TYPE: Schedule 40 PVC Flush Thread

RISER PIPE I.D.: 2"

BACKFILL TYPE: Grout & Cutting

DEPTH AT TOP OF SEAL: 69½'

SEAL TYPE: ¼" Bentonite Pellets; hydrated

DEPTH AT BASE OF SEAL / TOP OF SAND PACK: 72½'

DEPTH AT TOP OF SCREENED SECTION: 74'

SCREEN TYPE: Schedule 40 PVC Machine Slot

SCREEN OPENINGS: 0.010

SAND PACK TYPE: Colorado Silica Sand

DEPTH AT BASE OF SCREENED SECTION: 80'

DEPTH AT BASE OF PLUG: 80'

BOREHOLE DEPTH: 82'

MONITORING WELL REPORT

PROJECT: El Paso Natural Gas 63702

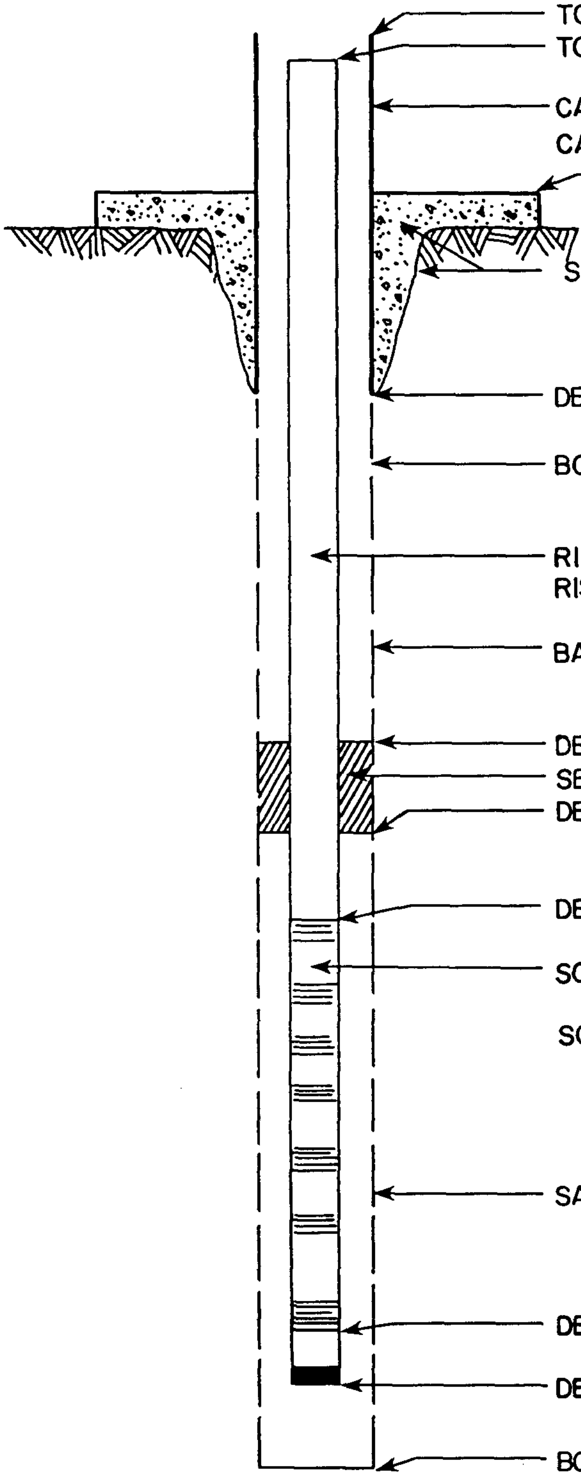
LOCATION: Southwest corner of East Site

CLIENT: San Juan River Plant

WELL NO: Monitoring Well # 3 DRILLED BY: MO-TE

DATE COMPLETED: 9/1/87 LOGGED BY: S. Johnson

SCREENED INTERVAL: 63-83 INSPECTED BY: S. Johnson



TOP OF CASING ELEVATION:

TOP OF RISER PIPE ELEVATION: 5296.4

CASING TYPE: None

CASING I.D.:

PLATFORM ELEVATION:

GROUND SURFACE ELEVATION: 5294.1

SURFACE SEAL: Grout

DEPTH OF CASING BELOW GROUND: 9'

BOREHOLE DIAMETER: 5 5/8" Ø

RISER PIPE TYPE: Schedule 40 PVC Flush Thread

RISER PIPE I.D.: 2"

BACKFILL TYPE: Grout & cutting

DEPTH AT TOP OF SEAL: 60'

SEAL TYPE: ¼" Bentonite Pellets; hydrated

DEPTH AT BASE OF SEAL / TOP OF SAND PACK: 62'

DEPTH AT TOP OF SCREENED SECTION: 63'

SCREEN TYPE: Schedule 40 PVC Machine Slot

SCREEN OPENINGS: 0.010

SAND PACK TYPE: Colorado Silica Sand

DEPTH AT BASE OF SCREENED SECTION: 83'

DEPTH AT BASE OF PLUG: 83'

BOREHOLE DEPTH: 83'

APPENDIX B

APPENDIX B

MONITORING WELL ANALYTICAL DATA

Report of Chemical Analysis

OCT 1 3 1987

Consulting Geotechnical, Materials and Environmental Engineers
Geologists, Scientists and Chemists

Raba-Kistner
Consultants, Inc.

P.O. Box 690287, San Antonio, TX 78269-0287
12821 W. Golden Lane, San Antonio, TX 78249
(512) 699-9090

To: El Paso Natural Gas Company
P.O. Box 4990
Farmington, New Mexico 87499

Attn: Mr. Kenneth E. Beasley

Project No.: SA0687-0003-020
Assignment No.: 6-11351
P.O. Number:
Date: 10/09/87
Correction Copy

Subject: Water Analysis

Background: Samples were provided by client from San Juan River Plant.

Test Methods: EPA 600/4-79-020, Standard Methods

Parameter	MW-1 (6-11351-1)	MW-2 (6-11351-2)	MW-3 (6-11351-3)
Arsenic, mg/L	<0.01	<0.01	<0.01
Barium, mg/L	<0.3	<0.3	<0.3
Cadmium, mg/L	<0.01	<0.01	<0.01
Calcium, mg/L	320	340	280
Chromium, mg/L	<0.02	<0.02	<0.02
Copper, mg/L	<0.01	<0.01	<0.01
Cobalt, mg/L	0.011	0.010	<0.005
Lead, mg/L	<0.05	<0.05	<0.05
Magnesium, mg/L	160	190	78
Manganese, mg/L	4.5	0.97	0.24
Mercury, mg/L	<0.001	<0.001	<0.001
Molybdenum, mg/L	0.28	0.022	0.015
Nickel, mg/L	0.10	0.10	0.10
Potassium, mg/L	17	8.7	4.9

Raba-Kistner Consultants, Inc.

by [signature]
Frank B. Schweitzer
Vice-President, Chemistry

Austin / El Paso / San Antonio

Project No.: SA0687-0003-020
Assignment No.: 6-11351
Date: 10/09/87

Parameter	MW-1 (6-11351-1)	MW-2 (6-11351-2)	MW-3 (6-11351-3)
Selenium, mg/L	<0.01	<0.01	<0.01
Silver, mg/L	<0.01	<0.01	<0.01
Sodium, mg/L	770	960	530
Zinc, mg/L	0.06	0.03	0.03
Specific Cond., umhos/cm **	5,800	6,800	4,200
TDS, mg/L	4,800	5,400	3,300
Alkalinity, Total as $CaCO_3$, mg/L	350	610	320
Alkalinity, Bicarbonate $CACO_3$, mg/L	350	610	320
COD, mg/L	31	33	0.18
Oil & Grease, mg/L	2.0	1.5	*
Cyanide, mg/L	<0.01	<0.01	<0.01
Ortho Phosphate-P, mg/L	<0.1	<0.1	<0.1
Chloride, mg/L	170	320	110
Nitrate-N, mg/L	3.1	0.21	0.87
Sulfate, mg/L	2,800	3,000	1,900
Boron, mg/L	0.77	0.54	<0.5
Total Nitrogen, mg/L	<0.4	0.59	0.47
Ammonia Nitrogen, mg/L	<0.4	<0.4	<0.4
Fluoride, mg/L	<0.1	<0.1	<0.1
TOC, mg/L	7	9	4
SAR	50	59	40

< = Less than

* Sample broken in shipment

** Corrected Data

APPENDIX C

APPENDIX C

COMPUTER MODEL OUTPUT

1MONITORING WELL #1 - EPNG - SJRP

INITIAL SOLUTION

TEMPERATURE = 25.00 DEGREES C PH = 7.010
ANALYTICAL EPMCAT = 63.058 ANALYTICAL EPMAN = 68.827

***** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 4.000 MG/L
EH MEASURED WITH CALOMEL = 99.0000 VOLTS
MEASURED EH OF ZOBELL SOLUTION = 99.0000 VOLTS
CORRECTED EH = 99.0000 VOLTS
PE COMPUTED FROM CORRECTED EH = 100.000

FLAG	CORALK	PECALC	IDAVES
2	1	2	0

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
CA	2	8.02082E-03	-2.0958	3.20000E+02
MG	2	6.61144E-03	-2.1797	1.60000E+02
NA	1	3.36475E-02	-1.4730	7.70000E+02
K	1	4.36764E-04	-3.3598	1.70000E+01
CL	-1	4.81718E-03	-2.3172	1.70000E+02
SO4	-2	2.92823E-02	-1.5334	2.80000E+03
HCO3	-1	5.76251E-03	-2.2394	3.50000E+02

*** CONVERGENCE ITERATIONS ***

ITERATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	2.538E-04	1.430E-02	.000E+00	.000E+00	.000E+00
2	1.319E-04	3.087E-03	.000E+00	.000E+00	.000E+00
3	1.230E-06	1.024E-05	.000E+00	.000E+00	.000E+00

****DESCRIPTION OF SOLUTION ****

	ANAL.	COMP.	PH	
				ACTIVITY H2O = .9986
EPMCAT	63.06	49.63	7.010	PCO2= 2.799788E-02
EPMAN	68.83	55.53		LOG PCO2 = -1.5529
			TEMPERATURE	PO2 = 9.055450E-02
EH = ******	PE = 13.510		25.00 DEG C	PCH4 = .000000E+00
PE CALC S =	100.000			CO2 TOT = 6.679544E-03
PE CALC DOX=	13.510		IONIC STRENGTH	DENSITY = 1.0000
PE SATD DOX=	3.400		8.305662E-02	TDS = 4587.0MG/L
TOT ALK =	5.762E+00 MEQ			CARB ALK = 5.763E+00 MEQ
ELECT	= -5.925E+00 MEQ			

IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE = 13.510 EQUIVALENT EH = .799VOLTS

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	ACTIVITY	LOG ACT	GAMMA
1	CA	2	1.8256E+02	4.5760E-03	1.8817E-03	-2.725	4.1122E-01
2	MG	2	9.6145E+01	3.9728E-03	1.6925E-03	-2.771	4.2601E-01
3	NA	1	7.3490E+02	3.2114E-02	2.5477E-02	-1.594	7.9334E-01
4	K	1	1.6036E+01	4.1199E-04	3.2031E-04	-3.494	7.7746E-01
64	H	1	1.1774E-04	1.1735E-07	9.7724E-08	-7.010	8.3277E-01
5	CL	-1	1.7000E+02	4.8172E-03	3.7452E-03	-2.427	7.7746E-01
6	SO4	-2	2.1060E+03	2.2024E-02	8.7086E-03	-2.060	3.9541E-01
7	HCO3	-1	3.2970E+02	5.4283E-03	4.3377E-03	-2.363	7.9909E-01
18	CO3	-2	3.0502E-01	5.1063E-06	2.0821E-06	-5.682	4.0774E-01
86	H2CO3	0	5.7660E+01	9.3391E-04	9.5293E-04	-3.021	1.0204E+00
27	OH	-1	2.2756E-03	1.3442E-07	1.0421E-07	-6.982	7.7523E-01
19	MGOH	1	1.4627E-03	3.5563E-08	2.8832E-08	-7.540	8.1073E-01
23	MGSO4 AQ	0	2.9971E+02	2.5013E-03	2.5496E-03	-2.594	1.0193E+00
22	MGHCO3	1	9.2725E+00	1.0917E-04	8.5374E-05	-4.069	7.8204E-01
21	MGCO3 AQ	0	2.7694E-01	3.2994E-06	3.3632E-06	-5.473	1.0193E+00
29	CAOH	1	3.4747E-04	6.1147E-09	4.9261E-09	-8.307	8.0561E-01
32	CASO4 AQ	0	4.4380E+02	3.2749E-03	3.3381E-03	-2.476	1.0193E+00
30	CAHCO3	1	1.3112E+01	1.3029E-04	1.0411E-04	-3.982	7.9909E-01
31	CACO3 AQ	0	7.2155E-01	7.2423E-06	6.5819E-06	-5.182	9.0881E-01
44	NASO4	-1	1.7268E+02	1.4571E-03	1.1644E-03	-2.934	7.9909E-01
43	NAHCO3	0	5.0973E+00	6.0969E-05	6.2146E-05	-4.207	1.0193E+00
42	NACO3	-1	1.0165E-01	1.2304E-06	9.8320E-07	-6.007	7.9909E-01
94	NACL	0	5.4456E-30	9.3608E-35	9.5416E-35	-34.020	1.0193E+00

46 KSO4	-1	3.3006E+00	2.4532E-05	1.9603E-05	-4.708	7.9909E-01
95 KCL	0	8.7340E-32	1.1769E-36	1.1996E-36	-35.921	1.0193E+00
63 HSO4	-1	1.0123E-02	1.0477E-07	8.2606E-08	-7.083	7.8845E-01

MOLE RATIOS FROM ANALYTICAL MOLALITY			MOLE RATIOS FROM COMPUTED MOLALITY			LOG ACTIVITY RATIOS		
CL/CA	=	6.0058E-01	CL/CA	=	1.0527E+00	LOG CA/H2	=	11.2946
CL/MG	=	7.2861E-01	CL/MG	=	1.2125E+00	LOG MG/H2	=	11.2485
CL/NA	=	1.4317E-01	CL/NA	=	1.5000E-01	LOG NA/H1	=	5.4161
CL/K	=	1.1029E+01	CL/K	=	1.1692E+01	LOG K/H1	=	3.5156
CL/AL	=	4.8172E+27	CL/AL	=	4.8172E+27	LOG AL/H3	=	21.0300
CL/FE	=	4.8172E+27	CL/FE	=	4.8172E+27	LOG FE/H2	=	14.0200
CL/SO4	=	1.6451E-01	CL/SO4	=	2.1872E-01	LOG CA/MG	=	.0460
CL/HCO3	=	8.3595E-01	CL/HCO3	=	8.8741E-01	LOG NA/K	=	1.9006
CA/MG	=	1.2132E+00	CA/MG	=	1.1518E+00			
NA/K	=	7.7038E+01	NA/K	=	7.7947E+01			

PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT
18 ANHYDRIT	1.639E-05	4.130E-05	-4.785	-4.384	3.967E-01	-.401
22 ARAGONIT	3.918E-09	4.612E-09	-8.407	-8.336	8.495E-01	-.071
151 ARTIN	7.972E-26	3.981E-19	-25.098	-18.400	2.003E-07	-6.698
20 BRUCITE	1.838E-17	3.890E-12	-16.736	-11.410	4.724E-06	-5.326
13 CALCITE	3.918E-09	3.312E-09	-8.407	-8.480	1.183E+00	.073
12 DOLOMITE	1.381E-17	8.128E-18	-16.860	-17.090	1.699E+00	.230
19 GYPSUM	1.634E-05	2.498E-05	-4.787	-4.602	6.541E-01	-.184
65 HALITE	9.542E-05	3.819E+01	-4.020	1.582	2.498E-06	-5.602
118 HUNTITE	1.714E-34	3.090E-31	-33.766	-30.510	5.548E-04	-3.256
39 HYDMAG			-50.550	-37.820		-12.730
11 MAGNESIT	3.524E-09	5.754E-09	-8.453	-8.240	6.124E-01	-.213
67 MIRABI	5.575E-06	7.709E-02	-5.254	-1.113	7.231E-05	-4.141
59 NAHCOL	1.105E-04	2.831E-01	-3.957	-.548	3.903E-04	-3.409
61 NATRON	1.333E-09	4.887E-02	-8.875	-1.311	2.727E-08	-7.564
150 NESQUE	3.509E-09	6.152E-06	-8.455	-5.211	5.704E-04	-3.244
66 THENAR	5.653E-06	6.622E-01	-5.248	-.179	8.536E-06	-5.069
62 THRNAT	1.350E-09	1.334E+00	-8.870	.125	1.012E-09	-8.995
60 TRONA	1.489E-13	1.603E-01	-12.827	-.795	9.290E-13	-12.032

1MONITORING WELL #2 - EPNG - SJRP

INITIAL SOLUTION

TEMPERATURE = 25.00 DEGREES C   PH = 7.190
ANALYTICAL EPMCAT = 74.576   ANALYTICAL EPMAN = 71.486

***** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 4.000 MG/L
EH MEASURED WITH CALOMEL = 99.0000 VOLTS
MEASURED EH OF ZOBELL SOLUTION = 99.0000 VOLTS
CORRECTED EH = 99.0000 VOLTS
PE COMPUTED FROM CORRECTED EH = 100.000

FLAG	CORALK	PECALC	IDAVES
2	1	2	0

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
CA	2	8.52411E-03	-2.0694	3.40000E+02
MG	2	7.85291E-03	-2.1050	1.90000E+02
NA	1	4.19598E-02	-1.3772	9.60000E+02
K	1	2.23572E-04	-3.6506	8.70000E+00
CL	-1	9.06974E-03	-2.0424	3.20000E+02
SO4	-2	3.13812E-02	-1.5033	3.00000E+03

*** CONVERGENCE ITERATIONS ***

ITERATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	.000E+00	1.715E-02	.000E+00	.000E+00	.000E+00
2	.000E+00	3.664E-03	.000E+00	.000E+00	.000E+00
3	.000E+00	2.387E-05	.000E+00	.000E+00	.000E+00

****DESCRIPTION OF SOLUTION ****

	ANAL.	COMP.	PH	
EPMCAT	74.58	59.58	7.190	ACTIVITY H2O = .9985
EPMAN	71.49	56.66		PCO2= .000000E+00
			TEMPERATURE	LOG PCO2 = -99.9000

EH = ****** PE = 13.330   TEMPERATURE 25.00 DEG C

PO2 = 9.055450E-02
PCH4 = .000000E+00
CO2 TOT = .000000E+00

PE CALC S = 100.000
PE CALC DOX= 13.330
PE SATO DOX= 3.220
TOT ALK = 1.305E-04 MEQ
ELECT = 2.929E+00 MEQ

IONIC STRENGTH 9.069528E-02

DENSITY = 1.0000
TDS = 4818.7MG/L
CARB ALK = .000E+00 MEQ

IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE = 13.330 EQUIVALENT EH = .789VOLTS

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	ACTIVITY	LOG ACT	GAMMA
1	CA	2	1.9814E+02	4.9676E-03	1.9928E-03	-2.701	4.0115E-01
2	MG	2	1.1647E+02	4.8139E-03	2.0053E-03	-2.698	4.1656E-01
3	NA	1	9.1725E+02	4.0091E-02	3.1597E-02	-1.500	7.8812E-01
4	K	1	8.1993E+00	2.1071E-04	1.6247E-04	-3.789	7.7108E-01
64	H	1	7.8114E-05	7.7869E-08	6.4565E-08	-7.190	8.2915E-01
5	CL	-1	3.2000E+02	9.0697E-03	6.9935E-03	-2.155	7.7108E-01
6	SO4	-2	2.1991E+03	2.3003E-02	8.8412E-03	-2.053	3.8434E-01
27	OH	-1	3.4724E-03	2.0516E-07	1.5770E-07	-6.802	7.6867E-01
19	MGOH	1	2.6372E-03	6.4134E-08	5.1698E-08	-7.287	8.0609E-01
23	MGSO4 AQ	0	3.5979E+02	3.0034E-03	3.0668E-03	-2.513	1.0211E+00
29	CAOH	1	5.6017E-04	9.8600E-09	7.8950E-09	-8.103	8.0071E-01
32	CASO4 AQ	0	4.7621E+02	3.5148E-03	3.5890E-03	-2.445	1.0211E+00
44	NASO4	-1	2.1880E+02	1.8468E-03	1.4661E-03	-2.834	7.9386E-01
94	NACL	0	1.2586E-29	2.1640E-34	2.2097E-34	-33.656	1.0211E+00
46	KSO4	-1	1.7105E+00	1.2716E-05	1.0095E-05	-4.996	7.9386E-01
95	KCL	0	8.2562E-32	1.1128E-36	1.1362E-36	-35.945	1.0211E+00
63	HSO4	-1	6.8390E-03	7.0796E-08	5.5408E-08	-7.256	7.8264E-01

MOLE RATIOS FROM ANALYTICAL MOLALITY		MOLE RATIOS FROM COMPUTED MOLALITY		LOG ACTIVITY RATIOS	
CL/CA =	1.0640E+00	CL/CA =	1.8258E+00	LOG CA/H2 =	11.6795
CL/MG =	1.1550E+00	CL/MG =	1.8841E+00	LOG MG/H2 =	11.6822
CL/NA =	2.1615E-01	CL/NA =	2.2623E-01	LOG NA/H1 =	5.6896
CL/K =	4.0567E+01	CL/K =	4.3045E+01	LOG K/H1 =	3.4008
CL/AL =	9.0697E+27	CL/AL =	9.0697E+27	LOG AL/H3 =	21.5700
CL/FE =	9.0697E+27	CL/FE =	9.0697E+27	LOG FE/H2 =	14.3800
CL/SO4 =	2.8902E-01	CL/SO4 =	3.9428E-01	LOG CA/MG =	-.0027
CL/HCO3 =	9.0697E+27	CL/HCO3 =	9.0697E+27	LOG NA/K =	2.2889
CA/MG =	1.0855E+00	CA/MG =	1.0319E+00		
NA/K =	1.8768E+02	NA/K =	1.9027E+02		

PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT
18 ANHYDRIT	1.762E-05	4.130E-05	-4.754	-4.384	4.266E-01	-.370
20 BRUCITE	4.987E-17	3.890E-12	-16.302	-11.410	1.282E-05	-4.892
19 GYPSUM	1.756E-05	2.498E-05	-4.755	-4.602	7.030E-01	-.153
65 HALITE	2.210E-04	3.819E+01	-3.656	1.582	5.785E-06	-5.238
67 MIRABI	8.692E-06	7.709E-02	-5.061	-1.113	1.128E-04	-3.948
66 THENAR	8.827E-06	6.622E-01	-5.054	-.179	1.333E-05	-4.875

1MONITORING WELL #3 - EPNG - SJRP

INITIAL SOLUTION

TEMPERATURE = 25.00 DEGREES C PH = 7.070
ANALYTICAL EPMCAT = 43.568 ANALYTICAL EPMAN = 42.661

***** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 4.000 MG/L
EH MEASURED WITH CALOMEL = 99.0000 VOLTS

MEASURED EH OF ZOBELL SOLUTION = 99.0000 VOLTS

FLAG	CORALK	PECALC	IDAVES
2	1	2	0

CORRECTED EH = 99.0000 VOLTS
PE COMPUTED FROM CORRECTED EH = 100.000

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
CA	2	7.00637E-03	-2.1545	2.80000E+02
MG	2	3.21763E-03	-2.4925	7.80000E+01
NA	1	2.31208E-02	-1.6360	5.30000E+02
K	1	1.25678E-04	-3.9007	4.90000E+00
CL	-1	3.11173E-03	-2.5070	1.10000E+02
SO4	-2	1.98366E-02	-1.7025	1.90000E+03

*** CONVERGENCE ITERATIONS ***

ITERATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	.000E+00	8.507E-03	.000E+00	.000E+00	.000E+00
2	.000E+00	1.746E-03	.000E+00	.000E+00	.000E+00
3	.000E+00	-6.386E-06	.000E+00	.000E+00	.000E+00

****DESCRIPTION OF SOLUTION ****

	ANAL.	COMP.	PH	
EPMCAT	43.57	35.09	7.070	ACTIVITY H2O = .9991
EPMAN	42.66	34.25		PCO2= .000000E+00
			TEMPERATURE	LOG PCO2 = -99.9000
EH = ******	PE = 13.449		25.00 DEG C	PO2 = 9.055450E-02
PE CALC S = 100.000				PCH4 = .000000E+00
PE CALC DOX= 13.449			IONIC STRENGTH	CO2 TOT = .000000E+00
PE SATO DOX= 3.339			5.616265E-02	DENSITY = 1.0000
TOT ALK = 9.955E-06 MEQ				TDS = 2902.9MG/L
ELECT = 8.375E-01 MEQ				CARB ALK = .000E+00 MEQ

IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE = 13.449 EQUIVALENT EH = .796VOLTS

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	ACTIVITY	LOG ACT	GAMMA
1	CA	2	1.7174E+02	4.2975E-03	1.9677E-03	-2.706	4.5787E-01
2	MG	2	5.0336E+01	2.0764E-03	9.7617E-04	-3.010	4.7012E-01
3	NA	1	5.1174E+02	2.2324E-02	1.8226E-02	-1.739	8.1641E-01
4	K	1	4.6795E+00	1.2002E-04	9.6600E-05	-4.015	8.0485E-01
64	H	1	1.0078E-04	1.0027E-07	8.5114E-08	-7.070	8.4884E-01
5	CL	-1	1.1000E+02	3.1117E-03	2.5045E-03	-2.601	8.0485E-01
6	SO4	-2	1.4581E+03	1.5223E-02	6.7880E-03	-2.168	4.4589E-01
27	OH	-1	2.5271E-03	1.4902E-07	1.1971E-07	-6.922	8.0329E-01
19	MGOH	1	9.4700E-04	2.2986E-08	1.9102E-08	-7.719	8.3105E-01
23	MGSO4 AQ	0	1.3581E+02	1.1315E-03	1.1462E-03	-2.941	1.0130E+00
29	CAOH	1	4.0727E-04	7.1550E-09	5.9170E-09	-8.228	8.2698E-01
32	CASO4 AQ	0	3.6460E+02	2.6859E-03	2.7208E-03	-2.565	1.0130E+00
44	NASO4	-1	9.3781E+01	7.9003E-04	6.4927E-04	-3.188	8.2183E-01
94	NACL	0	2.6257E-30	4.5059E-35	4.5645E-35	-34.341	1.0130E+00
46	KSO4	-1	7.5570E-01	5.6073E-06	4.6082E-06	-5.336	8.2183E-01
95	KCL	0	1.7754E-32	2.3882E-37	2.4193E-37	-36.616	1.0130E+00
63	HSO4	-1	6.6722E-03	6.8936E-08	5.6080E-08	-7.251	8.1350E-01

MOLE RATIOS FROM ANALYTICAL MOLALITY		MOLE RATIOS FROM COMPUTED MOLALITY		LOG ACTIVITY RATIOS	
CL/CA =	4.4413E-01	CL/CA =	7.2408E-01	LOG CA/H2 =	11.4340
CL/MG =	9.6709E-01	CL/MG =	1.4986E+00	LOG MG/H2 =	11.1295
CL/NA =	1.3459E-01	CL/NA =	1.3939E-01	LOG NA/H1 =	5.3307
CL/K =	2.4760E+01	CL/K =	2.5926E+01	LOG K/H1 =	3.0550
CL/AL =	3.1117E+27	CL/AL =	3.1117E+27	LOG AL/H3 =	21.2100
CL/FE =	3.1117E+27	CL/FE =	3.1117E+27	LOG FE/H2 =	14.1400
CL/SO4 =	1.5687E-01	CL/SO4 =	2.0440E-01	LOG CA/MG =	.3044
CL/HCO3 =	3.1117E+27	CL/HCO3 =	3.1117E+27	LOG NA/K =	2.2757
CA/MG =	2.1775E+00	CA/MG =	2.0697E+00		
NA/K =	1.8397E+02	NA/K =	1.8600E+02		

	PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT
18	ANHYDRIT	1.336E-05	4.130E-05	-4.874	-4.384	3.234E-01	-.490
20	BRUCITE	1.399E-17	3.890E-12	-16.854	-11.410	3.596E-06	-5.444
19	GYPSUM	1.333E-05	2.498E-05	-4.875	-4.602	5.337E-01	-.273
65	HALITE	4.565E-05	3.819E+01	-4.341	1.582	1.195E-06	-5.923
67	MIRABI	2.235E-06	7.709E-02	-5.651	-1.113	2.899E-05	-4.538
66	THENAR	2.255E-06	6.622E-01	-5.647	-.179	3.405E-06	-5.468

INITIAL SOLUTION

TEMPERATURE = 25.00 DEGREES C   PH = 7.690
ANALYTICAL EPMCAT = 9.072   ANALYTICAL EPMAN = 10.297

***** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 4.000 MG/L
EH MEASURED WITH CALOMEL = 99.0000 VOLTS
MEASURED EH OF ZOBELL SOLUTION = 99.0000 VOLTS
CORRECTED EH = 99.0000 VOLTS
PE COMPUTED FROM CORRECTED EH = 100.000

FLAG	CORALK	PECALC	IDAVES
2	1	2	0

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
CA	2	1.64788E-03	-2.7831	6.60000E+01
MG	2	6.99742E-04	-3.1551	1.70000E+01
NA	1	4.35286E-03	-2.3612	1.00000E+02
K	1	3.07109E-05	-4.5127	1.20000E+00
CL	-1	8.18568E-04	-3.0869	2.90000E+01
SO4	-2	3.02105E-03	-2.5198	2.90000E+02
HCO3	-1	3.44410E-03	-2.4629	2.10000E+02

*** CONVERGENCE ITERATIONS ***

ITERATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	8.289E-05	6.789E-04	.000E+00	.000E+00	.000E+00
2	1.047E-05	5.569E-05	.000E+00	.000E+00	.000E+00
3	-3.305E-07	-2.062E-06	.000E+00	.000E+00	.000E+00

****DESCRIPTION OF SOLUTION ****

	ANAL.	COMP.	PH
EPMCAT	9.07	8.18	7.690
EPMAN	10.30	9.41	

ACTIVITY H2O = .9998
PCO2= 4.024753E-03
LOG PCO2 = -2.3953

TEMPERATURE
25.00 DEG C

PO2 = 9.055450E-02

EH = ****** PE = 12.829

PCH4 = .000000E+00

PE CALC S = 100.000

CO2 TOT = 3.557087E-03

PE CALC DOX= 12.829

IONIC STRENGTH
1.329996E-02

DENSITY = 1.0000

PE SATO DOX= 2.719

TDS = 713.2MG/L

TOT ALK = 3.445E+00 MEQ

CARB ALK = 3.444E+00 MEQ

ELECT = -1.230E+00 MEQ

IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE = 12.829 EQUIVALENT EH = .759VOLTS

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	ACTIVITY	LOG ACT	GAMMA
1	CA	2	5.2881E+01	1.3203E-03	8.4095E-04	-3.075	6.3692E-01
2	MG	2	1.4025E+01	5.7729E-04	3.7073E-04	-3.431	6.4218E-01
3	NA	1	9.8985E+01	4.3087E-03	3.8387E-03	-2.416	8.9092E-01
4	K	1	1.1863E+00	3.0361E-05	2.6947E-05	-4.569	8.8754E-01
64	H	1	2.2755E-05	2.2591E-08	2.0417E-08	-7.690	9.0380E-01
5	CL	-1	2.9000E+01	8.1857E-04	7.2651E-04	-3.139	8.8754E-01
6	SO4	-2	2.4936E+02	2.5977E-03	1.6442E-03	-2.784	6.3294E-01
7	HCO3	-1	2.0367E+02	3.3403E-03	2.9845E-03	-2.525	8.9350E-01
18	CO3	-2	6.4511E-01	1.0758E-05	6.8566E-06	-5.164	6.3736E-01
86	H2CO3	0	8.4631E+00	1.3654E-04	1.3699E-04	-3.863	1.0032E+00
27	OH	-1	9.5662E-03	5.6287E-07	4.9934E-07	-6.302	8.8713E-01
19	MGOH	1	1.3931E-03	3.3739E-08	3.0260E-08	-7.519	8.9688E-01
23	MGSO4 AQ	0	1.2644E+01	1.0512E-04	1.0544E-04	-3.977	1.0031E+00
22	MGHCO3	1	1.2343E+00	1.4475E-05	1.2867E-05	-4.891	8.8888E-01
21	MGCO3 AQ	0	2.0379E-01	2.4186E-06	2.4260E-06	-5.615	1.0031E+00
29	CAOH	1	6.7204E-04	1.1781E-08	1.0548E-08	-7.977	8.9537E-01
32	CASO4 AQ	0	3.8201E+01	2.8080E-04	2.8166E-04	-3.550	1.0031E+00
30	CAHCO3	1	3.6197E+00	3.5829E-05	3.2014E-05	-4.495	8.9350E-01
31	CACO3 AQ	0	9.8379E-01	9.8362E-06	9.6867E-06	-5.014	9.8480E-01
44	NASO4	-1	4.4103E+00	3.7071E-05	3.3123E-05	-4.480	8.9350E-01
43	NAHCO3	0	5.3908E-01	6.4229E-06	6.4426E-06	-5.191	1.0031E+00
42	NACO3	-1	4.5286E-02	5.4601E-07	4.8786E-07	-6.312	8.9350E-01
94	NACL	0	1.6237E-31	2.7803E-36	2.7889E-36	-35.555	1.0031E+00
46	KSO4	-1	4.7067E-02	3.4847E-07	3.1136E-07	-6.507	8.9350E-01
95	KCL	0	1.4541E-33	1.9517E-38	1.9577E-38	-37.708	1.0031E+00
63	HSO4	-1	3.5491E-04	3.6588E-09	3.2585E-09	-8.487	8.9058E-01

MOLE RATIOS FROM MOLE RATIOS FROM

ANALYTICAL MOLALITY			COMPUTED MOLALITY			LOG ACTIVITY RATIOS		
CL/CA	=	4.9674E-01	CL/CA	=	6.1997E-01	LOG CA/H2	=	12.3048
CL/MG	=	1.1698E+00	CL/MG	=	1.4179E+00	LOG MG/H2	=	11.9491
CL/NA	=	1.8805E-01	CL/NA	=	1.8998E-01	LOG NA/H1	=	5.2742
CL/K	=	2.6654E+01	CL/K	=	2.6961E+01	LOG K/H1	=	3.1205
CL/AL	=	8.1857E+26	CL/AL	=	8.1857E+26	LOG AL/H3	=	23.0700
CL/FE	=	8.1857E+26	CL/FE	=	8.1857E+26	LOG FE/H2	=	15.3800
CL/SO4	=	2.7095E-01	CL/SO4	=	3.1511E-01	LOG CA/MG	=	.3557
CL/HCO3	=	2.3767E-01	CL/HCO3	=	2.4506E-01	LOG NA/K	=	2.1537
CA/MG	=	2.3550E+00	CA/MG	=	2.2871E+00			
NA/K	=	1.4174E+02	NA/K	=	1.4191E+02			

KENNEDY WELL - EPNG

	PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT
18	ANHYDRIT	1.383E-06	4.130E-05	-5.859	-4.384	3.348E-02	-1.475
22	ARAGONIT	5.766E-09	4.612E-09	-8.239	-8.336	1.250E+00	.097
151	ARTIN	1.208E-24	3.981E-19	-23.918	-18.400	3.035E-06	-5.518
20	BRUCITE	9.244E-17	3.890E-12	-16.034	-11.410	2.376E-05	-4.624
13	CALCITE	5.766E-09	3.312E-09	-8.239	-8.480	1.741E+00	.241
12	DOLOMITE	1.466E-17	8.128E-18	-16.834	-17.090	1.803E+00	.256
19	GYPSUM	1.382E-06	2.498E-05	-5.859	-4.602	5.532E-02	-1.257
65	HALITE	2.789E-06	3.819E+01	-5.555	1.582	7.302E-08	-7.137
118	HUNTITE	9.470E-35	3.090E-31	-34.024	-30.510	3.065E-04	-3.514
39	HYDMAG			-50.414	-37.820		-12.594
11	MAGNESIT	2.542E-09	5.754E-09	-8.595	-8.240	4.417E-01	-.355
67	MIRABI	2.417E-08	7.709E-02	-7.617	-1.113	3.136E-07	-6.504
59	NAHCOL	1.146E-05	2.831E-01	-4.941	-.548	4.046E-05	-4.393
61	NATRON	1.008E-10	4.887E-02	-9.997	-1.311	2.063E-09	-8.686
150	NESQUE	2.540E-09	6.152E-06	-8.595	-5.211	4.129E-04	-3.384
66	THENAR	2.423E-08	6.622E-01	-7.616	-.179	3.659E-08	-7.437
62	THRNAT	1.010E-10	1.334E+00	-9.996	.125	7.575E-11	-10.121
60	TRONA	1.157E-15	1.603E-01	-14.937	-.795	7.217E-15	-14.142

INITIAL SOLUTION

TEMPERATURE = 25.00 DEGREES C   PH = 7.780
ANALYTICAL EPMCAT = 9.196   ANALYTICAL EPMAN = 10.342

***** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 4.000 MG/L
EH MEASURED WITH CALOMEL = 99.0000 VOLTS
MEASURED EH OF ZOBELL SOLUTION = 99.0000 VOLTS
CORRECTED EH = 99.0000 VOLTS
PE COMPUTED FROM CORRECTED EH = 100.000

FLAG	CORALK	PECALC	IDAVES
2	1	2	0

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
CA	2	1.57299E-03	-2.8033	6.30000E+01
MG	2	6.17423E-04	-3.2094	1.50000E+01
NA	1	4.78817E-03	-2.3198	1.10000E+02
K	1	3.32703E-05	-4.4779	1.30000E+00
CL	-1	8.18572E-04	-3.0869	2.90000E+01
SO4	-2	3.12524E-03	-2.5051	3.00000E+02
HCO3	-1	3.28012E-03	-2.4841	2.00000E+02

*** CONVERGENCE ITERATIONS ***

ITERATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	7.977E-05	6.627E-04	.000E+00	.000E+00	.000E+00
2	1.008E-05	5.433E-05	.000E+00	.000E+00	.000E+00
3	-3.081E-07	-1.920E-06	.000E+00	.000E+00	.000E+00

****DESCRIPTION OF SOLUTION ****

	ANAL.	COMP.	PH
EPMCAT	9.20	8.33	7.780
EPMAN	10.34	9.48	

TEMPERATURE
25.00 DEG C

EH = ****** PE = 12.739
PE CALC S = 100.000
PE CALC DOX= 12.739
PE SATO DOX= 2.629
TOT ALK = 3.281E+00 MEQ
ELECT = -1.151E+00 MEQ

IONIC STRENGTH
1.338281E-02

ACTIVITY H2O = .9998
PCO2= 3.109416E-03
LOG PCO2 = -2.5073
PO2 = 9.055450E-02
PCH4 = .000000E+00
CO2 TOT = 3.358934E-03
DENSITY = 1.0000
TDS = 718.3MG/L
CARB ALK = 3.280E+00 MEQ

IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE = 12.739 EQUIVALENT EH = .754VOLTS

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	ACTIVITY	LOG ACT	GAMMA
1	CA	2	5.0136E+01	1.2518E-03	7.9638E-04	-3.099	6.3618E-01
2	MG	2	1.2306E+01	5.0652E-04	3.2492E-04	-3.488	6.4147E-01
3	NA	1	1.0885E+02	4.7381E-03	4.2200E-03	-2.375	8.9065E-01
4	K	1	1.2846E+00	3.2876E-05	2.9169E-05	-4.535	8.8725E-01
64	H	1	1.8500E-05	1.8367E-08	1.6596E-08	-7.780	9.0359E-01
5	CL	-1	2.9000E+01	8.1857E-04	7.2628E-04	-3.139	8.8725E-01
6	SO4	-2	2.6008E+02	2.7094E-03	1.7128E-03	-2.766	6.3218E-01
7	HCO3	-1	1.9364E+02	3.1757E-03	2.8367E-03	-2.547	8.9324E-01
18	CO3	-2	7.5522E-01	1.2594E-05	8.0177E-06	-5.096	6.3662E-01
86	H2CO3	0	6.5382E+00	1.0549E-04	1.0583E-04	-3.975	1.0033E+00
27	OH	-1	1.1773E-02	6.9271E-07	6.1432E-07	-6.212	8.8684E-01
19	MGOH	1	1.5025E-03	3.6389E-08	3.2628E-08	-7.486	8.9663E-01
23	MGSO4 AQ	0	1.1544E+01	9.5973E-05	9.6269E-05	-4.017	1.0031E+00
22	MGHCO3	1	1.0285E+00	1.2062E-05	1.0718E-05	-4.970	8.8860E-01
21	MGCO3 AQ	0	2.0885E-01	2.4786E-06	2.4863E-06	-5.604	1.0031E+00
29	CAOH	1	7.8319E-04	1.3729E-08	1.2289E-08	-7.910	8.9512E-01
32	CASO4 AQ	0	3.7685E+01	2.7701E-04	2.7786E-04	-3.556	1.0031E+00
30	CAHCO3	1	3.2590E+00	3.2259E-05	2.8815E-05	-4.540	8.9324E-01
31	CACO3 AQ	0	1.0895E+00	1.0893E-05	1.0727E-05	-4.970	9.8471E-01
44	NASO4	-1	5.0522E+00	4.2468E-05	3.7934E-05	-4.421	8.9324E-01
43	NAHCO3	0	5.6327E-01	6.7111E-06	6.7318E-06	-5.172	1.0031E+00
42	NACO3	-1	5.8231E-02	7.0209E-07	6.2714E-07	-6.203	8.9324E-01
94	NACL	0	1.7844E-31	3.0555E-36	3.0649E-36	-35.514	1.0031E+00
46	KSO4	-1	5.3091E-02	3.9307E-07	3.5111E-07	-6.455	8.9324E-01
95	KCL	0	1.5734E-33	2.1120E-38	2.1185E-38	-37.674	1.0031E+00
63	HSO4	-1	3.0061E-04	3.0991E-09	2.7591E-09	-8.559	8.9030E-01

MOLE RATIOS FROM MOLE RATIOS FROM

ANALYTICAL MOLALITY		COMPUTED MOLALITY		LOG ACTIVITY RATIOS	
CL/CA =	5.2039E-01	CL/CA =	6.5391E-01	LOG CA/H2 =	12.4611
CL/MG =	1.3258E+00	CL/MG =	1.6161E+00	LOG MG/H2 =	12.0718
CL/NA =	1.7096E-01	CL/NA =	1.7276E-01	LOG NA/H1 =	5.4053
CL/K =	2.4604E+01	CL/K =	2.4899E+01	LOG K/H1 =	3.2449
CL/AL =	8.1857E+26	CL/AL =	8.1857E+26	LOG AL/H3 =	23.3400
CL/FE =	8.1857E+26	CL/FE =	8.1857E+26	LOG FE/H2 =	15.5600
CL/SO4 =	2.6192E-01	CL/SO4 =	3.0212E-01	LOG CA/MG =	.3893
CL/HCO3 =	2.4956E-01	CL/HCO3 =	2.5776E-01	LOG NA/K =	2.1604
CA/MG =	2.5477E+00	CA/MG =	2.4714E+00		
NA/K =	1.4392E+02	NA/K =	1.4412E+02		

BOOTH WELL - EPNG

	PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT
18	ANHYDRIT	1.364E-06	4.130E-05	-5.865	-4.384	3.302E-02	-1.481
22	ARAGONIT	6.385E-09	4.612E-09	-8.195	-8.336	1.384E+00	.141
151	ARTIN	1.918E-24	3.981E-19	-23.717	-18.400	4.817E-06	-5.317
20	BRUCITE	1.226E-16	3.890E-12	-15.911	-11.410	3.152E-05	-4.501
13	CALCITE	6.385E-09	3.312E-09	-8.195	-8.480	1.928E+00	.285
12	DOLOMITE	1.663E-17	8.128E-18	-16.779	-17.090	2.046E+00	.311
19	GYPSUM	1.363E-06	2.498E-05	-5.865	-4.602	5.457E-02	-1.263
65	HALITE	3.065E-06	3.819E+01	-5.514	1.582	8.025E-08	-7.096
118	HUNTITE	1.129E-34	3.090E-31	-33.947	-30.510	3.653E-04	-3.437
39	HYDMAG			-50.249	-37.820		-12.429
11	MAGNESIT	2.605E-09	5.754E-09	-8.584	-8.240	4.527E-01	-.344
67	MIRABI	3.043E-08	7.709E-02	-7.517	-1.113	3.947E-07	-6.404
59	NAHCOL	1.197E-05	2.831E-01	-4.922	-.548	4.228E-05	-4.374
61	NATRON	1.424E-10	4.887E-02	-9.846	-1.311	2.915E-09	-8.535
150	NESQUE	2.603E-09	6.152E-06	-8.584	-5.211	4.232E-04	-3.373
66	THENAR	3.050E-08	6.622E-01	-7.516	-.179	4.606E-08	-7.337
62	THRNAT	1.428E-10	1.334E+00	-9.845	.125	1.070E-10	-9.970
60	TRONA	1.708E-15	1.603E-01	-14.767	-.795	1.066E-14	-13.972

INITIAL SOLUTION

TEMPERATURE = 25.00 DEGREES C   PH = 7.580
ANALYTICAL EPMCAT = 49.999   ANALYTICAL EPMAN = 51.217

***** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 4.000 MG/L
EH MEASURED WITH CALOMEL = 99.0000 VOLTS
MEASURED EH OF ZOBELL SOLUTION = 99.0000 VOLTS
CORRECTED EH = 99.0000 VOLTS
PE COMPUTED FROM CORRECTED EH = 100.000

FLAG	CORALK	PECALC	IDAVES
2	1	2	0

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
CA	2	4.75680E-03	-2.3227	1.90000E+02
MG	2	2.35257E-03	-2.6285	5.70000E+01
NA	1	3.57905E-02	-1.4462	8.20000E+02
K	1	1.61671E-04	-3.7914	6.30000E+00
CL	-1	1.13213E-02	-1.9461	4.00000E+02
SO4	-2	1.88023E-02	-1.7258	1.80000E+03
HCO3	-1	2.46676E-03	-2.6079	1.50000E+02

*** CONVERGENCE ITERATIONS ***

ITERATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	1.018E-04	7.459E-03	.000E+00	.000E+00	.000E+00
2	3.467E-05	1.121E-03	.000E+00	.000E+00	.000E+00
3	-2.330E-07	-1.201E-05	.000E+00	.000E+00	.000E+00

****DESCRIPTION OF SOLUTION ****

```
          ANAL.      COMP.          PH              ACTIVITY H2O =    .9988
EPMCAT     50.00      43.70        7.580            PCO2=  3.307646E-03
EPMAN      51.22      44.96                         LOG PCO2 =  -2.4805
                                 TEMPERATURE        PO2 =  9.055450E-02
EH = ******  PE =  12.939        25.00 DEG C        PCH4 =    .000000E+00
PE CALC S =  100.000                                CO2 TOT =  2.557387E-03
PE CALC DOX= 12.939             IONIC STRENGTH      DENSITY =    1.0000
PE SATO DOX=  2.829             6.402279E-02        TDS =     3423.3MG/L
TOT ALK =  2.467E+00 MEQ                            CARB ALK =  2.467E+00 MEQ
ELECT   = -1.272E+00 MEQ

IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE =  12.939      EQUIVALENT EH =    .766VOLTS
```

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	ACTIVITY	LOG ACT	GAMMA
1	CA	2	1.1904E+02	2.9802E-03	1.3171E-03	-2.880	4.4195E-01
2	MG	2	3.7466E+01	1.5463E-03	7.0362E-04	-3.153	4.5503E-01
3	NA	1	7.9227E+02	3.4580E-02	2.7966E-02	-1.553	8.0874E-01
4	K	1	6.0292E+00	1.5472E-04	1.2314E-04	-3.910	7.9587E-01
64	H	1	3.1326E-05	3.1184E-08	2.6303E-08	-7.580	8.4347E-01
5	CL	-1	4.0000E+02	1.1321E-02	9.0103E-03	-2.045	7.9587E-01
6	SO4	-2	1.4487E+03	1.5132E-02	6.4887E-03	-2.188	4.2880E-01
7	HCO3	-1	1.4217E+02	2.3381E-03	1.9040E-03	-2.720	8.1433E-01
18	CO3	-2	4.6177E-01	7.7213E-06	3.3954E-06	-5.469	4.3974E-01
86	H2CO3	0	6.8514E+00	1.1084E-04	1.1258E-04	-3.949	1.0157E+00
27	OH	-1	8.2648E-03	4.8762E-07	3.8723E-07	-6.412	7.9411E-01
19	MGOH	1	2.2249E-03	5.4032E-08	4.4540E-08	-7.351	8.2432E-01
23	MGSO4 AQ	0	9.3355E+01	7.7821E-04	7.8977E-04	-3.103	1.0149E+00
22	MGHCO3	1	1.6563E+00	1.9477E-05	1.5579E-05	-4.807	7.9985E-01
21	MGCO3 AQ	0	1.8880E-01	2.2467E-06	2.2801E-06	-5.642	1.0149E+00
29	CAOH	1	8.8900E-04	1.5626E-08	1.2812E-08	-7.892	8.1991E-01
32	CASO4 AQ	0	2.3274E+02	1.7154E-03	1.7409E-03	-2.759	1.0149E+00
30	CAHCO3	1	3.9575E+00	3.9280E-05	3.1987E-05	-4.495	8.1433E-01
31	CACO3 AQ	0	8.0671E-01	8.0876E-06	7.5129E-06	-5.124	9.2894E-01
44	NASO4	-1	1.3875E+02	1.1695E-03	9.5234E-04	-3.021	8.1433E-01
43	NAHCO3	0	2.4696E+00	2.9504E-05	2.9943E-05	-4.524	1.0149E+00
42	NACO3	-1	1.7878E-01	2.1613E-06	1.7600E-06	-5.754	8.1433E-01
94	NACL	0	1.4461E-29	2.4830E-34	2.5198E-34	-33.599	1.0149E+00
46	KSO4	-1	9.2882E-01	6.8954E-06	5.6151E-06	-5.251	8.1433E-01
95	KCL	0	8.1230E-32	1.0933E-36	1.1095E-36	-35.955	1.0149E+00
63	HSO4	-1	1.9901E-03	2.0572E-08	1.6566E-08	-7.781	8.0527E-01

MOLE RATIOS FROM   MOLE RATIOS FROM

ANALYTICAL MOLALITY			COMPUTED MOLALITY			LOG ACTIVITY RATIOS		
CL/CA	=	2.3800E+00	CL/CA	=	3.7988E+00	LOG CA/H2	=	12.2796
CL/MG	=	4.8123E+00	CL/MG	=	7.3214E+00	LOG MG/H2	=	12.0073
CL/NA	=	3.1632E-01	CL/NA	=	3.2739E-01	LOG NA/H1	=	6.0266
CL/K	=	7.0027E+01	CL/K	=	7.3173E+01	LOG K/H1	=	3.6704
CL/AL	=	1.1321E+28	CL/AL	=	1.1321E+28	LOG AL/H3	=	22.7400
CL/FE	=	1.1321E+28	CL/FE	=	1.1321E+28	LOG FE/H2	=	15.1600
CL/SO4	=	6.0212E-01	CL/SO4	=	7.4815E-01	LOG CA/MG	=	.2723
CL/HCO3	=	4.5895E+00	CL/HCO3	=	4.8422E+00	LOG NA/K	=	2.3562
CA/MG	=	2.0220E+00	CA/MG	=	1.9273E+00			
NA/K	=	2.2138E+02	NA/K	=	2.2350E+02			

ISHAM WELL - EPNG

	PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT
18	ANHYDRIT	8.546E-06	4.130E-05	-5.068	-4.384	2.069E-01	-.684
22	ARAGONIT	4.472E-09	4.612E-09	-8.349	-8.336	9.697E-01	-.013
151	ARTIN	8.800E-25	3.981E-19	-24.056	-18.400	2.210E-06	-5.656
20	BRUCITE	1.055E-16	3.890E-12	-15.977	-11.410	2.712E-05	-4.567
13	CALCITE	4.472E-09	3.312E-09	-8.349	-8.480	1.350E+00	.130
12	DOLOMITE	1.068E-17	8.128E-18	-16.971	-17.090	1.314E+00	.119
19	GYPSUM	8.525E-06	2.498E-05	-5.069	-4.602	3.412E-01	-.467
65	HALITE	2.520E-04	3.819E+01	-3.599	1.582	6.597E-06	-5.181
118	HUNTITE	6.098E-35	3.090E-31	-34.215	-30.510	1.973E-04	-3.705
39	HYDMAG			-50.466	-37.820		-12.646
11	MAGNESIT	2.389E-09	5.754E-09	-8.622	-8.240	4.152E-01	-.382
67	MIRABI	5.013E-06	7.709E-02	-5.300	-1.113	6.503E-05	-4.187
59	NAHCOL	5.325E-05	2.831E-01	-4.274	-.548	1.881E-04	-3.726
61	NATRON	2.623E-09	4.887E-02	-8.581	-1.311	5.368E-08	-7.270
150	NESQUE	2.380E-09	6.152E-06	-8.623	-5.211	3.869E-04	-3.412
66	THENAR	5.075E-06	6.622E-01	-5.295	-.179	7.663E-06	-5.116
62	THRNAT	2.652E-09	1.334E+00	-8.576	.125	1.989E-09	-8.701
60	TRONA	1.411E-13	1.603E-01	-12.851	-.795	8.798E-13	-12.056

INITIAL SOLUTION

TEMPERATURE = 25.00 DEGREES C PH = 7.110
ANALYTICAL EPMCAT = 21.835 ANALYTICAL EPMAN = 24.587

***** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 4.000 MG/L
EH MEASURED WITH CALOMEL = 99.0000 VOLTS
MEASURED EH OF ZOBELL SOLUTION = 99.0000 VOLTS
CORRECTED EH = 99.0000 VOLTS
PE COMPUTED FROM CORRECTED EH = 100.000

FLAG	CORALK	PECALC	IDAVES
2	1	2	0

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
CA	2	7.74768E-04	-3.1108	3.10000E+01
MG	2	5.35624E-04	-3.2711	1.30000E+01
NA	1	1.91715E-02	-1.7173	4.40000E+02
K	1	7.94146E-05	-4.1001	3.10000E+00
CL	-1	3.10797E-03	-2.5075	1.10000E+02
SO4	-2	8.13359E-03	-2.0897	7.80000E+02
HCO3	-1	5.25333E-03	-2.2796	3.20000E+02

*** CONVERGENCE ITERATIONS ***

ITERATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	7.935E-05	1.358E-03	.000E+00	.000E+00	.000E+00
2	9.562E-06	9.723E-05	.000E+00	.000E+00	.000E+00
3	-1.787E-07	-1.801E-06	.000E+00	.000E+00	.000E+00

****DESCRIPTION OF SOLUTION ****

	ANAL.	COMP.	PH	
EPMCAT	21.83	20.65	7.110	ACTIVITY H2O = .9994
EPMAN	24.59	23.40		PCO2= 2.265265E-02
				LOG PCO2 = -1.6449
			TEMPERATURE	PO2 = 9.055450E-02
EH = ******	PE = 13.409		25.00 DEG C	PCH4 = .000000E+00
PE CALC S = 100.000				CO2 TOT = 6.010892E-03
PE CALC DOX= 13.409			IONIC STRENGTH	DENSITY = 1.0000
PE SATO DOX= 3.299			3.036675E-02	TDS = 1697.1MG/L
TOT ALK = 5.253E+00 MEQ				CARB ALK = 5.253E+00 MEQ
ELECT = -2.760E+00 MEQ				

IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE = 13.409 EQUIVALENT EH = .793VOLTS

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	ACTIVITY	LOG ACT	GAMMA
1	CA	2	2.1228E+01	5.3054E-04	2.8374E-04	-3.547	5.3481E-01
2	MG	2	9.2912E+00	3.8282E-04	2.0810E-04	-3.682	5.4361E-01
3	NA	1	4.3030E+02	1.8749E-02	1.5952E-02	-1.797	8.5084E-01
4	K	1	3.0182E+00	7.7320E-05	6.5252E-05	-4.185	8.4392E-01
64	H	1	8.9426E-05	8.8867E-08	7.7625E-08	-7.110	8.7349E-01
5	CL	-1	1.1000E+02	3.1080E-03	2.6229E-03	-2.581	8.4392E-01
6	SO4	-2	7.0844E+02	7.3874E-03	3.8946E-03	-2.410	5.2720E-01
7	HCO3	-1	3.1475E+02	5.1671E-03	4.4183E-03	-2.355	8.5508E-01
18	CO3	-2	2.9918E-01	4.9941E-06	2.6699E-06	-5.574	5.3460E-01
86	H2CO3	0	4.7389E+01	7.6532E-04	7.7100E-04	-3.113	1.0074E+00
27	OH	-1	2.6441E-03	1.5573E-07	1.3129E-07	-6.882	8.4303E-01
19	MGOH	1	2.1390E-04	5.1855E-09	4.4660E-09	-8.350	8.6125E-01
23	MGSO4 AQ	0	1.6730E+01	1.3922E-04	1.4020E-04	-3.853	1.0070E+00
22	MGHCO3	1	1.0761E+00	1.2633E-05	1.0692E-05	-4.971	8.4639E-01
21	MGCO3 AQ	0	4.4326E-02	5.2657E-07	5.3027E-07	-6.276	1.0070E+00
29	CAOH	1	6.2116E-05	1.0899E-09	9.3572E-10	-9.029	8.5851E-01
32	CASO4 AQ	0	3.0381E+01	2.2354E-04	2.2510E-04	-3.648	1.0070E+00
30	CAHCO3	1	1.8874E+00	1.8701E-05	1.5991E-05	-4.796	8.5508E-01
31	CACO3 AQ	0	1.3169E-01	1.3179E-06	1.2726E-06	-5.895	9.6564E-01
44	NASO4	-1	4.5319E+01	3.8131E-04	3.2605E-04	-3.487	8.5508E-01
43	NAHCO3	0	3.3002E+00	3.9359E-05	3.9635E-05	-4.402	1.0070E+00
42	NACO3	-1	7.6496E-02	9.2321E-07	7.8942E-07	-6.103	8.5508E-01
94	NACL	0	2.4241E-30	4.1549E-35	4.1841E-35	-34.378	1.0070E+00
46	KSO4	-1	2.8183E-01	2.0886E-06	1.7859E-06	-5.748	8.5508E-01
95	KCL	0	1.2649E-32	1.6995E-37	1.7115E-37	-36.767	1.0070E+00
63	HSO4	-1	3.3470E-03	3.4539E-08	2.9345E-08	-7.532	8.4961E-01

MOLE RATIOS FROM MOLE RATIOS FROM

ANALYTICAL MOLALITY			COMPUTED MOLALITY			LOG ACTIVITY RATIOS		
CL/CA	=	4.0115E+00	CL/CA	=	5.8581E+00	LOG CA/H2	=	10.6729
CL/MG	=	5.8025E+00	CL/MG	=	8.1187E+00	LOG MG/H2	=	10.5383
CL/NA	=	1.6211E-01	CL/NA	=	1.6577E-01	LOG NA/H1	=	5.3128
CL/K	=	3.9136E+01	CL/K	=	4.0196E+01	LOG K/H1	=	2.9246
CL/AL	=	3.1080E+27	CL/AL	=	3.1080E+27	LOG AL/H3	=	21.3300
CL/FE	=	3.1080E+27	CL/FE	=	3.1080E+27	LOG FE/H2	=	14.2200
CL/SO4	=	3.8212E-01	CL/SO4	=	4.2071E-01	LOG CA/MG	=	.1346
CL/HCO3	=	5.9162E-01	CL/HCO3	=	6.0149E-01	LOG NA/K	=	2.3882
CA/MG	=	1.4465E+00	CA/MG	=	1.3859E+00			
NA/K	=	2.4141E+02	NA/K	=	2.4248E+02			

LESTER WELL - EPNG

	PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT
18	ANHYDRIT	1.105E-06	4.130E-05	-5.957	-4.384	2.675E-02	-1.573
22	ARAGONIT	7.575E-10	4.612E-09	-9.121	-8.336	1.643E-01	-.784
151	ARTIN	3.698E-27	3.981E-19	-26.432	-18.400	9.289E-09	-8.032
20	BRUCITE	3.587E-18	3.890E-12	-17.445	-11.410	9.220E-07	-6.035
13	CALCITE	7.575E-10	3.312E-09	-9.121	-8.480	2.287E-01	-.641
12	DOLOMITE	4.209E-19	8.128E-18	-18.376	-17.090	5.178E-02	-1.286
19	GYPSUM	1.104E-06	2.498E-05	-5.957	-4.602	4.417E-02	-1.355
65	HALITE	4.184E-05	3.819E+01	-4.378	1.582	1.095E-06	-5.960
118	HUNTITE	1.299E-37	3.090E-31	-36.886	-30.510	4.204E-07	-6.376
39	HYDMAG			-54.467	-37.820		-16.647
11	MAGNESIT	5.556E-10	5.754E-09	-9.255	-8.240	9.655E-02	-1.015
67	MIRABI	9.849E-07	7.709E-02	-6.007	-1.113	1.278E-05	-4.894
59	NAHCOL	7.048E-05	2.831E-01	-4.152	-.548	2.489E-04	-3.604
61	NATRON	6.751E-10	4.887E-02	-9.171	-1.311	1.382E-08	-7.860
150	NESQUE	5.546E-10	6.152E-06	-9.256	-5.211	9.015E-05	-4.045
66	THENAR	9.911E-07	6.622E-01	-6.004	-.179	1.497E-06	-5.825
62	THRNAT	6.790E-10	1.334E+00	-9.168	.125	5.092E-10	-9.293
60	TRONA	4.783E-14	1.603E-01	-13.320	-.795	2.983E-13	-12.525

INITIAL SOLUTION

TEMPERATURE = 25.00 DEGREES C   PH = 7.280
ANALYTICAL EPMCAT = 31.999   ANALYTICAL EPMAN = 31.500

***** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 4.000 MG/L
EH MEASURED WITH CALOMEL = 99.0000 VOLTS
MEASURED EH OF ZOBELL SOLUTION = 99.0000 VOLTS
CORRECTED EH = 99.0000 VOLTS
PE COMPUTED FROM CORRECTED EH = 100.000

FLAG	CORALK	PECALC	IDAVES
2	1	2	0

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
CA	2	3.25034E-03	-2.4881	1.30000E+02
MG	2	1.81361E-03	-2.7415	4.40000E+01
NA	1	2.17945E-02	-1.6617	5.00000E+02
K	1	1.43517E-04	-3.8431	5.60000E+00
CL	-1	1.13063E-02	-1.9467	4.00000E+02
SO4	-2	8.24119E-03	-2.0840	7.90000E+02
HCO3	-1	3.77735E-03	-2.4228	2.30000E+02

*** CONVERGENCE ITERATIONS ***

ITERATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	1.297E-04	3.065E-03	.000E+00	.000E+00	.000E+00
2	2.891E-05	3.533E-04	.000E+00	.000E+00	.000E+00
3	-4.648E-07	-7.733E-06	.000E+00	.000E+00	.000E+00

HANSEN WELL - EPNG

****DESCRIPTION OF SOLUTION ****

```
           ANAL.      COMP.          PH              ACTIVITY H2O =    .9992
EPMCAT     32.00      29.09        7.280             PCO2=  1.059733E-02
EPMAN      31.50      28.61                          LOG PCO2 =  -1.9748
                                 TEMPERATURE         PO2 =  9.055450E-02
EH = ******  PE =   13.239      25.00 DEG C          PCH4 =   .000000E+00
PE CALC S =  100.000                                 CO2 TOT =  4.120500E-03
PE CALC DOX= 13.239            IONIC STRENGTH        DENSITY =   1.0000
PE SATO DOX=  3.129            3.929870E-02          TDS =      2099.6MG/L
TOT ALK =  3.778E+00 MEQ                             CARB ALK =  3.777E+00 MEQ
ELECT   =  4.794E-01 MEQ

IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE =   13.239      EQUIVALENT EH =    .783VOLTS
```

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	ACTIVITY	LOG ACT	GAMMA
1	CA	2	9.5458E+01	2.3867E-03	1.1988E-03	-2.921	5.0228E-01
2	MG	2	3.3473E+01	1.3797E-03	7.0701E-04	-3.151	5.1244E-01
3	NA	1	4.9078E+02	2.1393E-02	1.7901E-02	-1.747	8.3679E-01
4	K	1	5.4745E+00	1.4030E-04	1.1619E-04	-3.935	8.2818E-01
64	H	1	6.1148E-05	6.0791E-08	5.2481E-08	-7.280	8.6330E-01
5	CL	-1	4.0000E+02	1.1306E-02	9.3637E-03	-2.029	8.2818E-01
6	SO4	-2	6.3989E+02	6.6752E-03	3.2912E-03	-2.483	4.9304E-01
7	HCO3	-1	2.2120E+02	3.6328E-03	3.0573E-03	-2.515	8.4156E-01
18	CO3	-2	3.2623E-01	5.4478E-06	2.7325E-06	-5.563	5.0159E-01
86	H2CO3	0	2.2112E+01	3.5726E-04	3.6069E-04	-3.443	1.0096E+00
27	OH	-1	3.9841E-03	2.3475E-07	1.9415E-07	-6.712	8.2706E-01
19	MGOH	1	1.0899E-03	2.6432E-08	2.2438E-08	-7.649	8.4890E-01
23	MGSO4 AQ	0	4.7915E+01	3.9889E-04	4.0251E-04	-3.395	1.0091E+00
22	MGHCO3	1	2.5752E+00	3.0244E-05	2.5136E-05	-4.600	8.3113E-01
21	MGCO3 AQ	0	1.5375E-01	1.8272E-06	1.8438E-06	-5.734	1.0091E+00
29	CAOH	1	3.9384E-04	6.9135E-09	5.8464E-09	-8.233	8.4565E-01
32	CASO4 AQ	0	1.0820E+02	7.9646E-04	8.0370E-04	-3.095	1.0091E+00
30	CAHCO3	1	5.6041E+00	5.5549E-05	4.6748E-05	-4.330	8.4156E-01
31	CACO3 AQ	0	5.7508E-01	5.7578E-06	5.5031E-06	-5.259	9.5576E-01
44	NASO4	-1	4.3649E+01	3.6741E-04	3.0920E-04	-3.510	8.4156E-01
43	NAHCO3	0	2.5563E+00	3.0499E-05	3.0776E-05	-4.512	1.0091E+00
42	NACO3	-1	8.9232E-02	1.0774E-06	9.0667E-07	-6.043	8.4156E-01
94	NACL	0	9.6876E-30	1.6611E-34	1.6762E-34	-33.776	1.0091E+00
46	KSO4	-1	4.3073E-01	3.1934E-06	2.6875E-06	-5.571	8.4156E-01
95	KCL	0	8.0216E-32	1.0782E-36	1.0880E-36	-35.963	1.0091E+00
63	HSO4	-1	1.9449E-03	2.0078E-08	1.6765E-08	-7.776	8.3501E-01

MOLE RATIOS FROM   MOLE RATIOS FROM

ANALYTICAL MOLALITY			COMPUTED MOLALITY			LOG ACTIVITY RATIOS		
CL/CA	=	3.4785E+00	CL/CA	=	4.7372E+00	LOG CA/H2	=	11.6387
CL/MG	=	6.2341E+00	CL/MG	=	8.1948E+00	LOG MG/H2	=	11.4094
CL/NA	=	5.1877E-01	CL/NA	=	5.2851E-01	LOG NA/H1	=	5.5329
CL/K	=	7.8780E+01	CL/K	=	8.0586E+01	LOG K/H1	=	3.3452
CL/AL	=	1.1306E+28	CL/AL	=	1.1306E+28	LOG AL/H3	=	21.8400
CL/FE	=	1.1306E+28	CL/FE	=	1.1306E+28	LOG FE/H2	=	14.5600
CL/SO4	=	1.3719E+00	CL/SO4	=	1.6938E+00	LOG CA/MG	=	.2293
CL/HCO3	=	2.9932E+00	CL/HCO3	=	3.1122E+00	LOG NA/K	=	2.1877
CA/MG	=	1.7922E+00	CA/MG	=	1.7299E+00			
NA/K	=	1.5186E+02	NA/K	=	1.5248E+02			

HANSEN WELL - EPNG

	PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT
18	ANHYDRIT	3.945E-06	4.130E-05	-5.404	-4.384	9.552E-02	-1.020
22	ARAGONIT	3.276E-09	4.612E-09	-8.485	-8.336	7.103E-01	-.149
151	ARTIN	1.477E-25	3.981E-19	-24.831	-18.400	3.709E-07	-6.431
20	BRUCITE	2.665E-17	3.890E-12	-16.574	-11.410	6.850E-06	-5.164
13	CALCITE	3.276E-09	3.312E-09	-8.485	-8.480	9.890E-01	-.005
12	DOLOMITE	6.328E-18	8.128E-18	-17.199	-17.090	7.786E-01	-.109
19	GYPSUM	3.939E-06	2.498E-05	-5.405	-4.602	1.577E-01	-.802
65	HALITE	1.676E-04	3.819E+01	-3.776	1.582	4.389E-06	-5.358
118	HUNTITE	2.362E-35	3.090E-31	-34.627	-30.510	7.643E-05	-4.117
39	HYDMAG			-51.432	-37.820		-13.612
11	MAGNESIT	1.932E-09	5.754E-09	-8.714	-8.240	3.357E-01	-.474
67	MIRABI	1.046E-06	7.709E-02	-5.980	-1.113	1.357E-05	-4.867
59	NAHCOL	5.473E-05	2.831E-01	-4.262	-.548	1.933E-04	-3.714
61	NATRON	8.684E-10	4.887E-02	-9.061	-1.311	1.777E-08	-7.750
150	NESQUE	1.927E-09	6.152E-06	-8.715	-5.211	3.133E-04	-3.504
66	THENAR	1.055E-06	6.622E-01	-5.977	-.179	1.593E-06	-5.798
62	THRNAT	8.749E-10	1.334E+00	-9.058	.125	6.561E-10	-9.183
60	TRONA	4.784E-14	1.603E-01	-13.320	-.795	2.984E-13	-12.525

INITIAL SOLUTION

TEMPERATURE = 25.00 DEGREES C   PH = 7.010
ANALYTICAL EPMCAT = 62.989   ANALYTICAL EPMAN = 65.610

***** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 4.000 MG/L
EH MEASURED WITH CALOMEL = 99.0000 VOLTS
MEASURED EH OF ZOBELL SOLUTION = 99.0000 VOLTS
CORRECTED EH = 99.0000 VOLTS
PE COMPUTED FROM CORRECTED EH = 100.000

FLAG	CORALK	PECALC	IDAVES
2	1	2	0

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
CA	2	7.01662E-03	-2.1539	2.80000E+02
MG	2	2.72660E-03	-2.5644	6.60000E+01
NA	1	4.36881E-02	-1.3596	1.00000E+03
K	1	8.99015E-05	-4.0462	3.50000E+00
CL	-1	1.27485E-02	-1.8945	4.50000E+02
SO4	-2	2.58253E-02	-1.5880	2.47000E+03
HCO3	-1	1.49791E-03	-2.8245	9.10000E+01

*** CONVERGENCE ITERATIONS ***

ITERATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	5.976E-05	1.160E-02	.000E+00	.000E+00	.000E+00
2	2.427E-05	1.977E-03	.000E+00	.000E+00	.000E+00
3	-1.214E-08	-8.823E-06	.000E+00	.000E+00	.000E+00

****DESCRIPTION OF SOLUTION ****

```
            ANAL.      COMP.          PH              ACTIVITY H2O =    .9985
EPMCAT      62.99      53.53        7.010             PCO2=  7.365353E-03
EPMAN       65.61      56.23                          LOG PCO2 =  -2.1328
                                 TEMPERATURE          PO2 =  9.055450E-02
EH = ******  PE =  13.510         25.00 DEG C         PCH4 =    .000000E+00
PE CALC S =  100.000                                  CO2 TOT =  1.739839E-03
PE CALC DOX= 13.510            IONIC STRENGTH         DENSITY =    1.0000
PE SATO DOX=  3.400             8.104991E-02          TDS =     4360.5MG/L
TOT ALK =   1.498E+00 MEQ                             CARB ALK =  1.498E+00 MEQ
ELECT   = -2.716E+00 MEQ

IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE =  13.510      EQUIVALENT EH =    .799VOLTS
```

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	ACTIVITY	LOG ACT	GAMMA
1	CA	2	1.6641E+02	4.1702E-03	1.7266E-03	-2.763	4.1405E-01
2	MG	2	4.1234E+01	1.7035E-03	7.3024E-04	-3.137	4.2868E-01
3	NA	1	9.5880E+02	4.1888E-02	3.3292E-02	-1.478	7.9479E-01
4	K	1	3.3152E+00	8.5155E-05	6.6354E-05	-4.178	7.7922E-01
64	H	1	1.1763E-04	1.1721E-07	9.7724E-08	-7.010	8.3378E-01
5	CL	-1	4.5000E+02	1.2748E-02	9.9338E-03	-2.003	7.7922E-01
6	SO4	-2	1.9385E+03	2.0268E-02	8.0769E-03	-2.093	3.9851E-01
7	HCO3	-1	8.6597E+01	1.4254E-03	1.1411E-03	-2.943	8.0054E-01
18	CO3	-2	7.9681E-02	1.3336E-06	5.4773E-07	-6.261	4.1071E-01
86	H2CO3	0	1.5179E+01	2.4580E-04	2.5069E-04	-3.601	1.0199E+00
27	OH	-1	2.2706E-03	1.3409E-07	1.0420E-07	-6.982	7.7704E-01
19	MGOH	1	6.3017E-04	1.5318E-08	1.2438E-08	-7.905	8.1202E-01
23	MGSO4 AQ	0	1.2002E+02	1.0014E-03	1.0203E-03	-2.991	1.0188E+00
22	MGHCO3	1	1.0504E+00	1.2364E-05	9.6902E-06	-5.014	7.8374E-01
21	MGCO3 AQ	0	3.1455E-02	3.7467E-07	3.8173E-07	-6.418	1.0188E+00
29	CAOH	1	3.1833E-04	5.6006E-09	4.5195E-09	-8.345	8.0697E-01
32	CASO4 AQ	0	3.7795E+02	2.7883E-03	2.8409E-03	-2.547	1.0188E+00
30	CAHCO3	1	3.1600E+00	3.1394E-05	2.5132E-05	-4.600	8.0054E-01
31	CACO3 AQ	0	1.7381E-01	1.7442E-06	1.5888E-06	-5.799	9.1091E-01
44	NASO4	-1	2.0895E+02	1.7628E-03	1.4112E-03	-2.850	8.0054E-01
43	NAHCO3	0	1.7535E+00	2.0969E-05	2.1364E-05	-4.670	1.0188E+00
42	NACO3	-1	3.4890E-02	4.2220E-07	3.3799E-07	-6.471	8.0054E-01
94	NACL	0	1.8888E-29	3.2460E-34	3.3072E-34	-33.481	1.0188E+00
46	KSO4	-1	6.3315E-01	4.7048E-06	3.7664E-06	-5.424	8.0054E-01
95	KCL	0	4.8024E-32	6.4697E-37	6.5915E-37	-36.181	1.0188E+00
63	HSO4	-1	9.3721E-03	9.6973E-08	7.6614E-08	-7.116	7.9006E-01

MOLE RATIOS FROM   MOLE RATIOS FROM

ANALYTICAL MOLALITY			COMPUTED MOLALITY			LOG ACTIVITY RATIOS		
CL/CA	=	1.8169E+00	CL/CA	=	3.0571E+00	LOG CA/H2	=	11.2572
CL/MG	=	4.6756E+00	CL/MG	=	7.4838E+00	LOG MG/H2	=	10.8835
CL/NA	=	2.9181E-01	CL/NA	=	3.0435E-01	LOG NA/H1	=	5.5323
CL/K	=	1.4180E+02	CL/K	=	1.4971E+02	LOG K/H1	=	2.8319
CL/AL	=	1.2748E+28	CL/AL	=	1.2748E+28	LOG AL/H3	=	21.0300
CL/FE	=	1.2748E+28	CL/FE	=	1.2748E+28	LOG FE/H2	=	14.0200
CL/SO4	=	4.9364E-01	CL/SO4	=	6.2900E-01	LOG CA/MG	=	.3737
CL/HCO3	=	8.5108E+00	CL/HCO3	=	8.9435E+00	LOG NA/K	=	2.7005
CA/MG	=	2.5734E+00	CA/MG	=	2.4480E+00			
NA/K	=	4.8595E+02	NA/K	=	4.9191E+02			

DAILEY WELL - EPNG

	PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT
18	ANHYDRIT	1.395E-05	4.130E-05	-4.856	-4.384	3.376E-01	-.472
22	ARAGONIT	9.457E-10	4.612E-09	-9.024	-8.336	2.051E-01	-.688
151	ARTIN	1.765E-26	3.981E-19	-25.753	-18.400	4.433E-08	-7.353
20	BRUCITE	7.928E-18	3.890E-12	-17.101	-11.410	2.038E-06	-5.691
13	CALCITE	9.457E-10	3.312E-09	-9.024	-8.480	2.855E-01	-.544
12	DOLOMITE	3.783E-19	8.128E-18	-18.422	-17.090	4.654E-02	-1.332
19	GYPSUM	1.390E-05	2.498E-05	-4.857	-4.602	5.565E-01	-.255
65	HALITE	3.307E-04	3.819E+01	-3.481	1.582	8.659E-06	-5.063
118	HUNTITE	6.051E-38	3.090E-31	-37.218	-30.510	1.958E-07	-6.708
39	HYDMAG			-54.695	-37.820		-16.875
11	MAGNESIT	4.000E-10	5.754E-09	-9.398	-8.240	6.951E-02	-1.158
67	MIRABI	8.819E-06	7.709E-02	-5.055	-1.113	1.144E-04	-3.942
59	NAHCOL	3.799E-05	2.831E-01	-4.420	-.548	1.342E-04	-3.872
61	NATRON	5.981E-10	4.887E-02	-9.223	-1.311	1.224E-08	-7.912
150	NESQUE	3.982E-10	6.152E-06	-9.400	-5.211	6.473E-05	-4.189
66	THENAR	8.952E-06	6.622E-01	-5.048	-.179	1.352E-05	-4.869
62	THRNAT	6.062E-10	1.334E+00	-9.217	.125	4.546E-10	-9.342
60	TRONA	2.299E-14	1.603E-01	-13.638	-.795	1.434E-13	-12.843

El Paso Natural Gas Company
San Juan River Plant
Kirtland, New Mexico

LAND APPLICATION FEASIBILITY STUDY
SAN JUAN RIVER PLANT

PHASE I FINAL REPORT

Submitted To:

El Paso Natural Gas Company
Farmington, New Mexico

August, 1987

K. W. Brown & Associates

LAND APPLICATION FEASIBILITY STUDY
SAN JUAN RIVER PLANT
PHASE I FINAL REPORT

prepared for

El Paso Natural Gas Company
Compliance Engineering Department
Farmington, New Mexico

prepared by

K. W. Brown & Associates, Inc.
6 Graham Road
College Station, Texas 77840

August, 1987

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

EXECUTIVE SUMMARY

El Paso Natural Gas (EPNG), as part of a discharge plan submitted to the New Mexico Oil Conservation Division, is proposing the land treatment and disposal of approximately 9.67 million gallons of non-contact wastewater produced annually at the San Juan River Plant (SJRP). The wastewater would be land applied on plant property using conventional irrigation equipment. A three phase study is currently being conducted to evaluate the feasibility of land treatment as a disposal option. The first phase of the study is complete and is described in this report.

The first phase addressed wastewater quality and site specific conditions which may impact the management of the land application program. Two sites were selected for possible use in the project, one on the east side of the facility and the other to the southwest of the main plant.

During Phase I, it was determined through chemical analysis that the wastewater contains significant amounts of sodium (2,034 mg/l), chloride (3,183 mg/l), and total dissolved solids (TDS = 6,399 mg/l). Although salts are present at relatively high concentrations by comparison to conventional agricultural irrigation water, levels present do not prohibit land treatment and disposal of the wastewater at the EPNG SJRP. These levels will, however, require that the selected site be carefully managed in respect to application rates and soil conditions to ensure successful operation of the land treatment program. Concentrations of other constituents in the wastewater do not pose any special management concerns.

Site specific characteristics investigated include soils, geology, hydrology, climatic factors, and local vegetation. From the investigative work conducted both in the field and by reviewing published information, it was determined that the soils present on the West site are inferior to the

East site soils. Due to physical and chemical characteristics, West site soils will require a higher level of management than East site soils. Physical characteristics of concern in West site soils include slope (greater than 4%), high wind erodibility, and low moisture holding capacity. Chemical properties of concern at the West site are high salt content and low cation exchange capacity. East site soils, although superior to West site soils, will require a moderate level of management to insure success of the land application project. The East site soils have excellent hydraulic conductivities, which are necessary for irrigation with saline wastewater, are sufficiently deep (> 72 inches), and are not as susceptible to wind erosion as the West site soils. In addition, the East site has a slope of 1 to 3%, which will reduce runoff problems and provide easier installation and operation of irrigation equipment. Furthermore, East site soils do not contain as high a level of native salts as West site soils.

In addition to determining the suitability of soils, Phase I of the study established that the geology and local hydrologic conditions in the area are amenable to wastewater irrigation. Local geologic materials, which primarily consist of alluvial sediments, are of the correct texture and sufficient thickness to protect the groundwater from any wastewater constituents which might migrate from surface soils. Furthermore, the groundwater is at a depth in excess of 50 feet on the West site and 60 feet at the East site. Hydrologic conditions across the area appear to be fairly consistent, exhibiting hydraulic conductivities of 2×10^{-5} cm/sec for the alluvial sediments.

The quality of the groundwater has been estimated using analytical results from wells sampled in the area. These results indicate the quality of groundwater to the east and south of the facility is poor (TDS = 3,233 mg/l), while groundwater quality to the southwest of the facility is within WQCC standards (TDS = 605 mg/l). Since the concentrations of sodium, chloride, and total dissolved solids of the wastewater exceed the values derived for the local groundwater, groundwater monitoring will be required when the project is implemented.

The local water balance was calculated to determine the acreage required for land treatment of the 9.67 million gallons of wastewater and to define the size of the wastewater storage facility required during periods when irrigation may not be possible (i.e., winter months). Based on the water balance calculations, the area required for efficient land treatment and disposal is 25 acres and the storage capacity needed is 1,642,671 gallons. These figures are initial estimates which may be refined during Phase II of the feasibility study, if implemented.

Finally, native plant species found at the site were identified and their relative tolerance to irrigation with salt water was evaluated. It was determined that most of the plant species present are relatively salt tolerant and should survive, if not thrive, on the irrigated area.

From the information gathered during Phase I, there is every indication that land application of wastewater is a viable option for the San Juan River Plant. Based on the results and conclusions presented in this report, it is recommended that Phase II be initiated.

1.0 INTRODUCTION AND GENERAL INFORMATION

In May 1987, El Paso Natural Gas (EPNG) contracted K. W. Brown & Associates, Inc. (KWB&A) to conduct a land application feasibility study at the San Juan River Plant (SJRP), located in Section 1, Township 29 N, Range 15 W, San Juan County, approximately 8 miles west of Farmington, New Mexico (Figure 1-1). Two potential EPNG land application sites have been identified. One site is located on the east side of the facility (East site) and the other is to the southwest of the main plant (West site).

This report addresses the requirements of Phase I of the feasibility study. The primary objectives of Phase I were to determine how site specific characteristics will influence land application of non-contact wastewater and to determine if those limitations found to exist were severe enough to prevent proceeding to Phase II. To determine the degree of influence of site specific factors it was necessary to obtain qualitative and quantitative information.

When conducting the Phase I site investigation, existing information concerning the proposed site, wastewater quality, groundwater presence and quality, and management of soils and plants to be irrigated with saline water was reviewed. This review identified information deficiencies which needed to be addressed during the site investigation and aided in the interpretation of data gathered during field work. Information reviewed included government documents on the soils, geology, hydrology, and climate for the Farmington area. Technical papers reporting on wastewater irrigation, impact of saline waters on soil, and salt tolerance of vegetation were also used. In addition, existing wastewater quality information provided by El Paso Natural Gas in the 1986 discharge plan was reviewed.

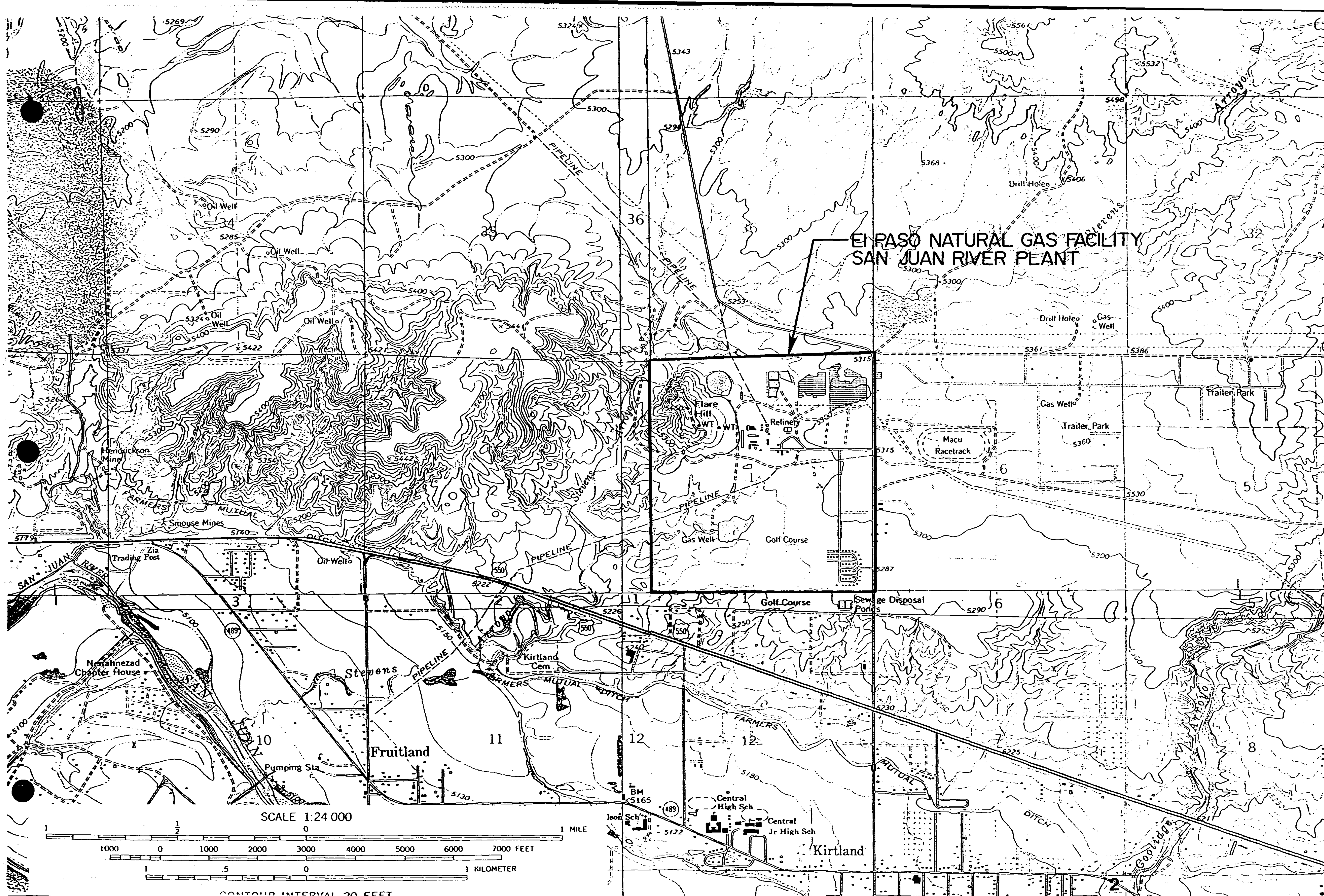


FIGURE 1-1. LOCATION OF El PASO NATURAL GAS, SAN JUAN RIVER PLANT.

The Soil Conservation Service (SCS) Soil Survey of San Juan County, New Mexico and the SCS National Soils handbook were used to review general soils information for the proposed irrigation site. Site suitability was determined by comparison of data acquired in the soil survey conducted by KWB&A with SCS-recommended chemical and physical properties for soils used in wastewater irrigation. These recommendations are listed in the National Soils Handbook. Furthermore, technical reports from scientific journals and agricultural handbooks were used to predict soil management needs arising from irrigation with saline water.

Geology and hydrology information published by professional societies (e.g., The New Mexico Geological Society, state agencies including the New Mexico Bureau of Mines and Mineral Resources, and federal agencies such as the U.S. Department of the Interior and U.S. Geological Survey) were used in the determination of the regional and local geology of the proposed irrigation sites. Review of this information provided guidance for the detailed field investigation of the geology at the EPNG SJRP.

National Oceanic and Atmospheric Administration (NOAA) climatological data from Farmington, New Mexico were obtained and reviewed. The data were used to compute a water balance for the proposed site. Subsequently, the water balance was used for determination of required acreage for irrigation and storage capacity for wastewater during winter months.

Scientific journals and texts reporting on native plant species located in the Farmington, New Mexico area and on salt tolerant vegetation were also reviewed. This information was used in identifying vegetation present at the proposed irrigation area and making recommendations on vegetation types which could be used in conjunction with the wastewater irrigation program at EPNG SJRP.

Before any determination concerning the suitability of the site for wastewater application could be made, it was necessary to define the characteristics of the water to be land applied (Section 2.0). To evaluate the nature of the wastewater, samples from the various waste streams were analyzed and a weighted average representative of the composited wastewater flow was determined. From this information, wastewater constituents present in concentrations which warrant concern were identified.

Objectives of the soils investigation (Section 3.0) were to identify the texture, water holding capacity, hydraulic conductivity of various horizons, and chemical characteristics of the soil. From this information, it was determined if the soil had the capacity to accept the quantity of wastewater and wastewater constituents generated without detriment to soil properties. This information also allowed predictions concerning the fate of wastewater constituents.

The objectives of the geologic investigation (Section 4.0) were to identify and describe unsaturated sediments between the surface soils and the groundwater. Information obtained from the geologic investigation included texture and moisture content as well as the chemical properties of the sediments. These sediments serve as a buffer to prevent migration to groundwater and define the ability of the site to isolate wastewater.

In order to assess the potential impact wastewater could have on the local groundwater resource, it was necessary to determine hydrologic parameters (Section 5.0) and groundwater quality (Section 6.0). To achieve these objectives, piezometer test data were used to define the depth to groundwater and the hydraulic conductivity of the sediments. In addition, the chemical characteristics of the groundwater were documented from samples collected at privately owned wells near EPNG's SJRP. This information established a baseline for the occurrence, movement, and quality of groundwater at the proposed land application sites.

Three final site specific conditions investigated included defining the local water balance (Section 7.0), identifying the influence of native plant species present (Section 8.0), and surveying the elevations and locations of piezometers, soil pits, and monuments at the facility (Section 9.0). Consideration of these items was essential in achieving the ultimate objective of the project since vegetation increases water loss through evapotranspiration and the water balance defines potential inputs and losses of moisture. Understanding these factors will, in part, determine the effectiveness of the land application project.

2.0 WASTEWATER

This section discusses possible sources of wastewater at the EPNG SJRP and the quality of each source. Also presented are factors which may limit the use of this water for irrigation purposes, and suggested management practices for irrigating with this wastewater.

2.1 SOURCES OF WASTEWATER

Seven sources of wastewater, each yielding different volumes (Table 2.1) and chemical compositions (Table 2.2), have been identified at the EPNG SJRP.

Table 2.1. Sources and Volumes of Wastewater Available at the EPNG SJRP.

Source	Volume (MG/yr)
Settling Tank	0.25
Evaporator	2.75
Boiler	2.00
Softener Regeneration Unit	1.25
CCD Regeneration Unit	1.38
Cooling Tower A	0.04
Cooling Tower B	2.00
TOTAL	9.67

2.2 WASTEWATER QUALITY

To determine the quality of this wastewater, each waste stream was analyzed for the parameters listed in Table 2.3. This table also contains Water Quality Control Commission groundwater standards, analytical methods, and detection levels. The results of these analyses are presented in Table 2.2 and Appendix A. It should be noted that the settling tank was empty

File Name: WASTWTR.WK1

Table 2-2. Watewater Analysis by Effluent Source, El Paso Natural Gas San Juan River Plant*.

Parameters (reported in mg/l)	Raw Water J87-22	Softener Reg. J87-25	CCD Alk Reg. J87-27	Cooling Tower A J87-26	Cooling Tower B J87-28	Evaporator Blowdown J87-23	Boiler Blowdown J87-24	Weighted Averages (Total)
COD	< 25	570	600	46	90	77.2	212	244.6
TOC	3	5	15	18	29	8	43	20
TDS	240	21,800	17,800	1,350	2,130	1,240	1,140	6,399
E.C. (umhos/cm)	350	35,000	30,000	1,500	3,000	1,900	1,800	10,354
SAR	0.6	81.5	228.6	1.6	2.5	56.4	45.9	69.2
Oil & Grease	1.50	1.00	1.00	1.00	1.70	3.28	3.35	2.29
Total K Nitrogen	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	0.40
Nitrate-N	0.50	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	8.99	1.95
Ammonia	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40	0.59	< 0.40	0.45
O-phosphate	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	30	6.3
Alkalinity (total)	64	36	310	27	18	143	436	185
Alkalinity (HCO3)	< 5	< 5	< 5	< 5	< 5	0	0	3
Arsenic	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.002	< 0.002	0.006
Barium	< 0.30	0.73	< 0.30	< 0.30	0.40	< 0.20	< 0.20	0.33
Boron	0.52	0.36	0.41	0.85	0.67	0.4	< 0.3	0.4
Cadmium	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.005	< 0.005	0.010
Calcium	33	360	45	170	270	1.97	< 1	111
Chloride	13	11,700	9,900	51	64	821	53	3,183
Chromium	< 0.02	0.03	0.02	0.05	0.03	< 0.005	< 0.005	0.016
Copper	0.01	0.04	0.02	0.17	0.10	0.01	0.24	0.08
Cobalt	< 0.05	0.10	0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.06
Cyanide	0.024	< 0.005	0.076	0.006	< 0.005	0.007	0.006	0.016
Floride	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	1.8	0.5
Lead	< 0.05	0.35	0.22	0.10	0.11	< 0.005	0.06	0.11
Magnesium	10	130	11	50	4	0.09	1.1	19.9
Manganese	< 0.01	0.61	0.01	0.08	0.04	< 0.01	< 0.01	0.09
Mercury	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001
Molybdenum	< 0.01	0.02	0.03	0.02	0.03	0.01	< 0.01	0.02
Nickel	0.08	0.32	0.27	0.21	0.15	< 0.01	< 0.01	0.12
Potassium	1.60	44.00	23.00	7.80	13.00	1.54	0.32	12.24
Selenium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.005	< 0.005	0.008
Silver	< 0.01	0.03	0.03	< 0.01	< 0.01	< 0.005	< 0.005	0.013
Sodium	15	7,100	6,600	90	150	298	280	2,034
Sulfate	77	96	570	730	1,140	172	30	390
Zinc	0.09	0.12	0.56	0.34	1.40	0.06	1.08	0.63
Estimated Flow (millions-gallons/year)	0.25	1.25	1.38	0.04	2.00	2.75	2.00	9.67
Percent of Total Flow	2.59%	12.93%	14.27%	0.41%	20.68%	28.44%	20.68%	100.00%
Regeneration Units Flow		47.53%	52.47%					
All Other Sources Flow	3.55%			0.57%	28.41%	39.06%	28.41%	

* Weighted average based on percent flow; other averages based on percent segregated flow.
E.C. values for evaporator blowdown and boiler blowdown are estimates.
Values reported below detection (<) are averaged at the detection limit.

K.W. BROWN & ASSOCIATES

Table 2.3. Analytical Parameters, Methods, and Detection Levels for Wastewater and Groundwater Samples, EPNG SJRP.*

	WQCC Standards (mg/l)	Method	Detection Level (mg/l)
pH	6 - 9	EPA 150.1	NA
EC	NS†	SM 908 A	3/100 ml
COD	NS	HACH	25
TOC	NS	EPA 415.1	1
TDS	1,000	EPA 160.1	10
Oil & Grease	NS	EPA 413.1	0.2
Total K Nitrogen	NS	EPA 351.3	1
Nitrate-N	10.0	EPA 354.1	0.01
Ammonia	NS	EPA 350.2	1
O-phosphate	NS	EPA 365.2	0.01
Alkalinity (total)	NS	EPA 310.1	5
Alkalinity (HCO3)	NS	EPA 310.1	5
Arsenic	0.1	EPA 206.2	0.005
Barium	1.0	EPA 208.1	1
Boron	0.75	EPA 212.3	0.1
Cadmium	0.01	EPA 213.1	0.05
Calcium	NS	EPA 215.1	0.2
Chloride	250	EPA 325.1	1
Chromium	0.05	EPA 218.1	0.5
Copper	1.0	EPA 220.1	0.2
Cobalt	0.05	EPA 219.1	0.5
Cyanide	0.2	EPA 235.2	0.1
Fluoride	1.6	EPA 340.1	0.1
Lead	0.05	EPA 239.1	1
Magnesium	NS	EPA 242.1	0.02
Manganese	0.2	EPA 243.1	0.1
Mercury	0.002	EPA 245.1	0.002
Molybdenum	1.0	EPA 246.1	1
Nickel	0.2	EPA 249.1	0.3
Potassium	NS	EPA 258.1	0.1
Selenium	0.05	EPA 270.2	0.005
Silver	0.05	EPA 272.1	0.1
Sodium	NS	EPA 273.1	0.03
Sulfate	600	EPA 275.3	10
Zinc	10.0	EPA 289.1	0.05

* Water Quality Control Commission Regulations amended June 18, 1986. EPA - Methods for Analysis of Waters and Wastes, EPA 600/4-79-020. SM - Standard Methods, AWWA 16th Ed.

† NS = No Standard

when wastewater samples were collected and an actual tank sample could not be obtained. Therefore, it was decided that a raw water sample would be submitted in its place since the chemical composition of the two are essentially the same, with the exception of suspended solids, which are present in the water stored in the settling tank. (The settling tank receives filter backwash water (raw water with suspended solids) from the wastewater treatment plant). The slight chemical differences which may exist between the two sources are not expected to be significant in terms of managing the land application project.

Constituents present in the wastewater can be divided into three categories: total salts, substances found in low or trace amounts, and cations and anions.

Total salt content is stated in terms of electrical conductivity (EC) or total dissolved solids (TDS). The weighted average calculated for the wastewater TDS is 6,399 mg/l, most of which can be attributed to sodium and chloride ions. A weighted average for EC was calculated using estimates reported for the evaporator and boiler.

Constituents found in low concentrations include Kjeldahl nitrogen, boron, fluoride, o-phosphate, nitrate, and ammonium ions. Among the trace elements present are arsenic, barium, cadmium, chromium, copper, cobalt, lead, manganese, mercury, molybdenum, nickel, selenium, silver, and zinc. Some of these trace elements are essential plant nutrients, such as copper, manganese, molybdenum, nickel, selenium, and zinc. However, if concentrations of these elements exceed plant requirements, they can be phytotoxic.

Cations present in the wastewater include calcium, magnesium, sodium, and potassium. Anions present are carbonate, bicarbonate, sulfate, chloride, and nitrate. These constituents contribute to the total osmotic effect and are essential for plant growth. They are additionally important because of their impact on the soil.

After reviewing the results of the wastewater analyses and comparing reported concentrations with recommended limits (Table 2.4), it was determined that total dissolved solids (6,399 mg/l), chloride (3,183 mg/l), and sodium (2,034 mg/l) are present in concentrations which warrant concern.

Table 2.4. Recommended Maximum Concentrations of Some Parameters in Irrigation Water.

Parameter	Average Wastewater Concentrations (mg/l)	Recommended Limits* (mg/l)	Reference
Total Dissolved Solids	4,198	2,250	USDA, 1969
Arsenic	0.006	0.1	EPA, 1981
Barium	0.33	None	No published value
Boron	0.44	4.0	McKee and Wolf, 1963
Cadmium	0.01	0.01	EPA, 1981
Chloride	3,183	1,500	McKee and Wolf, 1963
Chromium	0.016	0.05	EPA, 1981
Cobalt	0.06	0.1	EPA, 1981
Copper	0.08	0.2	EPA, 1981
Cyanide	0.016	0.2	McKee and Wolf, 1963
Floride	0.5	10	McKee and Wolf, 1963
Lead	0.115	5.0	EPA, 1981
Manganese	0.09	0.2	EPA, 1981
Mercury	0.001	None	No published value
Molybdenum	0.02	25	McKee and Wolf, 1963
Nickel	0.12	0.2	EPA, 1981
Selenium	0.008	0.02	EPA, 1981
Silver	0.013	None	No published value
Sodium	2,034	700	McKee and Wolf, 1963
Zinc	0.63	2.0	EPA, 1981

* Recommended limits based on wastewater and agricultural irrigation research.

2.3 FACTORS WHICH MAY LIMIT IRRIGATION

In any discussion regarding the quality of wastewater for irrigation, it is necessary to consider the effects of its constituents on plants and soils. Deleterious effects of wastewater constituents include:

1. Direct physical effects of salts preventing water uptake by plants (osmotic effects);

2. Direct chemical effects upon metabolic reactions in the plants (toxic effects); and/or

3. Indirect effects through changes in soil structure, permeability, and aeration.

Although recommended levels for constituents commonly found in wastewater are available, rigid limits can not be set due to variable factors such as gross osmotic and toxic effects. For example, the U.S. Salinity Laboratory does not recommend regular irrigation with water that has a TDS content above 2,250 mg/l (USDA, 1969). However, several cases have been reported in which irrigation waters with salinities of 4,500 mg/l TDS and higher were successfully used for agricultural purposes (van Hoorn et al., 1976; Dhir and Jain, 1976; Hardan, 1976).

Additional factors which complicate establishing absolute limits for constituents in irrigation water include site specific considerations, such as evaporation, transpiration, selective absorption by plants, variable salt tolerance of plants, and interaction among salt constituents. The effects of these site-specific conditions may result in concentrating salts in the soil-water fraction to levels which are 3 to 8 times greater than those occurring in the irrigation water (USDA, 1969).

Furthermore, good soil drainage may be a more important factor for crop growth than the salt concentration of the irrigation water. For example, even when waters of excellent quality are used, poorly drained soils will go out of production because those salts which are present can not be leached, whereas open, well-drained soils can tolerate irrigation with saline water since the salts can be leached (Eaton et al., 1941). In addition to considering possible retention of salts in the soil due to the degree of leaching, it is important to consider the effects cations and anions have on soil structure and soil chemistry.

Divalent cations, such as calcium and magnesium, act as cementing agents by helping to maintain stable soil structure. Good soil structure results in proper drainage and aeration. An abundance of monovalent cations, such as sodium and potassium, causes clays to disperse clogging soil-pores, resulting in poor drainage and aeration.

Anions, such as carbonate and bicarbonate, raise soil pH. They increase the impact of sodium on clays by precipitating calcium and magnesium out of the soil solution. This results in a greater percent saturation by sodium on the clay particle. Sulfate and chloride anions decrease soil pH. Sulfate helps remove sodium from clays and makes $NaSO_4$ available for leaching.

2.4 SUGGESTED MANAGEMENT PRACTICES

Because of the high concentrations of TDS, chloride, and sodium in the wastewater, the irrigation project should be managed for salinity and sodicity control. The following management practices are suggested:

1. Select crops that possess adequate salt and specific ion tolerance;
2. Provide proper seedbed management maintaining satisfactory levels of salinity, sodicity, and specific ion concentrations during germination;
3. Maintain adequate irrigation for crop growth and leaching; and
4. Ensure sufficient soil drainage to remove leaching waters.

3.0 SOIL SURVEY

A soil survey was conducted at the proposed EPNG wastewater irrigation site to determine soil irrigation suitability. Objectives of the survey, which included soil mapping, soil sample collection and analyses, and measurement of soil hydraulic conductivities, were as follows:

1. To determine the suitability of site soils for irrigation of non-contact wastewater;
2. To identify obvious limiting conditions for those soils that are deemed potentially suitable;
3. To provide data on soil physical and chemical properties for modeling the system; and
4. To provide an information base for facility design if the project is determined to be feasible.

Methods used by KWB&A to conduct the investigation of irrigation site soils and the results of this investigation are addressed in this section.

3.1 METHODS AND MATERIALS

To become familiar with the site, existing soils and geology information were reviewed, including the SCS soil survey of San Juan County (USDA, 1980a) and the New Mexico Geological Society report on the geology of the San Juan Basin (NMGS, 1977). The remainder of the soil survey work consisted of a field investigation at the proposed irrigation site.

After reviewing the literature, on-site soil mapping was conducted, beginning with the observation of site surface features such as:

1. Vegetation;
2. Percent cobbles on the soil surface;
3. Percent slope and slope position; and
4. Soil color and texture.

Based on these distinct features, pit locations were chosen and dug to facilitate describing, photographing and sampling of the soil profiles, thus becoming the basis for classifying the soil series within each mapping unit. (Note: A mapping unit is comprised mostly of one soil series with small inclusions of other soil series.)

A total of 10 pits were located and, using a backhoe (Photo 1, Photo Section), dug to a depth of 72 inches at the proposed irrigation sites (Figure 3-1). Four pits were dug on the East site, and six pits were dug on the West site. Two additional pits were dug on the West site because the initial reconnaissance of the sites indicated soils in this area were more variable than those on the East site.

Following soil pit descriptions and determination of mapping units, the extent of the soil mapping units was determined and mapped by:

1. Traversing each irrigation site radially from each pit in four directions to observe surface features listed above and matching them with the surface features of the map units;

2. Hand augering with a soil auger (Photo 2, Photo Section) to a depth of 2 to 3 feet to confirm subsurface horizon similarity to map units based on color, texture and structure; and

3. Plotting the extent of each map unit on a topographic map.

Upon completion of mapping the soils, soil samples were collected for chemical and physical analyses from the pit faces using a digging spade. The samples, collected from distinct soil horizons based on expressed color, textural and structural differences, were sealed in Ziploc bags and stored in an ice chest for shipping. Approximately one kilogram of soil was collected from each horizon for analyses. Analyses performed on the collected samples and analytical methods used are described in Section 3.1.2.

The last procedure in the soil survey was to measure the hydraulic conductivities of selected site soils using double-ring infiltrometers according to test method ASTM D3385-75. Hydraulic conductivities were determined for the top two horizons of pits 1, 3, 4, 6, and 8, and are

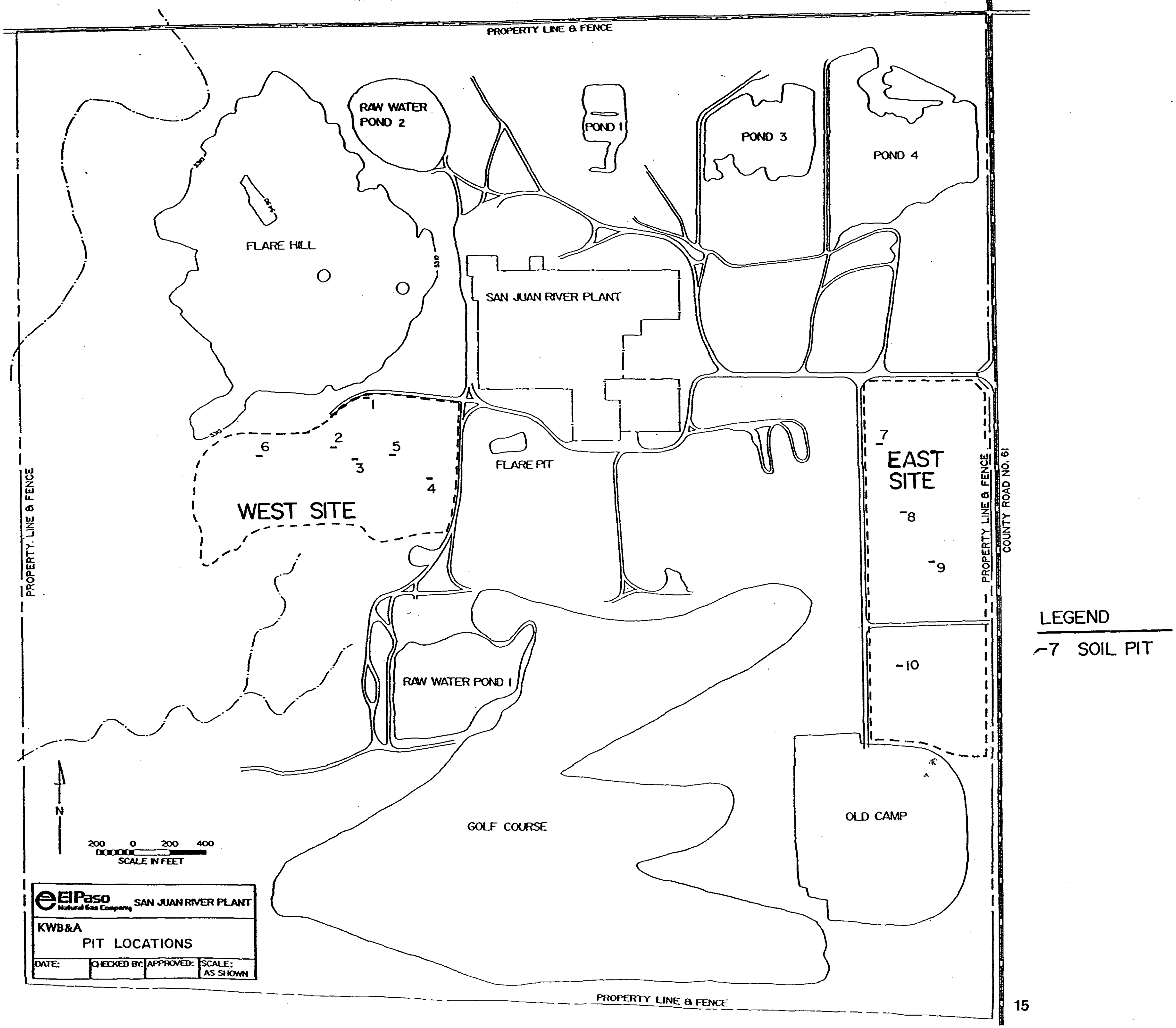


FIGURE 3-1. PIT LOCATIONS.

presented in Table 3.1. The top two horizons were chosen based on textural and structural differences which influence soil hydraulic conductivities. The lower of the two horizons generally contains more clay, and an accumulation of salts and, therefore, may possess a lower hydraulic conductivity. Photo 3 (Photo Section) shows the test equipment in place at the EPNG SJRP facility.

Table 3.1. Physical Properties of Soils at EPNG SJRP Wastewater Irrigation Sites.

Soil Series/ Depth (in)	Permea-bility (in/hr)	Erosion Factor* (K)	Wind Erodi-bility Group	Slope (%)	Available Water Capacity* (in/in)	Surface Texture
Blackston						
0-12	3.18#	0.28	5	1-3	0.14-0.17	Sandy loam
12-30	0.62#	0.10			0.07-0.10	
30-72	6.0-20.0*	0.10			0.03-0.06	
Haplargids						
0-8	1.42#	0.24	2	1-3	0.09-0.12	Loamy sand
8-13	1.38#	0.24			0.09-0.12	
13-72	6.0-20.0*	0.24			0.09-0.12	
Mayqueen						
0-4	6.0-20.0*	0.24	2	1-3	0.06-0.10	Loamy sand
4-16	2.0-6.0*	0.28			0.10-0.14	
16-72	6.0-20.0*	0.24			0.07-0.10	
Sheppard						
0-3	8.9#	0.15	2	1-3	0.06-0.08	Loamy sand
7-12	3.14#	0.15			0.06-0.08	
12-72	6.0-20.0*	0.15			0.06-0.08	
Doak						
0-6	1.33#	0.24	5	1-3	0.09-0.12	Sandy loam
6-19	1.84#	0.24			0.09-0.12	
19-72						

* Data from the San Juan County Soil Survey (USDA, 1980a).
\# Measured *in situ* using double-ring infiltrometers.

To measure hydraulic conductivities, the test required two cylinders: one with a diameter of 12 inches, and the other, 30 inches in diameter. Both rings were open at the top and bottom, with the bottom edge beveled. The outer ring was driven into the soil and care was taken to assure that the ring penetrated the soil uniformly to a depth of 6 inches. The smaller ring was centered inside the larger ring and seated in the soil. Both rings were checked for alignment with a carpenter's level.

A 50-gallon barrel supplied well water to the outer ring, and a 3-foot high, 6-inch diameter cylinder was used as the inner ring supply tube (Photo 4, Photo Section). While it would have been preferable for these infiltration tests to use water having the same quality as that which will be used during irrigation, process wastewaters were not available at the time these tests were conducted due to piping construction at the plant. Depth of water in both cylinders was maintained at 1.5 inches above the soil surface with automatic float valves (Photo 5, Photo Section). Changes in water level from the 6-inch supply tube were recorded using a Stevens Hydromark Data Logger and Stevens chart recorder (Photos 6 and 7, Photo Section). These recorded data were used to calculate the infiltration rate, as noted in Section 3.1.1 below.

3.1.1 Calculating the Infiltration Rate

During each time interval, water level drop in the 6-inch diameter cylinders was recorded, and data converted into incremental hydraulic conductivities using the following equations:

$$\text{Volume Infiltrated (V)} = \frac{d^2 H}{4} \quad (1)$$

$$\text{Infiltration Area (A)} = \frac{D^2}{4} \quad (2)$$

$$\text{Conductivity} = \frac{V}{A^* T} \qquad (3)$$

Substituting Equations 1 and 2 into Equation 3 results in Equation 4, which is used in calculating the hydraulic conductivity as follows:

$$\text{Conductivity} = \frac{d^2 x\ h}{D^2 x\ T} \qquad (4)$$

where: d = diameter of the inner ring water supply tube
D = diameter of inner ring
h = water level drop in the inner ring water supply tube
T = change in time

The conductivities were plotted and a regression analyses performed to obtain the best fitting line, with the "Y" intercept of the best fitting line recorded as the infiltration rate for the soil tested.

3.1.2 Soil Analyses

In order to estimate the potential impact of wastewater irrigation on soil chemical and physical properties, and to determine if the site quality is acceptable, certain baseline conditions were determined. A list of the analyses performed on soil samples and the analytical methods used to determine these baseline conditions is provided in Table 3.2. The analyses were performed by Deuel and Zahray Laboratories, College Station, Texas.

In addition to the laboratory analyses performed, other soil characteristics important to the evaluation of the site soils were observed in the field. These characteristics included:

1. Depth to high water table;
2. Depth to cemented pan;
3. Depth to bedrock; and
4. Slope.

Published SCS data were used to determine the susceptibility of the soils at the site to wind and water erosion.

Table 3.2. Soil Analyses Performed.

Parameter	Units	Method	Reference
Moisture Retention	--	8-2.3	Black (1965)
Bulk Density	g/cm^3	30-4.2	Black (1965)
Texture	--	43-4.0	Black (1965)
pH	s.u.	60-3.4	Black (1965)
EC	mmhos/cm	62-2.2	Black (1965)
Soluble Na	meq/L	62-3.1	Black (1965)
Soluble Ca	meq/L	62-3.1	Black (1965)
Soluble Mg	meq/L	62-3.1	Black (1965)
CO_3/HCO_3	meq/L	62-3.4.2	Black (1965)
Cl	meq/L	62-3.5.2	Black (1965)
SO_4	meq/L	NA	EPA (1979)
Extractable Cations	mg/kg	58.2	Black (1965)
CEC	meq/100 g	57.3	Black (1965)
NO_3-N	mg/kg	83-2.1	Black (1965)
PO_4-P	mg/kg	NA	USDA (1980)
K	mg/kg	NA	USDA (1980)

NA = Not applicable; no specific method number is used.

3.2 RESULTS AND DISCUSSION

Specific findings from the soil survey and how they impact the potential use of the area for wastewater irrigation are addressed in Sections 3.2.1 and 3.2.3. In summary, 5 soil series were located and mapped, 32 soil samples were collected and analyzed, and infiltration rates were determined for 11 soil horizons at 5 locations (Figure 3.2).

3.2.1 Soils Identified and Mapped

The following discussion on soils present at the proposed irrigation site is divided into three sections, as follows: 1) East site soils, 2) West site soils, and 3) general descriptions for the soil series which make up the site soils. Soil survey field notes, detailed profile descriptions, and profile photographs are included in Appendix B.

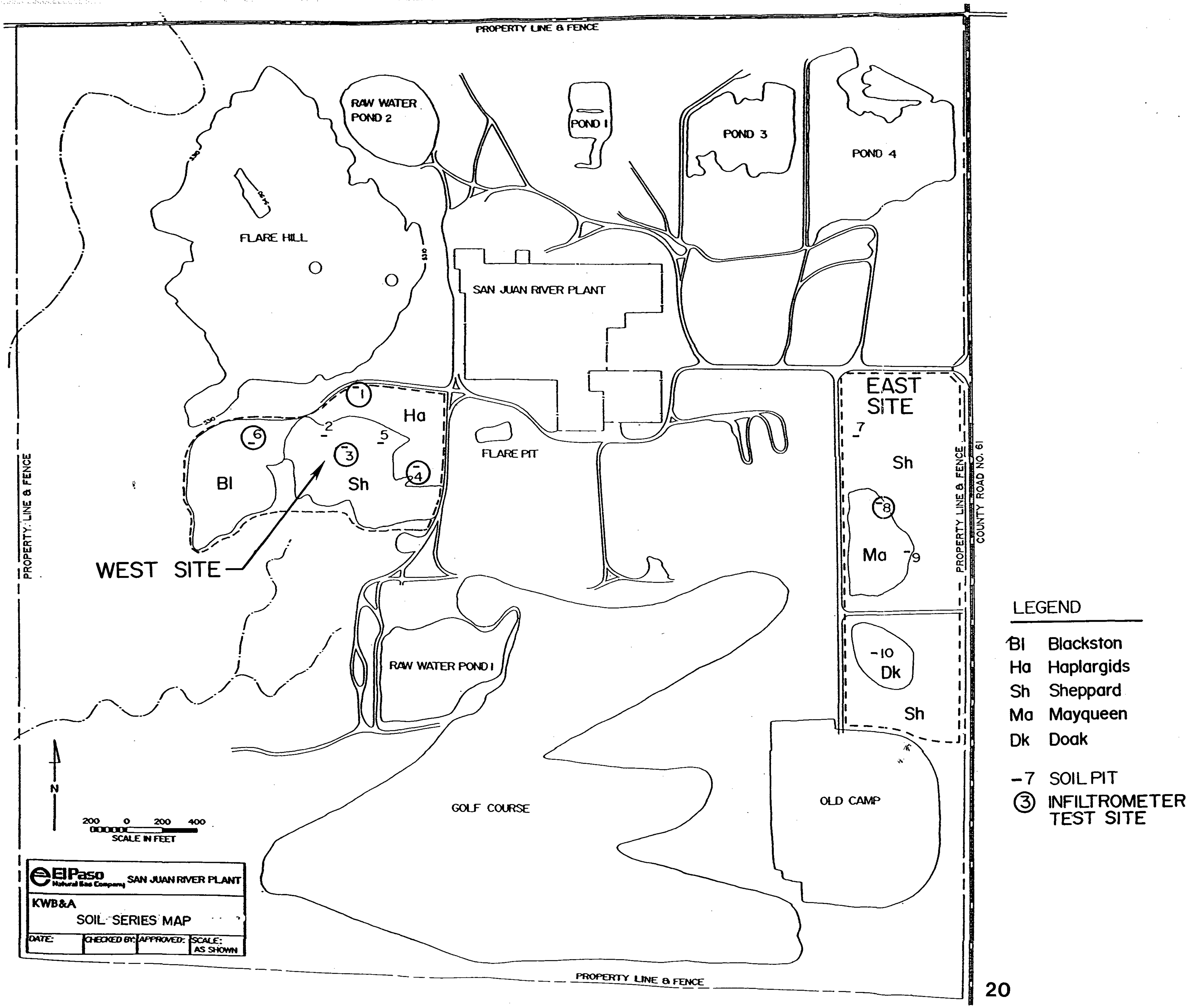


FIGURE 3-2. SOIL SERIES MAP.

3.2.1.1 East Site Soils --

The East site of the proposed irrigation site is comprised of Doak series, Sheppard series, and undifferentiated Haplargids (soil taxonomic class). These map units also include small areas of Avalon and Mayqueen soils. Doak (pit 10), Sheppard (pits 3 and 7) and Mayqueen (pits 8 and 9) series soils were located and sampled on the proposed East irrigation site. Soil series names, locations by pit numbers and acreage occupied on the proposed irrigation site are noted in Table 3.3.

3.2.1.2 West Site Soils --

Soils mapped on the West area of the proposed irrigation site include the Blackston series, Sheppard series, and undifferentiated Haplargids. Soil pedons of these map units were described and sampled. Soil map unit names, locations by pit numbers, and acreage occupied on the proposed site are noted in Table 3.3.

Table 3.3. Location and Acreage of Soils Present at the EPNG SJRP Wastewater Irrigation Site.

Soil Series	Pit No.	Acreage West	Acreage East
Blackston	6	4.5	0
Doak	10	0	1.6
Haplargids	1,4	3.5	0
Mayqueen	8,9	0	2.8
Sheppard	2,3,5,7	5.9	28.4
TOTALS		13.9	32.8

3.2.1.3 General Soil Series Descriptions --

Following are general descriptions of soil series for soils mapped at the proposed irrigation site.

Blackston Series

Blackston series soils are classified as Typic Calciorthids, loamy-skeletal, mixed, mesic. These soils are deep, well drained and formed in gravelly alluvium of mixed origin.

Doak Series

Doak series soils are classified as Typic Haplargids, fine-loamy, mixed, mesic. They are deep, well drained soils which formed in alluvial or eolian deposits derived from sandstone and shale.

Haplargids

Haplargids are well drained to excessively drained soils. The soils, formed in moderately fine textured alluvium of mixed origin, are cobbly and gravelly.

Mayqueen Series

The soils of the Mayqueen series are classified as Typic Haplargids, coarse-loamy, mixed, mesic. These are deep, somewhat excessively drained soils, and are formed in eolian sand and alluvium.

Sheppard Series

The soils in the Sheppard series are classified as Typic Torripsamments, mixed, mesic. They are deep and somewhat excessively drained soils formed in eolian material.

3.2.2 Soil Physical Properties

Soil physical features important in design and management of wastewater irrigation systems were determined at the proposed irrigation sites. These features included:

1. Depth to cemented pan;
2. Depth to high water table;
3. Depth to bedrock;

4. Available water holding capacity;

5. Hydraulic conductivity;

6. Susceptibility of the soil to wind and water erosion; and

7. Slope.

The soil survey revealed that none of the pits surveyed contained cemented pans. Furthermore, neither a seasonal high water table nor bedrock was encountered within 72 inches of the soil surface. Data for water holding capacity, hydraulic conductivity, susceptibility to wind and water erosion, and slope are detailed in Table 3.1. Hydraulic conductivity data for the site soils, determined during the soil survey, are noted in Figures 3.3 through 3.10.

An evaluation of physical properties for the irrigation site soils was made using SCS criteria (Tables 3.4 and 3.5). Although the SCS criteria are intended for use in designing conventional agricultural and municipal wastewater irrigation programs, the same soil physical and chemical characteristics are required for successful irrigation of industrial wastewater.

Based on a comparison of EPNG irrigation site data with SCS recommendations, the only site limitations based on soil physical properties are as follows:

1. High susceptibility to wind erosion (Sheppard and Mayqueen series soils);

2. Available moisture holding capacity <6 inches in upper 60 inches of soil profile (all soil series present at site); and

3. Slope of the west area (>3%).

The impact these limitations may have on the proposed irrigation project are moderate. That is, with a moderate level of site management, these soils are suitable for use in the proposed irrigation project. For

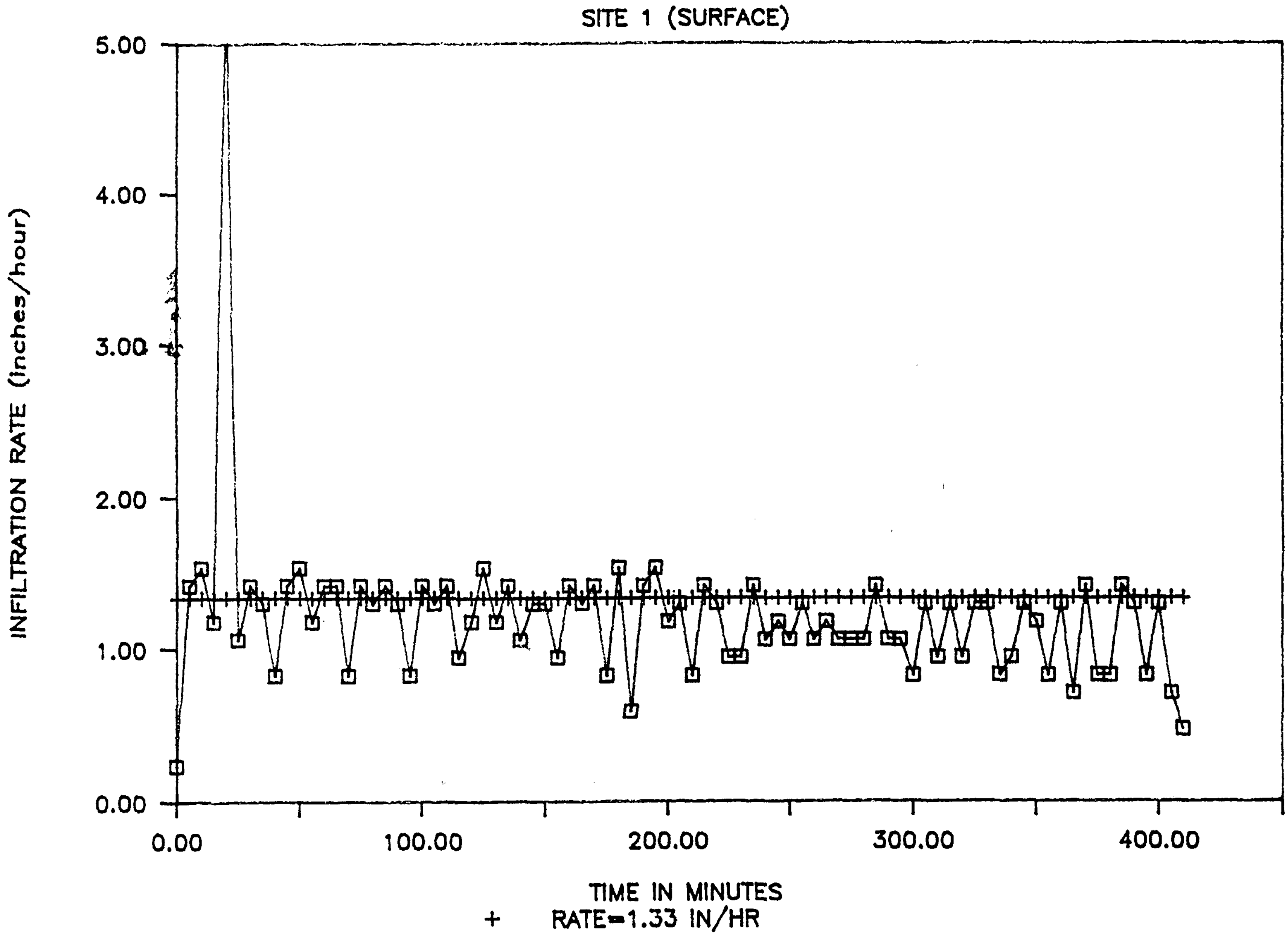


Figure 3.3. Graph of field infiltration data for the Shiprock soil series. (Surface of Pit 1).

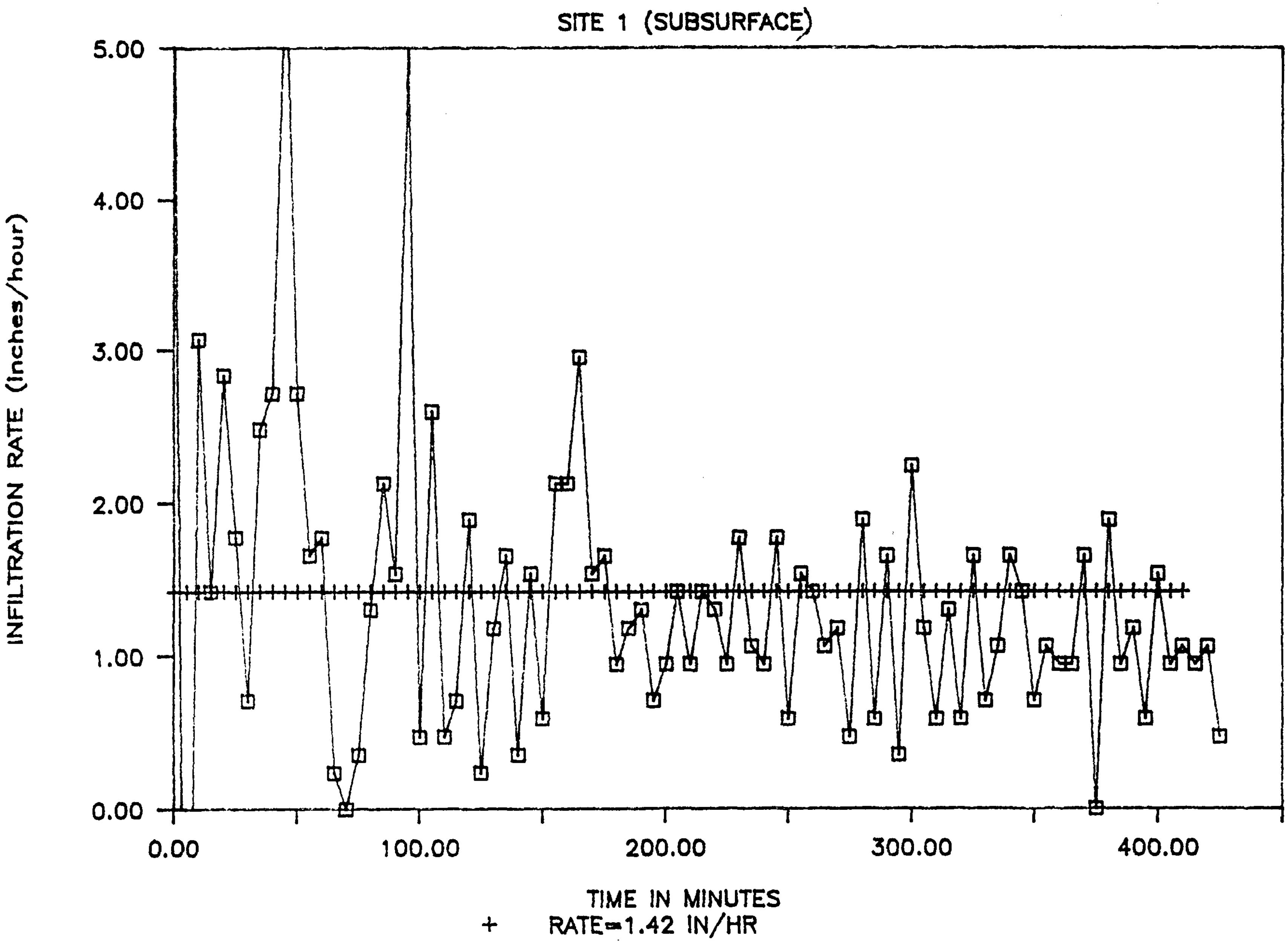


Figure 3.4. Graph of field infiltration data for the Shiprock soil series. (Subsurface of Pit 1).

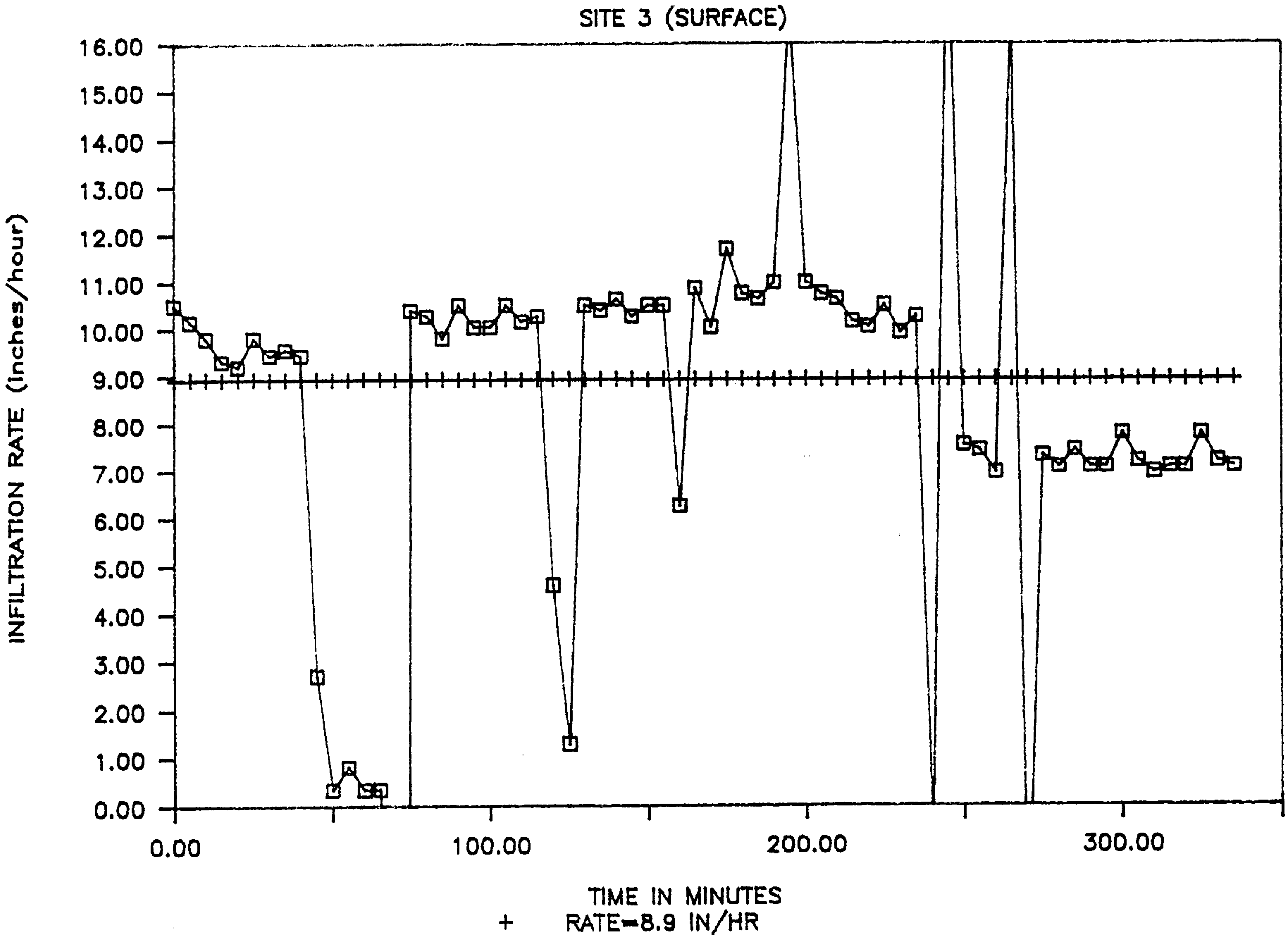


Figure 3.5. Graph of field infiltration data for the Sheppard soil series. (Surface of Pit 3).

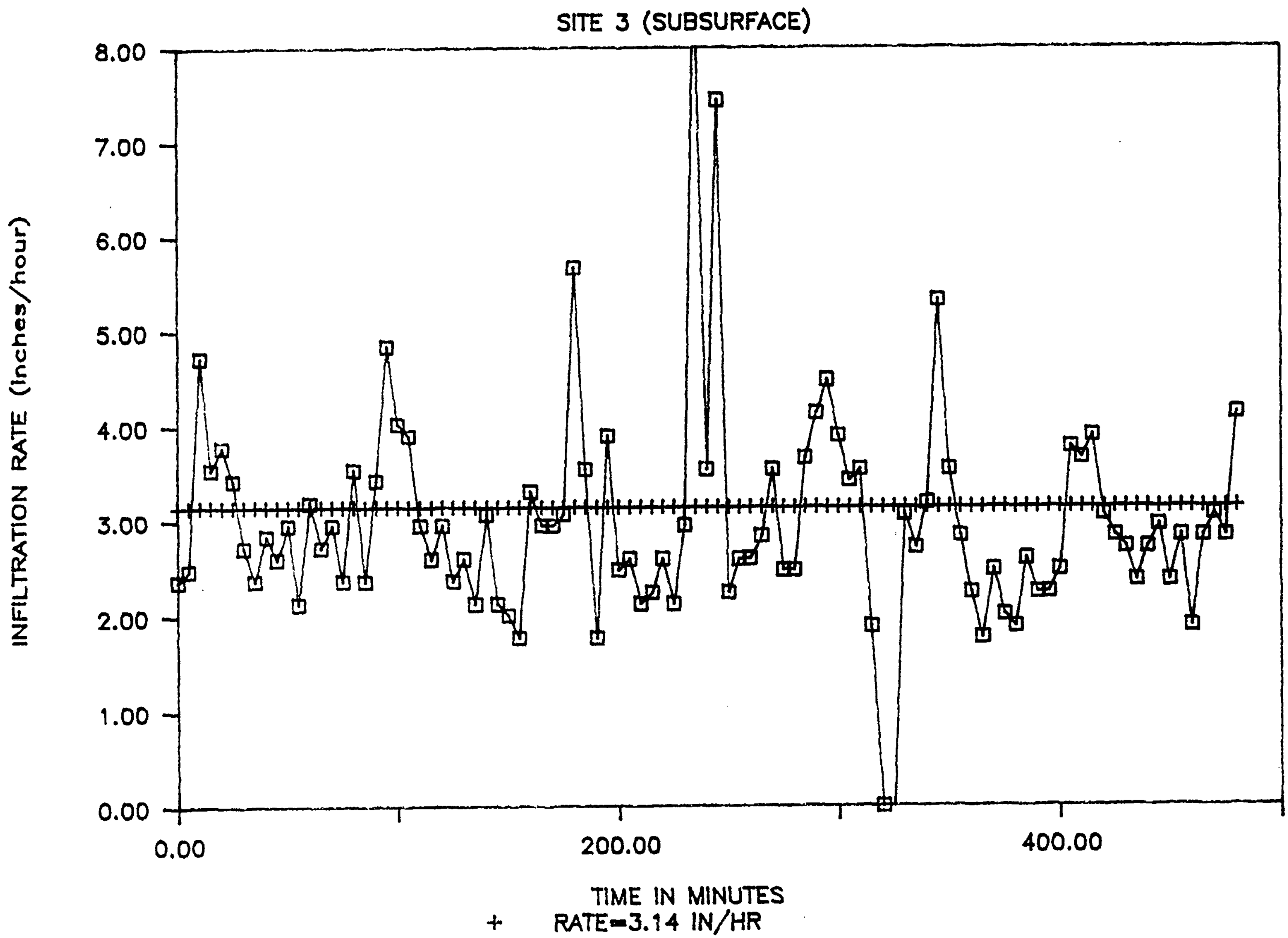


Figure 3.6. Graph of field infiltration data for the Sheppard soil series. (Subsurface of Pit 3).

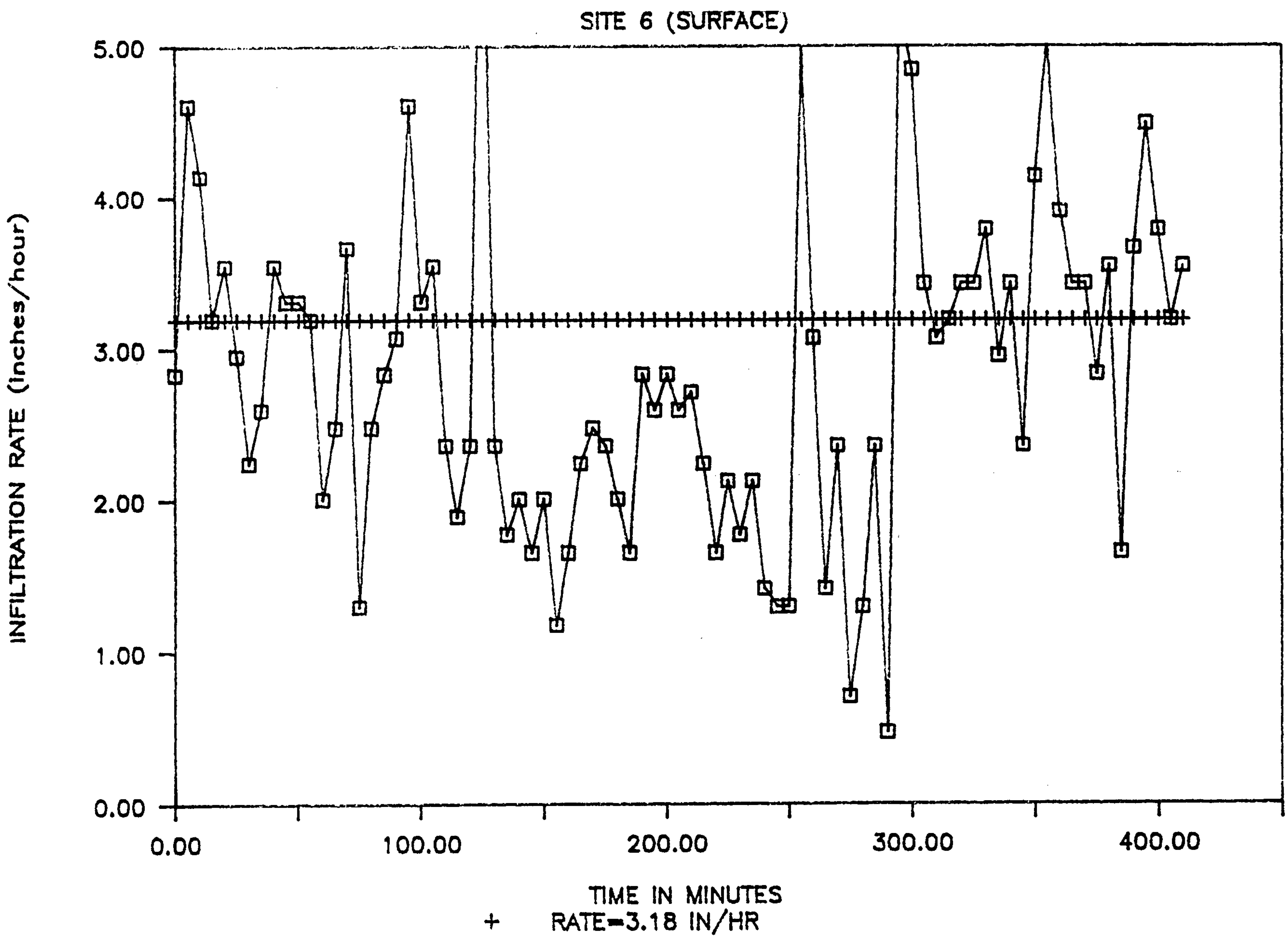


Figure 3.7. Graph of field infiltration data for the Blackston soil series. (Surface of Pit 6).

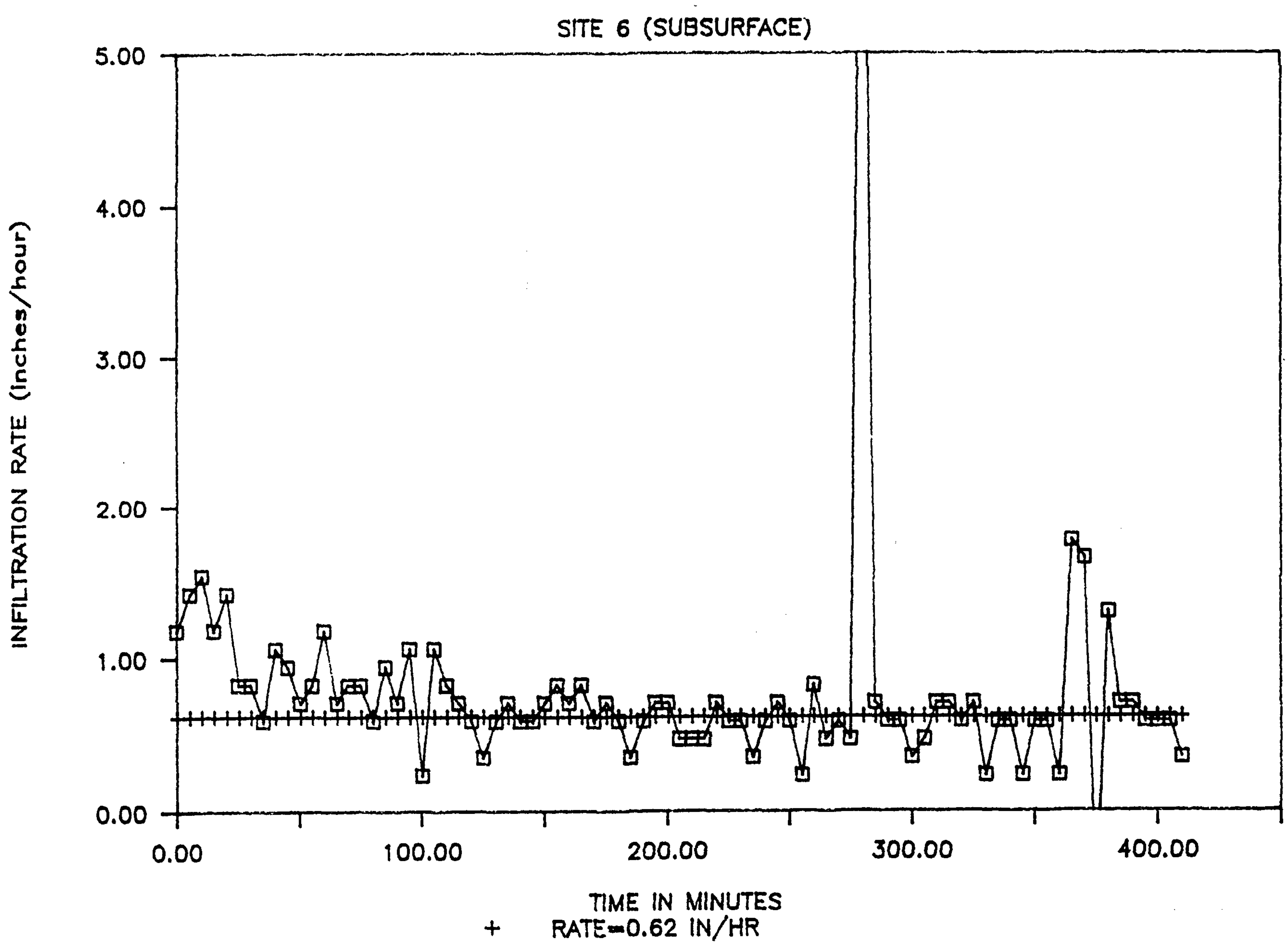


Figure 3.8. Graph of field infiltration data for the Sheppard soil series. (Subsurface of Pit 6).

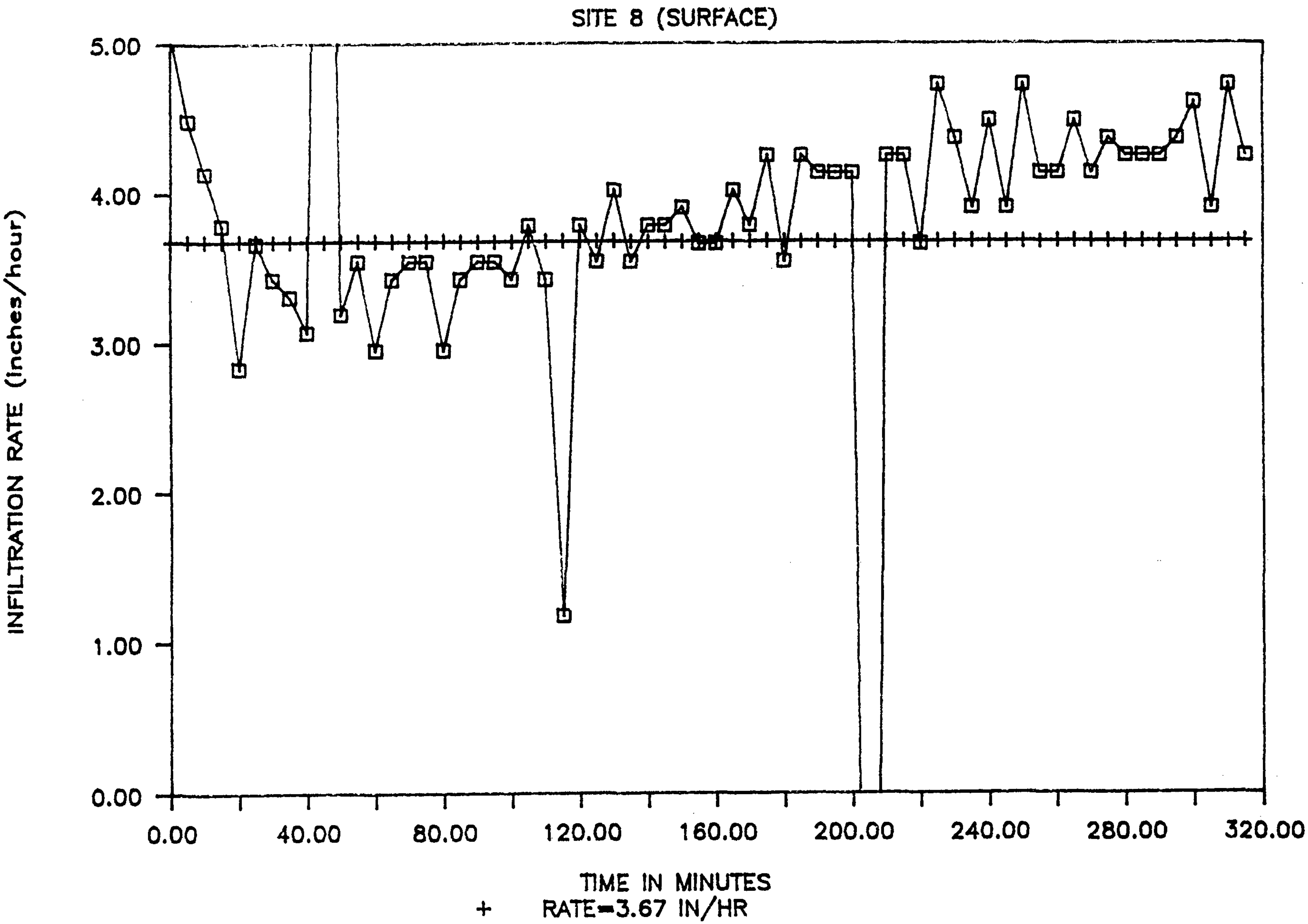


Figure 3. 9. Graph of field infiltration data for the Mayqueen soil series. (Surface of Pit 8).

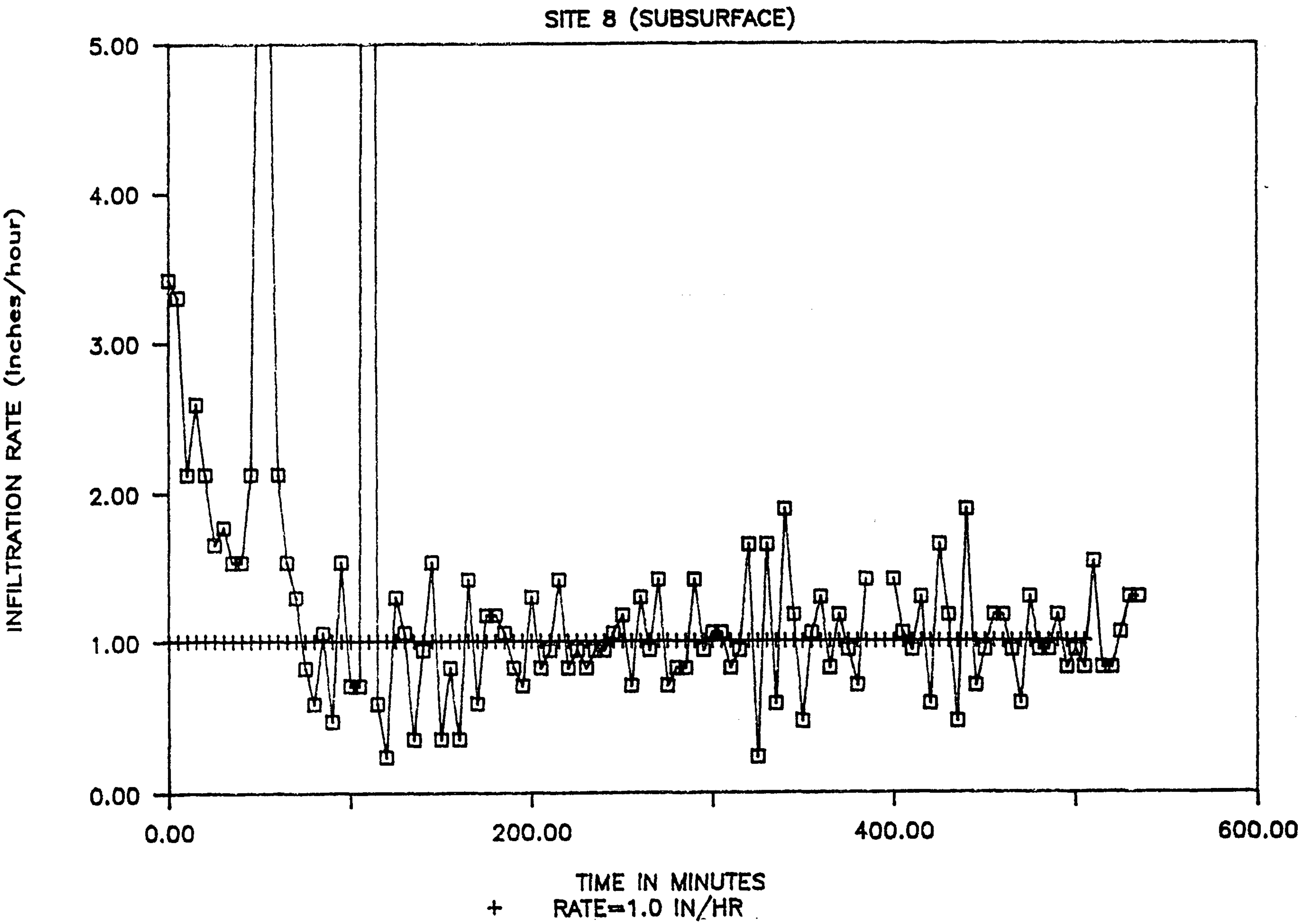


Figure 3.10. Graph of field infiltration data for the Mayqueen soil series. (Subsurface of Pit 8).

Table 3-4. SCS Criteria for Evaluating a Soil to be Conventionally Irrigated. (USDA, 1983).

PROPERTY	LIMITS	RESTRICTIVE FEATURE
1. USDA TEXTURE	ICE	PERMAFROST
2. SLOPE (PCT)	>3	SLOPE
3. 1/FRACTION >3 IN (WT PCT)	>25	LARGE STONES
4. DEPTH TO HIGH WATER TABLE (FT)	+ XIII/ <3	PONDING WETNESS
5. 1/AVAILABLE WATER CAPACITY (IN/IN)	<0.10	DROUGHTY
6. USDA TEXTURE (SURFACE LAYER)	COS, S, FS, VFS, LCOS, LS, LFS, LVFS	FAST INTAKE
7. USDA TEXTURE (SURFACE LAYER)	SIC, C, SC	SLOW INTAKE
8. WIND ERODIBILITY GROUP	1, 2, 3	SOIL BLOWING
9. PERMEABILITY (IN/HR) (0-60")	<0.2	PERCS SLOWLY
10. DEPTH TO BEDROCK (IN)	<40	DEPTH TO ROCK
11. DEPTH TO CEMENTED PAN (IN)	<40	CEMENTED PAN
12. FRAGIPAN (GREAT GROUP)	ALL FRAGI	ROOTING DEPTH
13. BULK DENSITY (G/CC) (0-40")	>1.7	ROOTING DEPTH
14. EROSION FACTOR (K) (SURFACE LAYER)	>.35	ERODES EASILY
15. FLOODING	COMMON	FLOODING
16. SODIUM ADSORPTION RATIO (0-40") OR GREAT GROUP OR PHASE	>12 (NATRIC, HALIC, ALKALI PHASES)	EXCESS SODIUM
17. SALINITY (MMHOS/CM) (0-40")	>4	EXCESS SALT
18. SOIL REACTION (pH) (ANY DEPTH)	<3.6	TOO ACID
19. COMPLEX LANDSCAPE	XI/	COMPLEX SLOPE
20. FORMATION OF PITS	XIV/	PITTING
21. CARBONATES	XV/	EXCESS LIME
22.	NONE OF ABOVE	FAVORABLE

1/Weighted average to 40 inches.

XI/If complex and irregular slopes cause difficulty in design, installation, or functioning of the system, list "COMPLEX SLOPE" as a restrictive feature.

XIII/Disregard if depth to water table is below 3 feet during growing season.

XIV/If the soil is susceptible to the formation of pits caused by the melting of ground ice when ground cover is removed, list "PITTING" as a restrictive feature.

XV/If the amount of carbonate is so high that it restricts the growth of plants, list "EXCESS LIME" as a restrictive feature.

Table 3-5. SCS Criteria for Evaluating a Soil to be Irrigated with Wastewater. (USDA, 1983).

PROPERTY	LIMITS SLIGHT	MODERATE	SEVERE	RESTRICTIVE FEATURE
1. USDA TEXTURE	---	---	ICE	PERMAFROST
2. SODIUM ADSORPTION RATIO (GREAT GROUP) (0-20")	---	---	12 (NATRIC, HALIC, ALKALI PHASES)	EXCESS SODIUM
3. SALINITY (MMHOS/CM) (0-20")	4	4-8	8	EXCESS SALT
4. SLOPE (PCT)				
SURFACE	3	3-8	8	SLOPE
SPRINKLER	6	6-12	12	SLOPE
5. DEPTH TO HIGH WATER TABLE (FT)	3	1.5-3.0	1.5	WETNESS
	---	---	+	PONDING
6. DEPTH TO BEDROCK (IN)	40	20-40	20	DEPTH TO ROCK
7. DEPTH TO CEMENTED PAN (IN)	40	20-40	20	CEMENTED PAN
8. PERMEABILITY (IN/HR) (0-60")	0.2-2.0	0.06-0.2	0.06	PERCS SLOWLY
	---	---	6	POOR FILTER
9. AVAILABLE WATER CAPACITY (IN) (0-60")	6	3-6	3	DROUGHTY
10. FRACTION 3 IN (WT PCT) (SURFACE LAYER)	15	15-35	35	LARGE STONES
11. FLOODING	NONE, RARE	OCCASIONAL	FREQUENT	FLOODING
12. EROSION FACTOR (K x % SLOPE) (SURFACE LAYER)	2	2-4	4	ERODES EASILY
13. WIND ERODIBILITY GROUP	4, 5, 6, 7, 8	3, 4L	1, 2	SOIL BLOWING
14. BULK DENSITY (G/CC) (0-40")	1.7	1.7	---	ROOTING DEPTH
15. SOIL REACTION (pH) (SURFACE LAYER)	6.5	3.6-6.5	3.6	TOO ACID
16. CATION EXCHANGE CAPACITY (AVE MEQ/100 G) (0-20")	15	5-15	5	

instance, maintenance of a good vegetative cover would minimize wind erosion. In addition, frequent water applications would be required to maintain adequate moisture in the root zone due to the low moisture holding capacity of the soil. The slope on the West side may contribute to excess runoff and create problems for irrigation equipment.

Although soils present at the proposed site have limitations due to inherent physical characteristics, these soils can be improved over time with proper management. Site organic matter management is one example. Through irrigation and correct cropping practices, soil organic matter will increase at the site. Increased organic matter will result in increased soil aggregation, thereby reducing wind erosion. Increased soil organic matter will also increase the available moisture holding capacity of the soil.

3.2.3 Soil Chemical Properties

Several important soil chemical properties for designing and managing a wastewater irrigation program were assessed at the proposed site. These included:

1. Salinity (EC);
2. Exchangeable sodium percentage (ESP);
3. Sodium adsorption ratio (SAR);
4. Cation exchange capacity (CEC); and
5. Soil reaction (pH).

Results of these chemical analyses are outlined in Table 3.6.

An evaluation of chemical properties for irrigation site soils was conducted using SCS criteria (Tables 3.4 and 3.5), and Diagnosis and Improvement of Saline and Alkali Soils, USDA Handbook 60 (USDA, 1969). Although these guidelines were designed to assist farmers in obtaining optimum crop yields from a given soil, they still serve as a standard used

Table 3-6. Soil chemical properties for samples collected from profile description pits.

Soil Series	Sample #	Pit #	Site	Depth (inches)	pH	EC mmho/cm	Soluble Cations Ca (meq/l)	Mg	Na	K	SAR	Soluble Anions CO3 (meq/l)	HCO3	Cl	SO4	Ex Na (meq/100g)	CEC	ESP %	NO3-N ppm	Plant-Available PO4-P ppm	K ppm
Haplargid	1	1	W	0-8	8.4	1.77	10.8	0.5	15.2	<0.1	6.4	<0.1	1.7	2.3	19.8	3.2	19.4	16.3	<0.1	30	205
	2	1	W	8-13	8.4	0.97	2.1	0.2	7.8	<0.1	7.2	<0.1	1.6	<0.1	7.3	2.3	26.0	8.7	<0.1	35	102
	3	1	W	13-30	8.6	1.81	7.1	0.5	15.3	<0.1	7.8	<0.1	1.4	1.8	16.2	3.0	19.9	15.1	<0.1	41	210
	4	1	W	30-35	8.6	1.85	2.8	0.4	15.2	<0.1	12.0	<0.1	1.0	2.4	16.7	2.2	15.7	13.8	<0.1	63	371
	5	1	W	35-72	8.1	4.00	22.3	3.1	21.0	<0.1	5.9	<0.1	1.0	3.6	46.6	1.2	13.0	8.9	<0.1	43	126
Sheppard	6	2	W	0-3	8.4	0.36	2.4	0.3	1.1	0.3	0.9	<0.1	1.4	0.6	2.1	<0.1	11.8	<0.1	<0.1	41	294
	7	2	W	3-7	8.3	0.42	2.2	0.3	2.4	<0.1	2.2	<0.1	1.6	1.0	2.7	0.3	18.1	1.6	<0.1	43	516
	8	2	W	7-12	8.6	0.72	2.6	0.4	4.6	<0.1	3.8	<0.1	1.2	0.2	6.7	<0.1	7.0	1.0	<0.1	46	74
	9	2	W	12-72	8.7	2.16	8.8	0.7	15.0	<0.1	6.9	<0.1	0.9	1.8	25.0	0.5	3.0	15.9	<0.1	29	63
Sheppard	10	3	W	0-7	9.0	0.19	3.3	0.4	1.2	<0.1	0.9	<0.1	1.4	0.4	0.9	<0.1	7.4	0.5	<0.1	30	86
	10d	3	W	0-7	8.8	0.19	4.4	0.5	1.2	<0.1	0.8	<0.1	1.6	0.5	1.0	<0.1	7.4	0.4	<0.1	30	82
	11	3	W	7-12	8.5	0.26	2.1	0.5	0.7	<0.1	0.6	<0.1	1.4	0.4	1.5	<0.1	11.5	<0.1	<0.1	29	143
	12	3	W	12-72	9.1	0.32	0.7	0.2	3.1	<0.1	4.7	0.3	2.0	0.6	1.6	0.6	8.2	7.9	<0.1	28	99
Haplargid	13	4	W	0-7	8.3	0.26	1.9	0.5	0.5	0.4	0.4	<0.1	1.9	0.5	1.3	<0.1	15.8	<0.1	<0.1	34	401
	14	4	W	7-20	8.8	0.40	1.3	0.2	4.5	<0.1	5.4	0.3	2.7	0.2	1.8	1.7	17.1	10.0	<0.1	29	162
	15	4	W	20-72	8.4	5.70	13.5	3.4	46.2	<0.1	15.9	<0.1	1.2	6.0	53.7	1.9	8.3	22.6	32.1	38	132
Blackston	16	6	W	0-17	8.9	1.44	1.3	0.2	12.2	0.4	14.2	0.5	7.2	1.8	9.8	7.7	25.7	29.9	0.5	47	374
	17	6	W	17-22	8.1	7.62	26.2	3.3	59.6	0.2	15.5	<0.1	1.3	21.4	66.2	4.8	17.0	28.5	<0.1	63	480
	18	6	W	22-32	8.8	2.24	3.9	0.7	18.4	<0.1	12.1	<0.1	1.2	4.8	21.1	1.1	5.5	21.0	<0.1	34	93
Sheppard	19	7	E	0-14	8.7	0.14	1.4	0.1	0.1	<0.1	0.2	<0.1	1.0	0.2	0.7	0.2	7.3	2.8	<0.1	42	109
	20	7	E	14-21	8.7	0.22	2.8	0.7	1.5	<0.1	1.2	<0.1	1.6	0.6	1.1	0.5	13.2	3.6	<0.1	28	142
	20d	7	E	14-21	8.7	0.22	1.5	0.5	1.5	<0.1	1.4	<0.1	1.6	0.5	0.9	0.5	12.4	3.8	<0.1	28	141
	21	7	E	27-72	9.0	0.46	2.2	0.2	4.9	<0.1	4.5	0.4	2.9	1.0	1.6	2.3	14.2	16.4	<0.1	23	454
Mayqueen	22	8	E	0-20	8.5	0.13	0.7	0.2	0.3	0.2	0.4	<0.1	1.0	0.5	0.3	0.2	9.3	2.1	<0.1	45	195
	23	8	E	20-32	8.5	0.27	1.4	0.5	0.8	<0.1	0.8	<0.1	1.3	0.6	1.0	0.3	12.5	2.5	0.8	20	189
	24	8	E	32-40	8.8	0.27	1.0	0.3	2.1	<0.1	2.5	<0.1	1.6	0.4	1.4	0.6	11.4	5.6	<0.1	35	626
	25	8	E	40-54	8.4	2.19	4.3	3.7	14.2	<0.1	7.1	<0.1	0.9	7.7	17.3	1.2	8.9	13.3	3.2	19	123
	26	8	E	54-72	9.0	0.94	0.6	0.6	8.4	<0.1	10.8	<0.1	1.6	3.6	3.9	1.3	6.6	19.1	<0.1	26	75
Mayqueen	27	9	E	0-18	8.5	0.12	0.8	1.2	0.1	0.3	0.1	<0.1	1.2	3.4	<0.1	0.2	6.3	3.0	<0.1	66	168
	28	9	E	18-32	8.4	0.13	2.4	0.6	0.5	<0.1	0.4	<0.1	1.4	0.6	1.2	0.4	9.1	3.9	<0.1	16	159
	29	9	E	32-72	8.8	0.20	2.5	0.8	1.0	<0.1	0.8	<0.1	1.0	0.6	1.0	0.3	5.6	5.7	<0.1	15	70
Doak	30	10	E	0-10	8.3	0.15	0.7	0.2	0.2	0.3	0.3	<0.1	1.2	0.5	0.2	0.3	13.0	2.1	<0.1	42	429
	30d	10	E	0-10	8.4	0.15	0.7	0.2	0.2	0.4	0.2	<0.1	1.3	0.4	0.2	0.3	12.7	2.4	<0.1	41	432
	31	10	E	10-23	8.6	0.16	0.9	0.5	0.2	<0.1	0.3	<0.1	1.6	0.5	0.3	0.3	10.8	2.6	<0.1	28	275
	32	10	E	23-72	8.8	0.38	3.0	0.7	3.2	<0.1	2.3	<0.1	1.2	0.6	2.5	0.9	11.2	8.4	<0.1	16	120

to judge the relative level of management required to maintain soil and vegetation in good condition. Maintaining adequate vegetation to control wind erosion, in addition to maintaining good soil tilth, permeability and fertility status, are based on soil chemical principles which are applicable to wastewater irrigation as well as conventional agricultural irrigation practices.

Based on these evaluations, the following soils have limitations due to inherent soil chemical properties. All soils sampled on the West site exhibited saline-alkali or alkali characteristics in one or more horizon. In addition, the Sheppard and Mayqueen soil series (pits 7 and 8) on the East site exhibited alkali soil characteristics. [Note: Soil is considered to be saline if the electrical conductivity (EC) of a saturated paste extract of the soil is in excess of 4 mmhos/cm but the exchangeable sodium percentage (ESP, defined as the percentage of the total cation exchange capacity of the soil occupied by sodium) is less than 15. An Alkali (sodic) soil is a soil with an ESP greater than 15.] The soils on the West site exhibiting these characteristics are the Sheppard and Blackston series and the Haplargids (pits 1, 2, 4, and 6). These limiting characteristics indicate the soils contain salts in excess of levels considered optimum for maximum vegetative yields (USDA, 1969). More specifically, for the wastewater irrigation program, the presence of these salts indicates the need for a moderate (East site) to high (West site) level of soil management. Table 3.7 compares averages for soluble sodium, soluble sulfate, EC, and ESP for West and East site soils. From these comparisons, it is evident that the soils on the West site will place an additional salt management burden on the proposed wastewater irrigation program through higher levels of site management, increased operating costs and increased risks of groundwater contamination.

Table 3.7. Comparisons of Select Soil Chemical Properties Between West and East Site Soils, EPNG SJRP.

Site	Soluble Na	Soluble SO_4	Total Soluble Salts	EC	ESP
	---------meq/L	-----------	(mg/L)	(mmhos/cm)	(%)
West	12.9	15.1	1100.8	1.72	10.6
East	2.5	2.1	243.2	0.38	6.1

3.2.4 Suggested Soil Management Practices

The development and maintenance of a successful land application system at the EPNG SJRP will involve not only the supplying of irrigation water to the site but also the control of salinity and sodicity (alkali). While there are no significant inherent soil properties of the East area soils that would limit their suitability for wastewater irrigation, these soils may develop unfavorable properties and become unproductive if excess salts or exchangeable sodium are allowed to accumulate due to improper soil management practices. This section discusses the kinds of salinity and sodicity problems that could develop and the counteractive measures that will be part of the soil management program.

The potential impacts on soils that can be anticipated from long-term wastewater irrigation are (1) salinity, the general salt effects on plant growth due largely to increased osmotic soil moisture potentials which decrease the ability of plant roots to absorb water effectively. Salinity effects are related to the total salt concentration rather than to the individual concentrations of specific salt constituents; and (2) sodicity, the effect of an excessive amount of exchangeable sodium on lowering soil permeability and infiltration rates, soil structure deterioration (crusting), and a direct toxic effect (reduced plant yields) for sodium-sensitive plants. While soil salinity will need to be monitored and managed for the irrigated soils, it is anticipated that potential sodicity impacts are of greater significance and will require that special precautions and management practices be taken.

Soil management practices that will be implemented to minimize salinity and sodicity impacts on the irrigated soils include:

1. Periodic leaching of accumulated salts with nonsodic irrigation water. These leaching events will be scheduled to provide favorable soil conditions during plant germination and emergence stages.

2. Addition of chemical additives such as gypsum, to replace exchangeable sodium and control pH;

3. If possible, incorporate organic matter such as manure, treated municipal sewage sludge, and straw or hay mulch to increase soil organic carbon contents;

4. Applying additional process irrigation water above the plant consumptive use requirements in order to move salts into the lower soil zones and prevent salt accumulation in the rooting zone; and

5. Use of a sideroll sprinkler irrigation system that will provide uniformity of application and downward movement of water through the soils, thereby favoring salinity control.

Due to the salinity of the wastewater (see Section 2.0), these management techniques will be used throughout the active life of the wastewater irrigation program. If the less suitable West area soils are selected for wastewater irrigation, they will need to be treated by one or more of these methods prior to start-up of the wastewater irrigation operation.

Soils on both the West and East sites possess moderate limitations toward vegetative productivity due to low cation exchange capacities (<15 meq/100 grams) which influence the ability of the soil to retain nutrients. Plant nutrient levels will need to be maintained by fertilizer or organic matter additions throughout the life of the irrigation project. This will be especially critical following periods of salt leaching.

4.0 GEOLOGY

In addressing site specific conditions for an area the size of the EPNG SJRP facility, it must be realized that many of the published descriptions for geologic features are limited due to their regional scope. In a detailed investigation such as this, the information gathered is more locally intensive and the correlation to regional descriptions often differs due to localized variations in a specific formation. Also, it is important to remember the scope-of-work for this project requires addressing the surface geology and shallow groundwater, not the deep formations which may contain confined aquifers. Bearing these points in mind, the following sections are offered on the regional and local geology.

4.1 REGIONAL GEOLOGY

The EPNG SJRP is located in the northeastern portion of the San Juan Basin, which is a geologic depression on the eastern edge of the Colorado Plateau. Formation of the basin began in the late Cretaceous (approximately 70 million years ago) and continued into the Tertiary. During the late Cretaceous, sediments were deposited in a shallow sea which was vacillating between transgressive and regressive sequences, giving rise to both marine and non-marine sediments (Stone et al., 1983). Sediments from the late Tertiary are rare within the basin and, therefore, it is speculated that this period of geologic time was either characterized by erosional processes or the conditions for sediment deposition did not exist (Stone et al., 1983).

Geologic formations mapped in the study area include the Kirtland Shale and alluvial sediments (O'Sullivan and Beikman, 1963). In some publications, the Kirtland Shale has not been differentiated from the underlying Fruitland Formation due to the similarity in lithology. It has been stated that the major reason for differentiating the two is based on the economic resources located within the Fruitland (Stone, 1987).

The Kirtland Shale is a late Cretaceous marine deposit which was divided into three members by Bauer (1916): the lower and upper shale members and a middle member, which he called the Farmington Sandstone. The lower member is described as a greenish-gray shale and is stated to be 271 to 1,031 feet thick; the middle sandstone member, which is described as a tan, fine- to medium-grained sandstone, has a thickness of 20 to 480 feet; and the upper member is once again described as a greenish gray shale which is 12 to 475 feet thick (Stone et al., 1983; O'Sullivan and Beikman, 1963). Although a middle sandstone member has been recognized, Stone et al., 1983) stated that sandstone is not restricted to the middle member but can also be found in the upper member, which is quite sandy.

In addition to the Kirtland Shale, alluvial sediments are present at the site. These sediments are Pleistocene and Holocene in age and are the result of alluvial and eolian processes. O'Sullivan and Beikman (1963) mapped the unconsolidated sediments at the site as Terrace Gravel and described the unit as a "surficial veneer of unconsolidated gravel and sand on stream-cut terrace surfaces along and near the San Juan River." In addition to the terrace deposits mapped at the site, O'Sullivan and Beikman (1963) describe other alluvial sediments found in the area as "unconsolidated surficial deposits of valley fill: mainly stream-deposited silt, sand, and gravel, but includes some wind-blown sand and silt, colluvial material, and locally, low-level terrace gravels."

4.2 IDENTIFICATION OF LOCAL STRATIGRAPHY

Formations present at the EPNG SJRP were identified from borings conducted on both proposed land treatment sites. Additional information reviewed includes logs from previous work conducted around the wastewater ponds, geotechnical borings associated with plant construction projects, records from local wells, and published U.S.G.S maps and reports.

4.2.1 Field Investigation

From June 8 to June 12, 1987, a total of 13 borings were drilled at the EPNG SJRP facility to describe the local surficial geology (Figure 4.1). Nine of 13 borings were on the East site and the remaining four were on the West site. Brief descriptions of the borings are included in Table 4.1 and the logs are included in Appendix C.

Table 4.1. Drilling Footage for East and West Sites, EPNG SJRP.

Location	Description	Depth (feet)
East Site		
E1A	Completed piezometer SE corner of East site	59
E1B	Completed piezometer SE corner of East site	79
E2A	Boring at NE corner of East site	21
E2B	Completed piezometer NE corner of East site	78.5
E3	Completed piezometer west side of East site	78
E4	Boring in north center of East site	26
E5	Boring in west center of East site	34
E6	Boring in southwest center of East site	34
E7	Boring in east center of East site	20
West Site		
W1	Boring NE corner of West site	12.5
W2	Completed piezometer south side of West site	62
W3	Boring at NW corner of West site	15
W4	Boring at NE side of West site	7
	TOTAL*	526

* Total footage for completed piezometer = 356.5 feet.
Total footage for borings = 169.5 feet.

Initially, a hollow stem auger drill rig (Photo 8), operated by Western Technologies out of Farmington, was contracted to provide drilling services. Due to the type of sediments encountered (i.e., cobbles) the hollow stem was unable to reach to the desired depth. Therefore, a rotary

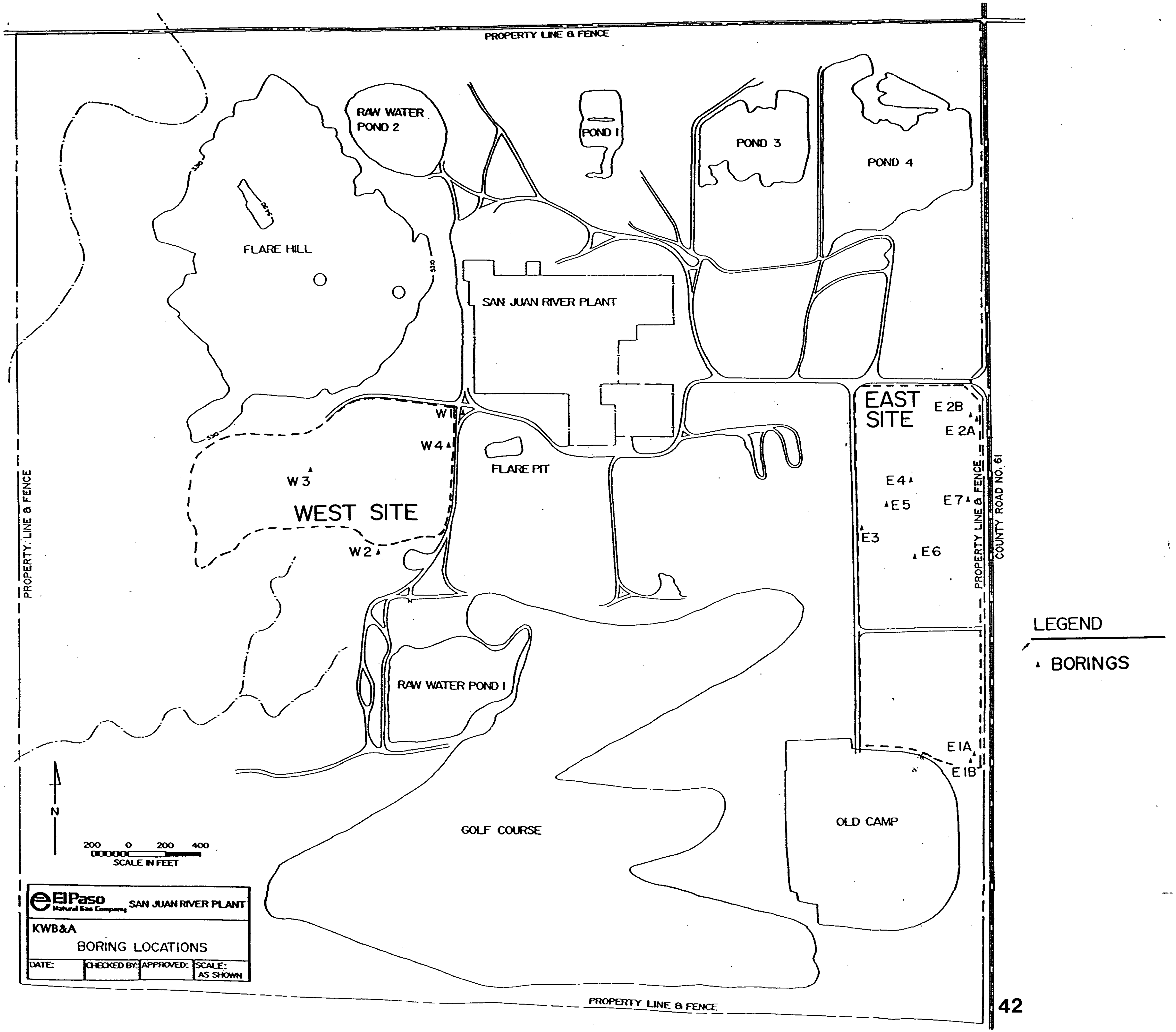


FIGURE 4-1. LOCATIONS OF BORINGS.

wash rig (Mayhew 1000) operated by MO-TE, also out of Farmington, was brought in to drill two deep borings.

Samples were collected from the hollow stem rig using 2-foot long split spoon samplers advanced through the auger. Sample collection from the rotary wash rig was via a 10-foot core barrel (Photo 9, Photo Section). All samples were described in the field and some were retained for laboratory analysis (Appendix D).

Of the 13 borings drilled, five were completed as cased piezometers. Two of the piezometers were installed above the saturated zone and three were completed in the first zone of groundwater encountered. Since specific site conditions were unknown prior to beginning field work, the installation of monitoring wells was not possible. Therefore, piezometers were installed which consisted of slip joint, 2-inch Schedule 40 PVC casings with 5-foot 0.010 machine slot Schedule 40 PVC screens. All casing connections were joined using 1/2-inch screws; no solvents or glues were used. A coarse-grained sand pack was placed around each screen and a bentonite seal was installed using 1/2-inch diameter pellets above the sand packs. Above the bentonite seal a grout slurry or a combination of cuttings and a grout slurry was used to seal the borehole to the surface. Although the piezometers are completed as monitoring wells, they are not designed for sample collection. Specific well details for each piezometer are included in Appendix E.

4.2.2 Results and Discussion

Two types of lithology have been identified from information gathered at the proposed land application sites. The uppermost and most prevalent are alluvial sediments, which cover the surface of the entire area (Photo 10, Photo Section). The alluvial sediments consist of fluvial deposits and, to a lesser extent, terrace deposits of gravel and cobbles. Beneath the veneer of unconsolidated sediments are the consolidated sediments of the Kirtland Formation, which include both shale and sandstone members. Figures 4.2 and 4.3 illustrate a map view and the geologic cross-section for the unconsolidated sediments and the consolidated members of the Kirtland Formation.

Descriptions for sediments identified during field work compare closely with the published descriptions for the Kirtland Shale, Quaternary alluvium, and the Quaternary alluvium terrace deposits. Thicknesses of unconsolidated sediments range from approximately 70 feet on the majority of the East site and in excess of 60 feet on the West site. These sediments are predominately quartzose sand with varying amounts of silt and clay. Textures of the sand vary from fine- to coarse-grained, and the degree of sorting is poor to well sorted. By and large, the matrix of the recovered samples was calcareous and cementation was limited to native salts which varied in abundance throughout the cores.

Sediments identified from borings E2A and E2B indicate that the same type of unconsolidated sediments as described above occurred to a depth of 17 feet. However, below 17 feet the lithology changed dramatically as cobbles and consolidated sandstone and shale were encountered. From a depth of 17 feet to 34 feet, gravel and cobbles were found. Below the cobbles a light tan, medium grained sandstone was found to extend to a depth of 45 feet (Photo 11), where it graded into a 1-foot layer of gray sandstone. At 46 feet there was a sharp contact with a blue-gray shale which showed evidence of weathering in the upper several feet (Photo 12). The shale continued to a depth of 69 feet, at which point a gray sandstone was encountered which contained inclusions of shale and carboniferous

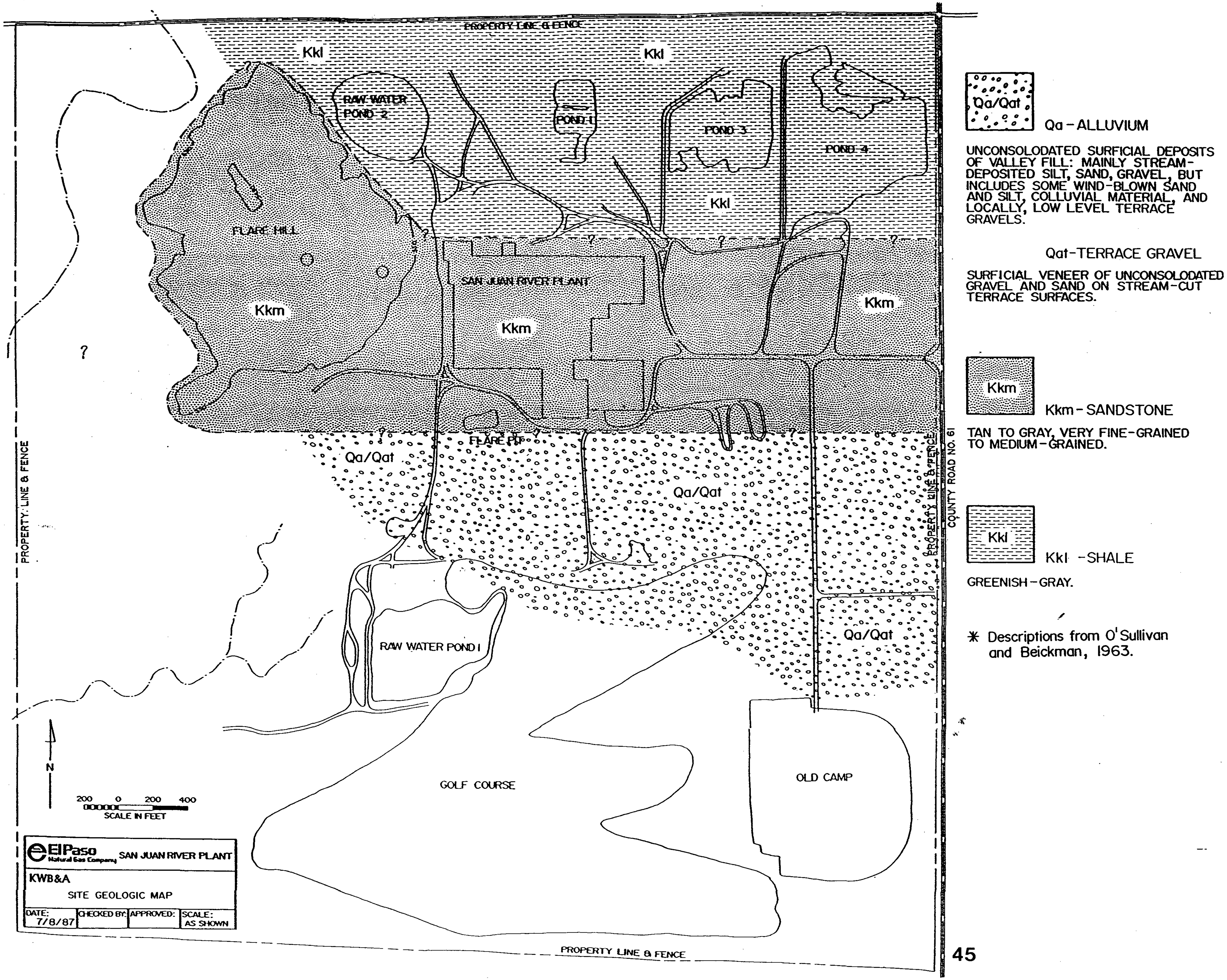


FIGURE 4-2. SITE GEOLOGIC MAP.

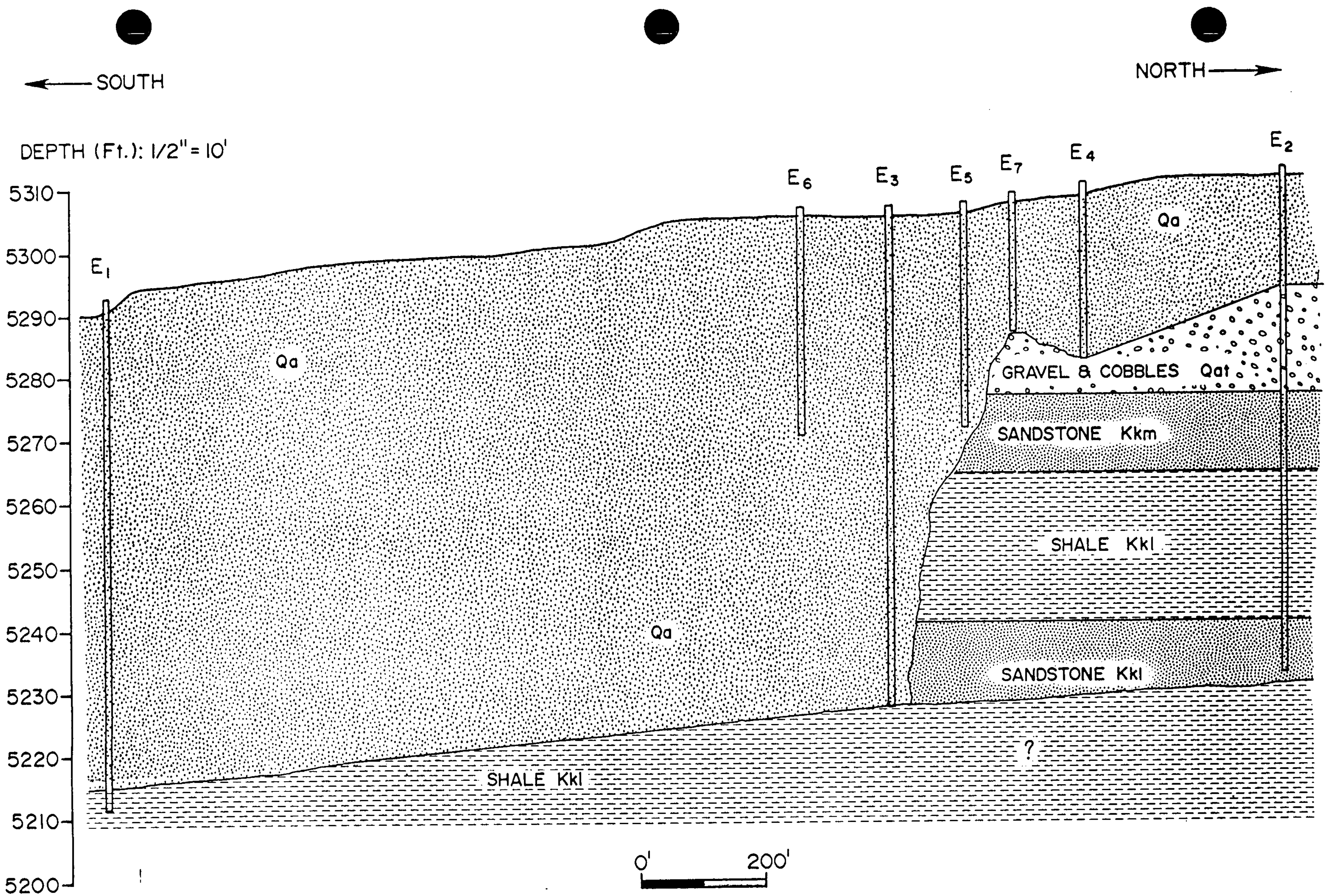


FIGURE 4-3. SITE CROSS-SECTION, EAST PLOT.

material along bedding planes (Photo 13). This gray sandstone continued to the bottom of the hole at a depth of 78.5 feet.

Materials encountered in boring E2A have been correlated with the Quaternary alluvial sediments (0 to 17 feet) and the Quaternary alluvial terrace deposits (17 to 34 feet). These have been correlated with the Jackson Lake Stream Terrace identified by Pastuszak (1968), the Farmington Sandstone, which is the middle member of the Kirtland Shale (34 to 46 feet), and the lower shale member of the Kirtland Shale (46 to 78.5 feet). The correlation between site-specific lithology and published description for the Quaternary sediments and the lower member of the Kirtland Shale is consistent. However, the occurrence of the Farmington Sandstone in this area is not. Justification for recognizing this unit can be found in the description of a "tan, fine- to medium-grained sandstone" offered by O'Sullivan and Beikman (1963) and an observation made by Pastuszak (1968), who states "terrace gravels are more extensively retained on coarse-grained or conglomeratic sandstone, such as as the Farmington Sandstone."

It is clear from Figure 4.3 that the thicknesses of the unconsolidated sediments are variable and controlled by the upper eroded surface of the underlying Kirtland Formation. The presence of erosional features, indicating removal of portions of the Kirtland shale, is consistent with the geologic history for the area, which indicates the period of time following the early Tertiary was characterized by erosional process.

4.3 GEOLOGIC STRUCTURAL FEATURES

Structural features associated with the San Juan Basin consist of thrust faults of the Cordilleran Fold Belt, upthrusts of the Rocky Mountain Foreland, a large monocline referred to as "The Hogback", volcanic intrusions associated with the Carrizo Igneous Center and Shiprock, numerous anticlines and synclines, and high angle faults (Woodward and Callender, 1977). The majority of these features are found around the perimeter of the basin.

Despite the presence of structural features around the basin, the area near EPNG SJRP is considered to be stable. Work conducted in the Farmington/Kirtland area by Pastuszak (1968) revealed the most notable structural feature to be gently southeast dipping strata (2 to 5 degrees). During his field work, Pastuszak also noted that structural features, such as folds and faults, were absent in the study area.

Observations made in the field and conclusions drawn from the site specific data are consistent with previous findings for the area. Specifically, no surface of shallow subsurface features were noted which indicate the presence of structural deformation or displacement.

5.0 HYDROLOGY

Since the potential exists for altering the quality of shallow groundwater in the area where the wastewater is to be land applied, it is necessary to identify and characterize local groundwater resources. To this end, piezometers were installed at the proposed land application areas (Section 4.0), water samples were collected from local wells (Section 6.0), and published literature for the area was reviewed. The information gathered provides an initial data base for characterizing the occurrence, quality, and movement of local groundwater.

5.1 AQUIFER IDENTIFICATION

Although deeper groundwater resources are available in the area around the EPNG SJRP, local groundwater use is primarily restricted to shallow resources located in the alluvial sediments. During the local water well survey (Section 6.0), six privately owned wells were sampled, all of which were screened in the alluvial sediments. While deeper wells were identified in the area (a 1,005 feet deep well on the EPNG facility and a 500-feet deep well to the north), it appears that these wells are screened in formations other than, and hydraulically isolated from, the alluvial sediments. Therefore, for the purpose of this study, the primary aquifer of concern will be the Quaternary alluvium.

Information offered by Stone et al. (1983) indicates that both the hydrologic and chemical characteristics of the alluvial aquifers in the region are quite variable. In terms of hydrologic characteristics, it is stated that the alluvial sediments associated with the larger river valleys in the area (San Juan, Animas, and La Plata) have transmissivities which range from 17,000 ft^2/d to 40,000 ft^2/d. Using these values and assuming a saturated thickness of 100 feet for the sediments exhibiting these transmissivities, hydraulic conductivities of 6.0 x 10^{-2} cm/sec to 1.4 x 10^{-1} cm/sec can be expected. If the saturated thickness for these same sediments is only 50 feet, the hydraulic conductivities would be increased to 1.2 x 10^{-1} cm/sec or 2.8 x 10^{-1} cm/sec. In either case, the hydraulic conductivity values are considerable. It should be noted, however, that these values are reported for "valley fill" and may not necessarily reflect conditions in alluvial sediments at higher elevations.

5.2 DETERMINATION OF HYDROLOGIC PROPERTIES

Piezometers were installed on both of the proposed land treatment sites to evaluate the behavior of groundwater beneath the study area. Information gained from the installation of the piezometers includes identification of saturated and unsaturated sediments, depth to groundwater, inferred groundwater flow direction, hydraulic conductivity of the screened sections, and transmissivities.

5.2.1 Methods and Materials

Bail tests were attempted in several of the piezometers. However, the rate of recharge was too rapid to measure a significant change in the water level. Therefore, in addition to the bail tests, falling head tests were conducted.

Bail tests followed a procedure developed by Hvorslev (1951) which is presented in Freeze and Cherry (1979). Prior to beginning the test, the static water level in the well was observed to verify the level had stabilized following piezometer installation. Having established the static water level, a 5-foot long PVC bailer was used to remove a single slug of water from the well. After the slug of water was removed, the recovery rate of the well was measured at regular intervals until the water level had returned to within 0.1 foot of the static water level. The formula for calculating hydraulic conductivity from this method is:

$$K = \frac{r^2 \ln(L/R)}{2LT_0}$$

where: K = hydraulic conductivity
r = radius of the piezometer
L = length of the screen
R = radius of the screen
T_0 = basic time lag.

Since several of the piezometers could not be tested using the Hvorslev Method, it was necessary to use a second method to determine hydraulic conductivities. The second method is referred to as a Falling Head Test and the procedure is presented in Ground Water Manual (U.S. Department of the Interior, 1981). This method is the inverse of the bail test method, in that instead of removing water and monitoring the rate of recharge, water is added to the piezometer and the head loss is measured. As in the bail test method, the static water level is determined prior to beginning the test. Once the static water level is established, a slug of water is added to the well and the rate at which the new water level drops is measured. The formula for calculating hydraulic conductivities using this method is:

$$K = \frac{r^2}{2A\,\Delta t}\left[\frac{\sinh^{-1}(A/r_e)}{2}\ \ln\left(\frac{2H_1 - A}{2H_2 - A}\right) - \ln\left(\frac{2H_1H_2 - AH_2}{2H_1H_2 - AH_1}\right)\right]$$

where: K = hydraulic conductivity
r = radius of piezometer
A = length of screen
r_e = effective radius of test section
H_x = length of water column in piezometer
t = time intervals.

Depth to water measurements for both of these methods were accomplished using a Well Wizard electronic water level indicator Model 6000.

5.2.2 Results and Discussions

Hydraulic Conductivity and Transmissivity

Piezometers tested using the bail (or pump test) method included W2, E1B, and E3. Of these, only W2 yielded useful data, whereas E1B and E3 exhibited recharge rates which exceeded the ability to remove water from the piezometers. The recharge rates for E1B and E3 were rapid enough so that it was impossible to measure changes in water levels. Therefore, these piezometers were tested using the falling head method. Once again, the rate at which water levels recovered during the falling head tests precluded the collection of useful data. However, unlike the bail tests, it was possible to estimate the hydraulic conductivity using what little data were obtained during the falling head tests. Appendix F includes the well test data and the hydraulic conductivity calculations for all piezometers, and Table 5.1 summarizes these data.

Analysis of the well test data indicates a fairly consistent hydraulic conductivity for the alluvial sediments, as seen in piezometers E1A, E1B, and E3. Respectively, the conductivities are 2.2×10^{-5}, 2.6×10^{-5}, and 2.1×10^{-5} cm/sec. Since E1B and E3 are screened in the water table just above the shale, it is possible to determine the saturated thickness of the sediments at these locations and thereby calculate transmissivity. Using saturated thicknesses of 9.68 feet for E1B and 5.75 feet for E3, and substituting the hydraulic conductivity values into the equation listed below, transmissivities of 0.62 ft^2/day and 0.34 ft^2/day are obtained.

$$T = kb$$

where T = transmissivity
k = hydraulic conductivity
b = saturated thickness

Table 5.1. Hydraulic Conductivities and Transmissivities.

Piezometer (cm/sec)	Method (ft^2/day)	Hydraulic Conductivity	Transmissivity
E1A	Falling Head	2.2×10^{-5}	ND
E1B	Falling Head	2.6×10^{-5}	0.71
E2B	Falling Head	3.3×10^{-9}	ND
E3	Falling Head	2.1×10^{-5}	0.34
W2	Bail Test	2.1×10^{-5}	ND

Hydraulic conductivity values obtained are considered to be representative of the alluvial sediments at the site. This observation is based on the comparison of results from the east piezometers and the result for W2. Hydraulic conductivities for the "E" piezometers were calculated using the falling head method, whereas the hydraulic conductivity for W2 was determined using the bail test method. Both of the methods yield values of approximately 2×10^{-5} cm/sec for the alluvial sediments, which suggests the well tests results are valid.

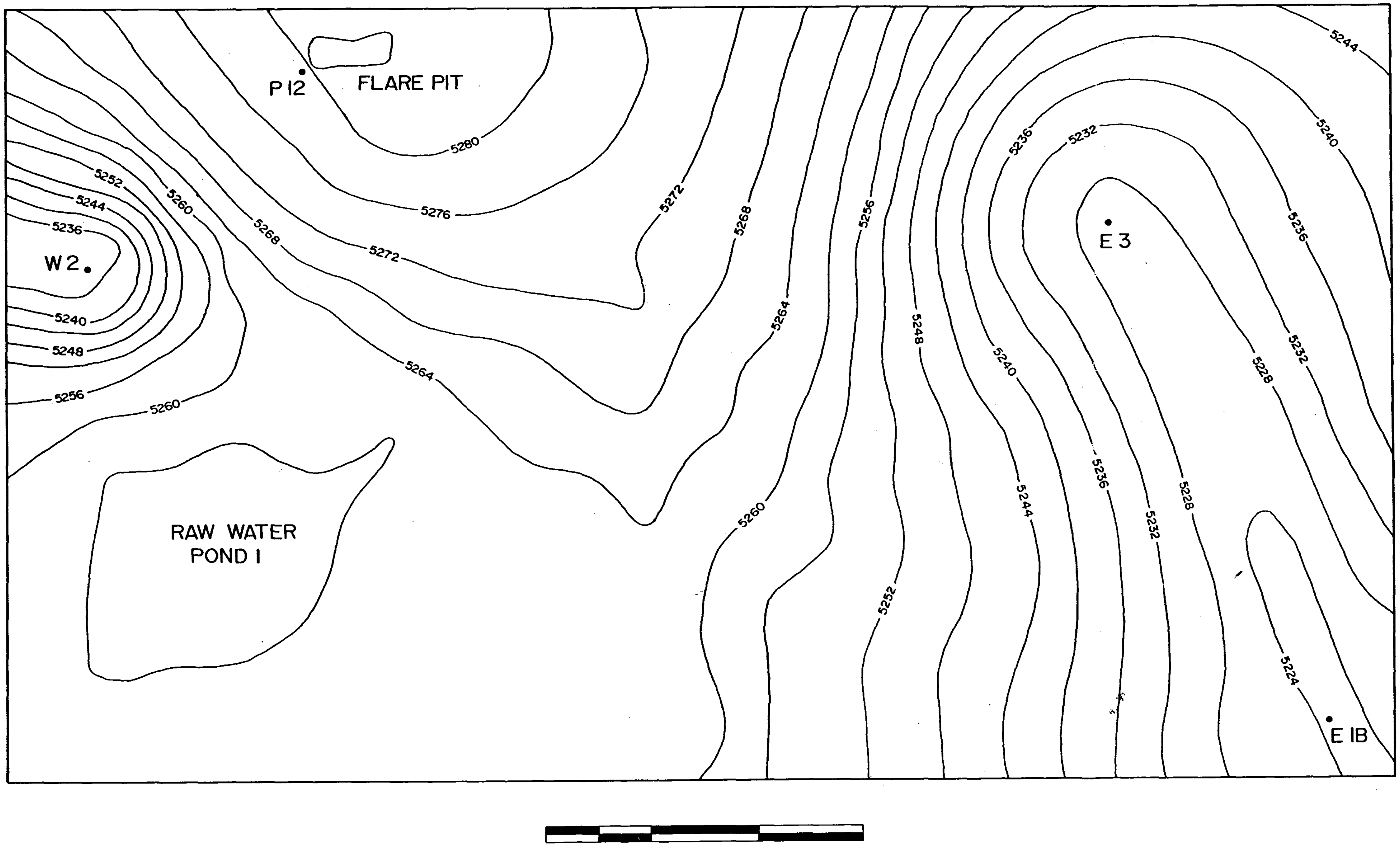
Unlike the other piezometers, E2B is screened in a sandstone within the Kirtland Shale. The falling head test method was used to determine the hydraulic conductivity of this unit. It was found that the sandstone exhibits a very low hydraulic conductivity of 3.3×10^{-9} cm/sec. This value is at or slightly below the lower limit for hydraulic conductivities of sandstones offered by Freeze and Cherry (1979). Since only one piezometer was completed in the sandstone, other data are not available to verify the reported value. It is worth noting, however, that shale clasts were identified at various levels within the sandstone (see Photo 14). Based on this observation it is reasonable to assume that the reported hydraulic conductivity value is accurate given the presence of shale in the core. The presence of this low permeability formation to the north of the proposed land application sites, if continuous, would in effect provide a no flow boundary.

Piezometric Surface

Since only three of the piezometers were actually completed in the saturated zone, and one of these is located on the West site, it is difficult to determine groundwater flow direction. The task of defining a piezometric surface is further complicated by the local areas of artificial recharge, such as the golf course and raw water pond, as well as the mounding seen at the west flare pit. Due to these local variations and the limited data available, the interpretation of potentiometric surface is questionable.

Graphic computer modeling of the potentiometric surface indicates a flow direction to the southeast (Figure 5.1). This is counter to previous findings offered in the original El Paso Natural Gas Discharge Plan (1986), which indicates groundwater flow to the southwest (Figure 5.2). In addressing the discrepancies between these findings, local topography, flow of the San Juan River (which represents the regional topographic low), and discussions with Bill Stone in the field were evaluated. Conclusions drawn from this information are consistent with the findings presented in the original discharge plan and conventional hydrogeologic interpretations. Given there are so few control points to support the southeasterly

PIEZOMETRIC SURFACE (UPPERMOST AQUIFER)-EPNG



N

FIGURE 5-1. PIEZOMETRIC MAP, EAST AND WEST SITES, EPNG SJRP.

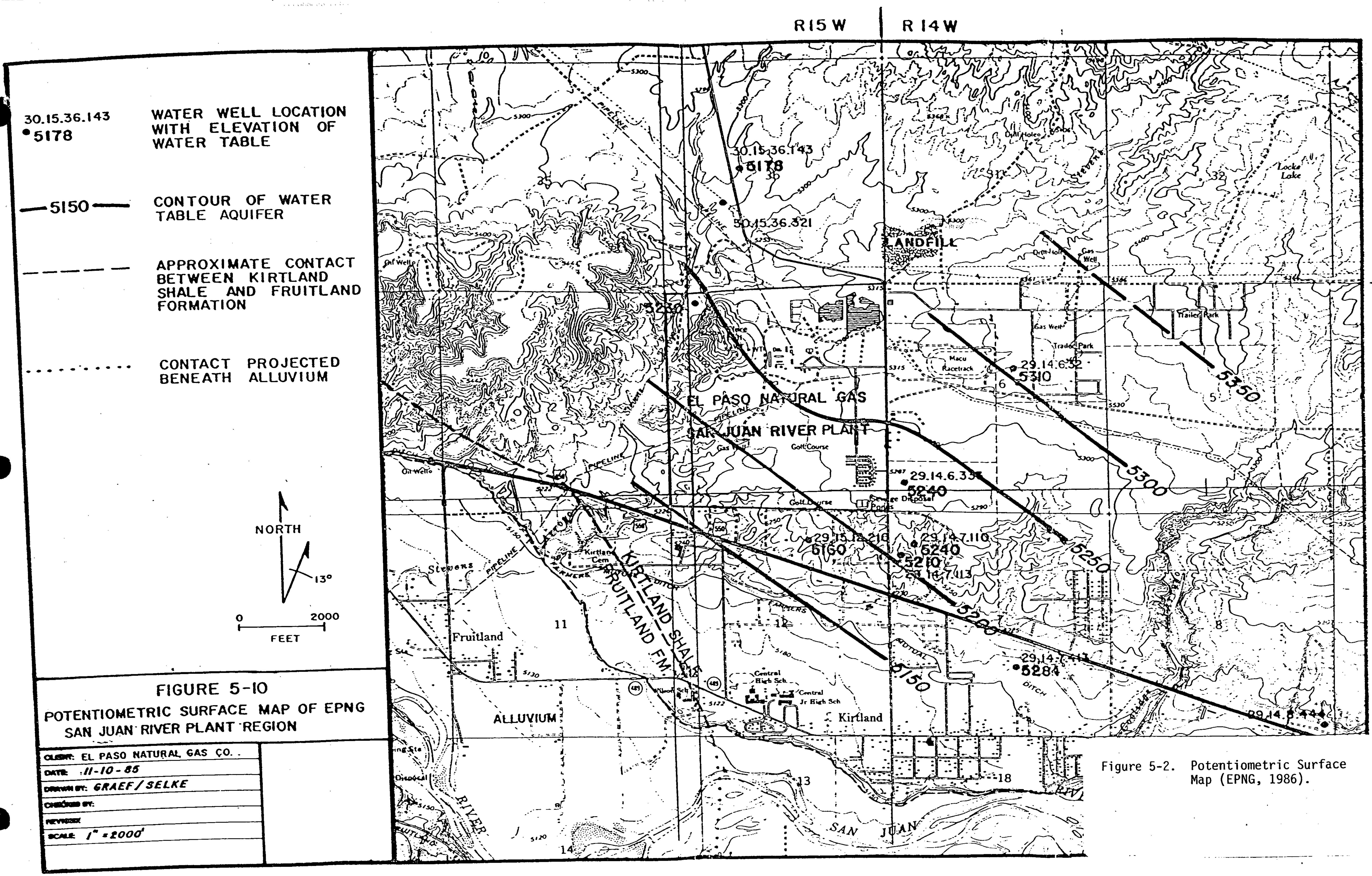


Figure 5-2. Potentiometric Surface Map (EPNG, 1986).

direction, it is felt that the southwest flow direction is more representative of actual conditions. However, since information gathered during Phase I suggests localized variations in the potentiometric surface, it will be necessary to gain additional data to fully define site specific water table contours. One item which should be noted is the water elevation in E3 (5,226.4 ft MSL), which is higher than the water elevation of E1B (5224.0 ft MSL) (refer to Figure 5-1). Although not confirmed, it is possible that recharge resulting from irrigating the golf course is influencing the water level in piezometer E3. If this is the case, and irrigation is causing a slight mound, the effect would be an altered groundwater flow direction to the southeast, which correlates with the situation defined by Phase I data.

Hydrology Conclusions

In conclusion, it can be stated that the depth to groundwater is in excess of 50 feet across both sites and what shallow groundwater is present is perched above the contact of the alluvial sediments and the underlying shale. From piezometers E1B, E3, and W2, it has been determined that the saturated thickness of the alluvial sediments does not exceed 10 feet and the unsaturated sediments above the water table are typically less than 10 to 15% moisture. From tests conducted at the piezometers it can be stated that the hydraulic conductivity of the saturated alluvial material is on the order of 2×10^{-5} cm/sec and approximately 3×10^{-9} cm/sec for the sandstone encountered on the northern portion of the eastern site.

One point which is not clear is the groundwater flow direction for the sites. From the information gathered during Phase I, it appears that the local flow is to the southeast. However, it should be noted that this interpretation does not agree with previous findings for the area nor is it consistent with conventional interpretations of groundwater flow patterns.

One possible explanation for the discrepancy lies in the amount of artificial recharge in the area and the insufficient amount of data to evaluate the effects on the local potentiometric surface. Until further information is available, it will be assumed that the groundwater flow pattern for the local area around the EPNG SJRP is to the southwest and it is recognized that localized variations in this pattern may exist.

6.0 LOCAL WATER WELLS AND GROUNDWATER QUALITY ASSESSMENT

In order to assess the occurrence and quality of shallow groundwater in the area around EPNG SJRP, nearby water wells were identified and available well records were obtained. From the wells identified, several were selected and water samples collected for laboratory analysis of routine water quality parameters.

6.1 IDENTIFICATION OF LOCAL WATER WELLS

Fourteen local water wells near EPNG SJRP were identified by OCD (Table 6.1). Of these, three were completed in formations other than the alluvial sediments being investigated, and well records were not available for three others. Therefore, of the 14 wells identified by OCD, only eight were considered for sampling, and of these, five were actually sampled. In addition to these 14 wells (identified by OCD), an additional well to the east of the facility was located and sampled bring the total number of wells sampled to six. Locations all of the wells sampled are illustrated on Figure 6.1 and listed on Table 6.1.

6.2 LOCAL GROUNDWATER QUALITY

Water quality in the alluvial sediments around the study area can be quite variable. However, it can be generally stated that groundwater from wells completed within the La Plata and San Juan River valleys exhibits specific conductance values in the 2,500 umhos/cm range (Stone et al., 1983).

To assess the quality of shallow groundwater near the facility, samples from the six privately owned wells listed on Table 6.2 were submitted for laboratory analysis of general groundwater parameters. All of the samples were collected by KWB&A with the assistance of OCD. All

Table 6-1. Local water wells sampled near the EPNG SJRP.

WELL NAME & OWNER	LOCATION (T,R,SEC. TRACT)	WELL DEPTH(ft)	DEPTH TO WATER	PRODUCING INTERVAL (FT)	PRINCIPAL WATER-BEARING UNIT	SPECIFIC CONDUCTANCE (UMHOS 25°C)	USE	
GT2 Coal Well	30.15.36.321	500	133	470-500		6570		no listing in SEO
SJ - 1407 Paul F. Hansen Box 822 Kirtland, NM (598-6256)	29.14.6.333	70	52	65-68? Estimated Yield: 2 gpm	0-5 Brown Sand 6-13 White Sandy Clay 14-48 Red-Brown Sand 49-68 Brown Sand & Gravel 69-70 Grey Sandy Shale		Drilled Domestic	
SJ -1568 Gordon Helmer Box 1073 Kirtland, NM (598-6824)	29.14.07.11	72	30	60-70? Estimated Yield: 12 gpm	0-24 Sand 24-30 Brown Clay 30-35 Gravel 35-50 Grey Clay 50-60 Grey Shale	60-70 Grey Shale & Sandy Gravel 70-72 Grey Shale	Drilled Domestic	
SJ -0226 Jack M. Swearingen Box 305 Kirtland, NM	29.14.07.113	100	50	90-100? Blue Water Sand	0-40 Overburden 40-100 Blue Shale		Drilled Domestic & Stock	Estimated Yield: 5 gpm

Table 6-1. Continued.

WELL NAME & OWNER	LOCATION (T,R,SEC. TRACT)	WELL DEPTH (ft)	DEPTH TO WATER	PRODUCING INTERVAL (FT)	PRINCIPAL WATER-BEARING UNIT	SPECIFIC CONDUCTANCE (UMHOS 25°C)	USE	
J -0971-Expl 242	30.15.36.143	Expl-1=532 Expl-2=524	101.5 131.5		P.C.		Drilled Exploratory	SEO says well to be plugged on completion but no plugging record
J -1343 sham, J.T. .O. Box 525 irtland, NM 598-5057)	29.14.27.1	70	55	0-1 Brown Sand 2-9 White Sandy Clay 10-38 red-brownsand 39-67 brown sand & gravel 68-70 Grey Sandy Shale			Drilled Domestic	
J - 0027 PNG	29.15.01.123		1005					No Record
J - 0291 avid R. Knoll .O. Box 774 irtland, NM 598-6232)	29.15.12.21 (should be 29.15.12.112 E/2 NW/4 NW/4	110		100 - 110 Estimated Yield: 15 gpm	0-80 Sand 80-100 Blue Shale 100 - 110 Gravel		Drilled Domestic & Stock	

Table 6-1. Continued.

WELL NAME & OWNER	LOCATION (T,R,SEC. TRACT)	WELL DEPTH (ft)	DEPTH TO WATER	PRODUCING INTERVAL (FT)	PRINCIPAL WATER-BEARING UNIT	SPECIFIC CONDUCTANCE (UMHOS 25°C)	USE	
SJ - 1136 Joseph S. Lester P.O. Box 948 Kirtland, NM (598-6293)	29.15.12.22 (should be 29.15.12.223 SW/4 NE/4 NE/4)	150	40	Casing to 41feet	0-25 Sand 25-40 Boulders 40-150 Sand Shale		Drilled Domestic	
Can't Find	29.14.06.32							
SJ - 1218 William H. Otte (598-6142)	29.14.06.21 NW/4 NE/4						Expired Domestic	No Record
SJ - 1377 Ronald K. Ashford (598-5956)	29.14.07.11						Expired Domestic	No Well Record

Table 6-1. Continued.

WELL NAME & OWNER	LOCATION (T,R,SEC. TRACT)	WELL DEPTH (FT)	DEPTH TO WATER	PRODUCING INTERVAL (FT)	PRINCIPAL WATER-BEARING UNIT	SPECIFIC CONDUCTANCE (UMHOS 25°C)	USE	
J - 2081 an Booth 881 Old Aztec Hwy lora Vista, NM 598-9816)	29.15.12.112 NE/4 NW/4 NW/4	50			No Drilling Record		Drilled Domestic	Drilling Permit Expires 8/15/87
SJ - 2071 John Leo Kennedy Box 571 Kirtland, NM (598-5056)	29.15.12.112 NE/4 NW/4 NW/4	50			No Drilling Record		Drilled Domestic	Drilling Permit Expires 7/15/87

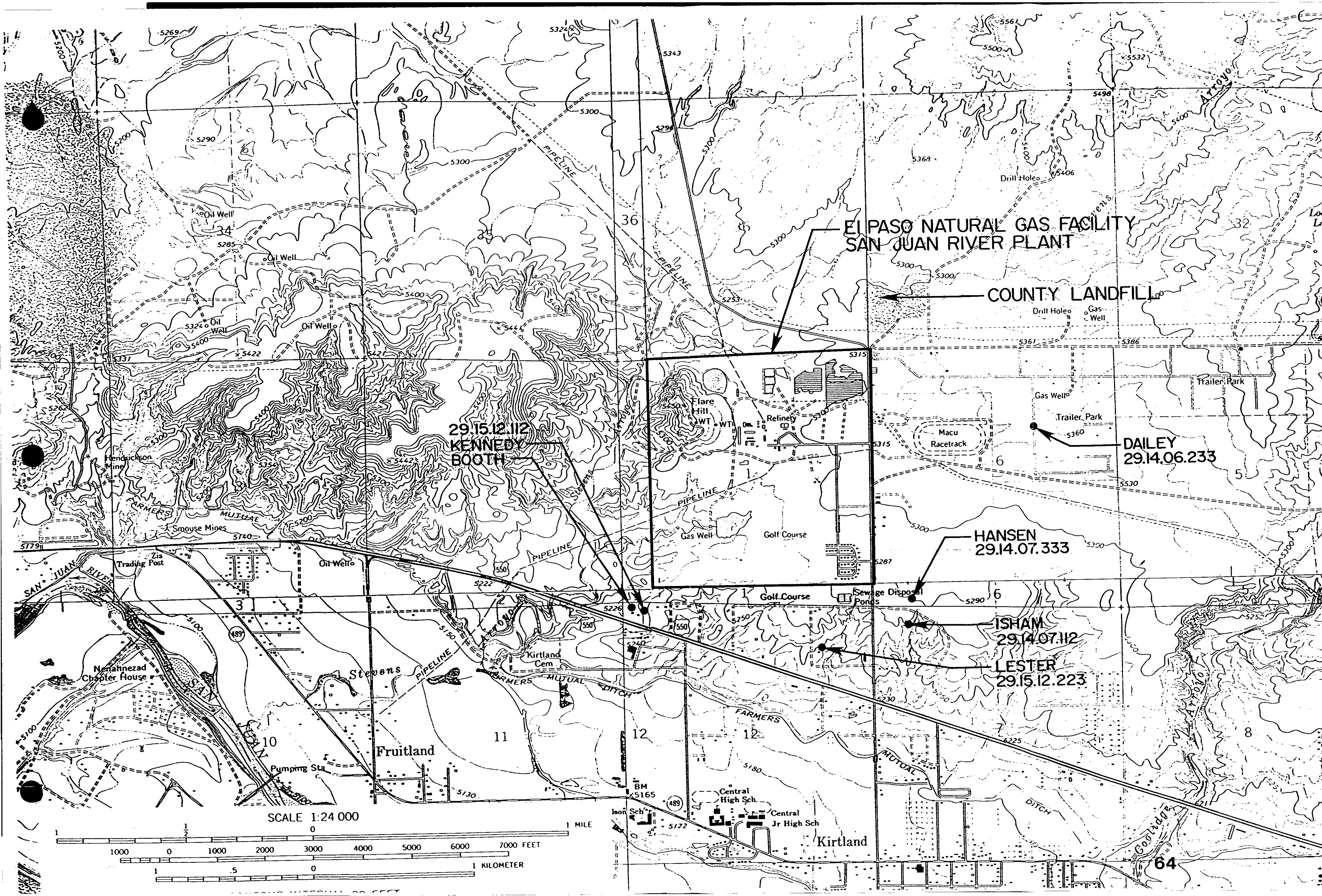


FIGURE 6-1. LOCATIONS OF PRIVATE WELLS SAMPLED.

wells, with the exception of Joe Lester's, were pumped prior to collecting samples. The pump was not in place at the Lester well, therefore, a bailer was used to collect samples. Measurements for pH, EC, and temperature were conducted at the wellhead. Samples were then collected for laboratory analysis, recorded on chain-of-custody forms, placed on ice, and shipped by overnight express to Raba-Kistner Labs in San Antonio, Texas. As needed, samples were preserved with nitric acid and sulfuric acid. Since metal analyses were not requested, none of the samples were filtered. Table 6.3 lists the lab results for these wells and the actual lab reports are included in Appendix G.

Table 6.2. Privately Owned Groundwater Wells Sampled.

Well Owner	Location* (Town, Range, Sec, Tract)	Well Depth#
Dan Booth	29.15.12.112	50
Dale Dailey	29.14.06.233	75
Paul F. Hansen	29.14.06.333	70
J. T. Isham	29.14.07.112	70
John Kennedy	29.15.12.112	50
Joseph S. Lester	29.15.12.223	94 (150)

* Locations determined from USGS quadrangle maps.
\# Lester's well was completed to a depth of 150; since completion the well has caved-in and the actual measured depth was 94 feet.

These analytical results provide the background data base to assess the quality of ambient groundwater in the alluvial sediments which underlie the proposed land treatment sites.

6.3 RESULTS AND DISCUSSION

Well descriptions for five of the six wells sampled were available, however, the descriptions for lithology were quite limited. Therefore, it

Table 6-3. Analytical Results for Groundwater from Local Wells Near the El Paso Natural Gas San Juan River Plant*.

Parameters	Units	Kennedy SJ-2071	Booth SJ-2081	Lester SJ-1136	Hansen SJ-1407	Isham SJ-1343	Dailey unknown	East Avg	Southwest Avg	Total Avg
		Well Owner/ID Number								
CATIONS										
Sodium	mg/l	100	110	440	500	820	1,000	773	105	495
Calcium	mg/l	66	63	31	130	190	280	200	65	127
Magnesium	mg/l	17	15	13	44	57	66	56	16	35
Potasium	mg/l	1.2	1.3	3.1	5.6	6.3	3.5	5.1	1.3	3.5
ANIONS										
Chloride	mg/l	29	29	110	400	400	450	417	29	236
Sulfate	mg/l	290	300	780	790	1,800	2,470	1,687	295	1,072
Bicarbonate	mg/l	210	200	320	230	150	91	157	205	200
Carbonate	mg/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
NITROGEN										
Nitrate	mg/l	< 0.1	< 0.1	< 0.1	5.6	5	3.9	4.8	0.1	2.5
Ammonia	mg/l	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	0.4	0.4	0.4
Total K Nitrogen	mg/l	< 0.4	< 0.4	0.4	< 0.4	0.5	0.4	0.4	0.4	0.4
INDICATORS										
pH	s.u.	7.69	7.78	7.11	7.28	7.58	7.01	7.29	7.74	7.41
EC	umhos	910	950	5,200	2,950	2,950	4,800	3,567	930	2,960
TDS	mg/l	600	610	1,400	2,000	3,400	4,300	3,233	605	2,052
Volatile Scan	mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cl Organic Scan	mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND

* Values reported below detection limit are averaged at the detection level.
ND = Not Detected
East Wells = Hansen, Isham, and Dailey (see Figure 6-1)
Southwest Wells = Kennedy and Booth (see Figure 6-1)
South Well = Lester (see Figure 6-1)

K. W. Brown & Associates, Inc.

is not possible to state in detail the type of materials into which these wells are completed. However, based on site-specific information gathered at the facility, published information about the area, and the limited descriptions on the drillers logs, it is possible to state that the wells are collecting water from the same Pleistocene alluvial sediments found at the proposed site. Hence, analytical results for samples obtained from these wells are considered to be representative of local groundwater quality at the EPNG SJRP.

Of the six wells sampled, three are east of the facility (Hansens, Isham, and Dailey), one is to the south (Lester), and two are southwest (Kennedy and Booth) of the proposed land treatment sites (Figure 6.1). Of these, the two southwest wells exhibit the best water quality, with an average EC of 930 umhos/cm and average TDS value of 605 mg/l. Values for the wells east of the facility average 3,567 umhos/cm for EC and 3,233 mg/l for TDS. Values for the other parameters (i.e., sodium, chloride, nitrate) also illustrate improved water quality southwest of the facility (Table 6.3).

Improved water quality in the southwest wells is thought to be the result of years of irrigation at the EPNG golf course which is located just to the northeast of these wells. Since the quality of the irrigation water is quite good (TDS = 240 mg/l), and large amounts of water are used daily, it is reasonable to assume that the net effect would be local recharge to the water table. In addition to the effects of irrigation, a raw water pond (river water) situated just north of these wells, provides an additional recharge source of high quality water.

Water quality in the wells located east of the facility is thought to represent true groundwater quality in the area near the proposed land application sites since they are not influenced by artificial recharge.

7.0 CLIMATOLOGICAL ASSESSMENT

A hydrological study of this site was performed to determine the local water balance, wastewater storage capacity, application rate and the acreage required to apply the amount of wastewater generated at EPNG's SJRP. To initiate the hydrological study, long-term climatological data from the Farmington, New Mexico Meteorological Observation Station were analyzed.

To calculate the hydrological balance, the following assumptions were made:

1. Average daily flow from the wastewater plant is equal to 26,493 gallons per day (9.67 million gallons/year);

2. The total area irrigated equals 25 acres;

3. Efficiency of the irrigation system is 80%;

4. The evaporation and infiltration from the unit used to store wastewater are assumed to be zero;

5. The electrical conductivity (EC) of the wastewater equals 6.6 mmhos/cm and the EC of the soil-pore water is maintained at or below 8.0 mmhos/cm. The EC of 6.6 mmhos is based on the TDS average value shown on Table 2-2 (4,198 ppm/640 = 6.6). The average value for EC shown on Table 2-2 was not used because the EC values shown for the evaporator and boiler blowdowns are estimates and their combined flow accounts for 49.12% of the total wastewater produced.

7.1 LOCAL WATER BALANCE

The water budget was calculated using an iterative computer spreadsheet (Table 7-1) and climatic data gathered at the Farmington observation station. All components of the water balance which account for net moisture gains and net moisture losses were considered. In the case of precipitation, the estimated total monthly amounts are increased by a safety factor of 75% to assure the system can function during unusually wet

WBAL2.WK1

Table 7-1. Hydrologic Analysis for the Site Used for Wastewater Land Application Study (acre-inches per acre irrigated)

Month	Mean Precip (in)	Design Precip (in)	SCS Runoff (in)	Infil-trated Precip (in)	E.T. (in)	Root zone moisture deficit (in)	Leaching require-ment (in)	Waste H2O req'd in root zone (in)	Waste-water req'd* (in)	Waste-water req'd* (ac-in)	Float-ing Pan evap. (in)	Gross surface evap. (ac-in)	Net surface evap.# (ac-in)	Evap. from res. surf.+ (ac-in)	Irriga-tion require-ments (ac-in)	Waste-water avail-able (ac-in)	Storage require-ments (ac-in)	Cum. storage require-ments (ac-in)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10a)	(10b)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Jan	0.90	1.58	0.01	1.57	0.96	0.00	0.00	0.00	0.00	0.00	0.96	24.00	-15.37	0.00	0	30.25	30.25	60.49
Feb	0.61	1.07	0.00	1.07	1.56	0.49	0.40	0.89	1.12	27.90	1.56	39.00	12.31	0.00	28	27.32	-0.58	59.92
Mar	0.72	1.26	0.00	1.26	3.79	2.53	2.06	4.59	5.74	143.41	3.79	94.80	63.30	0.00	143	30.25	-113.17	0.00
Apr	0.76	1.33	0.00	1.33	6.34	5.01	4.07	9.07	11.34	283.54	6.34	158.40	125.15	0.00	284	29.27	-254.27	0.00
May	0.40	0.70	0.00	0.70	8.02	7.32	5.94	13.26	16.58	414.38	8.02	200.40	182.90	0.00	414	30.25	-384.14	0.00
Jun	0.43	0.75	0.00	0.75	8.83	8.08	6.56	14.64	18.31	457.63	8.83	220.80	201.99	0.00	458	29.27	-428.36	0.00
Jul	0.78	1.37	0.00	1.37	8.74	7.37	5.99	13.36	16.70	417.50	8.74	218.40	184.28	0.00	417	30.25	-387.25	0.00
Aug	1.09	1.91	0.05	1.86	7.38	5.52	4.49	10.01	12.51	312.80	7.38	184.50	136.81	0.00	313	30.25	-282.55	0.00
Sep	0.84	1.47	0.00	1.47	5.72	4.25	3.45	7.70	9.63	240.78	5.72	143.03	106.28	0.00	241	29.27	-211.51	0.00
Oct	1.09	1.91	0.05	1.86	3.79	1.93	1.57	3.51	4.38	109.57	3.79	94.80	47.11	0.00	110	30.25	-79.32	0.00
Nov	0.58	1.02	0.00	1.02	2.03	1.01	0.82	1.84	2.30	57.38	2.03	50.70	25.33	0.00	57	29.27	-28.11	0.00
Dec	1.00	1.75	0.02	1.73	1.00	0.00	0.00	0.00	0.00	0.00	1.00	24.90	-18.85	0.00	0	30.25	30.25	30.25
Totals	9.20	16.10	0.13	15.97	58.15	42.18	35.36	78.88	98.60	2464.89	58.15	1453.73	1051.23	0.00	2,465	356.14	-2108.75	150.66

* Assuming a distribution system efficiency = 80 percent
\# Net evaporation = gross evaporation - precipitation
\+ Based on a storage impoundment surface area 0 acres

K.W. BROWN & ASSOCIATES, INC.

PHYSICAL CONSTRAINTS BASED ON DESIGN PRECIPITATION
Detention time = 0.00 days
Irrigated area = 25.00 acres
Wastewater volume = 26,493 gallons per day
Storage volume = 5.04 acre-ft or 1,642,671 gallons
or 39,111 bbls

years. As a result of using the safety factor, the system is over-designed for years when precipitation amounts are within normal ranges.

A column by column explanation of the items contained in the Table 7-1 follows.

Column 1: Month

Rather than simply presenting annual figures for the water budget, an individual balance for each month was calculated and totaled for an annual figure.

Column 2: Mean Precipitation

Daily precipitation data were gathered from the National Oceanic and Atmospheric Administration (NOAA) Farmington weather station (NOAA, 1987). Summations of the estimated monthly means for precipitation (and snowfall amounts after conversion to rainfall) were calculated for a period from 1947 to 1986.

Column 3: Design Precipitation

To calculate the design precipitation amount, the adjusted monthly precipitation was multiplied by a safety factor. The safety factor was used to allow for adequate storage during wet years. Precipitation frequency analysis was used to determine the safety factor according to the following equation:

$$SF = P_{90}/P_{avg},$$
$$= 0.75$$

where:

SF = the safety factor;

P_{90} = the 90% probability of receiving this amount of annual rainfall during wet years (estimated from 39 years data); and

P_{avg} = the mean annual precipitation for years 1948 through 1987.

For this analysis, P_{90} and P_{avg} were estimated to be 16.2 and 9.2 inches, respectively.

Column 4: SCS Runoff

Rainfall runoff for a single event was estimated using the SCS method. These results are based on the SCS curve number (39) and the antecedent moisture content (AMC classified as III). These values were estimated using data from USDA/SCS (1975) and soil characteristics obtained from site specific data collected during Phase I. The soils at the East site fall into hydrological group A, under good hydrologic condition.

Column 5: Infiltrated Precipitation

Infiltrating precipitation is based on the difference between the amount of runoff (Column 4) and the design precipitation amount (Column 3). From the SCS runoff analysis it is apparent virtually all precipitation infiltrates.

Column 6: Evapotranspiration

To determine moisture losses through evaporation/transpiration (ET), the amount and types of local cover were considered. The ET calculations are based on the gross lake surface evaporation (Column 12) and adjusted for the ET coefficient by cover type. Three cover types identified at the East site are grasses, shrubs, and bare ground. Percent cover along with the ET coefficient determine the ET values presented.

Column 7: Root Zone Moisture Deficit

Root zone moisture deficit (RZMD) values are determined by comparing the infiltrating amount of precipitation (Column 5) to the ET requirements (Column 6). The difference between the two defines the RZMD (Column 7).

Column 8: Leaching Requirement

To prevent build-up of soil salinity, a fraction of irrigation water must be leached through the root zone during periods when evapotranspiration exceeds infiltration. This fraction of water, defined as leaching requirement (LR), is calculated using the following equation:

$$LR = EC_{iw}/EC_{dw} \times RZMD$$

where:

- LR = leaching requirement;
- EC_{dw} = maximum allowable electrical conductivity of drainage water (8.0 mmhos/cm);
- EC_{iw} = electrical conductivity of irrigation water (6.5 mmhos/cm),
- RZMD = the root zone moisture deficit (Column 7).

Column 9: Wastewater Required in Root Zone

Wastewater requirement in the root zone is simply the sum of the amount of water needed to satisfy the root zone moisture deficit (Column 7) and the amount of water needed for leaching requirements (Column 8).

Column 10: Wastewater Required

Wastewater required is essentially the same as the amount of wastewater required in the root zone (Column 9), except the values presented in Column 10 have been adjusted to allow for the efficiency rating of the irrigation system used. (Since the irrigation system has not been selected, an efficiency rating of 80% was used in the calculations).

Column 11: Floating Pan Evaporation

The evaporation data presented were taken from the original discharge plan filed by EPNG for the SJRP (EPNG, 1986). These values represent floating evaporation pan data gathered by the Farmington observation station and reported by Gabin and Lesperance (1975).

Column 12 Gross Lake Surface Evaporation

The monthly floating pan evaporation data (Column 11) were multiplied by a pan coefficient to estimate the gross lake surface evaporation (Column 12). Since the evaporation potential during each month is slightly different, monthly pan coefficients were used. The annual average for the coefficients used is equal to 0.75 (Haan, et al., 1982).

Column 13: Net Lake Surface Evaporation

Net lake surface evaporation was calculated by subtracting the design precipitation amount (Column 3) from the gross lake surface evaporation (Column 12). During some months there is negative net lake evaporation, which indicates design precipitation exceeds gross lake evaporation.

Column 14: Evaporation From Surface Reservoir

Evaporation from a reservoir surface is included to compensate for evaporative losses from a surface impoundment in the event one was used to store the wastewater. For the calculations presented in Table 7-1, it is assumed that the wastewater will be stored in a tank; therefore, no values are presented in this column.

Column 15: Irrigation Requirements

Irrigation requirements are simply the sum of the wastewater required (Column 10) and the amount of water lost or gained by the surface impoundment (Column 14). Since a surface impoundment is not proposed to store the wastewater, Column 15 is equal to Column 10.

Column 16: Wastewater Available

The amount of wastewater available on a monthly basis was assumed to be a function of the annual flow of 9.67 million gallons. The resulting daily flow is 26,493 gallons. This daily flow value was multiplied by the days per month to determine the amount of wastewater available on a monthly basis.

Column 17: Storage Requirements

Storage requirements represent the difference between the amount of wastewater available (Column 16) and the amount of wastewater needed for irrigation (Column 15). During months where the irrigation requirements exceed wastewater production, the storage values are zero. For winter months, the amount of storage required increases proportionally to the relative difference between evaporation and wastewater flow.

Column 18 Cumulative Storage Requirements

Cumulative storage is simply the summation of the monthly storage values (Column 17). From Table 7-1 it is apparent that storage of wastewater will begin in December and continue through February. By March, however, the volume of wastewater stored can be irrigated and the cumulative storage value reduced to zero.

7.2 RESULTS AND DISCUSSION

Analysis of the climatic data indicates the local water balance is acceptable for the proposed project and will not place an undue burden on the management program. Based on the assumptions presented in this section and the site specific data gathered, it has been determined that the irrigation site will need to be approximately 25 acres in size. It should be noted that the full area will not be required year round. In the dry months of the year, the amount of land required to dispose of the wastewater will be less.

For periods when evaporation is reduced, it will be necessary to store the wastewater generated. To store the volume of water which can not be irrigated (from December through February), it will be necessary to construct a storage facility to hold 5.04 acre-feet (1.64 million gallons). For calculating the water balance, it was assumed that a tank would be constructed. However, it is possible that a surface impoundment will be used to store excess wastewater during the winter months.

These calculations are preliminary estimates to determine if sufficient land area is available and to determine if storage would be required. As the management plan is formulated in Phase II, these estimates are likely to change as input parameters are refined.

8.0 VEGETATION SURVEY

Determination of vegetative types was initially conducted with the aid of aerial photographs and range site assessments given in the SCS Survey for San Juan County. This initial review was followed by a site investigation in which vegetation types were identified and rated as to their respective salt tolerances. A visual vegetation inspection was also conducted on Stevens Arroyo that had been impacted with high salt concentrations near the plant property. The vegetative species persisting in this area and the specific habitats with which they were associated were recorded. Following the site investigation, a literature review on salt-tolerant vegetation was conducted to determine if alternative species would better facilitate the needs of the proposed irrigation plan.

8.1 SITE INSPECTION

8.1.1 Methods and Materials

The vegetation survey was conducted by Stephen Swetish and Ronald Shiver of KWB&A on June 10, 1987. Percent ground cover and species composition were determined by using the inclined 10 point frame method for vegetation sampling (Figure 8.1; Photo 15)(Chambers and Brown, 1983). Foliar hit by species was recorded first. Hits on bare ground and mulch were also recorded.

Vegetation measurements were taken along ten line transacts at the proposed East and West sites (Figure 8.2). Each transact was 100 feet in length and consisted of ten locations spaced at 10-foot intervals. At each sample location, the inclined 10 point frame was set up and the sample pin was lowered until first contact was made (Photo 16). This gave 100 sample points per transact and a total of 1,000 points per site.

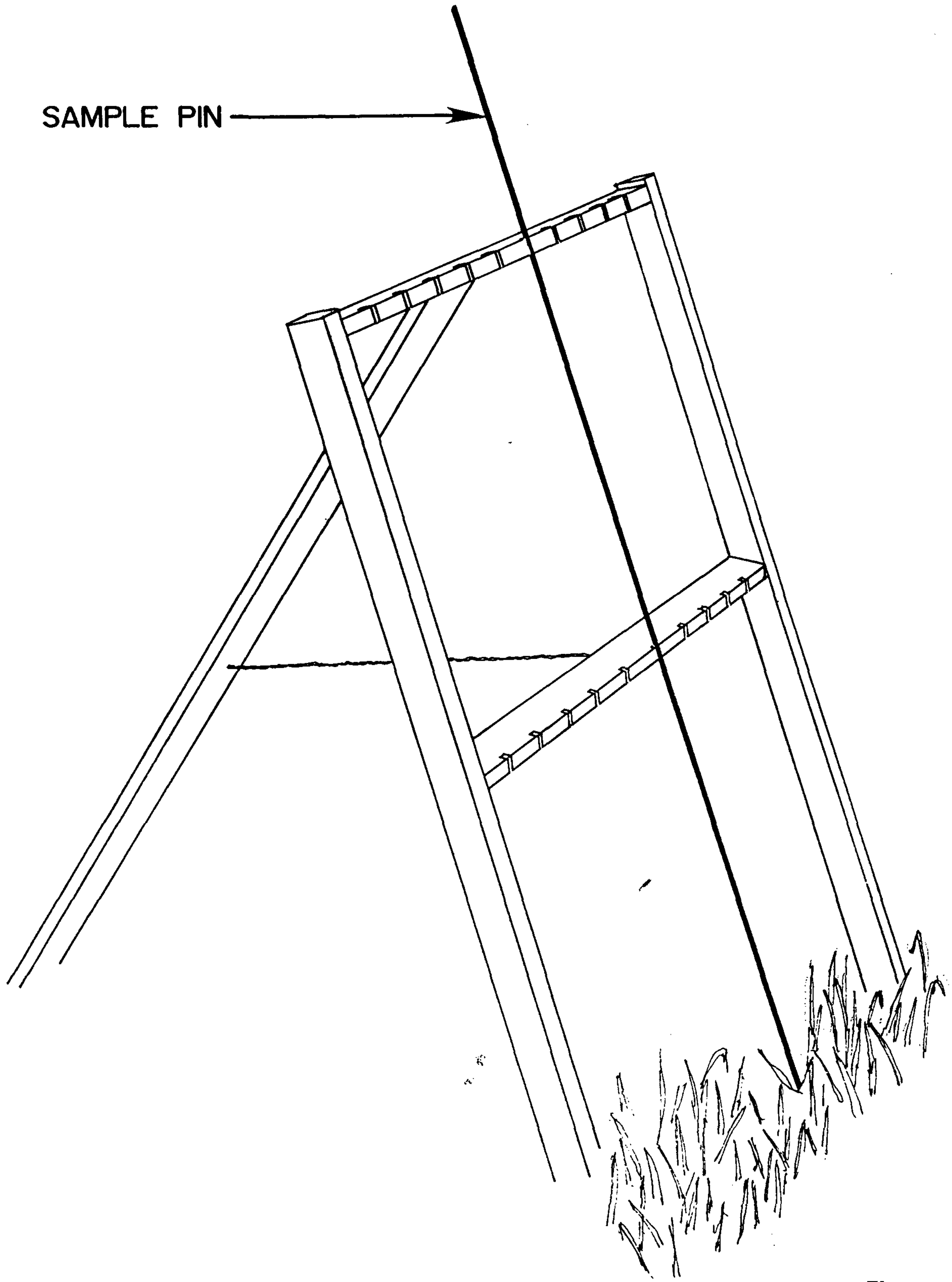


FIGURE 8-1. TEN POINT FRAME VEGETATION SAMPLING DEVICE.

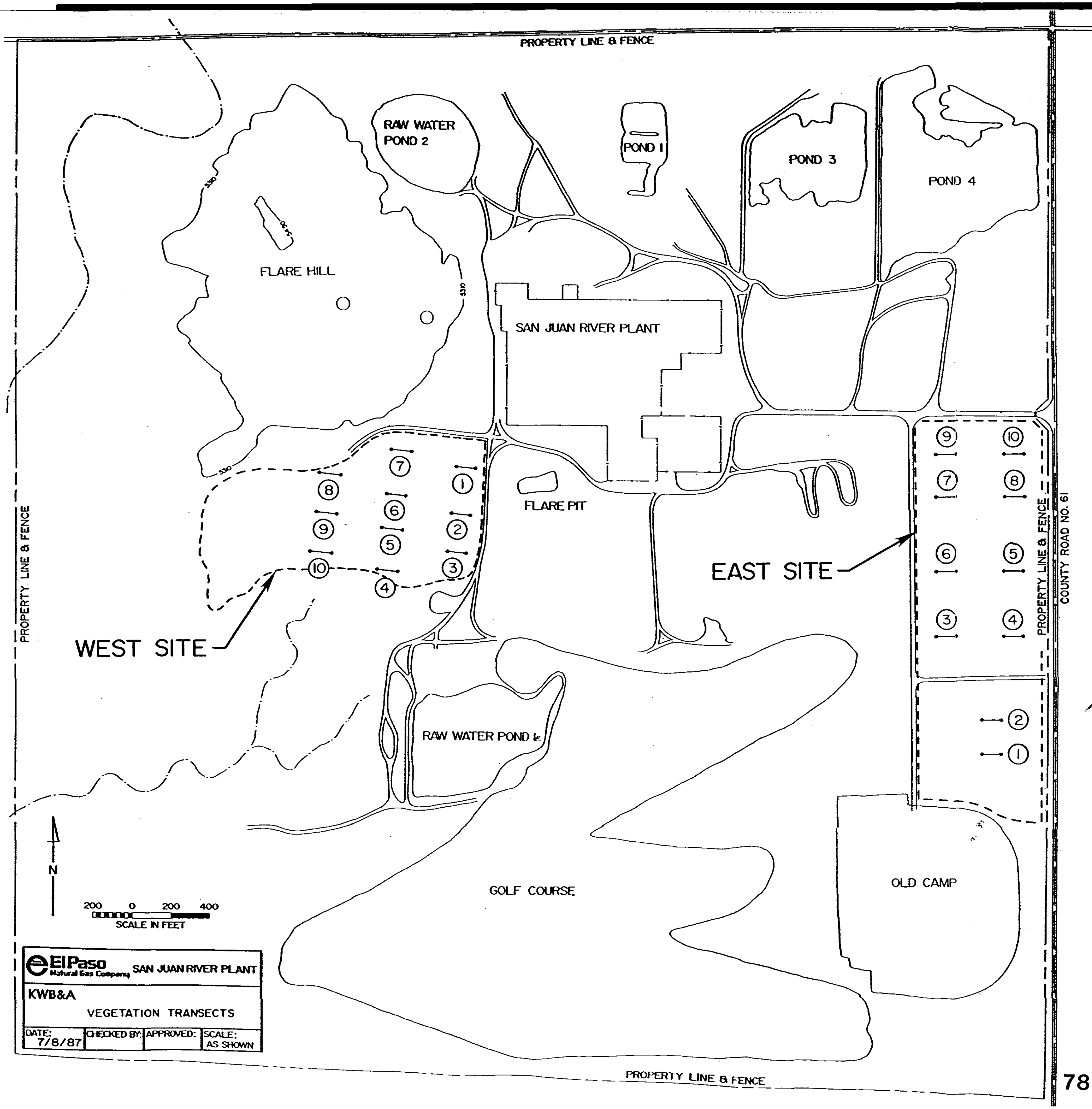


FIGURE 8-2. LOCATION OF VEGETATION TRANSECTS ON EAST AND WEST SITES.

8.1.2 Results and Discussion

East Site

Percent vegetated ground cover on the proposed East irrigation site was 49.7%. Cover vegetation consisted of grasses (27.3%), forbs (22.0%), and shrubs (0.4%) (Table 8.1). The remainder of the site was comprised of bare ground (22.7%) and vegetative mulch (27.6%). The combination of well to excessively-well drained soils and the lack of rainfall resulted in the vegetation experiencing drought stress at the time of the survey. Vegetative response to the drought stress was massive leaf and seed drop, which substantially increased the percent ground cover by mulch. Annual species comprised a large portion of the vegetative ground cover, with Brome grass (*Bromus tectorum*), Mustard (*Descurainia spp.*), and Mallow (*Sphaeralcea spp.*) comprising 25.5., 10.0, and 6.6% ground cover, respectively. These annual species were reaching the end of their growth cycle and also contributed to ground cover (mulch) by leaf and seed drop.

West Site

Vegetated ground cover on the proposed West irrigation site was 58.3%. Cover vegetation consisted of grasses, forbs, and shrubs at 29.8, 15.4, and 13.1% respectively (Table 8.2). The remainder of the site was comprised of bare ground (28.6%) and vegetative mulch (13.1%). The soils of the West irrigation site were much more favorable in texture and drainage for plant growth than soils of the East site. The majority of vegetation on this site was under considerably less drought stress than encountered on the East irrigation site. This fact was responsible for the decrease in vegetative mulch cover from 27.6% on the East site to 13.1% on the West site. Shrub species occurred more frequently on the West site with a ground cover value of 13.1%, as compared to the 0.4% shrub species for the East site.

Table 8.1. Percent Ground Cover and Relative Salt Tolerance of Vegetation Found on the Proposed East Site at EPNG SJRP.

Common Name	Scientific Name	Percent Ground Cover	Relative Salt Tolerance Sensitive	Moderate	Tolerant
Bare ground		22.7			
Mulch		27.6			
Grasses					
Brome	Bromus tectorum	25.5		x	
Gelleta	Hilaria jamesii	0.2		x	
Ricegrass	Oryzopsis hymenoides	1.6		x	
Sacaton	Sporobolus airoides	T			x

		27.3			
Forbs					
Broom snakeweed	Xanthocephalum spp.	T		x	
Fleabane	Erigeron spp.	0.2	x		
Greenmolly	Kochia scoparia	2.3			x
Groundsel	Senecio longilobus	T		x	
Halogeton	Halogeton glomeratus	0.5			x
Mallow	Sphaeralcea spp.	6.6		x	
Mustard	Descurainia spp.	10.0		x	
Nightshade	Solanum spp.	1.5		x	
Plantain	Plantago spp.	T		x	
Stickleaf	Mentzelia spp.	T	x		
Tumbleweed	Salsola iberica	T			x
Annual forb		0.9	x		

		22.0			
Shrubs					
Cacti	Opuntia spp.	T		x	
Mormon tea	Ephedra torreyana	0.4		x	
Saltbush 4-wing	Atriplex canescens	T			x
Winterfat	Ceratoides lanata	T		x	

		0.4			

T = vegetation present at site in trace amounts.

Table 8.2. Percent Ground Cover and Relative Salt Tolerance of Vegetation Found on the Proposed West Site at EPNG SJRP.

Common Name	Scientific Name	Ground Cover	Relative Salt Tolerance Sensitive	Moderate	Tolerant
Bare ground		28.6			
Mulch		13.1			
Grasses					
Brome	Bromus tectorum	23.0		x	
Gelleta	Hilaria jamesii	2.0		x	
Ricegrass	Oryzopsis hymenoides	3.1		x	
Sacaton	Sporobolus airoides	T			x
Squirreltail	Sitanion hystrix	1.1		x	
Threeawn	Aristida longiseta	0.6		x	
		29.8			
Forbs					
Broom snakeweed	Xanthocephalum spp.	2.8		x	
Fleabane	Erigeron spp.	0.2	x		
Greenmolly	Kochia scoparia	0.3			x
Groundsel	Senecio longilobus	0.4		x	
Halogeton	Halogeton glomeratus	T			x
Locoweed	Astragalus spp.	0.4		x	
Mallow	Sphaeralcea spp.	0.2		x	
Mustard	Descurainia spp.	9.6		x	
Plantain	Plantago spp.	T		x	
Stickleaf	Mentzelia spp.	T	x		
Tumbleweed	Salsola iberica	1.5			x
		15.4			
Shrubs					
Cacti	Opuntia spp.	T		x	
Mormon tea	Ephedra torreyana	3.8		x	
Rabbitbrush	Chrysothamnus spp.	2.5		x	
Saltbush 4-wing	Atriplex canescens	0.3			x
Shadscale	Atriplex confertifolia	6.2			x
Winterfat	Ceratoides lanata	0.3		x	
		13.1			

T = vegetation present at site in trace amounts.

Relative Salt Tolerance of Existing Vegetation

The majority of the vegetation on both the East and West sites exhibit moderate to high tolerance for soil salinity (Tables 8-1 and 8-2). Only a few annual forbs present are sensitive to salinity, and they occur in very small amounts on both sites. The remainder of the vegetation will tolerate moderate salt concentrations depending on the method of application, the concentration of salt in the irrigation water, and the resulting salt concentration in the soil-pore water.

8.2 VISUAL INSPECTION OF STEVENS ARROYO

The visual inspection of Stevens Arroyo north of the SJRP wastewater holding ponds was conducted on June 11, 1987. Salt concentrations of the soil were very high, and a thick salt crust was evident on the soil surface. Vegetation of the area was predominantly shrubs and grasses interspersed with barren spots often covered by salt crust. Vegetation in the shrub category consisted of greasewood (Sarcobatus vermiculatus), saltcedar (Tamarix gallica), shadscale (Atriplex confertifolia), and four-wing saltbush (Atriplex canescens). Grasses in the area consisted of saltgrass (Distichlis spicata), alkali sacaton (Sporobolus airoides), foxtail barley (Hordium jubatum), and little barley (Hordium pusillum).

Saltcedar, greasewood, saltgrass, little barley, and foxtail barley were growing in the low lying, moist areas. Salt concentrations in these areas were high, with salt crystals present on the soil surface and basal parts of the vegetation. Four-wing saltbush, shadscale, and alkali sacaton were found growing on higher, better drained locations. Thin salt crusts were also present in these areas. In the low lying, saturated areas, saltgrass, rushes, and sedges were predominant.

8.3 ALTERNATIVE VEGETATION

Though vegetation present on the chosen irrigation sites is tolerant to moderate salt concentrations, it may need to be altered to facilitate the maintenance of adequate ground cover and to promote higher evapotranspiration levels. Irrigation with saline wastewater is expected to impact the present vegetation, with shifts in plant communities towards species that are the most salt tolerant. It may be beneficial to revegetate the area with a desirable species or a combination of species that will be able to tolerate the expected higher salt concentrations and provide adequate ground cover with as little maintenance as possible. A few of the species that could be used are tall wheatgrass (*Agropyron elongatum*), alkali sacaton (*Sporobolus airoides*), and sweetvetch (*Hedysarum boreale*) (Table 8.3). Tall wheatgrass and alkali sacaton are well adapted to the area, thrive on deep, sandy, well-drained soils, and are tolerant to soil salinity and sodic soil conditions. Sweetvetch is a forb that grows in soils ranging from clay to sandy texture and can tolerate moderate soil salinity and sodicity. These species are but a few that could potentially be used if revegetation is chosen as an option.

Table 8.3. Alternative Vegetation for Use as a Cover Crop on the Wastewater Irrigation Site at EPNG SJRP.

Common Name	Scientific Name	Relative Salt Tolerance Sensitive	Moderate	Tolerant
Grasses				
Tall wheatgrass	*Agropyron elongatum*			x
Western wheatgrass	*Agropyron smithii*		x	
Blue grama	*Bouteloua gracilis*		x	
Saltgrass	*Distichilis spicata*			x
Galleta grass	*Hilaria jamesii*		x	
Foxtail barley	*Hordium jubatum*			x
Little barley	*Hordium pusillum*			x
Alkaili sacaton	*Sporobolus airoides*			x
Forbs				
Sweetvetch	*Hedysarum boreale*		x	
Alfalfa	*Medicago sativa*		x	
Common sainfoin	*Onobrychis viciaefolia*			x
Small burnet	*Sanguisorba minor*		x	

9.0 TOPOGRAPHIC SURVEY

KWB&A conducted topographic surveys of the two potential land application areas to provide the approximate locations and elevations of points of interest, such as piezometers, boreholes, soil survey pits, monitoring wells, and pond water elevations (Figure 9.1). The points were located by measurement of distances and angles with a transit, survey rod, and measuring tape (Photo 17 and 18). The survey was taken from a known benchmark located inside the EPNG SJRP, approximately 94 feet southwest of the plant office. The benchmark was a brass plate fixed in a concrete foundation, with the markings SJRP-2, 1969 and a recorded elevation of 5291.28 feet. Surveys to both the East and West sites were made with respect to this benchmark. Table 9.1 provides a list of the points and their corresponding elevations. Surveyed points and elevations were also located on a topographic map provided by EPNG. In general, the surveyed elevations corresponded well with the contours shown on the topographic map (Figure 9.2).

In addition to the benchmark located inside EPNG, another monument was found east of the plant office. This monument is also a brass plate mounted in concrete, and has the markings 5202 SJRP, 1974. It was located northeast of the intersection between the road leading directly into EPNG SJRP and the road leading to the ponds (i.e., Ponds 1, 2, and 3), and was assigned the elevation of 5297.0 feet during the survey. This monument can be used by KWB&A personnel as a temporary benchmark, if required in the future. Another temporary benchmark was located by Mr. Ken Beasley of EPNG. This temporary bench mark consist of a railroad spike in a telephone pole south of the main entrance, and has an elevation of 5311.76 feet. The KWB&A survey was also found to correspond approximately to this elevation.

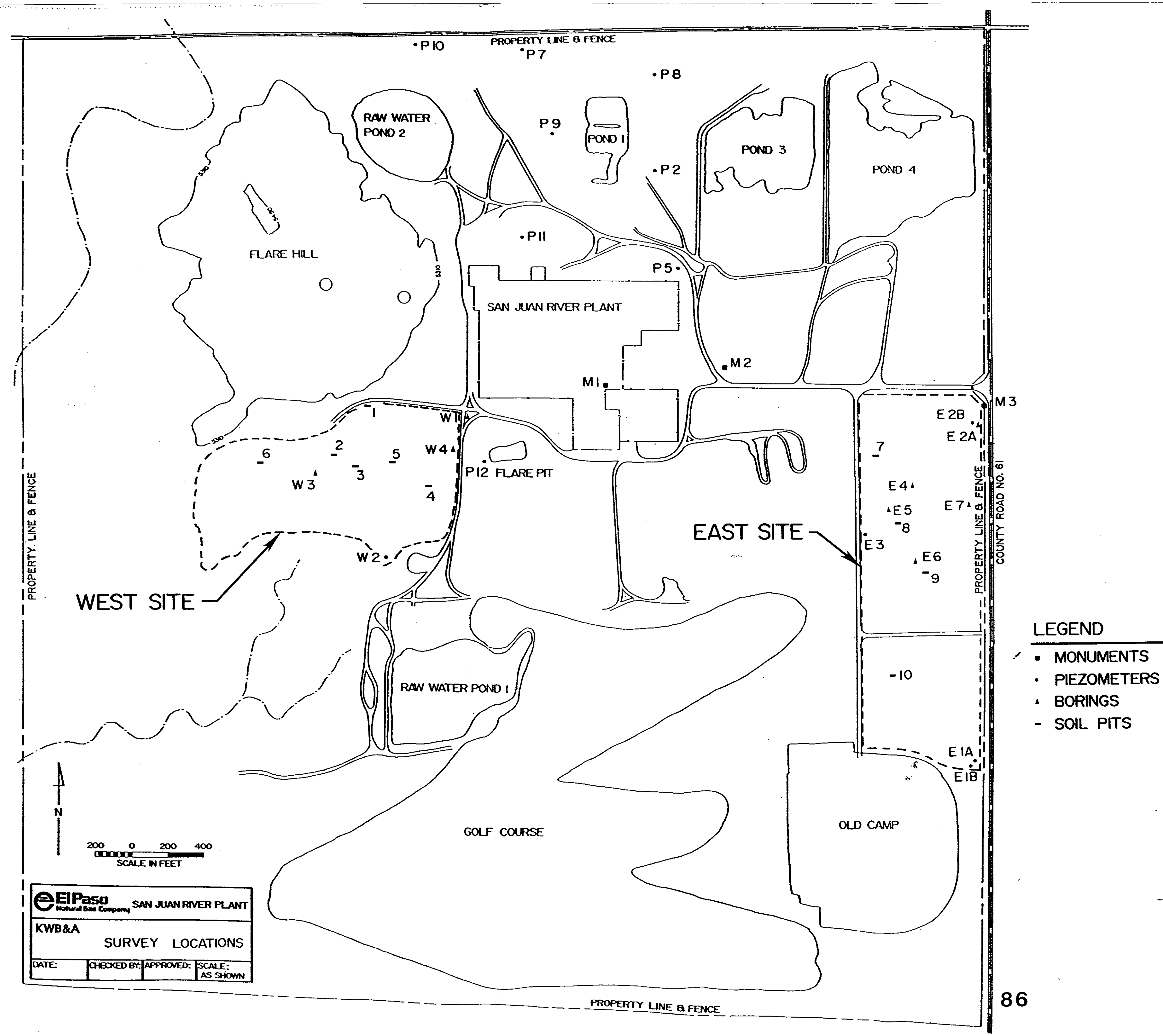


FIGURE 9-1. SURVEY LOCATIONS.

Table 9.1. Survey Elevations for the San Juan River Plant, June, 1987.

Location	Elevation (Feet MSL) Natural Grade	Top of PVC Casing
Monument 1 *	5291.28	NA
Monument 2 †	5296.9	NA
Monument 3 #	5311.76	NA
Piezometer 2	5291.8	5294.1
Piezometer 5	5293.0	5294.9
Piezometer 7	5260.1	5261.4
Piezometer 8	5277.9	5278.8
Piezometer 9	5271.8	5278.0
Piezometer 10	5258.1	5260.4
Piezometer 11	5291.3	5292.5
Piezometer 12	5284.8	5286.5
Piezometer E1A	5290.7	5292.0
Piezometer E1B	5290.4	5292.8
Piezometer E2B	5310.0	5312.8
Piezometer E3	5298.8	5299.7
Piezometer W2	5280.1	5280.9
Wastewater Pond 1	5272.0	NA
Wastewater Pond 2	5302.9	NA
Wastewater Pond 3	5291.3	NA
Raw Water Pond 1	5288.9	NA
Raw Water Pond 2	5262.4	NA
West Flare Pit	5287.0	NA
Boring E2A	5310.0	NA
Boring E4	5307.0	NA
Boring E5	5302.1	NA
Boring E6	5302.2	NA
Boring E7	5305.6	NA
Boring W1	5292.5	NA
Boring W3	5288.2	NA
Boring W4	5290.1	NA
Soil Pit 1	5305.3	NA
Soil Pit 2	5292.2	NA
Soil Pit 3	5296.1	NA
Soil Pit 4	5288.3	NA
Soil Pit 5	5292.9	NA
Soil Pit 6	5291.4	NA
Soil Pit 7	5302.0	NA
Soil Pit 8	5308.1	NA
Soil Pit 9	5302.1	NA
Soil Pit 10	5294.9	NA

Elevations for West Flare Pit and Raw Water Pond 2 are estimates.

* Monument 1 is located inside of main plant. Elevation from previous survey. Monument 1 is the reference point for this survey.

† Monument 2 is located east of lawn in front of office.

\# Monument 3 is a spike in the telephone pole south of the main entrance off of County Road 61. Elevation reported from previous survey.

ENGINEERING RECORD	
DRAWN BY	Aero-Graphics
TRACED BY	
CHECKED BY	
APPROVED	
DATE	
PHOTO DATE	10-18-82
CONTOUR INTERVAL	2'

200 0 200 400
SCALE IN FEET

El Paso Natural Gas Company

SAN JUAN RIVER PLANT

SEC. 1, TWS. 29-N, RANGE 15-W
SAN JUAN COUNTY, NEW MEXICO

DWG. NO.

SHEET 2 OF 2 REV.

In addition to the surveys to the East and West land application sites, a survey was conducted to the north of the facility to determine approximate elevations of the monitoring wells near the surface impoundments (i.e., Ponds 1, 2, and 3). The measurements will be used to determine the piezometric surface in that area, for use in interpreting groundwater conditions.

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 CONCLUSIONS

As stated in the introduction of this report, the objective of the feasibility study is to determine whether land application of wastewater is a viable option for the EPNG SJRP. To make this determination, the feasibility study has been divided into three phases. This report contains the results of the first phase, which consisted of investigating the chemical characteristics of the wastewater, as well as the chemical and physical characteristics of the selected land application sites. To achieve Phase I goals, extensive field work and analytical testing were conducted. In addition, published data about the proposed site were reviewed. Compiled information was evaluated and compared to pertinent references. Based on this study, KWB&A developed conclusions and recommendations for the planned land application program.

A review of the wastewater analyses indicates the constituents of primary concern are sodium, chloride, and TDS. These constituents are present at levels which exceed local groundwater concentrations and can impact physical and chemical soil quality. Therefore, they will influence the management of the land application site. Their concentrations are not high enough, however, to prohibit land application of the wastewater. Concerns raised by the concentrations of these constituents in the wastewater are their potential impact on soil structure, groundwater quality, and native plant species, as their concentrations increase within the soil profile over time.

Investigation of the soils present on both the East and West sites indicate the West site soils are inferior both in physical and chemical character when compared to the East site soils. Although both sites could be used for land disposal of the wastewater, the West site soils would require a higher level of site management. West site soils contain greater amounts of native salts, more clay, and are susceptible to wind erosion. The West site also has a steeper topography compared to the East site. The East site soils have excellent hydraulic conductivities required for rapid leaching of salts out of the root zone; less clay content, which reduces the chances for dispersion and subsequently reduces soil permeability following irrigation with saline wastewater; lower native salt content; greater depth to groundwater; and a relatively flat topography, which minimizes wastewater runoff problems. Although better suited than West site soils, East site soils exhibit limitations due to low cation exchange capacity, susceptibility to wind erosion, and low moisture holding capacity. These limitations indicate that the East site soils may require moderate levels of site management to operate a successful wastewater irrigation facility.

Management necessary at the East site will consist of leaching accumulated salts; additions of chemical additives such as gypsum, sulfur, or iron sulfate to replace exchangeable sodium; addition of organic matter such as manure, straw or hay mulch to improve soil structure; and additions of fertilizer nutrients. The site will also require appropriate and cropping practices to increase organic matter and incorporate it into the soil profile, thereby increasing available water holding capacity and reducing wind erodibility.

Groundwater contamination caused by vertical migration of wastewater constituents is a major concern, regardless of which site is selected. Therefore, the nature of the sediments, depth to groundwater, groundwater quality and groundwater movement at both sites is important in determining suitability for wastewater irrigation. Geologic investigations conducted indicated that the sediments at both sites are very similar in terms of texture and moisture content and are acceptable from the standpoint of providing a buffer zone for groundwater protection. In comparing depth to groundwater for both sites, it was determined that the East site is better suited for wastewater disposal since groundwater is in excess of 60 feet deep compared to 50 feet deep for the West site. In terms of groundwater quality and movement, both sites are essentially equal.

Water balance calculations indicated a requirement of 25 to 30 acres for land application of the annual production of wastewater from the EPNG SJRP. During the winter months, rainfall will exceed evapotranspiration from the site since vegetation will be dormant and evaporation is exceeded by precipitation. During this period, wastewater storage capacity of 1,642,671 gallons (5.04 acre-feet) will be required.

The final point of concern is the influence irrigating saline water would have on native vegetation. Studies at both sites indicate the presence of salt tolerant species. The West site plant community was slightly more diverse compared to the East site, however, the increased diversity is not expected to improve the effectiveness or reduce the management level of the proposed land application program.

The principal conclusion drawn from the Phase I investigation is that both sites at the EPNG SJRP are of suitable quality for use in the proposed wastewater irrigation project. However, the findings of the Phase I study determined the East site to be superior to the West site in terms of soil characteristics and depth to groundwater, and relatively equal in terms of native plant species present and groundwater parameters.

In summary, Phase I conclusions are:

1. The wastewater quality is acceptable for land application provided raw water is available for management purposes;

2. Wastewater constituents identified as management concerns include sodium, chloride, and total dissolved solids;

3. The East site is favored over the West site based on soil physical and chemical properties, and site topography;

4. Depth to groundwater at both sites is sufficient to afford adequate protection to groundwater quality;

5. Hydrologic properties at both sites are essentially equal and do not limit the use of either site for wastewater disposal;

6. Groundwater quality is assumed to be similar at both sites. Since concentrations occurring within the groundwater are less than concentrations of the same constituents in the wastewater, groundwater monitoring will be required;

7. Native vegetation on both sites is similar and relatively salt tolerant; and

8. The wastewater irrigation project will require intensive site management to maintain soil quality and continued successful operation.

10.2 RECOMMENDATIONS

Based on the findings of the Phase I investigation, KWB&A recommends that the West site be dropped from further consideration in favor of the East site. We also recommend that the feasibility study proceed to Phase II since a fatal flaw in the proposed irrigation project has not been discovered and an excellent data base has been developed which can be used to model the effects of wastewater irrigation.

10.3 DISPOSAL COST COMPARISONS

One aspect which must be considered when choosing a disposal option is the costs relative to other disposal methods. For comparison purposes four disposal options identified for handling wastewater at the EPNG SJRP were examined. These options are land application, surface impoundments, reverse osmosis, and commercial deep well injection. Of these, only land application and deep well injection result in total elimination of the wastewater. With surface impoundments and reverse osmosis, a portion of the waste stream remains and must eventually be disposed of in a different manner.

In the case of surface impoundments, as the salt concentration in the water increases, the evaporation rate of the water is reduced; thus, a brine is eventually produced which will not evaporate effectively (Table 10.1). The brine which ultimately will be produced will have to be disposed of by deep well injection. This is a problem which would have to be addressed in the long term (e.g., not something that will have to be addressed on an annual basis).

Table 10.1. Effects of Sodium Chloride Concentrations on Evaporation (Rohwer, 1933).

Sodium Chloride Concentration	Reduced Evaporation
2%	97%
5%	98%
10%	93%
20%	78%

With the reverse osmosis system, the efficiency of the desalination process is limited by the concentration of the wastewater. As the concentration of the salts in the waste stream increases, the effectiveness of the process decreases. For the wastewater generated at the EPNG SJRP, the effectiveness of reverse osmosis is estimated at 50%. This efficiency rating may be improved to 70% if a portion of the reject water is looped through the system. The portion of the water which can not be reclaimed (reject water) will have to be disposed of via another process (i.e., commercial deep well injection).

Table 10.2 lists comparisons of these four disposal options and is followed by a cost analysis of each. In order to estimate expenses associated with these options it was necessary to make some assumptions. Therefore, these figures should be used only for comparison purposes and should not be viewed as the actual costs for implementing these options.

Table 10.2. Disposal Options Cost Comparison.*

Disposal Options	First Year Costs	Annual Costs	5-Year Costs
Land Application	$571,775	$40,000	$716,775
Surface Impoundments	$1,402,509	None	$1,402,509
Reverse Osmosis			
50% Efficiency	$518,516	$253,516	$1,532,580
70% Efficiency	$384,999	$169,949	$1,064,795
Commercial Deep Well Injection	$516,471	$426,471	$2,231,215

* Costs for utilities are not included.

Land Application

Land application estimates are based on the wastewater quality presented in Section 2.0 and assume implementation at the East site.

Assumptions:

Annual wastewater production = 9.67 million gallons (229,286 bbl)
Area required = 30 acres
Sideroll irrigation system = $15,000
KWB&A feasibility study = $156,775 (assumes implementation of Phase 3)
Storage tank (60,000 bbl) = $360,000
Monitoring and analysis = $10,000/yr
Soil amendments = $5,000/yr
Maintenance (1 full-time employee; wages & benefits) = $25,000/yr
Raw Water = $0

TOTAL FIRST YEAR COSTS = $571,775

SUBSEQUENT ANNUAL COSTS = $40,000

Surface Impoundments

Cost estimates for surface impoundments are based on the yearly water budget, which allows for the total evaporation of all wastewater. Based on the initial water budget it has been estimated that a total capacity of 14.44 acre-feet will be required. However, it will be necessary to maintain a minimum surface area of 12 acres to achieve the necessary amount of evaporation. To derive the costs for constructing surface impoundments, a program designed for EPA was used (Table 10.3) (EPA, 1985). Costs listed in the program are in 1984 dollars; however, they were converted to 1987 dollars using a five percent per year inflation rate ($1.00 in 1984 = $0.86 in 1987).

Assumptions:

Annual evaporation cycle
Annual wastewater production = 30 acre-feet (9.67 million gallons)
Annual salt accumulation = 0.2 acre-feet
Large surface area to increase evaporation
No runoff
No discharge
Side slope = 3:1
Cut and fill design
Maintain 2 feet of freeboard
Double synthetic liner with leak detection

TOTAL CONSTRUCTION COSTS = $1,402,509

It should be noted that construction materials and specifications for surface impoundments are quite variable and cost estimates could vary.

Reverse Osmosis

Operation costs for a reverse osmosis system were obtained for Applied Water Engineering, Dallas, Texas. Estimates are based on the wastewater analysis supplied in this report.

Table 10.3. Unit Costs for Construction of 15 Acre Surface Impoundment.*

Component	Unit	Means (1984) Unit Cost	1987 Unit Cost	Number of Units	1987 Cost
Geotech. Invest.	site	$12,441.00	$14,466.28	1.00	$14,466.28
Clear & Grub	acre	$1,403.60	$1,632.09	20.00	$32,641.86
Excavation	cu. yd	$2.14	$2.49	49,286.08	$122,642.10
Grading & Compaction	sq. yd	$0.57	$0.66	59,047.99	$39,136.46
Berm Construction (fill & spread)	cu. yd	$2.19	$2.55	16,349.86	$41,635.12
Berm Compaction	cu. yd	$1.37	$1.59	16,349.86	$26,045.71
Clay Liner (material)	cu. yd	$4.90	$5.70	9,680.00	$55,153.49
Clay Liner (installation)	cu. yd	$2.73	$3.17	9,680.00	$30,728.37
Compaction (Clay)	cu. yd	$1.15	$1.34	9,680.00	$12,944.19
Drain Layer (material)	cu. yd	$6.50	$7.56	0.00	$0.00
Drain Layer (installation)	cu. yd	$2.73	$3.17	0.00	$0.00
Compaction (Drain Layer)	cu. yd	$1.24	$1.44	0.00	$0.00
Protective soil (material)	cu. yd	$8.50	$9.88	19,486.34	$192,597.56
Protective Soil (installation)	cu. yd	$2.73	$3.17	19,486.34	$61,857.80
Geotextile Protec.Layer (mat)	sq. ft	$0.09	$0.10	522,540.00	$54,684.42
Geotextile protec.Layer (inst.)	sq. ft	$0.07	$0.08	522,540.00	$42,532.33
Primary FML (mat.)	sq. ft	$0.28	$0.33	522,540.00	$170,129.30
Primary FML (inst.)	sq. ft	$0.18	$0.21	522,540.00	$109,368.84
Geotextile Support (material)	sq. ft	$0.09	$0.10	522,540.00	$54,684.42
Geotextile Support (instal)	sq. ft	$0.07	$0.08	522,540.00	$42,532.33
Upper FML -Composite Liner (mat)	sq. ft	$0.28	$0.33	522,540.00	$170,129.30
Upper FML -Composite Liner (inst)	sq. ft	$0.18	$0.21	522,540.00	$109,368.84
Leachate Drain Main (mat)	ft	$1.41	$1.64	743.00	$1,218.17
Leachate Drain Main (inst.)	ft	$2.16	$2.51	743.00	$1,866.14
Leachate Drain Lateral (mat.)	ft	$1.52	$1.77	840.00	$1,484.65
Leachate Drain Lateral (inst.)	ft	$1.11	$1.29	840.00	$1,084.19
Prefabricated Drain Layer (mat.)	sq. ft	$0.00	$0.00	522,540.00	$0.00
Prefabricated Drain Layer (inst.)	sq. ft	$0.00	$0.00	522,540.00	$0.00
Pump (materials)	each	$1,450.00	$1,686.05	1.00	$1,686.05
Pump (installation)	each	$265.00	$308.14	1.00	$308.14
Sump (materials)	each	$1,990.00	$2,313.95	1.00	$2,313.95
Sump (installation)	each	$385.00	$447.67	1.00	$447.67
Diversion Ditch	ft	$2.41	$2.80	3,147.98	$8,821.65
Rip Rap (materials)	cu. yd	$8.75	$10.17	0.00	$0.00
Rip Rap (installation)	cu. yd	$11.25	$13.08	0.00	$0.00
				TOTAL =	$1,402,509.33

* 1984 dollar estimates based on Godfrey, 1984.
1987 dollar estimates based on 5% yearly inflation from 1984 to 1987.

Assumptions:

50% System Efficiency

Chemical analyses are as presented in Section 2
Annual wastewater production = 9.67 million gallons
System efficiency = 50%, therefore, reject water = 4.82 million gallons
Cost of system = $125,000
Installation cost = $50,000
Activated charcoal filter = $2,000/yr
Water filters = $5,200/yr
Anti-scalent = $10,800/yr
Cleaning service = $8,000/yr
Cleaning solutions = $3,600/yr
Storage tank (10,000 bbl) = $90,000
Deep well injection of reject water = $213,236/yr
Maintenance (2 hrs/day @ $15/hr; wages & benefits) = $10,680/yr

TOTAL FIRST YEAR COSTS = $384,999

SUBSEQUENT ANNUAL COSTS = $169,949

70% System Efficiency

Chemical analyses are as presented in Section 2
Annual wastewater production = 9.67 million gallons
System efficiency = 70%, therefore, reject water = 2.93 million gallons
Cost of system = $125,000
Installation cost = $50,000
Activated charcoal filter = $2,000/yr
Water filters = $5,200/yr
Anti-scalent = $10,800/yr
Cleaning service = $8,000/yr
Cleaning solutions = $3,600/yr
Storage tank (10,000 bbl) = $90,000
Deep well injection of reject water = $129,669/yr
Maintenance (2 hrs/day @ $15/hr; wages & benefits) = $10,680

TOTAL FIRST YEAR COSTS = $434,949
SUBSEQUENT ANNUAL COSTS = $169,949

Commercial Deep Well Injection

Since an investigation was not conducted of the area to locate deep well injection facilities, the following estimates are based on quotes from New Mexico Oil and Gas Operation.

Assumptions:

Distance to Injection Well = 75 miles
Trucking costs = $1.43/bbl (assumes 75 miles to well)
Disposal costs = $0.43/bbl (assumes 1,000 bbl/trip disposal rate)
Annual wastewater production = 230,238 bbl
Storage tank (10,000 bbl) = $90,000

TOTAL COST FIRST YEAR = $518,243

SUBSEQUENT ANNUAL COST = $428,243

11.0 REFERENCES

ASTM. 1986. Standard Test Method for Infiltration Rate of Soils in Field Using Double-ring Infiltrometers. In 1986 Annual Book of ASTM Standards. ASTM, Philadelphia, PA.

Bauer, C. M. 1916. Stratigriphy of a Part of the Chaco River Valley: U.S. Geologic Survey, Professional Paper 98P; as cited in Stone et al., 1983.

Black, C. A. 1965. Methods of Soil Analysis. Agronomy Monogram 9. American Society of Agronomy, Madison, WI.

Brown, K. W., G. E. Evans and B. D. Frentrup. 1983. Hazardous Waste Land Treatment. Bitterworth Publishers. Boston. 692 pp.

Chambers, J. C. and R. W. Brown. 1983. Methods for Vegetation Sampling and Analysis on Revegetated Mined Lands. U.S.D.A. FS Report INT-151. 57 pp.

Dhir, R. D. and B. L. Jain. 1976. Investigations into the Use of Highly Saline Waters in an Arid Environment. II. Growth of Crops under High Saline Irrigation. In: H. E. Degne (Ed.). Managing Saline Water for Irrigation. Proceedings of the International Conference on Managing Saline Water for Irrigation: Planning for the Future. August 16-20, 1976. Texas Tech. University. Lubbock, Texas.

Doorenbos, J. and W. O. Pruitt. 1977. Guidelines for Predicting Crop Water Requirements. FAO Irrigation and Drainage Paper Vol. 24:20-30.

Eaton, F. M., R. D. McGallum and M. S. Mayhugh. 1941. Quality of Irrigation Waters of the Hollister Area of California. U.S. Dept. of Agric. Bull. 746.

EPA. 1979. Methods for Chemical Analysis of Water and Wastes. USEPA 600/4-79-020.

EPA. 1985. Estimate of Surface Impoundment Construction Costs Under the RCRA Amendments of 1984. USEPA 68-03-1816.

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

Gabin, V. L. and L. E. Lesperance. 1975. New Mexico Climatological Data, Precipitation, Temperature, Evaporation, and Wind Monthly and Annual Means 1850-1975.

Haan, C. T., H. P. Johnson and D. L. Brakensiek (Eds). 1982. Hydrologic Modeling of Small Watersheds. ASAE Monograph Number 5. St. Joseph, Michigan. 533 p.

Hardan, A. 1976. Irrigation with Saline Water Under Desert Conditions. In: H. E. Degne (Ed.). Managing Saline Water for Irrigation. Proceedings of the International Conference on Managing Saline Water for Irrigation: Planning for the Future. August 16-20, 1976. Texas Tech University. Lubbock, Texas.

Hvorslev, M. J. 1951. Time lag and soil permeability in groundwater observations. U.S. Army Corps of Engineers Waterways Experiment Station Bulletin 36, Vicksburg, MS.

Larcher, W. 1980. Physiological Plant Ecology. Berlin Heidelberg New York. 303 pp.

New Mexico Geological Society. 1977. Guide Book of San Juan Basin III, Proceedings of NMGS Twenty-eighth Field Conference. Sept. 15-17, 1977. J. E. Fassett (ed.). New Mexico Geological Society.

NOAA. 1987. Surface Land Daily Cooperative Summary of the Day TD-3200. National Climatic Data Center, Asheville, North Carolina. 25 p.

O'Sullivan, R. B. and H. M. Beikman, 1963. Geology, Structure, and Uranium deposits of the Shiprock Quadrangle, New Mexico. Miscellenous Geologic Investigations, Map I-345.

Pastuszak, R. A., 1968. Geomorphology of Part of the La Plata San Juan Rivers, San Juan County, New Mexico. Masters thesis from The University of New Mexico, Albuquerque, New Mexico.

Rohwer, Carl. 1933. Evaporation from Salt Solutions and from Oil-Covered Water Surfaces. Journal of Agricultural Research 46:715-729.

Stone W. J. 1987. Personal Communication in the Field at the El Paso Natural Gas San Juan River Plant, June 18, 1987.

Stone, W. J., F. P. Lyford, P. F. Frenzel, N. H. Mizell and E. T. Padgett 1983. Hydrogeology and Water Resources of the San Juan Basin, New Mexico. New Mexico Bureau of Mines and Mineral Resources.

Stubbendieck, J., S. L. Hatch, and K. J. Kjar. 1981. North American Range Plants. Natural Resource Enterprise, Inc., Lincoln Nebraska. 468 pp.

USDA. 1983. National Soils Handbook. Soil Conservation Service, Washington, DC.

USDA. 1980a. Soil Survey of San Juan County, New Mexico (Eastern Part).

USDA. 1980b. Soil Testing Procedures. Texas Agricultural Extension Service, U.S. Department of Agriculture, Washington, DC.

USDA. 1969. Diagnosis and Improvement of Saline and Alkali Soils. Agricultural Handbook 60. U.S. Govt. Printing Office, Washington, DC.

USDA. 1969. Improvement of Saline and Alkali Soils. USDA Agric. Handbook 60.

USDA/SCS. 1975. Urban Hydrology for Small Watersheds. Technical Release No. 55. Dept. of Agric., Washington, D.C. p. 90.

U. S. Department of the Interior. 1977. Ground Water Manual. Water Resources Technical Publication, Water and Power Resources Service, United States Government Printing Office, Denver, CO.

van Hoorn, J. W., J. Risseeuw and J. M. Jurado Prieto. 1976. Desalinization of a Highly Saline Soil. In: H. E. Degne (Ed.). Managing Saline Water for Irrigation. Proceedings of the International Conference on Managing Saline Water for Irrigation: Planning for the Future. August 16-20, 1976. Texas Tech University. Lubbock, Texas.

Wasser, C. H. 1982. Ecology and Culture of Selected Species Useful in Revegetating Disturbed Lands in the West. U.S. Dept. Int. FWS/OBS-82/56. 347 pp.

Woodward L. A. and J. F. Callender, 1977. Tectonic Framework of the San Juan Basin. in New Mexico Geologic Society Guidebook, 28th Field Conference, San Juan Basin III.

PHOTOS

PHASE I PHOTOGRAPHS

Photo 1. Backhoe used to excavate soil observation pits.

Photo 2. Hand soil auger used to explore subsurface horizons and collect soil samples.

Photo 3. Infiltrometers in place at EPNG SJRP.

Photo 4. Inner ring supply tube. Water level drop in this tube is measured to determine soil hydraulic conductivity.


STEVENS
HYDROMARK™
7 8 9
4 5 6
1 2 3
0

Photo 5. Float valves to regulate flow of water to inner and outer rings.

Photo 6. Stevens Hydromark data logger records water level drop in inner ring supply tube digitally.

Photo 7. Stevens water level recorder graphically records water level drop in inner ring supply tube.

Photo 8. Hollow stem drill rig used to drill most borings and install piezometers E1A, E3, and W2. Hollow stem rig operated by Western Technologies.

Photo 9. MO-TE drill rig and 10 foot core barrel used used to collect samples at E1B and E2B. Tan sandstone shown in core barrel.

Photo 10. Typical split spoon sample of the Quaternary Alluvial sediments.

Photo 11. Core sample of the tan sandstone identified as the Farmington Sandstone member (Kkm) of the Kirtland Shale. Sample collected at a depth of 34 to 44 feet during the installation of Piezometer E2B.

Photo 12. Weathered gray shale identified as the lower member the Kirtland Shale (Kkl). Sample collected at a depth of 46 feet during the installation of Piezometer E2B.


77

Photo 13. Gray sandstone from the lower member of the Kirtland Shale (Kkl). Sample collected at a depth of 77 feet at E2B. Hydraulic conductivity of this material was measured at 3.3 x 10^{-5} cm/sec.

Photo 14. Shale clasts identified in the sandstone collected from the lower portion of E2B.

Photo 15. Ten-point frame used during the vegetation survey to inventory native plant species.

Photo 16. Method used to inventory plant species along the vegetation transects.

Photo 17. Leveling the transit used to survey locations and elevations of Phase I sample locations.

Photo 18. Establishing the elevation of one of the wastewater ponds.

APPENDIX A

APPENDIX A

RESULTS OF WASTEWATER

ANALYSES

Report of Chemical Analysis

Consulting Geotechnical, Materials and Environmental Engineers
Geologists, Scientists and Chemists

Raba-Kistner
Consultants, Inc.

P.O. Box 690287, San Antonio, TX 78269-0287
12821 W. Golden Lane, San Antonio, TX 78249
(512) 699-9090

To: El Paso Natural Gas Company
P.O. Box 4990
Farmington, New Mexico 87499

Attn: Mr. Kenneth E. Beasley

Project No.: SA0687-0003-010
Assignment No.: 6-11101
Date: 7/02/87

Subject: Analysis of Wastewater Samples

Test Results:

Analyte	Method	J87-022 (11101-1) (mg/L)	J87-025 (11101-2) (mg/L)	J87-026 (11101-3) (mg/L)	J87-0-27 (11101-4) (mg/L)
Ammonia-Nitrogen	EPA 350.2	<.4	<.4	<.4	<.4
Chemical Oxygen Demand	Hach	<25	570	46	600
Kjeldahl Nitrogen	EPA 351.3				
Nitrate-Nitrogen	EPA 300	.5	<.1	<.1	<.1
Oil and Grease	EPA 413.1	1.5	1.0	1.0	1.0
Organic Carbon	EPA 415.1	3	5	18	15
Orthophosphate	EPA 300.0	<.1	<.1	<.1	<.1
Cyanide, Total	EPA 335.2	.024	<.005	.006	.076
Phenols	EPA 420.1	<.05	.06	<.05	<.05
Arsenic	EPA 206.2	<.01	<.01	<.01	<.01
Barium	EPA 208.1	<.3	.73	<.3	<.3
Boron	EPA 212.3	.52	.36	.85	.41
Cadmium	EPA 213.1	<.01	.03	<.01	<.01
Calcium	EPA 215.1	33	360	170	45

Raba-Kistner Consultants, Inc.

by [signature]
Frank B. Schweitzer
Vice-President, Chemistry

Austin / El Paso / San Antonio

Project No.: SA0687-0003-010

Assignment No.: 6-11101

Date: 7/02/87

Analyte	Method	J87-022 (11101-1) (mg/L)	J87-025 (11101-2) (mg/L)	J87-026 (11101-3) (mg/L)	J87-0-27 (11101-4) (mg/L)
Chromium, Total	EPA 218.1	<.02	.03	.05	.02
Hardness	SM 314A	120	1430	630	160
Lead	EPA 239.1	<.05	.35	.10	.22
Magnesium	EPA 242.1	10	130	50	11
Mercury	EPA 245.1	<.001	<.001	<.001	<.001
Nickel	EPA 249.1	.08	.32	.21	.27
Potassium	EPA 258.1	1.6	44	7.8	23
Selenium	EPA 270.2	<.01	<.01	<.01	<.01
Silver	EPA 272.1	<.01	.03	<.01	.03
Sodium	EPA 273.1	15	7100	90	6600
Zinc	EPA 289.1	.09	.12	.34	.56
Molybdenum	EPA246.1	<.01	.02	.02	.03
Alkalinity, Total	EPA 310.1	64	36	27	310
Alkalinity, Bicarbonate	EPA 310.1	<5	<5	<5	<5
Chloride	EPA 300.0	13	11700	51	9900
Fluoride	EPA 340.1	<.1	<.1	<.1	<.1
Residue, Filterable (TDS)	EPA 160.1	240	1770	1350	17800
Sulfate	EPA 300.0	77	96	730	570

< = Less than

Project No.: SA0687-0003-010
Assignment No.: 6-11101
Date: 7/02/87

Analyte	Method	J87-028 (11101-5) (mg/L)	J87-023 (11101-6) (mg/L)	J87-024 (11101-7) (mg/L)
Ammonia-Nitrogen	EPA 350.2	<.4	.59	<.4
Chemical Oxygen Demand	Hach	90		
Kjeldahl Nitrogen	EPA 351.3		<.4	<.4
Nitrate-Nitrogen	EPA 300.0	<.1		
Oil and Grease	EPA 413.1	1.7		
Organic Carbon	EPA 415.1	29		
Orthophosphate	EPA 300.0	<.1		
Cyanide, Total	EPA 335.2	<.005		
Phenols	EPA 420.1	<.05		
Arsenic	EPA 206.2	<.01		
Barium	EPA 208.1	.40		
Boron	EPA 212.3	.67	.40	<.3
Cadmium	EPA 213.1	<.01		
Calcium	EPA 215.1	270		
Chromium, Total	EPA 218.1	.03		
Hardness	SM314A	690		
Lead	EPA 239.1	.11		
Magnesium	EPA 242.1	4		
Mercury	EPA 245.1	<.001		
Nickel	EPA 249.1	.15		
Potassium	EPA 258.1	13		
Selenium	EPA 270.2	<.01		
Silver	EPA 272.1	<.01		
Sodium	EPA 273.1	150		
Zinc	EPA 289.1	1.4		
Molybdenum	EPA246.1	.03	.01	<.01
Alkalinity, Total	EPA 310.1	18		
Alkalinity, Bicarbonate	EPA 310.1	<5		
Chloride	EPA 300.0	64		
Fluoride	EPA 340.1	<.1		
Residue, Fiterable (TDS)	EPA 160.1	2130		
Sulfate	EPA 300.0	1140		

SAN JUAN RIVER PLANT WASTEWATER ANALYSES BY EFFLUENT SOURCE
(ALL ANALYSES IN MG/L)

	J85-0056 Water, 6" Drain	J85-0069 Water, 8" Drain	J85-0067 Boiler Blowdown	J85-0068 Evaporator Blowdown
COD	54.8	346.0	212.0	77.2
Nitrate-N	<0.1	<0.1	8.99	<0.1
Oil & Grease	3.61	8.02	3.35	3.28
TOC	4.0	91.0	43.0	8.0
O-phosphate	<0.1	<0.1	30.0	<0.1
Cyanide	0.017	ND	0.006	0.007
Phenolics	ND	ND	ND	ND
Arsenic	<0.002	ND	<0.002	<0.002
Barium	<0.2	<0.2	<0.2	<0.2
Cadmium	0.79	ND	ND	ND
Calcium	44.2	134.0	<1.0	1.97
Chromium	ND	0.063	ND	ND
Hardness	152.0	463.0	4.53	5.29
Lead	ND	ND	0.06	ND
Magnesium	10.0	31.3	1.1	0.09
Mercury	<0.001	<0.001	<0.001	<0.001
Potassium	2.13	12.3	0.32	1.54
Selenium	ND	ND	ND	ND
Silver	<0.01	ND	ND	ND
Sodium	950.0	787.0	280.0	298.0
Zinc	0.01	0.45	1.08	0.06
Alkalinity (total)	93.8	150.0	436.0	143.0
Alkalinity (Bicarbonate)	114.0	183.0	0.0	0.0
Chloride	15.1	1,190.0	52.7	821.0
Fluoride	<0.1	<0.1	1.80	<0.1
TDS	1,850.0	2,710.0	1,140.0	1,240.0
Sulfate	142.0	137.0	30.1	172.0
Carbon tetrachloride	ND	ND	ND	ND
PCE	ND	ND	ND	ND
1.1.2-Trichloroethane	ND	ND	ND	ND
PCB's	<0.0001	<0.0001	<0.0001	<0.0001
Benzene	ND	ND	ND	ND
Toluene	ND	ND	ND	ND
EDC	ND	ND	ND	ND
DCE	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND
Xylenes	ND	ND	ND	ND

ND = not detected

6" Drain is from water purification plant and B cooling tower blowdown

8" Drain is from south flare pit, A cooling tower blowdown and plant drains

APPENDIX B

APPENDIX B

SOIL PROFILE DESCRIPTIONS AND PHOTOGRAPHS

AL-95 BACK

Profile No. 1

Percent Slope 1-3% | Aspect South | Erosion Moderate

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH
A1	0-8"	10 YR 5/8	LS	GRAN	Soft Friable	None	Cobbles	None	8.4
B2t	8-13"	10 YR 5/6	CL	SAB	Very FIRM	NONE	Cobbles	Few Thin	8.4
B3	13-30"	10 YR 6/4	CL	MASSIVE	HARD, Firm	NONE	Cobbles	Few, Thin	8.6
C1	30-35"	10 YR 6/4	L	MASSIVE	HARD, FIRM	NONE	Cobbles	No	8.6
C2	35-72"	10 YR 5/8	L	MASSIVE	HARD, FIRM	NONE	Cobbles	NO	8.1

Additional Notes Cobbles 1-3" diam

Series Haplargid

Classification Depth 7 72"

Profile No. 2

Percent Slope 1-3% | Aspect South | Erosion Moderate

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH
A1	0-3"	10 YR 5/6	SL	Sngl gr.	Loose	None	Cobbles	NO	8.4
A2	3-7"	7.5 YR 6/4	LS	Sngl gr.	Loose	None	None	NO	8.3
C1	7-12"	10 YR 7/3	LS	Sngl gr	Loose	None	"	NO	8.6
C2	12-72"	10 YR 7/4	S	Sngl gr.	Loose	None	"	NO	8.7

Additional Notes Cobles

Series Sheppard

Classification 7 72" depth

Profile No. 3

Percent Slope 1-3% | Aspect South | Erosion Slight

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH
A1	0-7"	10 YR 5/6	LS	Sngl gr	Loose	None	NO	NO	9.0
C1	7-12	7.5 YR 6/4	LS	Sngl gr	Loose	None	NO	NO	8.8
C2	12-72"	10 YR 6/4	LS	Sngl gr	Loose	None	NO	NO	8.5

Additional Notes

Series Sheppard

Classification 7 72" depth

Profile No. 4

Percent Slope | Aspect | Erosion

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH
A1	1-3.5	10 YR 6/4	LS	GRAN.	Soft Friable	None	Cobles	None	8.8
B2t	3.5-8	10 YR 5/6	SCL	SAB	Very Firm, Hard		Cobbles	Few, thin	8.4
B3	8-27	10 YR 6/4	SL	SAB	Hard, Firm		Cobbles	Few, Thin	8.9
C1	27-39	10 YR 6/4	LS	Massive	HARD, Firm		Cobbles	NO	8.1
C2	39-66	10 YR 6/4	LS	MASSIVE	HRD, FIRM		NONE	NO	8.8

Additional Notes

C3 66-72 10YR 6/5 LS MASIVE HRD, FIRM NONE NO 8.1

Series Haplargid

Classification

USDA-SCS-FORT WORTH, TEX. 1967

AL-95 BACK

Profile No. 6

Percent Slope 1-3% | Aspect South | Erosion Moderate

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH
A1	0-4.25	7.5YR 6/4	SL	GRAN	FRIABLE	NO	Cobbles	NO	8.9
B2	4.25-7.5	10YR 6/4	SCL	SAB	HARD, FRIABLE	NO	Cobbles	Few, Thin	8.1
B3	7.5-22	10YR 7/3	SCL	SAB	V. Hard, Firm	NO	Cobbles	NO	8.8
C1	22-49	7.5YR 7/2	LS	MASSIVE	V. Hard, Firm	NO	cobbles	NO	8.7
C2	49-72	7.5YR 7/2	LS	MASSIVE	V. Hard, Firm	NO	cobbles	NO	8.6

Additional Notes

Cobbles in A & B 1-2" dia

Cobbles in C 3-6" dia

Series Blackston

Classification 7 72"

Profile No. 7

Percent Slope 1-3% | Aspect South | Erosion Slight

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH
A1	0-4"	7.5YR 5/6	LS	Sngl gr.	Loose	No	NONE		
C1	4-27"	10YR 5/8	SL	Sngl. gr	Loose	NO	NONE		
C2	27-72"	10YR 8/3	SL	Sngl. gr.	Loose	NO	NONE		

Additional Notes

Series Sheppard

Classification 7 72"

Profile No. 8

Percent Slope | Aspect South | Erosion Slight

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH
A1	0-4"	7.5YR 5/6	LS	GRAN	Loose	NO	NONE	NO	8.5
B1 ~~B2t~~	4-20"	10YR 5/6	SL	SAB	Firm, Friable	NO	NONE	Few thin	8.5
B2t	20-26"	10YR 7/3	SCL	SAB	HARD, Firm	NO	NONE	Few, thin	8.8
C1	26-40"	10YR 6/4	SL	Sngl gr.	HARD V. Friable	NO	NONE	NO	8.4
C2	40-72"	10YR 6/6	SL	Sngl. gr	HARD Friable	NO	NONE	NO	9.0

Additional Notes

Series ~~Sheppard~~ MAYQueen

Classification 7 72"

Profile No. 9

Percent Slope | Aspect South | Erosion None

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH
A1	0-4"	10YR 5/8	LS	GRAN	Loose	NO	NONE	NO	8.5
B2t	4-16"	10YR 6/4	SL	SAB	Firm Friable	NO	NONE	Few thin	8.5
C1	16-26"	10YR 5/8	S	SAB	HARD V. Friable	NO	NONE	~~Few thin~~	8.8
C2	26-38"	10YR 5/6	S	Sngl gr	HARD, Loose	NO	NONE	NO	8.8
C3	38-72"	10YR 5/8	S	Sngl. gr	HARD, Loose	NO	NONE	NO	8.6

Additional Notes

Series ~~Sheppard~~ MAYQUEEN

Classification 7 72"

AL-95 BACK

Profile No. 10

Percent Slope 1-3% | Aspect South | Erosion Slight

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH
A1	0-6"	7.5YR 5/6	SL	GRAN	Soft, V. Friable	NO	Cobble		8.4
B21t	6-19"	10 YR 6/4	SCL	SAB	Firm, FRIABLE	NO	Cobbles	Few Thin	8.6
B22t	19-28"	10YR 6/6	SCL	SAB	Firm, FRIABLE	NO	NO	Few Thin	8.6
C1	28-72"	10 YR 6/4	SL	MASSIVE	HARD, FIRM	NO	NO		8.8

Additional Notes Cobbles in A 1/4-2"

Cobbles in B 1-2"

Series OOAK

Classification

Profile No.

Percent Slope | Aspect | Erosion

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH

Additional Notes

Series

Classification

Profile No.

Percent Slope | Aspect | Erosion

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH

Additional Notes

Series

Classification

Profile No.

Percent Slope | Aspect | Erosion

Position on Slope

Horizon	Depth	Color	Texture	Structure	Consistence	Mottles	Fragments	Clay Films	pH

Additional Notes

Series

Classification

USDA-SCS-FORT WORTH, TEX. 1967

Photo 1B. Soil profile 1 located on the West Site mapped Haplargids.

Photo 2B. Soil profile 2 located on the West Site mapped Sheppard series.

Photo 3B. Soil profile 3 located on the West Site mapped Sheppard series.

Photo 4B. Soil profile 4 located on the West Site mapped Haplargids.


PIT 1 EPNG
FRMNGTON
MAY 29


PIT 2 EPNG
FRMNGTON
MAY 29


PIT 3 EPNG
FRMNGTON
MAY 29


PIT 4 EPNG
FRMNGTON
MAY 29


PIT 5 EPNG
FRMNGTON
MAY 30
1
2


PIT 6 EPNG
FRMNGTON
MAY 30


PIT 7 EPNG
FRMNGTON
JUNE 2


PIT 8 EPNG
FRMNGTON
JUNE 2


PIT 9 EPNG
FRMNGTON
JUNE 2


PIT 10EPNG
FRMNGTON
JUNE 2

Photo 5B. Soil profile 5 located on the West Site mapped Sheppard series.

Photo 6B. Soil profile 6 located on the West Site mapped Blackston series.

Photo 7B. Soil profile 7 located on the East Site mapped Sheppard series.

Photo 8B. Soil profile 8 located on the East site mapped Mayqueen series.

Photo 9B. Soil profile 9 located on the East Site mapped Mayqueen series.

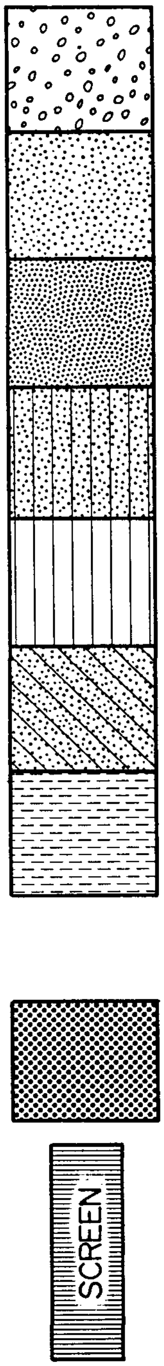
Photo 10B. Soil Profile 10 located on the East Site mapped Mayqueen series.

APPENDIX C

APPENDIX C

BORE LOGS

SYMBOLS USED FOR BORELOGS AND WELL REPORTS



Gravel and Cobbles

Unconsolidated Sand

Sandstone

Sandy silt or silty sand

Silt

Sandy clay or clayey sand

Shale

Bentonite Pellets

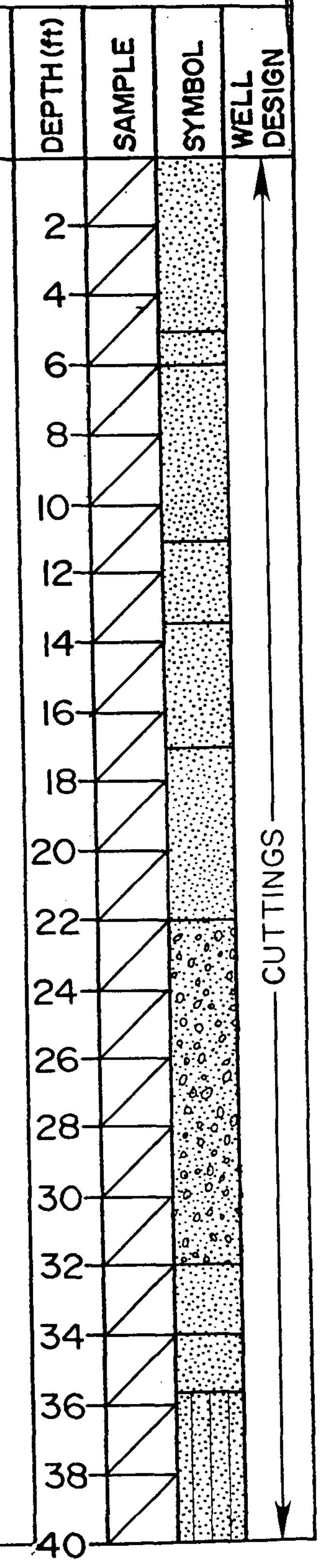
Well Screen

BORING LOG E-1A

Project: EPNG	Drilled By: Western Tech.
Client: EPNG East Site	Logged By: SJ, BS
Well Number: E-1A	Grade Elev: 5290.7' MSL
Location: Farmington, NM	Total Depth: 58.9'
First Encountered Water: Dry	Date Completed: 6/8/87

DESCRIPTION

0.0'-5.0'	Sand; light brown; some silt; fairly well sorted; 0 to 1' loose; below 1' some cementation; sand is well sorted and fine grained; below 2' native salts; well cemented
5.0'-6.0'	Sand; light brown to light gray; some silt; slightly friable; salts with cementation; below 5.5' loose sand to slightly friable, fairly well sorted; fine grained
6.0'-11.0'	Sand; light brown (tan); medium grained; moderate to well sorted; minor amounts of silt; loose; slightly moist; becoming slightly cemented below 9'; bedding structure
11.0'-13.5'	Sand; tan; medium grained; moderate to well sorted; medium grained; 2" slightly cemented zone at 11'; slightly moist below cementation; increasing cementation with depth; minor gravel <2 cm; subrounded; some bedding structure
13.5'-17.0'	Sand; fine grained with silt; no cementation; dry; grading into very coarse grained sand (poorly sorted) unconsolidated; no cementation; dry; downward fining below 15' to 17'
17.0'-22.0'	Sand; tan; coarse grained; some gravel; poorly sorted; dry; unconsolidated; no cementation; gradational to medium grained sand with some silt; alternating layers of downward coarsening and downward fining sands; gravel at 22' up to 3 cm
22.0'-32.0'	Sand and gravel; sand coarse grained and poorly sorted; gravel up to 4 cm; subrounded; dry and unconsolidated
32.0'-34.0'	No sample - rock in tube
34.0'-35.75'	Sand; tan; medium grained; moderately sorted; slightly friable
35.75'-43.0'	Silty sand; tan to olive gray; sand medium to fine grained; consolidated; thinnly bedded; some white precipitates along bedding planes; increasing consolidation with depth



K.W. BROWN & ASSOCIATES, INC.

BORING LOG E-1A (CONT.)

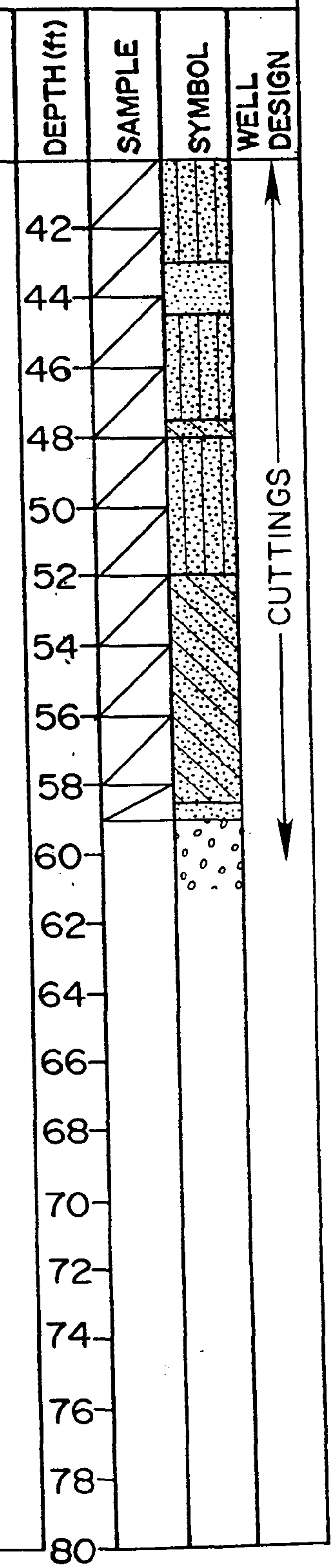
Project: EPNG
Client: EPNG East Site
Well Number: E-1A
Location: Farmington, NM
First Encountered Water:

Drilled By: Western Tech.
Logged By: SJ, BS
Grade Elev:
Total Depth: 58.9'
Date Completed: 6/8/87

DESCRIPTION

43.0'-44.5'	Sand; tan; fine to medium grained; unconsolidated; dry; poorly sorted with rare, coarse grained sand; grading to loosely consolidated silt at 44'
44.5'-47.5'	Silty sand; tan; sand; fine to medium grained; slightly consolidated; dry; thinnly bedded; grading into coarse grained sand at 47' to 47.5'; dry
47.5'-48.0'	Sandy clay; light brown; firm; moist; slightly friable; low plasticity
48.0'-52.0'	Silty sand; tan; fine to medium grained; slightly consolidated; thinnly bedded; minor amounts of clay; dry grading to a sandy clay at 52'
52.0'-58.5'	Sandy clay; light gray to light brown with orange mottling increasing with depth; sand medium to fine grained; moist; some interbedded sand lenses
58.5'-58.75'	Sand; tan to slightly red; medium to fine grained; some silt; moist

Auger Refusal at 58.9' - Cobbles



K.W. BROWN & ASSOCIATES, INC.

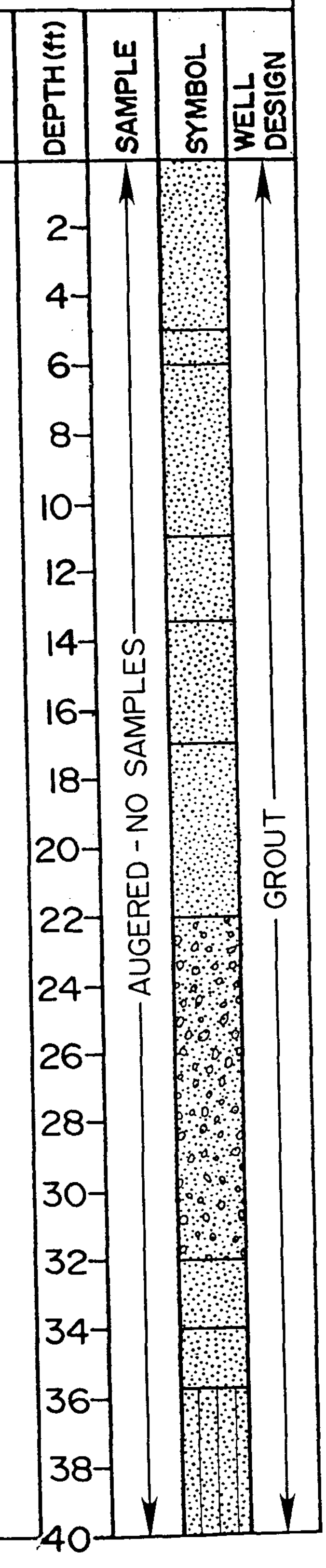
BORING LOG E-1B

Project: EPNG
Client: EPNG East Site
Well Number: E1-B Southeast - East Plot
Location: Farmington, NM
First Encountered Water: Rotary Wash

Drilled By: MO-TE
Logged By: SJ
Grade Elev: 5290.4' MSL
Total Depth: 79.0'
Date Completed: 6/12/87

DESCRIPTION

0.0'-5.0'	Sand; light brown; some silt; fairly well sorted; 0 to 1' loose; below 1' some cementation; sand is well sorted and fine grained; below 2' native salts; well cemented
5.0'-6.0'	Sand; light brown to light gray; some silt; slightly friable; salts with cementation; below 5.5' loose sand to slightly friable, fairly well sorted; fine grained
6.0'-11.0'	Sand; light brown (tan); medium grained; moderate to well sorted; minor amounts of silt; loose; slightly moist; becoming slightly cemented below 9'; bedding structure
11.0'-13.5'	Sand; tan; medium grained; moderate to well sorted; medium grained; 2" slightly cemented zone at 11'; slightly moist below cementation; increasing cementation with depth; minor gravel <2 cm; subrounded; some bedding structure
13.5'-17.0'	Sand; fine grained with silt; no cementation; dry; grading into very coarse grained sand (poorly sorted) unconsolidated; no cementation; dry; downward fining below 15' to 17'
17.0'-22.0'	Sand; tan; coarse grained; some gravel; poorly sorted; dry; unconsolidated; no cementation; gradational to medium grained sand with some silt; alternating layers of downward coarsening and downward fining sands; gravel at 22' up to 3 cm
22.0'-32.0'	Sand and gravel; sand coarse grained and poorly sorted; gravel up to 4 cm; subrounded; dry and unconsolidated
32.0'-34.0'	No sample - rock in tube
34.0'-35.75'	Sand; tan; medium grained; moderately sorted; slightly friable
35.75'-43.0'	Silty sand; tan to olive gray; sand medium to fine grained; consolidated; thinnly bedded; some white precipitates along bedding planes; increasing consolidation with depth



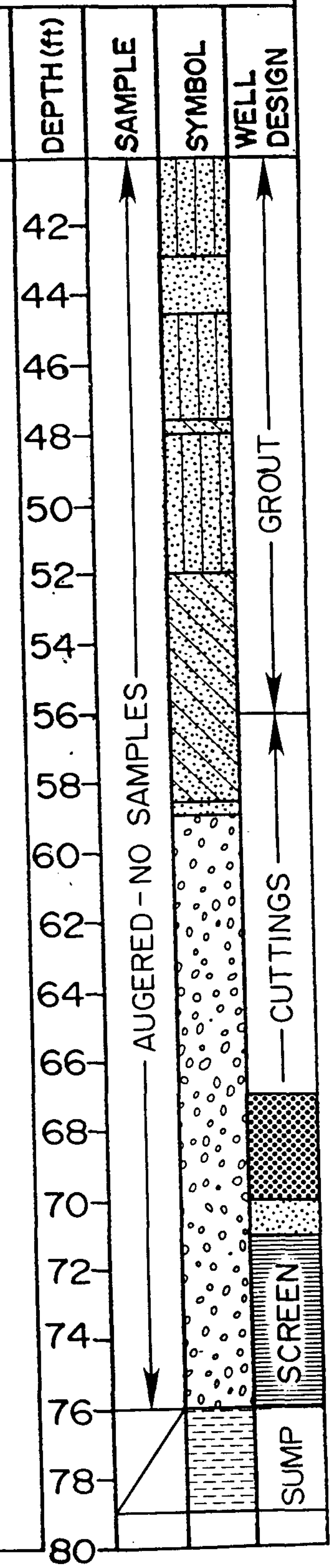
BORING LOG E1-B (CONT.)

Project: EPNG
Client: EPNG East Site
Well Number: E1-B Southeast - East Plot
Location: Farmington, NM
First Encountered Water:

Drilled By: .
Logged By: SJ
Grade Elev:
Total Depth: 79.0'
Date Completed: 6/12/87

DESCRIPTION

43.0'-44.5'	Sand; tan; fine to medium grained; unconsolidated; dry; poorly sorted with rare, coarse grained sand; grading to loosely consolidated silt at 44'
44.5'-47.5'	Silty sand; tan; sand; fine to medium grained; slightly consolidated; dry; thinnly bedded; grading into coarse grained sand at 47' to 47.5'; dry
47.5'-48.0'	Sandy clay; light brown; firm; moist; slightly friable; low plasticity
48.0'-52.0'	Silty sand; tan; sand; fine to medium grained; slightly consolidated; thinnly bedded; minor amounts of clay; dry grading to a sandy clay at 52'
52.0'-58.5'	Sandy clay; light gray to light brown with orange mottling increasing with depth; sand medium to fine grained; moist; some interbedded sand lenses
58.5'-58.75'	Sand; tan to slightly red; medium to fine grained; some silt; moist
58.75'-59.0'	Cobbles
59.0'-76.0'	Gravel; no sample; logged from cuttings
76.0'-79.0'	No sample recovery; logged from cuttings in core barrel; sandy clay/weathered shale; dark blue gray; sand fine to medium grained and poorly sorted; noncalcareous



K.W. BROWN & ASSOCIATES, INC.

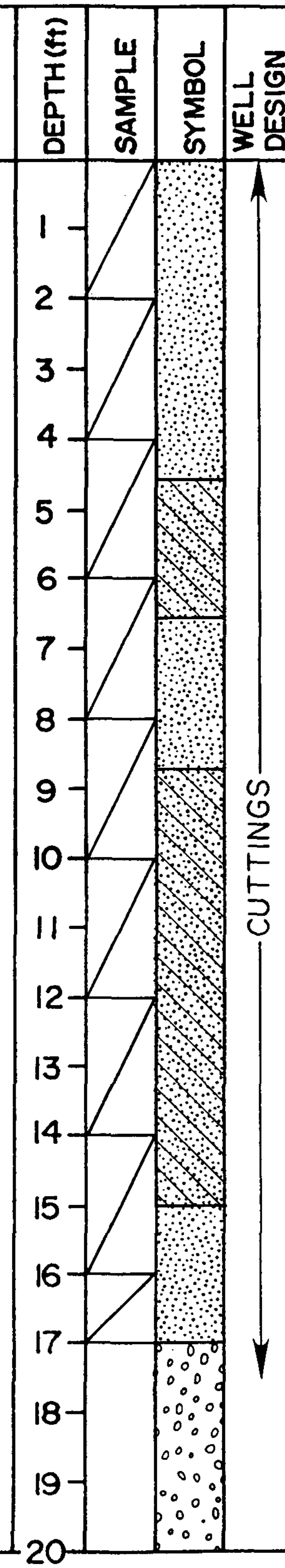
BORING LOG E-2A

Project: EPNG
Client: EPNG Northeast Corner
Well Number: E-2A
Location: Farmington, NM
First Encountered Water:

Drilled By: Western Tech.
Logged By: SJ, BS
Grade Elev.: 5310.0' MSL
Total Depth: 21.0'
Date Completed: 6/11/87

DESCRIPTION

0.0'-4.5'	Sand; light brown; fine grained; some silt; consolidated; slightly moist; calcareous matrix (10% HCL); moderately sorted; slightly cementation crystals 6" thick at 3'
4.5'-6.5'	Sandy clay; tan to olive gray; slightly consolidated; precipitated calcareous salts at 4.5' to 6.5'; moist; calcareous matrix
6.5'-8.75'	Sand; tan; medium to coarse grained; poorly sorted; dry; consolidated; 6" gravel layer at 7' (up to 3 cm); coarse sand at 7.5'; calcareous matrix; precipitated salts at 8.25'; loose coarse grained sand at 8.5'
8.75'-15.0'	Clayey sand; tan to light gray; well sorted medium grained sand; dry; well consolidated; calcareous matrix at 9.25'; some oxidized iron; friability increasing with depth; calcareous matrix below 12'; calcareous layer at 13'; gypsum crystals at 14 to 14.5' <5 mm
15.0'-17.0'	Sand; tan; fine grained; dry; slightly consolidated to loose; thinnly bedded; some gypsum crystals <5 mm; slightly calcareous
17.0'-21.0'	No sample; gravel
	Auger Refusal



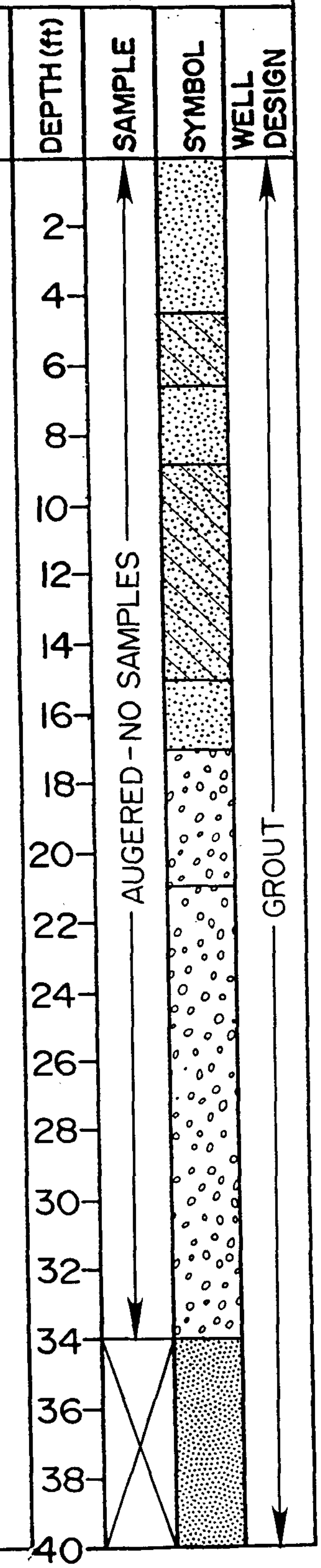
BORING LOG E-2B

Project: EPNG
Client: EPNG Northeast Corner
Well Number: E-2B
Location: Farmington, NM
First Encountered Water:

Drilled By: MO-TE
Logged By: SJ, BS
Grade Elev.: 5310.0' MSL
Total Depth: 78.5'
Date Completed: 6/11/87

DESCRIPTION

0.0'-4.5'	Sand; light brown; fine grained; some silt; consolidated; slightly moist; calcareous matrix moderately sorted; slightly cementation 6" thick at 3'
4.5'-6.5'	Sandy clay; tan to olive gray; slightly consolidated; precipitated calcareous salts at 4.5' to 6.5'; moist; calcareous matrix
6.5'-8.75'	Sand; tan; medium to coarse grained; poorly sorted; dry; consolidated; 6" gravel layer at 7' (up to 3 cm); coarse sand at 7.5'; calcareous matrix; precipitated salts at 8.25'; loose coarse grained sand at 8.5'
8.75'-15.0'	Clayey sand; tan to light gray; well sorted medium grained sand; dry; well consolidated; calcareous matrix at 9.25'; some oxidized iron; friability increasing with depth; calcareous matrix below 12'; calcareous layer at 13'; gypsum crystals at 14 to 14.5' <5 mm
15.0'-17.0'	Sand; tan; fine grained; dry; slightly consolidated to loose; thinnly bedded; some gypsum crystals <5 mm; slightly calcareous
17.0'-21.0'	No sample; gravel
21.0'-34.0'	No sample; gravel
34.0'-45.0'	Sandstone; light tan; fine to medium grained; well sorted; abundant iron staining of matrix and along bedding planes; abundant gypsum crystals along bedding planes ≤5 mm; some black staining below 39' becoming abundant below 41'; some staining along bedding appears to be Fe/mg; carbonaceous material at 41.5' along bedding planes; some interbedded layers of gray fine to medium grained sandstone (<3 cm); 44' to 45' strongly calcareous



K.W. BROWN & ASSOCIATES, INC.

BORING LOG E-2B (CONT.)

Project: EPNG
Client: EPNG Northeast Corner
Well Number: E-2B
Location: Farmington, NM
First Encountered Water:

Drilled By: Western Tech.
Logged By: SJ, BS
Total Depth: 78.5'
Dates Completed: 6/9/87 & 6/11/87

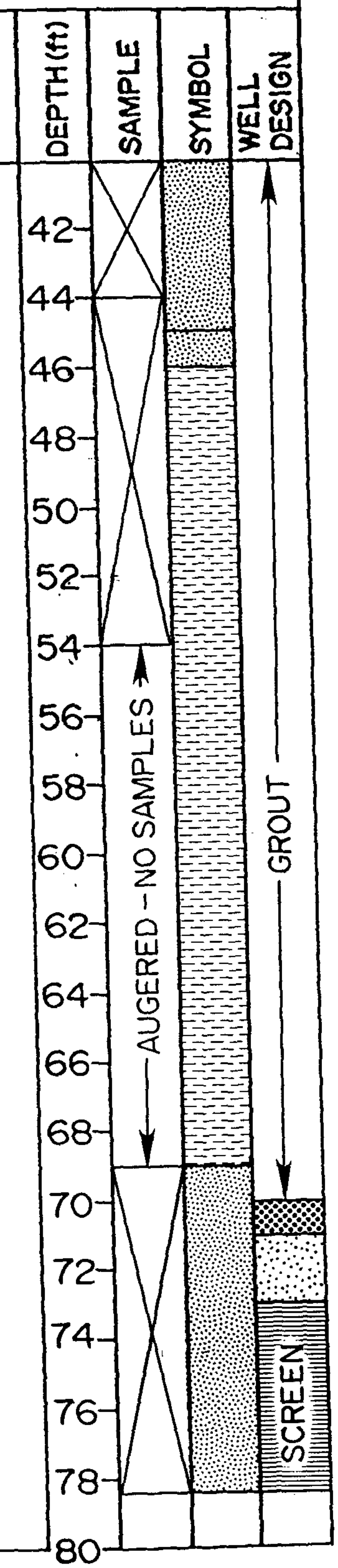
DESCRIPTION

45.0'-46.0' Sandstone; gray; medium to coarse grained; well sorted; thinnly bedded with carbonaceous material along bedding planes; strongly calcareous; gradational contact with overlying sandstone

Sharp contact with shale at 46'

46.0'-69.0' Shale; dark blue/gray; weathered near the upper contact to a depth of approximately 48' with some gravel; slightly carboniferous at 55'; core sample to a depth of 50'; augered to 69' and logged from cuttings

69.0'-78.5' Sandstone; gray; fine to medium grained; well sorted; thinnly bedded; some cross bedding; noncalcareous; carboniferous layer (thinnly bedded) approximately 1 cm thick at 71'; some shale clast at 72', 74', 75' and 76'; thinnly bedded carbonaceous layers <1 mm from 76' to 77'



BORING LOG E-3

Project: EPNG
Client: EPNG
Well Number: E-3 West Side - East Site
Location: Farmington, NM
First Encountered Water:

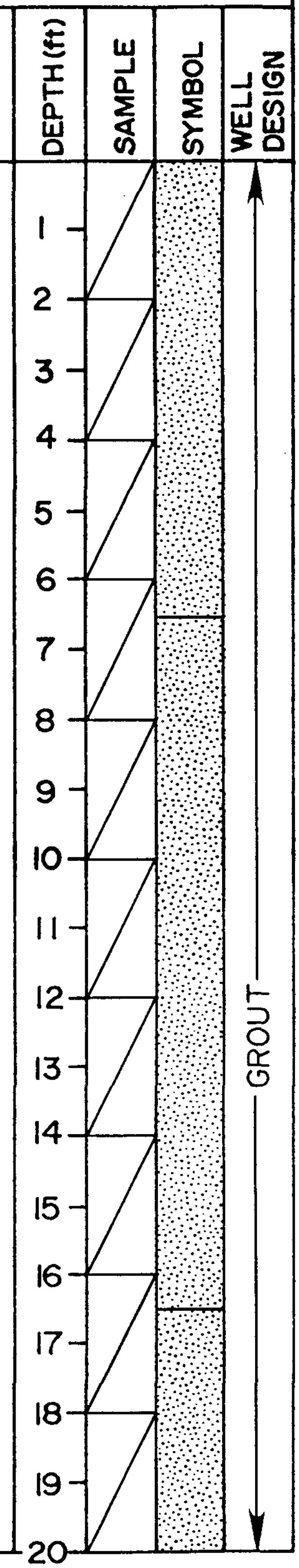
Drilled By: Western Tech.
Logged By: SJ, BS
Grade Elev.: 5298.8' MSL
Total Depth: 78.0'
Date Completed: 6/10/87

DESCRIPTION

0.0'-6.5' Sand; light brown/tan; fine to medium grained; poorly sorted with some silt; unconsolidated to 1'; slightly consolidated below 1'; cemented layer at 2' with highly calcareous salts; matrix is slightly calcareous; dry; below 2' moderately consolidated with abundant calcareous salts; becoming slightly moist below 3'

6.5'-16.5' Sand; tan; coarse grained and moderately sorted; unconsolidated; slightly moist; common calcareous layers <1 mm above 8'; noncalcareous matrix; slightly cemented/calcareous zone approximately 6" thick at 8.5'; clayey sand seam approximately 3" thick at 9.25' and 14' which is calcareous; sand matrix is noncalcareous; grading into gravel with coarse sand at 13.5'; gravel up to 5 cm

16.5'-21.0' Sand; tan; fine grained; fairly well sorted; unconsolidated; calcareous above 17'; dry; coarse sand seam 3" thick at 17' and 19'; becoming slightly calcareous below 19'; downward fining to fine grained sand with silt below 19'



K.W. BROWN & ASSOCIATES, INC.

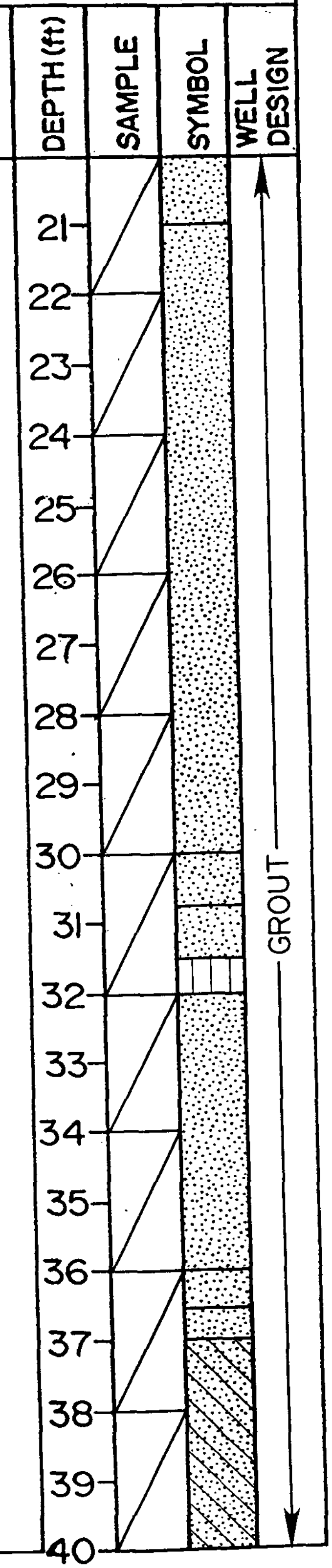
BORING LOG E-3 (CONT.)

Project: EPNG
Client: EPNG
Well Number: E-3 West Side - East Site
Location: Farmington, NM
First Encountered Water:

Drilled By: Western Tech.
Logged By: SJ, BS
Total Depth: 78.0' MSL
Dates Completed: 6/11/87

DESCRIPTION

21.0'-30.0'	Sand; tan; medium and coarse grained; poorly sorted; unconsolidated; dry to slightly moist; noncalcareous; some gravel up to 5 cm at 21'; calcareous matrix at 28'; downward fining; highly oxidized layer (orange) at 29.75' thinnly bedded
30.0'-30.75'	Sand; tan; medium to fine grained; poorly sorted; slightly moist; slightly calcareous
30.75'-31.5'	Sand; buff; coarse grained; poorly sorted; rare gravel <5 mm; noncalcareous; dry; unconsolidated
31.5'-32.0'	Silt; rust colored; thinnly bedded; consolidated; noncalcareous; soft black nodules; carbonaceous
32.0'-36.0'	Sand; tan/buff; coarse grained; well sorted; slightly moist; iron staining beginning at 33'; thinnly bedded (bedding planes stained with iron); noncalcareous; rock at 33'
36.0'-36.5'	Sand; light brown; coarse grained; poorly sorted; slightly moist; minor iron stains; rock at 36.5'; noncalcareous
36.5'-37.0'	Sand; gray; fine to medium grained; slightly moist; noncalcareous; well consolidated



K.W. BROWN & ASSOCIATES, INC.

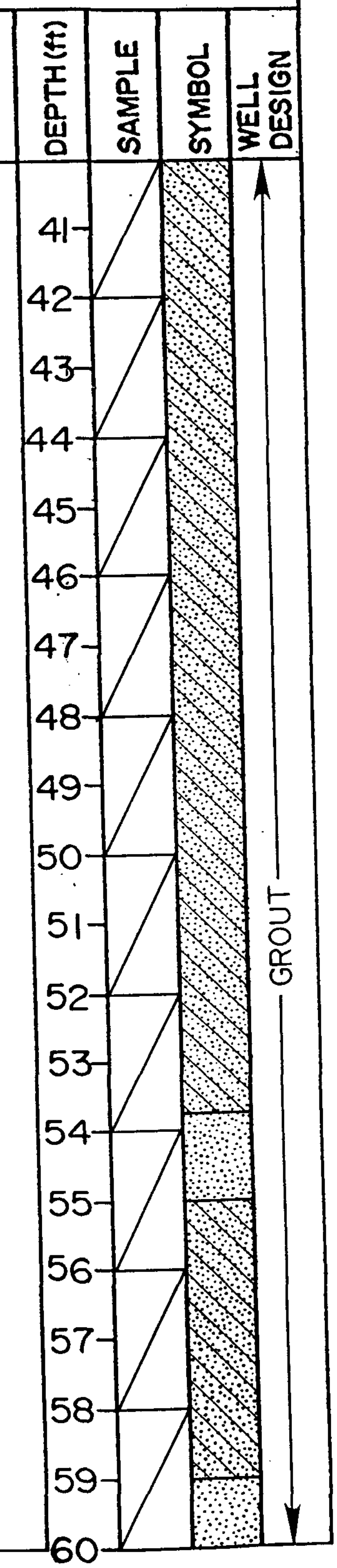
BORING LOG E-3 (CONT.)

Project: EPNG
Client: EPNG
Well Number: E-3 West Side - East Site
Location: Farmington, NM
First Encountered Water:

Drilled By: Western Tech.
Logged By: SJ, BS
Total Depth: 78.0' MSL
Dates Completed: 6/11/87

DESCRIPTION

37.0'-53.75'	Clayey sand; gray; medium to fine grained; well consolidated; noncalcareous; abundant gypsum crystals; abundant seams of yellow material (sulfur?); moderately plastic; slightly moist; decreasing clay content with depth; clay becoming olive to yellow with depth
53.75'-55.0'	Sand; gray to olive; coarse to medium grained with some gravel; unconsolidated; noncalcareous; iron staining; moist; emerald green mineral
55.0'-59.0'	Clayey sand; gray to olive; fine to medium grained; consolidated; noncalcareous; abundant gypsum crystals up to 2 cm; iron staining; plastic; moist
59.0'-60.0'	Sand; gray; fine to medium grained; sulfur stains; occasional iron staining; abundant gypsum crystals; moist; noncalcareous



K.W. BROWN & ASSOCIATES, INC.

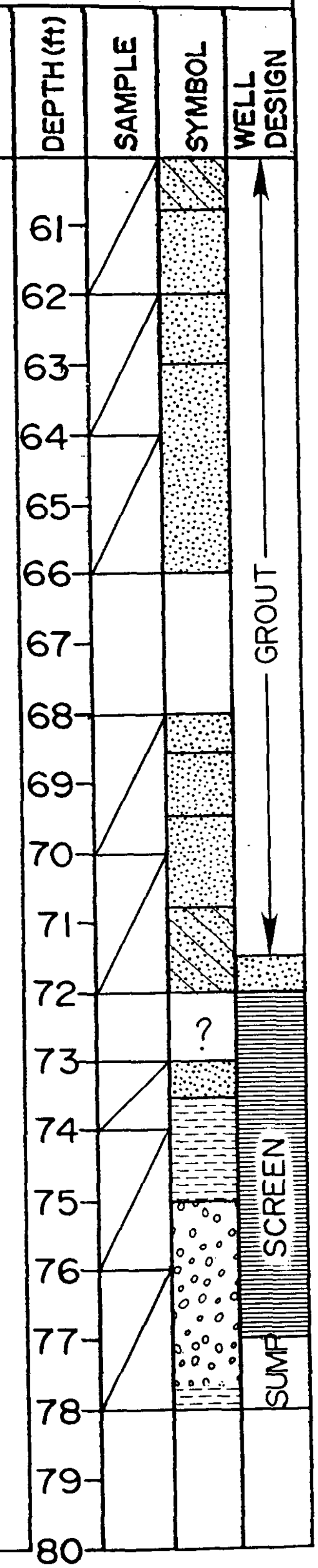
BORING LOG E-3 (CONT.)

Project: EPNG
Client: EPNG
Well Number: E-3 West Side - East Site
Location: Farmington, NM
First Encountered Water: Approximately 74'

Drilled By: Western Tech.
Logged By: SJ, BS
Total Depth: 78.0'
Dates Completed: 6/11/87

DESCRIPTION

60.0'-60.75'	Clayey sand; fine grained; reddish brown; large splotches of gray fine grained sand; no visible gypsum or sulfur; noncalcareous; moist; stiff
60.75'-62.0'	Sand; fine to medium grained; gray; moderately well consolidated; minor splotches of gray clay; abundant gypsum crystals; abundant sulfur staining; poorly sorted; occasional green mineral patches; noncalcareous; moist; frequent iron staining at 61.5'
62.0'-63.0'	Sand; gray; medium to coarse grained; unconsolidated; moist; noncalcareous; moderate amount of sulfur staining; gypsum crystals not apparent; occasional iron staining
63.0'-66.0'	Sand; rust colored; medium grained; moderately well consolidated; noncalcareous; occasional large crystals of gypsum (≤4 mm); abundant small gypsum crystals (≤0.5 mm); no visible sulfur stains; occasional dark red splotches of fine grained iron staining ($Fe(OH)_3$) (amorphous); occasional patches of uniformly gray clay; changes color to reddish olive-gray at 64.75'; moist; large gypsum crystals are convoluted plates approximately 3 mm thick oriented at oblique angles to horizontal; bedding planes not apparent
66.0'-68.0'	No sample recovery (rock in tube)
68.0'-68.5'	Sand; reddish olive gray; fine to medium grained; moderately well consolidated; moist; noncal- careous; occasional green mineral staining; occasional large gypsum crystals (≤4 mm); moderately sorted
68.5'-69.5'	Sand; dark olive brown; fine to medium grained; moderately well sorted; very moist; noncalcareous; unconsolidated; occasional gypsum crystals (<3 mm); some silt
69.5'-70.75'	Sand; dark olive gray; medium grained; moderately sorted; significant occurrences of gypsum crystals (≤8 mm); noncalcareous; moist
70.75'-72.0'	Clayey; silty sand; blue; sand is fine grained; significant clay content; very uniform in color; calcareous; moist; stiff; moderately well consolidated
72.0'-73.0'	No sample recovery
73.0'-73.5'	Sand; dark olive brown; fine grained; very moist; unconsolidated; noncalcareous; occasional gypsum crystals (≤3 mm); very uniform in color
73.5'-75.0'	Shale; blue; saturated (?); weathered portion at top of core appears light blue/gray in color; calcareous; highly consolidated
75.0'-78.0'	Gravel; clasts of shale and other rock types; saturated; interstitial fluid consists of high viscosity, gray liquid; occasional inclusions of saturated, dark olive brown, medium grained sand, with 3 mm gypsum inclusions; gravel is calcareous



K.W. BROWN & ASSOCIATES, INC.

BORING LOG W-1

Project: EPNG
Client: EPNG
Well Number: W-1 Northeast West Site
Location: Farmington, NM
First Encountered Water: Dry

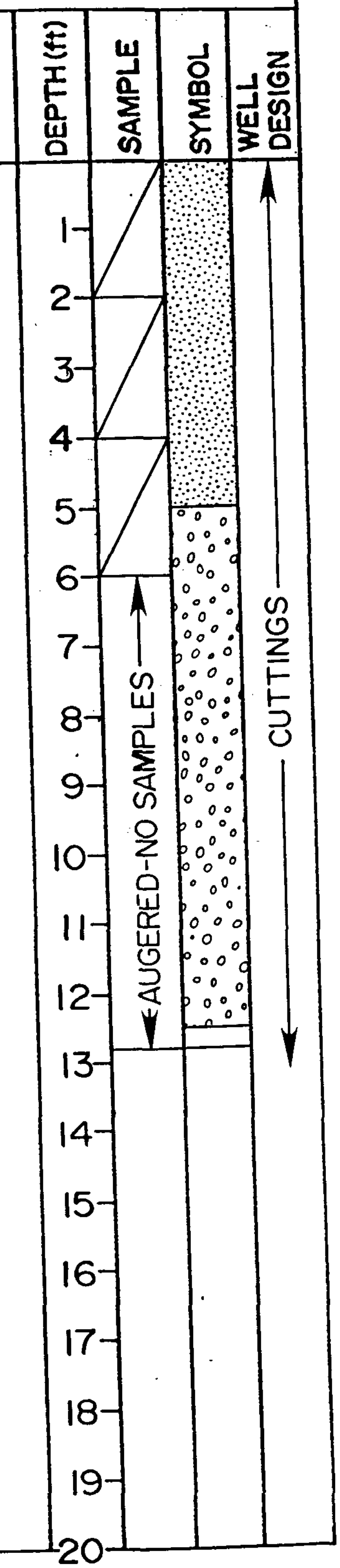
Drilled By: Western Tech.
Logged By: SJ, BS
Grade Elev.: 5292.5' MSL
Total Depth: 12.5'
Date Completed: 6/9/87

DESCRIPTION

0.0'-5.0' Sand; light brown; fine to medium grained; moderately well sorted; dry; slightly consolidated; calcareous matrix; downward coarsening to coarse grained sand at 4' with gypsum crystals; coarse sand is slightly moist

5.0'-12.5' Gravel, up to 4 cm; calcareous matrix; subrounded

Auger Refusal



K.W. BROWN & ASSOCIATES, INC.

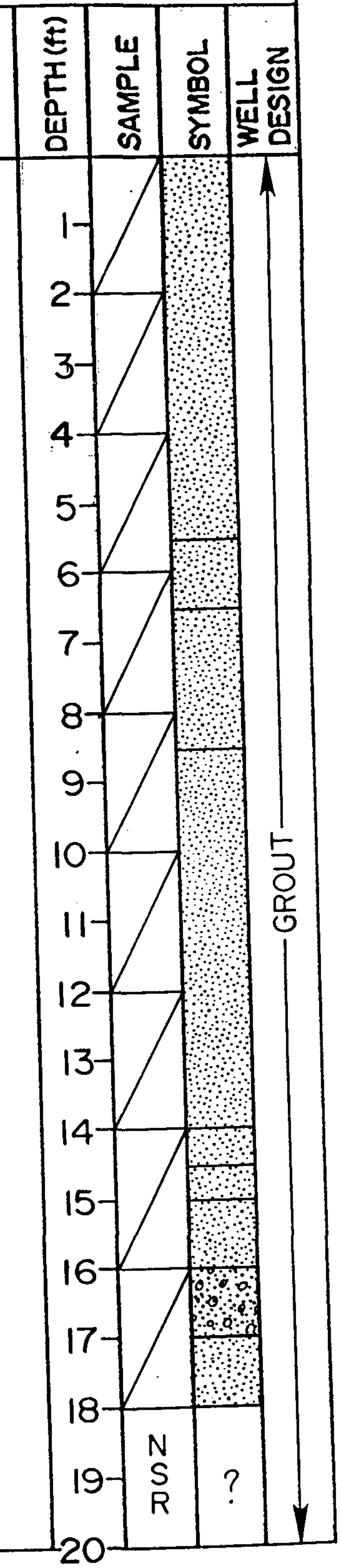
BORING LOG W-2

Project: EPNG
Client: EPNG
Well Number: W-2 West Site South Center
Location: Farmington, NM
First Encountered Water: 53.5'

Drilled By: Western Tech.
Logged By: SJ, BS
Grade Elev.: 5280.1' MSL
Total Depth: 62.0'
Date Completed: 6/9/87

DESCRIPTION

0.0'-5.5'	Sand; light brown; medium to coarse grained; medium-well sorted; unconsolidated; dry; calcareous matrix; downward coarsening to coarse sand at 5.5'
5.5'-6.5'	Sand; light brown; fine grained; moderately well sorted; slightly consolidated; dry; calcareous matrix; dry
6.5'-8.5'	Sand; light brown; medium grained; poorly sorted; slightly cemented with precipitated salts to 7.5'; 3" coarse grained sand below 7.5'; dry
8.5'-14.0'	Sand; tan; medium grained; well sorted; slightly to moderately cemented; thinnly bedded; precipitated salts to 11.25'; calcareous matrix; dry; unconsolidated below 10'; downward coarsening
14.0'-14.5'	Sand; light brown; fine grained; slightly cemented with calcareous material; rare precipitation zones (calcareous); well sorted; dry
14.5'-15.0'	Sand; light brown; coarse grained; poorly sorted; noncalcareous; uncemented; dry
15.0'-16.0'	Sand and gravel; fine to medium grained; poorly sorted; calcareous matrix; gravel up to 3 cm; dry
16.0'-17.0'	Sand and gravel; coarse grained; well sorted; slightly moist; gravel up to 3 cm; noncalcareous
17.0'-18.0'	Sand; tan; medium to coarse grained; poorly sorted; slightly moist; fairly well cemented; friable; precipitate salts; calcareous matrix; downward coarsening to coarse grained sand; poorly sorted; dry
18.0'-22.0'	No sample recovery



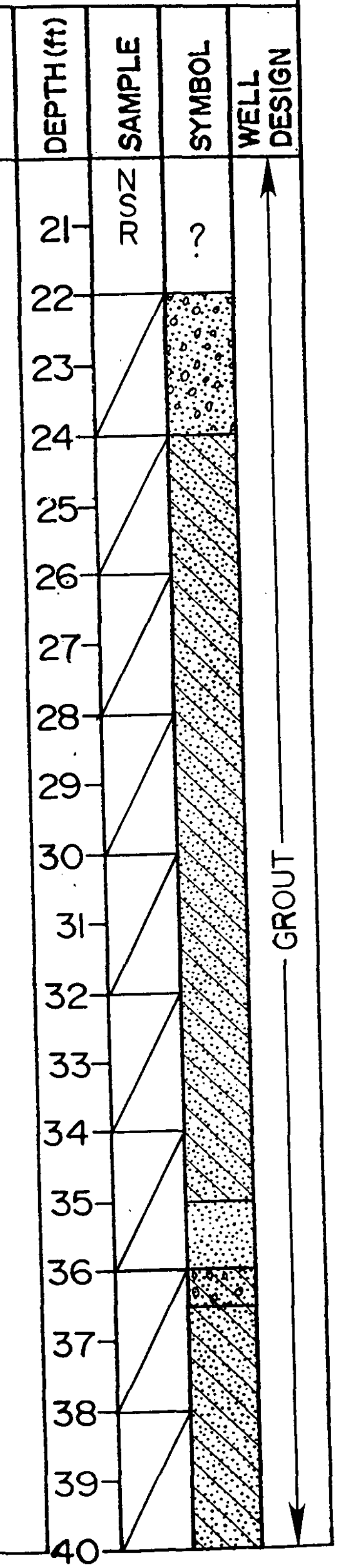
BORING LOG W-2 (CONT.)

Project: EPNG
Client: EPNG
Well Number: W-2 West Site South Center
Location: Farmington, NM
First Encountered Water: 53.5'

Drilled By:
Logged By: SJ, BS
Grade Elev.: 5280.1' MSL
Total Depth: 62.0'
Date Completed: 6/9/87

DESCRIPTION

22.0'-24.0'	Sand and gravel; buff; very coarse grained with gravel up to 3 cm; poorly sorted; dry; noncalcareous
24.0'-35.0'	Clayey sand; olive/tan; fine grained; well sorted; dry; consolidated; noncalcareous matrix with small calcareous nodules <1 mm; old organic matter (roots); some gravel at 26.75'; approximately 3" thick zone; slightly calcareous matrix below 26'; moisture increasing below 32' and becoming slightly plastic with rare iron staining
35.0'-36.0'	Sand; tan; medium grained; well sorted; unconsolidated; rare gypsum crystals; rare ferrous nodules <2 mm; slightly moist; noncalcareous matrix
36.0'-36.5'	Gravel with sand clay matrix; gravel dry; sandy clay moist; gravel <5 mm



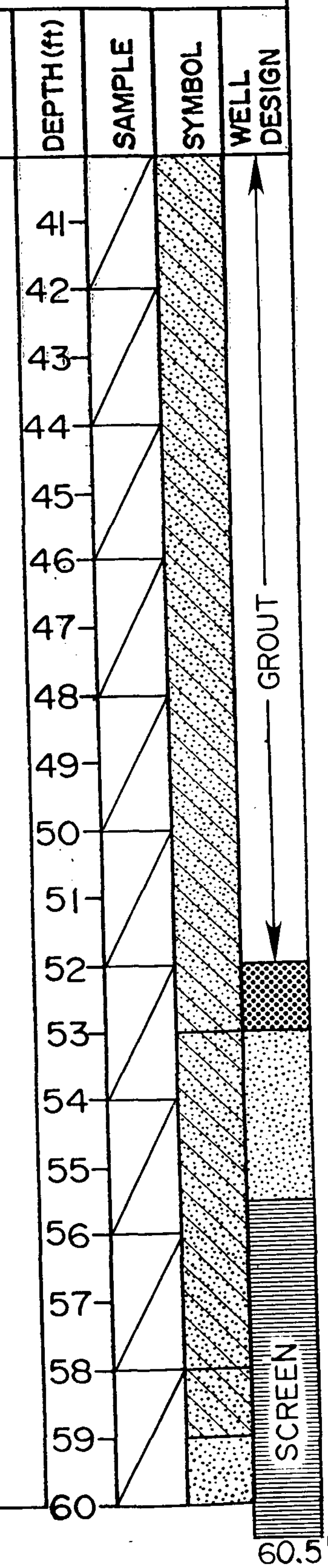
BORING LOG W-2 (CONT.)

Project: EPNG
Client: EPNG
Well Number: W-2 West Site South Center
Location: Farmington, NM
First Encountered Water: 53.5'

Drilled By:
Logged By: SJ, BS
Grade Elev.: 5280.1' MSL
Total Depth: 62.0'
Date Completed: 6/9/87

DESCRIPTION

36.5'-53.0'	Clayey sand; tan; medium grained; moderately well sorted; consolidated; moist and slightly plastic; calcareous matrix; increasing moisture with depth; increasing plasticity with depth; 40.0' to 42.0' - no sample recovery; sandy layer approximately 4" thick at 51.5' very moist
53.0'-58.0'	Clayey sand; light brown/tan; unconsolidated; plastic; saturated; calcareous matrix; sand; fine to medium grained; moderately well sorted; strongly calcareous above saturated zone
58.0'-59.0'	Clayey sand; light brown; fairly consolidated; medium grained; fairly well sorted; strongly calcareous matrix; calcareous nodule at 57.5'; very moist
59.0'-62.0'	Sand; brown; medium grained; moderately sorted; slightly consolidated; very moist to saturated; strongly calcareous matrix



K.W. BROWN & ASSOCIATES, INC.

BORING LOG W-3

Project: EPNG
Client: EPNG
Well Number: W-3 West Site Northwest Corner
Location: Farmington, NM
First Encountered Water: 13.0'

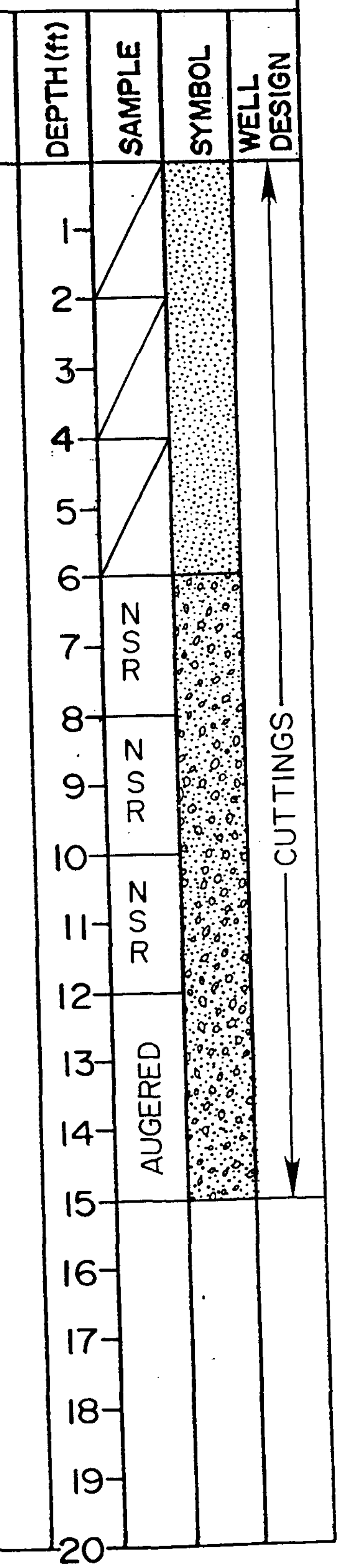
Drilled By: Western Tech.
Logged By: SJ, BS
Grade Elev.: 5288.2' MSL
Total Depth: 15.0'
Date Completed: 6/10/87

DESCRIPTION

0.0'-6.0' Sand; tan; coarse grained; poorly sorted; consolidated; cemented layer at 1' approximately 6" thick; calcareous matrix; slightly moist; becoming loose below 3' and noncalcareous; downward coarsening

6.0'-15.0' No sample sand; gravel and cobbles saturated; free water in hole; suspect broken water line uphill approximately 135'

Filled in hole with cuttings



K.W. BROWN & ASSOCIATES, INC.

BORING LOG E-4

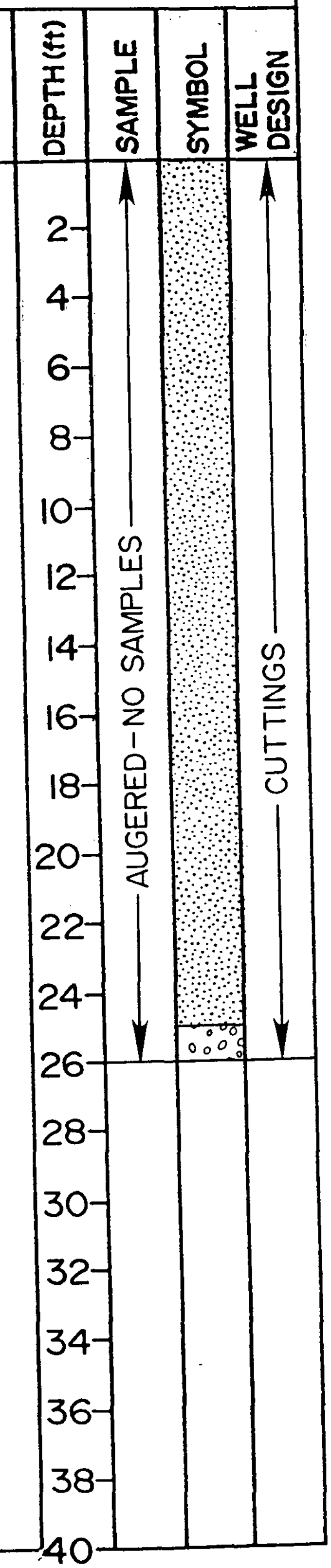
Project: EPNG
Client: EPNG
Well Number: E-4 East Site
Location: Farmington, NM
First Encountered Water: Dry

Drilled By: Western Tech.
Logged By: BS
Grade Elev.: 5307.0' MSL
Total Depth: 26.0'
Date Completed: 6/11/87

DESCRIPTION

Logged From Cuttings

0.0'-25.0'	Sand; light brown; fine grained
25.0'-26.0'	Gravel



K.W. BROWN & ASSOCIATES, INC.

BORING LOG E-5

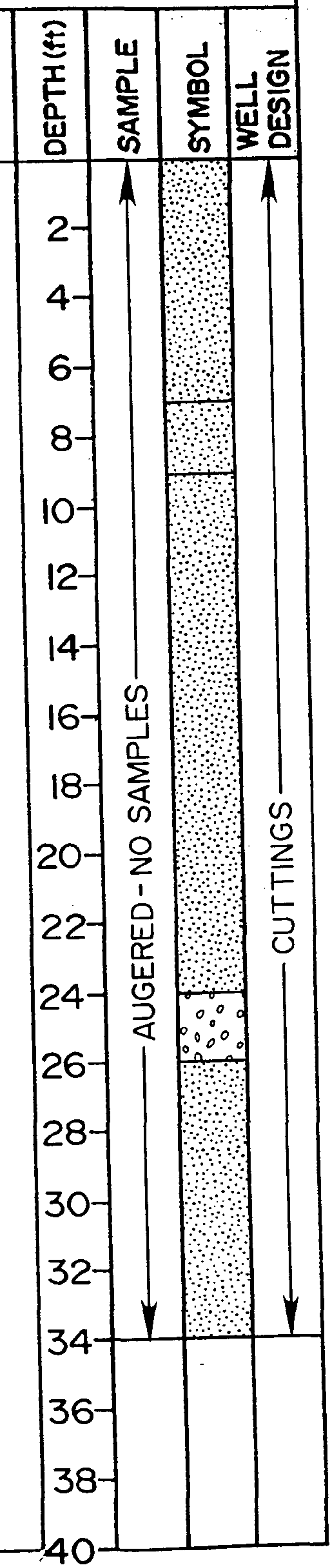
Project: EPNG
Client: EPNG
Well Number: E-5 East Site
Location: Farmington, NM
First Encountered Water: Dry

Drilled By: Western Tech.
Logged By: BS
Grade Elev.: 5302.4' MSL.
Total Depth: 34.0'
Date Completed: 6/11/87

DESCRIPTION

Logged From Cuttings

0.0'-7.0'	Sand; light brown; fine to medium grained
7.0'-9.0'	Sand; white; medium to coarse grained
9.0'-24.0'	Sand; light brown; coarse grained
24.0'-26.0'	Gravel
26.0'-34.0'	Sand; light brown; medium grained



K.W. BROWN & ASSOCIATES, INC.

BORING LOG E-6

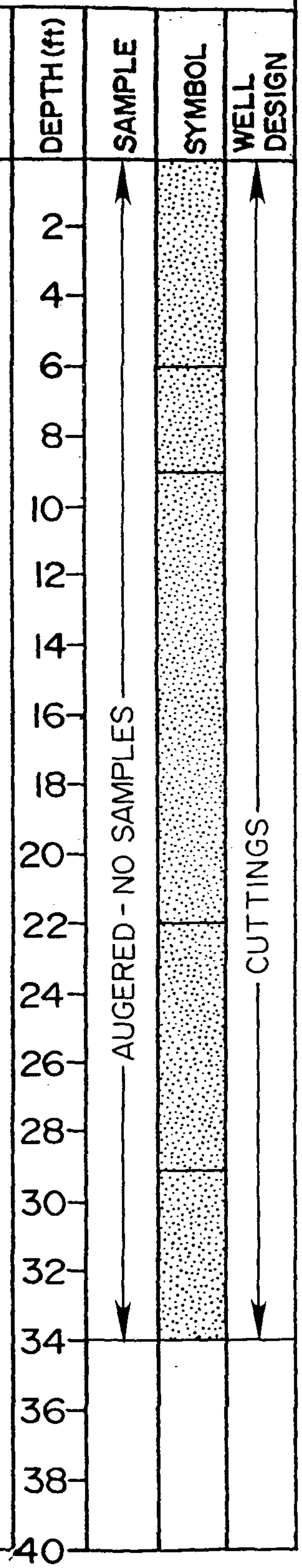
Project: EPNG
Client: EPNG
Well Number: E-6 East Site
Location: Farmington, NM
First Encountered Water: Dry

Drilled By: Western Tech.
Logged By: BS
Grade Elev.: 5302.2' MSL
Total Depth: 34.0'
Date Completed: 6/11/87

DESCRIPTION

Logged From Cuttings

0.0'-6.0'	Sand; light brown; fine to medium grained
6.0'-9.0'	Sand; white; medium to coarse grained
9.0'-22.0'	Sand; light brown; medium grained
22.0'-29.0'	Sand; light brown; coarse grained
29.0'-34.0'	Sand; light brown; medium grained



K.W. BROWN & ASSOCIATES, INC.

BORING LOG E-7

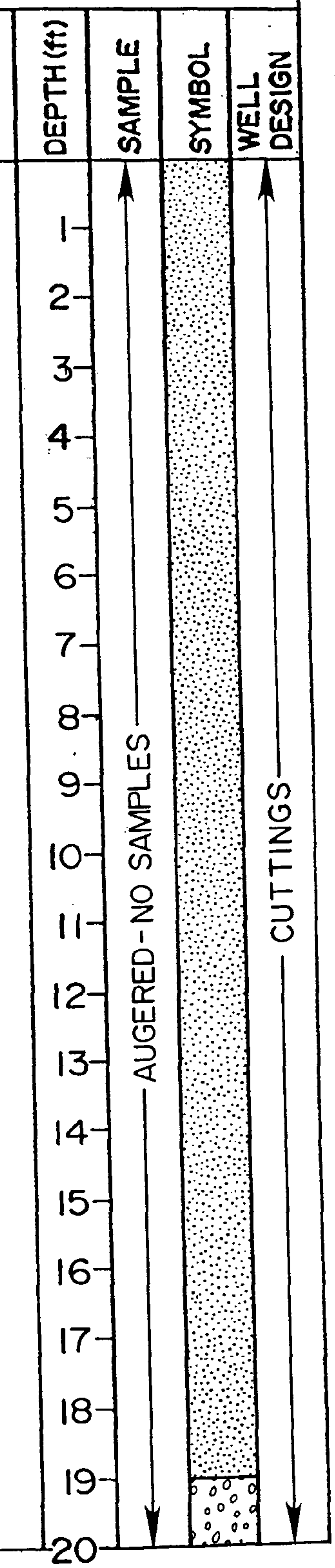
Project: EPNG
Client: EPNG
Well Number: E-7 East Site
Location: Farmington, NM
First Encountered Water: Dry

Drilled By: Western Tech.
Logged By: BS
Grade Elev.: 5305.6' MSL
Total Depth: 20.0'
Date Completed: 6/11/87

DESCRIPTION

Logged From Cuttings

0.0'-19.0'	Sand; olive brown; medium to fine grained
19.0'-20.0'	Gravel



K.W. BROWN & ASSOCIATES, INC.

APPENDIX D

APPENDIX D

LAB ANALYSIS
OF SOIL CORE SAMPLES

File Name: 17061071.WK1 26-Aug-87

Table D-1. Chemical and Physical Analysis of Core Samples E1 and W2 at El Paso Natural Gas's San Juan River Plant.

Sample #	Depth	pH	EC mmho/c	-Soluble Cations- Ca (meq/l)	Mg	Na	SAR	-----Soluble Anions----- CO3 (meq/l)	HCO3	Cl	SO4	Ex Na (meq/100g)	CEC	ESP %	1 bar Moi %	5 bar Moi %	-------Texture-------- Sand (%)	Silt	Clay	Class	Ground Mat'l g/cc	Natural Clod g/cc	%Moi	ec*10	Sum Anions	Sum Catio
EAST SITE																										
E-1	9	8.4	1.1	1.8	1.0	8.3	7.0	0.3	1.3	3.2	6.2	0.8	13.1	6.2	12.1	7.1	60.3	20.2	19.5	SL	1.41	--	1.28	10.8	10.9	11.1
E-1	15	8.6	0.6	1.0	0.5	4.7	5.4	<0.1	1.2	2.9	2.0	0.5	7.1	6.9	4.5	3.0	83.0	1.9	15.1	SL	1.26	--	0.44	6.1	6.0	6.3
E-1	18	8.8	0.7	1.5	0.8	4.5	4.2	<0.1	1.0	2.9	2.6	0.3	6.2	4.7	4.4	2.8	84.2	6.3	9.5	LS	1.36	--	0.50	6.6	6.4	6.8
E-1	21	8.7	0.7	2.0	0.9	4.1	3.4	<0.1	1.2	2.9	3.1	0.3	6.6	4.4	5.6	3.4	81.1	8.9	10.0	LS	1.49	--	0.54	6.7	7.1	7.0
E-1	24	8.9	0.4	0.9	0.5	2.8	3.3	<0.1	1.0	1.8	1.1	0.3	4.7	5.5	2.8	1.9	Insufficient Sample				1.62	--	0.21	3.8	3.9	4.3
E-1	27	8.9	0.3	0.9	0.4	2.2	2.8	<0.1	1.2	0.7	1.0	0.5	5.0	9.5	3.4	2.2	86.6	5.8	7.6	LS	1.66	--	0.18	2.8	2.8	3.5
E-1	36	8.6	0.6	1.9	0.5	4.3	3.9	<0.1	1.3	1.2	3.8	1.1	18.1	5.8	12.7	7.5	51.2	27.2	21.6	SCL	1.35	1.71	1.77	6.0	6.3	6.7
E-1	45	8.6	0.7	2.1	0.5	5.4	4.7	<0.1	1.2	1.2	5.4	1.1	20.8	5.4	16.2	9.8	Insufficient Sample				1.27	1.76	1.82	7.2	7.7	7.9
E-1	48	8.3	1.2	4.7	1.2	7.1	4.2	<0.1	1.2	0.8	12.1	1.0	21.9	4.6	13.4	8.8	51.1	15.0	33.9	SCL	1.33	1.72	2.39	11.8	14.0	13.0
E-1	51	8.4	1.3	5.6	1.4	7.9	4.2	<0.1	1.0	1.2	14.2	1.0	24.6	4.0	16.3	10.2	40.0	32.5	27.5	L	1.33	1.86	2.06	13.4	16.4	14.9
E-1	54	8.3	1.2	3.4	0.8	8.4	5.8	<0.1	1.0	1.2	10.1	2.6	45.5	5.6	30.7	19.4	7.1	43.3	49.6	SC	1.31	1.84	7.28	11.8	12.3	12.6
E-1	58	8.7	0.5	1.8	0.6	4.3	3.9	<0.1	0.7	0.7	4.2	0.4	8.1	5.2	6.1	---	73.6	3.0	23.4	SCL	1.27	--	0.48	5.4	5.6	6.6
WEST SITE																										
W-2	9	8.6	1.8	4.5	2.3	12.5	6.8	<0.1	1.2	4.8	15.1	1.0	11.4	8.7	9.8	6.0	69.3	10.0	20.7	SCL	1.45	1.92	1.17	17.6	21.0	19.3
W-2	15	8.9	1.0	1.3	0.5	8.4	9.0	<0.1	1.4	3.6	4.2	1.1	11.4	10.0	10.7	---	71.7	10.6	17.7	SL	1.38	--	1.00	9.6	9.2	10.2
W-2	18	9.0	0.6	1.0	0.3	5.3	6.5	<0.1	1.2	1.9	2.6	0.8	7.1	11.7	6.0	3.4	77.8	8.4	13.9	SL	1.56	1.82	0.60	5.6	5.7	6.6
W-2	26	8.4	1.7	2.5	0.8	15.1	11.9	<0.1	1.3	7.7	6.9	3.5	29.7	11.9	26.8	16.4	25.9	37.9	36.2	CL	1.35	1.83	3.34	17.3	15.9	18.3
W-2	36	8.5	1.8	3.0	0.9	15.7	11.2	0.4	0.9	2.4	16.2	2.8	24.9	11.4	19.8	12.0	41.9	26.7	31.5	CL	1.36	1.68	2.16	18.0	19.8	19.6
W-2	39	8.7	1.6	1.9	0.6	14.7	13.1	<0.1	1.4	2.4	13.0	4.0	28.9	13.8	22.5	13.7	74.1	15.4	10.6	SL	1.24	1.67	3.19	15.8	16.8	17.2
W-2	54	8.7	2.2	2.8	1.0	20.4	14.8	<0.1	1.0	5.4	18.5	2.9	20.5	14.4	16.4	9.0	59.6	25.2	15.2	SL	1.27	1.68	3.58	22.3	24.8	24.1
W-2	62	8.7	2.2	2.8	1.1	20.0	14.3	<0.1	0.9	3.6	19.2	1.8	17.5	10.5	12.9	7.2	Insufficient Sample				1.19	1.94	1.71	22.1	23.6	23.9

K. W. BROWN & ASSOCIATES, INC.

File Name: EPNGTXTR.WK1 26-Aug-87

Table D-2. Sediment Textures for El Paso Natural Gas San Juan River Plant.

Sample Location	Depth (feet)	Texture: Sand	Texture: Silt	Texture: Clay	Sum
		%			
EAST SITE					
E-1	9	60.3	20.2	19.5	100
E-1	15	83.0	1.9	15.1	100
E-1	18	84.2	6.3	9.5	100
E-1	21	81.1	8.9	10.0	100
E-1	24	Insufficient Sample			
E-1	27	86.6	5.8	7.6	100
E-1	36	51.2	27.2	21.6	100
E-1	45	Insufficient Sample			
E-1	48	51.1	15.0	33.9	100
E-1	51	40.0	32.5	27.5	100
E-1	54	7.1	43.3	49.6	100
E-1	58	73.6	3.0	23.4	100
WEST SITE					
W-2	9	69.3	10.0	20.7	100
W-2	15	71.7	10.6	17.7	100
W-2	18	77.8	8.4	13.9	100
W-2	26	25.9	37.9	36.2	100
W-2	36	41.9	26.7	31.5	100
W-2	39	74.1	15.4	10.6	100
W-2	54	59.6	25.2	15.2	100
W-2	62	Insufficient Sample			

K. W. BROWN & ASSOCIATES, INC.

File Name: EPNGMSTR.WK1 26-Aug-87

Table D-3. Moisture Content for Samples from East and West Sites
El Paso Natural Gas San River Plant.

Boring #	Depth (feet)	Can #	Can Wt.	Wet Wt. + Can	Dry Wt. + Can	Moisture -g/g-	Moisture %
E1A	3	27	48.25	113.57	110.43	0.05	5.0%
E1A	6	410	47.69	95.48	93.26	0.05	4.9%
E1A	12	306	47.71	112.04	109.16	0.05	4.7%
E1A	15	36	47.61	132.63	130.93	0.02	2.0%
E1A	18	A14	47.89	152.61	149.81	0.03	2.7%
E1A	20	A13	47.25	214.03	212.42	0.01	1.0%
E1A	21	31	47.95	149.85	130.16	0.24	24.0%
E1A	24	220	49.38	181.70	179.89	0.01	1.4%
E1A	27	08	47.00	199.05	195.98	0.02	2.1%
E1A	36	313	46.63	164.03	157.92	0.05	5.5%
E1A	39	305	47.34	133.66	128.57	0.06	6.3%
E1A	42	213	46.91	148.19	141.83	0.07	6.7%
E1A	45	406	46.64	122.24	115.89	0.09	9.2%
E1A	48	35	46.94	155.46	149.21	0.06	6.1%
E1A	51	405	47.48	132.64	124.68	0.10	10.3%
E1A	54	304	47.92	141.59	129.28	0.15	15.1%
E3	12	414	47.81	118.94	110.17	0.14	14.1%
E3	33	303	47.46	135.30	132.61	0.03	3.2%
E3	42	04	48.11	134.62	122.40	0.16	16.4%
W2	9	34	47.89	110.60	108.08	0.04	4.2%
W2	12	208	47.20	107.75	105.58	0.04	3.7%
W2	15	24	47.84	114.96	112.28	0.04	4.2%
W2	18	19	48.39	137.72	134.53	0.04	3.7%
W2	26	312	47.73	143.69	132.45	0.13	13.3%
W2	30	18	46.83	92.88	87.32	0.14	13.7%
W2	33	A12	47.09	133.77	124.19	0.12	12.4%
W2	36	06	47.90	141.19	129.92	0.14	13.7%
W2	39	421	47.71	165.75	148.98	0.17	16.6%
W2	45	39	47.93	127.94	116.46	0.17	16.8%
W2	52	311	46.61	103.45	94.26	0.19	19.3%
W2	54	404	47.45	114.34	101.23	0.24	24.4%
W2	60	A10	48.09	122.37	110.70	0.19	18.6%

K. W. BROWN & ASSOCIATES, INC.

APPENDIX E

APPENDIX E

CONSTRUCTION DETAILS FOR

PIEZOMETERS

APPENDIX E

CONSTRUCTION DETAILS FOR PIEZOMETERS

PIEZOMETER REPORT: CONSTRUCTION DETAILS

PROJECT: El Paso Natural Gas 63701

LOCATION: Southeast Corner of East Site

CLIENT: San Juan River Plant

WELL NO: E 1 A Southest Corner

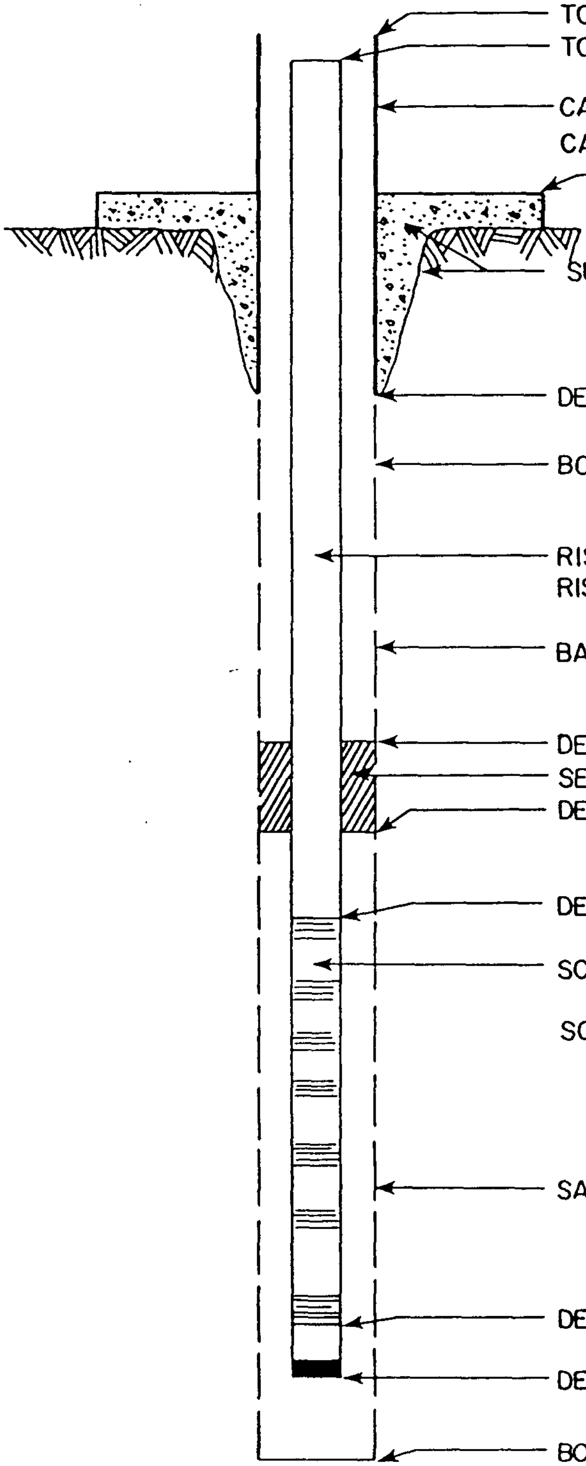
DRILLED BY: Western Technologies

DATE COMPLETED: 6-8-76

LOGGED BY: SJ & BS

SCREENED INTERVAL: 53.9 - 58.9

INSPECTED BY: SJ



TOP OF CASING ELEVATION:

TOP OF RISER PIPE ELEVATION: 5290.7'

CASING TYPE: None

CASING I.D.:

PLATFORM ELEVATION:

GROUND SURFACE ELEVATION: 5292.0'

SURFACE SEAL: Grout

DEPTH OF CASING BELOW GROUND:

BOREHOLE DIAMETER: 7" ϕ

RISER PIPE TYPE: Schedule 40 PVC

RISER PIPE I.D.: 2"

BACKFILL TYPE: Grout

DEPTH AT TOP OF SEAL: 50'

SEAL TYPE: Bentonite Pellets-hydrated

DEPTH AT BASE OF SEAL / TOP OF SAND PACK: 51'

DEPTH AT TOP OF SCREENED SECTION: 53.9'

SCREEN TYPE: Schedule 40 PVC

SCREEN OPENINGS: .010 Machine Slot

SAND PACK TYPE: Coarse Silica Sand

DEPTH AT BASE OF SCREENED SECTION: 58.9'

DEPTH AT BASE OF PLUG: 58.9'

BOREHOLE DEPTH: 58.9'

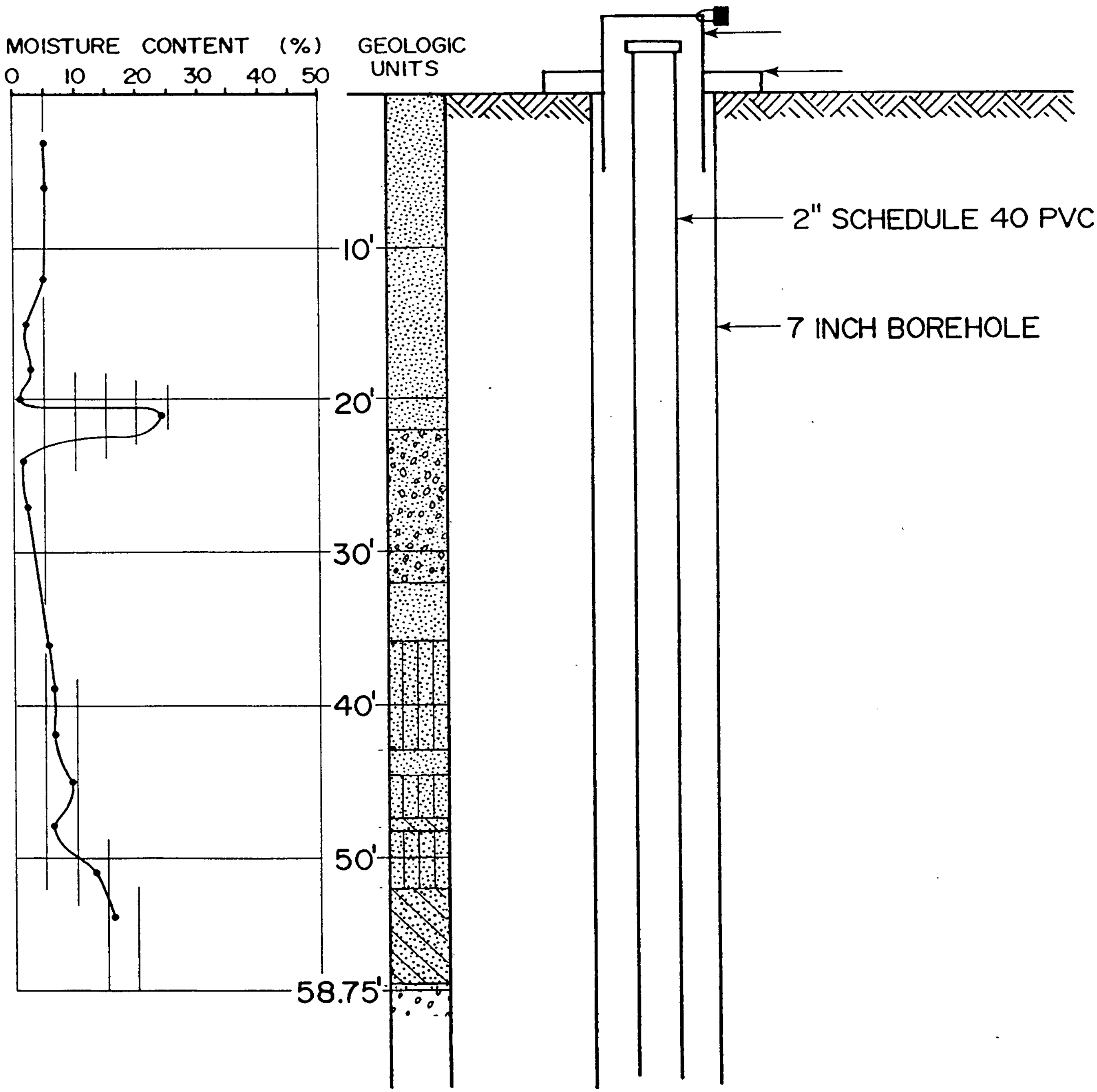
K.W. BROWN & ASSOCIATES, INC.

PIEZOMETER REPORT: CONSTRUCTION DETAILS

PROJECT: El Paso Natural Gas
CLIENT: San Juan River Plant

BORING NO.: EIA
WELL NO.: Piezometer EIA
LOCATION: SE Corner East Site
DATE STARTED: 6-8-87
DATE COMPLETED: 6-8-87
LOGGED BY: SJ & BS
INSPECTED BY: SJ

DRILLER: Western Technologies
RIG TYPE: Hollow Stem Auger
DRILLING METHOD: Auger
BIT/AUGER SIZE: 7 inch
ELEV. - GROUND SURFACE: 5290.7
ELEV. - STEEL CASING: None
ELEV. - RISER PIPE: 5292.0



PIEZOMETER REPORT: CONSTRUCTION DETAILS

PROJECT: El Paso Natural Gas 63701

LOCATION: Southeast Corner of East Site

CLIENT: San Juan River Plant

WELL NO: E1 B

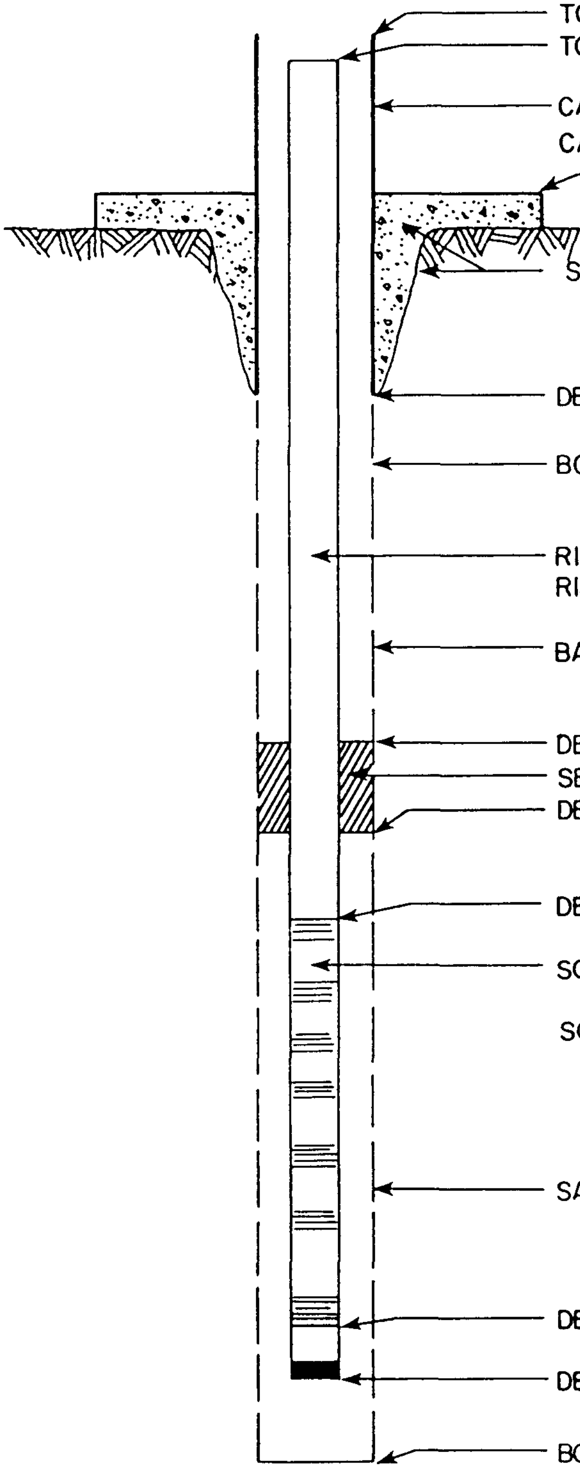
DRILLED BY: Mote

DATE COMPLETED: 6-12-87

LOGGED BY: SJ & BS

SCREENED INTERVAL: 71'-76'

INSPECTED BY: SJ



TOP OF CASING ELEVATION:

TOP OF RISER PIPE ELEVATION: 5292.8

CASING TYPE: None

CASING I.D.:

PLATFORM ELEVATION:

GROUND SURFACE ELEVATION: 5290.4'

SURFACE SEAL: Grout

DEPTH OF CASING BELOW GROUND:

BOREHOLE DIAMETER: 5 5/8" ϕ

RISER PIPE TYPE: Schedule 40 PVC

RISER PIPE I.D.: 2"

BACKFILL TYPE: Cuttings to 57', Grout to surface

DEPTH AT TOP OF SEAL: 67'

SEAL TYPE: Bentonite Pellets - hydrated

DEPTH AT BASE OF SEAL / TOP OF SAND PACK: 70'

DEPTH AT TOP OF SCREENED SECTION: 71'

SCREEN TYPE: Schedule 40 PVC

SCREEN OPENINGS: 0.010 Machine Slot

SAND PACK TYPE: Coarse Silica Sand

DEPTH AT BASE OF SCREENED SECTION: 76'

DEPTH AT BASE OF PLUG: 79'

BOREHOLE DEPTH: 79'

K.W. BROWN & ASSOCIATES, INC.

PIEZOMETER REPORT: CONSTRUCTION DETAILS

PROJECT: El Paso Natural Gas 63701

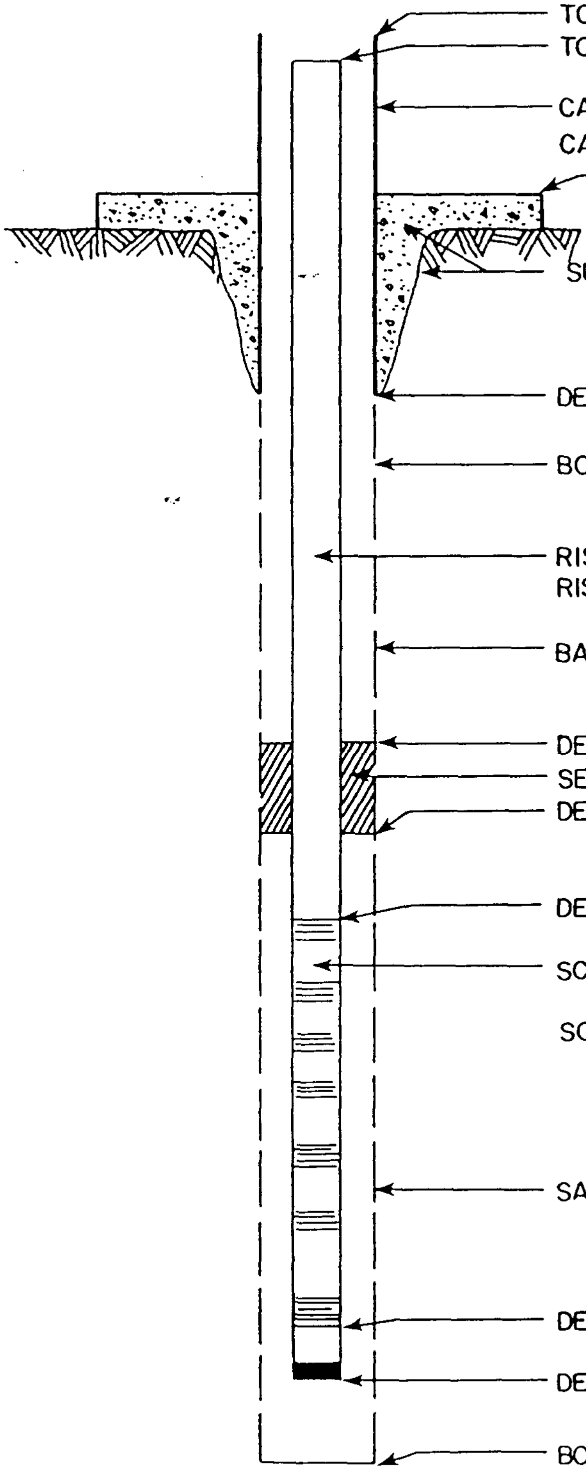
LOCATION: Northeast Corner of East Site

CLIENT: San Juan River Plant

WELL NO: E 2 B | DRILLED BY: Mote

DATE COMPLETED: 6/11/87 | LOGGED BY: SJ & BS

SCREENED INTERVAL: 73½-78½' | INSPECTED BY: SJ



TOP OF CASING ELEVATION:

TOP OF RISER PIPE ELEVATION: 5312.8'

CASING TYPE: None

CASING I.D.:

PLATFORM ELEVATION:

GROUND SURFACE ELEVATION: 5310.0'

SURFACE SEAL: Grout

DEPTH OF CASING BELOW GROUND:

BOREHOLE DIAMETER: 5 5/8" ϕ

RISER PIPE TYPE: Schedule 40 PVC

RISER PIPE I.D.: 2"

BACKFILL TYPE: Grout

DEPTH AT TOP OF SEAL:

SEAL TYPE: Bentonite Pellets-hydrated

DEPTH AT BASE OF SEAL/TOP OF SAND PACK: 71'

DEPTH AT TOP OF SCREENED SECTION: 73½'

SCREEN TYPE: Schedule 40 PVC

SCREEN OPENINGS: .010 Machine Slot

SAND PACK TYPE: Coarse Silica Sand

DEPTH AT BASE OF SCREENED SECTION: 78½'

DEPTH AT BASE OF PLUG: 78½'

BOREHOLE DEPTH: 78½'

K.W. BROWN & ASSOCIATES, INC.

PIEZOMETER REPORT: CONSTRUCTION DETAILS

PROJECT: El Paso Natural Gas 63701

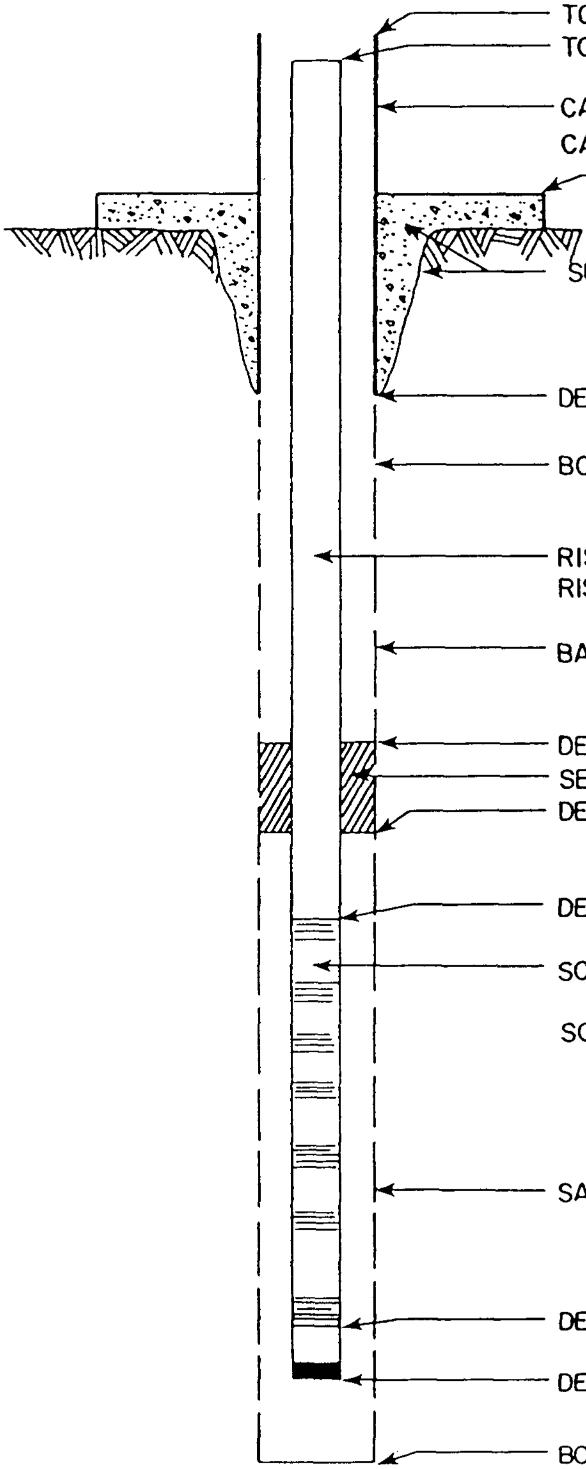
LOCATION: West Side of East Site

CLIENT: San Juan River Plant

WELL NO: E-3 | DRILLED BY: Western Technologies

DATE COMPLETED: 6-11-87 | LOGGED BY: SJ & BS

SCREENED INTERVAL: 72-77feet | INSPECTED BY: BS



TOP OF CASING ELEVATION:

TOP OF RISER PIPE ELEVATION: 5299.5'

CASING TYPE: None

CASING I.D.:

PLATFORM ELEVATION:

GROUND SURFACE ELEVATION: 5298.6'

SURFACE SEAL: Grout

DEPTH OF CASING BELOW GROUND:

BOREHOLE DIAMETER: 7" ϕ

RISER PIPE TYPE: 2" Schedule 40 PVC

RISER PIPE I.D.: 2"

BACKFILL TYPE: Grout

DEPTH AT TOP OF SEAL: 70'

SEAL TYPE: ½"Hydrated Benetonite Pellets

DEPTH AT BASE OF SEAL / TOP OF SAND PACK: 71½'

DEPTH AT TOP OF SCREENED SECTION: 72'

SCREEN TYPE: 2" Schedule 40 PVC

SCREEN OPENINGS: Machine Slotted .010

SAND PACK TYPE: Coarse Silica Sand

DEPTH AT BASE OF SCREENED SECTION: 77'

DEPTH AT BASE OF PLUG: 78'

BOREHOLE DEPTH: 78'

PIEZOMETER REPORT: CONSTRUCTION DETAILS

PROJECT: El Paso Natural Gas 63701

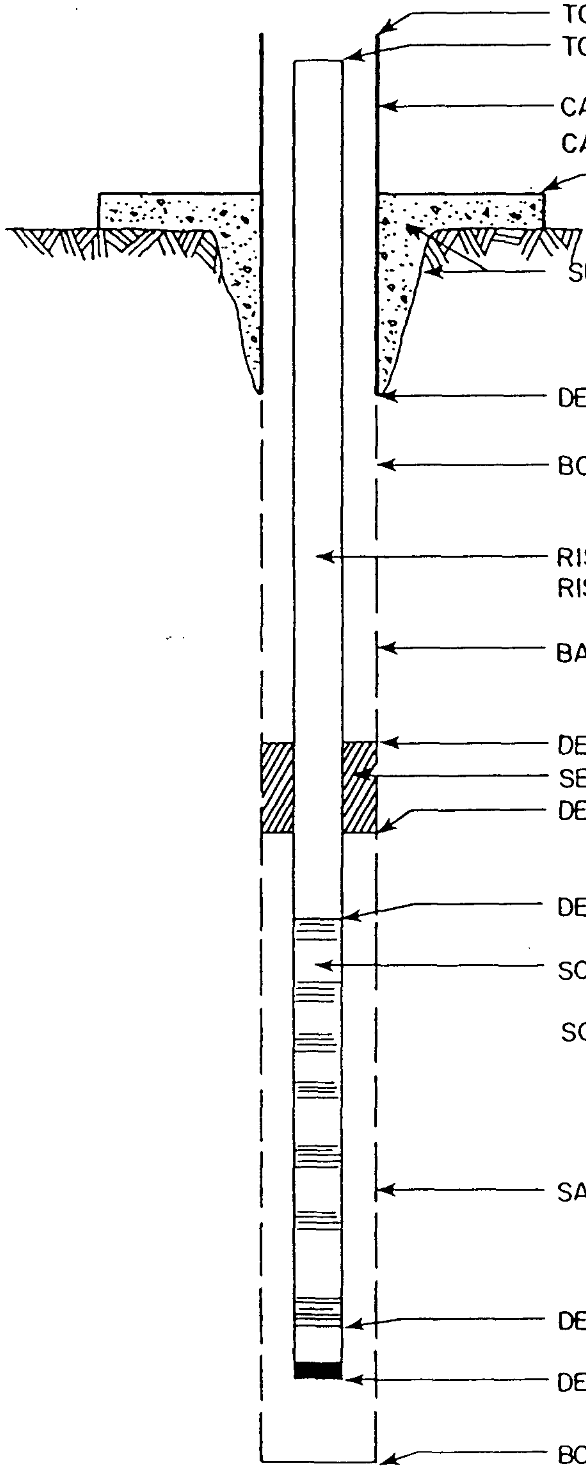
LOCATION: South Side of West Site

CLIENT: San Juan River Plant

WELL NO: W 2 DRILLED BY: Western Technologies

DATE COMPLETED: 6-9-87 LOGGED BY: SJ & BS

SCREENED INTERVAL: 54½ - 59½ INSPECTED BY: SJ



TOP OF CASING ELEVATION:

TOP OF RISER PIPE ELEVATION: 5281.9

CASING TYPE: None

CASING I.D.:

PLATFORM ELEVATION:

GROUND SURFACE ELEVATION: 5280.1

SURFACE SEAL: Grout

DEPTH OF CASING BELOW GROUND:

BOREHOLE DIAMETER: 7" 0

RISER PIPE TYPE: Schedule 40 PVC

RISER PIPE I.D.: 2"

BACKFILL TYPE: Grout

DEPTH AT TOP OF SEAL: 52'

SEAL TYPE: Bentonite Pellets-hydrated

DEPTH AT BASE OF SEAL / TOP OF SAND PACK: 53'

DEPTH AT TOP OF SCREENED SECTION: 55½'

SCREEN TYPE: Schedule 40 PVC

SCREEN OPENINGS: .010

SAND PACK TYPE: Coarse Silica Sand

DEPTH AT BASE OF SCREENED SECTION: 60½'

DEPTH AT BASE OF PLUG: 62'

BOREHOLE DEPTH: 62'

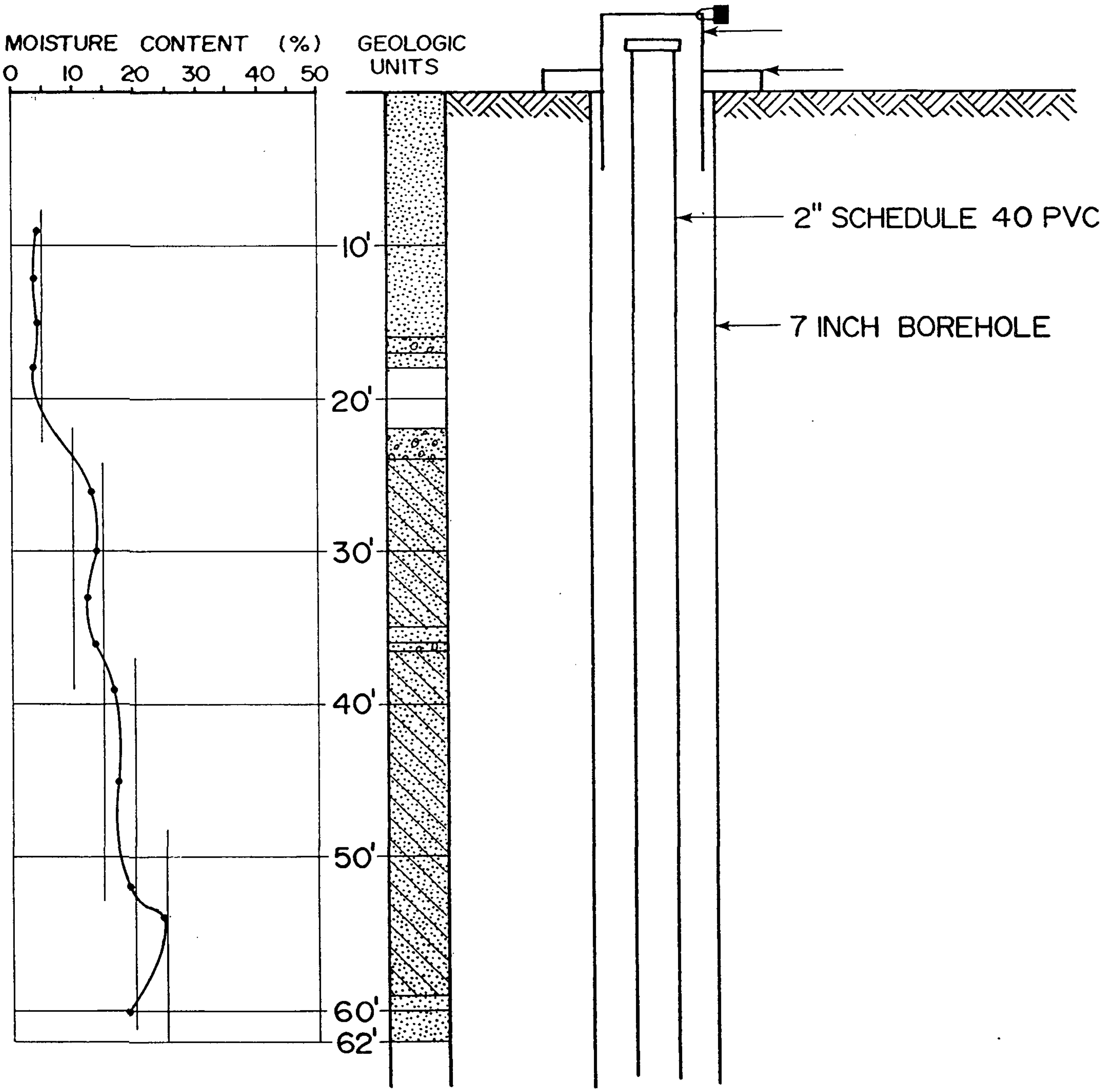
K.W. BROWN & ASSOCIATES, INC.

PIEZOMETER REPORT: CONSTRUCTION DETAILS

PROJECT: El Paso Natural Gas
CLIENT: San Juan River Plant

BORING NO.: W2
WELL NO.: Piezometer W2
LOCATION: South Side West Site
DATE STARTED: 6-9-87
DATE COMPLETED: 6-10-87
LOGGED BY: SJ & BS
INSPECTED BY: SJ

DRILLER: Western Technologies
RIG TYPE: Hollow Stem Auger
DRILLING METHOD: Auger
BIT/AUGER SIZE: 7 inch
ELEV. - GROUND SURFACE: 5280.1
ELEV. - STEEL CASING: None
ELEV. - RISER PIPE: 5281.9



APPENDIX F

APPENDIX F

PIEZOMETER TEST DATA AND

HYDRAULIC CONDUCTIVITY CALCULATION

File Name: EPNGPUMP.WK1 17-Jul-87

PIEZOMETER W2

EL PASO NATURAL GAS SAN JUAN RIVER PLANT

DATE: JUNE 12, 1987 BY: Robert Speake REFERENCE: Hvorslev, 1951

Ho =	7.98	GRADE ELEVATION =	5280.1		
H =	9.76	PVC ELEVATION =	5281.9	WELL RADIUS (in)=	1
TD =	62.3	SCREEN BOTTOM =	5219.6	SCREEN LENGTH (ft)=	5
		WELL DEPTH (FT) =	62.0	SCREEN RADIUS (in)=	1
DEPTH TO BOTTOM OF SCREEN (FEET) =			60.5	To (hr)=	1.10614
DEPTH TO STATIC WATER LEVEL (FEET) =			52.54	K (cm/sec) =	2.18E-05

DEPTH TO WATER (FT)	h (FT)	TIME	TIME (SEC)	INCR. TIME (SEC)	ELAPSED TIME (SEC)	ELAPSED TIME (HRS)	H-h / H-Ho	LOG H-h / H-Ho
54.32	7.98	8 :53 :30	32,010	0	0	0.0000	1.0000	0.0000
54.25	8.05	8 :54 :30	32,070	60	60	0.0167	0.9607	-0.0174
54.21	8.09	8 :55 :30	32,130	60	120	0.0333	0.9382	-0.0277
54.17	8.13	8 :56 :30	32,190	60	180	0.0500	0.9157	-0.0382
54.14	8.16	8 :57 :30	32,250	60	240	0.0667	0.8989	-0.0463
54.11	8.19	8 :58 :30	32,310	60	300	0.0833	0.8820	-0.0545
54.08	8.22	8 :59 :30	32,370	60	360	0.1000	0.8652	-0.0629
54.06	8.24	9 : 0 :30	32,430	60	420	0.1167	0.8539	-0.0686
54.04	8.26	9 : 1 :30	32,490	60	480	0.1333	0.8427	-0.0743
54.02	8.28	9 : 2 :30	32,550	60	540	0.1500	0.8315	-0.0802
53.99	8.31	9 : 3 :30	32,610	60	600	0.1667	0.8146	-0.0891
53.87	8.43	9 : 8 :30	32,910	300	900	0.2500	0.7472	-0.1266
53.75	8.55	9 :13 :30	33,210	300	1,200	0.3333	0.6798	-0.1676
53.69	8.61	9 :18 :30	33,510	300	1,500	0.4167	0.6461	-0.1897
53.61	8.69	9 :23 :30	33,810	300	1,800	0.5000	0.6011	-0.2210
53.54	8.76	9 :28 :30	34,110	300	2,100	0.5833	0.5618	-0.2504
53.46	8.84	9 :33 :30	34,410	300	2,400	0.6667	0.5169	-0.2866
53.41	8.89	9 :38 :30	34,710	300	2,700	0.7500	0.4888	-0.3109
53.35	8.95	9 :43 :30	35,010	300	3,000	0.8333	0.4551	-0.3419
53.29	9.01	9 :48 :30	35,310	300	3,300	0.9167	0.4213	-0.3754
53.25	9.05	9 :53 :30	35,610	300	3,600	1.0000	0.3989	-0.3992
52.85	9.45	10 :53 :30	39,210	3,600	7,200	2.0000	0.1742	-0.7591
52.67	9.63	11 :53 :30	42,810	3,600	10,800	3.0000	0.0730	-1.1365

Regression Output:

Constant	0
Std Err of Y Est	0.023097
R Squared	0.992428
No. of Observations	23
Degrees of Freedom	22
X Coefficient(s)	-0.39036
Std Err of Coef.	0.005507

K. W. BROWN AND ASSOCIATES, INC.

FALLING HEAD TEST (JARVIS, 1949)
GROUND WATER MANUAL, 1981, U.S. DEPT OF INTERIOR (page 283)

K = AVERAGE PERMEABILITY OF THE TEST SECTION, FT/SEC
A = LENGHT OF TEST SECTION, FT
r = INSIDE RADIUS OF DROP PIPE (PVC CASING), FT
re = EFFECTIVE RADIUS OF TEST SECTION, FT
T = ELAPSED TIME, SEC
H = INITIAL HEIGHT OF WATER COLUMN AT TIME 0, FT
h = HEIGHT OF WATER COLUMN AT TIME X, FT

TERM 1 TERM 2 TERM 3 TERM 4

$$K = \frac{(r)(r)}{2A(T)} * \left[\frac{\sinh^{-1}(A/re)}{2} * \ln \frac{2H-A}{2h-A} - \ln \frac{2Hh - Ah}{2Hh - AH} \right]$$

WELL #	A feet	r feet	re feet	t1 sec	t2 sec	T sec	H feet	h feet	K ft/sec	TERM 1	TERM 2	TERM 3	TERM 4	A/re	K cm/sec
E2B	5	0.08	0.23	0	2,700	2,700	80.20	80.14	3.7E-10	2.6E-07	1.88	7.7E-04	2.4E-05	21.3	1.1E-08
	5	0.08	0.23	2,700	57,000	54,300	80.14	79.60	1.6E-10	1.3E-08	1.88	7.0E-03	2.2E-04	21.3	5.0E-09
	5	0.08	0.23	57,000	236,160	179,160	79.60	78.65	8.9E-11	3.9E-09	1.88	1.2E-02	3.9E-04	21.3	2.7E-09
average	5	0.08	0.23	0	236,160	236,160	80.20	78.65	1.1E-10	2.9E-09	1.88	2.0E-02	6.3E-04	21.3	3.3E-09
E1A	5	0.08	0.29	0	60	60	7.40	5.90	5.9E-06	1.2E-05	1.77	3.7E-01	1.4E-01	17.2	1.8E-04
	5	0.08	0.29	60	120	60	5.90	5.70	9.4E-07	1.2E-05	1.77	6.1E-02	2.6E-02	17.2	2.9E-05
	5	0.08	0.29	120	180	60	5.70	5.50	9.9E-07	1.2E-05	1.77	6.5E-02	2.9E-02	17.2	3.0E-05
	5	0.08	0.29	180	240	60	5.50	5.40	5.1E-07	1.2E-05	1.77	3.4E-02	1.6E-02	17.2	1.6E-05
	5	0.08	0.29	240	300	60	5.40	5.35	2.6E-07	1.2E-05	1.77	1.7E-02	8.1E-03	17.2	8.0E-06
	5	0.08	0.29	300	360	60	5.35	5.35	0.0E+00	1.2E-05	1.77	0.0E+00	0.0E+00	17.2	0.0E+00
	5	0.08	0.29	360	420	60	5.35	5.30	2.7E-07	1.2E-05	1.77	1.8E-02	8.3E-03	17.2	8.1E-06
	5	0.08	0.29	420	480	60	5.30	5.20	5.4E-07	1.2E-05	1.77	3.6E-02	1.7E-02	17.2	1.7E-05
	5	0.08	0.29	480	540	60	5.20	5.10	5.6E-07	1.2E-05	1.77	3.8E-02	1.8E-02	17.2	1.7E-05
	5	0.08	0.29	540	600	60	5.10	5.10	0.0E+00	1.2E-05	1.77	0.0E+00	0.0E+00	17.2	0.0E+00
	5	0.08	0.29	600	660	60	5.10	5.00	5.8E-07	1.2E-05	1.77	3.9E-02	1.9E-02	17.2	1.8E-05
	5	0.08	0.29	660	720	60	5.00	4.95	3.0E-07	1.2E-05	1.77	2.0E-02	1.0E-02	17.2	9.0E-06
	5	0.08	0.29	720	780	60	4.95	4.85	6.1E-07	1.2E-05	1.77	4.2E-02	2.1E-02	17.2	1.9E-05
	5	0.08	0.29	780	840	60	4.85	4.80	3.1E-07	1.2E-05	1.77	2.2E-02	1.1E-02	17.2	9.5E-06
	5	0.08	0.29	840	900	60	4.80	4.78	1.6E-07	1.2E-05	1.77	1.1E-02	5.7E-03	17.2	4.8E-06
	5	0.08	0.29	900	1,200	300	4.78	4.30	6.6E-07	2.3E-06	1.77	2.3E-01	1.3E-01	17.2	2.0E-05
	5	0.08	0.29	1,200	1,500	300	4.30	3.85	7.7E-07	2.3E-06	1.77	2.9E-01	1.8E-01	17.2	2.3E-05
	5	0.08	0.29	1,500	1,800	300	3.85	3.65	4.1E-07	2.3E-06	1.77	1.6E-01	1.1E-01	17.2	1.2E-05
	5	0.08	0.29	1,800	2,100	300	3.65	3.40	6.0E-07	2.3E-06	1.77	2.5E-01	1.7E-01	17.2	1.8E-05
	5	0.08	0.29	2,100	2,400	300	3.40	3.20	5.9E-07	2.3E-06	1.77	2.5E-01	1.9E-01	17.2	1.8E-05
	5	0.08	0.29	2,400	2,700	300	3.20	2.95	9.8E-07	2.3E-06	1.77	4.4E-01	3.6E-01	17.2	3.0E-05
average	5	0.08	0.29	0	2,700	2,700	7.40	2.95	7.1E-07	2.6E-07	1.77	2.4E+00	1.5E+00	17.2	2.2E-05
E3 *	5	0.08	0.29	0	60	60	4.95	4.83	7.3E-07	1.2E-05	1.77	5.0E-02	2.6E-02	17.2	2.2E-05
	5	0.08	0.29	60	90	30	4.83	4.78	6.3E-07	2.3E-05	1.77	2.2E-02	1.1E-02	17.2	1.9E-05
estimate	5	0.08	0.29	0	180	180	30.00	5.00	1.4E-05	3.9E-06	1.77	2.4E+00	6.1E-01	17.2	4.3E-04
E1B *	5	0.08	0.23	0	60	60	15.40	14.86	8.5E-07	1.2E-05	1.88	4.3E-02	7.1E-03	21.3	2.6E-05
estimate	5	0.08	0.23	0	60	60	20.00	14.86	7.0E-06	1.2E-05	1.88	3.5E-01	5.1E-02	21.3	2.1E-04

* Permeabilities calculated for E3 and E1B are estimates. Water added to piezometer was sufficient to raise level approximately 20 to 30 feet, yet before probe could be lowered the water level had returned to near static level value.

APPENDIX G

APPENDIX G

WELL WATER ANALYSES

LAB RESULTS

Report of Chemical Analysis

Consulting Geotechnical, Materials and Environmental Engineers
Geologists, Scientists and Chemists

Raba-Kistner
Consultants, Inc.

P.O. Box 690287, San Antonio, TX 78269-0287
12821 W. Golden Lane, San Antonio, TX 78249
(512) 699-9090

To: El Paso Natural Gas Company
P.O. Box 4990
Farmington, New Mexico 87499

Attn: Mr. Kenneth E. Beasley

Project No.: SA0687-0003-008
Assignment No.: 6-11077
Date: 7/02/87

Subject: Water Analysis

Test Results:

	Method	#1 John Kennedy 6-11077-1	#2 Dan Booth 6-11077-2)	#3 Joe Lester 6-11077-3
I. Metals:				
Calcium, mg/L	215.1	66	63	31
Magnesium, mg/L	242.1	17	15	13
Potassium, mg/L	258.1	1.2	1.3	3.1
Sodium, mg/L	272.3	100	110	440

	Method	#4 Paul Hansen 6-11077-4	#5 J.T. Isham 6-11077-5	#6 Dale Dailey 6-11077-6
Calcium, mg/L	215.1	130	190	280
Magnesium, mg/L	242.1	44	57	66
Potassium, mg/L	258.1	5.6	6.3	3.5
Sodium, mg/L	272.3	500	820	1,000

Raba-Kistner Consultants, Inc.
by [signature]
Frank B. Schweitzer
Vice-President, Chemistry

Project No.: SA0687-0003-008
Assignment No.: 6-11077
Date: 7/02/87

	Method	#1 John Kennedy 6-11077-1	#2 Dan Booth 6-11077-2)	#3 Joe Lester 6-11077-3
II. General Parameters:				
Ammonia-N, mg/L	350.2	<0.4	<0.4	<0.4
Bicarbonate, mg/L as $CaCO_3$	310.1	210	200	320
Carbonate, mg/L as $CaCO_3$	310.1	<5	<5	<5
Chloride, mg/L	300.0	29	29	110
Nitrate-N, mg/L	300.0	<0.1	<0.1	<0.1
Sulfate, mg/L	300.0	290	300	780
Total Kjeldahl-N, mg/L	351.3	<0.4	<0.4	0.4
Total Dissolved Solids, mg/L	160.1	600	610	1,400
Anion/Cation Blance, meq./meq.		10.3/9.1	10.3/9.2	24.6/21.8

	Method	#4 Paul Harmen 6-11077-4	#5 J.T. Isham 6-11077-5	#6 Dale Daily 6-11077-6
Ammonia-N, mg/L	350.2	<0.4	<0.4	<0.4
Bicarbonate, mg/L	310.1	230	150	91
Carbonate, mg/L	310.1	<5	<5	<5
Chloride, mg/L	300.0	400	400	450
Nitrate-N, mg/L	300.0	5.6	5.0	3.9
Sulfate, mg/L	300.0	790	1,800	2,470
Total Kjeldahl-N, mg/L	351.3	<0.4	0.5	0.4
Total Dissolved Solids, mg/L	160.1	2,000	3,400	4,300
Anion/Cation Blance, meq./meq.		37.7/32.0	51.6/50.1	65.9/63.1

< = Less than

Project No.: SA0687-0003-008
Assignment No.: John Kennedy (6-11077-1)

(PURGEABLES)
(EPA Method 624)

Compound	Concentration (ug/L)	Method Detection Limits (ug/L)
Chloromethane	N.D.	5.0
Bromomethane	N.D.	5.0
Vinyl Chloride	N.D.	10.0
Chloroethane	N.D.	5.0
Methylene Chloride	N.D.	2.8
Trichlorofluoromethane	N.D.	5.0
1,1-Dichloroethene	N.D	2.8
1,1-Dichloroethane	N.D.	4.7
Trans-1,2-Dichloroethene	N.D.	1.6
Chloroform	N.D.	1.6
1,2-Dichloroethane	N.D.	2.8
1,1,1-Trichloroethane	N.D.	3.8
Carbon Tetrachloride	N.D.	2.8
Bromodichloromethane	N.D.	2.2
1,2-Dichloropropane	N.D.	6.0
Trans-1,3-Dichloropropene	N.D.	5.0
Trichloroethene	N.D	1.9
Dibromochloromethane	N.D.	3.1
1,1,2-Trichloroethane	N.D	5.0
cis-1,3-Dichloropropene	N.D.	5.0
Benzene	N.D.	4.4
2-Chloroethylvinyl Ether	N.D.	5.0
Bromoform	N.D.	4.7
1,1,2,2-Tetrachloroethane	N.D.	6.9
Tetrachloroethene	N.D	4.1
Toluene	N.D.	6.0
Chlorobenzene	N.D.	6.0
Ethylbenzene	N.D.	7.2

N.D.= Not Detected

Project No.: SA0687-0003-008
Assignment No.: Dan Booth (6-11077-2)

(PURGEABLES)
(EPA Method 624)

Compound	Concentration (ug/L)	Method Detection Limits (ug/L)
Chloromethane	N.D.	5.0
Bromomethane	N.D.	5.0
Vinyl Chloride	N.D.	10.0
Chloroethane	N.D.	5.0
Methylene Chloride	N.D.	2.8
Trichlorofluoromethane	N.D.	5.0
1,1-Dichloroethene	N.D	2.8
1,1-Dichloroethane	N.D.	4.7
Trans-1,2-Dichloroethene	N.D.	1.6
Chloroform	N.D.	1.6
1,2-Dichloroethane	N.D.	2.8
1,1,1-Trichloroethane	N.D.	3.8
Carbon Tetrachloride	N.D.	2.8
Bromodichloromethane	N.D.	2.2
1,2-Dichloropropane	N.D.	6.0
Trans-1,3-Dichloropropene	N.D.	5.0
Trichloroethene	N.D	1.9
Dibromochloromethane	N.D.	3.1
1,1,2-Trichloroethane	N.D	5.0
cis-1,3-Dichloropropene	N.D.	5.0
Benzene	N.D.	4.4
2-Chloroethylvinyl Ether	N.D.	5.0
Bromoform	N.D.	4.7
1,1,2,2-Tetrachloroethane	N.D.	6.9
Tetrachloroethene	N.D	4.1
Toluene	N.D.	6.0
Chlorobenzene	N.D.	6.0
Ethylbenzene	N.D.	7.2

N.D.= Not Detected

Project No.: SA0687-0003-008
Assignment No.: Joe Lester (6-11077-3)

(PURGEABLES)
(EPA Method 624)

Compound	Concentration (ug/L)	Method Detection Limits (ug/L)
Chloromethane	N.D.	5.0
Bromomethane	N.D.	5.0
Vinyl Chloride	N.D.	10.0
Chloroethane	N.D.	5.0
Methylene Chloride	N.D.	2.8
Trichlorofluoromethane	N.D.	5.0
1,1-Dichloroethene	N.D	2.8
1,1-Dichloroethane	N.D.	4.7
Trans-1,2-Dichloroethene	N.D.	1.6
Chloroform	N.D.	1.6
1,2-Dichloroethane	N.D.	2.8
1,1,1-Trichloroethane	N.D.	3.8
Carbon Tetrachloride	N.D.	2.8
Bromodichloromethane	N.D.	2.2
1,2-Dichloropropane	N.D.	6.0
Trans-1,3-Dichloropropene	N.D.	5.0
Trichloroethene	N.D	1.9
Dibromochloromethane	N.D.	3.1
1,1,2-Trichloroethane	N.D	5.0
cis-1,3-Dichloropropene	N.D.	5.0
Benzene	N.D.	4.4
2-Chloroethylvinyl Ether	N.D.	5.0
Bromoform	N.D.	4.7
1,1,2,2-Tetrachloroethane	N.D.	6.9
Tetrachloroethene	N.D	4.1
Toluene	N.D.	6.0
Chlorobenzene	N.D.	6.0
Ethylbenzene	N.D.	7.2

N.D.= Not Detected

Project No.: SA0687-0003-008
Assignment No.: Paul Hansen (6-11077-4)

(PURGEABLES)
(EPA Method 624)

Compound	Concentration (ug/L)	Method Detection Limits (ug/L)
Chloromethane	N.D.	5.0
Bromomethane	N.D.	5.0
Vinyl Chloride	N.D.	10.0
Chloroethane	N.D.	5.0
Methylene Chloride	N.D.	2.8
Trichlorofluoromethane	N.D.	5.0
1,1-Dichloroethene	N.D	2.8
1,1-Dichloroethane	N.D.	4.7
Trans-1,2-Dichloroethene	N.D.	1.6
Chloroform	N.D.	1.6
1,2-Dichloroethane	N.D.	2.8
1,1,1-Trichloroethane	N.D.	3.8
Carbon Tetrachloride	N.D.	2.8
Bromodichloromethane	N.D.	2.2
1,2-Dichloropropane	N.D.	6.0
Trans-1,3-Dichloropropene	N.D.	5.0
Trichloroethene	N.D	1.9
Dibromochloromethane	N.D.	3.1
1,1,2-Trichloroethane	N.D	5.0
cis-1,3-Dichloropropene	N.D.	5.0
Benzene	N.D.	4.4
2-Chloroethylvinyl Ether	N.D.	5.0
Bromoform	N.D.	4.7
1,1,2,2-Tetrachloroethane	N.D.	6.9
Tetrachloroethene	N.D	4.1
Toluene	N.D.	6.0
Chlorobenzene	N.D.	6.0
Ethylbenzene	N.D.	7.2

N.D.= Not Detected

Project No.: SA0687-0003-008
Assignment No.: J.T. Isham (6-11077-5)

(PURGEABLES)
(EPA Method 624)

Compound	Concentration (ug/L)	Method Detection Limits (ug/L)
Chloromethane	N.D.	5.0
Bromomethane	N.D.	5.0
Vinyl Chloride	N.D.	10.0
Chloroethane	N.D.	5.0
Methylene Chloride	N.D.	2.8
Trichlorofluoromethane	N.D.	5.0
1,1-Dichloroethene	N.D	2.8
1,1-Dichloroethane	N.D.	4.7
Trans-1,2-Dichloroethene	N.D.	1.6
Chloroform	N.D.	1.6
1,2-Dichloroethane	N.D.	2.8
1,1,1-Trichloroethane	N.D.	3.8
Carbon Tetrachloride	N.D.	2.8
Bromodichloromethane	N.D.	2.2
1,2-Dichloropropane	N.D.	6.0
Trans-1,3-Dichloropropene	N.D.	5.0
Trichloroethene	N.D	1.9
Dibromochloromethane	N.D.	3.1
1,1,2-Trichloroethane	N.D	5.0
cis-1,3-Dichloropropene	N.D.	5.0
Benzene	N.D.	4.4
2-Chloroethylvinyl Ether	N.D.	5.0
Bromoform	N.D.	4.7
1,1,2,2-Tetrachloroethane	N.D.	6.9
Tetrachloroethene	N.D	4.1
Toluene	N.D.	6.0
Chlorobenzene	N.D.	6.0
Ethylbenzene	N.D.	7.2

N.D.= Not Detected

Project No.: SA0687-0003-008
Assignment No.: Dale Dailey (6-11077-6)

(PURGEABLES)
(EPA Method 624)

Compound	Concentration (ug/L)	Method Detection Limits (ug/L)
Chloromethane	N.D.	5.0
Bromomethane	N.D.	5.0
Vinyl Chloride	N.D.	10.0
Chloroethane	N.D.	5.0
Methylene Chloride	N.D.	2.8
Trichlorofluoromethane	N.D.	5.0
1,1-Dichloroethene	N.D	2.8
1,1-Dichloroethane	N.D.	4.7
Trans-1,2-Dichloroethene	N.D.	1.6
Chloroform	N.D.	1.6
1,2-Dichloroethane	N.D.	2.8
1,1,1-Trichloroethane	N.D.	3.8
Carbon Tetrachloride	N.D.	2.8
Bromodichloromethane	N.D.	2.2
1,2-Dichloropropane	N.D.	6.0
Trans-1,3-Dichloropropene	N.D.	5.0
Trichloroethene	N.D	1.9
Dibromochloromethane	N.D.	3.1
1,1,2-Trichloroethane	N.D	5.0
cis-1,3-Dichloropropene	N.D.	5.0
Benzene	N.D.	4.4
2-Chloroethylvinyl Ether	N.D.	5.0
Bromoform	N.D.	4.7
1,1,2,2-Tetrachloroethane	N.D.	6.9
Tetrachloroethene	N.D	4.1
Toluene	N.D.	6.0
Chlorobenzene	N.D.	6.0
Ethylbenzene	N.D.	7.2

N.D.= Not Detected