Final Technical Report

Analysis of Source and Extent of Subsurface Oil Plume, San Marcos River Seep Site, Guadalupe County, Texas (RRC Site No. 01-51021)

by

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SUMMARY

A seep on the south bank of the San Marcos River, about 5 mi west of Luling, Texas, in the Luling-Branyon Oil Field is the discharge point of a subsurface plume of oil and saltwater. This investigation was to build on previous operator-sponsored attempts to identify the source of oil and map the extent of the oil plume in 2 weeks of field work. This effort provided:

- demarcation of the oil plume to an area of about 100 ft × 220 ft (~33,000 ft^2) adjacent to the seep;
- an improved map of the water table for inferring direction of oil movement, drawn on the basis of water-level measurements at 12 sites and an elevation survey;
- five new monitoring wells for water-level measurements and later use in fluid sampling and subsurface remediation;
- 10 archived subsurface cores of the oil-bearing zone;
- analysis of total petroleum hydrocarbons (TPH) compared with 1993 data; and
- a detailed map of producing, shut-in, and abandoned oil wells and monitoring wells, created with global positioning system (GPS) field data overlain on a digital photograph in a geographical information system (GIS).

No proof was found of an existing source within or adjacent to the oil plume. The most obvious candidate, an oil pipeline, had been tested in 1993

under RRC supervision. At the start of this study it was assumed that the pipeline was not the source of the oil, and the focus of work was to identify a more distant, less obvious source. The pipeline had been eliminated from consideration because of negative findings from the shallow excavation and the 2-day pressure test in 1993. A hypothetical pipeline source by itself would not account for the saltwater at the seep or elevated petroleum contaminant vapors elsewhere at the site. Other possible sources within the footprint of the plume, such as one or more undocumented abandoned wells or a natural fault zone, are unlikely but not readily disproven. This study, however, provides a more complete map of the present extent of the oil plume than was previously available and shows the pipeline to coincide with the approximate upgradient margin of the plume. This correspondence, plus the lack of strong evidence of an oil migration path from any more distant source, suggests that there is adequate cause to further evaluate whether the oil source was from leaking pipeline repaired some time before 1993.

Another very possible source is that the oil plume may have migrated to its present position from as far away as 2,500 ft and may have been undergoing natural attenuation. Possible sources, now inactive, within that distance include oil and saltwater storage pits; producing, shut-in, and abandoned wells; a tank battery; and a landfarm area. There may have been multiple point sources, and oil and saltwater may have had different sources. Drilling results confirmed the present limited extent of the oil plume and found suggestive indications of long flow paths from distant sources, but did not prove up any of these distant sources or tracks of plume migration.

Additional fieldwork could be done to add more evidence for and against possible sources. Evidence of a pipeline leak sometime in the past would include signs of a vertical column of oil between shallow depth and the water table. Cores to test the pipeline hypothesis should be taken from several 35-ft-deep boreholes targeting the interval between the base of the pipeline and the top of the sweep zone of water-table fluctuation. The boreholes should be positioned within 1 to 2 ft of the pipeline. Evidence could include the direct show of oil, as well as indirect indicators such as locally unique oxidation-reduction effects and mineralization. Evidence of a more distant source, such as oil storage pits, would also require examination of additional cores for similar features. Those cores should be located along the traces identified in this report.

Although the source could not be confirmed, evidence seems strong that there is not an active source of oil feeding the plume. It is recommended, therefore, that remedial feasibility studies proceed and target cleanup of the oil plume with the expectation that the source is already controlled and that the plume has been undergoing natural attenuation. If in fact there is a remaining active source within or immediately adjacent to the delimited oil plume, its position may be more readily pinpointed with the additional monitoring data collected during plume remediation. Further search for responsible parties can continue during the remedial feasibility study and site cleanup.

The design of plume abatement and selection of technologies to withdraw, degrade, and immobilize the oil should be based on an engineering analysis that considers both hydrogeologic properties and cleanup goals. Additional geological and geophysical work can provide useful information on the physical geometry and hydrological properties of the alluvial deposit, which could be helpful in remedial design. The engineering analysis should consider whether continued application and recovery of adsorbent material on the bedrock shelf at the riverbank would provide short-term control of oil discharge during plume abatement activities that would be more cost effective than construction of a riverside containment system. Further record research should focus on information about old pipelines and abandoned wells within 300 ft of the river, upgradient of the seep. Additional upgradient monitoring wells placed southwest of the seep would help to further define the water-table gradient in that area and evaluate possible inactive oil sources.

INTRODUCTION

Purpose and Scope

A seep of oil and saltwater on the south bank of the San Marcos River is located approximately 5 mi west of Luling, Texas, on the border of Guadalupe and Caldwell Counties (fig. 1). The site is at the southwest end of the Luling-Branyon Oil Field (fig. 1). At the riverbank, the oil appears to issue from the base of Quaternary alluvium, which overlies bedrock of the Tertiary-age Wilcox Group.

The objectives of this study were to:

(a) identify the most likely source or sources of oil, and

(b) mark the approximate extent of the subsurface crude-oil plume between the source(s) and the seep.

The project was designed to follow cost-effective investigation approaches that give a reasonable assurance of success in 2 weeks of fieldwork (appendix A). Fieldwork was conducted in July and August 1999. Additional work, as stated in the scope of work (appendix A), was expected to be needed to prove up the source or sources of oil, determine possible effects on surface-water quality, and evaluate remediation alternatives.

Site History

The Luling-Branyon Oil Field lies across the San Marcos Arch (fig. 1), with production mainly from the Austin Chalk and Edwards Group (Galloway and others, 1983, p. 39–41). Luling-Branyon field was discovered and first developed in the early 1920's; it was further developed in the late 1930's and again in the late 1940's and early 1950's (Davis and Goode, 1957). Field discovery was by wildcat drilling on the basis of geologic mapping of the surface expression of a fault exposed along the banks of the San Marcos River (Brucks, 1925). The Austin Chalk was a gas-solution drive, and the Edwards was a water-drive reservoir. Peak oil production from the Edwards was 11 million bbl from 391 wells in 1924 (Davis and Goode, 1957). Reservoir pressure dropped from more than 1,000 psi to less than 100 psi by the early 1950's. Waterflooding for enhanced oil recovery has been common in the field since the mid-1950's. Since the early years of the field, saltwater production has been high. Saltwater was run into earthen pits from separator tanks and eventually discharged into the San Marcos River (Davis and Goode, 1957). It is possible that oil was also stored in unlined earthen pits in the early history of the field, but this was not mentioned by Davis and Goode (1957). Unlined earthen collecting pits were used on the lease (September 11, 1968, letter from J. C. Herring [RRC] to E. J. Dickinson [Mobil Oil Corporation], RRC file document). Some oil-bearing BS&W material from pits was later used in well plugging (September 15, 1964, letter from R. J. Swaim [Socony Mobil Oil Company] to R. D. Payne [RRC], and October 21, 1964, letter from R. D. Payne [RRC] to Mobil Oil Company, RRC file documents). After 1948, saltwater disposal was incorporated increasingly into the water-flooding program (Davis and Goode, 1957). In the late 1960's, according to RRC file documents, use of remaining oil or separator pits was ended, and oil-contaminated sediments were landfarmed on site.

The oil seep is at the east side of the Roberts Fee lease in Guadalupe County, on the south bank of the San Marcos River. The oil is perched within alluvium, either because of the water-table position or the contrast in permeability between the Wilcox bedrock and alluvium. Traces of oil and staining of the bedrock at the riverbank suggest, however, that there is some oil percolation through vertical joints and bedding planes of the Wilcox bedrock, at least at the seepage face. Anecdotal evidence suggests that the oil seep has been present for 20 to 50 yr (April 5, 1994, letter from F. B. Morlock to T. L. Muchard, RRC file document). Early sightings of oil near the site, however, could have been related to oil discharged, along with saltwater, at this site or elsewhere, rather than seepage from a subsurface plume in the alluvium as is currently occurring.

Previous operator-sponsored studies and RRC inspections developed useful data but did not identify or confirm the source of the oil. Possible sources of oil considered in this study are listed in table 1. Previous work included

- installation of 9 boreholes and 3 monitoring wells within about 220 ft of the seep (fig. 2), with analysis of total petroleum hydrocarbons (TPH 418.1 method) in core samples;
- estimation of a water-table gradient close to the river (two of the three wells used for the gradient calculation included an oil column giving erroneous results);
- execution of a three-dimensional electromagnetic survey in the vicinity of the seep, which included collecting an additional soil sample for TPH analysis from a location targeted by the survey;

- analysis of oil from the seep, characterized as similar to a "fresh Edwards crude oil" (April 5, 1994, letter from F. B. Morlock [Mobil Oil Corporation] to T. L. Muchard [Meridian Oil], RRC file document);
- determination that chloride content of saltwater in the plume near the seep is about 5,000 mg/L (RRC Lease and Pit Inspection Report, November 16, 1993);
- a pipeline-pressure test;
- excavation of two trenches; and
- records research on producing, abandoned and shut-in oil wells (appendix B).

This investigation builds on and takes into account the findings of these previous efforts.

METHODS

Multiple techniques were used to map out the extent of subsurface contamination and evaluate possible sources. The variety of tools differ in their productivity of results and quality of information. Work included:

- GPS survey of locations of oil wells and sampling points,
- direct-push survey with collected soil cores and soil-vapor samples,
- solid-stem augering with examination of cuttings,
- hollow-stem augering with whole core recovery,
- installation of monitoring wells for later use in fluid sampling and remediation,

- analysis of total petroleum hydrocarbons in soil samples (TPH method 418.1) for comparison with 1993 data on comparable soil samples,
- measurements of depth to ground water, and
- measurement of elevations of wells and other key features for mapping the water-level gradient.

Two major assumptions were made. First, the source of the oil seep was assumed to be on the south side of the San Marcos River. Accordingly, no surveys or sampling was conducted across the north side of the river. Second, the subsurface oil plume was assumed to follow the local hydrologic gradient, which was assumed to change from southeasterly to easterly near the river. This was confirmed by mapping the water table, as discussed later. Fieldwork accordingly focused on the area from the southwest to north of the seep (fig. 3). The area south of the seep was not studied because it was assumed to be downgradient of the seep and its source.

GPS Surveys of Wells and Sample Locations

Spatial coordinates of oil wells in the site area (fig. 2) and of all sample locations were mapped by using GPS with ±3 ft accuracy (figs. 3, 4; appendix C). The GPS-surveyed locations were digitally superposed on a 1995 aerial photograph (www.tnris.state.tx.us, 2.5-m DOQ digital data) in a geographic information system (ArcView). The digital photograph did not need to be spatially rectified. Plate 1 is a 1:2,400-scale print of the aerial photo with well locations superposed. Additional hard-copy aerial photographs from archives at the Texas Natural Resources Information System (TNRIS) were studied; plate 1 includes features transcribed from a 1:69,000-scale Army Map Service (12/12/1952) black-and-white aerial photograph (TNRIS RSDIS No. 00212, FC04F).

Direct-Push Survey

Direct-push technology was used to obtain both

(a) narrow-diameter soil cores through expected contamination zones at three abandoned well locations and

(b) soil-gas samples at 46 locations for analysis of aliphatic and aromatic vapor concentrations in the unsaturated zone.

Sampling of soil cores can provide direct confirmation of the presence or absence of oil contamination. On the other hand, a soil-vapor survey, which generally has a somewhat higher productivity and gets information at depths above the contaminated horizon, runs less risk of creating vertical conduits for spread of contamination. The indirect results of a soil-vapor survey, however, can require more interpretation. Direct-push soil-probe holes were plugged with a cement grout.

Soil Cores

Soil cores were taken at three locations (47, 48, 49, fig. 3) to check out possible oil sources at abandoned wells targeted by RRC. Soil core was taken using the direct-push method to the limit of penetration, which for coring at this site was at 23 to 32 ft beneath ground surface, in dry sand (48 and 49) or coarse gravel (47). Coring rate in site materials was about 8 ft/hr. The soil cores were described and photoionization detector (PID) readings of headspace gas were taken on representative samples, as described later.

Soil-Vapor Survey

Volatiles in crude oil lying at the top of the capillary fringe of ground water tend to partition into the gas phase and diffuse upward through the unsaturated zone. Detection of these volatile petroleum-contaminant vapors has been shown to be useful for indicating the approximate subsurface position of a crude-oil plume (e.g., Silka and Jordan, 1993). The direct-push soil-gas survey approach can be rapid and minimally intrusive and was used to map the subsurface extent of petroleum-contaminant soil vapor at the San Marcos site. Direct-push, shallow sampling tubes were deployed to obtain gas samples, and onsite gas chromatography (GC) was used to analyze samples. Vapor samples were drawn through a well face, typically 6 inches high but as much as 12 inches high, at the bottom of the drive pipe, and collected from small-diameter nylon tubing at ground surface by using a 60-mL syringe. More than three borehole and tubing volumes were purged before vapor samples were collected for analysis. Soil-gas readings were taken at 46 direct-push boreholes (fig. 3) over three 10-hr work days. Samples were taken at the limit of direct-push penetration, generally 15 to 20 ft beneath ground surface in dry sand above the water table. At eight holes, including the three core holes just mentioned, additional soil-vapor samples were taken by using a peristaltic pump for repeated or follow-up analyses. For these eight boreholes, at least 1 to 2.5 borehole volumes of vapor were pumped before samples were taken. Appendix D presents details on the soil-gas survey measurements.

Types and concentrations of hydrocarbons detected in the GC analyses were mapped in an attempt to distinguish the location and characteristics of the oil plume. In addition, oil samples were collected from monitoring well MW2, from a storage tank collecting oil from an Edwards Group oil well on an adjacent lease and from an Austin Chalk oil well (No. 15, fig. 2). Headspace gases were equilibrated with the oil samples in VOA vials and analyzed on the GC to establish reference chromatograms. Equilibrated headspace gases were also analyzed for four water samples from monitoring wells MW1 and MW3, the direct-push core hole No. 47 (fig. 3), and from the San Marcos River.

Photoionization Detector (PID) Analysis

PID testing consisted of measuring total concentration of volatile petroleum vapors in headspace gas from representative soil samples collected from direct-push coring and from solid and hollow-stem augers. A portion of the core was sealed in a plastic bag for at least 15 min, then the PID sampling tip was inserted into the bag for a measurement. Analyses of total ionizable volatile organic carbon (VOC) are reported in parts per million (ppm) concentration units (appendix E). The PID meter and measurements were provided for this study by RRC personnel.

Solid-Stem Augering

Locations for eight auger holes (100 to 107; figs. 3, 4) were selected on the basis of results of the direct-push survey and the previous Fuqua and Holmes (1993) study. These eight holes were drilled by using a solid-stem auger to rapidly check for the presence or absence of crude-oil contamination. Auger holes 105, 106, and 107 were left open temporarily to allow water levels to be measured. All auger holes were plugged with a cement or bentonite grout. Drilling rates were about 30 ft/hr.

Hollow-Stem Augering with Core Recovery

Seven locations for taking whole cores by using a hollow-stem auger (MW3 to MW8 and 112, 114; figs. 3, 4) were selected on the basis of results of the direct-push survey, the previous Fuqua and Holmes (1993) study, and solid-stem auger tests. These holes were for installing monitoring wells and collecting core within the oil plume. Auger holes 112 and 114 were plugged with a cement or bentonite grout, whereas the others were completed as monitoring wells. Coring rates were 15 to 30 ft/hr.

Monitoring Wells

Five of the core holes were completed as monitoring wells (MW3 to MW8; figs. 3, 4; appendix F). The purpose of the wells was to prove up inferred oil sources, further evaluate the soil-vapor survey, and provide additional monitoring wells for fluid-level measurement and for possible future use in fluid sampling and site remediation. These wells are in addition to three monitoring wells MW1, MW2, and MW3 installed in 1995. A fourth monitoring well, MW9 (figs. 2, 3), was discovered during the course of this investigation. Information on the origin or date of this well has not been found, but the well may have been installed in association with the nearby land treatment unit.

TPH Analyses

Core samples collected from holes 100, 107, 112, 113 (MW8), and 114 were analyzed for TPH by the 418.1 method (appendix G). These samples were collected for comparison with data presented in Fuqua and Holmes (1993) to determine whether there had been major changes in oil content at sample locations. Hole 112 compares to TH3 of Fuqua and Holmes (1993) and hole 114 compares to TH9. Additional sample splits from holes 100 and 114, and a sample from a surface trench (fig. 3, sample T1), were analyzed for oil and grease and TPH by method 5520 (appendix G) by the RRC Surface Mining and Reclamation Division Laboratory. A TPH analysis of a soil sample ('3DR', fig. 4) reported by 3DR Surveys, Inc. (1994), did not reference an analytical technique. That sample was listed as taken by the hydropunch method at a depth of 33 ft in a hole that had a reported strong hydrocarbon odor at 29 ft (3DR Surveys, Inc., 1994)

Water-Level Measurements

Fluid levels were measured by using a standard electrical probe, oil-water interface probe, and a tape measure. Depth to oil in a monitoring well sometimes was found with more reproducibility by using a tape measure than by using an interface probe. The measuring point for monitoring wells was at top of casing and for uncased boreholes was at ground surface. Fluid-level elevation was calculated (appendix H) by using data from the elevation survey.

Elevation Survey

The elevation survey was based on a local datum, defined as 100 ft, set at the northern corner of a concrete foundation near the seep (appendix I). Site elevations were not defined relative to sea level. All site elevations were determined by successive transit sightlines relative to that local datum. The local datum suffices for calculating relative changes and gradients in hydraulic head. Elevations of measuring points were determined for the five new and four old monitoring wells, solid-stem auger holes where water-level measurements had been made, core holes, 20 of the direct-push sites, and the bedrock shelf on the bank of the San Marcos River below the seep. Elevations were determined at a precision of ±0.01 ft for monitoring wells and ±0.1 ft for auger and core holes and direct-push sites, commensurate with accuracy of the fluid-level readings. Elevation of the bedrock shelf was surveyed at an accuracy of ±1 ft.

RESULTS

Distribution of Free Product

Crude oil was found only within a radius of approximately 220 ft of the seep (fig. 5). This finding is based on analysis of whole-core, solid-stem-auger borings, soil-gas surveys, and results of the Fuqua and Holmes (1993) study. The subsurface oil plume is constrained at key locations where crude oil was not found in subsurface borings, as follows (fig. 5):

- to the west and northwest by holes 104, MW7, and 101 drilled in this study and by TH2 and TH7 drilled in 1993 (Fuqua and Holmes, 1993);
- to the south by hole 105 drilled in this study and by TH4 and TH8 drilled in 1993;
- to the southwest by hole 106 drilled in this study and by TH6 drilled in 1993; and
- to the north by hole TH1 drilled to a depth of 37 ft in 1993.

MW1 is thought to be at the north edge of the plume. Borehole 107 is also judged to lie at the edge of the oil plume, on the west side. Soil samples had low TPH (0.08 percent) and PID reading (~15 ppm). Low PID readings (≤20 ppm) from boreholes 101, 104, and 106 (fig. 5) were judged to reflect vapor transport and not to be evidence of the presence of crude oil because cuttings gave no sign or odor of hydrocarbons. The oil plume does not have a sharp edge. There is a sweep or smear zone at the top and sides of the oil plume owing to fluctuations in the elevation of the water table, as well as degradation of the oil plume, as discussed later.

The area of the estimated subsurface oil plume shown in figure 5 is approximately 33,000 ft^2. The volume of oil in the plume is estimated as being between 800 and 3,300 bbl (table 2), assuming the given plume area, porosity of 20 percent, and a range of possible plume thicknesses. An oil-column thickness of 2.8 ft was measured at MW2, giving the upper estimate of 3,300 bbl. Because the oil column is not uniform in thickness, it was also assumed to be nowhere more than 3 ft thick and that the area having a certain thickness follows a geometric progression, giving an average thickness of 0.7 ft (table 2). This average assumed thickness gives the lower estimate of 820 bbl.

At the northwest corner of the plume, TPH varied from 3.59 percent at TH9 in 1993 to 1.01 percent at hole 114 in 1999 (fig. 5). Within the footprint of the plume, TPH was 2.43 percent at TH3 in 1993 versus 2.35 percent at hole 112 and 2.43 percent at MW8 in 1999. On the basis of these few samples, we found that TPH within the center of the plume is unchanged, whereas it might have decreased at the northwest corner of the plume between 1993 and 1999. The small number of samples, probable differences in sampling and compositing techniques, and slight offset of sample locations limit further interpretation.

Summary of Site Hydrostratigraphy

The oil plume is found within Quaternary alluvium at the site. The stratigraphy, thickness, base elevation, and saturated thickness of the alluvium vary across the site. A typical stratigraphic section of alluvium at the site includes a 4-ft-thick surficial clayey soil, a 30-ft-thick fine-grained sand with varying clay content, interbedded with beds of clay and gravel, with a sandy gravel at the base of alluvium. Alluvium rests on the eroded surface of sandstone and claystone of the Wilcox Group at depths of 29 to 38 ft. Some of the bedrock sandstone is well indurated with iron-rich interstitial cement.

The thickest and coarsest sand section is found at MW7. At MW4, however, the 38-ft-thick alluvial section is predominantly sandy clay and with only two 1- to 2-ft-thick sand beds. Wilcox bedrock at MW4 is laminated claystone. This well might mark or lie beyond the southwest limit of the sandy part of the alluvial deposit. Caliche nodules (1 to 5 mm) are common in the uppermost 10 ft of alluvium. At hole 112, there is an unusual amount of caliche, which almost continuously pervades the section between depths of 4 and 18 ft.

The gravel and sand provide the transmissive material for movement of oil and ground water. Heterogeneity in the distribution of the gravel and sand would affect the flow path relative to the mapped gradient in the water table (see next section). Irregularities on the base of the underlying bedrock could also influence flow direction. The alluvial deposit may be shaped like a section of a cone; additional site work may be needed to define the shape of the deposit for improving remedial design.

Water-Table Gradient

Measurements of water level at 12 locations were used to map the local gradient in hydraulic head (fig. 6). Water-level elevation was surveyed relative to a local datum, not sea level. As expected, the gradient is easterly at the river, but varies away from the river (fig. 6). Fuqua and Holmes (1993) showed the gradient close to the river as being northeasterly. This result is thought to be incorrect because their limited data included water levels depressed by an oil column in monitoring wells MW2 and MW3.

Assuming uniform hydraulic conductivity and no vertical components of flow, the direction of ground-water movement can be inferred to be perpendicular to the contours of equal hydraulic head (fig. 6). The gradient ranges from 0.013 to 0.023 ft/ft depending on which data points are used. The magnitude of the gradient is reasonable for flow of unconfined ground water.

Records for the old monitoring well MW9 remain undiscovered at the time of this report. Water level in MW9 appears somewhat high although not inconsistent with measurements at other boreholes (fig. 6). It is possible that MW9 lies outside of the sandy alluvial deposit and is completed in Wilcox bedrock. The different water level might reflect hydrologic properties of the bedrock that are markedly different from those of alluvium.

It should be noted that the water table shown in figure 6 represents a single snapshot for the period of August 1999. Water-level fluctuations are likely to occur both seasonally and annually in this setting. It is probable, however, that the major feature of the water-table map, a change in gradient away from the river, would remain. That pattern reflects the movement of ground water on both regional and local scales between recharge and discharge locations and possibly the effect of hydrogeologic properties. The water-level fluctuations account for some of the smearing of the upper and lateral edges of the oil plume.

Petroleum-Contaminant Vapor Survey Results

Contaminant aromatic and aliphatic vapors in the unsaturated zone have a high background and high variability throughout the study area (figs. 7, 8). For example, there is a high value in the center of transect *A–A′* (sample 50) near the seep, a number of highs and lows along transects *B–B″*, *C–C″*, and a high value on transect *D–D′* (sample 76), where oil-stained soil was found. Note that the vertical scale in figures 7 and 8 is logarithmic, which tends to de-emphasize apparent differences in concentration. Linear trends in elevated aromatic and aliphatic concentrations, therefore, cannot be uniquely or unambiguously tracked upgradient from the seep between the successive transects.

Headspace gas from oil sampled out of MW2 (fig. 9a) appears depleted in light hydrocarbons (for example, C1 to C4 hydrocarbons, including methane and ethane) relative to that from oil samples representing the Edwards or Austin Chalk producing zones (fig. 9b, 9c). Edwards oil was described as a sour crude with an asphaltic base and average gravity of 27° API (Davis and Goode, 1957). The lighter hydrocarbons tend to be more volatile and can be lost from an oil plume in a shallow ground-water environment (Hult and others, 1991). Simple comparison of relative peaks in the three chromatograms suggests that the MW2 sample resembles the Edwards more closely than the Austin Chalk oil samples (fig. 9), but effects of other attenuation processes (including microbial degradation) have not been taken into consideration.

DISCUSSION

Source of Oil

Evaluation of the source of the oil requires considering the present extent of oil, site history, and water-level gradient and hydrogeologic properties. At present only a relatively small (33,000 ft^2) oil plume is found near the seep (fig. 5). There is, however, a high background of variable levels of aliphatic and aromatic contaminant vapors above the water table throughout the area. Table 1 lists sources of the oil seep considered in this study.

There are three main alternatives. First and second, the source may be within or adjacent to the present oil plume and may be either active or inactive. Third, the source may be at some distance upgradient from the present oil plume, may have become inactive some time ago, and the oil plume may have both migrated to its present position and undergone natural attenuation. As discussed in the following, the second and third alternatives appear at least as likely as the first. Assuming the oil source is inactive and the plume is undergoing attenuation will serve as an effective basis for planning the first stage of corrective measures.

Local Source within Footprint of Oil Plume

The most obvious candidates for a possible source (active or inactive) within approximately 220 ft of the seep, the present extent of the oil plume, are (table 1):

- the existing oil pipeline,
- an earlier oil pipeline in the same right-of-way or a leaking pipeline that was repaired or replaced,
- undocumented abandoned well bores,
- one or more leaking flow lines, and
- a natural source such as fluid movement along a fault zone.

In August 1993 the RRC monitored the excavation of a 200-ft-long, 3-ft-deep trench that exposed the oil pipeline. RRC also monitored a 2-hr pressure test of the pipeline. The pressure test was on the section of pipeline now known to lie above the subsurface oil plume. The pipeline was left exposed for 2 weeks, during which time it continued to convey oil under pressure. There was no evidence of crude oil or oil stains in the sediment adjacent to the pipeline exposed in the trench. A pipeline source would not account for the presence of saltwater along with oil at the seep. This evidence indicates that the current oil pipeline is not the source of the oil plume.

An earlier repaired or replaced oil pipeline in the same right-of-way is another hypothetical source of the oil plume. This scenario requires that the leak was detected and repaired and that contaminated soil immediately around the pipeline was cleaned up before August 1993. If the seep had been present for 20 to 50 yr (April 5, 1994, letter from F. B. Morlock to T. L. Muchard, RRC file document), it seems likely that early suspicion would have been of a pipeline within 220 ft of the seep and follow-up inspections and corrective measures taken. This explanation cannot be evaluated without records of the several companies that have operated the pipeline. Detection of a pipeline leak and corrective action should have been reported to the RRC.

The main reason that continued scrutiny is directed at the pipeline is the remarkable correspondence of the positions of the pipeline and the upgradient margin of the oil plume as mapped in figure 5. The plume margin is drawn as much as 50 ft upgradient of the oil pipeline, which might be explained by the drainage of oil out of a vertical column of oil beneath the hypothesized source. A counterargument to the oil pipeline as the source is the presumed time elapse since a leak was repaired and the continued movement and natural attenuation of the oil plume. A reasonable velocity of oil in the plume in the alluvium could be as low as approximately 0.3 ft/d or about 100 ft/yr (appendix J). Appreciable attenuation and retreat of the trailing edge of the oil plume would have occurred since 1993 or a year of a hypothetical cleanup action in the past.

If a pipeline had leaked enough oil to generate the subsurface plume and to sustain the oil seep for many years, there should be a mappable trace of a vertical oil column between the pipeline and the water table. A test for the presence of such a vertical column would be collection and examination of a series of cores taken from depths of 5 to 35 ft beneath ground surface targeting the interval between the base of the pipeline and the top of the sweep zone of water-table fluctuation. The boreholes should be positioned along the trace of the pipeline and spaced within 1 to 2 ft of the pipeline. This study did not conduct such a test because the 1993 tests supervised by the RRC were assumed to discount the pipeline as a possible source, so the risk of positioning a drilling rig immediately adjacent to the pipeline was not justified.

A variation on the pipeline-as-source scenario is a leak on the other side of the shutoff valve. The pressure test and excavation carried out in 1993 included the section of pipeline only on the side of a shutoff valve toward the oil seep. The section of the pipeline on the other side of a shutoff valve toward the San Marcos River was not tested. The gradient in hydraulic head of ground water beneath the oil plume, however, is easterly, directly toward the river (fig. 6). So unless the leak were close to or at the shutoff valve, movement of oil from that section of the pipeline could not reasonably account for either the position or extent of the oil plume. The possibility that this part of the pipeline might be involved cannot yet be fully excluded but appears unlikely. A hypothetical pipeline source does not explain the high background of aliphatic and aromatic vapors in the unsaturated zone throughout the site or the presence of saltwater at the seep.

One or more unknown abandoned wells as the source of the oil plume near the seep are unlikely but cannot be completely discounted. There are no known producing, shut-in, or abandoned oil wells within the footprint of the oil plume. The closest known well is the producing well No. 15, located approximately 200 ft south of the seep (fig. 2). Reservoir pressure had been depleted by the early 1950's (Davis and Goode, 1957). Waterflooding for enhanced recovery has been active since the mid-1950's. Davis and Goode (1957) refer to problems in early cementing jobs and casing corrosion from saltwater and hydrogen sulfide. The latter requires use of corrosion inhibitors in wells in the field. Accounting for the oil plume since the 1950's by movement of oil up an unplugged abandoned well would require a buildup of reservoir pressure from injected fluid sufficient to raise oil and saltwater to ground surface. In addition, an unreasonable amount of hydrodynamic dispersion would be required to broaden the oil plume to a width of 100 ft within the short, 220-ft travel distance to the seep. Two or more abandoned and leaking wells would seem to be needed to account for the breadth of the seep if the source is within 200 ft of the riverbank.

Discharge from a flow line seems unlikely to be the source because saltwater appears to be only a small constituent of the seep. Flow lines carry produced fluid (oil and saltwater) from wells to a central tank battery. The oil:water ratio of produced fluid is low (<5 percent). Also, oil tends to flow along the top of the fluid in the flow line. A leak in a flow line, therefore, would result in a greater loss of saltwater than of oil. Although saltwater is present, the available accounts of site history do not suggest there ever has been a great discharge of saltwater at the seep.

Leakage of oil up a fault zone, as for an abandoned well, requires reservoir pressure high enough to drive the oil and permeability of the fault zone sufficient to transmit the oil. Brucks (1925) stated that Luling field was discovered by wildcat drilling after a fault was mapped along the banks of the San Marcos River, upstream of the site. Brucks (1925) did not mention any oil seep. An oil seep from such a source should have been obvious from the earliest days of settlement, when reservoir pressure was at its highest, and should have been a noted exploration objective in Luling-Branyon field. There is no mention of a seep, however, prior to oil-field activities (e.g., Davis and Goode, 1957). Also, there is no sign of a corresponding oil seep along the opposite bank of the river, as would be expected from even a short length of fault. Leakage along a fault is an unlikely explanation for the observed seep.

Distant Source beyond Footprint of Oil Plume

There are several possible sources within approximately 2,500 ft southwest of the seep (table 1). If any of these were the source of the oil plume, they are now inactive and the oil plume has migrated to its present position. This inference is based on the observation that the plume is now limited to 220 ft of the seep, therefore separated from any more distant source. Accounting for a hypothetical inactive, distant source requires that oil-plume history be consistent with what is inferred about typical ground-water flow rates.

A conceptual model of the history of an oil plume at the site, regardless of the source, is shown in figure 10. At time A, a source begins to leak oil at a rate that is high enough to allow oil to move downward through the unsaturated zone, accumulate at the water table, and begin to move in the direction of ground-water flow. At time C, the oil plume reaches the river and forms a seep, while the source continues to leak more oil. At time D, the source is cut off, after which the tail of the oil plume begins to move away from the source, both by being carried along with ground water and by undergoing natural attenuation. Time E represents the present situation, in which the tail of the oil plume extends no more than about 220 ft upgradient of the seep.

Figure 11 shows possible tracks (I and II) of the oil plume from hypothetical, distant sources. Both tracks are feasible, given the alluvial deposit and the gradient in hydraulic head (fig. 6). The high background and variability in concentrations of aliphatic and aromatic vapors detected in the unsaturated zone (figs. 7, 8) mean that neither track at this site can be unambiguously proven solely on the basis of soil-gas results. Too much time is inferred to have passed since the hypothesized source was curtailed and the hypothesized oil plume passed through the area. Drilling results found no direct show of oil along either of these tracks, although MW5 showed a PID reading of 8.1 ppm (appendix E).

There are numerous wells in the area upgradient of track I. Cores 49, 48, and 47 were taken next to plugged and abandoned wells 4, 9, and 13, respectively (figs. 2, 3, 11). PID readings were made on core samples (appendix E), and headspace gas was analyzed on a water sample from hole 47 (next to well 13). These data showed no sign of oil. Hypothetical sources upgradient of track I (fig. 11) are unlikely to be active sources because the oil plume has moved downgradient and does not extend to this area. A producing well or a previously producing well that is now abandoned might have had a subsurface leak owing to corrosion or mechanical failure (Davis and Goode, 1957). A previous leak may have been repaired and the well brought back on line, or the leak may have been fixed when the well was plugged and abandoned.

In the source area upgradient of track II, there are several possible sources, including oil and saltwater storage pits and a tank battery, as well as a landfarm area, in addition to other producing, shut-in, and abandoned wells (fig. 11). The land-treatment project treated hydrocarbon-impacted soils from "relict oil pits" and other oily wastes (KEI Consultants, Inc., 1993). Eight soil samples tested for the land-treatment permit application had TPH values over detection limit; TPH was greater than 1,000 ppm for five samples and greater than 10,000 ppm for three samples (as much as 32,000 ppm).

Calculations of possible volume and flow rate of an oil spill are presented in appendix J. These calculations show that a distant, now inactive, oil source is a feasible explanation for the seep on the San Marcos River. These calculations require a number of assumptions and cannot be tested without additional data. They suggest that the total amount of spilled oil over a 40-yr hypothetical spill history (1930 to 1970) might have been roughly 6,500 to 27,400 bbl, or roughly eight times the present estimated volume. The spill rate, of course, might have varied over time. A reasonable estimate of oil velocity in the plume could be as low as 0.3 ft/d, accounting for travel time to the river and later plume attenuation.

CONCLUSIONS AND RECOMMENDATIONS

The preceding discussion presented the following findings:

(1) The oil plume is small (33,000 ft^2), limited to the area of about 100×220 ft adjacent to the river, and discharging at a very low rate (perhaps as low as 0.5 to 10 gal/d).

(2) An oil pipeline lying at the upgradient side of the oil plume was examined in 1993. No evidence was found that the pipeline had a leak or was the source. Another part of the pipeline, on the river side of the shut-off valve, was not tested but appears downgradient of the seep and is discounted as being a likely source. Whether the pipeline leaked in the past and was repaired prior to the 1993 inspection cannot be evaluated with available data. A pipeline source would not account for

the presence of saltwater at the seep or elevated petroleum contaminant vapors elsewhere at the site. An additional test to determine whether a previous pipeline leak was the source of the oil plume would be to look for traces of a vertical column of oil in a series of 35-ft-deep cores from holes located within 1 to 2 ft of the pipeline.

(3) Other possible sources within the footprint of the oil plume, such as a fault zone or unknown, abandoned, improperly plugged wells, also appear unlikely to be active sources but remain unproven. The 100-ft-wide plume probably would not result from only one well located within 200 ft of the seep. Reservoir pressures may be too low to account for discharge of oil at shallow depth up a fault plane or improperly plugged wells, but this issue merits further monitoring. Early reports of field discovery do not mention any natural oil seeps.

(4) Possibly active sources must be located within or immediately adjacent to the present oil plume. Other possible sources upgradient of the oil plume must have become inactive, after which the oil plume could have migrated to its present position with natural attenuation of the plume's upgradient margin.

(5) There are a number of reasonable candidates for upgradient, inactive sources: old locations of oil and saltwater storage pits; tank batteries; a landfarm area, and producing, shut-in, or abandoned wells. No unambiguous, consistent, or exclusive evidence was found linking any of these features to the present oil plume. The fact that saltwater impact

is small suggests that flow lines are not the main contributor to the oil plume. Aliphatic and aromatic vapors in the unsaturated zone are everywhere above background and do not discriminate one possible migration path from another. The high and variable petroleum-vapor concentrations may represent lateral vapor transport within thick unsaturated sand above an oil plume, many widespread but small near-surface spills of crude oil, or both.

Given these findings, a reasonable course of action is to proceed with remediation of this oil seep on the bank of the San Marcos River. RRC should assume that the source is controlled and that the plume already is in attenuation, with either of the following situations:

- the oil source was at some upgradient distance and has been inactive for some time, and the oil plume has migrated away from the source to its present position, or
- the oil source was within or adjacent to the oil plume but recently was cut off by unreported corrective action.

The possibility that an unknown oil source remains active within or adjacent to the present oil plume cannot be disproven with available data, although identifiable candidates have been discounted.

The following steps, therefore, are recommended:

(1) Conduct additional records research for information on old pipelines and abandoned wells within 300 ft of the river.

(2) Proceed with remediation while monitoring the attenuation of the oil plume. If an active oil source remains within or adjacent to the oil plume, its position may be more readily pinpointed with the additional monitoring data, especially as the volume of oil in the plume is reduced.

The principal objective of remediation at the site should be to control the discharge of oil to the San Marcus River in a cost-effective manner. An evaluation of remediation alternatives was not part of the scope of work. Two approaches, however, should be considered in light of the findings about the size and rate of discharge of the oil plume.

- One option is to construct some kind of barrier with a drain and sump at the riverbank. The barrier would lie at the base of a steep, 30-ft embankment on the cut bank of a large river. Installation probably would require a major, costly, earth-moving construction project. In addition to the construction project, cleanup of the oil plume would be targeted.
- Another option recognizes that release of free product to the river has been largely controlled for the past several years by application and recovery of adsorbent material. It seems likely that an abatement effort focused on the small plume could be carried out during a reasonably short period of time, soon making a riverside containment system obsolete. Remediation would include both existing monitoring wells and additional extraction wells and could employ a number of

technologies to withdrawal, degrade, and immobilize the oil, such as withdrawal of recoverable free product, air sparging, soil-vapor extraction, and bioremediation. The number and spacing of the extraction wells should be based on a later engineering analysis that considers both hydrogeologic properties and cleanup goals. While the oil is being removed from the subsurface, vigilant application and recovery of adsorbent material on the bedrock shelf at the riverbank may provide adequate, cost-effective control of the remaining oil plume.

Finally, although consideration of water-quality impacts was also beyond the scope of this study, RRC file documents indicate that saltwater is discharging in about equal amounts with oil at the seep. The saltwater undoubtedly contains dissolved organics and other contaminants leached from the oil. Testing of ground-water quality at the monitoring wells is recommended, as is evaluation of environmental risk associated with the amount of ground-water and solute discharge at the seep, so that appropriate measures directed at dissolved contaminants might be included in the remediation program at the site.

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APPENDIX A

Bureau of Economic Geology Scope of Work

WORK ORDER NO. 3

SAN MARCOS RIVER SITE INVESTIGATION,

GUADALUPE COUNTY, TEXAS

INTRODUCTION

The purpose of this work order is to

(1) conduct an investigation leading to the identification of the most likely source or sources of an oil seep on the San Marcos River at the border of Guadalupe and Caldwell Counties and

(2) delimit the approximate extent of the subsurface crude oil plume between the source(s) and the seep.

The intent of the work order is to use a cost-effective approach that can give a reasonable assurance of success during these 2 months of work.

The work order covers an initial step of a phased environmental assessment of the site. BEG will prepare a Phase 1 report, intended to be a brief summary of preliminary findings, which can serve as a basis for deciding what follow-up work is needed, if any, to support corrective-action and remediation decisions. Phase 2 as currently envisioned has three main goals: (1) proving up the source or sources of oil identified in Phase 1, (2) determining possible effects on surface-water quality, and (3) evaluating the extent of contamination and assessing remediation needs on the basis of risk to health and safety and the environment.

Phase 1 is expected to be completed during FY99 by August 31, 1999, assuming a start date no later than July 1, 1999. Subsequent phases of work in FY00 are pending contract renewal.

Previous operator-sponsored studies and RRC inspections have not identified or confirmed the source of the oil. The BEG phased investigation will build on or take into account the findings of previous work.

As part of its mission to support other Texas agencies, during the past year the BEG obtained funding from the U.S. Geological Survey to remap the geology of the region including the oil seep on the San Marcos River. On the basis of this geologic mapping, a site reconnaissance visit, and preliminary review of RRC site files, it appears that the seep manifests the discharge of oil being conducted toward the San Marcos River mainly in Quaternary alluvium. Underlying the alluvium is bedrock of the Tertiary Wilcox Group. At the riverbank, the oil is seeping out of the alluvium and appears to be perched on Wilcox Group deposits. The Wilcox generally seems to have a lower permeability that retards downward movement of the oil. Traces of oil and staining of the rock at the riverbank suggest, however, that there is some percolation through vertical joints and bedding planes of the Wilcox bedrock.

PHASE 1 SCOPE OF WORK

The BEG will (1) search for the source of the oil plume and map the lateral extent of the subsurface oil plume at the site using direct-push technology, (2) install monitoring wells, and (3) prepare a brief summary of preliminary findings. Details of these three tasks are found in the following sections.

Several assumptions underlie the scope of work and schedule:

(1) The source of the oil seep lies on the south side of the San Marcos River. No sampling is planned for the north side of the river or other oil seeps that might be found in the area.

(2) The subsurface oil plume follows the local hydrologic gradient, and the gradient at the site curves from southeast to east toward the river.

(3) The RRC will be responsible for arranging access to the site, obtaining permission to sample and drill holes, arranging for the oil operator to identify buried pipelines or flowlines on the property prior to drilling, and obtaining authorization for brush clearing as needed to allow access for sample collection at key sampling locations.

(4) The RRC will provide to the BEG no later than July 7, 1999, a map or maps showing the locations of wells and other site features. The RRC and BEG will use the maps to select the first set of field measurement locations.

(5) There is a potential to find pockets of contaminant vapor with pressures of a few psi that might flow to ground surface in the soil-probe pipe. These are most likely near the source. BEG assumes that there will not be more than one or two of these situations. Generally, soil-probe holes will be plugged at the end of each day. Probe holes that encounter contaminant vapor under pressure will be plugged right

after sample collection, which may negatively impact productivity and decrease the number of samples that can be collected within the present schedule and budget.

Task 1.1. Direct-Push Sampling

Direct-push technology includes obtaining both

(a) narrow-diameter soil cores through the expected contamination horizon and

(b) soil-gas samples for analysis of contaminant-vapor concentrations.

Sampling of soil provides direct confirmation of the presence or absence of oil contamination. On the other hand, a soil-vapor survey generally may have somewhat higher productivity and run less risk of creating vertical conduits for spread of contamination, while requiring more discernment for interpretation of its results. In several recent studies the soil-vapor survey has been shown to give reliable results when combined with core sampling for verification.

The approach to direct-push sampling is as follows:

- Soil-core samples will be taken through the expected contamination horizon at locations targeted by RRC and BEG to check out possible oil sources, including wells, pits, and pipelines upgradient from the oil seep. Soil core will be taken to the depth of the base of alluvium (top of Wilcox) or to the friction limit of probe penetration, whichever is less. As many as 20 soil cores will be taken, depending on site conditions and preliminary findings, comprising approximately half the expected number of sampling sites.

- Soil cores will be curated, sampled, and tested onsite following standard techniques.
- One or more head-space vapor samples from the oil seep will be analyzed on a field gas chromatograph (GC) to identify the typical C1-C12 peaks expected in the soil-vapor survey.
- Soil-vapor surveys with an onsite GC measuring C1-C12 hydrocarbons will be made to map the boundary of the plume, close the upgradient limit of the plume, and identify the main axis of the plume. Additional soil-gas or head-space samples will be taken at some but not necessarily all of the locations of soil-core samples, at the discretion of the BEG lead investigator, for calibration. Soil-vapor samples will be collected and analyzed at as many as 20 locations, depending on site conditions and preliminary findings.
- Depths of soil-vapor surveys will generally be less than 25 ft beneath ground surface and are intended to remain above the water table. Soil-vapor surveys will be designed on the basis of preliminary findings from examination of narrow-diameter soil cores.
- Most soil-core samples and soil-vapor surveys will be made using a direct-push probe mounted on a truck. Supplemental soil-vapor surveys in a few areas with limited physical access will be made with a hand-held, hammer-driven soil tube.

- Soil-probe holes will be plugged with a cement grout at the end of each day. Probe holes that encounter contaminant vapor under above-atmospheric pressure will be plugged right after sample collection.
- The map coordinates of all sample locations, targeted wells, pits, and pipelines will be surveyed using GPS with real-time correction.
- Map coordinates of features observable in aerial photographs will be surveyed on the ground to allow field and aerial-photograph data to be resolved.
- Field and aerial-photograph data will be loaded in a geographic information system for making site and interpretive maps. Aerial photographs will be rectified as needed using field data.

Task 1.2. Preliminary Borehole Verification

On the basis of the results of the soil-vapor survey, several boreholes will be drilled. The goal of the drilling is to:

(1) prove up inferred oil sources,

(2) document the reliability of the soil-vapor survey, and

(3) provide additional monitoring wells.

To the extent possible, it is also desirable that these monitoring wells be located for later use in a remediation program.

The approach to drilling is as follows:

- Drilling locations will be selected by the RRC and BEG on the basis of the results of the direct-push surveys. As many as five boreholes with monitoring wells are planned. This might not be sufficient to prove up or eliminate all possible sources. Additional drilling is expected in Phase 2 to build on the results of the Phase 1 study.

- At each drilling site, BEG will attempt to recover continuous core from ground surface to the base of alluvium using a hollow-stem auger drilling rig. BEG also will attempt to penetrate several feet into the Wilcox bedrock and take core with the hollow-stem auger drilling rig. Depths of boreholes generally will be no more than 40 ft.
- At each drilling site, BEG will complete a monitoring well. Well design will be decided by the RRC and BEG partly on the basis of the results of the direct-push surveys and constraints of the budget. Well design may be changed with approval of the RRC on the basis of additional data collected from each completed borehole.
- BEG will measure fluid levels in the open borehole and again in completed monitoring wells. BEG will measure the thickness of the oil column in each well upon completion.
- The map coordinates of all sample locations will be surveyed using GPS with real-time correction. The monitoring wells will also be surveyed to determine well-head measuring point elevations.

Task 1.3. Preparation of Phase 1 Report

BEG will prepare a Phase 1 technical report. The report is intended to be a brief summary of preliminary findings to serve as a basis for deciding what follow-up work is needed, if any, to support corrective-action and remediation decisions. The report will include the following information.

- Summary of objectives and scope of the Phase 1 study.
- Description of the findings of the Phase 1 study, including appropriate maps, summary tables, and other illustrations.
- Preliminary interpretation of the most likely source or sources of the oil seep, approximate extent of the subsurface oil plume, and recommendations for additional work.
- Appendices containing supporting documentation.

APPENDIX B

Information on Wells in Luling-Branyon Field at the San Marcos Seep Site

Table B1

Table B1. Information on wells in the Luling-Branyon Field at the San Marcos Seep site

Well ID	Well type*	Present status	Drilled date	Completion date	P&A date	Total depth (ft)	Perforation depth (ft)	Formation	Latitude °N	Longitude °W
J.E. Allen 'A' Lease (RRC Field ID #03671)										
18	1	Shut in			n/a				29° 42' 2.73	97° 44' 47.81
19	1	Shut in			n/a				29° 41' 58.44	97° 44' 39.80
22	1	P&A	12/5/54	12/11/54	6/22/72	2112	2100 to 2112	Edwards	29° 42' 1.65	97° 44' 43.53
26	1	P&A			n/a				29° 41' 59.09	97° 44' 58.54
32	1	Shut in			n/a				29° 41' 58.84	97° 44' 49.73
33	1	P&A							29° 41' 56.87	97° 44' 54.50
34	1	Shut in			n/a				29° 41' 50.41	97° 45' 1.47
37	1	P&A							29° 41' 53.82	97° 44' 58.80
39	1	P&A	2/9/27	2/25/27	11/24/71	2124	2069.5 to ?	Edwards	29° 41' 46.71	97° 44' 59.87
41	1	Shut in			n/a				29° 41' 49.57	97° 44' 56.43
43	1	P&A	2/29/76	6/2/76		2185	2137 to 2138	Edwards		
43	2	Operating				2400	2019 to 2400	Lower Edwards		
1D	2	Operating	4/4/89	4/15/89	n/a	2384	2221 to 2384	Lower Edwards	29° 41' 53.77	97° 44' 59.90
Unknown #1	3	Abandoned	n/a	n/a	n/a	n/a	n/a	n/a	29° 41' 59.69	97° 44' 52.11
Roberts Fee Lease (RRC Field ID #01101)										
3	1	Producing			n/a				29° 41' 55.34	97° 44' 51.78
4	1	P&A	8/21/24	9/18/24	11/20/64	2125	2105 to 2124	Edwards	29° 41' 56.82	97° 44' 48.16
5	1	Producing	9/2/26	9/13/26	n/a	2170		Edwards	29° 41' 39.68	97° 45"2 .23
6	1	P&A	3/13/27	3/26/27	11/23/71	2145	2117 to 2143	Edwards	29° 41' 43.62	97° 44' 57.14
8	1	P&A	11/30/54	12/5/54	11/12/71	2126	2116 to 2126	Edwards	29° 41' 39.73	97° 44' 56.98
9	1	P&A	12/17/54	12/21/54	11/12/71	2119	2116 to 2119	Edwards	29° 41' 49.21	97° 44' 48.44
11	1	Producing			n/a				29° 41' 46.51	97° 44' 52.94
12	1	Shut in	4/10/63	9/12/63	n/a	2095	2151 to 2179	Edwards	29° 41' 51.65	97° 44' 52.32
13	1	P&A	4/27/64	5/9/64	6/21/72	2119.5	2118 to 2120	Edwards	29° 41' 53.40	97° 44' 45.34
15	1	Producing	5/19/64	6/30/64	n/a	2050	1857 to 1977	Austin Chalk/Buda	29° 41' 48.09	97° 44' 37.82
16	1	Shut in	4/15/80	4/25/80	n/a	2050	1857 to 1977	Austin Chalk/Buda	29° 41' 35.23	97° 44' 57.14

* Well type: 1 — Oil production, 2 — Saltwater injection, 3 — Unknown

Abbreviations: P&A — Plugged and abandoned

APPENDIX C

Well Locations

Table C1. Spatial coordinates of monitoring wells, auger, and direct-push boreholes determined using GPS

Sample	Latitude	Longitude	Easting (m)	Northing (m)
MW1	29° 41' 50.73	97° 44' 38.01	621519.4	3285918.3
MW2	29° 41' 50.19	97° 44' 38.17	621515.5	3285901.7
MW3	29° 41' 50.37	97° 44' 38.66	621502.2	3285907.1
MW4	29° 41' 47.45	97° 44' 40.13	621463.8	3285816.6
MW5	29° 41' 51.52	97° 44' 41.93	621413.8	3285941.5
MW6	29° 41' 49.25	97° 44' 45.33	621323.4	3285870.6
MW7	29° 41' 54.32	97° 44' 40.71	621448.2	3285849.2
MW8	29° 41' 55.55	97° 44' 38.15	621516.5	3285888.0
MW9	29° 41' 41.55	97° 44' 43.82	621366.5	3285634.1
50	29° 41' 50.01	97° 44' 38.84	621497.4	3285896.1
51	29° 41' 48.84	97° 44' 37.79	621526.2	3285860.2
52	29° 41' 49.42	97° 44' 38.29	621512.5	3285878.0
53	29° 41' 50.37	97° 44' 39.04	621491.9	3285907.1
54	29° 41' 51.16	97° 44' 39.76	621472.4	3285931.0
55	29° 41' 49.21	97° 44' 43.01	621385.8	3285870.3
56	29° 41' 49.83	97° 44' 42.57	621397.4	3285889.4
57	29° 41' 50.60	97° 44' 42.12	621409.1	3285913.3
58	29° 41' 49.65	97° 44' 38.55	621505.4	3285884.8
59	29° 41' 50.17	97° 44' 38.86	621496.8	3285900.8
60	29° 41' 51.22	97° 44' 41.76	621418.7	3285932.5
61	29° 41' 52.10	97° 44' 41.66	621420.9	3285959.4
62	29° 41' 52.85	97° 44' 41.33	621429.7	3285982.5
63	29° 41' 53.43	97° 44' 40.91	621440.7	3286000.6
64	29° 41' 48.62	97° 44' 43.35	621376.6	3285851.9
65	29° 41' 47.95	97° 44' 43.74	621366.5	3285831.2
66	29° 41' 50.22	97° 44' 48.54	621236.7	3285899.6
67	29° 41' 50.83	97° 44' 48.05	621249.7	3285918.6
68	29° 41' 51.39	97° 44' 47.52	621263.9	3285935.8
69	29° 41' 52.02	97° 44' 47.02	621276.9	3285955.4
70	29° 41' 52.65	97° 44' 46.53	621289.9	3285975.0
71	29° 41' 53.01	97° 44' 44.11	621357.4	3285808.0
72	29° 41' 52.33	97° 44' 44.59	621344.6	3285786.8
73	29° 41' 51.74	97° 44' 45.01	621333.6	3285768.7
74	29° 41' 46.44	97° 44' 50.51	621185.2	3285782.8
75	29° 41' 45.77	97° 44' 50.15	621194.9	3285762.0
76	29° 41' 45.12	97° 44' 49.84	621203.5	3285742.1
77	29° 41' 44.43	97° 44' 49.52	621212.3	3285721.0
78	29° 41' 43.72	97° 44' 49.18	621221.7	3285699.2
79	29° 41' 43.29	97° 44' 49.13	621223.2	3285686.0
80	29° 41' 42.25	97° 44' 48.87	621230.6	3285654.1
81	29° 41' 41.51	97° 44' 48.59	621238.3	3285631.6
82	29° 41' 40.85	97° 44' 48.42	621243.2	3285611.2
83	29° 41' 40.09	97° 44' 48.24	621248.1	3285588.0

Table C1 (continued). Spatial coordinates of monitoring wells, auger, and direct-push boreholes determined using GPS

Sample	Latitude	Longitude	Easting (m)	Northing (m)
84	29° 41' 47.83	97° 44' 47.90	621254.7	3285826.1
85	29° 41' 47.18	97° 44' 47.87	621255.6	3285806.1
86	29° 41' 46.67	97° 44' 47.75	621259.0	3285790.4
87	29° 41' 46.12	97° 44' 47.67	621261.6	3285773.6
88	29° 41' 44.96	97° 44' 47.55	621265.1	3285737.8
89	29° 41' 44.28	97° 44' 48.03	621252.6	3285716.8
90	29° 41' 48.09	97° 44' 43.76	621365.8	3285835.4
91	29° 41' 49.50	97° 44' 42.96	621386.8	3285879.0
92	29° 41' 43.63	97° 44' 49.00	621226.6	3285696.6
94	29° 41' 54.13	97° 44' 45.68	621312.2	3286020.8
95	29° 41' 54.94	97° 44' 45.05	621328.8	3286046.0
96	29° 41' 51.81	97° 44' 52.09	621140.9	3285947.5
97	29° 41' 43.99	97° 44' 55.56	621050.0	3285705.9
98	29° 41' 43.73	97° 44' 56.96	621012.6	3285697.5
100	29° 41' 49.91	97° 44' 38.68	621501.9	3285892.8
101	29° 41' 48.36	97° 44' 40.83	621444.7	3285844.5
102	29° 41' 52.69	97° 44' 44.33	621351.6	3285798.0
103	29° 41' 49.65	97° 44' 42.52	621398.6	3285883.9
104	29° 41' 50.27	97° 44' 40.19	621461.2	3285903.6
105	29° 41' 48.92	97° 44' 37.52	621533.3	3285862.9
106	29° 41' 48.18	97° 44' 38.45	621508.7	3285839.7
107	29° 41' 49.59	97° 44' 39.20	621488.0	3285883.1
112				
113				
47	29° 41' 53.45	97° 44' 45.23	621324.6	3285999.9
48	29° 41' 49.45	97° 44' 48.09	621249.1	3285876.1
49	29° 41' 56.56	97° 44' 47.86	621253.0	3286095.1
Sump?	29° 41' 42.60	97° 44' 56.65	621021.3	3285662.5

Table C2. Spatial coordinates of oil wells determined using GPS

Sample	Latitude	Longitude	Easting (m)	Northing (m)
Unknown #1	29° 41' 59.69	97° 44' 52.11	621137.6	3286190.0
W1D	29° 41' 53.77	97° 44' 59.90	620930.3	3286005.4
W3	29° 41' 55.34	97° 44' 51.78	621147.9	3286056.2
W4	29° 41' 56.82	97° 44' 48.16	621244.8	3286102.9
W5	29° 41' 39.68	97° 45"2.23	620872.3	3285571.0
W6	29° 41' 43.62	97° 44' 57.14	621007.7	3285694.0
W8	29° 41' 39.73	97° 44' 56.98	621013.3	3285574.3
W9	29° 41' 49.21	97° 44' 48.44	621239.8	3285868.4
W11	29° 41' 46.51	97° 44' 52.94	621119.8	3285784.1
W12	29° 41' 51.65	97° 44' 52.32	621134.8	3285942.5

Table C2 (continued). Spatial coordinates of oil wells determined using GPS

Sample	Latitude	Longitude	Easting (m)	Northing (m)
W13	29° 41' 53.40	97° 44' 45.34	621321.6	3285998.5
W15	29° 41' 48.09	97° 44' 37.82	621525.4	3285837.1
W16	29° 41' 35.23	97° 44' 57.14	621010.5	3285435.6
W18	29° 42' 2.73	97° 44' 47.81	621252.2	3286284.8
W19	29° 41' 58.44	97° 44' 39.80	621469.0	3286155.2
W22	29° 42' 1.65	97° 44' 43.53	621367.4	3286253.0
W26	29° 41' 59.09	97° 44' 58.54	620965.1	3286169.7
W32	29° 41' 58.84	97° 44' 49.73	621201.8	3286164.7
W33	29° 41' 56.87	97° 44' 54.50	621074.2	3286102.5
W34	29° 41' 50.41	97° 45' 1.47	620889.3	3285901.7
W37	29° 41' 53.82	97° 44' 58.80	620959.8	3286007.3
W39	29° 41' 46.71	97° 44' 59.87	620933.4	3285788.3
W41	29° 41' 49.57	97° 44' 56.43	621025.0	3285877.2

APPENDIX D

Information on Soil Gas Survey

Information on Soil Gas Survey

More than 40 vapor and soil-gas samples (fig. 3) were collected and analyzed. Additional analyses of replicates, duplicates, and various quality assurance standards and blanks were made (table D1). Soil-gas samples were analyzed onsite using field gas chromatography (GC). Survey analyses of soil gases were made with a sample injection size between 100-µL and 1,000-µL, separation on a 5-percent SP 1200/1.75-percent Benton 34 packed column (conventionally called a 602 column), with hydrogen carrier gas. The 602 column was selected for rapid analysis and separation of volatile aromatic compounds (alicyclic carbon molecules with one or more ring structures, including a stable aromatic ring, for example, benzene and toluene). Additional analyses were made with separation on a 2-m × 3-mm Porapak-Q packed column, optimized for rapid analysis and separation of volatile aliphatic compounds (carbon molecules with only branched or unbranched chains and no ring structures, for example, methane, ethane, propane, butane). Detection was by flame ionization detector (FID), with standardization made to Scott calibration gases, headspace vapors from samples of crude oil, and pure-phase hydrocarbons.

Three oil samples, from MW2 monitoring well and Edwards and Austin Chalk oil wells, were collected in VOA vials. Equilibrated headspace gases were then withdrawn and analyzed to establish reference chromatograms for petroleum-contaminant vapors in the unsaturated zone.

Four water samples, from MW1 and MW3 monitoring wells, from core hole 47, and from the San Marcos River, also were collected in VOA vials. Equilibrated headspace gases were withdrawn and analyzed.

Figure D1 shows transect lines used to make figures 7 and 8.

Table D1. Reference information on gas chromatograph analyses of soil-gas and other gas samples and standards.

Sample*	File name	Dilution	Injection Size (μL)	Date	Time	Column	Aliphatics (mV-sec)	Aromatics (mV-sec)
SPW13	RCSMF005	1	250	7/28/99	12:43:41	Porapak-Q	54	na
CanMix 216	RCSMF007	0.01	250	7/28/99	13:40:58	Porapak-Q		na
Nat.Gas Mix	RCSMF009	0.1	250	7/28/99	14:27:52	Porapak-Q		na
SPW9	RCSMF010	1	250	7/28/99	15:04:13	Porapak-Q	52	na
SPW9D	RCSMF011	1	250	7/28/99	15:34:07	Porapak-Q	34	na
CanMix 216	RCSMF012	0.01	250	7/28/99	16:04:06	Porapak-Q		na
Nat.Gas Mix	RCSMF013	0.01	250	7/28/99	16:18:09	Porapak-Q		na
SPW4	RCSMF015	1	250	7/28/99	17:05:49	Porapak-Q	5,496	na
SP50-15	RCSMF016	1	250	7/28/99	17:44:58	Porapak-Q	9	na
SP50-19	RCSMF017	1	250	7/28/99	18:06:02	Porapak-Q	49	na
SP50-22	RCSMF019	1	250	7/28/99	18:56:21	Porapak-Q	2294	na
Blank Air	RCSMF021	1	250	7/29/99	9:26:09	Porapak-Q		na
Nat.Gas Mix	RCSMF022	0.01	250	7/29/99	9:55:39	Porapak-Q		na
SP51-20	RCSMF023	1	250	7/29/99	10:23:36	Porapak-Q	76	na
SP52-19	RCSMF024	1	250	7/29/99	10:46:47	Porapak-Q	116	na
SP53-20	RCSMF025	1	250	7/29/99	11:09:25	Porapak-Q	98	na
SP54-20	RCSMF026	1	250	7/29/99	11:32:04	Porapak-Q	121	na
SP58-18	RCSMF027	1	250	7/29/99	11:57:31	Porapak-Q	111	na
SP59-19	RCSMF029	1	250	7/29/99	12:37:46	Porapak-Q	82	na
SP55-20	RCSMF030	1	250	7/29/99	13:04:36	Porapak-Q	90	na
SP56-20	RCSMF031	1	250	7/29/99	13:31:23	Porapak-Q	109	na
SP57-20	RCSMF032	1	250	7/29/99	13:55:20	Porapak-Q	87	na
SP60-22	RCSMF033	1	250	7/29/99	14:15:18	Porapak-Q	25	na
SP61-19	RCSMF034	1	250	7/29/99	14:42:52	Porapak-Q	50	na
Blank Air	RCSMF035	1	250	7/29/99	15:01:45	Porapak-Q		na
SP62-16	RCSMF036	1	250	7/29/99	15:21:16	Porapak-Q	68	na
CanMix 216	RCSMF037	0.2	250	7/29/99	15:42:13	Porapak-Q		na
SP63-18	RCSMF038	1	250	7/29/99	15:57:54	Porapak-Q	89	na
SP64-19	RCSMF039	1	250	7/29/99	16:15:37	Porapak-Q	80	na
SP65-17	RCSMF040	1	250	7/29/99	16:36:04	Porapak-Q	130	na
Nat.Gas Mix	RCSMF041	0.01	250	7/29/99	16:55:13	Porapak-Q		na
SP68-16	RCSMF042	1	250	7/29/99	17:15:05	Porapak-Q	124	na
Blank Air	RCSMF043	1	250	7/29/99	17:34:35	Porapak-Q		na
MW2 oil headspace	RCSMF044	0.01	250	7/29/99	17:56:32	Porapak-Q	83	na
MW2 oil headspace	RCSMF045	0.1	250	7/29/99	18:17:11	Porapak-Q	209	na
Blank Air	RCSMF046	1	250	7/29/99	18:43:54	Porapak-Q		na
Nat.Gas Mix	RCSMF050	0.01	250	7/30/99	8:27:13	602		
CanMix 216	RCSMF051	1	250	7/30/99	8:45:50	602		
MW2 oil headspace	RCSMF052	0.02	250	7/30/99	9:05:09	602	191	126
MW2 oil headspace	RCSMF053	1	500	7/30/99	9:24:04	602	4,689	29,888
SP50@TD	RCSMF054	1	1000	7/30/99	9:43:16	602	705	413
SP71-20	RCSMF055	1	1000	7/30/99	10:02:39	602	1,057	109
SP72-18	RCSMF056	1	1000	7/30/99	10:22:22	602	756	198
SP73-16	RCSMF057	1	1000	7/30/99	10:37:28	602	219	42
Blank Air	RCSMF058	1	1000	7/30/99	10:52:14	602		
SP66-18	RCSMF059	1	1000	7/30/99	11:07:18	602	321	25

Table D1 (continued). Reference information on gas chromatograph analyses of soil-gas and other gas samples and standards.

Sample*	File name	Dilution	Injection Size (μL)	Date	Time	Column	Aliphatics (mV-sec)	Aromatics (mV-sec)
SP67-16	RCSMF060	1	1000	7/30/99	11:22:40	602	388	96
SP69-19	RCSMF061	1	1000	7/30/99	11:38:04	602	267	22
Edwards oil headspace	RCSMF063	1	1000	7/30/99	12:09:37	602	60,424	67,701
Blank Air	RCSMF064	1	1000	7/30/99	12:25:03	602		
SP70-19	RCSMF065	1	1000	7/30/99	12:41:01	602	510	155
SP75-17	RCSMF066	1	1000	7/30/99	12:57:51	602	311	49
SP74-16	RCSMF067	1	1000	7/30/99	13:14:34	602	344	44
SP76-16	RCSMF068	1	500	7/30/99	13:29:14	602	39,130	78
SP50@TD	RCSMF069	1	1000	7/30/99	13:43:30	602	8,607	6,424
SP59@TD	RCSMF070	1	1000	7/30/99	14:11:55	602	74	764
SP76-16D	RCSMF071	1	250	7/30/99	14:29:13	602	22,446	86
SP7-16	RCSMF072	1	1000	7/30/99	14:43:39	602	1,001	41
Blank Air	RCSMF073	1	1000	7/30/99	14:57:43	602		
SP80-15	RCSMF075	1	1000	7/30/99	15:27:50	602	295	24
Austin Chalk oil headspace	RCSMF076	0.01	250	7/30/99	15:46:06	602	10,793	5,840
SP81-15	RCSMF077	1	1000	7/30/99	16:00:21	602	581	146
Edward oil headspace	RCSMF078	0.01	250	7/30/99	16:15:12	602	2,702	4,981
SP53@TD	RCSMF079	1	1000	7/30/99	16:29:30	602	37	221
MW2 oil headspace	RCSMF080	0.5	250	7/30/99	16:44:36	602	701	3848
Blank Air	RCSMF081	1	1000	7/30/99	17:00:20	602		
CanMix 216	RCSMF082	1	250	7/30/99	17:15:08	602		
SP58@TD	RCSMF083	1	1000	7/30/99	17:30:19	602	120	248
CanMix 216	RCSMF084	0.1	1000	7/30/99	17:59:24	602		
SP52@TD	RCSMF085	1	1000	7/30/99	18:15:59	602	126	95
MW3 water headspace	RCSMF087	1	1000	7/30/99	18:51:33	602	131	4,242
MW1 water headspace	RCSMF088	1	1000	7/30/99	19:08:10	602	107	61
SPW13 water headspace	RCSMF089	1	1000	7/30/99	19:23:35	602	119	11
SP51@TD	RCSMF090	1	1000	7/30/99	19:38:41	602	27	561
Blank Air	RCSMF091	1	1000	7/30/99	19:53:13	602		
Blank Air	RCSMF093	1	1000	7/31/99	8:04:13	602		
SP54@TD	RCSMF097	1	1000	7/31/99	8:58:56	602	42	68
SP87-20	RCSMF098	1	1000	7/31/99	9:13:45	602	218	66
SP86-20	RCSMF099	1	1000	7/31/99	9:27:26	602	372	98
Blank Air	RCSMF100	1	1000	7/31/99	9:41:17	602		
CanMix 216	RCSMF101	0.1	250	7/31/99	9:55:22	602		
SP84-20	RCSMF102	1	1000	7/31/99	10:09:30	602	412	47
SP85-20	RCSMF103	1	1000	7/31/99	10:23:45	602	354	40
SP88-16	RCSMF104	1	1000	7/31/99	10:39:58	602	472	83
SPW9@TD	RCSMF105	1	1000	7/31/99	10:54:24	602	44	72
CanMix 216	RCSMF106	0.1	250	7/31/99	11:09:43	602		

Table D1 (continued). Reference information on gas chromatograph analyses of soil-gas and other gas samples and standards.

Sample*	File name	Dilution	Injection Size (μL)	Date	Time	Column	Aliphatics (mV-sec)	Aromatics (mV-sec)
SP89-15	RCSMF107	1	1000	7/31/99	11:24:12	602	972	34
Blank Air	RCSMF108	1	1000	7/31/99	11:38:48	602		
SPW13@TD	RCSMF109	1	1000	7/31/99	11:53:56	602	63	36
SPW13 water headspace	RCSMF110	1	1000	7/31/99	12:09:08	602	120	30
SP82-15	RCSMF111	1	1000	7/31/99	12:24:16	602	1,040	113
Blank Air	RCSMF112	1	1000	7/31/99	12:47:46	602		
SP90-16	RCSMF113	1	1000	7/31/99	13:01:59	602	236	34
SP91-19	RCSMF114	1	1000	7/31/99	13:15:40	602	372	32
SP94-15	RCSMF115	1	1000	7/31/99	13:30:03	602	528	64
SP95-19	RCSMF118	1	1000	7/31/99	14:47:29	602	791	44
SP68@TD	RCSMF119	1	1000	7/31/99	15:01:31	602	96	25
SP96-15	RCSMF120	1	1000	7/31/99	15:15:17	602	578	49
SPW4@TD	RCSMF121	1	1000	7/31/99	15:29:18	602	617	25
Blank Air	RCSMF122	1	1000	7/31/99	15:45:07	602		
MW1 water headspace	RCSMF123	1	1000	7/31/99	15:58:55	602	162	33
MW3 water headspace	RCSMF124	1	1000	7/31/99	16:13:01	602	232	1,541
SM River water headspace	RCSMF125	1	1000	7/31/99	16:27:16	602	203	25
MW2 oil headspace	RCSMF126	0.1	250	7/31/99	16:43:04	602	210	638
CanMix 216	RCSMF127	0.1	250	7/31/99	16:57:04	602		
SP97-14	RCSMF128	1	1000	7/31/99	17:11:09	602	1,178	449
SP98-8	RCSMF129	1	1000	7/31/99	17:25:31	602	767	45
Blank Air	RCSMF130	1	1000	7/31/99	17:39:35	602		
SP50@TD	RCSMF131	1	1000	7/31/99	17:53:19	602	8,359	2,582
SP76	RCSMF143	1	250	7/31/99	18:42:25	Porapak-Q	1,317	na
SP97	RCSMF144	1	250	7/31/99	19:04:34	Porapak-Q	22,516	na
SP98	RCSMF145	1	250	7/31/99	19:26:36	Porapak-Q	196	na
SP59@TD	RCSMF146	1	250	7/31/99	19:47:07	Porapak-Q	522	na

SP50@TD	RCSMF147	1	250	7/31/99	19:55:29	Porapak-Q	48	na
CanMix 216	RCSMF148	1	250	7/31/99	20:05:51	Porapak-Q		
Blank Air	RCSMF149	1	250	7/31/99	20:08:18	Porapak-Q		

* SP50-15 represents soil probe (SP) number 50 (fig. 3) at depth of 15 ft

na not applicable.

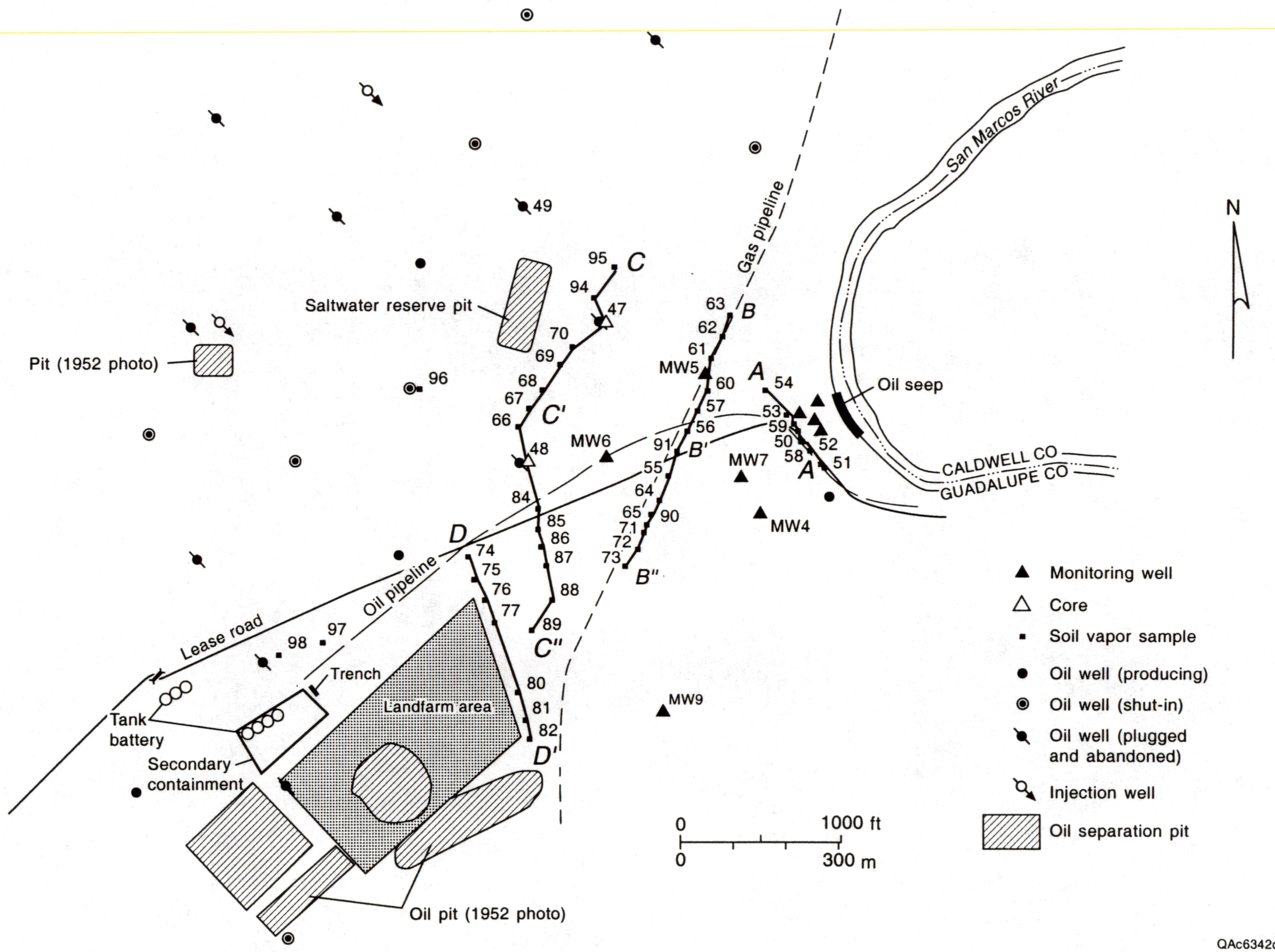


Figure D1. Transect lines *A-A′*, *B-B′-B″*, *C-C′-C″*, *D-D′* for graphs showing variation in aromatic and aliphatic vapors sampled from direct-push survey holes (figs. 7, 8).

APPENDIX E

Photo-Ionization Detector (PID) Data

Table E1. Photoionization Detector (PID) Data

ID	Date	Depth (ft)	Time	PID (ppmV)
47	7/28/99	26	10:29	ND
47	7/28/99	27	10:47	ND
48	7/28/99	15 to 16	12:20	ND
48	7/28/99	16 to 18	12:23	ND
48	7/28/99	18 to 20		ND
48	7/28/99	20 to 22		ND
48	7/28/99	22 to 24		ND
48	7/28/99	24 to 26	13:15	ND
49	7/28/99	13 to 15	16:12	ND
100	8/16/99	18 to 20	14:10	354
101	8/16/99	Water table	17:00	5
102	8/17/99	44 to 46	8:30	2.5
103	8/17/99		10:00	ND
104	8/17/99	46	11:50	20
105	8/17/99	54	14:30	ND
Trench	8/17/99	3.5 to 4.5	14:40	198
106	8/17/99		16:20	8
107	8/17/99		17:10	15.1
108	8/18/99	34.3 to 34.7	8:20	ND
109	8/18/99			8.1
110	8/18/99	30	17:00	ND
111	8/19/99	30		ND
112	8/20/99	25	9:45	219
112	8/20/99	31.6 to 32.3	9:45	1.9
113	8/20/99	16.7 to 17.2	11:35	150
113	8/20/99	18.2 to 18.4	11:35	170
113	8/20/99	20	11:55	445
113	8/20/99		12:05	440
114	8/20/99	16.4 to 16.9	15:20	3.2
114	8/20/99	18.5 to 18.8	15:20	150
114	8/20/99	21.5 to 21.9	15:30	442
114	8/20/99	30.5 to 31.5	15:50	103

ND - no detection

APPENDIX F

Monitor Well Reports

Send original copy by certified mail to: **TNRCC, P.O. Box 13087, Austin, TX 78711-3087**

Please use black ink.

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

State of Texas WELL REPORT

Texas Water Well Drillers Advisory Council
P.O. Box 13087
Austin, Texas 78711-3087
512-239-0530

BEG-MW#4

1) OWNER Railroad Commission of Texas (Name) **ADDRESS** 1701 N. Congress (Street or RFD) Austin (City) Texas (State) 78711-2967 (Zip)

2) ADDRESS OF WELL:
County Guadalupe Roberts Fee Lease/County Road 119 (Street, RFD or other) Stairtown (City) Texas (State) 78748 (Zip) **GRID #**

3) TYPE OF WORK (Check):
☒ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☒ Monitor ☐ Environmental Soil Boring ☐ Domestic ☐ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☐ Testwell
If Public Supply well, were plans submitted to the TNRCC? ☐ Yes ☐ No

5) Lat. 29.6965 Long. 97.7445 N↑

6) WELL LOG:
Date Drilling:
Started 8/18 1999
Completed 8/18 1999

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
7 7/8	Surface	48.6

7) DRILLING METHOD (Check): ☐ Driven ☐ Air Rotary ☐ Mud Rotary ☒ Bored ☐ Air Hammer ☐ Cable Tool ☐ Jetted ☒ Other Auger

From (ft.)	To (ft.)	Description and color of formation material
0.0	6.8	Clay Grey
6.8	14.2	Sand and clayey sand, very fine and fine grained,tan,clay interbeds
14.2	15.3	Sandy gravel
15.3	26.6	Clay Grey
26.6	28.3	Clayey sand, very fine and fine grained,Moist Tan
28.3	33.0	Clay, Mottled brown, grey, black
33.0	34.4	Clayey fine sand Moist Cross- bedded
34.4	36.7	Clay,Mottled brown, grey,black (Quaternary deposit)
36.7	48.6	Clay,dark grey,fissile(Wilcox bebrock)

(Use reverse side if necessary)

8) Borehole Completion (Check): ☐ Open Hole ☐ Straight Wall ☐ Underreamed ☐ Gravel Packed ☒ Other Grout & Cement
If Gravel Packed give interval . . . from ______ ft. to ______ ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2"	N	PVC Riser	0.0	36.1	
2"	N	PVC Screen	36.1	46.1	

9) CEMENTING DATA: [Rule 338.44(1)]
Cemented from 0.5 ft. to 22.9 ft. No. of Sacks Used 3
______ ft. to ______ ft. No. of Sacks Used ______
Method used Grout Machine
Cemented by Drill Crew
Distance to septic system field lines or other concentrated contamination ______ ft.
Method of verification of above distance

10) SURFACE COMPLETION
☐ Specified Surface Slab Installed [Rule 338.44 (2)
☐ Specified Steel Sleeve Installed [Rule 338.44 (3)(A)]
☐ Pitless Adapter Used [Rule 338.44 (3)(b)]
☒ Approved Alternative Procedure Used [Rule 338.71]

11) WATER LEVEL:
Static level ______ ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other
Depth to pump bowls, cylinder, jet, etc., ______ ft.

14) WELL TESTS:
Type test: ☐ Pump ☐ Bailer ☐ Jetted
Yield: ______ gpm with ______ ft. drawdown after ______ hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☐ No
Type of water? ______ Depth of strata ______
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME University of Texas/Bureau of Economic Geology (Type or Print) WELL DRILLER'S LICENSE NO. 3187-M

ADDRESS P.O. Box X University Station (Street or RFD) Austin (City) Texas (State) 78714 (Zip)

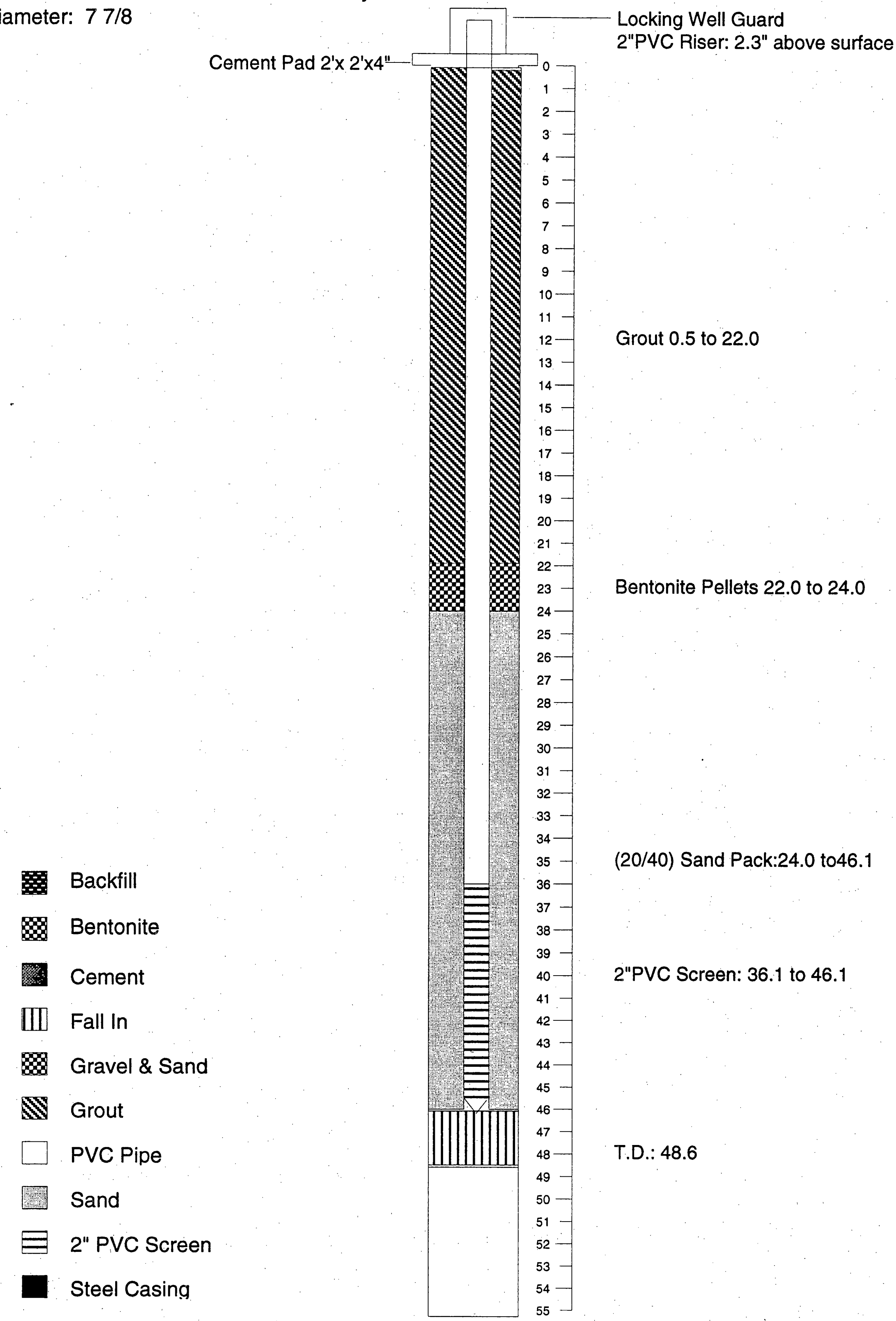
(Signed) James Doss (Licensed Well Driller) **(Signed)** Jordan Forman (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

TNRCC-0199 (Rev. 11-01-94) TNRCC COPY

Schematic
Bore Hole: BEG-MW#4
Drill Date: 8/18/99
Project: San Marcos Task 1.2

Hole diameter: 7 7/8



Send original copy by certified mail to: TNRCC, P.O. Box 13087, Austin, TX 78711-3087

Please use black ink.

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

State of Texas WELL REPORT

Texas Water Well Drillers Advisory Council
P.O. Box 13087
Austin, Texas 78711-3087
512-239-0530

BEG-MW#5

1) OWNER Railroad Commission of Texas (Name) **ADDRESS** 1701 N. Congress (Street or RFD) Austin (City) Texas (State) 78711-2967 (Zip)

2) ADDRESS OF WELL:
County Guadalupe Roberts Fee Lease/County Road 119 (Street, RFD or other) Stairtown (City) Texas (State) 78748 (Zip) **GRID #**

3) TYPE OF WORK (Check): ☒ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☒ Monitor ☐ Environmental Soil Boring ☐ Domestic ☐ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☐ Testwell

If Public Supply well, were plans submitted to the TNRCC? ☐ Yes ☐ No

5) Lat. 29.6976 Long. 97.7450

6) WELL LOG:
Date Drilling:
Started 8/18 1999
Completed 8/18 1999

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
7 7/8	Surface	36.0

7) DRILLING METHOD (Check): ☐ Driven ☐ Air Rotary ☐ Mud Rotary ☐ Bored ☐ Air Hammer ☐ Cable Tool ☐ Jetted ☒ Other Auger

From (ft.)	To (ft.)	Description and color of formation material
0.0	3.2	Clay Gery with caliche nodules<5mm
3.2	18.5	Clayey sand to sandy clay,very fine
		and fine grained, fining upward, gravel a
		base,caliche nodules <5mm throughout
18.5	23.6	Clay and interbedded clayey sand,tan
23.6	36.0	Sand,very fine and fine grained,fining upward

(Use reverse side if necessary)

8) Borehole Completion (Check): ☐ Open Hole ☐ Straight Wall ☐ Underreamed ☐ Gravel Packed ☒ Other Grout&Cement

If Gravel Packed give interval . . . from ft. to ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	N	PVC Riser	0.0	26.2	
2	N	PVC Screen	26.2	36.2	

9) CEMENTING DATA: [Rule 338.44(1)]

Cemented from 0.5 ft. to 22.0 ft. No. of Sacks Used 3
ft. to ft. No. of Sacks Used
Method used Grout Machine
Cemented by Drill Crew
Distance to septic system field lines or other concentrated contamination ft.
Method of verification of above distance

10) SURFACE COMPLETION
☐ Specified Surface Slab Installed [Rule 338.44 (2)
☐ Specified Steel Sleeve Installed [Rule 338.44 (3)(A)]
☐ Pitless Adapter Used [Rule 338.44 (3)(b)]
☒ Approved Alternative Procedure Used [Rule 338.71]

11) WATER LEVEL:
Static level ft. below land surface Date
Artesian flow gpm. Date

12) PACKERS: Type Depth

13) TYPE PUMP: ☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder ☐ Other
Depth to pump bowls, cylinder, jet, etc., ft.

14) WELL TESTS:
Type test: ☐ Pump ☐ Bailer ☐ Jetted
Yield: gpm with ft. drawdown after hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☐ No
Type of water? Depth of strata
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME University of Texas/Bureau of Economic Geology (Type or Print) WELL DRILLER'S LICENSE NO. 3187-M

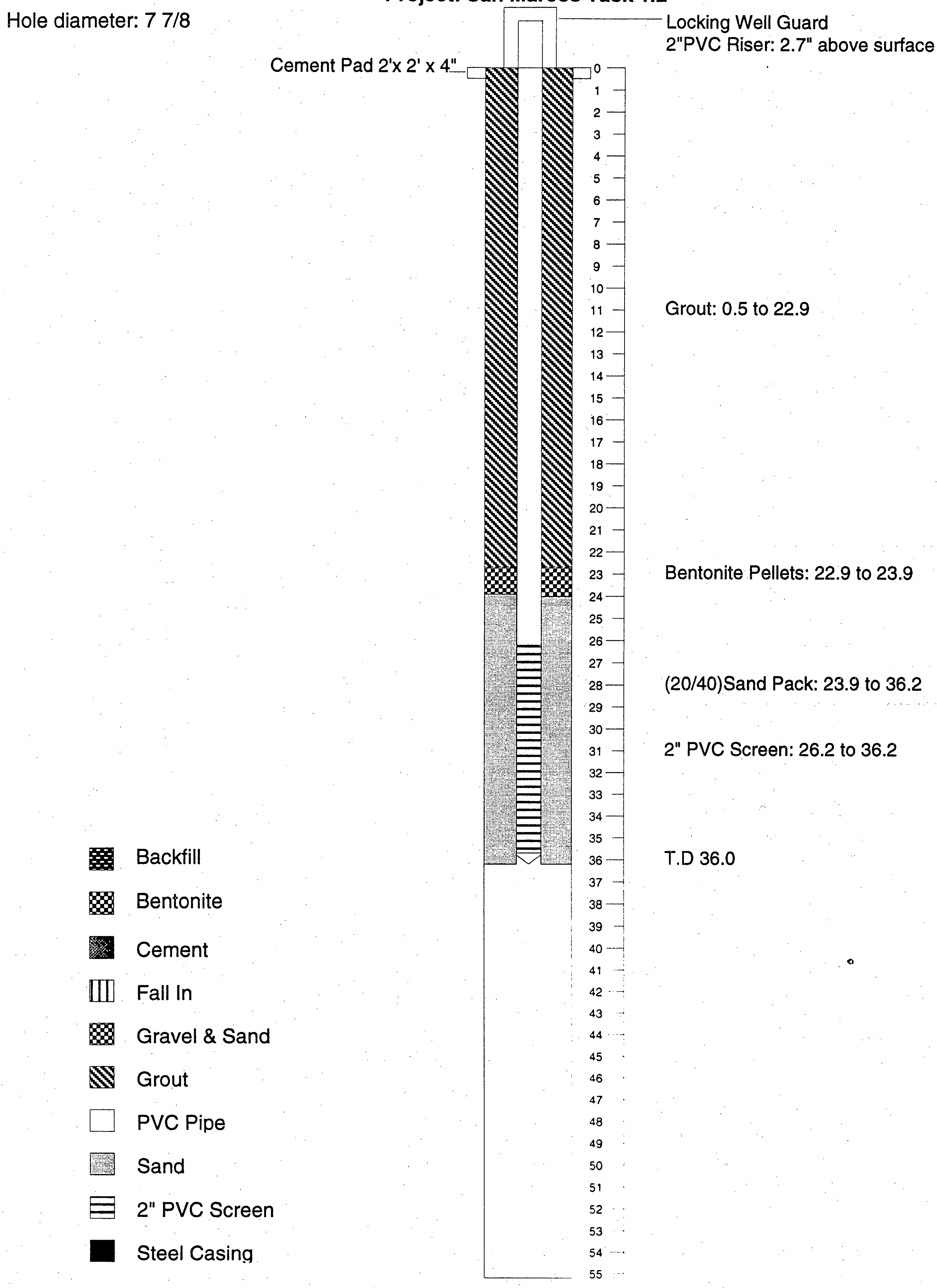
ADDRESS P.O.Box X University Station (Street or RFD) Austin (City) Texas (State) 78713 (Zip)

(Signed) James Doss (Licensed Well Driller) **(Signed)** Jordan Forman (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

TNRCC-0199 (Rev. 11-01-94) TNRCC COPY

Schematic
Bore Hole: BEG-MW#5
Drill Date: 8/18/99
Project: San Marcos Task 1.2



Send original copy by certified mail to: **TNRCC, P.O. Box 13087, Austin, TX 78711-3087**

Please use black ink.

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

State of Texas
WELL REPORT

Texas Water Well Drillers Advisory Council
P.O. Box 13087
Austin, Texas 78711-3087
512-239-0530

BEG-MW#6

1) OWNER Railroad Commission of Texas (Name) **ADDRESS** 1701 N. Congress (Street or RFD) Austin (City) Texas (State) 78711-2967 (Zip)

2) ADDRESS OF WELL:
County Guadalupe — Roberts Fee Lease/ County Road 119 (Street, RFD or other) Stairtown (City) Texas (State) 78748 (Zip) **GRID #**

3) TYPE OF WORK (Check):
☒ New Well ☐ Deepening
☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☒ Monitor ☐ Environmental Soil Boring ☐ Domestic
☐ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☐ Testwell
If Public Supply well, were plans submitted to the TNRCC? ☐ Yes ☐ No

5)
Lat. 29.6970
Long. 97.7459

6) WELL LOG:
Date Drilling:
Started 8/18 1999
Completed 8/18 1999

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
	Surface	

7) DRILLING METHOD (Check): ☐ Driven
☐ Air Rotary ☐ Mud Rotary ☐ Bored
☐ Air Hammer ☐ Cable Tool ☐ Jetted
☒ Other Auger

From (ft.)	To (ft.)	Description and color of formation material
0.0	14.8	Clay,grey and mottled grey brown
14.8	19.6	Clayey sand, ,very fine and fine grained with interbedded coarse sand stringers, upper contact gradational
19.6	34.0	Sand and clayed sand,zones thoroughly calichified

(Use reverse side if necessary)

8) Borehole Completion (Check): ☐ Open Hole ☐ Straight Wall
☐ Underreamed ☐ Gravel Packed ☒ Other Grout&Cement
If Gravel Packed give interval . . . from ____ ft. to ____ ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	N	PVC Riser	0.0	23.8	
2	N	PVC Screen	23.8	33.8	

9) CEMENTING DATA: [Rule 338.44(1)]
Cemented from 0.5 ft. to 18.4 ft. No. of Sacks Used 3
____ ft. to ____ ft. No. of Sacks Used ____
Method used Grout Machine
Cemented by Drill crew
Distance to septic system field lines or other concentrated contamination ____ ft.
Method of verification of above distance ____

10) SURFACE COMPLETION
☐ Specified Surface Slab Installed [Rule 338.44 (2)]
☐ Specified Steel Sleeve Installed [Rule 338.44 (3)(A)]
☐ Pitless Adapter Used [Rule 338.44 (3)(b)]
☒ Approved Alternative Procedure Used [Rule 338.71]

11) WATER LEVEL:
Static level ____ ft. below land surface Date ____
Artesian flow ____ gpm. Date ____

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ____
Depth to pump bowls, cylinder, jet, etc., ____ ft.

14) WELL TESTS:
Type test: ☐ Pump ☐ Bailer ☐ Jetted
Yield: ____ gpm with ____ ft. drawdown after ____ hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☐ No
Type of water? ____ Depth of strata ____
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME University of Texas/Bureau of Economic Geology (Type or Print) WELL DRILLER'S LICENSE NO. 3187-M

ADDRESS P.O.Box X University Station (Street or RFD) Austin (City) Texas (State) 78713 (Zip)

(Signed) James Doss (Licensed Well Driller) **(Signed)** Jordan Forman (Registered Driller Trainee)

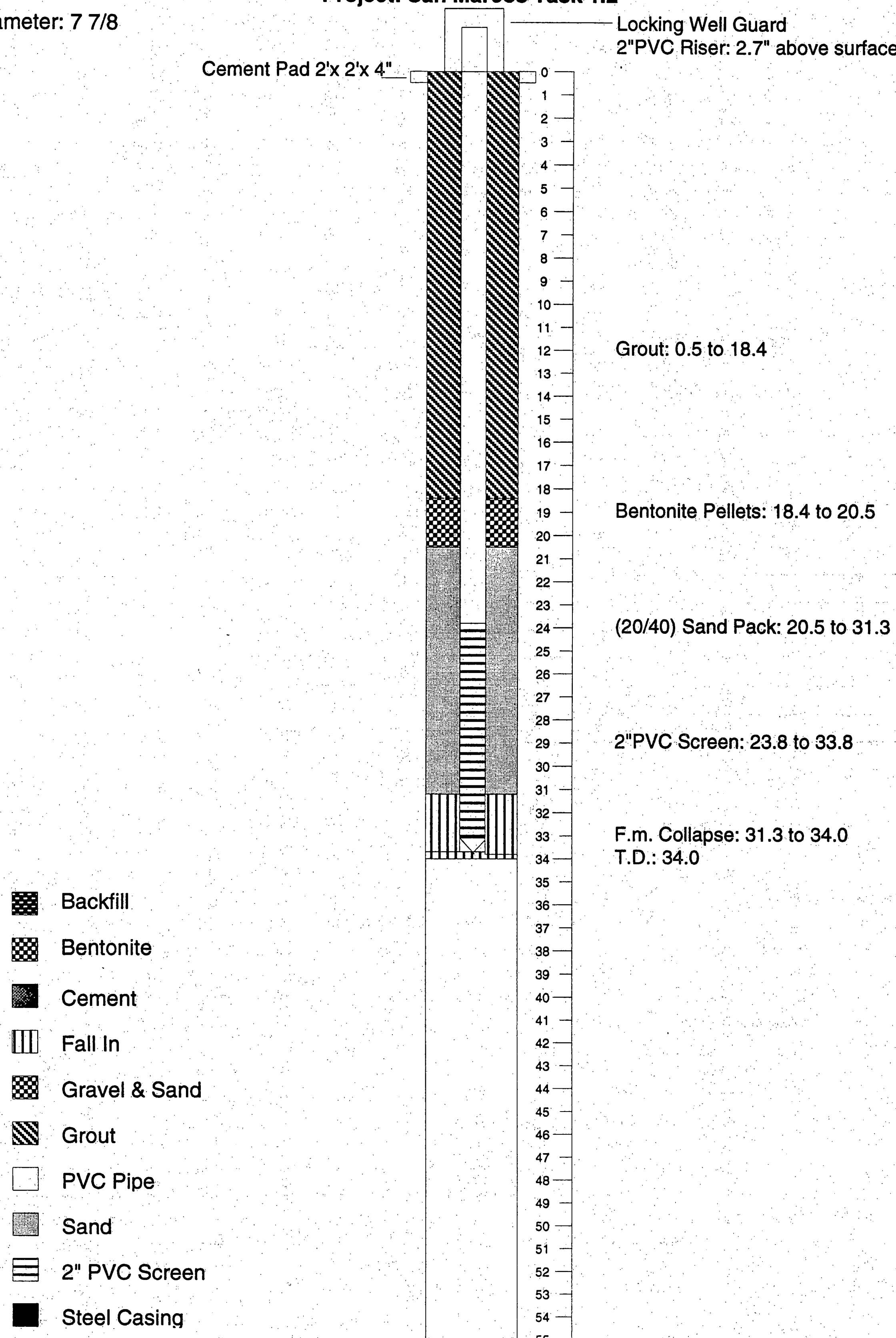
Please attach electric log, chemical analysis, and other pertinent information, if available.

TNRCC-0199 (Rev. 11-01-94)

TNRCC COPY

Schematic
Bore Hole: BEG-MW#6
Drill Date: 8/18/99
Project: San Marcos Task 1.2

Hole diameter: 7 7/8



Send original copy by certified mail to: **TNRCC, P.O. Box 13087, Austin, TX 78711-3087**

Please use black ink.

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

State of Texas
WELL REPORT

Texas Water Well Drillers Advisory Council
P.O. Box 13087
Austin, Texas 78711-3087
512-239-0530

BEG-MW#7

1) OWNER Railroad Commission of Texas (Name) **ADDRESS** 1701 N. Congress (Street or RFD) Austin (City) Texas (State) 78711-2967 (Zip)

2) ADDRESS OF WELL:
County Guadalupe Roberts Fee Lease/ County Road 119 (Street, RFD or other) Stairtown (City) Texas (State) 78748 (Zip) **GRID #**

3) TYPE OF WORK (Check):
☒ New Well ☐ Deepening
☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☒ Monitor ☐ Environmental Soil Boring ☐ Domestic
☐ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☐ Testwell
If Public Supply well, were plans submitted to the TNRCC? ☐ Yes ☐ No

5)
Lat. 29.6984
Long. 97.7446
N

6) WELL LOG:
Date Drilling:
Started 8/19 1999
Completed 8/19 1999

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
	Surface	

7) DRILLING METHOD (Check): ☐ Driven
☐ Air Rotary ☐ Mud Rotary ☐ Bored
☐ Air Hammer ☐ Cable Tool ☐ Jetted
☒ Other Auger

From (ft.)	To (ft.)	Description and color of formation material
0.0	3.8	Clay,grey
3.8	8.8	Clayed sand to sandy clay,very fine and fine
		grained,fining upward,large caliche nodules
8.8	33.8	Sand interbeded with gravel and clayed
		sand,limonitic staining,base containing
		ripup clasts of laminated clay
33.8	35.8	Clay, laminated brown and grey,upper
		contact sharp

(Use reverse side if necessary)

8) Borehole Completion (Check): ☐ Open Hole ☐ Straight Wall
☐ Underreamed ☐ Gravel Packed ☐ Other
If Gravel Packed give interval . . . from ft. to ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	N	PVC Riser	0.0	25.9	
2	N	PVC Screen	25.9	35.9	

9) CEMENTING DATA: [Rule 338.44(1)]

Cemented from ft. to ft. No. of Sacks Used
ft. to ft. No. of Sacks Used
Method used
Cemented by
Distance to septic system field lines or other concentrated contamination ft.
Method of verification of above distance

10) SURFACE COMPLETION

☐ Specified Surface Slab Installed [Rule 338.44 (2)
☐ Specified Steel Sleeve Installed [Rule 338.44 (3)(A)]
☐ Pitless Adapter Used [Rule 338.44 (3)(b)]
☐ Approved Alternative Procedure Used [Rule 338.71]

11) WATER LEVEL:

Static level ft. below land surface Date
Artesian flow gpm. Date

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other
Depth to pump bowls, cylinder, jet, etc., ft.

14) WELL TESTS:
Type test: ☐ Pump ☐ Bailer ☐ Jetted
Yield: gpm with ft. drawdown after hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☐ No
Type of water? Depth of strata
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME (Type or Print) WELL DRILLER'S LICENSE NO.

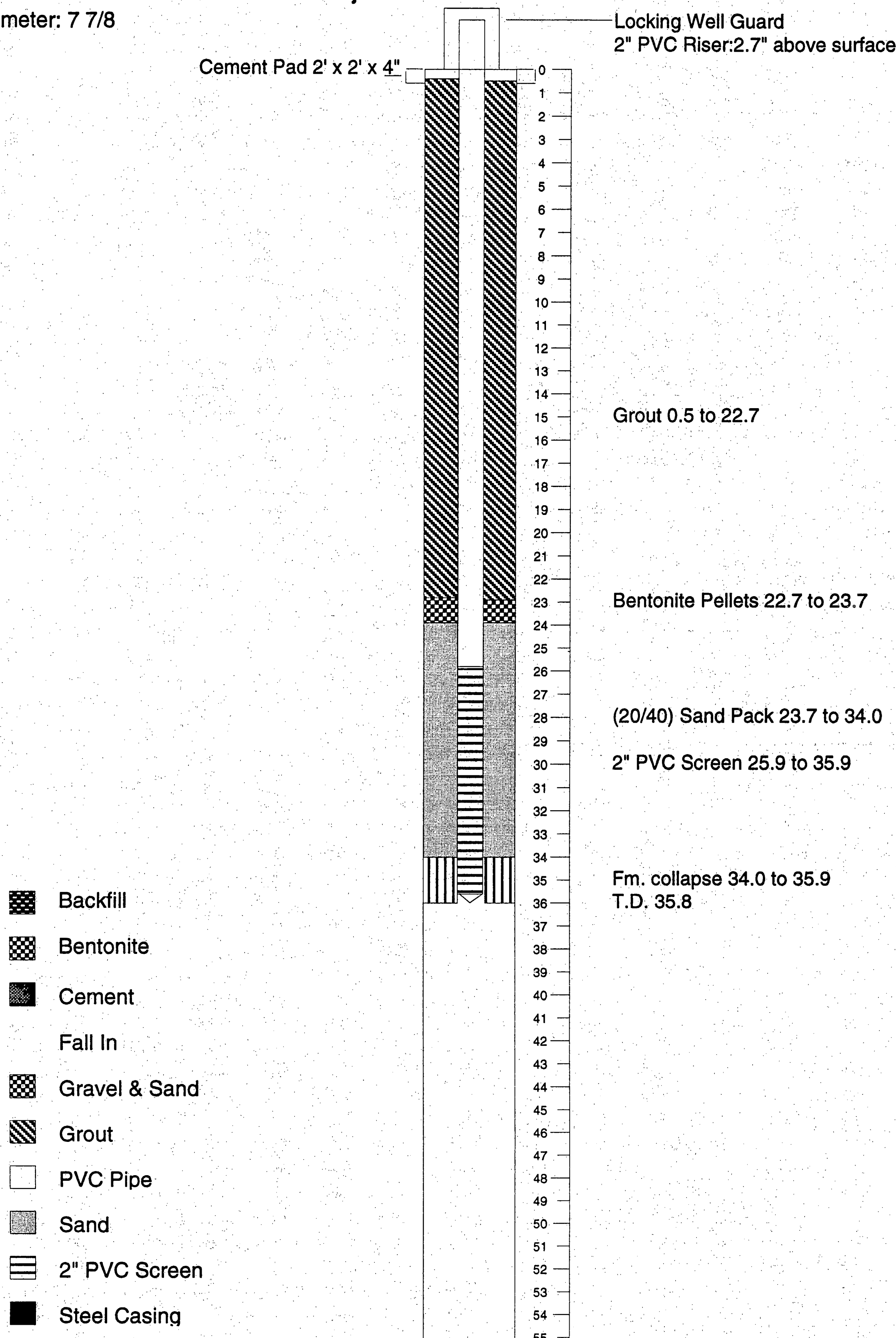
ADDRESS (Street or RFD) (City) (State) (Zip)

(Signed) (Licensed Well Driller) **(Signed)** (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

Schematic
Bore Hole: BEG-MW#7
8/19/99
Project: San Marcos Task 1. 2

Hole diameter: 7 7/8



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State of Texas WELL REPORT

Texas Water Well Drillers Advisory Council
P.O. Box 13087
Austin, Texas 78711-3087
512-239-0530

BEG-MW#8

1) OWNER Railroad Commission of Texas (Name) **ADDRESS** 1701 N. Congress (Street or RFD) Austin (City) Texas (State) 78711-2967 (Zip)

2) ADDRESS OF WELL:
County Guadalupe — Roberts Fee Lease/ County Road 119 (Street, RFD or other) Stairtown (City) Texas (State) 78748 (Zip) **GRID #**

3) TYPE OF WORK (Check):
☒ New Well ☐ Deepening
☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☒ Monitor ☐ Environmental Soil Boring ☐ Domestic
☐ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☐ Testwell
If Public Supply well, were plans submitted to the TNRCC? ☐ Yes ☐ No

5)
Lat. 29.6988
Long. 97.7439
N ↑

6) WELL LOG:
Date Drilling:
Started 8/20 1999
Completed 8/20 1999

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
7 7/8	Surface	33.4

7) DRILLING METHOD (Check): ☐ Driven
☐ Air Rotary ☐ Mud Rotary ☐ Bored
☐ Air Hammer ☐ Cable Tool ☐ Jetted
☒ Other Auger

From (ft.)	To (ft.)	Description and color of formation material
0.0	3.4	Clay,grey
3.4	16.3	Clayey sand to sandy clay,completely calichified
16.3	16.5	Clayed sand, hydrocarbon impacted, black
16.5	28.5	Very fine and fine grained sandy clay to clayed sand, interbeded layers of clay and coarse sand,hydrocarbon impacted greenish grey
28.5	33.4	Sandy gravel

(Use reverse side if necessary)

8) Borehole Completion (Check): ☐ Open Hole ☐ Straight Wall
☐ Underreamed ☐ Gravel Packed ☒ Other Grout&Cement
If Gravel Packed give interval . . . from ____ ft. to ____ ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	N	PVC Riser	0.0	18.4	
2	N	PVC Screen	18.4	28.4	
2	N	PVC Riser	28.4	33.4	

9) CEMENTING DATA: [Rule 338.44(1)]

Cemented from 0.5 ft. to 25.4 ft. No. of Sacks Used 3
____ ft. to ____ ft. No. of Sacks Used ____
Method used Grout Machine
Cemented by Drill Crew
Distance to septic system field lines or other concentrated contamination ____ ft.
Method of verification of above distance ____

10) SURFACE COMPLETION
☐ Specified Surface Slab Installed [Rule 338.44 (2)
☐ Specified Steel Sleeve Installed [Rule 338.44 (3)(A)]
☐ Pitless Adapter Used [Rule 338.44 (3)(b)]
☒ Approved Alternative Procedure Used [Rule 338.71]

11) WATER LEVEL:
Static level ____ ft. below land surface Date ____
Artesian flow ____ gpm. Date ____

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ____
Depth to pump bowls, cylinder, jet, etc., ____ ft.

14) WELL TESTS:
Type test: ☐ Pump ☐ Bailer ☐ Jetted
Yield: ____ gpm with ____ ft. drawdown after ____ hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☐ No
Type of water? ____ Depth of strata ____
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME University of Texas/ Bureau of Economic Geology (Type or Print) WELL DRILLER'S LICENSE NO. 3187-M

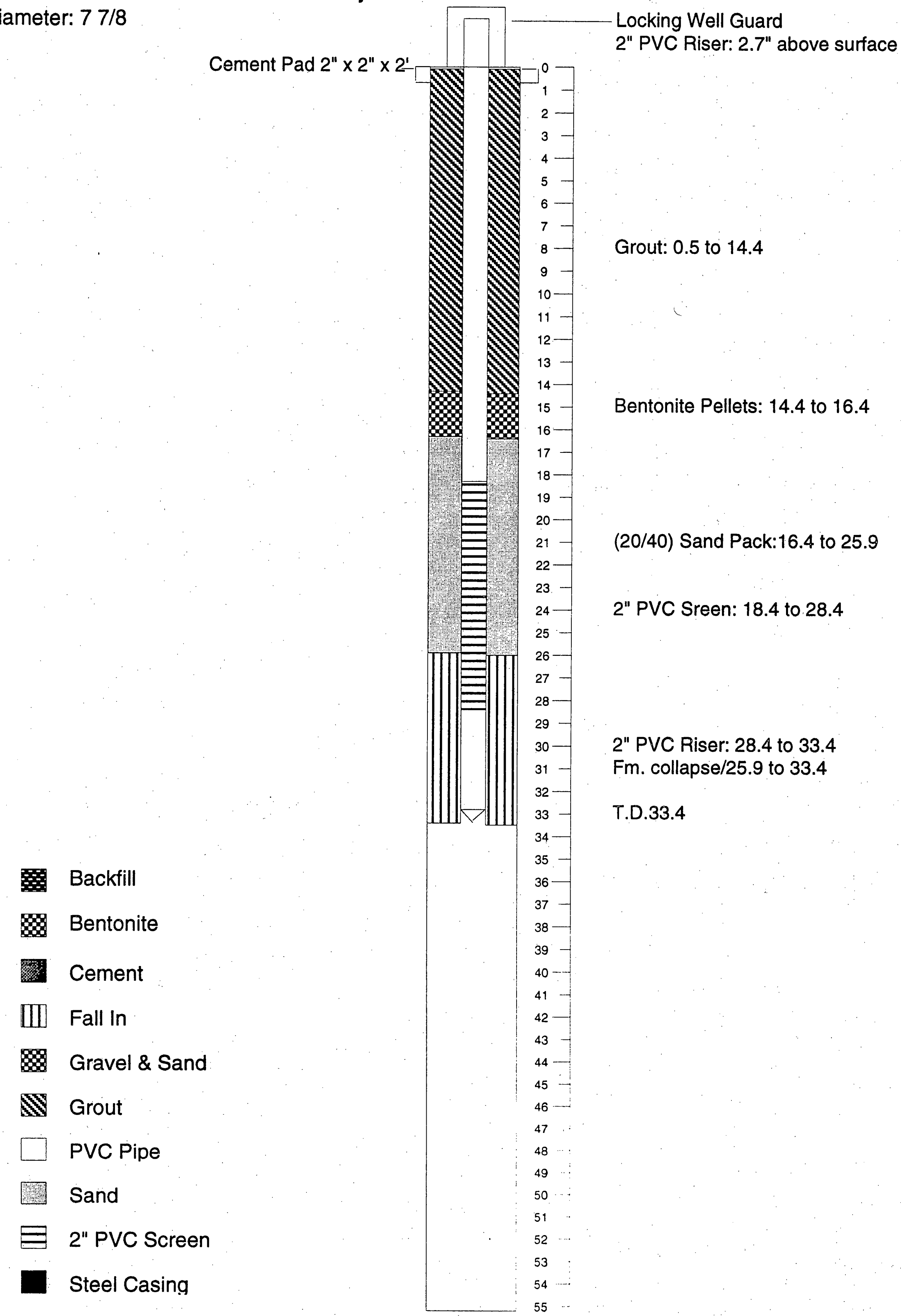
ADDRESS P.O.Box X University Station (Street or RFD) Austin (City) Texas (State) 78713 (Zip)

(Signed) James Doss (Licensed Well Driller) **(Signed)** Jordan Forman (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

Schematic
Bore Hole: BEG-MW#8
Drill Date: 8/20/99
Project: San Marcos Task 1. 2

Hole diameter: 7 7/8



APPENDIX G

Data on Total Petroleum Hydrocarbons (TPH)

1. Analyses by CHEMRON Incorporated

2. Analyses by RRC Surface Mining and Reclamation Laboratory

CHEMRON
INCORPORATED

10526 Gulfdale • San Antonio, Texas 78216-3601 • (210) 340-8121

CLIENT: University of Texas at Austin
Lab Order: 9908090
Project: RRC San Marcos Site Task 1.1

Date: *26-Aug-99*
Matrix: SOIL

PETROLEUM HYDROCARBONS, T/R **E418.1** **Analyst:** SLF

Lab ID	Chemron ID	Client ID	Collection Date	Analyses	Result	Rpt Limit	Units	Dilution	Date Analyzed
9908090-01A	79044	AU 114 30.5-31.5	8/20/99 3:50:00	Petroleum Hydrocarbons,	10100	500	mg/Kg	50	8/25/99
9908090-02A	79045	AU 107 37.6	8/17/99 3:10:00	Petroleum Hydrocarbons,	778	10	mg/Kg	1	8/25/99
9908090-03A	79046	AU 112 30.6-31.3	8/20/99 9:45:00	Petroleum Hydrocarbons,	23500	1000	mg/Kg	100	8/25/99
9908090-04A	79047	AU 113 20-21	8/20/99 12:05:00	Petroleum Hydrocarbons,	24300	1000	mg/Kg	100	8/25/99
9908090-05A	79048	AU 110 TD	8/16/99 2:10:00	Petroleum Hydrocarbons,	907	10	mg/Kg	1	8/25/99

5/6 100,

Approved by: R. Eldman

CHEMRON
INCORPORATED

10526 Gulfdale • San Antonio, Texas 78216-3601 • (210) 340-8121

Client: University of Texas at Austin
Lab Order: 9908090
Project: RRC San Marcos Site Task 1.1
Lab ID: 08BLK25A

Date: *26-Aug-99*
Matrix: Soil
Batch ID: IR_990825A
Prep Date: 8/25/99
Date Analyzed: 8/25/99 3:00:00 PM

QUALITY CONTROL REPORT

Method Blank

PETROLEUM HYDROCARBONS, T/R **E418.1** **Analyst:** SLF

Analyte	Result	Report Limit	Units:
Petroleum Hydrocarbons, TR	< 10	10	mg/Kg

CHEMRON
INCORPORATED

10526 Gulfdale • San Antonio, Texas 78216-3601 • (210) 340-8121

Client: University of Texas at Austin
Lab Order: 9908090
Project: RRC San Marcos Site Task 1.1
Lab ID: 9908090-02A

Date: *26-Aug-99*
Matrix: Soil
Batch ID: IR_990825A
Prep Date: 8/25/99
Date Analyzed: 8/25/99 3:00:00 PM

QUALITY CONTROL REPORT

Matrix Spike/Matrix Spike Duplicate

PETROLEUM HYDROCARBONS, T/R **E418.1** **Analyst:** SLF

Analyte	Amount Spiked	MS* Results	% Recovery	Control Limits	MSD* Results	% Recovery	% RPD	RPD Limits	Units
Petroleum Hydrocarbons, TR	200	778	0	77-131	1010	118	26	13	mg/Kg

* MS/MSD results reflect the amount spiked + the parent sample concentration.

CHEMRON
INCORPORATED

10526 Gulfdale • San Antonio, Texas 78216-3601 • (210) 340-8121

Client:	University of Texas at Austin	**Date:**	*26-Aug-99*
Lab Order:	9908090	**Matrix:**	Soil
Project:	RRC San Marcos Site Task 1.1	**Batch ID:**	IR_990825A
Lab ID:	08LCS25A	**Prep Date:**	8/25/99
		Date Analyzed:	8/25/99 3:00:00 PM

QUALITY CONTROL REPORT

Laboratory Control Sample

PETROLEUM HYDROCARBONS, T/R **E418.1** **Analyst:** SLF

Analyte	Amt. Spiked	Result	% Recovery	Control Limits	Units:
Petroleum Hydrocarbons, TR	200	221	111	75-125	mg/Kg

"Job #13565"

Bureau of Economic Geology

Mailing address:
Bureau of Economic Geology
University Station Box X
Austin, TX 78713
(512) 471-1534 Phone
(512) 471-0140 Fax

Shipping address:
Bureau of Economic Geology
J.J. Pickle Research Campus Bldg. 130
10100 Burnet Road
Austin, TX 78758

Please send report and billing invoice to: Alan R. Dutton (Name) 512-471-5739 (Phone)

CHAIN OF CUSTODY AND ANALYTICAL REQUEST RECORD

Project name: RRC SAN MARCOS SITE TASK 1.1

Project no.:

Turnaround: 1 WEEK REQUESTED

Sample ID	Date	Time	No. of Cont.	Matrix	TPH 418.1									Lab Number	Comment
AU 114 30.5-31.5	8/20/99	1550	1	Soil	X								789044	15-1001	Crude oil impacted soil
AU 107 37.6	8/17/99	1510	1	Soil	X								789045	15-1001	Crude oil impacted soil
AU 112 30.6-31.3	8/20/99	0945	1	Soil	X								789046	15-1001	Crude oil impacted soil
AU 113 20-21	8/20/99	1205	1	Soil	X								789047	15-1001	Crude oil impacted soil
AU ~~110~~ TD 100 ARD	8/16/99	1410	1	Soil	X								789048	15-1001	Crude oil impacted soil

Relinquished by:	Date	Time	Received by:	Carrier:	Date	Time
Marcus Barksdale	8/20/99	1700	Alan Dutton	ARD	8/20/99	1700
Alan Dutton	8/23/99	1200	E.K. Hallert	FEDEX	08-24-99	10:00

CHEMRON
INCORPORATED

10526 Gulfdale • San Antonio, Texas 78216-3601 • (210) 340-8121

SAMPLE LOG-IN CHECKLIST

DATE: 08/24/99 TIME: 10:00 a.m. / p.m. INITIALS: [illegible]

CLIENT: UNIVERSITY OF TX AT AUSTIN BUREAU OF ECONOMIC GEOLOGY PROJECT: RRC SAN MARCOS SITE TASK 1.1

1. Is a Chain of Custody present? **Yes** No
2. Is the Chain of Custody properly completed? **Yes** No
3. Are custody seals present? Yes **No**
   If yes, are they intact? Yes No
   Are they on: Sample ____ *or on* Shipping Container ____
4. Are all samples tagged or labeled? **Yes** No
   If yes, do the labels match the Chain of Custody? **Yes** No
5. Do all shipping documents agree (i.e, number of coolers arrived vs. on tickets?) *If not*, describe below. **Yes** No N/A
6. Are samples preserved properly? *If not*, describe below. Yes **No**
7. Are all samples within holding times on arrival? *If not*, describe below. **Yes** No

				Other
8.	Condition of shipping container:	Intact ✓	*or*	____
9.	Condition of samples:	Intact ✓	*or*	____
10.	Temperature of samples:	25°C		
11.	Delivery agent:	Client ___ UPS ___ Fed-Ex ✓	*or*	____

12. Sample disposal: Return to client ____ Chemron disposal ✓

COMMENTS (Reference checklist item number from above, or for comments on resolution below):

Record of contacting client for resolution of sample discrepancies (first and retry contact)

	Contacted How?		
Name: ____	Phone ___ Fax ___	Date: ___/___	Time: ____
Name: ____	Phone ___ Fax ___	Date: ___/___	Time: ____

Michael L. Williams, *Chairman*
Charles R. Matthews, *Commissioner*
Tony Garza, *Commissioner*

Melvin B. Hodgkiss, P.E., *Director*

Railroad Commission of Texas

Surface Mining and Reclamation Division

MEMORANDUM

TO: John Tintera, Assistant Director
Site Remediation, Oil and Gas Division

FROM: Carl Nelson, Laboratory Supervisor
Surface Mining and Reclamation Division Laboratory

SUBJECT: Analysis of the samples from Vintage Petroleum, Caldwell County

DATE: September 27, 1999

I have enclosed the analysis results of the three samples from the above referenced source. These samples were received at the Surface Mining and Reclamation Division Laboratory on August 23, 1999.

If additional information is needed, please contact me at (512) 926-3064.

Carl Nelson
Carl Nelson

CN/gm

enc.

RECEIVED
RRC OF TEXAS
SEP 2 8 1999
OG SR
AUSTIN, TEXAS

1701 NORTH CONGRESS AVENUE ★ POST OFFICE BOX 12967 ★ AUSTIN, TEXAS 78711-2967 ★ PHONE:512/463-6900 FAX:512/463-6709
TDD 800/735-2989 or TDY 512/463-7284 ★ AN EQUAL OPPORTUNITY EMPLOYER ★ http://www.rrc.state.tx.us

RAILROAD COMMISSION OF TEXAS
SURFACE MINING AND RECLAMATION DIVISION LABORATORY

Soil Analysis Report

Lab No. 9466E RRC Custody Tag No. 36809

Sample Identification: Vintage Petroleum, Roberts Fee Lease, Caldwell County, AU100 - San Marcos River Seep

Submitted by: Special Response

Date Collected: 08/16/1999 Date Received: 08/23/1999 Date Completed: 09/24/1999

ANALYSIS	VALUE	UNITS
Oil and Grease (as % dry solids)	0.14	%
Total Petroleum Hydrocarbons	0.12	%

Comments:

Data Verification Carl Nelson

RAILROAD COMMISSION OF TEXAS

Water Sample Custody Record No. № 36809

Operator Vintage Petroleum Lease Roberts Fee

Field — County Caldwell District 1

Source of Sample AU100 – San Marcos River Seep
(Stream Name, Water Well Owner, Sample Location, Etc.)

Well ___ Pit ___ Stream ___ Discharge ___ Other Subsurface Soil

Date Collected 8-16-99 Time Collected 1410 Date Shipped —

Method of Preservation ___ Method of Conveyance Hand Deliver

Sample Collector Certification RM Barksdale
(Signature)

Marcus Barksdale – RRC OG Site Remediation 3-5983

Requested Analysis or Remarks

5520 TPH

Date Received 08-23-99 Lab No 9466E Date Analysis Completed 9-24-99

Lab Receipt Certification Carl Nelson
(Signature)

Soil

RAILROAD COMMISSION OF TEXAS
SURFACE MINING AND RECLAMATION DIVISION LABORATORY

Soil Analysis Report

Lab No. 9467E   RRC Custody Tag No. 36811

Sample Identification: Vintage Petroleum, Roberts Fee Lease, Caldwell County,
T1 - San Marcos River Seep

Submitted by: Special Response

Date Collected: 08/17/1999 Date Received: 08/23/1999 Date Completed: 09/24/1999

ANALYSIS	VALUE	UNITS
Oil and Grease (as % dry solids)	11.	%
Total Petroleum Hydrocarbons	6.9	%

Comments:

Data Verification [signature]

RAILROAD COMMISSION OF TEXAS
Water Sample Custody Record

No. № 36811

Operator Vintage Petroleum Lease Roberts Fee

Field ——— County Caldwell District 1

Source of Sample T1 - San Marcos River Seep
(Stream Name, Water Well Owner, Sample Location, Etc.)

Well ____ Pit ____ Stream ____ Discharge ____ Other Subsurface soil

Date Collected 8-17-99 Time Collected 1440 Date Shipped ———

Method of Preservation ____ Method of Conveyance Hand Deliver

Sample Collector Certification RM Barksdale
(Signature)

Marcus Barksdale - RRC OG Site Remediation 3-5983

Requested Analysis or Remarks

5520 TPH

Date Received 08-23-99 Lab No. 9467 E Date Analysis Completed 9-24-99

Lab Receipt Certification Carl Nelson
(Signature)

soil

9467 E

RAILROAD COMMISSION OF TEXAS
SURFACE MINING AND RECLAMATION DIVISION LABORATORY

Soil Analysis Report

Lab No. 9468E RRC Custody Tag No. 36810

Sample Identification: Vintage Petroleum, Roberts Fee Lease, Caldwell County, AU114 - San Marcos River Seep

Submitted by: Special Response

Date Collected: 08/20/1999 Date Received: 08/23/1999 Date Completed: 09/24/1999

ANALYSIS	VALUE	UNITS
Oil and Grease (as % dry solids)	0.47	%
Total Petroleum Hydrocarbons	0.36	%

Comments:

Data Verification [signature]

RAILROAD COMMISSION OF TEXAS
Water Sample Custody Record

No. № 36810

Operator Vintage Petroleum Lease Roberts Fee

Field ——— County Caldwell District 1

Source of Sample AU 114 – San Marcos River Seep
(Stream Name, Water Well Owner, Sample Location, Etc.)

Well ___ Pit ___ Stream ___ Discharge ___ Other Subsurface Soil

Date Collected 8-20-99 Time Collected 1550 Date Shipped —

Method of Preservation ___ Method of Conveyance Hand Deliver

Sample Collector Certification RMBarksdale
(Signature)

Marcus Barksdale – RRC OG Site Remediation 3-5983

Requested Analysis or Remarks

5520 TPH

Date Received 08-23-99 Lab No. 9468E Date Analysis Completed 9-24-99

Lab Receipt Certification Carl Nelson
(Signature)

Soil

Appendix H

Water-Level Elevations

Table H1. Water level and oil column data

Well Id	Date	Time	Elevation measuring point (ft)	Depth to water below measuring point (ft)	Elevation ground water (ft)	Depth to oil below measuring point (ft)	Oil column thickness (ft)	Elevation oil surface (ft)
MW1	9/9/97	11:30	99.94	29.94	70.00	Trace oil		
MW1	7/2/99	13:20	99.94	29.31	70.63	Trace oil		
MW1	7/31/99	21:17	99.94	29.55	70.39	Trace oil		
MW1	8/18/99	8:26	99.94	29.57	70.37	Trace oil		
MW1	8/21/99	17:27	99.94	29.52	70.42	Trace oil		
MW1	8/25/99	13:30	99.94	29.67	70.27	Trace oil		
MW1*	11/2/99	11:58	99.94	30.03	69.91	Trace oil		
MW2	9/9/97	11:30	100.39	32.38	68.01	nm	nm	nm
MW2	7/2/99	13:35	100.39	31.87	68.52	29.1	2.8	71.3
MW2	7/31/99	21:04	100.39	32.00	68.39	29.2	2.8	71.2
MW2	8/18/99	8:40	100.39	32.10	68.29	29.3	2.8	71.1
MW2	8/21/99	17:20	100.39	32.10	68.29	nm	nm	nm
MW2	8/25/99	13:41	100.39	32.12	68.27	29.8	2.3	70.6
MW2	8/25/99	13:41	100.39	nm	nm	29.3	nm	71.1
MW2*	11/2/99	11:37	100.39	32.11	68.28	29.79	2.3	70.6
MW3	9/9/97	11:30	102.50	33.83	68.67	No oil		
MW3	7/2/99		102.50	31.24	71.26	No oil		
MW3	7/31/99	20:46	102.50	31.37	71.13	31.0	0.3	71.5
MW3	8/18/99	8:30	102.50	31.80	70.70	31.5	0.3	71.0
MW3	8/21/99	17:40	102.50	31.76	70.74	31.5	0.3	71.0
MW3	8/25/99	13:34	102.50	32.83	69.67	31.5	1.3	71.0
MW3*	11/2/99	11:50	102.50	32.37	70.13	31.95	0.4	70.6
MW4	8/18/99	18:38	100.49	44.61	55.88	No oil		
MW4	8/19/99	8:19	100.49	37.55	62.94	No oil		
MW4	8/19/99	18:35	100.49	26.24	74.25	No oil		
MW4	8/20/99	10:40	100.49	29.33	71.16	No oil		
MW4	8/21/99	17:05	100.49	29.23	71.26	No oil		
MW4	8/25/99	13:30	100.49	29.15	71.34	No oil		
MW4*	11/2/99	11:05	100.49	29.72	70.77	No oil		
MW5	8/18/99	14:00	106.48	31.40	72.38	No oil		
MW5	8/18/99	15:00	106.48	30.90	72.88	No oil		
MW5	8/19/99	10:28	106.48	30.95	72.83	No oil		
MW5	8/19/99	18:07	106.48	33.56	72.92	No oil		
MW5	8/21/99	17:12	106.48	33.56	72.92	No oil		
MW5	8/25/99	12:33	106.48	33.62	72.86	No oil		
MW5*	11/2/99	10:45	106.48	32.20	74.28	No oil		

* Reported by RRC personnel

Table H1 (continued). Water level and oil column data

Well Id	Date	Time	Elevation measuring point (ft)	Depth to water below measuring point (ft)	Elevation ground water (ft)	Depth to oil below measuring point (ft)	Oil column thickness (ft)	Elevation oil surface (ft)
MW6	8/18/99		107.96	31.70	73.54	No oil		
MW6	8/19/99	10:30	107.96	31.25	73.99	No oil		
MW6	8/19/99	18:30	107.96	33.82	74.14	No oil		
MW6	8/21/99	17:19	107.96	33.87	74.09	No oil		
MW6	8/25/99	12:45	107.96	33.95	74.01	No oil		
MW6*	11/2/99	10:55	107.96	34.20	73.76	No oil		
MW7	8/19/99		104.67	31.10	70.85	No oil		
MW7	8/19/99	18:28	104.67	33.05	71.62	No oil		
MW7	8/20/99	10:25	104.67	33.01	71.66	No oil		
MW7	8/21/99	17:07	104.67	33.05	71.62	No oil		
MW7	8/25/99	13:10	104.67	33.12	71.56	No oil		
MW7*	11/2/99	11:10	104.67	33.58	71.09	No oil		
MW8	8/25/99	13:56	98.63	28.20	70.43	27.8	0.4	70.9
MW8*	11/2/99	11:20	98.63	30.96	67.67	28.00	3.0	70.6
MW9	8/25/99	14:35	105.21	15.20	90.01	No oil		
MW9	8/25/99	15:52	105.21	15.10	90.11	No oil		
MW9*	11/2/99	10:35	105.21	17.17	88.04	No oil		
103	8/17/99	10:05	104.2	Dry	Dry	No oil		
103	8/19/99	12:45	104.2	31.55	72.7	No oil		
105	8/17/99	14:10	96.2	30.70	65.5	No oil		
105	8/18/99	8:07	96.2	25.97	70.2	No oil		
105	8/21/99	16:59	96.2	25.87	70.3	No oil		
106	8/17/99	17:55	96.6	23.98	72.6	No oil		
106	8/18/99	8:12	96.6	25.40	71.2	No oil		
106	8/21/99	17:01	96.6	25.43	71.2	No oil		
107	8/18/99	8:18	99.9	28.40	71.5	No oil		
107	8/21/99	16:58	99.9	28.47	71.4	No oil		
47	7/28/99	14:55	105.2	28.86	76.3	No oil		
47	7/28/99	18:37	105.2	28.80	76.4	No oil		
47	7/29/99	12:38	105.2	27.73	77.5	No oil		
47	7/29/99	16:35	105.2	27.65	77.6	No oil		
47	7/30/99	18:24	105.2	27.54	77.7	No oil		

* Reported by RRC personnel

APPENDIX I

Survey Elevations

SIGHTLI. 'E SUr'VE'I. 'G I. 'C.

738 Barchester San Antonio, Texas 78216 (210) 308-5650 ofc. (210) 308-5676 fax

MEMORANDUM

VIA FAX

To: Bureau of Economic Geology ATTN: Alan Dutton
From: Rick Shelley
Re: San Marcos Site - Luling, Texas
Date: August 26, 1999

Mr. Dutton,

Listed below are the results of the level work completed at the referenced site on Wednesday, August 25, 1999.

POINT	ELEVATION	POINT	ELEVATION
MW 8	98.47	MW 7	104.60
MW 2	100.42	101	101.4
MW 1	99.96	MW 5	106.41
MW 3	102.55	61	102.6
105	96.2	62	100.8
112	95.5	63	98.2
106	96.6	56	104.2
107	99.9	102	101.0
114	100.4	72	100.6
104	101.2	73	104.1
88	107.1	89	107.9
MW 9	105.21	MW 6	107.86
84	106.2	74	107.4
76	109.4	82	106.5
68	105.9	48	106.0
94	102.8	95	99.2
49	99.4	MW 4	100.04

Low Bank at River 68.7

BENCHMARK - Atop a 5/8" Iron Rod flush with the top of the remains and at the corner of a concrete foundation and being near MW's 1, 2 and 3. Painted Blue. Elevation is 100.00 assumed.

Please do not hesitate to call me if you have any questions.

With regards,

Rick Shelley, R.P.L.S.

APPENDIX J

Volume and Flow-Rate Calculations for a Distant Oil Source

The following calculations were made to characterize a range of possible volumes of oil lost in a subsurface spill from a hypothetical source at some distance from the oil seep. Estimating the total volume of spilled oil over time requires the following assumptions:

- how far was the source from the seep?
- when did the leak begin? (assume time A [fig. 9] was 1930),
- when did the plume reached the river and began seeping? (assume time C was 1950, a 20-yr travel time), and
- when was the leak cut off? (assume time D was 1970).

The oil plume most likely was narrow near its source and gradually widened with travel toward the seep. So if the oil plume at this site was as much as 2,500-ft long, it might have held only five times, rather than ten times, the volume of oil estimated to be in the present 220-ft-long plume. The hypothetical, 2,500-ft-long oil plume, therefore, is assumed to have held 4,000 to 16,000 bbl.

The size of the oil plume would have decreased since the source was cut off (assumed to have been in 1970) owing to migration and degradation. If plume length decreased from 2,500 to 220 ft between 1970 and 1999, the attenuation rate was about 3 percent/yr. Since 1970, using this rate, plume length might have decreased from about 270 ft at the time of the Fuqua and Holmes (1993) study to its present size of about 220 ft.

The total volume of the spill would have been the sum of the following amounts:

- volume of oil lying between the source and the seep (4,000 to 16,000 bbl),
- volume discharged at the seep during the assumed 20 yr (1950 to 1970) that the seep was fed by an active spill, and
- volume degraded in the subsurface over that time owing to adsorption, volatilization, solution, and biologic activity.

If seep discharge was 0.5 to 10 gal/d (5 to 90 bbl/yr), discharge over a 20-yr period would have added up to 100 to 1,800 bbl. A 1995 estimate of seepage rate was 10 gal of hydrocarbons per day (RRC file document dated 2/13/1995); the basis of this estimate was not reported. If the degradation rate was 3 percent/yr, the incremental volume of the spill consumed by degradation would have been about 120 to 480 bbl/yr. Over 20 yr, degradation could have accounted for perhaps 2,400 to 9,600 bbl. Thus, total spill amount could have been roughly 6,500 to 27,400 bbl over 40 yr (assumed spill history from 1930 to 1970). The spill and degradation rates might have varied over the life of the source and plume history.

Flow rate in the oil plume can be estimated from three different equations. First, the equation for average linear velocity (v) of a contaminant is

$$v = q/n = K\ \text{grad}\bullet h/n, \tag{1}$$

where q is seepage velocity (units of length/time [L/t]), n is effective porosity (dimensionless), K is hydraulic conductivity (L/t), and grad•h is gradient in hydraulic head (dimensionless). Assuming that hydraulic conductivity is 3.3 ft/d, reasonable for a clayey to clean sand, porosity is 20 percent, and the gradient is 0.02, the average linear velocity is found to be about 0.3 ft/d. Flow rate of water in the gravel probably is faster than flow rate of oil in the clayey fine-grained sand.

Second, assuming that the source was 2,500 ft from the seep and that the plume took 20 yr to reach the river, a simple velocity calculation ($v = D/t$) yields 0.3 ft/d. Of course, neither the distance nor the elapsed time between the first spill and formation of the seep is known.

Third, if the seepage rate is 0.5 to 0.8 gal/d across a seepage face that measures 100 ft wide, 0.7 ft high, and porosity is 20 percent, the fluid velocity arriving at the seep is 0.27 to 0.45 ft/d.

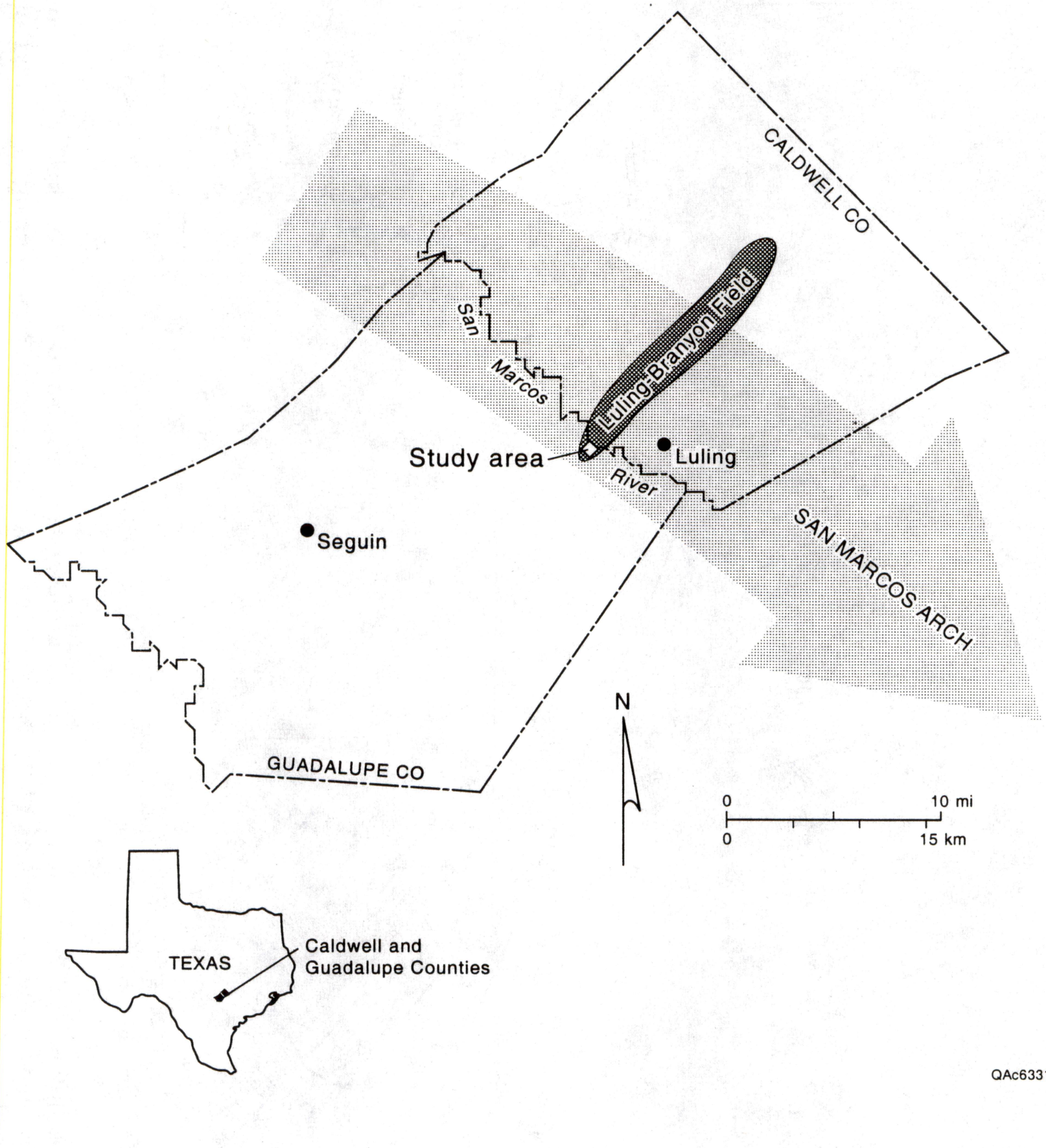


Figure 1. Location of study area on the south side of the San Marcos River in eastern Guadalupe County, Texas. The Luling-Branyon Oil Field includes reservoirs in the Austin Chalk and Edwards Group (Galloway and others, 1983).

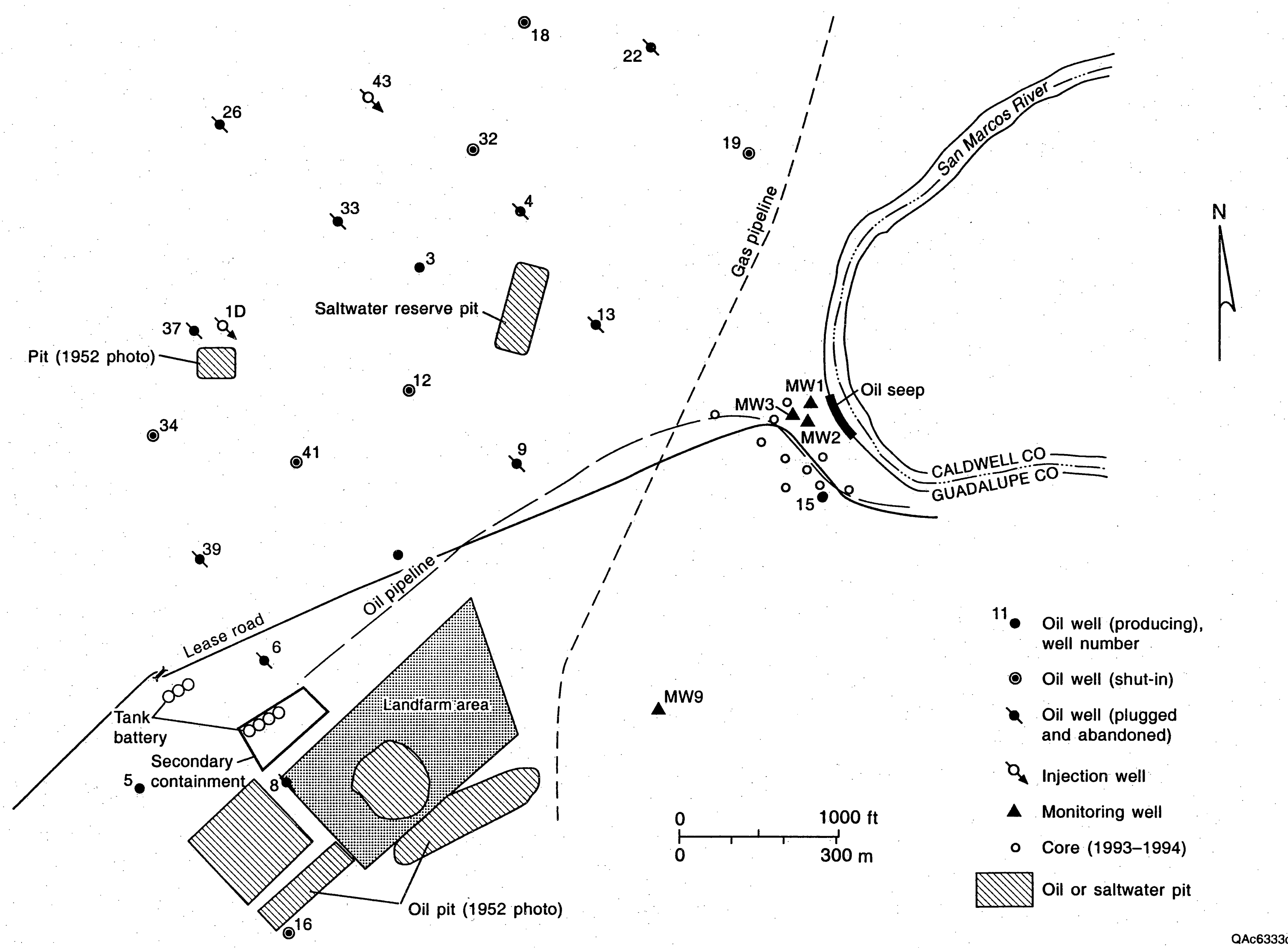


Figure 2. Site map showing oil wells surveyed by GPS and other features related to the oil field. Also shown are locations of the oil seep on the south bank of the San Marcos River and the four monitoring wells and nine test holes present at the start of this investigation. Position of old oil pits taken from aerial photo (Army Map Service, 12/12/1952, 1:69,000, TNRIS RSDS#00212, FC04F). Position of river, landfarm area, new saltwater reserve pit, lease road, and pipelines from aerial photo (www.tnris.state.tx.us, 1995, Digital data, 2.5-m DOQ).

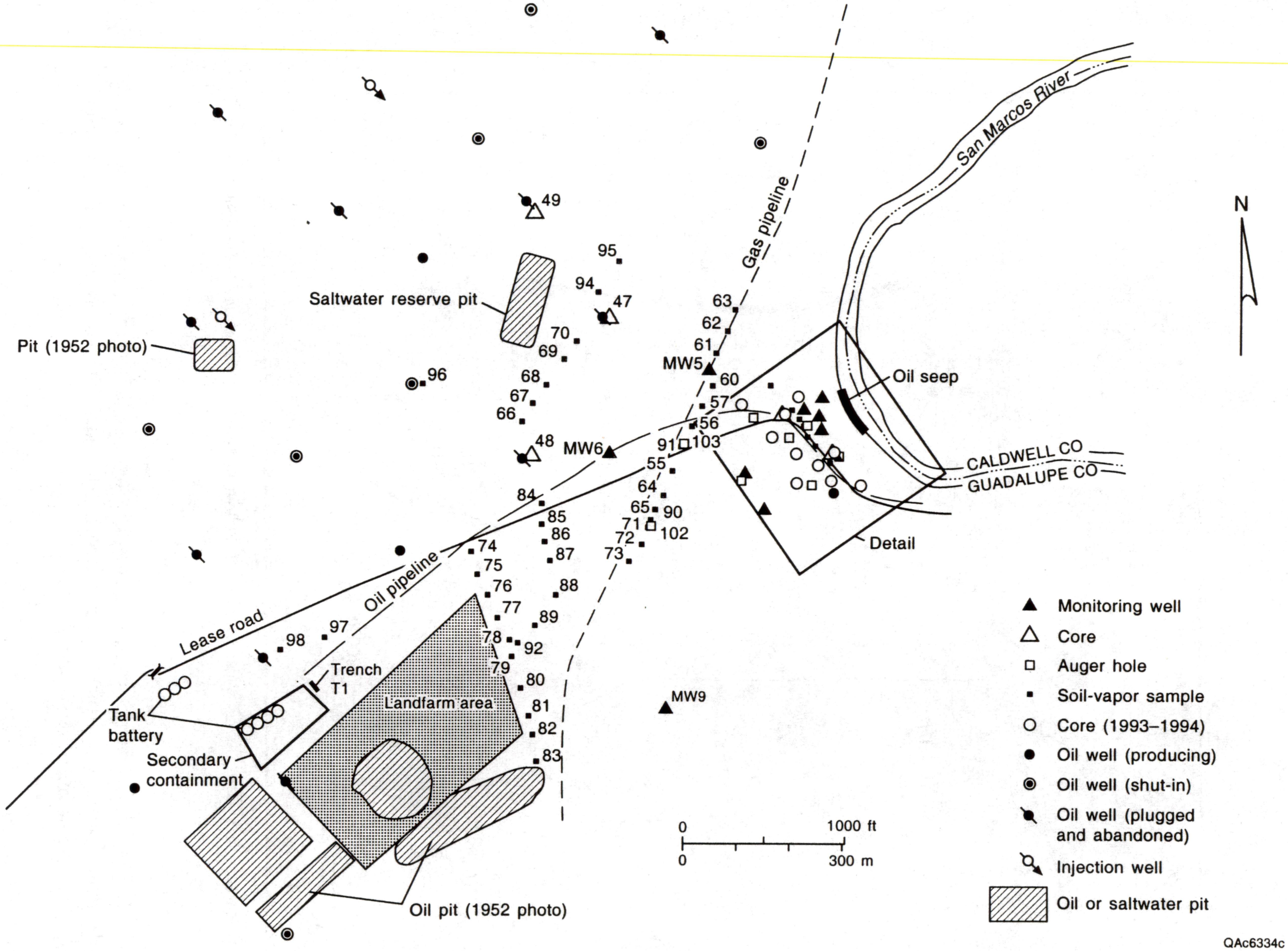


Figure 3. Site map with location of direct-push survey holes, solid-stem and hollow-stem sample holes, and monitoring wells installed during this study. See figure 2 for base map sources and figure 4 for sample ID's in detail area.

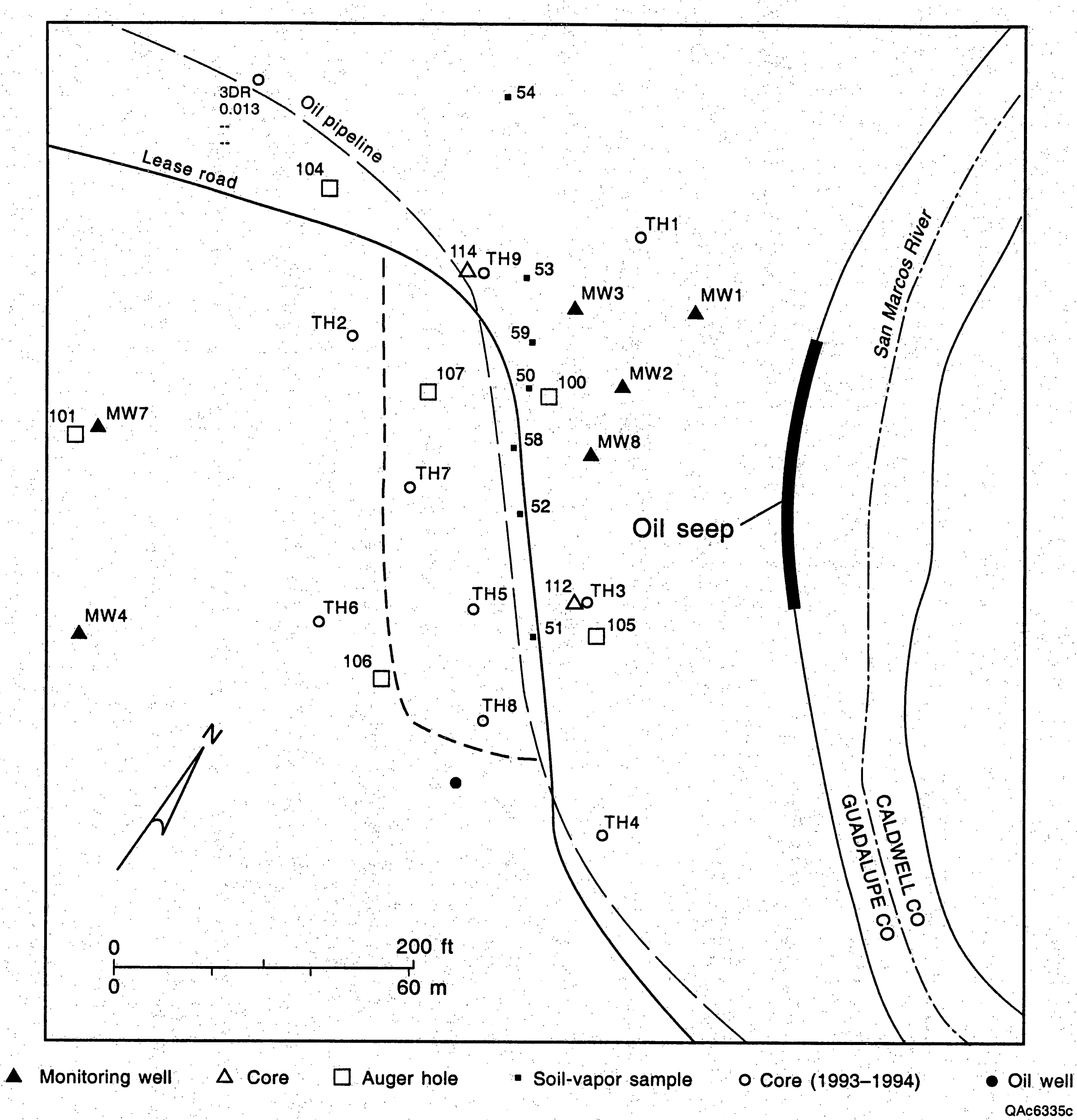


Figure 4. Detail of direct-push survey holes, solid-stem and hollow-stem sample holes, and monitoring wells installed near the San Marcos River. See figure 3 for position of detailed area.

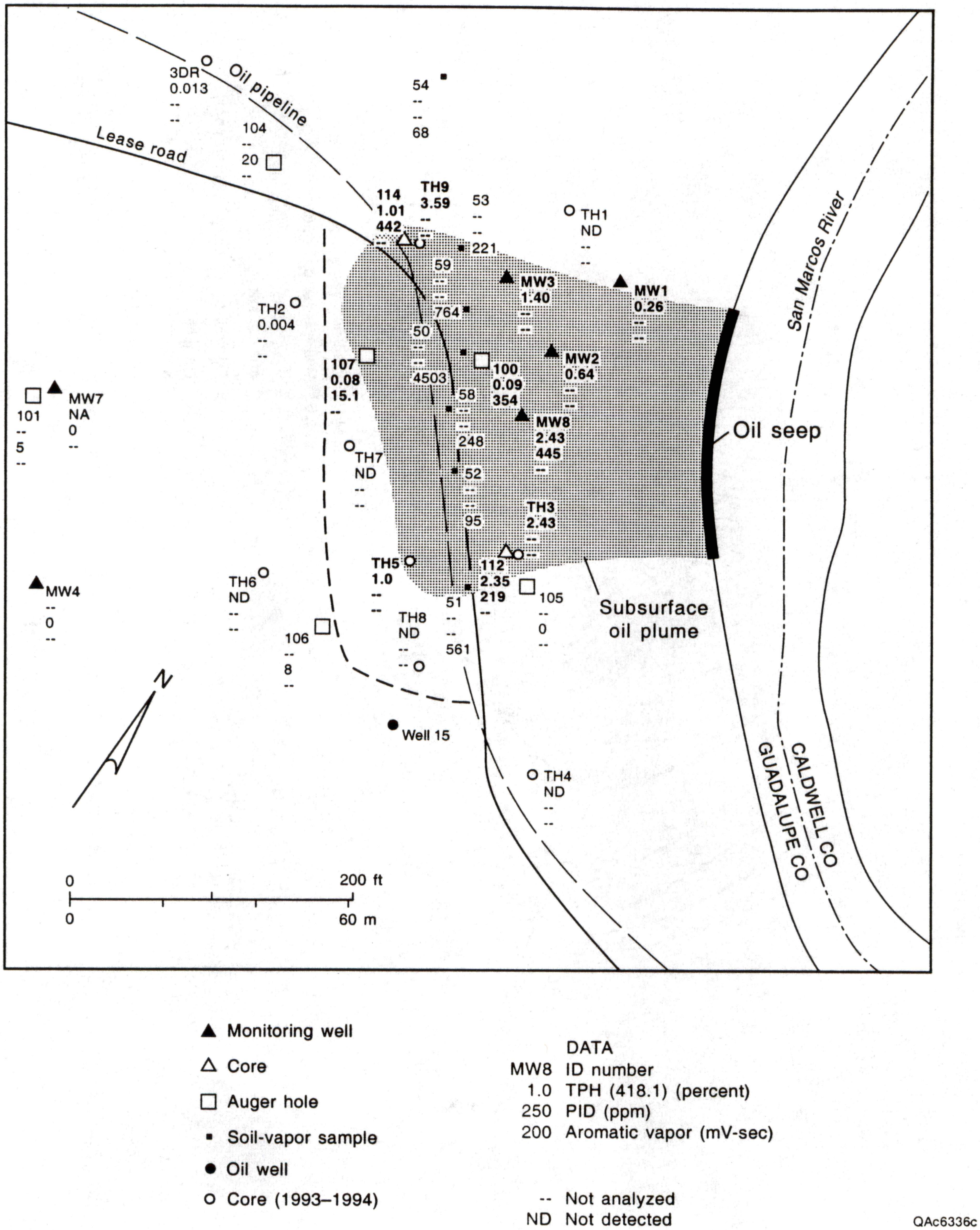


Figure 5. Position of subsurface crude-oil plume inferred on the basis of analytical results from direct-push survey holes, solid-stem and hollow-stem auger holes, and monitoring wells. Boldface data indicate confirmed presence of free-phase crude oil. See figure 3 for position of detailed area.

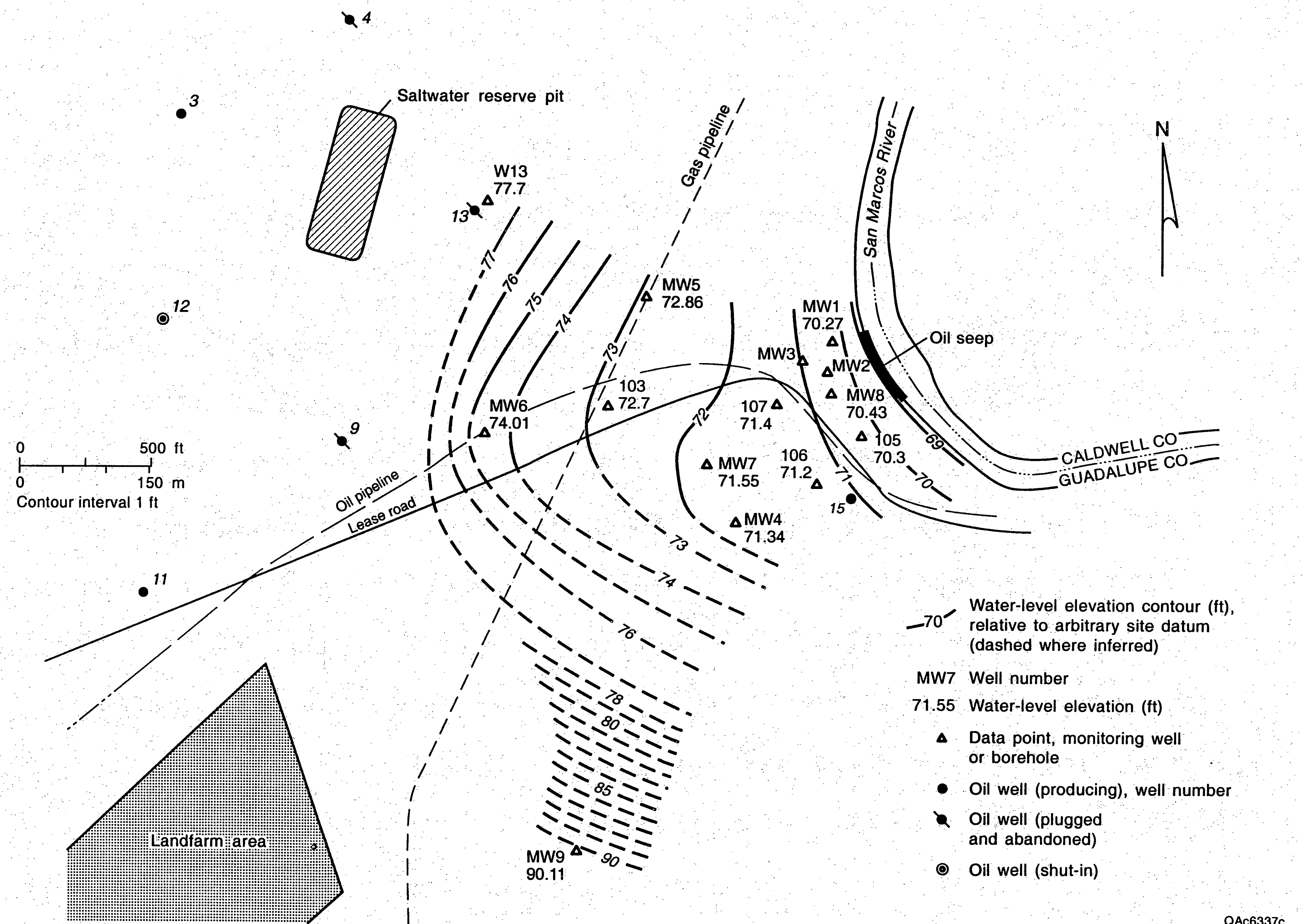


Figure 6. Elevation of water table estimated from water-level measurements in August 1999 at monitoring wells and boreholes. Data in appendix H. Measurements from MW2 and MW3 not used because of the presence of an oil column.

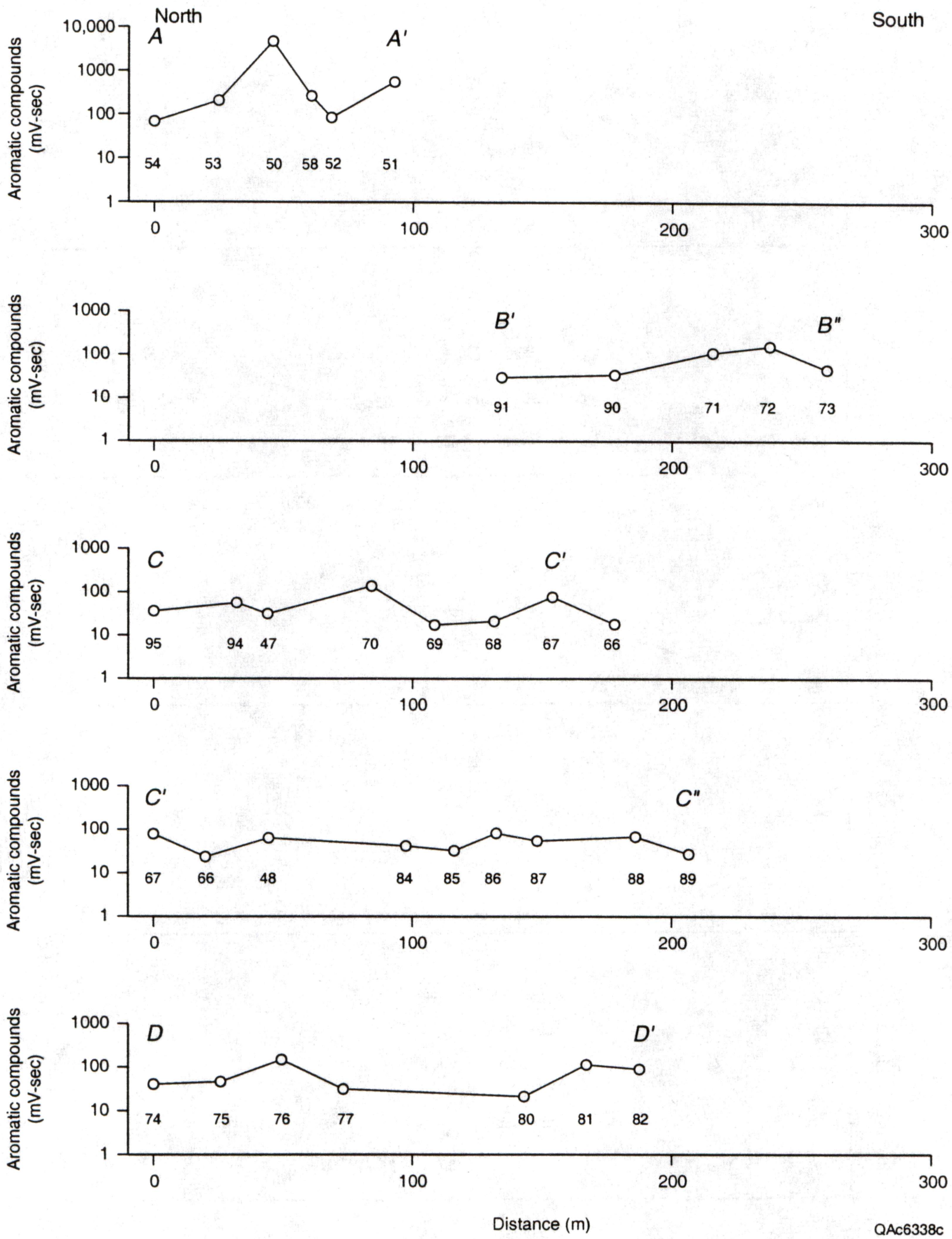


Figure 7. Profiles of aromatic compounds in vapor in the unsaturated zone. Numbers refer to soil-vapor probe holes (fig. 3). Note logarithmic vertical scale. Unit of mV-sec represents area under chromatogram curve, proportional to total mass of aromatic compounds in sample. Transect lines A–A′, B′–B″, C–C′–C″, D–D′ shown in figure D1.

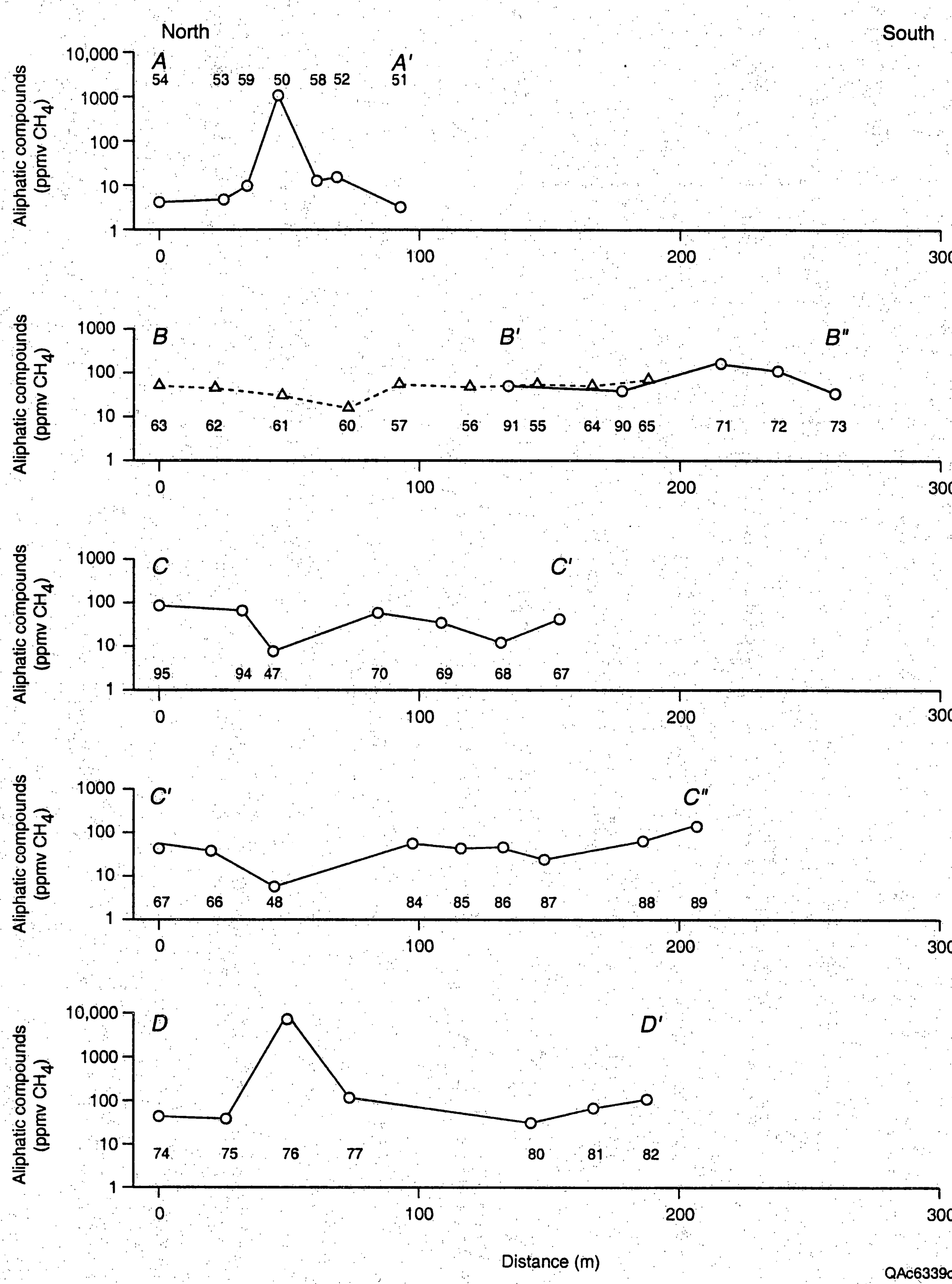


Figure 8. Profiles of aliphatic compounds in vapor in the unsaturated zone. Numbers refer to soil-vapor probe holes (fig. 3). Note logarithmic vertical scale. Unit of mV-sec represents area under chromatogram curve, proportional to total mass of aromatic compounds in sample. Transect lines A–A′, B′–B″, C–C′–C″, D–D′ shown in figure D1.

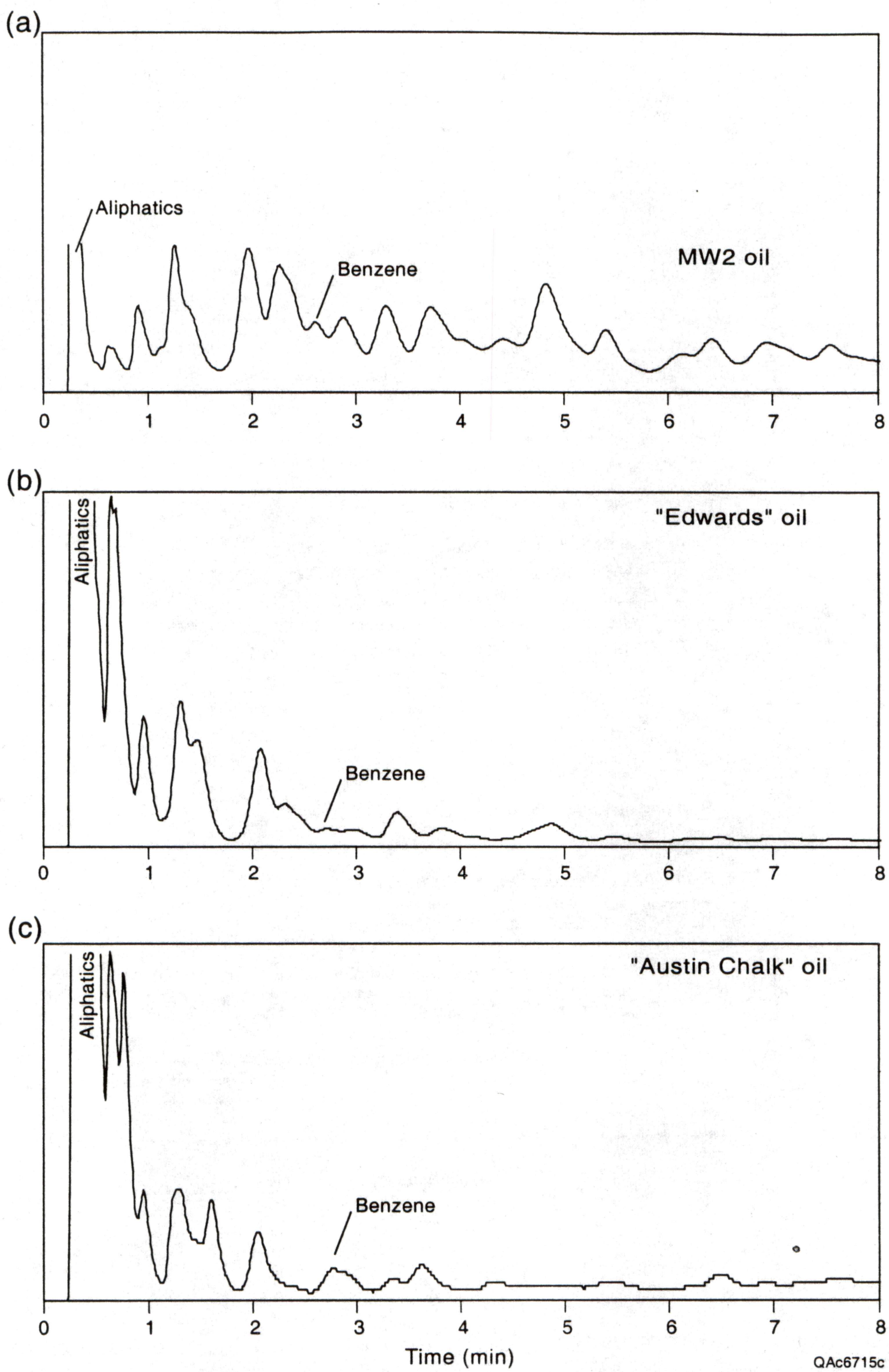


Figure 9. Chromatograms of headspace gas equilibrated with oil from (a) monitoring well MW2, (b) a tank battery collecting Edwards oil, and (c) oil well no. 15 producing from the Austin Chalk. Analyzed using an FID detector and "602" chromatography column with various injection concentrations. No vertical scale. Horizontal axis is time for hydrocarbons to migrate through the "602" column to the detector.

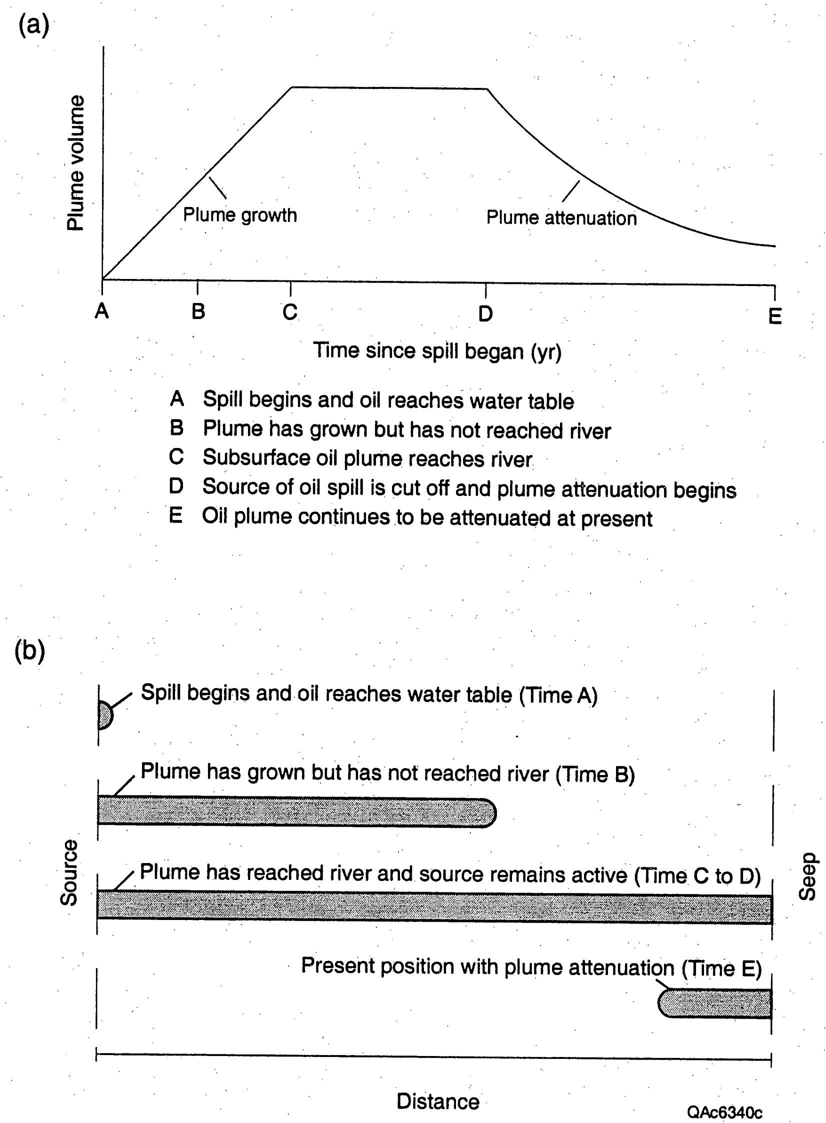


Figure 10. Conceptual model for growth and attenuation of a subsurface oil plume reaching a discharge seep. Different stages in plume history are illustrated in (a) graph of change in oil volume, and (b) model of position of oil plume between source and seep.

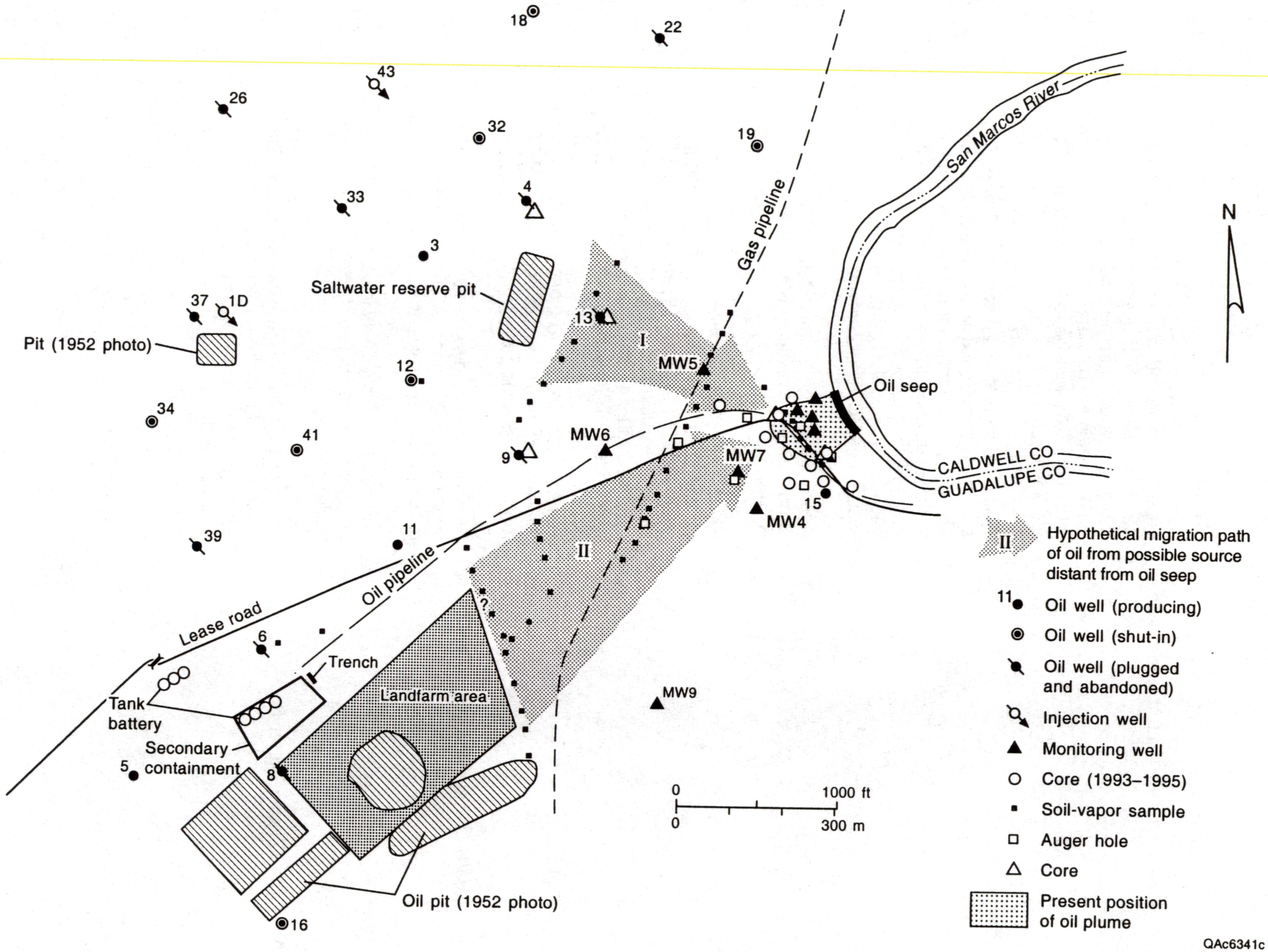


Figure 11. Hypothetical migration paths of oil from possible distant sources. No direct, unambiguous evidence for either track I or II was uncovered during this study.

Table 1. Possible sources of oil at the San Marcos River seep.

Possible source	Comment
Oil pipeline located within 220 ft of the seep	Pipeline was tested and a trench was dug in 1994. Based on RRC observations in 1994 there appeared to be no evidence to suggest an oil leak in the pipeline (September 14, 1994, letter from T. R. Melville to W. Madolora, RRC file document).
One or more oil wells	There are more than 24 known producing, shut-in, or abandoned oil wells located within about 2,500 ft northwest to southwest of the seep. Additional unknown abandoned well bores might exist within the study area (April 5, 1994, letter from F. B. Morlock to T. L. Muchard, RRC file document).
Tank battery	A tank battery for the lease has been located about 2,080 ft southwest of the seep for several decades.
Oil-separation pits	Pits are shown in October 19, 1996, aerial photographs within about 1,800 to 2,500 ft southwest of the seep; 15 unlined collecting pits and 7 unlined emergency pits are identified in a September 11, 1968, letter from J. C. Herring to E. J. Dickinson (RRC file document).
Landfarm area	Located about 1,250 to 2,050 ft southwest of the seep; probably used to remediate material from oil-separation pits.
Emergency saltwater storage and collection pit	Pit was constructed since 1993, after the oil seep came into existence, and meets RRC requirements for environmental protection.
Abandoned flow line	There are numerous flow lines crossing the area that may remain connected to abandoned wells.
Natural source(s) including faults	Faults in the area have a northeast strike. The updip trend of Luling-Branyon field is fault controlled. No fault at the site is shown on geological maps.

Table 2. Estimation of volume of oil in subsurface plume

Volume assuming maximum oil thickness

Plume area (ft^2)	33,000	
Maximum oil thickness (ft)	2.8	
Porosity	0.20	
Maximum oil volume	18,480	ft^3
	138,249	gal
	3,292	bbl

Volume assuming average oil thickness

Plume area (ft^2)	33,000	
Average oil thickness (ft)	0.7	
Porosity	0.20	
Average oil volume	4,614	ft^3
	34,520	gal
	822	bbl

Calculation of average oil thickness*

Oil column thickness (ft)	Plume area (%)**	Plume area (ft^2)	Oil volume (ft^3)†
2.75	1.6%	521	287
2.25	3.2%	1,043	469
1.75	6.3%	2,086	730
1.25	12.6%	4,171	1,043
0.75	25.3%	8,342	1,251
0.25	50.6%	16,685	834
Total		32,848	4,614

* (Assumed thickness × Assumed plume area)/Total area

** Smaller thickness assumed to cover twice the area of previous thickness class

† Assuming porosity of 20 percent