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FINAL REPORT ON
FLORA VISTA CONTAMINATION STUDY
OCTOBER, 1986

A Report to the Flora Vista
Water Users Association
Flora Vista, New Mexico

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Introduction

This report was prepared by the New Mexico Oil Conservation Division to summarize the work performed at the Flora Vista well field; to review the results of water quality sampling, aquifer testing, and other hydrologic measurements; to present conclusions based on this work, and to make recommendations for future monitoring of ground water to protect the currently used well field. The assistance of the staff of the Flora Vista Water Users Association, Lawrence A. Brewer & Associates, and the Environmental Improvement Division in providing data, reports, support equipment, and services is gratefully acknowledged. The assistance of other Oil Conservation Division staff in Santa Fe and Aztec in preparing this report is appreciated.

Background

The Flora Vista Water Users Association operates a State approved community water system for the Flora Vista area located approximately half way between Farmington and Aztec on U.S. Highway 550. In 1983, the system served approximately 1500 residents and small businesses through 431 connections. Maximum system delivery, as reported in New Mexico Environmental Improvement Division (EID) community water supply system inspection reports, was reported at 170,000 gallons per day (gpd) with average delivery in 1983 of about 100,000 gpd. The system was placed in service in 1981 with two wells each having pump capacities of 60-70 gallons per minute (gpm).

In January, 1980, a gas well owned by Manana Gas, Inc. of Albuquerque was drilled in unit M (SW/4 SW/4) of Section 23, Township 30 North, Range 12 West. The well, Mary Wheeler No. 1-E, was placed in service in July, 1980, with the natural gas being received by El Paso Natural Gas via a pipeline at the site.

Manana facilities at the site include the well, an oil-water separator, a fiberglass tank (capacity approximately 120 barrels) holding produced water and some oil from the separator, an oil tank for storing oil produced with the gas, and a tank drain pit for discharging water separated from the oil (now replaced with a small fiberglass tank). A reserve (mud pit) and a blowdown pit were both likely present at one time but have been covered over. The original fiberglass tank has been replaced with a second identical tank due to discovery of a leak. El Paso Natural Gas facilities include a gas dehydrator, a dehydrator pit with a 55-gallon drum serving as a collector, and a gas meter house.

The entire site occupies an area of approximately 220 x 75 feet and is located northeast of water supply well S1. Distances from the water well to the fiberglass produced water tank, gas well, and dehydrator pit are 235 feet, 255 feet, and 285 feet, respectively. Figure 1 shows the relationship of the various oil and gas facilities to the water wells. The location of the reserve (mud pit) is not directly evident from recent aerial photographs, but is thought to be south of the fiberglass tank for the oil-water separator.

In 1982, Oil Conservation Division records show gas well production of 39,584 million cubic feet of natural gas and 1022 barrels of oil. Water production is estimated by the company (1985) at approximately 210 gallons per day or about 76.6 thousand gallons per year. All produced water collected is removed from the site.

In February, 1983, at least one water supply well, S1, became contaminated with oil and grease and was taken out of service. The level of contamination was reported in Association records as 16 mg/l. To avoid further contamination, the system was shut down and water was purchased from the City of Aztec and delivered via an existing pipeline. At that time, the Association dug a pit between S1 and the gas well and detected a noticeable odor and an oily film. Between February and August, 1983, additional backhoe pits were dug and sampled for oil and grease. In August, the OCD sampled the water well S1, the Manana separator, the El Paso dehydrator, and a previously dug pit. Oil and grease levels reported ranged from 32 to 38 mg/l except for the dehydrator which was not reported. However, the dehydrator sample was reported to have 13 mg/l of both benzene and toluene.

In the summer of 1984, the EID attempted to drill monitoring wells in the area for the purposes of determining the contamination sources and the risk to the other supply wells. However, the hollow-stem auger drill rig was not able to penetrate the large boulders in the shallow subsurface and the attempt was discontinued.

Site Investigation

The following is a summary of work performed in 1985:

1) Five monitoring wells were placed around the original contaminated well in late March by OCD and EID staff. Due to large boulders in the shallow subsurface, the wells were installed with a backhoe provided by the water users association. The wells are 2-inch diameter steel casing, with a 48-inch long Johnson wire-wound stainless steel screen having a slot size of 0.07 inches. This slot size is too large for effective sand control, but it was the only screen available for immediate use. The wells and casing were provided by EID. Gravel packing was tried for the first well, but the large pit size and rapid slumping of the hole precluded further gravel use. The lack of a gravel envelope made the wells subject to rapid silting. Total depths of the wells range from 7 to 10.8 feet from the casing top. The wells extend about 20 inches above the land surface and are cemented at the surface. The monitor wells are capped and locked to prevent unauthorized entry.

2) Samples were taken from the water supply and monitor wells for organic analyses in March, June, August, September, and October, 1985. The results are shown in Tables 1 and 2. Results of samples from the fiberglass separator tank at the Mary Wheeler No. 1E gas well are shown in Table 3. Inorganic analyses were run on the water supply wells (including the previously contaminated well) and the Animas River in March, and the produced water from the gas well in October.

3) As expected, several monitor wells filled with sand and were cleaned twice using compressed air from two different compressors. The use of these compressors apparently affected the water quality as discussed below.

4) In September all monitor and supply wells were surveyed by Brewer and Associates for both location and elevation. Several well elevations were resurveyed in October. Blueprints from recent aerial photos were received in late December. Water levels were measured in September and October, 1985.

A summary of work performed in 1986 follows:

1) Water levels were measured in January, February, April and May. These are shown in Figures 3 to 6.

2) Samples from the monitoring wells for water quality analysis were taken in January, and April. The contaminated well was sampled in April and May. The water system was sampled for organics in January, April and May. The new fiberglass tank at the Mary Wheeler 1E oil storage tank (used to collect water drained from that tank) was sampled in April and May. The 55-gallon drum at the El Paso Natural Gas dehydrator unit was sampled in January and February. The results of organic analyses of these samples are shown in Tables 1 to 4. Inorganic analyses were run on samples from the contaminated water well in April, and from the dehydrator barrel in February. Discussion on the results is presented in the section on water quality.

3) A 72-hour aquifer test was performed on the contaminated well between April 21 and 25. The test consisted of water level measurements from the pumped well and monitor wells on April 21, 48 hours of pumping April 22-24, and 24 hours of recovery April 24-25. Approximately 5 hours into the test, oil was drawn into the well. The results of this test are discussed in detail in the hydrogeology and water quality sections.

4) A second, short duration test was performed in May to better characterize the volume and nature of the oil. These results are also presented below.

5) A study progress report was prepared in January.

Hydrogeology

The valley of the Animas River contains alluvium consisting mainly of sand and gravel which is outwash material from Pleistocene glaciers in the San Juan Mountains in Colorado. In the vicinity of the Flora Vista wells this alluvium is about 22 to 25 feet thick. Examination of the aerial photograph blueprints provided by Brewer & Associates shows old river channels and meanders in the flood plain. Finer grained silts and clays can be expected to have been deposited in low velocity areas such as point bars and areas of overbank flooding. However, the area where the monitor wells were drilled was found to be a zone of very coarse sand and gravel with some rocks exceeding a foot in diameter.

The presence of a coarse sand and gravel zone usually indicates high ground water permeability. Examination of the pumping level estimates provided in the 1982 EID community water system environmental survey, together with a 1982 Brewer and Associates infiltration gallery feasibility study shows an aquifer permeability of about 750 gallons per day per square foot, or 100 feet per day. This was confirmed by the aquifer test conducted in April. The value is at the lower end of the range for clean sand and gravel mixtures, but still allows for rapid ground water movement.

In September and October, 1985, ground water levels were measured in those monitoring wells where fluid levels were present. The results were used to calculate the direction of ground water flow and the hydraulic gradient. The gradient values were 0.0080 and 0.0081, respectively, or about 43 feet per mile. These values are intermediate between the average river gradient at Flora Vista of 0.004 and the topographic gradient of 0.014 perpendicular to the river at the well field location. The 1986 water levels, measured in January, February, April, and May, showed gradients of 0.0080, 0.0086 and 0.0079, and 0.0071 respectively. The average of the six measured values is 0.0080 or about 42 feet per mile.

The 1985 ground water flow directions are shown on Figures 1 through 2. The direction in September is slightly east of south. By late October, the direction had changed to nearly 20° east of south and continued that direction through January and February (Figures 3 and 4). The April and May measurements (Figure 5 and 6) again show the direction of flow as slightly east of south.

Some reasons for these observed changes in the ground water flow direction may be postulated based on surface and ground water interaction in the area. When river flows are generally low, as in the fall and winter, water stored in the permeable alluvial material in the immediate vicinity of the river during times of spring and summer high flows is discharged back into the river. Additional ground water discharge to the river comes from sources to the northwest of the well field including ground water recharged to the alluvium from the Flora Vista Arroyo, the Halford Independent Ditch, the Farmers Ditch, irrigation seepage, recharge due to septic tank discharges, and any runoff from precipitation events. In the spring and summer months river flow is high, and water enters the alluvium with the resultant flow direction shifted southward as shown in Figures 5 and 6. One likely entry area is the alluvium north of the Manana production area at the river bend.

As shown on the figures, the direction of ground water flow on all the dates measured was towards the river. Therefore, natural ground water flow in the vicinity of the Manana Mary Wheeler 1E Well moves in the direction of the river and not towards any of the water supply wells or monitor wells. Pumping of the water well changes the natural flow direction.

During the week of April 21-25, 1986, extensive field work was performed at the site to determine aquifer characteristics. On the morning of April 21, water level measurements were taken at all observation wells at the site. The centrifugal pump planned for use would not perform satisfactorily and the test was postponed one day until another pump was obtained. The following morning, a gasoline powered Honda 350 gpm centrifugal pump with approximately 25 feet of intake hose was installed adjacent to the well. The discharge hose outlet was placed 225 feet downgradient in a low spot between the well and the river. The discharge was not allowed to enter the river. The volume discharged was measured using a totalizer meter, and flow rates were obtained using a stop watch. Water levels were measured 60 to 90 minutes before beginning the test to obtain a static level for drawdown calculations. Six observation wells located between 30 and 200 feet from the pumped well were used to measure drawdown.

Beginning at 1 p.m. on April 22, 1986, a 72-hour aquifer test was performed on the previously contaminated supply well. The test consisted of pumping for 48 hours, followed by measuring water level recovery for 21 hours. The initial discharge rate was set at 100 gallons per minute (gpm). However, because of totalizer errors and because the pumping rate was very sensitive to the throttle adjustment, the actual rate for the first 8.5 hours was later calculated to be 108.4 gpm. At that point the drawdown was below the top of the screen, and water was cascading into the borehole. This caused the discharge to decrease slightly. The average rate for the next 5.25 hours was 102.8 gpm. At 2:37 a.m. on April 23, the pumping rate was lowered to 85 gpm to avoid uncovering the pump intake. The actual pumping rate for the next 21 hours was later calculated at 88.6 gpm. At 11:49 p.m. the pump shut off automatically for reasons unknown. It was started again after six minutes. The pump stopped five other times during the following ten hours, but was restarted within 4-7 minutes each time. The test ended at 1:34 p.m. on April 24. The average pumping rate for the final 13.75 hours was calculated at 85.9 gpm.

The unanticipated and unintentional changes in the pumping rate made analysis of the results difficult and a number of methods were used to calculate the aquifer coefficients for transmissivity (T) and storage(S). The methods and their application are briefly outlined below. A form devised to tabulate the data is shown in Figure 7. The results are shown in Table 5.

Before drawdown values could be used in the calculations, they were corrected for dewatering of the water table aquifer using the Jacob correction (2). This method uses the formula $s_c = s - (s^2/2m)$ where s_c is the corrected drawdown, s the observed drawdown, and m the saturated aquifer thickness (calculated at 19.6 feet from the drillers log and the static water level).

The following methods of analysis of pumping data were used:

1. Theis Method (modified for water table use) - This non-steady state procedure (4) assumes that gravity drainage of sediments near the pumping well slows the rate of drawdown until the sediments are dewatered. Graphs of time versus drawdown were plotted on log-log paper for each well and superposed on Boulton delayed-yield type curves (Figure 8). When matched for best fit, these curves produced the Theis values for T and S shown in Table 5. Because the Theis method and its modifications are based on constant discharge, this method could not be used after the rate was dropped to 88.6 gpm about 14 hours after the test began.

2. Jacob Method - This is a graphical method plotting time versus drawdown with time plotted on the log scale (3, 4). This method is accurate after pumping has continued long enough such that drawdown varies directly with log time, and the plotted data is a straight line. This method cannot be used with variable pumping rates, and delayed gravity drainage may cause variations in drawdowns such that transmissivity appears higher than actual values. Because of the short constant-rate pumping time, this method could only be used with wells S1, xS1, and M3.

3. Time-Recovery Method - This is a combination mathematical-graphical procedure (1) directly applicable when variable pumping rates occur during a test. It adjusts the drawdown and time coordinates for the variable rates, and gives transmissivity values for both pumping and recovery periods. Since pumping drawdown values are affected by well entrance losses, calculations using recovery values give the most accurate estimates of aquifer transmissivity. Recovery data was collected only at wells S1 and xS1.

Review of Table 5 shows only slight variations for T for the observation wells using the modified Theis method. Lower T values for the pumped well are due to well entrance losses. Variations using the other methods can be considered acceptable given the graphical nature of the

procedure, and the fact that the straight line methods do not consider the effect of delayed water table drainage in the calculations.
Based on the results, an average value of aquifer transmissivity of 14545 gallons per day per foot can be used for further computations. An average specific yield of 0.08 to 0.09 (ratio of volume of water released to volume of unconfined aquifer) was found for this portion of the aquifer. These parameters can now be used for a multitude of purposes including estimation of ground water seepage velocity, aquifer drawdown, interference of nearby pumping wells, design of pumping schedules, etc.

In this report, transmissivity was only used to calculate hydraulic conductivity to provide an estimate of travel times and capture radii. Transmissivity is divided by the saturated aquifer thickness, b, to obtain hydraulic conductivity (K). For b = 19.6 feet, K = 742 gallons per day per square foot. This value is in excellent agreement with the earlier estimate of 750 given in the January progress report. Therefore, the calculations presented in the January report do not need to be revised.

Because just under 14 hours of data were collected before the pumping rate was reduced, the presence and magnitude of river recharge on the aquifer system could not be determined. Recharge could be expected to occur, but a previous 12-hour test by Ranney (5) did not detect such river replenishment.

Several observation wells were used during the test, and the plotted water levels show the expansion of the pumping cone of depression after several hours. Figure 9 depicts the cone at 32 hours after the start of the test. The figures show that the pumping cone is elongated northeast-southwest. This can have several interpretations. In areas of homogenous material with only one source of recharge, a pumping well will cause steeper drawdown contours in the direction of recharge, and flatter contours on the opposite side of the cone. Figure 9 shows the expected steep, closely spaced contours near M3, but the flatter contours are rotated about 45° clockwise from the expected direction. This could be due to either induced recharge from the river, a natural increase in aquifer transmissivity towards the southwest, or a combination of both. Since the steepest gradient is in the direction from which ground water is flowing, it would appear that more water is being captured by the well from that source than from the river to the east. If a constant pumping rate could have been maintained for the entire 48-hour test, the effect of the river on recharge would be known.

Because of cone of depression elongation, a change in transmissivity can be postulated. Since T is equal to the product of hydraulic conductivity and saturated aquifer thickness, either one or both can increase T. The aerial photo shows that in the past the river has meandered, and old channel remnants can be seen that appear to coincide with the northeast-southwest elongation. Since the coarsest materials were deposited in these channels, they have preferential permeability in the direction of stream flow. Therefore, it is likely that sediments near the contaminated well have a higher permeability in the northeast-southwest direction. An old channel would likely have a greater depth to bedrock because of scouring by moving sediment. Association records show that well S4, located away from this feature, has a lower production rate.

Because of the change in aquifer test pumping rates, and the effect of delayed water table drainage, no clear pattern was present in the values of T shown in Table 5. However, all hydraulic effects are "integrated" by the aquifer to produce the shape of the drawdown seen in Figures 9.

Predictive Calculations

Since higher permeabilities are likely in the northeast-southwest direction, there are ground water quality implications. Because the Manana and El Paso production units are directly northeast of well S1, when the water well is pumping some of the water drawn into the well will be from the area of the production facility. The following paragraphs summarize predictive calculations made from the hydrologic information obtained at the site.

In February, 1983, with river water levels quite low (Table 6), water well S1 was contaminated by hydrocarbons. One suspected source was a leaky fiberglass tank (since replaced) containing produced water from the Mary Wheeler No. 1E gas well. As discussed elsewhere, the contamination could be from several sources. This source is only used to illustrate the predictive calculations.

The tank location is approximately 230 feet to the northeast of well S1. If the direction of ground water flow at this time was slightly east of south towards the river, other factors must have been operating for this to be the contaminant source. Using the available hydrologic data and the EID's January, 1983 report of estimated water use, drawdown calculations were made using the Theis non-equilibrium well formula (Table 7) . The calculations were made assuming 100,000 gallons per day pumped from two wells with a daily average of Q = 35 gpm/well. The results show a drawdown of 0.1 foot at the tank after only two days of pumping at the above rate. Though small, this value is enough to cause movement of water towards the well. After 100 days of pumping, the calculated drawdown is 1.1 feet at the tank location.

Since this well (S1) is only 250 feet from the river, it was reasonable to expect that river water is recharging a portion of the water removed from the aquifer by the well. However, calculations assuming steady-state flow and isotropic aquifer permeabilities show that the zone of capture only extends 69 feet down gradient for an average daily pumping rate of 35 gpm. This is because more water upgradient is captured, and the resultant asymmetrical cone of depression (zone of influence) does not extend as far downgradient in the direction of the flow (Figure 10). Since the well was reported to have pumped at a maximum of 60 to 70 gpm, a downgradient capture distance of 127 feet was calculated for Q = 65 gpm. Because the pump was cycled on and off, the stress on the aquifer would fluctuate. If the pump was on more than 50% of the time, the parabolic envelope shown in Figure 10 would approach that of the Q = 65 gpm curve.

These pumping capture curves were drawn assuming the flow direction in early 1983 was the same as January, 1986. Some variables that could change curve shape include non-homogenuous sediments, variations in permeability, non-equilibrium (vs. steady-state) flow, and the pumping cycles. Since the April, 1986, aquifer test showed a likely increase in permeability in the northeast-southwest direction, the right limb of the capture curve probably extends further eastward than shown.

If there is a drawdown of water under the produced water tank due to well S1, this would allow capture by the well of water under the tank. A simple calculation using only the volume of water in the aquifer, a porosity of 0.25, a radius of 230 feet, a saturated thickness of 17 feet, and pumping rate of 35 gpm finds that movement of contaminants from the tank to the well would occur in 105 days. Calculations for a drawdown of 1.1 feet after 100 days of pumping (average Q = 35 gpm) and taking into account changes in flow velocity near the well show that travel times for water movement from the tank location to the well would range between 96 and 103 days. These times do not take into account constant pumping at a higher rate or any mechanisms of attenuation such as contaminant retardation due to sorption, or biochemical transformation. More sophisticated techniques can produce more exact estimates of both flow and solute transport rates if actual pumping rates, and pumping cycles were known.

Under non-pumping conditions, ground water movement will be determined by the local hydraulic gradients, and the rates of movement can be calculated using the formula shown in Table 7. Using an average gradient of 0.0080 for fall, 1985 - spring, 1986, a porosity of 0.25 and hydraulic conductivity of 750 gpd/ft, an approximate horizontal seepage velocity of about 3.2 feet per day, or 1170 feet per year, was calculated. This shows rapid particle movement under natural conditions for those seasons. If these rates prevail all year, and the contaminant source was a one-time release of produced water with some oil, movement of the more mobile contaminants (e.g., chloride) would be out of the zone of influence of the well after only one year. In addition dilution with other water and other mechanisms would be expected to attenuate a single incident plume. Most effective attenuation would occur if a large oil phase was not present. Again, more sophisticated techniques using computers can produce a ground water model of plume movement and dispersion if more source information was available.

If a large oil phase was discharged, the presence of residual oil in the soil and water together with seasonal water level changes would cause continued leaching of soluble oil constituents into ground water. If present, these dissolved contaminants will again reach the well if it is put back into service. The remaining oil itself can also be mobilized under certain conditions and enter the well. These conditions are discussed later in the report.

Water Quality

The inorganic chemistry analyses of the all water supply wells sampled since March, 1985, show generally very good water quality. For four samples from two wells and a composite of two other wells, total dissolved solids (TDS) average 422 mg/l, chlorides average 17 mg/l and sulfates average 188 mg/l. A sample of Animas River water had concentrations of 368 mg/l, 12.5 mg/l and 116.3 mg/l for the same constituents. For the wells, only manganese with an average of 0.37 mg/l is elevated above acceptable levels. Manganese is naturally occurring in salt and minerals and the New Mexico Ground Water Standard is 0.2 mg/l. The effects of slightly elevated levels are generally limited to unpleasant taste and plumbing fixture staining.

The contaminated well, S1, was sampled for inorganics on April 23, 1986, 24-hours into the aquifer test. Values for TDS, chlorides and sulfates were 498 mg/l, 16.0 mg/l and 185 mg/l, respectively. Produced water from the Mary Wheeler 1E fiberglass separator tank was collected in September and October, 1985. The two analyses showed average TDS of 35,640 mg/l, chloride 20,380 mg/l and sulfate 3,000 mg/l. The El Paso Natural Gas dehydrator barrel was checked for conductivity in February, 1986. The value of 81 umho/cm at 17° C is equivalent to about 70 mg/l TDS. The barrel had elevated levels of iron, tin, and manganese thought to be from the barrel itself.

A sampling program for organic chemicals in the affected water supply wells, monitor wells, and operating supply wells was begun by the OCD in March, 1985. Subsequent testing was performed in June, August, September, and October, 1985; and January, April and May, 1986. The results are shown in Tables 1 and 2. Tables 3 and 4 show sampling results for Manana and El Paso units at the site.

The wells were sampled for aromatic hydrocarbons which have been found to be present in water and fluids produced concurrently with oil and gas. Once dissolved in water, these contaminants migrate with the ground water in the subsurface. At a point of use, such as a well, the hydrocarbons can be present in the water even though a separate oil phase may not be detected. Samples for aromatic hydrocarbon testing require only a small 40 ml volume of water, and no special treatment or preservation except chilling needs to be performed prior to analysis. In addition to aromatic hydrocarbons, tests for methane gas and halogenated hydrocarbons can be performed on the same sample. Prior to sampling, the monitor wells were "purged" by use of a clean bailer to obtain fresh samples.

In March, 1985, water samples were taken from the backhoe-dug pits prior to monitor well installation. An oily sheen appeared on the water in the pits. Examination of the backhoe bucket determined that hydraulic fluid was leaking from either a fitting or a cylinder and dripping into the pit. Samples of the pit water taken that day showed no contamination.

Sampling of the monitor wells was complicated by fine sand that entered the well as a result of the large screen size and lack of a gravel pack. Also, water levels in the monitor wells dropped between 4.6 and 7.6 inches from September to October, 1985. Wells M1, M2, and M4 were dry for one or more of the 1985 samplings.

On June 27, 1985, cleaning of all monitor wells was attempted using a small air compressor like that used for spray painting. Sampling done the following day detected low or trace levels of hydrocarbons in three of the five wells. At that time the use of air from a compressor to clean out shallow monitoring wells was thought by both OCD and EID to be a practical solution. Although EID had used this small compressor previously and not detected contamination, its air line was never tested for hydrocarbons, and the compressor is no longer available for testing. Therefore, the small compressor as a source for those contaminants detected in monitoring wells for the June sampling cannot be ruled out. The use of a larger air compressor to displace water and sand in the wells is known to have introduced small amounts of contaminants. In September, 1985, well S5 was pumped by introduction of air to displace several well water volumes to acquire a "fresh" sample. Samples taken that day and the following day from S5 had low levels of toluene and several other aromatic hydrocarbons. These levels were many times lower than either New Mexico or newly proposed EPA recommended levels.

After examination of these and other September results showing low levels of contamination, the air compressor was tested and found to have lubrication or combustion pollutants in the air line. The air line is thought to be the major source for the pollutants detected in wells S5, M1, M2, M3, and M5 for the September, 1985, sampling. However, well M4, which could not be reached by the air line in September, also showed a slight, but detectable level of toluene. Well S5 was resampled in October and trace levels less than 1 ppb were found for several aromatic hydrocarbons, not including benzene. Well M4 was dry at the time of the October sampling and no hydrocarbons were detected in the other wells.

After this experience, the use of air compressors to remove sediment from the wells was discontinued. Prior to the January, 1986, sampling; all monitor wells were cleaned by use of a homemade PVC hand auger that effectively removed all but a small volume of sand.

Results of the 1985 samplings of the previously contaminated well S1, well S5, and the monitor wells were inconclusive except where known contamination occurred after attempting to clean sediment out of the wells with an air compressor. Toluene at 6 ppb was detected in a bailed sample from S1 in June, along with another unidentified hydrocarbon (Table 1). The well was capped shortly thereafter, and remained sealed until the aquifer test. The air compressor was not used on well S1. Well S5 was in service until July, 1985, when the pump was removed. The samplings in March and August showed no contamination, but September and October results showed low levels. Only the September sampling would likely have been affected by the use of the air compressor. Well S5 remained uncapped through May, 1986.

For the monitor wells, the September cleaning is known to have introduced contaminants, and the June cleaning is also suspected to have done so. For the March, August, and October, 1985 samplings, no contamination was detected in any of the monitor wells having water. Since the range of seepage velocities was from 3 to 4 feet per day, low level contamination introduced from the compressors would have been diluted and quickly moved beyond the capture radius of the monitor wells. Well M4, cleaned with a compressor in June, but not in September, contained a very low level of toluene close to the detection limit at the time of the September sampling. This well was dry for the August and October samplings.

Results for 1986, prior to the aquifer test, showed continued low levels of organic contaminants in well S5 in January. Likewise, wells M3 and M5 showed some slight contamination in January. All values reported were close to the detection limit of 1 ppb. The April 21 sampling, one day prior to the start of the aquifer test, showed no contamination in wells S1 and S5, nor in any of the monitor wells. The impact of the aquifer test on water quality of the monitor wells is discussed later in the report.

Tests for dissolved methane gas were made on samples collected on several dates. Monitor wells 3 and 5 had greatly elevated levels of the gas in August but only slightly elevated levels in October. January, 1986, levels were not elevated above background. M5 is the monitor well nearest the gas well, and it may be located at or in the buried pits. It had the largest volume of gas and also was located in an area where dark black sediment was present. Soil sampling did not show oil present at detectable levels. The source of the gas may be natural material since the area is swampy, or it may be from shallow buried organic material deposited in the reserve pit during drilling and/or testing. Produced water containing small amounts of oil previously discharged from the leaky tank may also be the source. The gas well itself is not suspected because the surface casing extends to a depth of 227 feet and is cemented back to the surface. Because gas levels were not elevated above background in January, the effect may be seasonal and related to water table elevations.

Produced water from the Manana Oil Mary Wheeler 1E gas well was collected from the fiberglass tank at the separator in September and October, 1985 (Table 3). Benzene values were 8,700 and 16,000 ppb and other aromatic hydrocarbons exceeded 1,000 ppb except for ethylbenzene. April and May, 1986, samples were taken from the fiberglass tank at the oil storage tank. Benzene values were 550 and 150 ppb, and other aromatics were of similar magnitude except ethylbenzene which was lower.

The 55-gallon drum at the El Paso Natural Gas dehydrator was sampled in January and February, 1986. Levels of aromatics were from 2 to 600 times greater in January than in February (Table 4). Benzene levels were 14,000 ppb and 550 ppb for those two months, respectively.

A total of six samples representing a composite of the pumping wells were taken from the pump house tap in March, August, and October, 1985; and in January, April, and May, 1986. No contaminants were detected in 1985 except for a very small volume of chloroform. Chloroform might have been present as a result of chlorination which occurs immediately adjacent to, but downpipe from the pump house tap. In 1986, a laboratory solvent, dichloromethane was detected in April. Subsequent investigation determined that the sample vials were contaminated when received. No aromatic hydrocarbons were detected in the system's composites analyzed as part of this study.

Aquifer Test Water Quality

Approximately 5.25 hours after the aquifer test began, oil was detected in the pumped well during a water level measurement. The Water Users Association was notified and sampling of the well began. A bailer was used to obtain samples from the open bore-hole. This provided the most accurate sample for dissolved aromatic hydrocarbons since the pump outlet was 225 feet away, and contaminant volatization occurs during turbulent flow in the pipeline. An oil sheen was seen on the water surface in the well, the bailer was greasy and oily, and the wellbore had a very noticeable hydrocarbon odor. A similar odor was observed at the fiberglass water drain tank at Manana's oil storage area, but not at the produced water tank, or at the El Paso dehydrator barrel.

Analyses of samples taken the following three days were highly variable. Dissolved aromatic hydrocarbons (benzenes, toluene, xylenes) were detected four times at low parts per billion levels (Table 1). All levels were below health standards. One sample had a possible trace of toluene and xylenes. Other oil hydrocarbons were also detected in some samples. Four samples taken after the oil entered the well showed no aromatic hydrocarbons. Samples taken for phenols, oil and grease, and polynuclear aromatic hydrocarbons did not show those constituents at the detection level of the equipment used. Inorganic constituents did not appear elevated in a sample taken during pumping.

The variability of the samples is thought to be due to the arrival of oil as "blobs" instead of continuously. Turbulent conditions and cascading water in the well bore also caused sample variation.

Monitor wells 1, 2, 3 and 4 did not detect aromatic hydrocarbons before or after the test. A trace (<1ppb) of one unidentified oil hydrocarbon was found in M3 the day before the test. No hydrocarbons were detected in M5 the day prior to the test, but sampling the day after test completion showed elevated levels of toluene and xylene (Table 2). Although these levels did not exceed state or proposed federal standard levels, they were higher than any levels previously seen in any of the monitor or supply well samples. Well M5 is located approximately one-half the distance between the pumped well and the produced water tank at the Manana lease. The monitor well may be located in or near the area formerly used as the reserve pit.

On May 21, 1986, the well again was pumped, but only for 5.6 hours. The purpose of the test was to see what effect cyclic pumping had on oil nearby the well. After only 11 minutes, a sheen was noticed in the wellbore. At the end of one hour, an odor and heavy sheen were noticed. When the pump was restarted after filling its fuel tank, the rise in water level brought oil up in the well. Close to the end of the test, a thin oil layer was floating in the bore that produced a rainbow sheen in the reflected light. Aromatic hydrocarbons, phenols, and polynuclear aromatic hydrocarbons could not be detected in water samples taken during the May test.

Source of the Hydrocarbon

Based on the hydrologic data, the water quality data, and sampling of the effluents from the Manana Mary Wheeler No. 1E Gas Well, the source of contamination is from oil and gas activities at the Manana site. The exact mechanism of discharge could not be determined with the current information. Possible sources of contaminants included:

1. Produced Water - Discharges of about five (5) barrels (210 gallons) per day of water with some oil. Records of use and dates of use of fiberglass tanks or pits to contain the water are not available to OCD. The produced water has high concentrations of chlorides (20,000 mg/l) and total dissolved solids (36,000 mg/l). No elevated levels of inorganics were detected in the contaminated well during the OCD investigation. Chlorides were less than 20 mg/l and TDS ranged from 365 to 498 mg/l. TDS was reported highest at 570 mg/l in 1981 before the contamination. Since chlorides, sulfates, and some other constituents of TDS are highly mobile and move close to the seepage velocity of water, any single incident of brine contamination would have moved past or into the well before arrival of the less mobile oil phase. Therefore, the absence of brine contaminants in the water sampled does not eliminate oily produced water discharges as the contaminant source.

2. Water Drained from the Oil Storage Tank - Intermittent discharges of water and some oil of unknown volume. Records and dates of use of pits or fiberglass tanks are unknown to OCD. Since the water contained high salt concentrations (conductivity approximately 50,000 umho/cm), the same comments made for produced water apply here.

3. Oil in the Reserve, Blowdown and/or Mud Pit - Discharges during well drilling; volumes and quality unknown by OCD. Blowdown pit may receive oil after drilling and intermittently during well operation. None of these pits are currently visible at the site. Association records of

analyses from samples taken in 1983 show oil and grease and other hydrocarbons in the "slush pit" and in a pit dug east of the dehydrator pit. Again, the exact source (e.g., separator tank, reserve pit, etc.) of the hydrocarbons is unknown by OCD.

4. Steam Vapor Condensation, Water and Upset Fluids at El Paso Natural Gas Company dehydrator - Intermittent, very low volume fluids. Condensation water discharge similar to leaky faucet drip. Volume dependent on unit operation and efficiency; estimated at one, 55-gallon barrel per 30 to 60 days. Upsets occur when Manana separator does not operate properly and El Paso dehydrator must remove fluids prior to gas line transmission. Information on condensation wastes volumes, and dates or volumes of any upsets are not available to the OCD.

Information supporting one or more unspecified discharges at the Manana production unit as being the cause of the well contamination is based on:

1. Ground water flow past the production unit is captured by the well (S1) when the well is pumped. The zone of fluid capture includes the production area, dehydrator area, oil storage area, and the area thought to include the buried reserve, and blowdown pits.

2. The aerial photograph shows that the Animas River channel has meandered at Flora Vista. A feature that appears to to be an old straighter, river channel trending northeast-southwest can be discerned on the photograph. Subsurface evidence for this change comes from the coarse sand, gravel and boulders found when drilling the supply well, and from the elongated shape of the cone of depression formed when pumping the well. Supply well S4 (690 feet north of S1) is located outside this feature and has poor production. The gas well and associated production units are located at the northeast end of this channel feature at the river's edge. The contaminated well is southwest on a direct line with the axis of this postulated channel.

3. The monitor well, (M5), located between the Manana facility and the contaminated well, was the only monitor well to detect contamination at the time of the aquifer test.

4. Whereas S1 and M5 show contamination, S4, located 400 feet north of, and on the other side of the production unit, has not become contaminated.

5. The Manana facility is the only oil and gas production unit in the area of the waterwell. No industrial facilities are nearby, and no evidence of dumping of oil or other fluids at

the site was found.

Implications for Future Well Use

The pumping test showed that after three years, oil still remains close to the supply well. A simple calculation using pumping rate, time of oil arrival, aquifer thickness, and porosity, shows that oil was at a radius of about 20 feet when the test started. This calculation assumes that the oil will move to the well at the same velocity as the water, an assumption not always satisfied.

Once a source of hydrocarbon pollution is disrupted, and the main body of contaminants displaced, some of the oil remains trapped in the porous media above and below the water table because of capillary forces. Hydrocarbon migration halts as this lower, "residual saturation" is reached. The trapped hydrocarbon remains as pendular rings attached to the subsurface particles or as isolated "blobs" (7).

Below the water table, most residual oil exists as discontinuous blobs. It can be mobilized by increasing the hydraulic gradient or by reducing surface tension (as by surfactants). One method to increase the hydraulic gradient is by pumping. Therefore, when the Flora Vista well was in operation, the pumping cycles themselves acted to mobilize the blobs and move them towards the well. In the absence of a sufficient hydraulic gradient to move the oil itself, some constituents will leach into the water and move as dissolved species. Therefore, benzene, toluene, etc., can be detected in a well without the actual physical presence of an oil phase.

Because the amount, duration, and exact nature of the discharge is unknown, it cannot be predicted how long it will endure. However, it can be assumed that as long as oil remains nearby the well, it will be mobilized and captured by the cyclic pumping. Even if oil pumped with the water cannot be quantified in definite health terms, the presence of oil cannot be tolerated in drinking water systems for esthetic reasons.

Well S5 was taken out of service in summer, 1985. Since that time, the well has been left uncapped. Some low levels of hydrocarbons were found in that well, as in the other monitor wells, after using the air compressor in September, 1985. Unlike the others, continued traces of hydrocarbons have been found in the 1986 samplings. A zone of capture diagram (Figure 11) shows that during the 2 1/3 years the well was pumping after well S1 was contaminated, well S5 would have captured water from the area of S1. Therefore, the existence of hydrocarbons between S1 and S5 cannot be ruled out. Well S5 should be pumped and sampled to determine whether there is a hydrocarbon problem. The well should then be capped, but with access for sampling.

Not enough information is known by the OCD to provide information on the likelihood of the other wells being contaminated. Pumping and sampling

S5 will provide some information on hydrocarbon presence. Well S2 is along the assumed buried channel as described above, but the others are offset by some distance. If drilling logs, pumping rates, and cycles for the other wells are known, drawdowns, cones of depression, and capture zones can be calculated using data from the OCD aquifer test.

Conclusions

1) No verifiable contamination was detected in 1985 in either the unused water supply wells or the monitor wells except for low level contamination detected in samples taken within 24 hours of cleaning with an air compressor. The contaminated well was not pumped with a high capacity pump in 1985.

2) Methane at concentrations 1200 times ambient levels was detected in the monitor well closest to the gas well in August, 1985. The source is likely the decay of shallow buried organic material. It may be from natural material, from gas well drilling and testing fluids, or from the leaked produced water. The gas well itself is not likely the source of methane since it has 227 feet of surface casing cemented back to the surface. A January, 1986, sample showed no methane in any wells.

3) Natural ground water flow is from north to south. Under non-pumping conditions, ground water from the vicinity of the Manana production unit will not encounter supply well S1 or other supply wells.

4) An aquifer test performed by the OCD in April, 1986, found that average hydraulic conductivity of the sediments is approximately 750 gallons per day per square foot. Seepage velocity is in excess of 3 feet per day and about 1170 feet per year.

5) The aquifer test produced an elongated cone of depression which indicates a buried channel along a northeast-southwest axis. Supporting evidence includes aerial photographs, extensive subsurface sand, gravel and boulder deposits, and lower production at well S4 which is located away from this feature.

6) Zone of capture calculations for well S1 show that when the contaminated well is pumped at production rates, the well will draw water (and any contaminants) from the vicinity of the Manana facility. The presence of a buried channel likely having preferential permeability will enhance such capture.

7) Capture calculations for well S5 show that water (and contaminants) near S1 will be drawn to S5 when well S5 is in use.

8) Oil and dissolved hydrocarbon contamination remains in sediments immediately adjacent to well S1. Any production pumping will cause continued movement of contaminants into the well.

9) Concentrations of organic contaminants have not exceeded health

standards in OCD samples. However, if only for esthetic reasons, oil is not acceptable in drinking water systems.

10) At conclusion of the aquifer test, monitor well sampling detected elevated levels of organic aromatic hydrocarbons in well M5 approximately halfway between the contaminated supply well and the Manana produced water tank. These values were higher than in any previous sampling. All other monitor wells were free of detectable contamination.

11) Inorganic contaminant levels were not elevated at well S1 in any OCD sampling in 1985-86. Minor variations were noted that are attributable to natural fluctuations.

12) The source of contamination is past activities at the Mary Wheeler Gas well facility. The hydrologic and geologic evidence, especially from the aquifer test, supports this conclusion. Additional support for this conclusion comes from the fact that no other sources of hydrocarbons are in the area, and an upgradient well (S4) did not become contaminated when it was in service.

13) The exact discharge mechanism(s) at the gas well facility is unknown. Possible sources include Manana's fiberglass produced water storage tank (which was known to have leaked); the pit used to drain produced water from the oil storage tank; the mud, reserve or blowdown pits containing oil from drilling and completion operations; or oil from upsets of the El Paso Natural Gas Company's dehydrator. Oil from the latter facility would be discharged in the event of malfunction of Manana equipment. OCD does not have records of EPNG upsets nor does it have records of Manana tank replacement or other equipment malfunctions. The contamination may be a combination of one or more of these mechanisms.

14) The absence of brine contaminaton in the contaminated well does not eliminate produced water discharges as the cause of contamination. Since many inorganic constituents are very mobile and ground water flow is rapid, such contaminants, especially chloride, are likely gone from the area.

15) Residual oil, as hydrocarbon "blobs", will remain present in the sediments near the well. Oil will continue to move into the well in response to cyclic pumping if the well is put back in service.

16) Capture curves were not calculated for the pumping wells since conditions were not known at those sites. Knowledge of the natural flow at the new wells, pumping rates, and pumping cycles would allow such curves and cones of depression to be drawn. Such information would allow evaluation of the threat of those wells from the oil contamination.

Recommendations

1) Well S5 should be immediately capped and locked, but such capping

should allow for access for pumping and water level measurements.

2) Since well S5 is upgradient of the currently used well field, it should be used as a monitor well. The well should be pumped for a sufficient length of time to purge water in the immediate vicinity of the well bore. It then should be sampled for aromatic hydrocarbons, chlorides and total dissolved solids. Sampling should be on a regular schedule (perhaps quarterly or semiannually) depending on the most recent sampling results.

3) If the pumping of well S5 detects oil or high concentrations of dissolved hydrocarbons, other wells (especially S2) may be threatened. In that instance, additional extensive site work, including soil excavation, will be necessary to determine the threat to other wells. Removal of oil and contaminated soil may well be necessary to prevent continued movement to other supply wells.

4) Sampling of individual pumping water supply wells for purgeable aromatic hydrocarbons should be performed on a regular basis. For convenience, a sampling schedule identical to that required for total trihalomethanes is initially suggested.

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REPORT TABLES

TABLE 1. - Results[1] of Organic Chemical Analyses for Flora Vista Supply Wells
Supply Well No. 1 (Survey Point No. 6)

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	8/83	1538 3/20/85	1610 3/20/85	6/28/85
Benzene	10	0 f	ND	ND	ND	ND
Toluene	15,000 750 a	2000 p	ND	ND	ND	6
Ethyelbenzene	750 a	680 p	-	ND	ND	ND
p-xylene	Total xylenes 620 a	Total xylenes 440 p	-	ND	ND	ND
m-xylene			-	ND	ND	ND
o-xylene			-	ND	ND	ND
Chloroform	100 a	Total Trihalomethanes 100 m	-	ND	ND	1
Other Trihalomethanes	-		-	ND	ND	ND
Detection Limit	-	-	10	1	1	1
Analyzed by [4]	-	-	Ana Cor	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	-	-	-	1.3ppm
Detection Limit	-	-	-	-	-	1ppm

Comments: Well shut down in 1983 due to hydrocarbon contamination. Well capped and welded, shut July 1985. One unsaturated hydrocarbon detected 6/28/85 at 5ppb but unidentified.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted 1,000 ppb = 1 ppm or mg/l). ND- not detected, L-less than.

2) a - adopted December 1985 but not yet in effect.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable). m - maximum contaminant level (enforceable).

4) SLD- New Mexico Scientific Laboratory Division

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 1. - (Continued)
Supply Well No. 1 (Survey Point No. 6) - 1986

STANDARD	NM GROUND WATER STANDARD[2]	EPA RMCL[3]	1950 4/22/86	2010 4/22/86	2015 4/22/86	1310 4/24/86
Benzene	10	0 f	ND	ND	ND	1
Toluene	750 a	2000 p	ND	ND	1	ND
Ethyelbenzene	750 a	680 p	6	1	ND	ND
p-xylene	Total	Total	7	1	ND	ND
m-xylene	xylenes	xylenes	14	2	ND	ND
o-xylene	620 a	440 p	1	ND	ND	ND
Detection Limit	-	-	1	1	1	1
Analyzed by[4]	-	-	SLD	SLD	SLD	SLD

Comments: Well shut down in 1983 due to hydrocarbon contamination. Aquifer test on well 4/22-24/86. Hydrocarbons entered well at 1817 4/22. Analyses that date at 1950, 2010, and 2015 showed unsaturated C_7 aliphatics, and possible C_3 substituted benzene. Possible trace of toluene and xylenes 4/23 at 0832. No high levels of heavy metals or napthalenes detected. Chloride 16 mg/l and TDS 498 mg/l on 4/23/86.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted 1,000 ppb = 1 ppm or mg/l). ND- not detected.

2) a - adopted December, 1985.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable).
m - maximum contaminant level (enforceable).

4) SLD- New Mexico Scientific Laboratory Division

5) The following 1986 samples had no aromatic hydrocarbons detected: 4/21-0945; 4/22-1525; 4/23-1310; 4/24-1320, 1400; 4/25-1050; 5/21-0935, 1140, 1340.

TABLE 1 (Continued)
Supply Well No. 5 (Survey Point No. 14)

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	3/20/85	8/5/85	9/20/85	9/21/85	10/25/85
Benzene	10	0 f	ND	ND	ND	ND	ND
Toluene	15,000 750 a	2000 p	ND	ND	3	3	L1
Ethyelbenzene	750 a	680 p	ND	ND	2	2	L1
p-xylene	Total	Total	ND	ND	2	1	ND
m-xylene	xylenes	xylenes	ND	ND	4	4	L1
o-xylene	620 a	440 p	ND	ND	5	3	L1
Chloroform	100a	Total	ND	ND	ND	ND	ND
Other Trihalo-methanes	-	Trihalo-methanes 100 m	ND	ND	ND	ND	ND
Detection Limit	-	-	1	2	2	2	1
Analyzed by [4]	-	-	SLD	SLD	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	-	1.3ppm	-	-	1.8
Detection Limit	-	-	-	1ppm	-	-	0.4

Comments: Well on-line until July 85. Pump then removed and well left open. Well pumped with air 9/20/85. Air compressor exhaust present in air line introduced small quanitities of contaminants which may be those seen on 9/20 and 9/21.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected, L-less than.

2) a - adopted December 1985 but not yet in effect.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable).
m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 1 - (Continued)
Supply Well No. 5 (Survey Point No. 14) - 1986

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	1/17/86	4/21/86	4/25/86
Benzene	10	0 f	<1	ND	ND
Toluene	750 a	2000 p	2	ND	<1
Ethyelbenzene	750 a	680 p	ND	ND	ND
p-xylene	Total	Total	ND	ND	ND
m-xylene	xylenes	xylenes	<1	ND	ND
o-xylene	620 a	440 p	ND	ND	ND
Detection Limit	-	-	1	1	1
Analyzed by [4]	-	-	SLD	SLD	SLD

Comments: Well on-line until July, 1985. Pump then removed and well left open. Uncapped through May, 1986. On 1/17/86 trace quantities of two other unidentified compounds were detected.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected, <-less than.

2) a - adopted December, 1985.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable).
m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

Table 1. (Cont'd) System Composites

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	3/20/85	8/5/85	10/25/85
Benzene	10	0 f	ND	ND	ND
Toluene	15,000 750 a	2000 p	ND	ND	ND
Ethyelbenzene	750 a	680 p	ND	ND	ND
p-xylene	Total xylenes 620 a	Total xylenes 440 p	ND	ND	ND
m-xylene			ND	ND	ND
o-xylene			ND	ND	ND
Chloroform	100 a	Total Trihalo-Methanes 100 m	4	ND	ND
Other Trihalo-methanes	-		ND	ND	ND
Detection Limit	-	-	1	2	1
Analyzed by [4]	-	-	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	-	13.6ppm	1.1ppm
Detection Limit	-	-	-	1ppm	0.4ppm

Comments: 3/20/85-Wells S2 & S3 on line; 10/25/85 (and likely 8/5)-wells S2, S3 and S6 on line. All samples prior to chlorinator entry point several feet down pipe. By comparison City of Farmington sample on 10/23 had 50 ppb chloroform and total of 76 ppb THM.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected, L-less than.

2) a - adopted December 1985 but not yet in effect.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable). m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

Table 1. (Cont'd) System Composites - 1986

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	1/17/86	4/25/86	5/21/86
Benzene	10	0 f	ND	ND	ND
Toluene	750 a	2000 p	ND	ND	ND
Ethyelbenzene	750 a	680 p	ND	ND	ND
p-xylene	Total xylenes 620 a	Total xylenes 440 p	ND	ND	ND
m-xylene			ND	ND	ND
o-xylene			ND	ND	ND
Chloroform	100 a	Total Trihalo-Methanes 100 m	ND	ND	ND
Other Trihalomethanes	-		ND	ND	ND
Detection Limit	-	-	1	1	1
Analyzed by [4]	-	-	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	ND	-	-
Detection Limit	-	-	2 ppm	-	-

Comments: All samples prior to chlorinator entry point several feet down pipe. Dichloromethane at 14 ppb detected 4/25; further investigation determined sample vials contaminated.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected.

2) a - adopted December, 1985.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable). m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 2. - Results[1] of Organic Chemical Analyses For Monitor Wells at Flora Vista Monitor Well No. 1 (Survey Point No. 11).

STANDARD	NM GROUND WATER STANDARD[2]	EPA RMCL[3]	3/20/85	6/28/85	9/21/85	10/25/85
Benzene	10	0 f	ND	ND	ND	ND
Toluene	15,000 750 a	2000 p	ND	13	4	ND
Ethyelbenzene	750 a	680 p	ND	ND	2	ND
p-xylene	Total	Total	ND	ND	2	ND
m-xylene	xylenes	xylenes	ND	ND	7	ND
o-xylene	620 a	440 p	ND	1	7	ND
Chloroform	100 a	Total Trihalo-methanes	ND	ND	ND	ND
Other Trihalo-methanes	-	100 m	ND	ND	ND	ND
Detection Limit	-	-	1	1	2	1
Analyzed by[4]	-	-	SLD	SLD	SLD	SLD
Methane[5] (dissolved)	-	-	-	-	-	1.8ppm
Detection Limit	-	-	-	-	-	0.4ppm

Comments: 3/20 sample from pit prior to well installation. Well developed using compressed air on 6/27. Well dry on 8/5/85. Well cleaned and pumped with air 9/20/85. Air compressor exhaust present in air line introduced small quantities of contaminants which may be those seen in 9/21 analysis. Air compressor used on 6/27 not available for contaminant testing.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/1). ND- not detected, L-less than.

2) a - adopted December 1985 but not yet in effect.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable).
m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 2. - (Continued)
Monitor Well No. 1 (Survey Point No. 11) - 1986.

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	1/17/86	4/21/86	4/25/86
Benzene	10	0 f	ND	ND	ND
Toluene	750 a	2000 p	ND	ND	ND
Ethyelbenzene	750 a	680 p	ND	ND	ND
p-xylene	Total xylenes 620 a	Total xylenes 440 p	ND	ND	ND
m-xylene			ND	ND	ND
o-xylene			ND	ND	ND
Detection Limit	-	-	1	1	1
Analyzed by [4]	-	-	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	ND	-	-
Detection Limit	-	-	2 ppm	-	-

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected.

2) a - adopted December, 1985.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable).
m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 2. (Continued)
Monitor Well No. 2 (Survey Point No. 12)

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	3/20/85	6/28/85	9/21/85	10/25/85
Benzene	10	0 f	ND	ND	ND	ND
Toluene	15,000 750 a	2000 p	ND	5	3	ND
Ethyelbenzene	750 a	680 p	ND	ND	ND	ND
p-xylene	Total	Total	ND	ND	L2	ND
m-xylene	xylenes	xylenes	ND	ND	2	ND
o-xylene	620 a	440 p	ND	L1	L2	ND
Chloroform	100 a	Total Trihalomethanes	ND	ND	ND	ND
Other Trihalomethanes	-	100 m	ND	ND	ND	ND
Detection Limit	-	-	1	1	2	1
Analyzed by [4]	-	-	SLD	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	-	-	-	0.7ppm
Detection Limit	-	-	-	-	-	0.4ppm

Comments: 3/20 sample from pit prior to well installation. Well developed using compressed air 6/27. Well dry 8/5/85. Well cleaned and pumped with air 9/20/85. Air compressor exhaust present in air line introduced small quantities of contaminants which may be those seen in 9/21 analysis. Air compressor used on 6/27 not available for contaminant testing.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/1). ND- not detected, L-less than.

2) a - adopted December 1985 but not yet in effect.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable). m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 2. (Continued)
Monitor Well No. 2 (Survey Point No. 12) - 1986

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	1/17/86	4/21/86	4/25/86
Benzene	10	0 f	ND	ND	ND
Toluene	750 a	2000 p	ND	ND	ND
Ethyelbenzene	750 a	680 p	ND	ND	ND
p-xylene	Total	Total	ND	ND	ND
m-xylene	xylenes	xylenes	ND	ND	ND
o-xylene	620 a	440 p	ND	ND	ND
Detection Limit	-	-	1	1	1
Analyzed by [4]	-	-	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	ND	-	-
Detection Limit	-	-	2 ppm	-	-

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected.

2) a - adopted December, 1985.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable).
m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 2. (Continued)
Monitor Well No. 3 (Survey Pt. No. 8)

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	3/20/85	6/28/85	8/5/85	9/21/85	10/25/85
Benzene	10	0 f	ND	ND	ND	ND	ND
Toluene	15,000 750 a	2000 p	ND	ND	ND	ND	ND
Ethyelbenzene	750 a	680 p	ND	ND	ND	L2	ND
p-xylene	Total xylenes 620 a	Total xylenes 440 p	ND	ND	ND	L2	ND
m-xylene			ND	ND	ND	L2	ND
o-xylene			ND	L1	ND	L2	ND
Chloroform	100 a	Total Trihalomethanes 100 m	ND	ND	ND	ND	ND
Other Trihalomethanes	-		ND	ND	ND	ND	ND
Detection Limit	-	-	1	1	2	2	1
Analyzed by [4]	-	-	SLD	SLD	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	-	-	175ppm	-	8.4ppm
Detection Limit	-	-	-	-	1ppm	-	0.4

Comments: 3/20 sample from pit prior to well installation. Well developed using compressed air on 6/27. Well cleaned and pumped with air 9/20/85. Air compressor exhaust present in air line introduced small quanitities of contamiants which may be those seen in 9/21 analysis. Air compressor used on 6/27 not available for contaminant testing.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected, L-less than.

2) a - adopted December 1985 but not yet in effect.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable). m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 2. (Continued)
Monitor Well No. 3 (Survey Pt. No. 8) - 1986

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	1/17/86	4/21/86	4/25/86
Benzene	10	0 f	ND	ND	ND
Toluene	750	2000 p	ND	ND	ND
Ethyelbenzene	750 a	680 p	ND	ND	ND
p-xylene	Total	Total	ND	ND	ND
m-xylene	xylenes	xylenes	ND	ND	ND
o-xylene	620 a	440 p	ND	ND	ND
Detection Limit	-	-	1	1	1
Analyzed by [4]	-	-	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	ND	-	
Detection Limit	-	-	2 ppm	-	-

Comments: Trace of unsaturated hydrocarbon at less than 1 ppb on 4/21/86.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected.

2) a - adopted December, 1985.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable).
m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 2. (Continued)
Monitor Well No. 4 (Survey Point No. 10)

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	3/20/85	6/28/85	9/21/85
Benzene	10	0 f	ND	ND	ND
Toluene	15,000 750 a	2000 p	ND	ND	4
Ethyelbenzene	750 a	680 p	ND	ND	ND
p-xylene	Total xylenes 620 a	Total xylenes 440 p	ND	ND	ND
m-xylene			ND	ND	ND
o-xylene			ND	ND	ND
Chloroform	100 a	Total Trihalomethanes 100 m	ND	1	ND
Other Trihalomethanes	-		ND	ND	ND
Detection Limit	-	-	1	1	2
Analyzed by [4]	-	-	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	-	-	-
Detection Limit	-	-	-	-	-

Comments: 3/20 sample from pit prior to well installation. Well developed using compressed air on 6/27. Well dry on 8/5 and 10/25/85.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected, L-less than.

2) a - adopted December 1985 but not yet in effect.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable).
m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 2. (Continued)
Monitor Well No. 4 (Survey Point No. 10) - 1986

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	1/17/86	4/21/86	4/25/86
Benzene	10	0 f	ND	ND	ND
Toluene	750 a	2000 p	ND	ND	ND
Ethyelbenzene	750 a	680 p	ND	ND	ND
p-xylene	Total	Total	ND	ND	ND
m-xylene	xylenes	xylenes	ND	ND	ND
o-xylene	620 a	440 p	ND	ND	ND
Detection Limit	-	-	1	1	1
Analyzed by [4]	-	-	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	ND	-	-
Detection Limit	-	-	2 ppm	-	-

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected.

2) a - adopted December, 1985.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable). m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 2. (Continued)
Monitor Well No. 5 (Survey Point No. 4)

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	3/20/85	6/28/85	8/5/85	9/21/85	10/25/85
Benzene	10	0 f	ND	ND	ND	ND	ND
Toluene	15,000 750 a	2000 p	ND	ND	ND	2	ND
Ethyelbenzene	750 a	680 p	ND	ND	ND	3	ND
p-xylene	Total xylenes 620 a	Total xylenes 440 p	ND	ND	ND	2	ND
m-xylene			ND	ND	ND	1	ND
o-xylene			ND	ND	ND	ND	ND
Chloroform	100 a	Total Trihalomethanes 100 m	ND	1	ND	ND	ND
Other Trihalomethanes	-		ND	ND	ND	ND	ND
Detection Limit	-	-	1	1	5	2	1
Analyzed by [4]	-	-	SLD	SLD	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	-	-	1256ppm	-	1.1ppm
Detection Limit	-	-	-	-	1ppm	-	0.4ppm

Comments: 3/20 sample from pit prior to well installation. Dark black soil layer sampled 3/20 but oil not present at detectable levels. Well developed using compressed air on 6/27. 8/5 sample has strong swampy sulfur smell. Well cleaned and pumped with air 9/20/85. Air compressor exhaust present in air line introduced small quanitities of contamiants which may be those seen in 9/21 analysis.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected, L-less than.

2) a - adopted December 1985 but not yet in effect.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable). m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 2. (Continued)
Monitor Well No. 5 (Survey Point No. 4) - 1986

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	1/17/86	4/21/86	4/25/86
Benzene	10	0 f	<1	ND	ND
Toluene	750 a	2000 p	<1	ND	ND
Ethyelbenzene	750 a	680 p	ND	ND	6
p-xylene	Total xylenes 620 a	Total xylenes 440 p	ND	ND	13
m-xylene			ND	ND	22
o-xylene			ND	ND	ND
Detection Limit	-	-	1	1	5
Analyzed by [4]	-	-	SLD	SLD	SLD
Methane [5] (dissolved)	-	-	ND	-	-
Detection Limit	-	-	2 ppm	-	-

Comments: Possible trace of substituted benzene on 4/25.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected, <less than.

2) a - adopted December, 1985.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable).
m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 3. - Results[1] of Organic Chemical Analyses for produced water from the Manana Oil Company Mary Wheeler No. 1E Gas Well

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	8/83	9/21/85	10/25/85
Benzene	10	0 f	180	16000	8700
Toluene	15,000 750 a	2000 p	L10	20000	12000
Ethyelbenzene	750 a	680 p	-	630	570
p-xylene	Total	Total	-	1200	1000
m-xylene	xylenes	xylenes	-	3800	3000
o-xylene	620 a	440 p	-	1300	1200
Chloroform	100 a	Total	-	-	-
Other	-	Trihalo-	-	-	-
Trihalo-		methanes			
methanes	-	100 m	-	-	-
Detection Limit	-	-	10	10	100
Analyzed by [4]	-	-	AnaCor	SLD	SLD
Methane [5] (dissolved)	-	-	-	-	-
Detection Limit	-	-	-	-	-

Comments: 8/83 sample from separator, Oil & Grease 37.1 ppm. 1985 samples from fiberglass tank at separator. TDS and chloride 34,755 mg/l and 19,381 mg/l on 9/12/85; 36,530 mg/l and 21,377 mg/l on 10/25/85.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected, L-less than.

2) a - adopted December 1985 but not yet in effect.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable). m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 3. - (Continued)
Manana Oil Company Mary Wheeler No. 1E Gas Well - 1986

STANDARD	NM GROUND WATER STANDARD[2]	EPA RMCL[3]	4/23/86	5/21/86
Benzene	10	0 f	550	150
Toluene	750 a	2000 p	120	500
Ethyelbenzene	750 a	680 p	45	11
p-xylene	Total	Total	120	120
m-xylene	xylenes	xylenes	540	640
o-xylene	620 a	440 p	145	180
Detection Limit	-	-	1	5
Analyzed by[4]	-	-	SLD	SLD

Comments: 1986 Samples from fiberglass tank at oil storage tank. Napthalenes present at 350 ppb (total). Benzo(a) pyrene may be present but can't be quantified.

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND- not detected.

2) a - adopted December, 1985.

3) p - proposed, f-final EPA Recommended Maximum Contaminant Level (RMCL) for community drinking water supplies (RMCL's non-enforceable). m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

TABLE 4. - Results[1] of Organic Chemical Analyses for produced water from the El Paso Natural Gas dehydrator at the Manana Oil Company Mary Wheeler No. 1E Gas Well - 1986

STANDARD	NM GROUND WATER STANDARD [2]	EPA RMCL [3]	1/17/86	2/28/86
Benzene	10	0 f	14,000	550
Toluene	750 a	2000 p	37,000	350
Ethyelbenzene	750 a	680 p	1,200	2
p-xylene	Total	Total	3,000	1800
m-xylene	xylenes	xylenes	11,000	NR
o-xylene	620 a	440 p	4,100	499
Detection Limit	-	-	200	2
Analyzed by [4]	-	-	SLD	SLD
Methane [5] (dissolved)	-	-	0.5%	207 ppm
Detection Limit	-	-	2 ppm	0.3 ppm

Comments: Samples from 55-gallon drum at dehydrator. Conductivity 81 umho/cm at 17°c on 2/28/86. No heavy metals except iron, tin and manganese (likely from drum).

Footnotes:

1) Results in parts per billion or micrograms per liter unless otherwise noted (1,000 ppb = 1 ppm or mg/l). ND - Not Detected; NR - Not Reported.

2) a - adopted December, 1985.

3) p - proposed, f-final EPA Recommended Maximum Contaminant level (RMCL) for community drinking water supplies (RMCL's non-enforceable). m - maximum contaminant level (enforceable).

4) SLD - New Mexico Scientific Laboratory Division.

5) Methane may be from natural gas or marsh gas dissolved in sample. Normal range level in atmosphere from about 0.8 to 1.5 ppm.

TABLE 5 - Summary of Aquifer Test Results for Several Analytical Methods

Well	Aquifer Parameter	Theis - (Modified)	Jacob	Adjusted Time Drawdown	Dimensionless Time Recovery
S1	T(gpd/ft):	8,014	7,196	9429 (Step 1) 5500 (Step 2) 9962 (Step 3)	15,529
	S:	NA	NA	NA	NA
xS1	T(gpd/ft):	14,614	16,704	13,200	12,279
	S:	0.027	0.019	0.041	NA
M1	T(gpd/ft):	15,617	NA	NC	ND
	S:	0.100			
M3	T(gpd/ft):	14,855	12,752	NC	ND
	S:	0.078	0.070		
M4	T(gpd/ft):	15,227	NA	NC	ND
	S:	0.092			
M5	T(gpd/ft):	14,677	NA	NC	ND
	S:	0.097			

Notes: 1) T - Transmissivity, S - Storage Coefficient (dimensionless), NA - Not Applicable, NC - Not Calculated, ND - No Data.

2) Storage coefficient cannot be calculated for pumped well. Low T values for S1 during pumping are due to well entrance losses. Well M2 drawdown too small to analyze.

TABLE 6. Animas River Flow at Farmington, 1983 Water Year
(Source: U.S. Geological Survey)

09364500 ANIMAS RIVER AT FARMINGTON, NM
(National stream-quality accounting network station)

LOCATION.--Lat 36°43'17", long 108°12'05", in SW¼SW¼ sec.15, T.29 N., R.13 W., San Juan County, Hydrologic Unit 14080104, in Boyd City Park, on right bank 900 ft upstream from bridge on Miller Ave., 0.4 mi downstream from bridge on U.S. Highway 64 in Farmington, and 1.5 mi upstream from mouth.

DRAINAGE AREA.--1,360 mi^2, approximately.

WATER-DISCHARGE RECORDS

PERIOD OF RECORD.--June 1904 to October 1905 (published as "near Farmington"), September 1912 to current year. Monthly discharge only for some periods, published in WSP 1313.

REVISED RECORDS.--WSP 1243: 1931. WSP 1313: 1913.

GAGE.--Water-stage recorder. Altitude of gage is 5,280 ft, from topographic map. Prior to Nov. 1, 1905, non-recording gage at old bridge 0.1 mi upstream at different datum. Sept. 17, 1912, to Oct. 4, 1938, water-stage recorder at site 0.8 mi downstream at lower datums (datum lowered 2.0 ft Aug. 15, 1927, and raised 0.2 ft Dec. 16, 1929). Oct. 5, 1938 to Nov. 1, 1973 at site 900 ft downstream at datum 1.74 ft lower.

REMARKS.--Water-discharge records good except those for winter period, which are fair. Diversions for irrigation of about 30,000 acres above station.

AVERAGE DISCHARGE.--72 years, 916 ft^3/s, 663,600 acre-ft/yr.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, about 25,000 ft^3/s June 29, 1927, gage height, 8.5 ft, site and datum then in use, from rating curve extended above 10,000 ft^3/s; minimum, 1.0 ft^3/s Aug. 11, 1972.

EXTREMES OUTSIDE PERIOD OF RECORD.--Maximum flood occurred Oct. 6, 1911, when a stage of about 16.5 ft was reached (datum in use Oct. 1938 to Nov. 1973). Flood of Sept. 6, 1909, reached a stage of 11.1 ft, 1904-5 site and datum (discharge, about 19,000 ft^3/s).

EXTREMES FOR CURRENT YEAR.--Peak discharges above base of 4,000 ft^3/s and maximum (*):

Date	Time	Discharge (ft^3/s)	Gage height (ft)	Date	Time	Discharge (ft^3/s)	Gage Height (ft)
May 31	2330	*6320	8.59	Aug. 6	0100	5320	8.31
June 25	0330	5920	8.61				

Minimum daily discharge, 268 ft^3/s Sept. 20.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1982 TO SEPTEMBER 1983
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	858	411	432	345	353	564	692	1780	5810	3610	1260	421
2	890	409	415	341	336	510	652	1540	5250	3470	1270	406
3	790	411	395	346	332	508	636	1400	4370	3430	1390	442
4	746	389	385	385	353	593	652	1330	3630	3560	1320	400
5	710	396	405	391	365	633	660	1300	3640	3480	1230	379
6	656	390	380	390	330	498	572	1480	3650	3310	1810	349
7	592	390	388	355	298	468	588	1760	3570	3150	1330	343
8	554	380	384	369	296	465	561	1870	3740	3180	1430	345
9	535	395	411	376	308	481	527	1730	3810	2930	1280	387
10	511	462	553	358	311	503	559	2030	3510	2840	1150	385
11	499	450	544	365	302	548	555	2610	3340	2670	1090	353
12	491	444	481	376	317	611	573	2980	3920	2290	1080	335
13	448	395	432	365	328	647	630	2770	3930	2070	972	308
14	430	390	404	367	335	678	672	2340	3120	1860	859	297
15	429	390	396	370	336	830	645	2160	2730	1740	801	303
16	436	370	374	373	319	703	591	1900	2920	1590	757	293
17	455	370	382	376	341	606	602	1720	3190	1500	648	304
18	471	405	400	380	336	604	646	1620	3730	1470	547	278
19	464	405	391	366	341	597	783	1490	4610	1480	536	270
20	442	434	366	352	341	553	923	1450	5410	1570	607	268
21	430	428	363	350	345	490	1030	1470	5310	1530	504	275
22	398	405	373	351	345	500	1020	1360	5330	1520	471	295
23	387	387	423	335	390	580	1060	1430	5160	1610	435	312
24	389	390	416	328	444	540	1220	1950	5140	1690	414	326
25	387	374	367	332	468	540	1600	2660	5540	1660	415	302
26	384	377	339	330	504	548	1970	3900	4930	1810	466	304
27	425	371	348	318	480	556	1950	4210	4520	2110	473	298
28	437	371	325	321	492	528	1810	4940	4270	1690	579	309
29	407	385	306	341	---	522	1720	5510	3760	1430	480	322
30	403	385	288	334	---	556	1770	5460	3680	1360	466	392
31	404	---	336	321	---	660	---	5800	---	1340	433	---
TOTAL	15858	11959	12202	11007	10046	17620	27869	75950	125520	68950	26503	10001
MEAN	512	399	394	355	359	568	929	2450	4184	2224	855	333
MAX	890	462	553	391	504	830	1970	5800	5810	3610	1810	442
MIN	384	370	288	318	296	465	527	1300	2730	1340	414	268
AC-FT	31450	23720	24200	21830	19930	34950	55280	150600	249000	136800	52570	19840

CAL YR 1982 TOTAL 364553 MEAN 999 MAX 3660 MIN 209 AC-FT 723100
WTR YR 1983 TOTAL 413485 MEAN 1133 MAX 5810 MIN 268 AC-FT 820100

TABLE 7. Summary of Formulas used in Predictive Calculations

1) Seepage velocity using Darcy's Law:

$$v = \frac{K}{n} i$$

Where: K = Permeability (K = 750 gallons/day/ft^2 from Ranney report to Brewer & Assoc.)

n = Porosity (N = 0.25 assumed value for sand/gravel)

i = measured gradient (i = change in water level elevation per unit distance)

Reference: Todd, Eq. 3.21.

2) Drawdown using Theis non-equilibrium formula:

$$s = \frac{Q}{4\pi T} W(u) \text{ where } u = \frac{r^2 S}{4Tt}$$

Where: Q = pumping rate (Q = 35 gallons per minute, or Q = 65 gpm)

T = Transmissivity (T = Kb where K is permeability, b = saturated aquifer thickness = 17 feet from Ranney report; T = 12750 gpd/ft)

r = distance (from well to produced water tank, r = 230 feet)

S = storage coefficient (S = 0.2 for water table conditions)

t = time of pumping (t = 100 days for example used here)

Reference: Todd, Eq. 4.38, 4.36.

3) Zone of capture in a uniform flow field under steady state conditions:

a) Boundary equation: $-\frac{y}{x} = \tan\left(\frac{2\pi K b i}{Q} y\right)$

b) y - Limit: $y_L = \pm \frac{Q}{2Kbi}$

c) x - Limit: $x_L = -\frac{Q}{2\pi K b i}$

TABLE 7. (Continued)

Reference: Todd, Eq. 4.31 to 4.33.

4) Time of transport to pumping well:

a) $$t = \sum_{j} \left[\frac{n \Delta r_j^2}{K \Delta s_j} \right]$$

Where: Δs = change in drawdown over distance, Δr, moving towards pumping well.

b) $$\Delta s_j = \Delta s_Q \log \frac{r_{j+1}}{r_j}$$

Where: Δs_Q = change in drawdown over one log cycle of distance for given Q.
$\Delta s_{35} = 1.45, \Delta s_{65} = 2.70$

Reference: Todd, Eq. 3.23; Johnson Eq. 8, p. 123.

REPORT FIGURES

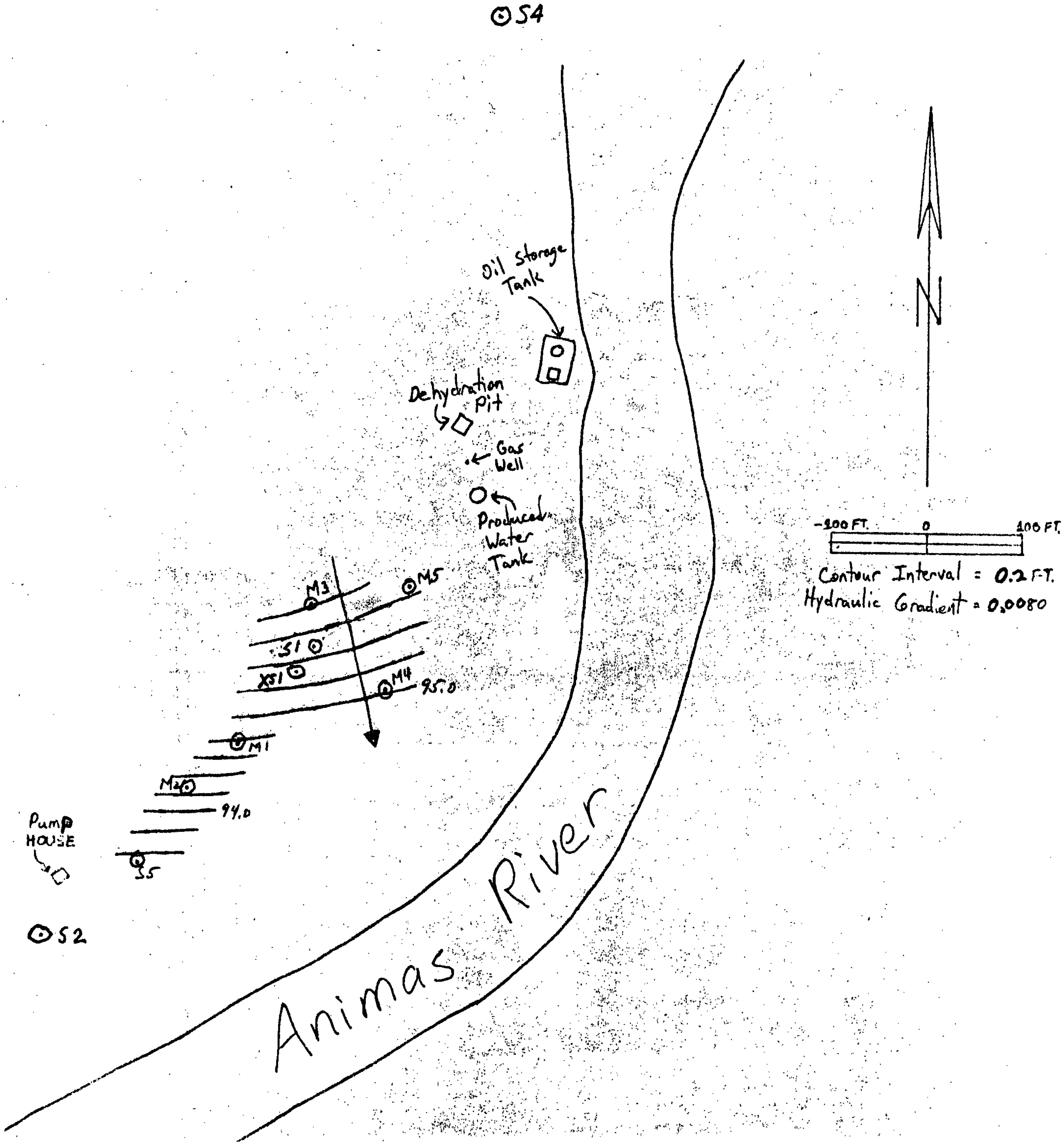


Figure 1. Ground Water Flow Direction, Vicinity of Flora Vista Well S1, 9/20/85.

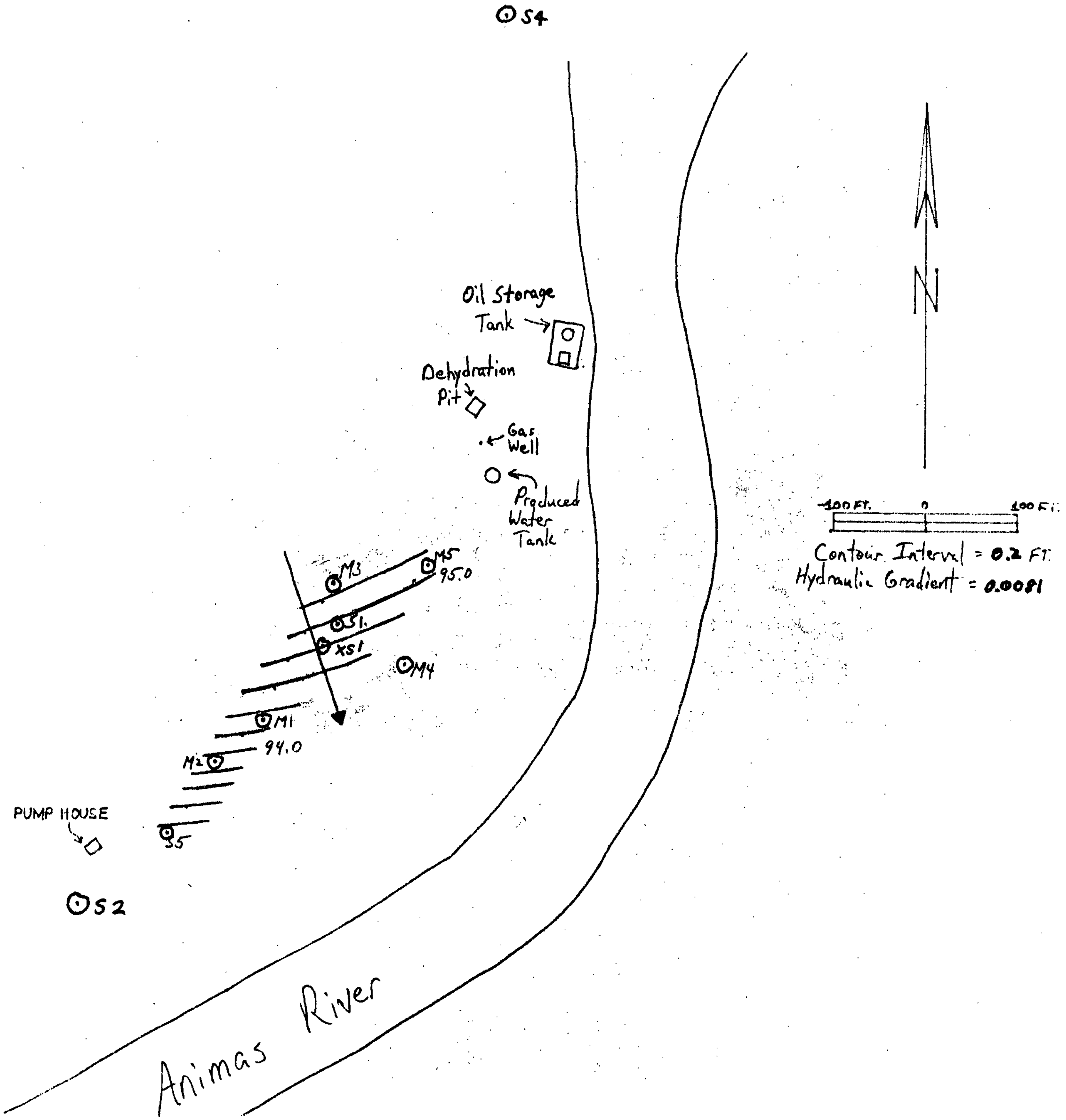


Figure 2. Ground Water Flow Direction, Vicinity of Flora Vista Well S1, 10/25/85.

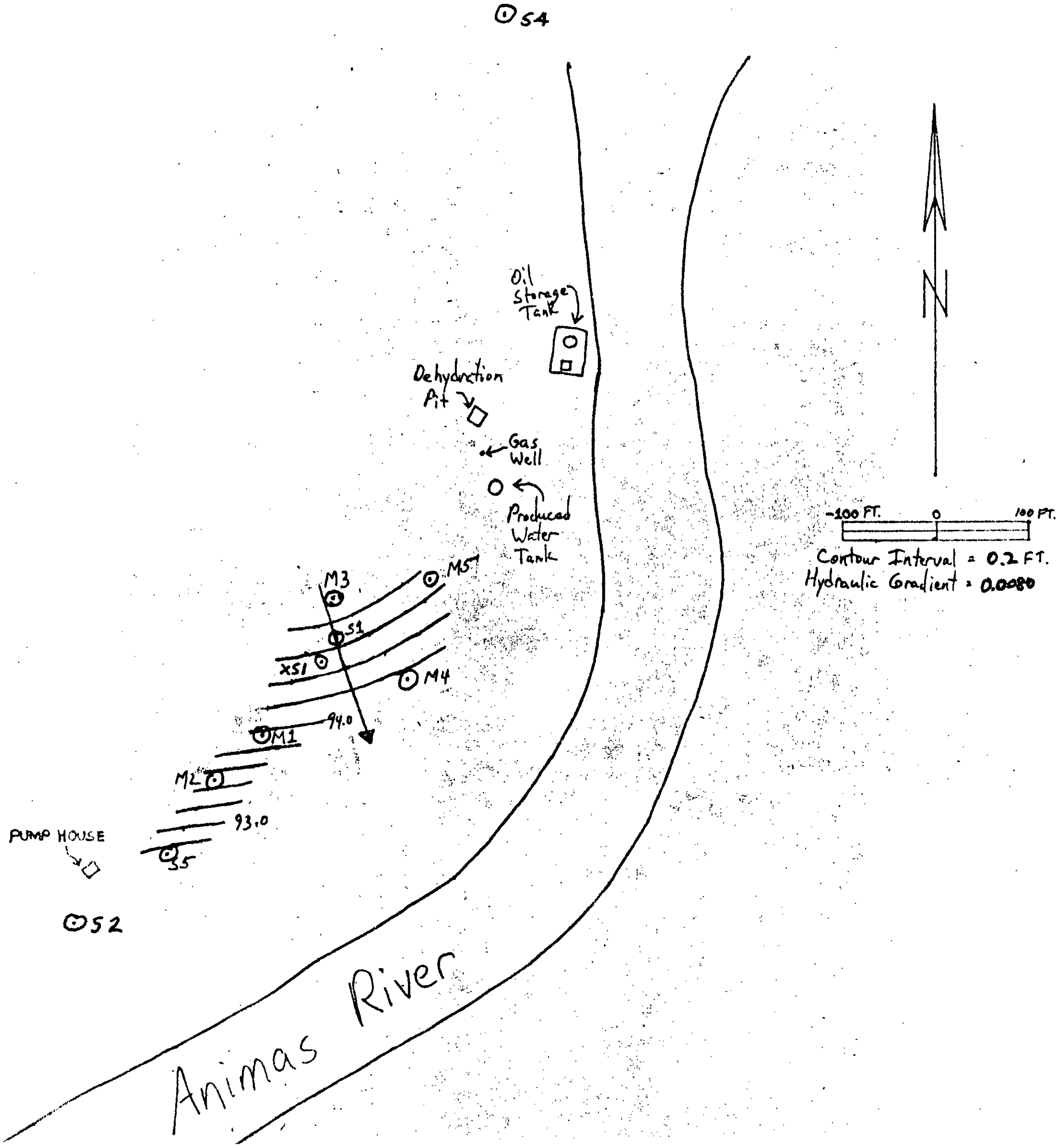


Figure 3. Ground Water Flow Direction, Vicinity of Flora Vista Well S1, 1/17/86.

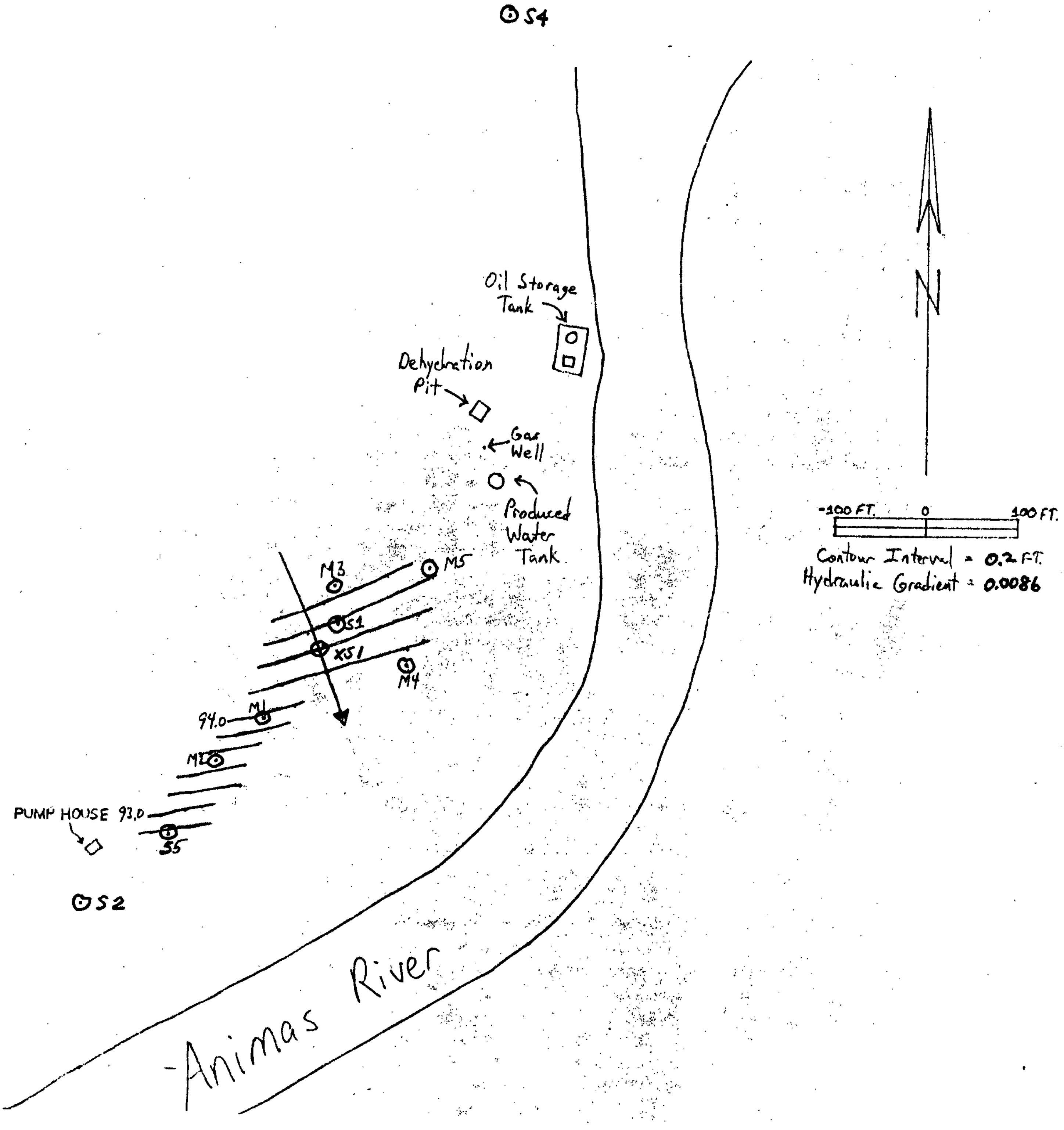


Figure 4. Ground Water Flow Direction, Vicinity of Flora Vista Well S1, 2/13/86.

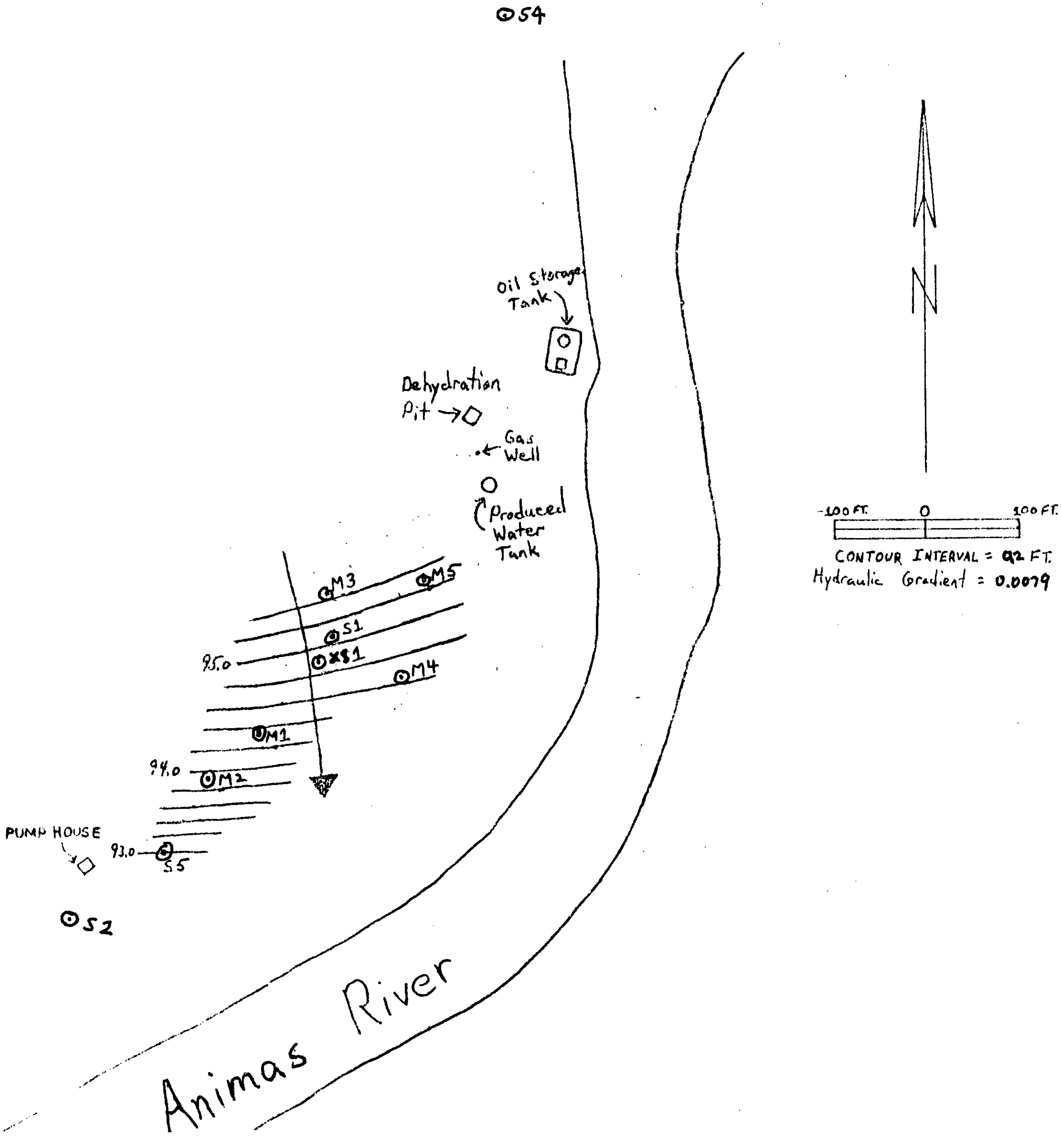


Figure 5. Ground Water Flow Direction, Vicinity of Flora Vista Well S1, 4/21/86.

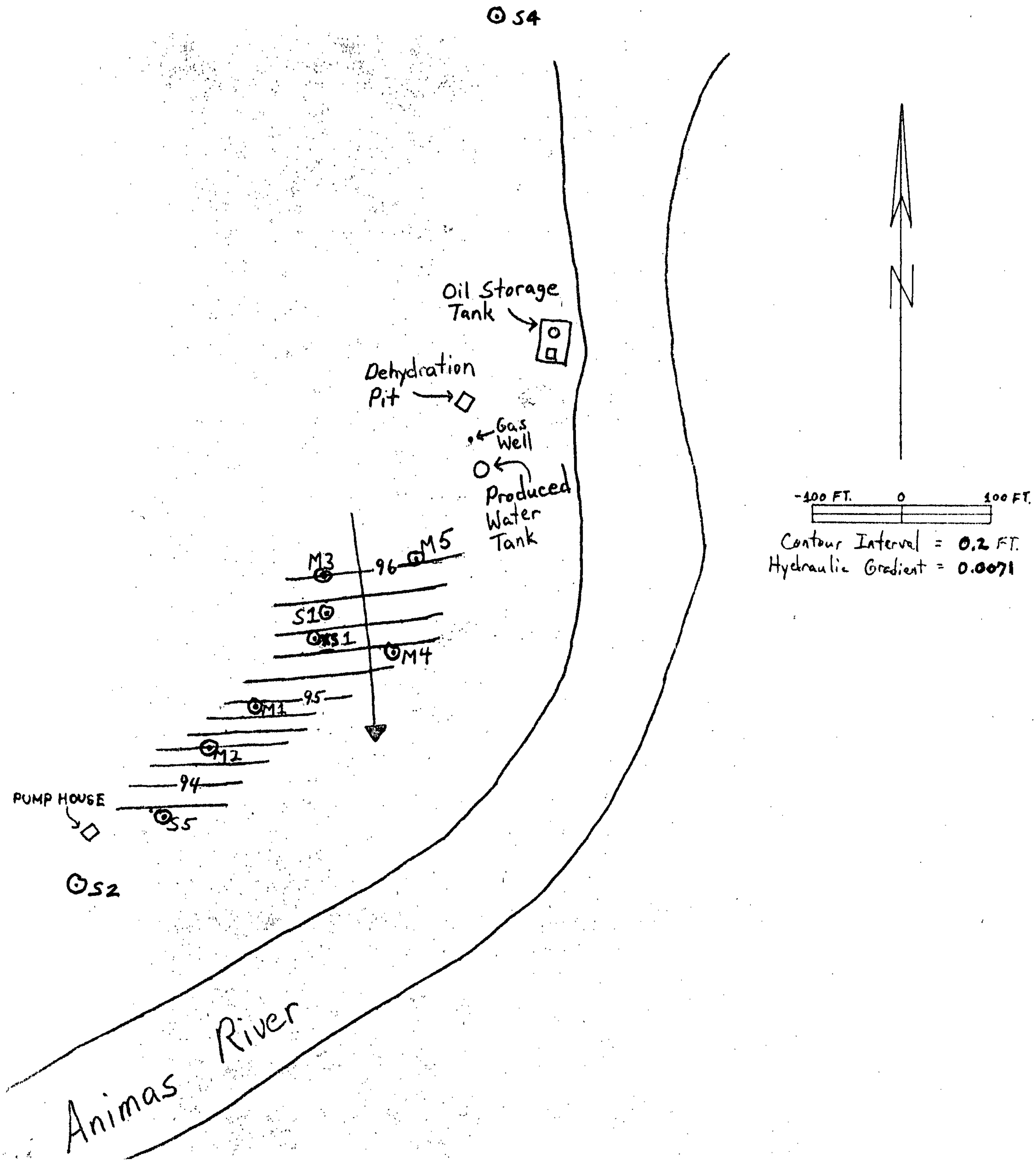


Figure 6. Ground Water Flow Direction, Vicinity of Flora Vista Well S1, 5/21/86.

AQUIFER TEST WELL ____________________

Owner ____________________ Well No. ____________________

______1/4______1/4______1/4 Section________, T.______N S, R.______E W, ______________B&M

SWL ________________ feet Date ____________________

Measuring point ____________________ which is __________ feet above ground surface

Discharge Diameter ____________________ inches Orifice ____________________ inches

Other Measuring Device ____________________

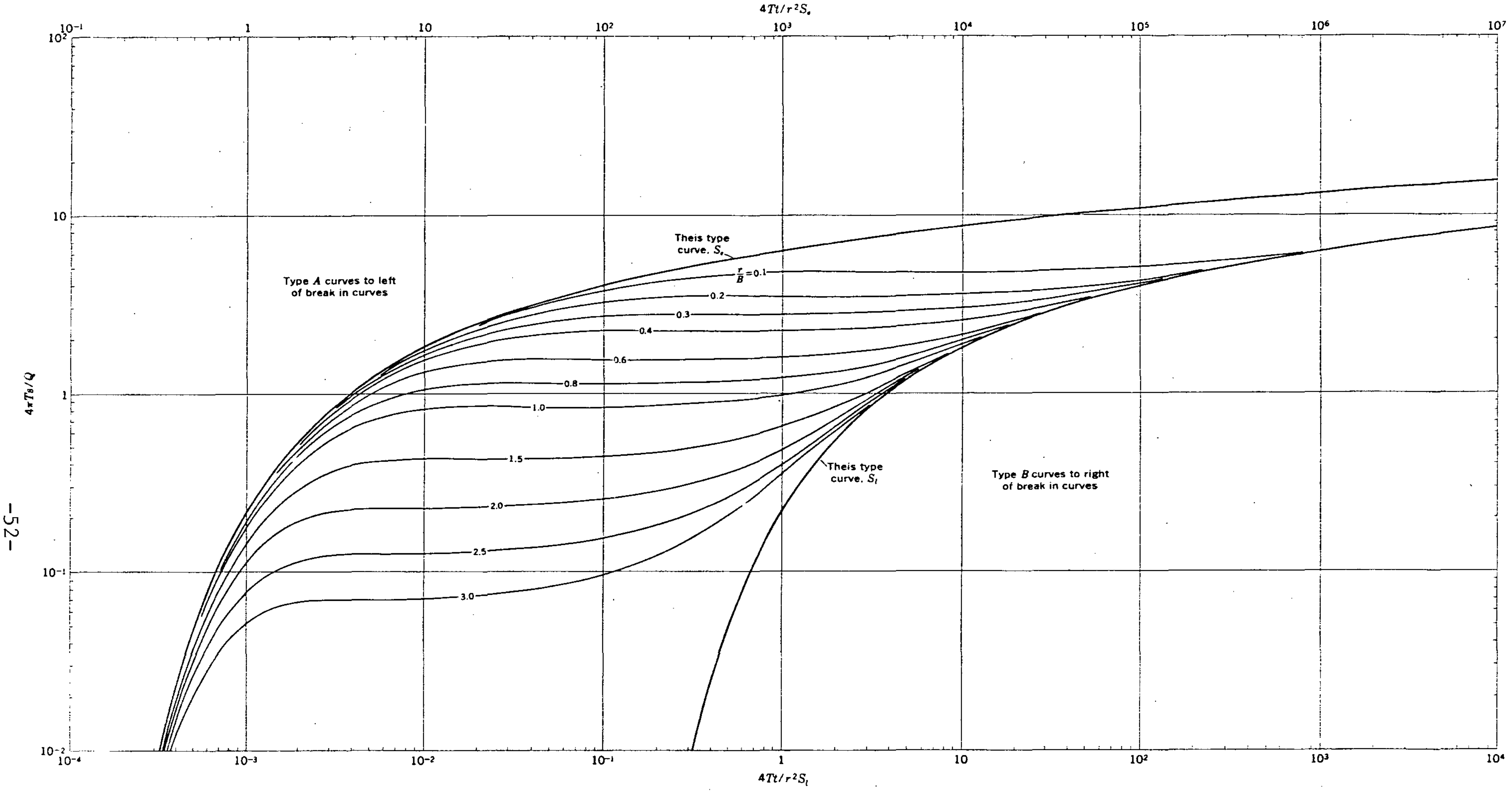
Perforated Interval ________________ Data collected by: ____________________

Date & Time	Time since start pump Minutes	Depth to water Feet	Observed Drawdown s_o Feet	Corrected Drawdown s_c Feet	$\frac{s}{Q_n}$ Ft/gpm	Adjusted time since start t_a (Min)	Time since pump stopped t' (Min)	t/t'	t_a/t'	Remarks

Figure 7. Form to Tabulate Aquifer Test Results

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROFESSIONAL PAPER 708
PLATE 8



DELAYED-YIELD TYPE CURVES

After Boulton(1963, fig. 1)

Figure 8. Type Curves for Determination of Aquifer Parameters

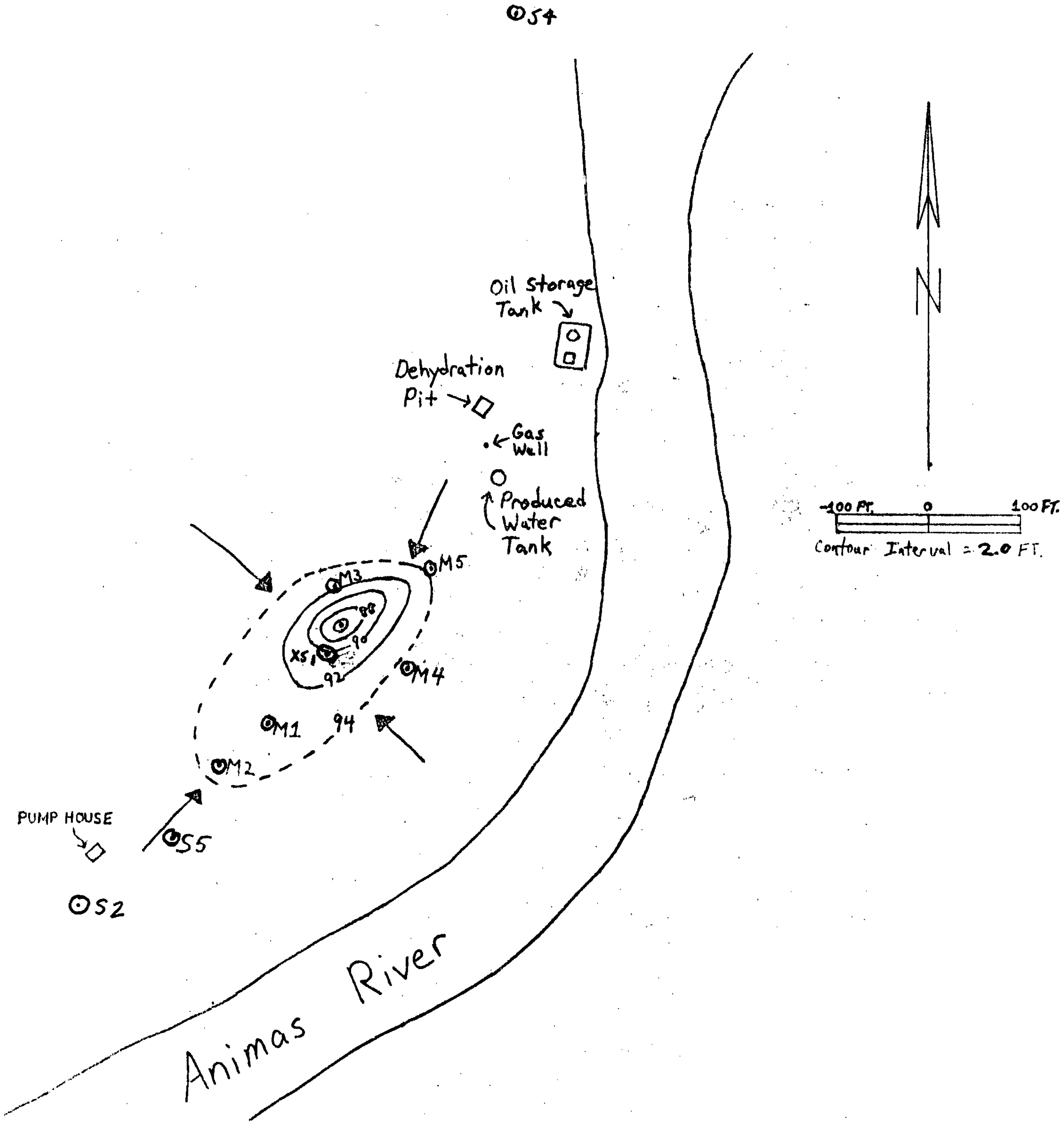


Figure 9. Pumping Cone of Depression at 32 Hours, Flora Vista Well S1, 9 P.M.,4/23/86.

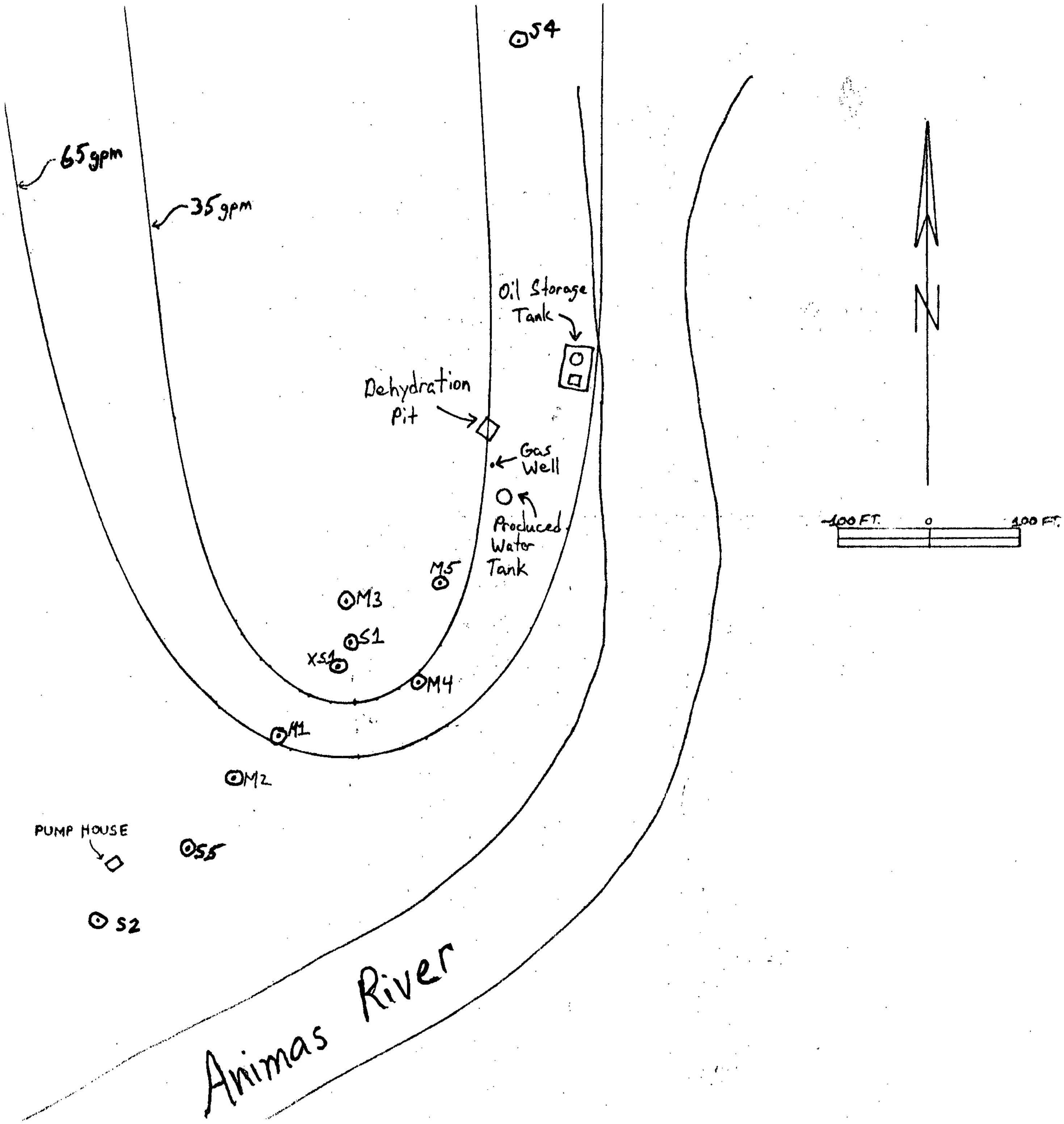


Figure 10. Pumping Zone of Capture, Flora Vista Well S1.

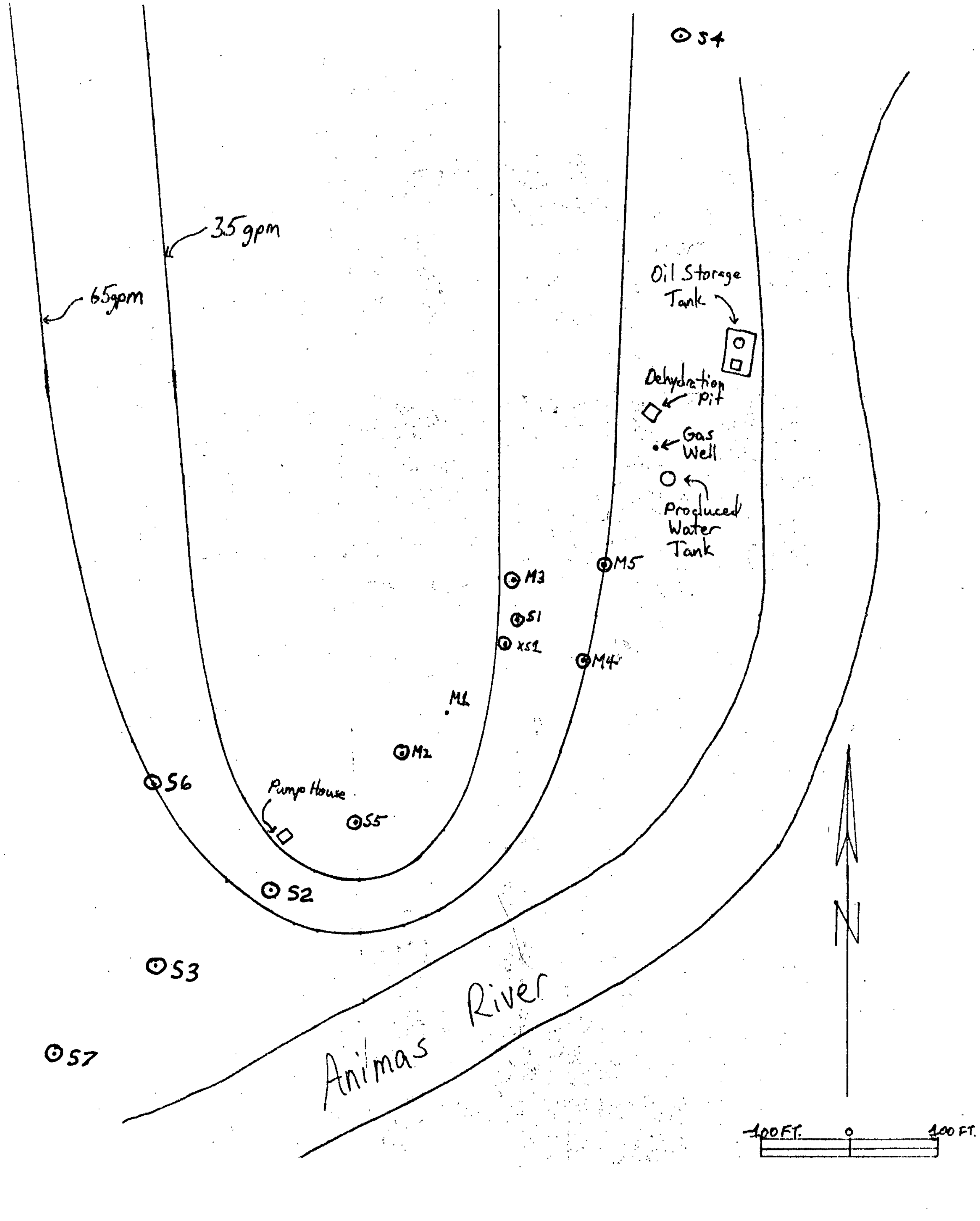


Figure 11. Pumping Zone of Capture, Flora Vista Well S5.

APPENDIX G
Analytical Data - Soil

imL

Inter-Mountain Laboratories, Inc.

Route 3, Box 256
College Station, TX 77840
Tel. (409) 776-8945
Fax. (409) 774-4705

Soil

Login # - 8907003
P.O. # - 25603

K.W. BROWN & ASSOCIATES, INC.
Project: EPNG FLORA VISTA - 63712

Page 1 of 1
July 18, 1989

Lab #	Location	pH	EC, mmhos/cm	Calcium ppm	Magnesium ppm	Potassium ppm	Sodium ppm	HCO3 ppm	CO3 ppm	Chloride ppm	Sulfate ppm	Oil & Grease ppm	3050 Barium ppm	3050 Cadmium ppm	3050 Chromium ppm	3050 Selenium ppm
C89021	T-1 EAST	7.9	0.79	116	9	10	39	48	0	20	285	268	285	0.7	7	0.16
C89022	T-1 CENTER	8.0	0.95	124	13	16	48	59	0	20	331	356	479	0.8	6	0.09
C89023	T-1 WEST	8.0	0.95	128	11	10	43	37	0	21	270	1608	314	0.6	3	0.23
C89024	T-2 EAST	8.2	0.58	64	4	10	39	54	0	17	197	96	607	0.6	16	0.23
C89025	T-2 CENTER	8.0	0.95	95	9	11	79	59	0	13	285	492	560	1.0	6	0.29
C89026	T-2 WEST	8.0	0.90	66	6	9	103	47	0	9	283	92	498	1.5	9	0.29
C89027	T-3 EAST	8.1	0.79	88	7	11	55	55	0	13	279	204	225	0.8	10	0.12
C89028	T-3 CENTER	8.2	0.65	93	12	27	28	45	0	5	230	784	212	0.5	4	0.13
C89029	T-3 WEST	8.2	0.56	75	5	7	21	38	0	7	187	192	508	1.1	8	0.27
C89030	T-4 EAST	8.1	0.58	81	4	8	24	58	0	2	186	268	490	1.3	5	0.20
C89031	T-4 CENTER	8.3	0.30	33	1	7	12	55	0	6	47	236	592	1.5	3	0.09
C89032	T-4 WEST	8.4	0.28	36	1	7	13	46	0	6	72	256	371	0.6	2	0.20
C89033	T-5	8.0	1.03	148	12	17	44	59	0	7	404	2253	322	1.7	8	0.17
C89034	PIT NORTH	8.4	1.30	83	11	14	161	121	0	35	305	3000	221	1.8	8	0.22
C89035	PIT SOUTH	8.1	1.86	188	30	7	168	81	0	83	424	4484	395	3.8	9	0.62
C89036	PIT EAST	8.3	3.32	127	44	9	592	154	0	98	1027	3316	368	2.9	8	0.22
C89037	PIT WEST	8.4	1.93	52	9	8	361	102	0	38	498	2224	238	2.0	8	0.12
C89038	T-6 EAST	7.9	1.76	294	21	11	67	53	0	38	687	1624	361	3.8	15	0.49
C89039	T-6 WEST	7.9	0.72	115	6	8	28	40	0	15	298	176	669	1.7	3	0.29
C89040	T-7	7.8	1.23	204	14	11	44	75	0	9	360	984	270	1.4	7	0.19
C89041	RP1-A	8.5	2.84	34	9	40	549	82	0	251	909	1124	28	2.6	56	0.90
C89042	RP1-B	9.0	2.98	162	1	26	487	34	0	174	1271	692	227	1.1	78	0.19
C89043	RP2	8.1	1.01	121	14	11	60	66	0	23	410	2028	107	2.1	161	0.62
C89044	BG-1	8.0	1.36	199	17	9	83	68	0	11	618	68	315	1.7	10	0.16
C89045	T-6 EAST(DUP)	7.9	1.83	304	22	11	68	59	0	39	756	1728	336	3.6	11	0.41
C89046	T-6 WEST(DUP)	7.9	0.67	101	5	7	25	37	0	11	279	100	601	1.4	3	0.29
C89047	T-7(DUP)	7.8	1.19	199	14	11	42	74	0	11	557	684	268	1.6	6	0.13

PNAs
(Soil)

APPENDIX D
Martin Investigation Report

W. B. MARTIN & ASSOCIATES, INC.
709 North Butler, Farmington, New Mexico 87401
Phone: (505) 326-4507

MAY - 7 1987

April 27, 1987

Flora Vista Water Users Association
P. O. Box 171
Flora Vista, New Mexico 87415

Attention: Bert Barns

The following are summarized lab results and recommendations from drilling 25± pilot holes around Mary Wheeler #1E's gas well.

1) S#1, #2, #3 were samples taken at different depths 15' SW of Supply Well #4. These samples showed no solubility and feel that the hydrocarbon level is undetectable. S#3 sample was used as a base for this particular area. Samples # B-3, C-1, K, and M showed moderate to vigorous gas evolution for 20-30 seconds. All of these samples are in the reserve pit area and the gas released was not broken down except in sample M. Sample M gave off H_2S (Hydrogen Sulfide gas) rotten egg scent. The reasoning for the H_2S evolution for this sample over the other samples is due to the high concentration of hydrocarbons. No solubility tests have been performed on the second set of samples, but feel that the only possible samples that might have H_2S evolution is sample O, see Fig. 7 in relation to sample M.

2) During the sulfate analysis of the first set of samples A-M, the sulfate count was extremely high as compared to samples N-V of the second set. The explanation for this, even though samples M and N are only 7 linear feet apart, the samples were taken 3 weeks apart. March, 1987, was an extremely cold month and the water table was lower than during the middle of April, 1987. Due to the permeability of the river rock and its high porosity of 25%, the system was probably flushed with the increase of runoff. Due to the high concentrations of sulfates recorded that a source for bacteria to thrive on in and around this area was present during the lessor flow periods fall-winter and then during the vast amount of runoff in the first part of April it had flushed the system. According to Boyar's report, that ground movement in this area is up to 100'/day, so to flush this area from the gas well to the supply well would take less than 3 days. These results can show the process of contamination from the reserve pit area to supply well #1 into the water system. A corrective method in treating high sulfates is by using chlorine in the water system. Since the sulfate content has been reduced from 14,000 ppm down to less than 1000 ppm in three weeks during the first part of run-off these flushings might have brought an excessive amount of sulfates into the system which it was unable to handle.

ND

?

3) Hydrocarbon test results were very noticeable in sample M from 5-7' depth ranging from 200-1000 ppm and also in sample O @ 7' ranging from 100-800 ppm. The high level of hydrocarbon detected from Richard Cheney's report did not exceed 23 ppm. Normal detection level is .01. Sample detection for representative sample No. A-M was less than 5 ppm and most of those second set of samples were less than .1 ppm. The level of hydrocarbons detected in samples M &O 100-1000± ppm of C_6-C_{22} shies very strongly away from the possibility of being dead animal decomposition. Most recent animal decomposition usually produces CO_2 and Methane, something similar at a fertilizing plant. From the gas, peaks on the chromatograph chart and comparing to other oilfield hydrocarbon source areas showed similar results, especially in the heavy carbon chain levels $C_7 - C_{10}$. During high runoff times and the permeability level of the ground water beds that a good implementation of a charcoal filter will aid in absorbing the hydrocarbons out.

4) Bentonite tests were high for sample K which from visual sample description can be assumed to be drilling mud residual.

In summary, there is a drastic change in sulfate content between samples A-M and samples N-V resulting from the increased water runoff. Sulfates can be treated out of the water with chlorine, but if hydrocarbons are present then the possibility of chlorinated hydrocarbons can be formed. Chlorinated hydrocarbons if ingested are usually detoxified in the liver and can be classified as a carcinagen. A solution to both of these problems would be by implementing both a charcoal filter and utilizing ozone to purify the system. There are probably some State guidelines on this type of system. The samples that were taken are still in cold storage and additional tests can be taken.

Sincerely,

Drew Bates
Engineering and Operations Manager

Date: 3-27-87

Mary Wheeler 1-E

Time	Location
7:00 AM	S_4 @ SW of S_4 #1 @ 2' #2 @ 4' #3 @ 6' #4 @ 8'
8:00 AM 11	A Location Southeast corner toward river edge reserve pit #1 @ 2' #2 @ 5' #3 @ 7' water table
8:30 AM 111	B Location 20' East of oil line in reserve pit #1 @ 3' #2 @ 4' CMT #3 @ 5' #4 @ 7' frac sand
9:10 AM 1111	C Location SE 24' NE of oil line #1 @ 3' #2 @ 4'
10:00 AM	Location @ 85' East of wellhead edge of Reserve pit
10:45 AM	D Location @ SW limit @ 2.5'
11:00 AM 1111	Location @ 11.5' East of B" East edge E @ #1 @ 3' E #2 @ 5'-7' 5' mud 7' water table
11:10 AM	F Location @ 12.5' SE of separator pit 2' soil very unconsolidated river rock very permeable #1 @ 3' #2 @ 5'-7' frac sand @ 6' water table @ 7'
12:00 PM	G Location 8' South of separator pit south post corner #1 sample @ 2' Unable to go below 3' check for hydrocarbon
12:30 PM	H Location 4' due South of Separator pit #1 @ 4' #2 @ 5' too rocky too many bits Shaley and very wet - little intermediate sand

Date: 3-27-87

Mary Wheeler 1-E

Time	Location
12:44 PM	I Location 12' SW corner separator pit I #1 @ 3' I #2 @ 4' very unconsolidated and permeable unable to go below 4-1/2'
1:15 PM	J Location @ 38' SE of separator pit J #1 @ 4' J #2 @ 9' frac sand water table @ 7.5'
1:45 PM	K 45' SE of pit on surface Mud with hydrocarbons bogged down
2:00 PM	L 55' SE of separator pit #1 @ 3-5' #2 @ 7' water table
2:30 PM	M 75' South of separator pit @ 5-7' Threw drive line

4-16-87 @ 7:30 AM

SAMPLING #	
N	@ 7' SE of M able to get down 5' sample taken @ 2' and 5' West edge of reservoir pit last of visible signs.
O	@ 20' East of M @ 2' @ 6' @ 7' still in reserve pit Black scent of drilling mud and possible hydrocarbons definitely not soil. 22' East of monitor well 7' definite hydrocarbons sample descriptions. Water table @ 7.5' Found combination lock @ 6'
P	@ 12' NE of monitor well @ 6.5' scent of hydrocarbons Black samples
Q	@ 17.5' East of P 24' NE of monitor well representative sample @ 6-7' no hydrocarbon clear sand check hydrocarbons no contamination.
R	@ 7' South of monitor well dark contaminated sample water table up to 3' in depth
S	@ 3', 5' water table 3'6" 8' West of drainage creek check sulfate and hydrocarbons.
T	@ 20' NE of S, @ 7' 3' water table Sulfates - Hydrocarbons
U	@ 20' East of S, total 10' depth samples out
V	@ 25' SW of S, total 6' deep very permeable sulfates and hydrocarbons.

Tech. Inc.
333 E. Main St.
armington, NM 87401
(505)327-3311

7 April 1987

Laboratory Analysis Report

alysis requested by: Mr. D. Bates

Mr Drew Bates

Farmington NM 87401

Solubility test in 15% HCl

Sample #	Analysis	Result
A#2	Solubility	Moderate gas evolution for 20 sec.
A#3	Solubility	Moderate gas evolution for 20 sec.
B#3	Solubility	Vigorous gas evolution for 30 sec.
C#	Solubility	Vigorous gas evolution 30 sec.
K	Solubility	Vigorous gas evolution 30 sec.
M	Solubility	Vigorous gas evolution for 30 sec.
M		Hydrogen sulfide gas evolved.
S#1	Solubility	Very slight gas evolution.
S#2	Solubility	Very slight gas evolution.
S#3	Solubility	Very slight gas evolution.

Analysis date: 5 April 1987

Sample Received: 28 March 1987

Analyst: H. P. Hamlow

Inc.
. Main St.
ington, NM 87401
5)327-3311

7 April 1987

Laboratory Analysis Report

sis requested by: Mr. D. Bates

Mr. Drew Bates

Farmington NM 87401

Analysis on Core Samples

Sample #	Analysis	Result
B#3	Sulfate	24450 ppm
B#4	Sulfate	3620 ppm
C#1	Sulfate	52800 ppm
F#1	Sulfate	1810 ppm
F#2	Sulfate	450 ppm
G#1	Hydrocarbons	none or < 5 ppm
J	Hydrocarbons	none or < 5 ppm
J#2	Hydrocarbons	none or < 5 ppm
	Sulfate	3160
K	Hydrocarbons	none or < 5 ppm
	Sulfate	24700 ppm
L#2	Hydrocarbons	none or < 5 ppm
	Sulfate	7280 ppm
K	Hydrocarbons	none or < 5 ppm
	Sulfate	24700 ppm
L#2	Hydrocarbons	none or < 5 ppm
	Sulfate	7280 ppm
M	Hydrocarbons	200-1000 ppm

Tech. Inc.
333 E. Main St.
Farmington, NM 87401
(505)327-3311

21 April 1987

Laboratory Analysis Report

FloraVista Water Users
109 N. Orchard
Farmington NM 87401

Analysis of dirt core samples.

Analysis requested by Mr. Drew Bates.

Sample #	Analysis	Result
N	Hydrocarbons	none or less than .1 ppm.
O @ 6'	Hydrocarbons	none or less than 0.1 ppm
O @ 7'	Hydrocarbons	100-800 ppm.
P @ 6.5'	Hydrocarbons	none or less than 0.1 ppm
Q	Hydrocarbons	none or less than 0.1 ppm
R	Hydrocarbons	none or less than 0.1 ppm
U	Hydrocarbons	none or less than 0.1 ppm
V	Hydrocarbons	none or less than 0.1 ppm

Clean sand

Analysis date: 20 April 1987

Sample Received:16 April 1987

Analyst:H. P. Hamlow

ab # 2509-949

NTBK# 1-81-AT

Tech. Inc.
333 E. Main St.
Farmington, NM 87401
(505)327-3311

21 April 1987

Laboratory Analysis Report

Flora Vista Water Users
108 N. Orchard
Farmington NM 87401

Analysis of dirt core samples.

Analysis requested by Drew Bates.

Sample #	Analysis	Result
N	Sulfate	760 ppm
O @ 6'	Sulfate	108 ppm
O @ 7'	Sulfate	162 ppm
P @ 6.5'	Sulfate	128 ppm
Q	Sulfate	172 ppm
R	Sulfate	84 ppm
U	Sulfate	172 ppm
V	Sulfate	240 ppm

Analysis date: 21 April 1987

Sample Received:16 April 1987

Analyst:H. P. Hamlow

ab # 2509-949

NTBK# 2-81

F-331

CDS LABORATORIES

A DIVISION OF CASA DEL SOL, INC.
1474 MAIN AVENUE #131
POST OFFICE BOX 2805
DURANGO, COLORADO 81301

(303) 247-4220

JESUS

Date: 8-1-83

To: Flora Vista Water User
Attn. Richard Cheyney
909 W. Apache
Farmington, N.M. 87401

CDS Lab ID #

Sample Description:

LAB. AUG 23 '83

Sample ID	Analyte	* Analytical results
2456 Gallon Jug	C_6-C_{22}	0.70 mg Total Hydrocarbons
2359 Old Pit	C_6-C_{22}	7.50 mg Total Hydrocarbons
2454 East of Pit	C_6-C_{22}	8.10 mg Total Hydrocarbons
2455 South of Pit	C_6-C_{22}	4.00 mg Total Hydrocarbons

Normal detection Limit 0.01

* Total Hydrocarbons in 350 ml sample

CONCENTRATION BASED ON mg/L

[illegible] 21.43 mg/L of Hydrocarbons
2456 [illegible] mg/L " " "
2455 11.43 mg/L " " "
2454 23.14 mg/L " " "

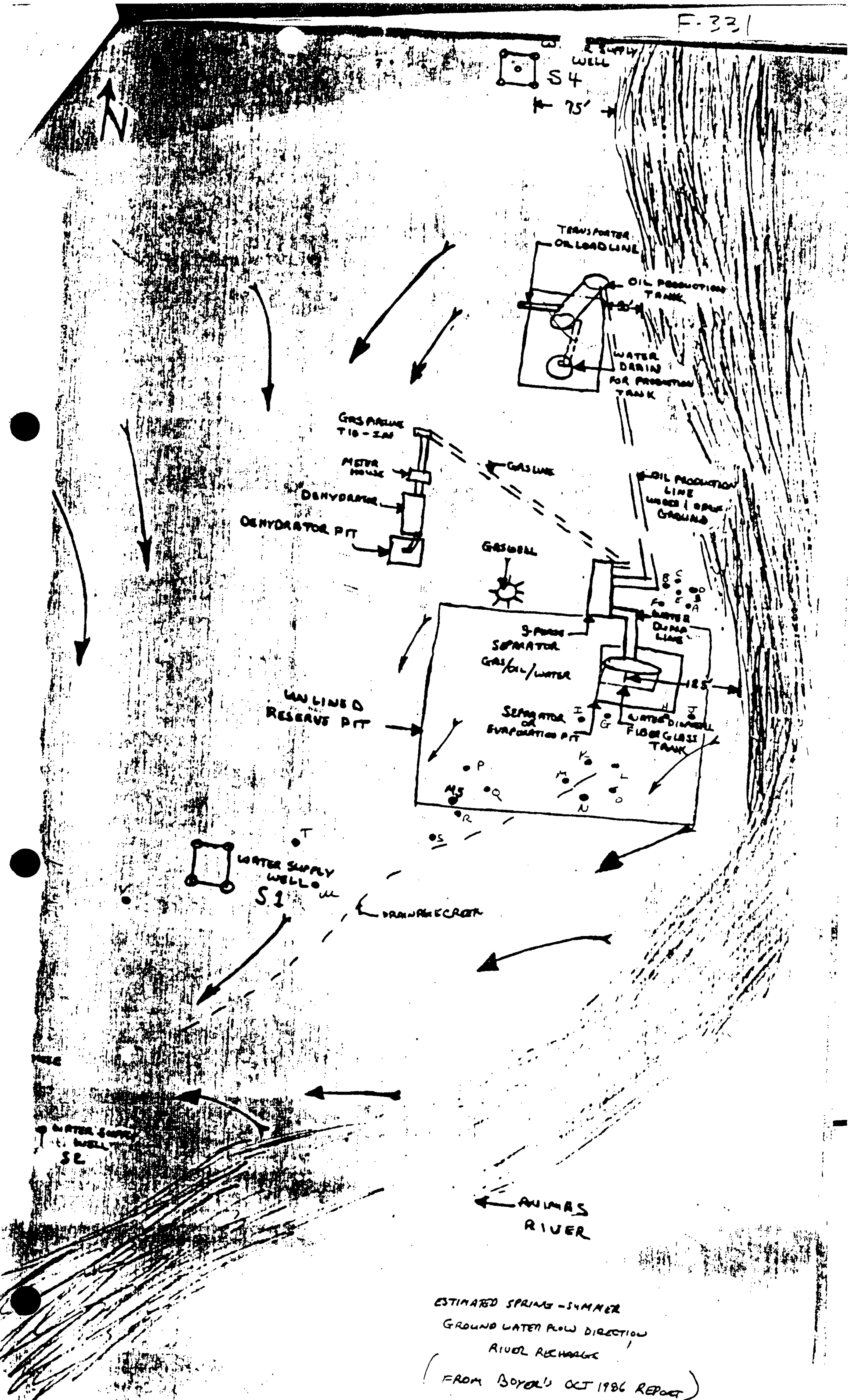
SEE AMMENDED
REPORT 8/24/83

Joe Bowden

Dr. Joe Bowden Director

Members of:
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
AMERICAN SOCIETY OF BIOLOGICAL CHEMISTS
AMERICAN SCIENTIFIC AFFILIATION
SIGMA XI

F-331



ESTIMATED SPRING-SUMMER
GROUND WATER FLOW DIRECTION
RIVER RECHARGE
(FROM BOYER'S OCT 1986 REPORT)
FIG 6

APPENDIX E
Blair Investigation Report

KB

88/001

Civerolo, Hansen & Wolf, P.A.

COUNSELORS & ATTORNEYS AT LAW

RECEIVED
JAN 21 1988

January 20, 1988

Mr. Thomas L. Wright
El Paso Natural Gas Company
P. O. Box 1492
El Paso, Texas 79978

Mr. David Siddall
El Paso Natural Gas Company
P. O. Box 1492
El Paso, Texas 79978

Re: Flora Vista v. Manana and EPNG

Dear Tom and David:

I enclose a map and a report which reportedly show some trench digging which Dr. Blair did for Brewer & Associates at the Flora Vista site. Brewer & Associates is Richard Cheney's company, and he, of course, is not only a consultant for Flora Vista but also is a resident in the area. As you will note, somehow they have been able to draw perimeters and somehow have been able to separate water specifically enough in their studies to come to a magic boundary for contamination.

I would appreciate your sending these on to Henry Van, Ken Beasley, Greg Kardos and whoever else you feel should have them to get their thoughts about the study. I think we will send it on to John Shomaker, if you approve, to get his thoughts, too. There is considerable additional material which I presume you will want. We are in the process of copying it and will forward it to you, also.

Very truly yours,

CIVEROLO, HANSEN & WOLF, P. A.

Wayne C Wolf

Wayne C. Wolf

WCW:jj
Enclosures

cc: Mr. Adolfo Campos II
Policy No. 46-LLR-G18538E
D/Loss: 2/24/83

500 Marquette NW, Suite 1400 P.O. Drawer 887 Albuquerque, NM 87103 (505) 842-8255 Telecopier 505-764-6099

RICHARD C. CIVEROLO
C. LEROY HANSEN
WAYNE C. WOLF
WILLIAM P. GRALOW
KATHLEEN D. LEBECK
DENNIS E. JONTZ
CARL J. BUTKUS
W. R. LOGAN
TERRY R. GUEBERT
CYNTHIA A. FRY
ROBERTO C. ARMIJO
PAUL L. CIVEROLO
R. GALEN REIMER
JULIA R. WALL
CLINTON W. THUTE
JAY E. STEIN
MICHAEL H. SMITH
ANTHONY J. D. CONTRI
R. THOMAS DAWE
BRUCE T. THOMPSON
MYRA F. MOLDENHAUER
PETER A. DOMENICI
ROBERT J. CURTIS
LENNY WILSON

Date: 8/25/87

Richard Cheney, President
Brewer Associates
P.O. Box 2079
Farmington, New Mexico 87499

Dear Mr. Cheney,

Attached is my summary of the Flora Vista contamination study conducted on August 18 and 19, 1987. The study, I believe, shows that 1) hydrocarbon contamination of water well S1 came from a hydrocarbon plume located east and north of the water well and 2) the source of contamination stems from an area immediately south of the dehydrator owned by El Paso Natural Gas Company.

If you have any questions concerning the report please contact me either at work (303) 247-7263 or at home 247-2703. I found the project to be very interesting and frankly, fun. If I can be of further service to you please don't hesitate to call.

Sincerely,

Dr. R. W. Blair, Jr.
Department of Geology
Fort Lewis College
Durango, CO 81301

FLORA VISTA CONTAMINATION STUDY
SUMMARY OF TRENCHING ACTIVITIES
8/18 TO 8/19 1987

by R. W. Blair, Jr.
consulting geologist

SITUATION

Systematic trenching with a backhoe was commenced on August 18th and 19th, 1987 between the Flora Vista Water Users Association's water well S1 and Manana Oil and Gas well, Mary Wheeler no. 1-E. The objective was to trace and isolate the source of hydrocarbon contamination to the S1 water well. Present during trenching on the 18th were Ed Hartman, President of Manana Gas, Inc.; David Boyer, hydrologist with New Mexico Oil Conservation Division; R. W. Blair, Jr., consulting geologist representing Brewer Associates; Ray Penrod, representing the Flora Vista Water Users Association and the backhoe operator. Present during trenching on the 19th were Ed Hartman, R. W. Blair, Jr., Ray Penrod, Frank Chavez, district supervisor, N.M. Oil Conservation Division, Ken Beasley and six other El Paso Natural Gas Company employees, and the backhoe operator.

TECHNIQUES AND METHODS

1. Thirteen trenches, seven to eight feet deep were dug in all, six (A thru F) on the 18th and seven (G thru M) on the 19th (see attached map). Trench location on the first day was determined by David Boyer. On the second day Mr. Ed Hartman, and myself (Blair) determined trench location.

2. All trenches were documented as to location, orientation and hydrocarbon contamination.

3. The trenches were dug in such a manner that: a) they intersected the existing water table, b) berms were placed every 8 to 10 feet at bottom of trench to minimize groundwater mixing, c) they were generally oriented perpendicular to the direction of groundwater flow direction, and d) they were positioned to maximize information concerning location and source of contamination.

4. Mr. Ed Hartman with my assistance obtained water samples from all contaminated trenches and a few of the uncontaminated trenches which are to be analyzed for hydrocarbons. David Boyer took water samples only from the six trenches excavated on August 18th. These are to be analyzed for specific organic pollutants such as benzene and toluene.

5. A map was constructed using standard pace and compass techniques of the trenches, well sites, and associated gas

production structures (see attached map).

DISCUSSION

The water and gas well are located upon a point bar deposit (sand and gravel deposited from a meandering river). Two flat depositional surfaces are evident (see attached map). The lower surface represents the modern floodplain and is found adjacent to the Animas River and the upper surface or terrace (18 to 24 inches higher) is an older floodplain. The point bar deposit consists of sand and gravel with cobbles commonly 12 inches in diameter. The upper 12 to 18 inches of both surfaces consists of a sandy loam soil.

The water table is measured in the trenches at 5 to 6 feet below the upper terrace surface. Uncontaminated water is slightly muddy with some natural organic foam or scum present on the surface. Contaminated water displays an iridescent oil film along with a strong hydrocarbon smell. The contaminated zones are recognized in the gravel deposits from a black stain which coats the sand and cobble surfaces and from strong noxious organic odors emanating from the stained horizon. The contaminated zone is found to coinside with the water table flux zone, because the hydrocarbons tend to float and be carried along at the top of the water table surface. Thus, only rarely is the contaminated zone found within the upper five feet. The smelly black organic stain is noted in the contaminated trenches and is marked on the attached map with cross hatching. The contaminated zones vary in thickness from a few inches to several feet (the thickest zone is found just south of the dehydrator).

In trenches A and C a thin discontinuous black stained zone is noted, but it is not associated with any hydrocarbon odor. This zone may have been contaminated during the producing periods of the water well S1, because the cone of depression would have captured the contaminated flow documented to the west of the well. Upon cessation of pumping, fresh, clean ground water probably flushed and leached out the volatiles, but still left an insoluble organic black stain.

As noted from the map, the contaminated zone appears to be confined to a narrow band and is shaped like a giant comma, trending south. Ground water flow is to the south, as recorded by David Boyer (1986); thus, the source of hydrocarbon contamination is found in the vicinity of the dehydrator and specifically from an area immediately south of the dehydrator (old dehydrator pit). If liquid hydrocarbon waste was dumped into the gravels south of the dehydrator near the surface and above the water table, they would spread laterally in all directions; and therefore, could conceivably contaminate an area immediately north of the dehydrator as indicated in trench I. Once the waste fed into the water table it would be carried in the direction of ground water flow. The slight westward trend of the contamination plume as it trends south may be due to natural flow along a highly permeable zone which corresponds closely with the upper and lower terrace boundary or it may reflect ground water capture due to the pumping of S1 and its associated cone of depression.

CONCLUSIONS

1. Contamination of the S1 water well was due to capture of the hydrocarbon plume identified from trenching and shown on the attached map.

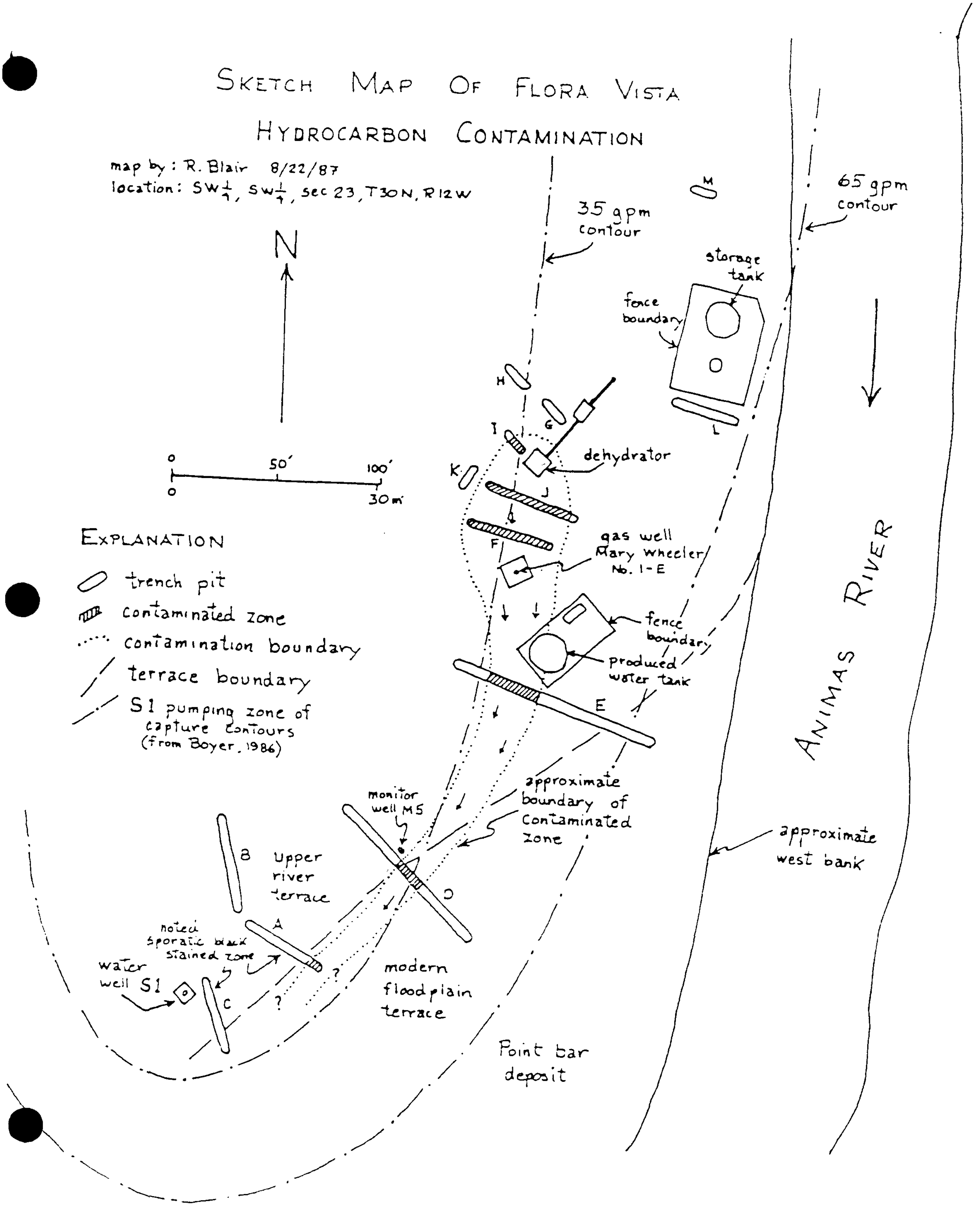
2. The source of the hydrocarbon plume appears to be a circular zone located immediately south of the present location of a dehydrator owned by El Paso Natural Gas Company.

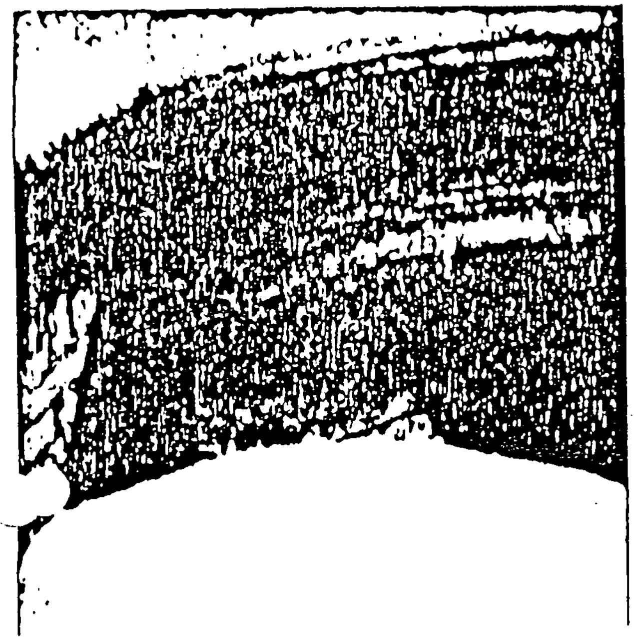
REFERENCES

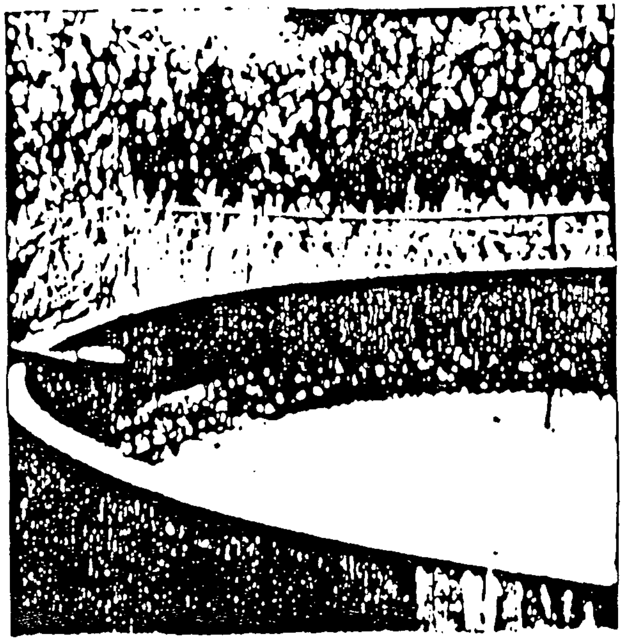
Boyer, David G., 1986, Final report on Flora Vista Contamination Study, October 1986: Sante Fe, N.M., Environmental Bureau, New Mexico Oil Conservation Division, 55p.

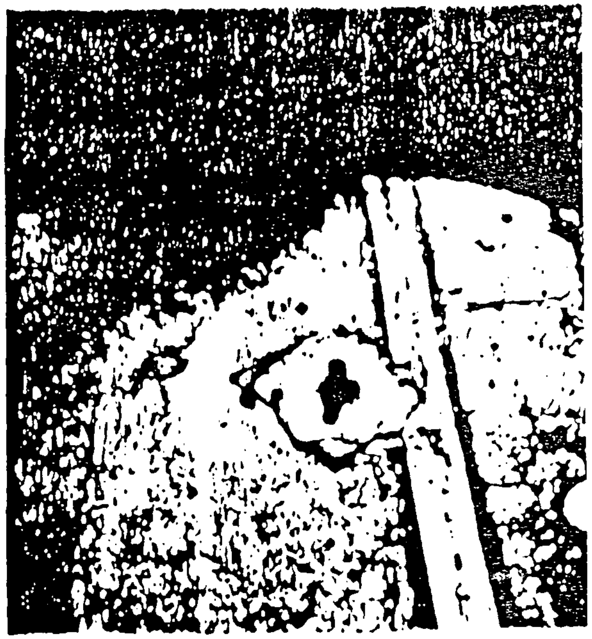
SKETCH MAP OF FLORA VISTA HYDROCARBON CONTAMINATION

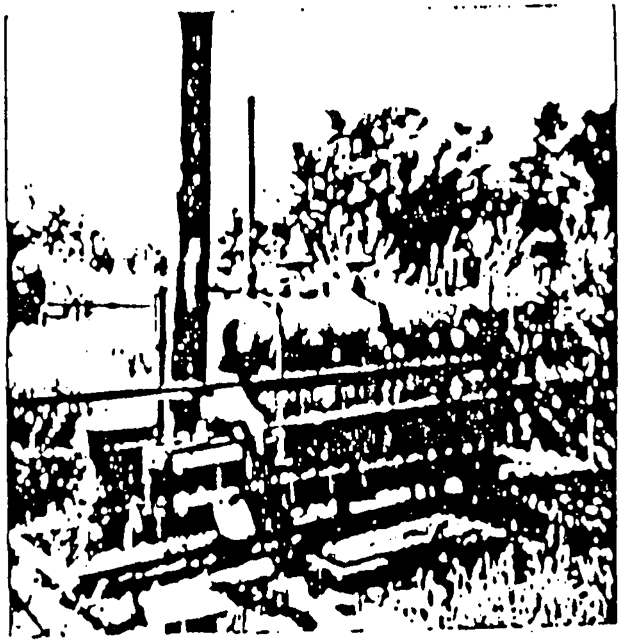
map by: R. Blair 8/22/87
location: SW$\frac{1}{4}$, SW$\frac{1}{4}$, sec 23, T30N, R12W











APPENDIX F
Photograph Log

PHOTOGRAPH LOG

Photo #1-2	Excavation of trench T-1.
Photo #1-3	Close-up of stained soil noted in trench T-1.
Photo #1-4	Installation of monitoring well EPNG-1 in a background location.
Photo #1-5	Setting the sand pack (Colorado Silica Sand) in monitoring well EPNG-1.
Photo #1-6	Checking the placement of the well casing for monitoring well EPNG-1.
Photo #1-7	Placing the bentonite pellets (1/4") in monitoring well EPNG-1.
Photo #1-8	Completed monitoring well (EPNG-3). Protective steel casing and 2′ x 2′ concrete pad represented the method of competition for each EPNG monitoring well.
Photo #1-9	Mixing the bentonite mud used to drill each of the EPNG monitoring wells. Bentonite mud was need to keep the coarse-grained sediment in place.
Photo #1-10	Setting the protective collar at monitoring well EPNG-3. Note the Portland Type I & II grout which was used as an upper seal. The form for the concrete pad is in place.
Photo #1-11	Installing monitoring well EPNG-2A near the Mary Wheeler well.
Photo #1-12	Preparing to jet out monitoring well EPNG-1 using the air compressor on the drill rig. The compressor was outfitted with a dry element to prevent oil from blowing past the compressor.
Photo #1-13	Jetting groundwater from EPNG-1. This portion of development was followed by pumping numerous gallons of water from the well using a noncontact sample pump.
Photo #1-14	Preparing to jet out OCD-4. This well had silted in to the point where a water level reading could not be obtained. Following jetting, water levels could be taken; however, groundwater samples could not be collected due to a bent well casing.
Photo #1-15	Bell-hole excavation in the area of the reserve pit. Note the dense dark gray clay in the bottom of the hole. These sediments appear to be associated with the cuttings from the reserve pit.

Photo #1-16	Bell-hole excavation in the area of the reserve pit. The gray material appeared to be a combination of cuttings and bentonite from the reserve pit.
Photo #1-17	Close-up of the gray material noted in photo #1-16.
Photo #1-18	Emmett Hudson, KWB&A, purging water from monitoring well EPNG-1 using a bailer.
Photo #1-19	Field lab used to test groundwater samples for pH, EC, and temperature. The black meter is the pH and compensates for temperature. The blue meter was used to measure EC. The pump, funnel, and side arm flask were used to filter samples for metal analysis.
Photo #1-22	Groundwater purged from monitoring well EPNG-2A prior to collecting a sample. A noncontact Isco sample pump was used along with dedicated sample tubing. All of the groundwater samples for the EPNG monitoring wells were collected using the Isco pump. Note the clear appearance of the produced groundwater.
Photo #1-23	Groundwater purged from monitoring well EPNG-2A prior to collecting a sample. A noncontact Isco sample pump was used along with dedicated sample tubing. All of the groundwater samples for the EPNG monitoring wells were collected using the Isco pump. Note the clear appearance of the produced groundwater.
Photo #1-24	An example of a completed EPNG monitoring well (EPNG-4). Note locking cap.
Photo #1-25	Sid Johnson, KWB&A, purging water from OCD-2 prior to collecting a groundwater sample. Bailers were used to purge and collect samples for the OCD wells due to the large amount of coarse-grained sediment present in the wells.
Photo #1-26	Sid Johnson, KWB&A, purging water from OCD-2 prior to collecting a groundwater sample. Bailers were used to purge and collect samples for the OCD wells due to the large amount of coarse-grained sediment present in the wells.
Photo #1-27	An example of the type of groundwater and the texture of the sediments produced from the OCD monitoring wells.
Photo #2-14	Excavation of trench T-1.
Photo #2-15	Excavation of trench T-1.
Photo #2-16	Excavation of trench T-1.
Photo #2-17	Sidewall profile of trench T-1. Depth to water in the trench is on the order of 6 feet. Due to the depth of the trenches and the instability of the sidewall, soil samples were collected from the backhoe bucket.

Photo #2-18	Stained soil and rocks removed from trench T-2.
Photo #2-19	Backfilling the east end of trench T-2.
Photo #2-20	Stained soil and rocks removed from the center portion of trench T-2.
Photo #2-21	Close-up of material seen in Photo #2-20.
Photo #2-22	Close-up of material seen in Photo #2-20.
Photo #2-23	Excavation of the west end of trench T-2
Photo #2-24	Material removed from the excavation of trench T-2.
Photo #2-25	Excavation pit used to collect a soil sample from the west end of trench T-2.

86/006

STATE OF NEW MEXICO
ENERGY AND MINERALS DEPARTMENT
OIL CONSERVATION DIVISION

TONEY ANAYA
GOVERNOR

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November 17, 1986

MEMORANDUM

TO: ADDRESSEES

FROM: DAVID BOYER, HYDROGEOLOGIST, OIL CONSERVATION DIVISION DJB

SUBJECT: CORRECTED PAGE 3, FINAL REPORT ON FLORA VISTA CONTAMINATION STUDY

The enclosed sheet replaces pages 3 and 4 of the above report. Page 3 is corrected to show that a study progress report was prepared in January, 1986. Please insert the corrected page in your copy of the report.

DB:dp

Enc.

86/003

PROGRESS REPORT ON FLORA VISTA CONTAMINATION STUDY

JANUARY 1986

A Report to the Flora Vista
Water Users Association
Flora Vista, New Mexico

Prepared by David G. Boyer
Hydrogeologist

Environmental Bureau
New Mexico Oil Conservation Division

Paul L. Biderman
Secretary, Energy and Minerals
Department

R. L. Stamets, Director
Oil Conservation Division

50 YEARS
1935 - 1985

STATE OF NEW MEXICO
ENERGY AND MINERALS DEPARTMENT
OIL CONSERVATION DIVISION

TONEY ANAYA
GOVERNOR

POST OFFICE BOX 2088
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SANTA FE, NEW MEXICO 87501
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January 31, 1986

Mr. Bert Barnes, President
Flora Vista Water Users
Association
P.O. Box 171
Flora Vista, NM 87415

Mr. Richard P. Cheney,
Vice President
Lawrence A. Brewer &
Associates, Inc.
P.O. Box 2079
Farmington, NM 87401

Gentlemen:

The New Mexico Oil Conservation Division (OCD) has completed a report on the activities through January, 1986, of this Division and the Environmental Improvement Division (EID) regarding the contamination investigation of Flora Vista Water Well No. 1 (S1). This well, which was contaminated by oil and grease in early 1983, has been out of service since that date. OCD activities in 1985 included installation of five monitoring wells, sampling of water quality from these wells and other ground water at this location, and measurement of water levels to determine ground water direction and rate of flow. EID supplied material and staff to assist in well installation.

The OCD report is enclosed with this letter but its major conclusions and recommendations for further study are summarized below:

1) No verifiable contamination was detected in 1985 in either the unused water supply wells or the monitor wells except for low level contamination detected in samples taken within 24 hours of cleaning the well with an air compressor. The latest sampling for which results are available (October 1985) did not detect hydrocarbons either in the monitor wells or in a composite of the water wells currently supplying the system.

2) Methane at concentrations 1200 times ambient levels was detected in the monitor well closest to the gas well in August. The source is likely the decay of

shallow buried organic material. The gas well itself is not a likely source of methane since it has 227 feet of surface casing cemented back to the surface.

3) Ground water movement in the vicinity of the monitor wells in fall 1985 - winter 1986 was towards the river and away from the currently used water supply wells. The flow has a seepage velocity range of 3 to 4 feet per day.

4) Based on the available information, the produced water tank at the Manana Mary Wheeler 1E gas well, the gas well itself, and the dehydrator pit are all likely to have been within the zone of influence ("cone of depression") of the pumping S1 well at the time the water well was contaminated in February 1983. Actual pumping rates and pumping cycle information at the time of contamination would better define the extent of pumping well influence.

5) The estimate of travel time for unretarded soluble contaminants to have moved from the vicinity of the gas well to the pumping water well is approximately 100 days.

6) The rate of ground water movement is such that a single plume of contaminated produced water originating in the vicinity of the gas well in 1983 has now moved beyond the water well.

7) Because of the passage of time, water pumped from well S1 would not show contamination unless a zone of residual oil saturation is present at or near the produced water tank or other facilities.

8) To determine the presence and concentrations of any residual oil between the site of the leaky pit and well S1, exploration digging with the backhoe is recommended, followed by sampling. If oil is found, capture of soluble constituents is again a possibility and well No. 1 (S1) may again evidence contamination if pumped continually.

9) The OCD intends to measure water levels and sample water quality of the monitor wells and other available wells through at least the fall of 1986.

10) Well S5 should be capped to prevent introduction of contaminants. However, both wells S1 and S5 should have caps that allow for access for periodic water level measurements, water quality sampling, and pumping if necessary.

11) An aquifer test using well S1 as the pumped well should be performed for at least 72 hours at a rate of 60 gpm or at the rate the well would be pumped if put back in service. This test would determine accurate aquifer parameters and detect any contamination in the immediate vicinity of the well.

12) Since well S5 is at a distance greater than 500 feet from the gas well and out of the direct path of ground water flow, it is unlikely that pumping S5 will cause capture of any remaining contaminants from the gas well. To test this assumption, additional flow calculations should be made before placing back in service.

13) Sampling of individual pumping water supply wells for purgeable aromatic hydrocarbons should be performed on a regular basis. For convenience, a sampling schedule identical to that required for total trihalomethanes is initially suggested.

The OCD would like to schedule a 72-hour aquifer test in March using well S1. Since we do not have a pump or a water flow measuring device, any assistance the Association could provide would be appreciated. A flow device could either be a calibrated in-line meter, orifice weir, or other accurate device. The pump should have a valve to control discharge so that a constant rate is maintained. Also, a pipe or hose will be needed to divert the water away from the monitor wells to prevent recharge. If these items can be obtained, the test can be performed.

The attached report and the proposed work represent a substantial commitment of time and effort by the three-person staff of the OCD Environmental Bureau. I hope that the information we have provided, and that which we will provide over the next eleven months, will be useful in any action you take to resolve the matter.

If you have any questions regarding this letter or the report, please contact me at 827-5812.

Sincerely,

David G. Boyer

DAVID G. BOYER,
Hydrogeologist
Environmental Bureau Chief

DGB/dp

Enc.

cc: Paul Biderman, Secretary EMD
R. L. Stamets, Director OCD
NM OCD, Aztec District Office
NM EID Water Supply Section
NM EID Ground Water/Hazardous Waste Bureau
NM EID, Farmington Field Office

PROGRESS REPORT ON
FLORA VISTA CONTAMINATION
STUDY - JANUARY, 1986

Introduction

This report was prepared by the New Mexico Oil Conservation Division to summarize the work performed to date at the Flora Vista well field, to review the results of water quality sampling and hydrologic mesurements, to present preliminary conclusions based on this work, and to make recommendations for future testing. The assistance of the staff of the Flora Vista Water Users Association, Lawrence A. Brewer & Associates, and the Environmental Improvement Division in providing data, reports, support equipment, and services is gratefully aknowledged.

Background

The Flora Vista Water Users Association operates an approved community water system for the Flora Vista area located approximately halfway between Farmington and Aztec on U S highway 550. In 1983 the system served approximately 1500 residents and small businesses through 431 connections. Maximum system delivery, as reported in New Mexico Environmental Improvement Division (EID) community water supply system inspection reports, was reported at 170,000 gallons per day (gpd) with average delivery in 1983 of about 100,000 gpd. The system was placed in service in 1981 with two wells each with pump capacities of 60-70 gallons per minute (gpm).

In January, 1980, a gas well owned by Manana Gas, Inc. of Albuquerque was drilled in unit M (SW/4 SW/4) of Section 23, Township 30 North, Range 12 West. The well, Mary Wheeler No. 1-E, was placed in service in July, 1980, with the natural gas being received by El Paso Natural Gas via a pipeline at the site.

Manana facilities at the site include the well, an oil-water separator, a fiberglass tank (capacity approximately 120 barrels) holding produced water and some oil from the separator, an oil tank for storing oil produced with the gas and a tank drain pit for discharging water separated from the oil (now replaced with a small fiberglass tank). A reserve (mud pit) and a blowdown pit were both likely present at one time but have been covered over. The original fiberglass tank was replaced with a second identical tank in early 1983 due to discovery of a leak. El Paso Natural Gas facilities include a gas dehydrator, a dehydrator pit with a 55 gallon drum serving as a collector, and a gas meter house.

The entire site occupies an area of approximately 220 x 75 feet and is located northeast of water supply well S1. Distances from the water well to the fiberglass produced water tank, gas well, and dehydrator pit are 235 feet, 255 feet, and 285 feet, respectively. Figure 1 shows the relationship of the various oil and gas facilities to the water wells.

In 1982, OCD records show production of 39,584 million cubic feet of natural gas and 1022 barrels of oil. Water production is estimated by the company (1985) at approximately 210 gallons per day or about 76.6 thousand gallons per year. All produced water collected is removed from the site.

In February, 1983, at least one well, S1, became contaminated with oil and grease and was taken out of service. The level of contamination was reported in Association records as 16 mg/l. To avoid further contamination, the system was shut down and water was purchased from the City of Aztec and delivered via an existing pipeline. At that time, the Association dug a pit between S1 and the gas well and detected a noticeable odor and an oily film. Between February and August, 1983, additional backhoe pits were dug and sampled for oil and grease. In August, the OCD sampled the water well S1, the Manana separator, the El Paso dehydrator, and a previously dug pit. Oil and grease levels reported ranged from 32 to 38 mg/l except for the dehydrator which was not reported. However, the dehydrator was reported to have 13 mg/l of both benzene and toluene.

In the summer of 1984, the EID attempted to drill monitoring wells in the area for the purposes of determining the contamination sources and the risk to the other supply wells. However, the hollow-stem auger drill rig was not able to penetrate the large boulders in the shallow subsurface and the attempt was discontinued.

Investigation in 1985

The following is a summary of work performed in 1985:

1) Five monitoring wells were placed around the original contaminated well in late March by OCD and EID staff. Due to large boulders in the shallow subsurface, the wells were installed with a backhoe provided by the water users association. The wells are 2-inch diameter steel casing, with a 48-inch long Johnson wire-wound stainless steel screen having a slot size of 0.07 inches. This slot size is too large for effective sand control, but it was the only screen available for immediate use. The wells and casing were provided by EID. Gravel packing was tried for the first well, but the large pit size and rapid slumping of the hole precluded further gravel use. The lack of a gravel envelope made the wells subject to rapid silting. Total depths of the wells range from 7 to 10.8 feet from the casing top. The wells extend about 20 inches above the land surface and are cemented at the surface.

2) Samples were taken from the water supply and monitor wells for organic analyses in March, June, August, September, and October, 1985; and again in January, 1986. The 1985 results are shown in Tables 1 and 2. Results from the Mary Wheeler No. 1E gas well are shown in Table 3. Inorganic analyses were run on the water supply wells (including the previously contaminated well) and the Animas River in March.

3) As expected, several monitor wells filled with sand and were cleaned twice using compressed air from two different compressors. The use of these compressors apparently affected the water quality as discussed below.

4) In September all monitor and supply wells were surveyed by Brewer and Associates for both location and elevation. Several well elevations were resurveyed in October. Blueprints from recent aerial photos were received in late December. Water levels were measured in September and October 1985, and January, 1986. This information allows ground water elevations to be directly compared, and estabishes the hydraulic gradient, direction of ground water flow, and flow velocity. These calculations and the resultant conclusions and interpretations are presented below.

Hydrogeology

The valley of the Animas River contains alluvium consisting mainly of sand and gravel which is outwash material from Pleistocene glaciers in the San Juan Mountains in Colorado. In the vicinity of the Flora Vista wells this alluvium is about 25 feet thick. Examination of the aerial photograph blueprints provided by Brewer & Associates shows old river channels and meanders in the flood plain. Finer grained silts and clays can be expected to have been deposited in low velocity areas such as point bars and areas of overbank flooding. However, the area where the monitor wells were drilled was found to be a zone of very coarse sand and gravel with some rocks exceeding a foot in diameter.

The presence of a coarse sand and gravel zone usually indicates high ground water permeability. Examination of the pumping level estimates provided in the 1982 EID community water system environmental survey, together with a 1982 Brewer and Associates infiltration gallery feasibility study shows an aquifer permeability of about 750 gallons per day per square foot, or 100 feet per day. This value is at the lower end of the range for clean sand and gravel mixtures, but still allows for rapid ground water movement.

In September and October, 1985, ground water levels were measured in those monitoring wells where fluid levels were present. The results were used to calculate the direction of ground water flow and the hydraulic gradient. The gradient values were 0.0080 and 0.0105, respectively, or about 42 and 55 feet per mile. These values are intermediate between the average river gradient at Flora Vista of 0.004 and the topographic gradient of 0.014 perpendicular to the river at the well field location. The January, 1986, water levels, measured after hand-augering sand out of holes, showed a gradient of 0.0097, or about 51 feet per mile.

The ground water flow directions in September and October are shown on Figures 1 and 2. The direction on September 20 is slightly east of south. On October 25 the direction had changed to nearly 25° east of south. The January 17 direction (Figure 3) is intermediate between the autumn directions. As shown in the figures, the direction of ground water flow on all sampling dates was towards the river. In the fall and early winter of 1985, ground water flow in the vicinity of the Manana Mary Wheeler 1E Well moves in the direction of the river and not towards any of the water supply wells or monitor wells.

Based on these water level measurements and some assumptions about surface and ground water interaction in the area, Figure 4 showing estimated fall-winter ground water flow directions was prepared. The assumptions used are:

1) River flows are generally low in fall and winter months;

2) Water stored in the permeable alluvial material in the immediate vicinity of the river during times of spring and summer high flows is discharged back into the river at low flow;

3) Additional ground water discharge to the river comes from sources to the northwest of the well field including ground water recharged to the alluvium from the Flora Vista Arroyo, the Halford Independent Ditch, the Farmers Ditch, irrigation seepage, recharge due to septic tank discharges, and any runoff from precipitation events.

Figure 5 shows a possible flow regimen for spring-summer ground water movement taking into account higher river runoff levels. Spring and summer measurements will be taken in 1986 to better define flow during these months.

In February, 1983, with river water levels quite low (Table 4), water supply well No. 1 (S1) was contaminated by hydrocarbons. One suspected source was a leaky fiberglass tank containing produced water from the Mary Wheeler No. 1E gas well. The tank is located approximately 230 feet to the northeast of well S1. If the direction of ground water flow at this time was towards the river, other factors must have been operating for this to be the contaminant source. Using the available hydrologic data and the EID's January, 1983, report of estimated water use, drawdown calculations were made (Table 5) using the Theis non-equilibrium well formula. The calculations were made assuming 100,000 gallons per day pumped from two wells with a daily average of Q =35 gpm/well. The results show a drawdown of 0.1 foot at the tank after only two days of pumping at the above rate. Though small, this value is enough to cause movement of water towards the well. After 100 days of pumping, the calculated drawdown is 1.1 feet at the tank location.

Since this well (S1) is only 250 feet from the river, it is reasonable to expect that river water is recharging a portion of the water removed from the aquifer by the well. However, calculations assuming steady state flow show that the zone of capture only extends 63 feet down gradient for an average daily pumping rate of 35 gpm. This is because more water up gradient is captured, and the resultant asymmetrical cone of depression (zone of influence) does not extend as far down gradient in the direction of the flow (Figure 6). Since the well was reported to have pumped at a maximum of 60 to 70 gpm, a down gradient capture distance of 117 feet was calculated for Q = 65 gpm.

Because the pump was cycled on and off, the stress on the aquifer would fluctuate. If the pump was on more than 50% of the time, the parabolic envelope shown in Figure 6 would approach that of the Q = 65 gpm curve. These capture curves were drawn assuming the flow direction in early 1983 was the same as January 1986; other variables that could change curve shape include non-homogenuous sediments, variations in permeability, non-equilibrium (vs. steady-state) flow, and the pumping cycles.

If there is a drawdown of water under the produced water tank due to well S1, this would allow capture by the well of water under the tank. Calculations for a drawdown of 1.1 feet after 100 days of pumping (average Q = 35 gpm) and taking into account changes in flow velocity near the well show that travel times for water movement from the tank location to the well would range between 96 and 103 days. These times do not take into account constant pumping at a higher rate or any mechanisms of attenuation such as contaminant retardation due to sorption, or biochemical transformation. More sophisticated techniques can produce more exact estimates of both flow and solute transport rates if actual pumping rates, pumping cycles, and measured aquifer parameters at well S1 were known.

Under non-pumping conditions, ground water movement will be determined by the local hydraulic gradients, and the rates of movement can be calculated as shown in Table 5. Using an average gradient of 0.009, for fall 1985 - winter 1986 and a porosity of 0.25, an approximate horizontal seepage velocity of 3.7 feet per day, or 1350 feet per year, was calculated. This shows rapid particle movement under natural conditions for that season. If these rates prevail all year, and the contaminant source was a one-time release of produced water with only a small oil phase, movement would be out of the zone of influence of the well after only one year. In addition dilution with other water and other mechanisms would be expected to attenuate a single incident plume. Again, more sophisticated techniques using computers can produce a ground water model of plume movement and dispersion.

If a large oil phase was discharged, the presence of residual oil in the soil together with seasonal water level changes could cause continued leaching of soluble oil constituents into ground water. If present, these contaminants could again reach the well if it was put back into service.

Water Quality

The inorganic chemistry analyses of the water supply wells sampled show generally very good water quality. For three samples from two wells and a composite of two others, total dissolved solids average 403 mg/l, chlorides average 17 mg/l and sulfates average 189 mg/l. A sample of Animas River water had concentrations of 368 mg/l, 12.5 mg/l and 116.3 mg/l for the same constituents. Only manganese with an average of 0.37 mg/l is elevated above acceptable levels. Manganese is naturally occurring in salt and minerals and the New Mexico Ground Water Standard is 0.2 mg/l. The effects of slightly elevated levels are generally limited to unpleasant taste and plumbing fixture staining.

A sampling program for organic chemicals in the affected water supply wells, monitor wells, and operating supply wells was begun by the OCD in March, 1985. Subsequent testing was performed in June, August, September, and October; and January, 1986. The results (except for the most recent sampling) are shown in Tables 1 to 3.

The wells were sampled for aromatic hydrocarbons which have been found to be present in water and fluids produced concurrently with oil and gas. Once dissolved in water, these contaminants migrate with the ground water in the subsurface. At a point of use, such as a well, the hydrocarbons can be present in the water even though a separate oil phase may not be detected. Samples for aromatic hydrocarbon testing require only a small 40 ml volume of water, and no special treatment or preservation except chilling needs to be performed prior to analysis. In addition to aromatic hydrocarbons, tests for methane gas and halogenated hydrocarbons can be performed on the same sample. Prior to sampling, the monitor wells were "purged" by use of a clean bailer to obtain fresh samples.

Results for three samplings of the water supply well originally shut down (S1) show a small amount (6 ppb) of toluene detected in the June sampling. The newly adopted New Mexico Ground Water Standard is 750 ppb, down from 15,000 ppb. The compound was detected only once and a sampling error cannot be ruled out. The well, which had remained open since the pump was removed, now has a plate welded over the top and is inaccessible for sampling.

Benzene, a known human carcinogen, was not detected in well S1 or in any other well in any sampling. Also, no separate oil phase was found in any of the wells during any of the samplings.

Sampling of the other unused well (S5) detected no contamination until September when it was pumped by introduction of air to displace several well volumes to acquire a "fresh" sample. Samples taken that day and the following day from S5 had low levels of toluene and several other aromatic hydrocarbons. These levels were many times lower than either New Mexico or newly proposed EPA recommended levels.

After examination of these and other September results showing low levels of contamination, the air compressor was tested and found to have lubrication or combustion pollutants in the air line. The air line is thought to be the major source for the pollutants detected in wells S5, M1, M2, M3, and M5 for the September sampling . However, well M4, which could not be reached by the air line in September, also showed a slight, but detectable level of toluene. Well S5 was resampled in October and trace levels less than 1 ppb were found for several aromatic hydrocarbons, not including benzene. Well M4 was dry at the time of the October sampling and no hydrocarbons were detected in the other wells.

Three samples representing a composite of the pumping wells were taken from the pump house tap in March, August, and October, 1985, and January, 1986. No contaminants were detected except for a very small volume of chloroform. Chloroform might have been present as a result of chlorination which occurs immediately adjacent to, but downpipe from the pump house tap.

In March, 1985, water samples were taken from the backhoe-dug pits prior to monitor well installation. An oily sheen appeared on the water in the pits. Examination of the backhoe bucket determined that hydraulic fluid was leaking from either a fitting or a cylinder and dripping into the pit. Samples of the pit water taken that day showed no contamination. Later, a sample of water mixed with hydraulic fluid showed a dissolved toluene concentration of 1700 ppb in the water.

Sampling of the monitor wells was complicated by fine sand that entered the well as a result of the large screen size and lack of a gravel pack. Also, water levels in the monitor wells dropped between 4.6 and 7.6 inches from September to October. Wells M1, M2, and M4 were dry for one or more of the samplings.

On June 27, cleaning of all monitor wells was attempted using a small air compressor like that used for spray painting. Sampling done the following day detected low or trace levels of hydrocarbons in three of the five wells. At that time the use of air from a compressor to clean out shallow monitoring wells was thought by both OCD and EID to be a practical solution. Although EID had used this small compressor previously and not detected contamination, its air line was never tested for hydrocarbons, and the compressor is no longer available for testing. Therefore, the small compressor as a source for those contaminants detected in the June sampling cannot be ruled out.

As previously mentioned, the compressor used in September to pump well S5 and to clean the monitor wells was known to have introduced low levels of contaminants. Therefore, it cannot be determined whether hydrocarbons were in the wells in September prior to the introduction of air. For the August and October samplings, no contamination was detected in any of the monitor wells having water. Since the range of seepage velocities was from 3 to 4 feet per day, low level contamination from the compressors would have been diluted and quickly moved beyond the capture radius of the monitor wells.

Prior to the January, 1986 sampling, all monitor wells were cleaned by use of a homemade PVC hand auger that effectively removed all but a small volume of sand. January test results are not yet available.

Tests for dissolved methane gas were made on samples collected on several dates. Monitor wells 3 and 5 had elevated levels of the gas in August but not in October. M5, the monitor well nearest the gas well, had the largest volume of gas and also was located in an area where dark black soil was present. Soil sampling did not show oil present at detectable levels. The source of the gas may be natural material since the area is swampy, or it may be from shallow buried organic material deposited in the reserve pit during drilling and/or testing. Produced water containing small amounts of oil previously discharged from the leaky tank may also be the source. The gas well itself is not suspected because the surface casing extends to a depth of 227 feet and is cemented back to the surface.

Produced water from the Manana Oil Mary Wheeler 1E gas well was collected from the fiberglass tank at the separator in September and October. Benzene values were 8,700 and 16,000 ppb and other aromatic hydrocarbons exceeded 1,000 ppb except for ethylbenzene. Total dissolved solids exceeded 34,000 mg/l (ppm) with chlorides about 20,000 mg/l.

In summary, the March, August, and October 1985 samplings detected no dissolved aromatic hydrocarbons in the monitor wells. With one exception, when such hydrocarbons were detected in the June and September samplings, air compressors had been used to clean the wells the previous day. Well M4, cleaned with a compressor in June but not in September, contained a very low level of toluene close to the detection limit at the time of the September sampling. This well was dry for the August and October samplings.

Conclusions

1) No verifiable contamination was detected in 1985 in either the unused water supply wells or the monitor wells except for low level contamination detected in samples taken within 24 hours of cleaning with an air compressor.

2) In wells S1 and M4 low levels of toluene near detection limits were found in one sampling, but the possibility of a sampling error cannot be ruled out.

3) The latest sampling for which results are available (October 1985), detected no hydrocarbons either in the monitor wells or in a composite of the water wells currently supplying the system.

4) Methane at concentrations 1200 times ambient levels was detected in the monitor well closest to the gas well in August. The source is likely the decay of shallow buried organic material. It may be from natural material, from gas well drilling and testing fluids, or from the leaked produced water. The gas well itself is not likely the source of methane since it has 227 feet of surface casing cemented back to the surface.

5) Ground water movement in the vicinity of the monitor wells in fall 1985 - winter 1986 was towards the river with a seepage velocity range of 3 to 4 feet per day. Ground water flow at this location is away from the currently used water supply wells.

6) Based on the available information, the produced water tank at the Manana Mary Wheeler 1E gas well, the gas well itself, and the dehydrator pit are all likely to have been within the zone of influence ("cone of depression") of the pumping S1 well at the time the water well was contaminated in February 1983. Actual pumping rates and pumping cycle information at the time of contamination would better define the extent of pumping well influence.

7) The distance between the water well S1 and the closest pit or tank at the gas well is 230 feet. The estimate of travel time for unretarded soluble contaminants to have moved that distance and reach the pumping water well is from 96 to 103 days.

8) The rate of ground water movement is such that a single plume of contaminated produced water originating in the vicinity of the gas well in 1983 has moved past the water well (S1). The current location and disposition of a plume is unknown because of the uncertainty of seasonal hydrologic conditions between the well field and river.

9) Because of the passage of time, water pumped from well S1 would not show contamination unless a zone of residual oil saturation is present at or near the produced water tank or other facilities. Extended pumping at 60 to 70 gpm in excess of 55 days would be required to detect by pumping any remaining oil present, since it would take at least that long for soluble constituents to travel 230 feet. Exploratory digging would also detect the zone, and it would define the extent of such a zone.

10) If residual oil is present, some soluble constituents will dissolve into ground water due to water level fluctuations and migrate towards the pumping well. These constituents are most likely to be purgeable aromatic hydrocarbons (i.e. benzenes, toluene, and xylenes). Whether these contaminants would actually reach the well, and what their concentrations would be, cannot be determined with the present information.

Recommendations and Proposed Future Work

1) To better define the hydrologic regimen at the site, the OCD intends to measure water levels and sample water quality of the monitor wells and other available wells through at least the fall of 1986. Spring-summer measurements, especially, will provide ground water movement data not yet available.

2) Well S5 should be capped to prevent introduction of contaminants. However both wells S1 and S5 should have caps that allow for access for periodic water level measurements, and pumping if necessary.

3) An aquifer test using well S1 as the pumped well should be performed for at least 72 hours at a rate of 60 gpm or at the rate the well would be pumped if put back in service. This test would determine accurate aquifer parameters and detect any contamination in the immediate vicinity of the well.

4) Since well S5 is at a distance of greater than 500 feet from the gas well and out of the direct path of ground water flow, it is unlikely that pumping S5 will cause capture of any remaining contaminants from the gas well location. To test this assumption, some additional ground water flow calculations should be performed using actual aquifer parameter data before placing S5 back in service.

5) To determine the presence and concentrations of any residual

oil (or any remaining free oil) between the gas well site and well S1, exploration digging with the backhoe is recommended, followed by immediate, witnessed sampling for purgeable and extractable hydrocarbons. The backhoe bucket should be cleaned prior to each use and all hydraulic lines should be checked for integrity. If residual oil is found, capture of soluble constituents is again a possibility and well No. 1 (S1) may again evidence contamination if pumped continually.

6) Sampling of individual pumping water supply wells for purgeable aromatic hydrocarbons should be performed on a regular basis. For convenience, a sampling schedule identical to that required for total trihalomethanes is initially suggested.

REPORT FIGURES

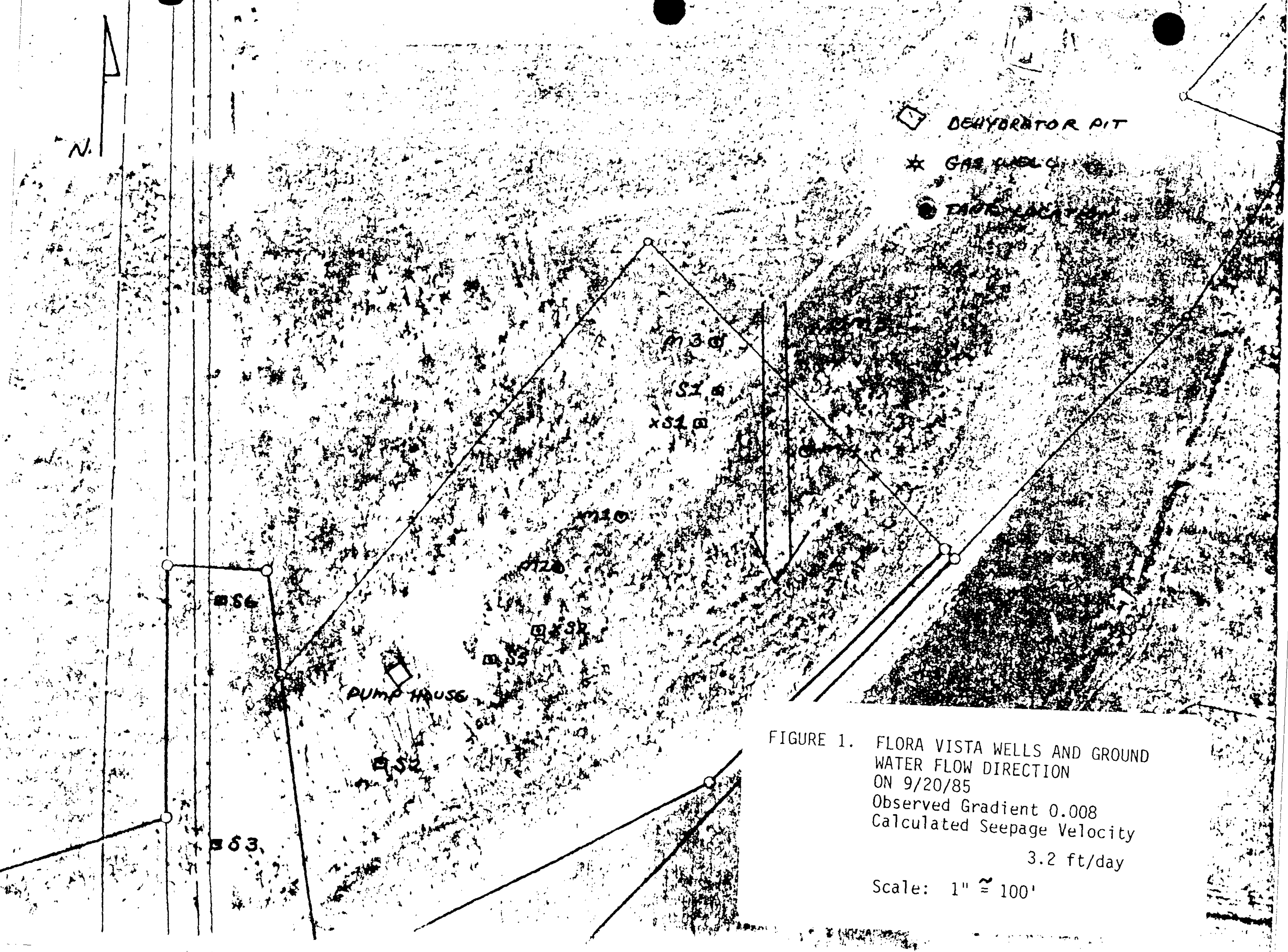


FIGURE 1. FLORA VISTA WELLS AND GROUND WATER FLOW DIRECTION ON 9/20/85
Observed Gradient 0.008
Calculated Seepage Velocity 3.2 ft/day
Scale: 1" ≅ 100'

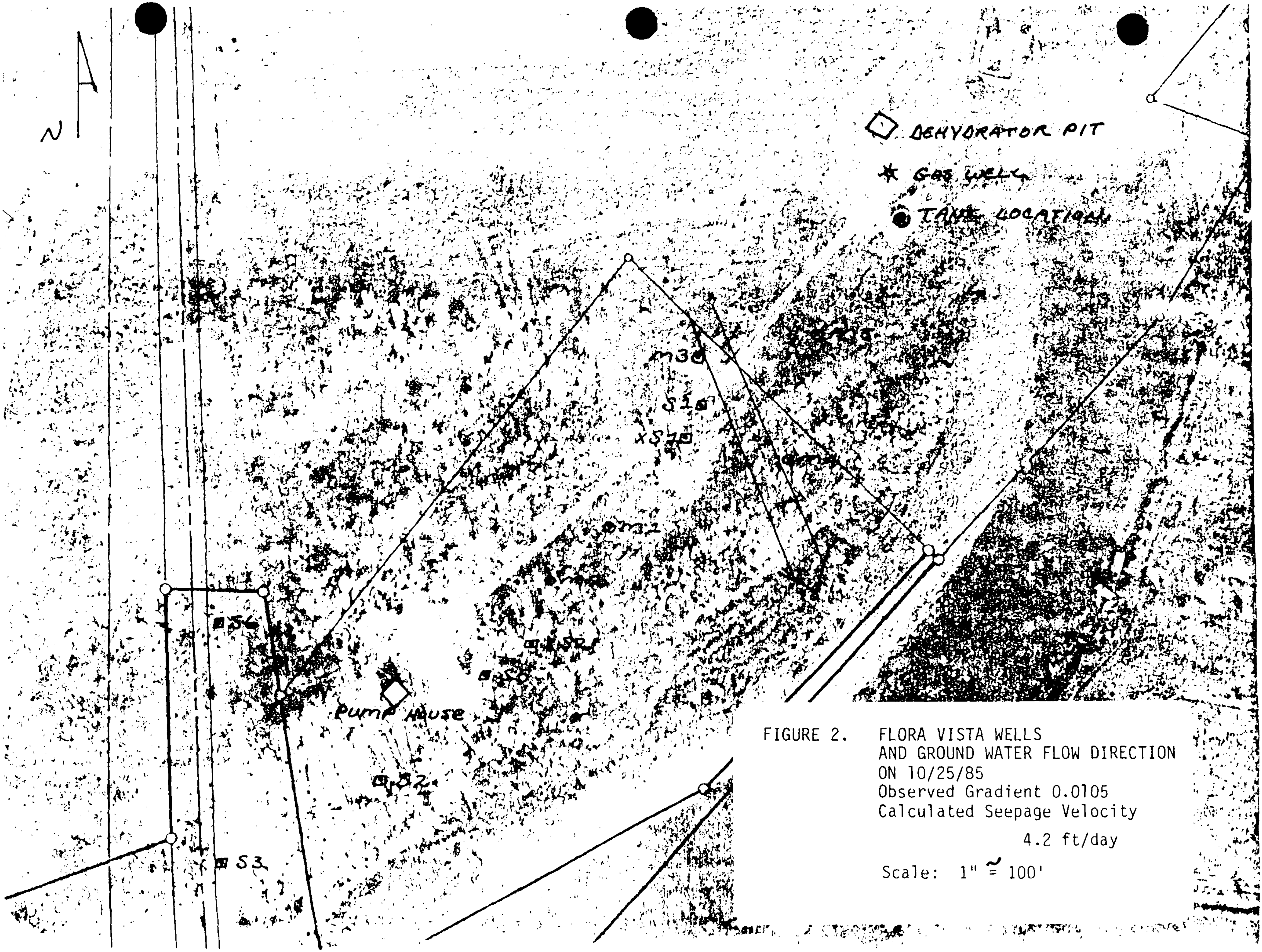


FIGURE 2. FLORA VISTA WELLS AND GROUND WATER FLOW DIRECTION ON 10/25/85
Observed Gradient 0.0105
Calculated Seepage Velocity
4.2 ft/day

Scale: 1" ≃ 100'

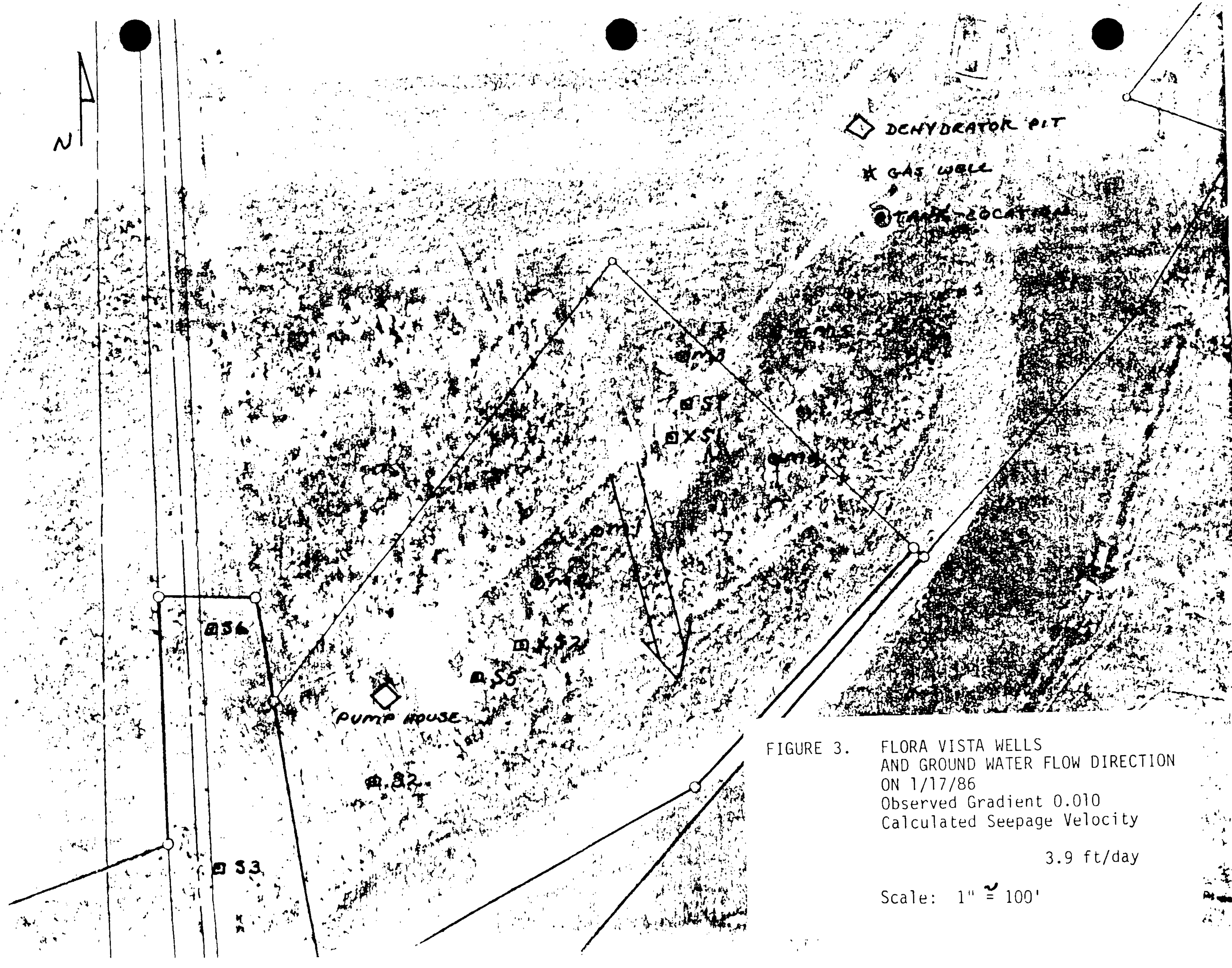


FIGURE 3. FLORA VISTA WELLS
AND GROUND WATER FLOW DIRECTION
ON 1/17/86
Observed Gradient 0.010
Calculated Seepage Velocity

3.9 ft/day

Scale: 1" ≈ 100'

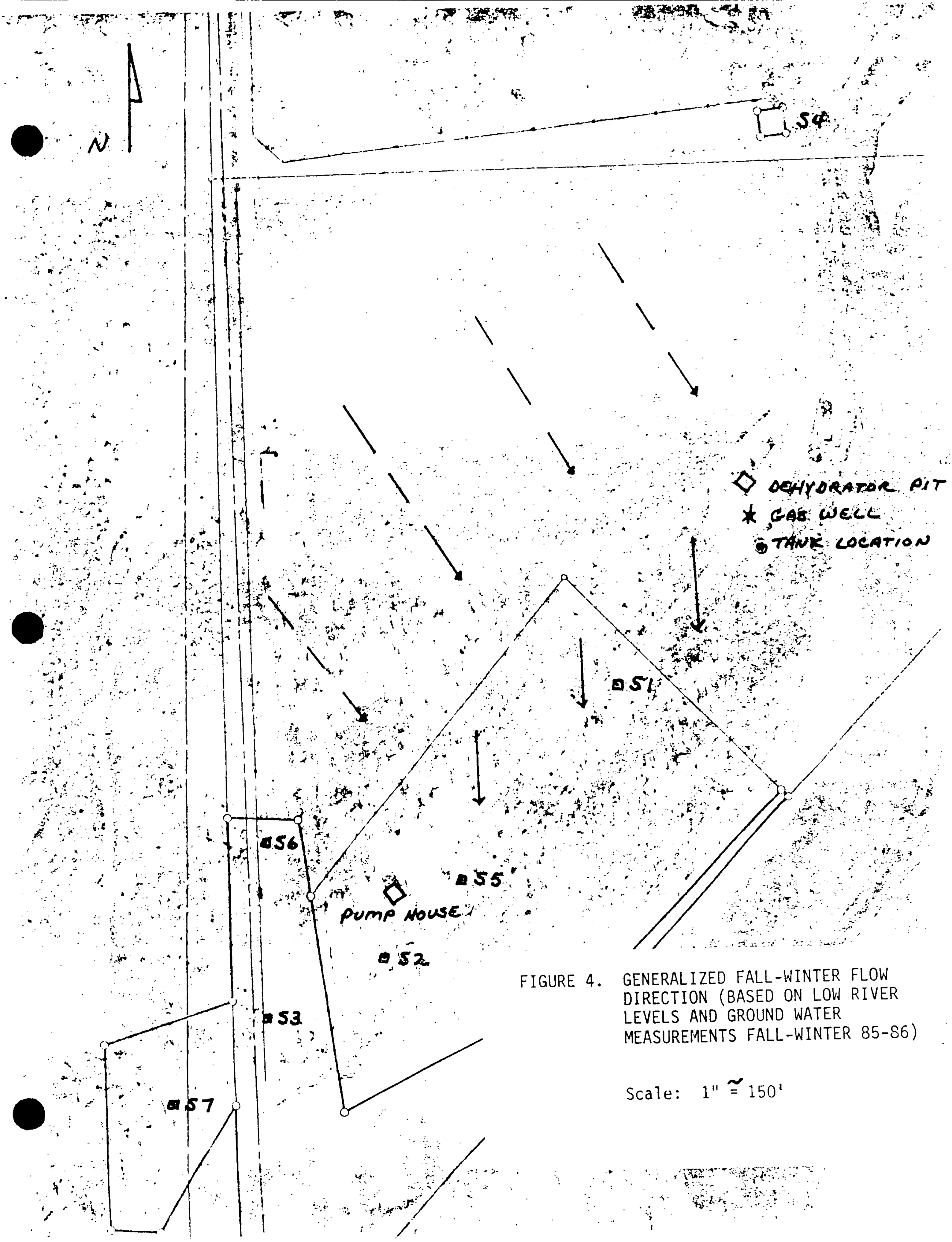


FIGURE 4. GENERALIZED FALL-WINTER FLOW DIRECTION (BASED ON LOW RIVER LEVELS AND GROUND WATER MEASUREMENTS FALL-WINTER 85-86)

Scale: 1" ≅ 150'

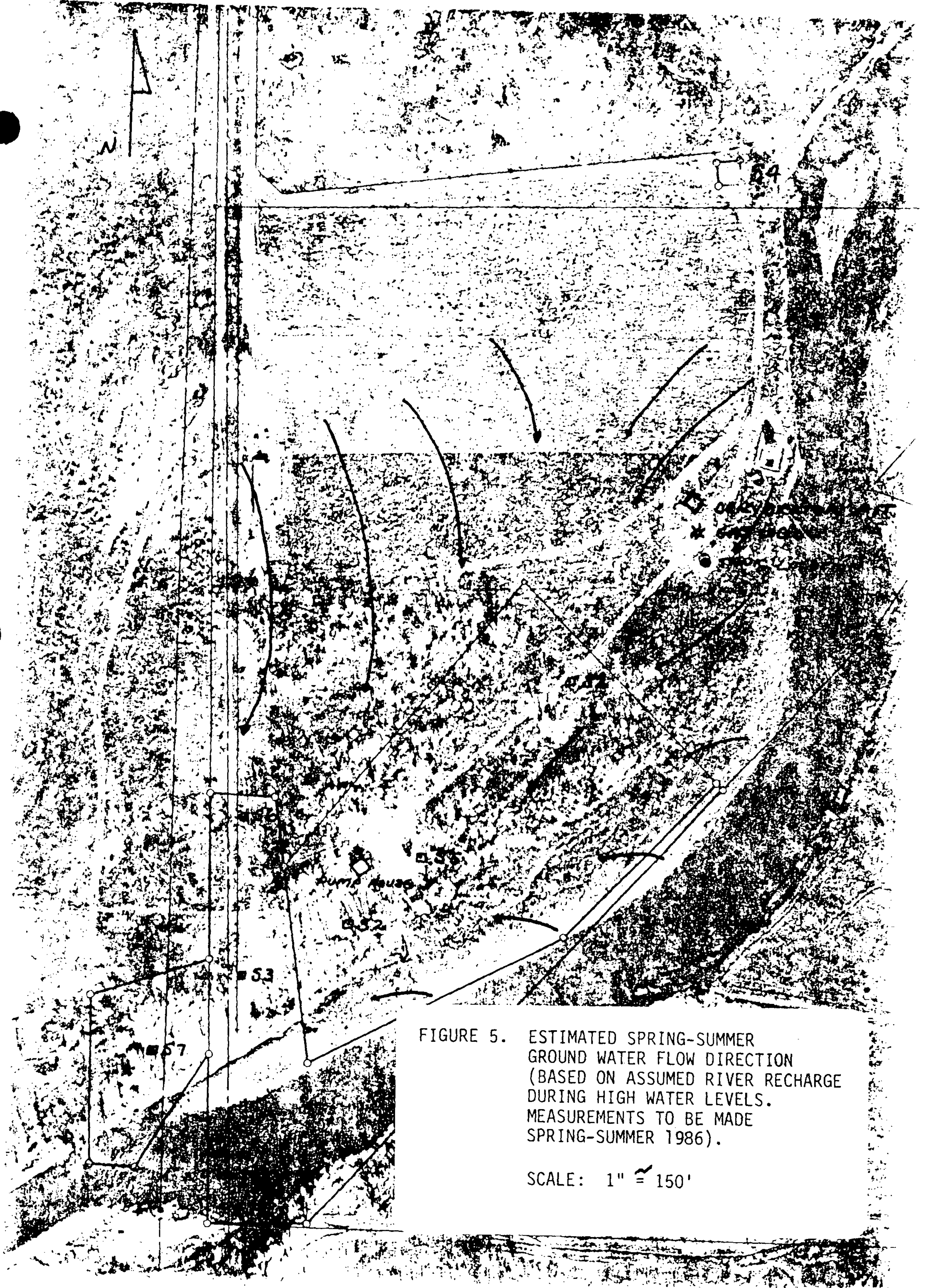


FIGURE 5. ESTIMATED SPRING-SUMMER GROUND WATER FLOW DIRECTION (BASED ON ASSUMED RIVER RECHARGE DURING HIGH WATER LEVELS. MEASUREMENTS TO BE MADE SPRING-SUMMER 1986).

SCALE: 1" = 150'

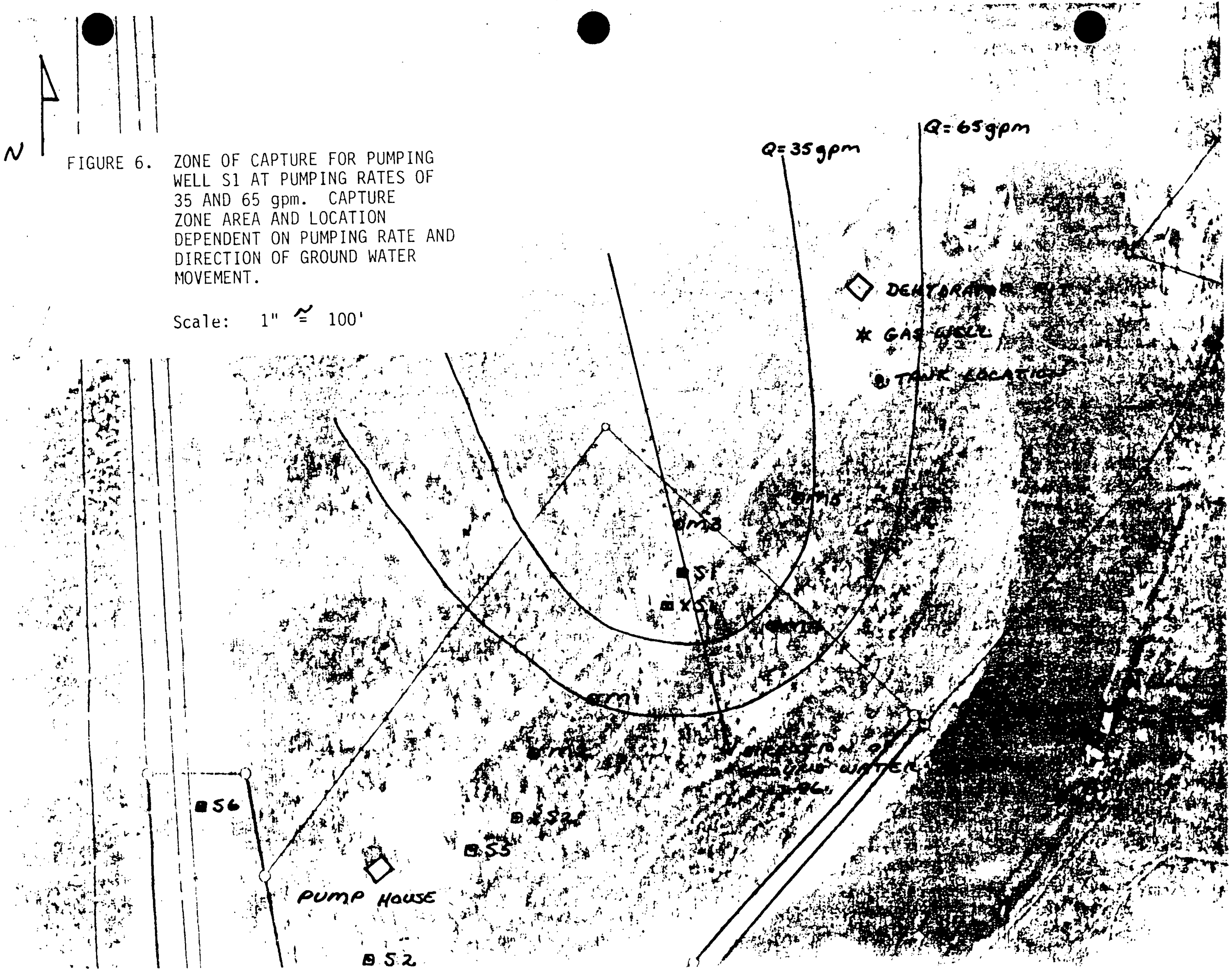


FIGURE 6. ZONE OF CAPTURE FOR PUMPING WELL S1 AT PUMPING RATES OF 35 AND 65 gpm. CAPTURE ZONE AREA AND LOCATION DEPENDENT ON PUMPING RATE AND DIRECTION OF GROUND WATER MOVEMENT.

Scale: 1" ≃ 100'

REPORT TABLES

09364500 ANIMAS RIVER AT FARMINGTON, NM
(National stream-quality accounting network station)

LOCATION.--Lat 36°43'17", long 108°12'05", in SW¼SW¼ sec.15, T.29 N., R.13 W., San Juan County, Hydrologic Unit 14080104, in Boyd City Park, on right bank 900 ft upstream from bridge on Miller Ave., 0.4 mi downstream from bridge on U.S. Highway 64 in Farmington, and 1.5 mi upstream from mouth.

DRAINAGE AREA.--1,360 mi^2, approximately.

WATER-DISCHARGE RECORDS

PERIOD OF RECORD.--June 1904 to October 1905 (published as "near Farmington"), September 1912 to current year. Monthly discharge only for some periods, published in WSP 1313.

REVISED RECORDS.--WSP 1243: 1931. WSP 1313: 1913.

GAGE.--Water-stage recorder. Altitude of gage is 5,280 ft, from topographic map. Prior to Nov. 1, 1905, non-recording gage at old bridge 0.1 mi upstream at different datum. Sept. 17, 1912, to Oct. 4, 1938, water-stage recorder at site 0.8 mi downstream at lower datums (datum lowered 2.0 ft Aug. 15, 1927, and raised 0.2 ft Dec. 16, 1929). Oct. 5, 1938 to Nov. 1, 1973 at site 900 ft downstream at datum 1.74 ft lower.

REMARKS.--Water-discharge records good except those for winter period, which are fair. Diversions for irrigation of about 30,000 acres above station.

AVERAGE DISCHARGE.--72 years, 916 ft^3/s, 663,600 acre-ft/yr.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, about 25,000 ft^3/s June 29, 1927, gage height, 8.5 ft, site and datum then in use, from rating curve extended above 10,000 ft^3/s; minimum, 1.0 ft^3/s Aug. 11, 1972.

EXTREMES OUTSIDE PERIOD OF RECORD.--Maximum flood occurred Oct. 6, 1911, when a stage of about 16.5 ft was reached (datum in use Oct. 1938 to Nov. 1973). Flood of Sept. 6, 1909, reached a stage of 11.1 ft, 1904-5 site and datum (discharge, about 19,000 ft^3/s).

EXTREMES FOR CURRENT YEAR.--Peak discharges above base of 4,000 ft^3/s and maximum (*):

Date	Time	Discharge (ft^3/s)	Gage height (ft)	Date	Time	Discharge (ft^3/s)	Gage Height (ft)
May 31	2330	*6320	8.59	Aug. 6	0100	5320	8.31
June 25	0330	5920	8.61				

Minimum daily discharge, 268 ft^3/s Sept. 20.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1982 TO SEPTEMBER 1983
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	858	411	432	345	353	564	692	1780	5810	3610	1260	421
2	890	409	415	341	336	510	652	1540	5250	3470	1270	406
3	790	411	395	346	332	508	636	1400	4370	3430	1390	442
4	746	389	385	385	353	593	652	1330	3630	3560	1320	400
5	710	396	405	391	365	633	660	1300	3640	3480	1230	379
6	656	390	380	390	330	498	572	1480	3650	3310	1810	349
7	592	390	388	355	298	468	588	1760	3570	3150	1330	343
8	554	380	384	369	296	465	561	1870	3740	3180	1430	345
9	535	395	411	376	308	481	527	1730	3810	2930	1280	387
10	511	462	553	358	311	503	559	2030	3510	2840	1150	385
11	499	450	544	365	302	548	555	2610	3340	2670	1090	353
12	491	444	481	376	317	611	573	2980	3920	2290	1080	335
13	448	395	432	365	328	647	630	2770	3930	2070	972	308
14	430	390	404	367	335	678	672	2340	3120	1860	859	297
15	429	390	396	370	336	830	645	2160	2730	1740	801	303
16	436	370	374	373	319	703	591	1900	2920	1590	757	293
17	455	370	382	376	341	606	602	1720	3190	1500	648	304
18	471	405	400	380	336	604	646	1620	3730	1470	547	278
19	464	405	391	366	341	597	783	1490	4610	1480	536	270
20	442	434	366	352	341	553	923	1450	5410	1570	607	268
21	430	428	363	350	345	490	1030	1470	5310	1530	504	275
22	398	405	373	351	345	500	1020	1360	5330	1520	471	295
23	387	387	423	335	390	580	1060	1430	5160	1610	435	312
24	389	390	416	328	444	540	1220	1950	5140	1690	414	326
25	387	374	367	332	468	540	1600	2660	5540	1660	415	302
26	384	377	339	330	504	548	1970	3900	4930	1810	466	304
27	425	371	348	318	480	556	1950	4210	4520	2110	473	298
28	437	371	325	321	492	528	1810	4940	4270	1690	579	309
29	407	385	306	341	---	522	1720	5510	3760	1430	480	322
30	403	385	288	334	---	556	1770	5460	3680	1360	466	392
31	404	---	336	321	---	660	---	5800	---	1340	433	---
TOTAL	15858	11959	12202	11007	10046	17620	27869	75950	125520	68950	26503	10001
MEAN	512	399	394	355	359	568	929	2450	4184	2224	855	333
MAX	890	462	553	391	504	830	1970	5800	5810	3610	1810	442
MIN	384	370	288	318	296	465	527	1300	2730	1340	414	268
AC-FT	31450	23720	24200	21830	19930	34950	55280	150600	249000	136800	52570	19840

CAL YR 1982 TOTAL 364553 MEAN 999 MAX 3660 MIN 209 AC-FT 723100
WTR YR 1983 TOTAL 413485 MEAN 1133 MAX 5810 MIN 268 AC-FT 820100

TABLE 4. Flow of Animas River at Farmington, 1983 Water Year
(Source: USGS Water Resources Data, New Mexico, W.Y. 1983)

TABLE 5. SUMMARY OF FORMULAS USED IN CALCULATIONS

1) Seepage velocity using Darcy's Law:

$$v = \frac{K}{n} i$$

Where: K = Permeability (K = 750 gallons/day/ft^2 from Ranney report to Brewer & Assoc.)

n = Porosity (N = 0.25 assumed value for sand/gravel)

i = measured gradient (i = change in water level elevation per unit distance)

Reference: Todd, Eq. 3.21.

2) Drawdown using Theis non-equilibrium formula:

$$s = \frac{Q}{4\pi T} W(u) \text{ where } u = \frac{r^2 S}{4Tt}$$

Where: Q = pumping rate (Q = 35 gallons per minute, or Q = 65 gpm)

T = Transmissivity (T = Kb where K is permeability, b = saturated aquifer thickness = 17 feet from Ranney report; T = 12750 gpd/ft)

r = distance (from well to produced water tank, r = 230 feet)

S = storage coefficient (S = 0.2 for water table conditions)

t = time of pumping (t = 100 days for example used here)

Reference: Todd, Eq. 4.38, 4.36.

3) Zone of capture in a uniform flow field under steady state conditions:

a) Boundary equation: $-\frac{y}{x} = \tan\left(\frac{2\pi Kbi}{Q} y\right)$

b) y - Limit: $y_L = \pm \frac{Q}{2Kbi}$

c) x - Limit: $x_L = -\frac{Q}{2\pi Kbi}$

TABLE 5. (con't)

Reference: Todd, Eq. 4.31 to 4.33.

4) Time of transport to pumping well:

a) $$t = \sum_{j} \left[\frac{n \Delta r_j^2}{K \Delta s_j} \right]$$

Where: Δs = change in drawdown over distance, Δr, moving towards pumping well.

b) $$\Delta s_j = \Delta s_Q \log \frac{r_{j+1}}{r_j}$$

Where: Δs_Q = change in drawdown over one log cycle of distance for given Q.
$\Delta s_{35} = 1.45, \Delta s_{65} = 2.70$

Reference: Todd, Eq 3.23; Johnson Eq. 8, p. 123

References

Johnson Division , UOP Inc., "Ground Water and Wells", 2nd ed. Edward E. Johnson, St. Paul, Minn. 440 pp, 1972.

Ranney Method Western Corporation, "Ranney Collector Water Supply, Flora Vista Water Users Association, Flora Vista New Mexico", 4p., tables, 10/28/81.

Todd, D. K., Groundwater Hydrology, 2nd ed. John Wiley & Sons, NY, 535 p. 1980.

APPENDIX C
OCD Final Report

E6/002

FINAL REPORT ON
FLORA VISTA CONTAMINATION STUDY

OCTOBER, 1986

NEW MEXICO OIL CONSERVATION DIVISION

2) Samples were taken from the water supply and monitor wells for organic analyses in March, June, August, September, and October, 1985. The results are shown in Tables 1 and 2. Results of samples from the fiberglass separator tank at the Mary Wheeler No. 1E gas well are shown in Table 3. Inorganic analyses were run on the water supply wells (including the previously contaminated well) and the Animas River in March, and the produced water from the gas well in October.

3) As expected, several monitor wells filled with sand and were cleaned twice using compressed air from two different compressors. The use of these compressors apparently affected the water quality as discussed below.

4) In September all monitor and supply wells were surveyed by Brewer and Associates for both location and elevation. Several well elevations were resurveyed in October. Blueprints from recent aerial photos were received in late December. Water levels were measured in September and October, 1985.

A summary of work performed in 1986 follows:

1) Water levels were measured in January, February, April and May. These are shown in Figures 3 to 6.

2) Samples from the monitoring wells for water quality analysis were taken in January, and April. The contaminated well was sampled in April and May. The water system was sampled for organics in January, April and May. The new fiberglass tank at the Mary Wheeler 1E oil storage tank (used to collect water drained from that tank) was sampled in April and May. The 55-gallon drum at the El Paso Natural Gas dehydrator unit was sampled in January and February. The results of organic analyses of these samples are shown in Tables 1 to 4. Inorganic analyses were run on samples from the contaminated water well in April, and from the dehydrator barrel in February. Discussion on the results is presented in the section on water quality.

3) A 72-hour aquifer test was performed on the contaminated well between April 21 and 25. The test consisted of water level measurements from the pumped well and monitor wells on April 21, 48 hours of pumping April 22-24, and 24 hours of recovery April 24-25. Approximately 5 hours into the test, oil was drawn into the well. The results of this test are discussed in detail in the hydrogeology and water quality sections.

4) A second, short duration test was performed in May to better characterize the volume and nature of the oil. These results are also presented below.

5) A study progress report was prepared in January.

Hydrogeology

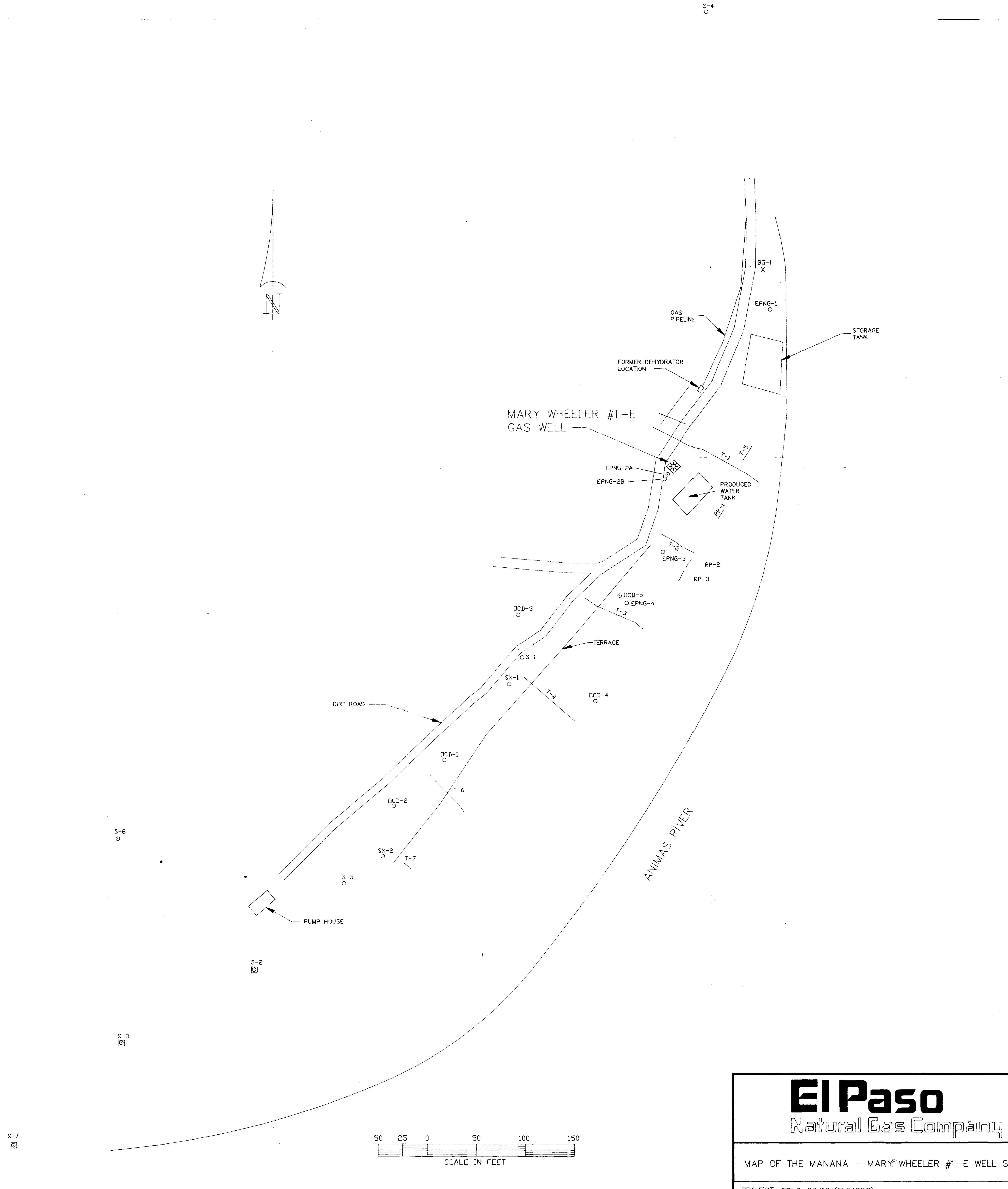
The valley of the Animas River contains alluvium consisting mainly of sand and gravel which is outwash material from Pleistocene glaciers in the San Juan Mountains in Colorado. In the vicinity of the Flora Vista wells this alluvium is about 22 to 25 feet thick. Examination of the aerial photograph blueprints provided by Brewer & Associates shows old river channels and meanders in the flood plain. Finer grained silts and clays can be expected to have been deposited in low velocity areas such as point bars and areas of overbank flooding. However, the area where the monitor wells were drilled was found to be a zone of very coarse sand and gravel with some rocks exceeding a foot in diameter.

The presence of a coarse sand and gravel zone usually indicates high ground water permeability. Examination of the pumping level estimates provided in the 1982 EID community water system environmental survey, together with a 1982 Brewer and Associates infiltration gallery feasibility study shows an aquifer permeability of about 750 gallons per day per square foot, or 100 feet per day. This was confirmed by the aquifer test conducted in April. The value is at the lower end of the range for clean sand and gravel mixtures, but still allows for rapid ground water movement.

In September and October, 1985, ground water levels were measured in those monitoring wells where fluid levels were present. The results were used to calculate the direction of ground water flow and the hydraulic gradient. The gradient values were 0.0080 and 0.0081, respectively, or about 43 feet per mile. These values are intermediate between the average river gradient at Flora Vista of 0.004 and the topographic gradient of 0.014 perpendicular to the river at the well field location. The 1986 water levels, measured in January, February, April, and May, showed gradients of 0.0080, 0.0086 and 0.0079, and 0.0071 respectively. The average of the six measured values is 0.0080 or about 42 feet per mile.

The 1985 ground water flow directions are shown on Figures 1 through 2. The direction in September is slightly east of south. By late October, the direction had changed to nearly 20° east of south and continued that direction through January and February (Figures 3 and 4). The April and May measurements (Figure 5 and 6) again show the direction of flow as slightly east of south.

Some reasons for these observed changes in the ground water flow direction may be postulated based on surface and ground water interaction in the area. When river flows are generally low, as in the fall and winter, water stored in the permeable alluvial material in the immediate vicinity of the river during times of spring and summer high flows is discharged back into the river. Additional ground water discharge to the river comes from sources to the northwest of the well field including ground water recharged to the alluvium from the Flora Vista Arroyo, the Halford Independent Ditch, the Farmers Ditch,



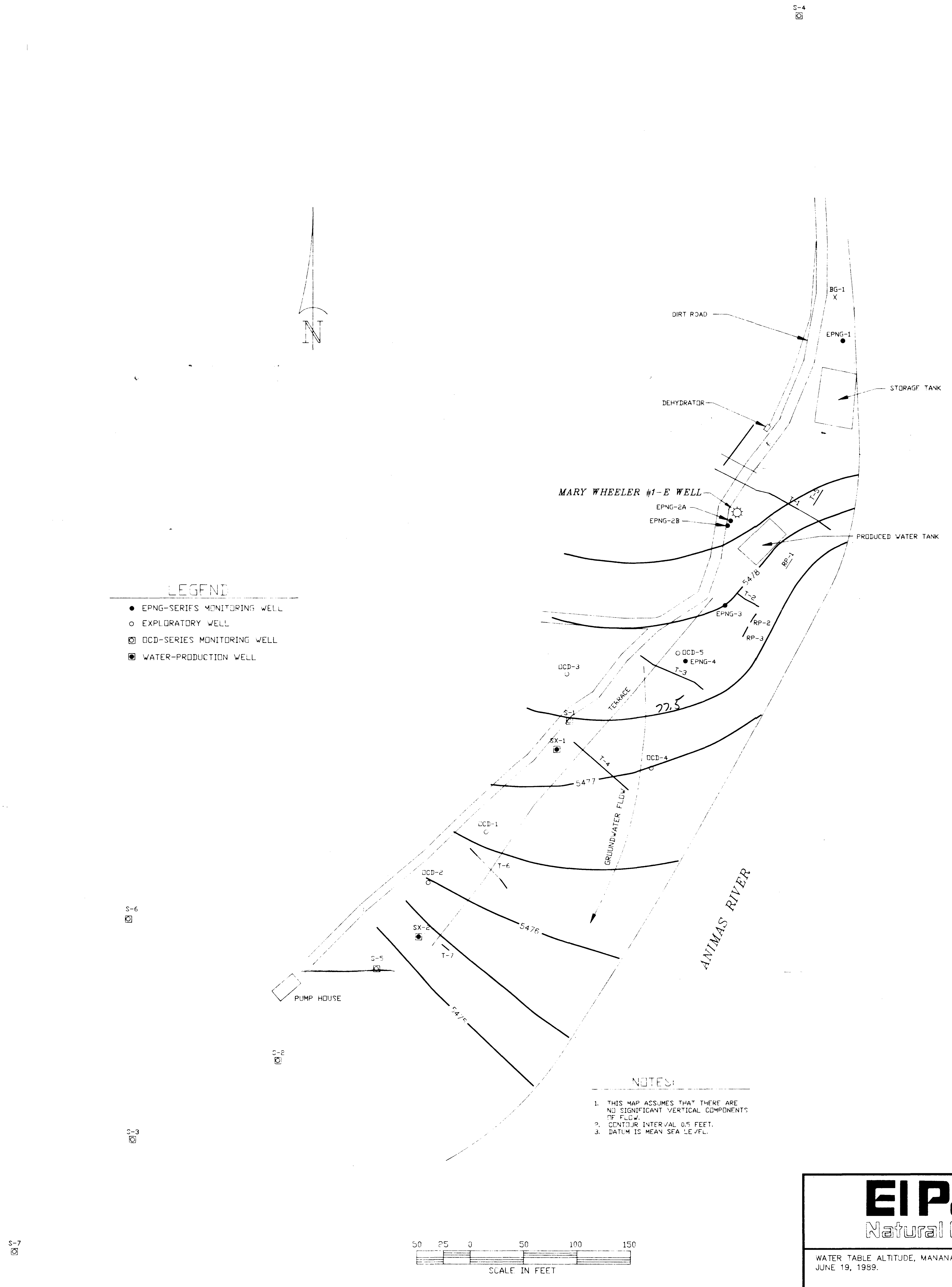
El Paso
Natural Gas Company

MAP OF THE MANANA – MARY WHEELER #1-E WELL SITE.

PROJECT: EPNG-63712 (FLOADDS)
LOCATION: FLORA VISTA, NEW MEXICO

K.W. BROWN
&
ASSOCIATES, INC.

DATE: 9-13-89
PLATE: 1
SCALE: AS SHOWN



LEGEND

- ● EPNG-SERIES MONITORING WELL
- ○ EXPLORATORY WELL
- ▣ OCD-SERIES MONITORING WELL
- ▣ WATER-PRODUCTION WELL

NOTES:

1. THIS MAP ASSUMES THAT THERE ARE NO SIGNIFICANT VERTICAL COMPONENTS OF FLOW.
2. CONTOUR INTERVAL 0.5 FEET.
3. DATUM IS MEAN SEA LEVEL.

El Paso
Natural Gas Company

WATER TABLE ALTITUDE, MANANA – MARY WHEELER #1-E WELL SITE, JUNE 19, 1989.

PROJECT: EPNG-63712 (FLOADDS)
LOCATION: FLORA VISTA, NEW MEXICO

K.W. BROWN & ASSOCIATES, INC.	DATE: 9-13-89 PLATE: 2 SCALE: 1"=50'

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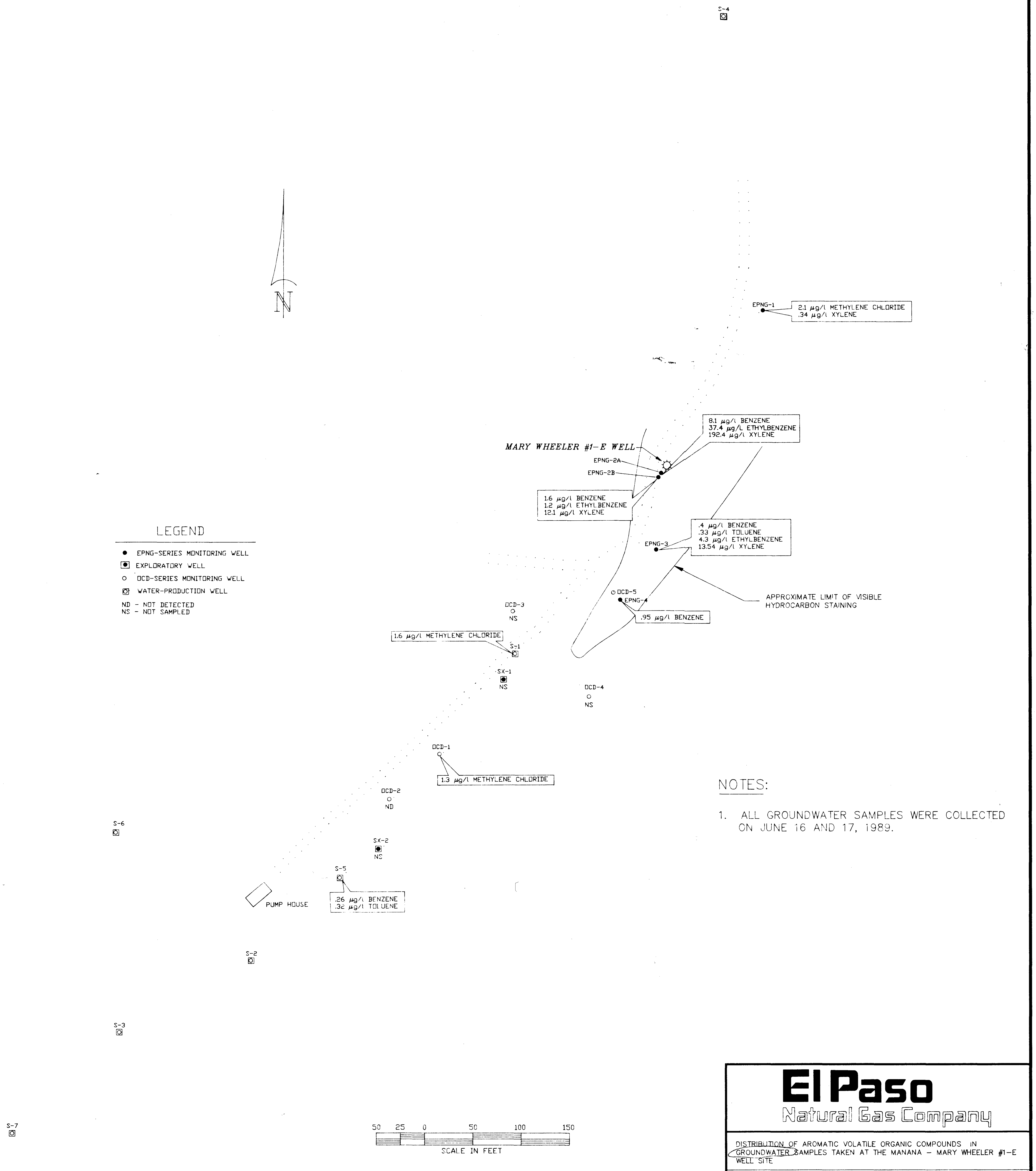
SANTA FE



NOTES:

1. ALL GROUNDWATER SAMPLES WERE COLLECTED ON JUNE 16 AND 17, 1989.

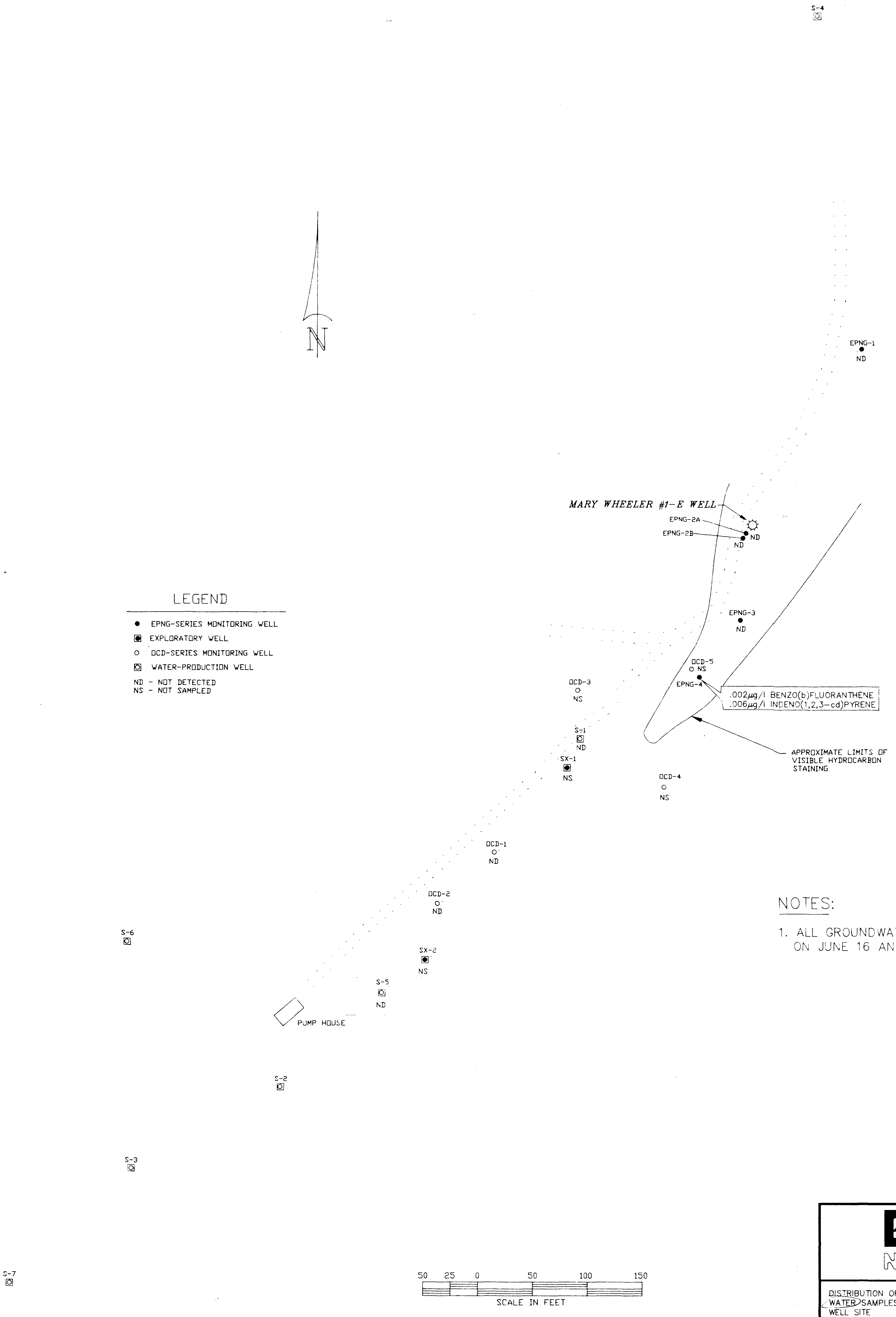
El Paso
Natural Gas Company

DISTRIBUTION OF AROMATIC VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER SAMPLES TAKEN AT THE MANANA – MARY WHEELER #1-E WELL SITE

PROJECT: 63712 EPNG–FLORA VISTA (FLOADDS)
LOCATION: FLORA VISTA, NEW MEXICO

K.W. BROWN & ASSOCIATES, INC.	DATE: 9–14–89 PLATE: 3 SCALE: AS SHOWN

RECEIVED
OCT - 2 1989
OIL CONSERVATION DIV.
SANTA FE



NOTES:

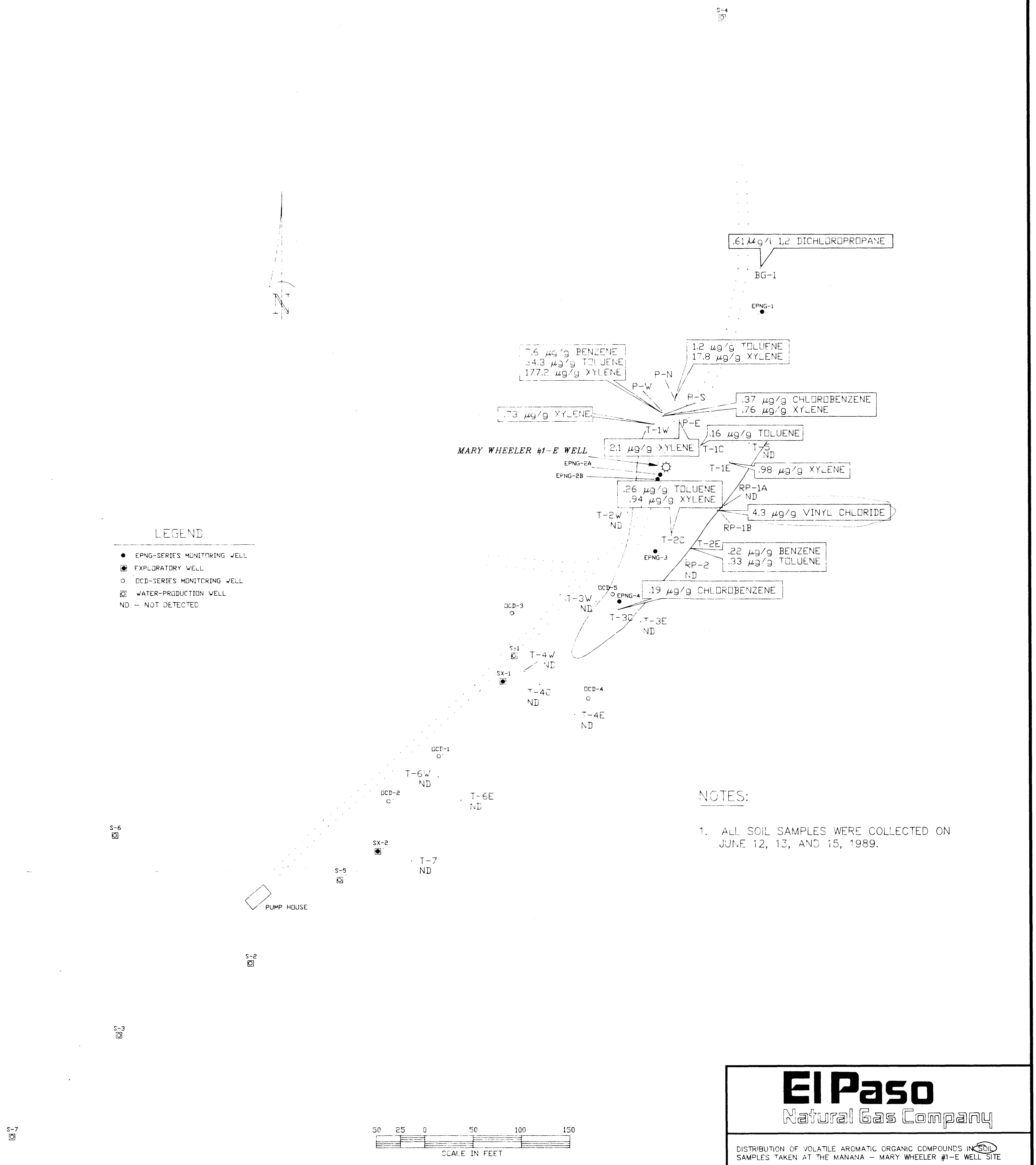
1. ALL GROUNDWATER SAMPLES WERE COLLECTED ON JUNE 16 AND 17, 1989.

El Paso
Natural Gas Company

DISTRIBUTION OF POLYNUCLEAR AROMATIC HYDROCARBONS IN GROUND-WATER SAMPLES TAKEN AT THE MANANA - MARY WHEELER #1-E WELL SITE

PROJECT: 63712 EPNG-FLORA VISTA (FLOADDS2)
LOCATION: FLORA VISTA, NEW MEXICO

K.W. BROWN & ASSOCIATES, INC.	DATE: 9-14-89
	PLATE: 4
	SCALE: AS SHOWN



NOTES:

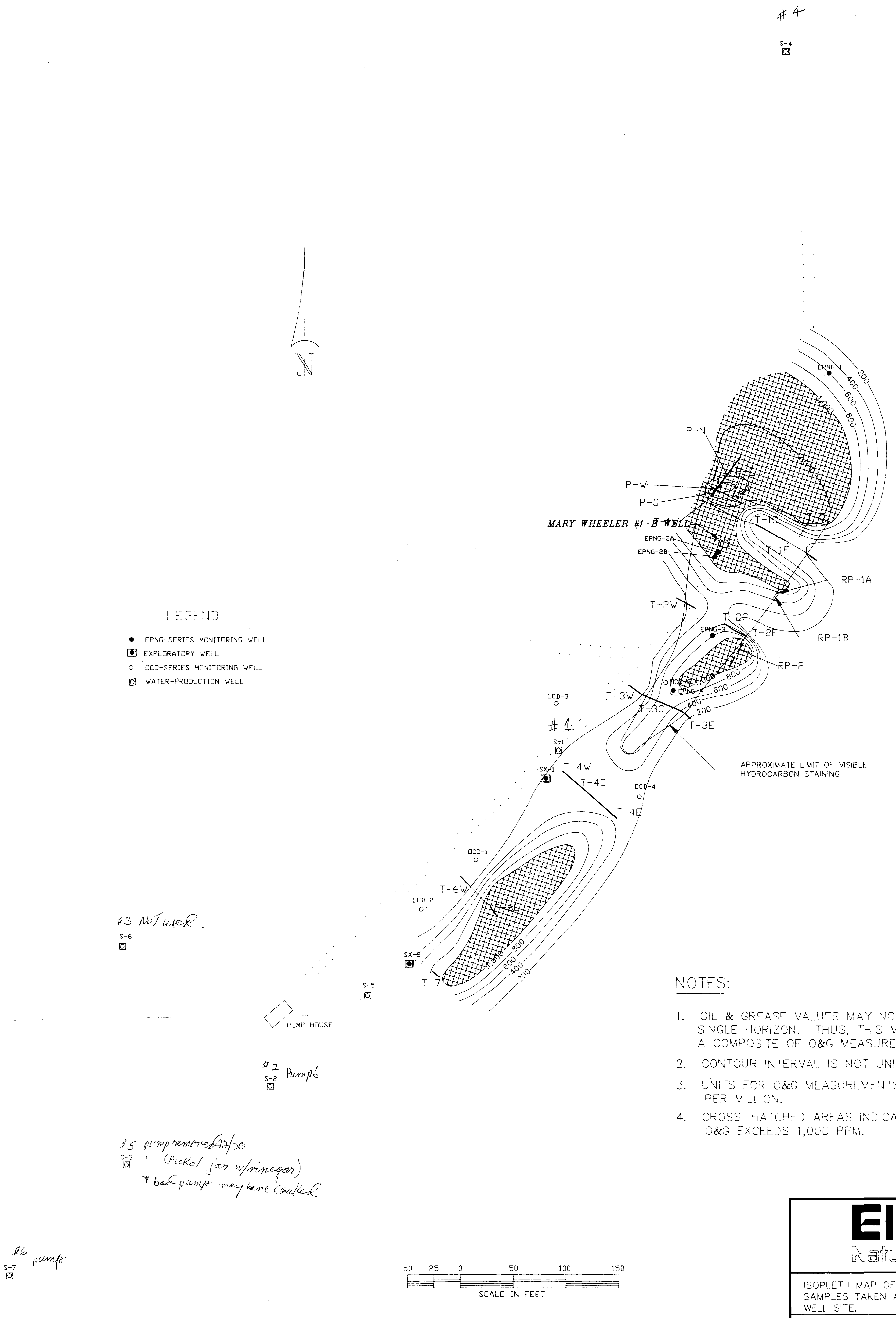
1. ALL SOIL SAMPLES WERE COLLECTED ON JUNE 12, 13, AND 15, 1989.

El Paso
Natural Gas Company

DISTRIBUTION OF VOLATILE AROMATIC ORGANIC COMPOUNDS IN [✓ SOIL] SAMPLES TAKEN AT THE MANANA – MARY WHEELER #1-E WELL SITE

PROJECT: 63712 EPNG-FLORA VISTA
LOCATION: FLORA VISTA, NEW MEXICO

K.W. BROWN & ASSOCIATES, INC.	DATE: 9-14-89 PLATE: 5 SCALE: AS SHOWN



#5 pump removed 12/20
(Pickel jar w/vinegar)
bad pump may have leaked

LEGEND

- ● EPNG-SERIES MONITORING WELL
- ▣ EXPLORATORY WELL
- ○ OCD-SERIES MONITORING WELL
- ▣ WATER-PRODUCTION WELL

NOTES:

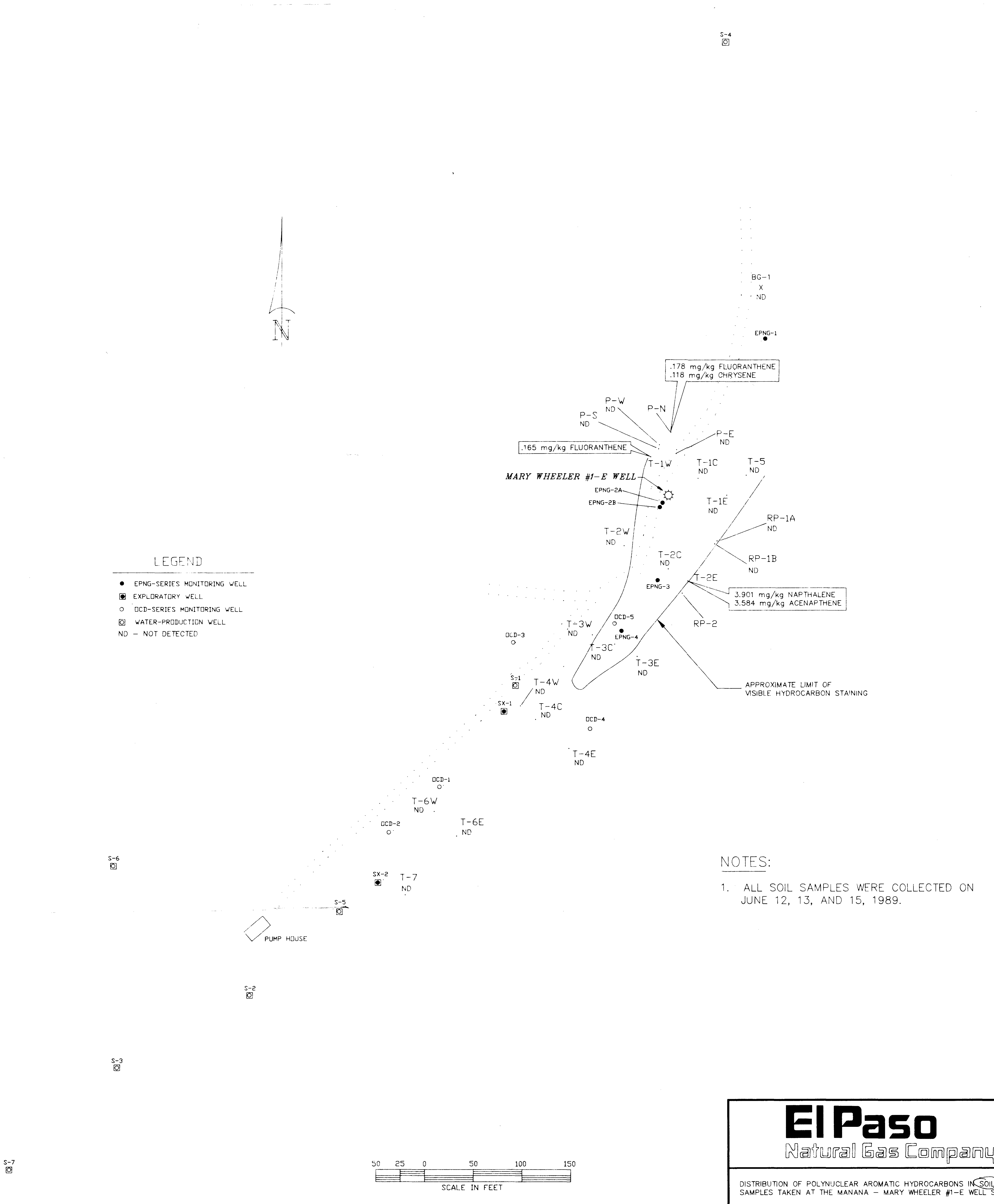
1. OIL & GREASE VALUES MAY NOT APPLY TO A SINGLE HORIZON. THUS, THIS MAP REPRESENTS A COMPOSITE OF O&G MEASUREMENTS.
2. CONTOUR INTERVAL IS NOT UNIFORM.
3. UNITS FOR O&G MEASUREMENTS ARE PARTS PER MILLION.
4. CROSS-HATCHED AREAS INDICATE REGIONS WHERE O&G EXCEEDS 1,000 PPM.

El Paso
Natural Gas Company

ISOPLETH MAP OF OIL & GREASE CONCENTRATION IN SOIL SAMPLES TAKEN AT THE MANANA – MARY WHEELER #1–E WELL SITE.

PROJECT: 63712 EPNG–FLORA VISTA (FLOADDS)
LOCATION: FLORA VISTA, NEW MEXICO

K.W. BROWN & ASSOCIATES, INC.	DATE: 9–14–89
	PLATE: 6
	SCALE: AS SHOWN



NOTES:

1. ALL SOIL SAMPLES WERE COLLECTED ON JUNE 12, 13, AND 15, 1989.

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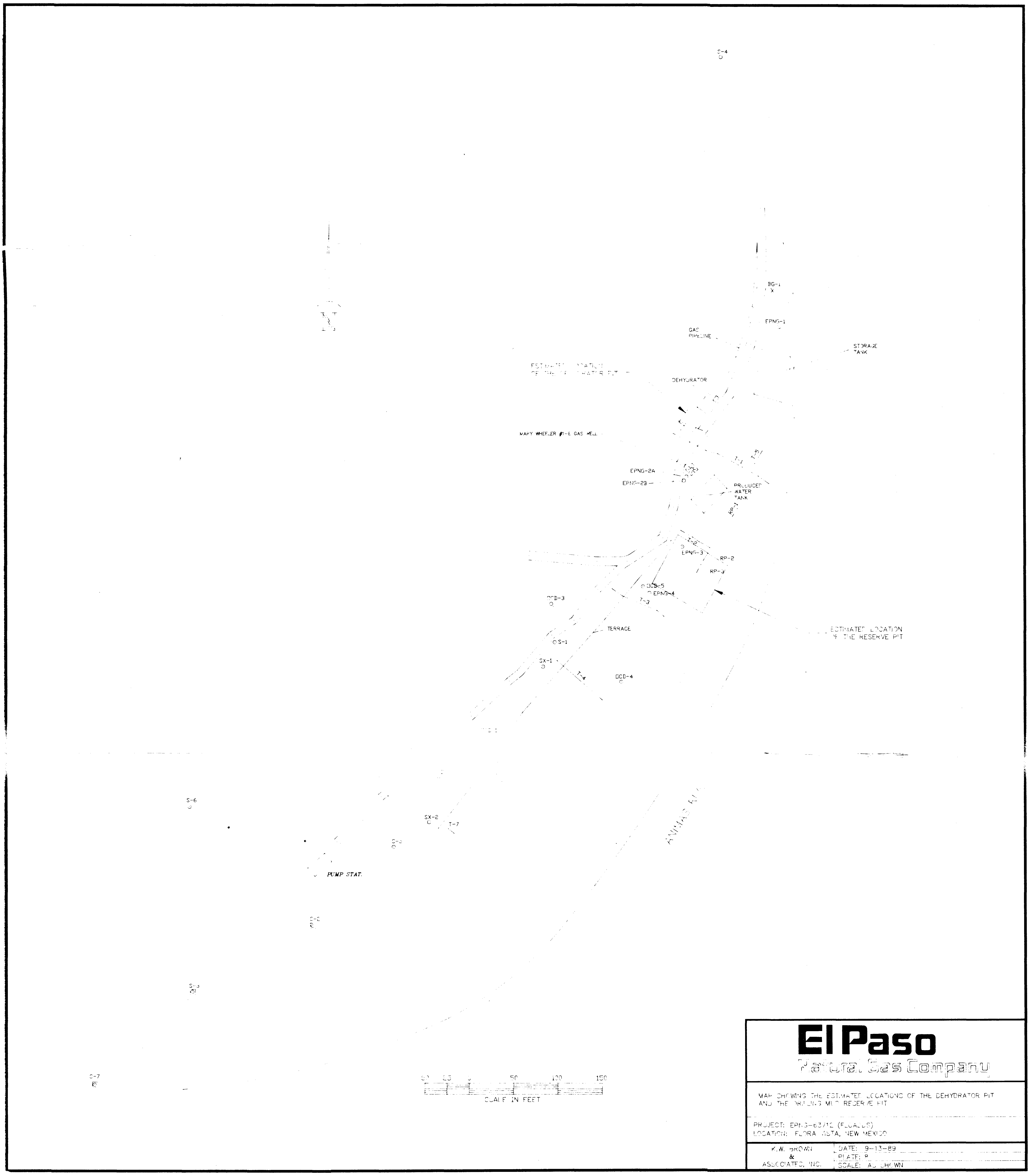
DISTRIBUTION OF POLYNUCLEAR AROMATIC HYDROCARBONS IN SOIL SAMPLES TAKEN AT THE MANANA - MARY WHEELER #1-E WELL SITE

PROJECT: 63712 EPNG-FLORA VISTA (FLOADDS2)
LOCATION: FLORA VISTA, NEW MEXICO

K.W. BROWN & ASSOCIATES, INC.	DATE: 9-14-89 PLATE: 7 SCALE: AS SHOWN



El Paso
Natural Gas Company

MAP SHOWING THE ESTIMATED LOCATIONS OF THE DEHYDRATOR PIT AND THE DRILLING MUD RESERVE PIT

PROJECT: EPNG-63712 (FLOALDS)
LOCATION: FLORA VISTA, NEW MEXICO

K.W. BROWN & ASSOCIATES, INC.	DATE: 9-13-89 PLATE: 8 SCALE: AS SHOWN

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